Ministry of Foreign Affairs

Electrifying Rural Tanzania

A Grid Extension and Reliability Improvement Intervention

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Impact Report

Evaluation of the ORIO Project ORIO10/TZ/01

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Electrifying Rural Tanzania. A Grid Extension and Reliability Improvement Intervention.

Impact Report

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Authors: Gunther Bensch, Willem Cornelissen, Jörg Peters, Natascha Wagner, Jan Reichert, Vendula Stepanikova

on behalf of the consortium

Erasmus University Rotterdam (EUR), Rheinisch-Westfälisches Institut für Wirtschaftsforschung (RWI), Georg-August Universität Göttingen

Contact: Jörg Peters, Leibniz Institute for Economic Research (RWI), Tel. +49 201 8149 - 247, peters@rwi-essen.de

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Abbreviations

Abbreviation	Meaning
ABC	Anglo Belgian Corporation
ATT	Average treatment effect on the treated (here: using the Diff-in-Diff approach)
AFD	Agence française de développement (French development agency)
CBA	Cost-benefit analysis
CCTV	Closed circuit television
CD	Compact disc
DfID	Department for international development of the United Kingdom
Diff-in-Diff	Difference-in-differences approach
EDCF	South Korea economic development co-operation fund
EIB	European Investment Bank
ESIR	Electricity supply industry reform strategy and roadmap 2014-2025
EWURA	Energy and water utilities regulatory authority
GPS	Global positioning system
ITT	Intention to treat (here: using the Diff-in-Diff approach)
JICA	Japan International Cooperation Agency
KfW	Kreditanstalt für Wiederaufbau (German state-owned development bank)
km	kilometres
kV	kilo volts
LED	Light emitting diode
LPG	Liquefied petroleum gas
LoC	Letter of credit
MEM	Ministry of energy and minerals
MW	Mega watts
O&M	Operation and maintenance
OLS	Ordinary least squares
ORET	Development-related export transactions programme funded by the Netherlands Ministry of Foreign Affairs
ORIO	Facility for Infrastructure Development funded by the Netherlands Ministry of Foreign Affairs
REA	Rural electrification agency
REF	Rural energy fund
PSM	Propensity score matching
PSMP	Power system management plan
SE4All	United Nations sustainable energy for all initiative
SME	Small and medium enterprises
TANESCO	Tanzania electric supply company
TSh*	Tanzanian shillings
TV	Television set
USAID	United States agency for international development
WTA	Willingness to accept
WTP	Willingness to pay

* At the time of the surveys in 2014 and 2018 the exchange rate between Euro and Tanzanian Shillings was 1 Euro for approx. 2,150 TSh and 2,600 TSh, respectively.

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Executive summary

Project background

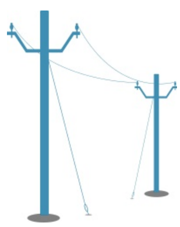
Access to reliable modern energy is one of 17 Sustainable Development Goals. Through the United Nations initiative Sustainable Energy for All (SE4All), the international community strives to provide modern and reliable energy to everybody by 2030. This report presents the results of an impact evaluation and institutional analysis of the *Electrifying Rural Tanzania* project, which is financed through the Dutch Facility for Infrastructure Development ORIO, with co-funding by the Tanzanian government. When launched in 2010 in collaboration with the Tanzanian parastatal utility TANESCO, the aim of the ORIO project was to replace existing diesel generators by two 1.25 MW state-of-the-art generators in three district towns in northern and western Tanzania each. In all three towns – Biharamulo, Ngara and Mpanda –, electricity grids were in place that were not connected to and not scheduled for connection to the national grid at the time. The higher capacity of the new generators also allowed the ORIO project to extend the local electricity grids to surrounding rural areas. Technical assistance and specific trainings for TANESCO and newly connected enterprise customers complemented these activities. It is the objective of the ORIO project to achieve 19,700 household, 4,000 enterprise and 500 public service connections ten years after project implementation.

The focus of this report is on the *new connection* of hitherto non-connected households and enterprises in the surrounding rural areas and the *service upgrade* of already connected households and enterprises in towns suffering from frequent outages and load shedding. The report furthermore documents an institutional analysis that was conducted in order to trace the project implementation at the level of TANESCO, including the influence of the broader policy context on project success. This institutional assessment is particularly important as the project has faced challenges that eventually triggered the cancellation of an *Operation and Maintenance phase*, which had originally been planned to follow the installation of the generators. A considerably share of the project budget, 38 percent, had been foreseen for this O&M phase. Context matters, also for this project: the political context has changed over the project cycle with rural electrification receiving a higher attention, both from the national government through the *Big Results Now* initiative launched in early 2013 and the international donor community and financiers.

All three generator sets were successfully installed, but the changing political context also entailed the connection of two of the three towns – Biharamulo and Ngara – to the national grid. These two ORIO generator sets are currently used as back-up capacities on a very regular basis due to an intermittent service of the national grid. However, this is expected to improve in the coming years due to investments in the regional electricity transmission infrastructure. Against this background, the impact evaluation in this report examines impacts that are attributable to a mix of ORIO and TANESCO investments. We refer to this mix as the *ORIO project* in the following.

Key components of the ORIO project *Electrifying Rural Tanzania*

Installation of six diesel generators to replace old generators with low efficiency and reliability



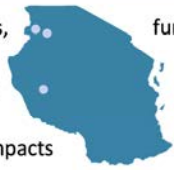
Extension of local rural grids by around 225 km

Complementary technical assistance and trainings for TANESCO and enterprises

Surveys and methods

The evaluation is based on a series of field visits and surveys. An inception mission was conducted in 2014, followed by two rounds of surveys: a baseline survey in 2014/2015 before project implementation and a follow-up survey in 2018/2019. Additional intermediate data collection specific to the institutional assessment took place in 2016. We employ a mix of methods to determine the impacts of the ORIO project. For rural households, we primarily use a quantitative difference-in-differences (Diff-in-diff) approach using the two survey waves with 58 treatment communities connected by the ORIO project and 42 control communities that remained non-electrified over the entire study period. For urban households and enterprises, we use a before-after comparison because identifying similar towns as control groups was not possible. In total, we surveyed 1155 households in rural areas as well as 300 households and 595 enterprises in towns. For rural enterprises, we conducted a smaller survey using qualitative interviews. We additionally use willingness-to-pay methods to assess the degree to which connected firms and households value changes in the electricity service quality in towns after implementation of the ORIO project.

1155 rural households from **100** communities,
300 urban households and **595** urban firms
traced over a **4**-year period to credibly assess project impacts



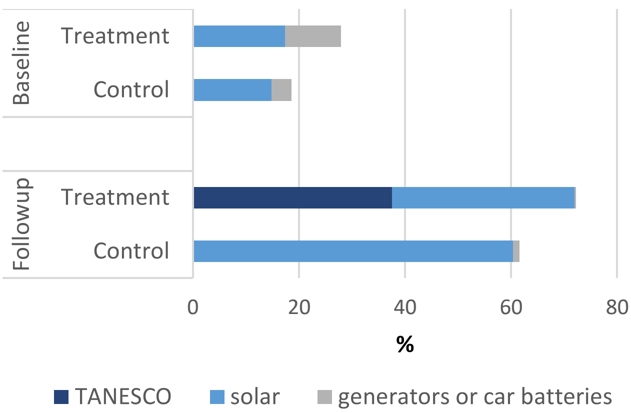
further information sources include village authorities, representatives of the implementing agency, TANESCO executives, TANESCO technicians, the generator manufacturer, other development partners and further local key informants

Impacts in rural areas

We find that 38 percent of households in newly grid-covered areas are connected to the grid at the time of follow-up, despite high connection subsidies provided by the governmental Rural Electrification Agency (REA). The most notable reasons for those who do not connect are connection fees, in-house installation costs, and running electricity costs.

One of the most striking findings is the massive rise of solar panel use among off-grid households (see figure). Without any external programme by a governmental or non-governmental organization, people have obtained panels on the local market. The vast majority are non-branded products, marketed through local shops by a Dar-es-Salam-based Tanzanian enterprise. In control communities, 60 percent of households satisfy their electricity demand through solar panels at follow-up, which is three times more than four years earlier. Given the availability of grid electricity in ORIO communities, solar panels are less common there and contribute to a total penetration rate of electricity sources of 72 percent. This finding is somewhat in line with previous research in the country (Chaplin et al. 2017) and elsewhere in Africa (Grimm and Peters 2016, Bensch et al. 2017, 2018). Because of this rise of solar panel usage, the ORIO project does not achieve an increase in access to electricity according to our Diff-in-Diff estimations. Quality and power of the service, though, are higher for grid-connected households.

Availability of electricity among rural households



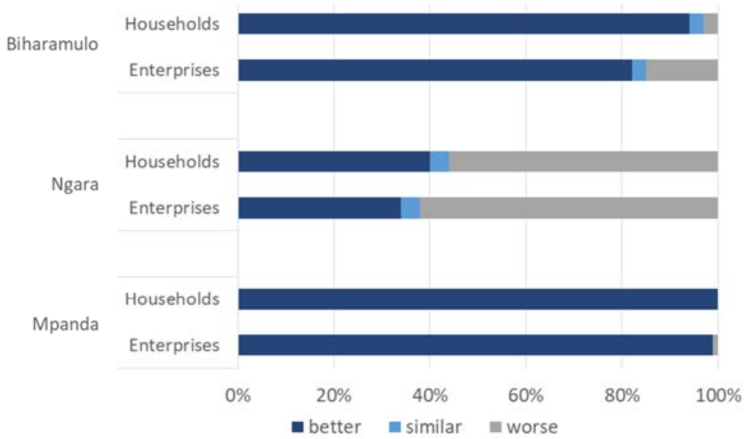
This is reflected in more grid-connected households using a TV set, line-powered radios and electric irons. Also the usage of artificial light is considerably higher. For example, 68 percent of grid-connected TANESCO clients use TV sets. In terms of energy expenditures, grid-connected households rather spend more on energy than before and more than the control group, which is due to the broader range of energy services available.

Poorer households tend to connect less. In the 50-metre corridor around the electricity grid, for example, 42 percent are connected among the poorest 20 percent of households and 69 percent in the richest 20 percent of households. Overall, electricity consumption is still low. After being connected to the grid for on average 1.7 years, the median electricity consumption is 21 kWh per month. We therefore observe a recurrent issue of electrification intervention in Sub-Saharan Africa: the concomitance of low demand and non-universal access (Blimpo and Cosgrove-Davies 2019).

The high TV usage rate in connected households affects time use the most. Male and female adults in connected households watch on average 1.3 and 1.1 hours per day, respectively, which is 50 minutes more than the average of non-connected households. Otherwise, there are no perceivable effects of the ORIO project on poverty indicators such as employment, income generation, and education. We do not see more people engaged in non-farm activities and the productive use of electricity in households is extremely rare. This is in line with the emerging rigorous literature on electrification and its impacts in rural Africa (Lee et al. 2019, Chaplin et al. 2017, Lenz et al. 2017).

Impacts in urban areas

Perception of electricity reliability among urban customers



The main objective of the ORIO project was to improve the service quality in the already grid-connected three towns Biharamulo, Ngara and Mpanda. Since Biharamulo and Ngara were connected to the national grid in 2015 and 2018, respectively, the generators here only serve as backup facilities. The generators are used more than 100 hours per month also in these two towns, since the grid is unreliable in the area as of now. Compared to the baseline situation in 2014, the service quality has clearly improved only in Mpanda, where the number of blackouts has gone down considerably. While the duration of blackouts has improved in all towns, frequency of blackouts has rather increased in Ngara. Reliability is still an issue for Biharamulo, where the situation is perceived to have improved from a worse level in 2014. This is consistent with subjective statements by households and enterprises on how satisfied they are with service quality (see figure). The amount of electricity consumed basically did not change, neither for households nor enterprises.

Strategies to cope with outages are an important question in the context of electricity reliability, especially for enterprises. Outages affect firms in different sectors differently. The majority of trade enterprises (around 70 percent) but only half of service and a third of manufacturing firms continue normal operations in case of outages. Half of manufacturing firms even have to stop their business.

Generator ownership has decreased from 18 percent in 2014 to 11 percent in 2019 – mostly driven by enterprises in Biharamulo and Mpanda. However, especially in the more electricity-reliant service and manufacturing sectors (as compared to trade) the decrease is very modest. Here, generators made up 90 and 88 percent of back-up facilities at baseline and 85 and 80 percent at follow-up, respectively. Four percent of firms have a solar panel, which does not allow running high-power appliances, though.

As an additional impact measure, we elicited the hypothetical willingness to pay (WTP) of urban enterprises for a service improvement. The results confirm the observations above to the degree that manufacturing and service firms state a higher WTP than trade firms. Firms operating under the 'heavy industry' tariff of TANESCO report the highest WTP. Moreover, the WTP of firms in Ngara and Biharamulo is higher than for those in Mpanda.

Several lessons learned and policy recommendations can be taken away from this study. First, electrification interventions are no longer about providing mere access to electricity. The solar market is working even in remote rural areas like those under evaluation in this report to cater for basic electricity demand. Grid extension in countries with low rural electrification rates should rather be focused on regions where more powerful electricity is needed. These regions could then also be subject to more targeted, holistic private sector development engagement. As this study has shown, in spite of an expensive grid extension and a simultaneous increase in solar panel uptake, a non-negligible share of around 28 percent of households in grid-covered areas are without electricity and hence, relatively even worse-off than before. Promotion policies for off-grid electricity should therefore be conditioned on a clear poverty targeting. Regarding off-grid solar, future policy intervention is required in particular when it comes to end-of-life electronic waste.

Second, it became evident that the adequacy of electricity generation is only one supply-side factor that affects reliability. Similarly important, reliability depends on and can be further enhanced through conditions of the power system infrastructure, incl. network expansion, network maintenance, and illegal connections, as well as utility financial and operational performance and energy sector regulation.

Third, the recurrent problem with setting up O&M components particularly calls for a clearer definition of modalities on how to contract out critical maintenance tasks, a definition that needs to be laid out early on in the design phase of an infrastructure development project.

Fourth, the design of the ORIO project did not seem to be sufficiently aligned with recent developments in policies, strategies, as well as operational and financing plans. To enhance the flow of information about the sector context in the partner country, it could be considered to give priority to infrastructural project proposals in those sectors and countries where the Netherlands is represented directly or through delegated participation in sector working groups or round tables. To further enhance the embedding of the supported project in the partner country's scheduled infrastructure investments, it could additionally be considered to expand the requirement for alignment of the envisaged project from the current alignment to general policies and sector strategies, but also to more specific sector-level financing plans and/ or sector-level medium-term expenditure frameworks.

Fifth and finally, the main outcome indicator of the ORIO project of 24,000 new and improved connections as basis of the value-for-money relation of the ORIO project was problematic from the outset. While it will possibly be achieved due to the unforeseen connection of two towns to the national grid and a considerable up-scaling of rural grid extension activities in the country, it would otherwise not have been achievable without considerable additional contributions from the

Tanzanian side. Among others, the low-voltage lines funded by ORIO were clearly insufficient to achieve the envisaged connection figures. To generally enhance realism in the underlying assumptions of project proposals submitted to RVO, it could be considered to condition part of the financial contribution to a limited number of process and output performance indicators in the financing contract.

1. Introduction

More than one billion people in developing countries lack access to electricity with a large share living in Africa. Connectivity is particularly low in rural areas. With its huge geographical extent and low population density, infrastructure development is a particular challenge in Tanzania. Electrification rates are 17 percent in rural and 65 percent in urban areas of mainland Tanzania (excluding Zanzibar, URT 2017). It is often hypothesized that lacking access to electricity hampers human development in many regards. The lack of access to modern lighting in households limits their possibilities to pursue productive activities after nightfall, but also educational and recreational activities. Likewise, enterprise development and the provision of public services becomes more difficult (APP 2015).

In addition, even in grid-covered areas service quality is often bad with frequent outages, forcing firms to interrupt their work or resort to expensive generators. According to Blimpo and Cosgrove-Davies (2019), "in 25 of the 29 countries in Africa with recent data, less than one-third of firms have reliable access to electricity". It is therefore often argued that addressing reliability of the grid should be given higher priority by policy.

This report evaluates the implementation and impacts of the *Electrifying Rural Tanzania* project that addresses both the low electrification rates in rural areas and the electricity service quality in already grid-covered town. The project is jointly funded by the Government of Tanzania and the Facility for Infrastructure Development (ORIO), which in turn is financed by the Netherlands Ministry of Foreign Affairs and managed by the Dutch implementing agency RVO. ORIO encourages public infrastructure development in developing and middle-income countries. The ORIO project in Tanzania rehabilitated and extended three isolated grids in northern and western Tanzania that are run by diesel generators with a total capacity of 7.5 MW. Around 133,000 beneficiaries are supposed to be reached in urban and rural areas as well as about 4,000 enterprises and 500 public service institutions, part of whom had suffered from supply shortages before the intervention.

The evaluation is based on a series of missions, field trips, and large surveys. We surveyed 300 urban households and 595 urban enterprises as well as 1155 households in rural areas for a before-after panel in 2014/2015 (baseline) and 2018/2019 (follow-up). Impacts are identified by means of a difference-in-differences approach in rural areas and a before-after comparison in urban areas.

The report is organized as follows: Section 2 and 3 introduce the project under evaluation as well as the methodological approach and the sampling. Section 4 summarizes the findings of an institutional assessment of the project policy context and project execution. Section 5 presents the survey and impact results in rural areas and shows the relevant socio-economic characteristics and energy consumption patterns, while Section 6 does the same for the urban part of the target population, with a particular focus on changes detected in terms of electricity reliability. Section 7 puts these medium-term impacts in the context of the long-term project cycle of this infrastructure intervention to gauge its overall costs and benefits. Section 8 provides a short conclusion. Along the report, boxes summarize findings for activities, outputs, outcomes, and impacts of the intervention.

2. The ORIO intervention *Electrifying Rural Tanzania*

This section outlines the original project design and goals of the *Electrifying Rural Tanzania* intervention. The project is part of the public infrastructure development programme ORIO. ORIO succeeded the Development-Related Export Transactions programme (ORET) in 2009 and in turn was closed in April 2014.[1]

The project was selected for ORIO grant financing in 2010, planned with a total budget of 32.7 million Euro, equally covered by ORIO and the Tanzanian government – represented by the Tanzanian Ministry of Energy and Minerals. The overall objective of the project was to support the parastatal electric utility TANESCO (Tanzania Electric Supply Company Limited) in upgrading and newly establishing local electricity infrastructure around the three non-adjacent district capital towns Biharamulo, Ngara, and Mpanda[2] (see also Figure 1 and Box 1). This is to benefit a total of 133,000 people ten years after project implementation, of which around 103,000 beneficiaries are to be attained through around 18,500 new connections in rural areas not yet covered by the grid. The vast majority of the roughly 24,000 new and improved connections are expected to be private households (19,700). The remainder is expected to be small businesses (3,700), local industry (320 connections) and public services like hospitals and schools (484 connections).

Figure 1: The target areas of the project

Source: Nations Online Project

The project was planned to cover two main phases, an *implementation phase* with a budget of 20.3 million Euro and an *operation and maintenance (O&M) phase*, for which 12.4 million Euro were allocated (TANESCO 2011). These were preceded by a *development phase* with an additional budget of 396,000 Euro fully covered by ORIO. The implementation phase was initially scheduled for the period March 2012 to June 2013, while the O&M phase was supposed to cover a period of 30 years where ORIO would co-finance maintenance that cannot be conducted by TANESCO staff in the first 10 years. As will be discussed in Section 4, actual implementation faced various hurdles, only took place between 2016 and 2018, and it was decided to cancel the O&M phase in late 2018.

The support provided by the ORIO project can be summarized into three core activities of the *implementation phase*, which will be outlined in the following: (i) replacement of old diesel generators by new models, (ii) grid extension to rural areas around the towns, and (iii) complementary trainings and technical assistance.

[1] In 2015, an adjusted programme for public infrastructure was launched, the Developmentally Relevant Infrastructure Investment Vehicle (DRIVE) for middle-income countries and Development2Build (D2B) for least developed countries (Kamerstuk 33625, nr.97).

[2] To be precise, a considerable part of the rural project actually belongs to Mlele district rather than to Mpanda district. In addition, Mpanda town is officially not part of Mpanda district. As the generator is located in Mpanda town, in the following we refer to this project area as Mpanda.

Box 1: Regional context of the *Electrifying Rural Tanzania* intervention

The two intervention sites in northern Tanzania, Biharamulo and Ngara, are located in Kagera region at the border to Rwanda. The third intervention site, Mpanda, is situated in Katavi region in the West of the country at the Congolese border. Both regions are at roughly 1,400 kilometres from Dar es Salaam. Road access is difficult, and social services are scarce in most rural areas. The three sites are named after their district capital towns with a population of around 20,000 in Biharamulo and Ngara and 80,000 in Mpanda (National Bureau of Statistics 2012, 2017). In 2016, 89 percent of urban and 16 percent of rural households had access to any sort of electricity in Kagera region, 67 percent of them via the grid. These numbers are 63 (urban), 32 (rural), and 41 percent (grid) for Katavi region, respectively (URT 2017).

Biharamulo and Ngara have extensive forests and some natural reserves, including game and natural forests. The Mpanda area consists of woodland and bush land. The mainly rural project area is dominated by subsistence farming (bananas, sorghum, maize, beans), and some cultivation of cash crops (jatropha, coffee, tobacco, cotton and tea), livestock production and beekeeping. It is estimated that 80 percent of the population are engaged in agriculture (URT 2017).

Mining is another important source of revenues in the three districts, often conducted by small-scale miners. Mineral commodities include gold, nickel, cobalt, green tourmaline, gemstone, and copper. The manufacturing sector is at its infancy stage in the regions. The activities are manufacturing simple consumer goods like food, beverages, textiles, tobacco, wood products, rubber products, iron, steel, and fabricated metal products, which are produced for the local market mostly.

Agricultural commodities also dominate the exports from the regions. Biharumulo is a market hub for trade and services and a crossroad linking the cities of Bukoba and Mwanza as well as Burundi and Rwanda. For Mpanda, trade opportunities with neighbouring countries are limited, because the border to the Democratic Republic of Congo is Lake Tanganyika and the border to Zambia is located at 330 kilometres from Mpanda district capital.

Replacement of old diesel generators by new models

Each of the three project towns had been covered by decentralized electricity networks powered by two stand-alone diesel generators before the ORIO project (also referred to the `intervention' in the following). They had a nameplate capacity of 424 to 660 kW each and were between 20 and 30 years old. According to project information, they ran at about 30 percent of their capacity only and consumed twice as much fuel as modern generators per unit of electricity produced. The grid-connected urban and peri-urban population experienced frequent outages and heavy load shedding. Furthermore, the risk was considered high that the generators fail completely in the very near future, which would effectively disconnect the users from the electricity services (ORIO 2013).

At the time of planning in 2011, the ORIO project developers considered all sites too far away to be connected to the national transmission and distribution grid in the then foreseeable future. The grid was mainly limited to the eastern parts of the country. The project therefore decided to replace the dilapidated generators by six modern generators of 1.25 MW each, relying on a model provided by the Dutch company Zwart Techniek B.V. that was already used and maintained by TANESCO in other parts of the country. The old generators were to be dismantled by TANESCO.

Grid extension to rural areas around the towns

The new higher-powered generators were supposed to not only increase reliability in the existing grid, but also to allow its extension to further rural areas in the town peripheries. The network was extended by a total of 171 km of 33 kV line, and 44 km of low voltage line, including a total of 44 sub-stations. Due to delays in the *implementation phase*, some of the project sites were incorporated in the grid extension activities of the governmental Rural Electrification Agency (REA). These were typically sites close to the existing decentralized electricity networks. Thereby, some of the low and medium voltage lines and sub-stations originally stipulated in the contract between ORIO and TANESCO were freed up. These were redirected by TANESCO to the extension of the networks to further villages in the intervention areas. Eventually, a total of 38 sites got electrified through ORIO.

In this evaluation, we cover those communities electrified by ORIO/ TANESCO and those electrified by REA, which will be referred to as 'TANESCO sites' and 'REA sites', respectively. This has to do with the fact that not only the "last mile" electrification by REA is identical to the one adopted by ORIO and critically relies on the generators and grid extension provided by the ORIO project. The communities targeted by ORIO, for their part, also benefitted from connection subsidies by REA. Instead of the standard connection fees of 177,000 TSh (400 Euro), households living up to 30 metres from the electricity grid, for example, only had to pay the value added tax of 18 percent on the usual connection charges, which amounted to 27,000 TSh (12 Euro).[3]

Key dates of the implementation phase for both types of sites are summarized in Table 1. The table furthermore indicates that the centralized grid underwent extension activities to Biharamulo and Ngara – independent of the ORIO project. The transmission network to the area, though, is rather weak and still in the process of being upgraded. Therefore, for now the generators in the two towns are actively required as back-up. This will be further discussed in Section 4 and 6.1.

Table 1: Starting dates of household connections

Project Region	Date of installation of ORIO generators	Starting date of household connections		Service status of ORIO generators in 2019	Date of connection to centralized grid
Biharamulo	July 2016	TANESCO:	September 2016	back-up	mid-2015
		REA:	November 2014		
Mpanda	May 2017	TANESCO:	October 2017	full electricity service	*(unlikely to be connected before 2024)*
		REA:	July 2015		
Ngara	August 2016	TANESCO:	December 2016	back-up	April 2018
		REA:	August 2014		

Complementary trainings and technical assistance

The third core activity of the *implementation phase* was complementary training and technical assistance, among others provided by the Dutch consultancy company Berenschot as the main contracted partner for the preparation stage (and later consultant to TANESCO). Partner representatives at TANESCO were trained in project management (2013), mechanical and electronic engineers were trained in technical maintenance (2016, 2017), while part of the small and medium enterprises (SME) in the intervention areas were aimed to be trained in the use of electricity. For more details on these complementary trainings, see Section 4.4.

[3] For TANESCO grid connection fees, see TANESCO (2019). Iron roofs were another prerequisite for getting connected to electricity, since thatched roofs are more prone to fires. The baseline report found that in fact 87 percent of households in communities to be electrified by the ORIO project had an iron roof (Bensch et al. 2017).

Box 2: Summary of key data on the project setup of the ORIO intervention

ORIO intervention	»	Output and Intermediate Outcomes	»	Outcomes	»	Impact and Cost-Benefit

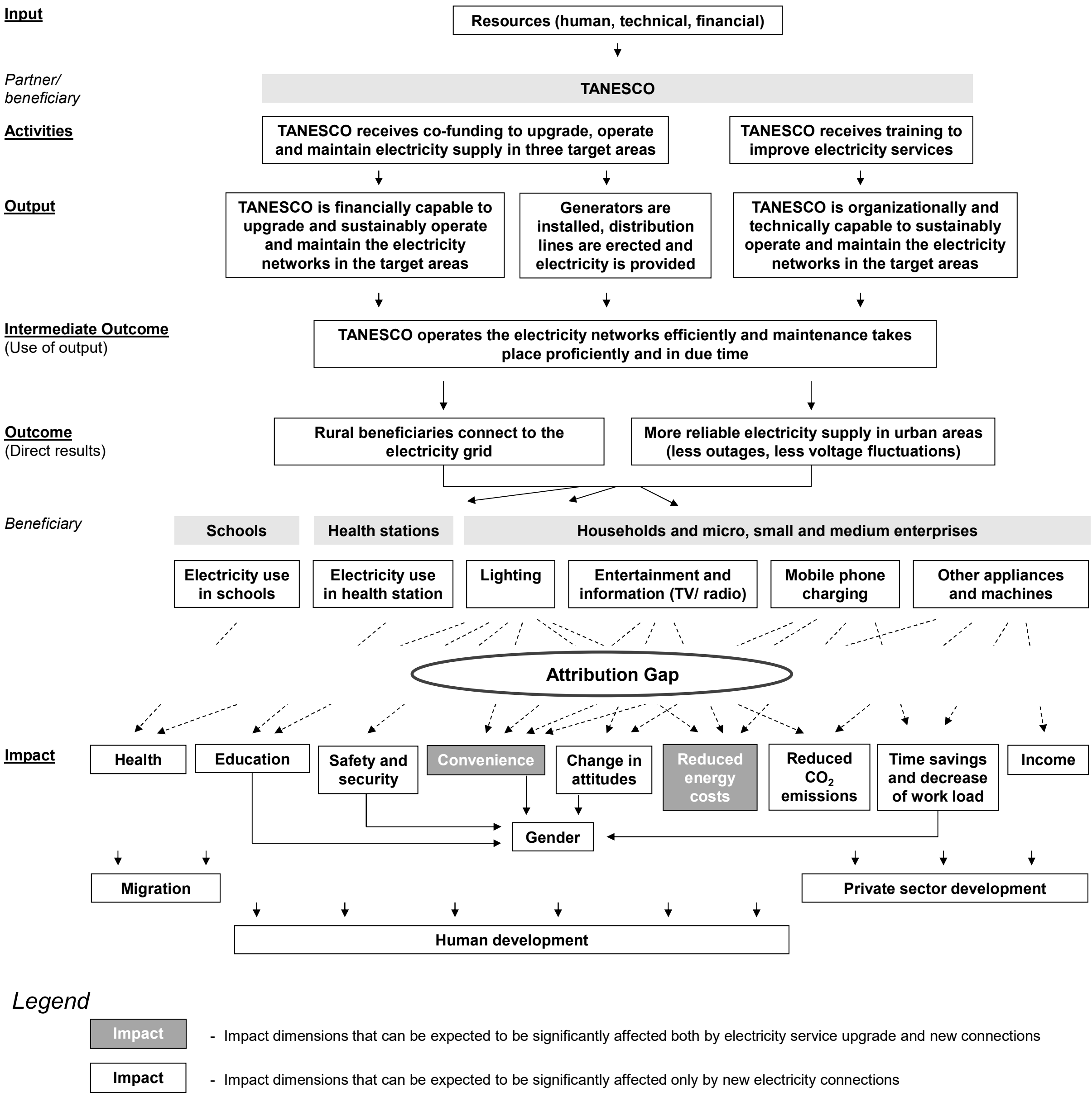
Project name:	*Electrifying Rural Tanzania*
Programme:	ORIO, a Dutch public infrastructure programme in developing countries
Project duration:	2010 – 2018
Project financing:	50% ORIO + 50% Tanzanian government
Project objective:	Provide 133,000 people with new or improved electricity access ten years after project implementation, while also catering to small businesses, local industry and public services like hospitals and schools
intervention zones:	The three district towns Biharamulo, Ngara, and Mpanda in northern and western Tanzania as well as the surrounding rural areas
project components:	*Implementation Phase (2016 – 2018, 20.3 million Euro budget)* 1. Installing new diesel generators to replace old generators with low efficiency and reliability (+ guaranteeing their dismantling) 2. Extension of the local rural grids by around 215 km 3. Complementary technical assistance and trainings related to O&M, health, safety and environment, project management at TANESCO, and business development of SME *O&M Phase (cancelled, planned budget of 12.4 million Euro)* ▪ Funding of maintenance that cannot be conducted by TANESCO staff in the first 10 years of operation

3. Evaluation Approach

3.1. Evaluation objective

The intervention logic of the ORIO project is outlined in Figure 2. It depicts the intended path from the inputs and activities provided by ORIO to the potential impacts on its targeted beneficiaries. The main objective of this impact evaluation is to quantify the actual impacts of the intervention among rural and urban households and enterprises. An additional goal is to tease out whether the links insinuated by this theory of change are appropriate in light of how the project actually worked.

