THE IMPACT OF RURAL ELECTRIFICATION

Results of the 2013 - 2019 Impact Monitoring of the Investments in Rural Electrification in West Nile Sub-Region, Uganda

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On behalf of Republic of Uganda, Ministry of Energy and Mineral Development (MEMD)

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Berlin, 1st of November 2019

Mirco Gaul (team leader SiNERGi GmbH) and Christian Berg (team leader comit GmbH)

Content

Abbreviations

CFL	Compact fluorescent lamp
DCO	District Commercial Officer
DPO	District Planning Officer
E-AIM	Electricity Access Impact Maximization
GHG	Green House Gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
HC	Health Center
HFO	Heavy Fuel Oil
ICT	Information and Communication Technology
IEA	International Energy Agency
IEC	International Electrotechnical Commission
IPCC	International Panel on Climate Change
ISO	International Organization for Standardization
KfW	Kreditanstalt für Wiederaufbau
LED	Light-emitting diode
LPG	Liquified Petroleum Gas
M&E	Monitoring and Evaluation
MCB	Miniature (or Micro) Circuit Breaker
MEMD	Ministry of Energy and Mineral Development
MHI	Manitoba Hydro International
OBA	Output Based Aid
REA	Rural Electrification Agency
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SME	Small and Medium Enterprises
SWOT	Strengths, Weaknesses, Opportunities, Threats
TC	Trading Center
TV	Television
UBOS	Uganda Bureau of Statistics
UEDCL	Uganda Electricity Distribution Co. Ltd.
UNEB	National Examinations Board
URA	Uganda Revenue Authority
WENRECo	West Nile Rural Electrification Company

Units

A	Ampere
km	Kilometer
kV	kilo Volt
kWh	kilo Watt hour
MWh	Mega Watt hour

Currencies and exchange rates (as of 30/06/2019)

EUR	Euro	1 EUR	= USD 1.14	= UGX 4,200
UGX	Ugandan Shillings	1,000 UGX	= EUR 0.24	= USD 0.27
USD	US Dollar	1 USD	= EUR 0.88	= UGX 3,693

Executive summary

This report aims to contribute to a better understanding of the challenges and dynamics of the implementation as well as of the strategic design of rural electrification programs in order to maximize development impacts of such interventions. For decades, grid extension has been perceived as the ultimate means for rural electrification, its high costs justified by the assumed welfare gains in rural development. Cost reductions in off-grid solar as well as sobering results of recent impact studies for grid and off-grid electrification emphasize that **policy makers should re-consider impact assumptions and cost-benefit rationales for future electrification planning and strategies**.

Prepared on behalf of the Ugandan Ministry of Energy and Mineral Development (MEMD) and KfW Development Bank, this report adds empirical evidence to the recent reassessments of grid electrification impacts. It is the result of a **rigorous impact monitoring exercise** of rural electrification in the West Nile region of Uganda. Over four consecutive monitoring surveys in 2013, 2015, 2017, and 2019, we conducted 9,750 interviews with households, businesses, secondary schools, and health centers, using a double-difference approach (with treatment and control groups) for impact attribution.

The pre-existing isolated network, operated by the local utility West Nile Rural Electrification Company (WENRECo), provided unreliable power supply to about 3,000 customers in three small towns with a peak demand surpassing the available 1 MW heavy fuel oil (HFO) based generation capacity in 2011. The West Nile electrification program invested in the

- construction of hydropower generation capacity (3.5 MW were completed in 2012, another 4.1 MW are planned) and thermal generation capacity (2.6 MW installed in May 2019, planned to be upgraded to 2 x 4 MW HFO generation by December 2019);
- rehabilitation and extension of 487 km distribution network, connecting 60 trading centers and 9 towns as well as improving the operational capacity of the local utility;
- connection of about 12,000 domestic and commercial customers including 29 health centers and 44 schools, as well as the promotion of productive, safe and efficient use of electricity.

Drivers and barriers of grid access

Grid electricity has been made available to about 1.6% of the population of West Nile, and to a significantly higher share of businesses and social infrastructure. But grid customers suffer from low reliability and poor service. **We consider unreliability of power supply as a major factor preventing intended positive effects of grid access** such as investment in productive activities and replacement of generators and fossil fuel use. Poor reliability might also cause losing dissatisfied commercial and industrial customers (accounting for 75% of revenues), which directly endangers WENRECo's financial viability. Furthermore, **the planned future grid extension and densification poses an additional threat to the operational viability of WENRECo**. We have demonstrated that additional customers are lowering the already poor income per customer ratio and that past subsidized connection offers resulted in a significant share of inactive customers. But future grid densification might even be less successful as expected, since 60% of not connected households state high costs as reason for nonconnec-

tion, regardless a standing offer of a 100% subsidized free 1-pole connection, which suggests that costs for inhouse wiring remain a serious barrier for poor households.

Impacts of grid access

Impacts of grid access have been much weaker as anticipated, partially due to much higher off-grid solar electrification levels both in the control and treatment group. Grid access leads to an increased use of electrical lighting and larger appliances in comparison to off-grid solar access, but for rural households the differences are limited. Similarly, grid connected level III health centers and secondary schools show a significant increase in electric lighting and appliance use, but this does not translate into significant impacts on the provision of educational or health services. The difference for larger level IV and V health centers is even less pronounced, as almost all of them had used solar systems and generators already before getting grid connected. It appears that **most households and even health centers and schools are able to satisfy their basic power demand based on off-grid solar**, provided that solar systems are reliable and maintenance and repair service is available, which so far seems not to be the case. Even for rural businesses in trading centers, grid electricity does not appear to be a game changer; even though more businesses used TVs and fridges, they neither increased business hours or employment nor their turnover. In contrast, businesses in towns increased employment by 22% and more than doubled their turnover in the same period of time. Observed **economic effects might be suppressed by low reliability of grid power and the limited business capacity and access to financing in rural areas**. But increased competition between rural and urban businesses should be investigated to check for possible crowding-out effects of grid access in rural areas.

Lessons learned

The experiences with this program confirm that **grid extension alone cannot reach the aim of universal access to electricity for all by 2030**. Despite a massive intervention, only small fractions of the total population of West Nile and of the population within the reach of the electrification corridor, respectively, can be connected to the grid. Even within the electrification corridor, **the current free 1-pole connection policy is not reaching the poor, as they still cannot afford the additional cost of inhouse wiring**.

The cost of grid extension (without the investments in power generation) has been in the range of USD 1,200 per connection. While this is a moderate value compared to other grid extension programs, we observed that **most rural household and business customers use only a fraction of the potential grid power access and accordingly reap little benefits**. For these customers, **adequate access could be provided by off-grid solar systems at a fraction of the cost**. Increasing the cost efficiency of the electrification strategy would release funds that could be used to finance social access programs for poor rural households that are currently not reached, neither by grid extension nor by the commercial off-grid solar market. Such **an integrated strategy could also avoid that better-off households are benefitting most of rural electrification programs while the poor are left behind**, which is effectively increasing the perceived relative poverty in rural areas.

Although the power utility received substantial support over past years, the performance is still unsatisfying. Especially **small utilities struggle to hire and keep qualified staff in remote rural areas**. And the initial investment to set up an effective administration and technical operation are high compared to the low power sales and related income. The required institutional support might be higher as often anticipated.

This experience should also **caution the enthusiasm of mini-grid deployment in remote rural areas**. Mini-grids often require higher tariffs to be economically viable. **In absence of larger customers, off-grid solar will in many cases represent the more cost-efficient option**.

Another lesson is that **impact assumptions should be realistic and not follow simplified linear impact chains**. Electricity can greatly increase efficiency of economic activities and social services, but this does not lead automatically to relevant economic or social impacts. Especially **rural economic development has complex dynamics that cannot easily be anticipated**.

For the impact monitoring, the **double-difference approach enabled the contrasting of patterns and trends within the treatment group to the general development trends in the region**. We used four data points over a six-year period to make existing fluctuations in variables visible and even trace medium-term impacts. The **combination of quantitative and qualitative surveys was crucial to be able to cross-check and discuss quantitative results with local stakeholders**.

Recommendations to the power utility

- **Increase the reliability of power supply** by improving the distribution network, switching procedures, network balance, and monitoring of outages (SAIDI, SAIFI).
- Focus on **expanding the large-commercial and industrial customers base**, who usually have their peak demand during the day, to increase the power sales and income to customer ratio.
- **Improve internal management procedures and record keeping,** systematically collecting and processing GIS data and customer information as well as defining internal routine workflows for maintenance and customer care.
- **Improve external communication** by providing continued training for staff and timely information to customers and local authorities on outages and load shedding as well as changes in tariff structures or procedures.
- **Encourage safe and efficient use of power**, e.g. by placing posters close to the MCB sockets of the in-house installation that highlight the main safety and efficiency rules in an easily comprehensible way (using pictograms and main local languages).

Recommendations to policy makers

- **Investigate reasons and trends of low water levels** at Nyagak river and identify feasible remedial action. As the planned additional hydropower plant (Nyagak III) is built on the same river, a permanent drop of water levels would critically endanger the power supply in West Nile.
- Instead of focusing on expensive grid extension only, **develop an integrated strategy to reach universal electricity access by grid and off-grid approaches**, thereby reducing the need of subsidies for grid extension while shifting such subsidies to social access programs for the rural poor. This would also mitigate political pressure to

connect more of the underserved poorer and remote rural households to the West Nile power grid.

- **Boost the impacts of grid access on health and educational services** by facilitating the connection of the remaining unconnected 25 secondary schools and 13 health centers in the proximity of the grid. For more remote institutions, least-cost options including off-grid solar should be analyzed instead.
- To increase economic impacts, existing commercial activities and capacities in West Nile as well as national and cross-border market potentials and linkages should be assessed to strategically target future support like e.g. **vocational training, business development services and SME financing**. In the best case, such prior assessment would actually guide rural electrification planning and the cost-benefit analysis of supply options such as grid extension, mini-grids or off-grid solar.

Introduction

Systematic long-term monitoring of electrification programs is rare. This report presents the results of a six-year monitoring exercise to track impacts of rural electrification in the West Nile sub-region of Uganda. It addresses stakeholders of the West Nile electrification program as well as a wider audience of experts and decision makers in this field. It aims at contributing to a better understanding of the challenges and dynamics of the implementation of rural electrification programs and the maximization of their impacts on rural development.

The challenges of rural electrification

Access to electricity is widely considered as a prerequisite for rural development. Efficient lighting, information, and communication technologies as well as advanced machinery for agro-processing and manufacturing depend on stable electricity supply. Universal access to affordable, reliable and modern energy services is part of target No. 7 of the Sustainable Development Goals to be reached by 2030. But while in 2017, 89% of the global population had access to electricity, in Sub-Saharan Africa less than half of it (44%) had access, and less than a quarter (22%) in Uganda. Over decades the population in Sub-Saharan Africa has been growing faster than the number of people with new access to electricity, and only due to increased efforts, this trend seems to have finally reversed in 2017 (IEA, IRENA, UNSD, WB, WHO 2019, 20).

The extension of the central power grid is by itself often considered already a symbol for development and social inclusion on a national scale. However, experiences of electrification programs are mixed. While successful examples are often emphasized (Barnes 2007) in many cases grid electricity has reached remote rural areas insufficiently, grid connection and electricity have been too costly for a large part of the rural population, and/or reliability and service of power supply have been poor (Kojima and Trimble 2016). Many electrification programs that aimed at providing grid electricity to the whole population caused massive costs for investment and operation, while evaluations showed that a significant number of poor households remained non-connected even after ten or 20 years (Kårhamar et al. 2013). Utilities that have been particularly successful in connecting high numbers of poor rural customers face heavy operational losses or are forced to increase tariffs e.g. in Mozambique , Rwanda (Baringanire, Malik, and Ghosh Banerjee 2014), or Kenya (Taneja 2019).

It has been long acknowledged that by itself electrification does not guarantee economic development (WEC/FAO 1999, 9) and that improvements in income, lifestyle and livelihood depend on complementary infrastructure, economic development, and good governance (Ramani and Heijndermans 2003, 65). While past research highlighted massive positive impacts of rural electrification, recent meta studies are more cautious (Bos, Chaplin, and Mamun 2018; Bonan, Pareglio, and Tavoni 2017; Jiménez 2017), challenge the transferability of impact findings from Asia and Latin America to the Sub-Sahara African context (Peters and Sievert 2016; Hamburger et al. 2019), and question the quality of the available data (Bayer et al. 2019; Bonan, Pareglio, and Tavoni 2017; Jiménez 2017).

At the same time, a recent analysis of rural electrification in six countries (Bangladesh, Cambodia, Ethiopia, Kenya, Myanmar, and Rwanda), conducted under the Multi-Tier Framework for Energy (MTF) highlights the growing importance of off-grid solar, driven by decreasing costs and maturing product portfolios (Gouthami et al. 2018; Bryan Bonsuk, Gouthami, et al. 2018; Bryan Bonsuk, Kyul, et al. 2018; Dave et al. 2018). Off-grid solar also increasingly offers cost-effective access alternatives for Tier 2 access and low-consuming productive applications (GOGLA 2018; Lighting Global 2019).This calls for a closer assessment of the impacts, economic viability, and cost-benefit ratio of grid electrification strategies and programs.

The West Nile electrification program

The sub-region of West Nile is located in the most north-western part of Uganda and is structured into 9 districts – Adjumani, Arua, Koboko, Maracha, Moyo, Nebbi, Yumbe, Zombo, and the recently formed Pakwach district, separated from Nebbi – from which the two districts Adjumani and Moyo are not covered by the rural electrification program. West Nile is among the six poorest sub-regions of Uganda, with a poverty rate of 35% in 2017 (UBOS 2018, 90). Due to political conflicts in this area between the 1980s and early 2000s, West Nile has considerably lagged behind in terms of economic and social infrastructure compared to other regions of the country.

Most people in the region live in the districts of Arua, Nebbi, and Yumbe and the equally named towns are the largest migration centers of the region. The biggest town in West Nile is Arua, which is also the main commercial supply center and transport hub in the region. Based on the 2014 census, the population in West Nile is estimated at 3.1 million by 2019, or 2.76 million, if only the seven districts covered by the electrification program are considered. Additionally, it is estimated that almost 400,000 refugees mainly from South Sudan are living in five large settlements in Arua and Yumbe districts. Detailed socio-economic information on the West Nile region is provided in Annex 2.

In 2003, the Ministry of Energy and Rural Development (MEMD) awarded to WENRECo a 20-year license to operate the existing distribution network in the remote West Nile region of Uganda.[1] At that time, the West Nile power grid was limited to a medium voltage distribution network connecting the three towns of Arua, Nebbi, and Paidha. WENRECo invested in a 1 MW heavy fuel oil generator and started to build the 3.5 MW hydropower plant Nyagak I. However, the construction of Nyagak I was considerably delayed and WENRECo was almost at the risk of insolvency in 2008. Against this background, the Governments of Uganda and Germany included the West Nile Grid Rehabilitation and Extension Program into the Investment Program in Renewable Energy and Energy Efficiency in Uganda, which is coordinated by MEMD, financed by KfW Development Bank, and implemented by UEDCL and WENRECo. The West Nile electrification program was financed with EUR 24.6 million by KfW Development Bank and with EUR 7.5 million by the Government of Uganda, while WENRECo contributed EUR 5.5 million to the investment into the hydropower plant Nyagak I. The program components grid extension and promotion of productive, safe and efficient use of electricity have been co-financed by the EU with EUR 3.5 million.

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[1] West Nile Rural Electrification Company (WENRECo) is a special purpose vehicle owned by Industrial Promotion Services (IPS), which is the industrial development arm of the Aga Khan Fund for Economic Development. The license has been recently extended to 2028.

The program aims at overcoming the challenges of providing clean, reliable and affordable electricity to rural populations in the seven districts Arua, Koboko, Maracha, Nebbi, Pakwach, Yumbe, and Zombo. Its main results have been:

- **Hydropower generation capacity**: completion of 3.5 MW hydropower plant Nyagak I, construction of a second 4.1 MW hydropower plant (Nyagak III) is planned at the same river.
- **Thermal generation capacity**[2]: 2.6 MW emergency diesel installed in May 2019, planned to be upgraded to 2 x 4 MW HFO generation by December 2019.
- **Rehabilitation and extension** of 487 km distribution network, adding 150 distribution transformers and connecting 60 trading centers and 9 towns.
- **Connection** of about 14,000 households and commercial customers, 29 health centers and 44 schools.
- Improving the **operational capacity** of the local utility.
- Promoting the **productive, safe and efficient use** of electricity.

The area covered by a 500 m range on both sides of the medium-voltage distribution network, which can be covered by low-voltage distribution, is called the electrification corridor. The corridor is depicted in figure 1 on the next page as wide red line. The 9 towns and 60 trading centers covered by the electrification corridor represent, with an estimated population of 730,000, about 30% of the total population of the covered 7 districts of West Nile. While the overall grid connection rate for the 7 districts is only about 1.6%, it is 5% for the people living within and close to the electrification corridor and the connection rates reach 26% to 43% for households in the direct vicinity of the medium-voltage network.

Methodical design and implementation

The electrification of a – by geographic conditions – fairly isolated region of Uganda provides an excellent case to study possible impacts of rural electrification on the broader socio-economic development of a whole region. Thus, MEMD and KfW Development Bank decided to invest in the setup of a comprehensive impact monitoring system (Gaul et al. 2011), which was applied for the monitoring period of 2013 until 2019. This final report presents the insights gained over four large consecutive monitoring exercises in 2013, 2015, 2017, and 2019.

A results chain was established (see figure 2) to identify key impact areas of the electrification program. Rather than focussing only on the household level impact, businesses, health centers, and secondary schools have been identified as key beneficiaries of improved grid access.[3] While the number of health centers of level III to V (100) and secondary schools (157) is known and feasible, West Nile comprises some 500,000 households and over 15,000

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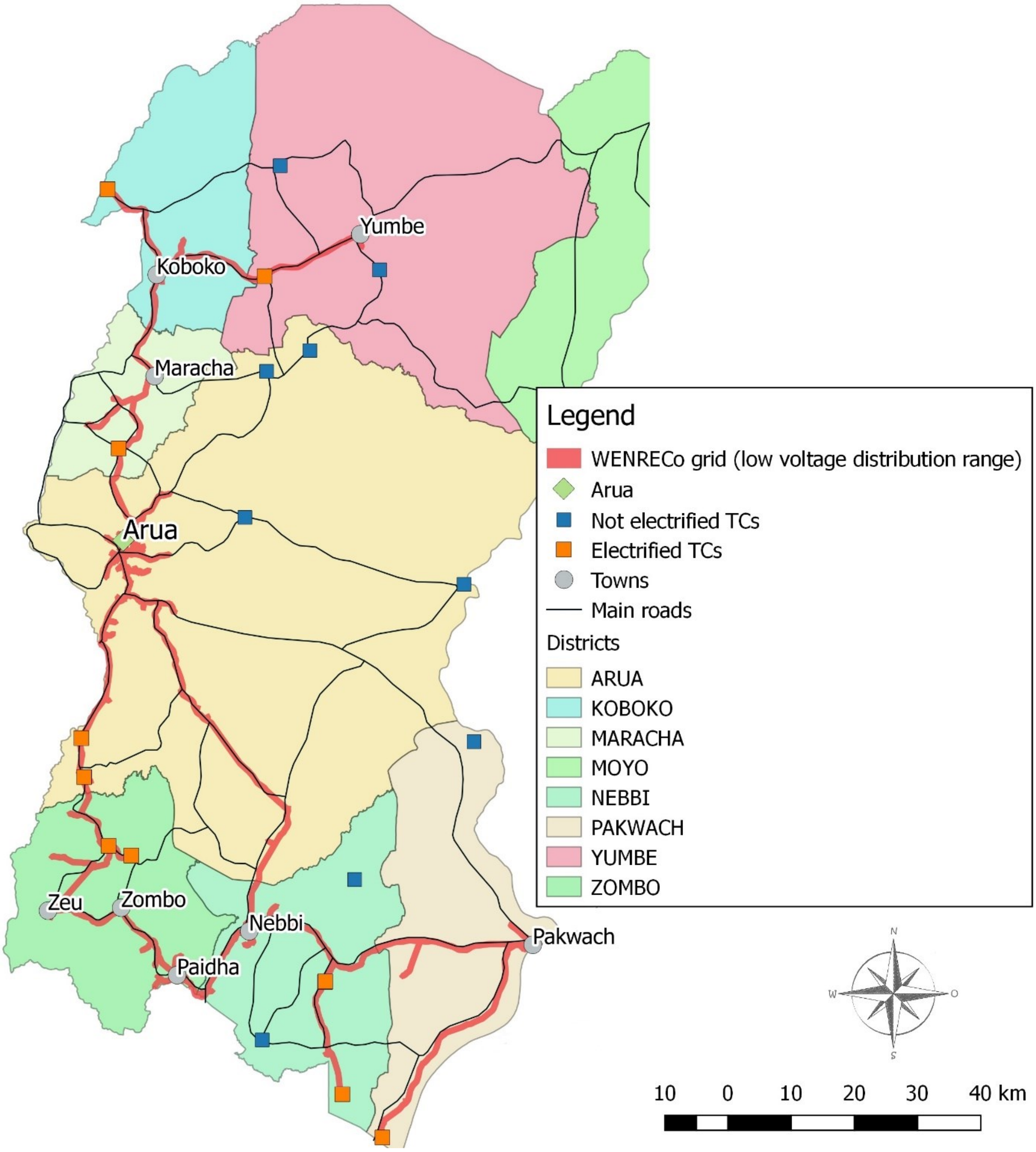
2 The installation of thermal capacity has not been planned from the start, but was required due to delays in the construction of Nyagak III and high demand growth caused by the connection of double as many customers as initially planned.

3 As level II heath centers provide only very basic health service and do not have permanent medical staff, we focus on health centers of level III to V only. Similarly, primary schools usually use very little electric appliances beside lighting. Vocational schools in West Nile comprise a great variety of institutions in terms of size and quality which makes quantitative comparisons difficult. We therefore focus on secondary schools only.

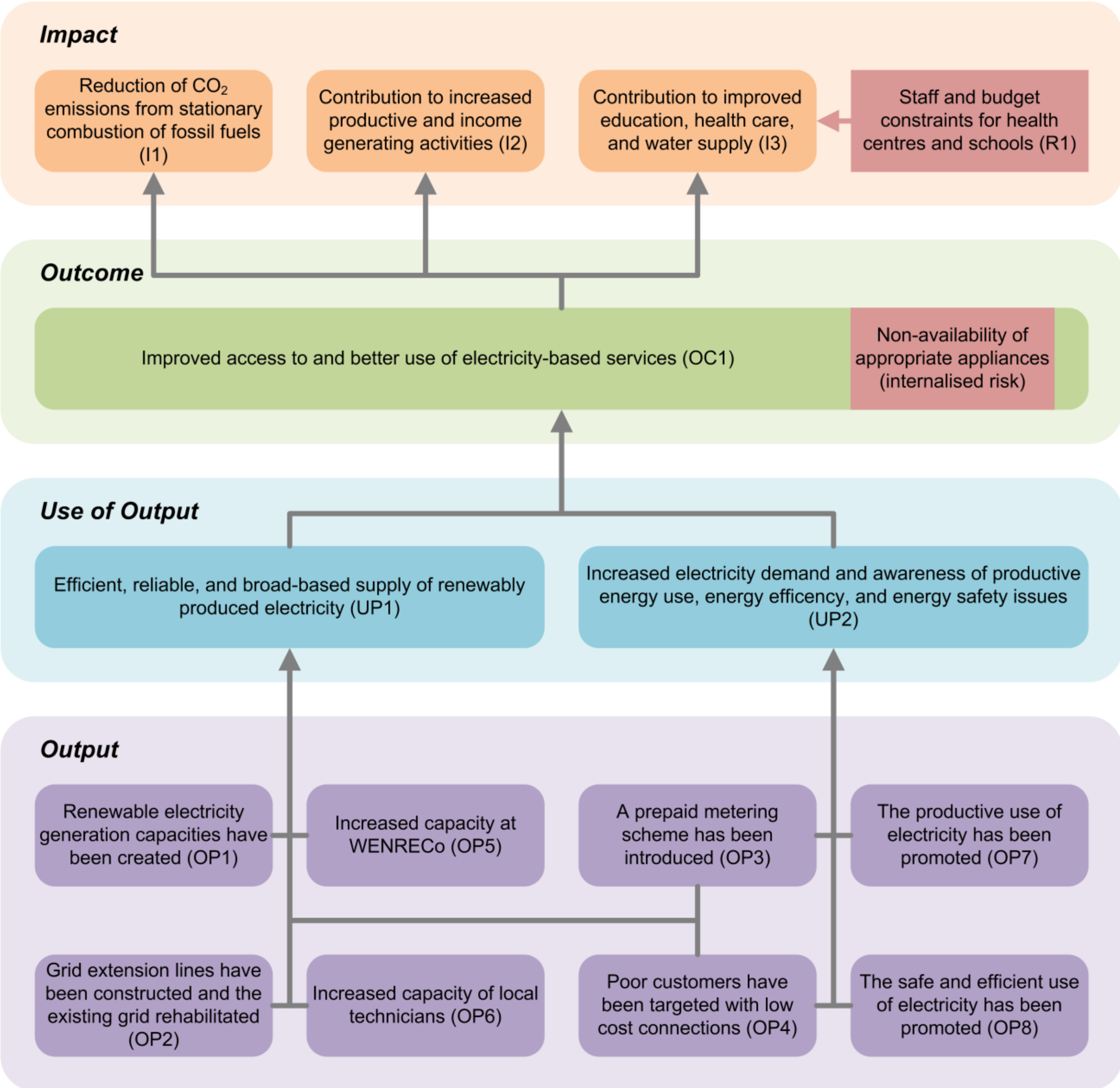
businesses, for which representative samples needed to be identified. As the electrification program is primarily connecting trading centers and towns along a clearly defined electrification corridor, they have been used as first stage sampling clusters.

Figure 1: The sub-region of West Nile



Based on a survey in 2011 of 80 trading centers and towns in West Nile, 10 out of 36 trading centers within the electrification corridor had been purposively selected as treatment group, representing all (at that time) six districts[4] of West Nile as well as different population sizes and economic characteristics. For each of the ten treatment trading centers, a trading center with similar socio-economic and infrastructural characteristics outside the electrification corridor had been identified as control group for a difference in difference analysis. Because no control group could be established for the six towns within the electrification corridor, these have been monitored separately using a simple before-after comparison.

Figure 2: The enhanced results chain



In difference to other grid electrification impact studies, we do not directly compare connected and nonconnected survey units (households and businesses), but a random sample of units

4 Pakwach district has only recently been separated from Nebbi district. However, also the new Pakwach district with 2 trading centers is covered by the monitoring.

both with and without grid access in 10 electrified trading centers[5] (treatment group), with a random sample in 10 not electrified trading centers (control group). In this way, we aim to reduce up-front the influence of confounding variables such as income effects (usually the better-off are the first to get grid connected), as the test survey showed that direct replies on income and expenditures or indirect wealth proxies such as roofing type were not sufficiently accurate for an ex-post disaggregation (e.g. by propensity score matching) of impact data according to income strata. This design results in weaker impact signals of average population values compared to other study designs.

Additionally, a full panel survey has been implemented for all health centers (91) and secondary schools (139) that had not been grid connected at the time of the baseline in 2013. Health centers and secondary schools that have been connected by 2019 have been used as treatment group (access social institutions), while the rest constitutes the control group (no-access social institutions). As a consequence, we have to consider possible bias of confounding variables, mainly the available budget of the respective institutions.

Table 1: Number of households, businesses, HCs and secondary schools interviewed

Survey cluster	Survey unit	2013	2015	2017	2019
Not electrified trading centers	Households	425	448	444	404
	Businesses	283	367	273	299
Electrified trading centers	Households	536	454 (4)*	451 (143)*	504 (135)*
	Businesses	286	325 (7)*	339 (217)*	315 (190)*
Electrified towns	Households	359	456 (7)*	306 (140)*	329 (142)*
	Businesses	423	333 (12)*	309 (227)*	316 (217)*
No-access social institutions	Health centers III	58	54	51	56
	Health centers IV & V	4	5	5	4
	Secondary schools	90	73	66	70
Access social institutions (connected by 2019)	Health centers III	20	20 (4)*	19 (10)*	19 (19)*
	Health centers IV & V	3	4 (1)*	4 (3)*	6 (6)*
	Secondary schools	33	33 (5)*	33 (26)*	35 (35)*
	Total number of interviews	**2,521**	**2,572**	**2,300**	**2,357**

* Number in brackets show how many of the randomly interviewed households, businesses, as well as of the panel of health centers and secondary schools have been grid-connected WENRECo customers.

In total between 2,300 and 2,572 interviews have been conducted every second year as presented in table 1 above. Detailed information on the conceptual approach, methodology and implementation is provided in Annex 1.

5 To verbally distinguish the access situation of households and businesses from trading centers and towns, we speak of grid connected households and businesses, but of electrified trading centers and towns. Of course, not all households within an electrified trading center are necessarily also grid connected.

Outline

While the main report focusses on the most significant and relevant insights from the impact monitoring, detailed information on methodology, implementation and detailed monitoring results can be found in the annexes. The report first describes drivers and barriers of electricity access in West Nile as the direct outcome of the electrification program as well as of solar off-grid market trends (Part I) and then analyses possible socio-economic and environmental impacts of the improved access situation (Part II).

Part I is structured in five chapters according to guiding questions on the electricity supply situation:

1 Who benefits from **improved electricity access**? The first chapter provides an overview of the development of energy access in West Nile between 2013 and 2019. Access of households, businesses, secondary schools, and health centers are presented and discussed in separate sections.

2 Is the grid power supply **reliable and efficient**? The second chapter discusses reliability and technical as well as operational efficiency of power supply.

3 Is the grid operation **viable** for the local utility WENRECo? The third chapter therefore describes the viability of power supply analyzing supply costs, demand structure and consumption trends.

4 Is grid power affordable for households and businesses? The fourth chapter discusses demand and affordability of power supply.

5 Is grid power safely and efficiently used in West Nile? The safe and efficient use of power are the topics of the fifth chapter, which completes the picture on the electricity access situation in West Nile.

Part II investigates socio-economic and environmental impacts of grid access:

6 Does grid access improve household welfare? Impacts on household welfare are traced based on household's appliance ownership, fossil fuel use, household expenditures and income generating activities.

7 Does grid access foster economic development? Impacts on economic activities are traced based on business appliance ownership, fossil fuel use, and business activities.

8 Do health services improve with grid electricity? Impacts on health services are traced based on appliance ownership, fossil fuel use, and differences in health services offered.

9 Do educational services improve with grid electricity? Impacts on secondary schools are traced based on appliance ownership, fossil fuel use, and differences in educational services offered.

10 Has grid access reduced the environmental impact of energy use in West Nile? Environmental impacts are traced for CO_2 emissions, replacement of dry-cell battery use as well as of biomass use.

The numbers at the end of the sub-headlines of each chapter refer to the respective indicators (as specified in the results chain). Detailed information on the monitoring results for specific indicators are provided in the respective indicator sheets in Annex 3.

The report concludes with **recommendations to the power utility** (on implementation issues) and to **policy makers** (on program design) and derives generalizable **lessons learned**.

In the annexes, further information is provided on the **design, methodology and implementation** of the impact monitoring (Annex 1); the general **socio-economic situation in West Nile** (Annex 2); the detailed results of **impact indicators** (Annex 3); and further references (Annex 4).

Part I

Drivers and Barriers of Electricity Access in West Nile

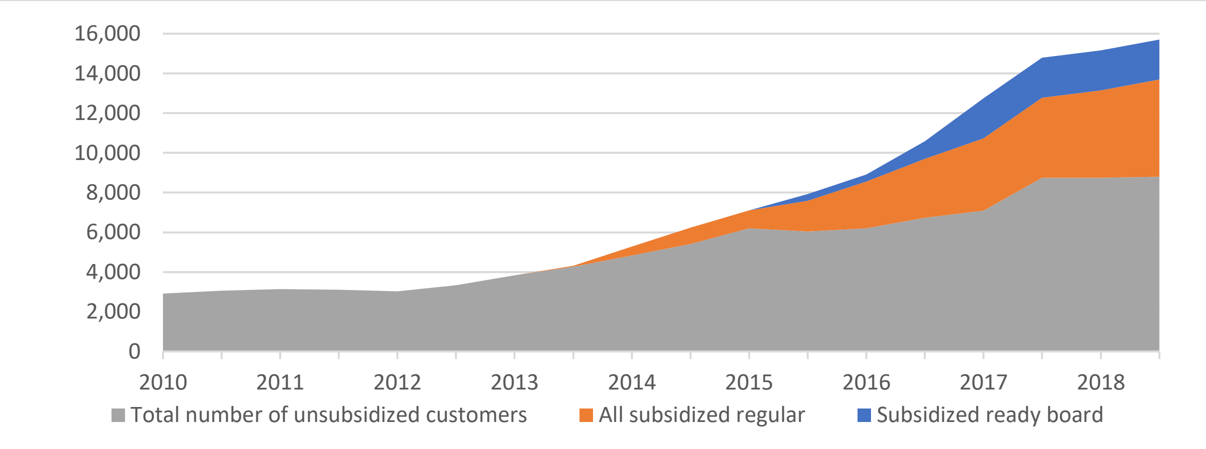
1. The electricity access situation in West Nile

Access to electricity services in West Nile is based on a variety of technologies ranging from small solar lamps to battery systems and solar home systems, to generators, and the power grid. However, there is a large difference of the service level these technologies can provide: while solar lamps only offer lighting and possibly phone charging, larger solar systems can also power electrical appliances such as a TV or fans, but a 3-phase grid power connection can provide for unlimited electricity-based services.

1.1. Grid extension and densification (UP1.1)

The West Nile grid rehabilitation and extension program (connecting the Nyagak I hydropower plant by mid-2012 and completing grid rehabilitation and extension by mid-2015) facilitated a sharp increase of customer connections which reached a total of 15,706 customers by end-2018. To reach this massive growth of customer connections, 31% have been subsidized and another 13% even included ready-boards, the costs for in-house wiring also for poor households. In total, 64% of the sharp increase of 9,469 new connections since 2015 were subsidized connections (see chart 1).

Chart 1: Development of grid customers and share of subsidized connections



By mid of 2019, 9,925 households have been grid connected, representing 58% of all customers. These households represent about 45,000[6] people that directly benefit from grid electricity, or a share of 1.6% of the about 2.8 million people in West Nile and 5% of the estimated 730,000 people living within the electrification corridor. In comparison, 17.1% of all households in West Nile used a solar system by 2016 (UBOS 2018).

The impact of grid electrification must therefore be rather measured by its geographic coverage (reaching most towns and trading centers in six districts of West Nile) and the number of connected industrial and large commercial customers, schools and health centers (see table 2

[6] This number represents the most conservative estimation, see Annex 3-3 on program outcomes for a detailed discussion of the number of direct beneficiaries.

below) all having indirect benefits for the off-grid population as presented in subsequent chapters.

Table 2: Development of grid customers by main customer groups

	06/2011	06/2013	06/2015	06/2017	06/2019
Household customers	1,538	1,965	4,107	7,258	9,925
Commercial customers	1,595	1,866	2,987	5,481	7,028
Schools	*44*	*48*	*59*	*84*	*92*[7]
Health centers	*9*	*9*	*10*	*27*	*38*[8]
3-phase commercial customers	*104*	*111*	*156*	*283*	*380*
Others (businesses, administration, NGOs, religious institutions)	*1,368*	*1,799*	*2,682*	*4,979*	*6,648*
Industrial customers	2	6	7	11	26
Total	**3,135**	**3,837**	**7,101**	**12,750**	**16,979**

To capture the differences in access, the Sustainable Energy for All (SE4All) tier access model has been used subsequently to present access levels of households and businesses within the surveyed trading centers, as well as of secondary schools and health centers in West Nile. A short overview on the SE4All tier access model is provided in Annex 4-1. All data presented for households and businesses were collected in the new grid extension areas only, where grid access started to spread from mid-2015 onwards. Data on health centers and secondary schools were collected in all seven districts inside and outside the electrification corridor.

1.2. Households and businesses (UP1.1)

As interviews with **households** were conducted within towns and trading centers[9], only households living close to the centers of towns and trading centers are covered. These households represent the upper 20% social strata of the population in West Nile.[10] Accordingly, the data on household access presented below cannot be extrapolated to the total population of West Nile. In fact, comparing our data with the results of the Ugandan National Household Survey of 2016/17 shows that average electricity access, including remote rural areas outside trading centers and towns, is significantly lower compared to the depicted situation within the trading centers[11].

In 2013, 78% of the households in towns, 82% of the households in trading centers within the electrification corridor, and 88% of the households in trading centers outside the electrification

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[7] Including 8 not reported secondary schools, who stated during the survey to be WENRECo customers.

[8] Including not reported 4 health centers, who stated during the survey to be WENRECo customers.

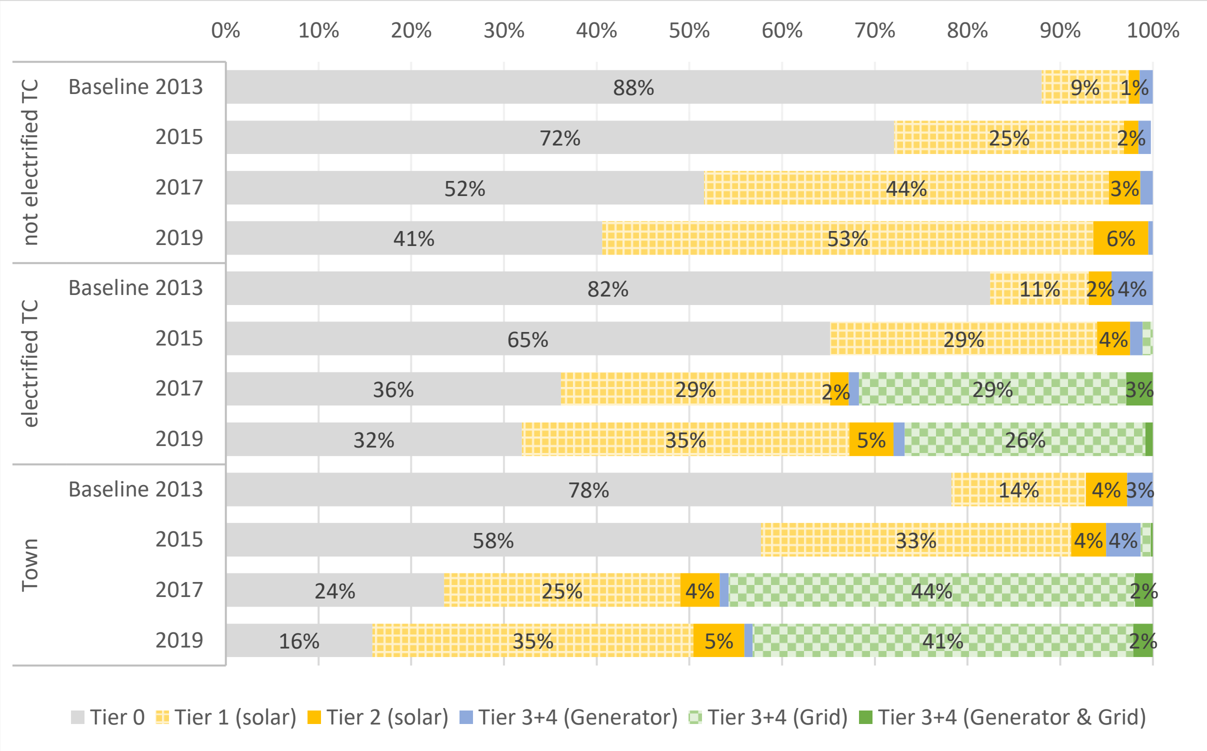
[9] In the context of West Nile, trading centers are clusters of settlements usually close to a road that comprise a couple of hundred to thousand households that administratively often belong to different villages. Most of these trading centers should be rather considered as rural than as urban settlements. For a detailed explanation of the sampling approach see Annex 1-2.

[10] For a detailed discussion of household income distribution in West Nile see Annex 2-1.

[11] In 2016/17 about 80% of households had Tier 0 access (using in equal shares kerosene and dry-cell batteries), while 17% used solar systems (mostly Tier 1) and 3% had grid access (Tier 3). See table A2-4 in Annex 2 chapter 1.3.

corridor had no access to electricity (Tier 0). This situation changed dramatically by 2019, when, driven both by increased grid and off-grid solar access, only 16% of the households in towns and 32% of the households in trading centers within the electrification corridor, as well as 41% outside the electrification corridor are without any access to electricity (see chart 2).

Chart 2: Household access to electricity by tiers



Tier 1 access describes households with a small solar or battery system for lighting and phone charging only, while for Tier 2, these households own larger solar systems together with a fan or TV. Tier 3/4 represents households with either generator, or grid connection, or both a generator and grid connection.[12]

In all clusters, Tier 1 access due to small solar systems increased significantly between 2013 and 2015 (before grid electrification arrived). By 2019, Tier 1&2 access further increased significantly and equally in all clusters, while generator use remained fairly stable at very low levels.

Within the electrification corridor, the combined Tier 3/4 access reached 28% and 44% in trading centers and towns, respectively. Many of the households with solar systems and some with generators got grid connected but are keeping their solar systems and generators as a backup option. Because households with multiple energy sources are counted according to the highest tier level reached, chart 2 above shows only half of the households with solar systems

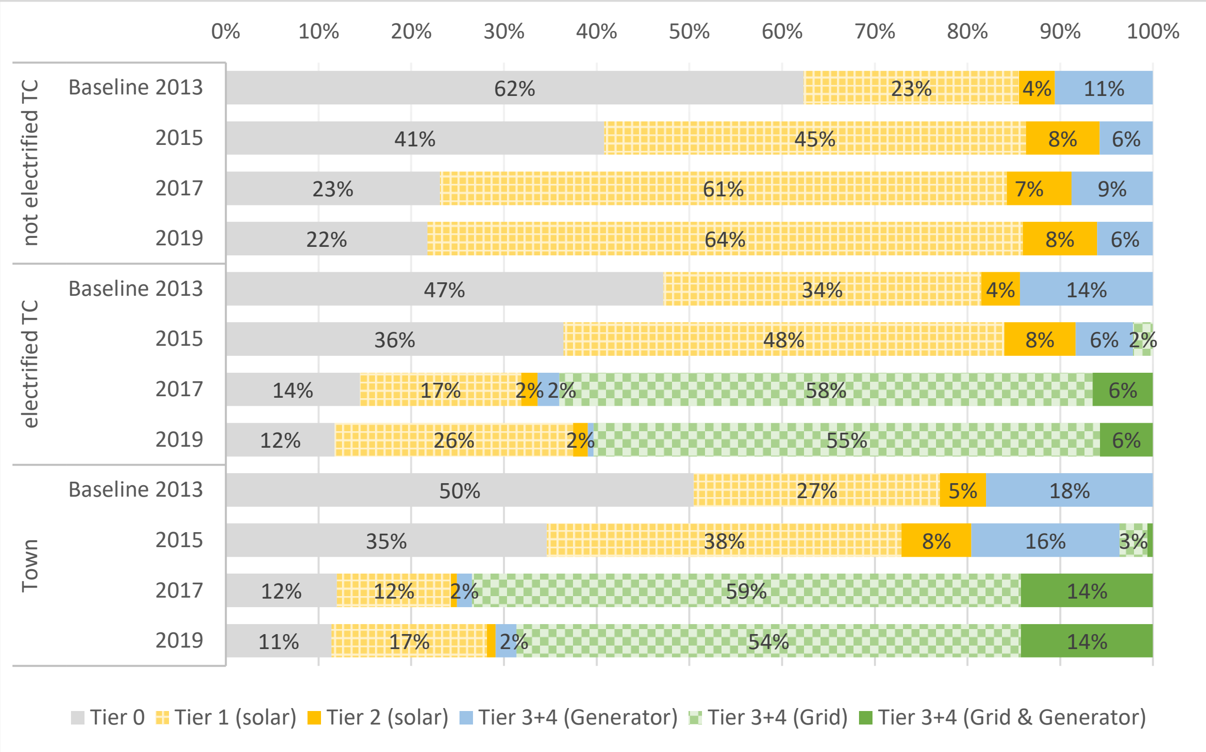
12 Both generators and grid are able to provide Tier 4 access but might be limited to Tier 3 due to cost or technical constraints. As no detailed data on daily use could be collected, the tier levels 3 and 4 were combined. See Annex 4-1 for a more detailed discussion.

(depicted as Tier 1&2): in 2019, 51% and 64% of households in electrified trading centers and towns respectively actually owned a solar system.

Outside the electrification corridor, Tier 3/4 (generators) access did not change much, while Tier 2 (large solar home systems) increased from 1% to 6% and Tier 1 access increased almost by a factor five from 9% to 53%, leaving only 41% of households without access to electricity.

In contrast to the household survey, business access to electricity in West Nile has been fairly well captured as the majority of **businesses** are based in the towns and trading centers where interviews were conducted. Again, access dramatically increased between 2013 and 2019, driven both by grid and off-grid solar access.

Chart 3: Business access to electricity by tiers



In 2013, 50% of businesses in towns and up to 63% of businesses in trading centers outside the electrification corridor had no access to electricity (Tier 0). This situation changed dramatically by 2019 when only 11-12% of businesses within the electrification corridor and 22% outside were still without any access (see chart 3 above).

In all clusters, Tier 1 access due to small solar systems increased significantly between 2013 and 2015 (before grid electrification started). By 2017, Tier 1&2 access further increased significantly outside the electrification corridor but decreased within the electrification corridor, while generator use remained fairly stable in all three survey clusters.

For grid connected trading centers, Tiers 3/4 access reached 61% in 2019, while Tier 1&2 access decreased from 38% to 28%. However, this does not mean that the use of solar systems decreased accordingly. In fact, ownership of solar systems even slightly increased by

2019 to 57% of businesses, so almost half of the businesses that own a generator and/or are grid connected also used a solar system in parallel.

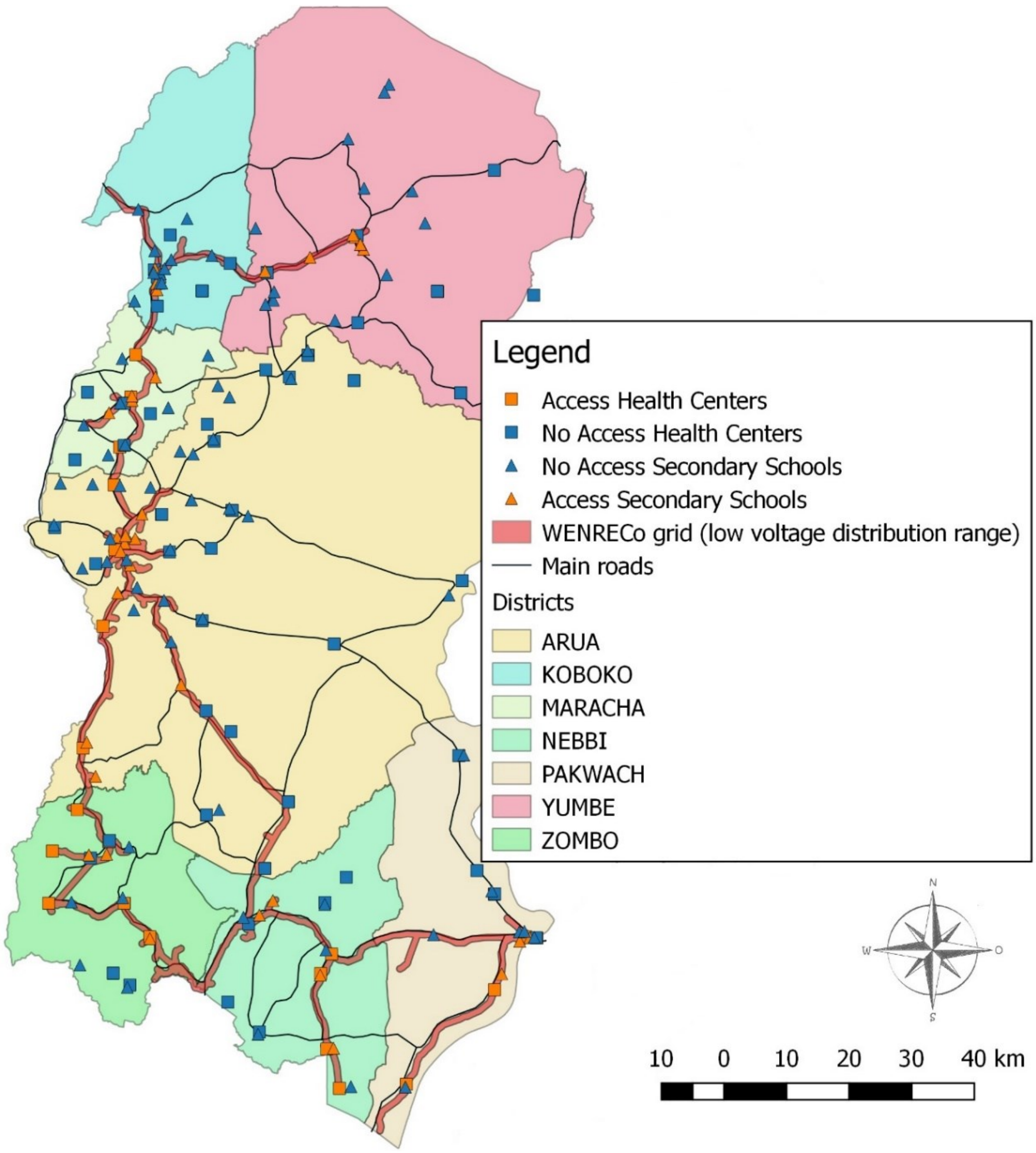
In grid connected towns, this dynamic has been even stronger, as Tiers 3/4 access reached 71% while Tier 1&2 access decreased from 32% to 18%: the use of solar systems increased from 35% to 53% in 2019 resulting again in about half of the businesses that own a generator and/or are grid connected using also a solar system in parallel.

Outside the electrification corridor, the share of Tier 2 (large solar home systems) doubled to 8% in 2019, while Tier 3/4 (generators) access has been moderately fluctuating. The main change was in Tier 1 access, which almost tripled from 23% to 64%

1.3. Health centers and secondary schools (UP1.1)

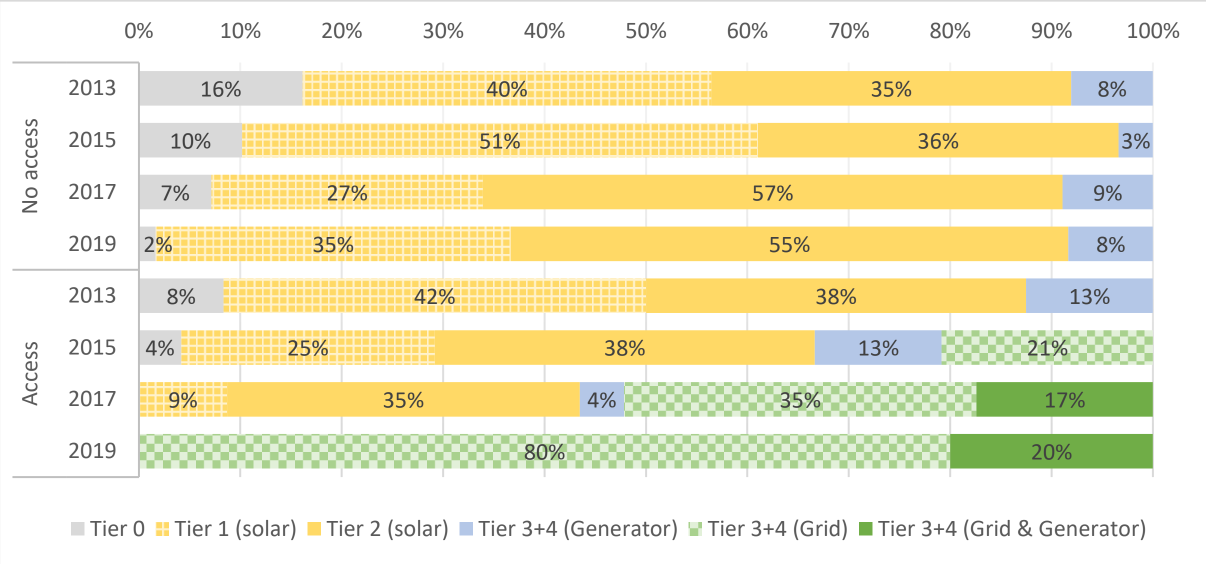
Health centers and secondary schools concentrate along the main roads in West Nile and a significant number close to the power network has not yet been connected (see figure 3).

Figure 3: Location of secondary schools and health-centers



In Uganda, **health centers** are classified from level II up to level V. Level II health centers do not operate with permanent staff and provide only few services that require electricity supply. Therefore, they are not included in the impact monitoring. Grid access increased from 9% in 2013 to 34% in 2019 (see chart 4 below). Of the 100 health centers of level III to V that had been operating in West Nile in 2013, nine were already connected and are therefore not included into the impact monitoring.[13] Of the remaining 91 health centers, 25 have been grid connected by 2019 representing the 'access cluster', while the 'no-access cluster' comprises 66 health centers.

Chart 4: Access to electricity by tiers for health centers of level III to V



By 2019, of the 60 health centers of the no-access cluster, 8% had a generator (tier 3/4), 63% large solar systems (tier 2), 13% small solar systems (tier 1), and only 6% had no access at all. Even though all 25 health centers of the access cluster have been grid connected by 2019, 20% also owned a generator and all 25 also a solar system. 16 of the not grid connected health centers were located close to the medium voltage network as specified in table 3 below.[14]

Grid access of secondary **schools** increased from 12% in 2013 to 34% by 2019. Of the 158 secondary schools that had been operating in West Nile in 2013, 19 had already been grid connected and not been included in the impact monitoring.[15] Of the remaining 139 secondary schools, 35 have been grid connected by 2019 representing the 'access cluster', while the 'no-access cluster' comprises 104 secondary schools.

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[13] For these nine grid-connected health centers, there is no information available whether they also use generators or solar systems in parallel to grid power.

[14] We have not checked the specific locations in relation to the power grid and in some cases; for the connection of these health centres, several poles or even an additional transformer might be required.

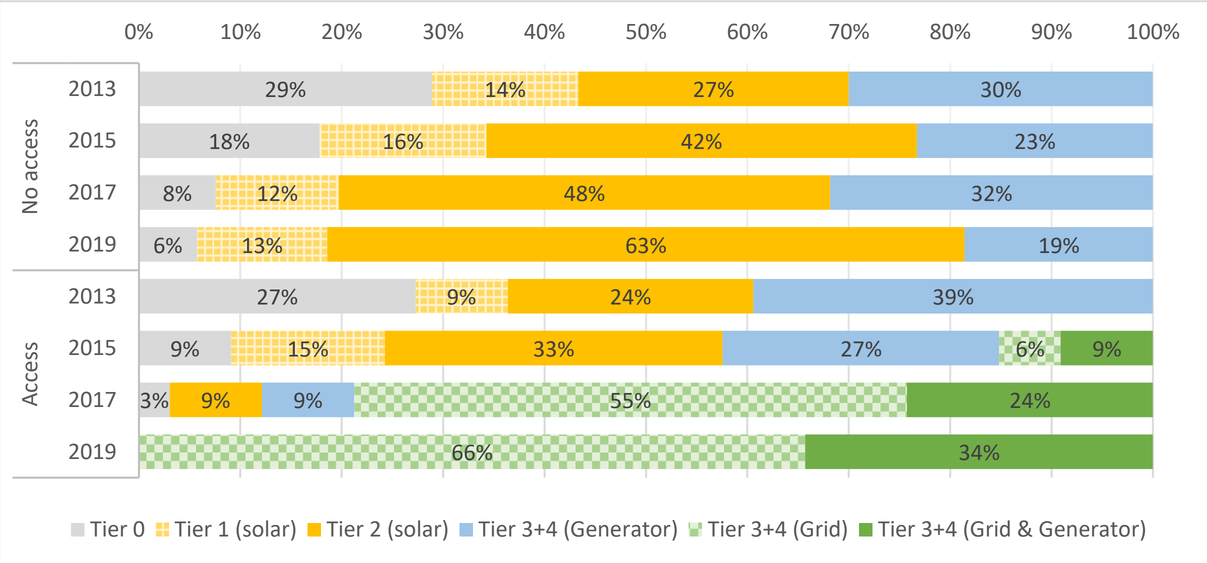
[15] For these 19 grid-connected schools, there is no information available whether they also use generators or solar systems in parallel to grid power.

Table 3: Nonconnected health centers in vicinity of the power grid

District	Health Center
Arua (7)	1. Adumi Health Center IV 2. Ajia Health Center III 3. Oluko Solidale Nutrition and Health Centre III 4. Orivu Health Center III 5. St. Francis Health Center III 6. St. Jude Olepi Health Center III 7. Ulepi Health Center III
Koboko (4)	8. Ayipe Health Center III 9. Dranya Health Center III 10. Gborokolongo Health Center II 11. Koboko Mission Health Center III
Maracha (1)	12. Ovujo Health Center III
Nebbi (1)	13. Kalwang Health Center III
Pakwach (1)	14. Siripi Health Center III
Yumbe (2)	15. Kochi Health Center III 16. Matuma Health Center III

By 2019, of the 104 secondary schools of the no-access cluster, 19% had by 2019 a generator (tier 3/4), 63% larger solar systems (tier 2), 13% small solar systems (tier 1), and only 6% had no access at all (see chart 5). Even though all 35 secondary schools of the access cluster have been grid connected by 2019, 34% also owned a generator and 83% also a solar system.

Chart 5: Access to electricity by tiers for secondary schools



With 88% of secondary schools benefiting from at least Tier 2 access, huge progress has been made in increasing energy access for these institutions. However, we will see in subsequent chapters that this achievement will not necessarily translate into development impacts if the service quality and reliability (both for grid and solar systems) is poor and if schools have not the budgetary means to invest in appliances and qualified staff. 24 of the not grid connected secondary schools were located close to the medium voltage network as specified in table 4 below.[16]

Table 4: Nonconnected health centers in vicinity of the power grid

District	School
Arua (5)	1. Arua Academy 2. Arivu Secondary School 3. Mandela Comprehensive Secondary School 4. Latino Foundation S.S 5. Ocoko Modern Day Secondary School
Koboko (8)	6. Day Star Secondary School 7. Koboko Parents Secondary School 8. Kochi Secondary school 9. Midland Secondary School 10. Millenium College 11. Nyai Secondary School 12. Ombachi Self help Secondary School 13. Progressive high school midia koboko
Maracha (2)	14. Maracha High School 15. Victory Secondary School
Nebbi (2)	16. Nebbi Progressive Secondary School 17. Nyaravur Secondary School
Pakwach (5)	18. Alwi Secondary School 19. Excel College Pakwach 20. Nam High Secondary School 21. Ogenda girls' High School 22. Panyimur secondary school
Zombo (2)	23. Atyak Secondary School 24. Zeu Secondary School

[16] We have not checked the specific locations in relation to the power grid and in some cases; for the connection of these secondary schools, several poles or even an additional transformer might be required.

2. Reliability and efficiency of power supply

Reliable and efficient power supply is a precondition for the viability of any power utility: only if the power supply is reliable, it can attract high consuming and therefore profitable commercial customers who provide the required income to cross-subsidize rural domestic consumption, provided such income is not required to compensate first for high technical and commercial losses.

2.1. Blackouts and load shedding (UP1.5)

As measures for network stability, the System Average Interruption Duration Index (SAIDI) and the System Average Interruption Frequency Index (SAIFI) are internationally used as benchmarks, but related reporting of sub-Saharan utilities is very poor in general (Kojima and Trimble 2016, 27). A recent Network Assessment Baseline Report for Uganda confirmed this observation for Uganda, recommended to improve reporting on SAIDI and SAIFI, and proposed annual benchmarks of 50 hours for SAIDI and 60 interruptions for SAIFI (AZOROM 2018, 48). The SE4All tier framework for electricity access also sets benchmarks on reliability of power supply: To qualify for Tier 4 access, a maximum of 14 power disruptions per week is acceptable, resulting in a SAIFI of 728 interruptions per year. To qualify for Tier 5 access, less than 2 disruptions per week (SAIFI of 104) and a total duration of less than 2 hours per week are required; the latter could be interpreted as a SAIDI of 104 hours.[17]

The calculations of SAIDI and SAIFI require the detailed documentation of the number of customers affected as well as the duration of each outage. Since WENRECo has not been able to provide such data, only the share and average duration of outages was monitored. As a planned interruption, load shedding was documented separately. Monitoring of outages and load shedding has been weak. During some periods in 2013 and 2014 WENRECo could not provide data for outages and load shedding (see charts 6 and 7 below).

Only 43% of household customers in trading centers stated in 2019 to be satisfied with the reliability of power supply compared to 60% of town customers. But 70% of both groups said that the situation improved compared to 2017. Still, supply reliability has been a key complaint over the whole monitoring period including the 2019 stakeholder workshops and interviews[18], and one out of five nonconnected businesses states low reliability as a reason not to get connected (see chapter 4). Especially large consuming industries, counting for 12% of total power consumption in 2018 down from 15% in 2017, are affected by the low reliability and drought

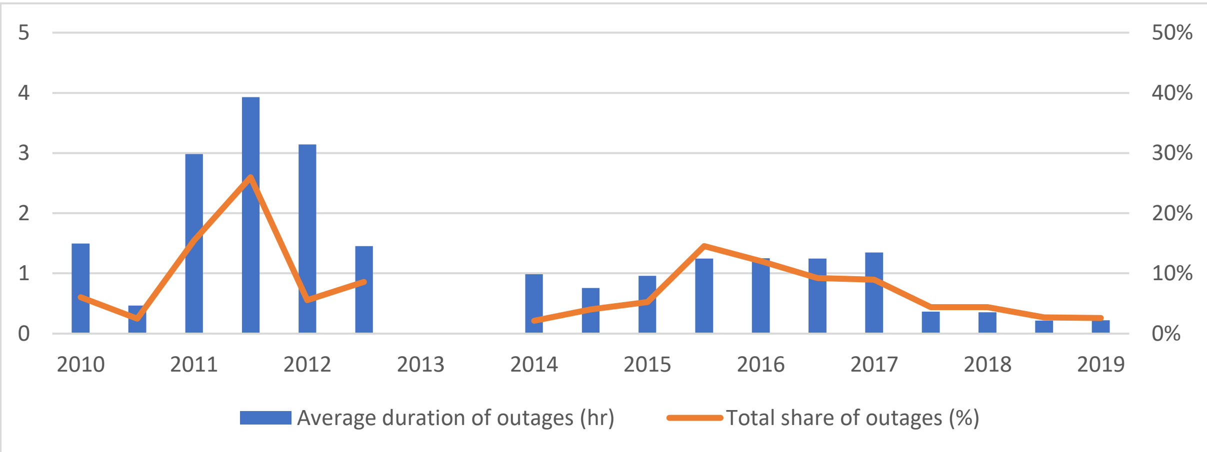
17 The SE4All framework (See Annex 4.1) does neither distinguish planned or unplanned interruptions, nor does it normalize interruptions regarding affected customers in relation to total number of customers. It also does not define a minimum threshold for interruptions such as defined for SAIDI and SAIFI, which only consider interruptions beyond 3 minutes. The comparison of the SE4All reliability requirement with a SAIFI value is therefore only an approximation.

18 Participants of stakeholder workshops repeatedly stressed that frequent outages and unannounced load shedding frustrate customers and particularly affect business activities. The positive perception of recent improvement might be influenced by the fact that just 2 weeks before the quantitative survey in 2019, MEMD added a 2.6 MW emergency diesel generator to the network, greatly improving the supply situation and leading to two weeks of little uninterrupted power supply just before the survey.

related supply bottlenecks. The largest customer, the Meridian Tobacco Company reported in 2017 an average availability of the WENRECo grid of only 64%.

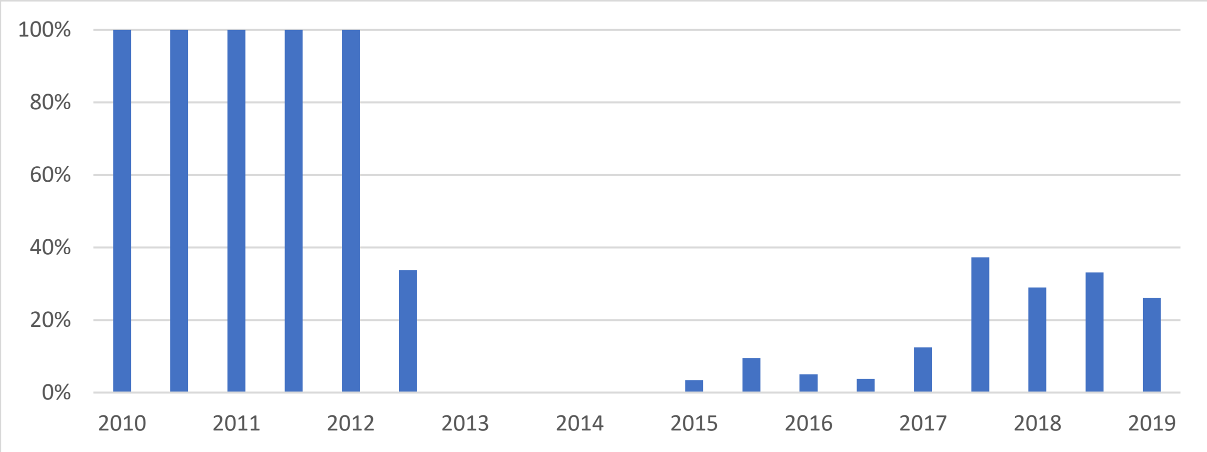
Outages (especially in the case of a failure in the power plant Nyagak I) might occur as or culminate in a total network break-down. In other cases, outages are caused by failures within a specific section of the distribution network, affecting limited grid areas and customers. According to WENRECo data, outages peaked in the second half-year of 2012, and again in 2015/2016, when the new network sections were commissioned. *"From a review of WENRECO generator outages during 2016 it was noted that of 668 outages the vast majority were due to network incidents" … "much better coordination is required to avoid machine tripping during network incidents – whether fault incidents or switching operations"* (AZOROM 2018, 40). By the end of 2018, the share of outage time decreased significantly to 3% or an average of 43 minutes per day. However, assuming that on average only 50% of the customers have been affected by each outage would still result in a SAIDI of 153 hours and a SAIFI of 850. These values are far beyond the proposed benchmarks of 50 hours for SAIDI and 60 interruptions for SAIFI and would also fall short of the SAIFI 728 benchmark to qualify for SE4All Tier 4 access level considering the requirement on reliability.

Chart 6: Share and average duration of blackouts



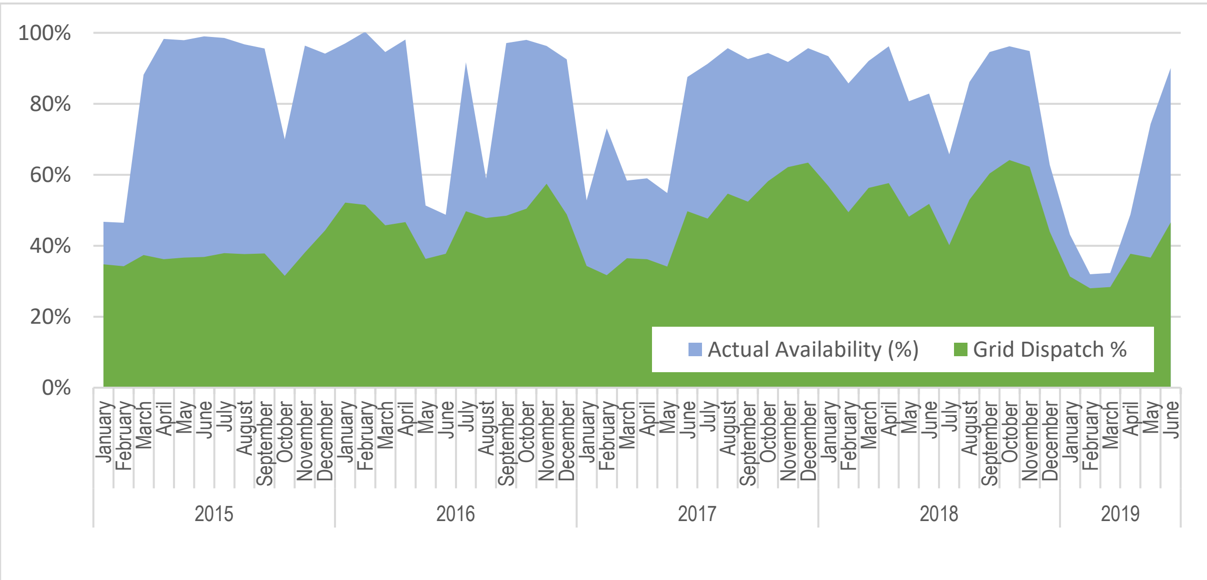
Operation of the isolated West Nile power grid expanding over 200 km from the only power plant Nyagak 1 in Zombo district up to Yumbe town is technically demanding even under favourable conditions. WENRECo also stresses that it is facing network design challenges, such as long, lightning prone distribution lines with comparatively low loads as well as maintenance challenges, as some parts of the distribution poles could not be accessed for tree clearance due to delayed compensation for land and way leave.

Chart 7: Share of load shedding



Load shedding occurs when the generation capacity is not sufficient to meet power demand in the network. Between 2013 and 2018, the West Nile power grid has been supplied only by the one hydro-power plant Nyagak I, without any redundancies in case of breakdowns or supply deficits, so main reasons for load shedding are technical failures of the power plant, drought-caused water scarcity, or power demand beyond supply capacity. Since the second half of 2015, WENRECo reported load shedding that increased to 37% or almost 9 hours per day for the end of 2017, and reached 33% or 8 hours per day by the end of 2018 and 26% or 6.2 hours per day by mid-2019.

