Electrification and Development: The case study of Rwanda

Joakim Hallander
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Joakim Hallander

Supervisor: Mark Howells
Evaluator: Dimitrios Mentis
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Electrification and Development: The case study of Rwanda

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Abstract

As of today, 1.1 billion people in the world lack access to electricity, while 2.9 billion rely on polluting fuels such as firewood, charcoal and kerosene for cooking. This is most prominent in Sub-Saharan Africa where two thirds of the population do not have access to electricity and modern cooking fuels. As electricity serves a prominent part of modern society, electrification is often referred to as a key enabler for socio-economic development. The United Nations have agreed on 17 Sustainable development Goals with the aim to stimulate action over the next fifteen years in areas of critical importance for ending poverty, protect the planet and ensure prosperity for all. According to the World Bank, energy is interconnected with 125 out of the total 169 sub-targets that are included in the Sustainable Development Goals. The goal of this thesis is to investigate the relation between access to electricity and relevant development indicators. By assessing previous research within the field of electrification and development, a number of key indicators have been selected for further analysis. A statistical analysis on the development of these indicators in the case study of Rwanda was performed and demonstrated that access to electricity services does have considerable impact on socio-economic development.

Keywords: Sustainable Development, Electrification, Rwanda, Literature Review, Statistical Analysis

Joakim Hallander, Department of Earth Sciences, Uppsala University, Villavägen 16, SE- 752 36 Uppsala, Sweden
Summary

Today, over one billion people in the world live without access to electricity, while 2.9 billion rely on traditional fuels such as firewood, charcoal and kerosene for cooking. This is most prominent in Sub-Saharan Africa where 600 million people (2 out of 3) do not have access to electricity and modern cooking fuels. Electricity poses as a crucial part of modern society and is integrated in almost everything we do and need, in terms of services. Without electricity, modern society would fail to support livelihood, education and health care as everything is based on a continuous and reliable electricity supply.

In recent years there have been considerable advancements in electrification on a global scale as the electricity deficit has declined from 1.3 billion to 1.1 billion, while the global electrification rate has increased from 77 to 85%. Sub-Saharan Africa has reported an increase in access to electricity from 27 to 38% since 2000 although the fast population growth in the region has inflated the number of people lacking access to electricity, which is rising. Since electricity serves as a prominent part of modern society, electrification is often referred to as a key enabler for socio-economic development.

The United Nations have introduced 17 Sustainable development Goals with the aim to stimulate action over the next thirteen years in areas of critical importance for ending poverty, protect the environment and ensure prosperity for all. According to the World Bank, the provision of energy is highly interconnected with 125 out of the total 169 sub-targets that are included in the Sustainable Development Goals.

The aim of this thesis is to investigate the relation between access to electricity and relevant development indicators. By assessing previous research within the field of electrification and development, a number of key indicators have been selected for further analysis. A statistical analysis of the development of these indicators in Rwanda demonstrates that access to electricity has an evident impact on socio-economic development although further investigation of how the indicators relate to access to electricity is needed.

Keywords: Sustainable Development, Electrification, Rwanda, Literature Review, Statistical Analysis

Joakim Hallander, Department of Earth Sciences, Uppsala University, Villavägen 16, SE- 752 36 Uppsala, Sweden
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<tr>
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<th>Full Form</th>
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<tr>
<td>AFDB</td>
<td>African Development Bank</td>
</tr>
<tr>
<td>ANOVA</td>
<td>Analysis of Variance</td>
</tr>
<tr>
<td>ARI</td>
<td>Acute Respiratory Infections</td>
</tr>
<tr>
<td>ESMAP</td>
<td>Energy Sector Management Assistance Program</td>
</tr>
<tr>
<td>GDP</td>
<td>Gross Domestic Product</td>
</tr>
<tr>
<td>GNI</td>
<td>Gross National Income</td>
</tr>
<tr>
<td>IEA</td>
<td>International Energy Agency</td>
</tr>
<tr>
<td>HDI</td>
<td>Human Development Index</td>
</tr>
<tr>
<td>kWh</td>
<td>Kilowatt hour</td>
</tr>
<tr>
<td>MINIRFA</td>
<td>Ministry of Infrastructure</td>
</tr>
<tr>
<td>MMR</td>
<td>Maternal Mortality Ratio</td>
</tr>
<tr>
<td>NISR</td>
<td>National Institute of Statistics Rwanda</td>
</tr>
<tr>
<td>NORAD</td>
<td>Norwegian Agency for Development Cooperation</td>
</tr>
<tr>
<td>RwF</td>
<td>Rwandan Franc</td>
</tr>
<tr>
<td>SDG</td>
<td>Sustainable Development Goal</td>
</tr>
<tr>
<td>SE4ALL</td>
<td>Sustainable Energy for All</td>
</tr>
<tr>
<td>SSA</td>
<td>Sub-Saharan Africa</td>
</tr>
<tr>
<td>UN</td>
<td>United Nations</td>
</tr>
<tr>
<td>UN DESA</td>
<td>United Nations Department for Economic and Social Affairs</td>
</tr>
<tr>
<td>UNDP</td>
<td>United Nations Development Programme</td>
</tr>
<tr>
<td>USAID</td>
<td>United States Agency for International Development</td>
</tr>
<tr>
<td>WB</td>
<td>World Bank</td>
</tr>
<tr>
<td>WEO</td>
<td>World Energy Outlook</td>
</tr>
<tr>
<td>WHO</td>
<td>World Health Organization</td>
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1. Introduction

1.1. Electricity access around the world

Access to electricity is a standard of living the majority of people take for granted nowadays. In some parts of the world access to electricity has been a given for several decades, while in other, electricity was recently introduced as part of the everyday life. As of today, 1.1 billion people in the world lack access to electricity, while 2.9 billion rely on the so called traditional fuels (firewood, charcoal, kerosene etc.) for cooking (Kooijman-van Dijk & Clancy 2010; SE4ALL 2016). This is most prominent in Sub-Saharan Africa where 600 million people (2 out of 3) do not have access to electricity and modern cooking fuels (IEA 2017). The absence of electricity can predominantly be seen in rural areas as electrification of urban areas has outpaced rural areas twice as fast since year 2000. In Sub-Saharan Africa the rates of access to electricity between urban and rural areas are larger than any other region of the world. Urban areas reach an electrification rate of 63% while rural areas only 19% (WB 2017).

Continuous and reliable access to electricity poses as a crucial part of modern society as it is embedded in almost everything we do and need, in terms of services as housing, food production, education and health care. Within states and communities where the access to electricity is limited or absent these societal services are often marginalised or non-existing as well (WB 2010). Encompassing most of the low energy access countries in the world, Sub-Saharan Africa is also one of the poorest regions having a multidimensional poverty index of 31% as in 2015. Constructed as a complement to traditional income-based poverty, multidimensional poverty captures the deprivations that each person faces simultaneously with respect to education, health and living standards (Oxford Poverty & Human Development Initiative 2016).

The picture below (Fig. 1) illustrates night time lights which can be used to demonstrate where electricity usage is evident in the world. As can be seen in the picture, Sub-Saharan Africa generate little indication of electricity usage, although close to a billion people live in the region.

