What is the link between power and jobs in Uganda?

Final Report

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steward redqueen

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A contribution to LET'S WORK
A global partnership to create more & better private sector jobs

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WHAT IS THE LINK BETWEEN POWER AND JOBS IN UGANDA?

FOR CDC GROUP PLC

EXECUTIVE SUMMARY

This study sets out the pathways through which improvements in the availability, affordability and reliability of electricity supply impact on businesses and households. Specifically, it evaluates whether more and better power helps create jobs and improve livelihoods.

Methodology

Between December 2015 and June 2016, Steward Redqueen developed and applied a methodology to evaluate the economic impact of improvements in the electric power sector in Uganda for CDC Group plc. The composite methodology developed in this research project consists of:

1. A survey of 119 companies focussed on the relationship between firm output, productivity and electricity usage;
2. Econometric and statistical analysis of the survey results and existing data sources to quantify how power availability (outages) and affordability (price) affect economic output;
3. Analysis of the observed changes in power outages using data from Umeme, the electricity distribution company;
4. Construction of an electricity price model based on the observed current supply and demand situation in Uganda; and construction of a hypothetical counterfactual, in which the additional power capacity was achieved not with hydro power but thermal power;
5. Construction of an economic input-output model with which the effect of outage time and electricity price changes on economic output, GDP and employment can be quantified; and
6. A survey of 262 households in parishes with and without access to electricity to investigate whether electricity access impacts on household income, spending, socio-economic status and access to public services.

Headline results

The main findings of this research are:

1. Because of the large increase in power provision from 2011-2014, load shedding ceased and power outage time reduced from 28 to 12 hours per month. This resulted in:
   - An increase in GDP by 2.6%, which constitutes about a fifth of the total GDP increase of 12.2% over that period;
   - The creation of some 201,600 jobs and livelihoods (1.4% of the labour force), of which an estimated 44% were for women and 86% for unskilled workers;
   - A reduction of government fuel subsidies of USD 180 million per annum, which is equivalent to 1.1% of GDP and 5.7% of government expenditures;
2. Had the same reduction of outages been achieved in a hypothetical case using thermal generation capacity instead of hydro (as had been the situation in Uganda prior to 2011), Uganda would have

seen a 2.2% energy-related increase in GDP (0.4% less than the actual case), and the creation of 153,000 jobs (48,500 fewer than was the case);

3. This study finds that every 1% increase in generation capacity caused a 0.06% increase in GDP and 0.03% increase in employment. These multipliers are in line with studies in other developing countries;
4. Electrification is associated with higher household incomes. Median household income in parishes with electricity access is 2.2x higher than in unconnected ones. However, the causality is complicated, with indications that parishes with higher incomes tend to get electrified faster than poorer parishes, and that electrification then only modestly increases already higher household incomes;
5. Electricity access has a number of non-financial benefits for households:
    - Improved quality of education and health care in schools and hospitals;
    - Increased home study time, especially for children in primary school; and
    - Enhanced feelings of safety at night.

Key issues

The main methodological and data issues in this report are:

- Most of the results are based on statistical analyses of cross-sectional observations, in combination with economic modelling and reasoning. Ideally, one would apply a longitudinal analysis, where businesses and households are followed over time to get direct observations of the effect of the increased availability and affordability of electricity on productivity and income generation. The business and household surveys conducted as part of this project should ideally be repeated to establish panel data sets;
- Due to budget constraints, the sample sizes for the business and household surveys were smaller than ideal. Although the margins of error are mostly within the 10-12% range, they are so only at the 90% confidence level. Achieving a maximum margin of error of 10% at the more customary 95% confidence level would have required more than tripling the sample size of the business survey and doubling that of the household survey;
- Although great care has been taken to obtain the most recent and detailed macro-economic and labour data from the Ugandan Bureau of Statistics for use in the economic analysis, the availability and reliability of this data is limited;
- The input-output model used to trace the effect of economic output changes associated with changes in power outages and price relies on a number of well-documented assumptions. Although we judge these assumptions to be justified, given the limited accuracy of macro-economic statistics in Africa, some of the economic growth and employment spill-over effects may have been overestimated.

A more elaborate overview of the various sources of methodological and data uncertainty is provided in Section 5.5

Recommendations

Based on the findings, we offer the following recommendations:

1. The methodology developed can be applied to other countries, as the availability of relevant power-sector data is typically good and firm-level surveys are conducted by the statistical services in many countries, as well as by the World Bank. Countries with a relatively sizeable industrial sector that suffer from significant power outages and have fairly recent enterprise survey data are

Ghana, Kenya, Senegal and Tanzania, as well as Cameroon, for which new data is expected early in 2017;

2. Applying the methodology in a variety of developing countries will enable a better understanding of which kinds of power sector interventions can maximise economic impact, given the particular mix of electricity consumption patterns, development stage and economic structure;
3. It would be valuable to repeat the business and household surveys in Uganda to establish a trend. Even greater insight could be gained by tracing these businesses and households over time, which would allow for longitudinal assessments of capital/labour substitution and household impacts;
4. To increase employment creation, power sector investments should primarily be aimed at increasing the productive use of (national grid and/or mini-grid) power in the private sector. In addition to productive use, rural electrification projects should also prioritise education and healthcare institutions, possibly through off-grid technologies. This is because:
   a. Enabling an increase in electricity consumption by companies has a significant impact on economic growth, income generation and employment, both within electricity-consuming and non-consuming sectors;
   b. Rural electrification does not appear to have significant household income effects, but does improve education and healthcare, both important enablers for increasing earning power and escaping poverty in the longer run;
5. Power sector investments should target the main bottlenecks in a country. With a potential surplus of power generation in Uganda and some other African countries in the future, transmission will increasingly be a bottleneck. Connecting existing mini and regional grids to national grids will increase the ability to evacuate power for productive purposes, thereby increasing demand. Distribution, although still much in need of further investment, has improved substantially as a result of private sector involvement. Given the fact that transmission in Africa is often a state-controlled natural monopoly, and the proven role of private sector investments in improving distribution, we recommend exploring ways of leveraging private sector expertise and capital in transmission.

1 INTRODUCTION

1.1 Structure of report

This report covers the following topics:

- Section 2: Macro-economic profile of Uganda and electricity intensity of the economy;
- Section 3: Overview of the organisation of and actors in the power sector, and of electricity consumption by end-users;
- Section 4: Literature review, overview of the analysis framework and data sources;
- Section 5: Analysis of the economic end employment impact of the productive use of electricity in Uganda;
- Section 6: Analysis of the impact of electricity access on households in rural Uganda;
- Section 7: Summary of main conclusions and implications.

1.2 Acknowledgements

We would like to thank a number of people and organisations who have played an important role in the collection of data, and the organisation of the business and household surveys:

Umeme

Selestino Babungi, Sam Zimbe, Florence Nsubuga, Henry Rugamba, Kirunda Magoola for their support of the study; and Allan Kamba, Samuel Magezi and Teddy Akeso for supplying us with data on power outages and electricity consumption;

Uganda Bureau of Statistics (UBOS)

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Uganda Small Scale Industry Association (USSIA)

John K. Walugembe and Andrew Walusimbi for introducing us to a number of their members to participate in the business survey;

Uganda Manufacturing Association (UMA)

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Fabian Ahaisibwe, for his help in the identification of the parishes and villages in which the household surveys were conducted;

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Vianney Mutyaba, Edward Iruura, Isaac Vivian Kinhonhi, Peter Kityo and John Julius Wandera for updating the generation, transmission, distribution and tariff data on the ERA website, and supplying us with relevant reports.

We would also like to extend our gratitude to the following organisations for their time, insights and advice:

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- GET FiT
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- KfW
- Ministry of Energy, National Planning Authority
- Rural Electrification Agency
- SolarNow
- Traidlink
- Uganda National Chamber of Commerce & Industry
- World Bank

2 ECONOMY AND ELECTRIC POWER PROFILE

2.1 Macro-economic profile

Uganda is a land-locked, fertile country with a relatively stable economy and an abundance of natural resources. Following macroeconomic liberalisation policies and investments negotiated with the World Bank and the IMF in 1987, the Ugandan economy experienced a period of high growth. As shown in Exhibit 1, GDP growth averaged 6.8% per year from 2000 to 2014, well above the average 3.6% growth in developing countries in Sub-Saharan Africa. However, from 2012 onwards Uganda experienced economic instability and GDP growth slowed to 4.1% on average. The weaker economic growth was due to weaker household and government consumption, as well as stagnating exports due to diminished demand from trading partners following the global economic downturn and regional conflicts.

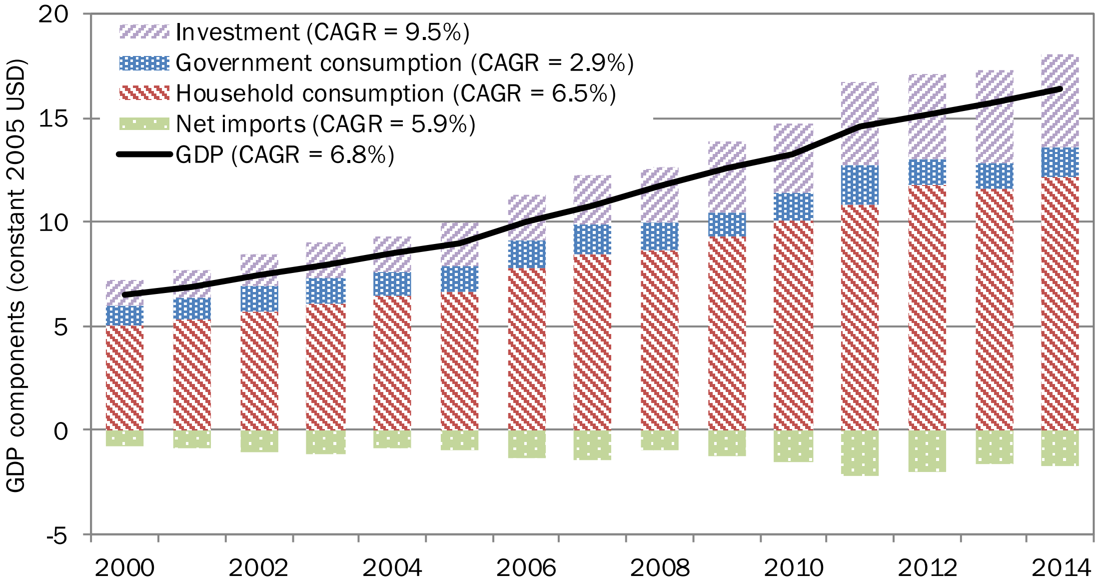


Exhibit 1: Time evolution of GDP components (Source: World Bank)

Despite having one of Africa's highest population growth rates, since 2000 GDP per capita in constant 2005 USD has grown by 3.3%. This growth has been faster than in Kenya and Tanzania, the two other large economies in the East African Community (EAC). Nevertheless, at USD 715 (USD 1,771 in PPP terms), GDP per capita is still more than 40% below Kenya and less than half the average in Sub-Saharan Africa. Real GDP growth per capita has stalled at about 1% over recent years, as economic growth was hardly above the population growth of 3.4% per year.

Historically, the Ugandan economy has been much more dependent on agriculture than Kenya and Tanzania. In the late 1970s agriculture made up more than 70% of GDP; but as shown in Exhibit 2, agriculture's share of total GDP has more than halved since and is now comparable to Uganda's neighbours.

Although in absolute terms it is the services sector that has grown most, growth rates in manufacturing and construction have been higher. For manufacturing, this growth contrasts with the decline observed in Kenya – historically East Africa's manufacturing hub – and Tanzania. This is encouraging because manufacturing has been a leading factor in the success of many Asian countries that have managed to escape low income status. However, manufacturing growth in Uganda has fallen substantially over the last 4 years.

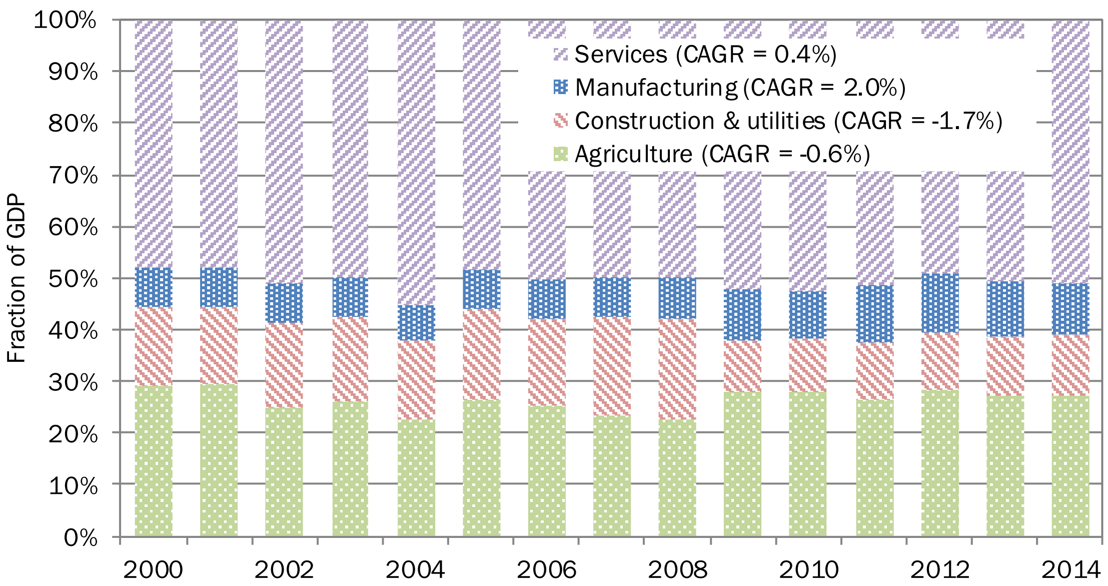


Exhibit 2: GDP breakdown by economic sector (Source: World Bank)

Despite the fact that Uganda is a land-locked country, trade (i.e. the sum of imports and exports), which historically was much smaller in Uganda than in Kenya and Tanzania, has caught up and is now 47% of GDP. Nevertheless, the balance of trade is still unfavourable. The growth in exports (currently worth USD 4.5 billion in 2005 constant dollars, or 18% of GDP), has largely come from services (including tourism), although exports of manufactured goods have grown almost as fast in relative terms (see Exhibit 3). Coffee, cement, fish and tobacco are the main export products.

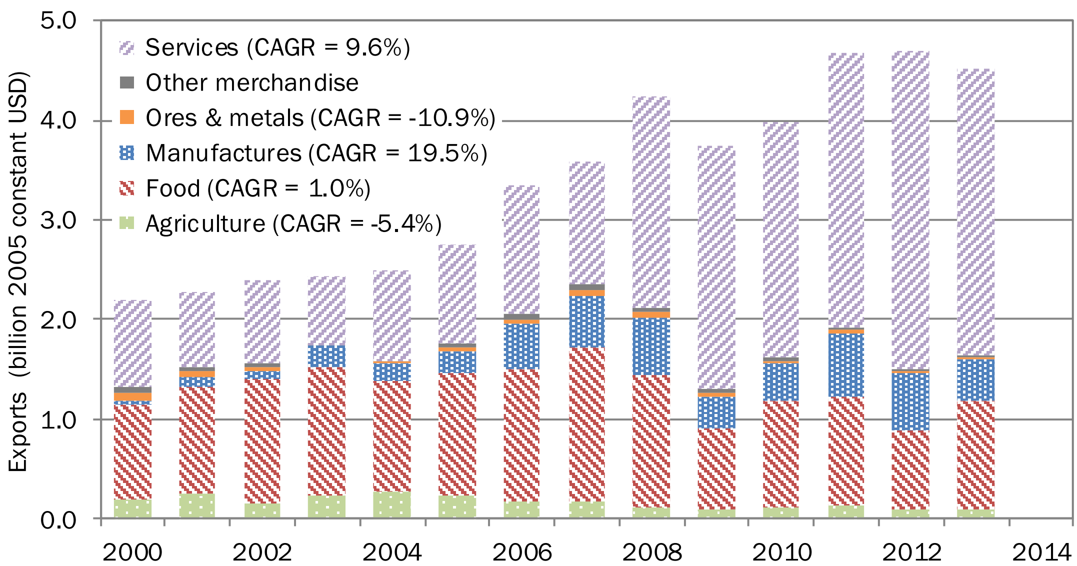


Exhibit 3: Export basket of Uganda (Source: World Bank)

Uganda is a member of three trade zones: the East African Community (EAC), the Common Market for Eastern and Southern Africa (COMESA) and the Intergovernmental Authority on Development (IGAD). The five largest destination countries for Uganda's merchandise exports, which together account for 50%, are Kenya, DRC, Sudan, South Sudan and Rwanda. All these countries belong to at least two of the aforementioned trade blocs. Over the last three years, exports have been hampered by the conflicts in the east of the DRC and South Sudan.

Because imports have grown in line with exports, Uganda's balance of trade has remained stable and negative at some 10% of GDP (see also Exhibit 1). The discovery of oil in Eastern Uganda was expected to improve the balance of trade, but the first oil is not expected before 2020, due to long negotiations and delayed investment decisions by oil companies as a result of the current low oil price.[1]

Investment has been an important driver for Uganda's economic growth. Gross fixed capital formation has grown steadily from less than 20% of GDP in 2000 to more than 25% since 2009, as depicted in Exhibit 4. Although slightly lower than Tanzania, capital formation is higher than in Kenya and above the Sub-Sahara African average of 20%. Whereas in the early 1990s private investment constituted less than half of all capital formation, over the past 10 years the private sector has been responsible for more than three quarters. Even a large infrastructure project, like the Bujagali power plant (USD 860 million over 4-5 years, i.e. 1% of GDP) was built entirely with private (loan and equity) capital. This shift was the result of liberalisation and privatisation policies pursued by the government.

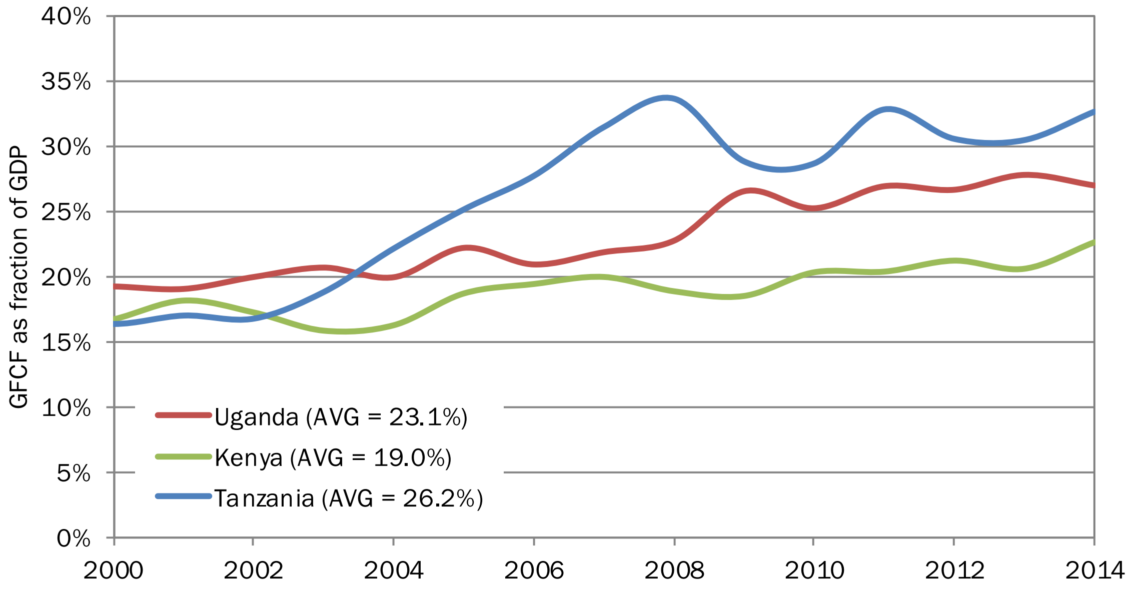


Exhibit 4: Gross Fixed Capital formation (GFCF) as % of GDP (Source: World Bank)

Notwithstanding the improved economic performance, Uganda has a human development index ranking of 163rd, which is below the Sub-Sahara African average. Gains have been made towards achieving the Millennium Development Goals, especially in the reduction of the number of people living in poverty. However, a key socio-economic challenge remains the importance of the informal agricultural sector for employment and subsequent high income inequality, particularly between regions. The regional disparities found in the development indicators can be largely attributed to unequal access to markets and services.

2.2 Macro-economic energy and electricity intensity

Uganda's total energy consumption in 2014 was 12,291,607 tonnes of oil equivalent (toe). This implies a per capita energy use of 715 kg oil equivalent (kgoe). As shown in Exhibit 5, most energy

[1] The break-even production costs for oil in Uganda are estimated to be USD 50 - 60 per barrel, which together with transportation cost of USD 15 per barrel means that commercial production is not expected to commence while oil prices are below USD 75. At that price, oil exports would amount to some USD 2 billion per year.

(68%) is consumed by households. With the exception of the transport sector, which obviously relies on oil, biofuels (wood) and waste are predominant and constitute 89% of Uganda's total energy consumption. Grid electric power contributes only 1.7% of total energy consumption, of which about two thirds is used by industry.

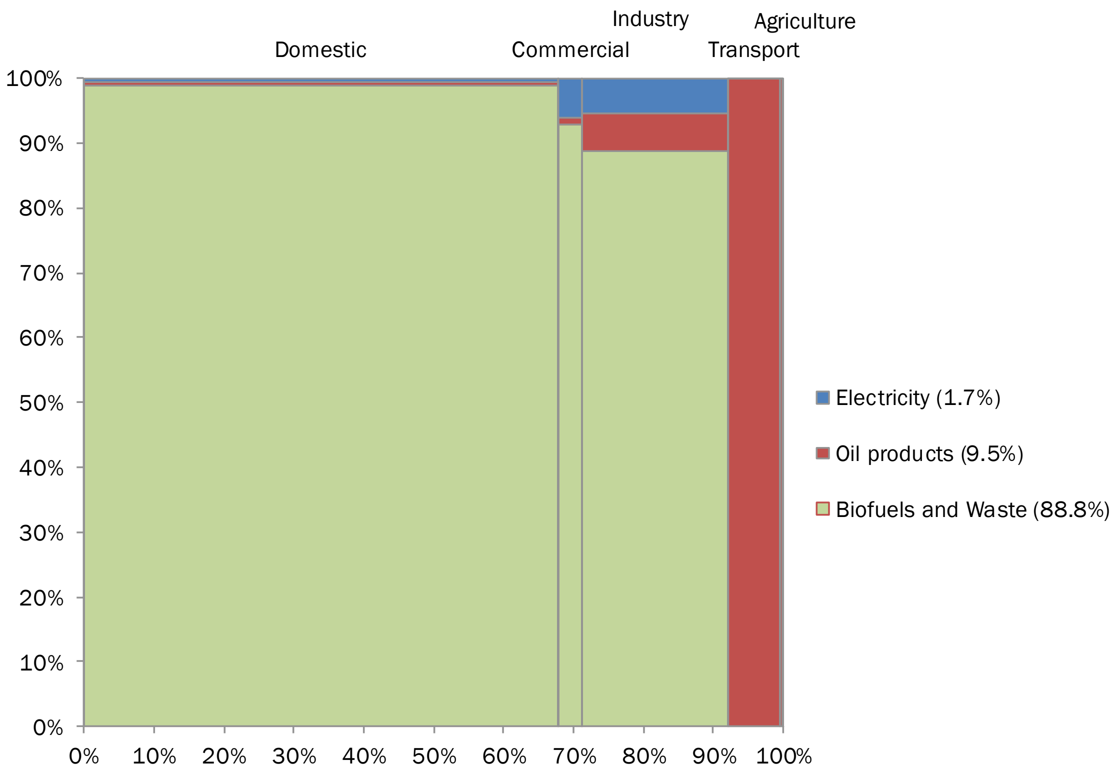
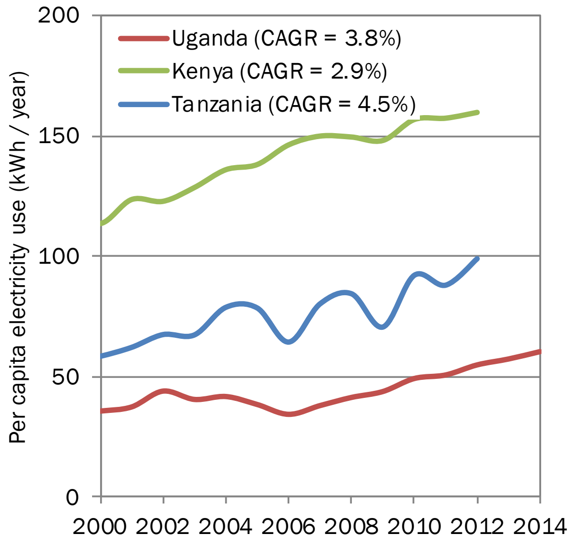


Exhibit 5: Breakdown of energy use in Uganda by end-user and fuel type (Source: IEA)

The fact that electricity use is very low is shown more clearly in Exhibit 6. At 61 kWh per year, per capita electricity use is significantly below Tanzania and Kenya[2], although it has been growing somewhat since 2006. An important reason for such a low per capita electricity use is that, as of 2012, only 15% of the population had access to electricity and usage by connected households is often low (as will be shown in 6.3).

The electricity intensity of the economy, as shown in Exhibit 6b, illustrates the same trend even more dramatically: with GDP per capita increasing and electricity use per capita declining, the electricity consumption per dollar GDP decreased substantially from 2002 to 2006. During that period, the low water levels of Lake Victoria meant the White Nile hydro power stations produced much less electricity. This instigated large power shortages and rampant load shedding. Slowing economic growth and increasing power supply have reversed that trend, but the electricity intensity is still only half that of Kenya. Of course, when economies grow their electricity intensity lessens, but such a decoupling of economic growth and energy consumption typically occurs at much more advanced stages of development. The historically inadequate power supply will likely have caused so-called X-inefficiencies in the economy: companies or sectors may not have adopted the more productive technology that they would have adopted under more favourable power conditions, rendering them less competitive and more growth-constrained.