Chart 8: Power generation and dispatch (2015 – mid-2019)



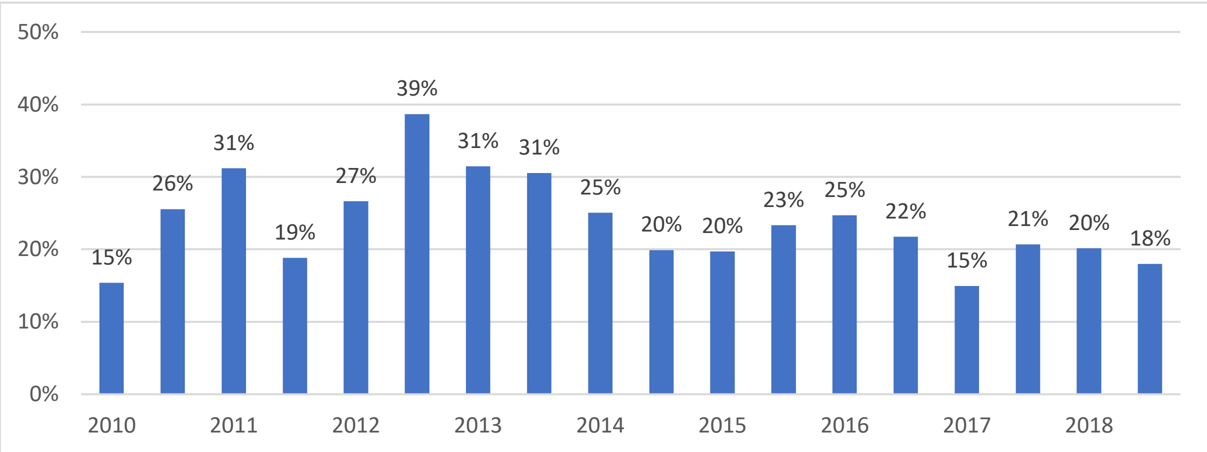
Analysis of generation data (chart 8 above) shows that power generation is influenced by seasonal water availability in Nyagak river and the technical availability of the hydropower plant. In May and June 2016, one of the two turbines of the hydropower plant was under repair, halving its technical capacity. In June 2018, a generator was under repair. In February and October 2015, August 2016, January until May 2017, January and November/December 2018, availability was limited by a drought that reduced the water level in Nyagak river. The drought in early 2019 was the most severe since 2015, but the monitored time period is too short to already deduct future trends.

In times of water scarcity, WENRECo is forced to shed loads over the day to guarantee sufficient water availability to reach full generation capacity in the evening, where the power demand peaks. But since 2017, we observe a stronger increase in load shedding which (especially in the second half of 2017) is not caused by a reduced availability and power dispatch of the power plant, but by the evening peak load surpassing the installed capacity of 3.5 MW.[19]

2.2. Technical and operational losses (UP1.3)

Technical and commercial losses (without tariff collection) stand at about 18% by end-2018 (see chart 9 below). The difference of generated and billed electricity compared to total generated electricity dropped from 39% in 2012 to 20% in 2015. This success in loss reduction can be attributed to the grid rehabilitation program reducing technical losses including the theft of electricity due to illegal grid connections. But losses increased again after lows in 2015 and 2017. WENRECo was able to push its losses down to 15% in 2017 by greatly reducing commercial losses due to manipulated meters. Meters have been moved from house walls to the top of the closest grid pole. However, during the massive connection of new customers in 2017/2018 again many meters have been installed on house walls instead. WENRECo is gradually moving also these new meters to pole tops (losses further reduced to 17.2% in mid-2019).

Chart 9: Technical and commercial losses



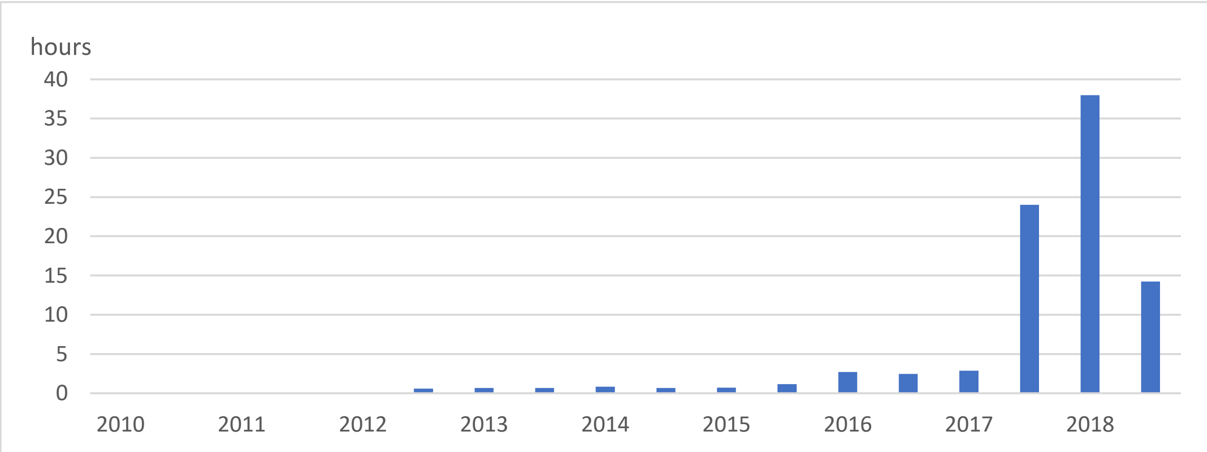
Furthermore, the switch to pre-paid metering improved billing accuracy and increased the collection rate since 2014. There have been indications that fee collection has significantly decreased since the second half of 2017, but WENRECo has not been able to provide consistent data. The WENRECo pre-paid customer data base reached 14,922 or 95% of customers in end-2018. As WENRECo has not been providing clear data on the fee collection rate it remains unclear whether the program target value for total loss reduction of 21% including tariff collection by 2018 has been reached.

19 MEMD recently mitigated this situation in May 2019 by adding 2.6 MW emergency diesel to the West Nile network, which are planned to be replaced by two 4 MW HFO generators to be installed by end of 2019.

2.3. Customer service (UP1.6)

47% of household customers in trading centers stated in 2019 to be satisfied with the customer service of WENRECo compared to 67% of town customers. However, 60% of trading center customers and 65% of town customers said that the situation improved compared to 2017. One continued source of complaint is that pre-paid units can only be purchased at one of the six WENRECo outlets in the district capitals, not easily reachable for rural customers. WENRECo introduced an own mobile payment system, which collapsed in 2018. Since then, there are only informal and insecure ways to purchase remotely power via private local agents.

Chart 10: Response time on customer complaints



WENRECo did not monitor its response time until mid-2012. Since then, the average response time on customer complaints increased from 0.6 h to 14 h in the second half-year of 2018, after a peak of 38 h in the first half-year of 2018 (chart 10). WENRECo justifies the increasing trend of response time with the fast growth of network and customers and a deteriorating staff to customer ratio. The strong increase since the second half-year of 2017 was explained by decentralization of customer care to the technical staff in WENRECo branch offices who lack structured work-flows for complaint management as well as training in customer care.

3. Viability of power supply

A recent review on 39 Sub-Sahara African power utilities revealed that while 95% were not able to cover capital costs, 45% could not even cover operational costs, thus placing a high burden on public budgets (Kojima and Trimble 2016, 7). For grid power to be economically sustainable in the long run, utilities must generate sufficient revenues, which usually come from a relatively small number of large commercial and industrial customers.[20] Therefore, beside reducing losses and maximizing operational efficiency (see previous chapter), a good understanding of the demand structure and density of the current and possible future customer base is essential.

Regarding the data provided in this chapter it is worth noting that due to a breakdown of its servers in summer 2018, WENRECo was not able to provide data for 2019 and also data provided for 2017 and 2018 was not fully consistent.

3.1. Supply costs (UP1.2)

For a power utility, low consuming rural customers represent an operational challenge. This is due to the fact that the costs of power, distribution, and billing (including both operational and capital costs) are often higher than the collected revenues (due to tariff regulation or limited demand and ability to pay by customers) and therefore need to be cross-subsidized. But West Nile does not have significantly large cities or economic centers and WENRECo has to balance high operational costs with a lower depreciation due to the high subsidies received for the initial investment into the grid infrastructure and power generation.[21]

During the planning of the West Nile electrification program two key strategies have been applied to balance operational costs and incomes:

1. Concentrating on customers in a limited number of towns and trading centers in defined corridors, thereby creating a higher demand density in areas with both wealthier households and commercial customers.
2. Giving preference to commercial customers who use electricity productively, which increases demand and thus revenues for the utility.

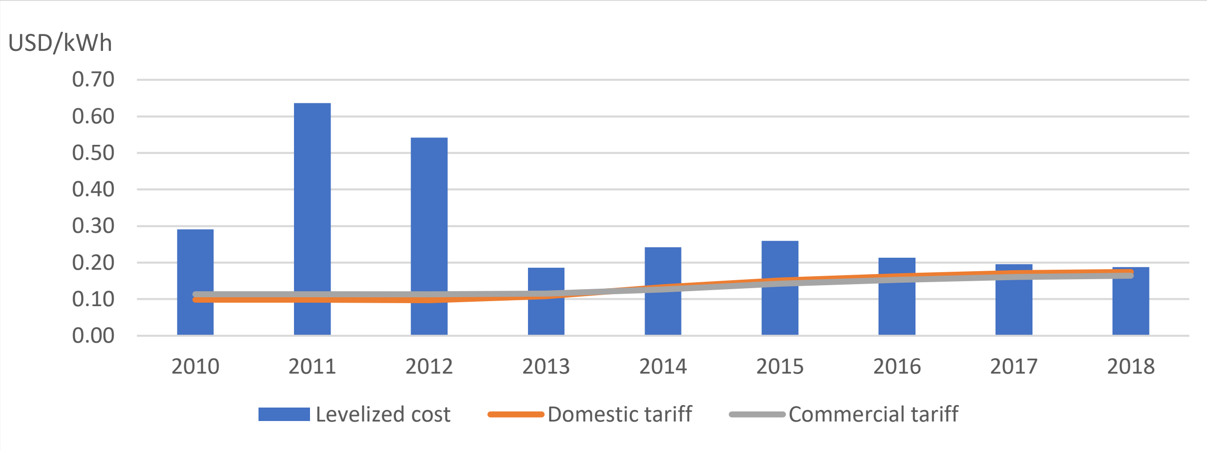
Over past years, WENRECo has increased its technical and commercial efficiency, reducing its levelized cost of electricity supply just below 700 UGX (USD 0.19) per kWh (see chart 11 below). Supported by significant subsidies, costs have now reached a range to be matched by income from tariff and fee collection. Over the past nine years WENRECo did break even only in 2016 and 2017, but costs have been strongly affected by the massive recent investments in additional customer connections. Whereas it can be stated that commercial viability of WEN-

[20] WENRECo generates about 40% of its revenues from large commercials and industries representing only 2.5% of its customers. Similarly, large commercials and industries represent only 0.06% of Kenya powers customers but consume 55.4% of its power (Taneja 2019).

[21] This of course bears the risk that WENRECo will not be able to independently cover the required future investments in rehabilitation and replacement of its infrastructure base (see Kojima and Trimble 2016).

RECo remains a concern, it is not possible to provide clear projections without a detailed financial assessment.[22]

Chart 11: Levelized cost of power generation



3.2. Demand structure (UP1.2)

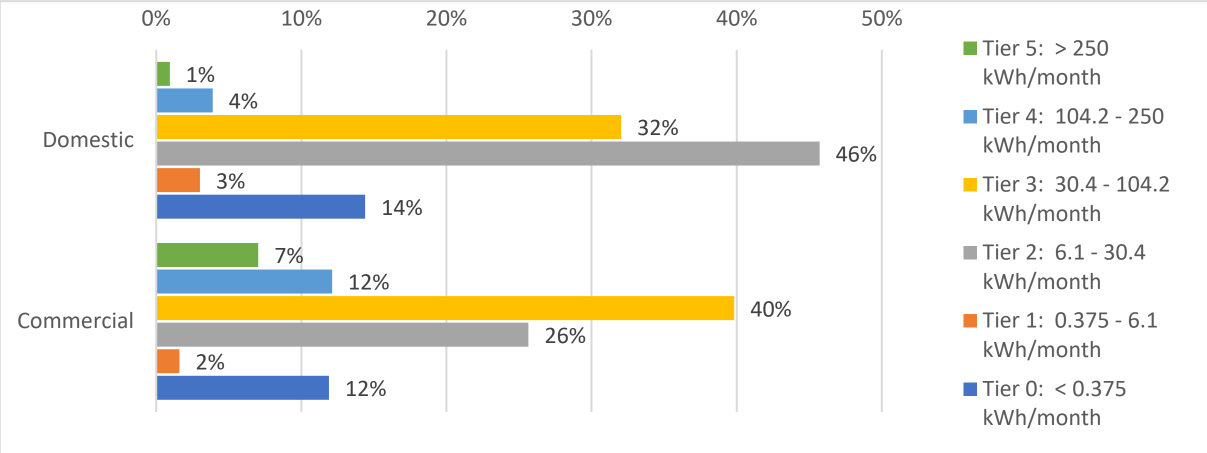
To effectively consume electricity, newly connected customers need investments in electrical appliances and machinery, which will only be made if funds are available, power supply is perceived to be reliable, and if customers see that gains in efficiency or service will pay off investments in a short time. As this trust building usually takes some time, utilities are faced with lower power demand in the first two years after grid connection (Taneja 2019).

To analyze the consumption of grid customers over the one-year period of 07-2016 until 06-2017, WENRECo's domestic and commercial customers have been clustered into SE4All Tier levels according to their actual monthly consumption (chart 12).[23]

[22] While KfW Development Bank provided materials for 3,000 connections, almost 14,000 connections have been implemented by WENRECo since 2013. Together with costs related to increased personnel and set-up of new offices, we can assume that a significant share of the total expenditures reported by WENRECo in recent years are not caused by normal O&M costs, but by these investments. It would need a financial audit to separate these costs from standard O&M costs and depreciation (see Annex 3, chart A3-3 for details).

[23] The consumption has been approximated by the total amount of purchased power over the 12-month period. The approximation should be fairly accurate, as customers frequently purchase small amounts of power (the average frequency for households to purchase pre-paid power at UGX 20,000 has been 2.4 times per month and for commercial customers 3.6 times per month at UGX 30,000 each).

Chart 12: Domestic and commercial electricity consumption by tiers



Most of the, at that time, 7,104 pre-paying households were Tier 2 (46%) and Tier 3 (32%) customers, while only 5% were consuming at Tier 4 and 5 levels. However, about 14% of the customers were using power only irregularly, having not or only once purchased power over the last 12 months, and another 3% were at the extremely low Tier 1 consumption level. Average consumption of Tier 1-5 customers was 41 kWh per month[24], while the median consumption was only 26 kWh per month. Tier 0, 1 and 2 customers, using less than one kWh per day, can usually be more cost-efficiently serviced by solar systems. This applies currently to about 64% of WENRECo's household customers.

Of at that time 5,333 pre-paying commercial customers, most were Tier 3 customers (41%), followed by Tier 2 customers (26%), while 20% were Tier 4 and 5 customers. 2% were using very little power at Tier 1, and 12% were not regularly using power and must be considered Tier 0. Average consumption of Tier 1-5 customers was 136 kWh per month[25], while the median consumption was only 48 kWh per month. Equally as for household customers, this signifies that currently about 40% of all commercial customers might have been more cost effectively serviced with solar systems – unless power consumption is increasing significantly over the next years.

3.3. Power consumption trends (UP1.2)

The development of the average power consumption of domestic and commercial customers over time shows that until commissioning of the Nyagak I powerplant in late 2012, supply shortage and resulting load shedding suppressed power consumption (see chart 13 below).

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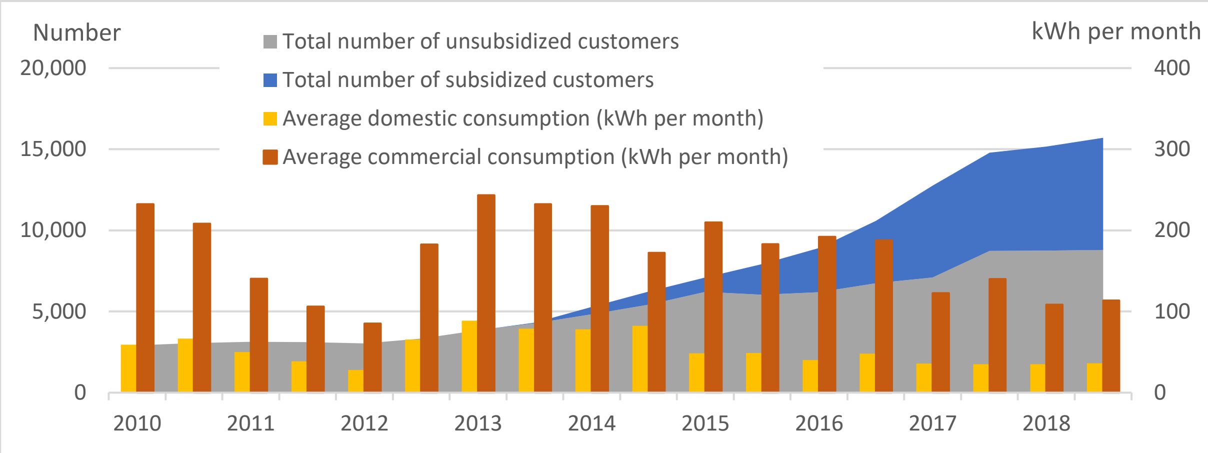
[24] As average consumption for all domestic customers has been 44 kWh, this data suggests that pre-paid customers are using less power compared to the remaining post-paid customers (see section 3.3).

[25] Again, average consumption of all commercial customers has been significantly higher at 190 kWh per month, highlighting the comparatively high power use of the remaining post-paid customers.

Chart 13: Average monthly power consumption



With sufficient power available, average consumption peaked in 2013 at 243 kWh and 89 kWh per month, respectively, for 1,866 commercial and 1,965 domestic customers at that time. Since 2013, the number of customers almost quadrupled, strongly driven by subsidized connection of almost 7,000 new customers. At the same time, average monthly commercial consumption decreased to 114 kWh by 2018, while average domestic consumption shrunk down to a mere 36 kWh per month. Since late 2017, the new occurrence of load shedding added to this downward trend.

This result is in line with a recent analysis of the impact of massive grid extension on average domestic consumption in Kenya: Aggressive grid extension more than doubled the connection rate to beyond 50% over the last decade, but resulted in a decrease of average domestic consumption by about 70%. While rural households connected in 2009 stabilized after 2 years at a median consumption of 30-35 kWh per month, households connected in subsequent years reached even lower levels down to 15-20 kWh per months for households connected in 2014/2015 (Taneja 2019).[26] As the electrification rate in West Nile is only 3%, we can expect that future grid extension and densification will further lower the average domestic and commercial demand.[27]

The analysis of the demand structure of WENRECo customers between July 2016 and June 2017 showed that 63% of domestic customers and 40% of commercial customers purchased less than one kWh per day or 30 kWh per month. Within the same period, the average domestic consumption was about 44 kWh per month and further decreased until the second half of 2018 by about 18% to 36 kWh per month, while the average commercial consumption, about 190 kWh per month, decreased even by 40% down to 114 kWh per month. These trends suggest that the share of domestic and commercial customers using less than 30 kWh, rather than

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[26] In contradiction, Khandker (2009) showed for rural Bangladesh that household electricity consumption increased by about 5 kWh per month for every five years a household was connected to the grid, but Peters et al. (2016) and Hamburger et al. (2019) challenged that impact findings from Asia and Latin America cannot directly be transferred to the Sub-Saharan African context.

[27] For the comparison with West Nile, it is important to note that Kenyan households are post-paid customers, while data e.g. from South Africa suggests that introduction of pre-paid meters has reduced domestic consumption by 12-15% (B. Kelsey Jack and Grant Smith 2019).

decreasing over time as assumed, actually is further increasing. The increasing share of low consuming customers combined with the effort for operation, maintenance and management of a growing network and customer base places a high burden on WENRECo's economic viability.

The ongoing additional grid extension activities by REA, ERT-3, plans to connect the large refugee settlements to the grid, as well as the pressure on WENRECo to further densifying its existing network risks to further impair the income per customer ratio undermining the little progress made so far.

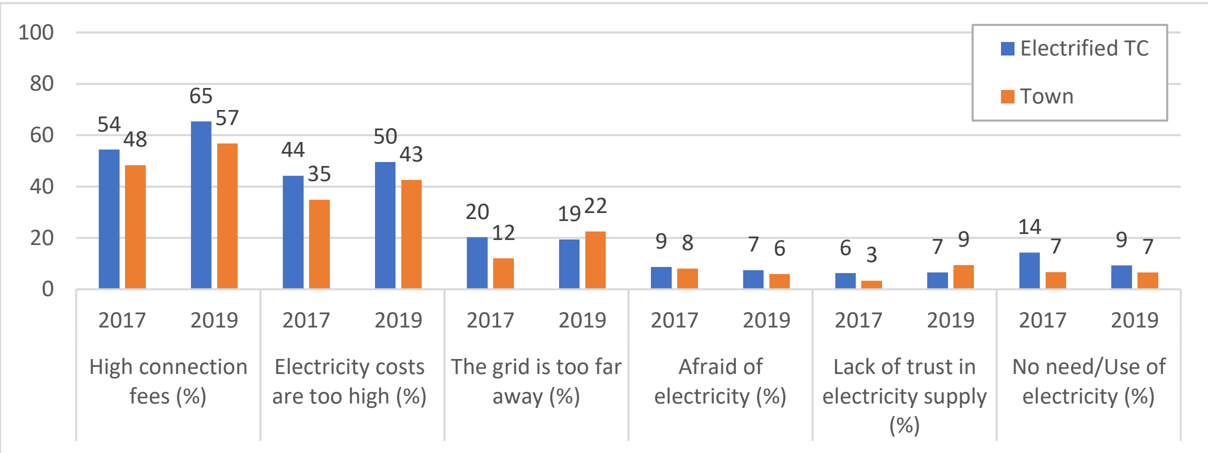
4. Affordability of grid access

In rural areas of Sub-Saharan Africa purchasing power is low; accordingly, tariffs have to be low as well when larger shares of the population are targeted with grid electricity. In fact, many countries offer subsidized connections (Golumbeanu and Barnes 2013) and about half of 39 surveyed national utilities were offering subsidized lifeline tariffs in 2015 with Uganda offering the smallest block limited to the first 15 kWh per month (Kojima and Trimble 2016).

4.1. Demand for grid connection (UP2.1)

Off-grid households and businesses in West Nile express a high demand for power, with 79-92% of interviewed not connected households and 89-94% of interviewed businesses stating that they would like to use electricity for private and/or commercial purposes. The demand is highest outside the electrification corridor, supposedly as in trading centers and towns within the electrification corridor the most interested households and businesses already got grid connected.

Chart 14: Reasons for off-grid households for not getting connected

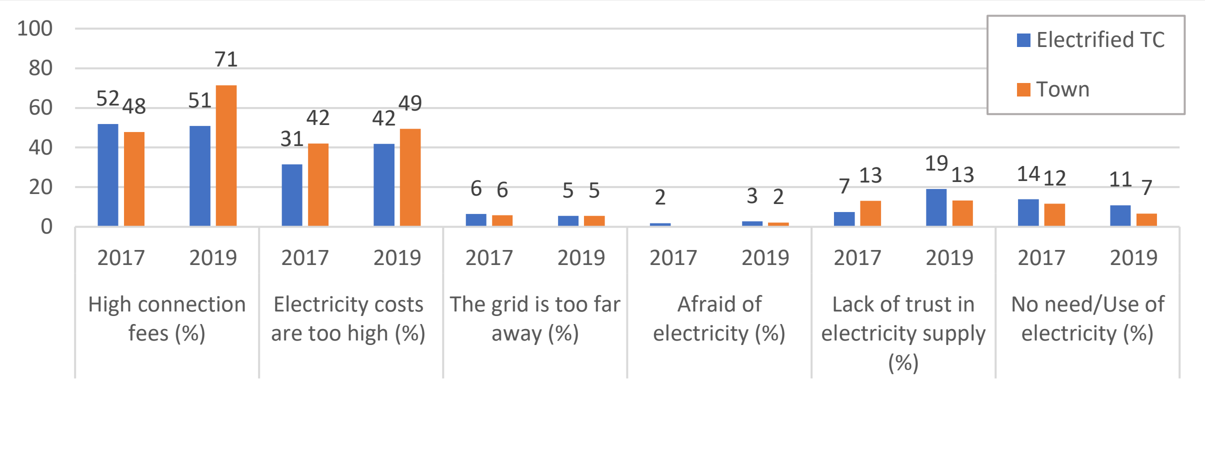


For off-grid households and businesses within the electrification corridor the main reasons preventing a grid connection are the costs for connection and electricity consumption (see charts 14 and 15). For households, also the distance to the grid is an issue (which possibly became a larger problem in towns as the electrification corridor covers only a small fraction of the towns and multi-pole connections remain very costly), while a decreasing share of 6-7% of the households stated to be afraid of electricity.

For businesses (see chart 15), also the lack of trust in the electricity supply has been stated by 13% of businesses in towns, while the share in trading centers more than doubled from 7% in 2017 to 19% in 2019.

While 7% of both businesses and households in towns and a little more in trading centers stated to have no need for electricity, most of these stated in the same interview the high costs as the main barrier. This could be seen as an indication for a “suppressed” demand for getting connected rather than the absence of the demand for electricity.

Chart 15: Reasons for off-grid businesses for not getting connected



It stands out that even though cost of grid connection has, by means of growing subsidies, been continuously decreasing over the program period[28], the perceived barrier of high connection fees still increased. This might have two reasons:

- Connection fees make only for a part of the cost of grid connection, as customers need to get first the inhouse wiring done by a certified technician. This cost is probably still prohibitive for many poor households.[29]
- Especially in towns, the electrification corridor covers only a fraction of the settlement area leaving many households and businesses outside the 90-meter range of a subsidized one-pole connection.

Untargeted subsidies for grid connection have been criticized to favor better-off households and recent empirical research showed that increasing subsidy levels do not yield proportional increases in uptake unless almost 100% are subsidized (Bos, Chaplin, and Mamun 2018; Chaplin et al. 2017; Lee, Miguel, and Wolfram 2016).

Furthermore, about half of nonconnected households and businesses also stated the costs of grid electricity as a main barrier. This will be discussed in the following section.

4.2. Affordability of grid electricity (OC1.4)

While most of the nonconnected households and businesses expressed their interest to get grid connected, about half of them stated cost of electricity a main barrier. But also 50-70% of grid connected households and 50-60% of grid connected businesses complained about high costs. Though, more than 90% of connected customers stated to have during the last two

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28 REA established a revolving Fund for electricity connections by the end of 2016, greatly reducing the cost of no-pole grid connection to UGX 98,000 (about USD 28). In 2018, the Government of Uganda launched a new Electricity Connection Policy aiming for a national connection rate of 60% by 2027. Since November 2019, all no-pole or one-pole connections up to 90 m distance are free (beside an inspection fee between UGX 20,000-41,300).

29 We have to remember that the interviewed households in trading centers already represent rather the upper 20% income quintile of the West Nile population and the perceived barrier can be expected to be much higher in remote rural areas.

months used power with less than 3 days of interruption. Therefore, while many customers complain about the cost, most can actually afford it, though maybe not to an extent they would wish.

Repeatedly stated complaints[30] about electricity cost focus on three issues:

1. **West Nile has not been included into the national lifeline tariff regime:**
   While customers of the national grid benefit from a lifeline subsidy that reduces the cost of the first 15 kWh per month to only UGX 250/kWh, WENRECo customers have to pay the full tariff of currently UGX 710 from the first consumed kWh on.
2. **WENRECo charges service fee for limited or no service:**
   Service fee is charged also for months in which no or very little power has been supplied by WENRECo due to outages or load shedding.
3. **Service fee is charged also for months with zero balance:**
   In case customers cannot afford to use power for a couple of months and purchase pre-paid power units after this period, the service fee for these past months is deducted first, leaving little or nothing for purchasing power units. This hurts especially poor customers with irregular income who cannot purchase power every month.

Table 5: Comparison of WENRECo and national (Umeme) tariff system for households

As of 2Q 2019	WENRECo		Umeme	
Monthly service fee	3,360 UGX		3,360 UGX	
Tariff	710 UGX		760 UGX	
Lifeline tariff	Not applicable		250 UGX for the first 15 kWh	
Monthly electricity bill	Per month	Per kwh	Per month	Per kwh
1 kWh/month	4,070 UGX	4,070 UGX	3,610 UGX	3,610 UGX
5 kWh/month	6,910 UGX	1,382 UGX	4,610 UGX	922 UGX
15 kWh/month	14,010 UGX	934 UGX	7,110 UGX	474 UGX
30 kWh/month	24,660 UGX	822 UGX	18,510 UGX	617 UGX

A comparison of WENRECo's current household tariff with the national tariff as collected by Umeme (table 5) shows why the above stated issues particularly hurt poor low-consuming households, which represent the vast majority of domestic customers: At an average consumption of 15 kWh per month, WENRECo customers pay with UGX 14,000 (USD 3.78) almost double compared to national grid customers, and the service fee represents roughly a quarter of the electricity bill, increasing the cost per kWh to almost UGX 1,000 (USD 0.27).

30 Strikingly, many people in West Nile showed a low understanding of the detailed tariff system, unable to quantify or even distinguish service fee and tariff; however, they could clearly express their concerns.

5. Safe and efficient use of electricity

Education on safe and efficient use of power is critical when power grids are rapidly expanded into rural areas. The West Nile electrification program tackled this issue from various ends:

- Customers who want to get grid connected need to get their in-house wiring certified first by an electrician who is approved by the national regulator ERA.
- In the context of the E-AIM campaign, local electricians were offered the required training and ERA examination in Arua town to increase the availability of qualified electricians. In 2016, 45 technicians got the required Permit-D certification, but only 17 got the certificate in 2017 as only few candidates participated in the 2017 examination (GIZ 2017, 44).
- Awareness on safe and efficient power use was addressed at road shows in 40 trading centers and towns, and in radio spots and quiz shows.

5.1. Safe use of electricity (OC1.6)

The additional awareness activities on safety aspects and the increasing exposure to electricity did not change the general awareness on potential risks of power use. The share of customers who could provide a correct example of how a person can be seriously injured or killed by electricity remained at the alarmingly low level of 25-30% for households and 33% for businesses, with no big difference between grid connected and not connected trading centers.

Regarding fire outbreaks, no direct effects, neither positive (reduction due to substituted kerosene lamps) or negative (increase due to short-circuits or faulty electrical appliances), could be observed, while the frequency of fire outbreaks in households remained stable at low levels, while for businesses frequency increased slightly, but also for the control group.

Numbers of injuries or fatalities due to electricity use are very small (in 2019 only 0.2% of households and 1% of businesses in electrified TCs reported an accident, down from 1.8% and 2.7% in 2017), and no trend can be generated. Still, the number of households and businesses reporting accidents has increased with start of grid access since 2017.

5.2. Efficient use of electricity (OC1.7)

Similar to the awareness on safety, the awareness on energy efficiency measures seems to be largely unaffected by the awareness campaign and a larger exposure to grid power. The share of customers who could provide a correct example of how to save energy remained fairly stable in the range of 10-19% for households and 15-28% for businesses, with the highest values in towns.

If asked in how far exemplified energy saving measures beside the use of energy saving bulbs (CFL or LED) are actually applied, only around 1% of households responded positively in 2013 and 2015, whereas in 2017 and 2019, numbers within the electrification corridor increased to 5-10% mainly driven by grid connected households. Businesses showed an even higher adoption of energy saving measures, with 2-8% in 2013 and 2015, which increased in 2017 within the electrification corridor to 12-19% (this time not particularly driven by grid connected businesses), and decreased again to 5-8% by 2019.

It seems that the general awareness on energy efficiency stays low and is difficult to change by awareness measures and power supply as long as it remains abstract and not applied. However, the actual adoption of saving measures seems to be influenced by grid access, even though still to a limited extent.

The share of energy saving bulbs seems to stagnate between 60% and 75%, but, as the data collected in 2017 and 2019 suggests, adoption might be far higher. The qualitative survey showed that normal incandescent light bulbs are not anymore available in local shops and, compared to 2013 where most energy saving lamps were compact fluorescent lamps, people now struggle to tell the difference between a retrofitted LED lamp and an incandescent lamp.

Part II

Impacts of Electricity Access in West Nile

6. Impacts on household welfare

Most impact studies focus on the impact of electrification on households that use electricity first of all for lighting causing a decrease of kerosene use and costs (Bos, Chaplin, and Mamun 2018; Chaplin et al. 2017; Lenz et al. 2017). Furthermore, effects on appliance ownership, expenditures, and income generation activities of households are mostly investigated (Lee, Miguel, and Wolfram 2016; Bonan, Pareglio, and Tavoni 2017; Jiménez 2017).Accordingly, we trace the effects on household's appliance use (6.1), the resulting changes in fuel use (6.2), as well as possible impacts on household expenditures as proxy for household income (6.3) and on income generating activities.

While at the national level, poverty incidence increased from 19.7% in 2012/2013 to 21.4% in 2016/2017, in West-Nile it reduced from 42% to 35%, but the sub-region keeps the third highest poverty prevalence in Uganda (UBOS 2018:90). Poverty incidence ranges from 20.1% in the districts Nebbi and Arua to 75% in the districts Yumbe and Koboko. 38% of all households in West Nile are considered food poor households compared to a national average of 37% and the average households spends 61% of its monthly expenditures on food compared to an 46% national average (UBOS 2018:80). The high poverty prevalence is also reflected in the low nominal monthly household income of UGX 294,000 (USD 79.61) in 2016/2017 up from UGX 223,600 in 2012/2013 compared to a national average of UGX 416,000 (UBOS 2018:109).[31]

We traced the impacts on appliance use of households (6.1), the resulting changes in fuel use (6.2), household expenditures and income generating activities (6.3), as well as indirect benefits for nonconnected households (6.4).

6.1. Appliance ownership (O1.2)

The share of households using small electric appliances such as light points, mobile phones, or radios was similar for trading centers regardless if electrified or not, but higher for towns (see table 6). Both the share of households using electric lighting and the average amount of light points used by households increased strongly for all clusters between 2013 and 2019, while the share of households using mobile phones remained stable at 70-75% in trading centers and 85% in towns; and the number of phones used remained stable at 1.5 per household on average. This is in line with the assumption that access to such small appliances is often provided by batteries or small solar systems and therefore less affected by grid electricity.

For larger appliances such as TV or iron, the difference becomes more apparent: the 2019 share of households in electrified trading centers is about double compared to households in not electrified trading centers. However, a strong difference already existed in 2013 and the net impact due to grid access is with 2 percentage points only a quarter of the absolute increase. And while in 2013, households in electrified trading centers on average owned about 150% more larger appliances compared to not electrified trading centers, this difference decreased to 33% by 2019.

[31] For a detailed presentation of the socio-economic situation of West Nile see Annex II.

Table 6: Proportion of households using specific electric appliances

Appliances	Not electrified TCs		Electrified TCs		Towns	
Year	2013	2019	2013	2019	2013	2019
Sample share of grid customers	0%	0%	0%	27%	0%	43%
Electric lighting	8%	42%	10%	41%	13%	64%
Mobile phone	72%	75%	75%	70%	85%	84%
Radio	24%	48%	37%	45%	52%	55%
TV	2%	8%	8%	16%	9%	31%
Video playback	3%	6%	6%	12%	7%	16%
Laptop computer	2%	1%	3%	6%	6%	15%
Fridge	0%	1%	1%	2%	1%	9%
Iron	0%	1%	2%	6%	2%	10%
Kettle	0%	0%	1%	2%	0%	5%

In contrast, the situation in trading centers and towns within the electrification corridor was fairly similar in 2013, but four years after electrification, 33-45% more households in towns own electrical appliances compared to electrified trading centers. The same dynamic exists for average appliance ownership. While in 2013, households in towns and trading centers within the electrification corridor owned similar amounts of appliances (not counting phones and light points), by 2019, town households owned on average 66% more appliances compared electrified trading centers. This second ratio is fairly proportional to the 63% higher share of grid connected households in the town sample (43% compared to 27% within the trading center sample), while the high difference in ownership of TVs, laptop computers, fridges and kettles suggests different wealth levels.

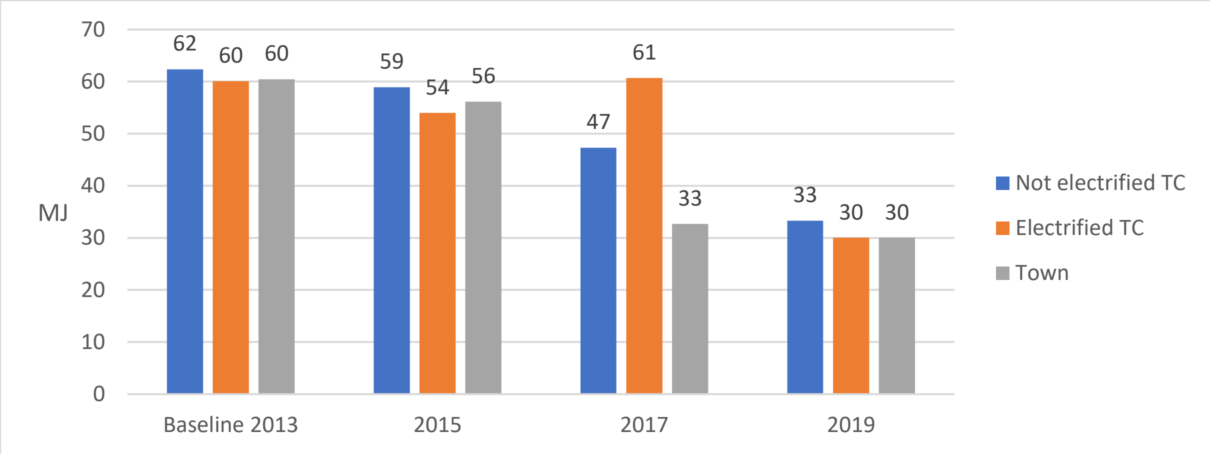
The effects are much lower than observed in Tanzania (Chaplin et al. 2017), Rwanda (Lenz et al. 2017), and Kenya (Lee, Miguel, and Wolfram 2016), which is partially caused by our methodical approach to use a mixed grid-connected/nonconnected treatment group with random shares of grid connected households of only 27% and 43% in 2019.

6.2. Fuel use in households (O1.3)

The average use of fossil fuel halved between 2013 and 2019 in all clusters including the control group (chart 16), confirming the effect of electrification (Chaplin et al. 2017; Lenz et al. 2017), but also showing that access to grid electricity had no larger effect on fossil fuel reduction compared to off-grid solar electrification. As in all clusters, also the use of dry-cell batteries significantly decreased (see chapter 10), and the data suggests that off-grid solar is equally effective in replacing kerosene as grid electricity (in case of unreliable rural grids).

While this indicator aggregates 5 types of fossil fuels (kerosene, candles, LPG, petrol, and diesel), kerosene alone represents 75-99% of the fuel use, only distorted by the erratic use of generators by very few households, which also caused the spike in 2017 for electrified trading centers in chart 16.

Chart 16: Fossil fuels used by a household on average per month (MJ)



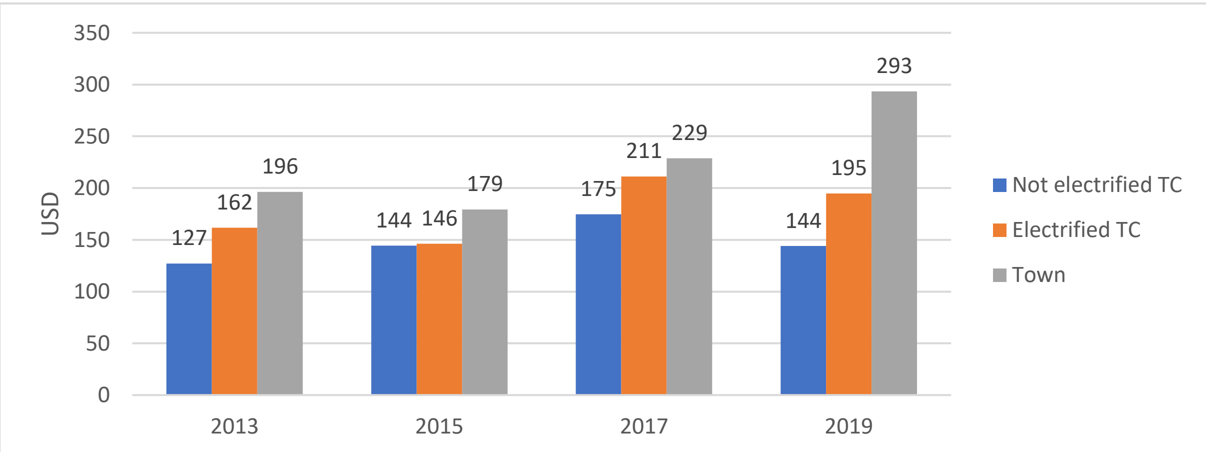
However, especially frequency and amount of kerosene use reduced even stronger in the control group compared to the treatment group. Furthermore, also the use of candles (usually only used by better-off households) increased in electrified trading centers after grid connection. This can be explained by a lower reliability of grid electricity compared to off-grid solar resulting in continued use of kerosene and candles during outages. A similar effect has been described by Lenz et al. (2017) for Rwanda.

Use of biomass fuels, mainly for cooking, has not been influenced by grid access, confirming that electricity is not used for cooking in West Nile. This is in line with many other impact studies (Bos, Chaplin, and Mamun 2018).

6.3. Household expenditures and income generating activities (I2.3)

Because it is difficult to directly assess household's income, the level of household expenditures is often used as a proxy to estimate the available income. Beside income, also savings and remittances have been surveyed as possible confounding variables, but were negligible in scale. Chart 17 below shows gross values not corrected for inflation. Considering inflation, only town households could maintain their wealth levels while all households in trading centers show lower spending levels over time.

Chart 17: Average monthly household expenditures (in USD)

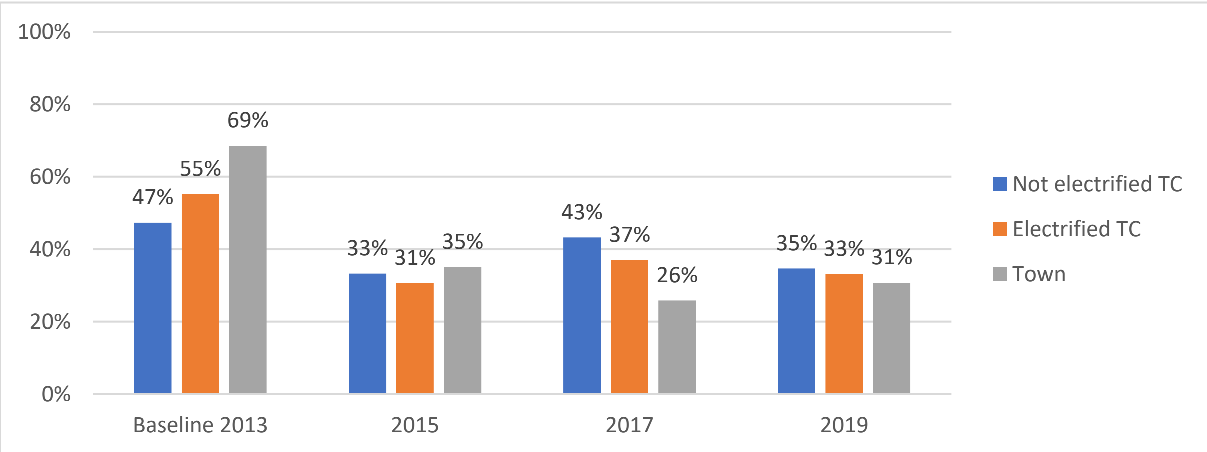


This result supports the recommendation (Peters and Sievert 2016; Hamburger et al. 2019) not to directly transfer expectations of high income effects reported mostly from Asia and Latin America (Bonan, Pareglio, and Tavoni 2017; Jiménez 2017) to Sub-Saharan Africa, where recent results have been more heterogeneous from 25% increase of income in Tanzania (Chaplin et al. 2017) to no effects in Rwanda (Lenz et al. 2017) and Kenya (Vernet et al. 2019).

Access to grid power enables households to expand their income generating activities, defined as micro-economic activities carried out directly from the household's premises, into the evening hours and to increase their efficiency with electrical appliances. However, focus group discussions during the qualitative workshops revealed that (seasonal) activities are carried out by women for whom either power is of little relevance (e.g. cooking), or funds are lacking to invest into required electrical machinery (e.g. artisanal crafting), which is in line with Lenz et al. (2017).

The survey results show that while the awareness on the income generating potential of electricity was in the range of 40% over all clusters and years, income generating activities decreased for all clusters to about one third of households (see chart 18 below). Data suggests that grid connection neither has boosted households' micro-business activities, nor could it reduce or even reverse the decreasing trend in trading centers. In contrast, being connected to the grid increased the use electricity for income-generation from 9% to 22% in Tanzania (Chaplin et al. 2017), but results from Rwanda have not been significant (Lenz et al. 2017).

Chart 18: Proportion of households with micro-business activities



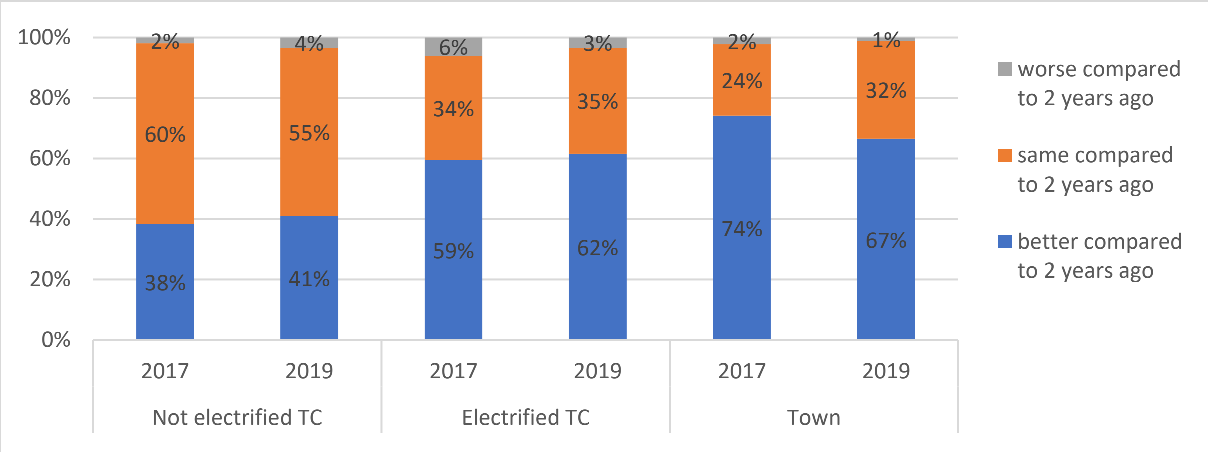
6.4. Indirect benefits at household level (OC1.5)

Regardless their individual connection status, all households, but especially those within electrified trading centers, benefit from indirect effects such as improved public infrastructure services as wells as more competitive private service markets. But in contrast to Chaplin et al. (2017) we do not observe a decrease of distance to health facilities that offer advanced health services, as this is defined by policy, However, households benefit from qualitative improvements of the existing range of services available in their vicinity. Such impacts on educational and health services are documented in the respective chapters 8 and 9.

Beyond these, public lighting has often been mentioned in stakeholder workshops and qualitative interviews as important impact as it increases the sense of security and facilitates social and economic activities especially during evening hours.

Households also benefited from improved access to ICT services, which has been monitored for mobile phone charging, copy and printing, computer usage for word processing, and internet access (see chart 19 below, representing the case of copying and printing).

Chart 19: Development of household access to copying and printing facilities



Households were asked if the access situation in terms of distance to reach the specific service has improved compared to the situation two years before. In all four categories, results have been fairly similar. The majority of households within the electrification corridor responded that their access to ICT services improved, while outside the electrification corridor it remained unchanged for the majority of households. This confirms that access to ICT services is less affected by Tier 1 access via small solar systems but much more by improved grid access. This can be easily explained as larger solar systems would be required to power ICT such as desktop computers, printers or photocopiers.

7. Economic impacts of grid access

International experiences on positive economic impacts of rural grid electrification in terms of employment effects and business turnover or profits are mixed but slightly positive (Bonan, Pareglio, and Tavoni 2017; Brüderle et al. 2017; Jiménez 2017), while rather insignificant for Sub-Saharan Africa (Peters, Vance, and Harsdorff 2010; Chaplin et al. 2017; Lenz et al. 2017). Brüderle et al. (2017) and Vernet et al. (2019) also highlight that, due to the increased competition, positive economic impacts might not result in increased turnover and profits of businesses, but rather accrue at household level in terms of reduced prices or increased range and quality of products and services offered. Also, the importance of parallel and continued development of technical and business capacities has often been stressed (Terrapon-Pfaff et al. 2018). We have seen that direct welfare impacts for rural households are moderate, especially if compared to off-grid solar access. The key rationale for rural grid electrification, justifying the high investment cost, is therefore the expected boost of economic activities.

The great advantage of grid power supply compared to off-grid solar is that it allows to operate at lower costs larger machines that are required for agro-processing and producing trade, both sectors with a significant value adding potential in rural areas. Value adding is of particular importance as remote rural regions such as West Nile suffer from low levels of productive activities. Local products (which are mainly agricultural) tend to be exported as raw materials, whereas manufactured goods tend to be imported. But the recent macroeconomic trend in West Nile has been rather poor, limiting the potential impact of improved grid access: while the number of working age population increased by one third from 980,000 in 2012/13 to 1,431,591 in 2016/17, the employment to population ratio decreased from 66.4% to 57.0%. Out of the entire employed population in West Nile, only 16.7% are classified as paid employees and 6% as casual laborers in agriculture. Furthermore, 69.4% are considered self-employed and 6.9% are contributing family workers, summing up to a total of 76.3% of the population being in vulnerable employment, as defined by the International Labor Organization (ILO). While for 34% of households, the main source of income has been in 2012/2013 'non-agricultural enterprises', the share decreased to 21% by 2016/2017, while the share of wage employment decreased from 25% to 16%, and the share of subsistence farming increased in the same period from 32% to 49% (UBOS 2018).[32]

To promote the productive use in West Nile, the Electricity Access Impact Maximization (E-AIM) campaign provided business development training in 12 trading centers, and three regional workshops with millers that resulted in a direct grant support to 13 millers that have been willing to cover 40% of the investment costs for electrical mills.

We traced the impacts on appliance use of businesses (7.1), the resulting changes in fuel use (7.2), and the share of different lines of business, average working time and employment, and business turnover (7.3).

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32 For a detailed presentation of the economic background situation in West Nile see Annex II.

7.1. Appliance ownership (OC1.2)

Both the share of businesses using electric lighting and the average amount of light points used by businesses increased strongly for all clusters between 2013 and 2019, while the share of businesses using mobile phones remained stable and the number of phones used per business was between 1.4 and 2 on average (see table 6). This is in line with the assumption that access to such small appliances is often provided by batteries or small solar systems and therefore less affected by grid electricity.

Larger appliances are rarely used by businesses in trading centers with TVs having with 20% the highest share within the electrified area. The only appliance for which an impact of grid electricity can be observed are fridges, for which the difference in share of businesses in electrified trading centers compared to not electrified trading centers increased from 100% in 2013 to 600% in 2019. For all other appliances, the difference in use remained equal or even decreased over time (see table 7). Between electrified trading centers and towns, the difference in ownership of larger appliances only increased for TVs and desk top computers but decreased for all other appliances.

Table 7: Proportion of businesses using specific electric appliances

Appliances	Not electrified TCs		Electrified TCs		Towns	
Year	2013	2019	2013	2019	2013	2019
Sample share of grid customers	0%	0%	0%	61%	0%	68%
Lighting	35%	54%	45%	64%	47%	66%
Mobile phone	82%	81%	86%	75%	87%	82%
Radio	32%	39%	44%	43%	39%	30%
TV	7%	10%	13%	20%	13%	28%
Video playback	7%	6%	7%	10%	9%	8%
Laptop computer	2%	10%	4%	9%	9%	13%
Desktop computer	1%	3%	5%	6%	8%	14%
Printer	2%	3%	3%	5%	6%	8%
Fridge	2%	3%	4%	18%	13%	24%
Freezer	0%	1%	0%	3%	1%	8%
Air condition	0%	2%	0%	3%	1%	4%
Hair cutting machine	4%	8%	5%	9%	3%	5%

Total average appliance ownership by business (not counting light points and mobile phones) equally increased between 2013 and 2019 for all clusters by about 45%, reaching on average 1.6 appliances per business in not electrified trading centers, 2.2 in electrified trading centers, and 2.8 in towns, suggesting that off-grid solar is similarly driving appliances ownership as grid access.

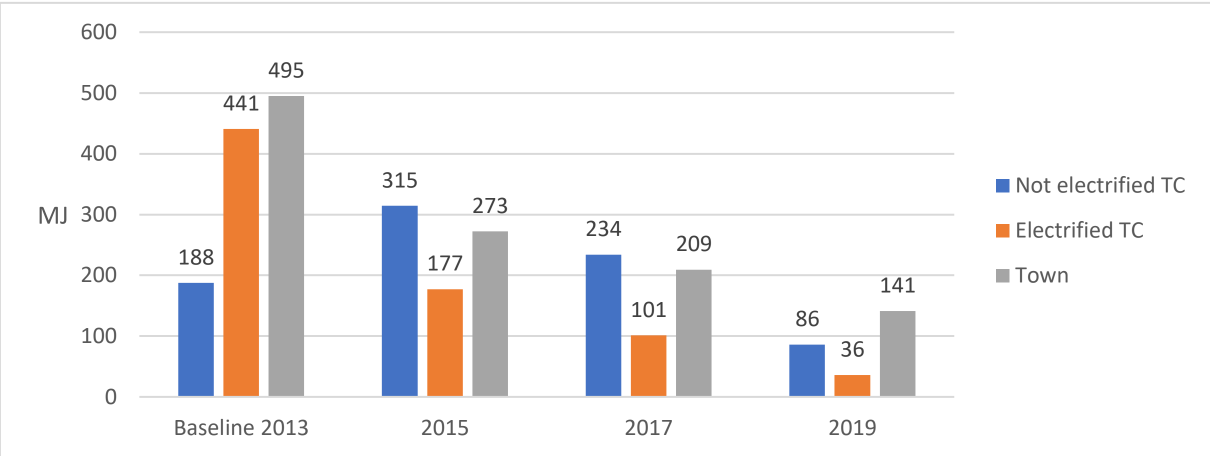
7.2. Fuel use by businesses (OC1.3)

Five types of fossil fuels (kerosene, candles, LPG, petrol, and diesel), have been considered, but diesel and petrol clearly dominate as generator fuels.

In total, the average use of fossil fuel by businesses has greatly decreased between 2013 and 2019 in all clusters including the control group (see chart 20 below).[33] Frequency and average use of diesel and petrol use has also decreased in all clusters, but strongest in electrified trading centers and weakest in towns. Generator ownership fluctuates between 6-17%, with highest values in towns. Petrol use without generator ownership hints to stationary use to power machinery. The use of fossil fuel by grid connected businesses is significantly higher compared to the average, indicating that back-up generators are still very much in use.

Kerosene reduction happened to a large part between 2013 and 2015 in all clusters and before any business got grid connected. This suggest that kerosene reduction was mainly caused by off-grid solar access. Even by 2019, not electrified trading centers show with only 4% the lowest share of kerosene lighting emphasizing again the effectiveness of off-grid solar to reduce kerosene use even in direct comparison with grid electricity.[34]

Chart 20: Fossil fuels used by a business on average per month (MJ)



7.3. Business activities (I2)

The measuring of selected proxies for business development in West Nile does not provide a clear result: The E-AIM business development trainings did not show measurable impact[35], but this would have been surprising considering the small scale of the intervention. The share in main lines of businesses was generally stable, with a slight shift from retail to service provision, but no increase in food procession or producing trade.

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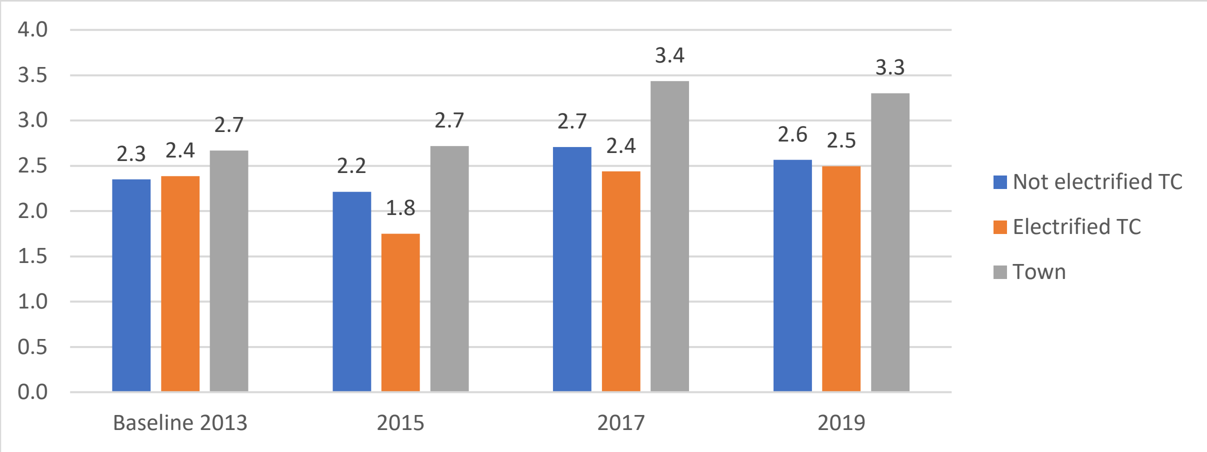
33 The 2013 average of only 188 MJ fossil fuel use in not electrified trading centers is mainly caused by a very low average use of diesel fuel in this year. As only very few businesses are using diesel generators, the measurement error for the reported average value might be large.

34 3% of grid connected businesses still used kerosene, probably due to the low reliability of the grid electricity.

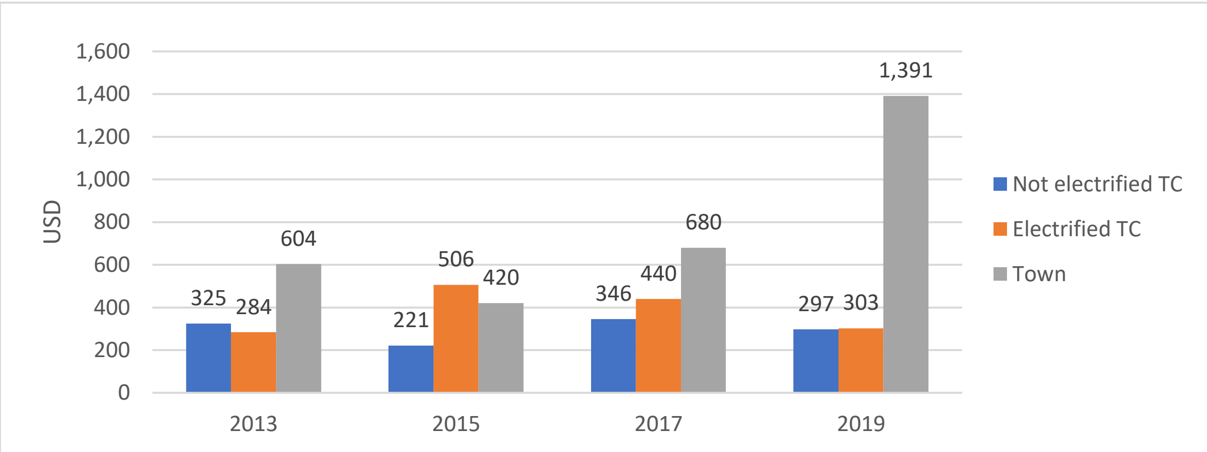
35 Out of the 12 trainings conducted, five took place in the six towns of the town survey cluster, whereas only one of the other seven trainings took place in a surveyed trading center within the electrification corridor. Impacts e.g. regarding an increased awareness on productive use should have been visible due to a significant stronger increase of awareness in towns compared to trading centers within the electrification corridor, which is not the case.

Chart 21: Number of employees



Working hours in businesses continued to be high since 2013 with 81 to 88 business hours per week. Average employment increased in towns, but remained stable in trading centers (see chart 21). If corrected for inflation, average monthly turnover even decreased in trading centers, regardless if electrified or not (see chart 22 below).

Chart 22: Average business turnover per month



The strong increase of turnover in towns by 2019 was driven by few retail companies located in the border town of Koboko, possibly benefiting from cross-border trade.

Interviews and focus group discussion during the qualitative survey suggest that strong barriers persist to unlock the business potential in West Nile. This is mainly due to limited access to capital and loans, and the lack of entrepreneurship skills, market information, and market linkages. It is therefore no surprise that the few successful businesses in West Nile are mainly backed-up by international parent companies or development agencies. Furthermore, the collapsed market in South Sudan in mid-2016 affected the economic situation for some companies in West Nile. And the unreliability of power supply has repeatedly been stressed to inhibit effective production and service provision.

8. Health impacts of grid access

As key health impacts of electrification, the reduction of indoor air pollution (IAP) due to kerosene lighting and biomass-based cooking is prominently discussed for its potential reduction of related respiratory or eye diseases. Some studies do support this hypothesis, e.g. Barron and Torero (2017) for El Salvador and Lenz et al. (2017) for Rwanda, but the latter only captured qualitative statements on indoor air pollution by households and could not observe any effect on related diseases. Bensch et al. (2017) suggest that due to the recent development of cheap LED lighting, kerosene (with its related indoor air pollution) is increasingly replaced by dry-cells, shifting the further replacement of such lighting sources into the field of environmental impacts. We already showed that in West Nile, same as for Sub-Saharan Africa in general, with the exception of South Africa, electricity does not replace biomass-based cooking and accordingly does not reduce related indoor air pollution.

Other assumed health impacts focus directly on the electrification of health centers. While surveys are often limited on assessing the access level of health centers, Bathia (2015) details main impact dimensions, lists prerequisites to be in place for such impacts to materialize, and highlights that detailed assessments of impact on health services are typically beyond the scope of not health sector specific surveys.

Access of West Nile communities to government health centers decreased since 2013 and 2017 from 10.1% to 9.1%[36], while the national average increased from 8.8% to 11.9%, and hospitals equipped with diagnostic appliances are very sparse. There is still lack of staff, medication and appliances for health diagnostic. Many health centers and hospitals report that their health service is massively overstretched by refugees from South Sudan and patients coming from the Democratic Republic of the Congo.

Of the 91 health centers that were selected in 2013 for the impact monitoring, five were type V hospitals, seven type IV health centers, and the remaining 79 were type III health centers. All health centers were still operational in 2019.[37] Health center staff mentioned budget, qualified staff, and power supply as main barriers to service quality.

We trace the impacts on appliance use of health centers (8.1), the resulting changes in fuel use (8.2), as well as impacts on key health services offered (8.3).

8.1. Appliance use in health centers (OC1.2)

When considering only the 12 large (level IV & V) health centers, appliance ownership is largely defined by policy and shows no significant change. As all level IV & V health centers have solar systems and either grid power, a generator or both in parallel, it seems that grid access has less of a direct effect on the use of electric appliances.

The analysis of appliance use (table 8) is therefore focusing on smaller level III health centers that usually suffer a far more unreliable access to electricity. One key impact is the general use of electric lighting: while most health centers had (some) electric light already in 2013,

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[36] As the number of level III to V health centers has been stable in this period, the trend might be caused by closure of level II health centers, the creation of new villages or the consideration of new refugee communities.

[37] But Yumbe hospital was in renovation and could therefore not be interviewed in 2019.

access increased to 100% of the grid connected health centers, and the average number of light points almost doubled in the access cluster compared to an insignificant increase within the no access cluster.[38] Beside lighting, also the use of other electrical appliances doubled to an average of 10 appliances in the access cluster compared to a 50% increase to an average of 6 appliances in the no-access cluster. This affected particularly the presence of computers, printers, and copying machines, but also autoclaves, kettles and boilers. The use of microscopes, fridges[39], freezers, and radio call antenna seems less affected by access to grid electricity. Lenz et al. (2017) report a similar pattern from Rwanda, were the difference in appliance ownership between grid connected and off-grid health centers was even less pronounced, which they explain with strong budget support to all health centers and the technical feasibility to operate most appliances also by off-grid solar access, even though at higher costs compared to grid access.

Table 8: Proportion of level III health centers using specific electric appliances

Appliance use in level III health centers	No access cluster		Access cluster	
Year	2013	2019	2013	2019
Sample share of grid customers	0%	0%	0%	100%
Electric lighting	72%	93%	90%	100%
Microscope with electric light	59%	63%	60%	84%
Fridge	81%	88%	85%	84%
Laptop computer	5%	50%	10%	53%
Desktop computer	9%	48%	15%	89%
Printer	2%	29%	5%	58%
Freezer	29%	30%	55%	21%
Autoclave (steam)[40]	38%	27%	25%	42%
Copying machine	0%	21%	0%	32%
Radio call antenna	21%	13%	30%	21%
Kettle	2%	0%	0%	16%
Ultrasound	2%	5%	0%	11%
Incubator	3%	0%	0%	11%
Boiler	0%	2%	0%	11%

38 Measurement of the number of light points is only a proxy for the actual lighting use as it does not record the luminous flux provided by each light point. An institution might significantly increase its illumination level without increasing the number of light points simply by replacing weak light points with stronger LED lights.

39 Some health centers are operating gas fridges, which might have been falsely reported as electric appliance; however, they are in fact providing the required service.

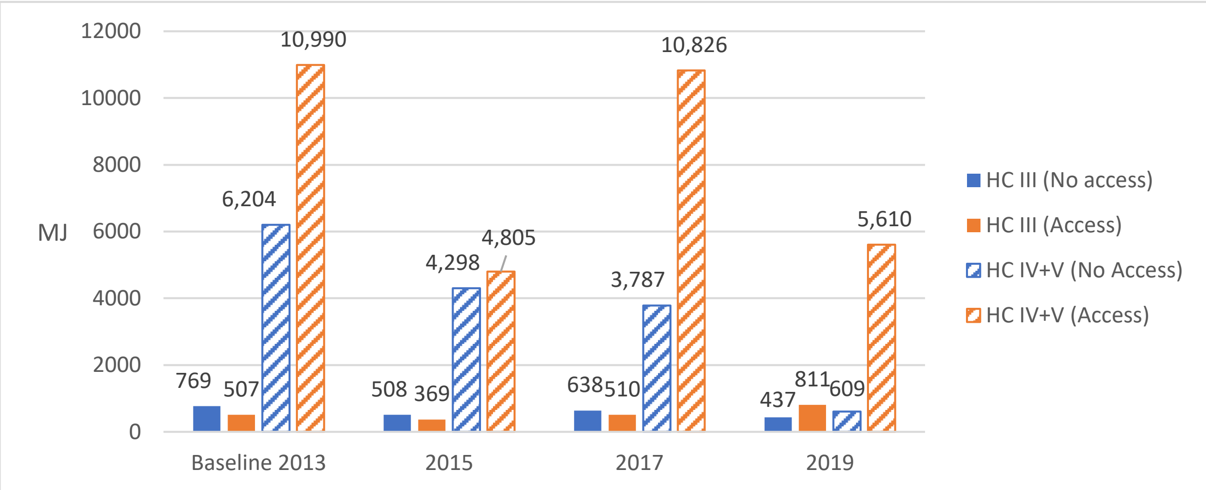
40 The qualitative survey showed that the use of electric autoclaves is rare and that autoclaves heated with charcoal are common. Regarding these results, it can be assumed that the respondents referred also to non-electric autoclaves when answering the question.

8.2. Fuel use in health centers (OC1.3)

For health centers, similar effects can be observed as in the case of households and businesses: while kerosene use by connected health centers has significantly decreased, this effect is overcompensated by highly fluctuating diesel/petrol consumption as generator fuel. [41] The large level IV and V health centers have massive consumptions compared to the large number of level III health centers and are therefore presented separately in chart 23 below.

The continued high use of fossil fuels and especially diesel and petrol as generator fuels in grid connected health centers can be explained with the poor reliability of power supply.

Chart 23: Fossil fuels used by a health center on average per month (MJ)



8.3. Health services offered (I3.2)

Interviews with staff in newly grid connected hospitals and type IV health centers indicated that these institutions could improve services based on a higher availability of lighting and electric appliances. With very few exceptions[42], most health centers could provide vaccinations and 24 hours emergency response with a 100% availability, regardless if grid connected or not. In 2013, only about 50% of health centers could offer maternity wards with full availability of sufficient lighting, which increased by 2019 to 84% for grid connected health centers compared to only 62% for off-grid health centers (see chart 24 below).