![Fig.1. Night time lights in the world. (Source: The National Oceanic and Atmospheric Administration, National Geophysical Data Centre 2010)](image)
In recent years there has been considerable advancements in electrification on a global scale as the electricity deficit has declined from 1.3 billion in year 2000 to 1.1 billion in 2014 while the electrification rate has increased from 77 to 85% globally. Most prominent is the increase of the global electrification rate for rural areas as it increased from 63 to 73% between 2000 and 2014 while urban areas already are close to having universal access at 97% as relatively insignificant increase of urban electrification has reported in the past 25 years. However, maintaining a rate this high is a great achievement when taking into consideration the rapid urbanization during this period which increased the world’s urban population with an additional 1.6 billion people (WB 2017).

Among the regions of the world, South Asia represents the most remarkable increase of electrification since year 2000 rising from 57 to 80%. Moderate increase has been reported in East Asia and the pacific representing an increase from 90 to 96%, the Middle East and North Africa increasing from 91 to 97% and the Caribbean and Latin America increasing from 92 to 97%. Having the lowest starting point of electrification rates, Sub-Saharan Africa has reported an increase from 27 to 38% since 2000 although the fast population growth in the region has inflated the number of people lacking access to electricity which is rising (Kanagawa & Nakata 2008; WB 2017).

Although there is a clear gap of electricity access among urban and rural communities, the expected population growth of 1.5 billion by 2030, is expected to affect mostly urban settings due to increasing urbanization rates. This suggests that the number of rural households in need of gaining access to electricity will become stabilized and not inflated by the population growth (WB 2017).

### 1.2. Electricity and development

As electricity holds such a prominent role in modern society, electrification efforts are often a key factor in achieving socio-economic development. The relation between access to electricity and human development as described by White (2002) (Fig. 2). White points out that from the very first kilowatt-hours provided, an evident direct benefit can be seen in human development, represented here by the Human Development Index (HDI).

![Macro-level correlations of access to electricity and human development. (Source: White 2002)](image)

The theory of access to electricity as an enabler of human development has since White’s publication in 2002 reached far beyond the scope of lifespan, educational levels and GDP which are the core components of HDI. Today, the theory takes on a more holistic view of the relation of access to
electricity and development. According to prominent actors within the field of electrification and development the levels and the quality of health services, education, gender equality, indoor environment, and daily activities like lighting, heating, cooking and transportation, as well as business, agricultural, infrastructure and telecommunications sectors may all be linked to access to modern energy services in forms of electricity (IEA 2017; SE4ALL 2016; UN 2016).

In 2015 heads of states, governments and high representatives met up at the United Nations headquarters in New York and agreed on the 17 Sustainable Development Goals (SDGs) with the aim to stimulate action over the next fifteen years in areas of critical importance for ending poverty, protect the planet and ensure prosperity for all. Each one of the goals with its specific targets to be achieved by 2030. In order to be able to measure the progress towards reaching the targets, specific indicators has been established for each target.

One of these goals, SDG 7, envisions access to affordable, modern, reliable and sustainable energy as one on the prime drivers for eradicating poverty and move towards a sustainable future (UN 2016).

“Energy is crucial for achieving almost all of the Sustainable Development Goals, from its role in the eradication of poverty through advancements in health, education, water supply and industrialization, to combating climate change.” (UN 2016)

SDG 7 consists of five set targets to be reached by 2030 which all are aiming toward the overall goal:

7.1 Ensure universal access to affordable, reliable and modern energy services.
7.2 Increase substantially the share of renewable energy in the global energy mix.
7.3 Double the global rate of improvement in energy efficiency.
7.4 Enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology.
7.5 Expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, Small Island Developing States, and land-locked developing countries, in accordance with their respective programs of support. (UN, 2016)

Out of these targets, target 7.1 has been of most interest for this thesis since it aims to ensure universal access to energy services by 2030. As this thesis focused on electricity and not energy in general, indicator 7.1.1 was of most relevance due to its specific aim towards electricity as it intended to measure the proportion of the population with access to electricity (UN 2016). The delimitation of SDG 7 utilized in this study can be seen below (Fig. 3).

According to a recent report from the World Bank a review of the SDG targets indicates that energy in general is interconnected with 125 out of the total 169 targets that are included in the SDGs. This represents 74% of the targets and justifies the argument to prioritize energy and access to electricity in the development agendas (WB 2017). Some examples of this relation can be seen in households lacking access to electricity and other modern sources of energy as they often have fewer opportunities for income generation, which is most prominent in non-farming communities. These households earn
less, spend more time on collecting biomass and less time on education and the money spent on modern energy is proportionally more expensive due to high cost of batteries (WB 2017). This interlinkage is illustrated by the World Bank below (Fig. 4).

**Fig. 4.** Illustration of energy as linked to all other Sustainable Development Goals according to the World Bank (source: WB 2017)

Moving forward, numerous states, institutions and international organisations are taking measures to lead the way to reach the SDGs by 2030. Sustainable Energy for All (SE4ALL) is a global, multi-stakeholder platform with a strong and structured relationship to the United Nations and is one of the most prominent global initiatives to improve energy efficiency, increase the share of renewable energy and achieve universal energy access (SE4ALL 2016). The initiative strive to empower leaders to establish partnerships and unlock finance to achieve the goal of universal access to sustainable energy, by contributing to a cleaner, just and thriving world.

The quantity of electricity access varies widely allowing for a range of different use of services. Depending on if a household consume 20 kWh per person/year or 220 kWh per person/year, may indicate a difference of having access to only task lighting and a radio or a television and air circulation as well (UN DESA 2016). As illustrated below (Fig. 5), access to electricity can be divided into five tiers indicating which services that are made possible when having a specific quantity of electricity. As this thesis focuses on the development of advancing from no access to gaining access to electricity, the first level of access is of most interest.
As the level of access to electricity can have significantly different impact on communities and households, the amount of electricity provided is of relevance for policy-makers when implementing electrification measurements. In order to provide useful insights of the implications of reaching different levels of access to electricity, a model for calculating the expected costs of reaching the target of universal electricity access by 2030 has been developed by KTH dESA (UN DESA 2016).

The theoretical concept underlining this thesis was simply the same as utilized by the international institutions leading the way for electrification, that electrification measures may have a key role as an enabler of sustainable development. The methodological measures undertaken will serve to investigate how this theory has been used in previous research on the subject and how new insights can be added. Although efforts to reach the SDGs are made by states, institutions and international organisations the road ahead is long and challenging.

1.3. Problem formulation

According to the population projections, it is estimated that by 2030 about 1.4 billion people will need to gain access to electricity services and about 2.6 billion people would have to improve their methods for cooking and heating (Kanagawa & Nakata 2008). This is a major challenge to overcome if SDG 7 is to be reached 2030, which will require efforts from governments, institutions, financiers, development banks, communities, and civil society etc.