Figure 2: Results chain of the ORIO project Electrifying rural Tanzania



Note: This results chain abstracts from the SME business development training component, since it was only implemented after the follow-up data collection for this evaluation.

Source: own representation

For these purposes, a quantitative *impact assessment* and a qualitative *institutional assessment* are conducted, addressing separate sets of evaluation questions at different levels of the results chain.

The institutional assessment addresses evaluation questions at output and intermediate outcome level, while the impact assessment addresses evaluation questions at outcome and impact level. The methodologies of these two approaches are outlined in the subsequent sub-sections.

- Output and intermediate outcome level:
  (i) Have the generators and distribution lines been installed and are these in operation?
  (ii) Have the new generators replaced the obsolete generators?
  (iii) Is TANESCO capable (in terms of financial, organisational and human capabilities) to adequately maintain the equipment and distribution lines?

- Outcome level:
  (i) What is the connection rate of households, enterprises, and social infrastructure institutions in the newly connected project area?
  (ii) How do connection rates evolve in the town centres with rehabilitated connections?
  (iii) How does the frequency and duration of outages change?
  (iv) For which purposes and how much electricity is used?
  (v) Which socio-economic groups (incl. income groups) benefit from availability of electricity?

- Impact level:
  (i) How have expenditures for energy changed?
  (ii) To what extent has safety/protection changed?
  (iii) To what extent has comfort/convenience changed? What monetary value do households attribute to this increased convenience?
  (iv) To what extent have activities during evening hours changed – both inside and outside the household? Have study hours/reading time of children changed? Have women and children enjoyed more or less rest for physical recuperation?
  (v) How have, in response to the possibly increased media exposure, attitudes and behaviours, such as fertility-related decisions and children's school enrolment changed?
  (vi) Has the availability of electricity triggered new economic activities or displaced old ones?
  (vii) Has school attendance changed as a result of electricity use?
  (viii) In how far have climate-relevant emissions been affected?
  (ix) How are impacts distributed across different income groups?
  (x) What (if any) positive and/or negative unintended effects have occurred?

3.2. Methodology and data of Institutional Assessment

The conceptual frame of the *Open Systems Approach* (EuropeAid 2011) could be fully applied in the 2016 intermediate institutional assessment (Cornelissen 2016) but was simplified for this final report. The institutional changes since 2016 in TANESCO are of modest importance to the ORIO project, reason why the current report refers less to the TANESCO institutional context. Instead, it focusses on the institutional relations among RVO, the Ministry of Foreign Affairs, TANESCO, Berenschot and

Box 3: Existing evidence on the impacts of rural electrification

On the **household level in newly electrified villages**, literature suggests that the major impact is on 'softer' levels such as increased convenience and comfort induced by using electric lighting and appliances such as radio, TV, or a mobile phone charger, as well as on the level of expenditures (see for example Acker and Kammen 1996, Bensch, Peters and Sievert 2013, Peters and Sievert 2016 or Lenz et al. 2017, Wamukonya and Davis 2001). There is also some evidence for effects on income and educational indicators (Khandker et al. 2012, Khandker et al. 2013), female labour supply (Dinkelman 2011; Grogan 2018) and general poverty as measured by the HDI (Lipscomb et al. 2013). Further studies suggest that the information and exposure provided by radio and (in particular) television can influence a wide range of attitudes and behaviour (see Olken 2006, La Ferrara et al. 2012, Chong and La Ferrara 2009, Peters and Vance 2011, Peters et al. 2014*a*, Jensen and Oster 2009). As the results chain shows health effects from reduced household air pollution are also possible. However, even if this impact exists, it will be rather small given that household air pollution is largely induced by cooking fuels, which are typically not affected by rural electrification interventions in Africa.

On the level of **rural micro-enterprises**, various effects are possible. In newly connected villages, manufacturing firms like carpenters or welders might use electricity to run new machinery, shops and service firms like hair cutters can use smaller appliances like fridges, radios or electric haircutting machines to improve services or attract customers. Electric lighting can improve processes in all type of companies and might lead to an increase in operation hours. For remote areas, research has shown that only in few cases electricity access in fact is a major bottleneck for firm performance. Most entrepreneurs are rather limited by the lack of access to markets. Only in exceptional cases, enterprises have the opportunity to sell their products on markets beyond their own community. Demand for their products is by and large coming from the community itself and thus already saturated. Accordingly, even if new products can be offered, they mostly attract local demand that has to be retracted from other locally offered goods such that the net effect on local businesses is often negligible. As a consequence, customers may benefit from few new locally available products and services, but productive use potentials are limited (see for example Peters et al. 2011, Peters and Sievert 2016 or Peters et al. 2015).

For **improved urban household connections**, the increased convenience and comfort might be induced through an increase in the usage intensity of electricity, more reliable service provision, and/or a reduction of back-up electricity generation. The latter may additionally trigger energy cost reductions. More critically, improvements of electricity service quality and reliability may trigger productivity enhancements among **urban enterprises**. To capture these partly intangible impacts, we particularly rely on approaches to elicit willingness-to-pay (WTP), i.e. customers are asked how much they would be willing to pay to get a well-defined package of reliable electricity services (cf. Carlsson et al. 2018). Using data from India, Allcott et al. (2016) find that productivity losses because of frequent outages are subtle only, because enterprises adapt activities and, most notably, because enterprises use generators as back-up. Small enterprises face much higher losses and hence impacts of service improvements can be expected to be more pronounced here. For Africa, Oseni and Pollitt (2015) find that firms engaging in self-generation would have suffered additional 1 to 183 percent outage losses had they not invested in self-generation. Grainger and Zhang (2017) quantify the effects of a 10 percent increase in the duration of outages for the case of Pakistan. They find an average decrease of 0.14 percent in a firm's total revenue and a 0.36 percent decrease in the value added. Industries that are most energy-intensive, such as manufacturers of metal, wood, and paper, are found to be affected most severely by shortages. Using data of Chinese firms, Fisher-Vanden et al. (2015) show that already the threat of shortages affects how firms produce. The authors find that especially energy intensive production processes were outsourced.

Similarly, only very few studies exist that exploit variation in electricity exposure at rural **community level**, where both impacts on households and enterprises may additionally be studied on a more aggregated level. For Africa, the only exceptions are Dinkelman (2011) and Peters et al. (2014*b*), although the number of surveyed villages in the latter is still rather small at 50. Outside of Africa, regional effects are examined in Brazil (Lipscomb et al. 2013) and India (Rud 2012, van de Walle et al. 2017).

Zwart Techniek, in particular in the light of the abandoned O&M stage and premature finalisation of the ORIO project.

Next to documentation, interviews were held in the Netherlands with key staff of RVO, TANESCO, Zwart Techniek, and Berenschot. Furthermore, TANESCO trainees were interviewed in 2016 and 2017 while they were trained in mechanical engineering and electronics by Zwart Techniek and their partners in the Netherlands and Belgium. The evaluation team registered data of the 24 trainees and conducted three focus group discussions in small workshops using structured and closed interview forms. In late 2018, all 24 trainees were recontacted by telephone by the Department of Economics, University of Dar es Salaam.[4] Out of the 24 participants, 23 could be traced. Out of these 23, 20 were still working with TANESCO, two were retired, while the contract of one engineer was suspended.

The results of the qualitative institutional assessment are presented in Section 4.

3.3. Methodology and data of Quantitative Impact Assessment

The quantitative impact assessment is the basis for the results presented in Section 5 and 6.

3.3.1. Identification strategy

A key element of a rigorous evaluation design is a convincing strategy to empirically identify which observed changes are genuine impacts of the intervention. Beyond the ORIO intervention, which we refer to as the *treatment* in line with evaluation terminology, there are many factors outside of the project's control that also cause changes in impact indicators. These factors may be general market trends, economic shocks, weather conditions, and other government or donor programmes. The challenge of an impact evaluation approach is thus to filter out the changes caused by these other external factors and isolate the changes that can be attributed solely to the project activities.

As can be taken from Table 2, impacts among the four beneficiary groups are assessed using data collected at different levels and using different identification strategies outlined in the following.

Table 2: Methodological approaches followed for the different beneficiary groups

Beneficiary group	Data collected at the level of…	Identification strategy	Main survey tool	Willingness-to-pay analysis
rural households & rural enterprises	rural communities	difference-in-differences	structured questionnaire	-
	rural households			-
	rural enterprises	qualitative difference-in-differences assessment	semi-structured questionnaire	-
urban households	urban households	before-after comparison	structured questionnaire	x
urban enterprises	urban enterprises			x

For **rural communities and households**, the main evaluation approach is a difference-in-differences (Diff-in-Diff) approach. Here, the treated units will be compared before and after the intervention. This first difference is adjusted by subtracting the same before-and-after difference in a control group. This control group is supposed to mimic (and thus filter out) the counterfactual development that would materialize in the treatment group in absence of the intervention. It thereby helps to account for general secular changes such as improvements of general economic conditions,

[4] Organisation and supervisor: Dr. Stephen Kirama. Interviews in Swahili conducted by Ms. Cecilia Mjingo.

technological change, or seasonality. Diff-in-Diff does not require the two groups to be at the same *level* for a certain indicator at baseline (e.g. income), but only requires that *changes* in this indicator would be the same in absence of the treatment. Whether this so-called *parallel trend assumption* holds cannot be ultimately tested, but the more similar the two groups are at the baseline stage, the more likely the assumption holds.

Both 'TANESCO sites' and 'REA sites' are treatment communities. For the selection of the control group, we restricted ourselves to communities in the ORIO project regions. Recruiting control communities from outside the project region would have implied different agricultural and climatic and thus socio-economic conditions. See next sub-section for more details on the sampling.

Two types of impacts can be determined. First, the impact on all those households or communities that are intended to be treated, irrespective of whether households actually connect to the grid or not – given that electricity costs are prohibitive for some households and electrification of the communities is partly recent, connection rates are below 100 percent. This analysis can be done using community level and household level data. The calculated impact is called the *Intention To Treat* (*ITT*) effect. This is the estimated impact of electrification on the community as a whole. It accounts for the (generally stronger) effect on the directly connected households as well as potential indirect effects on non-connected households. Second, we also assess the impact on those households that are effectively connected in treatment communities. This analysis on household level is called the *Average Treatment effect on the Treated (ATT)*. If all households in electrified communities would connect to the new grid, ITT and ATT would be the same. However, this is not the case in our study. In both cases, the control group are all households in control communities.[5] We thereby notably account for the fact that – as will be shown in the empirical analysis in Section 5 – electricity access via off-grid solar increased drastically over the project cycle, also in the control communities. Technically, we explicitly added a number of control variables related to individual socio-economic household characteristics (see Appendix B for technical details of the adopted estimations).

The challenge with this approach is that, at baseline, one can not foresee who will effectively connect to the grid. There is, hence, the risk that only few connected households are in the final sample. This is a problem, since it goes along with a loss in statistical power. While this turned out to be less a problem in our case, we also sampled additional connected households at follow-up, which doubled the number of connected households in the sample (see again the next sub-section for sampling). The downside to this is that we cannot apply the Diff-in-Diff comparison to these households, since we do not avail of baseline data. Instead, we use them for a complementary cross-sectional *Propensity Score Matching* (PSM) approach. The impact estimate is essentially also an ATT, although with stronger assumptions attached (see again Appendix B). For simplicity, we will call it PSM in the following and use ATT only for the ATT estimate using Diff-in-Diff. In sum, we present ITT and ATT effects using the Diff-in-Diff approach and try to corroborate these findings using PSM.

The number of different types of firms is one of the indicators that are elicited at the level of rural communities. It is an outcome indicator for how electrification affects **rural enterprises** and firm creation. On top of this, we use a small *n* qualitative case study approach to probe into impacts on firm performance and the relevance of electricity in tackling challenges experienced by rural entrepreneurs. In principle, it also follows a Diff-in-Diff technique by assessing the firms' performance in treatment and control communities before and after the treatment. Different from

[5] This control group can be considered as more appropriate than the non-connected households in treatment communities, since the latter group is likely less comparable to the connected households. This has to do with the fact that the decision to connect is usually driven by certain, partly not well measurable household characteristics so that these characteristics cannot be controlled for and would thus bias an impact assessment.

the structured quantitative analysis among rural households and communities, it does so in a qualitative and semi-structured flexible manner. This comparison is obviously less robust and more prone to different sources of bias, but it nonetheless offers insights into how access to electricity affects the micro-enterprises' scope of work.

For both **urban households and urban enterprises**, we apply a simple before-after comparison among already-connected customers. Identifying an appropriate control group for this urban intervention was not possible because towns of comparable size and a somewhat similar quality of electricity provision did not exist in the region. Towns far away from project towns would have been exposed to an uncontrollable number of other changing factors. The before-after comparison requires a stronger assumption than the Diff-in-Diff in that secular changes are not accounted for. A growing local economy, for example, might affect the household's income and thereby income-dependent outcome variables (e.g. expenditures). We therefore carefully discuss changes observed in the urban data and primarily focus on energy-related indicators for which potential changes can more clearly be ascribed to the electricity upgrading intervention.

In addition to effects on classical socio-economic indicators like income and employment we also anticipated effects on convenience and adaptation costs associated with coping with unreliable electricity. In order to assess this, we approximate the willingness to pay (WTP) for improved electricity quality applying contingent valuation before and after the rehabilitation of the grid (for urban enterprises, the WTP was only elicited after). This approach does not require a control group. The WTP reflects the overall value that the interviewee assigns to the improved service and thus not only includes economic benefits (e.g. kerosene savings or income generation potentials), but also convenience factors or subjective security issues. We obtain the WTP using the *double bounded dichotomous choice method.* This method asks respondents for a first stated WTP and then confronts them with follow-up questions on whether they are willing to pay a certain higher or lower amount depending on the first answer. For urban enterprises, we also assess the WTP econometrically in order to gauge the influence of various factors, including the type of business. For that purpose, a two-part model is performed. This method combines a binary choice model[6] that estimates the probability to observe a positive value, versus observing a zero. This is the first part. Conditional on a positive value, an Ordinary Least Squares (OLS) regression model is estimated in the second part. Compared to a standard one-stage model this two-part approach allows to better account for the fact that many enterprises report a WTP of zero, where these zeros can be considered to truly reflect a zero WTP and not a censored negative WTP.

Moreover, a willingness-to-accept (WTA) module is applied asking for the price at which connected households would accept to give up the current unreliable electricity connection. Again, we rely on field-tested tools for the formulation of our WTP and WTA questions (Whittington, 2002; Kremer et al., 2011; Devicienti et al., 2004; Abdullah and Jeanty, 2011; FAO, 2000).

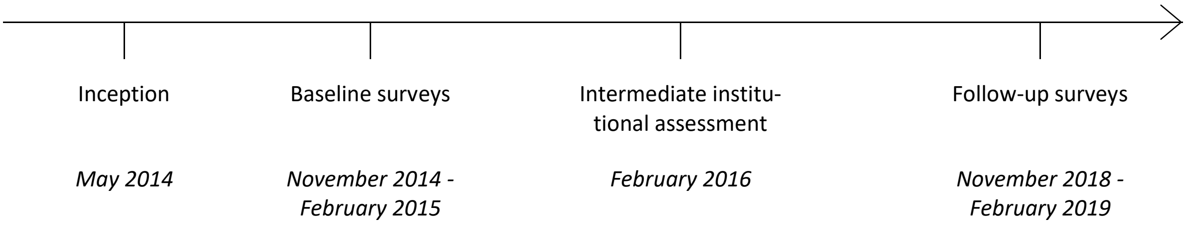
3.3.2. Data collection and sample composition

This sub-section describes the sampling and its implementation in the surveys conducted in rural areas at community, household and enterprise level and among urban households and enterprises. The baseline survey took place between November 2014 and February 2015, and the follow-up survey took place between November 2018 and February 2019. The approach was planned during an

[6] We chose a probit model (instead of the main alternative of a logit model) because it allows to compute cluster-robust standard errors as well as to adjust results for complex survey designs (cf. Cameron and Trivedi 2009).

inception phase in mid-2014 and was fine-tuned during in-country study preparation phases prior to the two survey rounds (see Figure 3 for the in-country study activities).

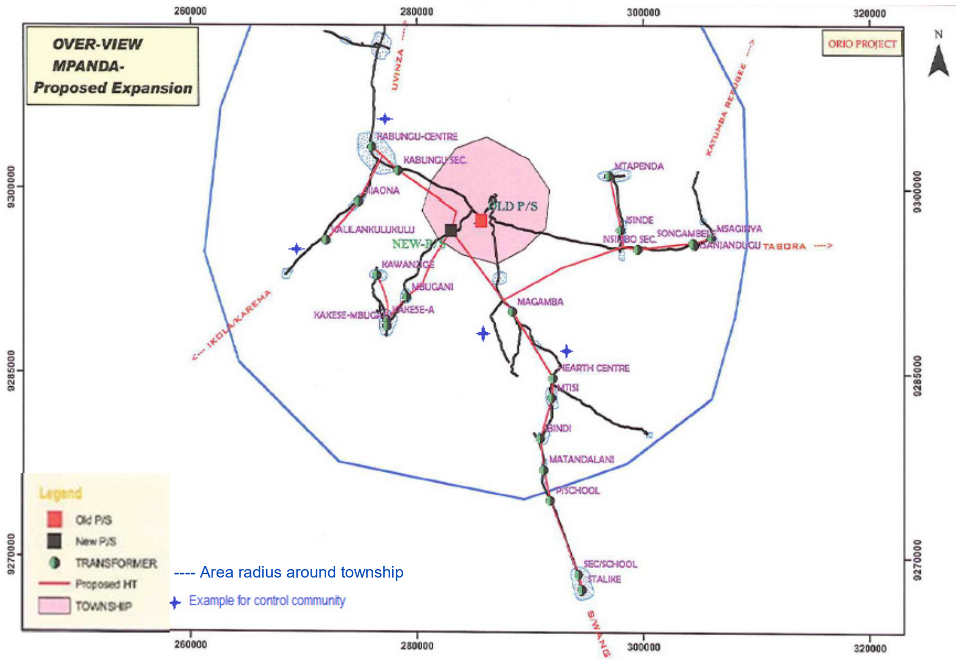
Figure 3: Evaluation study timeline



Rural survey data

The sampling for the rural survey was stratified along three dimensions: Districts, sub-villages, and households. Within the three districts – Biharamulo, Ngara, and Mpanda – the communities targeted by the ORIO intervention were identified, i.e. TANESCO and REA sites. The planned electricity grids often covered only parts of villages, which span several kilometres with scattered households and different sub-villages. About four such sub-villages usually make up a village, each having its own administrative structure. Community data has therefore been collected at the level of sub-villages. Households have then been sampled within sub-villages.

Figure 4: Planned electricity network around Mpanda town



Note: Scale is 1 : 300,000. The blue line is the 20km radius around the power station.

Source: TANESCO

To illustrate this, Figure 4 shows the area around Mpanda town, represented by the large red square in the pink circle. The extensions of the grid (red lines) mostly followed the main roads (black lines). As can be seen in the cases of Kabungu in the North, transformers (green/ black circles) could be placed in multiple sub-villages within the same village, such as in Kabungu centre and the one hosting the secondary school. The sub-villages further away from the main road, in contrast, would usually not get connected. Sub-villages were therefore the appropriate level for sampling households and for conducting interviews at the community level.

The selection of the control sub-villages was based on observable characteristics such as the presence of an economic centre or a primary school, the number of inhabitants, and the economic structure. In addition, they should not be scheduled for electrification within the two to three years after baseline. Control sub-villages were mostly chosen within the radius around the urban centres that were planned to be connected. Alternatively, they could be located slightly further down the main roads outside this radius. For the exemplary case of Mpanda, the location of treatment and control survey sites is shown in Figure A1 in the Appendix.

In total, 54 TANESCO and REA sites as treatment sub-villages existed at baseline. An additional 46 control sub-villages were sampled. This reflected the intention to have a balanced baseline sample between treatment and control sites. Thereby, a 'cushion' of extra control sites was built into the sample, since there was the risk that part of the control sites might later get unexpectedly treated through other electrification interventions and thus get lost as controls. In fact, three sites initially declared as control sites actually got electrified. Another 18 sites changed their status between TANESCO and REA, given that REA took over sites originally planned for TANESCO (as discussed in Section 2; see also Section 4). The sample eventually comprised 58 treatment and 42 control communities: since the status at follow-up is eventually the relevant one, we use this status to define our treatment (TANESCO and REA) and control units for our analysis (see Table 3). Our survey thereby covers 30 of the eventually 38 sites electrified by ORIO/ TANESCO.

Table 3: Sample composition

Beneficiary group		**TANESCO**	**REA**	**Control**	**Total**
Rural communities		30	28	42	100
Rural households	panel data	191	209	322	722
	baseline only (attritors)	57	49	98	204
	baseline only (replaced)	52	22	-	74
	follow-up only (connected)	89	66	-	155
	total	389	346	420	1155
		Biharamulo	**Ngara**	**Mpanda**	**Total**
Urban households	total/ panel data	98	77	75	250
Urban enterprises	panel data	88	104	135	327
	follow-up only (newly created)	28	31	59	118
	total	116	135	194	445

Note: The table does not report 50 attritors among urban households and 150 attritors among urban enterprises.

All 100 sub-village leaders and a random sample of ten households per sub-village were interviewed at baseline, thus leading to a baseline sample of 1000 households. The sampling within sub-villages was facilitated by the fact that lines were usually already demarcated by engineers hired by either REA or TANESCO. Based on the sketches of the planned electricity grids, households were randomly chosen in a corridor of around 100 metres along these planned lines. In control communities, it was estimated on the ground where a line would be placed if the community was to be connected. This would usually be along the main road so that the local road infrastructure served as a means of orientation. Furthermore, households were selected in approximately equal intervals (e.g., every tenth house), depending on the size of the sub-village.

At follow-up, all communities were re-interviewed, but not all households. This was, first, due to attrition, i.e. households that were initially interviewed at baseline could not be traced at follow-up

(20 percent of baseline households), often because they had left the village. A considerable effort was made by the survey team to minimize attrition due to non-traceability.[7] For each attritor in treatment communities, a connected household that was not sampled at baseline was interviewed instead. This connected household was randomly sampled from lists provided by TANESCO. In control communities, no replacement took place. A second reason for not re-interviewing a household was another replacement procedure adopted to further increase the number of connected households in the sample: since households that remained non-connected in treated communities were less needed for the implementation of our identification strategy, some of them could be replaced by connected households from the same communities, again based on the TANESCO customer list. For these additionally sampled households, we thus at least availed of follow-up data to conduct cross-sectional analyses (see Section 3.3.1). The replacement procedure was defined in a way that also a sufficient number of non-connected households in treatment households remained in the sample in order to be able to shed light on the matter as to why they remain unconnected.[8] We account for replacement in our analysis through appropriate sampling weights. In total, we observed 204 attritors and replaced 74 non-connected households in treatment communities while the eventual study sample amounted to 1155 households (Table 3).

Beyond sub-village leaders and households, rural entrepreneurs were sampled purposively in a way that each craft encountered was interviewed at least once in order to get a fair impression about their energy use and productive electricity use potentials. Rural entrepreneurs turned out to be few and mostly small shop keepers. In total, around 50 semi-structured interviews with rural entrepreneurs were conducted, around 20 of them at follow-up.

Urban survey data

For the urban household survey, 100 households were interviewed at baseline in each of the three towns Ngara, Biharamulo, and Mpanda. Urban neighbourhoods (or wards) were chosen based on a probability proportional to size approach. In each ward one TANESCO customer was identified based on available customer registers. Analogously to the rural household survey, then approximately every tenth house was selected, conditional on being a TANESCO customer as well. Similar to the rural household survey, we observed an attrition rate of 17 percent (50 attriting households in total). These attritors were not replaced by other interviewees.

Urban enterprises were sampled within urban wards in a way that equal numbers of the three enterprise types trade, services, and manufacturing were interviewed. Among 477 firms interviewed at baseline, 327 firms could be re-interviewed (attrition rate of 31 percent). Main reasons for this attrition were people moving out of town and firms shutting down. Only two sampled firms did not want to participate in the follow-up. For urban enterprises, we were additionally interested in collecting information on newly created firms. For that purpose, we randomly selected firms from an official business register, which we restricted to firms created after 2016, so after the intervention took place. By doing so we sampled 118 additional enterprises giving us a total of 445 interviewed enterprises in our sample used for the enterprise analysis.

[7] The threat of bias due to attrition is tolerable according to the classification methodology by IES (2017), which accounts for overall attrition and differential attrition across treatment and control. We therefore abstain from attrition adjustment procedures in our analysis.

[8] If the number of TANESCO customers in a sub-village was smaller than, or equal to seven, enumerators were to randomly replace as many non-connected households as possible. If the number of TANESCO customers in a given sub-village was larger than seven, enumerators were to randomly replace only one non-connected household. The household to be replaced were selected randomly.

4. Institutional Assessment

The ORIO programme, as follow-up of its predecessor programme ORET, aimed at the delivery of infrastructural services to the public sector, but – in addition to ORET – also aimed at improving the operations and maintenance of these services.

The ORIO project was implemented during a period of Tanzanian efforts to come to structural reorganisation of the energy sector, simultaneously to a substantial increase of external donor funding for rural electrification. These context factors influenced the ORIO project. The subsequent sections describe these context factors, the main stakeholders, and the Tanzanian policies on electrification (Section 4.1). Within that external context, the ORIO project had to be managed (Section 4.2), while dealing with a continuous process of internal reorganisation of TANESCO (Section 4.3). Subsequently, the effects on project objectives concerning training (Section 4.4), the provision of cleaner electricity (Section 4.5), and operation and maintenance (Section 4.6) are being assessed. The premature finalisation of the project is described at the end of the chapter.

4.1. Energy sector context

4.1.1. General Tanzanian energy sector context

Over the last years, Tanzania's economic growth (7 percent GDP growth per annum) has outpaced population growth (2.7 percent) and contributed to a rapidly increase demand for electricity by its 53 million inhabitants. The national poverty rate declined from 34.4 percent in 2007 to 28.2 percent in 2012 and then to 26.8 percent in 2016 (World Bank 2015; World Bank 2019).

By 2018, one third of all households and 17 percent of rural households were connected to electricity (IEA et al. 2019) and the electricity grid reached 4,400 out of 12,300 villages (Wilson 2018). The installed generation capacity in the country amounted to approximately 1,300 MW at that time (see Table 4), with a vast untapped potential in different sources including natural gas, geothermic energy, and solar. The TANESCO 2018 Tanzania Renewables Portfolio refers to 5,000 MW in geothermal energy, 2,600 MW in hydro and 350 MW in solar and wind energy (Wilson 2018; see also RVO 2018, ch.3 and 8). The electricity generation pattern is substantially different from the beginning of the century, when most electricity supply stemmed from state-owned hydropower plants.