[2] Kenya's per capita electricity consumption is more or less equal to the 150 kWh average of SSA countries (excluding South Africa).



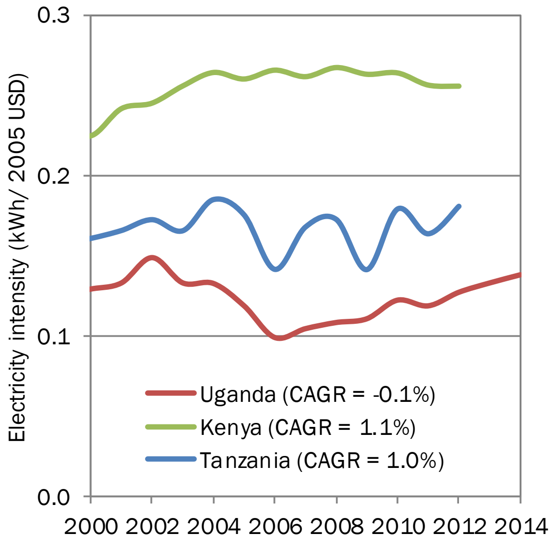


Exhibit 6: (a) Per capita electricity use and (b) electricity intensity of the economy (kWh / GDP in constant 2005 USD) (Source: World Bank)

3 POWER SECTOR OVERVIEW

3.1 Organisation of the power sector

As a result of the Electricity Act (1999), the Uganda Electricity Board was unbundled in 2001. This created three independent but fully government-owned companies:

- The Uganda Electricity Generation Company Limited (UEGCL) in control of electricity generation by the Nalubaale and Kiira power plants, although the actual operation and management of the power plants is provided by Eskom;
- The Uganda Electricity Transmission Company Limited (UETCL) to provide for the transmission of electricity to the distributors. UETCL owns and operates the transmission infrastructure above 33 kV;
- The Uganda Electricity Distribution Company limited (UEDCL) to distribute electricity to end consumers. UEDCL owns the distribution infrastructure at and under 33 kV. Except for some small individual concessions, Umeme Ltd operates the distribution network and sells electricity to end-users.

All companies are overseen and regulated by the government-owned but independent Electricity Regulatory Authority (ERA). Exhibit 7 summarizes the organisation of the power sector. Not shown in the exhibit is the Rural Electrification Agency (REA) which is charged with the transformation of the rural population away from traditional energy sources to electricity.

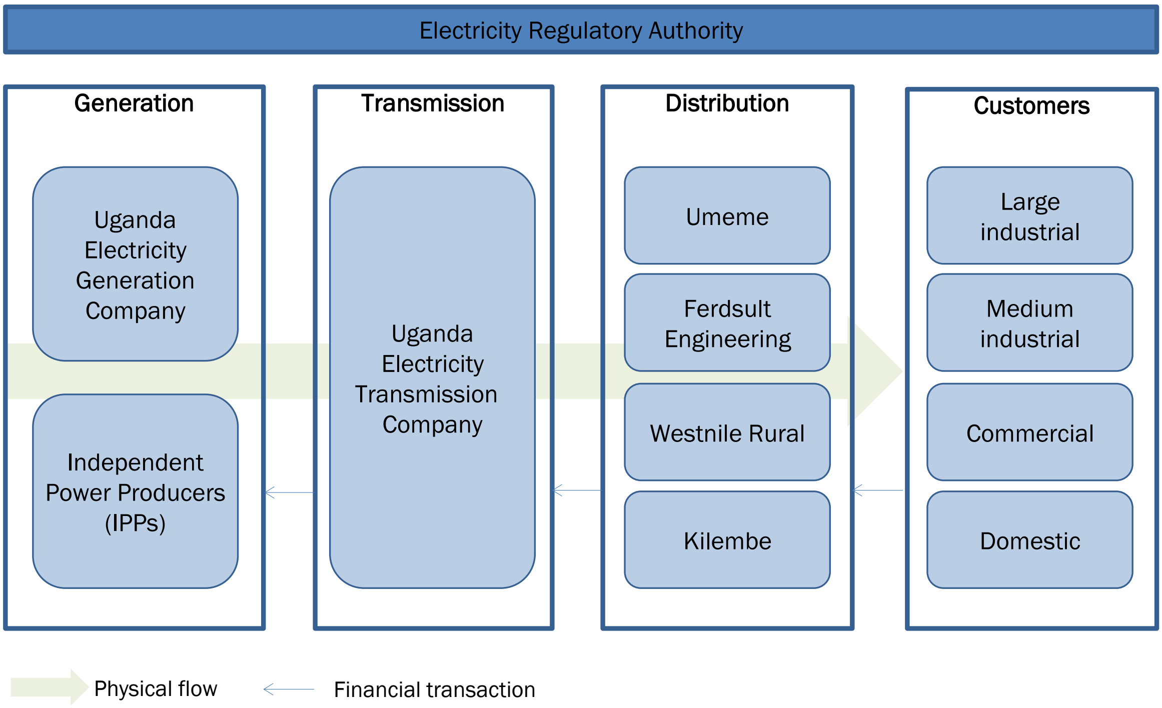


Exhibit 7: Overview of the electric power sector in Uganda after privatisation

3.2 Power production, sales and losses

Exhibit 8 depicts the amounts of electricity generated, transmitted and distributed. Before discussing each of the components, two important observations can be made. First, trade with neighbouring countries is somewhat limited, something one sees throughout Africa. Because of the nature of power, where supply and demand must be equal at all times, this is inefficient, as pooled generation and demand profiles are smoother and require less backup. Secondly, power losses in Uganda are significant, although comparable with other countries in Sub-Saharan Africa, where the average transmission and distribution losses are 18%.[3] Distribution losses in Uganda are especially high, causing electricity to be more expensive and less available.

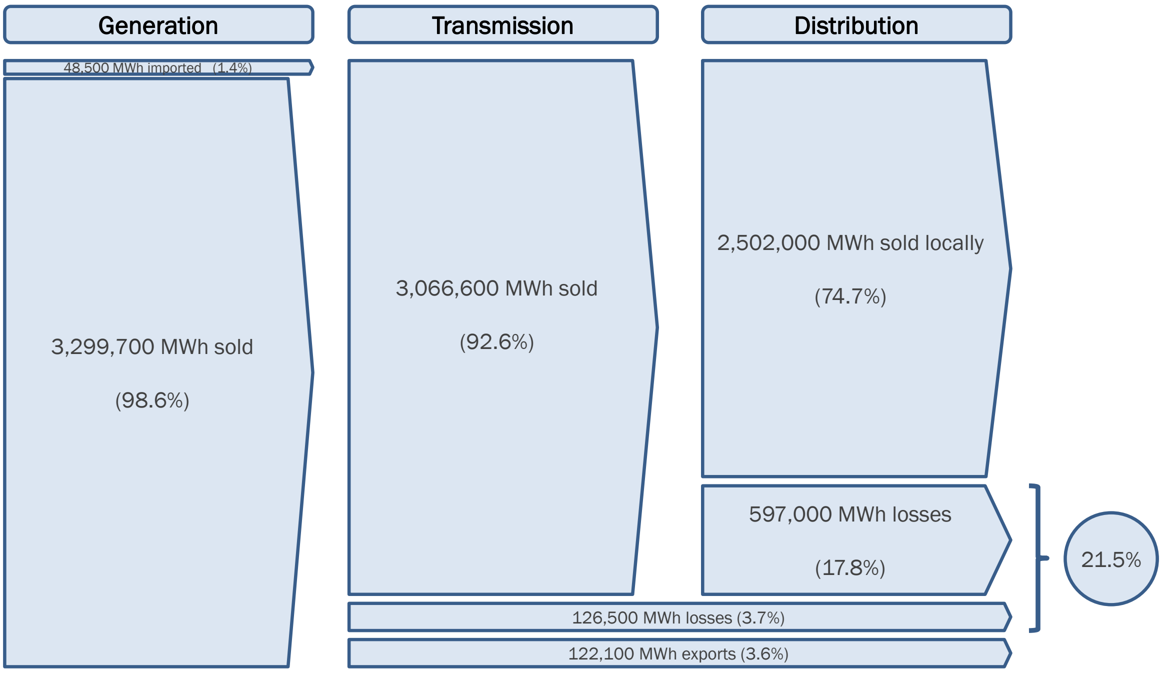


Exhibit 8: Generation, transmission and distribution[4] of electricity in 2015 (Source: ERA)

3.2.1 Electricity generation

Table 1 shows the installed and available generation capacity in Uganda in 2015. The latter is the capacity adjusted for utilization. Of the electricity generated in 2015, almost 90% came from hydropower plants, of which 88% was generated by the UEGCL-owned and Eskom-operated hydropower complex of Nalubaale (180 MW) and Kiira (200 MW), and the downstream Bujagali hydro power plant (250 MW), which is owned by private shareholders[5].

During the course of 2012, the five 50 MW units of the Bujagali hydropower plant were commissioned. Bujagali's 1,376 GWh electricity production in 2013 enabled the phasing out of 100 MW of diesel capacity (two 50MW plants operated by Aggreko, one in Mutundwe and one in Kiira, which together produced 460 GWh), while still increasing the total electricity production by 916 GWh, or 46%. This shift is clearly visible in Exhibit 9. The replacement of 460 GWh of expensive thermal power by cheaper hydro power represented a large cost saving for the Ugandan government, which had subsidised electricity by keeping tariffs more or less constant in real terms since 2009 (see Exhibit 11)[18]. With the high oil prices during 2009-2012, the fuel cost of diesel power was some 0.40 USD/kWh[6], whereas Bujagali's levelised costs are 0.11 USD/kWh. The replaced thermal power delivered an annual savings

[3] IEA. Africa Energy Outlook 2014 - A focus on energy prospects in Sub-Saharan Africa.

[4] The percentages express the fraction of total power sold by power generators in Uganda plus imports. The losses in distribution (here 17.8%) would be 19.3% (the Umeme figure) when measured against the power sold by the transmission company to the distributors.

[5] The 4.6% government equity stake in Bujagali was in return for land and development costs.

[6] The Aggreko diesel plants used 0.27 litres of diesel to generate 1 kWh. The price per litre was USD 1.5.

of some USD 180 million,[7] equivalent to 1.1% of GDP and some 5.7% of government spending.[8] Moreover, it produced a carbon reduction of approximately 1.1 million tonnes, valued at USD 7.7 million.[9]

Table 1: Overview of operational power plants in 2015 (Source: ERA)

Plant	Type	Installed capacity (MW)	Available capacity (MW)	Energy generated (MWh)
Nalubaale and Kiira	Large Hydro	380	230[10]	1,284,396
Bujagali	Large Hydro	250	250	1,456,512
Tororo	Thermal	86	7	61,294
Kakira	Co-generation	50	16	161,290
Namanve	Thermal	50	3	12,320
Mpanga	Mini-Hydro	18	9	76,720
Kinyara	Co-generation	15	0	N/A
Bugoye (Mobuku II)	Mini-Hydro	13	9	77,193
Mobuku III	Mini-Hydro	10	7	61,857
Kabalega (Buseruka)	Mini-Hydro	9	5	48,022
Ishasha (Kanungu)	Mini-Hydro	7	3	24,140
Mobuku 1	Mini-Hydro	5	3	24,481
Nyagak	Mini-Hydro	5	5	N/A
Total		**893**	**543**	

An important issue in the power sector is the reliance on hydropower in the face of changing and unpredictable weather patterns. Lake Victoria, from which the White Nile and the three largest hydro power stations receive all their water, has a somewhat anomalous hydrology. A remarkable 85% of the lake's inflow comes from rain rather than river inflows. And because the shallow lake has limited storage capacity, this means that water levels are sensitive to changing climate patterns.[11]

7 Total subsidies are reported at UGX 447 billion (USD 180m) in 2011, up from UGX 169 million in 2008. This is consistent with 460 GWh at a cost of USD 0.40 / kWh.

8 Uganda GDP was about USD 20 billion and Government expenses comprised 15.7% of GDP.

9 Based on the current price per metric ton of USD 7 (which is too low according to experts).

10 The available capacity for power dispatch is 290 MW at maximum water levels. This is because one of the 10 units of 18 MW at Nulubaale is out of order and 4 units are used as spinning reserve. Because of the low water levels in Lake Victoria the dispatchable capacity is taken in this study to be 230 MW.

11 After having been low for many decades, the water levels rose sharply (+2 m) in the early 1960s, after which they started falling again. The level dropped sharply (-1 m) from 2003-2007, back to pre-1960 levels, after which it stabilised. The water level needed for the Kiira dam to operate at full capacity is deemed undesirable from a lake management point of view. The Kiira dam, which would thus seem to be over-dimensioned, has been operating far below capacity (38% of installed capacity and 50% of available capacity of 290 MW between Nalubaale and Kiira in 2014 and 2015, compared with 70% for Bujagali, which is just 9 km downstream and reuses their discharged water), despite a larger water intake than agreed upon (in the 1991 agreement with Egypt) from Lake Victoria. According to a report by the International Rivers Organisation (www.internationalrivers.org/files/attached-files/full_report_pdf.pdf) this large water intake caused 55% of the drop in water levels after 2003. However recent water levels are high and expected to remain so over the next 10 years, underscoring the volatile nature of Lake Victoria's hydrology.

Uganda's electric energy potential is estimated at 2,000 MW of hydropower, 450 MW of geothermal power, and an as yet unspecified amount of petroleum from the recently discovered oil reserves. The current levels of energy generated from both sources constitute less than half of the potential available. That is about to change, as the 600 MW Karuma hydro power plant, constructed by Sinohydro, and the 183 MW Isimba hydro power plant, constructed by China International Water & Electric Corporation, are planned to be operational in 3-4 years. At a 70% capacity factor (the same as Bujagali), these plants will almost double Uganda's generating capacity, although they will also increase the country's dependency on the volatile hydrology of Lake Victoria, which is subject to environmental volatility and the effects of human intervention.[11] A number of small hydro plants, with a cumulative capacity of around 100 MW, are also being planned, as well as three larger run-of-river hydro plants (together some 130 MW) on other rivers than the White Nile. Capacity additions from the current 600[12] to the expected 1,600 MW by 2020 mean that Uganda will have plenty of room to grow its electricity use and still have excess capacity. It also means that generation will be less of a bottleneck in years to come.

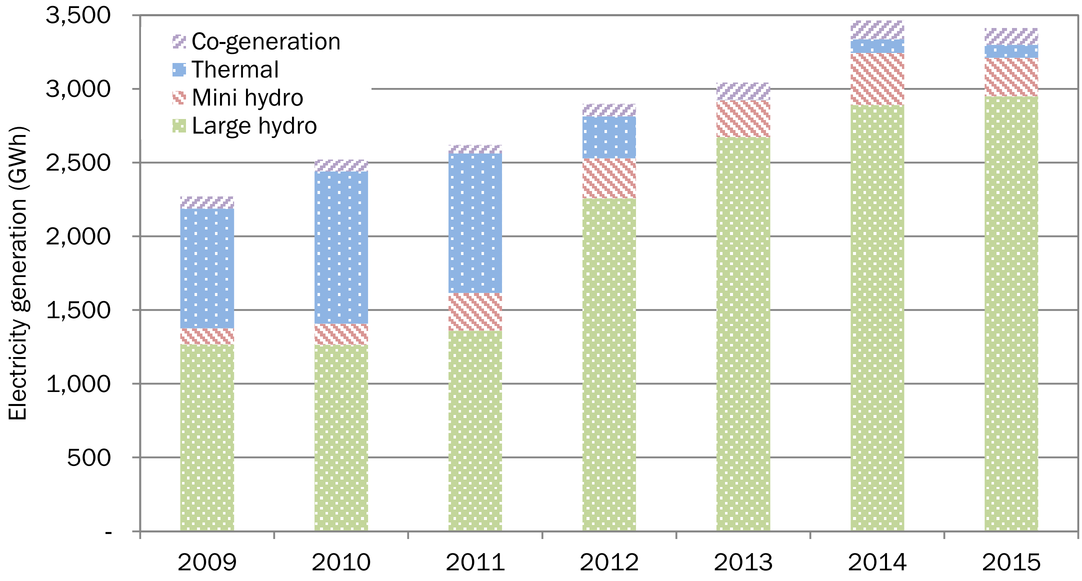


Exhibit 9: Electricity generation by fuel type in GWh (Source: ERA, UETCL)

3.2.2 Electricity transmission

Because of its capital intensity, power transmission is a natural monopoly which in Uganda is in the hands of the fully government-owned Ugandan Electricity Transmission Company Limited (UETCL). The latter owns, maintains, expands and operates the transmission network which encompasses 1,627 km of powerlines above 33 kV (150km of 220 kV; 1,442 km of 132 kV and 35 km of 66 kV).

UETCL is also the single buyer of power from the grid-connected generation companies, and is in charge of power import and export. Most of the power (94.8% in 2015) is sold to Umeme, the operator of the national distribution network. Export of electricity to Kenya, Tanzania, and to a lesser extent Rwanda and DRC, makes up 3.6% of electricity sales, with the remaining 1.5% being sold to smaller distribution companies, notably Ferdsult. Transmission losses in the network were 3.7% in 2015, and have fluctuated between 3.5% and 4.8% over the past 5 years.

[12] Including spinning reserve, etc.

3.2.3 Electricity distribution

The operation of distribution and end-user sales of electricity is carried out by Umeme Limited, under a 20-year concession awarded in March 2005. In 2015 Umeme was responsible for 98.2% of all electricity distribution in Uganda. The remaining 1.8% is provided by the WENRECo mini-grid in the West Nile region, which operates independently of the national transmission system, as well as by some small cooperatives and companies that distribute electricity in areas not covered by the Umeme concession.

The Umeme network encompasses 28,994 km of medium and low voltage lines.[13] In 2015 Umeme sold 2,458 GWh of electricity. Electricity sales have increased by on average 8.4% per year since 2009. Umeme bought 3,051 GWh from UETCL in 2015, meaning that 19.5% of the bought power was lost to technical and non-technical (i.e. theft) losses in the distribution network. Although these losses are still substantial, they have come down sharply from 34.9% in 2009. This improvement is to a considerable extent due to capital investment in the distribution network – a total of USD 328 million since 2009. To put the distribution loss into perspective: had the loss rates remained at 2009 levels, satisfying the 2015 electricity sales would have required an additional 77 MW generation capacity, assuming 70% utilisation. This is 31% of the Bujagali plant (which has a 70% capacity factor).[14]

The number of residential customers as at Year End 2015 was 793,544, an increase of 21.9% relative to 2014 and an average annual growth rate of 13.1% since 2009. Whereas in 2009 the average customer consumed 4,181 kWh, in 2015 this was 3,096 kWh, indicating that most of the customer growth has come from the residential segment. Section 3.3 deals with the various customer segments in more detail.

3.3 Electricity consumption

3.3.1 Access to electricity

Table 2 provides a breakdown of ERA customer data by segment and distribution company. Overall Umeme serves 93.2% of all residential customers, with an even larger share of the commercial and medium customers, and a 100% share of the large industrial companies.

Table 2: Customer breakdown per distribution company and segment (2015)

Company	Domestic	Commercial	Medium industrial	Large Industrial	Total
Umeme	742,303	67,859	2,416	311	**812,889**
WENRECo	4,653	3,539	7		**8,199**
Ferdsult	23,184	437	114	-	**23,735**
Pader Abim Comm	2,302	55	-	-	**2,357**
Bundinbugyo Coop	5,715	49	-	-	**5,764**
Kilembe Ltd	7,981	135	-	-	**8,116**
Kyegegewa Coop	2,019	49	-	-	**2,068**
UEDCL	7,113	126	4	-	**7,243**
Kalangala	1,935	17	-	-	**1,952**
Total	**797,205**	**72,266**	**2,541**	**311**	**872,323**

Source: ERA

[13] Umeme's Annual Report indicates a total of 12,169 km medium voltage and 16,825 low voltage lines, with the following regional distribution: Kampala 29.2%; Western region 29.6%; Eastern region 27.1%; and Northern region 14.1%.

[14] Assuming two thirds of the capital investment of USD 328 million was for grid maintenance and improvement (and the remaining third for grid extension), this implies an investment of USD 2,840 per GW, which is lower than the USD 3,450 per GW for the Bujagali hydro power plant.

The relatively strong focus of mini-grid WENRECo on commercial and industrial customers is striking: 43.2% of its customers are companies who use electricity to generate economic output; compared with Umeme, where companies represent 8.6% of the total customer base. Most small distribution companies and cooperatives focus on residential customers, often incentivised by the Rural Electrification Agency. We will revisit this in Section 6.

The number of residential customers is less than 800,000. With an estimated 7.5 million households[15] in Uganda, this means that about 11% of households have access to grid electricity. According to the IEA Energy Access database, the electrification rate is somewhat higher at 14.5% and the official rate is 15.2%, which can be explained by the fact that households often share a connection. The IEA estimates that 55.4% of all urban households, and only 7.1% of rural households, have access to electricity, with the remainder of rural households relying on biomass. The electrification rate is substantially below the averages for Sub Saharan Africa, where 32.4%, 59.3% and 16.8% of the total, urban and rural population respectively have access to electricity. There are only eight countries in Sub Saharan Africa that have lower electricity access than Uganda.[16] Currently, electrification rates are growing at an annual rate of 5-7%, similar to Kenya.

3.3.2 Electricity consumption per user group

As mentioned, at 61 kWh per capita per year, electricity consumption in Uganda is very low. Some 47% of all electricity is consumed by large industry, 17% by medium industry, 12% by the commercial sector (which includes not only trade and services companies, but also small industrial firms[17]) and 24% by domestic users (Exhibit 10). Growth in electricity use has been fastest in the large industrial sector and slowest in the domestic sector. The low electricity consumption of domestic users stems from the low electrification rate mentioned in the previous section, as well as limited electricity consumption by connected households (as will be shown in Section 6).

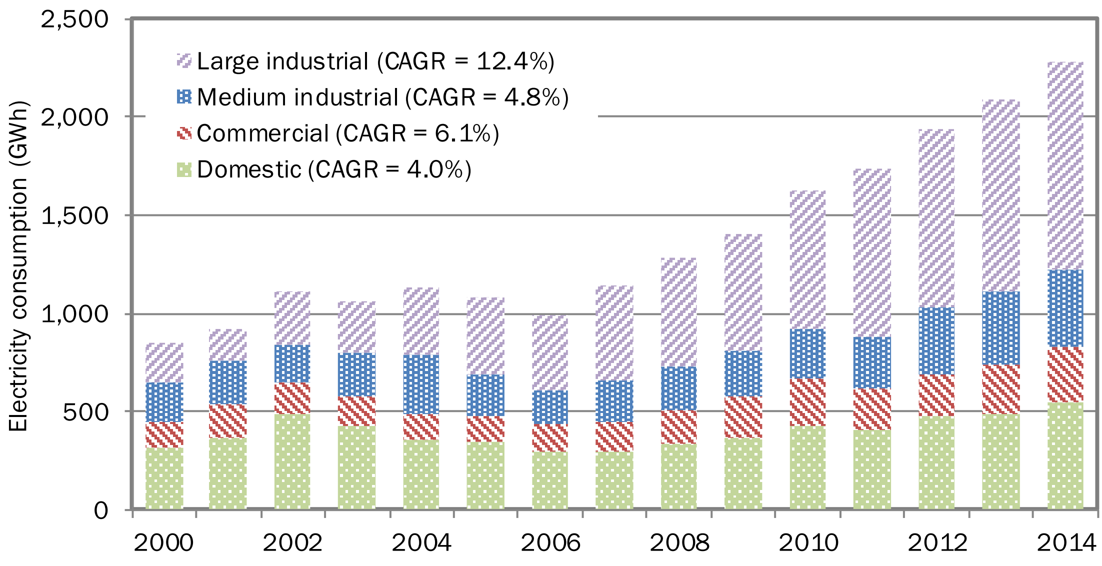


Exhibit 10: Electricity consumption per user group (Source: ERA)

[15] The UBOS National Population and Housing Census 2014 recorded 7.3 million households. Given the 3% population growth rate, this will become 7.5 million households in 2015.

[16] Liberia, DRC, Malawi, Burundi, Sierra Leone, Chad, CAR, South Sudan.

[17] Tariffs are based on the size of the connection and not on the economic sector.