According to a study on previous electrification measures conducted by the PRODUCE initiative, the empirical evidence that validate the arguments that access to electricity is a necessary requirement for sustainable development is scarce, and suggest that more evidence of the relation is needed (Attigah & Mayer-Tasch 2013). Their explanation to the scarcity of evidence could possibly be due to the difficulty in understanding the impact of electricity as one factor to a large set of activities that together improve development. The lack of evidence can have constricting effects on the development needed to reach SDG 7.

As identified by the SE4ALL and the PRODUCE initiative, further evidence and understanding of electricity as a driver for socio-economic development can have a positive effect on the ability to gather and convince policy makers and other leaders of the world to join up in the electrification of the unserved areas. As Sub-Saharan Africa is the region in the world most exposed to development challenges and lack of electricity, this thesis will further investigate upon electrification activities in a country within the region and how these are related to sustainable development.
1.4. Aim & Objectives

Due the expressed lack of evidence, the overall aim of this thesis is to further contribute to the understanding of the relation between access to electricity and indicators of sustainable development. The objective is to investigate how previous research has identified electrification measures to have an effect on specific development indicators and further investigate how these indicators have developed in relation to electrification.

In order to reach the goal, the following research questions were raised:

- Which development indicators are appropriate to investigate when estimating the impact of electrification?
- How have the identified development indicators advanced in relation to access to electricity?
- How may universal access to electricity impact other development indicators?

The end goal is to provide explanatory insights of how electrification efforts can impact specific development indicators, with the ambition to stimulate decision-makers to take further action for the electrification measures required to reach SDG 7 before 2030.

2. Methodology

In order to answer the research questions, disparate methods has been implemented, including both qualitative and quantitative methods of analysis. First, a qualitative literature review was conducted to provide a base for identifying which indicators can be of relevance for further analysis. The indicators identified were then tested through a statistical analysis, analysing the relation of electricity access and development. In the following sections of this chapter, further explanation of the methods used are presented.

2.1. Literature review

In order to gain understanding of which indicators that are relevant when examining the impact of electrification, a literature review was performed. The analytical framework of the literature review was a qualitative content analysis, which is a suitable approach when identifying patterns and trends within a field of study (Bergström & Boréus 2012). Further, a qualitative content analysis is an appropriate approach when the purpose is to systematically bring forth the main idea of texts (Esaiasson et al. 2012). By systematically analysing literature, key concepts of interest could be drawn out and collected as an indication of relevance within the field of research to be used as indicators in the statistical analysis.

The key concepts used in the literature review has been drawn from the Sustainable Development Goals (SDGs) presented by the UN as indicators for measuring development. Electrification has been the core component since it represents the base line for the analysis. In combination to electrification, other aspects of development have been used as additional components in order to find literature. A literature search of peer-reviewed literature on electrification and development has been performed as an initial step to identify relevant literature. As the literature review proceeded, the search of literature has been narrowing in on the development indicators that has been most prominent in the general literature in order to gain deeper understanding of their particular relation to electrification.
Reports and articles published by international organizations such as the World Bank (WB) United Nations (UN) and World Health Organization (WHO) has also been used in the literature review due to their prominence within the field of electrification and development.

The literature in which access to electricity and its relation to other development indicators has been identified is presented in following chapter. The presentation has been categorized into three sections based on the three pillars of sustainable development: economic, social and environmental. After the presentation of relevant literature an additional section presents the indicators chosen for further analysis with motivation of why those particular indicators have been selected and how they can be measured.

2.2. Statistical analysis

In order to investigate how the identified development indicators are affected by access to electricity, a statistical analysis has been implemented. Statistical analysis is suitable when dealing with large amounts of numerical data over a period of time in assessment of the change (Esaiasson et al. 2012). The statistical analysis in this study was performed in two steps including an assessment of the correlation and a linear regression, both of which are further described in the following sections. The development of each one of the identified development indicators and their statistical relation to access to electricity has been analysed separately, but their eventual co-dependency has been included in the final discussion.

2.2.1. Correlation

As a first step in the statistical analysis the correlation between access to electricity and the identified indicators were tested. The most commonly used correlation coefficient in social science is the Pearson’s correlation coefficient $r_{xy}$, which measures the strength in the covariance between two interval scales (Eggeby & Söderberg 1999).

Pearson’s correlation coefficient is a measure of interval scale variables which demonstrates the strength and direction of linear correlation between two variables $X$ and $Y$. In this study, the two variables are access to electricity ($X$) and each one of the identified indicators ($Y$). The measurement of the correlation varies between -1 (total negative correlation) and +1 (total positive correlation) where the closer to -1 or +1 the stronger correlation. Measurements of correlation close to 0 indicates that there is no linear statistical correlation between the two variables. Although a 0-correlation does not exclude a non-linear correlation such as a u-shaped correlation (Esaiasson et.al. 2012). The formula for Pearson’s correlation coefficient can be formulated as follows:

$$ r = \frac{\sum xy}{N S_x S_y} $$

Where $X$ and $Y$ are deviation scores, that is,

$$ x = X - \bar{X} \quad \text{and} \quad y = Y - \bar{Y} $$

And $S_x$ and $S_y$ are the standard deviation for the same variables. $N$ represents the number of observations measured.

A positive correlation coefficient means that high variable values on variable $X$ tends to occur together with high values on variable $Y$. A negative correlation coefficient mean that high values on the $X$ variable tend to occur together with low values on the $Y$ variable (Esaiasson et.al. 2012). What can be considered as strong correlation is relative and differs among studies depending on the field of study. Since there is already an outspoken relation between access to electricity and development, this study will value positive correlations over .70 as moderate and over .85 as strong, respectively -.70 and -.85 for negative correlations.
In order to estimate the proportion of the variance in the dependent variable Y that is predictable from the independent variable X the coefficient of determination \((r^2)\) has to be taken into consideration and is done by calculating the square for the correlation coefficient. The higher positive or negative value of the correlation coefficient the higher the \(r^2\) (Eggeby & Söderberg 1999).

\[ r^2 = Y^2 \]

An \(r^2\) value of for e.g. 0.70 would indicate that 70% of the variance in the dependable variable Y can be explained by the independent variable X (access to electricity). The higher the value of \(r^2\) the higher percentage of the dependant variable can be explained by independent variable (Eggeby & Söderberg 1999).

2.2.2. Linear regression analysis

When assessing how much the X variable, in this case access to electricity, affects other variables a regression analysis is an adequate method to use (Eggeby & Söderberg 1999). Since there is only one independent variable in this case a simple linear regression analysis is most fitting (Eggeby & Söderberg 1999). Following is a presentation of how the simple linear regression analysis was conducted.

The formula for a simple regression is as follows:

\[ Y = a + bX + e \]

- Where X is the independent variable and Y dependant variable.
- \( a \) is a constant which specifies the value of Y has when the value of X is zero.
- \( e \) is a residual (error term) which specifies how much of the observed value of Y that differs from the value that the model predicts. The smaller the difference between the observed value and the predicted value is better.
- \( b \) is the regression coefficient which indicates how much the Y variable change due to changes in the X variable.

All calculations have been performed in Microsoft Excel. The data outcome has then been used as a base for analysing the results. Following is an example of the output data generated (Table 1).