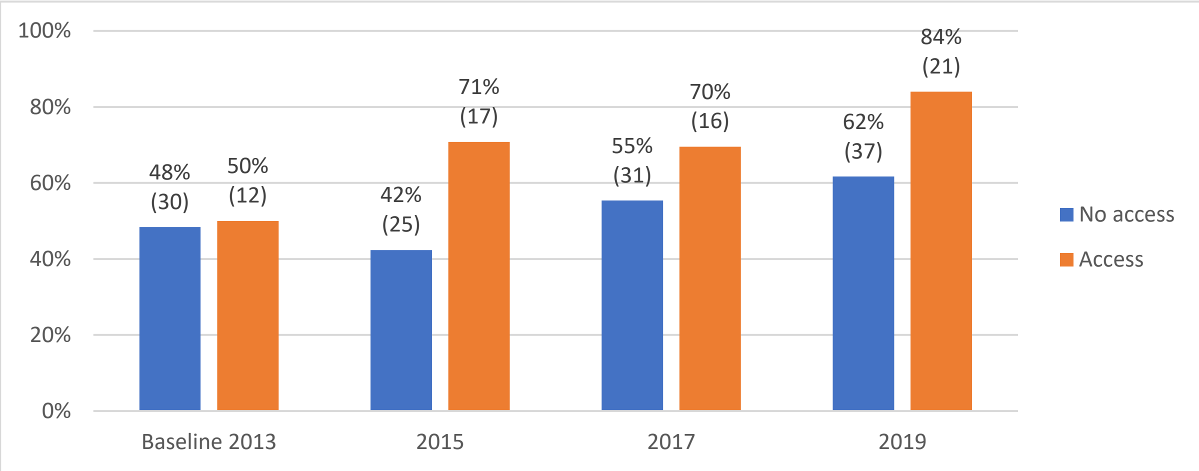
In this case, the only 62% share for off-grid health centers comes as no surprise as it correlates well with the 64% share of health centers with Tier 2 (solar) or Tier 3 (generator) access in 2019. In contrast, while 100% of the access cluster health centers had grid access in 2019 (25 of 25), only 84% (21) could provide the service always. This might be caused by the low reliability of the grid, but one health center also quoted budget constraints as a limiting factor. It is interesting to note that all these 25 health centers of the access cluster do also have solar

41 The strong fluctuations for level IV and V health centers are caused by the low number of institutions in the panel, by not being able to interview all health centers in all years, as well as by strong impacts of budget availability on fuel purchases. Combined, these effects render possible impacts of grid access invisible.

42 In one case, broken fridges have been stated as reason for unavailability of vaccination services.

systems, which seem not to work adequately in at least three of the cases. During the qualitative survey, some health centers reported that maintenance and repair of solar installations would be the responsibility of the ministry but is effectively lacking.

Chart 24: HC providing illuminated maternity rooms



According the health policy specifications, we monitored for the 12 larger health centers of level IV and V also advanced medical services such as blood transfusions, ultrasound diagnosis, surgeries, and x-ray, the latter for level V health centers only. However, a detailed analysis for each and every health center over the monitoring period revealed that most institutions offering the service in 2019 already offered it before getting grid connected. The only exception are the cases of Koboko and Yumbe health centers, but these have only recently been upgraded and are still establishing their operations. As already stated for appliance ownership, the range of health services offered is mainly defined by policy. However, staff interviews indicated that grid electricity facilitates the use of more light and even more larger appliances with beneficial effects on service quality, a dimension outside the scope of our quantitative monitoring.

9. Educational impacts of grid access

Compared to the national standard the general educational infrastructure in West Nile is weak with only 8.2% of communities having a secondary school and an enrolment rate of only 10.6% (decreasing) compared to the national average of 27.8% in the same year (latest available numbers of 2016, see Annex 2 for more details). Of the 129 secondary schools that were selected in 2013 for the impact monitoring, 17 were closed by 2019. Schools reported budget constraints as main obstacle that also influences staffing, available equipment, and power access. During the qualitative survey, schools stated that recent food cost increases due to tripling prices for basic food items since the influx of refugees to West Nile in 2015 as additional burden on the direct school budget, but also on school fee collection from poorer households.

Educational impacts of electrification are often investigated in terms of study time of children at home or school enrolment rates. While the result on these indicators is generally mixed (Bonan, Pareglio, and Tavoni 2017) and show the same difference of lower or no effects in Sub-Saharan Africa (Lenz et al. 2017) compared to positive effects in Asia and Latin America (Jiménez 2017), we focused on direct effects on secondary schools in terms of appliance ownership, fuel use, and educational services offered such as (1) computer classes, (2) internet classes, (3) natural science experiments, and (4) the number of boarding schools that provide evening lighting for the pupils.

We trace the impacts on appliance use of secondary schools (9.1), the resulting changes in fuels use (9.2), as well as impacts on key educational services offered (9.3).

9.1. Appliance use in secondary schools (OC1.2)

Recorded trends in appliance use are possibly influenced by budget effects: While in 2013, the share of schools using electric lighting was comparable at 54% and 58% for the no-access cluster and the access cluster, respectively, schools of the access cluster used on average 73% more light points compared to schools in the no access cluster. And while schools of the no-access cluster used on average even slightly more appliances, these were concentrated in fewer schools.

In 2019, 97% of grid connected secondary schools used electric lighting with an average of 44 light points per school (16% increase), while 91% of secondary schools of the no-access cluster used electric lighting with an average of 33 light points (50% increase).[43] An explanation for the difference might be that secondary schools of the access cluster had been able to satisfy a high share of their light demand already in 2013 by using solar systems and generators (which would suggest an at that time higher school budget or other equivalent support).

The average number of other electrical appliances increased in secondary schools within the access cluster by 48% compared to a decreasing trend in the no-access control cluster. In 2019, significantly more secondary schools of the access cluster owned larger appliances such as computers, printers, copying machines or overhead projectors compared to off-grid schools

[43] Measurement of the number of light points is only a proxy for the actual lighting use as it does not record the luminous flux provided by each light point. An institution might significantly increase its illumination level without increasing the number of light points simply by replacing weak light points with stronger LED lights.

(see table 9). This is notwithstanding the fact that a number of off-grid schools benefited from a public educational program providing solar powered computers, effectively doubling the share of off-grid schools with computers, printers and copying machines.

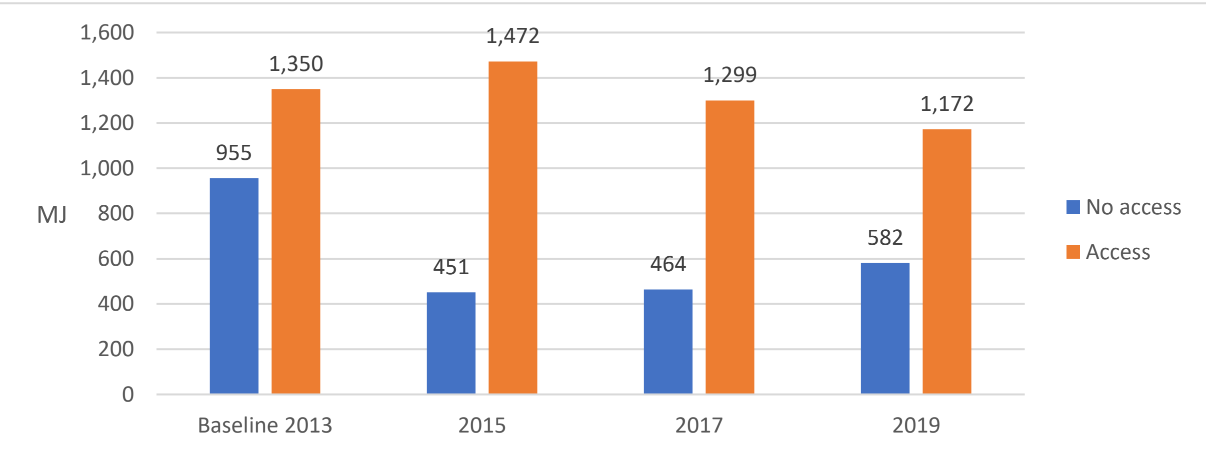
Table 9: Proportion of secondary schools using specific electric appliances

Appliances	Secondary schools (No access)		Secondary schools (Access)	
Year	2013	2019	2013	2019
Sample share of grid customers	0%	0%	0%	100%
Electric Lighting	54%	91%	58%	97%
Laptop computer	26%	57%	24%	83%
Desktop Computer	36%	60%	55%	80%
Printer[44]	31%	69%	48%	89%
Copying machine	22%	41%	21%	80%
Radio	38%	34%	30%	46%
Overhead projector	2%	10%	6%	26%

9.2. Fuel use in secondary schools (OC1.3)

Fuel use in schools in the access cluster decreased by 2019 (after an increase in 2015) to 85% of the 2013 value. Fuel use of schools in the no-access control cluster halved in 2015 (due to less consumption of diesel, petrol, and kerosene, which might be caused by reduced availability of funds) but increased again by 2019 (see chart 25).

Chart 25: Fossil fuels used in a secondary school on average per month (MJ)



[44] This also includes multifunctional devices (printing and copying).

By 2019, 12 (34%) of the 35 schools of the access cluster had back-up generators, while 29 (84%) also used additional solar systems. Of the 70 schools in the no-access cluster, only 13 (19%) had a generator, while 66 (94%) had solar systems.

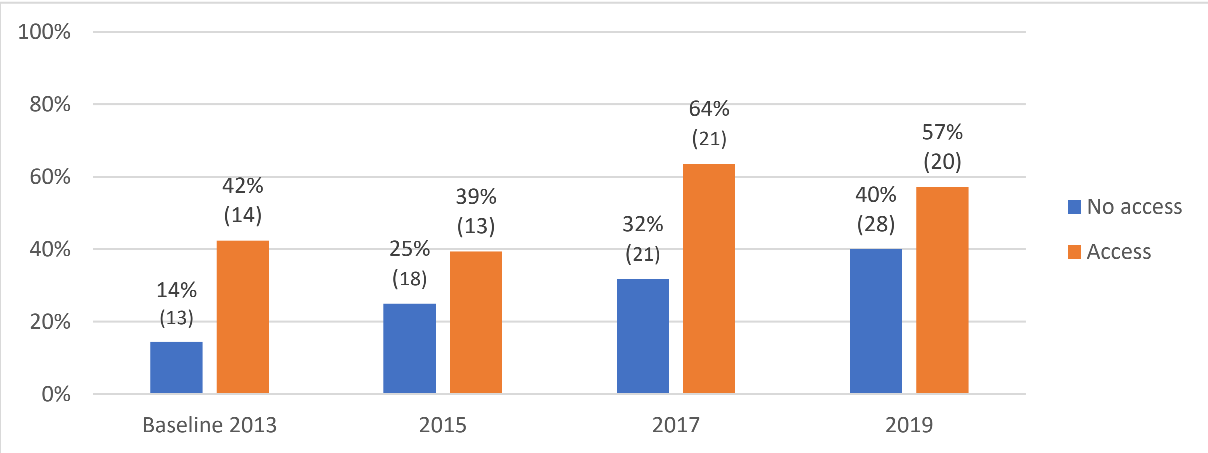
The share of kerosene in total fuel consumption remained more or less stable (32-37%) for the no-access cluster but decreased for the access cluster from 20% in 2013 to 9% in 2019, while candle use is negligible.

9.3. Educational services offered (I3.1)

The monitoring of educational services has been complicated by difficulties to reach school headmasters for interviews as well as by high fluctuations of services provided by specific schools over the years. Trends and reported constraints suggest a higher influence by the budget and staff situation of the respective school compared to health centers.

Schools were asked whether they offer computer classes where students can work on computers themselves (or in small groups). Therefore, positive answers have only been considered if schools owned at least five or more functional desktop or laptop computers (see chart 26).

Chart 26: Schools providing classes on computer

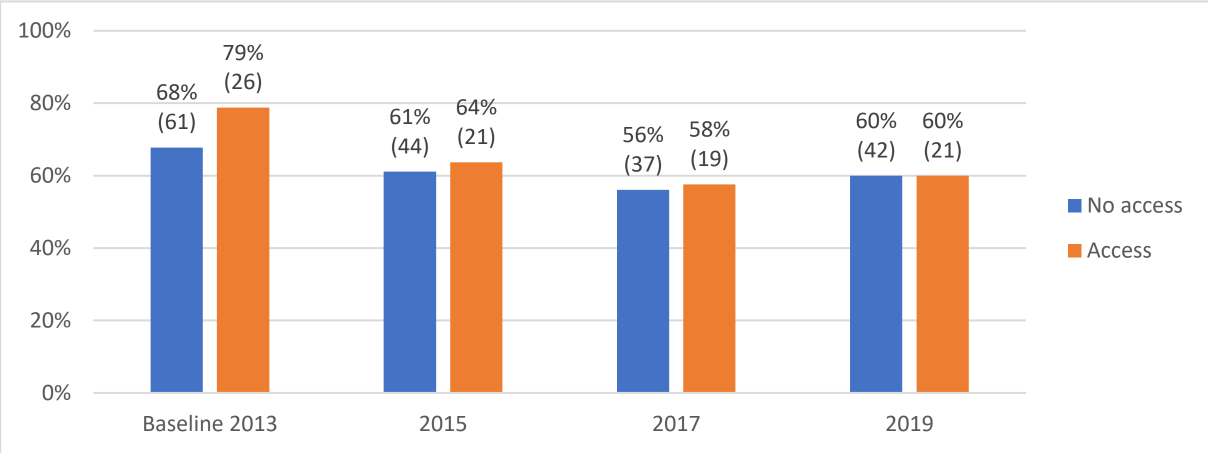


Within the access cluster, service levels increased significantly between 2015 and 2017 (when grid access increased from 42% to 64%) but did not increase further in 2019 (while grid access further increased to 100%). Within the no-access cluster, share and number of schools offering computer classes increased continuously, supported by a national program supporting off-grid schools with solar PV systems and computers, demonstrating that the service can also be offered without grid access. Of the 57 schools not offering computer classes in 2019, 12 are grid connected, while 45 have no grid access. Still, only 15 of the latter stated power as the main barrier, while 41 stated budget constraints as main barriers (including the ones with insufficient number of computers to offer classes).

Schools were also asked whether they offer internet classes where students actually work on computers. Therefore, positive answers have only been considered if schools owned at least five or more functional desktop or laptop computers and offered also computer classes. Overall, numbers are significantly lower compared to general computer classes. Of the 91 schools that did not offer internet classes in 2019, 30 are grid connected while 61 have no grid access. Still, only 23 of the latter stated power as the main barrier, while 45 schools stated budget constraints as main barriers (including the ones with insufficient number of computers to offer classes). Only eight schools stated that mobile network coverage is too poor at their location to access the internet. it seems that external factors such as school budget, but also internet access and qualified staff prevent even many grid-connected schools to offer internet classes.

The share of schools offering science experiments that require electricity decreased in general, both within the access cluster and the no-access cluster (see chart 27).

Chart 27: Number of secondary schools providing natural science experiments



Of the 42 schools (14 grid-connected, 28 not grid connected) that did not offer natural science experiments in 2019, 26 schools stated power as the main barrier, six budget constraints, five staff constraints, and three said that it was not part of the curriculum. However, this data needs to be interpreted with care as qualitative interviews indicated that many schools do simple natural science experiments using batteries but did not mention this during the quantitative survey as they did not consider batteries as electricity.

Finally, there was slight difference between grid connected (100%) and off-grid (91%) boarding schools' ability to offer electric lighting at night.

10. Environmental impacts of grid access

Human energy use is one of the great contributors to environmental pollution and global warming. Fossil fuel supply chains are associated with environmental pollution upstream (extraction, processing, transport) as well as downstream (pollution of earth and water due to leakages during storing and handling, combustion emissions). While kerosene use for lighting is associated with indoor air pollution and related diseases (see chapter 8), also the abundant use of small backup generators, counting for 9% of power consumption in Sub-Saharan Africa, causes relevant emissions of CO_2, nitrogen oxides (NOx) and fine particulate matter (PM2.5) harming human health and the environment (IFC 2019).

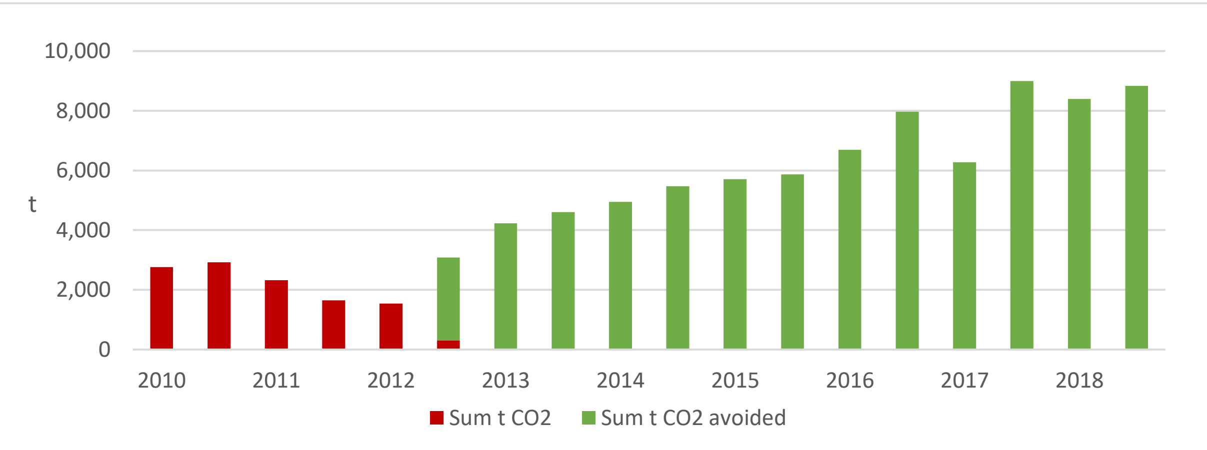
Recently, success of LED lighting resulted in a reduction of kerosene lighting at the price of increasing use of dry-cell batteries (Bensch, Peters, and Sievert 2017), which in rural areas are often not adequately disposed. Biomass use without sustainable supply chain causes deforestation and degradation of natural habitats, as well as emissions of CO_2 and black carbon. But in Sub-Saharan Africa, electricity is rarely used for cooking (Bos, Chaplin, and Mamun 2018).

We trace the impacts of CO_2 reductions due to the switch of power generation from heavy fuel oil to hydro power, as well as the possible replacement of fossil fuels such as kerosene and candles for lighting, or diesel and petrol for stationary power generation (10.1); the reduction in use and disposal of dry-cell batteries (10.2); and the possible replacement of biomass uses such as firewood, charcoal, or agricultural residues for cooking or process heat (10.3).

10.1. CO_2 reduction in power generation and use (I1)

Consumption of fossil fuels has been measured and aggregated by the net calorific value and the related reduction of CO_2 emissions. The switch of power generation from heavy fuel oil to hydro power in 2012 brought the use of fossil fuels and related CO_2 emissions in the West Nile power grid down to zero and made it to a fully green power grid. However, since May 2019, a 2.6 MW emergency diesel has been installed to stabilize the network, which is planned to be replaced by two 4 MW HFO generators by end-2019. Thus, starting from 2019, we will again observe a partially fossil footprint of power generation.

Chart 28: CO_2 emissions and avoided CO_2 emissions of WENRECo



The switch to hydropower generation has enabled WENRECo to avoid 72,000 tons of CO_2 between mid-2012 and end-2018, despite the massive increase in customers and power generation. Furthermore, the significant reduction of technical losses avoided an additional 9,000 tons of CO_2 emissions compared to the baseline situation in 2012. This resulted in a total accumulated emission reduction of about 81,000 tons of CO_2 (green bars in chart 28 above).

Increasing the access to grid power also aims at replacing inefficient and harmful energy use such as kerosene-based lighting or the operation of small and highly inefficient combustion engines powering generators and machinery. The issue of fossil fuel use was therefore covered in detail in the interviews with households and businesses and results have been presented in chapter 6 and 7. The monitored average CO_2 emission reductions per household and business (annex 2, I1.2) result from mixed samples of connected and unconnected households and cannot easily be generalized.

To estimate effects on kerosene use, we compared grid connected households and businesses with off-grid solar and Tier 0 households and businesses in the same locations: while before grid connection, average kerosene consumption was about 1.5 liter per household and month, this decreased for grid connected households to 0.5 liters per month (massive outages are probably preventing a full replacement), while other households still consumed about 1 liter per month.[45] This would result in an average additional fuel reduction for a grid connected household of about 6 liters per year and a related CO_2 reduction of about 15 kg per year. For businesses, there was no significant difference in kerosene consumption between grid connected and off-grid businesses. While the impact of grid access on diesel and petrol use of individual businesses can be massive, it is highly specific and cannot easily be generalized. Considering the 8,223 domestic customers of WENRECo, average kerosene reduction would reach about 50,000 liters of kerosene per year resulting in avoided annual CO_2 reductions of 126 tons. With a reliable grid electricity supply, these reductions could easily double, once grid connected households completely stop using kerosene.

Estimating effects on diesel and petrol use is not feasible for households due to the low and fluctuating numbers. For businesses, frequency of fuel use has halved to about 10% in trading centers (both electrified and not electrified) and 15% in towns, but the average monthly use decreased by more than 150% in electrified trading centers compared to 50% in not electrified trading centers and 100% in towns. On average, the net fuel reduction per business in grid connected areas was roughly in the range of 800 MJ or 50 liters[46] petrol per month. Provided the grid would be fully reliable, full replacement of the remaining diesel and petrol use would amount to another 50 liters per month in towns and 8 liters per months in electrified trading centers. To roughly estimate the fuel reduction potential, we assume that about half (3,600) of the 1-phase commercial customers are businesses, of which 360 (10%) operate combustion engines. We further assume that 50% of these 350 businesses are in towns while the rest is equally split between electrified and not electrified trading centers. The annual fuel reduction of 180 businesses in towns and 90 businesses in trading centers would amount to 162,000

45 The fact that in 2019 Tier 0 households and off-grid solar households had a similar low kerosene use of about 1 l per month hints at the high impact of dry-cell batteries on lighting habits, see next chapter.

46 This is just an illustrative approximation as in reality we consider a fuel mix of diesel and petrol with different net calorific values and densities.

liters of petrol resulting in avoided annual CO_2 reductions of 368 tons. With a reliable grid electricity supply, these reductions could increase to 278,000 liters and 633 tons of CO_2 reductions, once grid connected businesses completely stop using diesel and petrol.

Even with most optimistic assumptions, numbers would only reach 885 tons of CO_2 reductions (252 tons by kerosene and 633 tons by diesel and petrol), which remains moderate compared to the more than 8,000 tons avoided by hydropower generation. However, a much bigger impact of fossil fuel reduction can be expected, would the 406 industrial and 3-phase commercial customers (mostly not covered by our survey) fully replace their generator use.

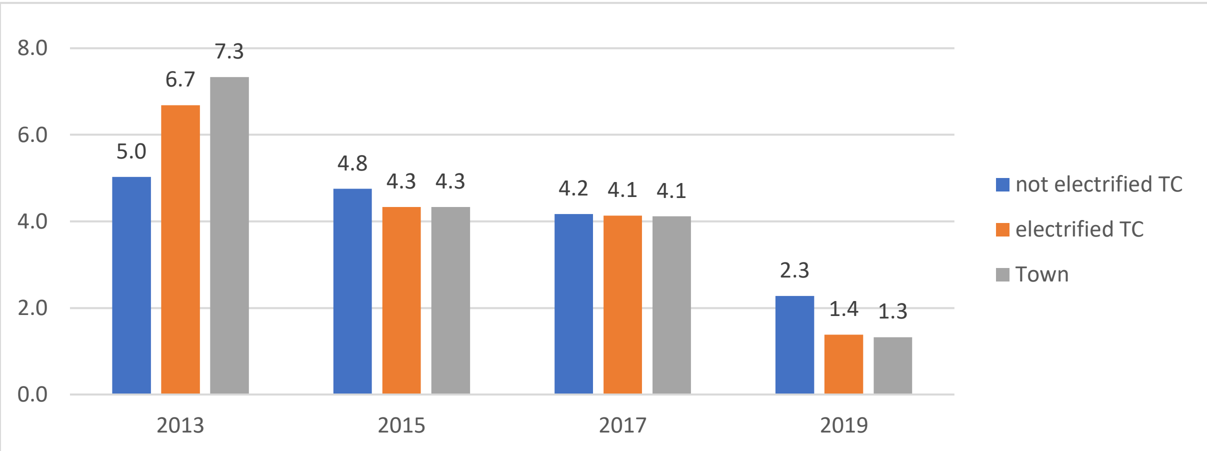
10.2. Replacement of dry cell use (OC1.3)

While the share of households using dry-cell batteries decreased between 2013 and 2019 by one third to about 40% of households in electrified areas, it only decreased by 20% in not electrified trading centers were more than half of households are still using dry-cell batteries. However, the mere use of any dry-cell battery is a poor indicator as batteries are used for many purposes, which are not all influenced by grid access. Therefore, we analyze the amount of dry-cell battery use (chart 29 below).

In the same time period, monthly battery consumption decreased in electrified areas by 80% from around 7 batteries per month in 2013 to only 1.4 batteries per month in 2019, while in not electrified trading centers, consumption only little more than halved from 5 batteries per month in 2013 to 2.3 batteries per month in 2019.

Numbers suggest a significantly higher impact of grid access on the reduction of battery use in rural areas even compared to off-grid solar access.

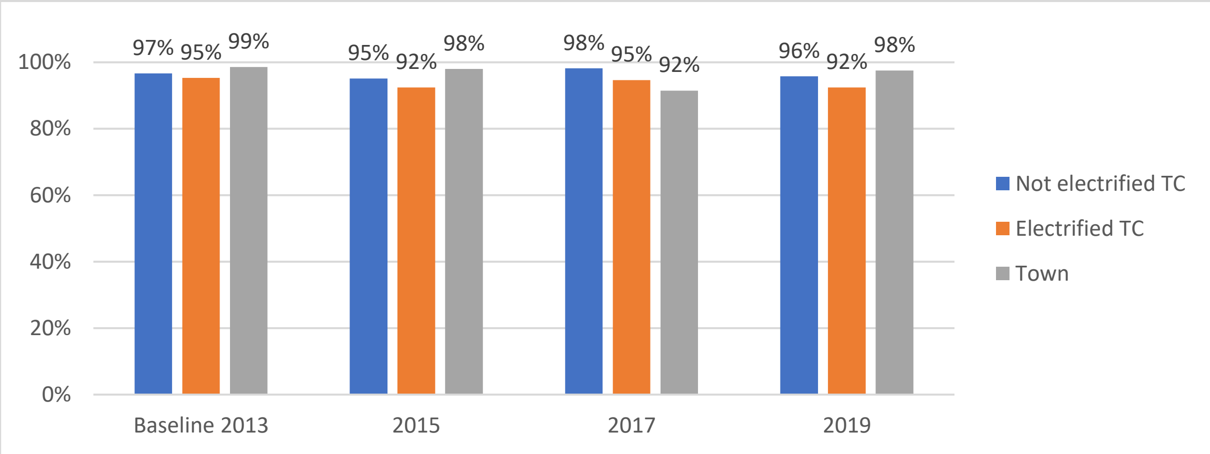
Chart 29: Number of dry-cell batteries used by households per month



10.3. Replacement of biomass use by grid electricity (OC1.3)

Reduction of the energetic use of biomass such as firewood, charcoal or agricultural residues has been included as a possible impact of increased grid access. However, as cooking with electricity implies the investment into an expensive stove as well as significant costs of electricity, a switch to electric cooking by a significant share of households has been considered as unlikely. Results of the impact monitoring show that biomass use of households remains largely unaffected by grid access (see chart 30), with similar results for health centers and secondary schools.

Chart 30: Share of households using biomass



Businesses both within and outside the electrification corridor reported a lower and decreasing use of biomass which suggests that the cause is rather a general shift of business activities (e.g. increase of retail activities) instead of the new grid access.

Conclusions and Recommendations

Drivers and barriers of grid access

The West Nile grid electrification program shows a **high effectiveness in terms of grid coverage and connected trading centers**. While the overall household grid connection rate in the region is only about 1.6%, within the electrification corridor the connection rate has been significantly higher in the range of 5%, and close to the power lines even 26% in trading centers and 43% in towns. High connection rates could be reached also for businesses in trading centers and towns (about 60%), health centers (34%) and secondary schools (34%). While 9,925 households are connected to the power grid, many more people benefit from improved public infrastructure services and ICT services.

The **low reliability and efficiency of power supply** is the main barrier to reach targeted development impacts. Outages (estimated SAIDI of 153 hours and a SAIFI of 850) and load shedding (8 hours per day) are too frequent and particularly affecting commercial and industrial customers. There are indications that the low water table of the Nyagak river is affected by deforestation and agricultural practices within its watershed area in West Nile and the Democratic Republic of Congo. This might have long-term implications for the operation of the Nyagak I hydropower plant as well as Nyagak III, which is planned on the same river. With peak demand surpassing supply capacity, no generation reserves, and no back-up power system, power supply was deteriorating and only recently stabilized by emergency diesel generation. Technical and commercial losses of the power grid were considerably reduced and the collection rate is high due to the pre-paid system.[47] However, the response time on customer complaints has been increasing recently and the service quality and communication of WENRECo is still considered unsatisfactory by many customers and local government officials.

The **viability of WENRECo's operations remains threatened** by its low reliability and fast growth in low-consuming household customers. WENRECo has been able to reduce its levelized supply cost since 2015, with the prospect to break even by 2019. However, this was only possible due to massive subsidies reducing capital cost of operation. In 2017, 64% of households and 40% of commercial customers consumed less than 1 kWh per day and the politically motivated massive connection of low-consuming rural customers is further impairing the income per customer ratios. This will prevent WENRECo from becoming financially more independent from additional subsidy injections for the required future reinvestments to maintain its infrastructure.

Demand for grid access is high, but affordability of power remains a barrier for poor households. Connection and electricity cost remain the main barriers for nonconnected households, while poor power reliability deters an increasing share of (larger) businesses. While connection costs are almost fully subsidized since 2018, the additional cost of inhouse wiring limits the connection of poor households. Connected households complain about higher costs compared to the national grid (as WENRECo has no lifeline tariff), but can mostly afford

47 Data submitted by WENRECo for 2017 and 2018 suggests that the collection rate decreased significantly over the past two years, but data might be distorted due to the server breakdown in 2018; WENRECo was not able to clarify the issue.

electricity. While in the past, before having a grid connection, irregular income only resulted for poor households in not being able to purchase kerosene, it is now leading to an accumulating debt of the monthly service fee for power that the household could not afford to use.

Despite the two-year Electricity Impact Access Maximization Campaign, **awareness on safe and efficient use of power has not improved**. While there was no correlation of fire outbreaks and grid access, serious and fatal accidents with electricity did slightly increase, but numbers of accidents are small and no trend can be observed. While the general awareness on energy efficiency remained stable at low levels, actual adoption of saving measures slightly increased with access to the grid. Energy saving lamps have become standard (quality has not been assessed) and normal light bulbs are not visible on the market.

In sum, grid electricity has been made available to a very small share of the population of West Nile, and a significant higher share of businesses and social infrastructure. But grid customers suffer from low reliability and poor service. **We consider unreliability of power supply as a major factor preventing intended positive effects of grid access** such as investment in productive activities and replacement of generators and fossil fuel use. Poor reliability might also cause losing dissatisfied commercial and industrial customers (counting for 75% of revenues), which directly endangers WENRECo's financial viability. **The planned future grid extension and densification poses an additional threat for the operational viability of WENRECo**. We have demonstrated that additional customers are lowering the already poor income per customer ratio and that past subsidized connection offers resulted in a significant share of inactive customers. But future grid densification might even be less successful as expected, as 60% of not connected households state high cost as reason, regardless a standing offer of a 100% subsidized free 1-pole connection, which suggests that cost for inhouse wiring will remain a serious barrier for poor households.

Impacts of grid access

Over the monitoring period, electricity access (mainly off-grid solar) increased in the control group to 60% for households and 78% for businesses, transforming the impact monitoring into a comparison of grid-access with off-grid solar access. While grid extension required massive investments in generation, distribution, connections and management, off-grid solar was more indirectly promoted by some national programs supporting solar companies, as well as by leakage of free solar giveaways in refugee camps creating a local second hand market.

While **grid access at household level** leads to a significantly higher use of larger appliances (TVs, laptop computers, fridges and kettles), this observation applies to towns with wealthier households, while in trading centers, the effect was much weaker. For ownership of small appliances (light points, mobile phones, radio) grid and off-grid solar resulted in similar increases, as well as in similar decreases for kerosene use, while biomass use was not affected at all. Household expenditures (as income proxy) decreased in trading centers (regardless if grid connected or not), and maintained stable in towns. There was also no impact on micro-economic activities neither by grid access, nor by off-grid solar. But households in grid connected locations stated higher improvement in access to ICT services (copying, printing, computer, and internet) compared to not connected trading centers.

The impact of **grid access of businesses** in trading centers has been limited as only few businesses do actually use larger appliances in West Nile. Fossil fuel use of businesses has been decreasing in all clusters and the trend started even before the grid arrived in 2015. At such low consumption levels of fossil fuels, there is no difference measurable between businesses in grid access and off-grid solar trading centers. Unsurprisingly, no higher aggregated impacts such as increased working hours and employment could be measured, and average business turnover even decreased. Businesses in town, on the other hand, show positive employment effects and significantly increased turnovers since the grid has arrived. This data suggests that businesses in towns can much better make use of grid access. It might even be that town businesses actually outcompete rural businesses, regardless of their grid access situation. Such competition effects have been observed by Brüderle et al. (2017) for Nepal and Vernet et al. (2019) for Kenya. Further research into this aspect would be of interest.

Impacts of **grid access of health centers** have been moderate. Health centers can provide basic health services (vaccination, 24h response, childbirth) both with grid or off-grid solar access, but reliability remains an issue for both. Grid connected health centers use more appliances, especially more light points, which has been described as improving general service delivery and management. Impacts on advanced medical services such as ultrasound, x-ray and surgeries are less evident, as higher-level health centers usually used solar systems and generators before grid connection and kept these as back up so that fuel or cost reduction effects could not be observed due to the low reliability of the grid.

Compared to schools with off-grid solar access, **grid connected secondary schools** use more appliances and reduced kerosene consumption, but impacts on educational services are less clear. The share of schools offering computer classes was higher in the access cluster but increased only by 36% compared to 186% in the no-access cluster who benefited from a public support program. Other services, such as internet classes, natural science experiments or evening lighting in boarding schools have even been less affected by the new grid access.

The main **environmental impact** of the new West Nile electrification program has been caused by the switch from thermal to hydropower generation resulting in about 81,000 tons of avoided CO_2 emissions between 2012 and 2018. So far, the targeted reduction of fossil fuel use on the demand side has only been realized for kerosene. Because kerosene consumption overall decreased due to the strong growth of off-grid solar systems, the grid caused reduction is very small reaching only 6 liters of kerosene per year and household. Petrol and diesel fuel consumption has not been reduced, probably due to the unreliable power supply, while dry-cell battery use showed a significant stronger decrease in electrified locations. As expected, biomass use has not been affected by grid access.

In sum, **impacts of grid access have been much weaker as anticipated** partially due to much higher off-grid solar electrification levels both in the control and treatment group. Grid access leads to an increased use of electrical lighting and larger appliances, but for rural households the effects are limited. Similarly, grid connected level III health centers and secondary schools show a significant increase in electric lighting and appliance use but this does not translate into significant impacts on educational or health services provided. The difference for larger level IV and V health centers is even less pronounced as almost all already used solar systems and generator before getting grid connected. It appears that **most households and even health centers and schools would be able to satisfy their basic power demand based on off-grid solar**, provided that solar systems are reliable and maintenance and repair service is available, which seems so far not to be the case. Even for rural businesses in trading centers, grid electricity does not appear to be a game changer; even though more businesses use TVs and fridges, they did not increase business hours or employment, nor their turnover. In opposite, town business increased employment by 22% and more than doubled their turnover in the same time period. Observed **economic effects might be suppressed by low reliability of grid power and the limited business capacity and access to financing in rural areas**. But increased competition between rural and urban businesses should be investigated, to check for possible crowding-out effects of grid access in rural areas.

Lessons learned

The West Nile electrification program has very specific circumstances as it uses an isolated network to provide grid access in a historically marginalized region with high poverty incidence and additional pressure from large refugee influx. Still, these characteristics are not untypical for rural electrification and lessons are relevant for similar programs in other countries of Sub-Saharan Africa.

The experiences with this program confirm that **grid extension alone cannot reach the aim of universal access to electricity for all by 2030**. Despite a massive intervention, only 1.6% of the total population of West Nile and 5% of the population within the reach of the electrification corridor have been connected to the grid. Even if connection numbers could be doubled in coming years, the major part of the population will still not be reached as it lives outside the electrification corridor. Even within the electrification corridor, **the current free 1-pole connection policy is not reaching the poor, as they still cannot afford the additional cost of inhouse wiring**.

The cost of grid extension (without the investments in power generation) has been in the range of USD 1,200 per connection (not including additional national subsidies for free 1-pole connections). While this is a moderate value compared to other grid extension programs, we observed that **most rural household and business customers use only a fraction of the potential grid power access and accordingly reap little benefits**. For these customers, **adequate access could be provided by off-grid solar systems at a fraction of the cost**. This would at the same time improve the income per customer ratio of the power utility, reducing the need for operational subsidies. Increasing the cost efficiency of the electrification strategy would release funds that could be used to finance social access programs for poor rural households that are currently not reached, neither by grid extension nor by the commercial off-grid solar market. Such **an integrated strategy could also avoid that better-off households are benefitting most of rural electrification programs while the poor are left behind**, which is effectively increasing the perceived relative poverty in rural areas.

The success of rural electrification depends largely on the technical and administrative performance of the utility to guaranty a high availability and reliability of the power supply. Although the power utility received substantial support over past years, the performance is still unsatisfying. Especially **small utilities struggle to hire and keep qualified staff in remote rural areas**. And the initial investment to set-up an effective administration and technical operation are high compared to the low power sales and related income. The required institutional support might be higher as often anticipated.

This experience should also **caution the enthusiasm of mini-grid deployment in remote rural areas**. Managing small rural networks with comparatively large load fluctuations, most mini-grids will struggle with similar human capacity and reliability issues, but often require higher tariffs to be economically viable. But smaller mini-grids depend even more on few large commercial customers, who might, at some point, opt for independent power supply if this can be realized with higher reliability at comparable costs. **In absence of larger customers, off-grid solar will in many cases represent the more cost-efficient option**.

Another lesson is that **impact assumptions should be realistic and not follow simplified linear impact chains**. Electricity can greatly increase efficiency of economic activities and social services, but this does not lead automatically to relevant economic or social impacts. Especially **rural economic development has complex dynamics that cannot easily be anticipated**. The rural private sector is often lacking business skills, access to finance, and linkages to national and international markets, while local demand alone might not justify large investments. Increasing efficiency in production might also have negative employment effects and increase competition, which might even reduce the total number of businesses on the market.

For the impact monitoring, the **double-difference approach enabled the contrasting of patterns and trends within the treatment group to the general development trends in the region**. Instead of relying on one baseline and one follow-up survey only, four surveys have been conducted at a two-year interval to collect more data points. Surveys with only two data points deliver more straightforward results, but make existing fluctuations invisible. We used four data points over a six-year period to be able to record such fluctuations and even trace medium-term impacts. The **combination of quantitative and qualitative surveys was crucial to be able to cross-check and discuss quantitative results with local stakeholders**, which greatly improved the interpretation of data patterns and trends.

The chosen methodology for the impact monitoring was also influenced by the demanding circumstances of the West Nile Electrification program. Comprising an area of almost 11,000 square kilometers (roughly the size of Jamaica), seven districts, 2.76 million inhabitants, and five linguistic groups, we needed **five separate teams of enumerators in the field to cover the large survey area and conduct interviews in five local languages**. The challenge to contract, train, and employ 55 staff in a short timeframe was only manageable due to the **extensive pretesting of questionnaires and survey procedures** during the development phase in 2011, combined with the happy circumstance to keep the same team of five survey coordinators involved over this long timeframe.

Recommendations to the power utility

First priority is to **increase reliability of power supply**. With the planned installation of the two 4 MW HFO generators, WENRECo should have a sufficient operational reserve and increased generation redundancy to prevent any future load shedding. Additional solar power generation could help to decrease the share of fossil generation. Furthermore, the distribution network and switching procedures need to be improved to avoid network incidents. SAIDI and SAIFI should be fully monitored and reduced. A detailed load assessment including the possible impact of time bound tariffs on reducing evening peak loads could improve balancing of the network and inform about technical limitations for connecting additional trading centers or refugee camps.

WENRECo already generates more than **40% of its total revenues only from the 406 industrial and 3-phase commercial customers**, who usually have their peak demand during the day. It should therefore focus on further expanding this customer base. With increasing reliability, customers will be more willing to invest in electrical appliances and machinery, and consider disposal of their back-up generators. This would increase the power sales and income to customer ratio.

WENRECO should also further **improve its internal management procedures and record keeping**. Throughout four monitoring cycles, WENRECo has not been able to deliver a full and consistent data set. The recent massive collection losses (if not caused by corrupted data) pose a serious concern and could not be explained. The setup of the new pre-paid system has been a lost opportunity to improve management and accounting: virtually nothing is known about specific customers beyond the connection type (1-phase/3-phase) and group (domestic, commercial, industrial). WENRECo should systematically collect and process GIS data and customer information, and define internal routine workflows for maintenance and customer care.

WENRECo should further **improve external communication** by providing continued training for its staff and timely information to its customers and local authorities on outages and load shedding, as well as changes in tariff structures or procedures. In the meantime, regular (quarterly or biannual) regional information events[48] in cooperation with relevant district structures (Planning office, Commercial office, Energy Focal Point) could help mitigating present communication gaps.

WENRECo should further **encourage safe and efficient use of power**, e.g. by placing posters close to the MCB sockets of the in-house installation, which highlight the main safety and efficiency rules in an easily comprehensible way (using pictograms and main local languages). These posters should also be shared with local electricians.

Recommendations to policy makers

MEMD should further **investigate reasons and trends of low water levels** at Nyagak river. As the planned additional hydropower plant (Nyagak III) is built on the same river, a permanent drop of water levels would critically endanger the environmentally friendly power supply in West Nile.

Political pressure to connect more of the underserved poorer and remote rural households to the West Nile power grid (for which increased generation capacities and additional operational subsidies would be required) could be mitigated by **public promotion of a competitive solar sector** that offers quality products and services at low costs. This would require a strategic communication of the respective benefits and costs of electricity access via grid and solar home systems (SHS). Such an intervention could quickly increase basic access to electricity in West Nile, but should be accompanied by strategies for electric waste disposal. Expectations on a such a campaign should also be realistic: wealthier households in trading centers can be reached with larger (Tier 2) SHS as sold by PAYGo companies. For other households, Tier 1 solar systems will be the only affordable option. And if the aim is to also reach the poorest (and possibly food insecure) households in rural West Nile, direct cash transfers, voucher schemes, utility service models would be required to channel targeted end-user subsidies.

To **boost the impacts of grid access on health and educational services**, more connections of schools and health centers in the proximity of the grid should be facilitated in terms of

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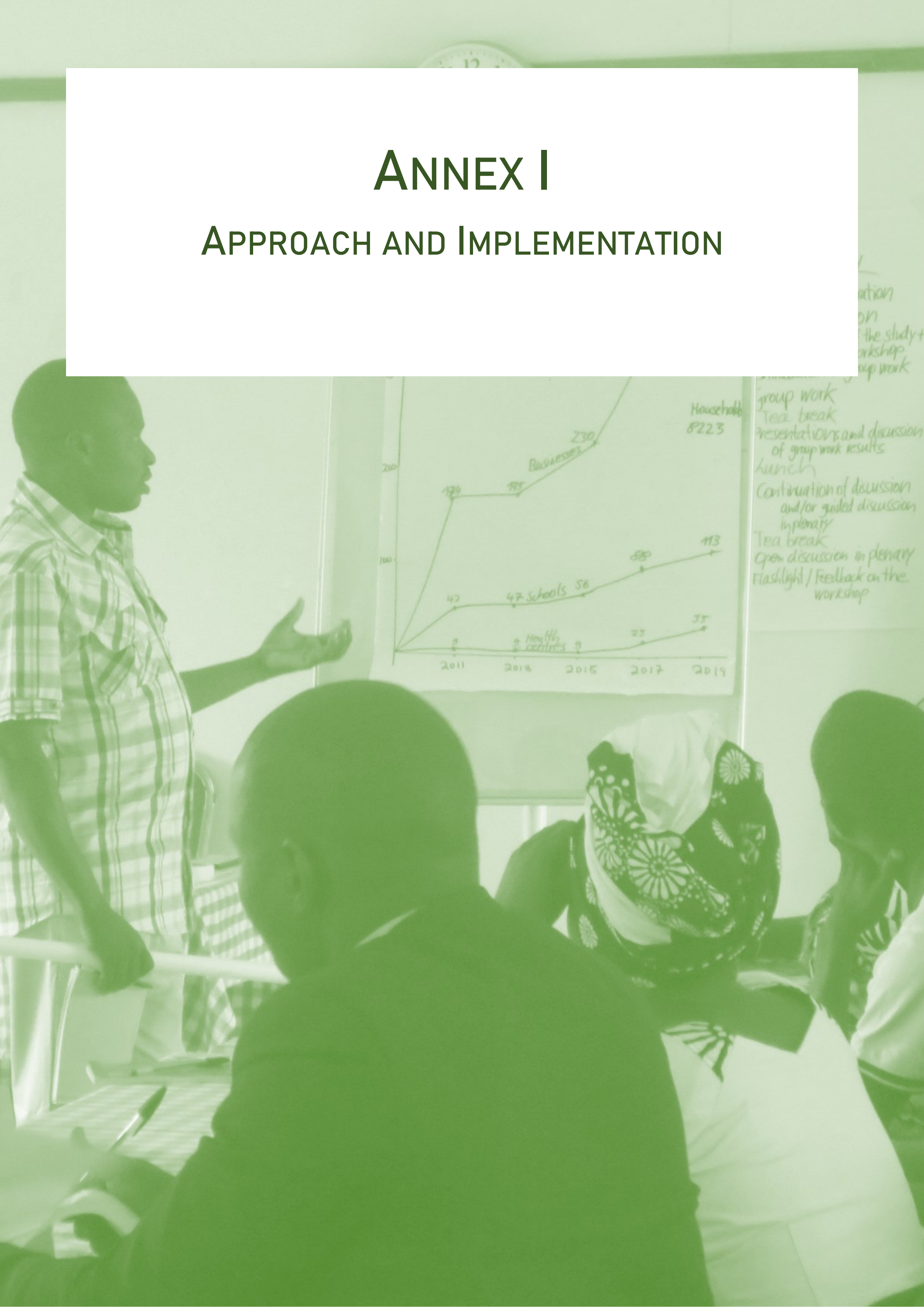
48 Such events were conducted within the context of the E-AIM Campaign and were received very positively by local government and customers.

financial assistance and technical support to implement the required extensive wiring on the often large premises of these institutions. During the survey we identified 24 secondary schools and 16 health centers that are located within the electrification corridor but stated not to be connected to the grid by May 2019. Possible synergies with activities of the respective line ministries should be investigated. However, if such institutions are not in low voltage distance to the grid, a least-cost analysis should compare cost of grid connection with off-grid solar.

Power supply does not change the economic development of a region overnight. To increase economic impacts of grid access, existing commercial activities and capacities in West Nile, as well as national and cross-border market potentials and linkages should to be assessed to strategically target future support activities e.g. in the form of **vocational training, business development services and SME financing**. In the best case, such prior assessment would actually guide rural electrification planning and the cost benefit analysis of supply options such as grid extension, mini-grids or off-grid solar.

ANNEX I

APPROACH AND IMPLEMENTATION



A1-1. Conceptual Design

This chapter is a summary of the equally named chapter 4 of the originally developed M&E framework (Berg and Gaul et al. 2011, 23–35).

1.1. Identification of beneficiaries

The M&E framework focuses on possible impacts of new access to electricity for the four beneficiary groups of the electrification program: households, businesses, health centers and secondary schools. Of the four beneficiary groups the number of benefiting people is calculated for households only. A parallel calculation of beneficiaries for the other groups is problematic, as such numbers will always overlap. The same person may live in a connected household, use a school or health station that has electric power and also be employed by, or buy products from, an electricity-using business.

While it is easy to count newly connected customers, it is much more complicated to measure the degree or extent of newly gained access to electricity-based services (such as phone charging, printing/copying or even milling) for the whole population of the electrified areas. As a consequence, households and businesses in the newly electrified areas are selected for the survey at random, regardless of whether they are connected to the grid or not. Since the electrification program aims at broad-based access and results, this approach allows average changes in access for the electrified areas to be measured.

However, random selection in electrified areas will start at the center of the connected trading center where the density of connected households and businesses is highest. As even within the electrification corridor, only a small share of households and businesses will be connected to the power grid, this represents the deliberate choice to increase the representation of grid connected households and businesses beyond their statistical share to make direct impacts on connected households and businesses more visible.

1.2. Mapping program results

The M&E framework is founded on the program's results chain. Based on that results chain, risks to the success of the program have been identified together with the potential positive and negative side effects of program implementation. Four results level have been conceptualized within the results chain (see Figure A1-1), which encompasses the rationale of the entire electrification program in West Nile. Each results level has its own distinct focus on expected results, and hence requires a separate reasoning for its indicators.

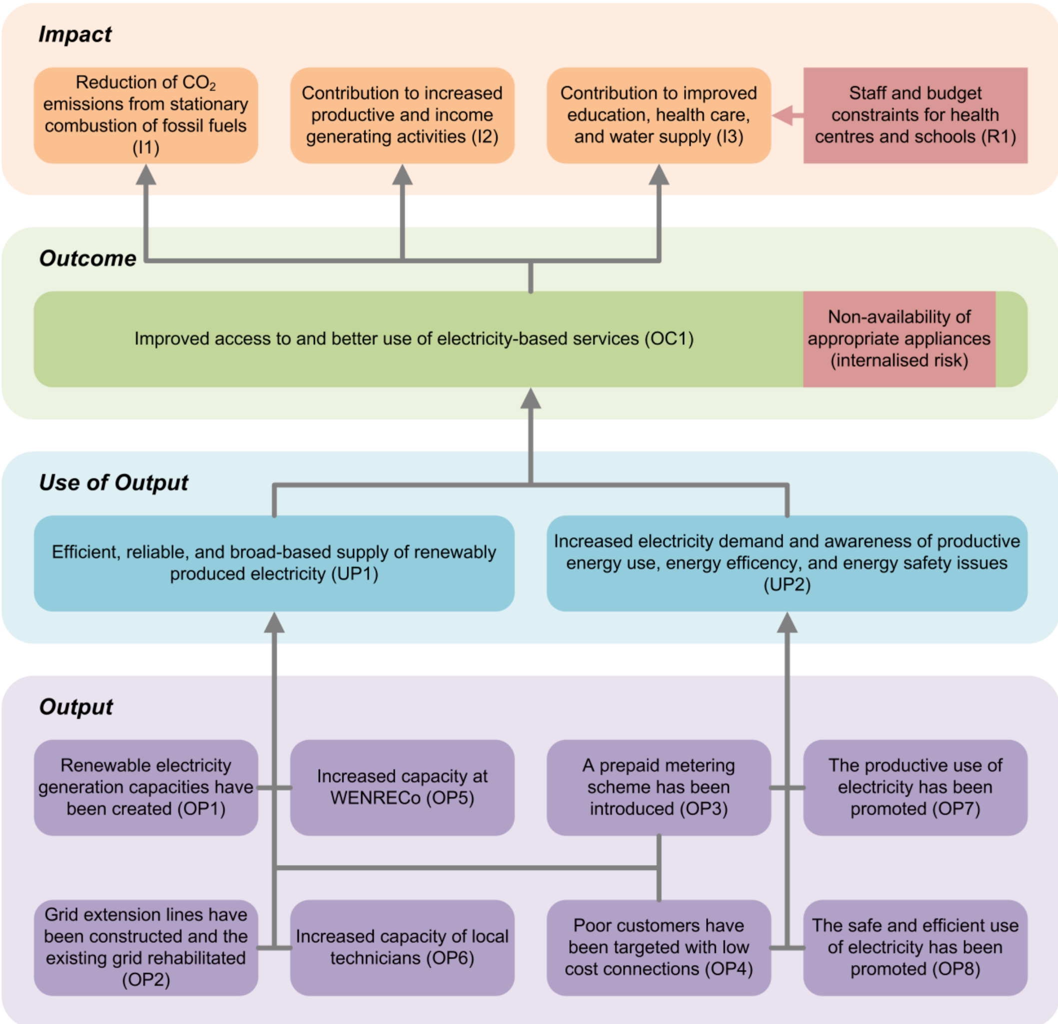
The Output level is concerned with the completion of program activities, such as the rehabilitation and construction of infrastructures, as well as the GIZ measures which relate to electricity demand and to the awareness of its safe and productive use.

At the Use of Output level, the M&E framework focuses on the intermediate results directly deriving from the Output level, for both electricity supply and electricity demand. On the supply side, this is the provision of reliable and affordable electricity by WENRECo, whereas the demand side is captured by monitoring the results of the E-AIM campaign, most notably the resulting degree of awareness within the population.

The Outcome level embeds the supply of, and demand for, electricity within the concept of access to electricity-based services. By putting direct and indirect users of electricity-based services at the center of observation, the M&E framework allows results to be traced progressively, both for users connected to the grid and for non-connected users who benefit from the provision of electricity-based services within the electrified areas and thus have indirect access to electricity.

Finally, the Impact level assesses results that are induced by an improved access in the electrified areas. The reduction of CO_2 emissions, an increase of productive and income-generating activities, as well as improved educational and health services or water supply in West Nile are all indirect positive results expected from the electrification program. These results are only partially attributable to the electrification program, because external variables may have a strong influence on their attainment.

Figure A1-1: The enhanced results chain



A major external risk to the achievement of the results on Impact level is also displayed (red box in Figure A1-1). The codes (e.g. OC1, UP2) allow for easier reference in the indicator sheets (see Annex 3). Another risk to the achievement of the outcome lies in the availability of affordable, easy-to-maintain appliances of adequate quality. This risk is partially internalized within the monitoring of indicator OC1.2. However, as this risk also contains qualitative aspects, it is proposed to complement indicator OC1.2 with qualitative evaluations if the number of appliances proves to be significantly lower than expected.

1.3. Defining program indicators

In order to make changes measurable at each of the results levels, indicators have to be designed for all the results identified. Each indicator comprises several data elements that need to be collected. Therefore, it is important to find a good balance between precise measurement of results (many indicators) and manageability (few indicators). For each indicator, an indicator sheet has been developed which is presented together with the monitoring results in Annex 3.

Outputs

The Output level results from clearly defined program activities. On the supply side, MEMD with support of KfW is investing in increased electricity generation capacity (OP1), in grid extension and rehabilitation (OP2), in a prepaid metering scheme and connections for poor customers, together with GIZ-supported promotion campaigns (OP3 and OP4), and in several capacity development activities (OP5 and OP6). These investments are accompanied by measures that address the demand for and use of electricity by customers. To this end, KfW has engaged GIZ to carry out awareness campaigns for current and potential electricity customers (OP7 and OP8). The expected results at the Output level are:

(OP1) Renewable electricity generation capacities have been created

(OP2) Grid extension lines have been constructed, and the existing grid rehabilitated

(OP3) A prepaid metering scheme has been introduced

(OP4) Poor customers have been targeted with low cost connections

(OP5) Increased capacity at WENRECo

(OP6) Increased capacity among local technicians

(OP7) The productive use of electricity has been promoted

(OP8) The safe and efficient use of electricity has been promoted

Use of Output

At the Use of Output level, there are two principle results that are monitored. On the supply side, these describe how the outputs are utilized by WENRECo. On the demand and awareness side, they describe how the outputs are absorbed by the electricity customers.

The supply of electricity by WENRECo is an essential precondition for the entire results chain. Development impact will only be achieved if electricity is supplied in a reliable, broad-based, and efficient manner, and if WENRECo is able to reach profitability. For this reason, the efficiency of the electricity supply is monitored. The M&E framework further covers the number of new connections in towns and rural areas, so that statements can be made on spatial distribution as well as on the number of low-cost connections, which are provided to poor people in the region. In addition, prepaid metering allows better control over expenditure on electricity. Finally, the monitoring scheme considers the number and durations of blackouts and WENRECo response times, if outages occur. This is of particular interest to commercial customers since they require a reliable supply to plan their investments in machines and equipment.

An increased electricity demand and an awareness of its productive, efficient, and safe use are the intermediate objectives of the GIZ measures (UP2). The M&E system captures the general demand among the units of analysis by monitoring the number of applications for an electricity connection and by direct interviews with beneficiaries.

Outcome

To measure the improvements in access to and use of electricity-based services, seven indicators are proposed. Indicator OC1.1 calculates the number of people living in households that are connected to the grid, while the other six indicators describe the benefits for both connected and nonconnected households and businesses, as well as for connected secondary schools and health centers.

The actual use of electricity-based services is of particular interest and is therefore specifically monitored by indicator OC1.2. End-use appliances play a key role by transforming the electricity provided into useful services. We therefore consider the number of appliances as a convenient indicator: when more appliances are in use, then access to these services has obviously improved.

If access to competitive electricity-based services is improved, it can be expected that this will partially substitute for the use of other energy sources such as fossil fuels (replacing kerosene or engine fuels), while the use of biomass will probably be less affected (electric stoves are too costly for most of the target groups). Thus, indicator OC1.3 serves to assess the amount of fossil fuels and biomass combusted.

Affordability is assessed indirectly by monitoring the extent of use (indicators OC1.2 and OC1.3). This is backed up by indicator OC1.4, which tracks how many households struggle to pay for the grid connection in the first place and are then able to keep their pre-paid meters charged. If the first number stays low and the second stays high, and the number of connections and extent of use increases, it is reasonable to assume that the electricity being supplied is affordable.

As well as substituting for other energy sources and making energy services competitively priced, electricity may also serve as a foundation for the provision of new services that are entirely based on electricity, most prominently ICT-related services. OC1.5 monitors improvements in access to electricity-based information and communication services, for both direct and indirect beneficiaries.

Finally, an improved access to electricity-based services should also consider the reliability of both the electricity supply and the electrical appliances used. However, the quality and reliability of appliances is beyond the program's influence, and thus not part of the monitoring. The reliability of the electricity supply, in contrast, is already captured at the Use of Output level.

The GIZ measures, which aim at improving productive, safe and efficient electricity use, are reflected in the indicators OC1.6 and OC1.7. While at the Use of Output level the measures have been assessed in terms of knowledge, the Outcome level quantifies the GIZ measures in terms of the degree to which their content is adopted in practice. The number and type of electrical appliances and machines in use also provides some insights into productive activities (OC1.2).

Impact

For result I1, (non-transport) CO_2 emissions are calculated both for the energy supplier WENRECo (I1.1) and for the population (I1.2). Emission reductions can be expected for the population because most energy services in West Nile have been fuel-based. With a switch to electricity-based services, the reduction of fuel-based emission can be attributed to the program intervention. However, only fossil fuels are considered for emission reductions, as there is no reliable data on the sustainability of the biomass used in West Nile, and the collection of such data is not feasible in the context of the monitoring process (see Chapter 2.4 in Annex I for a detailed explanation of how to calculate CO_2 emissions).

The contribution to productive and income-generating activities (I2) is measured by the increased number of employees and extended business hours (I2.1), the increased proportion of businesses with local value-adding (I2.2), and the increased proportion of households with productive activities (I2.3). Of course, the increase in productive and income-generating activities is not solely dependent on the use of electricity-based services, but is also influenced by other factors, which are outside the program's scope. Nevertheless, the hypothesis underlying the results chain assumes that productive activities can be stimulated, and their efficiency can be increased if businesses and households are able to reduce their total expenditures on energy and gain access to new ranges of products, services, and markets. Such an increase in productive activity can be then attributed to the program intervention, based on the double-difference approach.

With regard to social infrastructures, the results of electrification are expected to improve the delivery of services. Health centers and schools not only have access to key electricity-based services but are progressively incorporating them into the range of health or educational services they provide. Again, three dimensions of access are highly relevant at this level, and each will be monitored. Given that health centers and schools have access to electricity and can make use of it, the services provided must still be reliable and available as and when needed by patients or students alike. Access to clean drinking water is considered an important element in improving the rural health situation. Water supply is often limited by the costs of water pumping, which are particularly high if the pumps are powered by diesel engines. With an increased access to cheap electricity, one can also expect greater access to clean drinking water within the electrified area. Therefore, assessing the number of customers of central water suppliers serves to capture quite adequately the reliability of water provision and the range of service provided. Improved education, healthcare, and water supply (I3) are thus measured mainly in terms of the services that are offered in these fields (I3.1 to I3.3).

Risks

A major risk to achieving the Impact results lies in the inadequate volumes of qualified staff and budgetary funds available to the respective social services (R1). This is measured by indicators R1.1 and R1.2 for schools and health centers, respectively.

A1-2. Methodical design

This chapter is an updated summary of the equally named chapter 5 of the originally developed M&E framework (Berg and Gaul et al. 2011, 37–45).

2.1. Parent population

The beneficiaries of the electrification program are the subjects of statements on program progress and impact. To carry out the M&E surveys, however, units of analysis had to be defined, which are not necessarily identical with the beneficiaries. In the present case, the units of analysis at Outcome and Impact levels are households, businesses, secondary schools and health centers of level III and above.

Several types of educational institutions and health centers that fall within the beneficiary group had to be excluded to maintain feasibility. Both vocational schools and universities have not been considered for the sample as it is difficult to calculate average result values for such heterogeneous institutions. Furthermore, nursery and primary schools have been left out, as the results to be expected for these school types (except for lighting, which will also be monitored for secondary schools) are quite limited. The same holds true for level II health centers, which hardly offer any energy-dependent health services (Ministry of Health 2009).

A precise definition of the parent population is required in order to develop a sampling proposal for the impact monitoring surveys. According to the methodical design, the population had to be defined for all units of analysis, and for both the treatment group and the control group:

- For the treatment group, the parent population of households and businesses can be defined as all households and businesses in the electrification corridor. The electrification corridor can be described by the settlements (towns and trading centers) that received a transformer station. As a transformer allows connections up to a radius of 500 meters, only households and businesses within this range can be connected to the grid. The population of secondary schools and health centers of level III and above are simply all of these institutions that get connected to the grid.
- For the control group, the population of households and businesses was defined as all households and businesses in trading centers outside of the electrification corridor.
- The population of secondary schools and health centers of level III and above are simply all of these institutions in the six districts of West Nile covered by the grid that had not been connected to the grid in 2013.

2.2. Applied approaches for results attribution

For results attribution, the double-difference and the simple before-after approach have been selected:

- The double-difference approach has been implemented for secondary schools and health centers, as well as for households and businesses in trading centers.
- In contrast, the simple before-after approach has been applied for households and businesses in towns.

These methodical decisions have been influenced by considerations regarding the survey area, the units of analysis, the required statistical significance, and implementation feasibility.

For the double-difference approach, initially two different options had been considered:

A. For the first option all units of analysis both with and without grid connection in the electrified trading centers are compared with all units of analysis in trading centers that are not connected to the electricity grid. As it was clear from the beginning that only a limited number of households and businesses will be connected to the grid, the average changes in each cluster are compared. This option was proposed for households and businesses due to the assumption that electrified households and businesses are not generally comparable to households and businesses without grid electricity, because electrification usually favors the better-off (e.g. World Bank 2008). Separating the better-off from the poorer units of analysis, however, poses a substantial methodical challenge, and is hardly feasible within a lean, practical M&E system.

B. The second option directly compares grid connected units of analysis with not grid connected units of analysis and was proposed for health centers and secondary schools, because it was assumed that all secondary schools and health centers (of level III and above) within the electrified corridor will sooner or later be connected to the island grid in West Nile. However, even by 2019, a significant number of secondary schools and health centers has not been connected to the grid. Furthermore, it appeared that secondary schools and health centers are very heterogeneous institutions that differ considerably in their specific characteristics that are monitored, making the comparison of a connected cluster with a non-connected control group cluster unfeasible.

It was therefore decided to apply option (A) to both households and businesses, as well as to secondary schools and health centers:

- For households and businesses, the treatment group (called “Electrified TCs”) consists of all randomly selected interviewed households and businesses (regardless if grid connected or not) within the trading centers that have been grid connected by 2019. In opposite, the control group (called “Not electrified TCs) consists of all randomly selected interviewed households and businesses (regardless if grid connected or not) within the trading centers that have NOT been grid connected by 2019.
- For secondary schools and health centers, the treatment group (called the access cluster) consists of all secondary schools and health centers that have not been grid connected by 2013 but got grid connected at least by 2019. In opposite, the control group (called the no-access cluster) consists of all secondary schools and health centers that have not been grid connected by 2019.

As all towns in West Nile were supposed to be connected to the grid by 2019, it was not possible to identify an appropriate comparison group for households and businesses in towns. In addition, the development dynamics and conditions in town areas are significantly different from those in other areas within West Nile. Therefore, the simple before-after comparison was applied for households and businesses in towns.

2.3. Sampling and statistical significance

A decision needed to be taken with respect to the representativeness desired from the survey results. Both the level of confidence and the acceptable range of measurement error had to be defined. Generally, results with a level of confidence of 95 per cent are considered statistically significant. For this M&E framework, however, we proposed a level of confidence of 90 per cent. This is a value that has limited scientific pretensions but is still perfectly acceptable for practical purposes, and it also results in a manageable sample size.

A tolerance of ±5 per cent was proposed for the single-sided measurement error, as do most M&E-related surveys in the development cooperation field. Based on an exploratory survey in 2011, the population size of the towns and trading center areas within the electrification corridor as well as of the trading centers outside the electrification corridor has been estimated to be in the range of 20,000 households and 4,000 businesses each, which has been updated during the 2013-2019 monitoring to estimated 60,000 households for trading centers and 100,000 households in towns. To achieve the desired level of representativeness and considering a margin of failed interviews of about 2-5%, it was deemed necessary to survey about 300 households and 275 businesses in each survey area (treatment trading centers, control trading centers, towns), which amounted to 900 households and 825 businesses in total. This means that in each of the 20 trading centers an average of 30 households and 28 businesses needed to be interviewed, while in the towns approximately 50 household and 46 business interviews were required. For the secondary schools and health centers total population surveys were envisaged, resulting in a statistical significance surpassing the intended level.

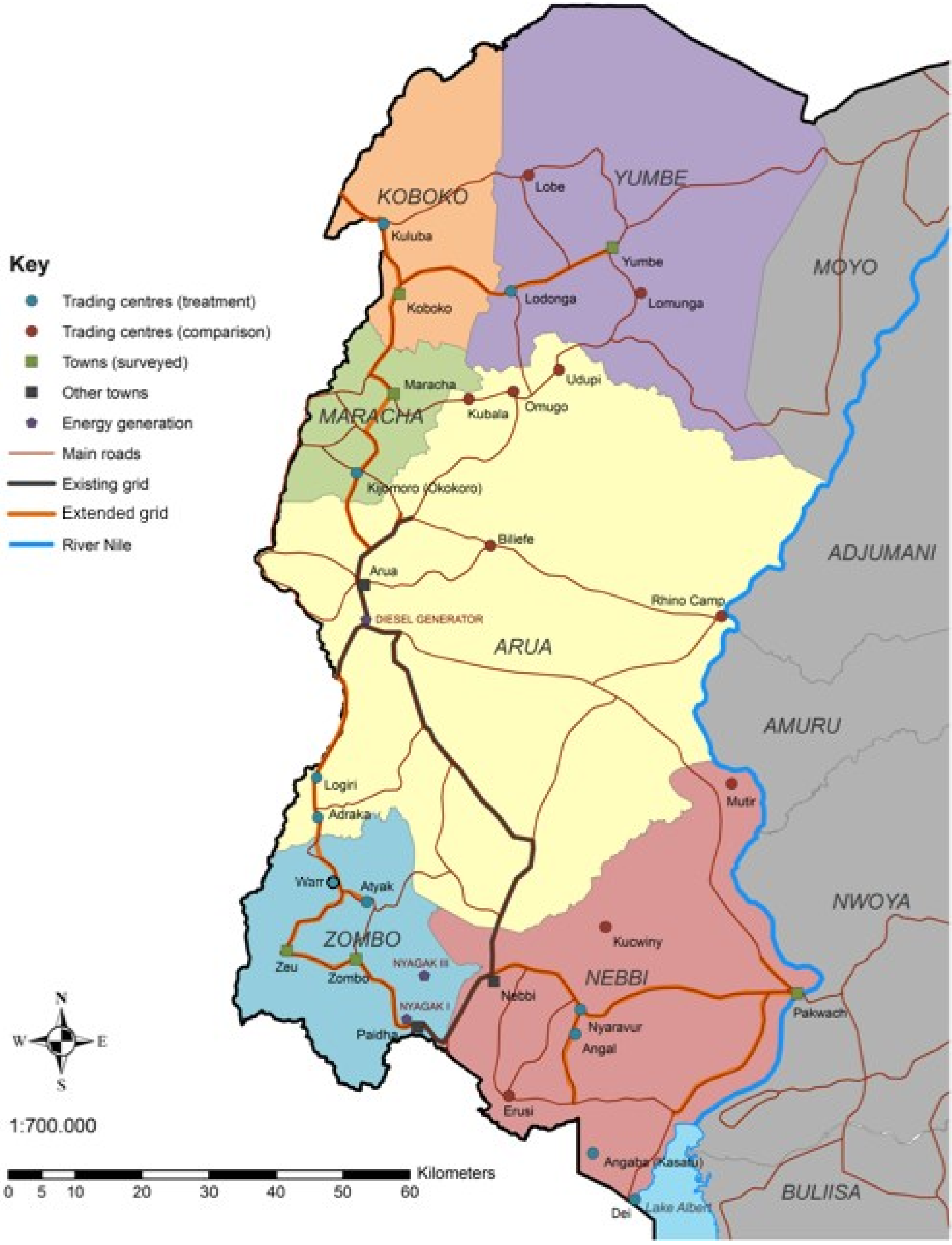
Due to the different characteristics of the units of analysis, sampling procedures varied for households and businesses as against schools and health centers. For each unit of analysis, a sample had to be drawn for both the treatment group and the comparison group. As specified above, the populations of the treatment group comprise all households and businesses in towns and trading centers that were supposed to receive a transformer, as well as all schools and health centers for which electricity connections were planned. Accordingly, the populations for the comparison group consisted of all units of analysis that (due to their physical distance to the grid) would not have the opportunity in the foreseeable future to be connected to the electricity grid in West Nile.