Table 4 also shows that approximately 20 percent of electricity in the off-grid systems is generated by diesel engines. A major constraint is the lack of private investment in energy generation and the vast distances to cover by the transition and distribution grids. High reliance on expensive thermal (diesel, increasingly natural gas) and emergency generation sources made the sector financially vulnerable or even unviable, also since electricity tariffs are rather determined by political considerations than on economic viability and sustainability. International financiers consider poor sector governance, the lack of a creditworthy off-taker, and the lack of cost-reflective tariffs as main reasons for low private sector investment in the energy sector (USAID 2018). Others refer to factors like poor planning and lack of transparency in bidding procedures (Eberhard et al. 2018) and limited technical and financial capacity of indigenous entrepreneurs. Lately, the international donor community has enabled Tanzania to progress in transmission and distribution grid expansion.[9]

[9] The expansion of rural distribution grids, to a large extent implemented by the Rural Electricity Agency (REA) implies also higher costs to TANESCO due to small volumes of electricity supplied to more remote areas with a population with low purchasing capacity. On top, not REA, but TANESCO is responsible for the maintenance to the grid. This increases the financial stress, since the marginal costs for maintenance outpaces by far the marginal increase in revenue from electricity sales.

The national grid covers the Eastern and Central parts of the country mainly, leaving out most of the other regions particularly in the West, where district capitals and other important centres are served by diesel generators. Overall, power supply does not meet the increasing demand with significant blackouts and power rationing as obvious consequences. Nevertheless, over the last decade substantial progress has been made in the electrification of the country, as indicated in the table below:

Table 4: Key electricity data for Tanzania 2010-2018

	2010	2018
Total population (million, estimated)	46	53
Percentage rural population	73	67
GDP (USD billion)	31.4	48.2
GDP per capita (USD)	701.6	1038
Total Grid installed capacity	851.3 MW	1319.5 MW
Maximum power demand	na	1110.7 MW
Electricity generation mix	Hydro: 37%; Gas: 46%; Liquid fuels: 19%; Others: 8%	Hydro: 38%; Gas: 49%; Liquid fuels: 11%; Solar/ biomass: 3%
Electricity imports		< 1% (from Kenya, Zambia, Uganda)
Total off-grid installed capacity	78 MW	84.2 MW
Off-grid dependence on diesel generators	18.9%	18%
Electricity consumption per capita	93 kWh	137 kWh
Total electricity customers	1.032.000	approx. 2.000.000
Electricity connection level	28.6% (55% urban; rural 11%)	32.8% (65.3% urban; rural 16.9%)

Sources: 2010 data: World Bank (2019), Msyani (2013); 2018 data: Wilson (2018)

4.1.2. Main policy stakeholders

The sector's main policy making and coordinating actor in Tanzania is the Ministry of Energy and Minerals (MEM). MEM developed the national energy policy and various related strategies outlined below, among others related to the role of TANESCO in the Tanzanian electricity sector. To date, TANESCO is responsible for generating, transmitting, and distributing electricity to all parts of the country and operates and maintains both the grid system and various off-grid systems, including those in the ORIO intervention areas.

The Rural Energy Agency (REA) is an autonomous body under MEM, established in 2008, to oversee the implementation of electrification projects in rural areas, using the Rural Energy Fund (REF) as established by the Rural Energy Act. Both REA and REF are governed by the Rural Energy Board, which is composed of delegates from different government agencies and the civil society. The Energy and Water Utilities Regulatory Authority (EWURA) is an autonomous multi-sectoral regulatory authority responsible for technical and economic regulation of the electricity, petroleum, natural gas and water sectors in Tanzania.

4.1.3. Energy and electricity policies

Energy is among the six National Key Results Areas identified in the *Big Results Now* initiative launched early 2013 with rural electrification as major focus. The aim of this initiative was to accelerate the achievement of middle-income status by 2025 and the transition out of aid dependency. Major institutional consequences for the energy sector were that the energy supply, transmission and distribution were no longer the sole concern of TANESCO but passed through the President's Delivery Bureau (PDB). Parallel, the Sustainable Development Goals (2015) made Development Partners to move towards the (renewable) energy sector. In Tanzania, Norway, Sweden, DfID, USAID, JICA, AFD and the World Bank intensified their contributions to the energy sector. The ORIO project was implemented against the background of the following energy and electricity policies:

(1) The *National Energy Policy*, still in draft status from 2015, states that energy is one of the important pillars to achieve the objectives of the Development Vision 2025 (MEM 2015; URT 1999). At the time, the government had planned to increase the connectivity level to 50 percent by 2025 and 75 percent by 2033. The policies encompass: (i) the elaboration of a Rural Electrification Master Plan, (ii) strengthening the institutional capacity for effective facilitation, administration and monitoring of modern energy services, (iii) facilitate private sector participation in the provision of modern energy services by providing fiscal incentives to both producers and users, (iv) build appropriate local capacity for manufacture, installation, maintenance and operation of appropriate energy technologies in rural areas. The policy challenge to achieve this electricity expansion rests mainly with REA, while in practice it affects TANESCO, since TANESCO is responsible for operating and maintenance of the systems built by REA.

(2) The *Electricity Supply Industry Reform Strategy and Roadmap 2014-2025* (ESIR, see MEM 2014) is related to the National Energy Policy and follows recommendations made by a series of consultancy reports. Some of these reports were product of discussions in the frame of the Energy Working Group with the main Development Partners present in the energy sector, such the World Bank, Norway, DfID, African Development Bank, and Sweden. The ESIR was welcomed by Development Partners and translated in an array of new projects to extend the electricity grid through support to REA. The Roadmap proposes to transition to a retail competition model in a staged approach of unbundling TANESCO generation, transmission, and distribution services to be completed in 2025. According to this model, transmission companies would remain under ownership of the Tanzanian government and facilitate the supply of electricity from generators to distributors, both of which would operate as separate public or private owned companies. This process, however, is stalled as of 2019. The Roadmap also envisages an increase in installed power producing capacity to 10,000 MW, as well by 2025. The Roadmap further indicates the provision of resources enabling TANESCO to pay off its debt.

(3) In 2016, the proposal for a major *electricity tariff increase* dominated the debate in the electricity sector. The tariff increase was among the measures proposed by TANESCO to reduce its high debt and to finance increased supply and maintenance costs, as well as its investment plan. It was also a condition set by World Bank to disburse a USD 250 million loan. TANESCO applied for an 18.5 percent average tariff increase and an 8.5 percent increase was approved by EWURA. However, even this increase was opposed by (mainly industrial) consumers and finally revoked by an intervention of the President of the Republic, who afterwards sacked the managing director of TANESCO. The subsequent demotion and firing of several of the utility's senior executives caused some upheaval and uncertainty among TANESCO management and staff.[10]

(4) To implement that Reform Strategy, MEM published the Tanzania *Power System Management Plan* (PSMP 2016). According to the PSMP, projects would be developed requiring investments of some USD 43 billion by "the government and/or the private sector", but no measures were taken to allocate more state resources to power developments or to attract more private players into the sector (Bhati and Koshy 2018).[11] Private developers were reluctant to invest given the frequent political interventions in TANESCO and the supposedly independent regulator EWURA.

[10] Information gathered in interviews with Dutch stakeholders in 2018 and 2019.

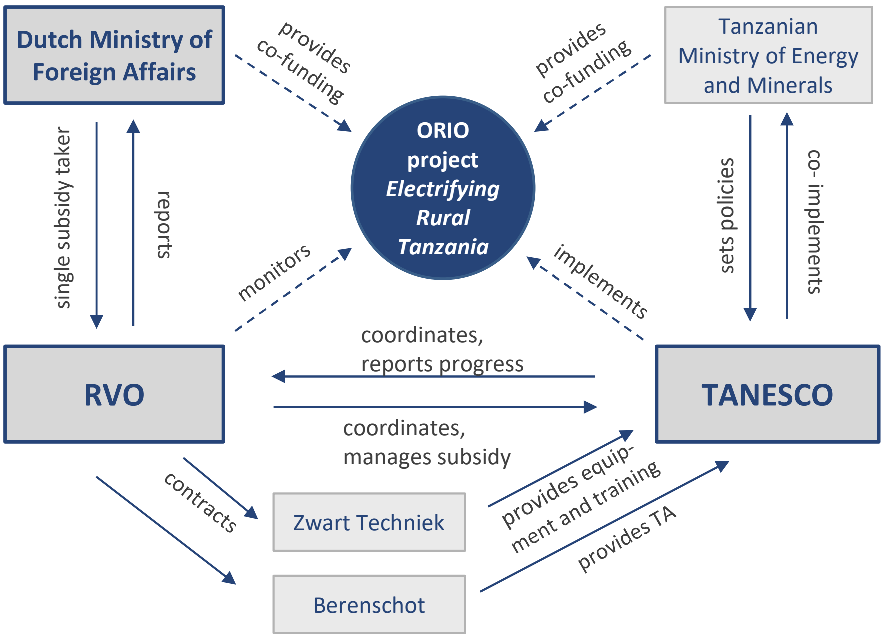
[11] In their analysis of the PSMP, Bhati and Koshy (2018) also concluded that demand projections were overly optimistic, and that the generation response was through gas-fired and coal-fired electricity supply with low attention to renewable sources. See also Clyde and Co. (2017).

(5) Related to the PSMP 2016, the *Electricity Sector Re-organisation Regulations* was published indicating a time schedule up to 2025, with as first step the unbundling of the electricity generation, envisaged to be completed by end 2017, followed by the unbundling of transmission from distribution (with EWURA as key actor) in mid-2018. By 2018, TANESCO was still in a take-off stage, having discontinued EPPs upon expiry of their contracts, and government investments still focused at gas-fired generation.

4.2. ORIO project management

The overall ORIO project management is sketched in Figure 5. It primarily rested with the three entities in bolder frame: (i) TANESCO – and here the Department for Thermal Generation as the formal Tanzanian partner –, (ii) RVO, and (iii) the Dutch Ministry of Foreign Affairs (in particular the Sustainable Economic Development Department (DDE)) at a certain distance.

Figure 5: Organisational structure of the ORIO project management



Source: own representation

4.2.1. The Tanzanian electricity utility company TANESCO

In 2011, the Tanzanian request for support through ORIO for delivery of Zwart Techniek generators was a 'regular' request for support by the international donor community. Over time, the increased support to REA for the expansion of the transmission lines and distribution network, also in the target districts of the ORIO project, changed the context for the ORIO project. While in 2011, ORIO support was one of the few support programmes to TANESCO, after 2015 it had become one among the many international support programmes. TANESCO modified its ORIO-related activities accordingly, with consequences to the use of the Biharamulo equipment and the distribution network extension.

TANESCO's management role encompassed the contracting of construction companies (platforms for the generators, distribution lines), the organisation of trainings (health and security; SME training; selection of candidates for training by Zwart Techniek). All these technical tasks were implemented properly, although with some delay (there was a lack of demand for the SME training). For administrative and reporting tasks to RVO, TANESCO had contracted the services of Berenschot. Berenschot was the consulting partner during the development stage with RVO as contracting authority and a 50 percent financial contribution by TANESCO. For the implementation stage TANESCO contracted Berenschot directly. The main purpose was to support TANESCO with reporting.[12]

4.2.2. The Dutch implementing agency RVO

RVO is an experienced agency entrusted with the implementation of all kind of subsidy and incentive programmes for private sector development on behalf of the Dutch government. Contrary to development organisations, RVO deals exclusively with commercial partners and hence all activities are based on contracts. As is common procedure in RVO, an ORIO desk was established, and specific staff was dedicated to the management of the programme. Over time, different RVO experts were in charge of the ORIO activities in Tanzania.

RVO used its experience (with ORET and other programmes) to detail the financing conditions and reporting criteria. During the preparation stage, working groups were set up by Berenschot between TANESCO, Zwart Techniek, and the trade attaché in Dar es Salaam, with sound communication to RVO. The institutional environment changed quickly. Since the Netherlands did not join the energy sector working group in Tanzania, the embassy was not always fully acquainted with the ins and outs of the energy sector in general and of TANESCO in particular. Although direct relations existed between the embassy and RVO, RVO became dependent on information from third parties (KfW, Zwart Techniek).

4.2.3. The Dutch Ministry of Foreign Affairs

The Ministry of Foreign Affairs had launched ORIO as successor of the ORET programme with as assumed improvement that the support was not restricted to the delivery of goods and services, but also included a development and preparation stage, as well as an operation and maintenance phase.

To the Ministry of Foreign Affairs, the ORIO programme was a subsidy arrangement with one single responsible entity for implementation: RVO. Hence, there is no direct relation between the Ministry and the subsidy users (commercial companies) and beneficiaries (in this case, TANESCO). The embassy of the Kingdom of the Netherlands in Tanzania is informed and was actively involved.

After a mid-term review by Carnegie Consult (2013) it was precisely this three-staged approach that was criticized; the review recommended disentangling these phases in order to enhance innovation and competition. Shortly afterwards, in May 2014 the Minister for Foreign Trade and Development Co-operation announced the discontinuation of ORIO and launched the successor programmes Developmentally Relevant Infrastructure Investment Vehicle (DRIVE) for middle-income countries and Development2Build (D2B) for the Least Developed Countries (Kamerstuk 33625, nr.97).

The Ministry urged RVO to speed up implementation. This start was further complicated by the fact that TANESCO faced problems to make the financial resources available to start construction works at the indicated sites. In June 2015, RVO increased the pressure by indicating in a letter to the Ministry of Finance of Tanzania that the grant would be prematurely discontinued. On top, the supply of diesel engines could hardly be matched with the Ministry of Foreign Affairs' policy to actively promote renewable sources of energy (Ministry of Foreign Affairs of the Netherlands 2008).

[12] TANESCO was aware the reporting was not precisely their professional strength and that by contracting Berenschot it would be better equipped to respond to the Dutch requirements and expectations regarding reporting.

TANESCO's argument that old, degenerated engines would be replaced by cleaner ones and the old ones would be dismantled was reluctantly accepted.

The Ministry of Foreign Affairs was not in favour of dwelling in a decade-long O&M stage. The embassy in Tanzania remained informed but did not assume an intermediary role when relations between TANESCO and RVO had soured (see Section 4.6).

4.3. TANESCO (re-)organisation

4.3.1. Reorganisation and the ORIO project

Since the initial stages of ORIO support to the Tanzania rural electrification programme in 2011, TANESCO has gone through a continuous process of reorganisation. This reorganisation has aimed at the modernisation and financial sustainability of electricity services in Tanzania, as expressed in the Electricity Supply Industry Reform Strategy and Roadmap 2014-2025 (ESIR).

In 2018, a Parliamentary committee on the mining sector concluded that the energy ministry was too large to be effective and that corrupt practices went unnoticed. The President decided to split the Ministry of Minerals and Energy into two portfolios, each with a separate Minister. The former deputy became Minister for the energy portfolio, responsible for state investments in a crude oil pipeline, upstream gas developments, state-led electricity-generation projects and donor-backed schemes to expand electrification. The step towards improved governance was also meant to deter the sharp deterioration of relation with private investors after the 2016 political intervention on electricity tariffs (EIU 2019). By late 2018 part of the higher management of TANESCO was moved from Dar es Salaam to the official government capital Dodoma.

The TANESCO reorganisation is of importance for the ORIO project, since it determines (i) the current and future financial sustainability of the electricity services supplied, as well as (ii) the future ownership and operational management of the generators. Both TANESCO staff and RVO programme management staff alike flagged[13] that the reorganisation absorbed a lot of time and attention of the organisation, while the transfer of high management to Dodoma did not contribute to smoothen communication and governance.

4.3.2. Decentralisation and management at district level

TANESCO has a workforce of approximately 4,900 persons as of 2019. TANESCO is a centralised organisation, despite its 23 regional offices (plus five on Zanzibar) and many district representations.

At district level there is neither a district budget nor management of financial resources.[14] Planning, extension of services, technical positions, training, communication and other activities are all determined at headquarters. There is neither a Rural Electrification Master Plan, nor district level electricity management plans, nor district level grid maintenance plans. Maintenance on generators is done according to manufacturer's instructions. Whatever is needed for operations and maintenance has to be requested from headquarters, such as moment of shutting down the generator for maintenance, and the supply of consumables and spare parts. In case financial resources were exhausted no repair can take place, while consumables (such as filters) are procured according to the maintenance schedules by the manufacturers, which are not always optimal for

[13] Information gathered in interviews with RVO programme staff (2019) and with trained engineers, 2018.

[14] Not in terms of budget management, but also not in revenue administration. The income captured from pre-payment is transferred directly to Dar es Salaam. There is a daily consolidation through the bank system.

Tanzanian circumstances.[15] At district level there is neither insight in the cost structure of the equipment, nor in the financial efficiency of the equipment, nor in the financial feasibility of extension of services.

Referring to the ORIO supported supply of generators there are consequences for the operations and maintenance, as well as sustainability of the generators. The centralisation may affect the quality of maintenance (timing of maintenance, availability of consumables and spare parts), while the proper maintenance of equipment is challenged by lack of diagnostic tools[16], also because there are no options to procure these tools or (additional) consumables at district level.

4.4. Training of TANESCO staff

In 2011, when the ORIO Training Plan (TANESCO and Berenschot 2011) was elaborated, the opportunities for in-house training at TANESCO were minor only[17], while training was considered an important component of the electrification programme in Tanzania, forming part of a broader effort to enhance capacities in the electricity sector in Tanzania.[18] In accordance to the ORIO Training Plan, the ORIO project encompassed the following training components:

- Project Management training. This training by Berenschot and the Management for Development Foundation (MDF) to two TANESCO officials was completed in 2014. One of the two officials retired in 2015, the other official was responsible for thermal electricity generation (and in charge for the ORIO project).
- Health Safety and Environmental Training to all TANESCO staff in Biharamulo, Ngara and Mpanda, to be delivered by the TANESCO Department for Safety and the Environment. These trainings were delivered as component of TANESCO's regular training programme without any specific component or funding from ORIO (Cornelissen 2016).
- Small Business Development Training envisaged to approximately 65 entrepreneurs per region (200 in total) on the productive use of electricity. The training was planned to be delivered by the Moshi University College of Co-operative and Business Studies (MUCCoBS), contracted and organized by TANESCO, while funded by ORIO. District Managers were involved in the identification of companies or entrepreneurs in their area that might be interested in such a training. In practice however, it was hard to identify interested entrepreneurs (survey results indicate that the number of rural enterprises is modest, while companies in the urban areas did have experience with electricity (the three generators replaced existing facilities mainly). As of May 2018, SME training took place once as a small-scale pilot.[19]
- Operation and Maintenance training to technical staff. This training was initially envisaged for six mechanical and two electrical engineers, but later expanded to three times eight

[15] TANESCO engineers indicated that certain filters have to be replaced more frequently than indicated in the maintenance schedule. These filters are stocked according to schedule, however. In absence of these filters, these are either not replaced in time or 'creative solutions' are applied on the spot.

[16] Information gathered in interviews with mechanical and electrical technicians, 2018, 2019.

[17] Since 2014, TANESCO counts with its own training centre for technical processes, IT, finance and management.

[18] A consideration to this effort was that the Netherlands envisaged opportunities for private sector development. In 2016, the Royal Netherlands' Embassy in Dar-es-Salaam reiterated to consider the energy sector a potential area of interest to the Dutch private sector. The Ministry of Foreign Affairs allocated 2 million Euro for capacity development and energy oversight institutions.

[19] Information retrieved in interview with RVO programme management, 2019.

technicians[20] not restricted to the three sites. Three trainings in equipment by Anglo Belgian Corporation (ABC) were organised and delivered by Zwart Techniek in the Netherlands and Belgium in 2016 and 2017. The 24 trainees were selected by the Training Department in coordination with the District Managers. The Department made a deliberate choice for mixing experienced with younger engineers (four engineers over 60 years[21], ten under 40 years, all male, mix of hierarchical functions).

In our assessment, we particularly focused on the effectiveness of the Operation and Maintenance training as the key training for the sustainable use of the ORIO-funded equipment. Based on the interviews with the 24 trainees, half of the participants considered that the training met their expectations in full, while one responded that the training did not meet expectations at all. The remainder indicated that expectations were partly met, with the main remark that the time had been too short. A few participants criticized that the training involved the use of analytical and measurement tools not at hand in Tanzania.

The training did not have an effect in either the position, career or salary of the trainees in TANESCO, but five out of the 23 respondents were invited to train and inform their direct colleagues who did not attend the course and /or were sent to other stations to provide assistance in case of operational problems with Zwart Techniek generators. Two of these five engineers were given the opportunity for further (long-term) training (one in Tanzania, one in Bahrein). Among the 20 technicians still working for TANESCO, 18 perform duties directly related to the operations and maintenance of Zwart Techniek generators.

All engineers from Biharamulo, Ngara and Mpanda indicated that the knowledge acquired cannot be applied, since maintenance requirements are negligible, because the new equipment is under guarantee and most maintenance is still handled by Zwart Techniek. On top, some of the equipment is used as stand-by only and hence do not require frequent maintenance.[22] To technicians working with older ABC equipment, maintenance knowledge is not considered the main bottleneck; the main constraint is the internal TANESCO procedures.

4.5. Greening of TANESCO's electricity supply

The Tanzania Government's policy documents outlined in Section 4.1 pay attention to the greening of energy and electricity supply and private (foreign) investors are invited to invest in renewables. In this context, Tanzania has also developed and adopted a 'Sustainable Energy Action Agenda' with a corresponding investment prospectus (for private investors), as part of the Sustainable Energy for All (SE4ALL) initiative. The Agenda set targets for 2030 of achieving more than 75 percent access to electricity, as well as at least 50 percent of renewable power. Tanzania also receives World Bank ESMAP[23] support in the area of renewable energy. The attention for geothermal, solar and wind renewables is also based on the tendency that the East Africa's previously predictable rainy seasons have become uncertain due to climate change, curtailing output of hydropower plants.

[20] The training of at least eight technicians were funded by ORIO resources (TANESCO 2016). Since TANESCO also purchased Zwart Techniek equipment (incl. training) beyond the ORIO project, the sources of funding of the training of the 16 other technicians are combined.

[21] Most likely, to engineers in the age bracket above 60 years, the training was also an 'award' for their services.

[22] Not all 'consumables', such as water filters are suitable for Tanzanian circumstances and have to be replaced prior to the moment in the maintenance schedule indicated by Zwart Techniek, resulting in insufficient stock of these spares and consumables.

[23] ESMAP is a partnership between the World Bank and 18 partners (incl. the Netherlands) to assist low- and middle-income countries to reduce poverty and boost growth through the provision of renewable energy.

In practice, a series of smaller renewable projects are all moving through their planning stages (EIU 2018), Tanzania's own investment is mainly in gas to power (3,900 MW additional 2014-2025; gas-fired plants [including two large offshore plants] near Dar es Salaam) and coal (2,900 MW additional 2014-2025, in particular a coal-fired power plant in Mbeya). This investment priority on gas and coal is based on the assumed lower costs of these energy sources and the technical consideration of rapid expansion.[24] In practice, in rural Tanzania a private sector parallel system is developing: Tanzania is a hotspot for the distribution of pico-solar lighting products and the development of mobile-based, pay-as-you-go business models for solar products.

Figure 6: Old diesel generator at Ngara

The ORIO project was not destined to renewable sources of electricity, since these were not considered viable options compared to diesel power plants that were preferred for the short time from machine order to commissioning, the low initial costs and the delivery of quality power at desired time (see TANESCO 2011*c*, p. 59). However, it did contain the 'greening' by focussing on the replacement of old polluting generators by more fuel efficient and cleaner ones. Concerning fuel efficiency, the generators turned out to generate lower fuel savings than projected by TANESCO (TANESCO 2011*b*). While it was expected that the specific fuel consumption (litres per kWh) decreases by between 43 and 48 percent, depending on the site, actual reductions amounted to 15 to 19 percent. Only for Ngara, inflated baseline fuel consumption values in the original projections can be blamed to have contributed to this difference. Otherwise, the main reason is that the new generators in fact consume more than projected. While it is beyond the scope of this study to disentangle different potential reasons, it could possibly be due to fuel quality and local climate conditions (ambient temperatures and humidity).[25]

To further reduce fuel inefficiency, air pollution and environmental damage due to spillage, the Grant Agreement contract between the Government of Tanzania and RVO for the utilisation of the ORIO resources furthermore foresaw the dismantling of the old generators. An amount of EUR 90,000 had been set aside to that end (see also TANESCO 2011*e*, p.40). In 2016, TANESCO headquarters was firm in its position that dismantling would take place once the new generators would be operative[26], while the disposal of the generators would be contracted out (tender). As of late 2018, of the eight old generators, four serve for spare parts, one remained as (an effectively non-used) stand-by service

[24] Bhati and Koshy (2018) indicate that the assumed higher costs of renewables in Tanzania are mainly due to the cost of distribution of renewable energy (DRE), but that modular technology options for DRE result in a viable option in terms of costs.

[25] Information received in email exchange with Zwart Techniek, 2019. Zwart Techniek assumes that lack of appropriate operation and maintenance may play a role as well, although Zwart Techniek catered for maintenance during the first year of operation. For Ngara and Biharamulo, low load running can also be a contributing factor. Finally, measurement problems or fuel supply inconsistencies may theoretically also play a role. However, note that TANESCO uses simple diesel (Gas Oil) with the new generators instead of Industrial Diesel Oil (IDO) used before and assumed to be used by the ORIO generators as well (TANESCO 2011*c*). IDO is a blend of heavy fuel oil and diesel and has a lower heating value per ton (cf. SenterNovem 2004, p.7) and, hence, also per litre (for being heavier). The fuel use should thus have rather improved the efficiency in kWh per litre.

[26] Information received in interviews with TANESCO, 2016.

and three were transported to other areas to serve – at least as a bridging solution[27] – for local electricity supply in Inyonga, Mdaba, and Tunduru.[28] The relocation and dismantling of the old generators has been subject of conversation and correspondence between RVO and TANESCO staff during various occasions, also given the relatively high costs of relocating the generators.

A positive side-effect was that the discussions about renewable energy in the context of ORIO contributed to awareness of Zwart Techniek that the international (donor) community had become reluctant to diesel engines (part of their portfolio is funded by development donors). In consequence, Zwart Techniek intensified its research and development in the combination of solar and diesel, adapted to 'harsh' conditions and operating without batteries. Zwart Techniek is now among the industry's leaders in 'context measurement' data knowledge and application for the practical operation of combined generation systems.[29] A first combined system was installed in Tanzania.

4.6. Operations and Maintenance phase

In the proposal for the Tanzania rural electrification project it was stated the electricity supply by the mini-grid systems in the medium and long term was challenged by the lack of adequate consumables and spares, as well as flaws in the technical knowledge on how to conduct and finance 'second level' repairs (repairs that cannot be conducted by TANESCO staff and for which external expertise is required). The ORIO project encompassed an Operation and Maintenance phase that was to follow the implementation phase. In its original design laid out in Mwantinda et al. (2011), this phase would cover a period of 30 years. ORIO would be co-financier of maintenance costs in the first 10 years. The establishment of a Fund for contracted (larger) maintenance of the electricity stations at Mpanda, Ngara and Biharamulo as well as the distribution network realised by the ORIO project was envisaged. It would cover the so-called *level two* maintenance activities. To that end the Tanzanian Ministry of Finance and Economic Affairs had issued a draft commitment for 50 percent of the costs to complement the ORIO financial contribution.[30]

Since Zwart Techniek delivered other generators of the same kind ('ABC generators') prior to and parallel to the ORIO project and since the electricity transmission and distribution network expanded rapidly as a result of intensified efforts to electrify rural areas in Tanzania, it was not realistic to separate the ORIO project delivered engines and network from the general system. In 2016, the O&M concept was modified and extended to ABC generators and connected distribution networks in general.[31] RVO shared Berenschot's view[32] that maintenance had to be perceived in a long-term perspective in order to contribute to durability and that the emphasis of that level two maintenance

[27] This could be witnessed with one old generator from Ngara, which was relocated to Mdaba in Ruvuma region in Southern Tanzania, where it served from December 2017 till October 2018. The distribution grid was already in place there but a generation facility or transmission grid connection was lacking. Now, the place is connected to the national grid via the Makambako - Songea line and the old generator will likely be dismantled together with other old generators that have become idle because of this new transmission line (namely in Songea, Mbinga, Ludewa, and Namtumbo).

[28] Information received in interviews with TANESCO, 2018.

[29] Information gathered in Interview with Zwart Techniek, 2019.

[30] Note that ORIO was – unlike its predecessor programme ORET – untied aid, but the OECD concessionality criterion still had to be taken into consideration. TANESCO's own contribution was of importance to remain within the conditionality restrictions.

[31] According to Zwart Techniek (interview 2019), there were approximately 30 Zwart Techniek generators in operation by 2019: 8 prior to ORIO, 6 with ORIO and some 15 generators were installed afterwards (not all to TANESCO, but also to private owners).

[32] Information retrieved in interviews with Berenschot in 2016 and 2019, and RVO in 2019.

should not be expected in the first years, but precisely in later years. However, all stakeholders involved lacked a clear view on how this O&M phase could be defined and made operational.