<table>
<thead>
<tr>
<th>Regression Statistics</th>
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<tr>
<td>Multiple-R</td>
<td>0.958</td>
</tr>
<tr>
<td>R-Square</td>
<td>0.917</td>
</tr>
<tr>
<td>Adj R-Square</td>
<td>0.911</td>
</tr>
<tr>
<td>St Error</td>
<td>6.298</td>
</tr>
<tr>
<td>Observations</td>
<td>16</td>
</tr>
</tbody>
</table>

The first part of the summary output provides the regression statistics and contains of the following information:

**Multiple-R** is the correlation coefficient which as mentioned above measures how the two variables move in relation to each other.

**R-square** indicates how much of the change in Y is caused due to the change in the X variable. In this example is 91.7 % and can be considered as very high.

**Adjusted R-square** is used when analysing more than one independent variable which is not the case in this study and can be ignored.
Standard error measures the variability of actual Y-values from the predicted Y-values and tells about the precision that the regression coefficient is measured. If the actual Y-values are located close to the predicted Y-values the standard error value is low and if the actual Y-values are located further away from the predicted Y-values the standard error value is high. In this example the typical miss in the predicted model is 6.3 indicating a resemblance between the actual and predicted values.

Observations is the number of observations used in the model which in this example is 16 (years).

The second part of the summary output represents the “analysis of variances” (ANOVA) (Table 2). The first column in the ANOVA represents the degrees of freedom (df). The degrees of freedom for the regression indicates the number of independent variables the analysis have, which in this case is one. The total degrees of freedom is calculated as the number of observations minus one and the degrees of freedom for residuals as observations minus the number of regressions minus one, (16-1-1). The fourth column represents the F-value which determines if the regression analysis is significant.

Table 2. ANOVA example.

<table>
<thead>
<tr>
<th>ANOVA</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>sign. F</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regression</td>
<td>1</td>
<td>6155.213</td>
<td>6155.213</td>
<td>155.205</td>
<td>0.000</td>
</tr>
<tr>
<td>Residual</td>
<td>14</td>
<td>555.219</td>
<td>39.659</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>15</td>
<td>6710.432</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The most interesting data to look at in this section is the probability that the regression output is not by chance, which is the p-value. That can be interpreted by the significance of F of the regression. The smaller the significance of F, the smaller the chance of the output being by chance. As can be seen in this example the significance of F is 0 which indicates that there is no probability that this regression result is by random chance.

The third section of the summary output (Table 3) is most relevant for the analysis as this provides the coefficients for the Y-intercept and the slope of the independent variable of the regression which are used in the regression equation, seen in the first column. This information provides the base for the regression equation which in this example would be the following: Y = 3,955*access to electricity + 9,796.

Table 3. Regression result example

<table>
<thead>
<tr>
<th>Coefs</th>
<th>St Error</th>
<th>t-stat</th>
<th>p-value</th>
<th>Lower 95%</th>
<th>Upper 95%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>9.796</td>
<td>4.011</td>
<td>2.442</td>
<td>0.028</td>
<td>1.193</td>
</tr>
<tr>
<td>Access</td>
<td>3.955</td>
<td>0.317</td>
<td>12.458</td>
<td>0.000</td>
<td>3.274</td>
</tr>
</tbody>
</table>

The next three columns, St Error, t-stat and p-value are related to each other and represents the significance of the relationship of the two variables. The St Error is the standard deviation for the coefficient and tells how much deviation there is in the predication for this coefficient. The t-stat represents the number of St Errors the coefficient is from zero. The p-value is the same as the significance of F in the ANOVA section indicating the chance of the regression occurring by chance at a 95% prediction level.

The relation between the X variable and the Y variable can best be illustrated in a scatter plot as seen below (Fig. 6). The dots in the scatter plot represent the observations made and the line represents the regression line. The regression line is the best-fitted straight line through the observation points and represents the predicted score on Y for each possible value of X. The distance between the observed points and the regression line is the errors of prediction. The closer the observation points are to the regression line the smaller the error in the prediction.
As the regression results provides indication of how the percentage increase of electricity access impacts the percentage change in the other development indicators, estimations could be made on future developments of the indicators and investigate the possible developments of the indicators if SDG 7 is reached by 2030.

2.2.3. Limitations

The limitations of conducting a statistical analysis on socio-economic indicators are prominent and requires to be handled with an understanding of their complexity. No statistical methods can prove the existence of causal relations, although statistical methods can still have a great value of causal analysis within the framework of a theory (Eggeby & Söderberg 1999). As all causal relations don’t have support in the data, a statistical method’s value can be found in its ability to provide guidance in estimation to what extent the theoretical models are compatible with the observed data.

In this case it can be rather controversial to talk about causality since there are certainly many other factors having an impact on the indicators other than just access to electricity. The purpose of this study is not to claim evidence of the causal links between access to electricity and the other indicators as the only causal factor, merely investigate the relation, including an assessment of electricity as an enabler of change in the other indicators. The motive of applying a regression analysis and assess the causal relation is dependable on the arguments that has been found in previous research activities within the studied area, claiming that access to electricity can play a role as an explanatory factor for the change of the other development indicators. Due to the limitations mentioned, extra caution has to be taken in the interpretation of the results. By relating to the results in a theoretical sense and avoiding unfounded assumptions of the impact of access to electricity, the statistical analysis has provided useful support for the discussion.

In order to perform a more comprehensive assessment on the relation between access to electricity and other development indicators, additional methods of analysis such as surveys, geospatial analysis or interviews could arguably add value to the results. Initially a geospatial analysis along with survey data were planned to broaden the analysis and provide a range of data which would enable a deeper understanding of the relation. The surveys were meant to be conducted at households, schools and health facilities around Rwanda in both rural and urban settings to generate micro-level data to complement the statistical macro-level data. However, due to unavailability of relevant geospatial data for the identified indicators in the literature review and logistical difficulties in the survey data collection, those data were inaccessible.
2.3. The case of Rwanda

In order to perform the statistical analysis of the indicators identified in the literature review, a country was chosen as object for analysis. As Sub-Saharan Africa is most affected by lack of electricity access, a country in the region and more specifically Rwanda, has been selected. Due to the availability of data, the time-frame of the analysis is between year 2000 and 2015.

Rwanda is located in the Eastern central part of Africa just south of the equator, bordering to Uganda, Burundi, Tanzania and the Democratic Republic of Congo and is one of the smallest states in Africa (NISR 2016). Rwanda is commonly known for the 1994 genocide during which more than one million people were massacred and an estimated 2 million people fled the country. The Rwandan Patriotic Front put an end to the massacre and took control over the country in 1994 (UNDP 2016).

The leadership implemented after the genocide inherited a decimated country without infrastructure and an impoverished population. However, Rwanda has made progress in many areas of social prosperity since the end of the war and has experienced steady economic recovery, due to government commitment to socio-economic reforms, support for private sector investment and steady foreign aid inflows (UNDP 2016).

Rwanda has been selected as the research object for this study due to several reasons. First, Rwanda is a relatively small country (26 338 km²) with the highest population density (445/km²) in SSA (AFDB 2017) which provides an opportunity to perform an analysis on the smallest available geographical scale for the largest number of people, which limits the risk of regional differences to interfere with the results.