Schools and health centers that were already connected, and households and businesses that were in areas already covered by the grid, were thus not part of the sample. There are two main reasons to exclude the populations that were already connected from the sample. (1) The areas that are already electrified had poor quality electricity provision due to the limited capacities of the diesel generator. The general conditions of electricity supply in the newly connected areas, however, were significantly different, and thus these two areas could not easily be compared. (2) Only some of the program results could be measured cleanly for these areas, since a baseline has not been established before the first electrification activity. While it would have be possible to measure the results of the GIZ complementary measures or the low-cost connections offered in this area, this could be done just as well in those areas that were newly connected by the program.

Households and businesses in trading centers

For households and businesses in trading centers, the double-difference approach was applied for results attribution. Therefore, units from both the electrification corridor as well as from not electrified areas had to be surveyed. However, it was logistically not manageable to select households and businesses at random from the entire region. Thus, it was necessary to follow a multi-stage sampling approach, and to group the units of analysis at a first stage into clusters. Geographical classification was chosen and trading centers and town areas comprised clusters. At a second step, a representative number of clusters was sampled and within those, randomly selected households and businesses were interviewed.

Figure A1-2: Sampling map



These clusters were deliberately selected to cover the maximum variance between the settlements (see Figure A1-2). Three main criteria were used for the selection:

- the sample represents all districts of West Nile;
- settlements with different population sizes and economic characteristics are considered;
- for each treatment cluster a comparison cluster can be identified, with similar socio-economic and infrastructural characteristics.

A random sample of households and businesses needed to be drawn based on the selected trading centers. As no sample frame was available, selection via a random route was applied.

Households and businesses in towns

It was not possible to identify a control group for the towns that were connected (Pakwach, Zombo, Zeu, Maracha, Koboko, Yumbe). Selecting a control group outside West Nile was not an option in terms of feasibility. Thus, the simple before-after comparison was applied for households and businesses in towns.

Since from the perspective of this M&E framework the main difference between towns and trading centers is the pace of development, it was sensible to concentrate on the dynamic areas of towns for the sampling of the units of analysis. The survey area in the towns was therefore limited to the town centers.

A random sample of households and businesses needed to be drawn based on the selected town areas. As no sampling frame was available, selection via a random route was applied.

Health centers and secondary schools

The double-difference approach is also applied to analyze the results for health centers and secondary schools. For these units of analysis, however, the situation is different compared to that of households and businesses, as the overall population is significantly smaller. In 2013, there were a total of 100 health centers of level III and above, and 158 secondary schools in West Nile. Nine health centers and 19 schools already had been connected at the time of the baseline survey and were thus not part of the parent population of 91 health centers and 139 secondary schools.

As it was not possible in 2013 to establish precisely which of these institutions would get grid connected and which not, a total population survey was conducted. For every survey, the composition of the access cluster and non-access control cluster was updated by adding all grid connected institutions to the access cluster. The clusters of previous survey years were re-established accordingly, resulting in coherent cluster compositions for all survey cycles.

2.4. Calculation of emission factors

The 2006 IPCC Guidelines for National Greenhouse Gas Inventories are used to calculate carbon dioxide emissions (IPCC 2006). The guideline proposes three different approaches for calculating emissions, depending on the availability of national data for the underlying emission models. Even though Uganda carried out a national greenhouse gas (GHG) inventory in 1994 (UNEP 1996), the data is rather limited and outdated, and is not very representative of the specific situation in West Nile. Therefore, only the simplified ‘Tier 1’ approach is used, calculating fuel-based emissions based on the quantities of fuel combusted and average emission factors.

Only fossil fuels are considered in the emissions calculation. For biomass, no data is available on the proportion which is produced sustainably (with no GHG footprint) and the proportion produced unsustainably, for which GHG emissions would need to be calculated. Furthermore, such a calculation would require detailed data on the energy value and carbon content of the biomass used and on possible emissions caused by changes in land use; such data is not available for West Nile.

Table A1-1: Net calorific values and default emission factors

Fuel Type	Definition	Net calorific value[a]	Density[b]	Default emission factor		
		(MJ/kg)	(kg/m3)	(kg CO_2 /GJ)c	(kg CO_2 /kg)	(kg CO_2/l)
Gas/ Diesel Oil	Gas/diesel oil distils between 180ºC and 540ºC. Several grades are available dependent on application: diesel oil for diesel compression ignition (cars, trucks, marine, etc.), light heating oil for industrial and commercial uses, and heavy fuel oil.	43.0	843.9	74.1	3.186	2.689
Motor Gasoline (Petrol)	Motor gasoline (petrol) is distilled between 35ºC and 215ºC and is used as a fuel for land-based spark ignition engines. Motor gasoline may include additives, oxygenates, and octane enhancers.	44.3	740.7	69.3	3.070	2.274
Other Kerosene	Kerosene comprises refined petroleum distillates, intermediate in volatility between gasoline and gas/diesel oil. It is a medium oil, distilling between 150ºC and 300ºC.	43.8	802.6	71.9	3.149	2.527
Liquefied Petroleum Gases (LPG)	LPG are the light hydrocarbons fraction of the paraffin series, comprising propane (C3H8) and butane (C4H10) or a combination of the two. They are normally liquefied under pressure for transportation and storage.	47.3	522.2d	63.1	2.985	1.559
Paraffin Waxes	Paraffin waxes are saturated aliphatic hydrocarbons (with the general formula CnH2n+2). They have a crystalline structure with n greater than 12 and are colorless and translucent, with a melting point above 45°C.	40.2	--	73.3	2.947	--

(a) Source: IPCC 2006: Volume 2, 1.12-1.19. (b) Source: IEA 2005: 181. (c) Source: IPCC 2006: Volume 2, 2.16-1.23. (d) Assumes a mixture of 70 per cent propane and 30 per cent butane by mass.

Of the GHG emissions, only carbon dioxide was considered, because data on combustion technologies and operating conditions were not systematically collected for West Nile and the “emission factors for methane and nitrous oxide depend on the combustion technology and operating conditions and vary significantly, both between individual combustion installations and over time. Due to this variability, use of averaged emission factors for these gases, that must account for a large variability in technological conditions, will introduce relatively large uncertainties” (IPCC 2006, Volume 2-1.6).

Attention focused on stationary combustion, targeting the six fossil fuels that are mainly used in West Nile: heavy fuel oil, diesel, gasoline (petrol), kerosene, liquefied petroleum gas (LPG), and paraffin wax. IPCC (2006) defines these fuels on the basis of IEA definitions (according to IEA 2005). Under this set of definitions, no distinction is made between heavy fuel oil and diesel.

Table A1-1 (on the previous page) shows the net calorific values and default emission factors for stationary combustion of the five fuel types presented. These are the same across all relevant sectors, including the energy industry, manufacturing and construction, commercial and institutional, as well as residential, agriculture, forestry, and fishing.

A1-3. Implementation

After the baseline survey in spring 2013, the first monitoring survey was implemented in autumn 2015[49], followed by a second monitoring survey in spring 2017. A final monitoring was implemented in spring 2019. While the baseline survey made a quantitative description of the status quo before the grid extension, each monitoring survey consisted of a two-step approach for which first a quantitative survey was implemented and data analyzed, before an additional qualitative survey aimed at providing more detail or explanations on recorded trends.

3.1. Quantitative surveys

For the quantitative surveys, data was collected from stakeholder institutions such as the Ministry of Energy and Mineral Development (MEMD), KfW Entwicklungsbank, the power distributor WENRECo and the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), who implemented the E-AIM campaign.

Additionally, data was collected from the Ugandan Bureau of Statistics (UBOS) for census data, socio-economical surveys and general statistics; from the Uganda Revenue Authority (URA) for data on tax registered businesses in West Nile, from the Uganda National Examination Board (UNEB) for data on examination scores in West Nile secondary schools. Furthermore, a desk survey on general socio-economic trends in West Nile was conducted in 2017 and updated in 2019, screening available literature published that covers West Nile development.

The quantitative field survey was implemented in May/June 2013, 2017, 2019 and in September 2015. Thus, for the comparison of the 2013 baseline with the 2017 and 2019 survey, we can eliminate the uncertainties of seasonal effects for the interpretation of data, which might have affected some of the 2015 results.

Table A1-2 provides an overview of the sample sizes of the survey units in the different survey clusters over the four surveys. While in 2015, the share of WENRECo customers had been negligible (because the total number of customers in the newly connected areas was still very low), 24% and 22% of the interviewed households, as well as 48% and 44% of the interviewed businesses were WENRECo customers in 2017 and 2019, respectively.

In the different survey clusters and units, the share of WENRECo customers compared to the total number of interviews reached from 27% in case of households in trading centers within the electrification corridor up to 74% of businesses in towns (see Table A1-2). This reflects the **deliberate sampling approach** to start interviews from the center of the trading centers, which naturally have the highest concentration of customers. This does **not reflect the general ratio of customers** in the respective trading centers compared to their total population.[50]

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[49] The 2015 survey was shifted from spring to autumn to better cover some early effects of the delayed grid extension project.

[50] The total population of the 6 districts covered in West Nile is about 2.4 million people that live in 4,316 villages. The WENRECo network in West Nile currently covers some 40-50,000 people in about 70 trading centers which might partially cover some 150-300 villages. In total, some 5% of the existing villages and about 2% of the total population are directly reached with grid electricity.

While the survey units of households and businesses were separated in the three survey clusters '**not electrified trading centers**' outside the electrification corridor, '**electrified trading centers**' within the electrification corridor, and '**electrified towns**' within the electrification corridor, for the survey units of health centers and secondary schools all institutions in the 6 grid covered districts of West Nile were targeted. As the focus of the impact monitoring was on new access, the panel of health centers and secondary schools for the baseline survey 2013 represented only (at the time of the baseline survey) **nonconnected** institutions. These institutions were separated into a '**no access cluster**' of institutions that have, even by 2019, not been grid connected, and an '**access cluster**' of institutions that have been grid connected.

Table A1-2: Number of households, businesses, HCs and secondary schools interviewed

Survey cluster	Survey unit	2013	2015	2017	2019
Not electrified trading centers	Households	425	448	444	404
	Businesses	283	367	273	299
Electrified trading centers	Households	536	454	451	504
	only WENRECo customers	0	4 (1%)	143 (32%)	135 (27%)
	Businesses	286	325	339	315
	only WENRECo customers	0	7 (2%)	217 (64%)	190 (60%)
Electrified towns	Households	359	456	306	329
	only WENRECo customers	0	7 (1.5%)	140 (46%)	142 (43%)
	Businesses	423	333	309	316
	only WENRECo customers	0	12 (3.6%)	227 (74%)	217 (69%)
No-access social institutions	Health centers III	58	55	51	56
	Health centers IV & V	5	4	5	4
	Secondary schools	90	73	66	70
Access social institutions (connected between 2013 and 2019)	Health centers III	20	20	19	19
	only WENRECo customers	0	4 (20%)	10 (53%)	19 (100%)
	Health centers IV & V	3	4	4	6
	only WENRECo customers	0	1 (25%)	3 (75%)	6 (100%)
	Secondary schools	33	33	33	35
	only WENRECo customers	0	5 (15%)	26 (79%)	35 (100%)
	Total	**2,521**	**2,572**	**2,300**	**2,357**

Of the 91 health centers of level III to V that represent the panel, 86/83/79/85 could be interviewed in 2013/2015/2017/2019, respectively. Of the 139 secondary schools that represented the panel, 123/106/99/105 could be interviewed in 2013/2015/2017/2019. The reason for not reaching all health centers is mainly caused by difficulties meeting sufficiently qualified staff for interviews (Yumbe hospital has been closed in 2019 due to renovation), while in case of the secondary schools, 17 of the 139 secondary schools have been closed since 2013, reducing the panel size to 122.

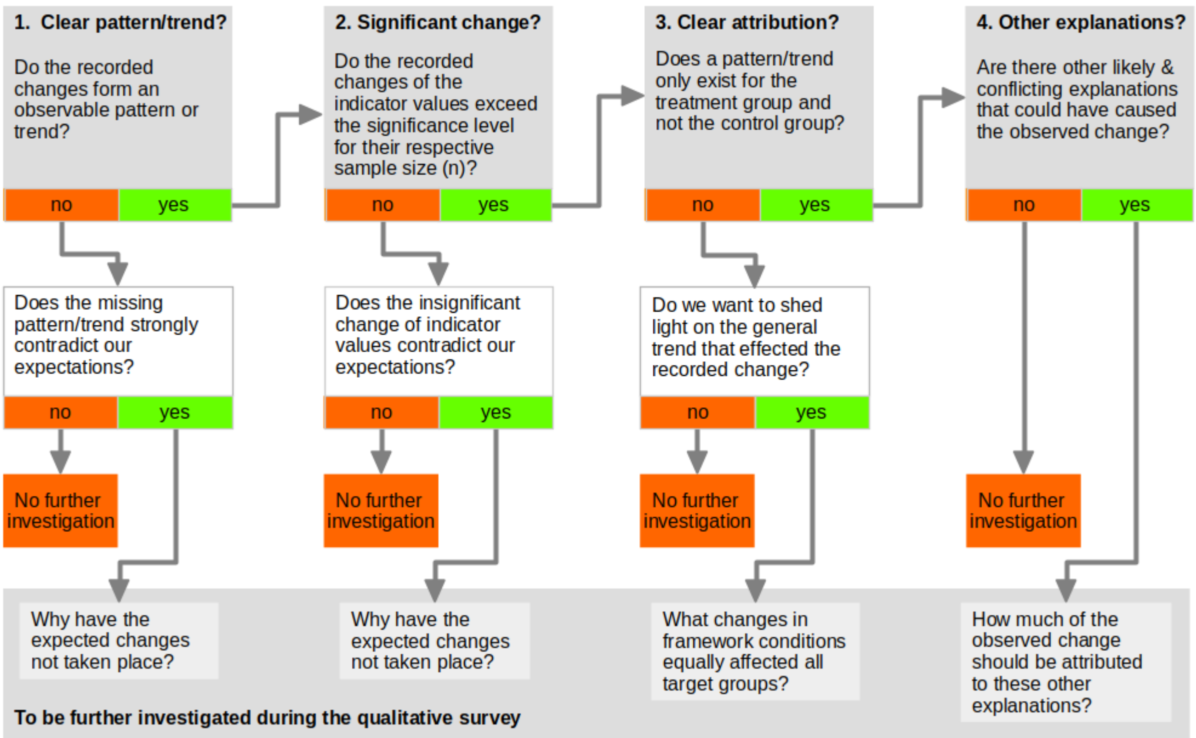
3.2. Quantitative data analysis

For the data analysis, raw interview data was extracted from the tablet computers and four data sets for households, businesses, health centers and secondary schools were assembled in one field data base. In a second step, data was checked for correct coding, formats, and empty cells, and then extracted into the respective indicator spread sheets.

For each indicator, data was again checked for inconsistencies, incorrect data entry and contradicting data (e.g. comparing data for fuel amount and fuel cost); and unrealistic values (e.g. due to unit errors) were deleted. Additionally, qualitative statements needed to be qualified as true or not true (e.g. customer statements on energy efficiency or safety measures).

Data interpretation was implemented in four steps as depicted in Figure A1-3:

Figure A1-3: Process flow of data interpretation



1. Checking patters and trends: The data set comprises a series of four points in time (2013, 2015, 2017 and 2019). The overall aim of the monitoring was to check for effects that can be attributed to either the new access to grid-based energy services (caused by OP1-5) or to the E-AIM campaign (caused by OP6-8). In October 2015, the effects of grid-based energy services in the newly connected areas were negligible for households and businesses and small for health centers and secondary schools (see Table A1-2). Consequently, the 2015 data points can be considered as an extension of the baseline values, providing us with a baseline trend for comparison with the 2017 and 2019 data points. The E-AIM campaign, which started with its roadshow shortly before the 2015 monitoring survey, may have had some ‘fresh’ effect on the awareness levels of interviewed individuals; however, most of the campaign was implemented after the monitoring survey, and the road show covered only 10 out of the 16 locations used for the monitoring survey.

2. Testing significance of observed changes: In general, the monitoring survey has been designed for a confidence level of 90% with a significance level of ± 5% (see chapter 2.3 in Annex I). This criterion is met for all indicators related to households and businesses if the sample size reaches 300 for households and 275 for businesses in each cluster. There are some questions for which only a subset of a cluster of households or businesses was asked, reducing the sample size. This results in a significance level of up to ±10% in some cases, which had been considered for the respective indicators.

Regarding secondary schools and health centers, we have been aiming for a full panel survey and compare the interviewed sample with the full number of institutions in the access and no access cluster. In general, a confidence level of 90% and a significance level of ±5% could be reached for secondary schools and health centers. However, as not all institutions had answered every question, a significantly higher significance level had to be accepted for specific indicators. Only when the recorded change between two data points exceeded the significance level of both data points, this change can be considered as significant.

3. Impact attribution of observed changes: We used two different mechanisms for impact attribution: double-difference and before-after comparison.

For households and businesses in trading centers, as well as for health centers and secondary schools, the double-difference approach was applied, comparing the pattern/trend of the control group with the treatment group. If a trend existed equally for treatment and control group, eventual changes would likely not be caused by the program interventions but by external and general effects (e.g. changes in the overall socio-economic development of the region).

For households and businesses in towns, only the before-after values were compared. Because we had two baseline points (2013-2015) that represented a baseline trend, this baseline trend could be compared with the new trend of the 2015, 2017 and 2019 data points. Additionally, for the 2017 and 2019 values, a separate value for the 'only WENRECo customers' subset was provided to test if for WENRECo customers the recorded change is stronger or weaker compared to the average cluster value of connected households or businesses. Where this was the case, possible effects of the grid connection needed to be investigated.

4. Other uncertainties or conflicting explanations: After steps 1-3 were completed and some attributable impact had been identified, still a level of uncertainty could remain that might be caused by possible conflicting alternative hypotheses that could also explain the observed impacts. In this case, further investigations on specific indicators were conducted during the qualitative survey.

3.3. Qualitative survey

In 2013, comit GmbH and SiNERGi GmbH thoroughly assessed the methodology applied for the quantitative survey – comparing it with state-of-the-art impact assessment methodologies – and found it to be adequate under the program-specific circumstances. However, shortcomings of a purely quantitative approach, in particular the limitations of pre-defined indicators and the challenges to analyze observed differences in-depth and discover unexpected results, were taken into account when designing the surveys in 2015, 2017 and 2019. The qualitative data were collected by a survey team of a senior and a junior consultant.

In 2015, the first qualitative monitoring activities in the two districts Arua and Paidah (Zombo-District), were designed to supplement the quantitative results by information that could not be generated in the quantitative survey. A similar procedure was applied in 2017 and 2019, when the quantitative surveys were complemented by four-week qualitative surveys investigating questions prompted by the results of the quantitative survey and referring to the general socioeconomic impact of the program.

The qualitative surveys of 2017 and 2019 composed of semi-structured in-depth interviews and one-day workshops in different districts in West Nile region – Arua district, Maracha district, Yumbe district, and Nebbi district. Qualitative aspects that were raised during these workshops and interviews took beneficiaries' perceptions and opinions of the Investment Program and their assessments (verification) of findings from the quantitative survey.

The team conducted semi-structured interviews with industries, businesses and institutions such as health centers and schools (commercial customers). Purposely, we decided to interview connected and not connected commercial customers in order to get information on reasons why to get or not to get connected to the WENRECo grid.

In addition to the interviews, the team organized workshops with beneficiaries selected via purposive sampling.[51] The participants were selected businessmen and businesswomen, representatives of institutions, and WENRECo staff (both local staff members and regional staff members from Arua head office). The workshops started with a short presentation of selected results of the quantitative survey, followed by parallel focus group discussions on critical quantitative results including WENRECo services. Finally, the groups presented their results and discussed certain aspects in the plenary. The discussions held were always highly appreciated by the participants. See table A1-3 for a detailed description of the qualitative monitoring activities.

In view of low connection figures in (newly) electrified areas in West Nile, KfW Development Bank, MEMD and WENRECo had expressed some interest to learn more about the factors that support or hinder potential customers from getting connected to the grid. As respective questions were not part of the quantitative survey questionnaire until 2017, field coordinators explored this issue when meeting with local authorities in the respective town areas and trading centers. In addition, the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) provided some indications on hindering factors as a result of their experience with and results of their promotional campaign (E-AIM).

[51] The participants were selected via the following criteria: The total number of participants of each workshop was 20. Precondition to participate at the workshop was to be connected to WENRECo grid. Approximately the half of participants were head of a household, the other half of participants were people that conduct trade. 30% to 50% of participants were women.

Table A1-3: Detailed activities of the qualitative surveys

2015	In-depth interviews with 23 selected businesses in Arua Town, who were connected to the WENRECo grid since 2012; the focus was on the use of outputs and perceived outcomes and impacts, in particular on perceptions of WENRECo services and changes (including employment effects).[52] Two stakeholder workshops with in total 31 representatives (households and businesses) of a community nearby Arua Town (Onziwu) that has been connected to the WENRECo grid about 1 year ago and from the surroundings of Paidha and Nebbi. Apart from the assessment of outcomes of electricity supply through WENRECo. The focus was on the motivation of households to connect to the grid and the perception of WENRECo's services.
2017	In-depth interviews with 10 industries, 13 businesses, 7 health centers, 2 secondary schools connected and not connected to the grid, as well as 11 District Government Officials of the three districts. The focus was on the use of outputs and perceived outcomes and impacts, in particular with respect to the socio-economic development of the region and on perceptions of WENRECo services and changes.[53] Three stakeholder workshops with in total 59 participants in Maracha, Nebbi and Yumbe. Here, apart from the assessment of outcomes and impacts of electricity supply, the focus was on issues of stable power supply, solar power as an alternative power source and WENRECo service provision.
2019	In-depth interviews with about 20 businesses, 4 health centers (3 connected, 1 not connected), 5 secondary schools (3 connected and 2 not connected) and 2 vocational schools as well as about 10 District government officials in the districts Yumbe and Nebbi. Two Stakeholder workshops with in total 44 participants (households, businesses, district government representatives, secondary schools and health centers) in Nebbi and Yumbe. The focus was on impact of electrification on fuel use, economic development and development of social infrastructure.

The qualitative monitoring surveys put particular emphasis on the situation of businesses (in 2017: incl. industries) in West Nile and their dependency on regular power supply. Participants of the workshops perceived the observations and findings as very fruitful. An indication was the broad attendance of business people, as most of them sacrificed a full business day. In general, the commitment of participants during the workshops was outstanding. The meetings between WENRECo staff and local population during all workshops gave opportunity to clarify misunderstandings and address unanswered questions between WENRECo and customers. Participants discussed many relevant aspects of customer satisfaction and reliability of power supplied by WENRECo and jointly developed possible solutions. The workshop procedure could be taken as a blueprint for possible similar events to be initiated by WENRECo customer service that facilitate regular communication between WENRECo and customers.

52 See interview guideline for businesses connected to the grid in the Digital Annex 10.

53 See interview guideline for businesses connected to the grid in the Digital Annex 10.

Annex II

Socio-Economic Change in West Nile

A2-1. Background on West Nile

The Republic of Uganda is a landlocked country stretching across the equator and borders with Kenya in the east, South Sudan in the north, the Democratic Republic of the Congo in the west, Rwanda in the south-west, and Tanzania in the south. In 2018, an estimated number of 38.8 million people live in Uganda with an annual population growth of 3% (UBOS 2019, 11). Uganda is one of the poorest countries in the world with a Human Development Index score of 0.516. It places the country in the "low human development" category and puts it on 162nd place out of 188 in the UNDP country rankings (UNDP 2018, 24). Uganda is structured into four regions – Central, Eastern, Northern and Western – and ten sub-regions.

West Nile is located in the most northerly part of the country and is among the six poorest sub-regions of Uganda, with a poverty rate of 35% in 2017 (UBOS 2018, 90). Due to political conflicts in this area between the 1980s and early 2000s, West Nile has considerably lagged behind compared to other regions of the country in terms of economic and social infrastructure.

In colonial times Uganda was part of the Lado Enclave and passed from the Belgian Congo to Anglo-Egyptian Sudan, and finally to the Ugandan Protectorate. After independence from Great Britain in 1962, Uganda has been marked by intermitted conflicts and frequent change-over of power from Milton Obote to the military dictatorship of Idi Amin. In 1986 Yoweri Museveni came to power in a guerrilla war against the former president Okello which resulted in several conflicts across the northern Ugandan, e.g. the Lord's Resistance Army and its leader Joseph Kony (Laruni 2015). However, since pacification in 2002, the situation in the northern region has been changing. A major highway has been built which allows travel from Kampala to Arua in six hours. The Ministry of Water and Environment currently supports the construction of a water pipeline that goes up to Koboko district. Since 2011, emphasis has been placed in cooperation by the Governments of Uganda and Germany on establishing a reliable, efficient, and sustainable electricity supply by financing a hydroelectric power station in West Nile. Additional grid extension and densification activities are planned by the World Bank financed Energy for rural transformation project (ERT-3), as well as selected additional densification projects targeting social infrastructure and refugee settlements. The region is also planned to be connected to the national grid within the next 5 years.

1.1. Demography and administration

West Nile sub-region is structured into 9 districts – Adjumani, Arua, Koboko, Maracha, Moyo, Nebbi, Yumbe, Zombo, and the recently formed Pakwach district, separated from Nebbi – from which the two districts Adjumani and Moyo are not included in the rural electrification project. The districts (administrative level 5) are divided into counties (administrative level 4), sub-counties (administrative level 3), parishes (administrative level 2), and villages (administrative level 1). To coordinate between the administrative levels, a local council with a chairman is elected as the people's political representatives in administrative level 5-1. In addition to these elected bodies, there is a parallel structure of representatives from central government (e.g. the chief administrative officer at the district level, and the sub-county chief at the sub-county level). Even though decentralization is progressing, economy-related decisions, e.g. in the energy sector, are still taken centrally, with little district government involvement.

Most people in the region live in the districts of Arua, Nebbi, and Yumbe which are also, besides Adjumani, the largest districts in the region if not these with the highest population density as shown in Table 4 (UBOS 2017, 145; 2019, 142). The biggest town in the West Nile is Arua, which is also the main commercial supply center and transport route in the region. According to the most recent numbers of UBOS, people tend to move into the main towns Arua, Nebbi, and Yumbe (ibid.).

Table A2-1: Statistical Overview of West Nile

District	Population (2011 estimate)	Population (census 2014)	Population (2019 estimate)	Area (km²)	Population Density 2019 (per km²)	Counties	Sub-Counties	Parishes	Villages
Adjumani	353,200	225,251	234,300	3,087	76	2	10	54	206
Arua	751,700	782,077	891,700	4,274	209	5	28	165	1377
Koboko	222,900	206,495	248,500	821	303	3	9	47	390
Maracha	193,200	186,134	204,500	381	537	2	8	42	408
Moyo	382,400	139,012	155,200	1,891	82	2	9	44	227
Nebbi	337,400	238,959	274,800	2,917*	254*	2	11	51	889
Pakwach	*	157,835	189,700	*	*	1	6	30	*
Yumbe	504,500	484,822	629,400	2,403	262	1	13	97	647
Zombo	214,200	240,081	275,400	*	*	1	13	46	605
Total	2,959,500	2,661,000	3,103,500	15,774	197	19	107	576	4749
Total II**	**2,223,900**	**2,290,698**	**2,758,700**	**10,796**	**256**	**15**	**88**	**478**	**4316**

* As Zombo and Pakwach have been separated from Nebbi District, some statistical data is not yet available and is still included in the numbers for Nebbi. ** The program region excluding the districts Adjumani and Moyo.

Population estimates for 2019 as presented in table A2-1 do not consider recent migration trends. Some districts experience such a high influx of people that it overstrains their local capacities. Especially Yumbe district is experiencing a high population growth due to the massive influx of refugees fleeing from the war in South Sudan. Since June 2016, the population of Yumbe district increased from approximately 500,000 people to 900,000 people of which 300,000 people are categorized as refugees (District Planning Officer Yumbe 2017). Other districts that are mostly not connected to the grid (e.g. Adjumani and Moyo) face a significant reduction of inhabitants since 2011 and since 2016 a slight increase of population due to the refugee influx (ibid.; UBOS 2017,145).

Like many African countries, Uganda has to cope with a demographic challenge. The country has one of the youngest and most rapidly growing populations in the world. The total fertility rate is with 5.8 children per woman among the world's highest (CIA 2017; Sippel et al. 2011, 13).

1.2. Economic background

Since the economic downturn in 2008 and the resulting food price crisis, Uganda with its dependence on the agricultural sector faced many economic uncertainties (CIA 2017). Annual GDP growth dropped from 10,8% in 2006 to 5.1% in 2017 (UBOS 2019, 234). In 2018, the GDP per capita lies with current USD 643 under the Sub-Saharan average (World Bank 2019). The most important formal and informal economic sector is agriculture (including fishing and forestry). 65% of the Ugandan population are active in agriculture in 2017 (down from 72% in 2013) and more than one third of the work force is formally employed in this sector (UBOS 2019, 29). Coffee, tea, cotton, and tobacco exports are the main traditional income generating commodities (UBOS 2017, 57) but maize and beans exports are growing strongly (UBOS 2019, 270) . Since the agricultural sector is mainly based on subsistence farming, the share of agriculture in gross domestic product is only around 24.2% percent in 2017/2018. About half of the GDP is generated in the service sector (47.6%). The third largest sector is the industry sector (20%). Industry is not particularly widespread in most regions (UBOS 2019, 101).

The number of working age population in West Nile increased by one third from 980,000 in 2012/13 to 1,431,591 in 2016/17. 88.6% of them are counted as working population. The employment to population ratio decreased from 66.4% in 2012/13 to 57% in 2016/17 in West Nile, which is in line with the decrease of the national average from 53.2% to 47.5%. Out of the entire employed population in West Nile, only 16.7% are classified as paid employees and 6% as casual laborer in agriculture. Furthermore, 69.4% are considered self-employed and 6.9% are contributing family workers, summing up to a total of 76.3% being in vulnerable employment, as defined by the International labor organization (ILO). The unemployment rate decreased from 5,6% in 2012/13 to 2.5% in 2016/17 (UBOS 2018, 50).

While in 2012/2013 the main source of income has been ‘non-agricultural enterprises’ for 34% of households, the share decreased to 21% in 2016/2017, while the share of wage employment decreased from 25% to 16% and the share of subsistence farming increased in the same period from 32% to 49% (UBOS 2018: 107).

Of the 16.7% paid employees, the proportion of persons employed in higher qualified occupations is quite low and below the national average. 2.5% are considered “Professionals” and 1.8% are considered “Technicians and associate professionals”. The majority is categorized as ‘Service and sales workers’ (27.3%), ‘Skilled agricultural, forestry and fishery workers’ (33.3%) and ‘Craft and related trades workers’ (20.7%), which are all above the national average. When looking only on the population employed by the industry, 42.8% are employed in the agricultural sector, which lies 7% above the national average. The share of 18.8% in the construction sector exceeds the national average by 6.3%. For the sectors ‘Trade’ (20.7%) and ‘Services other than trade’ (17.8%), the values in West Nile lie below the national average (UBOS 2018, 52).

Table A2-2: Number of businesses and GDP by district (UBOS 2011; Wang et al. 2019)

District	Number of businesses (%)	GDP per capita (USD)
Arua	8,509 (55%)	202
Maracha	20 (2%)	203
Yumbe	643 (2%)	91
Koboko	2,536 (16%)	44
Nebbi	2,464 (16%)	151
Zombo	1,156 (7%)	148

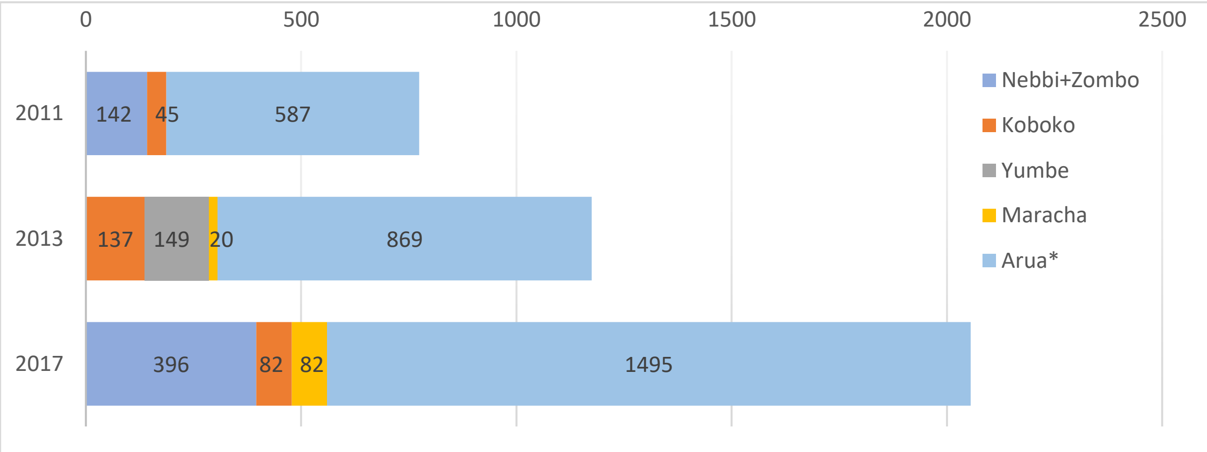
Much of trade in West Nile takes place in the markets of small agglomerations in rural areas, so called “trading centers”. In 2010, UBOS conducted a business census that resulted in

15,628 businesses employing 31,748 people in the six districts of West Nile covered by the power grid (see table A2-2 above). The regional disaggregation shows that economic activity in the region was foremost focused on Arua district, followed by Nebbi and, at that time, Koboko.

However, since the war in South Sudan started in 2013, the West Nile sub-region is seriously affected by instability in South Sudan impeding regional cross-border trade (District Planning Officer Yumbe 2017). Unfortunately, there is no current data on the economic impact available.

Our own survey of tax-registered businesses confirms the dominance of Arua district but records a decrease of tax-registered businesses for Koboko district in 2017[54]. The total number of tax-registered businesses almost tripled between 2011 and 2017 (see chart A2-1), but it is unclear whether this indicates a growth or maturation of the formal economic sector or simply an increased registration of existing businesses by the tax authority.

Chart A2-1: Number of tax registered businesses in West Nile (URA tax data)



* In 2013, the Arua tax office also covered Maracha and Yumbe. No consistent data could be collected for 2019.

A comparison of the main lines of business activities in West Nile based on URA data and our own survey shows that the share of retail activities is much higher in our survey data which includes many small shops in the trading centers that are probably not formally tax-registered. Especially in 2017, the share of service is much higher for tax-registered businesses. This might be explained by the fact that this category also covers private health and educational facilities, as well as motorcycle transport (*boda boda*), which have been excluded by our survey (see chart A2-2 on the following page).

A comparison of URA data of 2013 and 2017 shows that, regardless of the general growth of the total number of tax-registered businesses by 36%, the number of wholesale and retail businesses decreased even in absolute terms by 17% and 18%, respectively (while it remained rather stable in our surveys). At the same time, the service sector increased disproportionally by 63%. Unfortunately, different coding used in 2013 and 2017, as well as generic categories ("Other personal service activities n.e.c." alone counts for 23% of all services) prevent a further analysis of the type of businesses.

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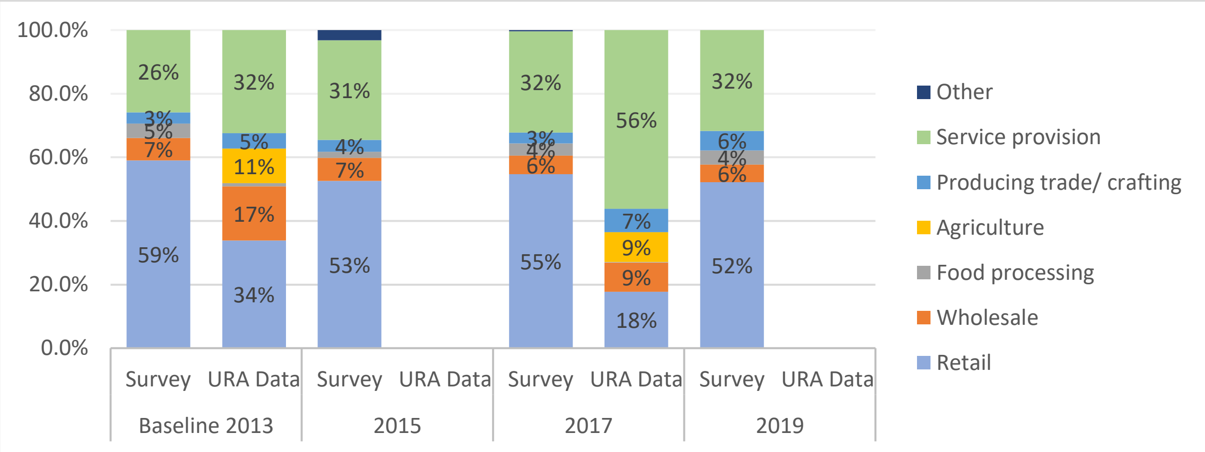
54 Unfortunately, the local URA office could not provide 2017 data for Yumbe district.

Chart A2-2: Line of businesses (tax registered and survey) [55]



Subsistence farming has again become the main source of earnings for households as displayed in table A2-3. The share increased from 32% in 2012/13 to 49% in 2016/17, while on the national level the share remained stable at 42.7%. Accordingly, wage employment of and non-agricultural enterprises decreased, while the share of households depending on remittances increased. These developments might indicate an economic regression, but might partially also be caused by the massive influx of refugees, mostly depending on subsistence farming. The refugee situation has been also associated with a strong increase in food prices (District Agricultural Officer Yumbe 2017).

Table A2-3: Distribution of households by Main source of Earnings

	West Nile		Uganda	
	2012/13	2016/17	2012/13	2016/17
Subsistence Farming (%)	31.9	48.8	42.6	42.7
Wage employment (%)	25.4	15.5	24.1	25.4
Non-agricultural enterprises (%)	33.7	21.0	23.9	20.2
Remittances (%)	6.3	10.0	6.5	6.9
Other (%)	2.7	4.8	3.0	4.7

1.3. Situation of households

While at the national level, poverty incidence increased from 19.7% in 2012/2013 to 21.4% in 2016/2017, in West-Nile it reduced from 42% to 35%, but the sub-region keeps the third highest poverty prevalence in Uganda (UBOS 2018, 90). Poverty incidence ranges from 20.1% in the districts Nebbi and Arua to 75% in the districts Yumbe and Koboko (World Bank 2018). 38% of all households in West Nile are considered food poor households compared to a national average of 37% and the average households spends 61% of its monthly expenditures on food

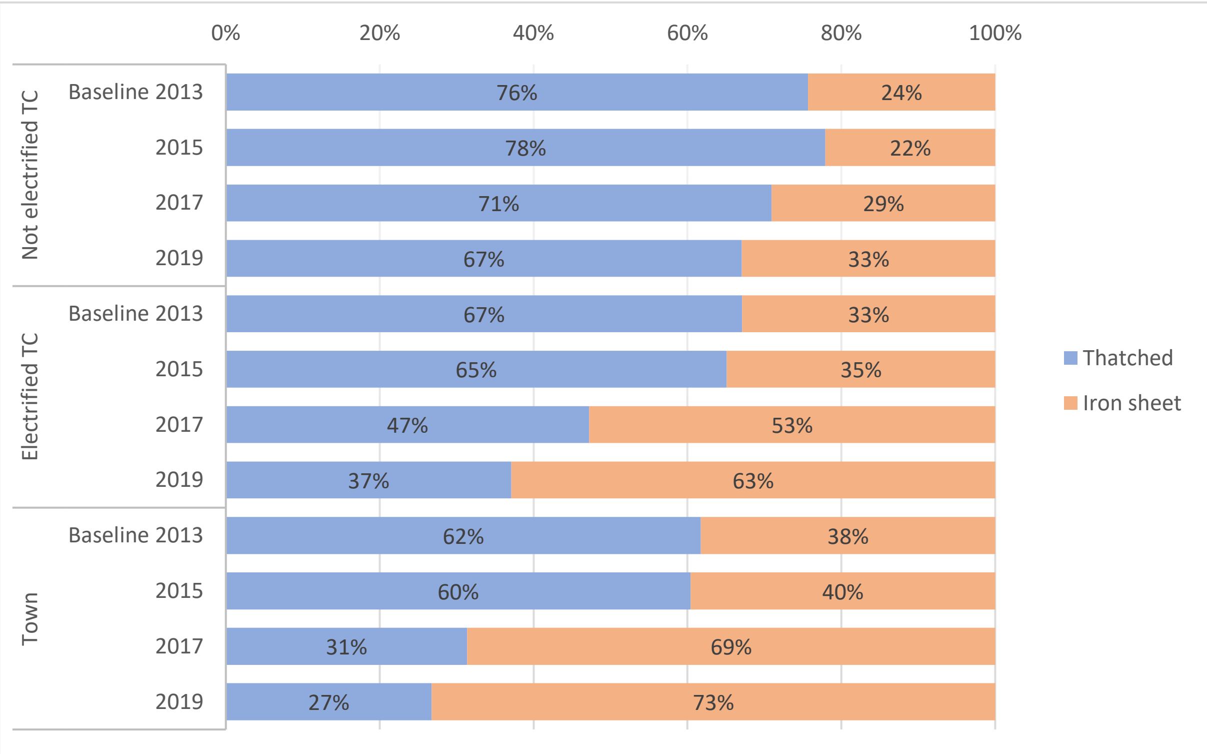
55 Only the tax registered data considers agriculture as business line, no data submitted by URA for 2015 and 2019.

compared to an 46% national average (UBOS 2018, 80). The high poverty prevalence is also reflected in the low nominal monthly household income of UGX 294,000 (USD 79.61) in 2016/2017 up from UGX 223,600 in 2012/2013 compared to a national average of UGX 416,000 (UBOS 2018, 109).

The data of the quantitative surveys also showed prevalence of poverty in West Nile, but it can be hardly compared with data of the Ugandan National Household Survey (UNHS) since our monitoring survey only covered household living in the middle of trading centers that represent the upper 20% social strata of West Nile. Therefore, the data collected in the impact monitoring exercise shows a more positive result than the UNHS 2013 and 2017 data. The average household size of West Nile lies with 4.3 (4.5 in 2013) slightly under the national average of Uganda with 4.7 (UBOS 2018, 2014), but more than 50% of the population in West Nile is under 17 years old and only around 27% of the population are older than 40 years (UBOS 2014, 12).

In the quantitative survey, data on household income was not directly asked since people are often reluctant to answer direct questions regarding their income and expenditures and even if willing, they struggle to provide consistent data. Consequently, data of roofing types and household expenditures has been collected and even with its limited robustness, this data can provide insights in major socio-economic changes and trends in West Nile (see chart A2-3).

Chart A2-3: Households by type of roofing

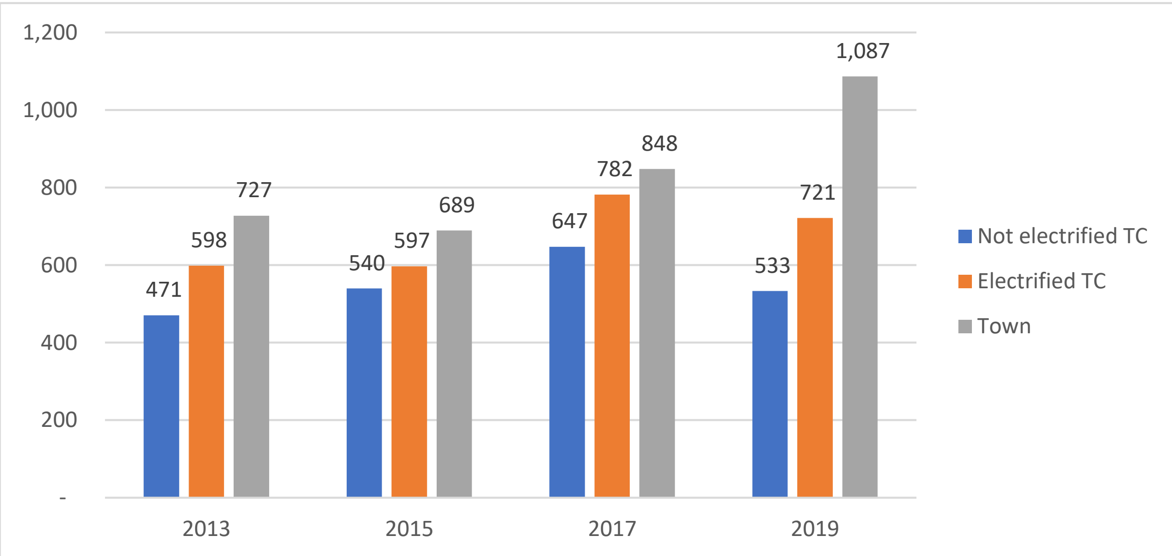


Type of roofing is considered a reasonable proxy for household wealth. In the surveys of 2013, 2015 and 2017, only 2 cases with tile roofing were recorded, while roofing is dominated by thatched roof and iron sheet. In 2013, thatched roofs were dominating with 78% in trading centers outside the future electrification corridor, and 67% and 62% in trading centers and towns within the future electrification corridor. According to UBOS, the proportion of houses with thatched roof dwellings in West Nile is 80%, which represents the second highest value in Uganda (UBOS 2018, 126).

While this situation did not change much until 2015, by 2017 we could observe a general trend to improved roofing, which, in absence of any support program subsidizing iron sheet roofing, speaks for a trend towards improved household income. This trend is more pronounced within the electrification corridor, especially in towns, which shows that these areas are benefiting from a stronger increase of household income. Disaggregating the data of 2019 for households that are WENRECo customers shows that 98% and 99% of the WENRECo customers in trading centers and towns, respectively, have iron sheet roofing, confirming the assumption that mainly better-off households can afford a grid connection.

The data on household income shows a different dynamic (see chart A2-4 below). Household expenditures increased for all households until 2017, but dropped in not electrified trading centers and electrified trading centers in 2019. When adjusting expenditures for inflation[56], only households in towns increased their expenditures by 17% compared to 2013. For trading centers within and outside the electrification corridor, inflation-adjusted expenditures decreased slightly. A disaggregation of 2019 data for WENRECo customers shows that these have significant higher expenditures than the average (UGX 1.2 Mio and UGX 1.4 Mio in trading centers and towns, respectively). Households in West Nile spent over half of their total household expenditure on food (60%).

Chart A2-4: Average monthly household expenditures (UGX 1,000)



In comparison, the Ugandan National Household Survey of 2016/17 showed much lower monthly nominal expenditure levels for the Northern Region, which increased from UGX 209,100 in 2012/2013 to 247,500 in 2016/2017, compared to UGX 325,800 in Uganda (UBOS

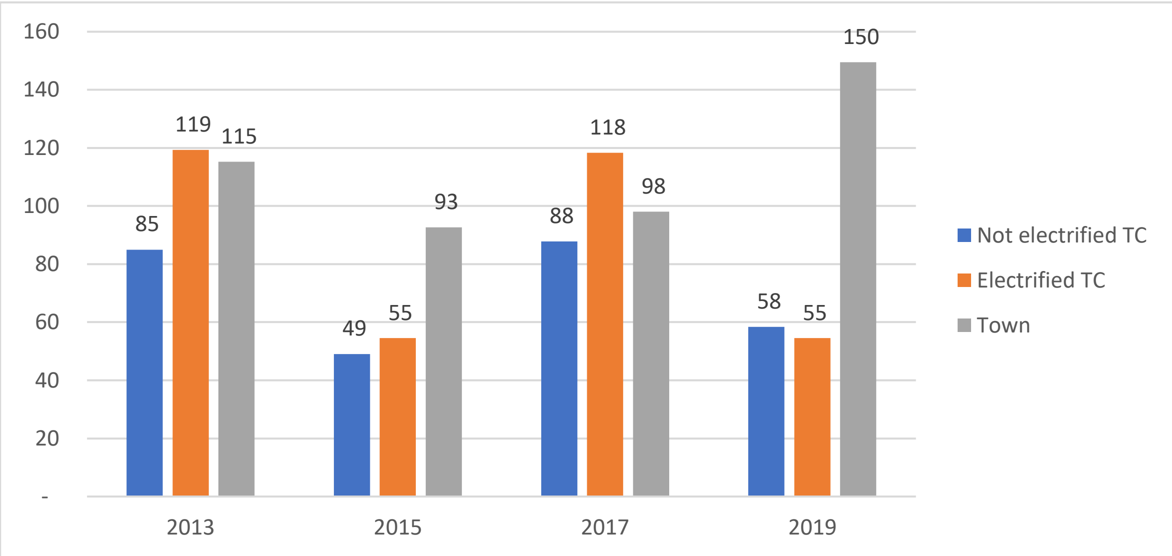
56 The average annual inflation rate for 2013 to 2018 was about 4%. Inflation has been 3.1% in 2014 and 5.5% in 2015 (UBoS 2016:90), while in Fiscal year 2016/2017 it was 6.4% and in 2018 it was 2.6% (website accessed on 01/10/19, https://www.statista.com/statistics/447810/inflation-rate-in-uganda/).

2018, 84). The average nominal monthly income in West Nile increased from 223,600 UGX in 2013 to 294,000 in 2016/17 (UBOS 2018, 179).

This indicates that both our samples within and outside the electrification area represented wealthier population living close to the center of trading centers, in opposite to peri-urban or rural households living in the countryside. In average terms for the Northern Region, our sample population represented in 2013 the upper 20% strata of the total population (UBOS 2014, 99). A decrease of the Gini coefficient from 0.34 in 2012/13 to 0.32 in 2016/17 indicates a slight decrease in income equality (UBOS 2018, 94).

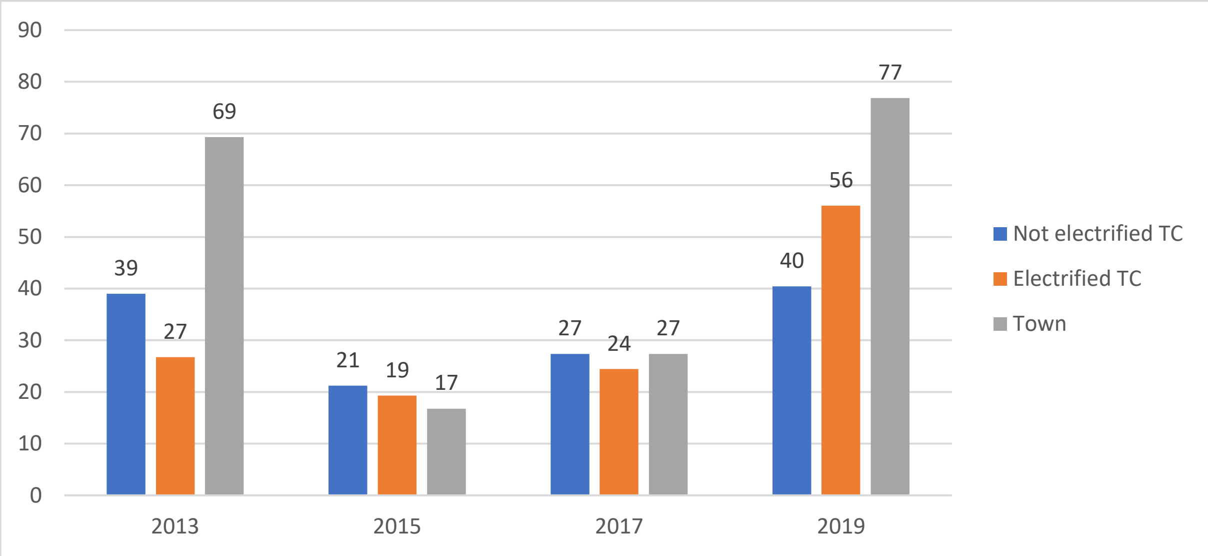
Households savings have always been low compared to expenditures and fluctuated strongly over the years (see chart A2-5). Comparing 2019 with 2013, households in not electrified trading centers and electrified trading centers decreased their savings strongly. This gets even clearer when considering the inflation rate. However, savings in towns increased by 5%, when adjusting them for inflation. Together with the increased household expenditure in towns, it seems that households in towns are becoming better-off. Low savings in the first place means that the increased expenditures have to be earned by the households via an increased income, unless households have additional sources of income or are increasingly in debt.

Chart A2-5: Average household savings (UGX 1,000)



But as chart A2-6 shows, remittances of households in not electrified trading centers and in towns decreased, whereas they increased in electrified trading centers by 40%. So, the increased expenditures together with the improved roofing can be construed as a slight trend towards an improved income situation within the survey area.

Chart A2-6: Average remittance received by household (UGX 1,000)



The Ugandan National Household Survey of 2016/17 also provides information on households' energy use and related welfare impacts perceived.

As Table A2-4 on the following page shows, improved electricity played a minor role (8.6% of all households) in making people's lives in West Nile better off in the past 5 years, which is much less than the national average, which results in 24.5% of all households. This can be explained by the very low connection rate in West Nile resulting in only 3.1% of surveyed households being connected to the power grid. In particular, development projects and the construction of new roads had a positive impact on people´s live in West Nile.

Table A2-4: Events that made people better off in the 5 years preceding the survey (%)

	West Nile	Uganda
	2016/17	2016/17
Improved transportation services	5.6	34.0
Improved electricity	8.6	26.8
Development project	38.7	24.5
New road	12.6	24.5
New school	3.6	18.3
New employment opportunities	3.7	14.2
New health facility	6.4	5.7
Other	18.6	7.5

At the same time, asked for events in the past 5 years that made people worse of, 99.6% of households stated to have been affected by droughts (compared to 77% national average) and 62% stated 'sharp change in prices' (compared to 62% national average), followed by 12% stating power outages (compared to 10% national average).

The type of main source for lighting in households changed thoroughly over time as shown in table A2-5. The use of kerosene consuming lighting options decreased from 72.9% in 2012/13 to 37.9% in 2016/17. But much of this decrease was replaced by dry-cell batteries that had a share of 39.2% in 2016/17, while off-grid solar had a share of 17.1%.

By 2017, about 80% of the population of West Nile had an electricity access level of Tier 0, while 17% used off-grid solar systems providing mostly Tier 1 access, and 3% had Tier 3 grid access. In contrast, in the trading centers and towns covered by our survey, Tier 0 access has been down to 52% in not electrified trading centers and 36% in electrified trading centers.

Table A2-5: Distribution of households by lighting fuel (%)

	West Nile		Uganda	
Type of lighting	**2012/13**	**2016/17**	**2012/13**	**2016/17**
Tadooba[57]	62.5	33.8	58.3	27.5
Lantern	10.4	4.1	12.3	6.2
Electricity	3.6	3.1	13.9	22.1
Solar	n/a	17.1	n/a	17.5
Dry-cell batteries	n/a	39.2	n/a	21.4
Candles	n/a	0.5	n/a	2.5
Other*[58]	23.6	2.1	15.5	2.9

Fuel used for cooking did not change as much as the type of lighting as shown in Table A2-6 on the following page. The share of households using firewood decreased by 8.1%, which resulted in an increase of 7.3% of the proportion of households using charcoal for cooking.

Table A2-6: Distribution of Households by cooking fuel used (%)

	West Nile		Uganda	
Type of cooking	**2012/13**	**2016/17**	**2012/13**	**2016/17**
Firewood	86.3	78.2	75.7	64.4
Charcoal	10.9	18.2	20.2	29.8
Other	2.8	3.7	4.1	5.8

1.4. Education and health sector

The spread and development of better access to the health care system is similarly difficult. The availability of government health centers decreased by one percent in 2017 (9.1%) compared to 2013 (10.1%), which lies below the Ugandan average (8.8% in 2013; 11.9% in 2017). Hospitals equipped with diagnostic appliances are very sparse in West Nile (UBOS 2014, 159). In 2016/17 83% (85% in 2013) of the population in West Nile sought health care when they

57 Local lantern fueled with kerosene.

58 This includes in 2012/13 gas, biogas, candles, firewood, cow dung, grass and others (not specified).

became sick. In this case 40% sought treatment in private hospitals, 30% in government health centers, 6% in government hospitals and 15% in pharmacies (UBOS 2018). The share of the population able to reach within a 5 km range a health facility for the first treatment, slightly improved in West Nile from 85.5% in 2012/2013 to 86,7% 2016/2017. However, there is a lack of staff, medication and important appliances for diagnostic investigation. Many health centers and hospitals report that their health service is massively overstretched by refugees from South Sudan and patients coming from DRC (Assistant District Health Officer Nebbi 2017; District Health Officer Yumbe 2017).

The education infrastructure in West Nile is weak compared to the country's average. The availability of governmental primary schools in communities increased slightly from 24.5% in 2013 to 25.1% in 2016/17. However, the enrolment rates of children in primary schools decreased from 85.4% to 80.3%. For the secondary schools, the development is similar. Availability of secondary schools in the communities in West Nile increased from 5.5% to 7.5%. However, these schools are only private schools. Enrolment rates of secondary schools were only 12.1% in 2013 (UBOS 2014, 158) and decreased to 10.6% by 2017, whereas the Ugandan average increased from 21.7 to 27.8% (UBOS 2018, 39). Of the persons leaving school (6 to 24 years), 65% stated the income situation as a reason. Due to the sparse educational infrastructure, more than 20% of the population that is 15 years and older received no formal schooling and less than 14% of the population enjoys education above secondary school (UBOS 2018, 24). Especially in Yumbe district demand for secondary schools is stagnant and enrolment rates drop. In Nebbi district officials showed positive trends in secondary school education (District Education Officer 2017; School Inspector Nebbi 2017). In 2019, representatives of schools reported that due to the population increase, the absolute number of school attendants in secondary schools is again increasing (District Education Officer 2019).

1.5. Environmental Trends

Due to the fact that 72% of the population are working formally or informally in agriculture (UBOS 2014, 48), Uganda’s population and economy is highly dependent on stable climatic conditions and its stock of environmental and natural resources (Ministry of Water and Environment Uganda 2017b, 4). Compared to the other regions of the country, Northern Uganda is more affected by erratic climate patterns and frequent droughts. The households’ vulnerability to climate change is very high, in particular in West Nile and Karamoja (east) where the lowest rainfalls and highest temperatures intersect (Ministry of Water and Environment Uganda 2017a, 72; UBOS 2017, 126). It can be expected that agricultural production will be hampered by climate change in the next coming years (UBOS 2017, 57).

One of the main environmental problems that the country already has to deal with on a large scale today, is the massive use of firewood and charcoal all over the country and especially in the poorer northern regions. The value of biomass consumption in the country went up by more than 10 times between 2006 and 2010. In 2017, further on very high consumption of biomass and related environmental degradation is reported. In the northern region, the status of deforestation is also due to large numbers of refugees and hence even more alarming than in the rest of the country (District Education Officer 2017; District Environment Officer Yumbe 2017; District Planning Officer Yumbe 2017; District Environment Officer Yumbe 2017). The need for fuelwood creates intense pressure on woody biomass, and there is a significant shortage of fuelwood. The extent of depletion of surrounding woodlands is severe (Duguma et al. 2019).

Main environmental consequences of the overuse of forest resources in the north are among others soil exhaustion and infertility, siltation, vegetation cover loss, wild fires and bush burning (UNHCR 2017, 11). Some efforts have been made by several development organizations and their partners to counteract at least some of the anxious alarming tendencies. From an ecological point of view, the rural electrification program is becoming increasingly important and threatened at the same time. Due to the vulnerability to climate change resulting in reduced rainfall, the hydroelectric power station “Nyagak I” faces especially in dry season serious difficulties to produce the necessary amount volume of power (District Energy Focal Point Yumbe 2017).

A2-2. Growth trends of trading centers

The characteristics and developments of the trading centers in the focus of the survey are not uniform within the clustered groups. The exemplary presentation of two electrified and two not electrified trading centers that were part of the survey gives an insight about the diversity of characteristics (number of population and SMEs, infrastructure) and trends.

2.1. Not electrified trading centers

Trading center:	**Erussi**
Electified:	No
Population:	5,614
Number of SMEs:	442
Infrastructure:	• Central water supply (solar) • 1 primary school • 1 secondary school • Dust road (30 km to next sealed road)
Characteristics:	• The main economic activity is agriculture, especially coffee farming. • Strategic location to the border of the Democratic Republic of Congo and intense cross-border trade. • Trade in general merchandise and regular official market.
Trends:	• Boost in the coffee market supported through Kawacom by providing inputs and extension services. • Population increase due to immigrants from Nwonya .

Trading center:	**Odupi**
Electrified:	No
Population:	4,111
Number of SMEs:	133
Infrastructure:	• No central water supply • Dust road (56km to next sealed road) • One Secondary School • One health center III
Characteristics:	• The major source of income is farming supplemented by trade. • Location of the trading center in between Yumbe and Arua Districts.
Trends:	• Attraction of local people to the trading center for business opportunities. • Influx of refugees increasing demand for local goods especially agricultural goods. • Proposal for the TC to become a Town Council has attracted people both within and outside. • Population increase by 166% compared to 2011

2.2. Electrified trading centers

Trading center:	**Kuluba**
Electrified:	Yes
Population:	12,815
Number of SMEs:	110
Infrastructure:	• No central water supply • 1 health center II • Sealed road
Characteristics:	• Trading center located close to the borders of the Democratic Republic of Congo and South Sudan. • Farming is the main Source of income supplemented by trade, especially cross border.
Trends:	• The trading center has declined economically due to the war in Southern Sudan. • Electricity plays a very small role in the development of the town because the economic activities in the trading center are at stand still.

Trading center:	**Adraka**
Electrified:	Yes
Population:	3,000
Number of SMEs:	243
Infrastructure:	• No central water supply • Dust road (19km to next sealed road) • One Secondary School
Characteristics:	• The major source of income is agriculture, supplemented by trade. • Strategic location close to Democratic Republic of Congo –Uganda Boarder. • Good roads connection, national road links the center to Zombo and DRC.
Trends:	• Land is getting expensive especially within the reach of the power grid. • Power encourages development in building and trade. • Increased of population by 900% compared to 2011.

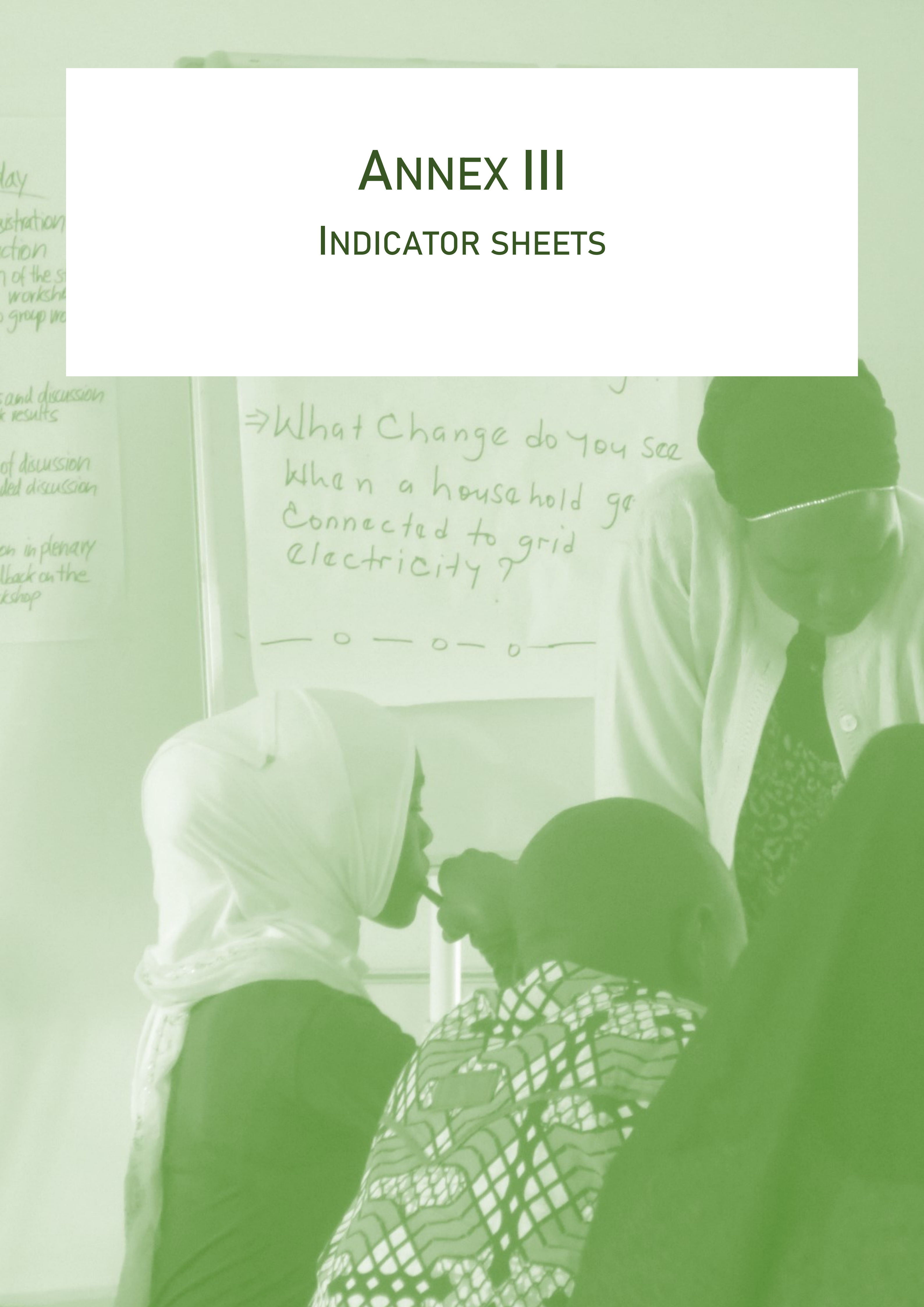
Most of the connected and nonconnected trading centers increased their population within the last six years, with some of them doubling or tripling their numbers. Electrified trading centers reported a pull-factor of electricity, causing an in-flux of people in the trading centers. According to our data, the population growth for not electrified trading centers is about 137% and for electrified trading centers 222%, when comparing 2011 and 2019. The general increase of the number of people in the trading centers is confirmed by local government representatives who attribute this growth to the general population growth and the in-flux of people from the rural areas. In contrast to that, only in a few trading centers, such as Kubala, population remained stable or even decreased. Accordingly, also the number of SMEs differs greatly among the trading centers. The median is 71 for not electrified and 129 for connected trading centers. However, the population of connected trading centers is also higher (median 6,660) than in not electrified trading centers (median 5,307), which is clearly related to the number of businesses.

According to our surveys, the impact of electricity on the number of businesses in trading centers seems to be marginal. Three out of ten nonconnected trading centers stated that four of their business sectors are currently increasing, whereas five out of eleven connected trading centers showed that pattern. Some businesses confirmed that they were motivated to open their business recently due to the availability of power. In contrast to that, two nonelectrified trading centers (Lomunga, Mutir) and two electrified trading centers (Kuluba, Atyak) did not report any increase of the number of businesses. A decrease was recorded in two nonconnected trading centers (Biliefe, Rhino camp). The decrease was caused by businesses moving to the refugee camps due to high demand in these areas. Otherwise, trading center authorities also reported that the presence of NGOs and refugees increased the economic activity in trading centers. One electrified trading center (Kuluba) showed stagnating economic activities due to closure of the border to South Sudan.

Altogether, data suggests that economic development of trading centers is linked to various factors. This can also be confirmed when looking at indicators such as frequency of kerosene use and share of micro-businesses, which do not develop in the same way in the trading centers within one cluster, but seem to depend also on other factors besides electricity access. Other factors that were stated during the interviews were the administration status of trading centers, and the presence of schools and health centers.

ANNEX III

INDICATOR SHEETS



Content of Annex 3

A3-1. Program Output

The output level results focus on the supply side, encompassing WENRECo's electricity generation initiatives and the supporting measures implemented by GIZ. The information required in order to report at the output level is provided by MEMD (including its Rural Electrification Agency / REA) and KfW Development Bank (for OP1, OP2, OP5), by WENRECo (for OP3.1, OP4.1), and by GIZ (for OP3.2, OP4.2, and OP6 to OP8). As the focus of the impact monitoring is not on the implementation level, only the status of each output is quickly summarized below.