Over the period indicated, the tariff structure for the individual user groups has changed markedly: prices have doubled for domestic users, whereas prices for large users have remained largely stable, as shown in Exhibit 11.[18] From 2008 – 2011 this stability was achieved through large subsidies.[7]

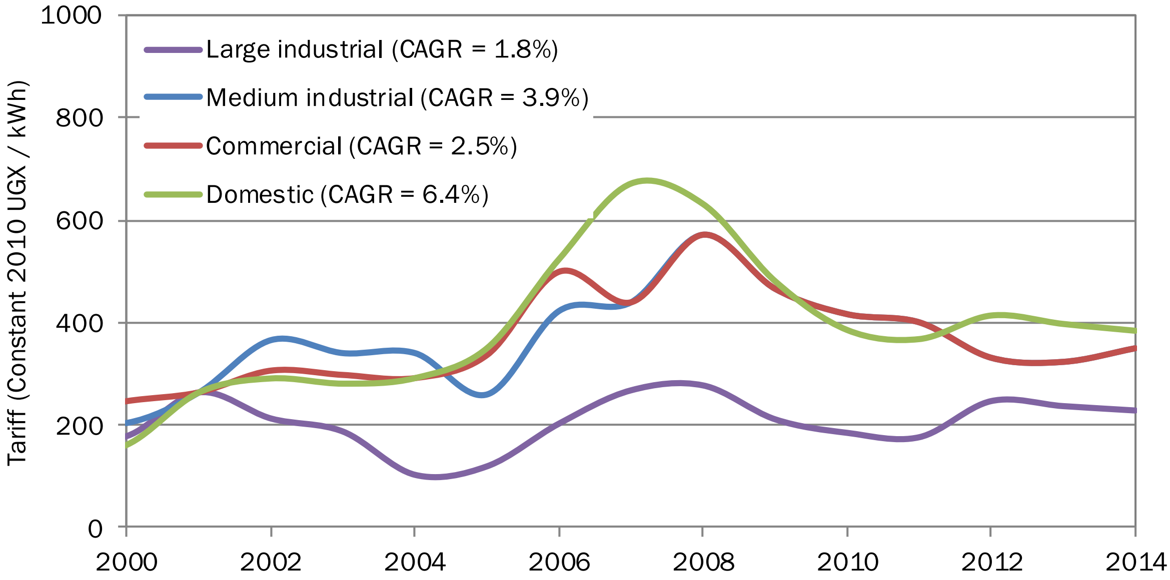


Exhibit 11: Evolution of electricity tariffs for four user groups (Source: ERA)

3.3.3 Drivers of electricity consumption

In order to better understand what drives electricity consumption, a regression analysis was performed for the period for which data is available: 1991 - 2014. For the commercial, medium industrial and large industrial[19] consumer groups we assume:

$$EC_i = A \cdot GDP_i^{\varphi} \cdot P_i^{\theta} \qquad (1)$$

Where for each group i, EC indicates the electricity consumption (as shown in Exhibit 10), GDP the GDP or income contribution in constant 2010 UGX (similar to the data shown in Exhibit 2[20]), P the average tariff in constant 2010 UGX (as depicted in Exhibit 11), φ the GDP (or value added or income) elasticity, θ the price elasticity of electricity use and A factor productivity constant. For the domestic user group, GDP is replaced by GDP per capita (GDP_PC) in constant 2010 UGX.

$$EC = A \cdot GDP\_PC^{\varphi} \cdot P^{\theta} \qquad (2)$$

Using log-linear regression, the elasticities φ and θ have been estimated and are shown in Table 3. For the overall economy they are highly significant (p-values < 0.01) and the two-variable model explains 95% of the observed variations in electricity use. The aggregate GDP and price elasticities possess the right sign and the magnitudes are similar to the ones found by Khanna and Rao (2009).[21] The results mean that electricity use rises in proportion with GDP and that a 1% price increase of electricity

[18] Between 2011 and 2015 nominal tariffs for domestic, commercial/medium and large clients increased 49%, 25% and 82% respectively.

[19] The medium and large industry groups have been combined because their individual GDP contributions are not known. The electricity price used in the regressions is their consumption-weighted average price.

[20] The commercial sector is assumed to coincide with the services sector, and the industrial sector is the sum of the manufacturing and construction & utilities sectors.

[21] Khanna, M and Rao, N.D., *Supply and Demand of Electricity in the Developing World,* Ann. Rev. Resour. Econ. (1), 567–95, 2009.

decreases its use by 0.24%. In more advanced economies, GDP typically increases faster than electricity use; but that is not the case in developing economies.

The results for the commercial users, which comprise services as well as smaller industrial firms, and (large) industrial users are also realistic, although the significance of the price elasticity is less. The results are well within the range indicated by Khanna and Rao (2009).[21] The income and price elasticities for domestic users are significant and realistic. The lower adjusted R^2 reflects the fact that behaviour of different income groups has often been observed to be markedly different: low income consumers are more income elastic – that is, they increase their normally low electricity use in response to income – whereas higher income consumers, who tend to use more electricity, respond to price. Table 3 leaves unanswered the question of whether economic growth drives electricity consumption or vice versa. We will address this in Section 4.1.

Table 3: Income and price elasticities of electricity use per economic sector

Regression	All	Commercial	Industry	Domestic
φ	0.99	1.11	0.93	1.06
p-value	*0.00*	*0.00*	*0.00*	*0.00*
θ	-0.24	-0.43	-0.42	-0.26
p-value	*0.01*	*0.00*	*0.09*	*0.00*
Adjusted R^2	0.95	0.94	0.85	0.55

3.3.4 Incidence of power outages and self-generation

Power outages are a fact of life for Ugandan companies. Based on data from the World Bank Enterprise Survey 2013 (WBES), Table 4 shows that in 2011 the monthly duration of power outages was in the 30 – 52 hour range (median – average).[22] Using the sample median of 278 productive hours per month, this means that power outages affected companies for 11% - 19% of their operational time.

Table 4: Monthly outages[23] and self-generation in 2011 by firm size and sector

Company size	Number of outages		Duration of outages (h)		Total outage time (h)		% with generator
	median	average	median	average	median	average	
All	7.0	11.9	5.0	10.2	30.0	51.8	47%
Small >=5 and <=19	7.0	12.1	5.0	9.4	29.0	46.8	36%
Medium >=20 and <=99	7.0	11.6	6.0	12.5	36.0	62.3	69%
Large >=100	8.0	10.9	5.0	14.6	25.0	52.5	80%
Food	7.0	8.8	5.0	9.9	31.0	50.9	58%
Other manufacturing	7.0	14.6	5.0	14.1	31.0	55.2	53%
Services	8.0	11.8	5.0	8.3	30.0	53.9	55%
Retail	6.0	10.0	5.0	8.9	25.0	44.4	52%

[22] Data on outages experienced by an enterprise during working hours in a typical month.

[23] The margin of error of this data in the World Bank Enterprise Survey is 6.7% for manufacturing firms, and 2.6% for services and retail firms. The data exhibits a substantial right skew. The median value is therefore a better single number description than the average. The median also deals more robustly with the presence of unrealistic and/or "protest" responses. The median value can, however, be overly conservative because it is not affected by very large values even when they are real. These large values are better represented in the average value of the sample. In this report we therefore pragmatically define the median and average as realistic minimum and maximum values. It is worth noting that the difference between average and median is equal to the product of non-parametric skew and standard deviation of the underlying probability distribution; the larger the skew and/or variance of values are, the wider the range of realistic values.

Whether or not companies own or share a generator depends primarily on their size and not at all on the total outage time they experience. Although this may seem surprising, the fact is that the generators of most companies in Africa are much smaller than that needed for full back-up of grid electricity use (See Section 5.1.2). The limited generating capacity means self-generation is only a small fraction of electricity consumption for small and medium-sized companies: 10-14%. Larger companies self-generate a larger fraction (27%-43%) of their total electricity consumption, which reflects the substantial scale advantages present in power generation.

Observed data from Umeme[24] shows similar outage times to the WBES. In 2011, the median Umeme client experienced 333 hours of outages per year (i.e. 28 hours per month), or 10.0% of median operation time. The reason for the blackouts was predominantly load-shedding (66% of the total blackout time). Since 2011, outage times have reduced by more than a factor of two, as shown in Exhibit 12, largely due to a very significant reduction in load-shedding. In 2012 and 2013, electricity was cut off for 161 and 124 hours, respectively 4.8% and 3.7% of company working hours. A slight rise of total outage time was recorded in 2014 (141 hours, 4.2% of operations), which is explained by (i) the expansion of the distribution network and (ii) the growth in demand due to the increased generation and its availability, as this tends to subject the network to more stress, which manifests itself as faults in the network. Furthermore, the increase was mainly due to an increase in planned outages. In 2014 load-shedding accounted for 1% and distribution faults for 45% of total outages. The strong reduction in load-shedding is predominantly due to the introduction of the 250 MW hydro capacity of Bujagali, but also to a substantial decrease in distribution losses from Umeme, from 27.3% in 2011 to 21.3% in 2014 and 19.5% in 2015. In 2015 there were no changes in the total time of electricity disruptions, however faults and emergency outages increased (due to safety considerations).

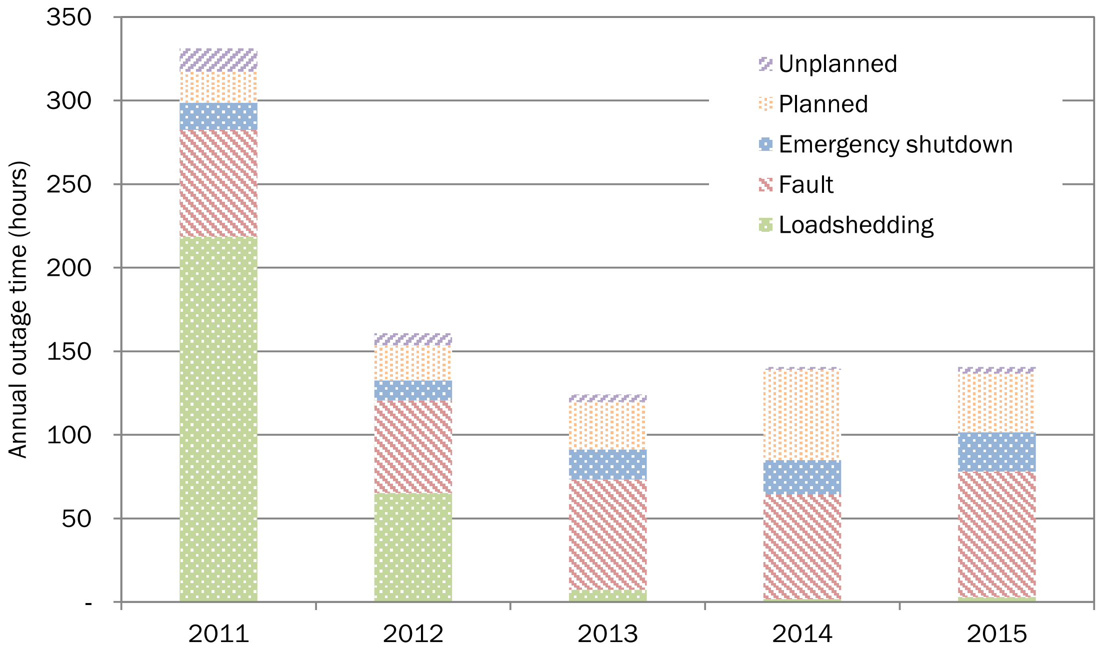


Exhibit 12: Annual outage duration time in hours 2011-2015 (Source: Umeme)

[24] Data on total outage time per feeder for a sample of 70% of Umeme's network. Since feeders connect residential, industrial and commercial clients, we could not distinguish between outage times per group. There was no data available on the time of day/month when the outages occurred.

This trend in the outage data is recognised by local businesses. During a survey of 119 Ugandan companies carried out as part of this project (see section 4.4.2), all firms acknowledged the elimination of load shedding, but many were concerned with ongoing distribution issues. Even though respondents recognised that most outages were due to maintenance and planned in advance, in their experience the number of blackouts that are not communicated in advance increased in 2015 and 2016. Nevertheless, most of those interviewed agreed that the power situation in Uganda has improved considerably since 2011, and that the availability and quality of the electricity is sufficient to carry out operations.

For our analysis in section 5.1 we will use the 5.8 percentage point reduction (192 hours) in outages from the Umeme data (10.0% [333 hours] of operations time in 2011 minus 4.2% [141 hours] in 2014).

3.4 Outlook for the power sector

As mentioned in Section 3.2.1, major investments in power generation are ongoing and the available generation capacity is set to double by 2020. As a result, power generation will be even less of a bottleneck in the provision of electricity. Substantial investment will be needed in transmission to connect the new hydro plants to the grid, but also to both expand the network in the west of the country and create interconnections with neighbouring countries.

Using the regression results from Section 3.2.3, and assuming 6% GDP growth[25] and stable (real) prices[26], electricity consumption will increase by 6% annually.[27] This implies that there will be excess capacity for some 12 years.[28] Although a generation surplus would allow for reduced water release from Lake Victoria, a substantial capacity surplus is economically undesirable. In order to use the surplus capacity productively, the demand for electricity could be stimulated. The three main ways to do this are to (i) connect more households and businesses; (ii) increase demand from connected households and businesses and; (iii) export electricity. All of these are discussed below.

Over the past few years the average growth rate of the number of connections has been 15-18%, with the lowest use residential and commercial sectors growing fastest. Although electrification rates are low, increasing the already considerable growth rates might be difficult for operational and financial constraints. And because domestic electricity use makes up only a small fraction of total consumption (see Exhibit 10), even a doubling of the number of domestic connections (which would take 4 to 5 years at 15-18% growth rates) would increase total electricity use by less than 25%.

Connected households and businesses will grow their demand in response to income increases and price decreases respectively. These have already been incorporated in the used electricity growth forecast. The Bujagali generation tariffs will come down in the future once debt has been repaid[29] and this may provide room for some decrease in end-user tariffs; but this also depends on many other factors. Availability and reliability improvements may activate supressed demand (e.g. acquisition of more capital and electricity- intensive equipment) but this is hard to quantify.

[25] World Bank forecast http://www.worldbank.org/en/country/uganda/overview

[26] It remains to be seen whether the Isimba and Karuma hydro power plants currently under construction will bring about lower tariffs, as there are no reliable details on their expected cost levels or power purchase agreements.

[27] The UETCL base case scenarios for demand growth assume 15% demand growth: the optimistic scenario is 22% and the conservative scenario 6.5%.

[28] At a growth rate of 6.0% it will take 12 years to double electricity demand. The number of years of excess capacity at the growth rates mentioned in the previous footnote of 15% and 22% are 5.0 and 3.5 years respectively.

[29] As per the PPA, the current tariff is USD 0.11 per kWh. When the corporate tax holiday expires in 2017, the tariff will increase to 14 cents per Kwh. After which it will drop to about 8 cents in 2022, when the senior debt is retired; and then drop again to 7 cents in 2027, when the subordinate debt is paid off.

Export potential looks promising, given the large power deficits in the region, but requires the construction of costly interconnections. Meanwhile, other countries have ambitious plans to increase their own exports. Although Rwanda, South Sudan and DRC are expected to remain electricity importers (albeit with limited capacity, given their size and/or the state of their electricity networks), Tanzania and especially Kenya have advanced plans to become exporters, and with the commissioning of the Renaissance dam in Ethiopia, 6,000 MW will come on stream, which will reduce the opportunity for financially attractive exports.

To summarise, it is highly likely that Uganda will have a generation surplus for many years to come and investment should be geared toward transmission and distribution.

4 ECONOMIC IMPACT ANALYSIS FRAMEWORK

In this section we introduce the analysis framework. Because employment creation is a function of economic growth, a literature review of the causal relationship between electricity consumption and economic growth is given in in Section 4.1, followed by a review of the relationship between power outages and economic output in Section 4.2. Based on these literature reviews and the characteristics of the Ugandan power sector, the analysis framework is presented in Section 4.3, followed by a discussion of the used data sources in Section 4.4.

4.1 Relationship between electricity consumption and economic growth

A large body of academic literature exists on the relationship between energy or electricity consumption and economic growth, and which one causes the other. Typically, the findings depend on the country, analysis methodology[30], selected variables and period under consideration. Four possible relationships between electricity consumption (EC) and GDP have been identified:

- Growth hypothesis: electricity consumption causes GDP growth (EC ⟹ GDP);
- Conservation hypothesis: GDP growth causes electricity consumption (GDP ⟹ EC)
- Feedback hypothesis: electricity consumption and GDP growth cause each other (EC ⟺ GDP);
- Neutrality hypothesis: electricity consumption and GDP growth are uncorrelated (EC ⇎ GDP).

We are not aware of any study that has investigated which of the four hypotheses holds in Uganda. Lemma et al. (2016)[31], in a study for CDC Group, provide a detailed overview of the academic literature on the relationship between energy or power and economic growth. They observe that, depending on the country and time period studied, all different hypotheses are supported. Because the neutrality hypothesis seems less prevalent than the other three, they conclude that in most cases power plays, if not a facilitating role, then at least an enabling one in economic growth.

Wolde-Rufael (2006)[32] looked at 17 African countries, but Uganda was not included in the sample. The study concluded that for the period 1971-2004, for three countries the (Granger) causality ran from electricity consumption to GDP per capita growth; for six countries the causality was from GDP per capita growth to electricity consumption; for three countries there was a bidirectional causality; and for 5 countries there was no relationship. However, the study only considered grid electricity, which covered a very small fraction of total energy consumed, and the author advised that the results be interpreted with caution.

Analysing data from a large number of countries, Adhikari and Chen (2012)[33] found a strong relation running from energy consumption to economic growth for upper-middle income countries and lower-middle income countries, and a strong relation running from economic growth to energy consumption for low income countries.

Nondo et al. (2010)[34] found support for the feedback hypothesis for a panel of 18 COMESA countries in the long run and for the neutrality hypothesis in the short run.

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[30] Notably Granger causality and co-integration analysis, applied in bivariate or multivariate ways.

[31] Lemma, A., Mass, I. and te Velde, D.W. *What are the links between power, economic growth and job creation?*, Development impact elevation, 2016.

[32] Wolde-Rufael, Y, *Electricity consumption and economic growth: a time series experience for 17 African countries*, Energy Policy 34, 1106-1114, 2006.

[33] Adhikari, D. and Chen, Y., *Energy Consumption and Economic Growth: A Panel Cointegration Analysis for Developing Countries*, Review of Economics & Finance, 2012.

[34] Nondo, C., Kahsai, M and Schaeffer, P., *Energy Consumption and Economic Growth: Evidence from COMESA Countries*, Southwestern Economic review, 107-119, 2012

Looking at a broader set of infrastructure variables for a large number of African countries, Escribano et al. (2010)[35] found that in Uganda electricity-related variables explain about 25% of the observed total factor productivity.[36] Musini (2006)[37] found that in Uganda a 1% increase of public infrastructure[38] causes an approximately 0.35% increase in firm value added.

Despite the lack of econometric consensus for a single hypothesis regarding the nexus of economic growth and electricity, it is hard to deny the importance of energy in production. Economic production is in its essence the transformation of material inputs into outputs through the addition of energy, knowledge and organisation (i.e. labour and capital). In this thermodynamics-based view of the production process, energy and materials are the primary factors of production, in contrast to mainstream economics which considers capital, labour and land as the primary factors. And because electricity has become the dominant carrier of energy[39], one might extend this to say that electricity is a primary factor. It is clear that electricity cannot be substituted (entirely or considerably) by capital or labour. Indeed, the Industrial Revolution was made possible by extracting thermodynamic work from energy sources other than humans.

Viewed this way, energy, and thus electricity, play an especially important role in manufacturing. A number of studies have confirmed this. Inglesi-Lotz and Blignaut (2011)[40] concluded that in South Africa only industrial output exhibits statistically significant price elasticity. Soytas and Sari (2007)[41] found that in Turkey causality runs from electricity consumption to manufacturing value added, and seems to affect value added somewhat more than labour and investment inputs. They also found that manufacturing output responds positively to positive shocks in electricity consumption. For manufacturing in Malaysia, Bekhet and Harun (2012)[42] observe long-run (but not short-run) unidirectional causality from energy consumption to production for the period 1978-2009. Harun and Ishak (2014)[43] also found that, compared to capital and labour, energy is a more important factor for the manufacturing sector in Malaysia. Qazi et al. (2012)[44] draw the same conclusion for electricity consumption and industrial output in Pakistan from 1972-2010, and even conclude that “energy shortage is one of the main reasons for the downturn of the industrial sector, particularly in large-scale manufacturing. As a result, plenty of small-scale industries are shut down and many large-scale industries are moving out of Pakistan.” Kwakwa (2012)[45] found that, although in Ghana economic growth (unidirectionally) Granger causes energy consumption, electricity consumption and

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[35] Escribano, A., Guasch, J.L. and Pena, J., *Assessing the Impact of Infrastructure Quality on Firm Productivity in Africa*, World Bank Policy Research Working Paper 5191, 2010.

[36] Infrastructure variables (electricity, transportation, water, customs clearance and water) together explain some 60% of TFP and electricity variables explain slightly over 40% of the total infrastructure effect.

[37] Musini, A. A. *Physical public infrastructure and private sector output/productivity in Uganda: a firm level analysis*, Working Paper Series no. 24, Institute of Social Studies, 2006

[38] The public infrastructure index was derived for 25 districts and captured length of paved roads, electricity connections and telephone connections.

[39] Electricity is the highest grade (lowest entropy) form of energy which can be converted into other forms (heat, motion etc.) at great efficiency and is easily transported over distances.

[40] Inglesi-Lotz, R and Blignaut, J.N., *Estimating the price elasticity of demand for electricity by sector in South Africa*, South African journal of economic and management sciences, 14(4), 2011.

[41] Soytas, U. and Sari, R., *The relationship between energy and production: evidence from Turkish manufacturing*, Energy Economics, 2007.

[42] Bekhet, H.A. and Harun, N.H.B., *Energy essential in industrial manufacturing in Malaysia,* International Journal of Economic and Finance, 4(1), 2012.

[43] Harun, N.H. and Ishak, M.S., *Analysis of the production theory for manufacturing industry and construction industry in Malaysia*, Proceeding of the Global Summit on Education GSE 2014.

[44] Qazi, A.Q., Ahmed, K. and Mudassar, M., *Disaggregate Energy Consumption and Industrial Output in Pakistan: An Empirical Analysis*, Economics E-Journal, 2012.

[45] Kwakwa, P.A., *Disaggregated energy consumption and economic growth in Ghana*, International Journal of Energy Economics and Policy, 2(1), 2012.

manufacturing output Granger cause each other. In Kenya, Nelson et al. (2013)[46] found short and long-run bidirectional causality between electricity consumption and manufacturing output. Electricity consumption was found by Abid and Mraihi (2014)[47] to Granger cause industry GDP in the long run in Tunisia. Most recently, in a working paper of the IMF, Alvarez and Valencia (2015)[48] conclude that in Mexico a 1% decrease in electricity prices would increase manufacturing value added by 0.28%.

The reason that the manufacturing output response to cheaper electricity is found to be stronger than that of commercial sectors is because electricity is largely a variable cost for manufacturing and largely a fixed one in most other sectors. (Put very simply, an office needs to be lit or cooled independent of the number of employees present, whereas increasing manufacturing output requires more electricity.) This is probably the main reason why the World Bank Enterprise Surveys only ask for information on electricity use from companies in the industrial sector.

Because electricity is so crucially important, many companies that can afford investments in back-up generation capacity will do so. Companies that turn to self-generation to substitute grid electricity typically incur a cost increase because of the scale advantages present in electricity generation and because expensive fuel must be transported to the site. Power outages for these firms mean higher costs, which render them less competitive and lowers the output level at which they maximise profits. Power outages are effectively a time-varying tax on electricity. This tax is lower for larger companies due to scale advantages in power generation. The effect of outages on companies is discussed in Section 4.2.

Based on the literature overview presented above, we conclude the following:

- Although the econometric evidence is not entirely clear cut, the balance of evidence from Uganda and countries in a similar development stage points to a bidirectional relationship between energy and electricity use on the one hand, and economic growth on the other;
- This causal relationship runs primarily through electricity-intensive sectors, and first and foremost through manufacturing;
- The pathways through which electricity shortages affect companies are different for companies with and without (sufficient) backup generation capacity.

4.2 Impact of power outages on economic output

The overview in the previous section demonstrates the role of electricity consumption as a facilitator or enabler of economic growth. One can thus safely assume that power outages negatively affect economic output. Because power outages are frequent in Uganda, we discuss here in detail the literature on how outages affect economic output.

Power outages can affect economic output through (i) loss of production; (ii) restart costs; (iii) equipment damage; and (iv) spoilage of raw or finished materials. Companies can completely or partly mitigate these negative impacts. In addition to self-generation, which was discussed in the previous section, firms can (i) continue operations without electricity or reschedule production; (ii) adopt technologies that allow faster production during hours when power is available; or (iii) procure energy-intensive semi-finished goods, and thereby eliminate power-intensive production steps. These diverse impacts and mitigation measures make it plausible that the ensuing effect of power outages varies substantially between economics sectors.

[46] Nelson, O., Mukras, M.S. and Siringi, E.M., *Causality between disaggregated Energy Consumption and manufacturing growth in Kenya: an Empirical Approach*, J. Econ. and Sust. Development 4(16), 2013.

[47] Abid, M. and Mraihi, R., Energy consumption and industrial production: Evidence from Tunisia at both aggregated and disaggregated levels, J. Knol. Econ, 2014.

[48] Alvarez, J. and Valencia, F., *Made in Mexico: Energy Reform and Manufacturing Growth*, IMF WP/15/45, 2015.

An often used indicator to monetize the impact of outages is the so-called "Value of Lost Load" (VoLL). The VoLL expresses the value per kW power load, although it is more commonly expressed as the value lost per kWh foregone electricity consumption (Value of Lost Consumption, VoLC). It can be expressed for an individual firm, for an economic sector or for an entire economy. When expressed as loss of value added per kWh, it is essentially the inverse of electricity intensity. Using Exhibit 6b, this means that the VoLC for Uganda is 11.85 USD per kWh.[49] VoLC values are nearly always an order of magnitude higher than the all-inclusive cost of power, an argument that is often used for saying that investments in power yield great economic returns. But because the VoLC does not reflect self-generation or any of the other mentioned mitigation measures, it is obvious that it is a drastic overestimation. Moreover, were the VoLC to be determined for individual sectors, it would yield the logical but counterintuitive result that it is highest for the least electricity-intensive sectors. For example, construction is not very electricity-intensive and thus has a very large VoLC, but it is obvious that the bulk of construction activities can continue when there is no power.