Secondly, the increase of access to electricity has been steady in Rwanda in the past 15 years which is preferable since this study aims at analysing the impact of gained access to electricity. Rwanda also had one of the lowest rates of access in SSA in the 2000 which increases the ability to analyse how gaining access impact other development indicators (USAID 2017).

Since the genocide in 1994 the political and economic situation in Rwanda has been relatively stable which also is preferable for the analysis since it minimizes the risk of other factors disturbing the analysis. From 2000 to 2015 the GNI per capita has increased from 240 to 700 US$ (AFDG 2017) which is an eminent increase that has to be taken into consideration when analysing the results later in this study. Lastly, although of high importance for this study, Rwanda provides comprehensive amounts of statistical data for several development indicators since 2000.

As illustrated below (Fig. 7), the development of access to electricity in Rwanda has been steadily increasing since 2000. At a rate of 6.2 % in 2000 the percentage of the Rwandan population with access to electricity has increased up to a rate of 21.3 % in 2015 (WB 2016; UNDP 2016; USAID 2017).
Fig. 7. Illustration of the development of the percentage of population with access to electricity in Rwanda 2000 – 2015 (source: WB 2016, UNDP 2016; USAID 2017)

According to the Ministry of Infrastructure in Rwanda efforts are made for developing the access to electricity in the country as it recognizes its role in accelerating economic development. The Energy Sector Strategic Plan and the National Energy Policy in Rwanda has implemented its ambitious target of providing 70% of the Rwandan population with electricity by 2018 and a 100% access in 2020 (MININFRA 2016). As the majority of the population live in rural areas a Rural Electrification Plan has been implemented as the main driver for electrification which is expected to channel hundreds of million dollars of investments on both off-grid and on-grid sectors providing electricity for up to a million households in Rwanda (MININFRA 2016).

The data used for the statistical analysis has been collected mainly from national statistical databases of Rwanda. The National Institute of Statistics of Rwanda (NISR) provide adequate amounts of statistical data on several development indicators. Additional statistical data has been collected from the World Bank database, United Nations Development Program database and the World Health Organization database.

3. Literature Review

In this section a compilation of some identified indicators are presented. The presentation of the identified indicators is categorized according to each indicator within the three pillars of sustainable development: Economic, Social and Environmental. In the end of the chapter a decision of which indicators are relevant for further assessment is presented.

3.1. Economic indicators

3.1.1. Poverty

Fan et al. (2005) demonstrates in the article “Public Investment and Poverty Reduction in Tanzania: Evidence from Household Survey Data” how household survey data can be used to analyse the impacts of infrastructure investments such as electrification on growth and poverty. A conclusion drawn from the results presented was that a correlation between access to electricity and poverty reduction can been seen. If a household has electricity access in any of the regions analysed, the
probability of being poor falls by between 4 and 13%, which would lift approx. 140 000 people out of poverty. (Fan et al. 2005).

According to a survey study in Mozambique performed by the Norwegian Agency for Development Cooperation (NORAD) electrification efforts had significant impact on poverty reduction in the lowest-income communities due to the reduced energy expenditure (NORAD 2013).

3.1.2. Employment
In general, studies provide some indication that there is some correlations of access to electricity and employment rates on a micro-level in SSA. According to a study by ESMAP (2005), no net increase in employment can be found, although a shift from using family members to recruiting full-time employees is identified through an enterprise survey with small and medium sized enterprises with and without access to electricity.

An analysis on 11 African countries by Goedhuys and Sleuweagen (2010) shows that access to grid electricity in combination with backup diesel generators has a positive impact on employment rates. The combination of grid connection and back up generation creates a reliable source of electricity which has caused a mean employment growth of approx. 2% among the 11 countries.

By comparing data from electrified and non-electrified areas in post-apartheid South Africa, Dinkelman (2011) estimates the impact of electrification on employment for rural households. Conclusions from the study show that household electrification enables women to be released from time-consuming household activities leading to an increase of female employment by over 13% but no significant improvements for male employment.

3.1.3. Growth
Electricity access is analysed in a broader set of indicators measuring the impacts of infrastructure development on growth and inequality in SSA by Calderón and Servén (2008). By using comparative cross-regional perspectives incorporating data from infrastructure quantity and quality indicators, positive effects on long-run growth has been identified.

In another study by Calderón (2009) further links between infrastructure development and economic growth are identified as the study evaluates the impact of electrification in 39 African states. In the analysis of both the impacts from increasing the infrastructure services and the quality of existing infrastructure in three key subsectors: telecommunications, electricity and roads, electricity generating capacity is identified as a major contributor to growth. The results further estimates that the 39 African states generally are more likely to benefit from higher volumes of infrastructure rather than an enhancement of quality in the existing infrastructure.

A study by Estache et al. (2005) provides a systematic quantitative analysis of the importance for SSA’s GDP growth of investments in various infrastructure sub-sectors of which electricity is portrayed as a major one. A result drawn from the analysis is that most infrastructure sub-sectors are shown to be statistically significant engines of GDP growth in the region with a highlighted importance of telecommunication, electricity access and roads, which also has been identified results in studies above.

3.1.4. Productivity
Several studies have linked electricity access and productivity of firms, although the impacts are highly relying on the country and context in which the firm operates (Attigah & Mayer-Tasch, 2013). An example where electricity has been proven to have a positive impact on productivity and growth in society in general is in South Africa, according to a study by Fedderke and Bogetic (2006) where data ranging from 1970-2000 has been assessed.

In a paper by Arnold et al. (2008) World Bank Enterprise Survey data of more than 1000 firms in 10 SSA countries has been assessed in order to calculate the total firm productivity due to infrastructure
service inputs, such as electricity. The results presented in the paper suggests that access to, and the quality of the electricity access has a significant impact on firm’s productivity. Further, the authors stresses the importance of establishing an environment with reliable access to electricity as firms productivity are essential to a regions economic growth and strategies towards eradicating poverty. Similar conclusions are presented in a study by Eifert et al. (2008) where 17 developing African countries are analysed. According to the study, firms are highly affected by electricity access and particularly their ability to afford a steady supply. The high energy costs are presented as a major factor in explaining the low productivity of firms and enterprises in the 17 countries.

The total factor productivity is especially dependant on electricity access in low-income countries according to a paper by Escribano et al. (2010). By conducting an investment climate survey in 26 African countries the paper comes to the conclusion that lack of reliable electricity supply is the element of infrastructure that has most negative impacts on productivity in several of the assessed countries, especially the lowest-income ones.

A more micro-scale analysis of productivity in rural villages in Kenya demonstrates that electricity access enables small and micro-scale enterprises to increase their productivity due to use of electric tools and equipment (Kirubi et al. 2009). The improved productivity varies depending on task, with a productivity increase as high as 200% for carpenters resulting in a parallel increase in income by 20-70%. Tailors and agricultural activities are other examples of areas of increased productivity.