In 2014, when the development stage of the project was still ongoing, the Ministry of Foreign Affairs observed that preparation took more time than expected and that the implementation stage had to start as soon as possible, this also in the light of budget availability. This position was further stressed by the formal finalization of the ORIO programme in 2015. Prior to having clarified the O&M phase, the arrangement with Zwart Techniek for the delivery of the generator sets was set in motion, as were the construction of the installation platforms in Tanzania as well as the contracting for the distribution networks with the national companies NAMIS Corporate (Biharamulo and Ngara) and Nakuroi Investment Company (Mpanda) for in total 166 km of medium voltage lines (33kV); 44km of low voltage lines and the construction and technical installation of 44 substations.

TANESCO was responsible for constructing the platforms and fencing at the plant sites. When financial resources happened to be not available to that end, RVO considered a premature discontinuation mid-2015, but tendering of the construction of the platforms was set in motion soon afterwards. In the meantime, the commissioning of the power plants by Zwart Techniek had taken place already by the end of 2014**.**

The assumption was that when all contracting procedures would have been finalised, also a final O&M proposal would be ready (2015).[33] If ORIO would contribute with EUR 6 million, this would have required EUR 6 million in counterpart funds as well, and although TANESCO had signed a commitment to that end, it faced serious financial constraints at the time. No procedures about management and drawing rights of these funds had been elaborated (Cornelissen 2016).

In this context of the fragile financial position of Tanesco RVO was reluctant to accept TANESCO's proposal to secure the funding needed for the O&M phase out of its operational budget.

Another uncertain factor was how to put the maintenance component in the market, in particular the soft components[34] RVO is a contract management agency and the O&M stage had to be contracted out. Any commercial company that assumes the support to the O&M stage needs a guarantee that the counterpart (TANESCO) has capacity to pay for its share to the services. Although banks are willing to provide buyer's credit[35] to governments, (if and when covered by an export guarantee, in this case by Atradius) usually this is for a period of maximum three years only and preferably for 'hardware' components, not for soft components like training.[36] The envisaged duration of the O&M stage played a more important role than the soft components, since the latter was rather small in this project.

In the meantime, in 2015, TANESCO had launched a framework contract to suppliers for spare parts, and for technical assistance. Among the spare parts contracts awarded for a period of three years, one was with Zwart Techniek (period 2016-2018).[37] According to RVO this tender was never

[33] Information retrieved in interview with RVO programme management, 2019.

[34] This uncertainty was not exclusive to this project but refers to various ORIO projects.

[35] Buyer's credit is a short term credit available to an importer (buyer) from overseas lenders such as banks for goods they are importing. The overseas banks usually lend the importer (buyer) based on the letter of comfort (a bank guarantee) issued by the importer's bank. The duration of buyer's credit may vary from country to country, but usually does not exceed one year for tradeable goods and three years if the import is for capital goods.

[36] Information gathered in Interview with ORIO programme management, 2019. On top, RVO had to take into account the debt sustainability threshold according to the IMF debt sustainability assessments, for which the condition is that the grant component meets the concessionality criterion (OECD).

[37] TANESCO's benefit would be in order spare parts directly from Zwart Techniek without passing through a competitive bidding process and / or avoiding accumulation of unused stock at TANESCO warehouses.

communicated to RVO. To RVO it was a concern that the ORIO generators were delivered with a warranty covering a one-year supply of consumables and spares,[38] assuming full utilisation of the generators. Since some generators were used for stand-by only, the supply of spares would last for a longer period. Despite this guarantee (and the framework contract), TANESCO's estimates of the required spare parts for the O&M phase were extraordinarily high.[39]

Late 2016, a new proposal had been elaborated for the O&M phase. This new proposal basically referred to the procurement of spare parts during a four year period after completion of the ongoing spare part programme with Zwart Techniek (up to 2018), as well as the dismantling of the old generators.[40] According to the ORIO grant arrangement, the funds should not be used for operational expenditures. For operations and maintenance this was a complicating restriction to the design and in fact 'invited' to consider spare parts mainly.[41] After the presentation of a third draft in 2017 (see TANESCO 2017), RVO reacted with a formal rejection. Afterwards, no final proposal was presented.

4.7. A premature finalisation and programme constraints

Over time, the initially sound and smooth relations among the stakeholders concerned soured due to an accumulation of mutual irritations leading to a gradual erosion of trust and confidence.

TANESCO, Zwart Techniek and to a lesser extent Berenschot consider the rotation and change of staff at RVO contributed to a deterioration of mutual trust. To quote a remark by a TANESCO district manager: "RVO considers the *contracts* as critical factor, we the *contacts*". According to TANESCO, RVO showed little sensitivity for the changing environment and the political pressure in Tanzania, while RVO argued to have been open and flexible to that context.

Over time, RVO's irritations increased with TANESCO and encompassed gradually Zwart Techniek as well To RVO, the major point was the late – or no – information from TANESCO about developments affecting directly or indirectly the ORIO programmes, such as the KfW funding enabling the extension of the national grid in the Biharamulo and Ngara regions. To RVO, the concern was not about the new extension, but about the lack of communication and information. In fact, RVO was in favour of changing locations to areas lacking electricity, so the generators could operate at full capacity and not as back-up or stand-by (Biharamulo). But to TANESCO this was not possible in terms of works already contracted and politically not feasible.[42]

A rather ongoing issue was about the dismantling of the old generators. The objective of the new generators was to replace the old polluting ones and financial resources had been set aside to that end. TANESCO indicated frequently to dismantle the old machines but postponed the moment to do so continuously and even started to transport some old generators to other locations at a high cost, without informing RVO about this alternative use.[43] RVO felt that TANESCO did no longer consider

[38] Information retrieved in interview with RVO programme management, 2019.

[39] In the various proposals elaborated by TANESCO the required budget always summed to the maximum amount available for the O&M phase.

[40] TANESCO put the dismantling under the O&M phase in order to buy time since the old generators still had operational functions.

[41] Neither TANESCO nor RVO explored alternative options, such as supply of measurement tools for the ABC equipment, and /or the structural improvement of the in-house training (facilities and course delivery, scholarships).

[42] TANESCO had contracted construction works for new platforms and fencing at Biharamulo station. The north-west area of Tanzania is the constituency area of the President.

[43] Source: RVO in comment on draft report, 2019.

the dismantling as part of the Grant Agreement, aggravated when TANESCO inserted the dismantling as component of the O&M stage (2017).

At terms of financial administration there were differences as well. . Since part of the resources for the network extension had been used – at the request of TANESCO – to cover additional costs for the implementation of the Biharamulo and Ngara works, later payments for the extension of the distribution network could not be fully compensated by ORIO. RVO's deduction of the previous costs caused serious problems to TANESCO, causing feelings of discomfort.

In three instances, the budget proposal for the O&M phase (in RVO's view three times higher than the real requirement), was "the straw that broke the camel's back".[44] After RVO had rejected TANESCO's budget proposal for the O&M phase, TANESCO refused to re-elaborate the progress report. RVO called upon the embassy in Dar es Salaam to intermediate between the parties. Although the embassy initially agreed to do so, later it preferred to avoid a confrontational discussion. RVO concluded that it would be better to end the relationship. As indicated by RVO: "both parties regained their freedom".

In the view of the evaluators, the relations between TANESCO and RVO deteriorated due to lack of understanding of each other's interests, responsibilities and contractual obligations[45]. Since the Netherlands, unless its interests in the energy sector in Tanzania, did not join the energy sector working group in the country, information about new developments and positions were communicated to RVO by third parties. TANESCO did not take initiatives to inform RVO timely. RVO may have underestimated that TANESCO was subject to a continuous reorganisation process and subject to political influences, while RVO's position – as intermediary – with contracts with commercial companies – was possibly not well understood by TANESCO (RVO is not a development agency, as most of TANESCO's partners). Intermediation by the embassy was requested at a rather late moment in time. . Although the request for intermediation by the Netherlands' embassy was a logical step, RVO could have opted for an independent negotiator (for example the chair of the Energy Sector Working Group) at a much earlier stage.

The dismantling of the old generators was an ongoing subject of debate between TANESCO and RVO. In a closed and static environment, the assumption that the replacement of old machines makes these superfluous and hence ready to be dismantled is logic, but in a dynamic environment with a rapid expansion of rural electrification and pressure to set up mini-grids, the demand for generators is larger. While TANESCO decided to transport some of these generators at a high cost in RVO's view, it would have been more efficient to transport a new generator from Biharamulo[46]. In the medium term it is not in TANESCO's interest to keep inefficient generators (so they will be taken out anyhow) and, it is questionable whether the dismantling of the old generators would have contributed more to development than their continued operation.

The O&M phase did not materialize, implying that one of the objectives of the ORIO programme was not achieved: maintenance and sustainability have not been anchored better as compared to the predecessor programme ORET. In part this is due to an omission in the design of ORIO, since it remained unsolved how to arrange for a maintenance stage through a private sector arrangement, while the grant arrangement establishes that no operational costs can be covered by the ORIO

[44] Source: RVO in comment on draft report, 2019.

[45] In its comments on the draft report, RVO indicated to disagree with this view and that RVO had been open and has showed flexibility. In view of RVO the crucial issue was the lack of comunication and information

[46] Source: RVO in comment on draft report, 2019.

subsidy. RVO experienced the grant agreement ("schenkings arrangement") increasingly as a straightjacket in the management of ORIO, restricting its flexibility to adapt to circumstances.

From the perspective of private sector development, the ORIO project did contribute to a strengthened position of a Dutch company in the electricity market in Tanzania and beyond. Although Zwart Techniek had already delivered generators to public and private clients in Tanzania, the ORIO project did contribute to the presence of the company, as expressed by delivery of at least 15 generators afterwards (2018). The preference for the Dutch equipment did not remain unnoticed in other African countries, like Burundi, Mali and South Africa, where sales increased as well.

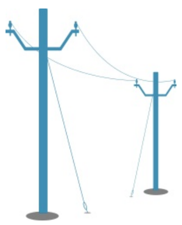
The outputs and intermediate outcomes of the ORIO intervention and its three core activities of the implementation phase are summarized in Box 4.

Box 4: Summary of key output and intermediate outcome indicators of the ORIO intervention

ORIO intervention » **Output and Intermediate Outcomes** » Outcomes » Impact and Cost-Benefit

Replacement of old diesel generators by new models

- total generator capacity in the three towns increased by 90 percent (from around 4 MW* to 7.5 MW)
- two sets of two generators each serve as back-up facilities in Biharamulo and Ngara as the towns are now connected to the central grid
- the generators in Mpanda as main electricity source running 98.8 percent of the time since they went online in mid-2017, leading to an increase in electricity production by about 25% there
- mean hours run per generator and month of 150 (Biharamulo and Ngara**), and 720 (Mpanda), compared to an expected 610 hours
- total electricity production of 15 mio. kWh per year
- generator efficiency in terms of litres/ kWh improved by 15 to 19% (compared to an expected 43 to 48% improvement)
- old generators have not yet been dismantled but are rather dismantled piecewise by serving as spare parts stock for other generator-run TANESCO sites or as short-term electricity source in other off-grid areas



Grid extension to rural areas around the towns

- in line with planned figures, the project installed 171 km of 33 kV lines, 50 km of low voltage lines as well as a total of 42 sub-stations (planned figures were 171 km, 44 km, and 44 sub-stations, respectively)
- in line with planning, REA subsidized household connections at a rate equivalent to the value added tax of 18 percent on the usual connection charges; the subsidy was available for about two years after the respective community was electrified, but not later than end of 2018

Complementary trainings and technical assistance

- TANESCO trainings occurred in line with planning
  - » 24 staff members in O&M training
  - » 66 staff members in health, safety and environment training
  - » 2 head office staff in project management training
- Only a pilot training to a small number of enterprises conducted

Note: * The baseline total generator capacity is determined based on the maximum sustained load of the individual generators as indicated in the monthly Power Station Reports prepared at each of the three sites. It is clearly higher than the 2.2 MW considered as available capacity (as of 2009) in the project design phase according to the calculations underlying TANESCO (2011*b*). ** The Ngara value refers to the time since connection to the central grid in April 2018. Before that, the average in Ngara was 400 h, which is lower than in Mpanda, since oftentimes only one of the two generators was lit due to lower power demand in Ngara.

Sources: Monthly Power Station Reports for the three sites for the years 2014 to 2019; ORIO Indicator Framework; Interviews with TANESCO headquarter and district offices, 2018; Interviews with village representatives, 2018

5. Impact results for rural intervention areas

This section discusses the impacts of the ORIO project beneficiaries in rural areas around the three towns Biharamulo, Ngara and Mpanda. As discussed in the previous sections, two major developments occurred that had a bearing on the attributability of impacts to the ORIO intervention. First, REA electrified additional communities in the intervention areas. These REA communities have also been included in this study. We will not discern between them and those communities where connections were funded completely by the ORIO project, the *TANESCO communities*. We do so because the actual implementation was basically the same in the two types of communities (only some technical components such as poles might have been of different, presumably higher quality in TANESCO communities), and since we gain statistical power by pooling the two types of communities in the analysis. While impacts can be assumed to be uniform across the two types of communities, the later attribution of impacts to the ORIO intervention needs to take into account that REA can be credited for part of these impacts in the REA communities.

Secondly, Biharamulo and Ngara were connected to the central national grid. Accordingly, part of the potentially observed impacts for those intervention areas would need to be attributed to the electricity centrally provided by TANESCO. We will discuss attribution in Section 7 and now look at the aggregate impacts of the changed electricity supply in the intervention areas, irrespective of these two developments. Accordingly, we will only selectively distinguish between TANESCO and REA communities (notably in the following descriptive background chapter 5.1) and between the three district town regions.

5.1. Community and household profile

In this section, we briefly present basic community-level data that portray the baseline livelihood in the three rural sub-groups, TANESCO, REA, and control communities. This helps to scrutinize the key assumption of our identification approach: the comparability of the treatment groups (TANESCO and REA) and control group.[47] The baseline data also represents the yardstick from which to determine effects in our outcome and impact indicators in the following sub-chapters. If the background indicators experienced major changes between baseline and follow-up, these are additionally discussed. Note that both TANESCO and REA sub-villages are not entirely covered by the new electricity grids. Elected sub-village leaders as community representatives estimated at follow-up that three-fourth of non-connected households in their sub-villages are located too far from the grid to be able to connect. Since this was foreseen, not the entire sub-villages were sampled at baseline but only households in a corridor along the planned lines (see Section 3.3.2). We nevertheless present sub-village data in the following, given sub-villages are the lowest administrative unit in rural Tanzania.

Table 5 shows demographic statistics and additional data on basic physical infrastructure of the sampled sub-villages at baseline. These values are again self-reported by community representatives who usually do not avail of sub-village specific statistics. The numbers should therefore be taken with a pinch of salt. In general, the control group does not differ considerably from the two treatment groups. In particular, the availability of social infrastructure is very similar. Among others, we see that almost all sub-villages have access to some sort of school in their village. Availability of a mobile phone network was almost universal for all communities at baseline, while all interviewed communities at follow-up stated that mobile phone network is available in their community (follow-up values not shown in the table).

[47] We redo this exercise from the baseline report (Bensch et al. 2017) also considering the changes in group status that happened between baseline and follow-up (see Section 2).

With population sizes of on average over 1000 inhabitants, sub-villages are already fairly large rural agglomerations. While the treatment communities seem to be slightly larger in terms of population size, this difference is far from statistically significant. This can be taken from the *p*-value in the very right column of Table 5, which is clearly above 0.1, which is generally considered a threshold indicating statistical significance once it is undercut. The major difference is the distance to the main road, which is roughly double for control communities. This difference is significant at the one percent significance level. Relatedly, the relationship between accessibility to the main road during rainy season and whether a community is in the treatment or control group is significant. The following has to be noted, though: while the distance to the next road is larger for control communities, this may not be the case for the distance to the district capital cities, a similarly important locational factor. The map of Mpanda in Figure A1 in the Appendix, for example, makes clear that control communities are closer to Mpanda town than treatment communities, despite being further away from main roads.

Table 5: Community demographics and basic physical infrastructure available to the communities at baseline

		TANESCO	**REA**	**Control**	**TANESCO & REA vs. Control** *p*-value
Number of communities (sub-villages)		30	28	42	
Average population per sampled community		1298 (1483)	1252 (1400)	1077 (1022)	0.44
Social infrastructure in the village, in %	primary schools	97	96	95	0.74
	secondary schools	37	43	33	0.52
	any schools	97	96	100	0.22
	dispensaries	53	54	43	0.30
	health centres	3	7	12	0.22
	religious buildings	87	89	86	0.75
Financial services in community, in %	formal banking#	10	11	0	0.03**
	informal banking	53	82	62	0.58
Distance from main road, in km		3.2 (4.1)	2.9 (4.9)	6 (5.9)	0.01***
Accessibility to main road during rainy season, in %	good	33	57	21	0.03**
	average	50	29	50	
	possible with difficulties	17	14	21	
	possible in case of emergency	0	0	7	
Mobile phone network is available, in %		97	100	95	0.38
Mobile phone network quality, in %	good	40	71	33	0.16
	medium	33	21	36	
	bad	23	7	26	

Note: # Formal banking refers to commercial banks and micro-finance institutions, informal banking are saving groups, money lenders, or mobile banking agents. Standard deviations in brackets. *p*-values refer to two-sided *t*-tests (and chi^2 tests for categorical variables) on difference in means between treatment (TANESCO & REA pooled) and control. Asterisks represent differences that are statistically significant at the 10 (*), 5 (**), and 1 (***) percent level.

Source: If not mentioned otherwise, all data presented in this section refers to the baseline and follow-up data collected in the context of this study (see Section 3.3.2).

In addition to the community-level data, household-level baseline data on socio-economic characteristics help to portray our study sample. This information is presented in Table 6. For the purpose of our study, we adopt a common working definition of a household as a group of individuals who live in the same house. These individuals pool their resources together to meet their basic needs under the authority of a single person, called the *head of the household*. Our sample includes 1000 (879) rural households with a total of 5,644 (5,402) members in 2014 (2018). The average share of children under seven years was 22 percent, which decreased over time to 18 percent, while household size and the proportion of female-headed households increased over time (household size from an average of 5.7 in 2014 to 6.2 in 2018, follow-up values again not shown in the table). We see the same trend for all variables when differentiating between control and treatment groups.

Virtually all households engage in land cultivation. Agriculture is the main source of income for most of the sampled household heads, more so in control than in treatment households. Generally, we observe an increasing trend in other market activities and decreasing trends in land cultivation and livestock ownership, but farming remains the dominant source of income. Note that household size, sex of the household head, and the share of children below seven years old are very similar for treatment and control communities in 2014, suggesting that the two groups of communities are comparable along these demographic dimensions. Still, statistically significant differences can be observed for the age of the household head and whether s/he is engaged in farming.

Table 6: Household descriptive baseline statistics

	TANESCO	**REA**	**Control**	**TANESCO & REA vs. Control** *p-value*
Number of households	300	280	420	
Household characteristics				
Household size	5.7	5.6	5.7	0.98
	(2.4)	(2.4)	(2.6)	
Age of household head	43.6	42.4	41.5	0.08*
	(13.8)	(13.1)	(12.8)	
Female household head, in %	10	11	9	0.51
Share of children 0-6, in %	22	21	23	0.16
Household head is farmer, in %	85	82	91	0.00***
Share of expenditure categories in annual core expenditure[#], in %				
Food	69	65	71	0.00***
Water	2	2	2	0.45
Telecommunication	10	11	10	0.17
Schooling	8	9	6	0.00***
Annual non-energy core expenditures, in TSh	1,546,840	1,615,340	1,546,760	0.67
	(1,252,090)	(1,269,870)	(1,173,930)	
Annual core expenditures, in TSh	1,708,470	1,782,820	1,710,470	0.68
	(1,351,960)	(1,335,600)	(1,235,690)	
Perception of household's income, in %				
Sufficient	12	15	14	0.63
Tight	40	39	33	0.05**
Insufficient	48	46	53	0.11
Household agriculture, in %				
Landowners without title	75	88	80	0.72
Keep livestock	67	67	69	0.43
Household cultivates land	98	97	98	0.85
Household asset ownership				
Savings account in bank or saving association, in %	25	36	18	0.00***
Number of rooms	3.3	3.6	3.3	0.13
	(1.5)	(1.5)	(1.7)	
Bicycle, in %	63	58	65	0.20
Motorcycle, in %	18	24	15	0.02**
Car, in %	2	4	1	0.06*

Note: [#] Core expenditures include food, water, telecommunication, schooling, traditional energy and electricity. Expenditures do not cover auto-consumption. Energy and electricity expenditures are covered in the next chapter. Standard deviations in brackets. *p*-values refer to two-sided t-tests on difference in means between treatment (TANESCO & REA pooled) and control. Asterisks represent differences that are statistically significant at the 10 (*), 5(**) and 1(***) percent level.

The table furthermore lists core expenditure categories, a subjective indicator on the income situation and main non-electric household assets (electric assets being discussed in the next section). The clearly largest expenditure item is food, showing also a significant difference between treatment and control sites. Treatment households tend to be slightly more satisfied with their income, yet even in these groups roughly half of the households considered their income to be insufficient. Overall, we can say that households subjectively felt less satisfied in 2018 than in 2014. At baseline there was a significant difference between the control and treatment group in ownership of saving accounts and cars. Motorcycle ownership increased over time – about 29 percent owned at least one motorcycle in 2018, compared to 15 percent in 2014. In contrast, car ownership remains rare.

The results indicate that a number of key variables differ between sites selected for electrification and those that remained non-electrified. It is not surprising that despite the careful selection of control sites such differences do not vanish completely. It is therefore important to control for structural differences in our empirical impact analysis, which we do along the methodological approaches outlined in Section 3.3.1.

5.2. Effects on energy service provision among rural households

5.2.1. Electricity access

In spite of the officially very low official electrification rate in the surveyed regions in 2014, around 25 percent of households already had some type of electricity source at baseline, with a larger penetration in treatment sites (Table 7). The national energy survey URT (2017) later found electricity access numbers that were better in line with these figures. It was found that, in 2016, the rural electricity access rate in Kagera region in the North basically correspond to the national average of 16 percent whereas the rate was twice as high in rural Katavi, the region where Mpanda is located.

The electrification rate in our sample increased further over time, not only in treatment communities, but also in control communities. Table 7 shows the effect of the intervention on electricity access rates. This table and the following tables show baseline and follow-up data, now simply comparing treatment and control and not differentiating between TANESCO and REA anymore. Remember that *treatment* in our case refers to community *electrification*, whereas we refer to *access* or *(grid) connection* if an individual household actually connected to the newly erected electricity grid.

Table 7: Electricity access

	Baseline (2014)		**Follow-up (2018)**		**ITT**	**ATT**	**PSM**
	Treatment	Control	Treatment	Control			
HH uses electricity, in %	28.4	19.0	72.3	62.1	1.8	34.3***	38.2***
Number of observations	1000		724		1601	1601	641

Note: Asterisks indicate that the impact estimates are statistically significant at the 10, ** at the 5, *** at the 1 per cent level. IIT and ATT with controls (both using the Diff-in-Diff approach) as well as PSM as specified in Section 3.3.1. ITT and ATT exclude the connected households that have non-randomly been added to the sample at follow-up. They also exclude the replaced non-connected households in treatment communities, which are accounted for through sampling weights in these estimations. The 1601 observations are thus composed of the 1444 panel observations (baseline + follow-up) and the 204 baseline attritors, minus a few observations with missing data on control variables. PSM only includes follow-up observations and here excludes the 224 non-connected households in treatment communities as explained in Section 3.3.1. See also Table 3 on page 13.

The table shows the three effect estimates introduced in Section 3.3.1., namely *Intention To Treat* (*ITT*), *Average Treatment effect on the Treated (ATT)* and the one based on *Propensity Score*

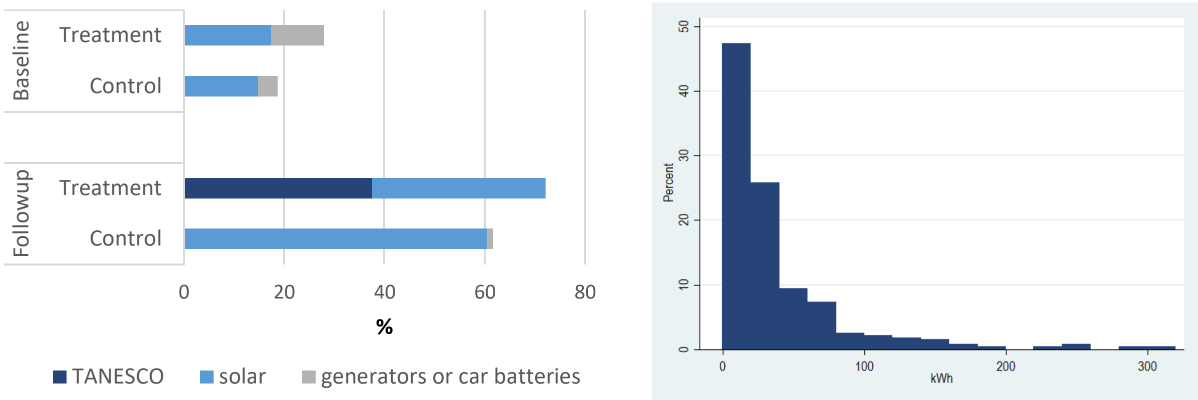
Matching (PSM). The ATT and PSM are, unsurprisingly, significant for this first indicator: TANESCO customers are more likely to have electricity access than in their counterfactual situation of not living in a TANESCO-served community. More specifically, they are around 35 percent more likely to have an electricity source thanks to the ORIO intervention. The more relevant indicator in this case, however, is the ITT, i.e. the effect of the ORIO intervention on the electricity access rate in the entire community with grid electricity. Here, the ITT exposes that no discernible effect can be seen on community level: interestingly, the ORIO intervention triggered an increase in electricity access rates that is only 2 percentage points higher in treatment communities compared to control communities; an increase that is too small to be statistically significant. Communities served by the ORIO intervention already had higher electricity usage rates at baseline and, similarly, at follow-up.

As further illustrated in Figure 7 (a), a larger diffusion of solar panels mostly compensates for the absence of grid electricity in off-grid control communities. Instead of using grid electricity, control communities more strongly rely on solar panels to satisfy their electricity demand. Some households reported to have had solar panels since 2000, but the majority – over 60 per cent – had installed solar panels during the last four years. The clearly most popular brand is Sundar Solar, a Dar-es-Salaam-based company that imports non-branded solar panels, mostly from China, and markets them via resellers in rural areas.[48]

Figure 7 (a) also indicates that, as we expected, individual and village generators were widely replaced by solar panels and TANESCO grid connections. Of the seven small village grids run by a generator at baseline (two TANESCO and four REA sites and one control site), only one remained in operation in 2018.

Figure 7: Electricity sources and electricity consumption

(a) Electricity sources used by households *(b) Monthly electricity consumption in kWh*



Note: Solar includes solar panels and pico-PV kits and generators cover individual generators and village generators. Figure (a) does not include double counts, i.e. households with TANESCO and solar or other sources are counted as TANESCO, those with solar and other sources as solar.

Looking closer into the survey data on TANESCO customers, 67 percent of households reported that the decision to connect was made solely by the head of household, in 19 percent of cases by the head of household and his/ her spouse. Figure 7 (b), furthermore, shows the consumption patterns of households. About half the households have an average monthly consumption below 25 kWh. This corresponds to using three 10-Watt energy-saver bulbs, two 40-Watt neon tubes, a 10-Watt radio and one 80-Watt TV for about four hours per day. Almost 90 percent fall under the 75 kWh threshold, which households are not supposed to exceed for more than three months in a row if they

[48] An overview of main solar brands in Tanzania can also be taken from Ipsos Tanzania (2017, slide 54).

want to benefit from a much cheaper lifeline tariff. The average consumption is 36 kWh, the median consumption 21 kWh per month.

Further survey data on TANESCO customers reveals that shared connections are very uncommon: merely five percent of connected households reported to be connected through a neighbouring household. Less than ten percent of connected households have a ready-board, which is a wall box with integrated circuit breakers, socket outlets and a light targeted to poor low-consuming households. This low penetration rate of ready-boards is likely due to TANESCO having problems in procuring these devices. 32 percent of TANESCO customers report to have had access to an electricity source before, mainly solar panels (24 percent). Around 6 percent of customers have a back-up electricity source, often still a solar panel they owned before. In contrast, for 68 percent of TANESCO customers, the grid connection was their first-time use of electricity at home. Table 8 shows that most TANESCO customers got access to electricity before 2017 (over two years ago), whereas around 15 percent got access somewhere in 2017 (one to two years). Due to the later connection in Mpanda, connection dates are more recent there. Still, average duration of connection is decently high with around 1.7 years.