The heterogeneity of the effect of power outages on firm output is illustrated by Alam (2013)[50], who studied brick kilns, rice mills and steel mills in India. The majority of brick kilns do not use any electricity at all and their output is thus not seriously affected by outages. Rice mills are electricity-intensive but can change their production such that a 10% increase in outages affects their output by only 0.1% (although profitability is affected more because material use goes up by 7%). An identical increase of outages in steel mills, in contrast, leads to 11% loss of output (and 2% lower use of materials). Alcott (2014)[51] also found that electricity shortages have very different effects for self-generators and grid dependents in India, but notes that power shortages affect profitability much less than revenues, due to avoidable cost. Abotsi (2016)[52] found that the number of power outages impacts negatively on firm production efficiency, using World Bank data on 2,755 firms in 10 African countries. In Senegal, Cissokho (2013)[53] showed that in response to more frequent power outages, ownership of generators increased by 47% between 2006 and 2011. The same study shows that although SMEs tend to become better in dealing with outages (higher technical efficiency), outages do still hinder their growth (scale efficiency).

Using three different methods, Oseni and Pollitt (2013)[54] estimate the outage cost to African firms to be in the range USD 0.87 – 4.81[55] per kWh. They also point out that the back-up rate of companies which own backup power generators ranges from 14% in Kenya to 43% in Nigeria. As shown in Table 4, in Uganda more than 36% of firms have a backup generator.

Finally, Andersen and Dalgaard (2013)[56] performed a regression analysis of 39 African countries and estimated that GDP per capita decreases by 2.86% for every 1% increase in the logarithm of the number of outages.

[49] The electricity intensity is 0.138 kWh / 2005 USD GDP. Taking the inverse and multiplication by the 2014/2005 GDP inflator of 1.65 yields USD 11.85 / kWh. Developed economies VoLC values are typically USD 10-25.

[50] Alam, M.M, *Coping with Blackouts: Power Outages and Firm Choices*, Working Paper, Dept. Economics, Yale University, 2013.

[51] Alcott, H., Collard-Wexler, A. and O'Connell, S.D., *How Do Electricity Shortages Affect Productivity? Evidence from India,* American Economic Review, 2015.

[52] Abotsi, A.K., *Power Outages and Production Efficiency of Firms in Africa*, Int. J. Energy Econ. and Policy, 6(1), 2016.

[53] Cissokho, L. and Seck, A., *Electric Power Outages and the Productivity of Small and Medium Enterprises in Senegal*, ICBE-RF Research Report No. 77/13, 2013.

[54] Oseni, M.O. and Pollitt, M.G., *The Economic Costs of Unsupplied Electricity: Evidence from Backup Generation among African Firms*, Cambridge working papers in Economics, EPRG Working paper 1326, 2013

[55] The range found by the authors was USD 0.60 – 3.32 in 2007 dollars, which here have been inflated to 2014.

[56] Andersen, T.B. and Dalgaard, C.J., *Power outages and economic growth in Africa*, Energy Economics 38, 2013

4.3 Analysis framework

Based on the overview in Sections 4.1 and 4.2, the analysis framework for the economic impact of an increase in power supply is presented in Exhibit 13, which covers two separate analysis steps. Exhibit 13A describes the actual change that has occurred from 2012 (when the Bujagali plant became operational) until 2015. This change consists of three components:

1. As described in Section 3.2.1, the inauguration of the Bujagali plant in 2012 allowed the retirement of 100 MW diesel power plants of Aggreko. Had tariffs not changed, the retirement alone would have saved the government USD 180 million (UGX 447 billion) annually in electricity subsidies. End-user tariffs, however, increased, which will have supressed economic output. In addition, Umeme's investment in the distribution network decreased losses, which meant that less generation capacity was needed to satisfy the same load;
2. Due to internal and external demand, the economy grew by 12.2% from 2011 to 2014;
3. The net expansion of available power capacity by 150 MW (addition of 250 MW hydro power minus retirement of 100 MW diesel power) caused a substantial reduction in outage time.

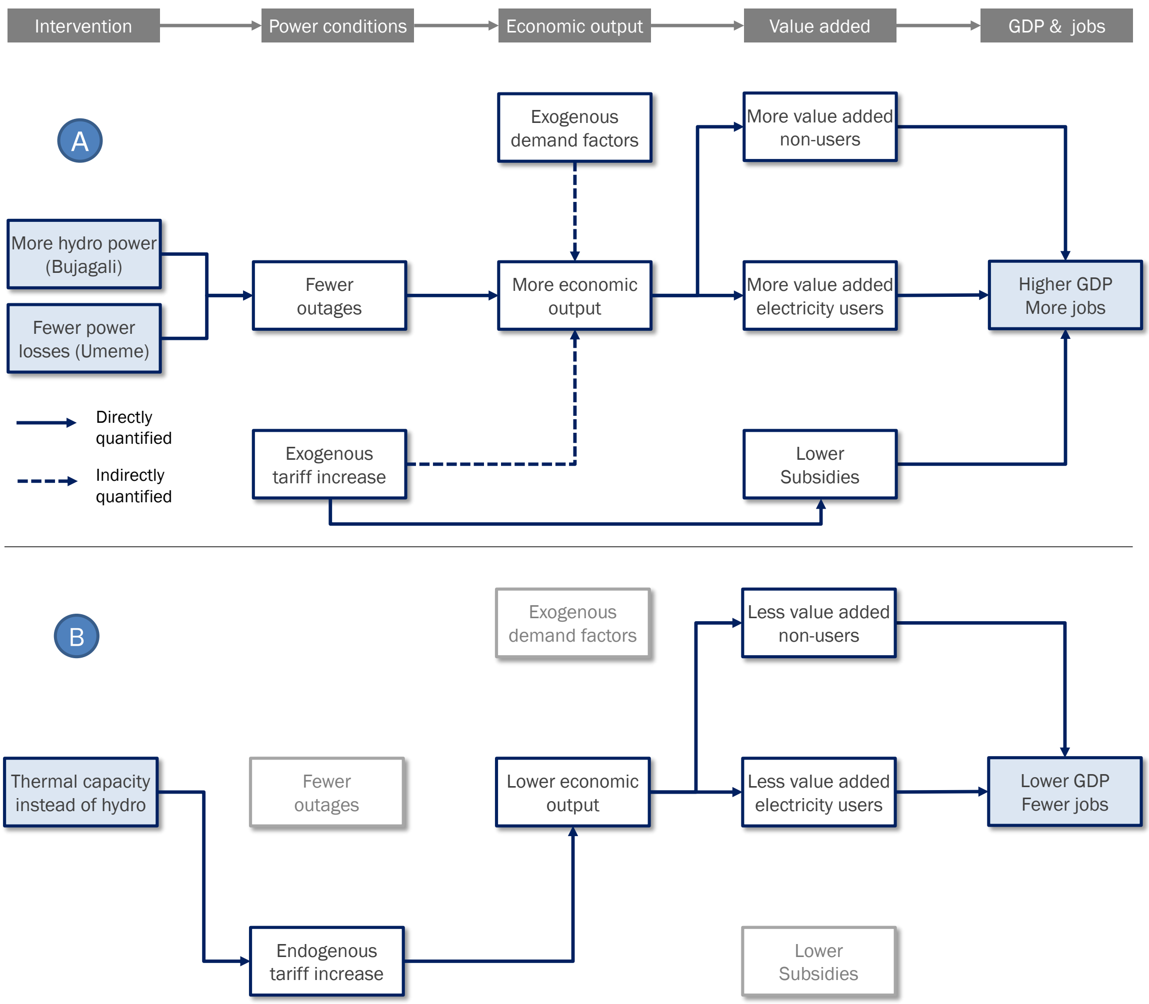


Exhibit 13: Analysis framework for the impact of increase in power sent into the grid on GDP and employment

The reduction of outage time can be observed from Umeme outage statistics (Exhibit 12), and the associated effect on economic output of different sectors can be quantified. The effect of economic growth and electricity tariff increases (both exogenous) on economic output[57] cannot reliably be untangled. Their combined effect is taken as the difference between the observed increase of economic output and the output increase which is explained by outage time reduction.

Exhibit 13B describes a (hypothetical) counterfactual of what would have happened had Bujagali not been built and the capacity expansion been realised by expanding thermal power capacity to 250 MW (i.e. running the existing HFO plants at full capacity with the remainder being supplied by diesel power plants identical to those at Aggreko until 2011). Assuming electricity subsidies would have ended (as they had become untenable), this would have spurred a large (endogenous) increase of end-user tariffs. These higher tariffs would have reduced electricity use (because of the negative price elasticity in Table 3) and as a result economic output, value added and employment would have dropped. The impact of reduced outage time and lower subsidies are already included in Exhibit 13A, and are thus not considered in this analysis step. The loss of GDP and employment determined in this way can be interpreted as a "hidden" economic impact of the change to hydro power.

The described counterfactual – emergency thermal generation at cost-reflective prices - is essentially an extrapolation of the observed behaviour of the government of Uganda between 2005 and 2011. During this period, the government resorted to contracting thermal power producers in order to offset the shortfall in power due to drought and to meet the increasing power demand. In 2011, when subsidies had reached 37%[58] of the budget of the Ministry of Energy and Mineral Development and 1.1% of GDP, the government argued that there were simply no resources to continue subsidising electricity.[59]

Combined, the two analysis steps cover the effect of availability (capacity addition followed by outage reduction; step A) and affordability (lower cost technology, which reduces tariffs when they are fully cost reflective; step B).

4.4 Data sources

The analysis framework requires use of a number of different data sources, each of which is described in this section.

4.4.1 Power sector data

The data on the power sector that will be used is:

1. Generation (per plant), transmission, distribution and end-user tariffs from ERA;
2. Power capacity data, as presented in Table 1;
3. Outage data from Umeme, as presented in Exhibit 12;
4. System load data from Umeme.

[57] Tariff increase leads to decrease of economic output (Exhibit 13A). To avoid confusion, the relationship is not presented in a feedback graph.

[58] Mawejje J, Munyambonera E, Bategeka L., *Powering ahead: the reform of the electricity sector in Uganda*, Energy and Environment Research 3 (2), 126, 2013.

[59] International Monetary Fund, *Energy Subsidy Reform in Sub-Saharan Africa: Experiences and Lessons,* International Monetary Fund (Washington), 2013.

4.4.2 Firm-level data

A. Existing data sets

Firm-level data is needed to quantify the effect of power outage duration on economic output (Exhibit 13A). In this study, we have used data from the 2013 World Bank Enterprise Survey, to our knowledge the only source for this type of data. The survey sampled 762 firms, of which 385 provided realistic answers (see also Table 4).

In order to determine the relationship between electricity price, electricity consumption and manufacturing output, one would ideally deploy a longitudinal analysis using panel data[60] of output and cost attributes of individual firms. Unfortunately, such data is not available. As an alternative, a cross-sectional analysis, which considers a sample of firms at a single point in time, can be applied. A possible source for this data is again WBES, but due to data gaps and inconsistencies, the analysis could only be performed for a total of 73 manufacturing and 156 services companies. The second source is the Business Inquiry carried out by the Uganda Bureau of Statistics in 2011 among 4,721 manufacturing businesses. Because of data gaps, we could only carry out the analysis for a total 219 of manufacturing firms.

B. Electricity-focussed business survey

Together with Research Solution Africa (RSA), we have constructed a third dataset from private sector interviews among 119 businesses in Uganda. The sample included 64 manufacturing and 55 services firms (of which, 47 in wholesale, retail or restaurants). Compared to the WBES, the interviews conducted by RSA focused more on changes that have happened over time, asking for data in 2011 and 2015, in order to get a better view on how access and use of power have changed, and their effect on firm output and investment. The interviews were conducted face-to-face with senior managers of establishments.

For the survey, we chose a stratified sampling strategy in order to resemble the WBES sample with respect to sector and company size distribution. Given the small sample size of our survey, we could not replicate the regional distribution of the WBES sample. The interviews were therefore conducted in three regions: Kampala/Wakiso (where 50% of Uganda's business activity takes place); Jinja (the second largest economy in the country, and for a long time a preferred location for companies due to its proximity to the hydro power stations), and in the West Nile region, where the WENRECo mini-grid operates. The smaller manufacturing establishments were selected together with the Uganda Small Scale Industry Association (USSIA)[61], and the larger ones together with the Uganda Manufacturing Association (UMA).[62] The establishments in the retail, hotels and services sectors were selected randomly by RSA. More details about the sample of the RSA/SRQ survey can be found in Annex 2.

C. Usage of data sources

The 2011 outage data in the RSA/SRQ have not been used to enlarge the sample of the WBES. The reason for this was that, although most interviewees felt confident to answer questions on the current incidence and duration of outages, they were much less certain about the 2011 situation because it was so long ago.[63] Based on the significance of the coefficients (p-values), the goodness-of-fit (adjusted R^2) and the realism of results, the regressions to determine the effect of price on output (Section 5.2.4) for the manufacturing sector have been calculated based on the 2011 data of the UBOS and RSA/SRQ surveys. Because UBOS data only includes manufacturing firms, the WBES and

[60] Panel data is a time series of at least two parameters which allows the analysis of relationships between them.

[61] USSIA has 1,600 members in 12 industrial sectors. For more information: http://www.ussia.or.ug/

[62] UMA has more than 160 members. For more information: http://www.uma.or.ug/

[63] A second reason was that the outage question in the RSA/SRQ survey was framed on a per day basis, rather than a per month basis. The answers therefore were systematically higher than WBES data and inconsistent with actual Umeme outage statistics.

RSA/SRQ datasets were used for the service sectors (retail, wholesale, restaurants, construction and transportation).

Table 5 summarises the data sources used to determine the effects of outages and electricity price on firm economic output, as will be discussed in Section 5.1 and Section 5.2 respectively.

Table 5: Firm-level data sources used for outages and price effect on output

	Manufacturing	Trade & Services
Outages effect on output	WBES (195 firms)	WBES (190 firms)
Price effect on output	UBOS & RSA/SRQ (271 firms)	WBES & RSA/SRQ (213 firms)

4.4.3 Input-output table

In order to determine how a change of economic output translates into changes in GDP and employment, we use the Input-Output methodology. The core ingredient of this methodology is the input-output table (IOT). The most recent IOT for Uganda comes from the Global Trade Analysis Program (GTAP), which contains information for 57 economic sectors and is based on 2011 data. Using the most recent data from UBOS on economic output and GDP contribution for 34 sectors, the IOT has been updated to 2014 using the often-used RAS method (see section 5.3.1).

The economic input-output model applied in the report makes a number of assumptions. The most important ones being:

- Fixed production coefficients, meaning that technological changes induced by cheaper/better available power are not included. These changes typically occur over longer time scales and do not substantially affect the results presented here in the short- to medium-term;
- Linear relations between economic inputs and outputs. In this report we have applied a non-linear analysis of the manufacturing output response to changes in the effective power price. This means that the assumption of linearity applies to the second order effects of how the manufacturing response affects the rest of the economy. We also note that the quality of Ugandan economic data would greatly limit the applicability of the more advanced *General Computable Equilibrium* models, meaning these are unlikely to be able to capture reliably the effect of structural changes.

4.4.4 Employment data

Information on Uganda's labour market is scarce. The latest data is from the 2013 Labour Force Survey and contains a breakdown of the total working population into subsistence farmers and people employed.[64] The latter is split into 9 high-level sectors, including agriculture, manufacturing, retail, trade and services. Using the corresponding economic output figures (which were also used in the updating of the input-output table), the employment intensity – the number of people employed per million UGX of economic output – is determined for all sectors. The survey also contains data on gender breakdown per sector and average salary per skill level, which, together with data on total salaries for skilled and unskilled employees for 57 sectors from GTAP, was used to provide gender and skill breakdowns of the employment results in section 5.3.

[64] UBOS defines a person in employment as anyone who has worked a minimum 1 hour during the previous week.

5 ECONOMIC IMPACT OF IMPROVED POWER AVAILABILITY AND AFFORDABILITY

In this section we explore how improved power availability and affordability affects business productivity, in order to quantify the impact on GDP and jobs, using the framework presented in Section 4. In Section 5.1 the impact of reduced outages on economic output will be quantified as outlined in Exhibit 13A. In Section 5.2 the impact of higher cost electricity on economic output will be determined as outlined in Exhibit 13B. In Section 5.3 the economic output effects are translated into GDP and employment impacts across the economy. In Section 5.4 all results are aggregated and expressed as multipliers and in 5.5 the accuracy of the results is addressed.

5.1 Effect of reduced outage on firm output

5.1.1 Sales losses due to outage time

By and large, the range of sales losses due to power outages is slightly larger for the companies without generators than for the ones with generators (see Table 6).

Table 6: Relative sales losses due to power outages and self-generation

Company size	% self generation		% sales lost		# with sales lost
	median	average	median	average	
All			5%	14%	385
generator	*10%*	*18%*	*7%*	*13%*	*223*
no generator			*5%*	*15%*	*162*
Small >=5 and <=19			5%	13%	233
generator	*10%*	*14%*	*6%*	*13%*	*104*
no generator			*2%*	*13%*	*129*
Medium >=20 and <=99			10%	14%	116
generator	*10%*	*14%*	*10%*	*13%*	*88*
no generator			*10%*	*20%*	*28*
Large >=100			5%	17%	36
generator	*27%*	*43%*	*5%*	*15%*	*31*
no generator			*25%*	*28%*	*5*
Food			8%	19%	62
generator	*10%*	*16%*	*5%*	*14%*	*44*
no generator			*33%*	*31%*	*18*
Other Manufacturing			5%	14%	133
generator	*15%*	*22%*	*10%*	*13%*	*70*
no generator			*5%*	*14%*	*63*
Services			10%	15%	108
generator	*15%*	*20%*	*10%*	*14%*	*66*
no generator			*4%*	*16%*	*42*
Retail			2%	10%	82
generator	*5%*	*11%*	*2%*	*12%*	*43*
no generator			*1%*	*7%*	*39*

The lower (median) value is most likely due to the fact that companies for whom electricity is less important tend not to invest in generators, whereas the higher (average) value reflects their lower ability to (partially) mitigate losses. The larger difference for large companies is not statistically significant, due to the small sample size. When looking at the economic sectors, the difference in sales losses for companies with and without generators is by far the largest in the food sector, probably due to spoilage of raw materials. Sales losses in the retail sector for companies without a generator are about half the losses incurred by companies that do have one; retail companies that rely less on electricity tend not to invest in back-up capacity.

5.1.2 Quantification of the effect of outages

Based on the statistics on power outages and the associated sales lost, the monetary impact can be quantified. For all companies combined, the total outage time ranges between 30 and 52 hours per month (Table 4), or 11% - 19% of operational time. The range of output lost due to power outages, however, ranges between 5% and 14% of total output (Table 6). This means that most, but not all, of the entries in Table 6 are able to partly mitigate the effect of power outages. For each firm we therefore define a loss mitigation factor ϕ, which is the ratio of relative sales losses to relative production time losses:

$$\phi = \frac{Y^{lost}/Y}{T^{lost}/T} \qquad (3)$$

with T^{lost} the production time lost (number of outages per month multiplied by their average duration), T the operation hours per month)[65]. It thus follows that the lost output for sector i is expressed as:

$$Y_i^{lost} = \phi_i \cdot \frac{Y_i}{T_i} \cdot T_i^{lost} \qquad (4)$$

Finally, the output increase of sector i is equal to the reduction of output loss that results from a decreased outage time (be it a lower outage frequency or a reduced average duration), and is expressed as:

$$\Delta Y_i = -\Delta Y_i^{lost} = -\phi_i \cdot \frac{\Delta T_i^{lost}}{T_i} \cdot Y_i \qquad (5)$$

Consistent with the use of median and average value[23] in Section 5.1.1, the limiting values of ϕ are determined using the median and average value of the lost sales and outage time values. The results, as well as the mid-point value which will be used in the calculations, are shown in Table 7.

In line with what was found in the previous section, across the entire sector the mitigation factor is very similar for firms with and without generators. One reason for this is the relatively small capacity of the back-up generators, which can only partially cover a firm's operations. Based on data from the survey of local firms (see Section 4.4.2), self-generation covers 70%, 40% and 20% of the operations of large, medium and small companies respectively. Small firms without generators are less affected by power outages, most likely because their operations rely less on electricity. Medium firms without generators suffer more, but are likely to lack the financial resources to invest in (sufficiently large) generators. The data for large firms without generators is not reliable due to the very small sample. As indicated by the mitigation factor larger than 1 (i.e. loss amplification), food producers without generators suffer most from power outages, most likely due to spoilage of raw materials and/or finished goods. Food producers with generators, on the other hand, suffer the least from outages, due to the fact that, according to the survey, they can run 75% of their operations on back-up generators. In the services and retail sectors, firms without generators suffer less from outages, again because companies which are not dependent on power will not have invested in back-up generators.

[65] The fraction outage time for a firm is defined as the outage hours per month (outage frequency multiplied by average duration) divided by the number of monthly operation hours. Where a firm has not reported the number of operation hours, the median value of 278 hours has been used.

Table 7: Mitigation factor ϕ (% sales lost / % outage time)

Company size	ϕ		
	median	average	mid point
All	0.42	0.52	0.47
generator	*0.58*	*0.47*	*0.52*
no generator	*0.38*	*0.59*	*0.48*
Small >=5 and <=19	0.43	0.58	0.50
generator	*0.61*	*0.64*	*0.63*
no generator	*0.17*	*0.55*	*0.36*
Medium >=20 and <=99	0.69	0.40	0.55
generator	*0.63*	*0.35*	*0.49*
no generator	*0.83*	*0.55*	*0.69*
Large >=100	0.50	0.68	0.59
generator	*0.50*	*0.52*	*0.51*
no generator	*3.13*	*4.36*	*3.74*
Food	0.60	0.50	0.55
generator	*0.32*	*0.35*	*0.34*
no generator	*2.71*	*0.88*	*1.79*
Other manufacturing	0.40	0.39	0.40
generator	*0.63*	*0.32*	*0.47*
no generator	*0.46*	*0.47*	*0.47*
Services	0.83	0.77	0.80
generator	*0.83*	*0.74*	*0.79*
no generator	*0.28*	*0.82*	*0.55*
Retail	0.20	0.61	0.41
generator	*0.20*	*0.68*	*0.44*
no generator	*0.09*	*0.51*	*0.30*

As shown in Section 3.3.4, outages as a share of company working hours decreased from 10.0% in 2011 to 4.2% in 2014, or by 5.8 percentage points. Applying these figures to Equation 5 yields the increase in sector output resulting from the reduction in outage time. The results are presented in Exhibit 14. The services sectors, with a mitigation factor of 0.8, have benefited most from the decrease in blackouts: an output increase of 4.6%. Production in the food & beverage sector increased by 3.2%, while output in other manufacturing sectors and in retail went up by some 2.3%. The overall economic output in the country grew by 2.7%

Even though impossible to verify, the quantitative results in the businesses survey point in very much the same direction: 87% of firms acknowledged that increased availability of electricity has had a positive impact on their turnover. In the services sector, 75% of interviewed companies experienced a small or moderate positive impact on turnover, while 25% indicated a large or huge impact, and responses in the trade sector were much the same. In the food industry, 38% of the interviewed companies mentioned a large or huge impact and 37% a small or moderate impact, while 25% did not think the reduction in outages benefited turnover. In the other manufacturing sectors, the large majority of companies (75%) responded that the increased availability of electricity had a small or moderate effect on turnover.

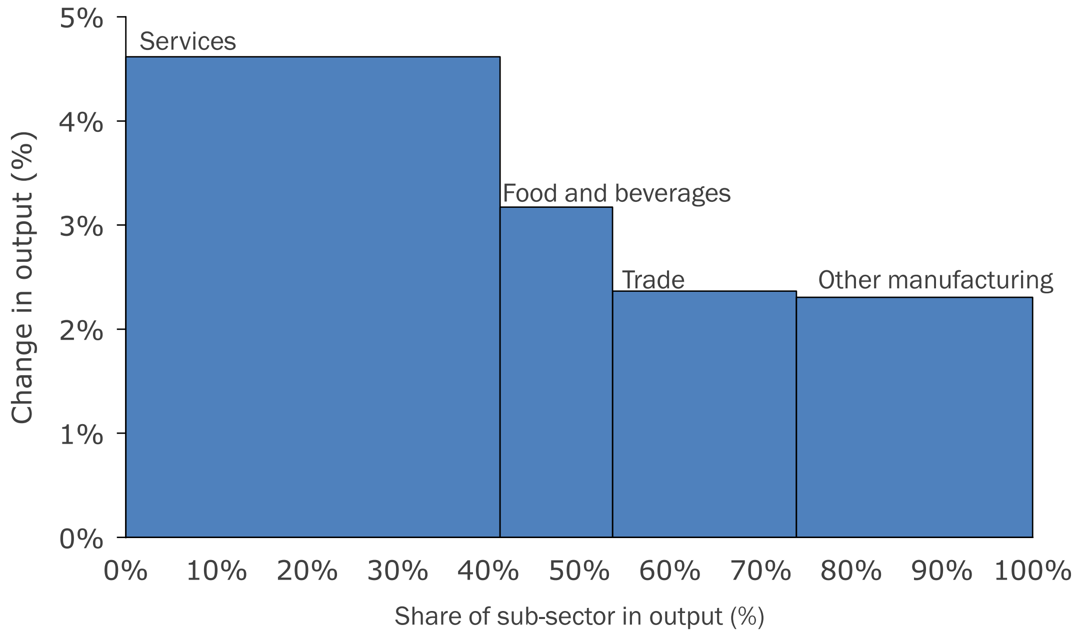


Exhibit 14: Response of output to decrease in outage time

5.2 Effect of electricity price on firm output

In order to quantify the impact of affordability (Exhibit 13B), we construct a hypothetical counterfactual showing what the power situation would have been had Bujagali not been built and its generation capacity instead been provided by thermal HFO and diesel generation.[66] To do this, in section 5.2.1 we will first show the current power supply curve for Uganda, encompassing the 250 MW capacity of Bujagali. We then construct a curve with the 250 MW Bujagali capacity provided by the HFO and diesel generation.