3.2. Social indicators

3.2.1. Health

Healthcare is considered as a basic human need which in many regions are scarce, non-existing or holds low quality due to lack of the funding required for utilities such as electricity. Access to electricity can provide health clinics with the ability to operate longer hours, perform night-time surgery, child delivery services and store vaccines in refrigerators (NORAD 2013). Although the report by NORAD is unable to report on the exact numbers of health facilities that has been electrified, their survey on 11 electrified health clinics in Mozambique provides information that electrification has been a crucial implementation for providing services in the majority of the cases (NORAD 2013).

In a report by the World Bank and World Health Organisation (2014) the impact of access to electricity in areas of high poverty rates are examined. The report identifies electricity as a crucial component in the development of health care services and highlight the importance of access to electricity for safe maternal care, especially in rural areas. According to the report, electrified areas and health facilities have difficulties recruiting skilled health staff as they often prefer or demand electricity. This pattern is further identified by the organization Voluntary Service Overseas (2012) which in their report on health care workers in Uganda describes how poor working conditions have severe impacts on health staff’s ability to operate after dark, leading to a dislocation of skilled health staff and unsafe methods.

The most prominent consequence of the lack of electricity and skilled health staff is according to the report mentioned above, on the maternal health care. In many cases, birth deliveries are performed under extremely unsafe conditions without the attendance of skilled health staff (WHO & WB 2014).

A sustainability indicator identified by the UN as directly linked to electricity access in general and to the attendance of skilled health staff at delivery is the Maternal Mortality Ratio (UN, SDG 3.1). This relationship is also identified by WHO & WB (2014), which in a report on success factors for reducing maternal and child mortality, identifies electricity access as an independent variable having an impact on the dependant variable Maternal Mortality.

Isha Ray further discuss the relation of electricity access and maternal mortality in her book “Gender Equality and Sustainable Development” (2015), in which she argues that the correlation of the two are particularly strong due to the unsafe conditions lack of electricity causes. Extending access to
electricity as a measure to improve health care facilities abilities to properly attend to births in order to improve maternal and child health has also been presented by USAID in their report “Ending Preventable Maternal Mortality” (2014). According to the report the benefits from electrifying health care facilities are far more than attracting skilled health staff, since electricity generally impact all parts of the health care facility. Gained access can provide the ability to perform child birth at night due to proper lighting, also increase the ability to store vaccines, use proper air ventilation, sterilize the equipment etc. which all increase the ability to provide proper health maternal care (USAID 2014).

Household electrification can have large impacts on health due to the decreased use of kerosene and fuelwood as the source of energy for cooking, lighting and heating as burning these generate harmful particles to spread and accumulate in poorly ventilated areas. According to a study by Barron and Torero (2014) households utilising electricity for lighting can lower the overnight air pollutant concentration by 63% compared to lightning run on kerosene. Particularly high health implications are found in children under the age of six, of whom acute respiratory infections (ARI) decreased by 37-44% among electrified households (Borron & Torero 2014). Children living in un-electrified households using kerosene as the main source of lighting during darker hours often get exposed to the harmful particles while studying or performing household activities due to the need or lighting during those activities (Borron & Torero 2014). This does not only affect the children’s physical health but can also have a negative impact on their willingness of studying during those times.

The impacts on health from electrification is comprehensively assessed in a joint report by the World Health Organisation and the World Bank (2014). The report delivers similar results as the studies above regarding the link between electrification and healthcare clinics and household pollutants.

3.2.2. Education
The NORAD study in Mozambique further investigated the impact electrification has had on education. Based on surveys conducted, the electrified schools have been able to expand and increase educational tools and working hours (NORAD 2013). Extended operating hours have had a particular effect on female students which in many cases are bound to households during the day and the ability to introduce TV’s and computers had improved planning and generated to a higher degree of optimism among students and teachers (NORAD 2013).

The ability to study after dark increased as households electrifies. According to the study by Barron and Torero (2014) households with lighting indicate that more time are spent on schoolwork at home, which is especially represented by girls in the age of 6-15. This is further assessed in a study by Daka and Ballet (2011) as the link between electrified households and the ability to keep up with schoolwork is examined, as well as the inequalities between genders. According to the results, girls with access to household electricity do perform better in school as a result from better circumstances for studying at home, as well as a reduction of gender inequality can be linked to the girls ability to do homework even though they are required to partake in households tasks (Daka & Ballet 2011). The results from the increased capability to attend school and do schoolwork at home at night can be seen in the increasing female literacy rate among younger women, especially from homes and villages recently electrified.

3.2.3. Security
Electrification programs in rural villages in Mozambique has enabled lighting of streets and public areas which has had a positive effect on security. Among participants in surveys conducted by NORAD (2013) 80 % of the population in the electrified villages state that street lighting is one of the most highly valued effects of electrification as it has reducing effects on thefts and has improved the perceived security and increased social activities (NORAD 2013).
3.3. Environmental indicators

3.3.1. Deforestation

The use of alternative sources of energy such as fuelwood/firewood are frequently used in non-electrified areas as a primary source of energy for cooking and heating. Several studies have linked the demand for fuelwood with the increasing deforestation seen in the same areas (Specht 2015; Pant 2007), although in recent years this theory has been challenged. According to a recent study, deforestation patterns can be linked to the use of fuelwood demand on highly populated rural areas affected by poverty, having degrading impacts on biodiversity (Specht et al. 2015). On the African continent 58% (2015) and significantly higher in rural areas, of the energy consumed comes from fuelwood and charcoal which according to the authors cannot be neglected as a potential contributor to ecosystem disturbance. As the same populations relying on fuelwood as a source of energy are highly dependent on the ecosystem services provided by the same vanishing forests, the problem increases (Specht et al. 2015).

Mazimpaka (2014) argues that fuelwood consumption has long been targeted as the main cause for deforestation in Rwanda and the policies implemented to reduce the fuelwood consumption has failed to reach the desired ambitions of reducing deforestation in the county. On a global scale fuelwood consumption represents less than 15% of the causes for deforestation while subsistence farming, permanent agriculture and cattle ranging represent 85%, which indicate a fairly low contribution to deforestation from fuelwood consumption even in countries as Rwanda where the dependency on fuelwood is high (Mazimpaka 2014).

Other studies argue that the dependence and use of fuelwood cannot be linked to deforestation and on the contrary rather can be seen as a generator of reforestation in previously deforested areas. Based on a case study conducted in the Philippines, Bensel (2008) argues that the demand for fuelwood has led to an organized reforestation by smallholder farmers and other landowners to meet the demand. The reforestation of the studied island has strengthened the ability for struggling animals and plants to survive while local communities regained their primary source of energy.

3.4. Indicators selected for further analysis

The choices of indicators for further analysis were based on their relevance in terms of sustainable development and the availability of data for measuring the development over time in Rwanda. Following is a presentation of the five chosen indicators and motivation for why they were chosen.

3.4.1. Poverty rates

Among the economic indicators, poverty rate is not the most prominent one in previous studies although of high relevance due to its close relation to sustainable development as SDG 1 “No Poverty” has a clear and direct link to this indicator. The UN approach for this goal is expressed in target 1.2 which is stated as “By 2030, reduce at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions” (UN, SDG 1). This target provides this study with a clear indication for measurement, as the poverty rate in Rwanda can be measured and has support in previous studies as an indicator of high interest when assessing the impact of access to electricity.