Table 8: Duration of access to electricity access among treated TANESCO customers in the sample

	Town			**Total**
	Biharamulo	Ngara	Mpanda	
Duration of access to TANESCO grid, in %				
0-3 months	2	1	5	2
3-12 months	0	8	34	11
1-2 years	20	20	16	19
over 2 years	78	71	45	68
TANESCO connection rate, in %				
Entire sample	47	47	22	38
Households within 100 m of grid	61	64	26	48
Households within 50 m of grid	66	78	32	57
Share in sample used for analysis, in %	22	41	37	100

According to Figure 7 (a), TANESCO is used by 38 percent of sampled treatment households at follow-up. Remember that these households were sampled at baseline in areas along the planned electricity grid. They may thus have turned out to be living too far from the actual electricity grid (like some of the control households who would also live too far from the grid if it reached their community). If we restrict the sample to households living within 100 metres of the actual grid, the share of connected households amounts to 48 percent; within 50 metres, it increases to 57 percent. Access to the TANESCO grid is furthermore correlated to income: in the 50-metre corridor, 42 percent are connected in the poorest quintile (i.e. the 20 percent of households with the lowest level of expenditure as a proxy for income), 69 percent in the richest quintile. This difference is even stronger for solar panels in control communities: here, 35 percent of households own one in the poorest quintile, whereas 87 percent do in the richest quintile.

We generally see rather small differences in access rates and thus of distribution of potential impacts of grid electricity across different dimensions: Access rates in female-headed treatment households of 39 percent are quite similar and even slightly higher than the 37 percent found for male-headed households; similarly, little differences are observed when comparing the oldest and youngest quintile of household heads (36 against 32 percent) and households with and without migrants (31 and 40 percent). The major difference lies between households where the household head is only engaged in farming (34 percent) and households with household heads that are also engaged in non-farm activities (54 percent).

Non-connected treatment households in the sample gave several reasons why they are not connected. 40 percent mention that they cannot afford the one-time connection fee, while 37 percent indicate that they cannot afford the in-house installation (with median costs among TANESCO customers amounting to 150,000 TSh (58 Euro)). 30 percent cannot afford the running electricity costs. Other reasons for not being connected include the house being too far from the grid (36 percent), the house having no iron roof (6 percent), or the household being generally uninterested in connection to the grid (4 percent). Another issue are constraints in connecting households at the side of TANESCO: as many as 28 percent of the non-connected households mention that they already applied for a TANESCO connection (distance does not seem to be a hindering factor).

Most use a pre-paid meter and thus cannot get into debt. Yet, due to a lack of credit on their pre-paid meter 23 percent of the households were without electricity for some time during the 60 days prior to the interview. The average time was 8.5 days and in 15 percent of cases the reconnection took more than two weeks.

To conclude, we see that off-grid households found ways to meet their electricity demands, predominantly via solar panels. In how far grid connections and solar panels are comparable, though, depends on the amount of energy services demanded and consumed by households. It may, for example, be the case that grid-connected households are able to make use of higher-powered appliances and machines, or that solar panels are only enough to illuminate certain parts of a household, while other parts remain without electric lighting. Electricity costs may also be different. We will probe into electricity usage in the next section.

5.2.2. Use of traditional energy sources

In line with the observation that grid electricity and solar panels made inroads to the survey region, households widely abandoned traditional energy sources for services replaceable by electricity.

Table 9: Usage of traditional energy sources

	Baseline (2014)		**Follow-up (2018)**		**ITT**	**ATT**	**PSM**
	Treatment	Control	Treatment	Control			
Use at least once in last 30 days, in %							
Kerosene	53	53	10	10	2	-1	-4
Dry-cell batteries	81	87	45	52	-2	-24***	-23***
LPG	0.2	0.2	3.8	0.3	4**	7**	7***
Monthly kerosene consumption, in litres	1.18	0.96	0.09	0.09	-0.2	-0.2	1.6
Monthly consumption of batteries	7.0	8.5	1.6	1.8	1.3	1.4	-0.2

Note: The shares refer to households referring to purchases of these energy sources in a typical month. Asterisks indicate that the impact estimates are statistically significant at the 10, ** at the 5, *** at the 1 per cent level. IIT and ATT with controls as well as PSM as specified in Section 3.3.1.

In Table 9, we look at usage of kerosene, dry-cell batteries, and Liquefied Petroleum Gas (LPG). Candles are only irregularly used, already at baseline. Kerosene was another important source of lighting at baseline, and its consumption decreased drastically (from 53 percent to 10 percent), which is in line with other studies (see Bensch et al. 2017*b*, Grimm and Peters 2016). The use of dry-cell batteries decreased considerably as well: In 2014, more than 80 percent of the households used batteries, mainly for radio and lighting (see next sub-section), whereas only around 50 percent of the households used them in 2018, with a significant reduction among connected households according to the ATT and PSM estimates. The ITT for kerosene and dry-cell use, which also accounts for non-connected households, indicates that the effect on community level is negligible. What is more, neither for kerosene nor for dry-cell batteries, an effect can be observed in terms of average actual consumption (see the lower part of the table). The changes are thus not an impact of the electrification intervention but rather reflect a general trend, also away from fuel stacking, i.e. the simultaneous use of multiple different fuels (see also Choumert-Nkolo et al. 2019). It is furthermore interesting to see that LPG usage slowly kicks off in treatment communities. This might be explained by better connectivity of treatment communities (see Section 5.1), which the impact estimates may not be able to fully account for. LPG is most prevalent in the highest expenditure quintile (six percent), while two to three percent of households in quintiles two to four are found to use LPG and none in the lowest quintile (not shown in the table). Hence, LPG usage remains very low even among richer households, which is not unsurprising for the rural African context.

5.2.3. Appliance usage

Appliances are the main means to make use of the new or improved energy services enabled by electricity. We see that appliance ownership changed stronger for the grid-connected treatment households than for control households. Table 10 suggests that an additional five to 15 percent of households in treatment communities replaced charcoal irons by electric irons, battery-powered radios by line-powered radios and acquired TVs (see ITT column). Among grid-connected TANESCO clients, 68 percent own a TV (not shown in the table). Mobile phones are very common in both type of communities and the gap of almost 7 percent at baseline remained roughly the same at follow-up; households without access to electricity charge phones in shops or at their neighbours' house for an average price of 190 TSh per time (0.07 Euro). This is one way non-connected households indirectly benefit from electrification in their community. They pay slightly less than households without electricity source in non-electrified communities and usually the place is closer. To conclude appliance ownership, only three households from our sample in Ngara region own electric stoves.

In 2014, only 32 households (three percent) used any of their appliances for some productive purpose (17 in treatment group, 15 in control group), with no significant change for treatment communities over time: In 2018, 10 households (2 per cent) in treatment communities were using their appliances for their business. In control communities this number declined to 5 households (1.5 per cent). Most of these households used their sewing machine to produce goods as a business. Other appliances used for business include grain mills, mobile phones and radios.

Table 10: Appliance ownership

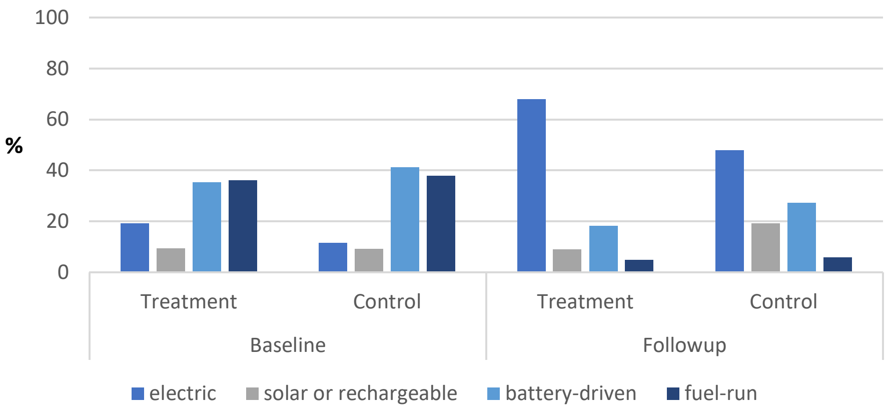
		Baseline (2014)		**Follow-up (2018)**		**ITT**	**ATT**	**PSM**
		Treatment	Control	Treatment	Control			
Mobile phone		83	76	91	86	-2	-2	9**
Radio	battery only	60	53	22	33	-12**	-24***	-19***
	line power only	4	3	24	17	6	25***	20***
Iron	charcoal	39	27.9	27	30	-11**	-8	2
	electric	3	1	10	0	9***	24***	22***
TV		15	8	35	16	14***	40***	46***
Satellite receiver		8	3	21	7	10***	27***	35***
Electric stove		0.0	0.0	0.4	0.0	0.3	0.7	0.6

Note: All values in percent. Asterisks indicate that the impact estimates are statistically significant at the 10, ** at the 5, *** at the 1 per cent level. IIT and ATT with controls as well as PSM as specified in Section 3.3.1.

Other main appliance types are lighting devices. We present measures of lighting consumption and quality in Figure 8 and Table 11. The figure shows that electric lighting became the most popular source of lighting in both treatment and control communities. The table, furthermore, exposes significant effects in terms of the hours of artificial light consumed for nearly all devices, except for gas and hurricane lanterns. We observe a similar trend over time for daily lumen hours, which account for different levels of brightness. Battery-driven LED lamps, gas and hurricane lamps and traditional tin lamps as well as kerosene are decreasingly used in treatment communities.

Follow-up satisfaction with lighting quality is lower for all lighting devices in control communities (Figure 9). In treatment communities, especially the satisfaction with more advanced lighting devices is higher, i.e. with electric light and rechargeable & solar LED. In addition, TANESCO customers are more satisfied with electric lighting than users of other electricity sources (not shown in the figure): 18 percent of the TANESCO customers are very satisfied and 72 percent are satisfied, compared to two and 22 percent for users of other electricity sources, respectively.

Figure 8: Primary lighting devices according to hours lit



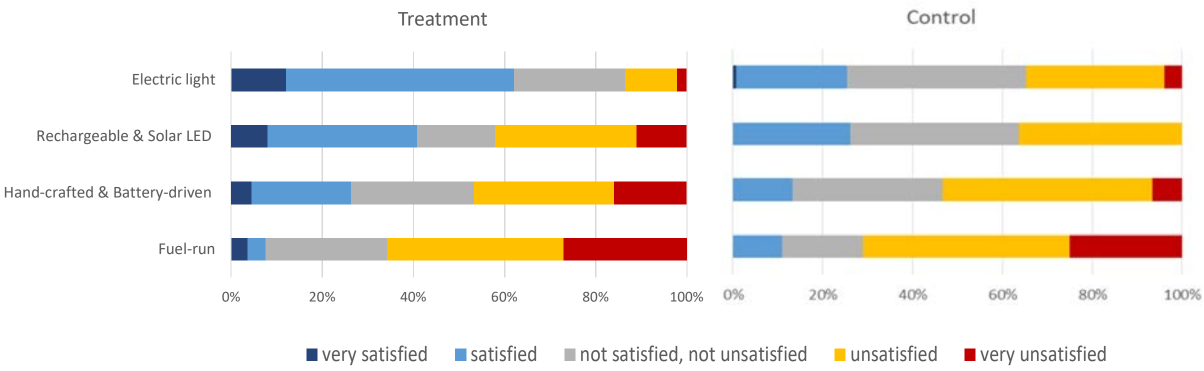
Note: Electric lighting includes fluorescent tubes, energy savers and incandescent lamps. Fuel-run includes traditional tin lamps, gas and hurricane lanterns.

Table 11: Daily artificial lighting and lumen hours, by source of lighting

	Baseline (2014)		**Follow-up (2018)**		**ITT**	**ATT**	**PSM**
	Treatment	Control	Treatment	Control			
Hours of light per day							
electric light[#]	5.4	3.7	28.5	17.5	9.9***	26.8***	23.2***
solar LED or rechargeable	1.9	1.3	2.4	4.6	-2.8**	-4.9***	-4.9***
battery-driven LED[#]	1.3	0.6	0.5	0.6	-0.6*	-0.8**	-0.4
gas and hurricane lanterns	0.8	0.6	0.1	0	-0.2	-0.2	0
traditional tin lamps	3	3.4	0.3	0.5	0.5	0.5	-0.5**
Lumen hours per day							
electric light[#]	3720	2580	19,530	12,110	6620***	16580***	14460***
solar LED or rechargeable	180	130	230	450	-270**	-470***	-490***
battery-driven LED[##]	270	340	120	160	50	-80**	-90***
gas and hurricane lanterns	960	890	150	40	20	-20	50
traditional tin lamps	34	39	3	6	5	5	-5**

Note: [#] includes fluorescent tubes, energy savers and incandescent lamps. [##] includes hand-crafted LED lamps powered by batteries. Asterisks indicate that the impact estimates are statistically significant at the 10, ** at the 5, *** at the 1 per cent level. IIT and ATT with controls as well as PSM as specified in Section 3.3.1.

Figure 9: Satisfaction with lighting quality of different lighting devices at follow-up



Note: Satisfaction with lighting quality is based on few observations only for fuel-run, which includes traditional tin lamps, gas and hurricane lanterns.

5.2.4. Energy expenditures

Table 12 shows running energy and electricity expenditures as the share of total core household expenditures (see Table 6 in Section 5.1 for the list of non-energy core expenditures). We observe that the share of electricity in core expenditures increased significantly in treatment communities. We also look at traditional energy which covers candles, kerosene, batteries, wood, charcoal, and LPG. The share of this traditional energy in core expenditures reduced for treatment communities and increased for control communities, both insignificantly. In sum, households with TANESCO rather spend more on energy than before and more than the control group. This reflects that they now make use of a broader range of energy services.

Table 12: Energy expenditures

	Baseline (2014)		**Follow-up (2018)**		**ITT**	**ATT**	**PSM**
Share in core expenditures, in %	Treatment	Control	Treatment	Control			
electricity	1.3	0.8	2.7	0.9	1.5***	3.6***	4.3***
kerosene for lighting and batteries	5.4	5.9	1.1	1.3	0.3	0.3	0.0
traditional energy	10.6	10.8	9.6	11.9	-2.1	1.1	1.1
total energy	11.9	11.6	12.3	12.8	-0.6	4.7**	5.4***
total energy, only households without electricity source	11.3	11.1	9.3	12.2	–	–	–

Note: Installation costs of the electricity sources are not included in the energy expenditures. Asterisks indicate that the impact estimates are statistically significant at the 10, ** at the 5, *** at the 1 per cent level. IIT and ATT with controls as well as PSM as specified in Section 3.3.1.

The running costs, though, do not account for the investment costs in electricity sources. Since the grid connection cost of 27,000 TSh is subsidized by REA, households with alternative electricity sources have considerably higher investment costs: The solar panels that were in place in 2014 cost on average 335,000 TSh (155 Euro) and incur negligible annual maintenance cost of around 8,200 TSh. In 2018, the average cost of solar panels decreased to 210,000 TSh, while households spent more on maintenance, on average 29,000 TSh per year. The price paid for panels bought in 2017 and 2018 was even lower at 190,000 TSh (75 Euro) and thus about half the cost of the panels in place in 2014. Grid-connected households thus spend less upfront but have to bear the running electricity costs. If one spreads these investment and maintenance costs evenly over time, solar panels would have to last on average for around three years and four months in order to break even with costs of grid electricity. This is a very conservative figure as it assumes that the solar panels deliver the same energy services as grid electricity and it abstracts from interest rates that have to be considered in the higher up-front solar panel purchase costs. To conclude, TANESCO customers likely indirectly benefit from not having to purchase solar panels, not only through more power but also lower lifetime costs.

We delve further into energy expenditures by disaggregating them by wealth level for the aggregate sample (again running costs only). In Table 13, we observe significant differences across expenditure quintiles for almost all the presented energy expenditures in terms of their share in core expenditures. Overall, richer households spent a significantly higher share of their core expenditures on electricity and wood or charcoal at baseline, but lower shares on energy, batteries, and kerosene. In 2018, the poorest households have caught up with richer households in terms of the share spent on electricity – an indicator that electricity has become more available to even the poorest. Expenditure shares on batteries and kerosene remain significantly lower for households in the highest quintile, whereas the expenditure share on energy is now significantly higher. The share of wood or charcoal in core expenditures increased over time for both wealth groups and remained significantly higher for households in the highest quintile in both 2014 and 2018, especially due to the increased use of charcoal. Finally, we see that households without electricity source do not spend a much different share of their household budget on energy.

Table 13: Energy expenditures, by wealth level

	Baseline (2014)			**Follow-up (2018)**		
Share in core expenditures, in %	Lowest quintile	Highest quintile	Difference *p*-value	Lowest quintile	Highest quintile	Difference *p*-value
electricity	0.5	1.3	0.03***	2.1	2.2	0.73
traditional energy	14.3	7.1	0.00***	8.4	14.4	0.00***
batteries	6.3	1.3	0.00***	2.0	0.1	0.00***
kerosene	5.3	0.8	0.00***	0.7	0.1	0.02**
wood/ charcoal	2.1	3.6	0.04**	4.4	11.7	0.00***

Note: Asterisks indicate that the impact estimates are statistically significant between the two presented quintiles at the 10, ** at the 5, *** at the 1 per cent level.

5.2.5. Quality of electricity service

When asked about advantages and disadvantages of being connected to the grid, some households mention that electricity is less expensive than traditional power sources, that it is more reliable, and that it provides the household with enough energy for appliance usage.

At follow-up, TANESCO customers in treated communities were asked about experiences with outages, coping strategies in case of blackouts and their customer satisfaction. 93 percent of connected households experienced a blackout in the last 30 days prior to the interview. 38 percent of households experienced five or fewer outages in the month prior to the survey. Another 14 percent experienced 10 outages, 22 percent even experienced 30 outages. The average number of blackouts was 14 in the last month. 22 percent of households reported that their appliances were damaged due to voltage fluctuations or power cuts, in most cases a light bulb, but the figure also includes a few broken meters. The occurrence of blackouts will be discussed more extensively when assessing the potential improvements in grid reliability in Section 6.1.

We already learnt that hardly any electricity sources are used besides solar panels and TANESCO, some of which are kept as back-up sources in case of blackouts. During blackouts, 21 percent use an electric back-up source, including solar lanterns but also mobile phone torches, for example. Another roughly half of the households (48 percent) have to rely on traditional energy during a blackout and 30 percent wait until the service is re-established.

The perceived reliability of the grid shown by the stated satisfaction of respondents is mixed with more people expressing their dissatisfaction (Figure 10). 26 percent of the interviewed households are either satisfied or very satisfied with the reliability of the grid. Another 35 percent claimed that they are unsatisfied, and 10 percent of the customers even reported to be very unsatisfied. Considering voltage stability, another indicator of the quality of the technical service, satisfaction is higher with 15 percent of the respondents claiming to be very satisfied and 58 percent to be satisfied. The numbers regarding reliability and voltage stability are substantiated by community-level data, presented in Figure 11. In 79 percent of the cases, the village leader had received one or more complaints on the reliability of the grid. For the electricity price, only 14 percent of village representatives were approached with complaints.

Apart from that main complaints by village leaders relate to grid coverage in their villages, which they expected to be higher. The grid extension activities did not seem to have created discontent: there was a general agreement between TANESCO/ REA and the villagers that the project can be carried out without compensation to destroyed properties (e.g. trees, bananas, coffee), which has been documented in village assembly meetings minutes and supported by elected ward members.

Figure 10: Satisfaction with different aspects of TANESCO's service

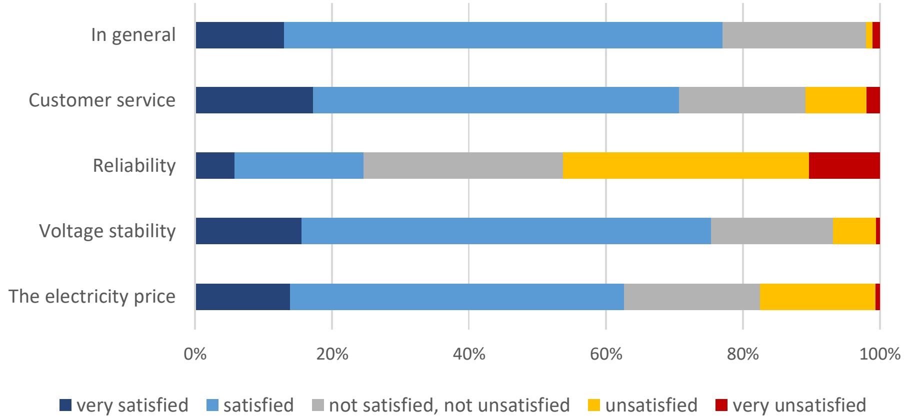
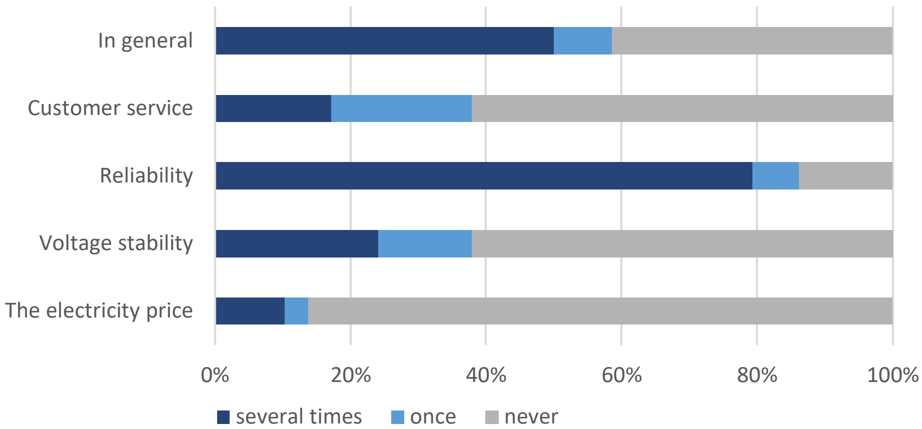


Figure 11: Complaints received by village leaders on different aspects of TANESCO's service



To conclude, we could not find significant differences between treatment and control in the use of the traditional energy sources kerosene and batteries, which are typically replaced by electricity. Yet, we found indications that grid electricity – despite being partly intermittent – delivers better energy services than the off-grid sources uses in the control communities: ownership of TV and electric irons increased significantly as well as the use of lighting. The following sub-section scrutinizes whether this translates into palpable impacts in the indicators presented in Section 3.3.1.

5.3. Impact assessment for rural households

Figure 2 in Section 3.1 introduced the results chain of the ORIO intervention in Tanzania. As already noted in Box 3 of the same section, health impacts were a priori rather unlikely. Given the very low shares of cooking with electricity and the universally low rate of lighting with kerosene, health is in fact unlikely to be affected and is therefore not covered here. Instead, the following analysis covers time allocation (also for income-generating activities and studying as an early indicator of education), safety and security (including attitudes related to preventive health measures), environmental impacts, and migration. For all impact dimensions, the findings on high counterfactual solar panel usage lower expectations as to what the grid electrification intervention may have caused.

5.3.1. Time allocation

In this section we look at time allocation more broadly, including study time of school children and enrolment, income-generating activities, and free-time activities.

Electricity usage may impact study time, since non-connected people are limited in the usage of artificial light in their evening hours (as evidenced in Section 5.2.3). This creates increased opportunity for children to study during evening hours. Through this and other indirect channels of increased opportunity, school enrolment may as well be affected.

Table 14 presents the results for school enrolment and study time for children in the primary school age, and for boys and girls in the secondary school age. To examine the treatment effect, we again present ITT, ATT and PSM. In line with expectations, changes can rather be observed for children of secondary school age and even these are mostly subtle. There is a general trend of more children going to secondary school, even being statistically higher for boys in treatment communities. Here, we find a statistically significant effect on whether all boys of secondary school age go to secondary schools (ITT) – a difference that, however, disappears when we focus on connected households (ATT), thus suggesting that there were either stronger spillovers to non-connected households or idiosyncratic developments in the treatment communities. At the same time, we can rule out that this effect is due to treatment households having less boys in the respective age bracket: in fact, treatment households rather have more boys between age 12 and 17 (average of 0.61 compared to 0.52 in control communities (*p*-value on difference in means of 0.23)).

Table 14: Schooling and study time

	Baseline (2014)		**Follow-up (2018)**		**ITT**	**ATT**	**PSM**
	Treatment	Control	Treatment	Control			
Children (6-11)							
Study home after school, in %	43	36	41	32	-3	15*	7
Study home after nightfall, in %	26	18	33	26	-1	12	1
Late study time, in hours	0.40	0.25	0.49	0.31	0.04	0.24*	0.12
Total study time, in hours	0.70	0.66	0.70	0.57	0.03	0.25	0.13
Share of late study time, in %	56	42	70	61	-4	13	12
All children 6-11 in school, in %	60	52	69	71	-10	-9	0

Table continues on next page

	Baseline (2014)		Follow-up (2018)		ITT	ATT	PSM
	Treatment	Control	Treatment	Control			
Boys (12-17)							
Study home after school, in %	54	47	50	36	12	20	-6
Study home after nightfall, in %	40	32	45	34	3	16	-5
Late study time, in hours	0.72	0.51	0.79	0.57	-0.04	0.12	-0.31
Total study time, in hours	1.04	0.88	0.98	0.74	0.14	0.08	-0.34
Share of late study time, in %	69	62	84	80	-2	19	-12**
All boys 12 - 17 in school, in %	55	54	80	61	21**	6	3
Girls (12-17)							
Study home after school, in %	58	53	52	35	8	36***	6
Study home after nightfall, in %	42	30	45	28	4	30***	6
Late study time, in hours	0.72	0.51	0.76	0.43	0.18	0.63***	0.25
Total study time, in hours	1.03	1.01	1.02	0.59	0.44	1.11***	0.40*
Share of late study time, in %	69	53	78	73	-5	3	13
All girls 12 - 17 in school, in %	62	55	81	74	2	5	11

Note: Asterisks indicate that the impact estimates are statistically significant at the 10, ** at the 5, *** at the 1 per cent level. IIT and ATT with controls as well as PSM as specified in Section 3.3.1.

Secondly, less households report that their children study at home, and this being mostly driven by studying during day time. Here, we find ATTT effects on girls' study time in that the treatment group maintains the studying hours, while rather increasing those after nightfall, whereas there is large drop in girls studying after school in control sites. The negative PSM estimate for the share of late study time among boys has to be taken with care, since the cross-sectional PSM in our case seems to be less capable in eliminating structural differences between the two compared groups than the ATT based on Diff-in-Diff estimations. Apart from that, no significant changes can be observed regarding education-related outcomes.

Table 15: Income-generating activities and household duties

	Baseline (2014)		Follow-up (2018)		ITT	ATT	PSM
	Treatment	Control	Treatment	Control			
Engaging in non-farm activities, in %							
Head of household	33	30	43	38	5	-4	7
Spouse of head of household	17	12	20	16	0	-3	-3
Hours per day spent on income-generating activities (incl. farming)							
Father	7.09	6.72	7.13	6.61	0.13	0.32	0.82**
Mother	5.92	6.70	5.65	5.69	-0.29	-0.59	-0.90**
Engaging in household duties, in %							
Father	19	14	23	19	-2	-5	-7
Mother	85	86	87	90	-2	-10**	-7**
Hours per day spent on household duties							
Father	0.64	0.38	0.92	0.75	-0.10	0.20	-0.25
Mother	4.03	3.97	3.87	3.85	0.12	0.05	-0.23

Note: Asterisks indicate that the impact estimates are statistically significant at the 10, ** at the 5, *** at the 1 per cent level. IIT and ATT with controls as well as PSM as specified in Section 3.3.1.

Income-generating activities and household duties are listed in Table 15. Virtually all adults at working age are involved in income-generating activities, predominantly farming (at least as secondary occupation). The time spent on these activities did not change remarkably, neither over time nor across treatment and control communities. The main development that can be observed – for both treatment and control – is a slightly stronger engagement in non-farm-activities, mainly as secondary occupation. These micro-enterprise activities are discussed more extensively in Section 5.4.

Exposure to television seems to have affected the time use of connected households most. At baseline, the main source of entertainment during evening hours was radio, and the second most important activity was evening praying with the family members. Over time, radio became less important whereas praying kept its importance for rural households. The main change occurred in usage of TV where we can find a large increase over time. While only 10 percent of household watched TV at home during baseline, at follow-up this share was already at 23 percent of all households, and at 33 percent among treatment households (Table 16). Accordingly, we find a significant increase in the time household members watch TV in connected households of between 25 to 45 minutes, with the lowest effect on children and girls and the largest effect on fathers in households. Male and female adults in connected households watch on average 1.3 and 1.1 hours per day, respectively, which is 50 minutes more than the average of non-connected households.

Table 16: Television consumption

	Baseline (2014)		Follow-up (2018)		ITT	ATT	PSM
	Treatment	Control	Treatment	Control			
Watching TV at home, in %	13	7	33	13	14***	41***	47***
Watching TV, in %							
Father	11	7	37	18	16***	36***	36***
Mother	9	4	31	12	15***	39***	45***
Girls 12-17 yrs.	7	5	24	9	13*	27***	34***
Boys 12-17 yrs.	9	10	24	13	10	26***	26**
Children 6-11 yrs.	8	4	25	15	7	27***	26***
Hours watched TV per day							
Father	0.22	0.15	0.74	0.41	0.27**	0.72***	0.67***
Mother	0.18	0.09	0.54	0.28	0.19*	0.69***	0.76***
Girls 12-17 yrs.	0.11	0.05	0.45	0.19	0.23	0.40**	0.66***
Boys 12-17 yrs.	0.15	0.16	0.51	0.25	0.23	0.56**	0.64***
Children 6-11 yrs.	0.12	0.06	0.52	0.30	0.20	0.58***	0.50***

Note: Asterisks indicate that the impact estimates are statistically significant at the 10, ** at the 5, *** at the 1 per cent level. IIT and ATT with controls as well as PSM as specified in Section 3.3.1.