Indicator sheet OP1 to OP8

Result	Indicator
(OP1) Renewable electricity generation capacities have been created	(OP1.1) SHP Nyagak I is operational and is supplying electricity to the grid
	(OP1.2) SHP Nyagak III is operational and is supplying electricity to the grid
(OP2) Grid extension lines have been constructed, and the existing grid rehabilitated	(OP2.1) Over 400 km of new 33 kV grid, including low voltage distribution lines, has been constructed and transferred to WENRECo
	(OP2.2) About 20 km of the existing 11 kV grid in Arua town have been rehabilitated
(OP3) A prepaid metering scheme has been introduced	(OP3.1) WENRECo has replaced all household meters with prepaid meters
	(OP3.2) GIZ designed and implemented a campaign to educate consumers on the advantages of a prepaid metering system
(OP4) Poor customers have been targeted with low cost connections	(OP4.1) WENRECo uses KfW funding and existing REA schemes to offer low-cost connections to poor households
	(OP4.2) GIZ developed an implementation strategy and implemented a promotion campaign for low cost connections
(OP5) Increased capacity at WENRECo	(OP5.1) A long-term consultant has been recruited as General Manager of WENRECo to increase management capacity
(OP6) Increased capacity among local technicians	(OP6.1) At least three technicians from each major trading center in the grid extension areas have been trained in safe house wiring practice
(OP7) The productive use of electricity has been promoted	(OP7.1) GIZ designed and implemented an awareness campaign on the productive use of electricity
	(OP7.2) GIZ designed and organized business training and coaching for businesses on the productive use of electricity
(OP8) The safe and efficient use of electricity has been promoted	(OP8.1) GIZ designed and implemented an awareness campaign on safety issues
	(OP8.2) GIZ designed and implemented an awareness campaign on energy efficiency

With regard to presenting the delivery status for different outputs (see Table A3-1), the major milestones reached so far have been:

- Commissioning of Nyagak I in 2/2012
- Grid extension & rehabilitation in 2/2015
- Connection of new customers in 2015 - 2017
- E-AIM Campaign in 2/2017

The remaining output to be achieved is the construction and commissioning of Nyagak III.

Table A3-1, OP1-OP8: Reporting on the status of indicators on Output level

Indicator	Half-year reporting															
	1/11	2/11	1/12	2/12	1/13	2/13	1/14	2/14	1/15	2/15	1/16	2/16	1/17	2/17	1/18	2/18
(OP1.1)	*	*	*	√												
(OP1.2)	-	-	-	-	-	-	-	-	*	*	*	*	*	*	*	*
(OP2.1)	-	-	-	-	-	-	*	*	*	√						
(OP2.2)	-	-	-	-	-	-	*	*	*	√						
(OP3.1)	-	-	-	*	*	*	*	*	*	*	*	*	√			
(OP3.2)	-	-	-	-	-	-	-	-	-	*	*	*	√			
(OP4.1)	-	-	-	-	-	-	*	*	*	*	*	*	√			
(OP4.2)	-	-	-	-	-	-	-	-	-	*	*	*	√			
(OP5.1)	-	-	-	-	*	*	*	*	*	√	-	-	-			
(OP6.1)	-	-	-	-	-	-	-	-	-	*	*	*	√			
(OP7.1)	-	-	-	-	-	-	-	-	-	*	*	*	√			
(OP7.2)	-	-	-	-	-	-	-	-	-	*	*	*	√			
(OP8.1)	-	-	-	-	-	-	-	-	-	*	*	*	√			
(OP8.2)	-	-	-	-	-	-	-	-	-	*	*	*	√			

Key: - not started, * in progress, √ activity completed

With an installed capacity of 3.5 MW, the hydro-power Nyagak I is operational since 2012 **(OP1.1)**. The second hydro-power project (Nyagak III) on the same river has not yet reached financial close **(OP1.2)**.

The construction of the new 33kV grid extension **(OP2.1)**, and the replacement of 20km of the existing 11kV grid in Arua **(OP2.2)** were completed by end of 2015.

By end-2018 95% of the 15,706 WENRECo customers had been switched to pre-paid metering **(OP3.1)**.

By end-2018 WENRECo implemented 4,896 subsidized connections for households and businesses with support of REA and KfW funding **(OP4.1)**. Additionally, WENRECo promoted 2,013 ready board connections for poor households with KfW support.

GIZ implemented the Electricity Access Impact Maximization (E-AIM) campaign from July 2015 until June 2017 in all 6 districts of West Nile affected by the grid extension. The E-AIM Campaign included the following activities:

- Promotional and awareness campaign on pre-paid metering **(OP3.2)**, low-cost connections **(OP4.2)**, productive use of electricity **(OP7.1)**, safety issues **(OP8.1)** and energy efficiency **(OP8.2)**: road show in 40 communities including community follow-up visits and community discussion. Additionally, flyers and poster were disseminated and a radio campaign with announcements and talk shows was aired in 4 languages.

- 10-days modular refresher training of technicians at Arua Technical Institute (ATI-RAGEM) in safe house wiring (according to ERA Permit D criteria), with 72 participants of which 41 passed Permit D certification (compared to only 12 certified electricians in 2015), while 25 candidates had not been admitted to the examination due to formal criteria **(OP6.1)**.
- Promotion of Productive Use of Electricity (PUE) trainings (3 days) for SMEs and follow-up coaching (2 days) in 12 trading centers that reached 242 participants of which 55 elaborated business ideas **(OP7.2)**.
- PU grant scheme providing 60% subsidy on electric mills and hullers for 10 millers (operating 9 grain mills, 3 hullers) **(OP7.2)**.
- Support of 13 schools and health centers in getting connected to the grid through providing internal wiring.
- Establishment of a WENRECo help desk and improvement of WENRECo's customer care **(OP5)**.

In 2019, MEMD contracted the independent power producer Electro-Maxx to mitigate power supply deficits until the commissioning of Nyagak III or the interconnection of the isolated West Nile network with the national grid. Since May 2019, an 2.6 MW emergency diesel generator is operating from the same site of the earlier HFO generator close to Arua town. By 2019, it planned to replace the diesel generator with two 4 MW heavy fuel oil (HFO) generators.

A3-2. Use of Output

This chapter provides an overview on the status of the indicators on Use of Output level.

Indicator sheet UP1

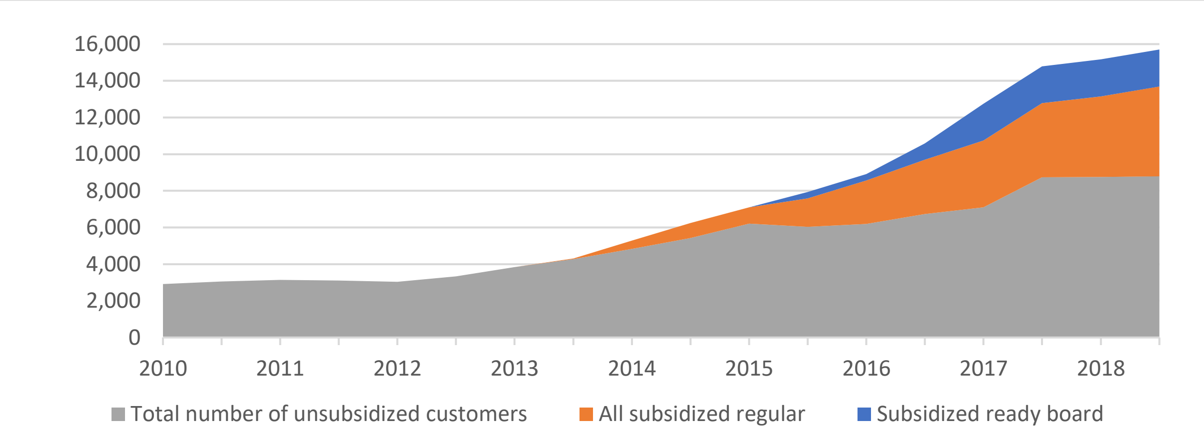
Result UP1: Efficient, reliable, and broad-based supply of renewably produced electricity	
Indicators	Data elements
(UP1.1) a) The number of households, businesses, health centers, and schools, as well as the total number of customers with a physical connection to the island grid and b) the proportion of connections in rural areas and c) the proportion of connections for poor households has increased	(1) Number of all WENRECo customers, as well as of connections for households, businesses, schools (Primary, Secondary, Vocational) and health centers (II, III, IV, V)
	(2) Average number of neighbors additionally connected per connected household and business
	(3) Number of connections in rural areas
	(4) Number of connections of poor households (consumers with subsidized low-cost connections and/or < 2.5 A connections)
(UP1.2) WENRECo has reached break-even point	(1) WENRECo's total income per half year
	(2) WENRECo's total expenditure per half year
(UP1.3) WENRECo has reduced its technical and commercial losses[59] and improved its collection rate	(1) Electricity generated per half year (MWh)
	(2) Electricity consumption billed per half year (UGX and MWh)
	(3) Payments received for electricity consumption per half year (in UGX)
(UP1.4) The proportion of electricity produced from renewable energy sources in the island grid has increased	(1) Total electricity generated per half year (MWh)
	(2) Total electricity generated from renewable sources per half year (MWh)
	(3) Electricity generated (MWh) per half year by Nyagak I and Nyagak III
(UP1.5) The proportion of blackout hours and load shedding in the island grid has decreased	(1) Total accumulated duration of outages per half year
	(2) Total accumulated duration of load shedding per half year
(UP1.6) WENRECo's maximum response time for blackouts and customer complaints has decreased	(1) Average duration of each outage
	(2) Average response time for customer complaints
(UP1.7) The proportion of WENRECo customers using a prepaid meter has increased	(1) Total number of prepaid meters in operation per half year
	(2) Total number of customers per half year
(UP1.8): The proportion of productively used electricity in the WENRECo grid is high	(1) Electricity consumption of households billed per half year (MWh)
	(2) Electricity consumption of commercial customers billed per half year (MWh)

[59] Technical losses are not measured separately by WENRECo.

Data presentation for UP1

For the UP1 indicators, data has been collected from WENRECo on a half-year basis for the period of 2010 until 2019. Due to a breakdown of its servers in summer 2018, WENRECo was not able to provide full data for 2019 and also some data provided for 2017 and 2018 was not fully consistent as indicated below. Area diagrams are used to display absolute values reached by the end of the half-year period, while bar charts are used to present half-year average values. To keep the horizontal axis easily readable, only the first half-year is indicated by the respective year date.

Chart A3-1: UP1.1 - Regular and subsidized connections[60]



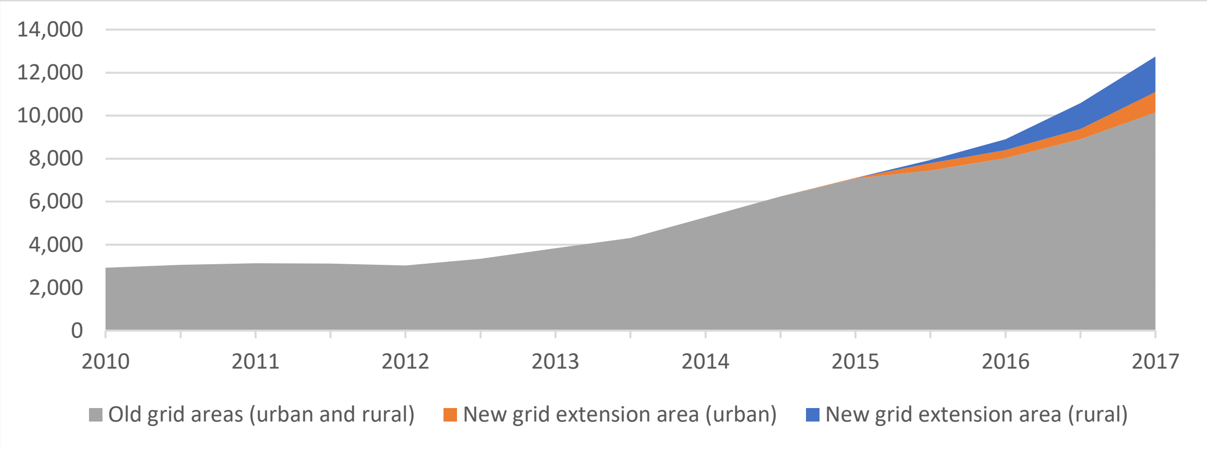
As of 30 June 2019, WENRECo has a total of 16,979 customers out of which 9,925 are households. Additional customers have been connected to the grid since operation of the hydropower plant Nyagak I started in late 2012. In the new grid extension areas, first customers have been connected in April/May 2015 in Zombo district, were the grid extension was completed first. However, grid extension was completed in July and bulk procurement of pre-paid meters was only executed by August 2015 so that area-wide connection of customers only started in September 2015. Also, the E-AIM road show started in September that covered 40 towns and trading centers within the new electrification corridor speeding up the application process of new customers. 6,909 subsidized connections have been implemented by WENRECo, most of them targeting households. However, poverty targeting was limited to a self-targeting of households applying for one of the 2,013 ready-board connections, for which the cost of in-house wiring was greatly reduced. The other 4,896 subsidized connections have been offered in a general promotion approach on a “first come, first served” basis to any new customer that could be serviced without requiring additional poles[61]. As a consequence, the wording of the respective indicator has been changed from ‘poor households connected’ to a more neutral ‘subsidized connections’.

[60] Do data received from WENRECo for first half of 2019.

[61] Since late 2018, the national policy by REA extended the support even to one-pole connections, for which now only a very low inspection fee has to be paid beside the cost for in-house wiring.

By mid-2019, WENRECo registered 7,028 commercial customers, of which only 380[62] represent larger three-phase customers, compared to 6,648 single-phase customers. While most three-phase customers represent commercial businesses, the single-phase customers also include public administration, schools (92)[63], health centers (38)[64], NGOs, donors, and religious institutions. Additionally, WENRECo has 15 industrial customers, mainly millers, public water suppliers, two cotton factories, and one tobacco factory.

Chart A3-2: UP1.1 - Connections in rural and urban areas[65]



As of 31 of December 2018, WENRECo has a total number of 15,706 customers. According to WENRECo's numbers, 12,297 customers are in the old grid areas (Arua, Nebbi, Paidha), whereas 3,409 are situated in the new grid areas. Unfortunately, WENRECo has not been able to quantify the share of rural customers in the old grid area, but we can assume that a limited number of possibly a few hundred customers would qualify as rural. It can be stated that the new grid extension area is particularly focusing on rural areas.

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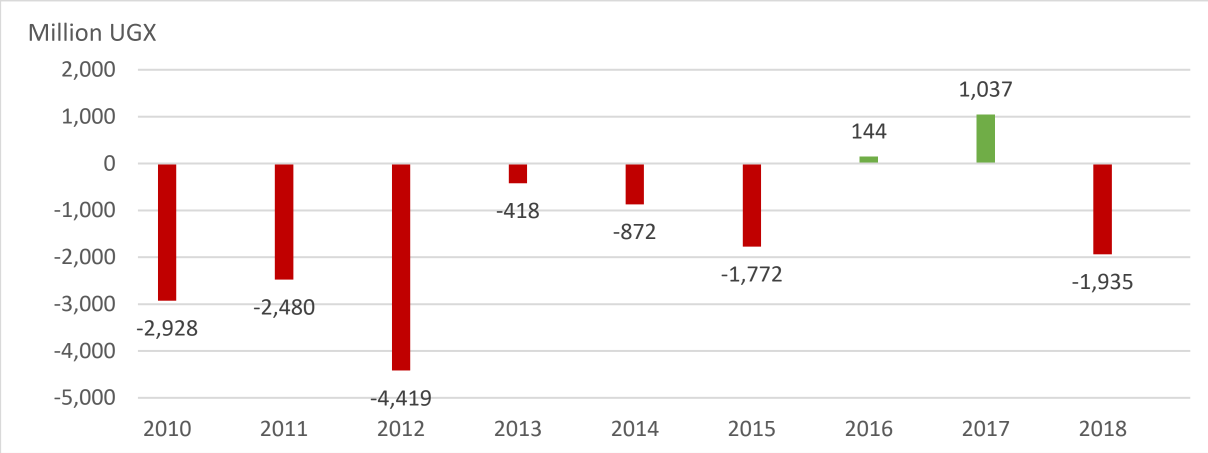
62 By end of 2018, the number of 3-phase customers has been 380, no data received from WENRECo for mid-2019.

63 8 schools have not been reported by WENRECo, but have been identified during the survey.

64 4 health centers have not been reported by WENRECo, but have been covered by the survey.

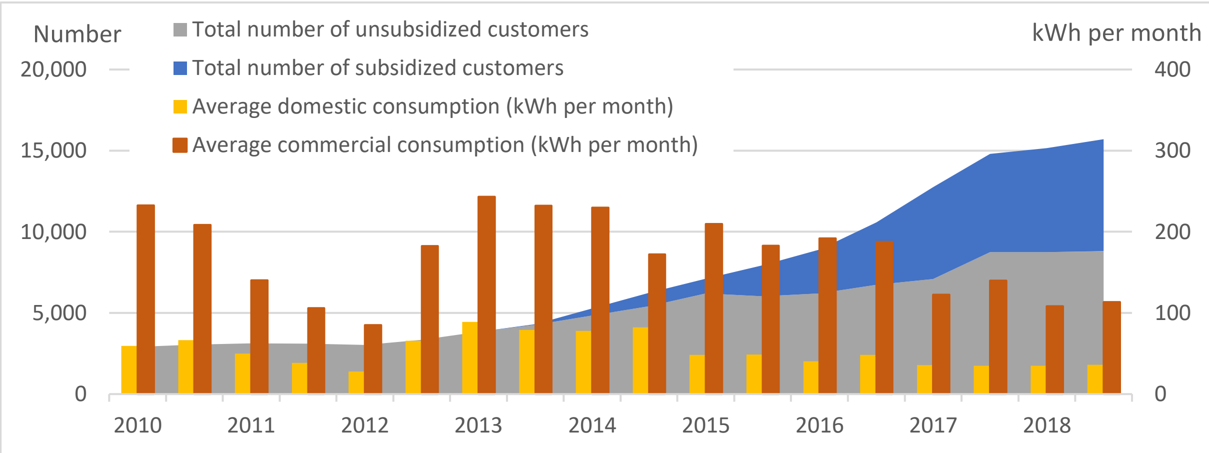
65 No data received from WENRECo for second half of 2017, 2018, and early 2019.

Chart A3-3: UP1.2 - Gross profit margin of WENRECo[66]



WENRECo reached its first positive gross profit margin in 2017, but again lost money in 2018, which could partially be caused by the significantly decreased fee collection rate since late 2017 (see UP1.3). However, a proper evaluation of WENRECOs economic viability based on these aggregated figures is not possible as they include both significant additional investments and incomes due to the large number of new customer connections implemented over the last years. As a detailed financial evaluation of the expenditures of WENRECo is outside the scope of this impact monitoring, we can only briefly discuss the potential for increasing its revenues, while loss reduction is discussed further below.

Chart A3-4: UP1.2 - Average monthly power consumption



The development of the average power consumption of domestic and commercial customers over time shows that until commissioning of the Nyagak I powerplant in late 2012, supply shortage and resulting load shedding suppressed power consumption. With sufficient power available, average consumption peaked in 2013 at 243 kWh and 89 kWh per month respectively for, at that time, 1,866 commercial and 1,965 domestic customers. Since 2013, the number of customers almost quadrupled, strongly driven by subsidized connection of almost 7,000 new

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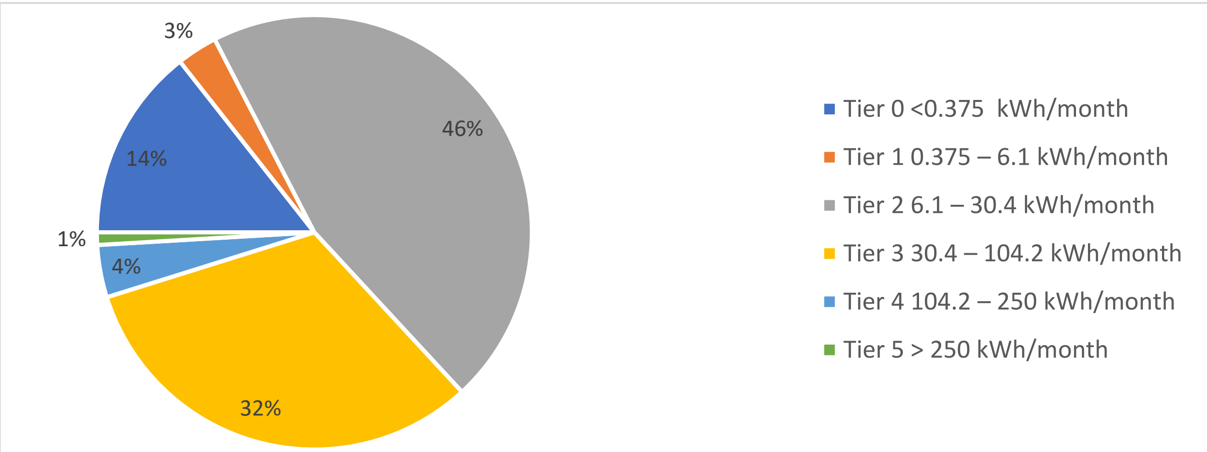
[66] WENRECo did not submit data for 2019.

customers. As a result, average monthly commercial consumption decreased to 114 kWh by 2018, while average domestic consumption shrunk down to a mere 36 kWh per month. Since late 2017, the new occurrence of load shedding added to this downward trend.

An analysis of one year of pre-paid customer data between July 2016 and June 2017 (see chart A3-5 and A3-6 below) showed that 63% of domestic customers and 40% of commercial customers purchased less than one kWh per day or 30 kWh per month. Within the same period, the average domestic consumption was about 44 kWh per month and further decreased by the second half of 2018 by about 18% to 36 kWh per month, while the average commercial consumption, about 190 kWh per month, decreased even by 40% down to 114 kWh per month. These trends suggest that the share of domestic and commercial customers using less than 30 kWh, rather than decreasing as assumed, actually is further increasing. The increasing share of low consuming customers combined with the effort for operation, maintenance and management of a growing network and customer base places a high burden on WENRECo's economic viability.

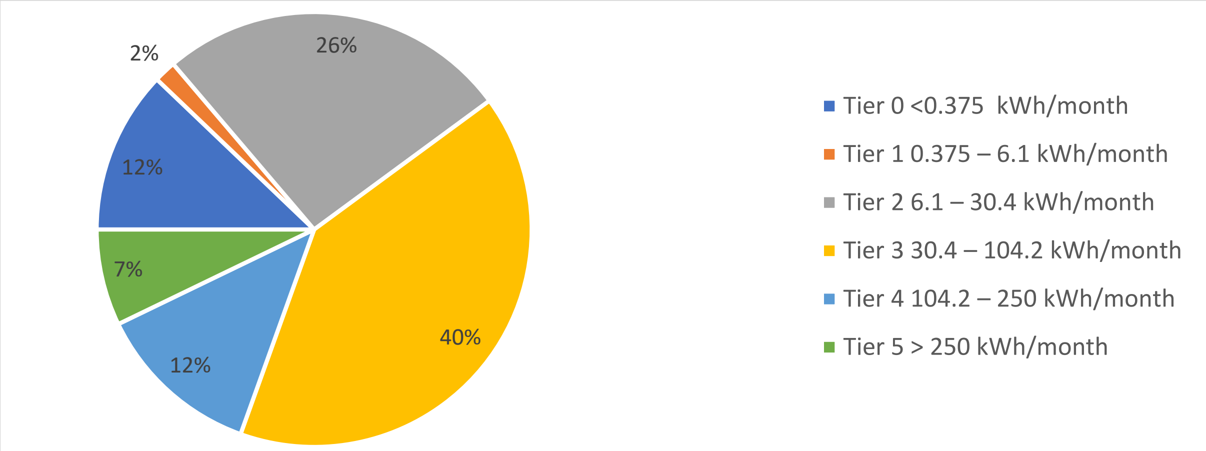
As WENRECo already generates more than 40% of its total revenues only from the few industrial and 3-phase commercial customers, who usually have their peak demand over the day, it should focus on further expanding this customer base. However, industrial and commercial customers are most affected by unreliable power supply (see UP1.5 and UP1.6). This calls for a key strategy to increase revenues by investing in a higher reliability of power supply to be able to keep existing and attract even more commercial and industrial customers.

Chart A3-5: UP1.2 - Electricity consumption of domestic customers by tiers



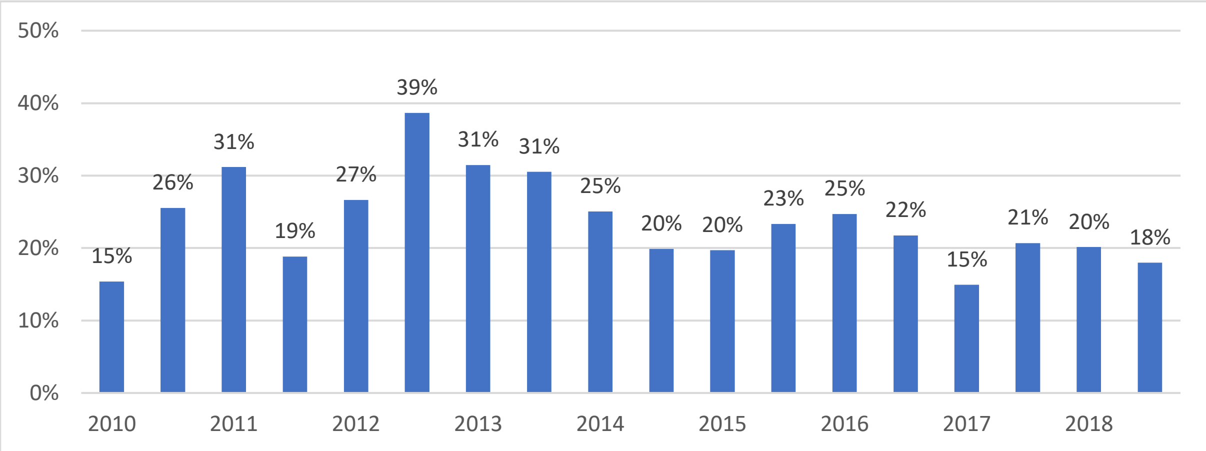
Pre-paid domestic customer purchases of July 2016 to June 2017 have been analyzed for average power purchases per month. Most of the (at that time) 7,104 pre-paying households can be classified as Tier 2 (46%) and Tier 3 (32%) customers, while only 5% are consuming at Tier 4 and 5 levels. However, about 14% of the customers have been using power only irregularly, having not or only once purchased power over the last 12 months, and another 3% are at the extremely low Tier 1 consumption level. Tier 0, 1 and 2 customers, using less than one kWh per day, can usually be more cost-efficiently serviced by solar systems. This applies currently to about 64% of WENRECo's household customers.

Chart A3-6: UP1.2 - Electricity consumption of commercial customers by tiers



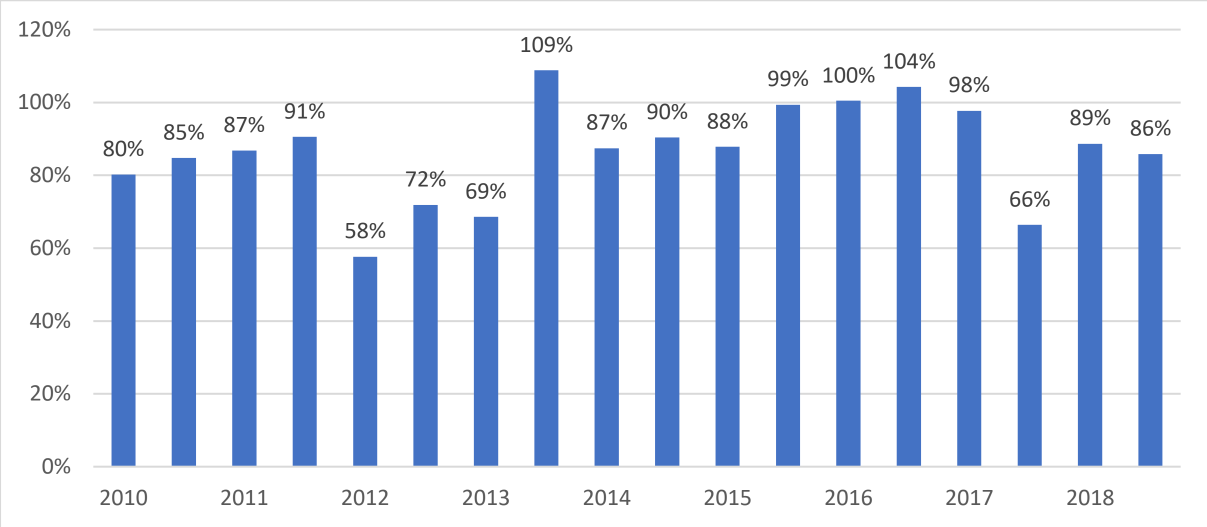
Pre-paid commercial customer purchases of July 2016 to June 2017 have been analyzed for average power purchases per month. Of (at that time) 5,333 pre-paying commercial customers, most are Tier 3 (40%) followed by Tier 2 (26%), while 21% are Tier 4 and 2% are using very little power at Tier 1, and 12% are not regularly using power and must be considered Tier 0. Equally as for household customers, this signifies that currently about 40% of all commercial customers might have been more cost effectively serviced with solar systems – unless power consumption is increasing significantly over the next years.

Chart A3-7: UP1.3 - Technical and commercial losses (without collection rate)



According to WENRECo, the combined technical and commercial losses (without tariff collection) stand at about 18% by end-2018. The difference of generated and billed electricity compared to total generated electricity dropped from about 40% in 2012, but increased again after lows in 2015 and 2017. WENRECo was able to decrease its losses down to 15% in 2017 by greatly reducing commercial losses due to manipulated meters. Meters have been moved from house walls to the top of the closest grid pole. However, during the massive connection of new customers in 2017/2018 again many meters have been installed on house walls instead. WENRECo is gradually moving also these new meters to pole tops (losses reduced to 17.2% in mid-2019). The program target value of 21% (including collection) by 2018 has been reached.

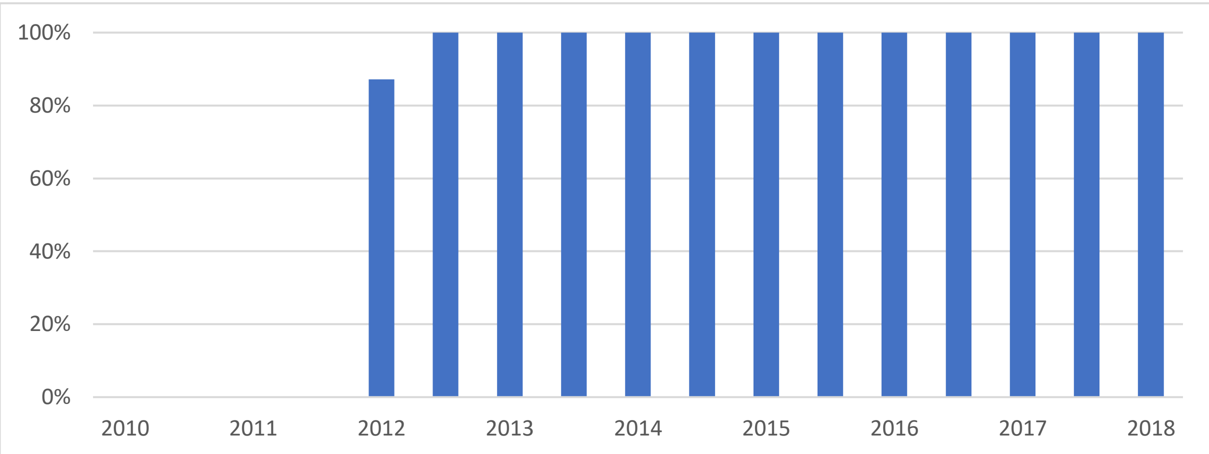
Chart A3-8: UP1.3 - Collection rate



WENRECo is providing biannual data on the amount of electricity supplied, but not about the electricity cost billed to the customers. The electricity cost billed to the customers for the respective half-year is approximated by multiplying the average number of customers by the average tariff and power supplied for each customer group plus the service fee charged.

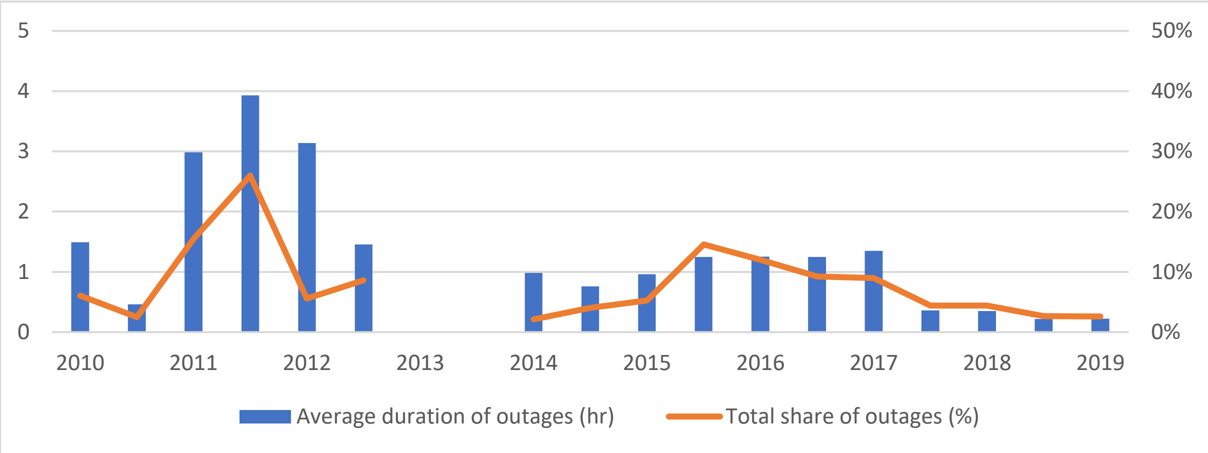
The collection rate reached a low of 58% in the second half of 2012. It has increased since and stands close to 100% since 2016. Some distortions in the past (especially the spike in 2014) can be explained by outstanding fees of post-paid customers collected in the subsequent half-years. Even with the pre-paid system this effect can occur as customers might not purchase power for a couple of months within one half-year and then pay the service fee for the past months with the next purchase in the following half-year. The greatly decreased collection rate in the second half of 2017 and 2018 could not been explained by WENRECo but data might be distorted due to the aforementioned server breakdown at WENRECo's main office.

Chart A3-9: UP1.4 - Proportion of electricity produced from renewable sources



With the start of the operation of the hydro power plant Nyagak I, the proportion of renewable energy increased sharply in the second half-year 2012 and reached 100% in 2013. Since then, power for West Nile has been fully generated by the hydro power plant Nyagak I. This has recently changed, as since May 2019, a 2.6MW emergency diesel generator has been added to the West Nile network at the position of the 1MW HFO generator that had been running close to Arua town until the commissioning of Nyagak I. By end-2019, MEMD plans to replace the emergency diesel with two 4 MW HFO generators. As a consequence, the share of fossil fuel-based generation will increase again in 2019. In the long-run, the HFO generators will be disconnected once the West Nile power network will be connected to the national grid.

Chart A3-10: UP1.5 – Average duration and share of outages



As measures for network stability, the System Average Interruption Duration Index (SAIDI) and the System Average Interruption Frequency Index (SAIFI) are internationally used as benchmarks, but related reporting of sub-Saharan utilities is very poor in general (Kojima and Trimble 2016, 27). The SE4All tier framework for electricity access also sets benchmarks on reliability of power supply (see Annex 4.1). To qualify for Tier 4 access, a maximum of 14 power disruptions per week are acceptable, resulting in a SAIFI of 728 interruptions per year. To qualify for Tier 5 access, less than 2 disruptions per week (SAIFI of 104) and a total duration of less than 2 hours per week are required; the latter could be interpreted as a SAIDI of 104 hours.[67] A recent Network Assessment Baseline Report for Uganda recommended to improve reporting of small distribution licensees on SAIDI and SAIFI and proposed annual benchmarks of 50 hours for SAIDI and 60 interruptions for SAIFI (AZOROM 2018, Part I-48).

The calculation of SAIDI and SAIFI require the detailed documentation of the number of customers affected, as well as the duration of each outage. As WENRECo had not been able to provide such data in 2011, simplified indicators of share (blackout time vs. total supply time) and average duration of outages had been proposed. As a planned interruption, load shedding is documented separately in chart A3-11 below. The company cautions that their monitoring of these indicators is weak.

[67] The SE4All framework does neither distinguish planned or unplanned interruptions, nor does it normalise interruptions regarding affected customers in relation to total number of customers. It also does not define a minimum threshold for interruptions such as defined for SAIDI and SAIFI which only consider interruptions beyond 3 minutes. The comparison of the SE4All reliability requirement with a SAIFI value is therefore only an approximation.

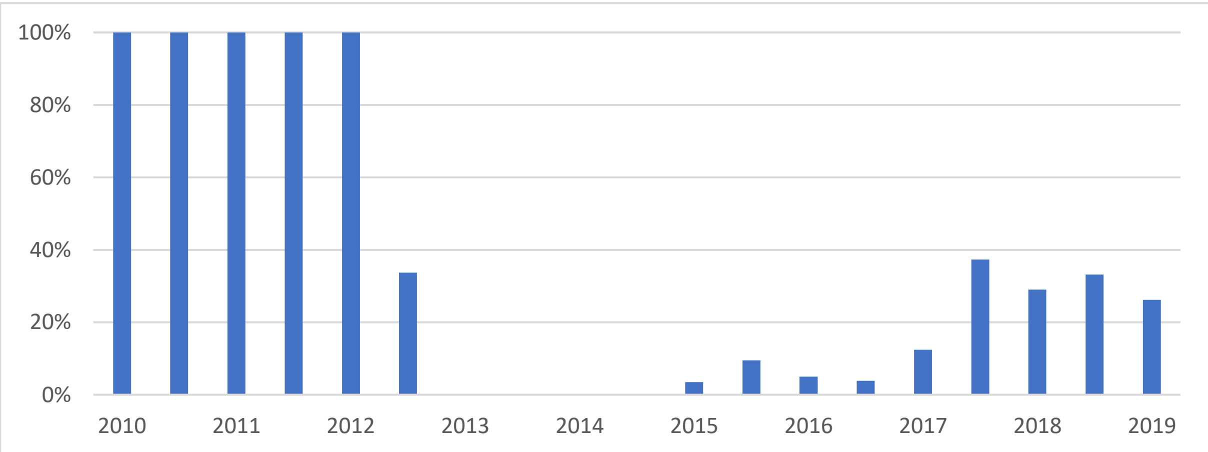
According to WENRECo data, the share of accumulated blackout duration compared to the total supply time peaked with 26% in the second half-year of 2012, and again with 15% in the first half-year of 2016.[68] “From a review of WENRECO generator outages during 2016 it was noted that of 668 outages the vast majority were due to network incidents” … “much better coordination is required to avoid machine tripping during network incidents – whether fault incidents or switching operations” (AZOROM 2018, Part V-40).

By mid of 2019, the share of outage time decreased significantly to 3% or an average of 43 minutes per day. Even assuming that on average only 50% customers have been affected by each outage would result for the year 2018 in a SAIDI of 153 hours and a SAIFI of 850. These values are far beyond the proposed benchmarks of 50 hours for SAIDI and 60 interruptions for SAIFI and the network would still fail the SAIFI 728 benchmark to qualify for SE4All Tier 4 access level regarding the requirement on reliability.

After a 4-hour peak in early 2012, the average duration of outages decreased to 1.5 hours in early 2013. From late 2013 until the first half of 2015, WENRECo did not provide data on the duration of outages. Since late 2015, average duration of outages decreased to less than half an hour in the second half-year of 2018. This is indicating that outages are less severe and/or the response time on technical issues has improved.

WENRECo stresses that it is facing network design challenges, such as long, lightning prone distribution lines with comparatively low loads as well as maintenance challenges, as some parts of the distribution poles could not been accessed for tree clearance due to delayed compensation for land and way leave.[69]

Chart A3-11: UP1.5 - Share of load shedding



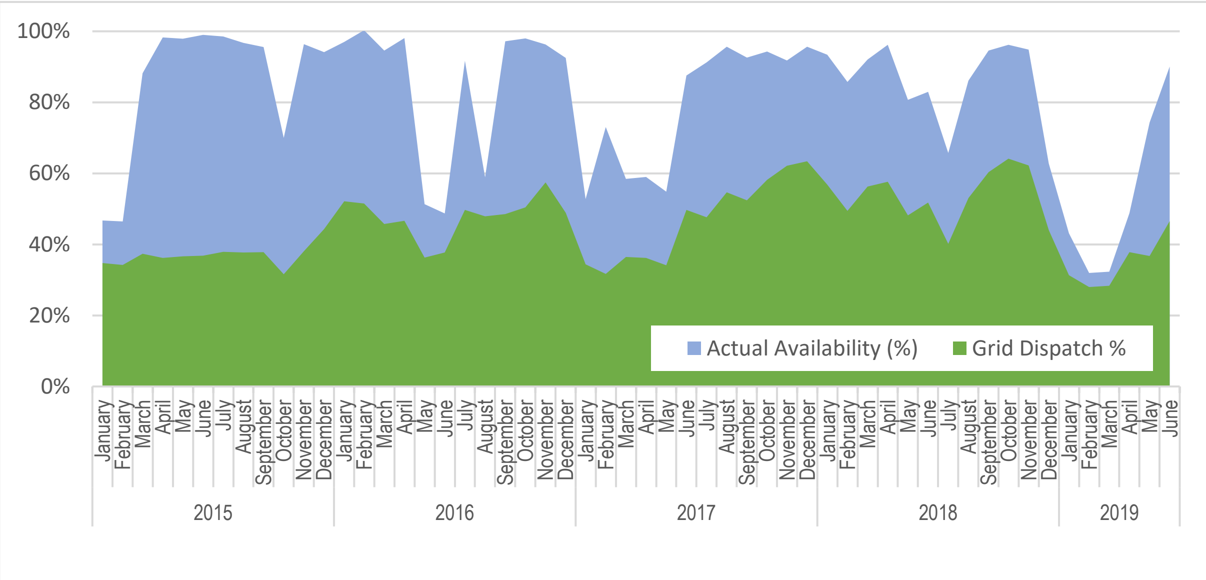
Load shedding occurs when the power generation capacity is not sufficient to meet power demand in the network. Reasons can be technical failures of the power plant or drought-caused water scarcity. Because the whole West Nile power grid is supplied by one hydro-

[68] WENRECo did not provide figures of accumulated blackout duration for the second half-year of 2013 and the first half-year of 2014.

[69] MEMD informed that about 90% of compensation has been processed by summer 2019, so tree clearance should be less of an issue in the future.

power plant only, Nyagak I, there are no redundancies in case of supply deficits. While load shedding has significantly decreased since the start of operation of Nyagak I, WENRECO did not report on load shedding for the years 2013, 2014 and the first half of 2015. For the second half of 2015, WENRECo reported load shedding of in average 10% (2.4h per day) which decreased to 4% (1h per day) by end of 2016, but increased to 37% or almost 9 hours per day for the end of 2017, and reached 33% or 8 hours per day by the end of 2018 and 26% or 6.2 hours per day by mid-2019. The increase in 2017 and 2018 was due to the drought-caused water shortage that limited the hydro-power generation capacity (see Chart A3-12 below). Low reliability of the power supply due to load shedding and outages are the main customer complaint. Since the installation of the emergency diesel generator in May 2019, load shedding could be avoided.

Chart A3-12: UP1.5 - Power generation and dispatch (01/2015 – 01/2019)

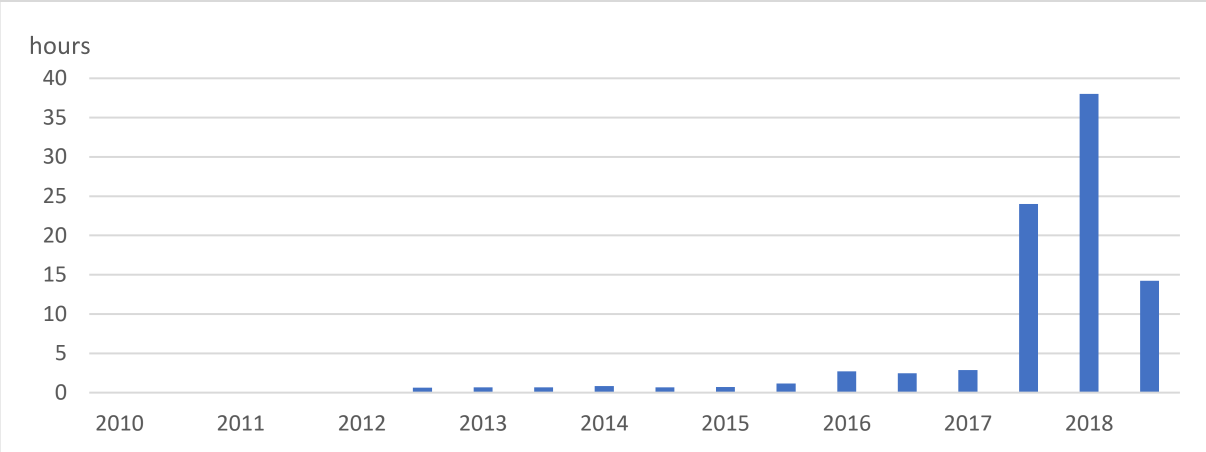


The chart above shows power generation and dispatch since 2015, the year when load shedding started again. Power generation is influenced by seasonal water availability in Nyagak river and the technical availability of the hydropower plant. In May and June 2016, one of the two turbines of the hydropower plant was under repair, halving its technical capacity. In June 2018, a generator was under repair. In February and October 2015, August 2016, January until May 2017, January and November 2018 until May 2019, availability was limited by drought that reduced the water level in Nyagak river.

The power dispatch into the West Nile network is also seasonally influenced by its few industrial customers who are involved in agricultural processing (cotton, tobacco). The capacity factor of the hydro-power plant Nyagak I reached a first peak in January 2016, but dispatch decreased in February to April when the cotton season ended. Dispatch peaked again in November 2016, November 2017, and September 2018.

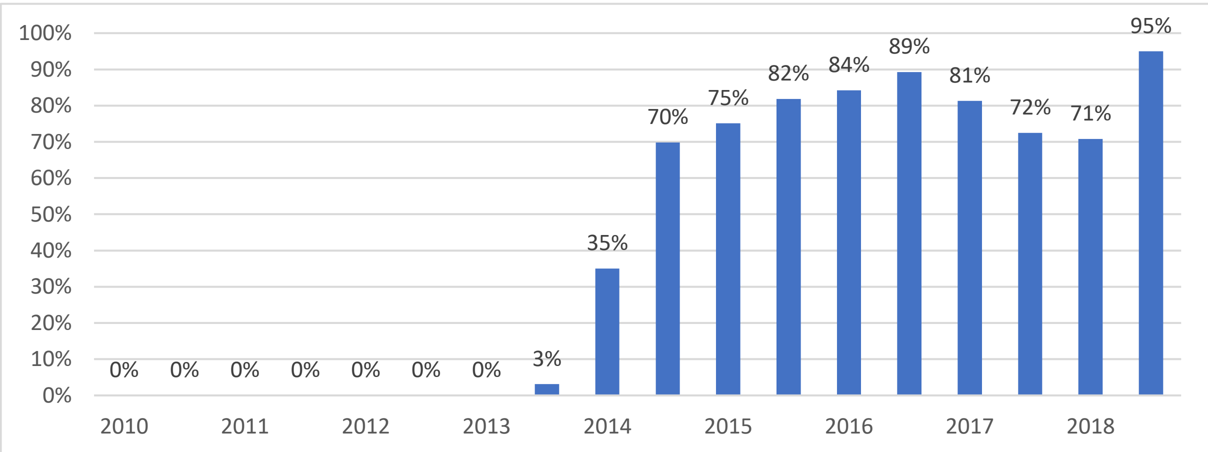
In times of water scarcity, WENRECo is forced to shed loads over the day to guarantee sufficient water availability to reach full generation capacity in the evening, where the power demand peaks. But since 2017, we observe a stronger increase in load shedding which (especially in the second half of 2017) is not caused by a reduced availability and power dispatch of the power plant. Since 2017, the evening peak load has been increasingly reaching and surpassing the installed capacity of 3.5 MW, resulting in a significant share of load shedding. This situation has been mitigated by MEMD in May 2019 by adding 2.6 MW emergency diesel to the West Nile network which are planned to be replaced by two 4 MW HFO generators to be installed by end of 2019.

Chart A3-13: UP1.6 - Response time on customer complaints



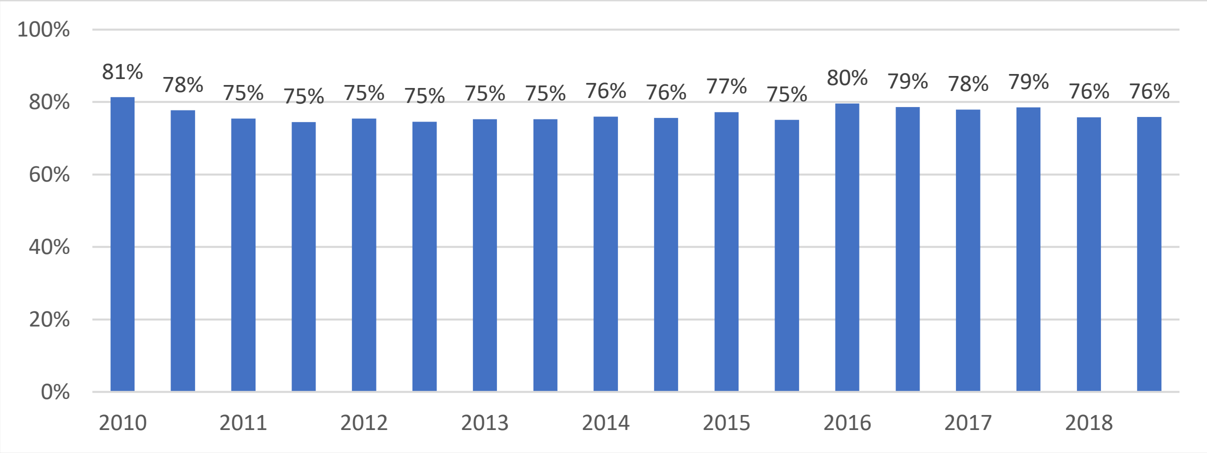
WENRECo did not monitor its response time until mid-2012. Since then, the average response time increased from 0.6h to 14 h in the second half-year of 2018, after a peak of 38h in the first half-year of 2018. WENRECo justified the increasing trend of response time with the fast growth of network and customers and a deteriorating staff to customer ratio. The strong increase in the second half-year of 2017 was explained by decentralization of the customer care to the technical staff in WENRECo branch offices who lack structured work-flows for complaint management as well as training in customer care.

Chart A3-14: UP1.7 - Proportion of customers on a prepaid tariff



The proportion of prepaid customers reached 95% by end-2018. Only 784 post-paid customers remain, who are industrial customers and health centers or other institutions. All 6,000 prepaid meters funded by KfW Development Bank are in use. The WENRECo pre-paid customer data base reached 14,922 customers in end-2018. Data provided by WENRECo in the second half of 2017 and in 2018 is very likely not correct since no new post-paid meters were installed during that period.

Chart A3-15: UP1.8 - Proportion of productively[70] used electricity in the WENRECo grid



The proportion of electricity used by commercial[71] and industrial customers remained fairly stable since 2010 and ranged from 75% to 80% between 2013 and 2018. About 60% of the productively used electricity is only consumed by the few industrial and 3-phase commercial customers.

This indicator cannot cover the proportion of electricity used productively by households (for their micro-business activities see I2.3), as households are not able to provide this information.

[70] In this context, productive use needs to be understood in a very broad sense, as this indicator presents the ratio of commercial customers to household costumers. Commercial customers of WENRECo include public institutions such as administration, health centers and schools, as well as churches, mosques and NGOs.

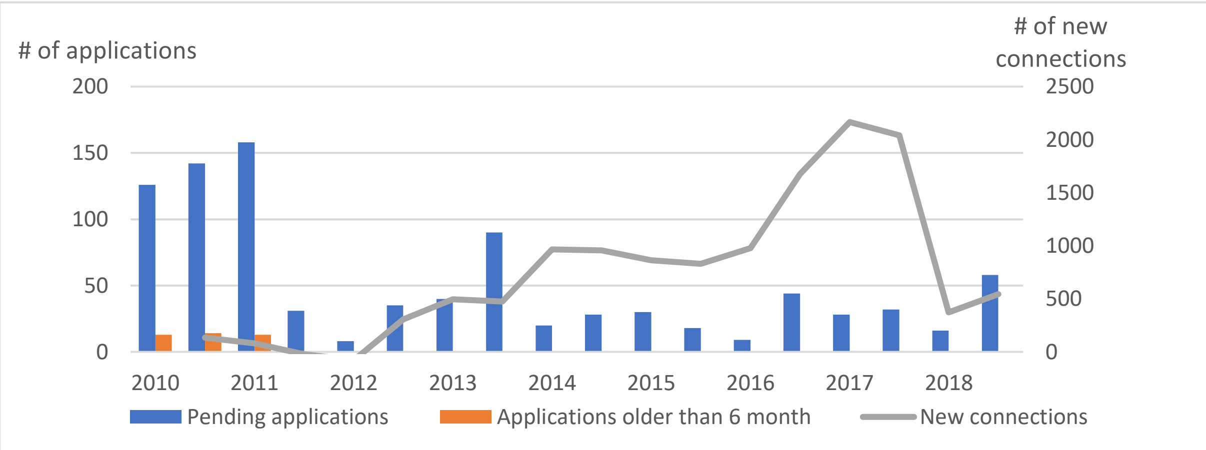
[71] Note that commercial customers include all kinds of non-domestic customers, i.e. NGOs, public administration, social infrastructure, as well as religious institutions.

Indicator sheet UP2

Result UP2: Increased demand for electricity and greater awareness of productive energy use, energy efficiency, and energy safety issues	
Indicators	Data elements
(UP2.1) Increased demand for electricity from the WENRECo grid	(1) Overall number of new connections per half-year
	(2) Number of paid applications that have not yet been connected by the end of the half-year
	(3) Number of paid applications older than six months that have not yet been connected by the end of the half-year
(UP2.2) Increased awareness of the potential for productive energy use through the use of electrical appliances	(1) Proportion of households and businesses able to name and explain the function of at least one appliance that can increase their productivity or profit
(UP2.3) Increased awareness of energy efficiency measures	(1) Proportion of households that can name at least one energy efficiency measure besides (compact) fluorescent bulbs
	(2) Proportion of businesses that can name at least one energy efficiency measure beside (compact) fluorescent bulbs
(UP2.4) Awareness of electricity safety issues in households and businesses	(1) Proportion of households that can name at least three (verified) major risks from electricity use (wiring/appliances)
	(2) Proportion of businesses that can state at least three (verified) major risks from electricity use (wiring/appliances)

Data presentation of UP2

Chart A3-16: UP2.1 - Electricity demand

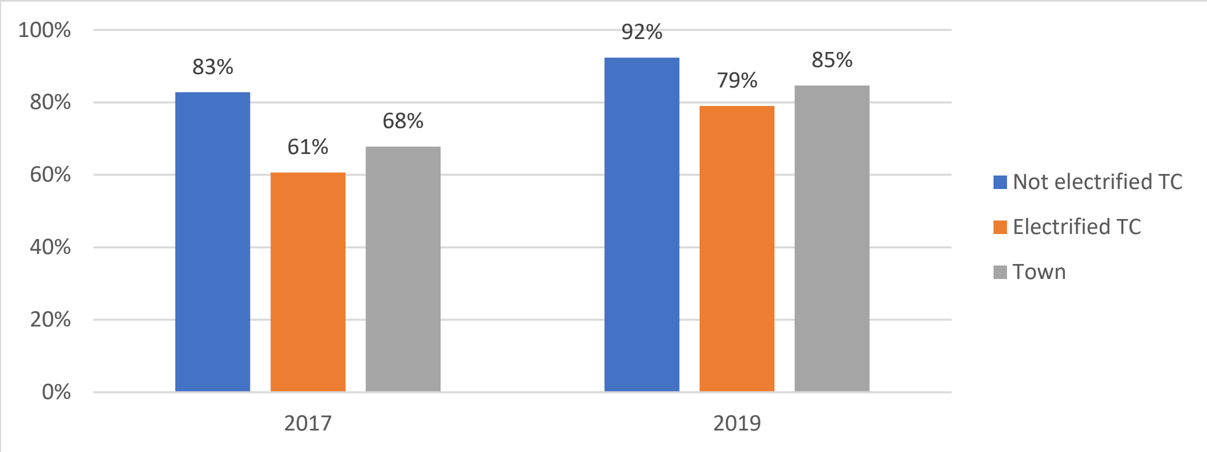


Considering the massive increase of new connections that peaked at 2,166 for the first half-year of 2017, the number of paid pending applications has since 2014 been below 3% compared to the implemented connections, but jumped up to 11% by end-2018. Since the second half of 2011, WENRECo reports that the number of pending applications older than 6 months is zero. In the second half-year of 2011 and the first half-year of 2012, the number of disconnected customers exceeded the number of new customers, which resulted in a net decrease of connections.

In spring 2017, nonconnected households and businesses were asked for their interest to get grid connected. Especially outside the electrification corridor 83% and 93% of households and businesses, respectively, confirmed their interest in a grid connection (see Chart A3-18 and

19 below). It can be stated that the demand for power is high. OC1.4 gives more insights on in how far this demand is effective in terms of affordability of grid connections and power supply.

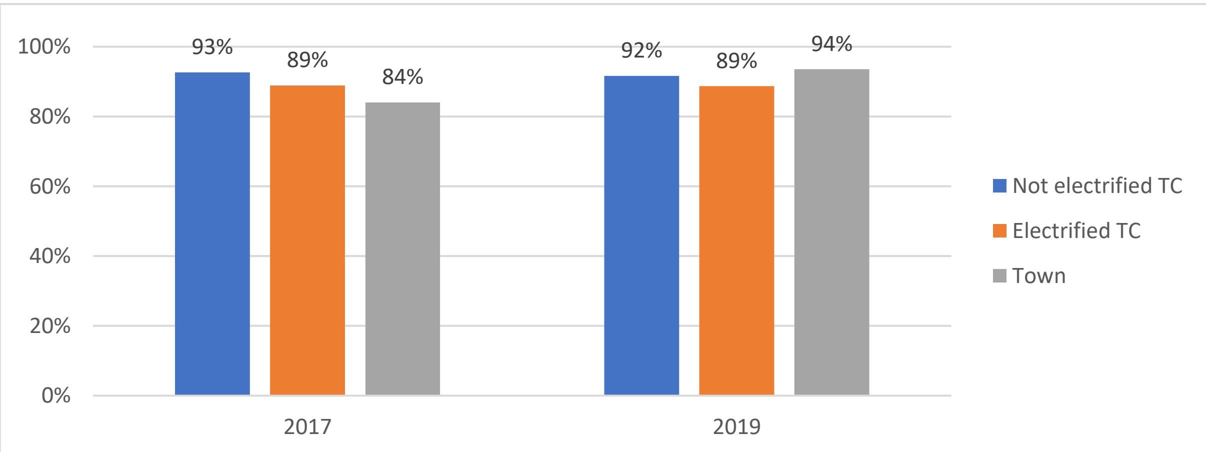
Chart A3-17: UP2.1 - Nonconnected households with explicit interest in grid connection



Since 2017, nonconnected households have been asked if there is “any activity you would like to carry out if you were connected to the grid?” As answer, households could choose from the options: 1. “private use”, 2. “business use”, or 3. “private & business”, and 4. “none”. The chart combines the options 1-3 to describe a clearly expressed interest.

For all survey clusters, an increase of demand for grid access can be observed in 2019. The higher interest in not-connected trading centers might be explained by the fact that within the electrification corridor, households with the highest interest already could get connected and accordingly have not been asked this question. And aspirations of nonconnected households within the electrification corridor might be more ‘realistic’ compared to households in not grid connected trading centers as they can directly observe connected neighbors facing reliability and cost issues of grid access.

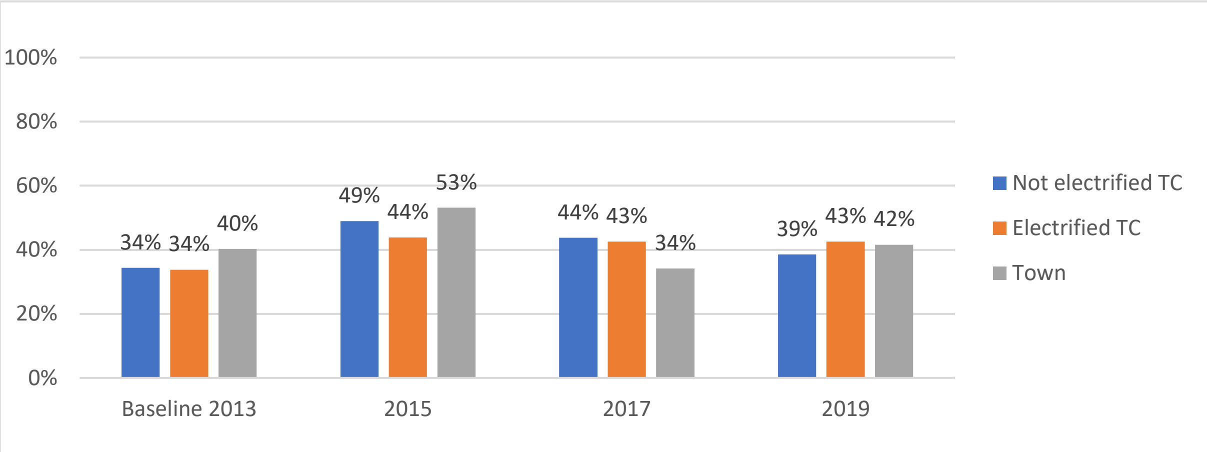
Chart A3-18: UP2.1 - Nonconnected businesses with explicit interest in grid connection



Since 2017, nonconnected businesses have been asked if there is “any activity you would like to carry out if you were connected to the grid?” As answer, households could choose from the options: 1. “private use”, 2. “business use”, or 3. “private & business”, and 4. “none”. The chart combines the options 1-3 to describe a clearly expressed interest.

In 2019, the level of interest in trading centers remained at the already high levels of 2017 and did further increase to 94% for businesses in towns.

Chart A3-19: UP2.2 - Proportion of households with micro-businesses able to name and explain the function of an electrical appliance that can increase their productivity



If we compare households in non-electrified and electrified trading centers between 2013 and 2019, a slight increase of awareness can be observed.[72] In the electrified trading centers, the general increase was mainly caused by a higher awareness of the newly connected customers, while the awareness of non-customers remained stable (WENRECo customers 2017/2019: electrified TC: 58%/66%; Town: 42%/53%). But the awareness in the control group of non-electrified trading centers also increased. This could be to some parts the impact of E-AIM awareness measures that affected also non-electrified trading centers (e.g. via radio spots). But the control group also shows an exceptional growth of use of solar systems (from 8% in 2013 to 51% in 2019, while in electrified trading center the increase was from 13% to 47% in the same period), which might have some influence on increased awareness of electric appliances.

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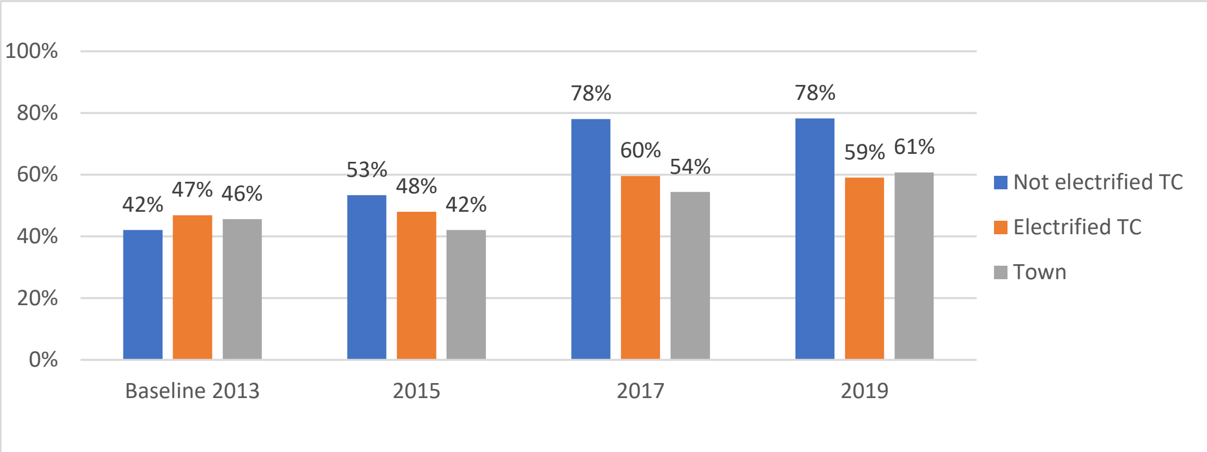
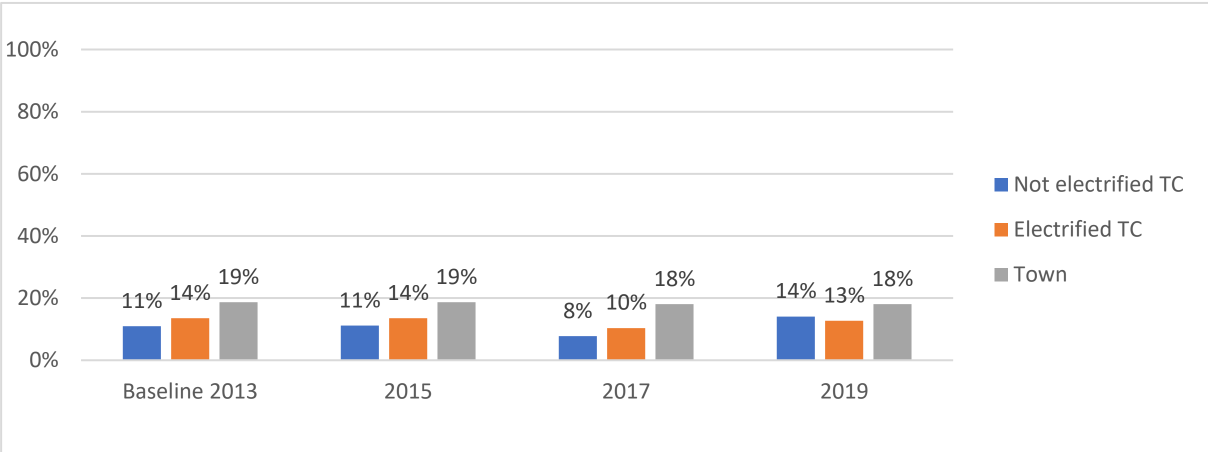
72 Because the 2015 survey had been implemented later in the year as the other surveys, data might be distorted due to seasonal effects (especially during the main period of harvest and agricultural processing, people might be more aware of productive potentials) and cannot be directly compared. Due to cancelling of invalid answers, the proportion was reduced for all years and clusters by 2 to 7 percent points. In a more detailed qualitative interview, the respondent might have been able to better explain his answer, possibly resulting in slightly higher proportions.

Chart A3-20: UP2.2 - Proportion of businesses able to name and explain the function of an electrical appliance that can increase their productivity



If we compare businesses between 2013 and 2019, a stronger increase is observable compared to households, probably because businesses are generally more aware of the economic potential of electrical appliances. While the control group showed the steepest increase, the smaller growth of awareness in electrified trading centers and towns was not significantly caused by grid connected businesses (WENRECo customers 2017 and 2019 in electrified TCs: 59% and 64%; in towns: 58% and 62%). The high awareness of the control group might be influenced by the E-AIM awareness measures that partially affected also non-electrified trading centers (e.g. via radio spots). The control group also shows an exceptional growth of use of solar systems (from 28% in 2013 to 69% in 2019), which might have some influence on increased awareness of electric appliances.

Chart A3-21: UP2.3 - Proportion of households able to name energy efficiency measures

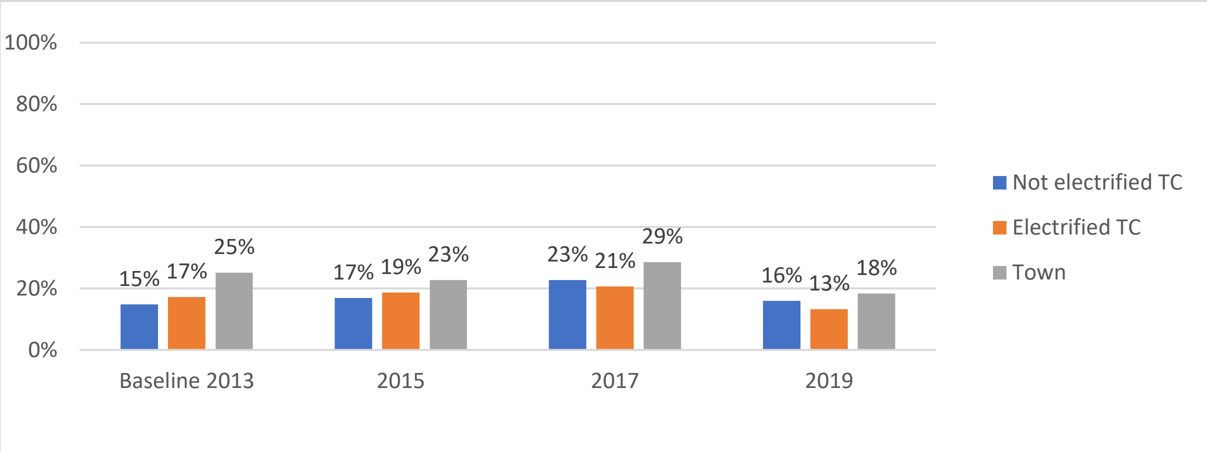


The share of households that could provide a correct example of how to save energy remained fairly stable in the range of 11-19% with the highest values in towns.[73] Awareness seems

[73] Due to cancelling of invalid answers, the proportion was reduced for all years and clusters by 2 to 6 percent points. But in a more detailed qualitative interview, the respondent might have been able to better explain his answer, possibly resulting in slightly higher proportions. However, many wrong answers also indicated a clear

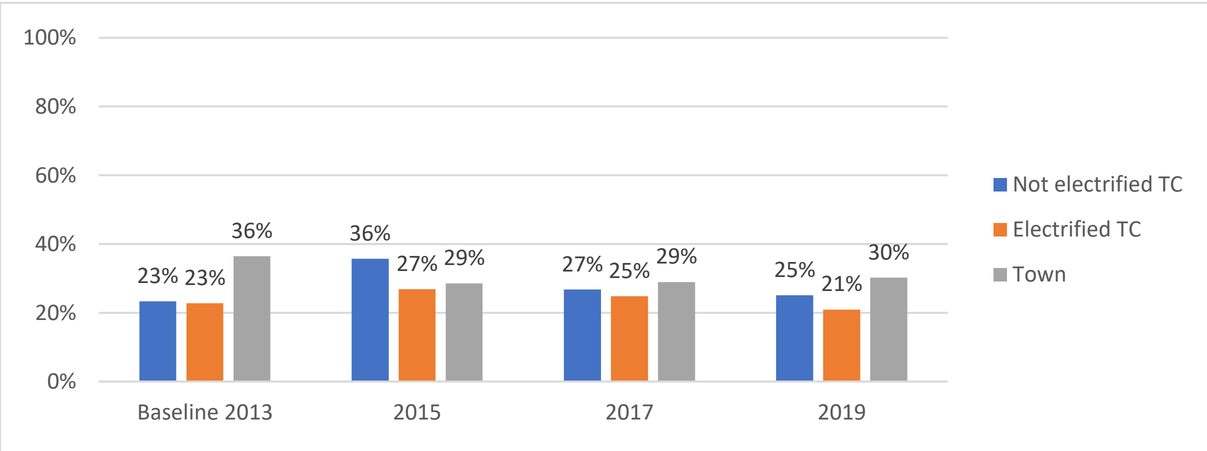
largely unaffected by the E-Aim campaign, but connected households showed a significant higher awareness (WENRECo customers 2017 and 2019 in electrified TCs: 23% and 24%; in towns: 27% and 29%).