Among the other remaining three economic indicators identified in previous literature there is relevance to sustainable development in their relation to SDG 8 – “decent work and economic growth” as all of them revolves around the importance of creating opportunities for people to economically sustain themselves.

As real GDP growth per capita is set as an indicator for measuring the progress towards SDG 8, it could arguably be considered as a relevant indicator further analysed in this study. However as growth is an economic phenomenon having an impact on communities in general, poverty has a direct impact
on people’s lives hence more relevant for this study. Employment and productivity can in this case be seen as enablers of poverty reduction through electrification as the main outcome of improvements of these indicators are to create opportunities for communities to lift people out of poverty.

In the case of poverty rates it is important to be aware of the potential correlation between access to electricity and poverty does not imply causality. The possibility of a reversed causal link or a third factor causing both poverty to decline and access to electricity to increase is present. However, there can arguably be of interest to assess the relation between the two indicators.

In addition to the reduction of the poverty rate, extreme poverty can be of interest here as an additional sub-indicator strengthening the understanding of the development of poverty in Rwanda. In the case of extreme poverty, the UN SDG is even more drastic as the target for this is “By 2030, eradicate extreme poverty for all people everywhere, currently measured as people living on less than $1.25 a day” (UN, SDG 1.1).

The definitions of poverty and extreme poverty used in this study are the same as used by the National Institute of Statistics of Rwanda (NISR) which is the amount spent per adult per year. The poverty line in Rwanda has changed in conjunction with the economic development which can be seen in the table below (Table 4).

**Table 4. Development of poverty rates in Rwanda 2000 – 2014 and the value in USD at the time (source: NISR 2012; UNDP 2016)**

<table>
<thead>
<tr>
<th>Year</th>
<th>Poverty rate (Rwf)</th>
<th>USD</th>
<th>Extreme poverty rate (RwF)</th>
<th>USD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>64.000</td>
<td>205</td>
<td>45.000</td>
<td>144</td>
</tr>
<tr>
<td>2005</td>
<td>90.000</td>
<td>200</td>
<td>63.000</td>
<td>140</td>
</tr>
<tr>
<td>2010</td>
<td>118.000</td>
<td>201</td>
<td>83.000</td>
<td>141</td>
</tr>
<tr>
<td>2014</td>
<td>160.000</td>
<td>290</td>
<td>105.000</td>
<td>190</td>
</tr>
</tbody>
</table>

The data on poverty rates in Rwanda has been collected from the National Institute of Statistics of Rwanda (NISR) for the years of 2000 – 2010. Additional data for poverty rates in Rwanda has been collected from the UNDP.

### 3.4.2. Attendance of skilled health staff at delivery

Among the social indicators identified, health related indicators are prominent. One of the development indicator identified in previous studies as closely related to the access of electricity is the attendance of skilled health staff at delivery of birth in health facilities. According to the review presented above, health care facilities with access to electricity holds a significantly higher chance of attracting skilled health staff. Due to this indicator’s close relation to electricity it can be of interest for further assessment in the statistical analysis.

A clear link to the SDGs can be seen as SDG 3 “Ensure healthy lives and promote well-being for all at all ages” uses a target for measuring maternal and child health by applying the exact same indicator. Target 3.1 on maternal health is divided into two indicators utilized for measuring the progress towards the target as indicator 3.1.2: “Proportion of births attended by skilled health personnel” is set up. Due to the recognition of this particular indicator by the UN as a measurement for development of maternal health and the identification of its relation to access to electricity in previous research, it can be of high relevance for further assessment in the statistical analysis in order to investigate if a relation between the development of access to electricity and this indicator can be seen in the case of Rwanda.

All data used for the statistical analysis of this indicator is provided by the National Institute of Statistics of Rwanda (NISR). The data available ranges for the time span 2000 – 2015 hence the time span used in the analysis. The definition used of this indicator is: percentage of live births in five years preceding the survey delivered by skilled health staff which includes doctor, nurse/medical assistant, and midwife (NISR 2016).
3.4.3. Maternal Mortality Ratio

Closely related to the previous indicator, Maternal Mortality Ratio (MMR) is identified in previous studies as linked to increased attendance of skilled health staff at delivery due to the increased ability to attend to the needs required to perform safe deliveries. Thus decreasing MMR can be explained by the increased percentage of skilled health staff in previous research, access to electricity also provides more direct benefits for health care facilities such as abilities to store vaccines and sterilize equipment and can due to this be of interest to investigate independently from the previous indicator.

As mentioned in the discussion of the previous indicator chosen for further analysis, MMR is closely related to SDG 3.1. Maternal health care is presented by the UN SDGs as a sub-group to health care in general in which the MMR is considered as the one of the indicators for measuring the progress towards reaching its goal of reducing the MMR to less than 70 deaths per 100,000 births by 2013 in target 3.1.1. According to the UN and as argued in the previous literature, MMR can be approached both as a result of increased attendance of skilled health staff, as well as an independent indicator being directly affected by access to electricity among other factors, hence this study will utilize it as a separate indicator in the statistical analysis. The close relation between the two indicators will be recognized in the discussion.

Data used for the statistical analysis of this indicator is provided by the National Institute of Statistics of Rwanda (NISR), the World Health Organization and the World Bank. National data for Rwanda available for the years 2000 – 2015 hence the time span used for the statistical analysis. The definition of this indicator is: the annual number of female deaths from pregnancy-related causes per 100,000 live births (NISR 2001; WHO & WB 2014).

3.4.4. Symptoms of Acute Respiratory Infections among children under five

A third health related development indicator has been identified and chosen for further analysis. As acute respiratory infections (ARI) has been identified as a health related indicator affected by household electrification rather than health care facilities access to electricity, it can offer an interesting addition to the analysis.

As well as the two previous health related indicators, ARI is recognized by the UN in the SDG 3. Several targets under SDG 3 can be related to symptoms of ARI among children under five with target 3.2 with indicator 3.2.1 as the most apparent one as it sets a target for ending preventable deaths among children under five years of age. In addition, target 3.9 recognizes ARI as it sets a target for substantially reducing the number of deaths and illnesses from indoor pollution which is specified in indicator 3.9.1. Symptoms of ARI among children under five can due to the recognition of its relation to access to electricity in previous literature, its distinct and clear relation to the SDGs and the availability of data be considered as an interesting indicator for further analysis.

Data used for the statistical analysis of this indicator is provided by the National Institute of Statistics of Rwanda (NISR). National data for Rwanda available for the years 2005 – 2015 hence the time span used for the statistical analysis. The definition of this indicator is the same used by NISR in their collection of the data: the percentage of children under five who had symptoms of acute respiratory infections in the two weeks preceding the survey. Acute respiratory infections are defined as “cough accompanied by short, rapid breathing that is chest-related and/or by difficult breathing that is chest-related” (NISR 2016: pp 134) and can be considered as a proxy for pneumonia.