These longer hours in watching TV do, however, not negatively affect the frequency of adult household members leaving home after nightfall (Table 17). For boys, however, we see a general trend to more time spent outside the house at night, with this trend being significantly lower in connected households.

Table 17: Going out after nightfall

Days per week outside after nightfall	Baseline (2014)		Follow-up (2018)		ITT	ATT	PSM
	Treatment	Control	Treatment	Control			
Man	1.32	1.66	1.35	1.55	0.09	-0.23	0.04
Woman	0.45	0.53	0.35	0.48	-0.04	-0.17	-0.18
Boys 12-17 yrs.	0.35	0.28	0.67	0.50	0.06	-0.46**	-1.19***
Girls 12-17 yrs.	0.19	0.13	0.16	0.18	-0.10	-0.14	-0.02

Note: Asterisks indicate that the impact estimates are statistically significant at the 10, ** at the 5, *** at the 1 per cent level. IIT and ATT with controls as well as PSM as specified in Section 3.3.1.

5.3.2. Safety and security

The propensity to leave the house after nightfall shown in the previous sub-section has already been a first indicator on the perception of safety and security: once electric lighting is available and more shops and enterprises are open after nightfall, people may be more inclined to leave the house. In that sense, watching TV on the one hand and increased security and night-time opportunities on the other hand may have had countervailing effects. In any case, the electrification treatment does not seem to have affected the effective behaviour much.

Table 18 presents perception questions related to safety and security. While we generally find no impacts, a notable difference is whether the household interviewee claimed to be afraid when at home – this improved considerably among connected households with an ATT of minus 18 percent.

The table furthermore shows two indicators on protective health measures, which also serve as proxies for whether households adopt different attitudes. We see no effect on the use of mosquito nets, but control households more than offset the lower usage rates of modern contraception from baseline.

Table 18: Perceived safety and security and protective health measures

	Baseline (2014)		**Follow-up (2018)**		**ITT**	**ATT**	**PSM**
	Treatment	Control	Treatment	Control			
Afraid when at home, in %	60	65	44	46	5	-18***	-15***
Afraid when you outside, in %	63	69	42	43	2	-2	-12*
Afraid when children outside, in %	72	70	41	44	-7	-10	-10
Darkness dangerous, in %	98	97	97	97	-2	-2	-1
All sleep under mosquito net, in %	86	83	92	88	2	4	6
Use of modern contraception, in %	40	29	44	50	-12*	-1	-2

Note: Asterisks indicate that the impact estimates are statistically significant at the 10, ** at the 5, *** at the 1 per cent level. IIT and ATT with controls as well as PSM as specified in Section 3.3.1.

5.3.3. Environmental effects

Potential environmental effects of the intervention might have occurred at three levels: first, households might have replaced harmful or inefficient traditional fuel types, namely kerosene, dry-cell batteries or biomass. Kerosene, for example, as a fossil fuel emits globally harmful carbon dioxide as well as locally harmful pollutants such as carbon monoxide. Households might also have replaced individual generators. However, as exposed in the sections on electricity access and the use of traditional energy sources (5.2.1 and 5.2.2), we do not find effects on the use of traditional energy sources (neither for the ITT nor ATT), electric stoves are not yet in use and individual generators have basically vanished in all households. Second, villages formerly powering their local village grids by diesel generators might have switched to grid electricity from TANESCO. Here we saw that merely one of the 42 rural control communities had a generator-run micro-grid in place at follow-up, with only a single household in our sample connected to this micro-grid.

The third level, and the only relevant level for the ORIO intervention in Tanzania, is the generation stage. With a current total electricity production of the three generator sets of 15 mio. kWh per year (see Box 4 on page 30), the efficiency gains derived from the new generators of 15 to 19 percent (see Section 4.5) translate to relative savings of around 800.000 litres of generator fuel per year or 500 tons of CO_2.[49] This corresponds to the car emissions of 175 Dutch households.[50] While we see these

[49] Using the "well-to-tank" emission factor for diesel marketed in Europe of 620 g CO_2 per litre (CO2emissiefactoren 2018). Considering that TANESCO uses standard diesel in their generators, using this value seems appropriate.

smaller gains in relative terms, in absolute terms, the three towns still rely on a similarly substantial level of environmentally unfriendly diesel used in the generators supported by ORIO: In Mpanda, consumption slightly increased due to the 25 percent higher electricity production level in that town (see again Box 4). Consumption decreased in Ngara and Biharamulo, however, not because of the ORIO intervention but due to the connection to the central grid. Finally, while the generators have the capacity to make use of biofuels, it is very unlikely that biofuels will become available in the project area given the high land pressure and risk of food competition (Ecorys-Aidenvironment 2012).

The environmental aspects of the dismantling of the old generators could not be assessed, since – up to late 2018 – none of them had been fully dismantled.

5.3.4. Migration

Finally, migration is probably the least reactive indicator among those assessed. It therefore does not come as a surprise that the migration pattern was not affected, measured by whether any previous household member migrated (Table 19). Migration is mostly driven by work (partly also seasonal work) and studies, with around 40 percent of migration happening within the same district, around ten percent to Dar es Salaam and basically no international migration.

Table 19: Migration

	Baseline (2014)		**Follow-up (2018)**		**ITT**	**ATT**	**PSM**
	Treatment	Control	Treatment	Control			
Any household member migrated, in %	29	25	38	30	5	-4	-2

Note: Asterisks indicate that the impact estimates are statistically significant at the 10, ** at the 5, *** at the 1 per cent level. IIT and ATT with controls as well as PSM as specified in Section 3.3.1.

5.4. Impact assessment for rural micro-enterprises

This section assesses more qualitatively the experienced impacts of electrification on rural micro-enterprises based on a number of semi-structured interviews with local entrepreneurs, community leaders and field observations. This information is complemented by data on enterprise creation and connection rates among enterprises elicited at community level.

5.4.1. Enterprise availability and creation in the communities

We first show some data on the main micro-enterprises in the interviewed communities and to what extent there were changes in the structure from the baseline situation compared to the follow-up situation (see Table 20). Kiosks are still the most widespread micro-enterprise type. They are found in virtually all of the communities and the average number per sub-village has even gone up from 16 to 22. Flourmills, restaurants, tailors, bars and carpenters are similarly among the most frequent enterprises to be found in at least three out of four sub-villages.

Noteworthy is the increase in the number of bars and restaurants, from between one and two at baseline, to around five per sub-village at follow-up. This could signal improved economic conditions and resulting demand for amusement along with a change in lifestyle. Yet, it could also suggest a

[50] Real-world emissions of cars in the Netherlands average around 160 g CO_2/km (TNO 2018), while a Dutch person travels an average of 8000 km per year by car (CBS 2016), with the average household size being 2.2 (UN 2019).

shift at the supply side away from agriculture towards service-driven, rather low-skill operations. The increase in beauty salons hints in the same direction. At the same time, manufacturing businesses such as carpenters, builders and tailors rather seem to decrease in number. In comparison to the control communities, only sawmills and welders, i.e. enterprises with the largest demand for electricity, experienced a significant increase in treatment communities (see ITT column). Completely new enterprises such as photocopying are an absolute exception (not shown in the table).

Table 20: Main micro-enterprises in study communities

	Available in community, in %		Average number per community			Net share created in last two years, in %	
	all communities		treatment		ITT	treatment	ITT#
	Baseline	Follow-up	Baseline	Follow-up		Follow-up	
Kiosk	99	97	18	22	-3.9	4	-5
Stores	36	32	1	1	-0.3	14	5
Bars	41	79	1	4	-0.1	4	-11
Restaurants	36	86	2	5	0.6	-1	-10
Carpenters	81	76	4	3	-0.7	5	-7
Builders	91	73	11	9	-1.2	0	-4
Tailors	93	81	8	8	1.0	14	0
Hairdressers	76	62	3	3	-0.6	56	20
Beauty salons	13	39	0	1	0.5	21	6
Flourmills	85	87	3	3	-0.6	21	-1
Sawmills	37	28	2	3	2.3*	19	8
Auto workshops	16	25	0	0	0.1	25	-2
Welder	16	25	0	1	0.3*	66	20***

Note: # This ITT does not use the Diff-in-Diff setup from Section 3.3.1 but rather a cross-sectional estimation using the same control variables but an outcome (enterprises created in last two years) that already captures the over-time dimension. Asterisks indicate that the impact estimates are statistically significant at the 10, ** at the 5, *** at the 1 per cent level.

The last columns of Table 20 show the share of businesses which were created in the two years preceding our two surveys net of those that were shut down. For stores this means that – in the 32 percent of sampled communities with stores at follow-up –, 14 percent of these stores were newly added in the two years preceding the follow-up survey, already accounting for stores that shut down. The largest increase in newly created businesses can be observed for welders and hairdressers, followed by auto workshops, flourmills and beauty salons. Comparing these changes with the counterfactual in the control communities shows that only for welders the increase is significant, whereas auto workshops and flourmills show no difference at all (See ITT# column). Despite the considerable increase in the average number of bars and restaurants in treatment communities, their ITT are negative, meaning that bars and restaurants have recently been opened up more frequently in the control communities.

For the micro-enterprises in place, Table 21 shows average baseline and follow-up connection rates. Hairdressers, beauty salons and flourmills are the enterprises with the highest shares of off-grid electricity access (see the columns Baseline and Follow-up, Control). To the contrary, carpenters and builders, but also tailors and stores mostly do not connect even when grid electricity is available. Here, the benefits of electric appliances do not seem to outweigh the investment in the necessary appliances. At the same time, we already see high TANESCO grid connection shares at follow-up among welders, beauty salons and hairdressers. When considering the counterfactual in the control communities (see column ITT), we see that the largest impact on electricity access by the intervention is on kiosks, bars and restaurants (beyond flourmills and auto workshops). This is likely due to the fact that these are the enterprises most centrally located in the sub-villages and thus most likely close to the new grid. Furthermore, we have seen above that these categories saw new enterprises coming up in the past four years, which might have directly taken the opportunity to connect to the grid. This information is corroborated by the perception of village representatives at follow-up: In 52 of 58 treatment communities it was perceived that at least one of the micro-enterprise types was newly created or increased its sales. In most cases this was noted for kiosks (64 percent), but also for flour millers (40 percent), bars (29 percent), and hairdressers (27 percent).

Table 21: Connection rates among micro-enterprises in study communities, in percent

	Baseline (2014)		Follow-up (2018)			ITT#
	Treatment	Control	Treatment		Control	
			TANESCO	other source		
Kiosk	36	32	54	32	60	23***
Stores	0	9	14	9	18	4
Bars	56	56	46	32	55	15
Restaurants	33	29	37	14	43	12
Carpenters	0	2	9	0	0	7
Builders	0	0	0	0	0	0
Tailors	5	3	11	4	16	3
Hairdressers	84	91	67	20	83	-3
Beauty salons	0	50	85	10	90	-
Flourmills	83	83	51	42	83	13
Sawmills	20	26	27	4	25	6
Auto workshops	10	18	29	6	13	13
Welder	0	40	92	0	60	-6

Note: # This ITT does not use the Diff-in-Diff setup from Section 3.3.1 but rather a cross-sectional estimation using the same control variables but an outcome (enterprises created in last two years) that already captures the over-time dimension. Negative values may imply that control sites have merely caught up with the connection rates at treatment sites, since connection rates obviously cannot exceed 100 percent. Asterisks indicate that the impact estimates are statistically significant at the 10, ** at the 5, *** at the 1 per cent level.

5.4.2. Recap of impacts of electrification expected by rural micro-entrepreneurs

The interviews in 2014 made it very clear that the micro-entrepreneurs had high expectations for income and business growth once their communities would be connected to the TANESCO grid. At the time, our interviewees argued that access to electricity can impact their businesses through four possible pathways. These four pathways are: (i) cost saving through substitution, (ii) extended operation and opening hours, (iii) purchase of electric machinery and appliances to increase productivity and business proceeds, and (iv) generating new and/ or increased demand.

As pointed out in Table 21 above, already at baseline, when communities were not yet connected to the grid, some enterprises used off-grid electricity sources. Many kiosks, bars, and restaurants used solar panels. Hairdressers tended to rely on car batteries and solar panels. Flourmills mostly ran on fuel. Some sawmills had generators, but in most cases, they relied on manual labour.

Most of the interviewed micro-entrepreneurs repeatedly pointed towards the high cost of off-grid electricity (see Box 5), which brings us to our first channel, namely cost savings. Enterprises that originally used expensive off-grid electricity sources might save money since they can substitute away from fuel for the generators. Second, electric lighting was expected to allow the micro-entrepreneurs to extend their operation and opening hours. Opening hours after sunset could be further encouraged through improved security in the villages, which was repeatedly mentioned as another important result of electric lighting. However, most enterprises already operated from 8am to 8pm.

Box 5: Selected responses of rural micro-entrepreneurs on the costs of electricity

A businessman running a restaurant in Ntungamo village about the costs of generator use for his business:

"I use 75,000 Tsh for oil to refuel the generator. I need 3 litres for music to operate from 16:00 to 22:00. Imagine each litre is 2500 TSh, a total of 7500 each day. This is too much, but I have to incur these costs because without electricity, we cannot sell any products in this restaurant. Even if not many customers are coming, by playing music and lighting you get some of them anyhow."

A ward leader from the well-developed village Kasulo, which has a generator, explained:

"Since 1997 the source of energy in the village is an own generator and nearly three quarters of the households use this source of energy for about 5 hours per day. […] Per month it costs 7000 TSh to charge mobile phones and the households or shops pay 50,000 TSh for a fridge, 20,000 for a TV and they nearly need 90,0000 to 200,000 TSh for light. Due to these high costs for energy and lack of access to electricity [from the national grid], small enterprises such as carpenters, saloons, and hotels are not performing well in the area."

A larger seller of agricultural products in the village Mbugani, who operated an own minigrid prior to electrification, explained:

"Now I am spending 700 TSh for a whole day compared to previously 60 000 TSh for only 5 hours."

Third, a stable electricity supply supposedly incentivizes the purchase of electric machinery and other electric appliances to increase productivity. Especially kiosk owners saw business opportunities in having a refrigerator to cool soft drinks and other food items. The refrigerators would allow them to buy larger stocks of perishable food such as fish and meat and keep it for longer time without perishing. The ordering costs for larger quantities would be lower and the overall availability of products would increase. This was expected to ultimately lead to a price cut of products and an increase in sales volumes and profits for shopkeepers. In terms of new services and products, especially bar and restaurant owners hoped that with electricity the broadcast of football matches on TV would increase their returns. Interestingly, interviewees did not highlight cash or credit constraints in connection with getting new machinery and appliances during the baseline interviews, while during our follow-up, this was the most mentioned bottleneck.

The fourth and last channel is about local demand, to be more precise, about the lack of local demand. It remained unclear, whether electrification would simply shift local demand for goods and service within the village towards those entrepreneurs who got a connection and could therefore produce at lower prices, faster pace and better quality. Or, whether new businesses would be created, which might attract demand from other villages.

5.4.3. Actual impacts of electrification as perceived by rural micro-entrepreneurs

We now confront the four impact channels suggested in the previous sub-section with the findings from our interviews with local entrepreneurs at follow-up.

Only two of the enterprises that were interviewed at follow-up agreed that they indeed save money due to the grid connection. These two are among the only interviewed enterprises that managed to attract a larger share of customers from other villages. It needs to be noted, though, that many of the interviewed enterprises only started their operation after the grid connection was established and thus had no prior energy costs.

Many of the other enterprises did already operate from 8am (sometimes they start with sunrise around 6am) to 8pm – even without electricity or electric lighting. Still, about half of the interviewed enterprises expanded their hours of operation due to electric lighting. Several interviewees mentioned that an important advantage of access to the grid is the possibility to spend time during the day with their many other activities and open during the evening. Opening hours are thus more of a reference than a rule. Most owners and employees also engage in other activities such as agriculture or livestock farming. They cultivate at least some food products and keep some livestock to ensure food security throughout the year and to increase their disposable income.

This shifting of activities across the day was indicated as resulting in more customers because the customers also prefer to come in the evening. Yet, the more important impression we gained from the interviews was that demand is generally quite low. Generating new and/ or increased demand is therefore difficult and not for every enterprise the need arises to allocate additional time towards longer opening hours.

The limited demand also has to do with the customer base being rather concentrated within the enterprises' communities. We encountered only two enterprises who stated to attract at least half of their customers from other villages. One is a veterinary and the other one an entrepreneur, who is selling digital music and movies as well as printing pictures, including passport pictures, for his customers. These businesses are unique among the surveyed enterprises in what they offer. Otherwise, the enterprise structure tends to be the same across villages, i.e. for most products and services there is no need to go to another village.

Shop and kiosk owners explain that even if they were to add new products to their existing stock there would not be sufficient demand. An additional explanation for the general pessimism towards the development of demand may be that our interviews took place during a low demand season, i.e. at the beginning of the small rainy season. As most villagers generate their income from agriculture, they realize most of it during the harvest, which usually takes place after the rainy season. In consequence, the villagers' demand for other products and services tends to increase after harvest.

Coming to the last potential impact channel, i.e. increases in electric machinery, the use of electric appliances and machines is still low. Shops, kiosks, pharmacies or tailors often added a radio or TV to their business in order to attract customers. However, it is unclear whether they could also sell more products as a consequence. Most of the entrepreneurs mentioned that they now provide the service of charging the villagers' mobile phones, which is largely appreciated and made use of. This might also result in some additional income. When it comes to more expensive appliances, such as a refrigerator, electric mills, or an electric sawing machine, most businesses would like to purchase them but mention financial constraints as the major supply-side bottleneck (see Box 6).

Box 6: Selected responses of rural micro-entrepreneurs on financial constraints

The owner of a carpentry in Kachwamba about his expansion plans:

"If we get the loan, we can expand our business."

M-Pesa seller in Masemba explained his plans:

"I need more capital because I wish to buy a computer and open a new stationery shop."

The combination of financial constraints and the lack of potential customers leads to a lock-in effect, which keeps most small, rural enterprises from benefitting fully from grid electricity. Frequent blackouts add to the shortcoming of potential benefits from electrification. All our interviewees mentioned frequent outages often taking place around dusk. Yet, it needs to be noted that there are also some success stories as presented in Box 7.

Box 7: Selected response from semi-structured interviews about the positive impacts of a grid connection

Welder in Nyarutemba about the importance of electricity for his business:

"If there is no electricity, there is no business."

Owner of a shop, which provides music and passport pictures on how important the business is for his well-being:

"Because of this business I do not have to go to bed being hungry."

Teacher from the village Masemba, who owns stationery shop, summarized his situation:

"I am a teacher and this business is enough to pay my employee and help myself as well."

6. Impact results for urban intervention areas

We start our analysis with assessing whether the existing electricity service actually improved. This is discussed in Section 6.1. The subsequent sub-sections then show how the changes affected the use of energy sources and electricity services, expenditures and the customers' valuation of the electricity service.

As outlined in the methodological section, identifying similar towns for a control group was not possible. We therefore rely on a simple before-after comparison using only survey households and enterprises from the three treatment towns Ngara, Biharamulo and Mpanda. For urban households presented in Section 6.2 and 6.3, we only interviewed connected customers, also because most households in the considered town areas have grid connections. Regarding urban enterprises discussed in Section 6.5 and 6.6, we considered both connected and non-connected enterprises in our sampling strategy. As will be shown, enterprises are mostly connected as well.

6.1. Quality of electricity service

In the absence of comprehensive outage data from TANESCO, we rely on blackout information reported by households and enterprises. We asked for the 30 days prior to the interviews. Interviews for households and enterprises took place during different periods, so both may refer to different reliability levels. Indeed, blackout levels and use of generators tend to fluctuate over time (cf. the data for Biharamulo and Ngara in Figure 13), e.g. due to the rainy season and storms[51], fuel availability, changes in the transmission system[52], or generator maintenance (more relevant during baseline). Moreover, households and enterprises are differently exposed to blackouts: while households rely on electricity in particular during evening hours, enterprises rather need electricity during the day. Also remember that Mpanda entirely relies on electricity generated by the two ORIO generators, whereas the other two towns are connected to the yet underperforming national grid and use the ORIO generators as back-up electricity sources.

Table 22 shows the number of blackouts and the duration of the longest blackout in the month preceding the interviews, differentiated by town and by the household and enterprise survey. This information is complemented by data on the perception of reliability in Table 23 and Figure 13 for enterprises and households, respectively. Generally, a mixed picture emerges. The clearest conclusion that can be drawn is that the reliability in Mpanda improved significantly. Furthermore, we observe that the occurrence of long blackouts has decreased significantly. In this context, the availability of the back-up generators plays a role in Ngara and Biharamulo. While they are not switched on automatically, TANESCO uses them as back-up in case

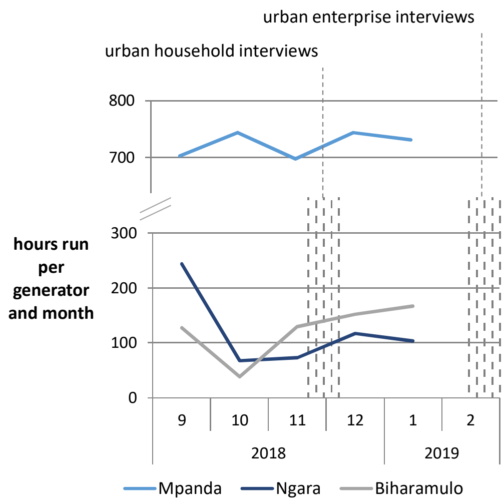


Figure 12: Generator use during survey period

Source: own representation

[51] For example, according to the Regional Manager of TANESCO in Kagera, a cause of power cuts in the past were pine trees falling on transmission lines along the electricity grid. Measures have been taken in the meantime to clear stretches along the grid from such trees.

[52] For example, a new Automatic Voltage Regulator was installed along the transmission line to Ngara shortly before the follow-up survey.

of longer national grid outages. Still, these grid outages use to be smaller than the outages previously experienced with the old generators. The reduction in long-lasting blackouts is therefore both due to the connection to the national grid and due to the additional availability of the generators as back-up. At the same time, the national grid in the north-western area of Ngara and Biharamulo is – as of now – unreliable and suffers from frequent blackouts. In consequence, the frequency of blackouts has rather increased or remained stable at best in Ngara and Biharamulo, in Biharamulo from a worse level in 2014. In particular the situation during peak times seems to have deteriorated, also because of considerably increased demand.

Table 22: Blackouts in last 30 days, by districts

	Households			Enterprises		
	Baseline (2014)	Follow-up (2018)	Difference *p*-value	Baseline (2015)	Follow-up (2019)	Difference *p*-value
Number of blackouts experienced in last 30 days						
Biharamulo	9.4	15.6	0.00***	26.6	24.6	0.58
Ngara	3.7	28.5	0.00***	20.2	22.9	0.33
Mpanda	7.5	5.2	0.02**	22.7	3.3	0.00***
Duration of longest black-out in last 30 days, in hours						
Biharamulo	-	2.4	-	18.7	4.6	0.00***
Ngara	-	4.8	-	18.2	8.0	0.00***
Mpanda	-	4.3	-	22.7	9.2	0.00***

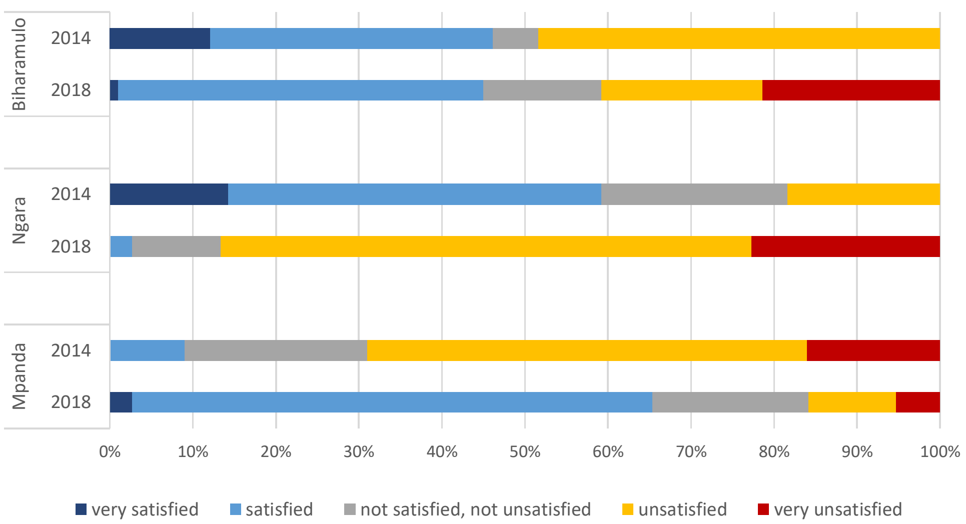
Note: Asterisks represent statistical significance of the orthogonality mean test between 2014 and 2018 observations.
* indicates that the difference is statistically significant at the 10, ** at the 5, *** at the 1 percent level.

Source: If not mentioned otherwise, all data presented in this section refers to the baseline and follow-up data collected in the context of this study (see Section 3.3.2).

Table 23: Perception of reliability among urban customers at follow-up

Perceived reliability in 2019 in comparison to 2014, in %	Households			Enterprises		
	Biharamulo	Ngara	Mpanda	Biharamulo	Ngara	Mpanda
better	94	40	100	83	34	99
similar	3	4	0	3	4	0
worse	3	56	0	15	62	1

Figure 13: Perception of reliability among urban households

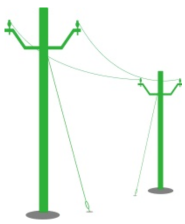


Box 8: Summary of outcomes of the ORIO intervention

ORIO intervention » Output and Intermediate Outcomes » **Outcomes** » Impact and Cost-Benefit

Electricity access

- 1,500 customers connected at TANESCO sites supported by ORIO (as of October 2018)
- among them around 600 enterprises and 130 public service facilities such as schools
- according to TANESCO, more than 97% of the connections are in the domestic user tariff category with monthly consumption below 75 kWh, which can also be considered as a customers' poverty indicator
- at least the same amount of connections has been made in the REA sites connected to the ORIO-supported generators and grid
- this compares to a project objective of 18,500 new connections to be achieved 10 years after project implementation



Reliability

- reliability of electricity supply in Mpanda is considered high and considerably better than in 2014; here the two ORIO-supported generators operate full-time
- in the other two towns, the generators serve as back-up on a very regular basis for a so far unreliable connection to the national central grid, especially during evening hours, which are most critical for household customers
- despite the combination of grid electricity and back-up generators, overall reliability of electricity supply in Ngara has deteriorated
- reliability is still an issue for Biharamulo, where the situation is perceived to have improved from a worse level in 2014

Sources: ORIO Indicator Framework; Interviews with TANESCO headquarter and district offices, 2018; Interviews with village representatives, 2018; ORIO (2013)

6.2. Urban household profile

Our baseline sample included 300 households with 1,649 members. Due to survey attrition, in 2018 we could re-interview only 250 households with 1,346 household members. In the before-after comparison that follows, we only consider these 250 households for which data is available for both survey rounds. We start by portraying the sample on the basis of selected socio-economic indicators, also to give an idea of the dynamics between the two surveys rounds (see Table 24).

Table 24: Household characteristics

	Baseline (2014)	Follow-up (2018)	Difference *p*-value
Household structure			
Household size	5.55	5.38	0.44
Share of children 0 - 11, in %	26	24.1	0.35
Share of children 0 - 6, in %	12.4	11.9	0.68
Characteristics of the household head			
Female household head, in %	23.8	26.4	0.50
Age of household head	48.41	52.65	0.00***
Sector of activity of primary occupation			
farming	49.2	36.4	0.00***
public sector	19	20	0.77
other market work	22.2	28	0.14
Educational attainment			
less than primary education completed	13.2	7.2	0.03**
primary education completed	44	50	0.18
secondary education - ordinary level	25.2	24.8	0.92
higher education level	17.6	17.6	1.00
Household agriculture, in %			
Land owners without property	83.4	83.7	0.95
Household cultivates land	84.4	80.8	0.29
Household keeps livestock	54.4	48.4	0.18

Note: The *p*-values refer to statistical significance of the orthogonality mean test between 2014 and 2018 observations. Asterisks indicate that the impact estimates are statistically significant at the 10, ** at the 5, *** at the 1 per cent level.

The household structure did not significantly change over time. Comparing the figures with the rural households we observe that – in line with expectations – urban households are on average smaller and have a lower share of children. Female-headed households have become slightly more common. There are usually no spouses present in these households, partly because husbands have migrated or died, and the women live with their children, sometimes with their parents.

Although we use the term "urban" for the three towns, these could as well be described as rural centres and have not much in common with what one might relate to the term "urban" in a developing countries context. In line with this, farming is still a very important source of income, even though one observes a significant decrease over time. This goes along with an increase of household heads running a business or being employed in the private sector. The percentage of people working in the public sector has not changed. These are mainly teachers, policemen and nurses.