Chart A3-22: UP2.3 - Proportion of businesses able to name energy efficiency measures



The share of businesses that could provide a correct example of how to save energy remained fairly stable in the range of 16-29% with the highest values in towns.[74] A slight increase of awareness in 2017 can be noted. In electrified areas, this increase was partially caused by grid connected households (WENRECo customers 2017 and 2019 in electrified TCs: 24% and 17%; in towns: 33% and 20%). If the slightly increased awareness even within the control group might partially attributed to the E-Aim campaign (billboards, radio spots), it shows that such one-time measure does not have a lasting effect, as awareness decreased again by 2019.

Chart A3-23: UP2.4 - Proportion of households able to name main risks of electricity use



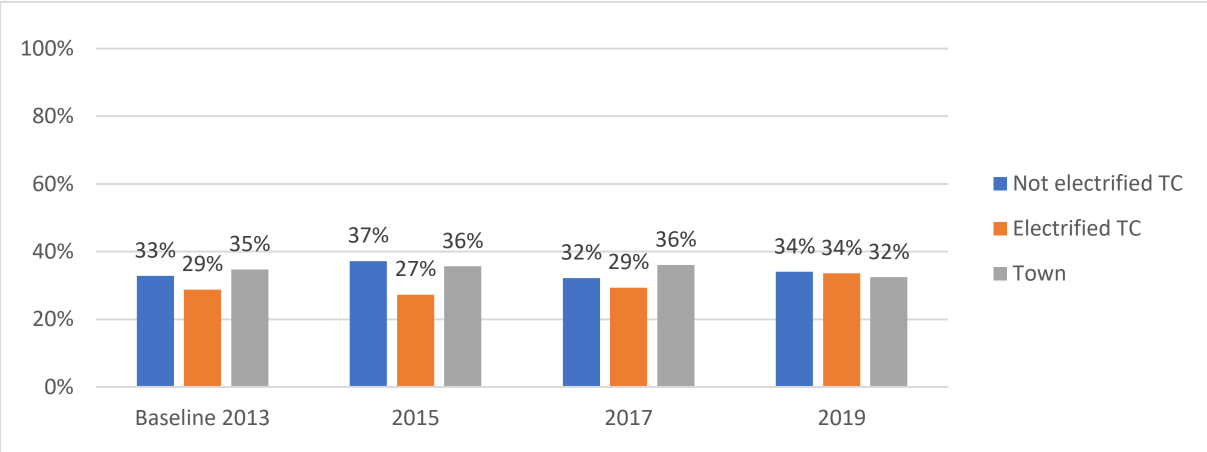
ignorance of efficient use of appliance e.g. many people are convinced that switching off the fridge, after items are cold, is an effective measure to save energy.

74 Due to cancelling of invalid answers, the proportion was reduced for all years and clusters by 2 to 10 percent points, which particularly affected the 2019 results of electrified TCs and towns. In a more detailed qualitative interview, the respondents might have been able to better explain their answers, possibly resulting in slightly higher proportions.

The share of households that could provide a correct example of how a person can be seriously injured or killed by electricity remained at an alarmingly low level with no big differences between grid connected and not connected trading centers (25% and 21% respectively), and a slightly better value for households in towns (30%).[75] WENRECo customers again showed slightly higher values compared to the average (2017 and 2019 in electrified TCs: 37% and 32%; in towns: 27%and 41%).

Low awareness should give reason to concern even though results on indicator OC1.6 indicate that the number of serious accidents of households, which had been an issue in 2017, decreased again in 2019.

Chart A3-24: UP2.4 - Proportion of businesses able to name main risks of electricity use



The share of businesses that could provide a correct example of how a person can be seriously injured or killed by electricity remained stable at an alarmingly low level of 32-34%, with WENRECo customers having almost average levels of awareness (2017/19: electrified TC: 29%/35%; Town: 36%/33%).[76]

Low awareness should give reason to concern, even though results on indicator OC1.6 indicate that the number of serious accidents of businesses, which have been an issue in 2017, decreased again in 2019.

[75] Due to cancelling of invalid answers, the proportion was reduced for all years and clusters by 6 to 13 percent points. Many of invalid answers have been too general, e.g. stating the risk as 'shock'. In a more detailed qualitative interview, the respondent might have been able to better explain his answer (e.g. how you can get an electric shock), possibly resulting in slightly higher proportions.

[76] Due to cancelling of invalid answers, the proportion was reduced for all years and clusters by 7 to 15 percent points. Many of invalid answers have been too general, e.g. stating the risk as 'shock'. In a more detailed qualitative interview, the respondent might have been able to better explain his answer (e.g. how you can get an electric shock), possibly resulting in higher proportions.

A3-3. Outcome Level

This chapter presents the status of the indicators at outcome level. These focus on the program's main goals and describe whether activities have achieved the desired results. Table A3-2 gives an overview on the seven indicators that describe the program outcome (OC1).

Table A3-2: Outcome indicators

Result	Indicator
(OC1) Improved access to and better use of electricity-based services	(OC1.1) The number of beneficiaries who are directly connected to the electricity grid has increased
	(OC1.2) In electrified areas, the average number of electrical appliances used in households, businesses, schools and health centers has increased compared to business-as-usual
	(OC1.3) In electrified areas, households, businesses, schools and health centers have reduced their fossil energy consumption and their use of biomass compared to business-as-usual
	(OC1.4) In electrified areas, the number of households and businesses that are not able to pay for their monthly electricity consumption from the island grid remains low
	(OC1.5) Households in electrified areas are better able to satisfy their ICT service needs compared to business-as-usual
	(OC1.6) In electrified areas, accidents caused by electricity use which lead to serious injuries, death or property damage have reduced compared to business-as-usual
	(OC1.7) In electrified areas, electricity-saving measures implemented by households and businesses have increased compared to business-as-usual

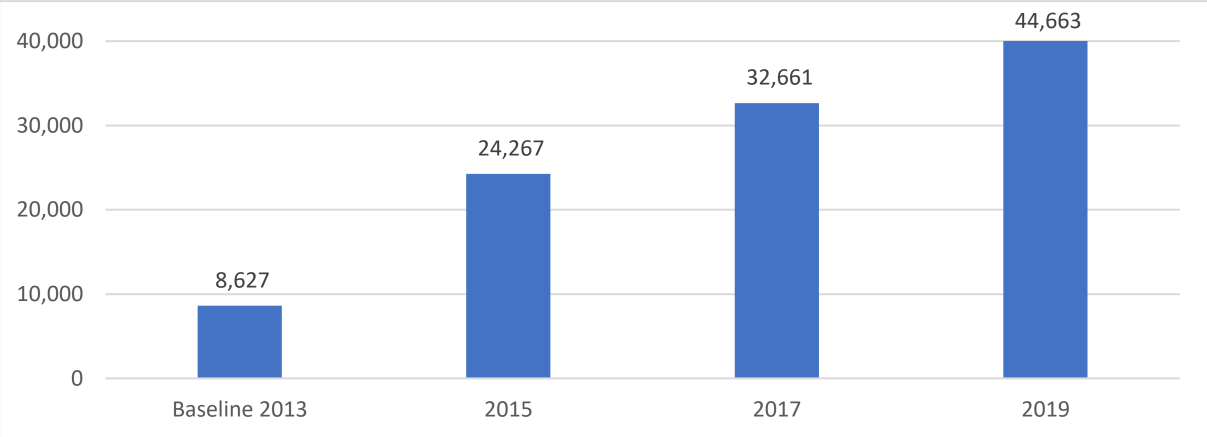
In contrast to the indicator sheets at output and use of output levels, a discussion on each indicator is also included. Furthermore, each indicator sheet provides relevant definitions, information on the data source, the name of the indicator calculation spreadsheet, and details on the data elements.

Indicator sheet OC1.1

Result OC1: Improved access to and better use of electricity-based services		
Indicator	(OC 1.1) The number of beneficiaries who are directly connected to the electricity grid has increased	
Definitions	Directly connected beneficiaries are all people living in households that have or share a direct electricity connection.	
Discussion	Rationale: the calculation of number of beneficiaries translates the number of connections to the island grid into the number of individuals actually benefiting from access to electricity-based services. However, considering the varying degrees of access and to avoid double counting, only household members are included for indicator calculation. Calculations are based on the number of connections for households as provided by WENRECo, the average number of households that share an electricity connection and the average household size, which is established during the field survey. The mean household size is cross-checked with statistical data from UBOS. Limitations: the indicator cannot provide a precise number of beneficiaries, as the data elements are based on average numbers for household members in West Nile. Finally, the number does not only refer to the grid extension area but to the complete grid-electrified area in West Nile.	
Source	WENRECo, field survey: households	
Indicator calculation	4.03_Indicator_OC1.1_2019	
Data elements and variable code	Number of households connected to the grid	WE05
	Average number of neighbors additionally connected per connected household	HH: GI11
	Average number of members per household in connected areas	4.5 according to UBOS 2018: 14

Data presentation for OC1.1

Chart A3-25: OC1.1 - Beneficiaries in terms of members of connected households



For the calculation of beneficiaries, the household size of 5.2 has been used in 2013 and 2015, while for 2017 the number has been further decreased to 4.5 based on data for West Nile of the Ugandan National Household Survey (UNHS) of 2012/2013 (UBOS 2014, 17) which remained unchanged also for the UNHS of 2016/2017 (UBOS 2018, 14). In opposite to the UNHS data, the monitoring surveys of 2017 and 2019 resulted in an average household size of 7.7 and 7.3 persons per household, respectively, and of 6.6 and 7.1 persons when only the connected households are considered. Assuming an average household size of 7.1 for all 9,925 WENRECo customer households, the total number of beneficiaries would have increased to 61,301 by mid of 2019.

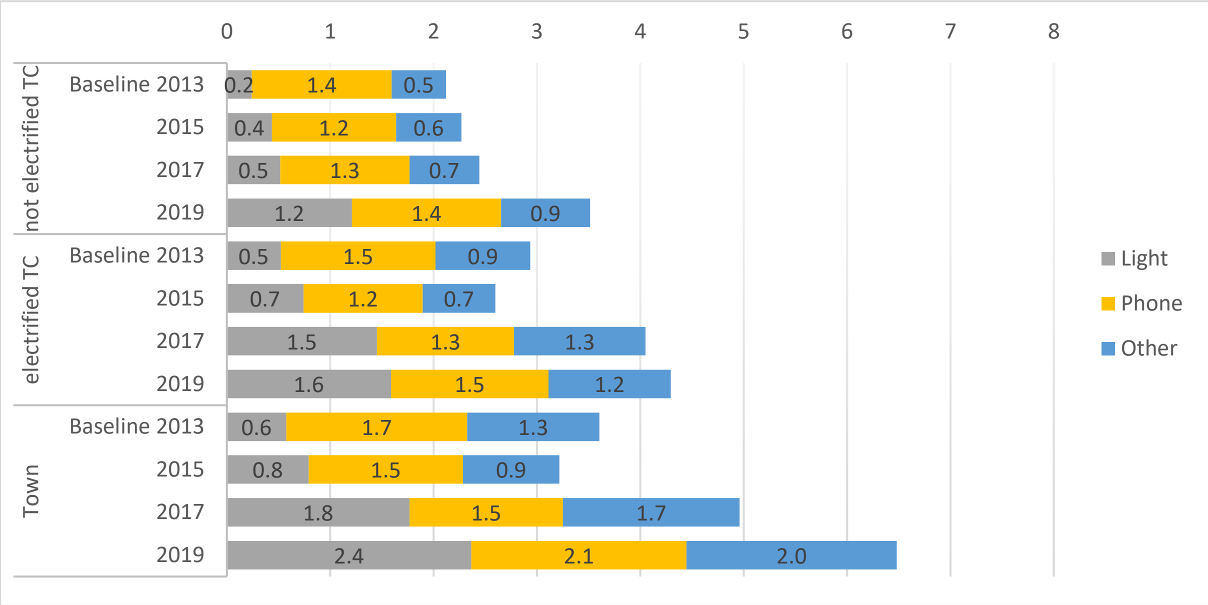
The impact monitoring surveys also identified indirect (informal) household connections. While in 2013 and 2015 there have been no indirect connections, in 2017/2019 a total of 30/32 out of 284/277 connected households (11%/12%) stated to connect on average 2/2.9 additional households (or an average of 0.21/0.33 for all 284/277 households). However, due to the low figure of only 30/32 households answering this question, to extrapolate this value to the total of 7,258/9,925 WENRECo household customers would result in very high uncertainties (the result would be an additional 1,887/2,928 households in mid-2017 and mid-2019 with either 8,491/13,176 people when a household size of 4.5 is considered, or 12,454/20,789 people when a household size of 6.6/7.1 is considered). Combined all these considerations, the program might have directly benefited a maximum of 88,156 people.

Indicator sheet OC1.2

Result OC1: Improved access to and better use of electricity-based services		
Indicator	(OC1.2) In electrified areas, the average number of electrical appliances used in households, businesses, schools and health centers has increased compared to business-as-usual	
Definitions	Electrical appliances include appliances in various categories, such as appliances for (i) lighting, (ii) heating, (iii) cooling, (iv) ICT (information, entertainment, communication, computer, internet), (v) mechanical power, (vi) charging, and (vii) medical appliances used in health centers. However, battery-powered appliances, such as torches, or appliances which only run on solar power, such as solar lamps, solar chargers, and inverters are excluded. Phone chargers have been excluded, as they belong to mobile phones.	
Discussion	Rationale: electricity can only be transformed into the electrically powered services that people need through appropriate appliances. Hence, the number of electrical appliances reflects the extent of access in terms of availability, affordability, and even quality, if certain assumptions hold true. The relevant data is collected during the field survey. Limitations: this is an index type of indicator. All electrical appliances are put into one average, so detailed information on the different types of appliances in use (and hence on the electricity services required) is not presented. However, disaggregated information can still be drawn from the database. Furthermore, certain assumptions have to be made, e.g. for lighting: if any electrical appliance is used, the energy service is already improved, even though the data set does not provide details on specific conditions, such as wall color or the size of the room to be lit. The latter would have gone far beyond the scope of the questionnaires and proved unmanageable.	
Source	Field survey: households, businesses, schools, health centers	
Indicator calculation	4.04_Indicator_OC1.2.xlsx	
Data elements and variable codes	Average number of electrical appliances used in households	AP01 to AP111 (excluding AP02, AP04, AP101, AP102, AP103)
	Average number of electrical appliances used in businesses	AP01 to AP111 (excluding AP02, AP04, AP101, AP102, AP103)
	Average number of electrical appliances used in schools	AP01 to AP128 (excluding AP21, AP23, AP101, AP102)
	Average number of electrical appliances used in health centers	AP01 to AP128 (excluding AP02, AP04, AP121, AP122)

Data presentation for OC1.2

Chart A3-26: OC1.2 - Average number of electrical appliances used in a household



The use of electrical appliances has been increasing especially in the case of lighting and, to a lesser extent, in the case of general appliances. Growth is strongly driven by grid access, while the ownership of mobile phones shows no direct relation to grid access. Strongest increase happened between 2017 and 2019 within the electrification corridor, caused by a disproportional high growth in grid connected households that showed in 2019 an average of 7.6 and 9.5 appliances in trading centers and towns, respectively (WENRECo customers in electrified trading centers 2017/19: Light: 3.3/3.1; Phone: 1.9/2.1; Other: 2.4/2.4; WENRECo customers in towns: Light: 2.7/3.8; Phone: 1.8/2.5; Other: 2.5/3.2). But in not electrified trading centers, ownership of appliances also increased in 2019, probably driven by widespread solar access. According to the UBOS report in 2018, 1% of the households in West Nile reported that they own a television individually.

Table A3-3: Proportion of households using specific electric appliances

Appliances	Not electrified TCs		Electrified TCs		Towns	
	2013	2019	2013	2019	2013	2019
Mobile Phone	72%	75%	75%	70%	85%	84%
Radio	24%	48%	37%	45%	52%	55%
TV	2%	8%	8%	16%	9%	31%
Video playback	3%	6%	6%	12%	7%	16%
Laptop computer	2%	1%	3%	6%	6%	15%
Fridge	0%	1%	1%	2%	1%	9%
Iron	0%	1%	2%	6%	2%	10%
Kettle	0%	0%	1%	2%	0%	5%

An analysis of main appliances used (see table A3-3) reveals that WENRECo customers own significantly more larger appliances such as TV, video playback or fridges compared to off-grid customers. However, this result includes wealth effects as WENRECo customers are comparatively better-off.

Chart A3-27: OC1.2 - Average number of electrical appliances used in a business

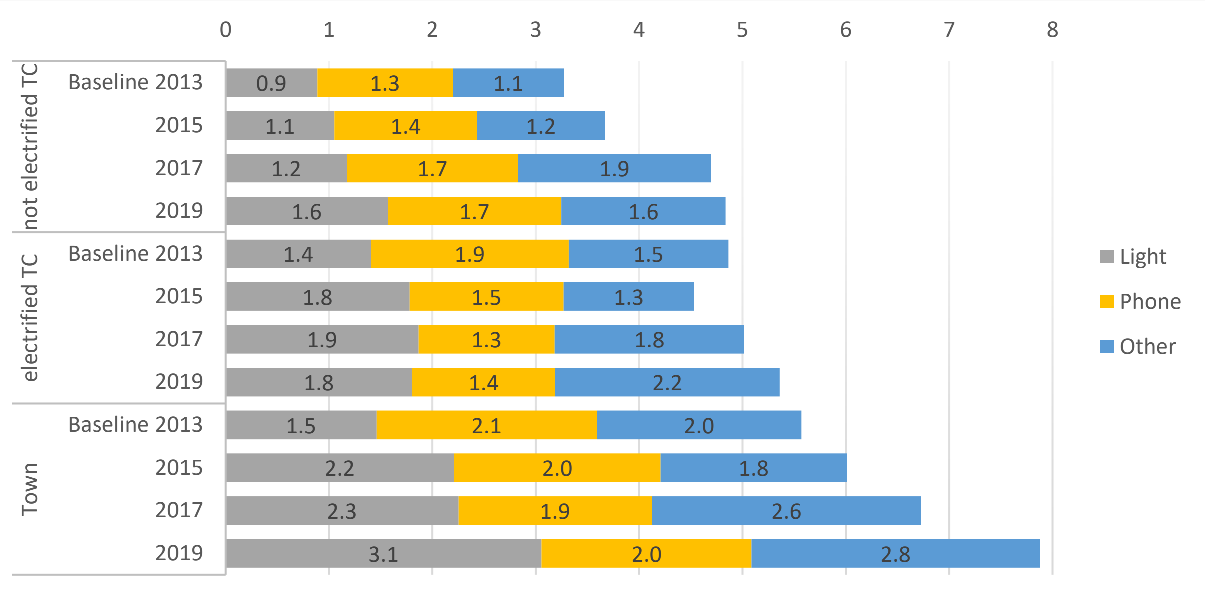


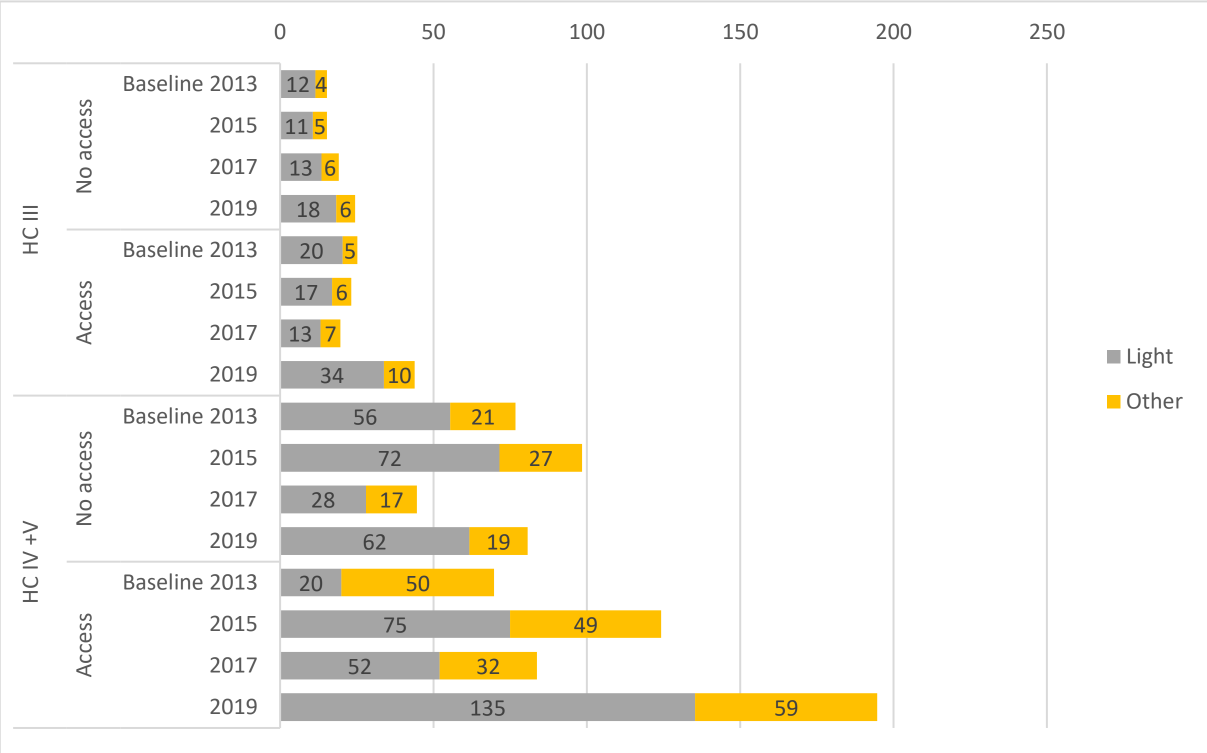
Table A3-4: Proportion of businesses using specific electric appliances

Appliances	Not electrified TCs		Electrified TCs		Towns	
	2013	2019	2013	2019	2013	2019
Share of grid-connected	0%	0%	0%	60%	0%	69%
Lighting	35%	54%	45%	64%	47%	66%
Mobile phone	82%	81%	86%	75%	87%	82%
Radio	32%	39%	44%	43%	39%	30%
TV	7%	10%	13%	20%	13%	28%
Video playback	7%	6%	7%	10%	9%	8%
Laptop computer	2%	10%	4%	9%	9%	13%
Desktop computer	1%	3%	5%	6%	8%	14%
Printer	2%	3%	3%	5%	6%	8%
Fridge	2%	3%	4%	18%	13%	24%
Freezer	0%	1%	0%	3%	1%	8%
Air condition	0%	2%	0%	3%	1%	4%
Hair cutting machine	4%	8%	5%	9%	3%	5%

In case of businesses, the average number of appliances is higher compared to households and growing slower. Growth has been notably driven by grid access mostly for light and general appliances, while ownership of mobile phones showed no direct relation to grid access (WENRECo customers in electrified trading centers 2017/19: Light: 2.6/2.5; Phone: 1.4/1.7; Other: 2.3/3.2; WENRECo customers in town: Light: 2.8/4.1; Phone: 2.1/2.4; Other: 3.2/3.7). But in not electrified trading centers, ownership of appliances also increased in 2019, probably driven by widespread solar access.

An analysis of main appliances used (see table A3-4) reveals that WENRECo customers own significantly more larger appliances such as TV, computer, fridges, or freezers compared to off-grid customers. However, this result includes wealth effects as WENRECo customers are comparatively better off.

Chart A3-28: OC1.2 - Average number of electrical appliances used in a health center



The average number of light points in level III health centers increased by one third in the no access cluster (mainly caused by sample fluctuations) and almost doubled in the access cluster (caused by grid connected health centers). Beside lighting, the number of electrical appliances in use remained relatively stable in the no-access cluster, but doubled in level III health centers of the access cluster. This affected particularly the presence of computers, printers, and copying machines, but also autoclaves, kettles and boilers. The use of microscopes, fridges, freezers, and radio call antenna seems less affected by access to grid electricity (see table A3-5 below).

Table A3-5: Proportion of level III Health centers using specific electric appliances

Appliance use in level III health centers	No access cluster		Access cluster	
Year	2013	2019	2013	2019
Sample share of grid customers	0%	0%	0%	100%
Electric lighting	72%	93%	90%	100%
Microscope with electric light	59%	63%	60%	84%
Fridge	81%	88%	85%	84%
Laptop computer	5%	50%	10%	53%
Desktop computer	9%	48%	15%	89%
Printer	2%	29%	5%	58%
Freezer	29%	30%	55%	21%
Autoclave (steam)[77]	38%	27%	25%	42%
Copying machine	0%	21%	0%	32%
Radio call antenna	21%	13%	30%	21%
Kettle	2%	0%	0%	16%
Ultrasound	2%	5%	0%	11%
Incubator	3%	0%	0%	11%
Boiler	0%	2%	0%	11%

When considering only large (level IV & V) health centers, both clusters do not show a significant growth in appliance use, while high fluctuations are caused by low numbers of only 10 institutions as well as by not being able to interview all institutions in all years. As all level IV & V health centers have either grid power or a generator, it seems that grid access has less of a direct effect on the use of electric appliances.

While secondary schools in both clusters significantly increased average use of electric lighting and appliances, the access cluster reached significantly higher shares: Secondary schools in the access cluster increased their average use of light points only by 16% but reached an average of 44 light points per school with 97% of schools using electric lighting. Secondary schools of the no-access cluster have been able to increase their average use by even 50%, reaching an average of 33 light points in 2019 with 91% of schools using electric lighting.[78] An explanation for the difference might be that secondary schools of the access cluster had been able to satisfy a high share of their light demand already in 2013 by using solar systems and generators.

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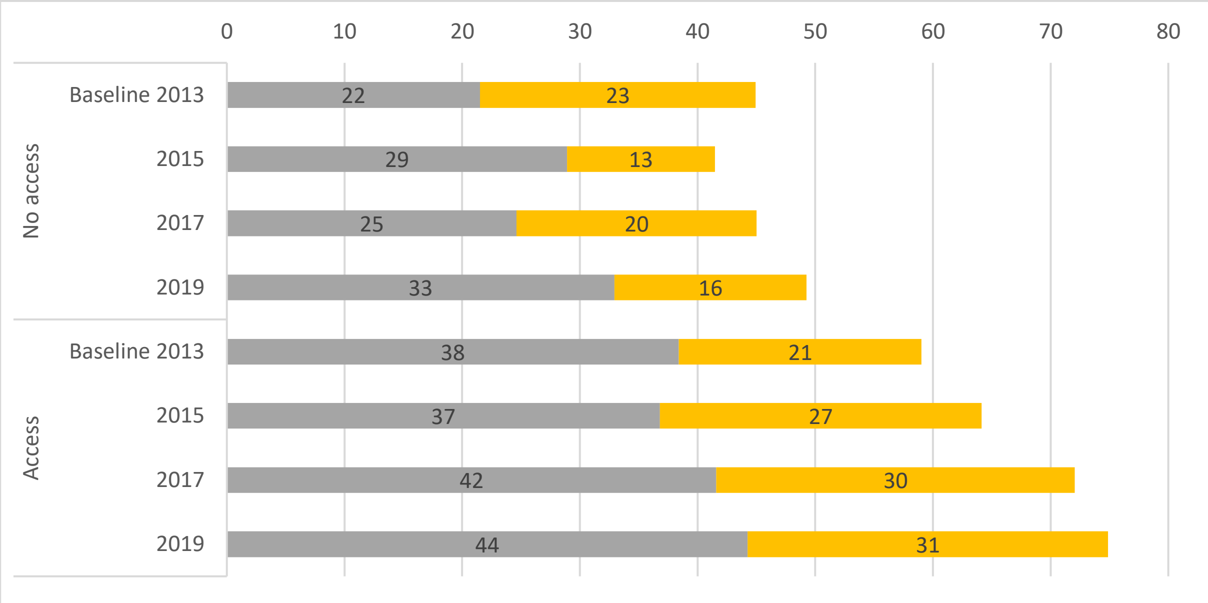
[77] The qualitative survey showed that the use of electric autoclaves is rare and the autoclaves heated with charcoal are common. Regarding these results, it can be assumed that the respondents referred also to non-electric autoclaves when answering the question.

[78] Measurement of the number of light points is only a proxy for the actual lighting use as it does not record the luminous flux provided by each light point. An institution might significantly increase its illumination level without increasing the number of light points simply by replacing weak light points with stronger LED lights.

Chart A3-29: OC1.2 - Average number of electrical appliances used in a secondary school



The average number of non-lighting electrical appliances increased in secondary schools within the access cluster by 48% in opposite to a decrease in the no-access control cluster. In 2019, significantly more secondary schools of the access cluster owned larger appliances such as computers, printers, copying machines or overhead projectors (see table A3-6).

Table A3-6: Proportion of secondary schools using specific electric appliances

Appliances	Secondary schools (No access)		Secondary schools (Access)	
Year	2013	2019	2013	2019
Sample share of grid customers	0%	0%	0%	100%
Electric Lighting	54%	91%	58%	97%
Laptop computer	26%	57%	24%	83%
Desktop Computer	36%	60%	55%	80%
Printer[79]	31%	69%	48%	89%
Copying machine	22%	41%	21%	80%
Radio	38%	34%	30%	46%
Overhead projector	2%	10%	6%	26%

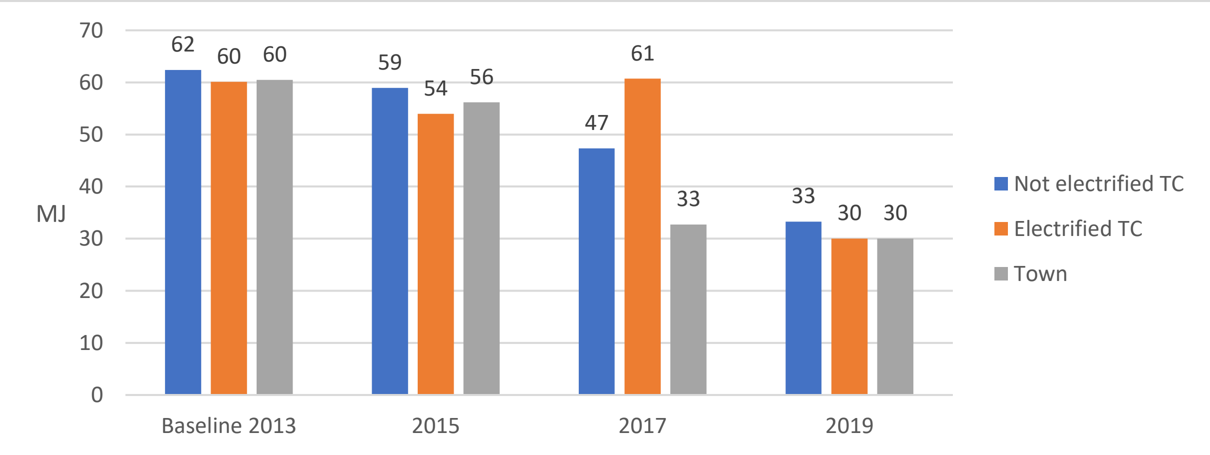
79 Also includes multifunctional devices (printing+coping).

Indicator sheet OC1.3

Result OC1: Improved access to and better use of electricity-based services		
Indicator	(OC1.3) In electrified areas households, businesses, schools and health centers have reduced their fossil energy consumption and their use of biomass compared to business-as-usual	
Definitions	Fossil energies: include diesel, petrol, kerosene/petroleum/paraffin, candles, gas (LPG) Biomass: include firewood, charcoal, animal dung, crop residues	
Discussion	Rationale: improved access to electricity is assumed to lead to the substitution of fossil and/or biomass energy sources to meet energy service needs. Hence a reduction of the quantity and frequency of use of fossil and biomass energy sources is expected and is used as an indicator for the gradual move from fossil fuels and biomass to electricity. The data needed to calculate the indicator is collected during the field survey. Information is collected on the most commonly used energy sources. As the conversion of biomass used into units of energy cannot be standardized, only the frequency of use of any biomass energy source is calculated. Limitations: a reduction in fossil fuel or biomass usage could also arise as a result of substitution with solar energy, or due to budget constraints; this cannot be separated within the aggregated indicator presentation. Furthermore, the indicator does not allow any detailed statements regarding which energy services are substituted by the conversion of which energy source.	
Source	Field survey: households, businesses, schools, health centers	
Indicator calculation	Indicator_OC1.3.xlsx	
Data elements and variable code	Quantity of fossil energy sources used for stationary combustion in households, businesses, schools and health centers	HH, B, HC, S: EF01 to EF29
	Proportion of households, businesses, schools and health centers using biomass energy sources (firewood, charcoal, animal dung, crop residues)	HH, B, HC, S: EF52 to EF78
	Conversion factors	Annex 1.2

Data presentation for OC1.3

Chart A3-30: OC1.3 - Fossil fuels used by a household on average per month (MJ)



The average use of fossil fuel halved between 2013 and 2019 in all clusters including the control group, while the use of fossil fuel by grid connected households is not significantly lower than the average (WENRECo customers 2017/2019: electrified TC: 69/30 MJ; Town: 25/30 MJ). It seems that access to electricity had no direct effect on the observed trend.

As this is a highly aggregated indicator combining the five fossil fuels (diesel, petrol, kerosene, candles, LPG), the changes of the separate components must be considered to attribute this change to specific interventions and trends. LPG has only been used by three households in

2017 and 2019 combined and can be ignored. Diesel and petrol consumption is largely determined by the use of generators but fluctuates strongly, representing between 1 and 29% of total fuel use. As the total number of households using petrol and diesel as generator fuel is very low, they bring a high uncertainty into the picture and must be interpreted with care:

Non-electrified trading centers: Generator use reduced to 0.5% by 2019, remaining diesel and petrol use was caused by one household only.

Electrified trading centers: Generator use fluctuates between 4.5% in 2013 to 1.5% in 2015, 4% in 2017, and 2% in 2019 (with 3% in 2019 when only WENRECo customers are considered). As the recorded diesel and petrol fuel use (received valid answers) was very low in 2013, 2015, and 2019, but spiked in 2017, it caused the 2017 recorded increase in total fuel use regardless the shrinking kerosene consumption.

Towns: Generator use remains stable around 3% (with 5% in 2019, if only WENRECo customers are considered). The recorded diesel and petrol fuel use (received valid answers) was low in 2013 and 2017, spiked in 2015 and was average in 2019. This partially compensated a continued decrease in kerosene consumption.

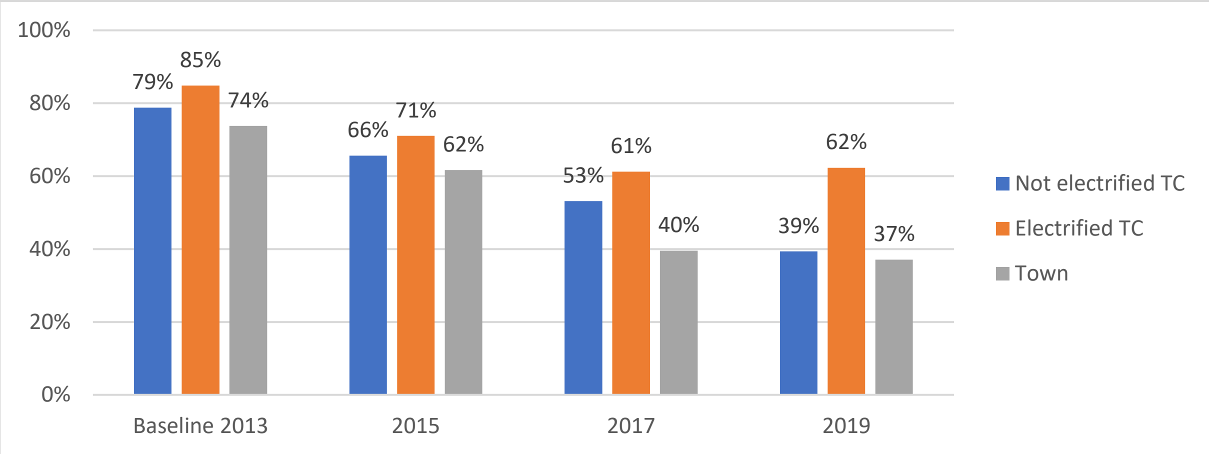
Candle use has a minor impact, representing only 1-4% of the total fuel use by households. However, as table A3-7 shows, frequency of candle use, while decreasing in 2015/2017, increased again by 2019. The increase of candle use in 2019 was even more pronounced for grid connected households. It might therefore be attributed to the poor reliability of grid power supply, resulting in increased use of candles by better off households (which most grid connected households are).

Table A3-7: OC1.3 - Frequency of candle use in households

Households	2013	2015	2017	2019
Not electrified Trading Centers	16%	16%	7%	10%
Electrified Trading Centers	15%	8%	11%	17%
WENRECo customers only	--	--	10%	20%
Towns	15%	11%	10%	18%
WENRECo customers only	--	--	13%	25%

Kerosene has the highest share of fossil fuel consumption, representing 70-99% of total fuel use by households, mainly used for lighting as it is an easily accessible and flexible option with low upfront costs. The frequency and total amount of kerosene use decreased significantly in all 3 clusters (see chart A3-31 below).

Chart A3-31: OC1.3 - Frequency of households using kerosene



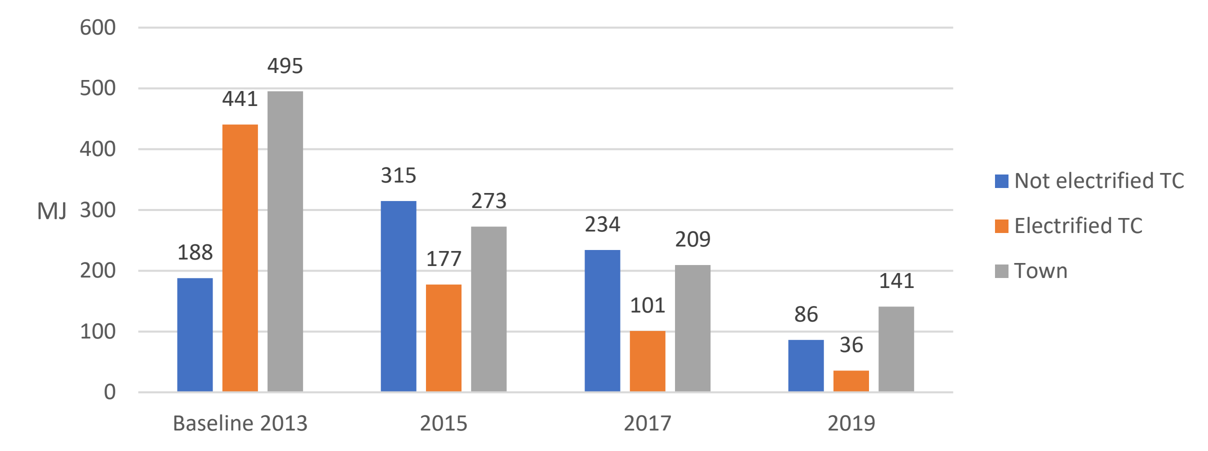
Because the decrease in kerosene consumption started already in 2015, including the control group, this reduction can be attributed to the increased use of solar lighting, while the observed kerosene reduction in electrified areas in 2017 and 2019 was largely driven by WENRECo customers and can be attributed to increased grid access:

Non-electrified trading centers: Kerosene use decreased from 79% of households and 25 GJ in 2013, to 39% of households and 10 GJ in 2019, while the use of solar lamps and solar home systems increased from 6% and 8% in 2013 to 26% and 51% respectively in 2019.

Electrified trading centers: Kerosene use decreased from 85% of households and 31 GJ in 2013, to 62% of households and 17 GJ in 2019. Grid connected households use significantly less kerosene (36%/ 3.4 GJ and 31%/ 3.3 GJ if only WENRECo customers are considered), which means that the decrease since 2017 is mostly driven by grid connected households. Still, use of solar lamps and solar home systems increased from 7% and 26% respectively in 2013 to 22% and 47% respectively in 2019 (22% and 40% if only WENRECo customers are considered).

Towns: Kerosene use decreased from 74% of households and 21 GJ in 2013, to 37% of households and 6 GJ in 2019. In towns also, grid connected households use significantly less kerosene (34%/ 3 GJ and 24%/ 1.5 GJ if only WENRECo customers are considered), and therefore are driving the total decrease since 2017, even though the use of solar lamps/solar home systems increased from 11% and 15% respectively in 2013 to 33% and 55% respectively in 2019 (38% and 39% if only WENRECo customers are considered).

Chart A3-32: OC1.3 - Fossil fuels used by a business on average per month (MJ)



The average use of fossil fuel by businesses greatly decreased between 2013 and 2019 in all clusters including the control group[80], while the use of fossil fuel by grid connected businesses is significantly higher compared to the average, indicating that back-up generators are still very much in use (WENRECo customers 2017/2019: electrified TC: 62 and 45 MJ; Town: 278 and 185 MJ).

This is a highly aggregated indicator combining the five fossil fuels (diesel, petrol, kerosene, candles and LPG). To understand the dynamics and trends, the changes of the separate components must be considered. LPG has been used by very few businesses (max 5 per cluster) but due to high amounts used it can make up for up to 8% of total fuel use.

Frequency of petrol and diesel use decreased by 44% in not electrified trading centers compared to 64% in electrified trading centers, while in towns the decrease was lowest with 35%. The average monthly use of diesel and petrol decreased by 50% in not electrified trading centers (using 2015 as baseline) compared to 81% in electrified trading centers, while in towns the decrease was lowest with 52%. Generator ownership fluctuates between 6-17%, with highest values in towns. Petrol use without generator ownership hints to stationary use to power machinery. The use of fossil fuel by grid connected businesses is significantly higher compared to the average, indicating that back-up generators are still very much in use.

Candle use is low with up to 3% of total fuel use and frequency reduced between 2013 and 2019 for all clusters. Frequency and total amount of kerosene consumption is decreasing in all 3 clusters. A large part of this decrease already shows in 2015 and equally for the control group, so this can be attributed to the increased use of solar lighting, while some of the reduction in 2017 and 2019 in electrified trading centers and towns can also be attributed to increased grid access.

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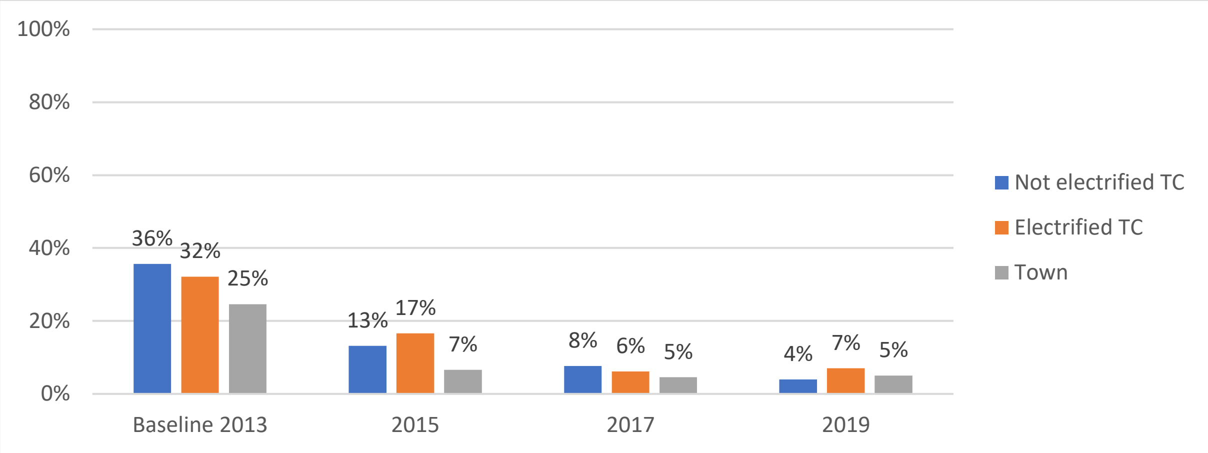
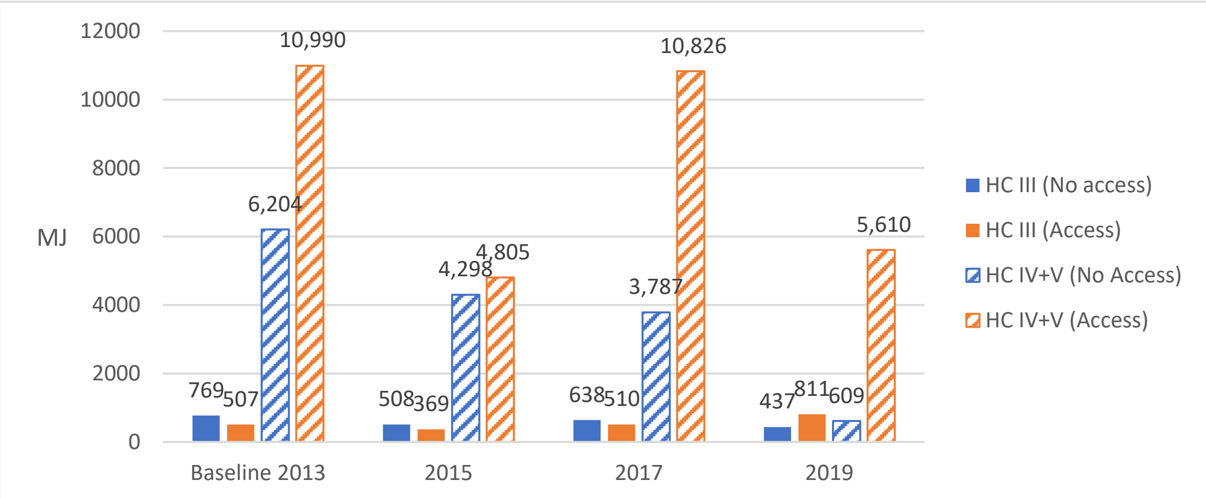
80 The 2013 average of only 188 MJ fossil fuel use in not electrified trading centers is mainly caused by a very low average use of diesel fuel in this year. As only very few businesses are using diesel generators, the measurement error fort the reported average value might be large.

Chart A3-33: OC1.3 - Frequency of businesses using kerosene



In not electrified trading centers, kerosene use decreased from 36% of businesses in 2013 to 4% in 2019. The use of solar lamps and solar systems increased from 9% and 27% in 2013 to 27% and 69% in 2019. In e**lectrified trading centers,** kerosene use decreased from 32% of businesses in 2013 to 7% in 2019 (3% for WENRECo customers). The use of solar lamps and solar systems increased from 18% and 43% in 2013 to 30% and 54% in 2019 (28% and 50% when only WENRECo customers are considered). In t**owns,** kerosene use decreased from 25% of businesses in 2013 to 5% in 2019 (3% for WENRECo customers. The use of solar lamps and solar systems increased from 12% and 31% in 2013 to 23% and 47% in 2019 (22% and 43% when only WENRECo customers are considered).

Chart A3-34: OC1.3 - Fossil fuels used by a health center on average per month (MJ)



For health centers, similar effects can be observed as in the case of households and businesses: while kerosene use has significantly decreased, this effect is overcompensated by highly fluctuating diesel/petrol consumption as generator fuel. The large level IV and V health centers have massive consumptions compared to the large number of level III health centers and are therefore presented separately in the chart A3-34 above. As the panel size of level IV and V health centers is only 12 and not all institutions could be interviewed in all years, fluctuations are even higher and values need to be interpreted with care. Table A3-8 below presents the fossil fuel consumption of specific health centers over time.

Table A3-8: OC1.3 – Total fuel use of level IV and V Health Centers (GJ)

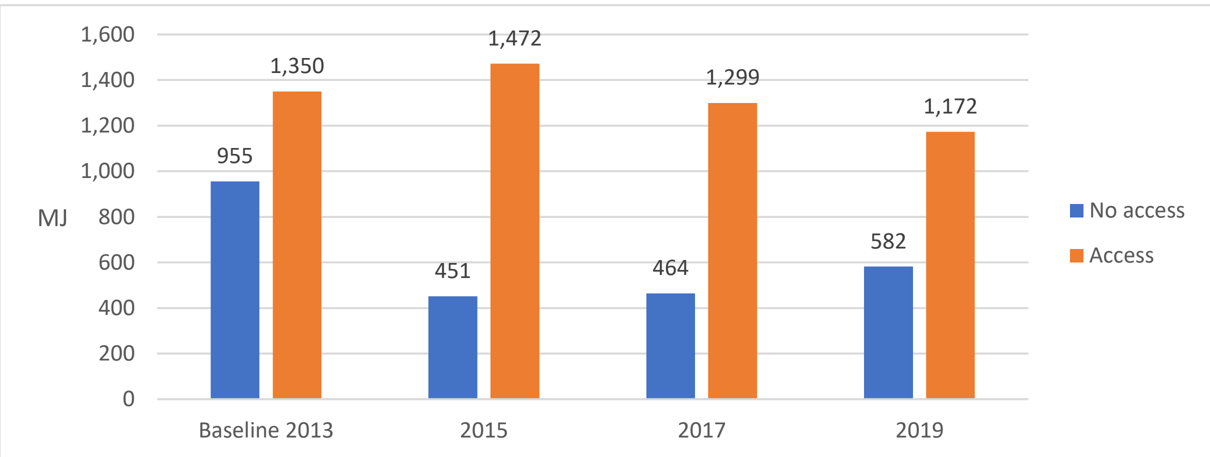
	Health Center	Level	2013	2015	2017	2019
Access cluster (6)	Koboko hospital	V	38.8	1.9	40.5	9.3
	Maracha hospital	V	n/a	13.9	1.5	4.8
	Nyapea hospital	V	3.8	0.1	n/a	11.5
	Pakwach Health Center	IV	0	0	0	2.0
	St.Luke Hospital Angal	V	1.5	n/a	n/a	2.6
	Yumbe Health Center	IV	n/a	0.2	0.1	3.4
No Access cluster (6)	Adumi Health Center	IV	0	n/a	1.7	1.1
	Rhino camp Health Center	IV	n/a	0	0	0.3
	Omugo Health Center	IV	0.1	0	0	0
	Yumbe Hospital	V	2.0	14.5	11.2	n/a
	ST. Josephs Hospital	V	13.0	n/a	n/a	n/a
	Midigo Health Center	IV	7.2	2.5	2.6	1.0

n/a = the health center could not be interviewed in the respective year. Grid connection status of health centers is indicated by a green shaded background.

In some years, some of the large health centers have not been available for interview or provided very different replies compared to the previous year. By 2019, five out of 25 health centers of the access cluster are using back-up generators, while all 25 have additional solar systems. Of the 60 health centers of the no-access cluster, only five have a generator, while 59 have a solar system.

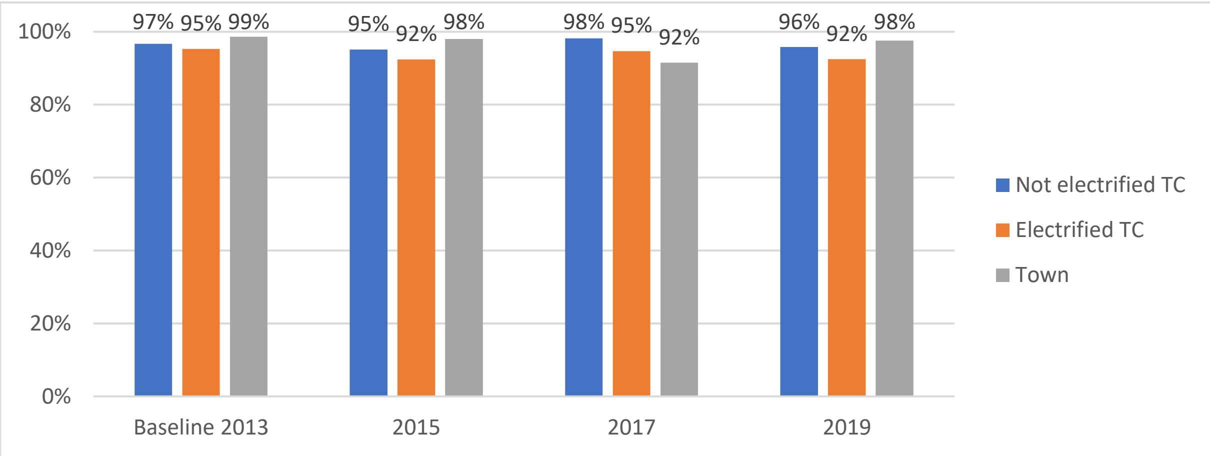
Furthermore, the reported LPG use significantly increased by 2019, but numbers are distorted as the medical distribution center switched to bigger 36 kg cylinders (and health centers tend not to report partial use of cylinders). And some hospitals that could not be interviewed in previous years reported particularly high LPG consumptions. For example, St. Luke Hospital Angal used 100kg LPG because they provide gas for the cooking facilities in their guest houses.

Chart A3-35: OC1.3 - Fossil fuels used by a secondary school on average per month (MJ)



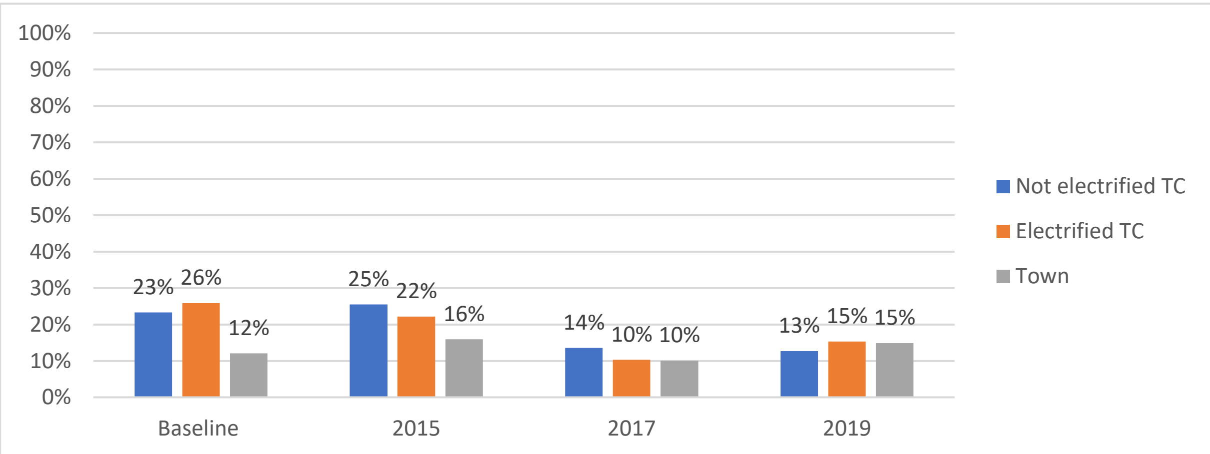
Fuel use of schools in the access cluster decreased by 2019 (after an increase in 2015) to 85% of the 2013 value. Fuel use of schools in the no-access control cluster halved in 2015 (due to less diesel, petrol, and kerosene use, which might be caused by reduced availability of funds) but increased again by 2019. By 2019, 12 (34%) of the 35 schools of the access cluster had back-up generators, while 29 (84%) also used additional solar systems. Of the 70 non-connected schools in the no-access cluster, only 13 (19%) had a generator, while 66 (94%) had solar systems. Share of kerosene in total fuel consumption remained more or less stable (32%-37%) for the no-access control cluster but decreased for the access cluster from 20% in 2013 to 9% in 2019, while candle use is negligible.

Chart A3-36: OC1.3 - Proportion of households using biomass



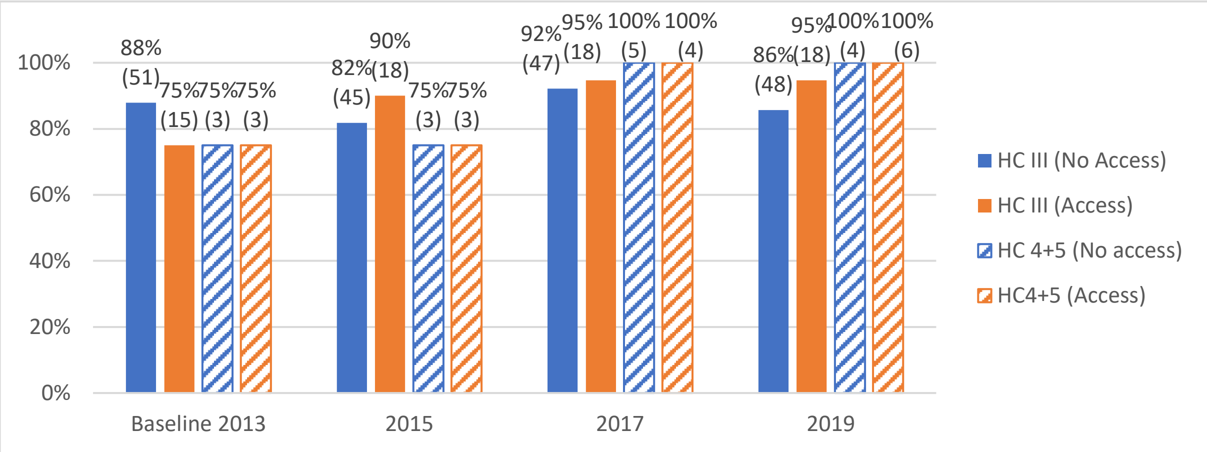
Biomass use remains stable in both electrified and non-electrified trading centers. There is no significant difference neither between households in electrified and not electrified TCs, nor between electrified and not electrified households in TCs and towns (WENRECo customers in 2017 and 2019 in electrified TCs: 95% and 92%; in Towns: 92% and 98%). This fulfils the expectation that power supply does not immediately affect biomass consumption of households as power is not used for cooking. Replacement with LPG could not be recorded.

Chart A3-37: OC1.3 - Proportion of businesses using biomass



In 2017, businesses within and outside the electrification corridor reported a decreasing use of biomass, which suggests that there may have been a general shift of business activities (e.g. increase of retail activities) rather than an effect of the new grid access. WENRECo customers only show an insignificantly lower biomass use (WENRECo customers 2017 and 2019 in electrified TCs: 9% and 13%; in towns: 10% and 13%). However, in 2019, an increase can be observed for the electrified areas only, which is mainly caused by increased charcoal use and could be related to business activities that require biomass, such as restaurants, hotels, and catering services.

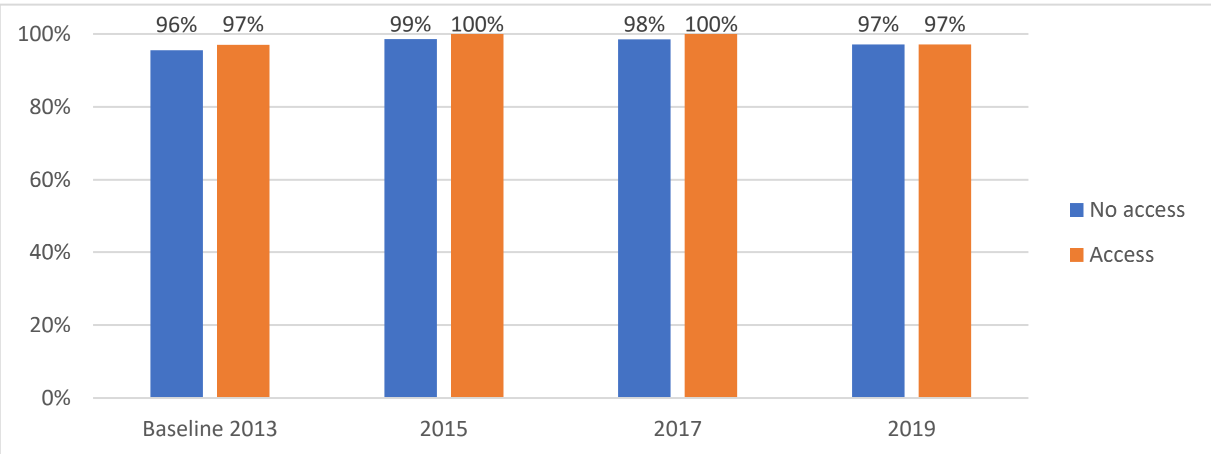
Chart A3-38: OC1.3 - Proportion of health centers using biomass



Use of biomass by health centers has not been affected by grid connection. As the panel size of level IV and V health centers is only 12 and not all institutions could be interviewed in all years, fluctuations are higher and values need to be interpreted with care. Of the 6 large health centers of the access cluster, only Pakwach HC IV stated in 2013 and 2015 not to use biomass, while in the no access cluster Omugo HC IV (2015) and Yumbe Hospital (2013) stated not to use biomass.

One key use of biomass is the use of charcoal to fuel sterilizing ovens. Some health centers also run nutrition units to treat malnourished children with food. During the qualitative survey, one grid connected health center stated that even though owning electric sterilizers, they lack power stabilizers to protect these expensive appliances from effects of the unstable network and therefore refrain from using them at all.

Chart A3-39: OC1.3 - Proportion of secondary schools using biomass



Use of biomass in secondary schools has not been affected by grid connection. Almost all schools use fuelwood for cooking and charcoal for preparing tea.

Indicator sheet OC1.4

Result OC1: Improved access to and better use of electricity-based services		
Indicator	(OC1.4) In electrified areas, the number of households and businesses remains low that are not able to get connected, are not able to constantly pay for electricity, or are dissatisfied with the reliability, cost, and service of power supply.	
Discussion	Rationale: this indicator reflects the affordability dimension of access. Improved access to electricity-based services can only be assumed if households and businesses can afford a grid connection and if connected households and businesses can constantly afford their electricity demand. The information is available directly from the electricity provider. Limitations: this indicator does not capture aspects of preferences. It is assumed that households and businesses desire a constant supply and that the amount of their consumption reflects their total need.	
Source	WENRECo	
Indicator calculation	Indicator_OC1.4.xlsx	
Data elements and variable code	Number of customers stating to be able to use power always, predominantly, or intermittently.	Z01
	Satisfaction of customers with WENRECo reliability, cost, and customer service of power supply.	Z22 – Z29
	Reasons for not getting connected to the power grid.	Z7 - Z12

After the monitoring exercise in 2015, MEMD and KfW Development Bank expressed interest in more information regarding the existing barriers to get swiftly connected to the newly extended grid. Accordingly, an additional set of questions has been developed and included into the existing household and business questionnaires.

Data presentation for OC1.4

Charts A3-40 and A3-41 have been introduced in 2017 as WENRECo was not able to directly monitor power consumption with their pre-paid meters (technical constraint of meters used).

Chart A3-40: OC1.4 - Continued power use of pre-paid household customers

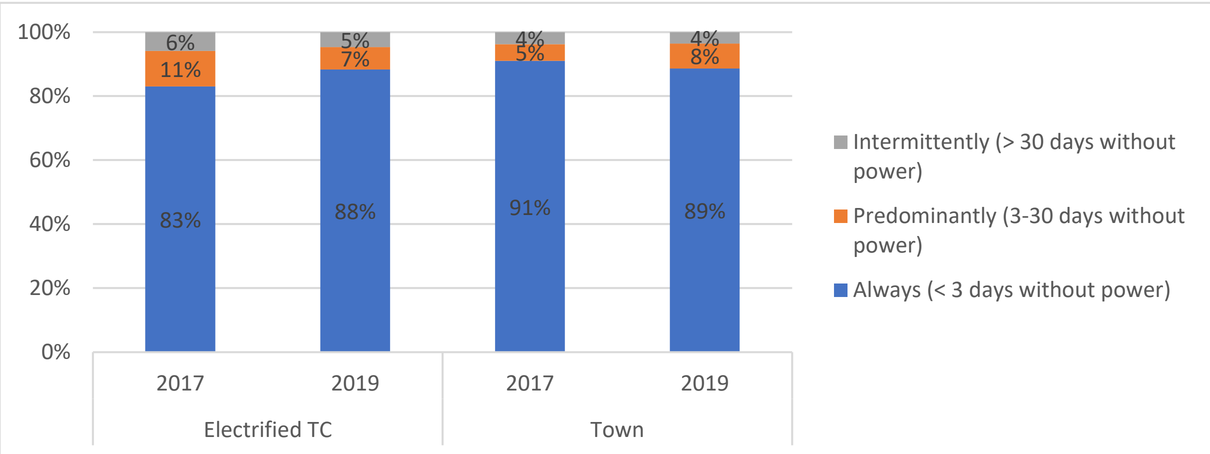
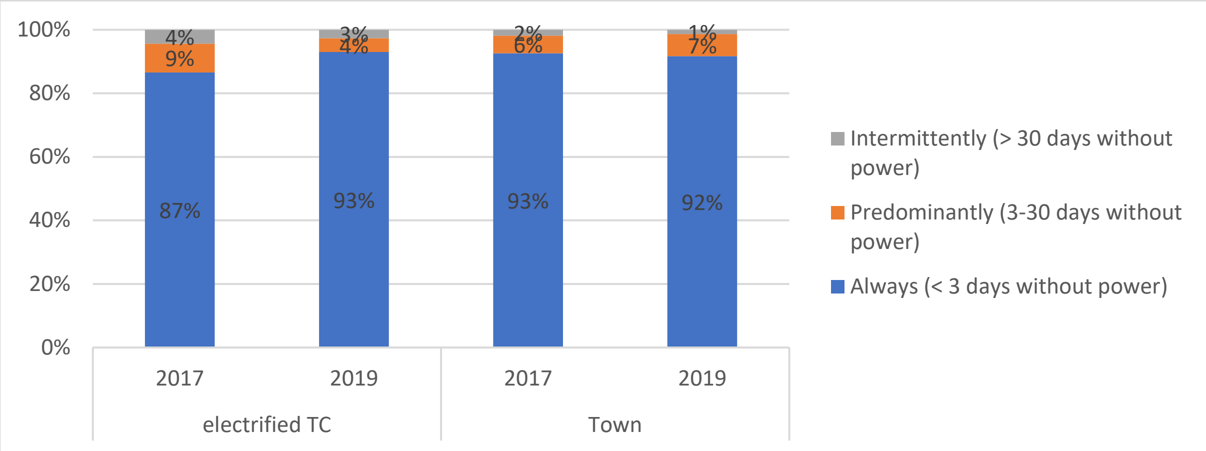


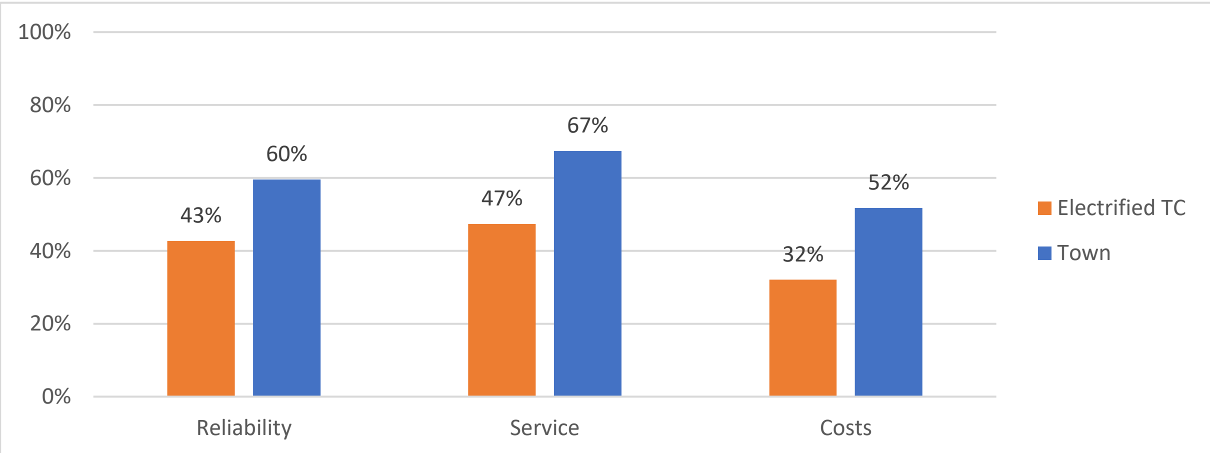
Chart A3-41: OC1.4 - Continued power use of pre-paid business customers



It can be observed that continued power use is very high for households and businesses. The few customers that replied to use power only predominantly or intermittently have been asked for the main reason. Difficulties to purchase pre-paid power together with affordability and irregular income have been reported as issues.