In Section 5.2.2 we will describe the observed monthly average power load curves for 2015, which we will combine with the actual and counterfactual supply curves in Section 5.2.3 to derive the difference between the actual generation cost in 2015 (with Bujagali) and the counterfactual situation. Assuming that, under the counterfactual thermal scenario, the end-user tariffs would have been cost-reflective, we will compare the difference in the final electricity price under the two scenarios.

5.2.1 Supply curve for on-grid electric power

The actual 2015 on-grid profile is constructed by analysing capacity and cost information for all operational power plants in the country. According to data from ERA, there were 13 operational on-grid power plants with an installed capacity of 895 MW. As shown previously in Table 1, the available capacity (i.e. the dependable capacity adjusted for utilization) in 2015 was 543 MW. All power plants have been assigned a cost per kWh based on the generation tariff by ERA.

The resulting dependable power supply curve is shown in Exhibit 15. The Eskom power plants and Bujagali are located at the left of the supply curve because of their take-or-pay contracts, followed by the other hydro plants due to their low costs per kWh. The HFO plants, Tororo and Namanve, are at the

[66] Diesel generation could have been provided as emergency power (akin to the Aggreko situation) or off-grid self-generation by companies. The available thermal capacity in the beginning of 2011 was: Aggreko-Mutundwe 50MW; Aggreko-Kiira 50 MW; Jacobsen (Namanve) 50MW; Electro-maxx (Tororo) 20MW (increased to 90MW in 2012). Aggreko operated another 50MW plant in Lugogo/Kampala between 2005 and 2008.

expensive end of the curve. The large difference between the costs of hydro and thermal electricity generators is evident in the graph.

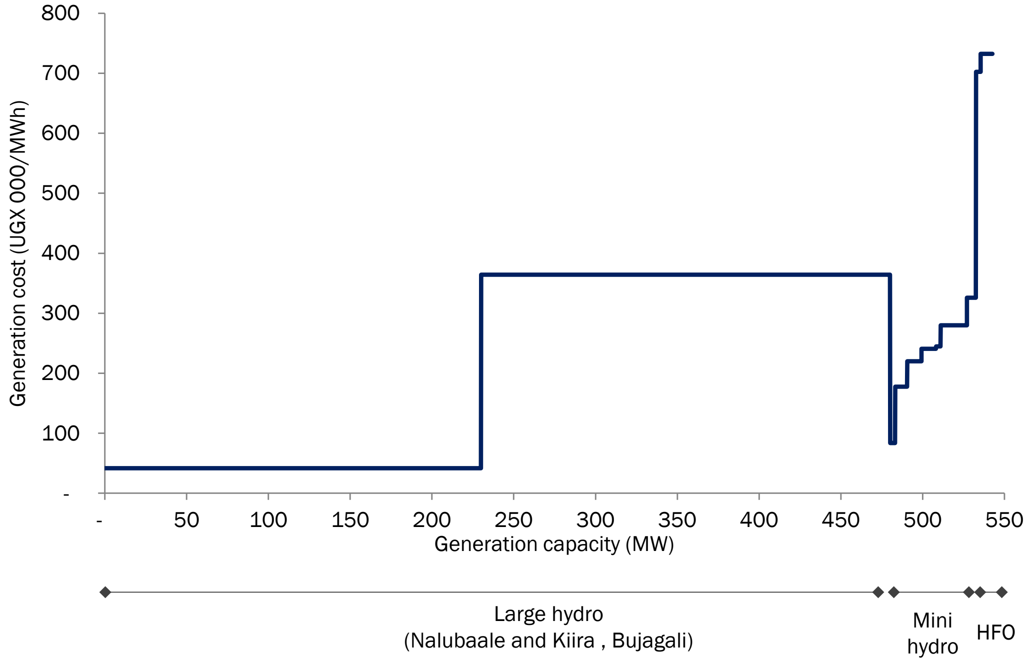


Exhibit 15: Available power supply curve in Uganda (source: ERA and SRQ analysis)

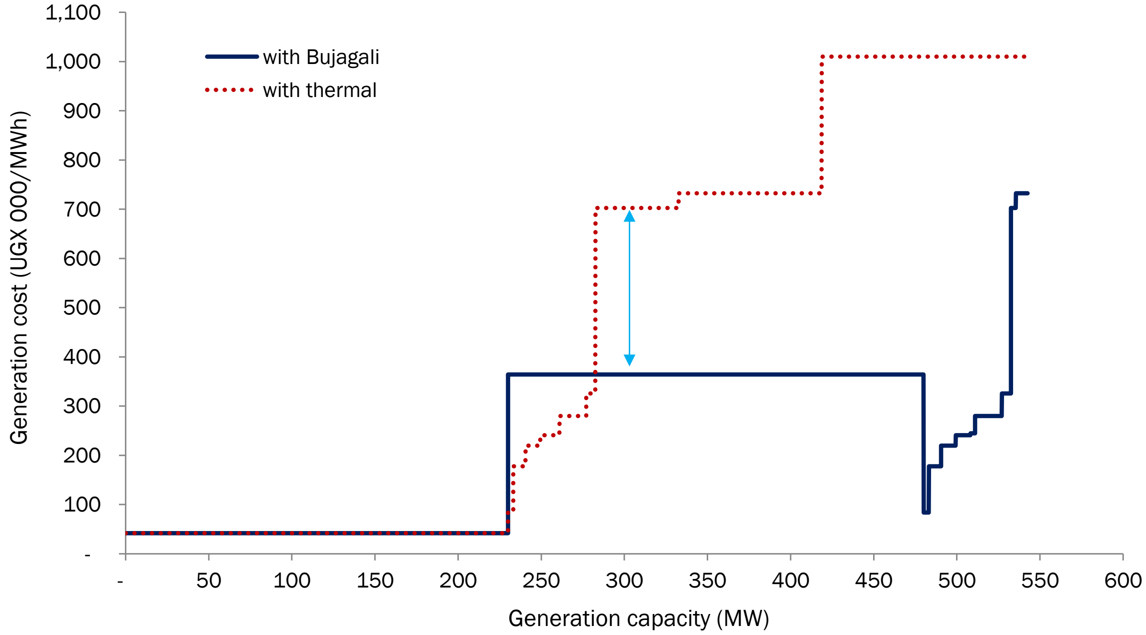


Exhibit 16: Actual supply curve from Exhibit 15 and hypothetical supply curve with thermal power replacing Bujagali hydro power plant (source: SRQ analysis)

Exhibit 16 combines the supply curve of Exhibit 15 with the hypothetical supply curve in which Bujagali's 250 MW is covered by thermal power (i.e. the HFO plants Namanve and Tororo (at full capacity)), and diesel power plants like the ones provided by Aggreko until 2012. As the exhibit shows, for any demand above 280 MW, the generation cost under the Aggreko scenario would have been higher than the generation cost with Bujagali. On average, the generation cost under the thermal scenario is 1.6 times higher than under the hydro scenario. Here we are using the 2015 diesel price of USD 0.70 per litre (UGX 2,360 per litre). Prior to 2015, when fuel prices were much higher, this difference would have been greater. A two-fold increase in the fuel prices (to roughly 2012 levels) would make the generation cost under the thermal scenario 2.51 times higher than under Bujagali situation.

5.2.2 Observed power load curves

The observed monthly average daily load curves reflect the actual demand of end-users (plus the technical and theft-related losses, but not the supressed demand). Power demand fluctuates over the course of the day, with peak usage between 19:00 and 22:00 at 490 - 530MW. Demand is lowest between 23:00 and 6:00. The 180 MW difference between daily peak and base load demand is much larger than the approximately 50 MW difference between months.

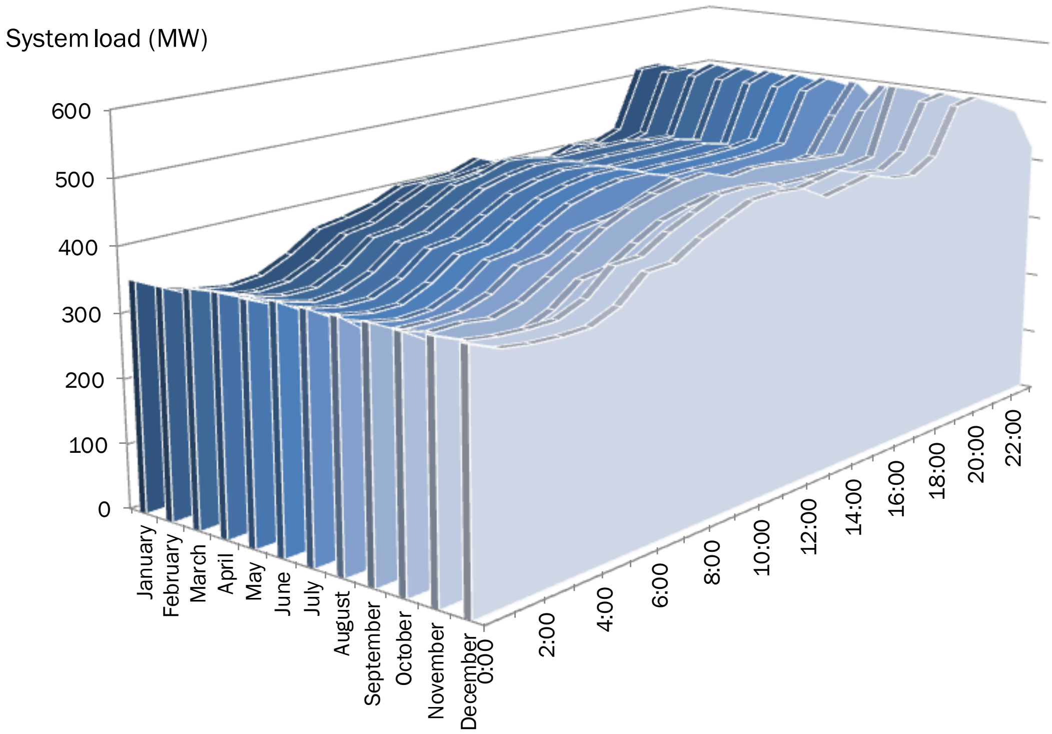


Exhibit 17: Power load curve based on average monthly data (source: Umeme)

5.2.3 How grid power supply changes affect the effective electricity price

The actual and hypothetical power supply curves of Exhibit 16, and the power load curve of Exhibit 17, have been combined in a model. Average daily load profiles can be selected for each month for the year 2015. The model then matches the hourly demand to the available capacity and yields the (load-weighted) average generation cost per MWh for each month of the year.

We first match the actual 2015 supply curve (with Bujagali) to the 2015 load to simulate the 2015 monthly average generation cost. We then add the transmission and distribution margins[67] to arrive at the final weighted average tariff paid by electricity users in Uganda.

The same process is repeated using the 2015 monthly demand profile and the hypothetical supply curve in order to derive the average generation cost under the counterfactual scenario. Given the high cost of thermal generation, the weighted average generation cost of the counterfactual power situation is 62% higher than under Bujagali. To derive the hypothetical end-user tariff, from each average monthly generation cost we add up the 2015 bulk supply tariff and distribution margin, as explained above. We thus isolate the effect of the change in generation costs. The results show that under thermal generation, the weighted average cost-reflective tariff would have been 26%[68] higher than the actual tariffs. As mentioned, this is based on the 2015 diesel litre price of USD 0.70. At higher diesel prices this differential would have been larger: twice as high fuel prices (close to 2012 levels) would have led to a 63% higher cost-reflective end-user tariff in the thermal scenario than the actual hydro-based tariff of 2015 (i.e. 2.45[69] times higher price differential).

5.2.4 Response of company production to changes in electricity price

The objective of this section is to determine the effect of the electricity price change determined in Section 5.2.3 on economic output. In Paragraph A we will determine the electricity factor share of manufacturing output. The factor share describes the change of manufacturing output resulting from a change in electricity usage. Together with the price elasticity determined in Section 3.3.3, the impact of the change of manufacturing output will be determined in Paragraph B.

A. Electricity factor share of manufacturing output

In order to determine the elasticity of output with respect to electricity cost, one can apply the extended Cobb Douglas[70,71] production function:

$$Y = A \cdot L^{\alpha} K^{\beta} M^{\gamma} E^{\varepsilon} \qquad (6)$$

With Y firm sales; L labour (number of employees); K capital (here replacement capital[72]), M (annual cost of materials - USD), and E annual electricity use (MWh). A is the so-called total factor productivity (TFP)[73] and α, β, γ and ε the factor shares or output elasticities. In the case of constant returns to

67 The prices between generation and Transmission Company are negotiated between them in the form of a Power Purchase Agreement, which is subject to oversight and approval by ERA. The Transmission Company sells power to any distribution company (buyer) connected to the transmission network at a Bulk Supply Tariff. The Bulk power supply tariff reflects the costs of power acquisition and transmission costs.

68 The 26% estimate is based on the assumption that the HFO plants would have been able to run at full capacity. Given transmission issues in the country, it is uncertain whether this could indeed have been the case, particularly for the plant in Tororo. Assuming maximum capacity of 7MW for the Tororo plant (thus an additional 79MW of diesel generation compared to Exhibit 16), the price increase would be 34%. On the other hand, Bujagali is able to store water for a couple of hours in order to satisfy peak demand without larger intake from Lake Victoria, which reduces the price difference.

69 2.45 = 63%/26%

70 Charnes, Cooper, W.W., and Schinnart, A.P., *A theorem on homogeneous functions and extended Cobb-Douglas forms*, Proc. Natl. Acad. Sci. USA 73(10), 1976.

71 Constant Elasticity of Substitution (CES) production functions may be preferable in theory, but nesting forms for factors make determination less reproducible. Moreover, given the limited importance of capital, it would lead to unconventional 'nests'. Transcendental Logarithmic (Translog) production functions (which are generalised Cobb Douglas functions) become too unwieldy in terms of parameters that need to be estimated when more than two variables are considered.

72 The Enterprise Survey has two indications for capital: book value and replacement value, of which the latter is deemed more representative, although the analyses are hardly affected by the choice between the two.

73 TFP is a dimensionally meaningless 'fudge' factor to account for changes in productivity unexplained by changes of factor inputs. It does not feature in this study.

scale, the elasticities sum up to 1. The elasticities can be determined using multiple linear regression analysis on the logarithmic form:

$$\log Y = \log A + \alpha \log L + \beta \log K + \gamma \log M + \varepsilon \log E \qquad (7)$$

When performing the regression analysis on the data sources indicated in Table 5, the sample size is restricted by the number of companies for which all variables are available. It thus makes sense to eliminate the variables with the least explanatory value in order to obtain statistically meaningful results for the entire sample, as well as for sub-sectors or size segments. Specifically, if a regressor could not be determined with more than 95% confidence (i.e. p-values larger than 0.05) it is omitted from the regression. We are aware that removing insignificant variables is not recommended, as it might introduce bias to the coefficients. However, it allowed us to increase the sample size (because not all inputs are known for all firms) while still not significantly altering the coefficient of the electricity use. This procedure was repeated until all remaining regressors were estimated with more than 95% confidence.

The results are presented in Table 8. All factor shares for the manufacturing sub-sectors are significant at the 5% or 10% level, except for the electricity factor shares for the chemicals sector, which is significant at the 20% level.[74] The electricity factor share for the retail and restaurants sectors are significant, while the one for service sectors is not significant. For these last two, the adjusted R^2 is low (due to the large heterogeneity of business activities that are aggregated into them, and the small sample size).

It is interesting to note that from 2011 to 2015 the electricity factor share of all manufacturing firms in the RSA/SRQ sample increased from 0.18 to 0.21, although this result is within the margin of error and thus not statistically meaningful. Such a change would suggest substitution of labour by electric equipment, and be consistent with (but not necessarily caused by) the greater reliability of grid electricity. Unfortunately, there was no further data or anecdotal evidence collected during the survey to assess whether companies responded to the changes in electricity by altering technologies. Repeating the survey in a couple of years from now would probably allow identification of the extent of capital/labour substitution.

We have decided to analyse the effect of electricity price on economic output only for the manufacturing sectors because the statistical results are more reliable (smaller sampling margin of error and larger explanatory value (R^2) of the production function model). As described in Section 4.1, the reason for this is that, for manufacturing companies, electricity is largely a variable cost of production; while for retail, restaurants and services firms it is a fixed one. One would therefore expect manufacturing companies to respond more directly to electricity prices.

As mentioned in Section 4.4.2, due to lack of panel data, the estimation of the production function is based on available cross-sectional observations. Even though factor shares estimated, based on various cross-sectional data sets (the World Bank Enterprise Survey, UBOS Business Inquiry Research Solutions Africa survey), were of a similar magnitude, empirical studies suggest estimates derived from cross-sectional data could be upward biased, as they do not account for persistent differences in firm efficiency.[75] Furthermore, as can be seen in Table 8, the sample sizes for the sector regressions are quite small, so the coefficients need to be interpreted with caution. In Section 5.5, we elaborate in more detail on the implications of these uncertainties for the results, and potential remedies.

[74] The significance level of 20% of the electricity use in the chemical sector means that there is a 20% chance that the estimated effect will be zero. Nevertheless, in our analysis we have used the estimated factor share of 0.06 because of the goodness-of-fit of the regression estimation and the consistency of the coefficient with other studies.

[75] See Klette, T.J., and Griliches, Z., *The inconsistency of common scale estimators when output prices are unobserved and endogenous*, Journal of Applied Econometrics 11:343–61, 1996. The upward bias is also confirmed in a forthcoming study by Steward Redqueen on the impact of electricity investments in Turkey, where the authors estimate substantially lower coefficients using panel data than cross-sectional data from the World Bank.

Table 8: Factor shares for labour (L), electricity use (E), material cost (M), and capital (K)

	Total manufacturing	Small	Medium	Large	Food	Textiles, garments	Chemicals, plastic, rubber	Furniture, wood, paper	Metals, machinery	Non-metallic mineral products	Retail, restaurants	Services
Log labour		0.14 (0.10)		0.16 (0.10)			0.13 (0.024)				0.24 (0.231)	1.10 (0.006)
Log electricity	0.18 (0.000)	0.26 (0.000)	0.15 (0.000)	0.15 (0.006)	0.24 (0.000)	0.12 (0.025)	0.06 (0.187)	0.22 (0.063)	0.11 (0.061)	0.30 (0.001)	0.66 (0.000)	0.30 (0.238)
Log materials	0.59 (0.000)	0.56 (0.000)	0.59 (0.000)	0.79 (0.000)	0.55 (0.000)	0.73 (0.000)	0.58 (0.000)	0.65 (0.000)	0.56 (0.000)	0.54 (0.000)		
Log capital	0.14 (0.000)	0.14 (0.001)	0.15 (0.000)		0.17 (0.000)	0.10 (0.000)	0.20 (0.000)	0.05 (0.545)	0.22 (0.001)	0.15 (0.084)		
Total	**0.77**	**1.09**	**0.74**	**1.10**	**0.79**	**0.95**	**0.97**	**0.87**	**0.68**	**0.84**	**0.90**	**1.40**
Adjusted R^2	0.94	0.93	0.92	0.97	0.94	0.96	0.96	0.93	0.92	0.87	0.25	0.36
Observations	271	118	129	26	97	32	46	31	41	20	178	35
Margin of error (90% confidence)	9.9%										13.6%	30.8%

Note: Labour defined as number of employees, electricity use in MWh/year; material cost in USD; capital as book value USD. P-values indicated in brackets.

B. Change of output per manufacturing sector

By multiplying the factor share of electricity use in manufacturing, ε, with the price elasticity of electric power consumption, θ, one arrives at the elasticity of economic output with respect to electricity price P.

$$\frac{dY}{dP}\frac{P}{Y} = \frac{dY}{dE}\frac{E}{Y} \cdot \frac{dE}{dP}\frac{P}{E} = \varepsilon \cdot \theta \qquad (8)$$

This allows the change of output of manufacturing sector i to be expressed as:

$$\Delta Y_i \approx \varepsilon_i \cdot \theta_i \cdot \frac{\Delta P}{P} \cdot Y_i \qquad (9)$$

Using the manufacturing factor shares ε_i from Table 8, the price elasticity of demand of -0.42 (see Table 3) for all sectors and the hypothetical power price increase of 26% (Section 5.2.3), the decrease in manufacturing output follows from Equation 9. The results are presented in Exhibit 18. Overall, the decrease in manufacturing output would be 2.2% as a result of more expensive power in the counterfactual situation. As a share of the overall economy, this decrease represents -0.26% of the total output.

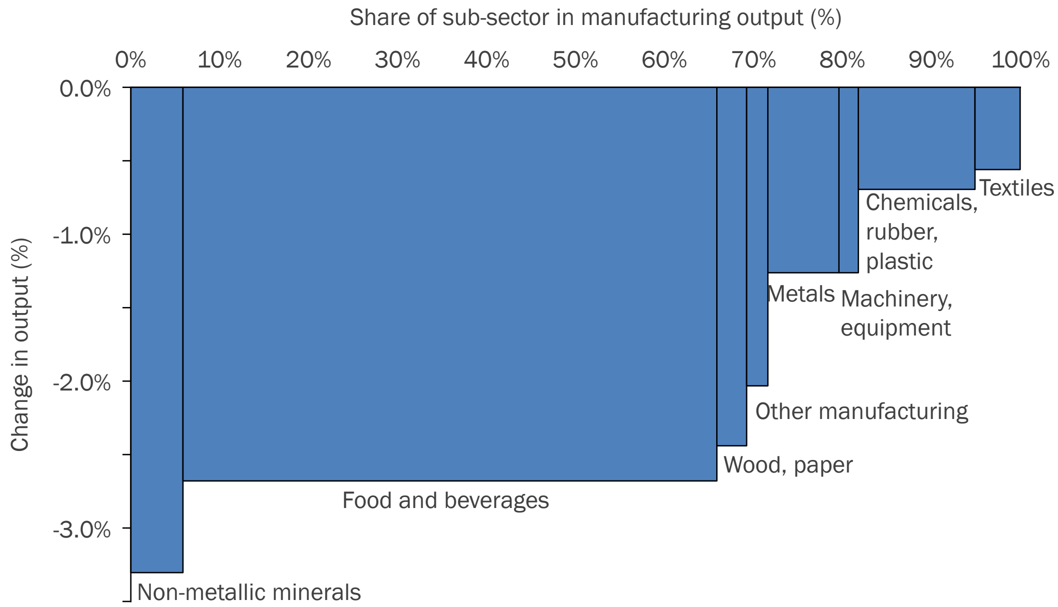


Exhibit 18: Response of the manufacturing output to decrease in energy consumption

5.3 Value added and employment impact

Having determined the change of output due to the reduction of outages time and (counterfactual) price change, the final analysis step comprises the determination of the associated value added and employment. We do this using the Ugandan input-output table, since it allows us to trace the knock-on effects of changes in manufacturing output on other sectors.

5.3.1 Treatment of output changes in the Ugandan input-output table

The most recent input-output table (IOT) for Uganda is for the year 2011. The IOT contains 57 sectors but in this report an aggregated 31 sector version will be used because the 2014 sector output data, needed for updating the 2011 IOT to 2014, is available for 34 economic sectors. Notwithstanding the loss of some detail, the resulting IOT still allows the routing of output changes.

The so-called RAS[76] procedure is applied to update the 2011 IOT to 2014. Based on new output and GDP contribution figures for 34 sectors, column and row coefficients are alternatingly and iteratively updated until the table reflects the new figures and is balanced again. It is important to note that the table leaves the 'technology coefficients' essentially unchanged. This means that it nudges the table to reflect the new totals but does not significantly change the implicit production structure of the sectors.

The same RAS procedure is also used to analyse the effects of increased output of one sector on another, as shown in Exhibit 19.

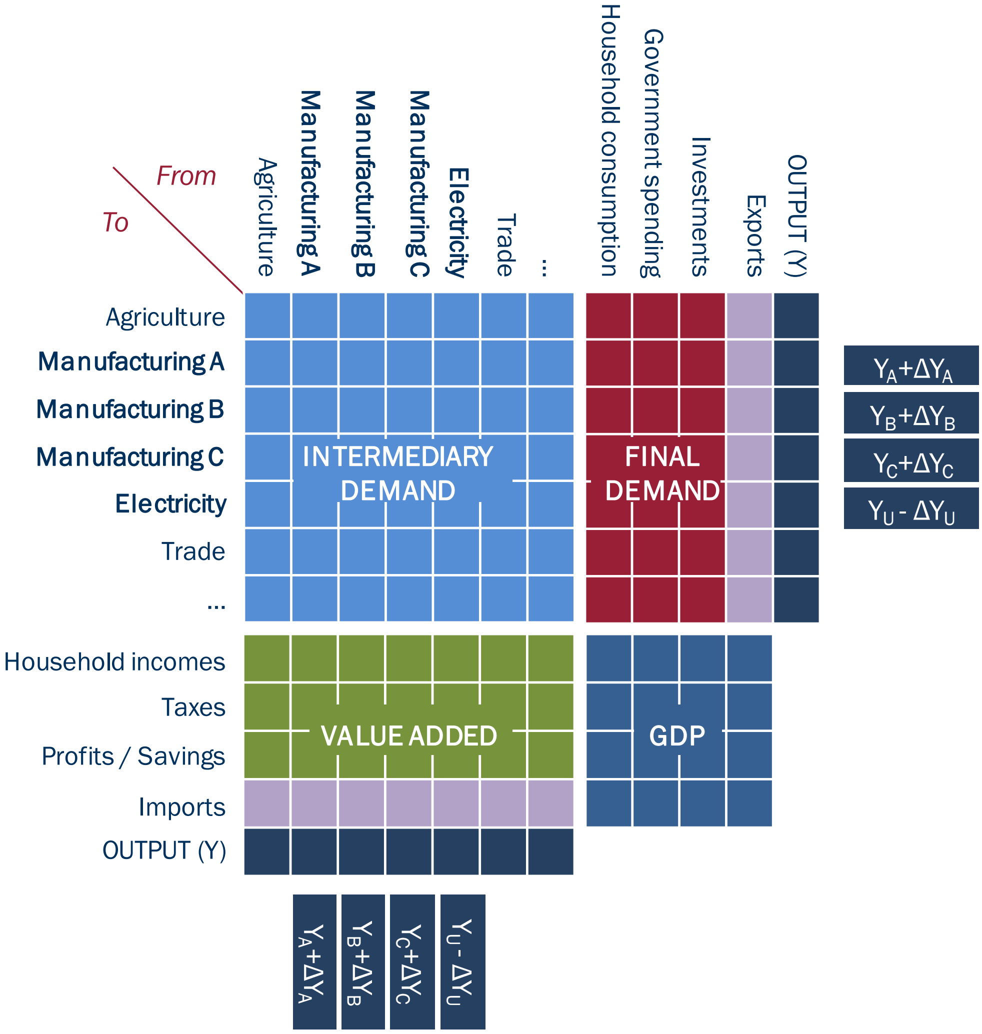


Exhibit 19: RAS methodology to rebalance the Input-Output table for changes in manufacturing and electricity

In order to approximately balance the input-output table to allow the RAS procedure to converge, we introduce the following changes:

1. Change the electricity spending of all sectors by ΔP (which is zero for the outages case); [77]

[76] The RAS method is a bi-proportional matrix balancing techniques (the letters reflect the symbols in a matrix multiplication rather than an acronym). A detailed description can be found in Miller, R.E. and Blair, P.D., *Input-Output Analysis – Features and Extension*, pp 784, 2009.