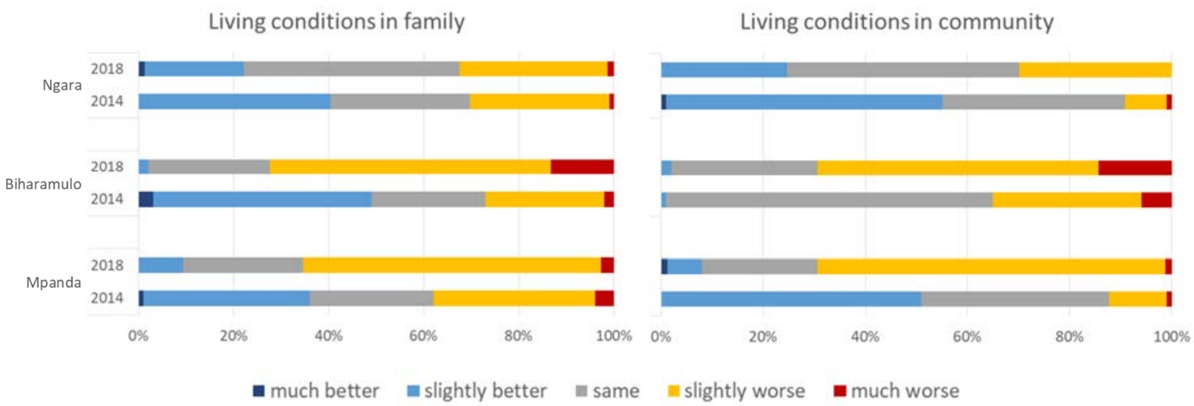
In Table 25, we additionally show expenditure and income information. We consider the six core expenditures food, water, schooling, telecommunication, traditional energy and electricity. Among these, food clearly occupies the highest share as we have already seen for rural areas. The table also provides a qualitative income assessment by looking at the households' perception, which has deteriorated from 2014 to 2018. In 2018, 62 percent of households considered their income as insufficient compared to 49 percent in 2014. Relatedly, Figure 14 depicts the households' perception of the general living conditions in their family and community in comparison with the situation three years ago, differentiated by the three towns. Households in Ngara seem to perceive the living conditions better than in other towns (despite the worse level of electricity reliability). Nevertheless, households in all regions assess living conditions in 2018 more pessimistic than during the baseline survey round.

Table 25: Household expenditures and income

	Baseline (2014)	Follow-up (2018)	Difference *p*-value
Share of expenditure categories in annual core expenditure#, in %			
food (including restaurants)	57.1	60.5	0.06*
water	3.1	4.2	0.00***
telecommunication	7.4	4.5	0.00***
schooling	17.7	13.9	0.03**
Annual core expenditures, in TSh	3,808,300 (2,104,300)	3,185,600 (2,178,100)	0.00***
Perception of household's income, in %			
sufficient	17	12	0.09*
tight	34	26	0.07*
insufficient	49	62	0.00***

Note: # Core expenditures include food, water, telecommunication, schooling, traditional energy and electricity. Energy and electricity expenditures are covered in the next sub-chapter. Standard deviations in brackets. The *p*-values refer to statistical significance of the orthogonality mean test between 2014 and 2018 observations. Asterisks indicate that the impact estimates are statistically significant at the 10, ** at the 5, *** at the 1 per cent level.

Figure 14: Perception of living conditions compared to 3 years ago situation by regions, in percent



6.3. Effects on energy service provision among urban households

6.3.1. Electricity access

Our sample of TANESCO household clients in town has been connected to the grid for on average 8.7 years at follow-up in 2018. There is hardly any other source of electricity used by the urban households: 249 out of 250 sampled households were connected to TANESCO in both survey rounds, three households used private generators in 2014 while in 2018, five solar panels and one individual generator were used. These alternative electricity sources are mainly kept as back-up sources in case of blackout.

Electricity consumption has increased only slightly in that we observe few more people with consumption levels exceeding 75 kWh per month at follow-up compared to baseline (Figure 15).

6.3.2. Appliance usage

Urban households own considerably more appliances than those in the rural areas. Changes over time can primarily be observed in key appliances (mobile phones, TV and radio), whereas ownership of electric irons, fridges and stoves stagnated (Table 26). Similar to other electrified regions in Africa, use of electric stoves remains particularly low at six percent.

Table 26: Appliance ownership, in percent, and lighting usage

		Baseline (2014)	Follow-up (2018)	Difference *p*-value		Baseline (2014)	Follow-up (2018)	Difference *p*-value
Phone	mobile	90	95	0.04**	TV	75	91	0.00***
	landline	5	1	0.01***	Satellite receiver	58	62	0.32
Radio	battery	14	8	0.02**	Electric fridge	24	26	0.47
	bivalent#	37	8	0.00***	Electric stove	5	6	0.70
	line power	38	57	0.00***				
Iron	charcoal	46	29	0.00***	Daily hours of artificial light	40.4	62.0	0.00***
	electric	52	56	0.42	Daily lumen hours	30,216	42,210	0.00***

Note: # bivalent refers to radios that can be run both with batteries and grid electricity (line power). The *p*-values refer to statistical significance of the orthogonality mean test between 2014 and 2018 observations. Asterisks indicate that the impact estimates are statistically significant at the 10, ** at the 5, *** at the 1 per cent level.

Figure 15: Monthly electricity consumption, in kWh

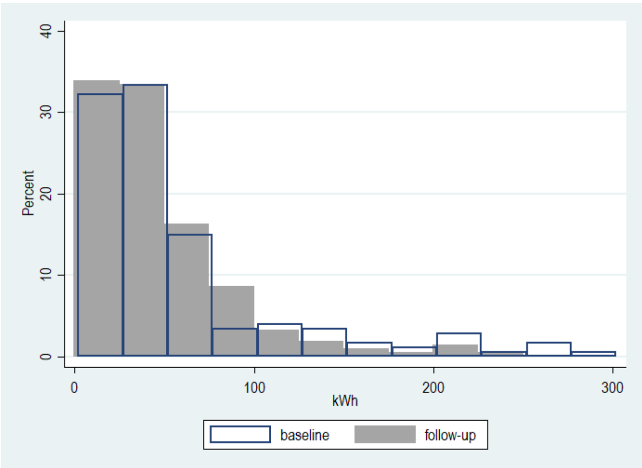
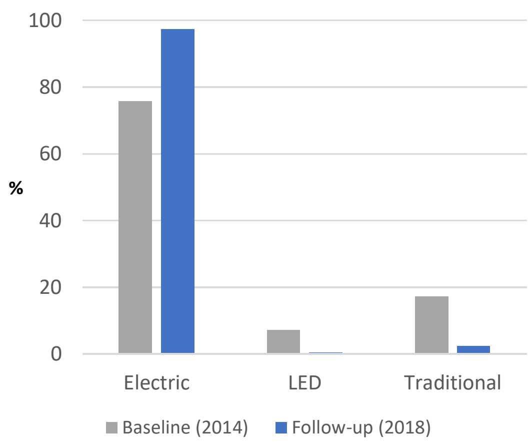


Figure 16: Households' primary light sources



The share of households that employs some of their appliances for home businesses or home production is low at baseline and follow-up and rather seems to have decreased (from 14 to eight households). In most of these cases, households use their mechanic or electric sewing machines to make goods for the market. But also, refrigerators, an iron, a sound system and a computer serve non-private uses.

Electric lighting almost completely replaced all alternative lighting devices as the dominant lighting source (Figure 16). There is a significant increase in the total hours of artificial light consumed by households (see again Table 26). Due to usage of better-quality lighting devices, lumen hours increased even stronger. These lighting patterns are also dependent on income levels: poorer households changed their lighting habits less than richer households (not shown in the table).

6.3.3. Use of different energy sources and expenditures

As for the rural sample, electricity strongly crowds out traditional energy sources. We now also show energy use data for the lowest and highest expenditure quintile, i.e. for the 20 percent of poorest and wealthiest households according to expenditures (Table 27). While a large share of households used kerosene and dry-cell batteries in 2014, this share dropped to six percent (kerosene) and nine percent (dry-cell batteries). Irrespective of electricity, LPG has become much more used among households, especially among wealthier households, even though all households remain strongly dependent on charcoal.

Charcoal also takes the lion's share in energy expenditures, which put a particular burden on poorer households, who spend more than 15 percent of their core expenditures on traditional energy, compared to six percent for the richest quintile. Similarly, poorer households spend more on electricity than richer households, who even experienced a borderline significant decrease in the share of electricity in their core expenditures. The overall increase in the share of traditional energy expenditures in core expenditures can be explained by the strong increase in LPG usage.

Table 27: Use of energy sources, by expenditure quintiles

	All households			**Lowest expenditure quintile**		**Highest expenditure quintile**	
	Baseline (2014)	Follow-up (2018)	Difference *p*-value	Baseline (2014)	Follow-up (2018)	Baseline (2014)	Follow-up (2018)
Use at least once in last 30 days, in %							
kerosene	44	8	0.00***	37	7	49	11
dry-cell batteries	40	11	0.00***	13	16	42	8
LPG	6	28	0.00***	8	11	9	51
wood	38	37	0.82	62	60	26	29
charcoal	88	88	0.78	80	75	94	100
Share of expenditures on kerosene for lighting and for batteries in core expenditures, in %	0.8	0.1	0.00***	1.4	0.3**	0.5	0.1***
Share of traditional energy in core expenditures, in %	10	12	0.01**	16	15	6	7
Share of electricity in core expenditures, in %	5	5	0.97	9	7	3	2*

Note: The *p*-values refer to statistical significance of the orthogonality mean test between 2014 and 2018 observations. Asterisks indicate that the impact estimates are statistically significant at the 10, ** at the 5, *** at the 1 per cent level.

6.4. Impact assessment for urban households

Potential impacts among the urban beneficiaries of the ORIO intervention generally are less tangible than those for the new-access customers in rural areas. When asked about advantages and disadvantages of being connected to reliable electricity, most households mention a reduction in costs compared to traditional energy sources (see also Table 27 above), or increase in convenience. For example, due to the lack of other electricity sources, most households have to rely on traditional energy sources in case of blackouts such as battery or mobile phone torches.

To gauge the improvements experienced by urban households, we asked them for their willingness to pay (WTP) for fully reliable electricity access. One would expect that this WTP decreased over time if actual reliability levels improved, and vice versa – a household that already enjoys reliable electricity supply is willing to spend less to eliminate blackouts entirely. Specifically, we asked for households' WTP as follows:

> "Currently your electricity source is unreliable; you experience frequent blackouts and low voltage. Imagine you could have an electricity connection that enables you to always use electricity 24 hours a day without interruptions. Would you be willing to pay additional 2,000 TSh each month to get this better service?
> Please consider your real budget, that means your revenues and all other expenses you have to pay each month. Please note that your answer does not have any effect on any real prices. So would you be willing to pay the 2,000 TSh each month to get this better service?"

If households agreed that their WTP was 2,000 TSh, i.e. around one Euro, they were asked whether it was also of higher amount, otherwise we asked for a lower amount, in order to eventually come up with a WTP value for each household. Considering the results presented in Table 28, the WTP for stable electricity has decreased over time. Whereas in 2014, 16 percent of households were unwilling to pay any money for improved electricity supply, this share was at 31 percent in 2018. Average WTP fell significantly from 3,440 TSh to 1,660 TSh per month (1.6 and 0.6 Euro, respectively), or – put in relation with core expenditures – from 1.3 percent to 0.9 percent. This WTP decrease seems to indicate that households are generally more satisfied with actual level of electricity and reliability. This argument is supported by the increased satisfaction with reliability of TANESCO electricity as already exposed in Section 6.1.

Table 28: Willingness-to-pay for stable electricity supply

	Baseline (2014)	Follow-up (2018)	Difference *p*-value
Monthly willingness-to-pay for stable electricity supply, in %			
0 TSh	16	31	0.00***
less than 2,000 TSh	13	14	
2,000 to less than 5,000 TSh	53	52	
5,000 TSh or more	18	3	
average, in TSh	3,440 (370)	1,660 (100)	0.00***
as share in core expenditures, in %	1.3	0.9	0.00***

Note: Standard deviations in brackets. The *p*-values refer to statistical significance of the chi^2 and orthogonality mean test between 2014 and 2018 observations. Asterisks indicate that the impact estimates are statistically significant at the 10, ** at the 5, *** at the 1 per cent level.

Disaggregating the data by town, we see that the share of people unwilling to pay any money for improved electricity supply does not differ strongly across towns. This share may rather reflect a general unwillingness to pay for more reliable electricity access, be it, because households consider this as a core duty of TANESCO that should not be additionally paid for or because households doubt TANESCO's capacity to improve the situation, even with more tariff receipts available. To the contrary, average WTP levels differ across towns in line with perceived reliability levels: with WTP being on average equivalent to 1.2 percent of core expenditures, it is highest in Ngara, compared to 0.8 percent in Biharamulo and 0.7 percent in Mpanda.

We additionally approached the question of changes in electricity reliability in a second manner: we first asked respondents whether they agreed that the reliability of the electricity supply has improved compared to the time of our previous visit in 2014 (see again Section 6.1). We then asked those who stated that reliability has improved whether they would be willing to accept the worse level of 2014 if we paid them 2,000 TSh each month, i.e. we elicited their so-called *willingness to accept* (WTA). Conversely, we asked those who stated that reliability has not improved whether they would be willing to pay additional 2,000 TSh per month to get these better services from 2014. We find that 77 percent of households are not willing to accept any payment to get worse reliability, the remainder mostly being willing to accept an amount below 3,000 TSh per month. The WTP question merely applied to 44 respondents, the majority coming from Ngara, and – similar to what we found above – almost half of them declared to be unwilling to pay for getting better services.

To conclude, we see some valuation for improved electricity services, reductions in this valuation indicating improvements in the reliability over the project cycle and a strong unwillingness to accept a worsening of electricity reliability.

6.5. Urban enterprise profile

In this section we present descriptive statistics for a total of 327 SMEs from the three surveyed towns, Ngara, Biharamulo and Mpanda, which were surveyed in both survey waves. The SMEs are categorized into *Trade, Services, Manufacturing* and *Mining*. *Trade* is defined as SMEs which sell goods or merchandise that do not involve their transformation. *Services* are SMEs which focus on serving the customer rather than transforming or just selling physical goods, and *Manufacturing* is the production (or maintenance) of merchandise for use or sale using mainly labour and machines or tools. It can be expected that this classification does not only provide a differentiation of the core activities of the enterprises but also strongly determines their energy needs: trade usually only requires electric lighting and maybe a refrigerator, services typically rely on some sort of devices and manufacturing often requires machines with high energy demand.

Table 29: Basic structure of the enterprise

		Trade	Service	Manufacturing
Number of enterprises		102	105	120
Number of enterprises that changed sector between 2015 and 2019		3	3	3
Year of foundation, in %	before 2000	10	8	12
	2000 - 2011	44	48	49
	2012 - 2014	46	43	39
Business is proprietary, in %		96	92	91
Member of business association, in %		31	28	17
Male enterprise owner, in %		75	68	86
Age of enterprise owner, average		40.1 (9.5)	43.0 (12.2)	43.3 (10.6)
Education of enterprise owner, in %	less than primary completed	13	8	13
	primary completed	48	37	50
	high school	28	33	24
	vocational training	3	4	7
	higher education	9	19	6
At least three years of business experience at baseline, in %		73	78	83

Note: Standard deviations in brackets.

Some enterprises perform activities that qualify for more than one of the SME categories, such as stationary shops that also offer photocopying services. We classify SME according to their main activity, based on an assessment of the business by the enumerators and the entrepreneurs themselves. After some reclassifications, there are in total 102 enterprises in trade, 105 in services, and 120 in manufacturing (Table 29). Main enterprises in trade are mixed consumer goods shops, small kiosks, clothes shops and shops selling hardware and drinks, but the category also includes more specialized shops like CD and cosmetics shops. Service providers found in the sample are mostly guest houses, barbers, photocopying, pharmacies, beauty salons, and restaurants. Finally, manufacturing is less diversified and is concentrated to mills, tailoring, carpentry and welding/ garages. Merely nine enterprises changed sector between 2015 and 2019.

Many of these enterprises were established in the last decade. Table 29 additionally presents the ownership structure and business association membership as two indicators of how established these enterprises are. Note that these business associations are mostly on the local level. There is no substantial difference between sectors in term of business association membership. Similarly, ownership structure of the sampled enterprises is very similar in all sectors. Information on enterprise owners in the table makes clear that there are more male than female enterprise owners in all sectors. Female entrepreneurs are more active in trade and services sectors than in manufacturing. Most entrepreneurs are experienced in their business with 73 to 83 percent of entrepreneurs already being active in the respective business for at least three years at baseline. While most of the entrepreneurs have completed primary level of education, those involved in services tend to be most educated.

Table 30 adds information on how the enterprises run their operation, now differentiating between baseline and follow-up. Most owners have only one business and the average workforce in the SMEs is relatively small. This is especially true for trade businesses, where half the enterprises were without employees in 2015. In 2019, still 38 percent were run by owners only. It has to be noted though that this sector involves frequent out and in of employees during a calendar year. Manufacturing firms tend to employ more people, while both enterprise types rarely employ women. In contrast, the service sector is not only more often run by women, half of the workforce is female.

Table 30: Enterprise business information

	Baseline (2015)			Follow-up (2019)		
	Trade	**Services**	**Manufacturing**	**Trade**	**Services**	**Manufacturing**
Owner has another business, in %	23	30	18	16	27	18
Enterprises without employees, in %	53	19	28	38	15	30
Average number of employees	1.1 (2.4)	2.8 (2.9)	2.6 (3.6)	1.3 (2.6)	2.7 (4.8)	4.3 (22.9)
Share of employees by employee category, in %						
family members	39	18	15	55	12	20
Apprentices	2	1	12	0	2	12
male employees, permanent	28	31	46	22	24	45
male employees, temporary	20	11	24	15	18	19
female employees, permanent	10	32	1	4	34	2
female employees, temporary	1	8	2	4	10	3

Note: Standard deviations in brackets.

6.6. Effects on electricity service quality among urban enterprises

With a few exceptions, all sampled enterprises are connected to the TANESCO grid (Table 31). The main reasons for not being connected are the inability to afford the initial connection charges and electricity bills. Many non-connected enterprises also stressed that they recently requested a TANESCO connection. What is more, 25 percent of non-connected SMEs at follow-up stated that their operation does not need electricity, compared to only 5 percent at baseline. The table furthermore shows that electric lighting is the most common and most intensely used appliance type. Further appliances used are entertainment devices (most common among service enterprises) and machines (among manufacturers). Internet connectivity is still low.

Table 31 additionally shows that electricity consumption patterns have not changed over time: there is basically no difference in the amount of electricity consumed. Consumption is highest among manufacturing and lowest for trade. While still around 10 percent of enterprises were charged post-paid in 2015, basically all enterprises have a pre-paid meter in 2019. Enterprises are seldom without credit on the prepaid meter and if so, they recharge their prepaid meter immediately, on average within two days. There are slight differences in the actual price paid for electricity between the enterprise sectors that are due to the increasing block tariff structure applied by TANESCO according to which per kWh prices increase if certain consumption thresholds are exceeded, with 75 kWh being the lowest threshold. Note that the level of prices per kWh decreased between 2015 and 2019.

Table 31: Enterprises' electricity use

	Baseline (2015)			Follow-up (2019)		
	Trade	**Services**	**Manufacturing**	**Trade**	**Services**	**Manufacturing**
Connection to electricity grid, in %	95	96	88	97	98	89
Average duration of electricity connection, in months	65 (63)	59 (67)	74 (64)	98 (66)	96 (55)	110 (73)
Non-shared electricity connection, in %	77	78	81	94	94	92
Main appliances used, in %						
Electric lighting	95	96	85	97	96	85
Telephone (fixed line)	7	11	1	1	3	1
Radio or sound system	54	50	23	34	25	13
TV (colour)	41	57	7	25	45	5
Fan	20	33	2	20	26	4
Internet	6	6	6	10	9	6
Monthly electricity consumption, in kWh	125 (195)	150 (215)	290 (470)	125 (245)	155 (425)	315 (580)
Monthly expenditure on pre-paid electricity, in TSh	34,530 (52,870)	45,700 (57,520)	96,730 (192,590)	33,005 (53,265)	42,955 (61,005)	120,440 (222,080)
Price paid per kWh on prepaid system, TSh	377 (304)	404 (253)	442 (317)	275 (142)	326 (174)	332 (126)
Without electricity in the last two months because of missing credit#, in %	-	-	-	13	7	6
average number of days without electricity#	-	-	-	2.3 (1.0)	3.8 (5.1)	1.5 (0.5)

Note: Standard deviations in brackets. # questions not asked at baseline

How do enterprises cope with unreliable electricity access? A main coping strategy shown in Table 32 is to use back-up electricity sources. The share of enterprises owning such sources has decreased from 22 to 16 percent, mostly driven by enterprises in Biharamulo and Mpanda where reliability has improved. Main back-up source are individual generators. The share of enterprises with a generator went down from 18 to 10 percent, in this case mostly driven by trade enterprises. They prefer solar power in 2018 due to their lower power requirements. The decrease in the more electricity-reliant service and manufacturing sectors is very modest. Here generators made up 90 and 88 percent of back-up electricity facilities at baseline and still 85 and 80 percent at follow-up, respectively.

The table also lists additional coping strategies in case of blackouts. Responses differ across the three sectors: For trade enterprises blackouts apparently do not pose major problems. Around 70 percent of trade enterprises simply continue normal operations (which may, nevertheless, imply less customers or other negative implications) and another around 20 percent switch to activities that do not require electricity. Merely 2 and 12 percent of trade enterprises mentioned to stop operations until electricity supply is resumed at baseline and follow-up, respectively. Electricity again proves to be more essential for the production process for service and, in particular, manufacturing enterprises, something also observed in Grainger and Zhang (2017): 16 percent of service companies had to stop their operations (37 percent at follow-up) and this number was even higher for manufacturing companies at 39 percent (52 percent at follow-up). Still, over 60 percent of service companies and about half the manufacturing companies either continue their operations or engage in non-electric operation. The majority of companies in both sectors thus seems to be able to deal with blackouts in a rather smooth way, even though dealing with blackouts became less smooth in 2019. The share of enterprises stopping their operation until electricity supply is resumed increased throughout all sectors. A shift in operation hours does not seem to be an option to cope with shortages.

Beyond blackouts, voltage fluctuations (brownouts) are another problem of unreliable electricity supply. Only around 23 percent of enterprises had an electricity stabilizer at baseline, 12 percent at follow-up. As a consequence, around 40 percent of enterprises have already experienced appliance damages, most often with TV sets but also with fridges, light bulbs and motors among others.

Table 32: Electricity interruptions and coping strategies of enterprises

	Baseline (2015)			Follow-up (2019)		
	Trade	Services	Manufacturing	Trade	Services	Manufacturing
Availability of back-up facility, in %						
total	19	40	8	16	26	6
Biharamulo	17	35	5	14	12	4
Ngara	17	28	7	18	24	14
Mpanda	22	55	9	17	38	4
Type of alternative electricity sources, in %						
Individual generator	50	90	88	33	85	80
solar power	29	5	0	67	12	20
car batteries or other rechargeable batteries	21	5	12	0	4	0
Coping strategy in case of electricity blackout, in %						
Continue normal operations	70	52	24	67	45	33
Engage in non-electric operation	21	18	31	17	16	15
Shift hours of operation	3	2	3	0	0	0
Stop business until resumed	2	16	39	12	37	52
Other	4	11	3	4	2	0
Ownership of electricity stabilizer among TANESCO clients, in %	19	30	19	14	12	11
Experienced appliance damages due to blackouts, in %	40	38	45	33	53	34

6.7. Impact assessment for urban enterprises

We assess firms' WTP to gauge the value the firms assign to reliable electricity. This is to approximate the aggregate impact that a reliability improvement intervention may achieve – e.g. on convenience and adaptation costs (see also Section 3.3.1). The question we posed is analogous to the one asked to urban households (see Section 6.4). Table 33 depicts the results of a two-part model, where the

WTP divided by current monthly electricity expenditures is the dependent variable. We thus do not explain the absolute value of the WTP but the WTP as a share of electricity expenditures in order to account for largely different electricity consumption patterns across enterprise types (see last section). The left column (Part 1) shows in how far different factors correlate with whether an enterprise report a positive WTP (or instead chose to state a zero WTP). The right column (Part 2) depicts the size of the effect on WTP given that the reported WTP is positive.

In both parts, correlations of WTP with potentially relevant factors are assessed. These factors comprise the frequency of blackouts of different durations reflecting the level of current reliability, enterprise characteristics – including the location, enterprise type and tariff level – as well as entrepreneur characteristics. The presented coefficients can be interpreted in the following manner: with each blackout more lasting more than three hours, entrepreneurs are 12 percentage points more likely to report a positive WTP for reliable electricity, whereas the bare number of blackouts rather makes entrepreneurs slightly more likely to report a zero WTP (see the first coefficient of -0.030 in Part 1). The coefficients in the right column imply, for example, that the same additional occurrence of a blackout lasting more than three hours makes the entrepreneur to increase her/his WTP equivalent to 0.7 percentage points of the electricity bill.

Having a back-up electricity source at disposal increases the likelihood of reporting a non-zero WTP (although this increase is statistically only borderline significant). This is understandable given these enterprises experience actual costs with blackouts and likely depend more heavily on reliable electricity. Counterintuitively, customers in higher-consumption tariff levels are less likely to report a positive WTP. In line with expectations, enterprises in Ngara and particularly Biharamulo have a significantly higher WTP than enterprises in Mpanda, although they are less likely to report a positive WTP in the first place. The sector type of the enterprise does not show any significant coefficients. Note that this, however, does not rule out that manufacturing firms have a higher WTP in *absolute* terms, given that they consume more electricity so that a 1 percentage point increase for manufacturing firms implies a higher WTP than a 1 percentage point increase for service or trade firms.

Among the entrepreneur characteristics, the asterisks indicate that only a higher education is significantly related to whether the entrepreneur has a positive WTP for reliable electricity. Here, the higher educated entrepreneurs are considerably less likely to report a positive WTP.

To conclude, there is a mixed pattern related to the likelihood of stating a non-zero WTP in the first place, which may also be affected by factors such as trust in TANESCO or regional differences in the business culture, for example. The clearest pattern that emerges is that WTP increases both in terms of non-zero WTP and in terms of size for longer-lasting blackouts (more than three hours). It has to be noted, though, that enterprises reported merely 0.9 occurrences in a normal week of such long-lasting blackouts. Given the rather small observed coefficients, we therefore do not find evidence for a high valuation of grid reliability among enterprises based on the adopted WTP approach.

Table 33: Urban enterprises' WTP determined by two-part model estimations

	Part 1	Part 2
	Binary Probit	OLS
# of blackouts per week	-0.030***	0.007
	(0.000)	(0.320)
# of blackouts lasting more than 3h	0.122***	0.007*
	(0.000)	(0.064)
Enterprise possesses a back-up electricity source	0.339	-0.019
	(0.128)	(0.295)
TANESCO tariff level		
D1 (domestic users)	Reference case	Reference case
T1 (small business)	-0.190	-0.025***
	(0.612)	(0.000)
T2 (light industrial)	-0.456**	-0.058
	(0.024)	(0.288)
T3 (heavy industry)	-1.237***	0.019
	(0.000)	(0.659)
Location		
Mpanda	Reference case	Reference case
Ngara	-0.380*	0.013
	(0.084)	(0.742)
Biharamulo	-0.426**	0.072***
	(0.011)	(0.013)
Enterprise type		
trade	Reference case	Reference case
services	0.377	-0.008
	(0.268)	(0.594)
manufacturing	0.148	0.007
	(0.305)	(0.852)
# of employees	0.009*	-0.000***
	(0.087)	(0.028)
Enterprise created after 2015	-0.842***	0.017
	(0.000)	(0.717)
Education of entrepreneur		
less than primary education	Reference case	Reference case
primary education completed	-0.343*	0.030
	(0.092)	(0.627)
high school	-0.238	0.035
	(0.564)	(0.685)
vocational training	0.449	0.019
	(0.276)	(0.348)
higher education	-0.439***	0.048
	(0.000)	(0.541)
Constant	2.040*	0.092
	(0.055)	(0.509)
Number of observations	331	178

Note: The estimations additionally control for the gender, age and squared age of the entrepreneur and whether the interviewee is the entrepreneur or a manager of the enterprise. *p*-values in brackets. The *p*-values refer to statistical significance of the respective coefficient. Asterisks indicate that the impact estimates are statistically significant at the 10, ** at the 5, *** at the 1 per cent level.