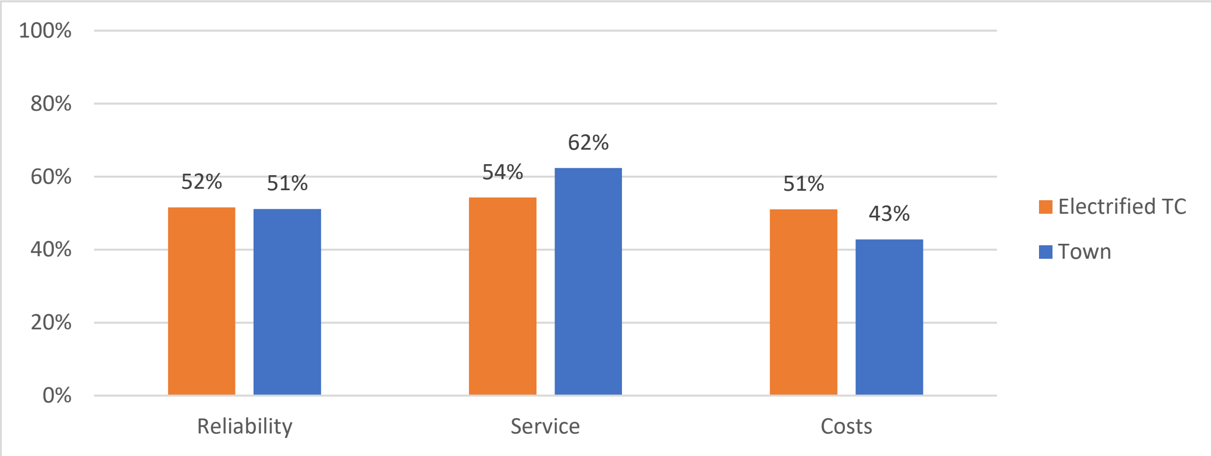
The evaluation of WENRECO's pre-paid customer data base revealed that over the period of July 2016 and June 2017, 14% of the household customers and 12% of the commercial customers have purchased power never or only once. As the survey was only conducted in the new grid areas, while the larger share of new customers has been added in the old grid areas, this result might indicate that in the old grid areas the share of households unable to use power continuously is significantly higher compared to the monitored new grid areas.

Chart A3-42: OC1.4 – Satisfaction of WENRECo customer households



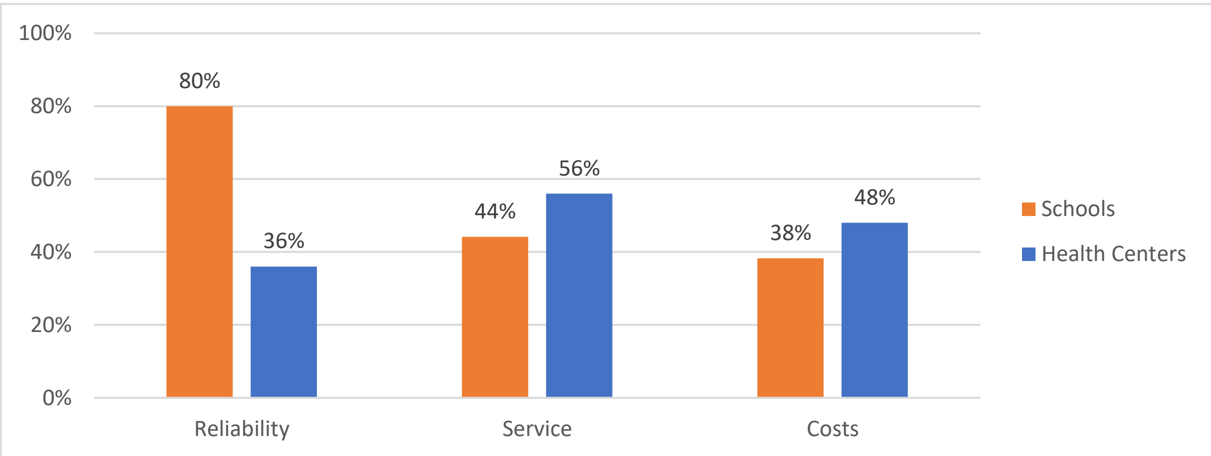
In 2019, customer satisfaction of households was higher in towns compared to trading centers. Satisfaction with the electricity costs was lowest, followed by reliability and service. Differences can be explained with a possible higher level of reliability and service in towns compared to rural trading centers, while rural households might use less power compared to town households, which makes them feel stronger the missing lifeline subsidy for the first 15 kWh per month compared to the national grid. About 70% of households in trading centers and towns stated that reliability had improved compared to 2017, while 60% of trading center households and 65% of town households stated that customer service improved compared to 2017.

Chart A3-43: OC1.4 – Satisfaction of WENRECo customer businesses



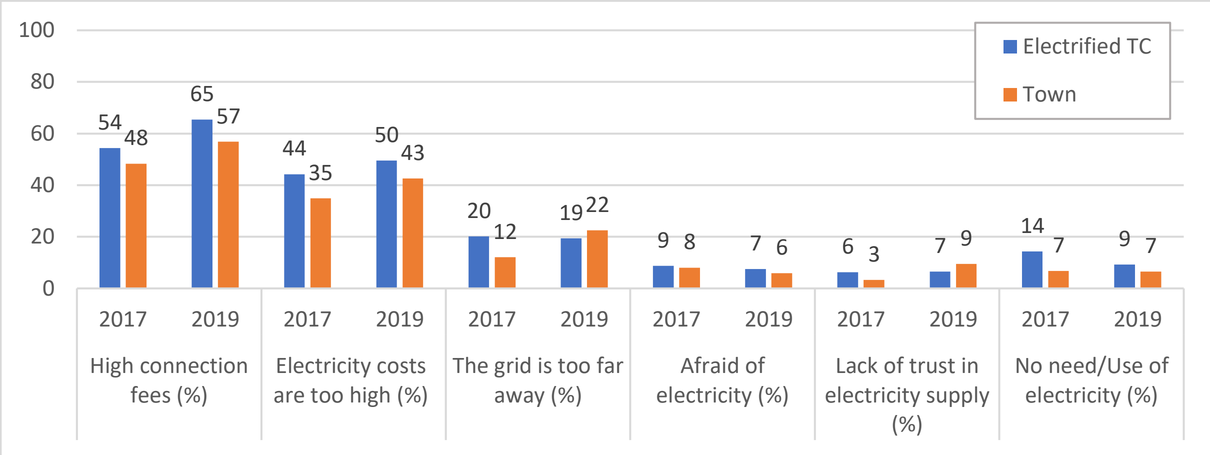
Customer satisfaction of businesses was lowest for electricity costs in towns, which surprises as cost of electricity is similar to commercial tariffs in the national grid and town businesses can be expected to use even more power compared to rural businesses. While satisfaction of businesses with customer services is (similar to that of households) higher in towns, there is no difference of satisfaction with reliability between trading centers and towns. About 73% of businesses in trading centers and towns stated that reliability had improved compared to 2017, while about 65% stated that customer service improved compared to 2017.

Chart A3-44: OC1.4 – Satisfaction of WENRECo customer schools and health centers



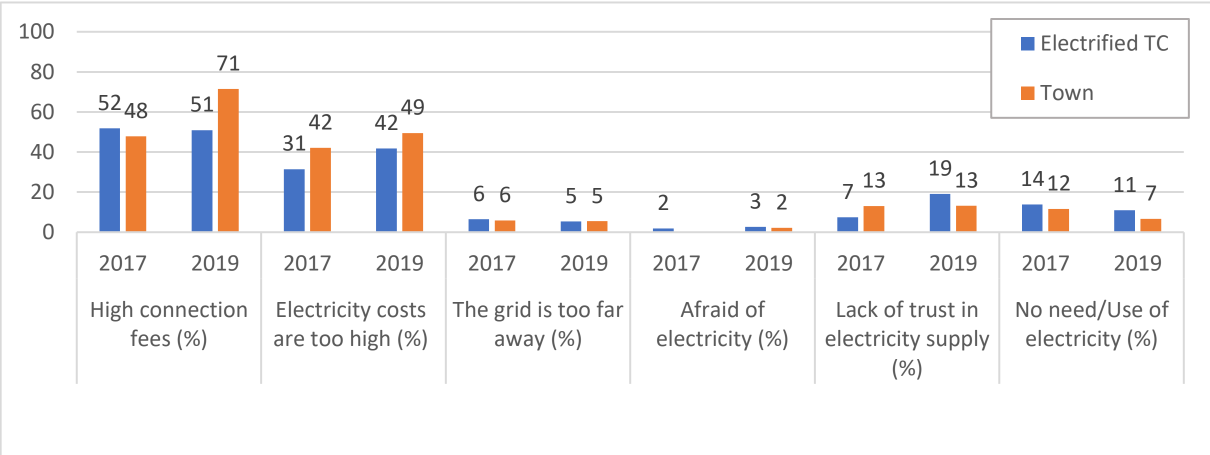
Satisfaction with customer service and costs was higher for health centers compared to schools, while two third of health centers were dissatisfied with the network reliability compared to 80% of schools that stated to be satisfied. The latter is most probably caused by the fact that schools are less dependent on power supply in the evening peak hours, which are most affected by outages and load shedding. Still 69% of health centers stated that reliability improved and 60% stated that customer service improved compared to 2017. For secondary schools, 70% stated that reliability improved and 65% that customer service improved compared to 2017.

Chart A3-45: OC1.4 - Reasons stated by households for not getting grid-connected



High connection fees and electricity costs have been clearly stated by households as the main barrier, but lack of trust in electricity supply slightly increased especially in towns, while still 6-7% of households state to be afraid of electricity.

Chart A3-46: OC1.4 - Reasons stated by businesses for not getting grid-connected



High connection fees and electricity costs are also by businesses stated as the main barrier, but an increasing share of 19% of businesses in electrified trading centers stated in 2019 to not have trust in the electricity supply, while numbers for towns remained stable.

While WENRECo started in late 2018 to implement connections under the new REA fully subsidized program under which customers pay only a negligible inspection fee for grid connections including up to one pole, it seems that either even by May 2019, most customers have not been aware of this offer, or the cost of the required inhouse wiring by a certified electrician is still considered as too high for about 50% of the customers.

Indicator sheet OC1.5

Result OC1: Improved access to and better use of electricity-based services		
Indicator	(OC1.5) Households in electrified areas are better able to satisfy their ICT service needs compared to business-as-usual	
Definitions	ICT service needs: ICT is the abbreviation for Information and Communication Technology. Key ICT services which most households are assumed to need include electricity for charging mobile phones, photocopying, powering computers, and facilitating computer-based internet access.	
Discussion	Rationale: this indicator allows both the direct and indirect aspects of improved access to be measured. On the one hand, an individual connection provides the opportunity to satisfy individual ICT service needs at that location. On the other hand, market mechanisms and business development can bring these services closer to users. This reduces the overall effort individuals need to make in order to satisfy their ICT service needs, which in turn improves access to electricity-based services. The data required is captured during the field survey by directly interviewing households. Limitations: this is an index type of indicator. All distances are put into one average; hence detailed information on the different distances to the services becomes lost. However, disaggregated information can still be obtained from the database. Furthermore, the indicator does not capture information about the actual level of demand for these specific services.	
Source	Field survey: households	
Indicator calculation	Indicator_OC1.5.xlsx	
Data elements and variable codes	Average distance to key electricity-based services (nearest place to charge mobile phones, to copy or print, to use a computer, and to access the internet with a computer)	AP126, AP127, AP128, AP129

Experience in the field showed that data collected from households describing distances in meters or kilometers is highly unreliable. Beside the distance, households had to specify whether the service is available in the same or another trading center. Distances stated by households of the same trading center, regardless whether the service should be available within the trading center or in neighboring trading centers, differed to such a degree that no conclusions could be justified. As much emphasis was placed on this issue during the enumerator trainings in 2015 and 2017, it seems that interviewed households struggled with estimating correct distances.

For this reason, in 2017 questions were added to simply compare the quality of access to the situation two years before. Subsequently only this result is presented.

Data presentation for OC1.5

Households benefit from improved access to ICT services, which has been monitored for mobile phone charging, copy and printing, computer usage for word processing, and internet access. Households have been asked in 2017 and 2019 if the access situation in terms of distance to reach the specific service has improved compared to the situation without grid access in 2015 and 2017, respectively. In all 4 categories, results have been fairly similar. The majority of households within the electrification corridor responded that the access to ICT services (further) improved in both intervals, while outside the electrification corridor it remained unchanged (even though possibly on a higher level in 2019 compared to 2015) for the majority of households (with the exception of phone charging, which improved for the majority of households even in not electrified TCs).

Chart A3-47: OC1.5 - Development of access to mobile phone charging facilities

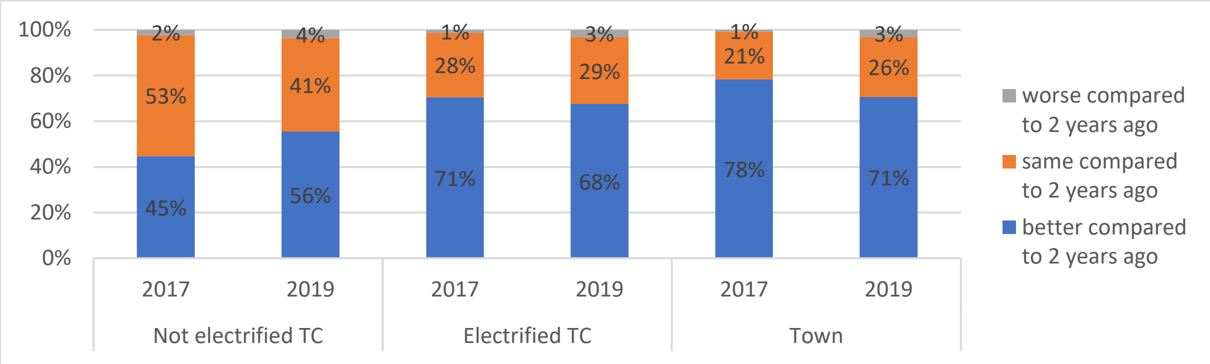


Chart A3-48: OC1.5 - Development of access to copy and printing facilities

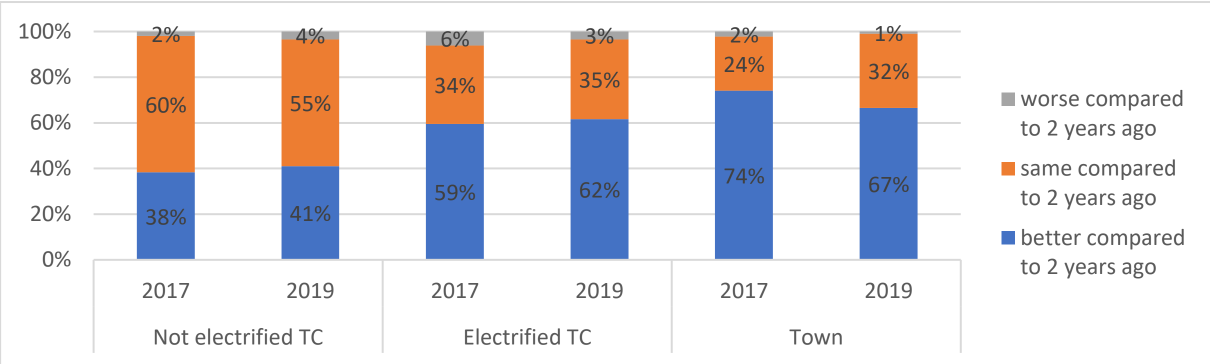


Chart A3-49: OC1.5 - Development of access to a computer to type

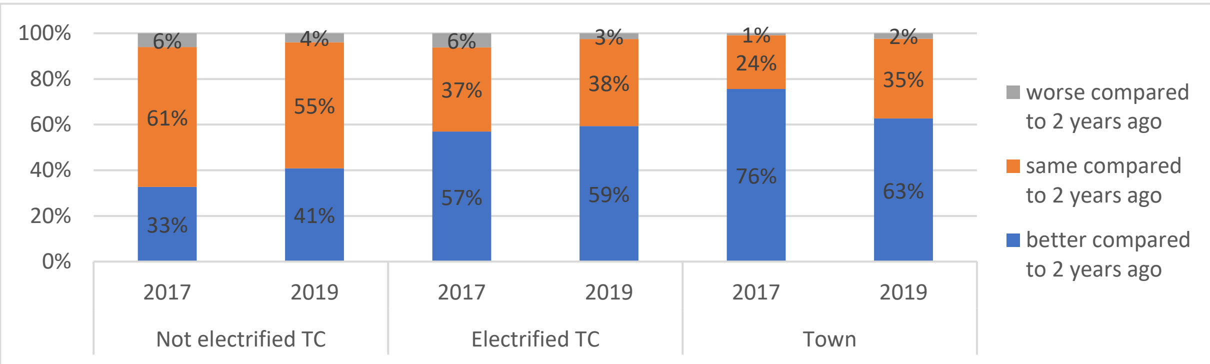
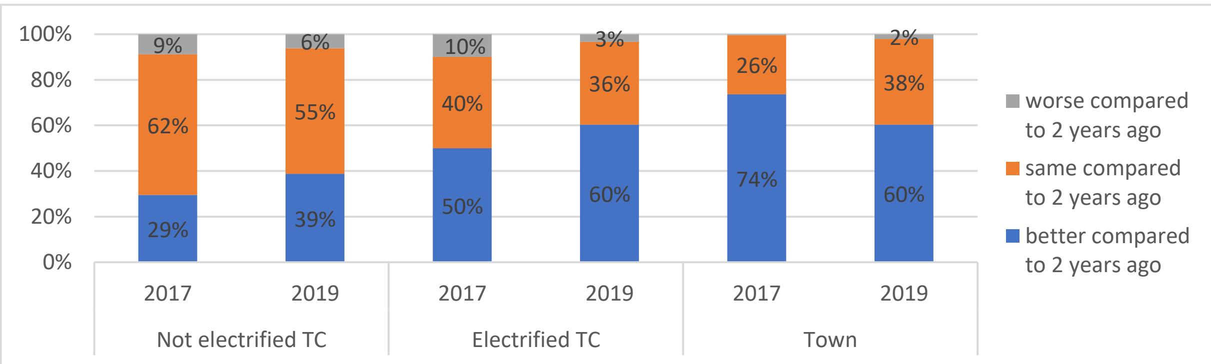


Chart A3-50: OC1.5 -Development of access to internet with laptop or desktop

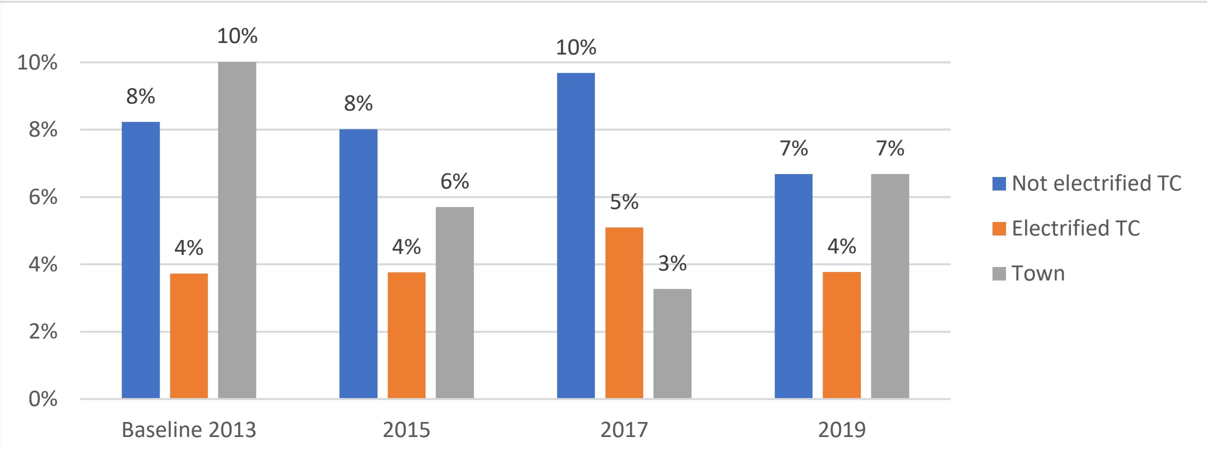


Indicator sheet OC1.6

Result OC1: Improved access to and better use of electricity-based services		
Indicator	(OC1.6) In electrified areas, accidents caused by electricity use which lead to serious injuries, death or property damage have reduced compared to business-as-usual	
Definitions	Accidents caused by electricity: refers to serious and fatal accidents due to electricity (e.g. caused by electric shock, short circuits, fires caused by poor wiring) as well as fire outbreaks on the premises.	
Discussion	Rationale: unsafe practices in electricity use can cause serious and even fatal injuries. A fall in these numbers reflects safer (hence better) use of electricity-based services. The use of biomass and fossil energy sources in the region frequently leads to the outbreak of fire. The increased use of electricity to satisfy energy service needs can thus reduce the number of fires and in turn make better use measurable. Limitations: the presented data on the number of fire outbreaks does not-specifically capture the cause of the fire. The reasons need to be discussed separately.	
Source	Field survey: households, businesses	
Indicator calculation	Indicator_OC1.6.xlsx	
Data elements and variable code	Average number of people who died due to accidents involving electricity in households and businesses within the last twelve months	HH, B: SE11
	Average number of people who were seriously injured due to accidents involving electricity in households and businesses within the last twelve months	HH, B: SE10
	Average number of households and businesses reporting fire outbreaks within last twelve months	HH, B: SE01

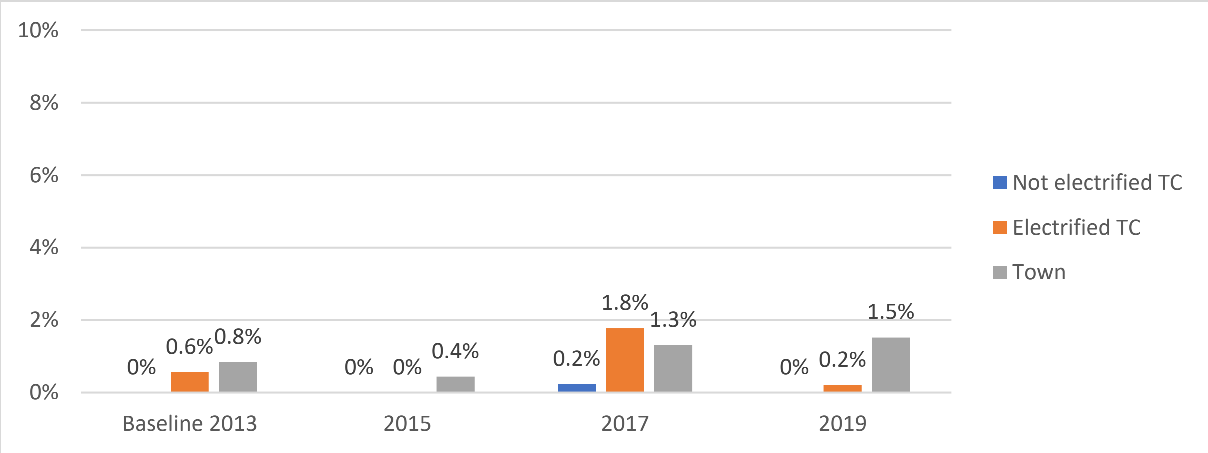
Data presentation for OC1.6

Chart A3-51: OC1.6 - Share of households with incidents of fire outbreaks within 12 months



No direct effects, neither positive (reduction due to substituted kerosene lamps) nor negative (increase due to short-circuits or faulty electrical appliances), have been observed, even though, more fires have been caused by fuel use than by electricity in 2019. The frequency of fire outbreaks remains stable at very low levels. No significant increased risk of fire outbreaks has been observed for informally grid connected customers possibly without certified inhouse wiring: less than 6% (2017) and 10% (2019) of reported fire outbreaks within the electrified area happened in informally connected households, while this group represented about 6% (2017) and 8% (2019) of interviewed households within the electrified areas.

Chart A3-52: OC1.6 - Share of households with seriously injured due to accidents with electricity within 12 months

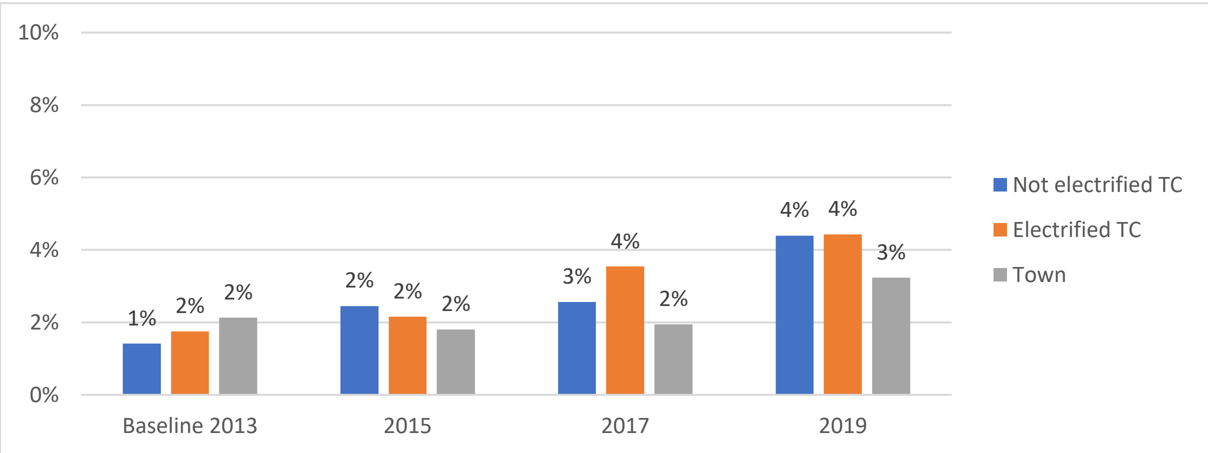


Numbers are very small (in 2019 only 0.2% of households in electrified TCs reported an accident, down from 1.8% in 2017), and no trend can be generated. Still it seems that the number of households reporting accidents is increasing with start of grid access since 2017.

In 2019, serious accidents in 6 households have been recorded of which 1 occurred in a grid connected households, while a fatal accident has been reported by one grid connected town household.[81] In 2017, 13 households reported serious accidents (of which six occurred in grid connected households) and no fatal accidents. In comparison, six households reported serious and three fatal accidents in 2013, while two reported serious and no fatal accidents in 2015.

Informal connections might cause safety issues due to not certified in-house cabling, but of 49 and 66 cases that have been interviewed in 2017 and 2019 only one case was reported in each of the years. However, the example of the one single informally connected household with multiple accidents and fire outbreaks shows how fatal such accidents can be.

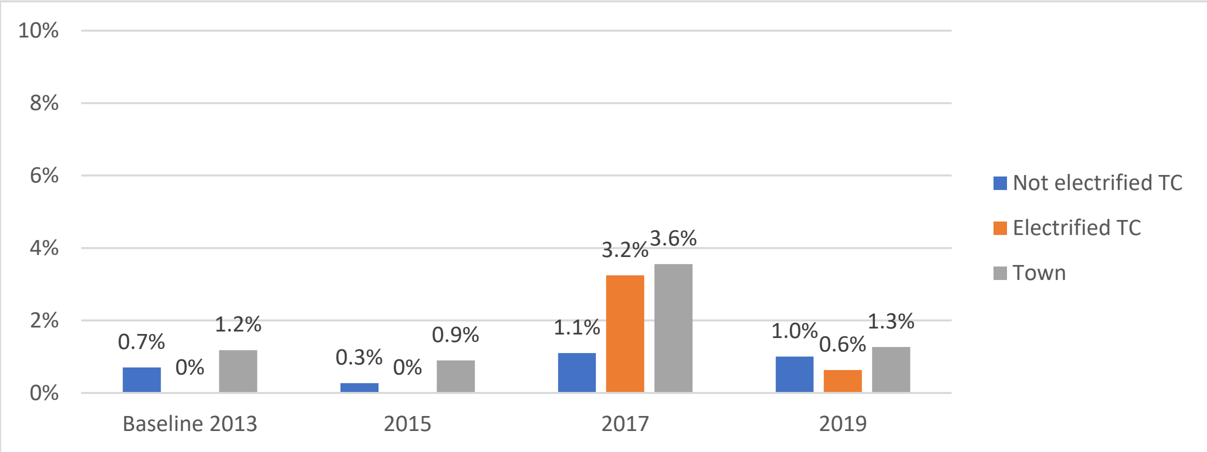
Chart A3-53: OC1.6 - Share of businesses affected by fire outbreaks within the last 12 months



81 This household is an informally connected household (no WENRECO customer, probably without certified in-house wiring.

A slight tendency of an increased frequency of fire outbreak in businesses can be observed. Of 25 and 37 businesses that reported fire outbreaks in 2017 and 2019, respectively, 14 (56%) and 16 (43%) have been grid connected. In electrified areas, electricity supply has been stated as cause in most cases, which should give reason for concern. In 2017, none of the fire outbreaks have been reported by informally connected businesses, possibly without certified in-house wiring, while in 2019, 3 of the 37 cases (8%) have been reported by informally connected businesses, which is far below their share of 14% of the interviewed businesses.

Chart A3-54: OC1.6 - Share of businesses with seriously injured due to accidents with electricity within 12 months



Numbers are very small (in 2019 less than 1% of businesses reported an accident, down from 2.7% in 2017) and no trend can be generated. Still it seems that the number of businesses reporting accidents is increasing with start of grid access since 2017.

In 2019, nine businesses reported serious accidents in 2019, of which five have been grid connected. No accidents have been reported by the 88 interviewed informally connected businesses without own meter. In 2017, 25 businesses reported serious accidents, of which 17 have been grid connected, as well as five businesses reported fatal accidents, of which three occurred in grid connected businesses. Out of 89 cases of informally connected businesses that have been interviewed, 3 businesses reported serious accidents and only one reported a fatal accident. In 2015, 4 businesses reported serious accidents and no fatal ones, while in 2013, 7 businesses reported serious accidents and one even a fatal accident.

Informal connections might be expected to cause safety issues due to possibly not certified in-house cabling, but only in 2017 three cases have been reported and none in 2019. However, the single fatal accident reported in 2017 was reported by one informally connected saloon killing 8 people.[82] This shows how dangerous the impact of a single substandard customer can be.

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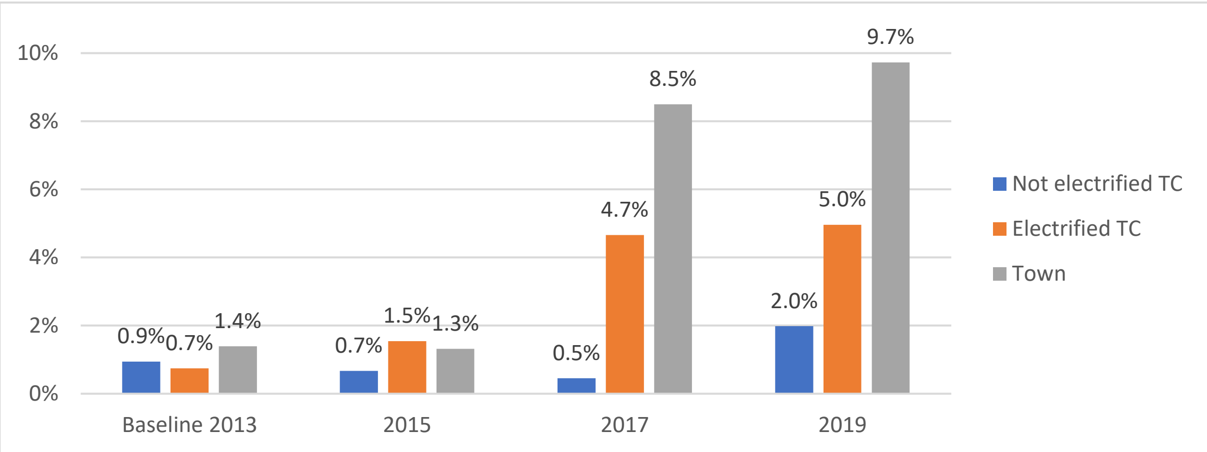
[82] This number might indicate either a very singular incident, which could not be explored further into.

Indicator sheet OC1.7

Result OC1: Improved access to and better use of electricity-based services		
Indicator	(OC1.7) In electrified areas, electricity-saving measures implemented by households and businesses have increased compared to business-as-usual	
Definitions	Energy-saving measures: refer to certain behavior and measures to reduce the use of electricity needed to produce the same level of output	
Discussion	Rationale: the implementation of electricity-saving measures, such as the use of energy-saving bulbs or switching off appliances when not used, reflects a change not just in attitude but also in behavior. Limitations: the indicator is based on revealed behavior to a limited extent only (number of bulbs); it also relies on stated behavior, which could be biased and is not cross-checked.	
Source	Field survey: households, businesses	
Indicator calculation	Indicator_OC1.7.xlsx	
Data elements and variable code	Proportion of households and businesses that have implemented at least one energy-saving measure, in addition to energy-saving bulbs	HH, B: SE08, SE09
	Proportion of energy-saving bulbs of all electric lights used in an average of households and businesses	HH, B: AP01, AP03

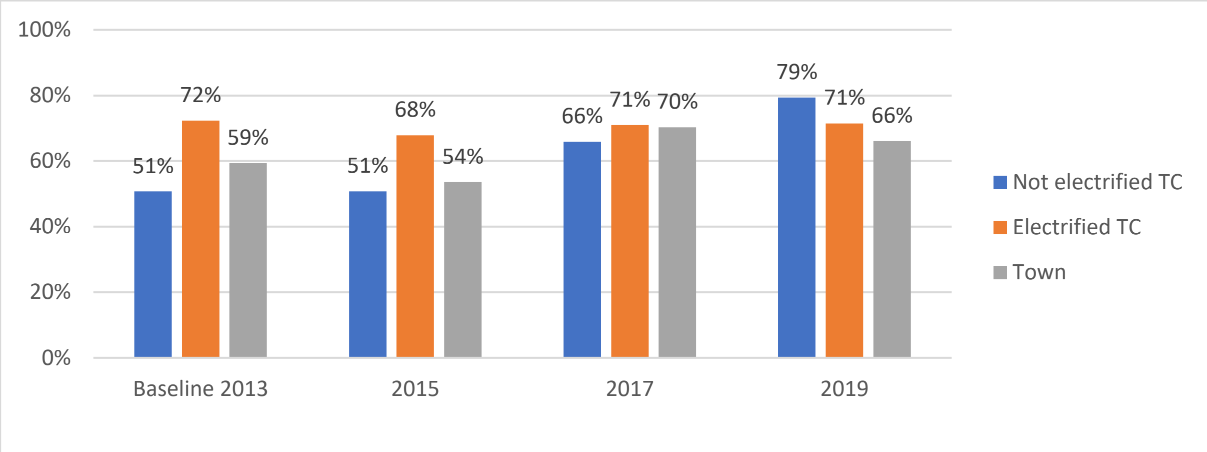
Data presentation for OC1.7

Chart A3-55: OC1.7 - Proportion of households that implemented at least one energy saving measure, besides energy saving bulbs



Asked in how far exemplified energy saving measures (compare UP 2.4) beside the use of energy saving bulbs (CFL or LED) are actually applied, only around 1% of households responded positively in 2013 and 2015, whereas numbers within the electrification corridor increased to 5-8.5% in 2017, and to 5-10% in 2019, mainly driven by grid connected households (WENRECo customers 2017 and 2019 in electrified TCs: 13% and 12%; in towns: 19% and 20%).

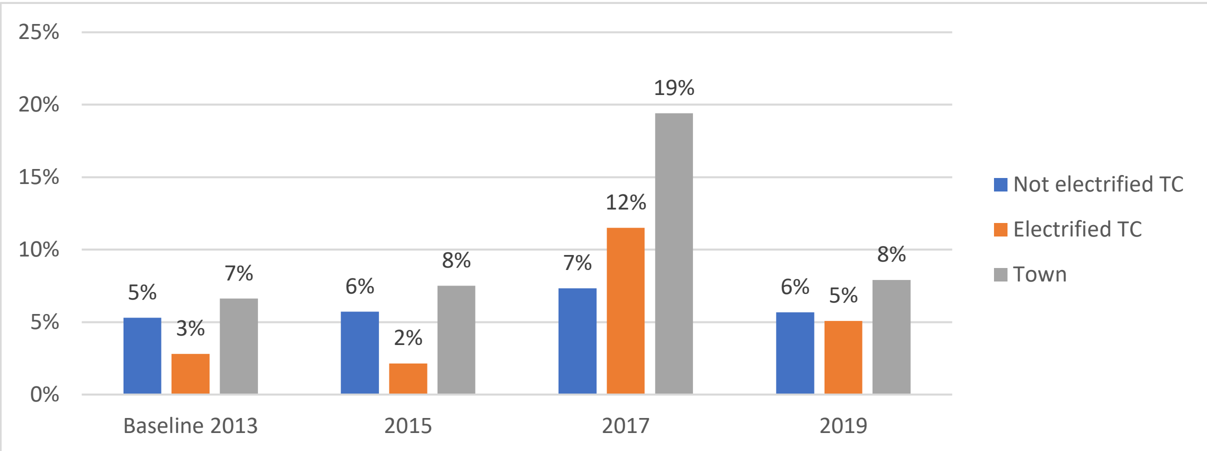
Chart A3-56: OC1.7 - Proportion of energy saving bulbs of all electric lamps used in an average household



The share of energy saving bulbs slightly increased in households to about 66-80%, regardless of the survey cluster or grid-connection status. In fact, WENRECo customers sometimes even used less energy saving bulbs compared to the average (WENRECo customers 2017 and 2019 in electrified TCs: 75% and 62%; in towns: 73% and 54%).

The proportion of energy saving lights might be far higher as the data collected in 2017 and 2019 suggests. The qualitative survey showed that normal incandescent light bulbs are not anymore available in local shops and, compared to 2013 where most energy saving lamps were compact fluorescent lamps, people now struggle to tell the difference between a retrofitted LED lamp and an incandescent lamp.

Chart A3-57: OC1.7 - Proportion of businesses that implemented at least one energy saving measure, besides energy saving bulbs

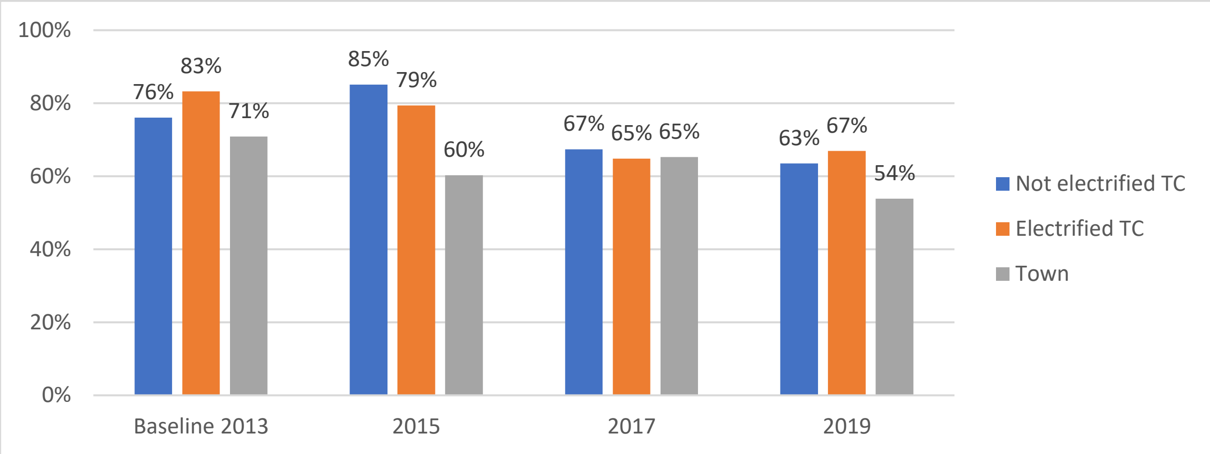


By 2017, energy efficiency increased in all clusters, but then reduced again by 2019. WENRECo customers showed a higher adoption rate and equally dropped in 2019 (WENRECo customers 2017 and 2019 in electrified TCs: 17% and 7%; in towns: 26% and 10%).83 As

[83] This data includes only validated answers on energy saving practices (so e.g. switching off the fridge once cold has not been counted as this would only save energy in the case of a broken thermostat), but even the total

most towns and 6 of the 10 electrified trading centers were visited by the E-AIM campaign road show, the general higher degree of applied awareness might be attributed to the campaign (however, as indicator UP 2 has shown, this effect did not extend to the general awareness). But if the E-AIM campaign contributed to the increase in 2017, the decrease in 2019 would stress that such one-time campaigns has little lasting impact.

Chart A3-58: OC1.7 - Proportion of energy saving bulbs of all electric lamps used in an average business



The share of energy saving bulbs used in businesses slightly decreased especially in trading centers within and outside the electrification corridor, with no direct relation to grid access, as both businesses in not-electrified TCs and electrified TCs, as well as grid connected and not grid connected businesses in electrified TCs and towns do not differ significantly (WENRECo customers 2017 and 2019 in electrified TCs: 65% and 70%; in towns: 64% and 54%).

For the same reason stated above for household, the proportion of energy saving lights might be far higher as the data collected in 2017 and 2019 suggests.

share of all households giving any kind of answer follows the same trend (e.g. in the case of electrified trading centers: 2.5% in 2015, 16% in 2017, and 9% in 2019).

A3-4. Impact Level

This chapter provides an overview on the status of the indicators at impact level. Despite the challenges the attribution gap poses, these assess the long-term effects of the electrification program in West Nile. Table A3-9 gives an overview on the eight impact indicators that measure the program impacts (I1) Reduction of CO_2 emissions from stationary combustion of fossil fuels, (I2) Increased productive and income-generating activities, and (I3) Contribution to improved education, healthcare, and water supply.

Table A3-9: Impact Indicators

Result	Indicator
(I1) Reduction of CO2 emissions from stationary combustion of fossil fuels	(I1.1) CO2 emissions from the stationary combustion of fossil fuels for grid electricity generation have been reduced in both absolute and relative terms
	(I1.2) In electrified areas CO2 emissions from the stationary combustion of fossil fuels have been reduced compared to business-as-usual
(I2) Increased productive and income-generating activities	(I2.1) In electrified areas, businesses have expanded their productive and commercial activities in terms of number of employees and length of business hours compared to business-as-usual
	(I2.2) In electrified areas, productive activities have increased, in terms of the proportion of lines of businesses which have local value adding
	(I2.3) In electrified areas, the share of households with income-generating activities in general and the lines of business with local value adding have increased compared to business-as-usual
(I3) Contribution to improved education, healthcare, and water supply	(I3.1) In electrified areas, the proportion of secondary schools providing electricity-dependent educational services has increased compared to business-as-usual
	(I3.2) In electrified areas, both (a) the proportion of health centers (level III and above) that offer key electricity-dependent health services, and (b) the proportion of such health centers that are able to provide such services whenever they are needed, has increased compared to business-as-usual
	(I3.3) The average number of customers of central water providers and the reliability of water supply in electrified areas has increased compared to business-as-usual

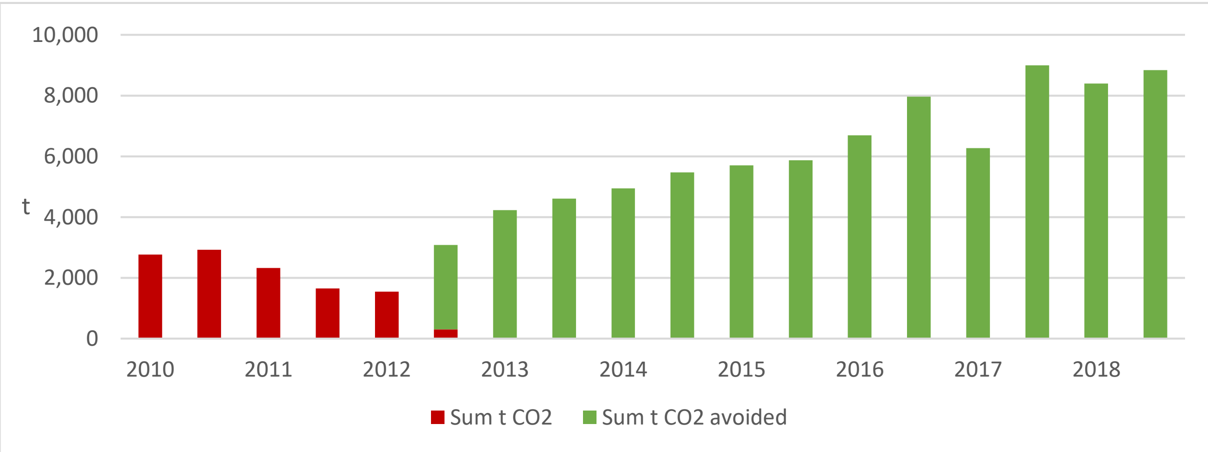
As with the outcome level indicator sheets, each indicator is discussed in brief, and information is provided on data source, data elements, indicator calculation, and variable codes.

Indicator sheet I1.1

Result I1: Reduction of CO_2 emissions from stationary combustion of fossil fuels		
Indicator	(I1.1) CO_2 emissions from the stationary combustion of fossil fuels for grid electricity generation have been reduced in both absolute and relative terms	
Definitions	Stationary combustion: combustion of fossil fuels to generate heat, power and electricity for stationary use (no transport)	
Discussion	Rationale: the indicator refers to the direct link between fossil fuel combustion and CO_2 emission. The substitution of the WENRECo heavy oil fuel generator by Nyagak I and III will contribute significantly to the reduced use of fossil fuels for electricity generation in the region. Absolute emissions could also fall as a result of lower overall electricity generation; therefore, to avoid biased reduction statistics, relative emissions per kWh of electricity produced are included as well. Limitations: the application of standardized conversion factors will lead to a general uncertainty in the calculated values. Other greenhouse gas emissions are not included into the calculations, due to their variability and dependence on the mode of combustion.	
Source	WENRECo	
Indicator calculation	Indicator I1.1.xlsx	
Data elements and variable codes	Amount [kg] of diesel used for electricity generation by WENRECo per half-year	WE01
	Amount [kg] of heavy fuel used for electricity generation by WENRECo per half-year	WE02
	Conversion factors [CO_2 per kg]	Annex 1.2
	MWh generated by WENRECo	WE40

Data presentation for I1.1

Chart A3-59: I1.1 - CO_2 emissions and avoided CO_2 emissions of WENRECo



With the hydro-power plant Nyagak I starting its operation in the second half-year 2012, the specific CO_2 emissions of WENRECo have decreased to zero. At the same time, the power generation and supply increased significantly. Above, also the avoided emissions are displayed (green), compared to a business as usual scenario for which WENRECo would have continued to thermally generate its power based on heavy fuel oil and diesel with high technical losses of about 31% in the distribution network. In this case, WENRECo would have emitted between 2012 and end 2018 a total of 80,774 tons of CO_2.

Indicator sheet I1.2

Result I1: Reduction of CO_2 emissions from stationary combustion of fossil fuels		
Indicator	(I1.2) In electrified areas, CO_2 emissions from the stationary combustion of fossil fuels have been reduced compared to business-as-usual	
Definitions	Stationary combustion: combustion of fossil fuels to generate heat, power and electricity for stationary use (excludes fuel used for transport)	
Discussion	Rationale: this indicator refers to the direct link between fossil fuel combustion and CO_2 emissions. As well as the electricity supplier WENRECo, other user of electricity-based services will also reduce their CO_2 footprint, as energy services generated from fossil fuels are replaced by renewably generated electricity. Limitations: fuel combustion to generate heat for cooking also results in substantial CO_2 emissions, and it is less likely that these will be replaced by the use of electricity in the near future. Even though most households also use biomass as fuel, there are three reasons that impede its inclusion in CO_2 emissions monitoring: (1) the heating value of biomass varies strongly according to its type and humidity, making measurement very complicated, (2) climate-relevant emissions from biomass vary substantially according to the type and management of the combustion process, and this cannot be monitored, and (3) biomass might or might not be a renewable resource depending on how it is produced, which again cannot be monitored.	
Source	Field survey: households, businesses, schools, health centers	
Indicator calculation	Indicator I1.2.xlsx	
Data elements and variable codes	Volume of diesel [l], petrol [l], kerosene/paraffin [l], LPG [kg], and paraffin wax [kg candles] used for energy services (other than transport) by households, businesses, schools and health centers	HH, B, HC, S: EF01 to EF29
	Conversion factors	Annex 1.2

Data presentation for I1.2

Because CO_2 emissions are proportional to fossil fuel consumption, for this indicator the same discussion applies as for indicator OC1.3.

Chart A3-60: I1.2 - Average CO_2 emissions of a household per month

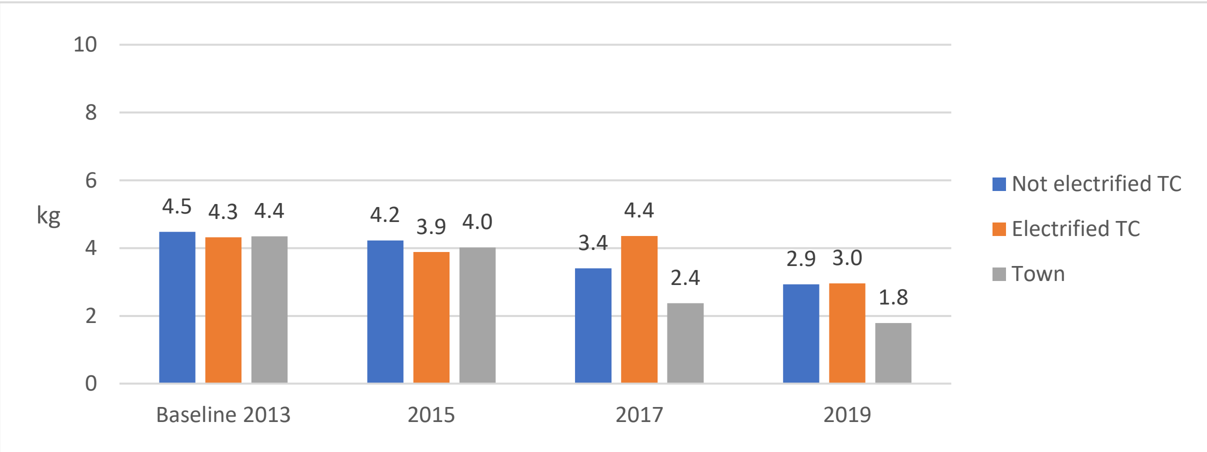


Chart A3-61: I1.2 - Average CO_2 emissions of a business per month

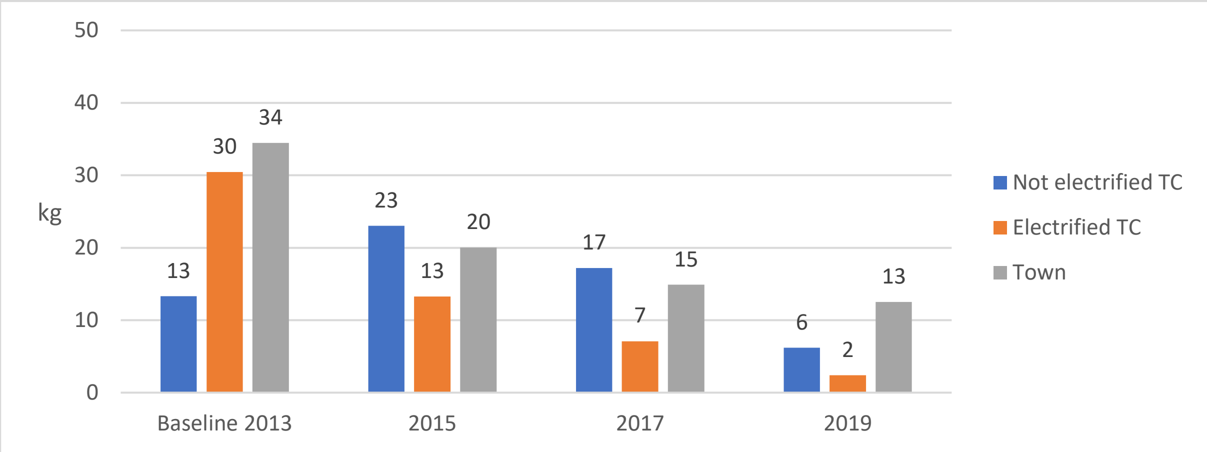


Chart A3-62: I1.2: - Average CO_2 emissions of a health center per month

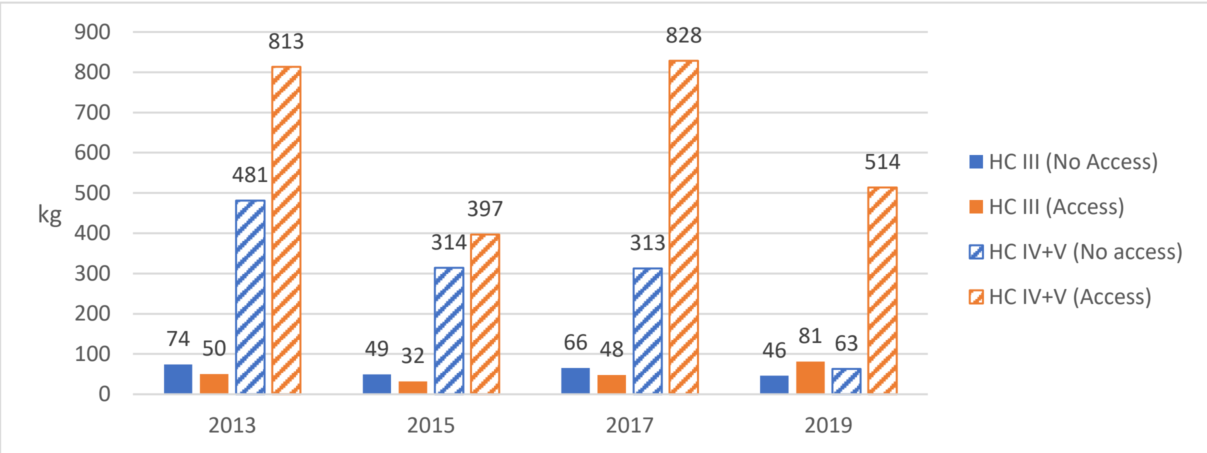
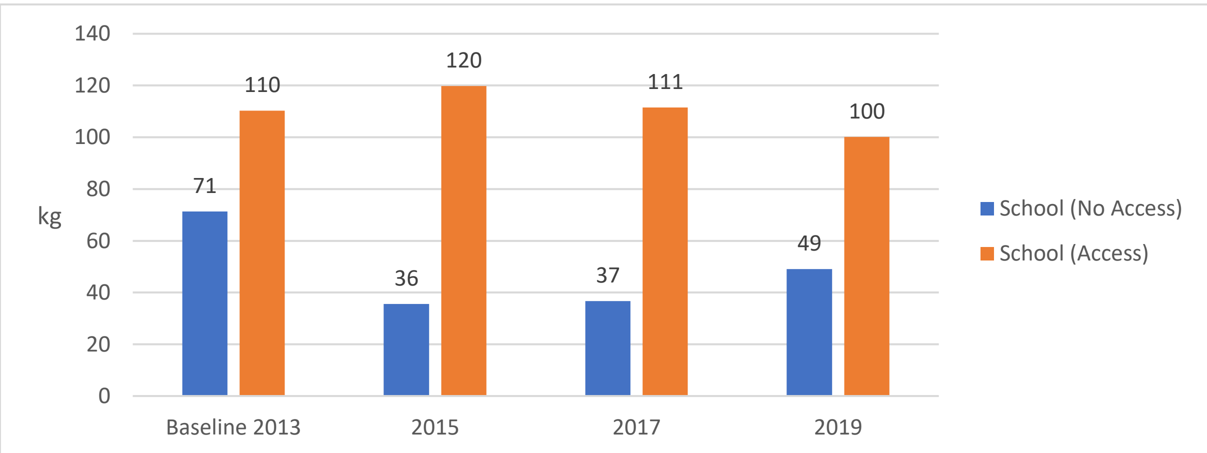


Chart A3-63: I1.2 - Average CO_2 emissions of a secondary school per month

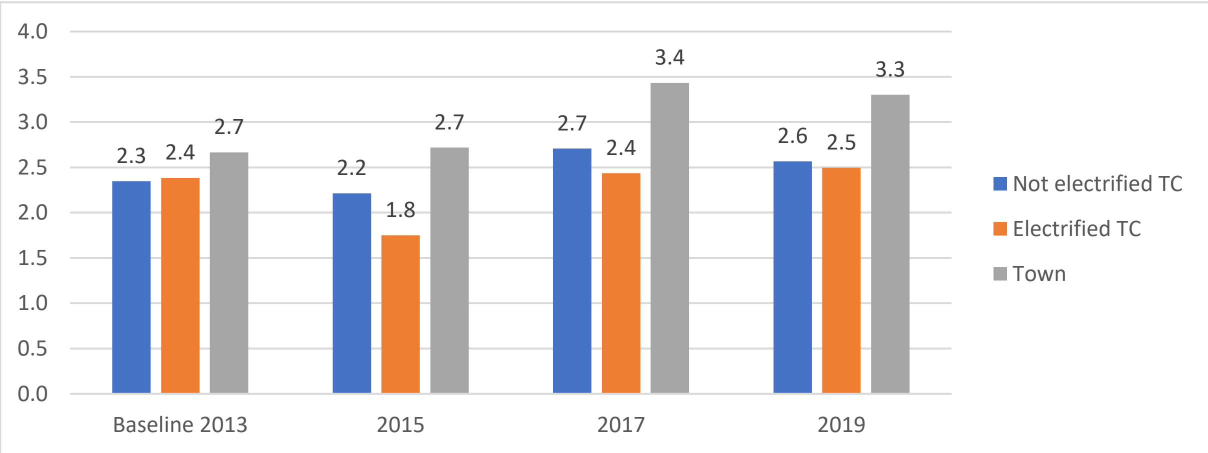


Indicator sheet I2.1

Result I2: Increased productive and income-generating activities		
Indicator	(I2.1) In electrified areas, businesses have expanded their productive and commercial activities in terms of number of employees and length of business hours compared to business-as-usual	
Definitions	Businesses: describes all businesses and income-generating activities that go beyond household activities, have a stationary place of business, and operate on a regular basis. The definition excludes taxi services, but includes small kiosks.	
Discussion	Rationale: the number of employees reflects the scope of business activities and potential turnover. Generally, increased business hours allow for a longer period of income generation, and a higher number of employees allows for an increased volume of activity. Limitations: employee qualification levels are an important aspect for business success which is not captured by the indicator. Only permanent employees are included into the indicator calculation, and seasonal changes in the number employed are not reflected. For production and manufacturing businesses, the investment in electrical machines and appliances might also lead to a reduction in employees. An analysis of the indicator for these specific types of business lines could inform discussion of the results.	
Sources	Field survey: businesses	
Indicator calculation	Indicator I2.1.xlsx	
Data element and variable codes	Number of permanent employees in businesses	IE08
	Business hours of businesses [hrs/week]	IE04, IE05, IE06, IE07

Data presentation for I2.1

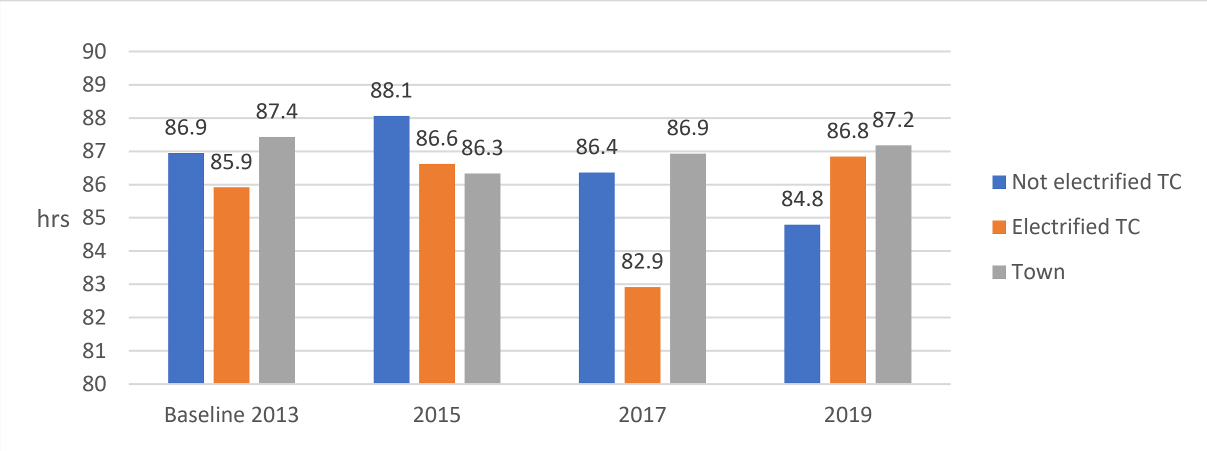
Chart A3-64: I2.1 - Average number of employees including the owner of a business



In trading centers, the change in employment has not been significant (the 2015 values are possibly distorted by seasonal effects). The slight increase of employees in towns cannot be directly attributed to the connection to the grid since WENRECo customers show only slightly higher values compared to the average (WENRECo customers 2017 and 2019 in electrified TC: 2.5 and 2.6; in town: 3.7 and 3.6).

The numbers indicate that there is no direct relationship between the connection to the grid and the average number of employees. The average number of employees per business for the UBOS business census of 2011 has been with 2 even lower for the six districts of West Nile. However, this survey covered some 15,628 “businesses” of which many have probably been micro-businesses such as self-employed *boda* drivers, which have not been considered in this survey.

Chart A3-65: I2.1 - Average weekly business hours of a business



Business hours remain high. A slight decrease for businesses in electrified trading centers was recorded in 2017, but values are back to average in 2019. There is no significant difference between WENRECo customers and other businesses (WENRECo customers 2017 and 2019 in electrified TCs: 83 and 86 hrs.; in towns: 88 and 85 hrs.).

However, participants of the qualitative workshops and interviews repeatedly stated that grid electrification of trading centers has resulted in improved public lighting, extended business hours and more social life in the evenings.

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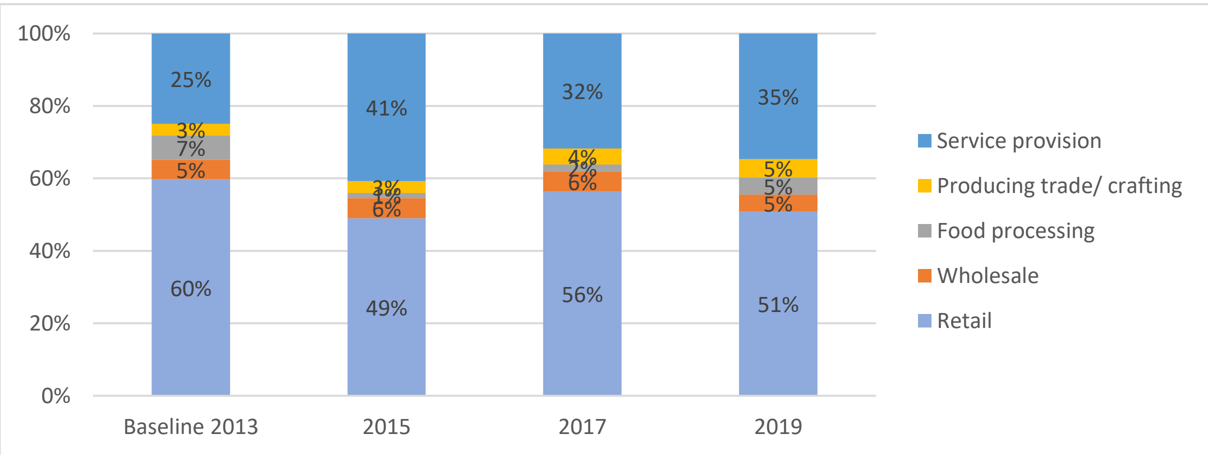
Indicator sheet I2.2

Result I2: Increased productive and income-generating activities		
Indicator	(I2.2) In electrified areas, productive activities have increased, in terms of the proportion of lines of businesses which have local value adding	
Definitions	Line of business: production/manufacturing (the production of tangible goods), food processing (a special production category, included because of its high potential in rural areas), service (the production of intangible goods), retail and wholesale. Value adding/regional income: 'value adding' means to increase the value of a good by an additional production or processing step. In this definition, service, retail, and wholesale are considered as income-generating activities, but not as value-adding.	
Discussion	Rationale: value adding has particular importance for regional rural development. Rural areas typically suffer from low levels of productive activities. Local products (which are mainly agricultural) tend to be exported as raw materials, whereas manufactured goods tend to be imported. An increase in the number and proportion of productive and food processing activities carried out within West Nile should lead to higher regional income. This would arise from two sources: firstly, by substituting products which would otherwise be imported, and thereby reducing outflows of money from the region; and secondly, by encouraging the emergence of new processing and producing businesses, thereby generating inflows of money into the region when these products are sold outside the area. Limitations: the classification of business activities is basic and does not contain precise details on business types and selling activities. The increase in the absolute number of businesses and of the actual turnover, as a more direct reflection of increased productive activities at the Impact level, is not included in the indicator, due to the difficulties in obtaining this information. However, when evaluating the program, it will be possible to obtain information on the total increase in registered companies in all six districts, and this can be used for interpretation.	
Source	Field survey: businesses	
Indicator calculation	Indicator I2.2.xlsx	
Data elements and variable codes	Proportion of different lines of businesses of businesses	IE02, IE03

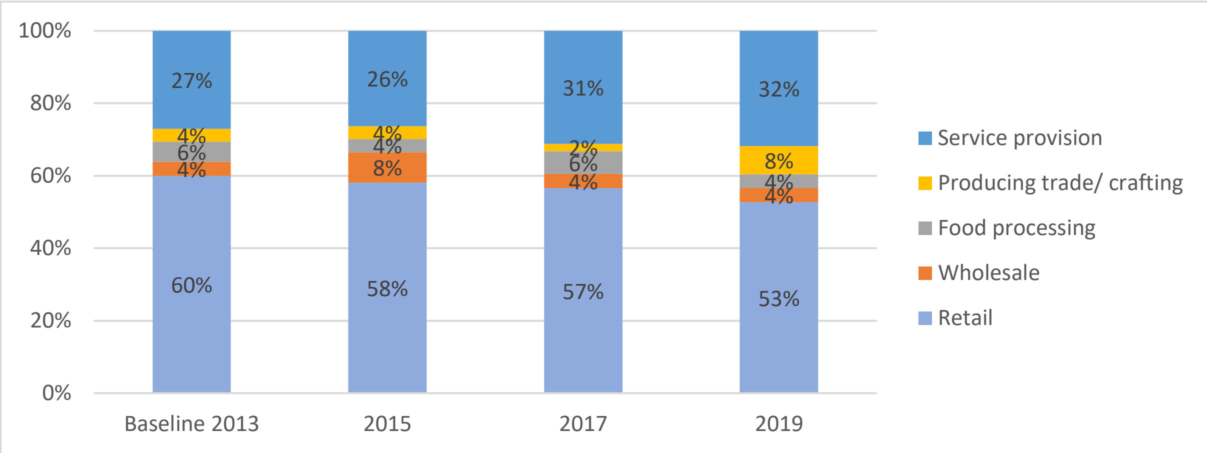
Data presentation for I2.2

Chart A3-66: I2.2 - Businesses and their different lines of businesses in non-electrified trading centers



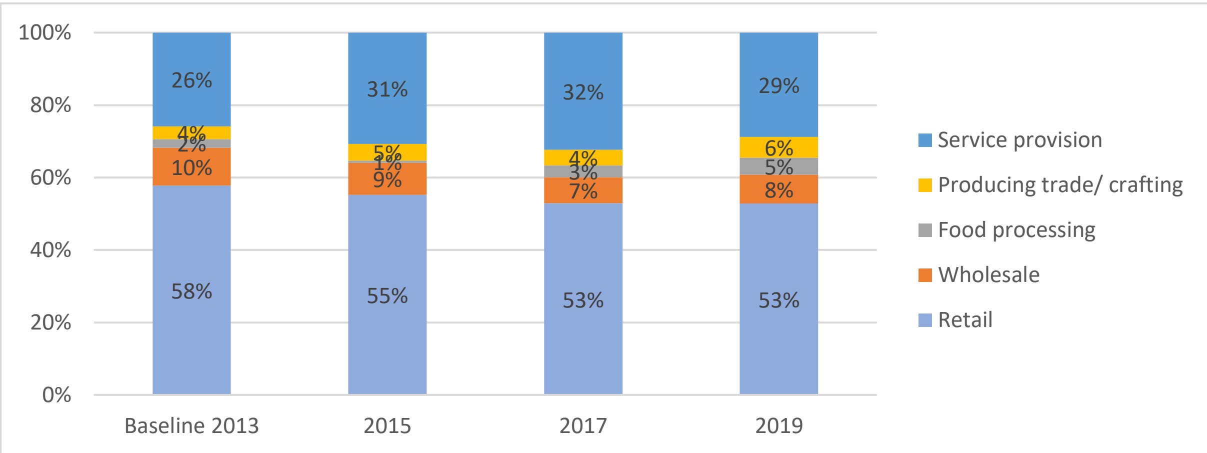
The share of business lines in non-electrified trading centers remained largely stable over time with small increases in service and producing trade.