[77] The price effect of decrease in back-up generation due to more available power has not been evaluated. Data from companies surveyed during this project suggest that, in total, companies in Uganda have back-up generation sufficient to cover between 0% and 20% of their operations (based on median and average values).

2. Change the profits and taxes (respectively 70% and 30%[78]) of all sectors to compensate for the changed electricity spending in step 1, reflecting the fact that cheaper electricity increases profits;
3. For all sectors i, change the elements in the columns by the relative change in output ΔY_i in Exhibit 14 and Exhibit 18;
4. For all sectors i, change the elements in the rows by ΔY_i and change the imports row by $-\Delta Y_i$, reflecting the change in output substituted for imports[79].

Driven by these changes, the RAS procedure will, after a number of iterations, yield a balanced IOT[80] in which all the sectors produce the intermediary output needed to produce the output changes in Exhibit 14 and Exhibit 18. The economy-wide decrease in output and value added corresponding with the decrease in manufacturing output is thus quantified.

It is important to note that the typical application of input-output modelling, and indeed the original formulation by Leontief, is demand driven: changes in final demand cause changes in supply, and thereby changes in value added. The chain of events here is different: a change in sector output causes changes in demand in other sectors, which in turn drives changes in value added. This formulation is more akin to the so-called Ghosh input-output model, except that in the Ghosh model the event chain starts with a change in value added, which drives a change in output, which then forces a change in demand. The Leontief and Ghosh formulations are two sides of the same coin, each with its own limitations.[81] Given the small output changes imposed, the formulation used here (falling somewhere in between Leontief and Ghosh) is adequate.

5.3.2 Value added impact

The output changes described in the previous sections were routed through the input-output table.[82] The resulting changes in value added (or GDP contribution) due to outages and price effects are presented in the following paragraphs.

A. Due to outages effects

The decrease of outages of 5.8 percentage points of operations time (or 192 hours per year) has resulted in an increase of value added of some UGX 1.7 trillion, equal to 2.6% of GDP (see Exhibit 20). According to data from UBOS, between 2011 and 2014 Uganda's GDP grew by 12.2% (in constant 2009 UGX terms), meaning that about a fifth of the economic growth can be attributed to the improvements in electricity availability (with the rest due to exogenous factors). As discussed in section

Even though self-generation is more expensive than grid electricity, we expect a limited effect of the switch from off- to on-grid electricity, given the limited capacity and associated small volumes.

[78] Corporate Tax is 30%.

[79] For example, a reduction of imports serves to minimise differences between row and column total, which would force the RAS method to make unrealistic numerical changes. Economically, it can reasonably be expected that lower electricity costs render local manufacturing firms more competitive vis-a-vis imports, and vice versa.

[80] Economic interpretations of the RAS methodology have been given; the alternating rounds of adjustments essentially being changes of intra-sector production efficiency and inter-sector substitution. In fact, we start two simultaneous RAS procedures, one starts by modifying columns coefficients and the other by modifying the row coefficients. Because of the linear nature of the input-output table, the average of the two RAS procedures is also a valid solution. Indeed, one can show that the average is the optimal solution because it affects the diagonal elements of the table the least.

[81] For a more in depth discussion: Manresa, A. and Sancho, F., *Leontief versus Ghosh: two faces of the same coin*, REAP2012-18, Xarxa de Referencia en economia Aplicada, 2012.

[82] The RAS led to a change of economy output of 2.3% in the outages analysis and 22% in the price analysis. Any overestimation of the spill-over effects as a result of using the IO methodology would have a marginal effect on the results from the outages analysis and small effect on the results from the price analysis.

3.3.4, the majority of this effect is due to the virtual elimination of load-shedding, which is the result of the additional Bujagali generation capacity and reduced network losses accomplished by Umeme.

The value added increase due to reduced outage time was highest in the services sector, 4.6%, in line with the increase in output. As a reference, the real growth which took place in the services sector between 2011 and 2014, as reported in the national accounts, was 14%. The manufacturing sector experienced a 2.7% increase in value added, compared with the total 3.5% increase in value added over this period. It thus seems that a substantial part of the increase in manufacturing value added is related to the decrease in outage time. Nearly half of the manufacturing value added growth (UGX 70 million) comes from the food & beverage sector. Other industries, such as mining, utilities and construction, increased their value added by 2.0%, about one fifth of the observed growth over this period. As a result of the increased electricity usage by the rest of the economy, the electricity sector value added (part of "other industry" in Exhibit 20) increased by 0.7%. The agricultural sector, although not directly affected by the decrease in outage time, saw an increase in value added of UGX 48 billion, or 0.3%. This effect was due to increased procurement from other sectors (most notably food & beverage). Finally, Exhibit 20 shows that the value added increase ends up as mostly household income and profits, with taxes accounting for some 8%.

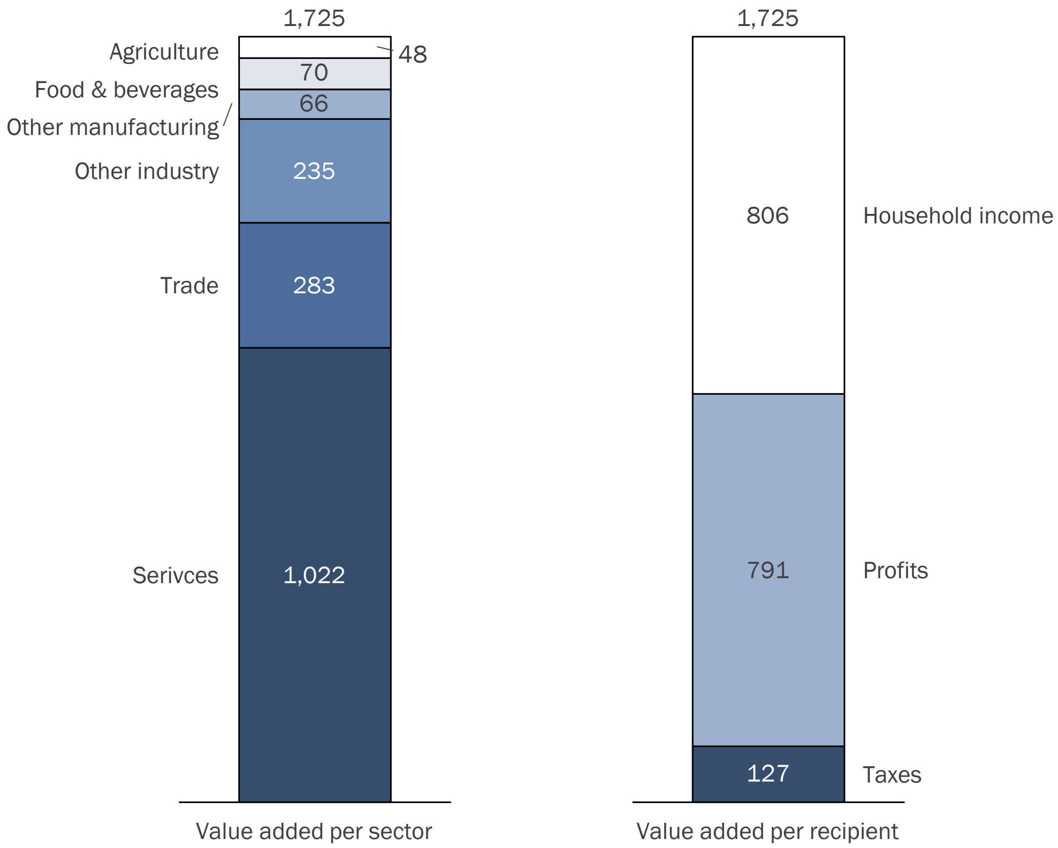


Exhibit 20: Change in value added due to outages (UGX billion)

The 2.6% GDP effect due to outages (i.e. 20% of total GDP growth) can be put in perspective. The power crisis in South Africa has caused a large increase in load shedding, which is estimated to shave 0.4 percentage points off the current 2% GDP growth rate[83], or some 20%. The African Development Bank in its 2014 Annual Report estimates the economic cost of power outages at some 1-2% of GDP, not too dissimilar to the results found here.

83 According to the Free Market Foundation think tank.

B. Due to price effects

As discussed in section 5.2.4, the reliance on thermal power in the counterfactual would have resulted in a 2.2% loss of manufacturing output compared to the actual situation. This in turn would have led to 0.3% lower overall GDP, or UGX 277 billion, as shown in Exhibit 21. Manufacturing would have suffered the largest loss of value added: UGX 146 million, or 2.9% of its GDP contribution. Because manufacturing firms would have required fewer inputs for their falling production, other industries would also have lost out: the agriculture, trade and services sectors would have experienced value added decreases of 0.3%, 0.2% and 0.3% respectively compared to the actual 2014 situation.

It is interesting to note that even though electricity sector revenues would have been higher under the thermal scenario (due to the higher electricity price), value added would have reduced because of higher spending on imported fuels.

As shown on the right-hand side of Exhibit 21, profits would have suffered most from higher costs of thermal power generation (UGX 136 billion lower). Household income would have been UGX 82 billion lower. Lower profits and household incomes would have resulted in fewer taxes paid to the government (UGX 59 million).

The difference between the counterfactual and actual situation can be considered as a "hidden" effect of the greater affordability of electricity due to lower cost hydro power. Because we have only considered the manufacturing sector, for reasons explained in 5.2.4, the negative effects of thermal power would probably have been larger than indicated here.

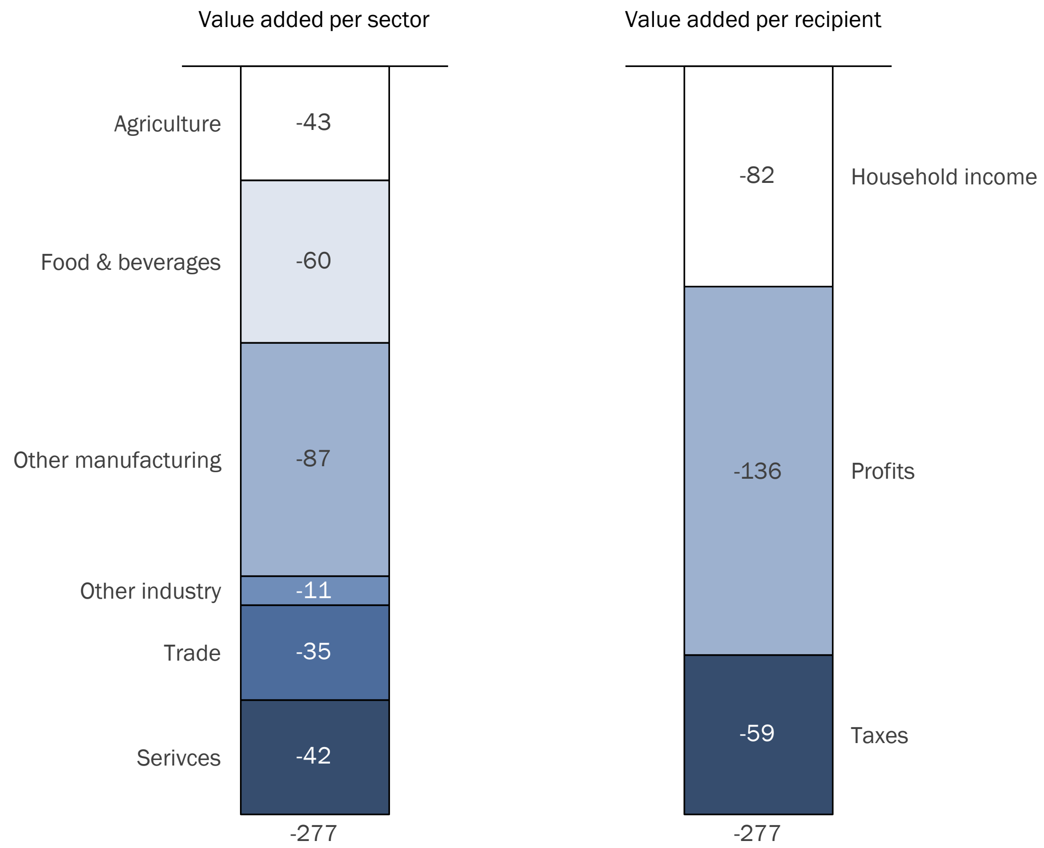


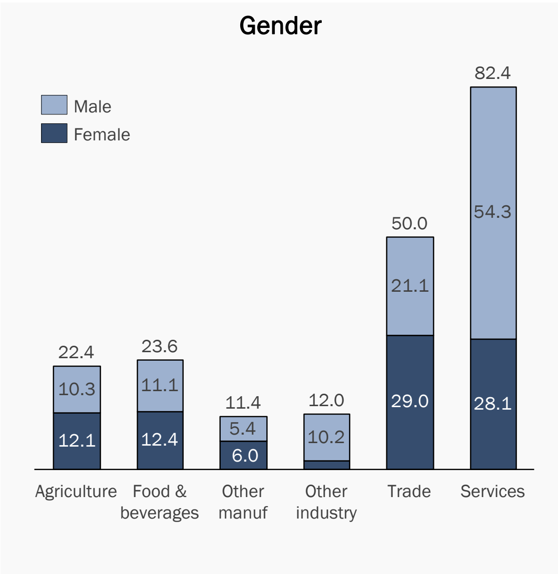
Exhibit 21: Change in value added due to price effects (UGX billion)

5.3.3 Jobs impact

Using the employment intensities together with the economic output derived from the input-output analysis yields the effect on jobs due to outages and price effects. The results are not estimated in full-time equivalents (FTE) because UBOS does not provide such statistics.

A. Due to outages effects

A total of 201,600 jobs can be attributed to the decrease in power outages, which is equivalent to 1.4% of the total labour force (Exhibit 22). Most jobs have been added in the services sectors, which experienced the highest output growth: 82,400 jobs representing an increase of 4.6% for the sector. The results are logical, since all service firms interviewed by RSA recognized that the improvements in electricity (i.e. outage reduction) contributed to employment, with 25% even indicating that the better supply had a large impact on their workforce. The labour-intensive trade sector, in which 75% of interviewed companies also saw a link between the improvements in electricity and job creation, added 50,000 employees. The manufacturing sector added nearly 35,000 jobs (or 2.8%), of which 23,600 were in the food & beverage sector. 22,400 jobs were created in the agriculture sector (an increase of 0.3%), due to procurement by the food industry from local agriculture, and the fact that the sector is very labour-intensive. Other industries, such as construction and mining, experienced an increase in employment of 12,000 jobs. The change in employment in the electricity sector has been set to zero as it is unlikely that in the short-term higher grid capacity utilisation will lead to a significant increase in employment.



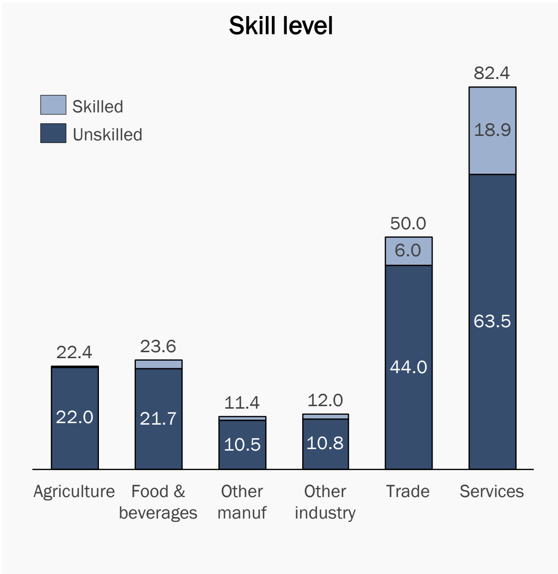


Exhibit 22: Change of jobs due to lower outage duration, broken down by gender and skill level (in ,000s)

Of the total 201,600 jobs, approximately 44% are for women[84]. The largest number (29,000) are in the trade sector, which in general has a higher share of women than men. 28,100 jobs for women are also provided in the otherwise male-dominated services sector. Agriculture and manufacturing also provide opportunities for female workers.

Exhibit 22 also shows that the created jobs are mostly unskilled ones (i.e. requiring no or only primary education) – 172,500, or 86%.[85] This is not surprising, given that many of the jobs supported are in

[84] The gender split of the workforce per sector is based on the UBOS Labour Force survey 2013.

[85] The input-output table provides information on the total amounts paid for skilled and unskilled workers by sector. The employment breakdown follows from using the UBOS finding that the average salary for skilled

the agriculture and trade sectors. Altogether 29,100 jobs are skilled jobs which require secondary education or higher. These are mainly in the services sector and to a lesser extent the trade and food & beverage sectors.

B. Due to price effects

Had Uganda continued to rely on thermal power generation rather than on the Bujagali dam, we estimate that some 48,500 jobs would not have been created. Most of which (26,900) in the manufacturing sector, as it would have been most affected by the high electricity cost, as shown in Exhibit 23. This would have been equivalent to 2.2% of the 2014 employment in that sector.

Although the agriculture sector hardly uses electricity, it would have been affected indirectly by high electricity prices. Some 18,400 (0.2%) jobs would not have been created because companies, especially in the food & beverage sector, would have lowered local procurement.

The trade sector, which has limited links to the manufacturing sector, would have had some 2,200 fewer jobs (0.1%). Other industries (such as construction and mining) and services – all relatively low labour-intensive sectors – would have been affected much less.

Since a large majority of these jobs are in the agriculture and food & beverage sectors, in which many women work, female employment would have been impacted more than male employment in this counterfactual scenario. As depicted in Exhibit 23, of the total loss of 48,500 jobs, 53% would have been lost for women, and some 96% of the job losses would have affected individuals with no or only primary education (unskilled).

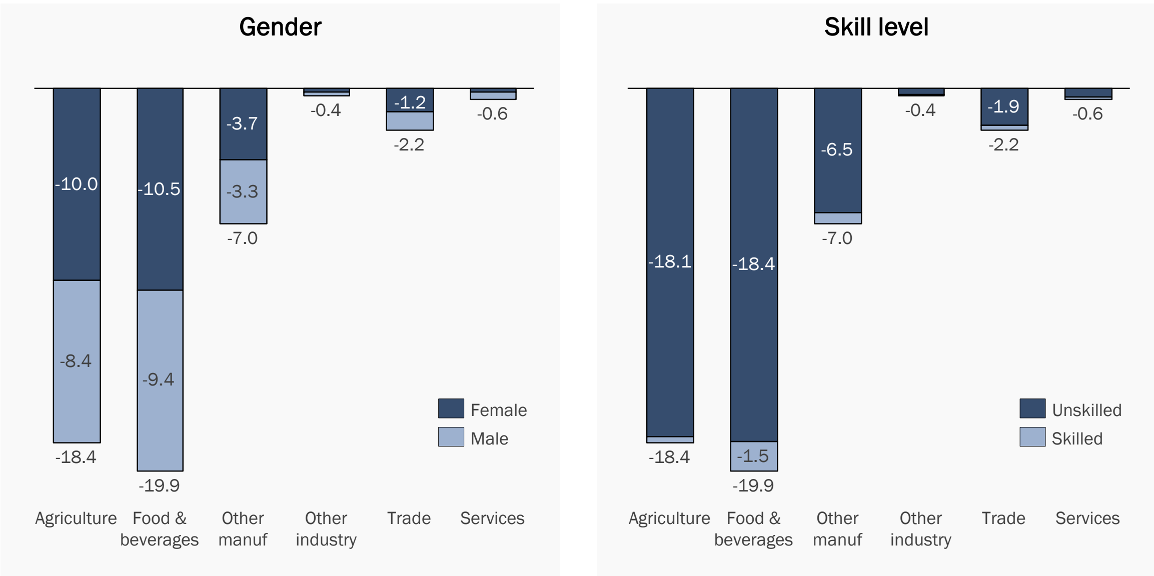


Exhibit 23: Change of jobs due to price effects broken down by gender and skill level (in ,000s)

5.4 Headline economic results and multipliers

The value added and employment results presented in sections 5.3.2 and 5.3.3 are summarised and aggregated in Table 9. The total actual and hidden impact of the changes in the power sector between 2011 and 2014 can be summarised as follows:

workers (who have completed secondary and higher education) is five times higher than for unskilled (i.e. primary or no education).

1. An increase in output of the Ugandan economy of UGX 2,944 billion, or 2.6% of total output. In the event that the capacity increase had been achieved through thermal power, this would have been UGX 377 billion less (-0.3%);
2. An increase of GDP by UGX 1,725 billion, equivalent to 2.6% of current GDP. This would have been UGX 277 billion (-0.4%) less in the case of a thermal power expansion;
3. The creation of some 201,600 jobs, about 1.4% of the total labour force. This would have been 48,500 lower (-0.3%) in the case of thermal power expansion;
4. UGX 806 billion of the increase in value added ends up as household income (i.e. UGX 110,000 per Ugandan household), UGX 791 billion as profits for business, and UGX 127 billion as taxes. In addition, (not shown in the table) electricity subsidies have decreased by some UGX 447 billion annually as a result of cheaper power (see Section 3.2.1);
5. Reflecting the increased competitiveness of Ugandan businesses, imports have decreased by 4.7% and exports increased by 1.3%, as a result of which the trade deficit decreased by 15.4%. Had the capacity expansion been achieved with thermal power, the opposite would have been true (an increase in imports and decrease in exports), especially given the required imports of fossil fuel.[86]

Table 9: Output, value added and employment effect of the actual and counterfactual power conditions

	Output (UGX billion)				Value added (UGX billion)				Employment (Jobs '000)			
	Actual	%	C.Factual	%	Actual	%	C.Factual	%	Actual	%	C.Factual	%
Agriculture	54	0.3%	-45	-0.2%	48	0.3%	-43	-0.3%	22	0.3%	-18	-0.2%
Industry	876	2.4%	-299	-0.8%	371	2.2%	-157	-0.9%	47	2.4%	-27	-1.4%
Food and beverages	*341*	*3.2%*	*-288*	*-2.7%*	*70*	*3.3%*	*-60*	*-2.8%*	*24*	*3.2%*	*-20*	*-2.7%*
Other manufacturing	*164*	*2.3%*	*-102*	*-1.4%*	*66*	*2.3%*	*-87*	*-3.1%*	*11*	*2.3%*	*-7*	*-1.4%*
Electricity	*5*	*0.7%*	*96*	*12.1%*	*2*	*0.7%*	*-1*	*-0.3%*	*0*	*0.0%*	*0*	*0.0%*
Other industry	*366*	*2.0%*	*-5*	*0.0%*	*233*	*2.0%*	*-10*	*-0.1%*	*12*	*1.8%*	*0*	*-0.1%*
Trade	366	2.1%	-18	-0.1%	283	2.4%	-35	-0.3%	50	2.4%	-1	0.0%
Services	1,649	4.6%	-15	0.0%	1,022	4.6%	-42	-0.2%	82	4.6%	-2	-0.1%
Total	**2,944**	**2.6%**	**-377**	**-0.3%**	**1,725**	**2.6%**	**-277**	**-0.4%**	**202**	**1.4%**	**-48**	**-0.3%**
Household income					806	2.5%	-82	-0.3%				
Profits					791	2.7%	-136	-0.5%				
Taxes					127	2.6%	-59	-1.2%				
Total					**1,725**	**2.6%**	**-277**	**-0.4%**				
Export	151	1.3%	-201	-1.7%								
Import	-949	-4.7%	1,197	5.9%								
Trade deficit	**-1,100**	**-15.4%**	**1,398**	**19.5%**								

The results have been expressed as absolute and relative multipliers in Table 10. At the 2014 exchange rate, the GDP increase per MW is USD 2.1 million. This is slightly higher than the USD 1.9 million per MW found in an IFC study in the Philippines in 2015.[87] The 800 jobs created per MW is some 3.5 times higher than in the Philippines, reflecting Uganda's lower labour productivity. The relative multipliers have been derived using the fact that the 250 MW capacity of Bujagali represents 46% of the current dependable capacity. For a 1% capacity expansion, GDP increases by 0.06%,

[86] This can be inferred from the UGX 96 billion output increase of the electricity sector which does not translate into a larger value added. The UGX 96 billion is the net effect of higher fossil fuel payments and lower interest payments to foreign entities for the Bujagali project.