7. Cost-Benefit Analysis and sustainability of the ORIO activities in Tanzania

This section puts the medium-term impacts presented above in the context of the long-term project cycle of this infrastructure intervention. It thereby also addresses the sustainability of the ORIO activities in Tanzania. A starting point for this discussion is the cost-benefit analysis (CBA) prepared for the project in 2012 (Ecorys-Aidenvironment 2012). This CBA came to the conclusion that the project was commercially not viable, but economically it was. In addition, it was considered financially sustainable. The different assessments and conclusions can be explained as follows: for the analysis of economic instead of commercial viability, the (economic) benefit was not determined by receipts according to the assumed future TANESCO tariffs, but by means of customers' so-called *affordability to pay* (ATP) per kWh of electricity, referring to the assumed valuation of electricity by the population. The financial sustainability additionally accounted for the ORIO grant, the matching grant from the government and cross-subsidies by TANESCO (from hydropower with its low variable costs). This contribution was calculated to make up 61 percent of total project financing over the expected technical life cycle of the procured goods of 30 years, while the ORIO grant contributed four percent. Even when excluding the 31 percent covered by customer payments for electricity, the ORIO contribution would only amount to six percent.

Considering the main assumptions underlying these calculations, two factors turned out to develop more favourably, and two less favourably than expected. Compared to the assumptions underlying the previous CBA…

+ tariffs were in fact 66 to 90 percent higher in year 1 of the project, depending on tariff category;
+ fuel prices are around 20 percent lower so far;
- fuel consumption per kWh of the new generators is 33 to 67 percent higher up to date, depending on project site;
- actual electricity production in 2018 was half the production expected for year 1.

Even more importantly, two of the generator sets serve as back-up electricity generation facilities only, with the third site potentially being connected to the national grid in a couple of years as well. In addition, REA additionally contributed to the project through connection subsidies and complementary grid extension efforts. Finally, future maintenance may not follow the initial planning given that the O&M phase of the project has been cancelled.

Against this background, it seems inappropriate to redo a quantitative cost-benefit analysis of the ORIO Tanzania project at this stage. Instead, the following discussion addresses the outlook for three main aspects that are critical for how project costs and benefits will stand against each other in the long term: (i) generators, (ii) transmission and distribution network and (iii) grid connection numbers.

Similar to the initial appraisal exercise in Ecorys-Aidenvironment (2012), such an assessment remains partly speculative and has to acknowledge the dynamics of the (politicized) electricity sector.

Outlook for the ORIO generators

The two ORIO generators in Mpanda can be expected to serve as primary electricity generation units in the area for the coming years, since the national grid is unlikely to reach the area before 2024 (see Box 9). Due to considerable demand increases, TANESCO even added a third generator from nearby Loliondo (a 1.25MW ABC generator as well), where it was standing idle and a second generator from there may follow later.[53]

[53] Information retrieved in interview with TANESCO headquarter, 2018

Box 9: Current developments in the national electricity sector

Two developments in the Tanzanian electricity sector are of particular importance when it comes to rural electrification: the current phase of the rural electrification scheme, REA III, and large transmission network extension projects.

The third phase of the Tanzanian rural electrification scheme under the aegis of REA, REA III, has the ambitious target of electrifying another 3,500 villages (remember that the electricity grid reached 4,400 out of 12,300 villages by 2018, cf. Section 4.1.1). The first of multiple rounds started in 2018. In Kagera region, the region of the sites Biharamulo and Ngara, for example, 132 among the 312 villages without any access to the national grid (among a total of 648 villages) are planned to be electrified at least partly during the first round of REA III. This round is planned to last until June 2019, with others intended to follow suit.[i]

At the same time, substantial international financial support is secured for transmission network expansion and interconnection. In 2018 alone, the World Bank approved funding for the Tanzania-Zambia Transmission Interconnector Project in southern Tanzania going up to Sumbawanga, as well as the Backbone Transmission Infrastructure Project in central Tanzania, which also involves other donors including the African Development Fund, JICA, EIB and the South Korea Economic Development Co-operation Fund (EDCF). Moreover, AfDB and EDCF agreed to provide a loan for the North-West Grid reaching Kigoma, scheduled to be completed by 2024. Mpanda then forms part of the remaining portion of the North-West Grid between Kigoma and Sumbawanga of roughly 500 km, a project that is still at preparatory phase by AfDB and TANESCO with a project appraisal scheduled for 2021 (AfDB 2018).

In the North, a 220kV line is to be mentioned that will connect a new sub-station in Nyakanazi, which is about 50 km from Biharamulo and Ngara each. The sub-station is being built in the context of a three-country hydropower plant at the border to Rwanda and Burundi, from which 26.6 MW will go to Tanzania. This connection to an enhanced transmission network, which is planned to be in place sometime between 2020 and 2022, can be expected to considerably improve electricity supply in the towns. Additional incremental improvements in the existing transmission network are put in place, such as higher-capacity Automatic Voltage Regulators.

[i] Information retrieved in interview with Regional Manager of TANESCO in Kagera, 2018

The two ORIO generator sets in the North best serve as a bridging back-up technology for a few additional years. Electricity supply is still too intermittent at these sites, but it can be expected to improve considerably in the coming years (see Box 9). It would not be understood politically if the generators were removed already now – also given that Biharamulo connects Chato to the national grid, the area where the current president John Magufuli comes from.

Once grid reliability has improved, it is also TANESCO's intention to relocate the generators in Ngara and Biharamulo. They may thus well serve off-grid demand gaps in the mid-term future, although the prospects are highly unclear for different reasons. First, this will depend on finding off-grid places with geographically sufficiently concentrated demand. Second, TANESCO rather intends to reduce its reliance on the highly expensive diesel generators and, third, further generators will likely become idle due to the connection of their locations to the national grid, notably Kigoma and Sumbawanga (see Box 9). Fourth, renewable technologies have picked up and the urgency of minimizing fossil fuel use in the energy system and awareness of external costs of their use increased. Hence, the pressure to either retire the generators or switch to alternative fuels (including solar-diesel hybrid systems) will likely increase in the future.

Outlook for the transmission and distribution network

The second factor upon which the long-term effectiveness of the project will hinge is the grid network, and here particularly its maintenance. While the ORIO-supported grids seem to be constructed using higher-quality material, some issues occurred at REA sites with poles and transformers.[54] In both cases, maintenance will become necessary, which cannot be covered by ORIO funds given the O&M phase has been cancelled.

On the one hand, grid maintenance took only a minor share of around 10 percent of the originally proposed Maintenance plan (TANESCO 2011d, p.15). TANESCO may thus face less drastic challenges in covering these costs from internal funds. At the same time, TANESCO is already fully responsible for the maintenance of the rapidly expanding grids of the donor-supported REA programmes, which do not provide for maintenance funds (see also Cornelissen 2016). Given the government-controlled electricity tariffs in combination with low electricity consumption patterns in rural areas, maintaining the grid in these areas may remain a loss-making operation. Hence, there is some risk that not all sections of the grids will be properly maintained. Also considering that the intervention sites are fairly close to the urban centers, this risk, however, can be considered to be rather low.

Outlook for the grid connection numbers

The objective of 24,000 new and improved connections to be achieved within ten years included 5,500 improved urban connections and 18,500 new connections in rural areas.

The Mpanda site, which fully relies on the ORIO generators, shows that the generators are indeed capable of improving the electricity access situation in the towns. The other two towns, however, are currently served by a mix of a rather make-shift, unreliable connection to the national grid and the ORIO generators as back-up. Here, an improvement in the reliability of electricity access will only be witnessed if the national grid is upgraded as planned (see Box 9), which can then not be attributed to the ORIO intervention.

The current number of new rural connections, including those at REA sites, is not exactly known but definitely exceeds 3,000. This is slightly below planning. These connections already translate to a high household connection rate of 57 percent within 50 metres of the ORIO and REA grids in our survey areas. Hence, there is rather little room for increases of connection numbers under the existing distribution grids; generally, the envisaged connection figures are not attainable with the relatively few LV lines of 44 km constructed by ORIO. In order to reach the planned connection numbers, additional distribution lines are therefore required. These are expected to be erected in the context of the grid extension efforts under REA III (see again Box 9). Thanks to these considerably up-scaled electrification efforts, connection figures in the intervention areas may well increase over the coming years in line with planning. The achievement of this target thus again requires additional contribution by national partners.

In sum, like in any cost-benefit analysis, the outcome depends largely on the assumptions made. At two of the three ORIO sites, the generators play a different role than initially expected in the short term, but may serve off-grid demand gaps in the mid-term future. The sustainability of the transmission and distribution network will face financial challenges, but the concentration around rural-urban centres may imply that maintenance will take place. To reach the expected connection numbers, additional investments and efforts will be required.

[54] Information retrieved in interviews with TANESCO in Biharamulo, 2018

Box 10: Impacts and Cost-benefit discussion

ORIO intervention » Output and Intermediate Outcomes » Outcomes » **Impact and Cost Benefit**

Impacts on rural households

- connected households less likely to use batteries, but overall reductions in use of traditional energy sources reflect a general trend and not an effect of the ORIO intervention
- significant increase in ownership of TV and electric irons and in the use and quality of lighting
- TV usage as strongest factor affecting time use in electrified communities
- neither domestic nor other non-farm activities increased in the wake of electrification
- no perceivable effects of the ORIO project on poverty indicators such as employment, income generation, and education

Impacts on rural enterprises

- sawmills and welders are more likely to be found after electrification
- welders, beauty salons, and hairdressers are most likely to connect to the new grid
- kiosks observe the highest increase in the availability of an electricity source
- unclear whether enterprises save money due to grid connection, also because of few electric appliances and machines available to entrepreneurs so far
- about half the interviewed enterprises expanded their hours of operation, but demand remains low

Impacts on urban households

- TV sets almost omnipresent in urban grid-connected households, while ownership rates of electric irons and fridges remain at around 50 and 25 percent, respectively
- only small increase in electricity consumption in that slightly more people have consumption levels exceeding 75 kWh per month
- average household valuation of an uninterrupted electricity access fell significantly from 3,440 TSh to 1,660 TSh per month (1.6 and 0.6 Euro, respectively)
- households express a strong unwillingness to accept a worsening of electricity reliability

Impacts on urban enterprises

- basically no difference in the amount of electricity consumed
- majority of trade enterprises but only half of service and a third of manufacturing firms continue normal operations in case of outages
- ownership of back-up electricity sources decreased from 22 to 16 percent – mostly driven by enterprises in Biharamulo and Mpanda
- in the more electricity-reliant service and manufacturing sector, generators still make up more than 80 percent of back-up facilities
- manufacturing and service firms state a higher WTP for improved reliability than trade firms; otherwise no strong patterns in the valuation of improved reliability

Environmental impact of generator replacement

- relative savings of around 800.000 litres of generator fuel per year or 500 tons of CO_2
- absolute fuel consumption slightly increased in Mpanda, the only town relying exclusively on the ORIO generators

8. Conclusion

This report presented the results of an evaluation of the *Electrifying Rural Tanzania* intervention, jointly financed by the Dutch infrastructure facility ORIO and the Government of Tanzania and implemented by TANESCO. The aim of the intervention has been to improve the service quality of three isolated grids in three towns in northern and western Tanzania that had been run by old generators and only connected the township areas prior to the intervention.

The following briefly summarizes the findings along the research questions determined at the outset of this study. In addition, lessons learned and recommendations are derived from that.

8.1. Summary on research questions

- Output and intermediate outcome level:

  (i) Have the generators and distribution lines been installed and are these in operation?

  Generators and distribution lines have been installed in accordance to planning. The set of two generators in Mpanda is in full operation. The other two sites, Biharamulo and Ngara, were connected to the central national grid in 2015 and 2018, respectively. As a consequence, the generators there are only used as back-up, which currently implies that they are used about 20 percent of time. Upgrades of the central national grid in the area are expected to increase reliability and thus decrease the need for back-up capacities in the coming years.

  (ii) Have the new generators replaced the obsolete generators?

  Old generators have not yet been dismantled but are rather dismantled piecewise by serving as spare parts stock for other generator-run TANESCO sites or as short-term electricity source in other off-grid areas. TANESCO did so without informing RVO about these alternative uses, which was one aspect that contributed to an erosion of trust.

  (iii) Is TANESCO capable (in terms of financial, organisational and human capabilities) to adequately maintain the equipment and distribution lines?

  At the start of the ORIO project, TANESCO's precarious financial situation has triggered a process of ongoing reorganisation in which electricity generation, transmission and distribution were to be separated from each other. In addition, the parastatal TANESCO has been brought under the supervision of the President's Delivery Bureau, further restricting its autonomous decision-making. While REA realizes the donor-supported extension of the grid in rural areas, TANESCO is responsible for the maintenance of it, which creates additional financial commitments. The attention to human capabilities has improved substantially over time, among others with the opening of a TANESCO training centre. Although TANESCO has secured the supply of spare parts at central level, the lack of decentralisation of TANESCO is a constraint on the effective maintenance of both equipment and distribution lines.

- Outcome level:

  (i) What is the connection rate of households, enterprises, and social infrastructure institutions in the newly connected project area?

  At the time of follow-up, 38 percent of households in newly grid-covered areas are connected to the grid, for an average of 1.7 years. Together with alternative electricity sources, mainly individual solar panels, 72 percent of households in ORIO-supported communities have an electricity source at their disposal. This is not statistically significant from electricity access rates in comparable non-electrified villages, given that households in these villages more strongly rely on individual solar solutions.

Among enterprises, the highest TANESCO grid connection rates at follow-up are found among welders, beauty salons and hairdressers (92, 85, and 67 percent, respectively). Builders and carpenters are the least likely to be connected (0 and 9 percent, respectively). Similar to households, the impact of grid electrification on enterprises is rather small. It is largest on kiosks, bars and restaurants, probably because they are most centrally located and because many of them have been recently created, i.e. they might have directly taken the opportunity to connect to the grid at the time of establishing their business.

Social infrastructure institutions were generally connected with priority if available in the sub-villages targeted by the ORIO project.

(ii) How do connection rates evolve in the town centres with rehabilitated connections?

All but one of the 250 sampled urban households at follow-up were found to be still connected to the urban electricity grids. Disconnections therefore seem to be negligible. Overall connection rates have somewhat increased, but data is lacking to quantify this increase.

(iii) How does the frequency and duration of outages change?

The occurrence of long-lasting outages has decreased significantly. Otherwise, reliability of electricity supply differs considerably between Mpanda and the other two sites. Service reliability has improved considerably in Mpanda, the only non-grid connected town where the ORIO-supported generators operate full-time. This is not the case in the other two towns, where the default electricity source is the central grid, which suffers from serious supply problems. In Biharamulo, outages are still frequent, but shorter. The service in Ngara does not seem to have improved.

(iv) For which purposes and how much electricity is used?

Electricity largely replaced traditional energy sources among newly connected rural households – except for biomass cooking fuels, since electric stoves have not made inroads into the rural Tanzanian kitchens. Electricity access led to an increase in the use of TV, electric irons and particularly artificial lighting. The productive use of electricity at household level is largely absent.

Half the households consume less than 25 kWh per month. This corresponds to using three 10-Watt energy-saver bulbs, two 40-Watt neon tubes, a 10-Watt radio and one 80-Watt TV for four hours per day. Almost 90 percent fall under TANESCO's lifeline tariff of 75 kWh per month. Further increases in electric appliance ownership and electricity consumption may be modest only (cf. Fobi et al. 2018, but also Richmond and Urpelainen 2019).

Regarding the effect of electricity reliability on electricity use in towns, we have also confirmed expectable differences in how firms of different sectors are affected by outages: Manufacturing firms are suffering most. Coping strategies for enterprises also vary by sector: While trade firms simply continue their operation, many service and especially manufacturing firms have to stop their work. Nevertheless, back-up electricity sources remain rather scarce and their ownership even decreased in the wake of the improvements in electricity reliability in Biharamulo and Mpanda, from 22 to 16 percent.

(v) Which socio-economic groups (incl. income groups) benefit from availability of electricity?

Different socio-economic strata can afford to connect to a different extent: the poorest 20 percent of households in the communities are 40 percent less likely to be connected than the richest 20 percent. This gap in connection rates is smaller than the access gap for solar panels in non-electrified communities. Apart from that, one observes rather small differences in access rates across different dimensions, such as the gender and age of the household head.

- Impact level:

(i) How have expenditures for energy changed?

Expenditures for traditional energy sources go down only marginally. Electricity expenditures more than compensate these expenditure reductions. In sum, households with TANESCO rather spend more on energy than before and more than the control group. This reflects that they now make use of a broader range of energy services. Beyond running energy costs, newly grid-connected households likely indirectly benefit from lower electricity source lifetime costs compared to the costs of solar panels.

(ii) To what extent has safety/protection changed?

There are generally no impacts on safety and protection, which can be explained by the high availability of alternative electricity sources in off-grid areas. A notable difference is whether the household interviewee claimed to be afraid when at home – this improved considerably among connected households.

(iii) To what extent has comfort/convenience changed? What monetary value do households attribute to this increased convenience?

Households particularly value the increase in comfort due to electric lighting. While this does not reflect only the valuation of increased convenience, households exposed their high valuation of electricity in that 77 percent of urban households would not even be willing to accept any payment to get worse reliability of electricity access, let alone getting disconnect from the electricity grid.

(iv) To what extent have activities during evening hours changed – both inside and outside the household? Have study hours/reading time of children changed? Have women and children enjoyed more or less rest for physical recuperation?

The burden of household duties has not been reduced considerably. Main change in time allocation is the availability of TV. For boys, this seems to have made them spent less time outside the house at night. Girls generally spent little time outside the house at night. For them, study time increased, even though this was not due to the availability of artificial light: the share of studying at night has not been affected – neither for girls nor for boys.

(v) How have, in response to the possibly increased media exposure, attitudes and behaviours, such as fertility-related decisions and children's school enrolment changed?

No short- to midterm impact pattern could be observed for these aspects. They are slower-trending indicators, for which more time needs to pass for them to unfold.

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

Grid electricity access has not yet led to a transformative change involving the emergence of new and decline of old businesses. Completely new enterprises such as photocopying are an absolute exception. The businesses with the strongest increase in number in the wake of electrification are welders, followed by hairdressers. On average, there is one welder and there are three hairdressers per sub-village.

(vii) Has school attendance changed as a result of electricity use?

More children going to secondary school in 2018 compared to 2014. This increase is even statistically higher for boys in treatment communities. Since we cannot explain this increase by a significant increase among connected households, however, we cannot rule out that this is due to idiosyncratic developments in treatment communities that have less to do with electrification per se.

(viii) In how far have climate-relevant emissions been affected?

The use of fossil-fuel energy or electricity sources has not been considerably affected, since they have similarly vanished in off-grid households. Main sources of climate-relevant emissions remain cooking with biomass, which is not affected by rural electrification, and the large diesel-run generators installed in the three towns. In Mpanda, consumption slightly increased due to higher electricity production in that town. Consumption decreased in Ngara and Biharamulo, however, not because of the ORIO intervention but due to the connection to the central grid.

(ix) How are impacts distributed across different income groups?

Unequal access to electricity itself is the main factor driving an unequal distribution of the modest impacts experienced so far (see point (v) under *Outcome level* above.)

(x) What (if any) positive and/or negative unintended effects have occurred?

No such unintended effects could be detected.

8.2. Lessons learned and recommendations

The report documented that all three generators were successfully installed, but TANESCO nonetheless connected two of the three towns to the national grid. Here, the ORIO generators are used as back-up facilities. Therefore, the outcomes and impacts identified in this report are attributable to a mix of ORIO and TANESCO investments financed partly by other donors. Regardless of this unanticipated change, the main outcome indicator of the ORIO project of 24,000 new and improved connections was problematic from the outset. It would anyways not have been achievable without considerable additional contributions from the Tanzanian side: first, the cost-benefit analysis prepared for the ORIO project in 2012 already made clear that the ORIO grant would contribute only six percent to the total electricity provision costs over the expected 30-year life cycle. Thus, 94 percent would come from Tanzanian sources, i.e. the government and TANESCO. Second, the low-voltage lines funded by ORIO were clearly insufficient to achieve the envisaged connection figures. Both aspects should have been accounted for when defining the outcome indicator and thus the value-for-money relation of the ORIO project. To generally enhance realism in the underlying assumptions of project proposals submitted to RVO, it could be considered to condition part of the financial contribution to a limited number of process and output performance indicators in the financing contract (compare ‘variable tranche’ release in budget support operations to governments).

Beyond investments in generator replacement and grid expansion, the ORIO project allocated 38 percent of its original budget to O&M. This component was eventually abandoned, also because the original design remained unclear about how to involve the private sector. The recurrent problem with setting up O&M components particularly calls for a clearer definition of modalities on how to contract out critical maintenance tasks, a definition that needs to be laid out early on in the design phase of an infrastructure development project.

The most notable finding in the quantitative part of this evaluation is the concomitance of rising connection rates thanks to the ORIO intervention and the massive increase in home solar usage, which has happened without any governmental support. Even in off-grid communities, the share of households with an electricity source more than tripled between 2014 and 2018. This was hardly foreseeable back in 2010, but clearly has to be considered for upcoming electricity expansion interventions. Electrification interventions are no longer about providing mere access to electricity. There is a growing body of evidence that the solar market is working, even in remote rural areas like those under evaluation in this report (see as well Chaplin et al. 2017, Grimm and Peters 2016, Bensch et al. 2018). “Cream-skimming and cherry-picking the ‘rich poor’” (Karplus and von Hirschhausen 2019) is a legitimate business strategy for branded solar products, but should not be sufficient for receiving scarce public subsidies. Electronic waste is an emerging and potentially burning issue where future policy intervention is required given these high solar usage levels and the absence of effective waste management systems in rural areas. Promotion policies for off-grid electricity should also be conditioned on a clear poverty targeting. As this study has shown, in spite of an expensive grid extension and a simultaneous increase in solar panel uptake, a non-negligible share of around 28 percent of households in grid-covered areas are without electricity and hence, relatively even worse-off than before.

Among those new rural connected customers, electricity is mostly used for lighting and entertainment devices (with television usage being the major difference to solar users). Impacts on productive uses and enterprises are very modest. Against this background, grid extension in countries with low rural electrification rates should rather be focused on regions where more powerful electricity is needed. These regions could then also be subject to more targeted, holistic private sector development engagement. Complementary SME training curricula could be designed in cooperation with local business associations to make sure these trainings create an added value for entrepreneurs. In light of the low interest in the SME trainings supported by the ORIO project, entrepreneurs did not see such added value in the trainings offered.

This study did not allow substantiating the role electricity reliability improvements play for local entrepreneurs already connected to grid electricity. Nonetheless, it became evident that the adequacy of electricity generation is only one supply-side factor that affects reliability. Similarly important, reliability depends on and can be further enhanced through conditions of the power system infrastructure, incl. network expansion, network maintenance, and illegal connections, as well as utility financial and operational performance and energy sector regulation.

Generally, the design of the ORIO project did not seem to be sufficiently aligned with recent developments in policies, strategies, as well as operational and financing plans. To enhance the flow of information about the sector context in the partner country, it could be considered to give priority to infrastructural project proposals in those sectors and countries where the Netherlands is represented directly or through delegated participation in sector working groups or round tables. To further enhance the embedding of the supported project in the partner country’s scheduled infrastructure investments, it could additionally be considered to expand the requirement for alignment of the envisaged project from the current alignment to general policies and sector strategies, but also to more specific sector-level financing plans and/ or sector-level medium-term expenditure frameworks.

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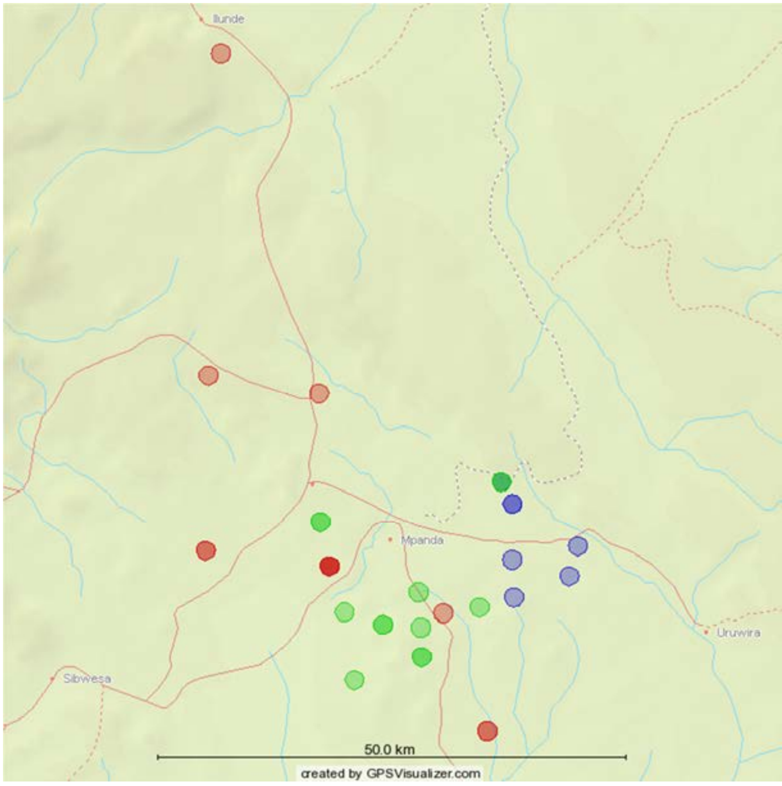
Appendix

Figure A1: Location of treatment and control sites for the case of Mpanda



Note: Red circles refer to TANESCO sites, blue ones to REA sites and green ones to control sites. Darker circles represent places with multiple survey sites (e.g. more than one sub-village of one village was sampled).

Source: own representation using GPSVisualizer.com

Appendix B. Impact estimation design

We adopt two estimation approaches: a difference-in-differences (Diff-in-Diff) approach and Propensity Score Matching (PSM). These are popular approaches to the identification of impacts where treatment participation is not by random assignment (experimental) but where the researcher adopts strategies to mimic or come close to the unbiasedness of random assignment. Such approaches are called quasi-experimental (for a more extensive introduction to different identification approaches, see Pattanayak 2009, for example).

The following presents technical details on these two approaches additional to the more intuitive discussion presented in the main report.

Difference-in-differences

Technically, we use the data for household or community observations *i* at time t (equal to 0 for baseline and to 1 for follow-up) to estimate the estimation equation

$$Y_{i,t} = \alpha + \beta \quad {}_t + \beta_2 \quad {}_t T_i + \beta_3 X_{i,t} + \gamma_i + \varepsilon_{i,t}.$$

We do so for the various outcome and impact indicators Y outlined in Section 3.1 of the report. The estimated coefficient of interest is β_2, the Diff-in-Diff estimate, since it reflects observations for which both dummy variables and T are equal to one: the period is follow-up and the individual is subject to the treatment condition T. Depending on whether the ITT or ATT is estimated, the treatment T refers to village electrification or household connection, respectively (the difference between ITT and ATT is also discussed in Gertler et al. 2016, for example, who call ATT the treatment-on-the-treated (TOT)).

Beyond the standard error term $\varepsilon_{i,t}$, the estimation additionally includes the dummy variable $\quad {}_t$, which controls for time effects that occurred irrespective of the treatment. Similarly, the individual fixed effect γ accounts for individual particularities that go beyond the set of individual-specific control variables X.

For the household-level data, this set of observable control variables X includes the gender and age of the head of household and whether his/her main occupation is farming, the total number of household members (in logarithmic terms), the share of children of age 0 to 6, whether the household keeps livestock, whether the household has a savings account and a community fixed effect. For community-level data, the control variables are the logarithm of the baseline population, the logarithm of the baseline distance to the closest road, the availability of secondary schools, of health facilities and of markets as well as a control for the district.

Propensity Score Matching

In cases where one does not dispose of baseline data (=0), one may at least account for observable characteristics as controls that have been collected at follow-up, i.e. X . Beyond controlling for these variables in a simple (parametric) Ordinary Least Squares estimation, an alternative is to use them in (non-parametric) Propensity Score Matching (PSM). Here, the control variables are used to find appropriate matches among the reservoir of comparison units (non-connected households in electrified communities or non-electrified communities as a whole) for the treatment units (connected households in electrified communities or electrified communities as a whole). This is done by creating a propensity score *p* ranging from zero to one based on the controls X . The propensity score *p* can be estimated using, for instance, a probit or logit model. In our case, *p* reflects the propensity to connect to an electricity grid if one has the chance to do so.

A main challenge with PSM is to find controls X that are plausibly not affected by the treatment while still being good predictors of what is supposed to be explained, in our case again the connection to an electricity grid. The variables mentioned above under Diff-in-Diff, which we also use for PSM, likely fulfil this condition. Yet, there are probably additional unobserved characteristics that explain selection into treatment such as aspiration or astuteness, which can be better captured in the Diff-in-Diff approach as it accounts for baseline levels. This is the main shortcoming of PSM.

Another key aspect to the application of this approach is the co-called common support condition, i.e. there should be enough comparison units that share the same characteristics as the treatment units. This ensures that we have untreated matches for the treated observations for every level of *p*.

Note also that the literature proposes a number of other matching estimators. We adopted the standard approach of nearest neighbour matching, with one comparison group "neighbour" in terms of the propensity score being matched to a treatment group unit.

For a more detailed presentation and the underlying mathematics of this approach see Caliendo and Kopeinig (2008) or Cameron and Trivedi (2009), for example.

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Netherlands Enterprise Agency
Prinses Beatrixlaan 2
PO Box 93144 | 2509 AC The Hague
T +31 (0) 88 042 42 42
E klantcontact@rvo.nl
www.rvo.nl

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