Chart A3-67: I2.2 - Businesses and their different lines of businesses in electrified trading centers



The share of business lines in electrified trading centers remained largely stable over time with small increases in service and producing trade. No direct impact of electrification can be observed as there are no significant changes in comparison with the control group and values for WENRECo customers are not significantly different (WENRECo customers 2017 and 2019: electrified TC: Retail: 54% and 50%; Wholesale: 4% and 5%; Food processing: 6% and 3%; Producing trade: 1% and 6%; Service provision: 34% and 36%). However, 2019 data might hint at a trend of increase in producing trade/crafting in electrified TCs.

Chart A3-68: I2.2 - Businesses and their different lines of businesses in towns



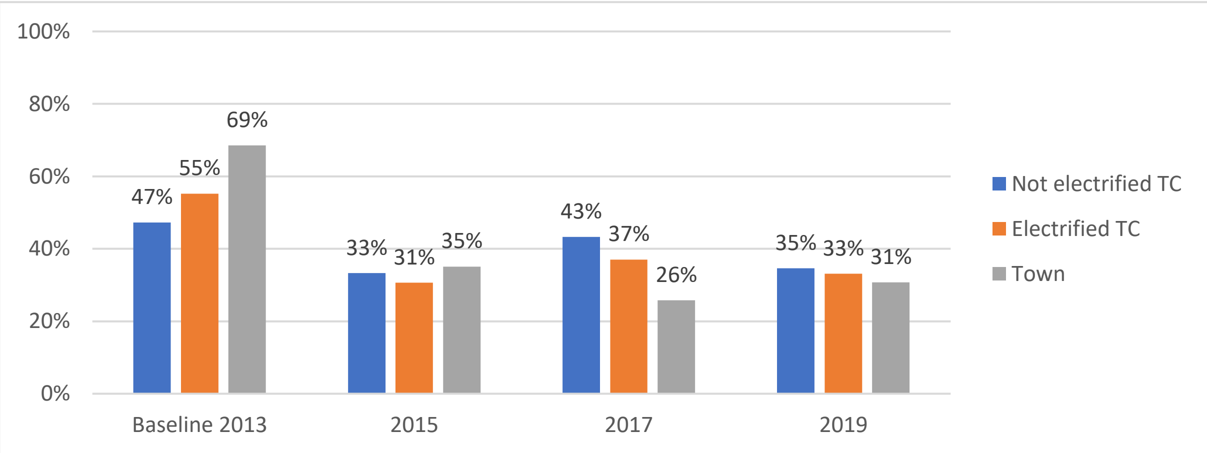
The share of business lines in towns remained largely stable over time with a small increase in service, producing trade, and food processing. However, values for WENRECo customers show that only service provision might be influenced by grid access, while the shares of producing trade and food processing were even higher for not connected businesses (WENRECo customers 2017 and 2019: Retail: 50% and 54%; Wholesale: 8% and 8%; Food processing: 3% and 3%; Producing trade: 5% and 4%; Service provision: 35% and 31%).

Indicator sheet I2.3

Result I2: Increased productive and income-generating activities		
Indicator	(I2.3) In electrified areas, the share of households with income-generating activities in general and the lines of businesses with local value adding have increased compared to business-as-usual	
Definitions	Household with income generating activities: small-scale business activities taking place on household premises, for which no permanent extra space is rented	
Discussion	Rationale: business activities at a household level reflect regional income-generating activities (see I2.2). The relevant information is collected during the field survey and obtained by questioning households directly. Limitations: imprecise definition of micro businesses. Emerging business activities do not necessarily depend on, or relate to, electricity.	
Source	Field survey: households	
Indicator calculation	Indicator I2.3.xlsx	
Data elements and variable codes	Proportion of households with business activities	IE01
	Proportion of different lines of businesses of and proportion of business activities with productive and food processing business activities	IE02, IE03

Data presentation for I2.3

Chart A3-69: I2.3 - Proportion of households with micro-business activities

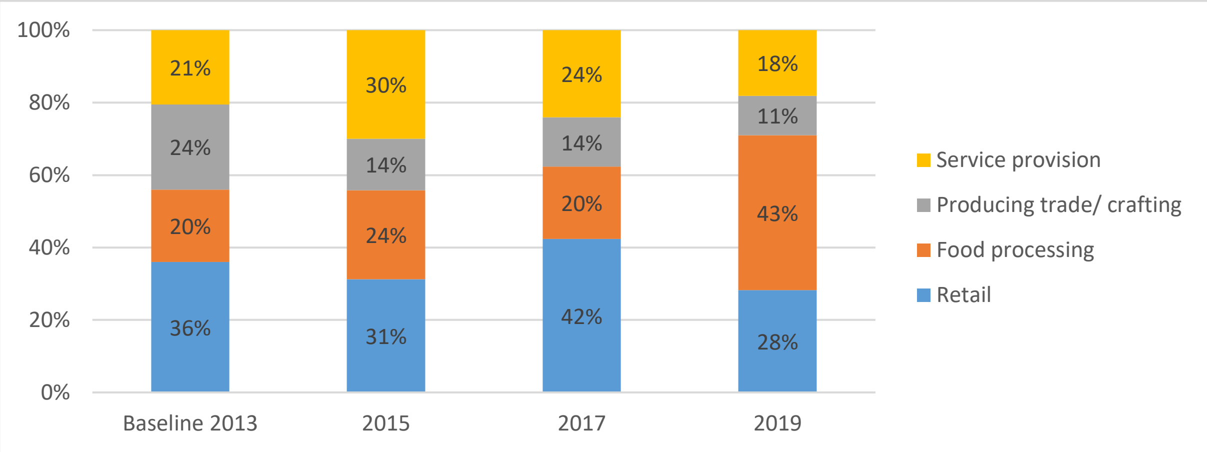


The share of households pursuing micro-economic activities decreased both in electrified trading centers and in the control group since 2013. Data of 2015 is possibly distorted by seasonal influences as the survey was carried out at a different time of the year. In 2017, the proportion of households with micro-businesses showed a steeper decrease since 2013 in electrified trading centers compared to the control group. However, the difference is less pronounced, if only grid-connected households are considered, of which 48% pursued micro-economic activities compared to the average of 37%. Similarly, households in towns showed in average an even steeper decrease in micro-economic activity down to 26%, but grid-connected households showed a slightly higher level of 29%. In 2019, the share of micro-economic activity is converging for all clusters at about one third of households, with no difference for grid connected households (WENRECo customers 2017 and 2019 in electrified TCs: 48% and 33%; in town: 29% and 32%). According to the UBOS report in 2018, 52% of the households in West Nile operated household enterprises in 2016/17.

Focus group discussions during the qualitative workshops also revealed that most micro-businesses are (seasonal) activities carried out by women for which either power is of little relevance (e.g. cooking), or funds are lacking to invest into required electrical machinery (e.g. artisanal crafting).

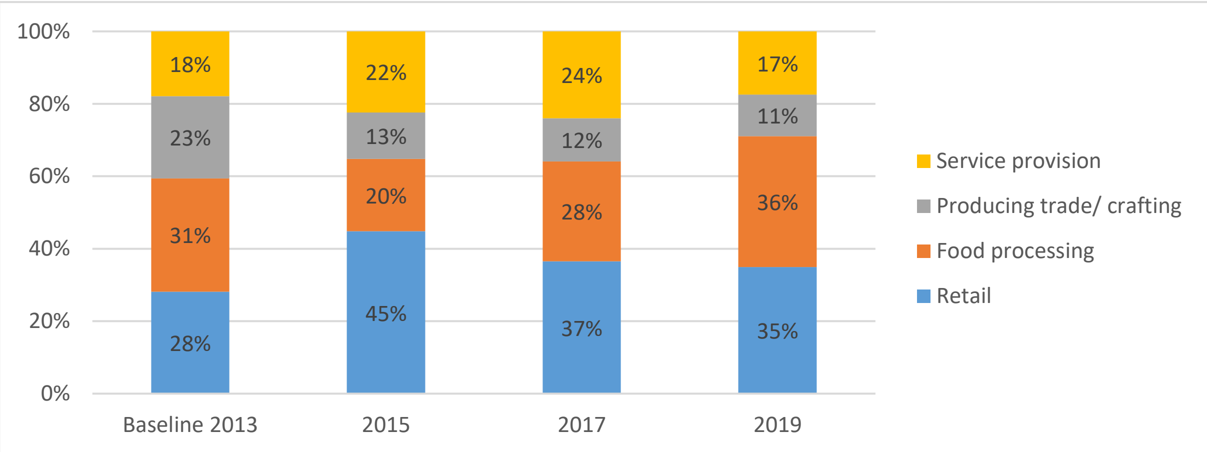
Overall, the data shows that grid connection has certainly not boosted households' micro-business activities, neither could it reduce or even revers the decreasing trend.

Chart A3-70: I2.3 - Different lines of household micro-businesses in non-electrified trading centers



Most lines of businesses remained stable in 2017 (compared to 2013, 2015 ignored due to possible distortions), but producing trade significantly decreased by 42%. In 2019, the decreasing trend of producing trade continued but the share of food processing more than doubled, while retail and service activities decreased in households outside the electrification corridor.

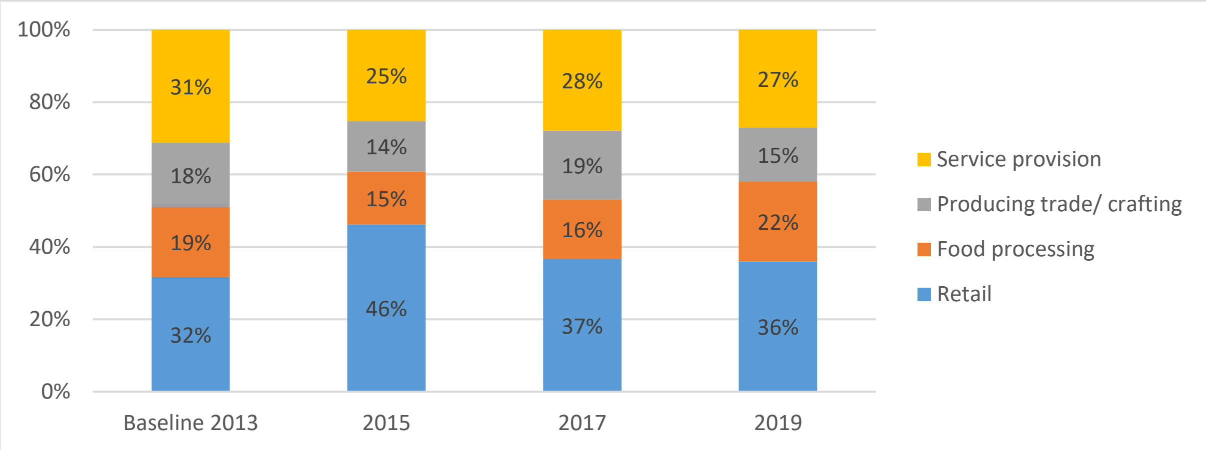
Chart A3-71: I2.3 - Different lines of household micro-businesses in electrified trading centers



Inside the electrification corridor the overall trends are similar as in the control group. But it seems that connected households tend to pursue more service and retail activities and less food processing and producing trade (WENRECo customers 2017 and 2019: Retail: 42% and 51%; Food processing: 17% and 21%; Producing trade: 7% and 5%; Service provision: 33%

and 23%). Participants in focus group discussions could not explain a possible cause-effect relation.

Chart A3-72: I2.3 - Different lines of household micro-businesses in towns



Micro-economic activities of household in towns show no strong changes compared to 2013. Grid connected households tend to pursue more service and less retail activities, while there are no significant differences for food processing and producing trade (WENRECo customers 2017 and 2019: Retail: 32% and 27%; Food processing: 17% and 21%; Producing trade: 17% and 16%; Service provision: 34% and 36%).

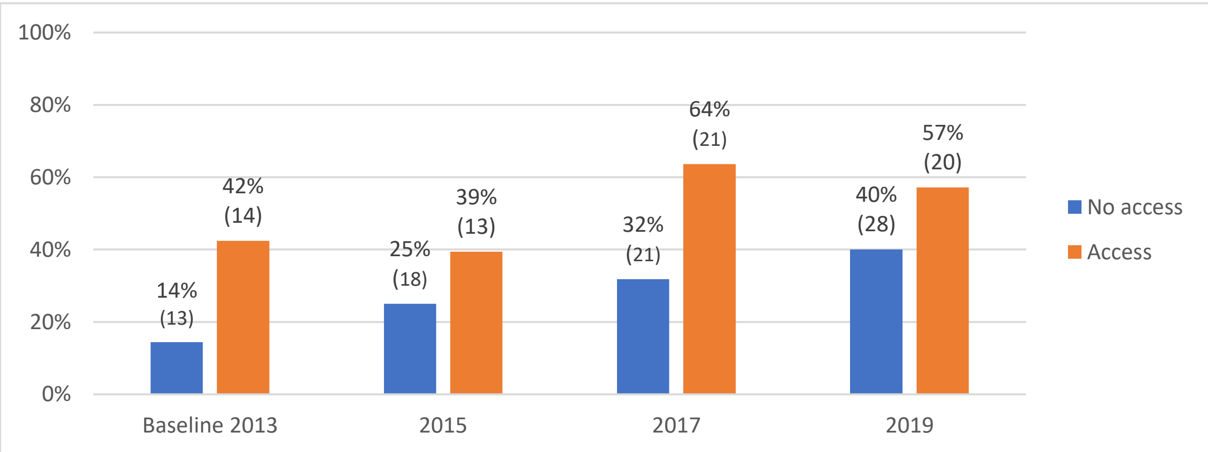
Same as for the analysis of total proportions (chart A3-69), recorded trends in micro-economic activities of households regarding the share of line of businesses cannot be directly attributed to new grid access.

Indicator sheet I3.1

Result I3: Contribution to improved education, healthcare, and water supply		
Indicator	(I3.1) In electrified areas, the proportion of secondary schools providing electricity-dependent educational services has increased compared to business-as-usual	
Definitions	Electricity-dependent educational services: refers to educational methods that need electricity, such as classes using computers, internet classes, and classes with natural science experiments which require electricity	
Discussion	Rationale: it is assumed that a connection to the grid opens a broad range of options for additional educational methods, which, taken overall, reflects an improved education. In addition, pupils at electrified boarding schools benefit from extended learning time for reading and homework when electric lighting is provided. Limitations: this indicator neglects the importance of other contributing factors, such as the existence, qualification and motivation of the teaching staff. Furthermore, no information is provided on the quality of the respective educational service.	
Source	Field survey: secondary schools	
Indicator calculation	Indicator I3.1.xlsx	
Data elements and variable codes	Proportion of secondary schools providing computer classes using computers, internet classes, and natural science experiments requiring electricity	GI18, ED01, ED04, ED07
	Proportion of boarding schools that provide lighting for assignments at night	GI07, ED10

Data presentation for I3.1

Chart A3-73: I3.1 - Share and number of secondary schools providing computer classes



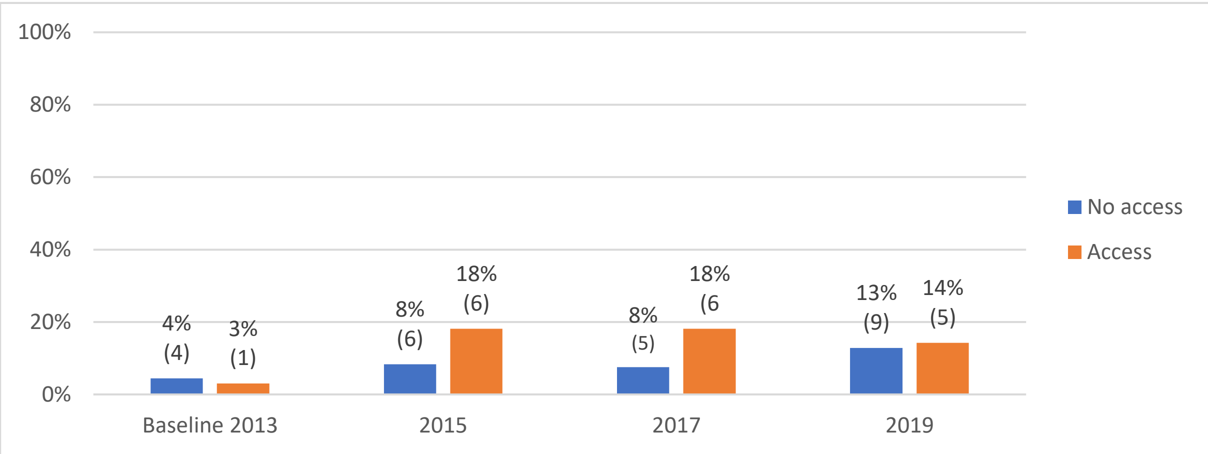
Schools were asked whether they offer computer classes where students can work on computers themselves (or in small groups). Therefore, positive answers have only been considered if schools owned at least five or more functional desktop or laptop computers.

Within the access cluster, service levels increased significantly between 2015 and 2017 (when grid access increased from 42% to 64%) but did not increase further in 2019 (while grid access further increased to 100%). Within the no-access cluster, share and number of schools offering computer class increased continuously, supported by a national program supporting off-grid schools with solar PV systems and computers, demonstrating that the service can also be offered without grid access.

It is important to note, however, that the bars in chart A3-73 hide a high fluctuation in schools actually offering the service over the years: four schools of the access-cluster and six of the no-access cluster that offered the service in 2017, dropped it in 2019. While in six cases, schools were not counted anymore due to insufficient numbers of computers (which equals budget constraints as faulty computers cannot be replaced). Three schools explicitly stated budget constraints as reason for not offering the service anymore. Similarly, one school of the access cluster and six of the no-access cluster that offered the service in 2015, dropped it in 2017 (in most cases, they were not counted due to insufficient numbers of computers, but five of the seven offered it again in 2019).

Of the 57 schools not offering computer classes in 2019, 12 are grid connected, while 45 have no grid access. Still, only 15 of the latter stated power as the main barrier, while 41 stated budget constraints as main barriers (including the ones with insufficient number of computers to offer classes). Staff constraints have been mentioned by three, one, and six schools in 2013, 2015, and 2017, respectively, but were not stated in 2019.

Chart A3-74: I3.1 - Number of secondary schools providing internet classes



Schools were asked whether they offer internet classes where students actually work on computers. Therefore, positive answers have only been considered if schools owned at least five or more functional desktop or laptop computers and offered also computer classes.

Overall, numbers are significantly lower compared to general computer classes, which can only partially be explained by the limited access to mobile data (see below).[84] In both clusters, total numbers increased but three schools that offered the service in 2017 dropped it in 2019 due to budget constraints (4) and staff constraints (1). Four schools of the access cluster and three of the no-access cluster that offered the service in 2015 dropped it in 2017 (none due to insufficient number of computers, and only two of the three no-access schools offered it again in 2019).

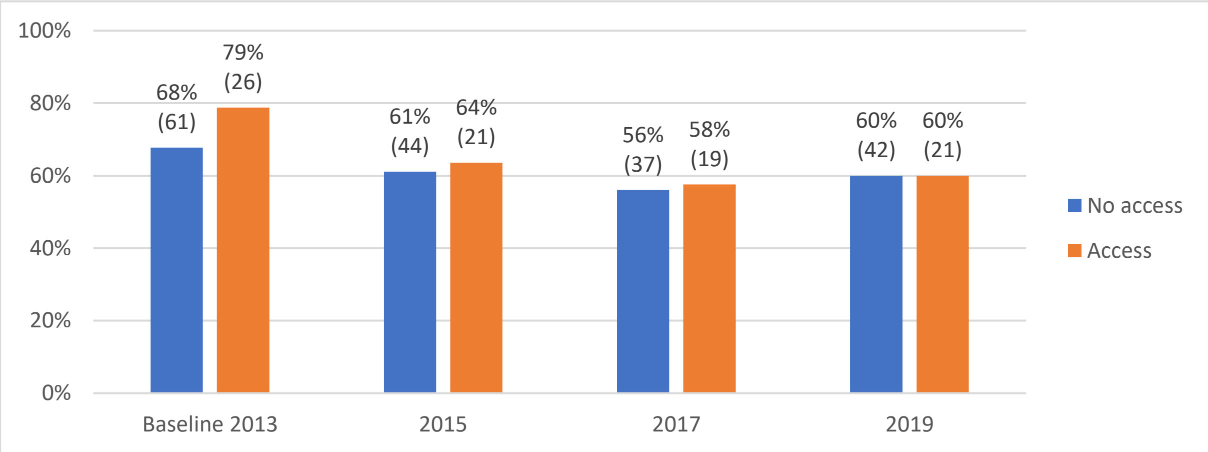
Of the 91 schools that did not offer internet classes in 2019, 30 are grid connected while 61 have no grid access. Still, only 23 of the latter stated power as the main barrier, while 45

84 The qualitative survey revealed that at least some schools consider internet as part of their computer classes and did not state it as separate offer, which might have contributed to a lower total value.

schools stated budget constraints as main barriers (including the ones with insufficient number of computers to offer classes). Only eight schools stated that mobile network coverage is too poor at their location to access the internet. Staff constrains have been mentioned by four schools, while six schools stated that internet classes are not part of the school's curriculum.

In sum, it seems that external factors such as school budget, but also internet access and qualified staff prevent even many grid-connected schools to offer internet classes.

Chart A3-75: I3.1 - Number of secondary schools providing natural science experiments

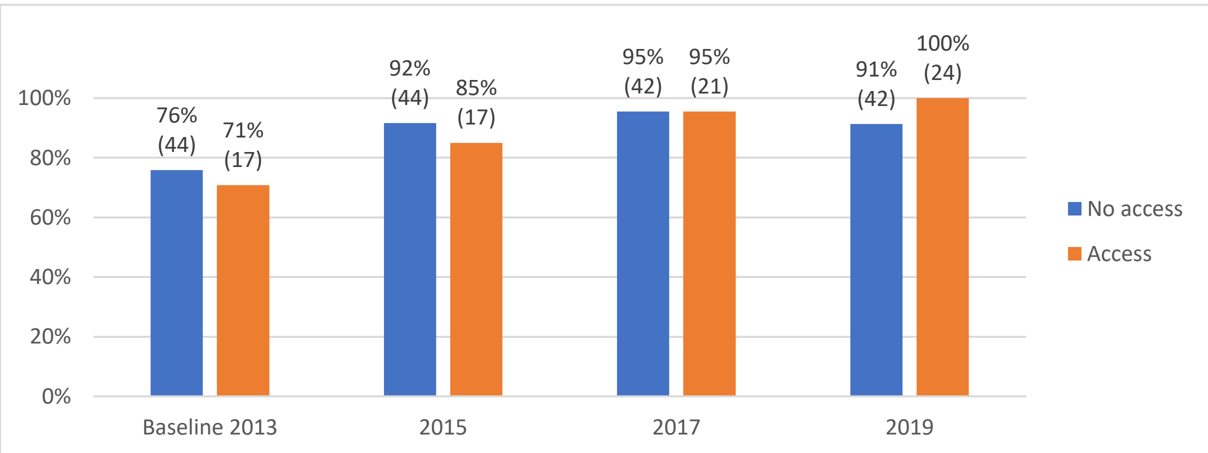


The share of schools offering science experiments that require electricity decreased in general, with 87 schools in 2013, 65 in 2015 (six grid-connected), 56 in 2017 (17 grid-connected) and 63 in 2019 (21 grid-connected).

Of the 42 schools (14 grid-connected, 28 not grid connected) that did not offer natural science experiments in 2019, 26 schools stated power as the main barrier, six budget constraints, five staff constraints, and three said that it was not part of the curriculum.

However, this data needs to be interpreted with care as qualitative interviews indicated that many schools do simple natural science experiments using batteries but did not mention this during the quantitative interview as they did not consider batteries as electricity.

Chart A3-76: I3.1 - Proportion of boarding schools providing evening light



The number of schools offering lighting at night increased from 61 (17 grid-connected in 2013 and 2015, to 63 (21 grid-connected) in 2017 to 65 (24 grid-connected) in 2019. While the share of boarding schools offering lighting reached 100% for grid connected schools in 2019, also over 90% of not grid connected schools have been able to offer such services using solar systems and generators.

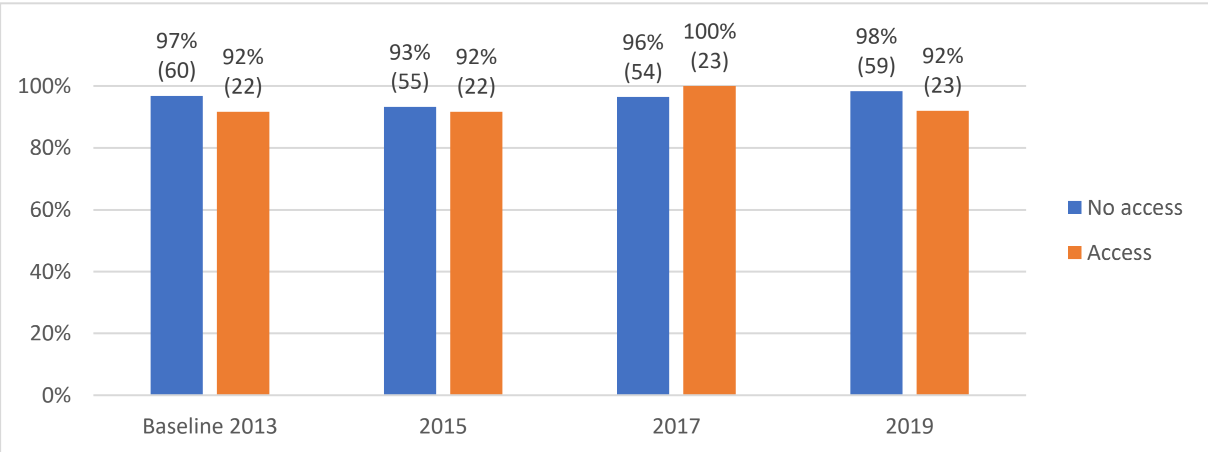
Indicator sheet I3.2

Result I3: Contribution to improved education, healthcare, and water supply		
Indicator	(I3.2) In electrified areas, both (a) the proportion of health centers (level III and above) that offer key electricity-dependent health services, and (b) the proportion of such health centers that are able to provide such services whenever they are needed, has increased compared to business-as-usual	
Definitions	Electricity-dependent health services: refers to all level III and above health centers offering vaccination, delivery wards (childbirth), and 24hr emergency response. For advanced medical services such as surgical procedures, blood transfusion and ultrasound diagnosis only health centers of level IV and V are considered, as such services are usually not provided by level III health centers. X-ray services are only provided by level V health centers. Other limitations besides electricity such as budget or staff constraints can be the cause for not providing the service.	
Discussion	Rationale: electricity-dependent health services such as those named above are of key importance and are considered essential for improving healthcare. The addition of "whenever they are needed" reflects the importance of the time dimension regarding the availability of such health services. In the	
Source	Field survey: health centers	
Indicator calculation	Indicator I3.2.xlsx Indicator_R1_R2.xlsx	
Data elements and variable codes	Proportion of health centers providing: surgical procedures, vaccinations, blood transfusions, X-rays, ultrasound diagnosis, obstetrics under artificial lighting, and 24hr emergency response	GI02, HS01, HS05, HS09, HS13, HS17, HS21, HS25
	Proportion of health centers where key electricity-dependent health services are always available whenever they are needed	GI02, HS02, HS06, HS10, HS14, HS18, HS22, HS26
	Number of connected health centers quoting constraints in providing the health service	GI02, HS01, HS03, HS05, HS07, HS09, HS11, HS13, HS15, HS17, HS19, HS21, HS23, HS25, HS27

Data presentation for I3.2

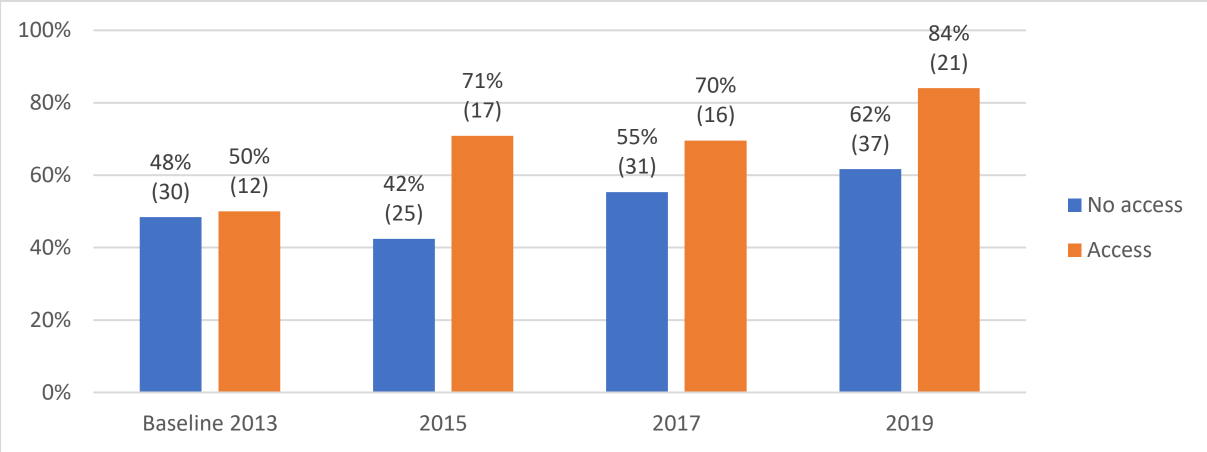
Subsequently, the number and share of institutions offering specific health service with full availability is presented, while the number and share of institutions might be higher that are able to offer such services occasionally or with limited availability.

Chart A3-77: I3.2 – Number and share of health centers offering vaccinations with full availability



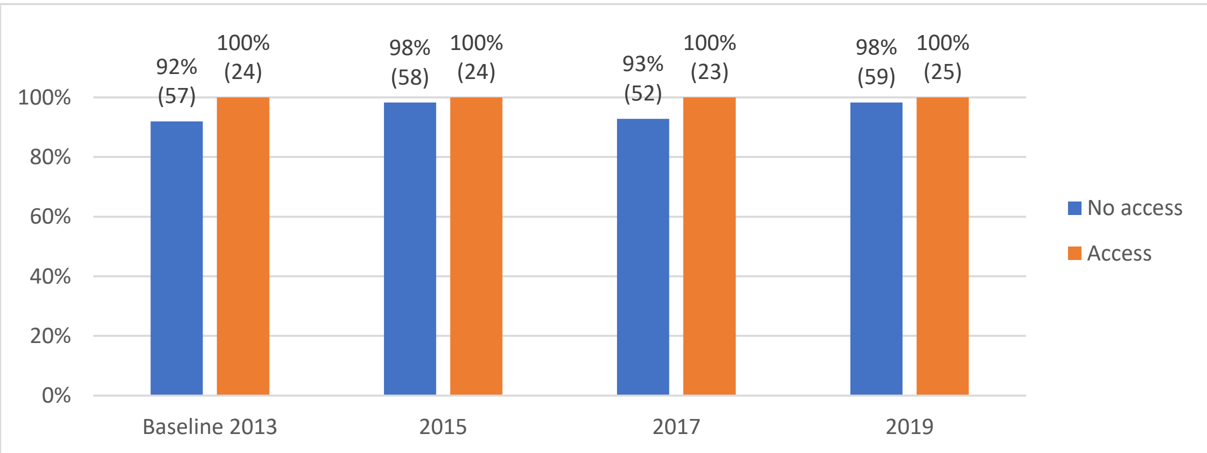
The share has always been very high regardless the grid access situation, which suggests that grid access is no decisive factor for the ability of a health center to offer vaccinations. It seems to be feasible to provide a sufficient level of off-grid electricity access to off-grid health centers. The reason for not always offering the service has in one case been related to the presence and/or functioning of fridges.

Chart A3-78: I3.2 - Number and share of health centers, where it is possible to give birth under sufficient lighting with full availability



In the access cluster, the share of health centers providing the service with full availability has increased from 50% in 2013 to 84% in 2019, while the control group only increased from 48% to 62%, which correlates with the 64% share of health centers with tier 2 (solar) or tier 3 (generator) access in 2019. In opposite, while 100% of the access cluster health centers had grid access in 2019 (25 of 25), only 84% (21) could provide the service always. This might be caused by the low reliability of the grid. One health center quoted budget constraint as a limiting factor. It is interesting to note that all these 25 health centers of the access cluster do also have a solar system, which seems not to work adequately in 3 of the cases. During the qualitative survey, some health centers reported that maintenance and repair of solar installations would be the responsibility of the ministry but is effectively lacking.

Chart A3-79: I3.2 – Number and share of health centers that provide 24h emergency response service with full availability



The share of institutions providing 24 hours emergency response has always been very high regardless of their grid access situation. However, all grid connected health centers could provide the service with full availability.

Table A3-10: Level IV and V health centers offering blood transfusion service with full availability

	Level	Name	2013	2015	2017	2019
Access cluster (6)	V	Maracha Hospital	n/a	yes	yes	yes
	V	Nyapea Hospital	yes	yes	n/a	yes
	V	St. Luke Hospital Angal	no	n/a	n/a	yes
	IV	Koboko health center	no	yes	yes	yes
	IV	Pakwach health center	yes	yes	yes	yes
	IV	Yumbe health center	n/a	n/a	no	yes
No access cluster (6)	V	Yumbe Hospital	no	no	yes	n/a
	V	St. Josephs Hospital	yes	n/a	n/a	n/a
	IV	Adumi health center	n/a	n/a	no	no
	IV	Midigo health center	yes	yes	yes	yes
	IV	Omugo health center	no	no	no	no
	IV	Rhino camp health center	n/a	no	no	no

n/a = the health center could not be interviewed in the respective year. Grid connection status of health centers is indicated by a green shaded background.

Of the 12 level IV and V health centers that by public health policy should offer blood transfusions, only seven offered the service in 2019, up from four in 2013. However, not all institutions could be interviewed in all years. While all six health centers of the access cluster offer blood transfusions in 2019, most of them did this already before they got grid connected. Only for the Yumbe health center IV did the new introduction of the service coincide with the grid connection.

Of the seven no-access health centers, only one offered blood transfusions, but we can assume that Yumbe Hospital and St. Josephs Hospital, which could not be interviewed in 2019, also offer the service, as they did offer it already in the past.

Of the 12 level IV and V health centers that by public health policy should offer ultrasound diagnosis, only four offered the service in 2019, up from three in 2013. However, not all institutions could be interviewed in all years. Four of the six health centers of the access cluster offer ultrasound diagnosis in 2019. While Maracha Hospital did offer the service in 2015 and 2017, Pakwach health center never offered it before. Both health centers stated staff constraints as the reason for not offering the service in 2019. Only for Yumbe and Koboko health center does the new offer of ultrasound diagnosis follow the grid connection.

Of the seven no-access health centers, only two offered the service of ultrasound diagnosis always in one year during the whole survey period. In 2019, none of the interviewed level IV and V health centers offered the service always. Adumi health center quoted staff problems as the reason for not being able to offer the service. Omugo and Rhino camp health center named unreliable power supply as the reason.

Table A3-11: Level IV and V health centers that provide ultrasound diagnosis with full availability

	Level	Name	2013	2015	2017	2019
Access cluster (6)	V	Maracha Hospital	n/a	yes	yes	no
	V	Nyapea Hospital	yes	yes	n/a	yes
	V	St. Luke Hospital Angal	yes	n/a	n/a	yes
	IV	Koboko health center	no	no	no	yes
	IV	Pakwach health center	no	no	no	no
	IV	Yumbe health center[85]	n/a	n/a	no	yes
No access cluster (6)	V	Yumbe Hospital[86]	no	no	no	n/a
	V	St. Josephs Hospital	Yes	n/a	n/a	n/a
	IV	Adumi health center[87]	n/a	n/a	no	no
	IV	Midigo health center	no	no	yes	no
	IV	Omugo health center	no	n/a	no	no
	IV	Rhino camp health center	n/a	no	no	no

n/a = the health center could not be interviewed in the respective year. Grid connection status of health centers is indicated by a green shaded background.

Of the 12 level IV and V health centers that by public health policy should offer surgeries, only eight offered the service always in 2019, up from five in 2013. However, not all institutions could be interviewed in all years. Within the access cluster, five health centers offered the service always in 2019, all since before getting grid connected. Only Yumbe health center did not offer the service stating staff constraints as the reason.

Table A3-12: Level IV and V health centers that conduct surgeries with full availability

	Level	Name	2013	2015	2017	2019
Access cluster (6)	V	Maracha Hospital	n/a	yes	yes	yes
	V	Nyapea Hospital	yes	yes	n/a	yes
	V	St. Luke Hospital Angal	yes	n/a	n/a	yes
	IV	Pakwach health center	yes	yes	yes	yes
	IV	Yumbe health center	n/a	n/a	no	no
	IV	Koboko health center	no	yes	yes	yes
No access cluster (6)	V	Yumbe Hospital	no	yes	yes	n/a
	V	St. Josephs Hospital	yes	n/a	n/a	n/a
	IV	Adumi health center	n/a	n/a	yes	yes
	IV	Midigo health center	yes	yes	yes	no
	IV	Omugo health center	no	n/a	yes	yes
	IV	Rhino camp health center	n/a	no	yes	yes

n/a = the health center could not be interviewed in the respective year. Grid connection status of health centers is indicated by a green shaded background.

85 Ugraded from level III to level IV between 2015 and 2017.

86 Closed in 2019 for reconstruction.

87 Upgraded from level III to level IV between 2013 and 2017.

Of the seven no-access health centers, 3 offer the service always. However, three of the health centers in the panel were not interviewed in 2019. Midigo health center quoted unreliable power supply as an obstacle to offer the service always.

Table A3-13: Level V health centers that provide X-ray service with full availability

	Level	Name	2013	2015	2017	2019
Access cluster (3)	V	Maracha Hospital	n/a	yes	yes	no
	V	Nyapea Hospital	yes	yes	n/a	yes
	V	St. Luke Hospital Angal	yes	n/a	n/a	yes
No access cluster (2)	V	Yumbe Hospital	yes	yes	no	n/a
	V	St. Josephs Hospital	yes	n/a	n/a	n/a

n/a = the health center could not be interviewed in the respective year. Grid connection status of health centers is indicated by a green shaded background.

Only health centers of type 5 are offering X-ray service. Of the five level V health centers that by public health policy should offer X-ray diagnosis only two offered the service in 2019, down from four in 2013.

However, not all institutions could be interviewed in all years. Within the access cluster, two out of three hospitals offered the service; in the case of Maracha Hospital, the service was not offered in 2019 due to staff constraints.

The two no-access level V health centers could not be interviewed in 2019 but offered the service always in 2013, Yumbe hospital also offered it in 2015 and can be expected to offer it again once reconstruction has been completed.

Indicator sheet I3.3

Result I3: Contribution to improved education, healthcare, and water supply		
Indicator	(I3.3) The average number of customers of central water providers and the reliability of water supply in electrified areas has increased compared to business-as-usual	
Discussion	Rationale: central water supply improves the availability of safe water to the population, and also enables an increased number of people to be supplied. Moreover, grid electricity permits more dependable water pump operations, as electricity is cheaper compared to using other energy sources. An approximation of reliability is established by counting the number of days per year that water pumps are out of operation. This information is obtained by direct enquires with local water suppliers.	
Source	Field survey: water supplier	
Indicator calculation	Indicator I3.3. xlsx	
Data elements and variable codes	Average number of customers from central water suppliers	WS11, WS13
	Average number of days per year when pumps are out of operation	WS13, WS18

Data presentation for I3.3

Table A3-14: Average number of customers and days without service of water suppliers

	Name	Number of customers				Days without service			
		2013	2015	2017	2019	2013	2015	2017	2019
Access cluster (5)	Angal	n/a	n/a	n/a	108	n/a	n/a	n/a	9
	Dei	n/a	n/a	n/a	10,000	n/a	n/a	60	8
	Koboko	228	295	383	710	3	n/a	3	16
	Pakwach	200	n/a	1200	1,755	1	n/a	n/a	0
	Yumbe	364	458	486	658	14	14	n/a	124
No access cluster (4)	Erussi	100	n/a	500	n/a	60	45	150	6
	Kubala	n/a	n/a	900	14	n/a	n/a	1	48
	Lodonga	n/a	800	62	67	0	20	0	12
	Maracha	n/a	61	n/a	??	120	3	n/a	??
	Omugo	n/a	n/a	245	205	n/a	n/a	0	48

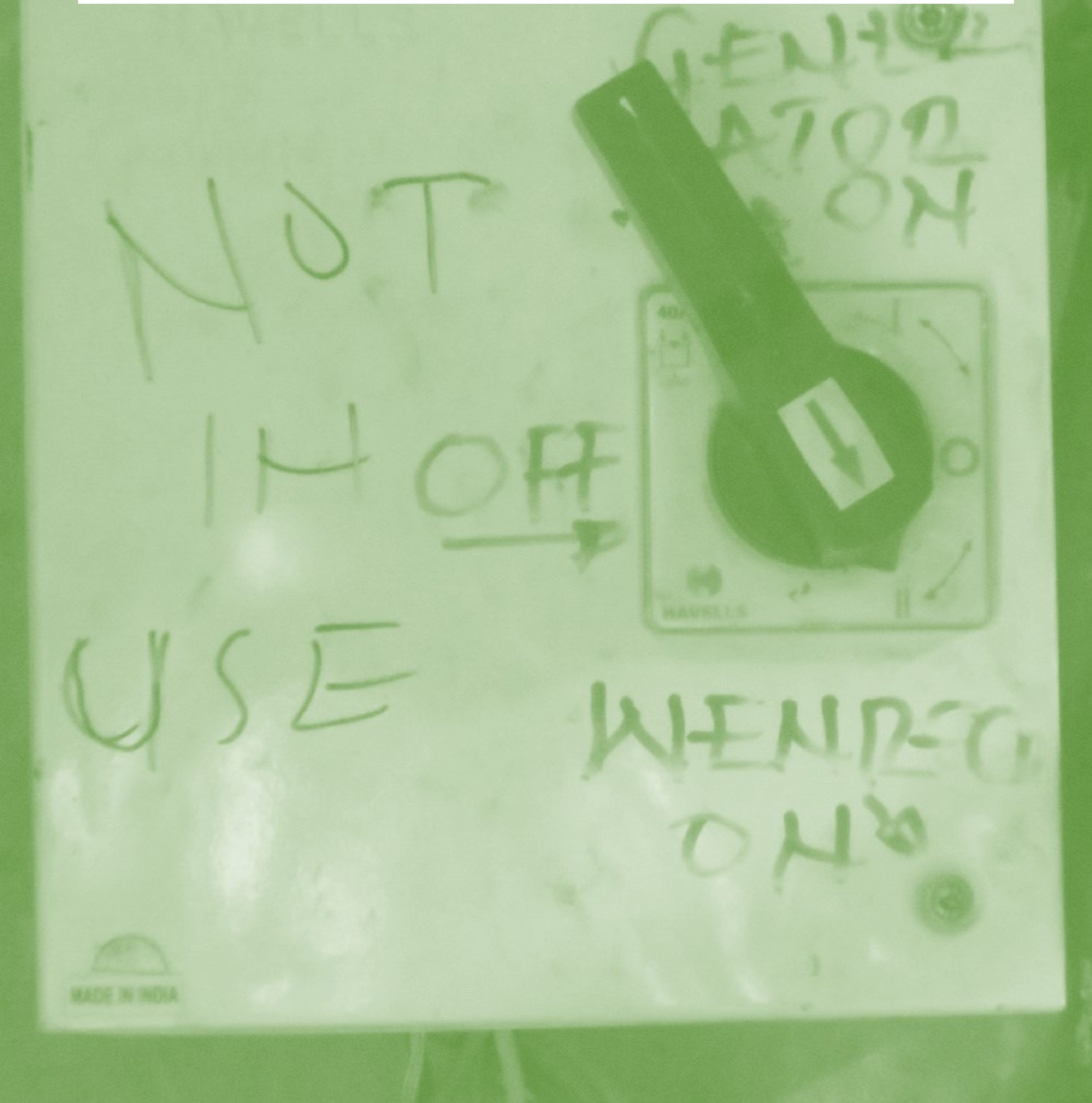
n/a = no central water supply, the water supplier could not be interviewed or did not answer the question in the respective year. Grid connection status of water suppliers is indicated by a green shaded background.

By 2019, nine out of 26 surveyed locations (three towns, three electrified trading centers, and three not-electrified trading centers) are centrally supplied with water. Five of the six water suppliers in towns and grid-connected locations are also grid-connected. Four of the nine water suppliers are not grid-connected, but used solar pumps (2), solar-diesel-hybrid pumps (1) or only diesel-generators (1). In general, the number of customers has been increasing continuously in both groups. The strong increase of customers of grid connected water suppliers is caused by a sharp growth of the number of customers in towns, in particular from 2017 to 2019.

Values for non-operational pumps have a high variance, which in specific cases can jump up to 150 days. Only one out of five electrified water suppliers reported no outages in 2019, while Yumbe reported 4 days caused by breakdowns and 120 days due to lack of power supply.

Annex IV

References



A4-1. The SE4All tier access system

In the context of the SDG 7 for universal energy access, World Bank has developed a tier access model[88] which distinguishes 6 levels of access to electricity varying from tier 0, no access to electricity, to tier 5, unlimited, stable and reliable grid power supply (see Figure A4-1).

Figure A4-1: Tier access definition for electricity (World Bank et al. 2015, 175).

Attributes		Tier 0	Tier 1	Tier 2	Tier 3	Tier 4	Tier 5
1. Peak capacity	Power		Very low power, minimum 3 watts	Low power, minimum 50 watts	Medium power, minimum 200 watts	High power, minimum 800 watts	Very high power, minimum 2 kilowatts
	and Daily capacity		Minimum 12 watt-hours	Minimum 200 watt-hours	Minimum 1.0 kilowatt-hours	Minimum 3.4 kilowatt-hours	Minimum 8.2 kilowatt-hours
	or Services		Lighting of 1,000 lumen-hours per day	Electrical lighting, air circulation, television, and phone charging are possible			
2. Duration	Hours per day		Minimum 4 hours	Minimum 4 hours	Minimum 8 hours	Minimum 16 hours	Minimum 23 hours
	Hours per evening		Minimum 1 hour	Minimum 2 hours	Minimum 3 hours	Minimum 4 hours	Minimum 4 hours
4. Affordability					Cost of a standard consumption package of 365 kilowatt-hours per annum is less than 5 percent of household income		
3. Reliability						Maximum 14 disruptions per week	Maximum 3 disruptions per week of total duration less than 2 hours
5. Legality						Bill is paid to the utility/prepaid card seller/authorized representative	
6. Health and safety						Absence of past accidents/ no perception of high risk in the future	
7. Quality						Voltage problems do not affect use of desired appliances	

According to this tier logic, we stratified households in West Nile into four groups:

Tier 0: all households without any access to electricity neither grid-based nor stand-alone systems

[88] For a detailed definition and discussion of the tier access levels see (World Bank et al., 2015, p. 175).

Tier 1: households with a solar lamp, a small solar home system, or a battery system, but without a generator or grid connections. If these households also own a TV or fan, they are considered tier 2[89].

Tier 2: households with a solar lamp, solar home system, or battery system, but without a generator or grid connections, that also own a TV or fan.

Tier 3/4: households with a generator or grid connection. It is difficult to distinguish the tier 3 and tier 4 access levels for this group: Generators are in theory able to provide a tier 4 access (or even tier 5) however, in practice, this would be very costly for the households and might therefore apply only to very few rich households. The WENRECo grid would qualify for tier 4 access provided that an uninterrupted power supply for at least 16 hours a day can be guaranteed of which at least 4 hours need to be supplied in the evening. Furthermore, there must be a maximum of 14 disruptions per week and voltage must be stable enough to not endanger appliances. So, the current situation might be better characterized by tier 3, but tier 4 access level might be reached by WENRECo in the future.

[89] There are a number of households (e.g. 9% in 2017) that only own a solar lamp. Some solar lamps are that small that they do not qualify to be considered as tier 1 access for a full household but are only counted for a fraction of this household (World Bank et al., 2015, pp. 212–214). As we do not record the specific type of solar lamp, we cannot separate how many of these household would only qualify for a fractional accounting as tier 1.

A4-2. Glossary

Access: Describes the degree of availability, affordability and reliability of energy services demanded, such as illumination, heat, and transport, including the appliances needed to convert primary energy into the respective energy service. Energy services demanded vary among user types and according to their preferences; gaining access to energy services is not a sudden event, but a continuous process.

Beneficiaries: All institutions or individuals that have or share an electricity connection are considered as direct beneficiaries. Of these, only households, businesses, schools, and health centers are specifically reported by the M&E framework, while the rest are summarized within the number of commercial customers. For the considered beneficiary groups, only household members are calculated and reported as direct beneficiaries, to avoid double counting. All people living in electrified areas can be considered as indirect beneficiaries, but with widely varying access to electricity-based services. Even households or businesses without an electricity connection benefit indirectly from improved educational, health and commercial services.

Counterfactual: The counterfactual describes a situation or condition that hypothetically would appear without the development intervention (treatment).

Customers: Are either individuals (e.g. household heads, owners of businesses), or institutions (e.g. health centers, schools, businesses) that hold a contract with WENRECo for electricity supply.

Data element: An indicator is composed of one or several data elements, each comprising specific information. If several data elements exist for one indicator, they can be used independently to describe a given situation, or can be used to calculate sample statistics.

Double-difference comparison: Collects information on treated and non-treated units of analysis before and after an intervention. The changes in Outcome variables in the comparison group are the counterfactual. The underlying trends for both the treatment and comparison group are assumed to be identical.

Electricity-based services: Energy services that use electricity as the final form of energy. In the case of the M&E framework for West Nile, electricity-based services are all services that depend on grid electricity provided by WENRECo.

Electrification corridor: The electrified corridor is the geographical area along the grid course where transformers are planned and a low-voltage connection could potentially be established (within a radius of 500 meters from the transformer). Localities that are close to the grid but lack a transformer are thus not considered as part of the electrification corridor.

Electrified area: See electrification corridor.

Energy service: An energy service comprises both the supply chain and the user demand. The supply chain is concerned with the conversion and distribution of final energy. The demand side considers the user's desire for certain energy services (such as lighting, heating, mechanical power, etc.) for which the final energy is used.

Evaluation: Evaluation is a systematic and objective assessment of a still ongoing or completed development intervention. It assesses the design, implementation, and results achieved. The aim is to determine the relevance and effectiveness, efficiency, impact, and sustainability of that intervention.

Household: A household is defined as all people living with the head of that household.

Household head: In West Nile, a household head is the household member who guides decision-making on major issues affecting the household.

Impact map: An impact map is based on a results chain, but enhances it with external factors (e.g. droughts, changes in national policies) that cannot be influenced directly, but have an influence on a project's or program's success. Additionally, a results map also considers unintentional side effects of a project/program. The latter can be of a negative nature (e.g. increased prostitution) or a positive (e.g. improvements in drinking water supply).

Impact: Positive and negative, primary and secondary long-term effects produced by a development intervention, directly or indirectly, intended or unintended.

Indicator: A quantitative or qualitative factor or variable that provides a simple and reliable means to measure achievement, to reflect the changes connected to an intervention, or to help assess the performance of a development actor.

M&E framework: A M&E framework for a development intervention describes the results chain (including causes and effects) and the methodical approach; defines tools for data collection; proposes procedures for data analysis and interpretation; and defines roles and responsibilities within the M&E process. A M&E framework enables the performance of a development intervention to be assessed. Hence, it is important for program management and informed decision-making by stakeholders.

Monitoring: A regular observation activity to systematically collect data, providing management and the main stakeholders of an ongoing development intervention with indications on progress and the achievement of objectives.

Multistage sampling: The total population is divided into a number of groups from which a sample is drawn. If necessary, this procedure can be repeated several times. Finally, only randomly selected entities from the groups are included in data collection.

Outcome: The likely or achieved short-term and medium-term effects of an intervention's outputs.

Output: The products, capital goods and services which result from a development intervention; may also include changes resulting from the intervention which are relevant to the achievement of outcomes.

Results: The Output, (Use of Output), Outcome, or Impact (intended or unintended, positive and/or negative) of a development intervention.

Results-based M&E: Regularly assesses the progress of a development intervention, and provides information for all results and for each level (Output, Use of Output, Outcome, and Impact).

Results chain: A results chain anticipates the causal sequence between a project's/program's activities, its Outputs (products or deliverables), the Use of these Outputs, its Outcomes (direct effects) and eventually the more indirect, long-term Impacts.

Rural electrification: Describes the physical set-up of electricity generation and distribution infrastructure in rural areas. The main approaches for rural electrification are the extension of the national grid to rural areas, the set-up of medium-scale generation capability and island grids, and the dissemination of household size generation systems (mainly based on solar power).

Sample: A subset drawn from the parent population. The sample is selected according to the criteria of interest and in accordance with sampling procedures, in order to define the base of survey.

Sampling frame: The source material (e.g. household lists) from which a sample can randomly be drawn.

Simple before-after comparison: Collects information on treated units of analysis before and after the intervention. The baseline is used as counterfactual. To isolate the net effect, no underlying trend in the relevant Outcome variables is assumed to exist that would not also occur in the program’s absence.

Survey area: The survey area is the location in which the field survey is conducted.

Towns: Settlements in West Nile that have a town council status as district capitals or have a minimum of 20,000 inhabitants.

Trading centers: A trading center is not an administrative unit in Uganda. It can best be understood as small rural settlement serving as the main site for local trade. Many trading centers are stretched across several villages (the smallest administrative units in Uganda) or even across several parishes.

Unit of analysis: Is the major entity analyzed in a study, and the subject of the statements produced in the study. In the M&E framework, they refer to some program beneficiaries analyzed at the Outcome and Impact level (households, businesses, secondary schools, and health centers of level III and above).

Use of Output: At the Use of Output level, the Outputs of a development intervention are used by the target group or intermediaries, and thereby contribute to the results at the Outcome and Impact levels.

A4-3. Literature

Assistant District Health Officer Nebbi. 2017. Interview.

AZOROM. 2018. “Network Assessment Baseline Report.” GET FiT TA Facility Optimization of Compliance Monitoring of Distribution and Transmission Licensees and Regulatory Capacity Building. Uganda: Electricity Regulatory Authority.

B. Kelsey Jack, and Grant Smith. 2019. “Charging Ahead: Prepaid Metering, Electricity Use and Utility Revenue.” *American Economic Journal: Applied Economics*. https://doi.org/10.1257/app.20180155.

Baringanire, Paul, Kabir Malik, and Sudeshna Ghosh Banerjee. 2014. “Scaling Up Access to Electricity: The Case of Rwanda.” https://52.21.52.208/handle/10986/18680.

Barnes, Douglas. 2007. *The Challenge of Rural Electrification: Strategies for Developing Countries*. 1st ed. Washington DC: Energy Sector Management Assistance Program (ESMAP).

Barron, Manuel, and Maximo Torero. 2017. “Household Electrification and Indoor Air Pollution.” *Journal of Environmental Economics and Management* 86 (November): 81–92. https://doi.org/10.1016/j.jeem.2017.07.007.

Bayer, Patrick, Ryan Kennedy, Joonseok Yang, and Johannes Urpelainen. 2019. “The Need for Impact Evaluation in Electricity Access Research.” *Forthcoming*.

Bensch, Gunther, Jörg Peters, and Maximiliane Sievert. 2017. “The Lighting Transition in Rural Africa — From Kerosene to Battery-Powered LED and the Emerging Disposal Problem.” *Energy for Sustainable Development* 39 (August): 13–20. https://doi.org/10.1016/j.esd.2017.03.004.

Bhatia, Mikul, and World Bank, eds. 2015. *Access to Modern Energy Services for Health Facilities in Resource-Constrained Settings: A Review of Status, Significance, Challenges and Measurement*. Geneva, Switzerland: World Health Organization. https://apps.who.int/iris/handle/10665/156847.

Bonan, Jacopo, Stefano Pareglio, and Massimo Tavoni. 2017. “Access to Modern Energy: A Review of Barriers, Drivers and Impacts.” *Environment and Development Economics* 22 (5): 491–516. https://doi.org/10.1017/S1355770X17000201.

Bos, Kristine, Duncan Chaplin, and Arif Mamun. 2018. “Benefits and Challenges of Expanding Grid Electricity in Africa: A Review of Rigorous Evidence on Household Impacts in Developing Countries.” *Energy for Sustainable Development* 44 (June): 64–77. https://doi.org/10.1016/j.esd.2018.02.007.

Brüderle, Anna, Jenny Tracy, Witold Teplitz, Kilian Reiche, and Monika Rammelt. 2017. “Productive Use of Energy – PRODUSE II Measuring Impacts of Electrification on Micro and Small Enterprises in Nepal.” Eschborn, Germany: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH.

Bryan Bonsuk, Koo, Padam Gouthami, Rysankova Dana, Portale Elisa, Keller Sandra, and Angelou Niki. 2018. “Rwanda – Beyond Connections : Energy Access Diagnostic Report Based on the Multi-Tier Framework.” Washington DC: World Bank. http://hdl.handle.net/10986/30101.

Bryan Bonsuk, Koo, Yoo Kyul Han, Rysankova Dana, Portale Elisa, and Keller Sandra. 2018. “Myanmar – Beyond Connections : Energy Access Diagnostic Report Based on the

Multi-Tier Framework." Washington DC: World Bank. http://hdl.handle.net/10986/32381.

Chaplin, Duncan, Arif Mamun, Ali Protik, John Schurrer, Divya Vohra, Kristine Bos, Hannah Burak, et al. 2017. *Grid Electricity Expansion in Tanzania by MCC: Findings from a Rigorous Impact Evaluation*. Washington, DC: Mathematica Policy Research. https://www.mathematica-mpr.com/our-publications-and-findings/publications/grid-electricity-expansion-in-tanzania-by-mcc-findings-from-a-rigorous-impact-evaluation.

CIA. 2017. "The World Factbook 2017." 2017. https://www.cia.gov/library/publications/the-world-factbook/geos/ug.html.

Dave, Rutu, Keller Sandra, Koo Bryan Bonsuk, Fleurantin Gina, Portale Elisa, and Rysankova Dana. 2018. "Cambodia – Beyond Connections : Energy Access Diagnostic Report Based on the Multi-Tier Framework." Washington DC: World Bank. https://openknowledge.worldbank.org/bitstream/handle/10986/29512/124490.pdf?sequence=5&isAllowed=y.

District Agricultural Officer Yumbe. 2017.

District Education Officer. 2017. Interview.

———. 2019. Interview.

District Energy Focal Point Yumbe. 2017. Interview.

District Environment Officer Yumbe. 2017. Interview.

District Health Officer Yumbe. 2017. Interview.

District Planning Officer Yumbe. 2017. Interview.

Duguma, Lalisa, Cathy Watson, Judith Nzyoka, Clement Okia, and Bernard Fungo. 2019. "The Migration-Environment Nexus: The Situation in Northwest Uganda." Nairobi: World Agroforestry. http://old.worldagroforestry.org/downloads/Publications/PDFS/B17977.pdf.

Gaul, Mirco, Christian Berg, Benjamin Korff, Kathrin Raabe, Johannes Strittmatter, Katharina Tröger, and Valeriya Tyumeneva. 2011. *Tracing the Impacts of Rural Electrification in West Nile, Uganda - A Framework and Toolbox for Monitoring and Evaluation*. Berlin, Germany: Humboldt Universität zu Berlin, SLE Postgraduate Studies on International Cooperation. http://edoc.hu-berlin.de/series/nestor-materialien/245/PDF/245.pdf.

GIZ. 2017. "Electricity Access Impact Maximization (E-AIM) Campaign in the West Nile Region of Uganda." Kampala: GIZ International Services.

GOGLA. 2018. "Powering Opportunity The Economic Impact of Off-Grid Solar." https://www.gogla.org/sites/default/files/resource_docs/gogla_powering_opportunity_report.pdf.

Golumbeanu, Raluca, and Douglas Barnes. 2013. "Connection Charges and Electricity Access in Sub-Saharan Africa." Policy Research Working Paper 6511. Washington, DC: The World Bank. http://www-wds.worldbank.org/external/default/WDSContentServer/IW3P/IB/2013/06/27/000158349_20130627091637/Rendered/PDF/WPS6511.pdf.

Gouthami, Padam, Koo Bryan Bonsuk, Rysankova Dana, Portale Elisa, Keller Sandra, and Fleurantin Gina. 2018. "Ethiopia – Beyond Connections : Energy Access Diagnostic

Report Based on the Multi-Tier Framework.” Washington DC: World Bank. http://hdl.handle.net/10986/30102.

Hamburger, David, Joel Jaeger, Patrick Bayer, Ryan Kennedy, Joonseok Yang, and Johannes Urpelainen. 2019. “Shades of Darkness or Light? A Systematic Review of Geographic Bias in Impact Evaluations of Electricity Access.” *Energy Research & Social Science* 58 (December): 101236. https://doi.org/10.1016/j.erss.2019.101236.

IEA. 2005. *Energy Statistics Manual*. Luxembourg: OECD/IEA. http://www.iea.org/stats/docs/statistics_manual.pdf.

IEA, IRENA, UNSD, WB, WHO. 2019. “Tracking SDG 7: The Energy Progress Report 2019.” Washington DC. http://trackingsdg7.esmap.org/data/files/download-documents/2019%20Tracking%20SDG7%20Report.pdf.

IFC. 2019. “The Dirty Footprint of the Broken Grid.” Washington DC: International Finance Cooperation/World Bank Group. https://www.ifc.org/wps/wcm/connect/Industry_EXT_Content/IFC_External_Corporate_Site/Financial+Institutions/Resources/Dirty-footprint-of-broken-grid.

IPCC. 2006. *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Hayama, Japan : Institute for Global Environmental Strategies. http://www.ipcc-nggip.iges.or.jp/public/2006gl/.

Jiménez, Raúl. 2017. “Development Effects of Rural Electrification.” Inter-American Development Bank. https://doi.org/10.18235/0000629.

Kårhamar, Ralph, Ingar Flatlandsmo, Louis Pauchon, and Ryan Anderson. 2013. “Impact Assesment of Rural Electrification.” Oslo: Norwegian Agency for Development Cooperation (Norad)/Norplan. http://www.multiconsult.no/Documents/Publications%20Renewable%20energy%20advicory/Impact%20Assessment%20of%20Rural%20Electrification%20Projects%20in%20Mozambique.pdf.

Khandker, Shahidur R., Douglas F. Barnes, and Hussain A. Samad. 2009. *Welfare Impacts Of Rural Electrification: A Case Study From Bangladesh*. Policy Research Working Papers. World Bank. https://doi.org/10.1596/1813-9450-4859.

Kojima, Masami, and Chris Trimble. 2016. *Making Power Affordable for Africa and Viable for Its Utilities*. Washington DC: World Bank. https://doi.org/10.1596/25091.

Laruni, Elizabeth. 2015. “Regional and Ethnic Identities. The Acholi of Northern Uganda, 1950-1968.” *Journal of Eastern African Studies* 9 (2): 212–30.

Lee, Kenneth, Edward Miguel, and Catherine Wolfram. 2016. “Appliance Ownership and Aspirations among Electric Grid and Home Solar Households in Rural Kenya.” w21949. Cambridge, MA: National Bureau of Economic Research. https://doi.org/10.3386/w21949.

Lenz, Luciane, Anicet Munyehirwe, Jörg Peters, and Maximiliane Sievert. 2017. “Does Large-Scale Infrastructure Investment Alleviate Poverty? Impacts of Rwanda’s Electricity Access Roll-Out Program.” *World Development* 89 (January): 88–110. https://doi.org/10.1016/j.worlddev.2016.08.003.

Lighting Global. 2019. “Market Research on Productive Use Leveraging Solar Energy (PULSE) –.” Washington DC: International Finance Corporation (IFC). https://www.lightingglobal.org/resource/pulse-market-opportunity/.

Ministry of Health. 2009. "Annual Health Sector Performance Report." Financial Report 2009/2010. Kampala: Ministry of Health Uganda. http://www.health.go.ug/docs/AHSPR09.pdf.

Ministry of Water and Environment Uganda. 2017a. "Forest Investment Programme for Uganda." Investment plan endorsed by the Climate Investment Fund. Kampala. https://www.climateinvestmentfunds.org/sites/cif_enc/files/fip_18_7_investment_plan_for_uganda_final.pdf.

———. 2017b. "Ministerial Policy Statement 2016/2017." http://www.mwe.go.ug/sites/default/files/library/MPS%202016-2017.pdf.

Peters, Jörg, and Maximiliane Sievert. 2016. "Impacts of Rural Electrification Revisited – the African Context." *Journal of Development Effectiveness* 8 (3): 327–45. https://doi.org/10.1080/19439342.2016.1178320.

Peters, Jörg, Colin Vance, and Marek Harsdorff. 2010. "Grid Extension in Rural Benin: Micro-Manufacturers and the Electrification Trap." *World Development*, December. https://doi.org/10.1016/j.worlddev.2010.09.015.

Ramani, K. V., and Enno Heijndermans. 2003. *Energy, Poverty, and Gender - A Synthesis*. Washington, DC: World Bank Group/Asia Alternative Energy Program. http://go.worldbank.org/X6GEOG9WH0.

School Inspector Nebbi. 2017.

Sippel, Lilli, Tanja Kiziak, Franziska Woellert, and Reiner Klingholz. 2011. "Afrikas Demographische Herausforderung. Wie Eine Junge Bevölkerung Entwicklung Ermöglichen Kann." Berlin Institut für Bevölkerung und Entwicklung.

Taneja, Jay. 2019. "If You Build It, Will They Consume? Key Challenges for Universal, Reliable, and Low-Cost Electricity Delivery in Kenya -." Working Paper 491. CGD. Washington DC: Center for Global Development. https://www.cgdev.org/publication/if-you-build-it-will-they-consume-key-challenges-universal-reliable-and-low-cost.

Terrapon-Pfaff, Julia, Marie-Christine Gröne, Carmen Dienst, and Willington Ortiz. 2018. "Productive Use of Energy – Pathway to Development? Reviewing the Outcomes and Impacts of Small-Scale Energy Projects in the Global South." *Renewable and Sustainable Energy Reviews* 96 (November): 198–209. https://doi.org/10.1016/j.rser.2018.07.016.

UBOS. 2011. "Census of Business Establishments 2010/11." Kampala: Uganda Bureau of Statistics (UBOS). https://www.ubos.org/wp-content/uploads/publications/03_20182010_COBE_Report.pdf.

———. 2014. "Uganda National Household Survey 2012/2013." Kampala: Uganda Bureau of Statistics (UBOS). http://www.ubos.org/onlinefiles/uploads/ubos/UNHS_12_13/2012_13%20UNHS%20Final%20Report.pdf.

———. 2017. "Statistical Abstract 2016." Kampala: Uganda Bureau of Statistic. http://www.ubos.org/onlinefiles/uploads/ubos/statistical_abstracts/2016%20Statistical%20Abstract.pdf.

———. 2018. "Uganda National Household Survey 2016/2017." Kampala: Uganda Bureau of Statistics (UBOS). https://www.ubos.org/wp-content/uploads/publications/03_20182016_UNHS_FINAL_REPORT.pdf.

———. 2019. “Statistical Abstract 2018.” Kampala: Uganda Bureau of Statistic. https://www.ubos.org/wp-content/uploads/publications/05_2019STATISTICAL_ABSTRACT_2018.pdf.

UNDP. 2018. “2018 Statistical Update | Human Development Reports.” New York, NY: United Nations Development Programme. http://www.hdr.undp.org/en/2018-update/download.

UNEP. 1996. *Sources and Sinks of Greenhouse Gases in Uganda : A UNEP GEF Sponsored Project : Final Report*. Kampala Uganda: Ministry of Natural Resources. http://www.gcrio.org/CSP/pdf/uganda_inven.pdf.

UNHCR. 2017. “Safe Access to Fuels and Energy Strategy, 2016-2020.”

Vernet, Antoine, Jane N.O. Khayesi, Vivian George, Gerard George, and Abubakar S. Bahaj. 2019. “How Does Energy Matter? Rural Electrification, Entrepreneurship, and Community Development in Kenya.” *Energy Policy* 126 (March): 88–98. https://doi.org/10.1016/j.enpol.2018.11.012.

Wang, Xuantong, Mickey Rafa, Jonathan Moyer, Jing Li, Jennifer Scheer, and Paul Sutton. 2019. “Estimation and Mapping of Sub-National GDP in Uganda Using NPP-VIIRS Imagery.” *Remote Sensing* 11 (2): 163. https://doi.org/10.3390/rs11020163.

WEC/FAO. 1999. *The Challenge of Rural Energy Poverty in Developing Countries,*. London: World Energy Council (WEC) and Food and Agriculture Organization of the United Nations (FAO). www.worldenergy.org/publications/314.asp.

World Bank. 2008. “The Welfare Impact of Rural Electrification: A Reassessment of the Costs and Benefits - An IEG Impact Evaluation.” Washington, DC: The Independent Evaluation Group (IEG)/World Bank. http://siteresources.worldbank.org/EXTRURELECT/Resources/full_doc.pdf.

———. 2018. “Poverty Maps of Uganda.” 127635. The World Bank. http://documents.worldbank.org/curated/en/456801530034180435/Poverty-Maps-of-Uganda.

———. 2019. “Uganda | Data.” 2019. https://data.worldbank.org/country/uganda.

World Bank, Vivien Foster, Gabriela Azuela, Morgan Bazilian, Jonathan Sinton, Sudeshna Banergee, Joeri de Wit, et al. 2015. *Sustainable Energy for All 2015: Progress Toward Sustainable Energy*. The World Bank. https://doi.org/10.1596/978-1-4648-0690-2.