[87] *Economic impact of IFI investments in power generation in the Philippines,* Steward Redqueen 2015

somewhat lower than the 0.09% in the Philippines. The 0.06% is also a little lower than the 0.10% which is assumed in the CDC job tool. The job multiplier of 0.03% per % capacity addition is about half that of the Philippines. This somewhat counterintuitive result is explained by the fact that the increase in economic output in the food & beverage sector in the Philippines was particularly large compared with Uganda (the sector constitutes almost 10% of GDP in the Philippines compared to about 4% in Uganda). Because in both countries roughly a third of this sector's economic output is payments to (labour-intensive) agriculture, this leads to many jobs: in the Philippines about half of all jobs created by improvements in the electricity sector are in the agricultural sector, compared to only 11% in Uganda.

Table 10: Absolute and relative multipliers associated with hydro capacity addition and capacity change

Absolute multipliers	1 MW hydro capacity addition	1 MW capacity change	Relative multipliers	1% hydro capacity addition	1% capacity change
Δ Outage (h/year)	-0.77		Δ Outage (%)	-1.3%	
Δ Price (UGX /MWh)		-1,110	Δ Price (%)		-1.37%
Δ GDP (UGX billion)	6.90	-2.69	Δ GDP (%)	0.056%	-0.022%
Δ Jobs	807	-471	Δ Jobs (%)	0.030%	-0.017%

Note: 1 MW capacity change means replacing 1 MW or 1% hydro power with 1 MW or 1% thermal power

5.5 Accuracy of results

The methodological approach uses a variety of modelling techniques and data sources. Although it is impossible to reduce all sources of bias and uncertainty into a single margin of error, it is worth discussing the various sources of error. Table 11 provides an overview of the seven main aspects of the methodology. We believe the model results exhibit a slight positive bias and that the margin of error for most data sources is about 10-15% at a 90% confidence level.

Heuristically combining bias and data uncertainty leads us to believe with a 90% confidence level that the results can be 15% lower or 10% higher. This means that we are 90% confident that the GDP contribution is between UGX 1,470 and 1,900 billion (2.2% - 2.9% of GDP), and that the employment creation is between 172,000 and 222,000 jobs. The GDP and employment multipliers per 1% capacity addition are therefore in the 0.048% - 0.062% and 0.021% - 0.033% ranges respectively.

While the outages results are based on observed Umeme data, which is consistent with World Bank data and anecdotal evidence from the business survey, the effects due to price change are based on factor share estimated using cross-sectional data regression analysis. As noted in Section 5.2.4, these estimates could have an upward bias. The exact magnitude of the bias cannot be assessed in the absence of panel data. Assuming factor shares have been overestimated by a factor of 2, the manufacturing response to the price increase would be twice as low. Consecutively, the loss of jobs would have been 50% lower, or 24,200 jobs (compared to 48,400), while the drop in GDP would have been around 30% lower – UGX 188 billion UGX, compared to UGX 277 billion.

It should be pointed out that the relative expansion of power supply in Uganda has been rather large, and this may lead to structural adjustments in the economy that have not been incorporated in this study. We believe that the best way to study this, and to reduce the overall uncertainty, is to repeat and expand the business survey in order to establish a reliable panel of observations that will allow for longitudinal estimation of the impact of power outages and production functions. Although one could adopt a more advanced Computable General Equilibrium model than the chosen input-output model to eliminate some of the biases described, this would introduce additional data uncertainty (especially around price and substitution elasticities) due to the paucity of data for many low- and middle-income countries.

Table 11: Sources of bias and data uncertainty for the seven main components of the methodology

Component	Bias	Uncertainty
Outage mitigation factor	Bias due to inaccurate WBES answers on outage time and lost sales removed, as the mitigation factor combines these two.	With a 10% sampling margin of error (90% confidence level) of both outage time and lost sales the resulting error margin is 14%.[88]
System outages	None.	<1% (actual Umeme measurements).
Electricity factor share	Simultaneous equation bias.	Sampling margin of error 9.9% (90% confidence level). Regression outcomes are significant mostly at 95% confidence (see Table 8).
	Upward biased as cross-section estimations do not account for persistent differences in efficiency between firms.	Unknown uncertainty of factor shares in absence of panel datasets, but it could be an overestimation by a factor 2.
Price elasticity of electricity demand	No simultaneous equation bias in the regression analysis, since tariffs and GDP growth are independent.	The data only allowed the derivation of a uniform price elasticity for all manufacturing sectors.
Electricity price model	Constant capacity factor assumed for all power plants. Bujagali can store water for several hours, thereby reducing the need for thermal generation, which results in a positive bias of the price effect. In the counterfactual, we assume relatively more (cheaper) HFO generation than Diesel, which results in a negative bias.	<1% (actual ERA tariffs used).
Fuel price	Prices of fuel and diesel taken at 2015 level (i.e. USD 0.70 per litre).	Two-fold increase in the litre price of fuel would lead to 2.45 times increase in the price differential between the hydro and thermal scenarios, from 26% to 63%, therefore increasing the GDP and jobs results by the same amount (2.45 times higher[69]).
Input-output model	Well documented assumptions, most importantly linearity of inputs, constant prices and time invariance. Closed models thus tend to overestimate multipliers. Bias countered by applying	Unknown uncertainty of the technical coefficients of the input-output table. The calculated spill-over effects represent 2% of additional output in the outages analysis, and 22% in the

[88] Error margin: $e = \sqrt{0.1^2 + 0.1^2} = 0.14$

	an "open" model (no feedback of incomes on value added), which in our experience yields realistic estimations.	price analysis. An overestimation of these effects would therefore have a marginal effect on the results. Unknown uncertainty of macro-economic output figures for Uganda in 2014.
Employment intensity	Slight positive bias because employment intensities are taken as constant at 2014 levels, whereas productivity increases may have reduced them.	Uganda Labour Survey sampling error of about 5% (95% confidence level).

6 IMPACT OF ELECTRICITY ACCESS ON HOUSEHOLDS IN WEST NILE SUB-REGION

The previous section focussed on the impact of productive use of electricity, and the associated impact of economic output and job creation. Electricity access also directly affects households, as it enables them to light their houses, charge their phones, cool their food, etc. In order to get an impression of how electricity access has impacted households, together with RSA we conducted a survey amongst households in the West Nile sub-region, in North-Western Uganda. The West Nile sub-region is home to 2.6 million people and has Arua as its capital. According to the 2014 Uganda Poverty Status Report, 42.3% of the households in West Nile are below the poverty line, compared to 19.7% for all Uganda. Higher poverty rates than this are only to be found in the North East region.

Electricity is scant in West Nile, as the region is not connected to the main grid. The West Nile Rural Electrification Company (WENRECo) — a programme of the Aga Khan Fund for Economic Development that is funded by the government of Uganda, KfW, the World Bank and the Industrial Promotion Services (IPS) — has been operating a mini-grid in this area since 2003. Since late 2012, the company has been using the 3.5 MW Nyagak I hydro power plant as its main power source.[89] As shown in Table 2, WENRECo served 4,653 residential and 3,539 commercial customers as at 2015.

6.1 Sampling strategy

262 households were surveyed in the Arua district. This sample of households was constructed such that a distinction can be made between grid-connected and unconnected villages. 137 households in connected parishes (including 13 who do not have electricity access) have been sampled from 12 different villages in the Ombokoro and Eruba parishes. The other 125 households have been sampled from 5 different villages in 2 parishes that are not connected to the grid, Komite and Driwala. Exhibit 24 shows the location of the four parishes, as well as the WENRECo electricity grid and power plant.

The connected and unconnected parishes were selected based on desk research by the enumerators, and discussions with WENRECo staff and officials from the Arua district. For each of the selected parishes, the enumerators compiled a list of villages which were randomly selected for the household survey. In these villages, households were selected using a systematic random sampling technique: starting from the village centre, one household was selected and thereafter every fifth household selected. If the household head (i.e. the household member who makes the financial decisions) was not present, the enumerators replaced the household with the next one.

When assuming that the 262 households are entirely representative of the 2.6 million people in West Nile, and when using a confidence level of 0.90, the margin of error of income and spending data is 9.5%. However, because we effectively sampled two populations, the margins of error for the connected and unconnected households are 12.4% and 12.2% respectively.[90] Achieving the more customary 95% confidence level with a 10% margin of error would have required a sample more than twice the size (311 connected and 264 unconnected households), which was not possible for budgetary reasons. The differences between the connected and unconnected households are in most cases substantially larger than the margin of error, thereby excluding any possibility that the results are spurious.

[89] The company also has a 1.5 MW thermal power plant, which it used until 2012 and since then as a backup plant.

[90] While the size of the total connected population is larger than the size of the unconnected households, the within-group variation of the unconnected group is larger, leading to a similar margin of error.

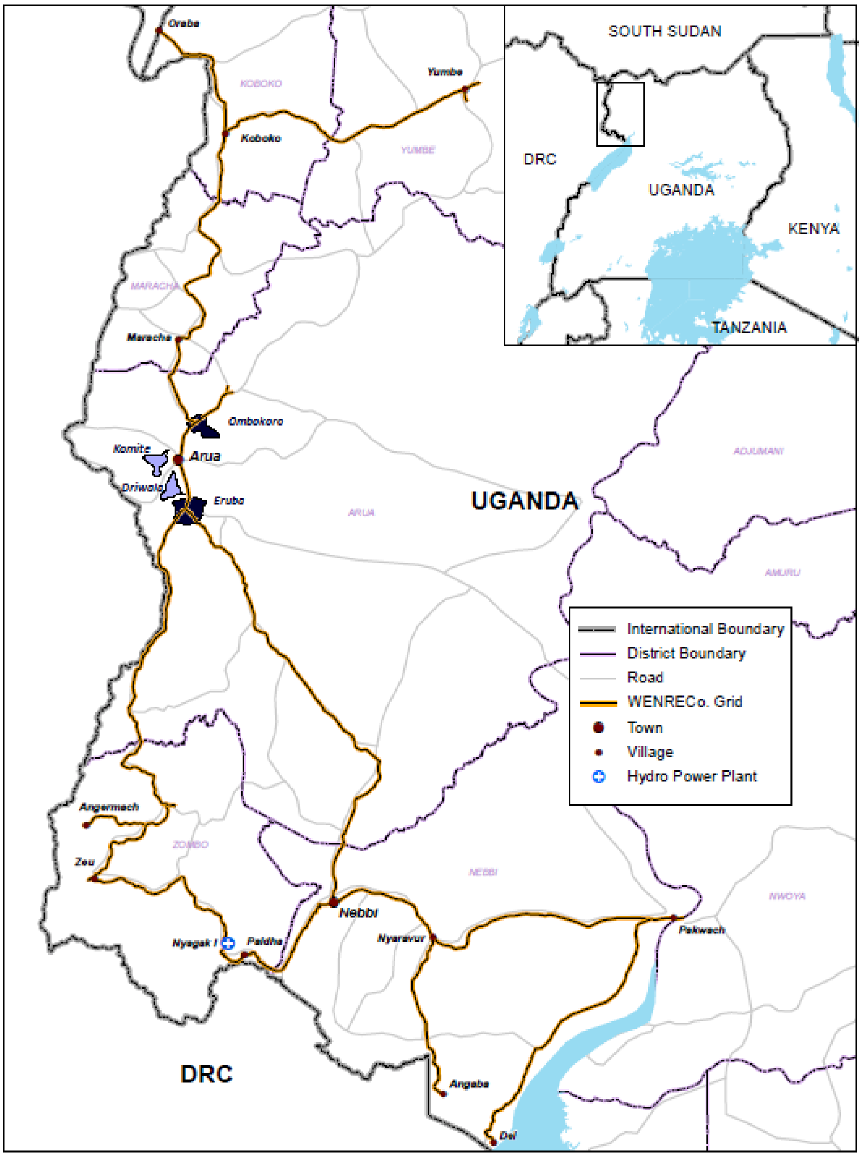


Exhibit 24: Surveyed connected (dark) and unconnected (light) parishes in the West Nile sub-region and the WENRECo grid.

6.2 Household income

The first observation from the survey is that household incomes in the connected parishes are higher than those in the unconnected parishes, as shown in Exhibit 25. The median household salary of the households in connected areas is more than double that of households in the unconnected parishes. In the unconnected parishes almost 60% of the households earn less than UGX 300,000 whereas in the connected parishes this is only 30%.

When expressing the monthly income in purchasing power parity terms, the percentage of household members that live on less than USD (2011, PPP) 1.90[91] is 44% in the unconnected parishes compared with 13% in the connected areas. Compared to the World Bank figure of 33% of the Ugandan population living under USD 1.90 (2011, PPP) in 2012, this indicates that the incomes of the

[91] Based on an USD/UGX exchange rate of 3,500 and the PPP conversion factor of 2.5 and US compounded inflation of 10% since 2011, USD (PPP, 2011) 1.90 is equivalent to UGX 89,800 per month.

household from areas without grid electricity are well below the Ugandan average, whereas the households in the connected villages are above it. Because the household definition in this survey excluded members who had been away for more than three months, the actual number of dependents is probably somewhat higher, meaning that the indicated poverty rates are likely to be a bit higher still.

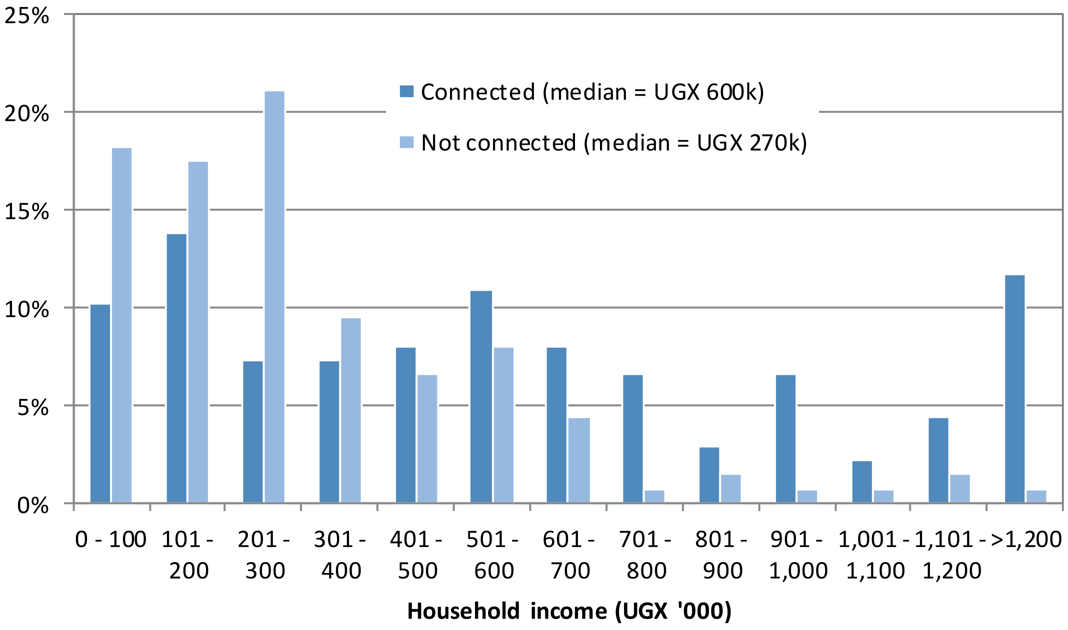


Exhibit 25: Monthly Income distribution of households in connected and unconnected parishes

As shown in Exhibit 26, the sources of household income are markedly different. 'Other income' (e.g. selling of assets and social payments) is an important income component for both household groups. But households from connected parishes receive an equally large part through wage payments, while the ones from unconnected areas receive only 11% from wages.

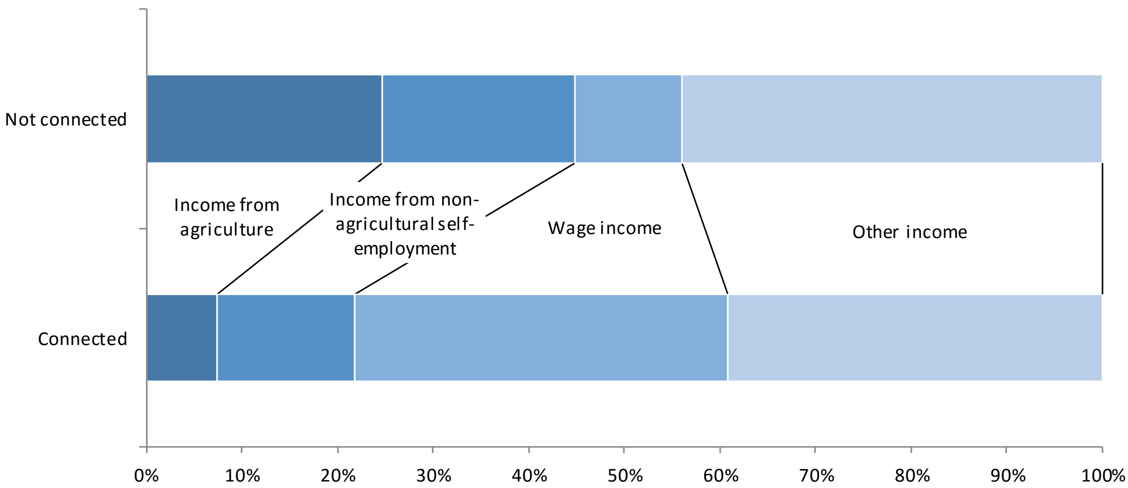


Exhibit 26: Source of income (as a % of total income) per household group

The incomes of households in unconnected parishes are not only lower but also less stable, as shown in Table 12. The main reason for this is the much smaller wage component.

Table 12: Stability of household income

Income stability	Connected	Not connected
Very unstable	18%	29%
Somewhat unstable	45%	50%
Stable	38%	22%

6.3 Household spending

The difference in spending between households in the connected and unconnected parishes largely resembles the differences in income, but is somewhat more pronounced. Exhibit 27 shows that the median household in connected parishes spends almost three times more than the median household in unconnected ones. 65% of the households in unconnected parishes spend less than UGX 300,000 per month, whereas this is true for only 17% of households in connected parishes.

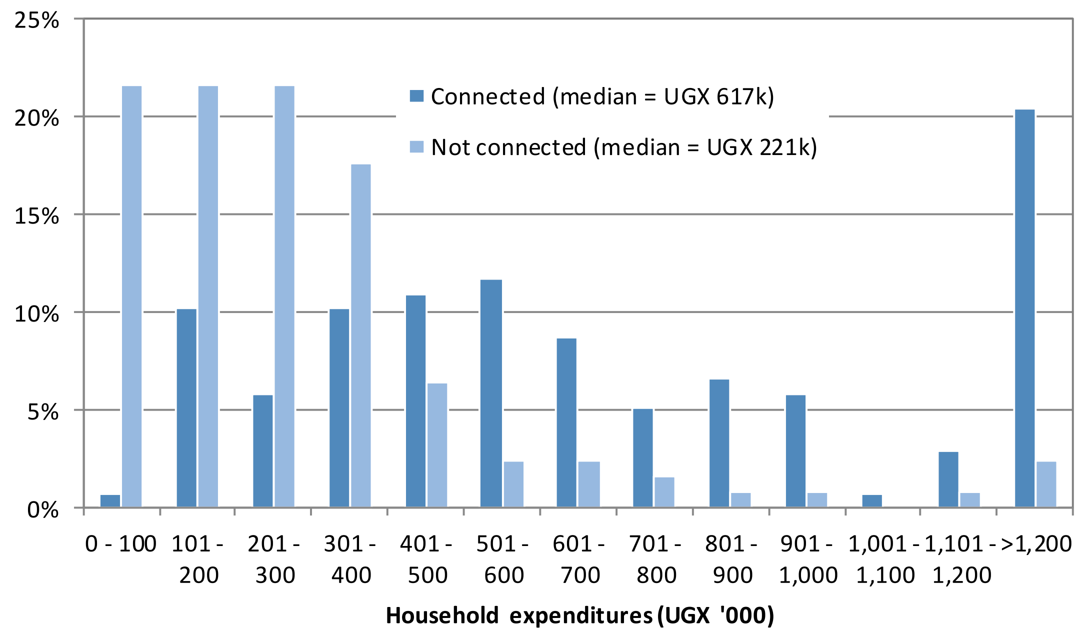


Exhibit 27: Monthly expenditure distribution of households in connected and unconnected parishes

Although the households in unconnected villages spend half as much on basic food, beverages and clothing as the households in the connected ones, this spend is 10% more as a fraction of their total spending, as shown in Exhibit 28. On health services, the unconnected households spend less in absolute but more in relative terms. The converse is true for education: households from connected villages spend more in relative terms and about 3.5 times more in absolute terms. For electricity and other forms of energy, the difference is most extreme: households from connected areas spend twice as much as a fraction of income on this, which is almost six times as much in absolute terms.

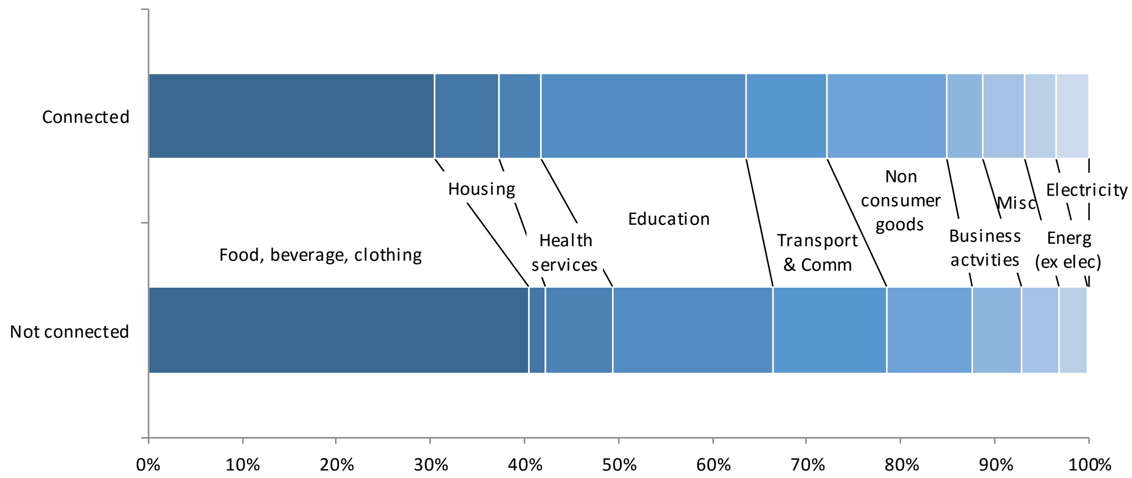


Exhibit 28: Expenditures per category (as % of total spending) per household group

When looking in more detail at the energy spending of households, the differences are obvious. Households from connected parishes indicate that their main energy source for lighting is grid electricity and for cooking 90% use charcoal, which is the preferred (yet more expensive) option to firewood. In unconnected parishes, households mainly use paraffin (55%) and solar electricity (35%) for lighting, and over 60% use firewood instead of charcoal for cooking. Ownership of solar panels/electric converters is higher among households from unconnected than connected areas: 42% vs 25%. In addition to lighting, small solar panels are also used to charge mobile phones, which are owned by 96% and 64% of households living in connected and unconnected parishes respectively.

Grid-electricity is highly valued by connected households, as demonstrated by the fact that they spend half their energy budget on it. But interestingly, 60% of them indicated that they had not increased their consumption since they connected to the grid. There might be several reasons for this. Almost 50% of the connected households indicate that they consider the price of grid-electricity too high[92], while 55% indicate that they face more than three outages a day. Affordability and availability issues notwithstanding, 70% of the households perceive access to electricity to have improved their lives. Of the 13 households in connected parishes that are not connected (i.e. 9%), 8 indicate that this is because they consider electricity too expensive.

6.4 Socio-economic status

A good way to measure socio-economic status is the Pan-African Socio-Economic Status (PA-SES) measure developed by TNS South Africa.[93] The PA-SES score, which ranges from 0 to 100, combines different variables that indicate a household's wealth (or lack thereof) such as type of dwelling, source of water, access to electricity grid, and the use of television, telephone and computer in order to compare the socio-economic status of a household. The algorithms were developed from an Afrobarometer dataset of 32,400 people from 20 countries (including approximately 1,200 from Uganda). The higher the score of a household, the higher its socio-economic status.

Because households do not always accurately know their spending and income, the PA-SES provides a more reliable indication of how well-off a household actually is. Exhibit 29 shows that the Pan-African Socio-Economic Status (PA-SES) scores are higher for households in connected parishes than

[92] The ERA-set WENRECo domestic tariffs are slightly lower than the Umeme tariffs, although they probably ought to be higher if truly cost-reflective.

[93] TNS South Africa developed the PA-SES for the Pan-African Marketing Organisation (PAMRO).

unconnected ones. In fact, Exhibit 29 scores are higher than the average for Uganda (from the Afrobarometer dataset), whereas the later scores are lower. This is consistent with the incomes per household member described in Section 6.2. Overall, the PA-SES scores resemble the distribution patterns of household income and expenditures.

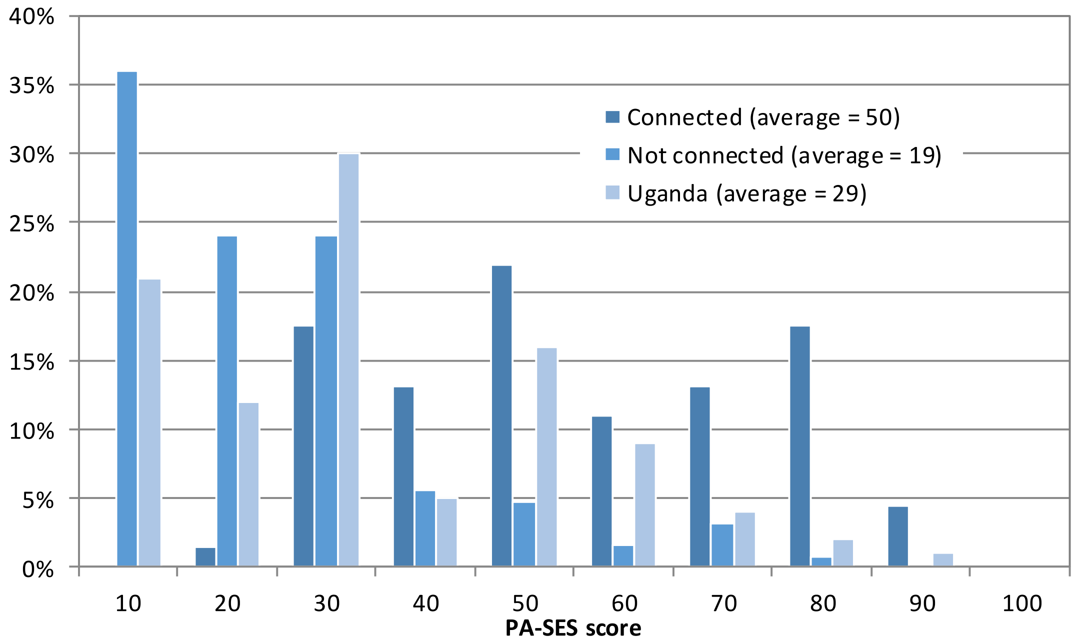


Exhibit 29: Number of households for each PA-SES score group per household group

6.5 Causality of the relationship between income and electricity access

Although electricity might have a positive impact on household earnings and spending power, there are three strong reasons why causality likely runs primarily from (the ability to generate) income to electricity access.

First, the business strategy of WENRECo, the electricity provider in West Nile, has focussed on connecting businesses and public institutions (health centres and schools) to the grid, as evidenced in Table 2. The likelihood of households being able to connect to the grid therefore depends strongly on their proximity to commercial centres. These households are, of course, more likely to have waged jobs and thus, on average, higher incomes.

Secondly, household income is strongly correlated with educational background. Of the 391 household members in connected parishes (including the ones still in school), almost half have completed at least secondary education and 18% even hold a university degree. Education in West Nile is highly valued, something that, according to the enumerators, goes back to the days of Idi Amin (who came from West Nile), who favoured the region and as a result many people there were better educated. In fact, of the 102 connected households who stated their profession, 24 are teachers. Education levels among the households living in parishes without electricity are substantially lower.

Thirdly, income levels do not go up with the number of years that people have had access to electricity. This is shown in Exhibit 30, which shows how in the connected parishes the only significant income difference that exists is between the unconnected and connected households.

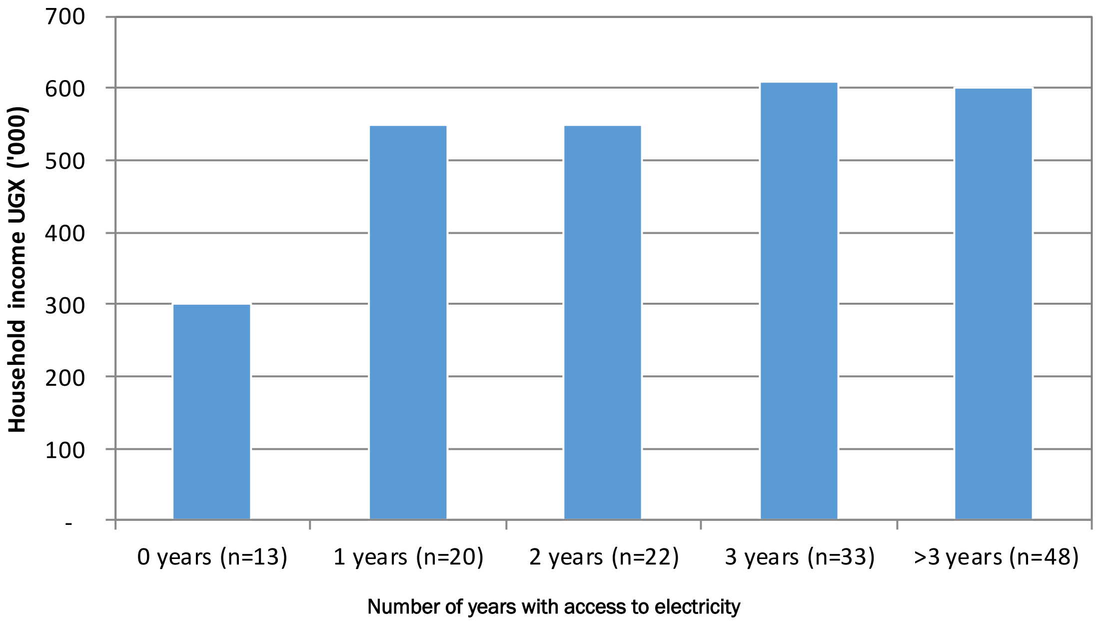


Exhibit 30: Income vs. number of years with electricity access for households in connected parishes

Nevertheless, 21% of the connected households indicate that access to electricity has helped them start a business activity and 29% said it has helped them improve their business. Unconnected households are a bit more optimistic about what electricity access would mean to them - 55% think that electricity access would enable them to start a business.

6.6 Non-financial aspects

6.6.1 Education

As shown in Section 6.3, households in connected parishes spend three and a half times as much on education compared to the ones in unconnected parishes. But, as shown in Exhibit 31, this does not seem to affect their access to education, which is nearly identical for respondents in connected and unconnected parishes (although the number of enrolled children per household is larger for households in connected villages, reflecting the larger average household size).

In the parishes with electricity access, 50% of the children in primary education are enrolled in schools that have access to electricity. For the children in the unconnected parishes, this figure is only 4%. For secondary education, the situation is better: 81% and 42% for the connected and unconnected parishes respectively. For primary education, the difference can be attributed to electricity access, as children from connected and unconnected parishes travel equally far to school, about 1 -2 km. For secondary school, the difference could also be the result of school selection: children from connected parishes travel about three hours to school (average distance of 70 km), whereas those from unconnected parishes travel a little over one hour (average distance of 20 km).

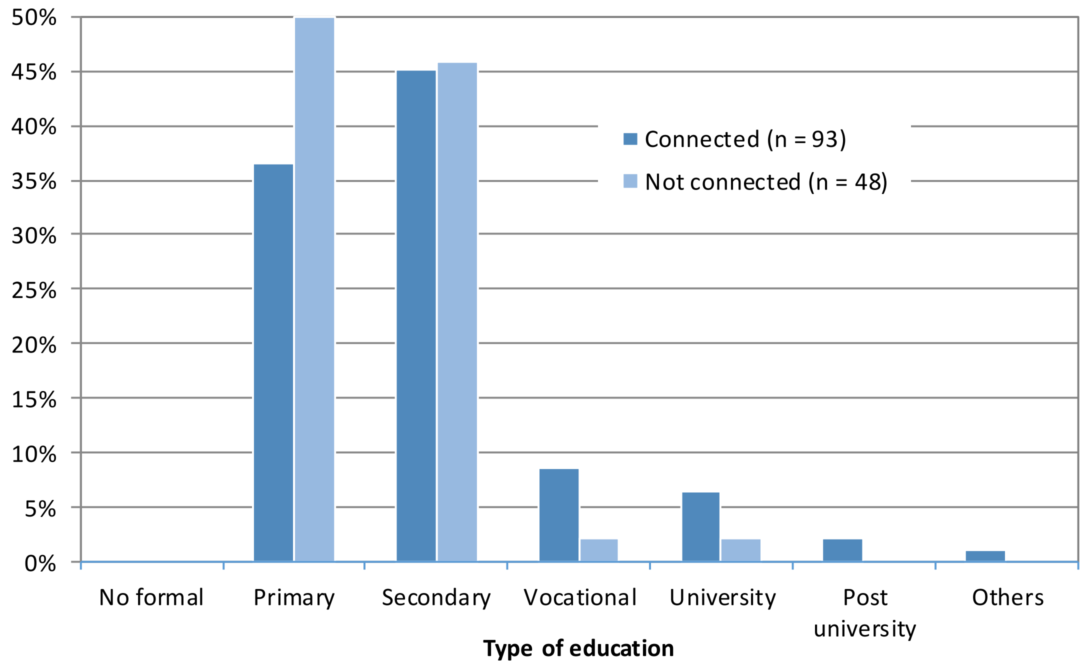


Exhibit 31: Household members enrolled in education

For 63 of the 93 enrolled students in the connected parishes it was indicated that access to electricity had improved the quality of school education, while for only three this was not the case. In the unconnected parishes, only 14 people were able to answer the question, of which 12 answered positively. Assuming that those who did not answer the question have not discerned a positive effect, this means 68% of the households in connected villages and 25% of the households in unconnected villages think that electricity access has improved the quality of educational services.

The impact of electricity access is even more pronounced on the study patterns of students. For 85% of the enrolled students in the connected parishes, electricity access has allowed them to study during different hours and/or study more hours per day. In contrast, in the unconnected parishes 82% of the households have not observed any change. This is evidenced by the 10-36 minutes increased home study time of students, shown in Table 13. Kumar and Rauniyar (2011)[94] similarly found that electricity access increased the home study time by 10 minutes in Bhutan. But one must be careful not to attribute the differences entirely to access to electricity. As noted earlier, the households in the connected parishes are better educated and therefore likely to attach more value to education and the time their children spend on it.[95]

Table 13: Average study time at home in minutes per day

	All school types	Primary	Secondary
Connected	76	63	78
Not connected	51	27	67
Difference	25	36	10

94 Kumar, S and Rauniyar, G., *Is electrification welfare improving? Non-experimental evidence from Rural Bhutan*. MPRA paper 31482, 2011 (https://mpra.ub.uni-muenchen.de/31482/).

95 Another reason might be that they spend more on school fees. These children might go to better schools where homework is encouraged.

6.6.2 Health

Access to health for both household groups is almost identical, as shown in Exhibit 32, and the travel time to these services is also more or less equal. With the availability of grid-electricity, the quality of these health services has improved, with more than 90% of households from connected parishes, and more than 95% from unconnected ones, indicating that health services have improved since facilities connected.

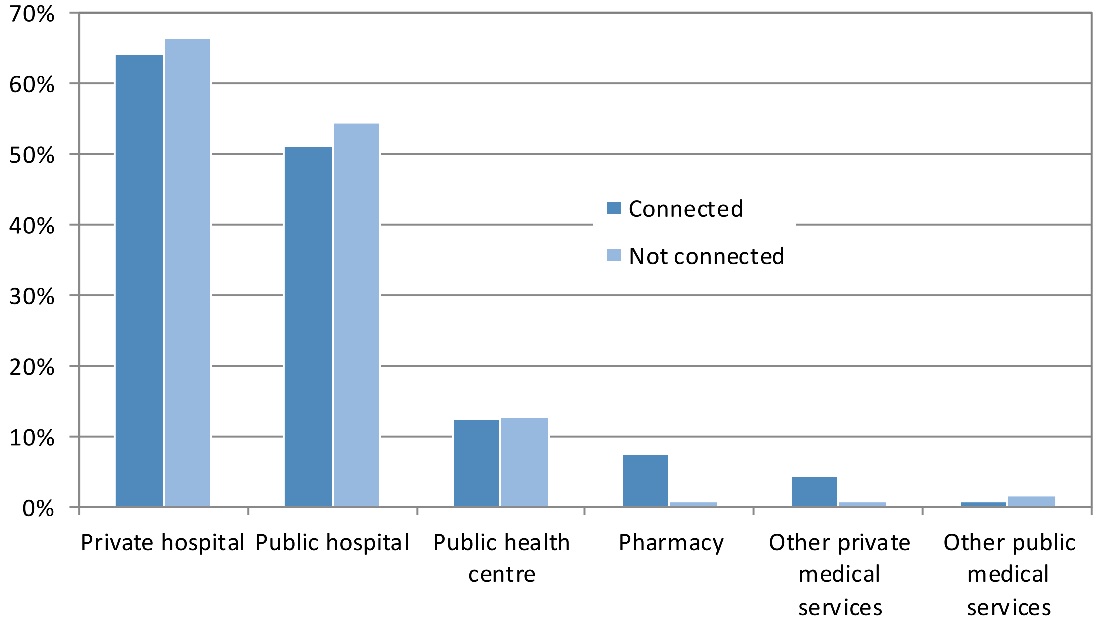


Exhibit 32: Access to health care

6.6.3 Safety

In the connected parishes, 26% of the households feel unsafe at night. In the unconnected parishes, this is significantly higher at 45%. The difference is likely due to electricity access, because in the connected parishes 86% of the households indicated that safety has improved since electricity became available in the village.

Besides safety on the street, household safety and living conditions have also improved. 70% of households from connected parishes indicated that grid electricity improved household safety and living conditions. Although there might be other factors that also affect safety, these results indicate that electricity positively affects how safe people feel.

6.6.4 Public and business services

Unsurprisingly, the connected parishes have a wider range of public and business services available than the unconnected ones, as shown in Exhibit 33 and Exhibit 34. As already explained in Section 6.2, this is more likely to be the cause than the result of electricity access. Anecdotal evidence, however, points to a positive feedback, whereby the availability of electricity attracts services and improves service quality (e.g. banks and shops operate for longer hours). The largest difference is in the availability of hospitals, which we cannot explain; as described in Section 6.6.2, access to health care for households in connected and unconnected villages is basically identical[96].

[96] Unfortunately, the low response rate for questions on the distance from households to hospitals, and the time it takes to reach them, prevents us from exploring these issues in greater detail.

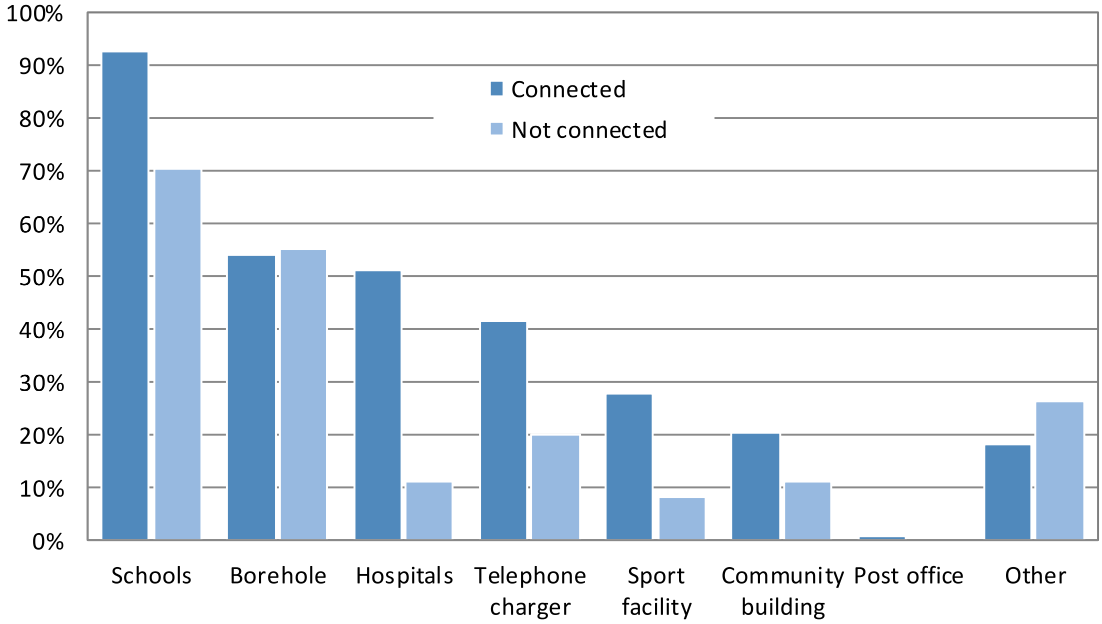


Exhibit 33: Availability of public services

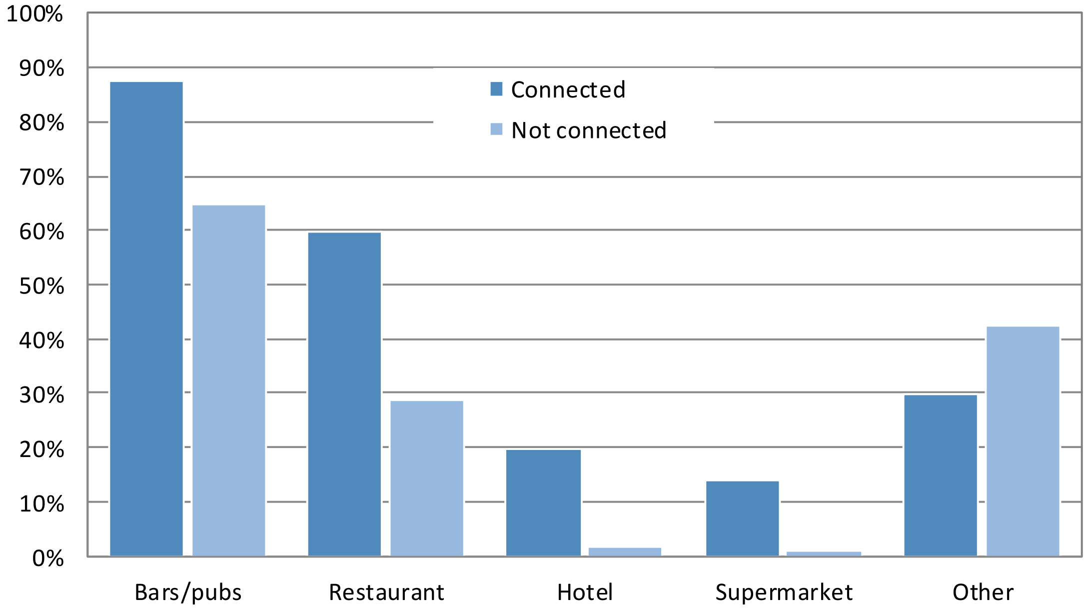


Exhibit 34: Availability of business services

7 Conclusions and recommendations

In this study we have investigated the economic and employment impact of the availability and affordability of electricity for private sector firms, as well as the effect of access to electricity for households. We have divided the main conclusions in three categories regarding: i) the methodology used; ii) the economic and employment effects of power availability and affordability for the private sector; and iii) household-level impacts of electricity access.

7.1 Conclusions regarding methodology used

1. The methodology developed here has proven useful in delineating the effects of power availability (i.e. outages) and affordability (i.e. price):
    a. By combining firm-level survey data on the effect of outages, and observed changes in the frequency and duration of power outages, the change in economic output can be reliably estimated;
    b. Using observed electricity consumption, in conjunction with actual and counterfactual power supply curves, allows for the quantification of the price effect of different interventions. Combining this price signal with sector production functions (derived from firm-level data on employment, capital, materials and electricity use) yields the change of economic output of individual sectors;
    c. The change of economic output mentioned in 1a and 1b can be routed through a country-specific input-output table to yield GDP and employment impact. These impacts can be attributed to specific interventions in the power sector.
2. The business survey focussing on electricity use has proven useful to fill data gaps and to verify, albeit qualitatively, the modelled results;
3. The household study allowed us to identify financial and non-financial aspects of electricity access that would not otherwise follow from the above-described economic analysis;

7.2 Conclusions on the economic and employment impact on companies

4. From 2011 until 2014 (i.e. from before the commissioning of the Bujagali hydro power plant until well after) the electricity outage time has decreased from 28 hours per month to 12 hours per month on average. This reduction is entirely due to less load shedding, as a result of an increase in power generation capacity and loss reduction in the distribution network. Based on the median of 278 operational hours per month, this means that companies have 5.8% more production time, during which they produce 2.7% more output;
5. The reduction of outage time accounts for 2.6%, or about one fifth, of the cumulative real economic growth of 12.2% over that period. The associated employment creation is 201,600 (1.4% of the labour force). 44% of the created jobs were for women and 86% for unskilled persons;
6. If the net expansion of generation capacity had been achieved with thermal power plants rather than the Bujagali hydro power plant, generation costs would have been 62% higher and cost-reflective end-user tariffs would have increased by 26%;
7. An increase of 26% of end-user electricity tariffs in the manufacturing sector would have reduced economic output by 0.3%, GDP growth by 0.4% and employment creation by 48,500 jobs (0.3%);
8. Although economic growth and employment (or livelihood) effects are driven by power consuming sectors and firms, they do reach well beyond them. The increase in economic

output by the food processing sector, for example, spills over to the (largely unconnected) agricultural sector;

9. The results can also be expressed as multipliers: a 1% increase of generation capacity causes a 0.06% increase in GDP and a 0.03% increase in employment;
10. With a 90% confidence level, the results can be up to 15% lower or up to 10% higher than indicated;
11. Not included in the previous conclusions is the fact that the retirement of 100 MW emergency power made possible by the presence of the Bujagali dam allowed the Government of Uganda to reduce electricity subsidies by USD 180 million per year, which is equivalent to 1.1% of GDP and 5.7% of government spending;

7.3 Conclusions on the household-level impact of electricity access

12. Median household income and spending in parishes with electricity access are respectively 2.2x and 2.8x higher than in unconnected ones. The causality, however, is primarily that (the ability to generate) a higher income explains the electricity connection status of a household, rather than vice versa, although there is a positive but smaller feedback from electricity access to household income;
13. Households use electricity mainly for lighting and hardly at all for other purposes (e.g. cooking), probably because electricity is considered expensive. This also explains why the electricity consumption of the median household does not increase over time;
14. Households perceive the quality of education to improve with electricity access of the schools. Electricity access also increases the time spent studying at home, especially for children in primary school; although other factors, such as parent educational background, are likely to play an important role here as well;
15. Access to health care centres that have electricity access is identical for households in connected and unconnected villages. The overwhelming majority of both groups think that the quality of health care services has improved with electricity access;
16. Twice as many households in unconnected parishes feel unsafe at night than households in connected ones;
17. Connected villages offer a broader range of public and business services. This is more a driver of, rather than a result of, electricity access, although electricity access does seem to positively affect service offering and quality.

7.4 Recommendations

Based on the findings, we offer the following recommendations:

1. The methodology developed can be applied to other countries, as the availability of relevant power sector data is typically good and firm-level surveys are conducted by the statistical services in many countries, as well as by the World Bank. Countries with a relatively sizeable industrial sector that suffer from significant power outages and have fairly recent enterprise survey data are Ghana, Kenya, Senegal and Tanzania, as well as Cameroon, for which new data is expected early in 2017;
2. Applying the methodology in a variety of developing countries will enable a better understanding of which kind of power sector interventions can maximise economic impact, given the particular mix of electricity consumption patterns, development stage and economic structure;

3. It would be valuable to repeat the business and household surveys in Uganda to establish a trend. Even more insight could be gained by tracing these businesses and households over time, which would allow for longitudinal assessments of capital/labour substitution and household impacts;

4. To increase employment creation, power sector investments should primarily be aimed at increasing the productive use of (national grid and/or mini-grid) power in the private sector. In addition to productive use, rural electrification projects should also prioritise education and healthcare institutions, possibly through off-grid technologies. This is because:

   a. Enabling an increase in electricity consumption by companies has a significant impact on economic growth, income generation and employment, both within electricity-consuming and non-consuming sectors;

   b. Rural electrification does not appear to have significant household income effects, but does improve education and healthcare, both important enablers to increasing earning power and escaping poverty in the longer run;

5. Power sector investments should target the main bottlenecks in a country. With a potential surplus of power generation in Uganda and some other African countries in the future, transmission will increasingly be a bottleneck. Connecting existing mini and regional grids to national grids will increase the ability to evacuate power for productive purposes, thereby increasing demand. Distribution, although still much in need of further investment, has improved substantially as a result of private sector involvement. Given the fact that transmission in Africa is often a state-controlled natural monopoly, and the proven role of private sector investments in improving distribution, we recommend exploring ways of leveraging private sector expertise and capital in transmission.

Annex 1: Glossary

Term	Definition
Available capacity	The capacity at which a plant could be accessible for electricity production over a certain time period.
Capacity factor	A measure (expressed as a percentage) of how often an electric generator operates over a specific period of time, using a ratio of the actual output to the maximum possible output over that time period.
Installed capacity	The maximum capacity at which a generator can produce without exceeding design limits.
Load-shedding	The deliberate shutdown of electric power in a part or parts of a power-distribution system, generally to prevent the failure of the entire system when the demand strains the system's capacity.
Mini-grids	The interconnection of small, modular generation sources to low voltage ac distribution systems). These mini-grids may be powered by a combination of PV, wind, micro-hydro, fossil fuel gensets and other sources. They typically supply multiple users and may be interconnected with (or be part of) the distribution grid of the local electric utility.
Off-grid generation	Electricity generation in stand-alone systems, such as back-up generators.
Rural electrification	The process by which access to electricity is provided to households or villages located in isolated or remote areas of a country.
Spinning reserve	The additional generation capacity that can be made available for transmission within short notice.

ANNEX 2: RSA/SRQ BUSINESS SURVEY SAMPLE

Table 14: RSA/SRQ survey sample per sector and size

Sector	Small (<20)	Medium (<100)	Large (>100)	TOTAL
Retail, wholesale, motor vehicle service	29	3	0	32
Food, beverages, tobacco	12	4	5	21
Hotels, restaurants	8	5	2	15
Furniture, wood, paper manufacturing	12	2	0	14
Fabricated metals, machinery, electronics, basic metals	10	3	1	14
Textiles, leather, garments	5	2	0	7
Construction, transport	4	0	0	4
Non-metallic minerals	1	1	0	2
Publishing, printing	4	0	0	4
Chemicals, rubber, plastics	3	0	3	6
TOTAL	**88**	**20**	**11**	**119**

Table 15: RSA/SRQ survey sample per region and size

Region	Small (<20)	Medium (<100)	Large (>100)	TOTAL
Kampala	48	18	8	74
Jinja	20	0	3	23
West Nile	20	2	0	22
TOTAL	**88**	**20**	**11**	**119**