3.4.5. Female literacy rate, women aged 15-24

As identified in the previous studies on the relation between access to electricity and education, access to electricity can have a great impact on young people’s lives and future as it provides homes and communities with increased abilities to spend more time on schoolwork. As the studies have identified, girls and women having the most benefits from gaining access to electricity, female literacy rate is of most interest for further analysis.
The most prominent link between this indicator and the SDGs can be seen in SDG 4 which is set on ensuring inclusive and equitable quality education. Among the targets set up by SDG 4, target 4.6 is focused on that by 2030 women in the same degree as men achieve literacy which according to the related indicator 4.6.1 should be measured as a given percentage of a population. Additionally, SDG 5 representing gender equality has a clear link to female literacy rate since it recognises the importance of generating equal educational environments for both boys and girls. There is no specific target under SDG 5 that in directed towards literacy although equal opportunity to quality education can be seen as the overall theme of SDG 5.

Data used for the statistical analysis of this indicator is provided by the National Institute of Statistics of Rwanda (NISR). National data for Rwanda available for the years 2005 – 2015 hence the time span used for the statistical analysis. The definition of this indicator is the same used by NISR in their collection of the data: percentage of women that are literate, which refers to women who attended secondary school or higher and women who can read a whole sentence or part of a sentence (NISR 2016). NISR collects and presents Rwandan data on female literacy rates in age groups. The age group chosen for this study is 15-24 since it is the most appropriate age group to assess the change among children and young in the past 10 years.

4. Results from statistical analysis

In this section the results from the statistical analysis of the relation between access to electricity and the chosen indicators are systematically presented. The interpretation and argumentation of the results and their value are further dealt with in the discussion chapter.

4.1. Poverty Rate & Extreme Poverty Rate

The years of measurements for this indicator range from 2000 to 2014. As illustrated (Fig. 8) below, the poverty rate decreased from 58.9% in year 2000 to 39.1% in 2014 as the extreme poverty rate decreased from 40% to 16.3% over the same period of time.

![Development of poverty rates](image)

**Fig. 8.** Illustration of the development of poverty and extreme poverty rates in Rwanda, 2000 – 2014. (Sources: NISR 2017, UNDP 2016)
4.1.1. Poverty rate

The correlation coefficient between the development of access to electricity and the poverty rate has a correlation value of -0.932, indicating a strong negative correlation. This means that increase in the access to electricity is strongly associated with a decrease in poverty. The coefficient of determination ($R^2$) of 0.869 indicates that 87% of the variance in the assumed dependent variable (poverty) can be explained by the assumed independent variable (access to electricity).

A simple linear regression was calculated to assess how the poverty rate in Rwanda is affected by the increased percentage of access to electricity (Fig. 9). With a p-value of 0, a significant regression equation was found with a $R^2$ of 0.869. The regression can be formulated as illustrated in the figure below: $\hat{Y} = -1.476X + 66.86$. This indicates that without any other factors taken into consideration, one percent of increase in access to electricity results in a decrease of the poverty rate by 1.476%.

![Fig. 9. Scatter plot. The relation of access to electricity and poverty rate in Rwanda year 2000 – 2014.](image)

Based on the regression results that every percent increase in access to electricity decreases the poverty rate by 1.48%, future predictions of the poverty rate in Rwanda indicate that if the same pattern continues regardless of any other factor, a fulfilment of SDG 7 would mean that the poverty rate in Rwanda reaches a rate of 0%. If the electrification rate would increase at the same rate the coming fifteen years as the past fifteen years, reaching an access rate of approx. 37%, the poverty rate in Rwanda would according to the regression equation still reach a rate of 0%.

4.1.2. Extreme Poverty Rate

The correlation coefficient between the development of access to electricity and the extreme poverty rate has a correlation value of -0.943, indicating a strong negative correlation. This means that increase in the access to electricity is strongly associated with a decrease in extreme poverty. The coefficient of determination ($R^2$) of 0.890 indicates that 90% of the variance in the assumed dependent variable (extreme poverty) can be explained by the assumed independent variable (access to electricity).

A simple linear regression was calculated to predict the extreme poverty rate in Rwanda based on the percentage of access to electricity (Fig 10). With a p-value of 0, a significant regression equation was found with a $R^2$ of 0.890. The regression can be formulated as illustrated in the figure below: $\hat{Y} = -1.683X + 48.35$. This indicates that without any other factors taken into consideration, one percent of increase in access to electricity results in a decrease of the extreme poverty rate by 1.684%.
Fig. 10. Scatter plot. The relation of access to electricity and extreme poverty rate in Rwanda year 2000 – 2014.

Based on the regression results that every percent increase in access to electricity decreases the extreme poverty rate by 1.68%, future predictions of the poverty rate in Rwanda indicate that if the same pattern continues regardless of any other factor, a fulfilment of SDG 7 would mean that the extreme poverty rate in Rwanda reaches a value of 0. If the electrification rate would increase at the same rate the coming fifteen years as the past fifteen years, reaching an access rate of approx. 37%, the extreme poverty rate in Rwanda would according to the regression equation still reach a value of 0%.

4.2. Skilled health staff at delivery

The years of measurement for this indicator range from 2000 to 2015. With an initial value of 31.3 % the percentage of births attended by skilled health staff has increased up to 90.7 % in 2015 as is illustrated below (Fig. 11).

Fig. 11. Illustration of the development of percentage of births attended by skilled health staff in Rwanda, 2000 – 2015. (Source: NISR 2001; 2006; 2012; 2016, UNDP 2016)

The correlation coefficient between the development of access to electricity and the attendance of skilled health staff at delivery has a correlation value of 0.957, indicating a strong positive correlation. This means that increase in the access to electricity is strongly associated with an increase in the percentage of attendance of skilled health staff at delivery in Rwanda. The coefficient of determination
(R²) of 0.917 indicates that 92% of the variance in the dependant variable (Skilled Health Staff) can be explained by the independent variable (access to electricity).

A simple linear regression was calculated to predict the percentage of births in Rwanda attended by skilled health staff based on access to electricity (Fig 12). With a p-value of 0, a significant regression equation was found with a R² of 0.917. The regression can be formulated as illustrated in the figure below: Ŷ = 3.954X + 9.796. This indicates that for every percent of increase in access to electricity the percentage of attendance of skilled health staff at delivery increases by 3.955 %, if no other factors are taken into consideration.

**Fig. 12.** Scatter plot. The relation of access to electricity and attendance of skilled health staff at delivery in Rwanda year 2000 – 2015.

Based on the regression results that every percent increase in access to electricity increases the percentage of births attended by skilled health staff by 3.96%, future predictions of the percentage of births attended by skilled health staff in Rwanda indicate that if the same pattern continues regardless of any other factor, a fulfilment of SDG 7 would mean that the percentage of births attended by skilled health staff reaches a value of 100%. If the electrification rate would increase at the same rate the coming fifteen years as the past fifteen years, reaching an access rate of approx. 37%, the percentage of births attended by skilled health staff in Rwanda would according to the regression equation still reach a value of 100%.

### 4.3. Maternal Mortality Ratio

The years of measurement for this indicator range from 2000 to 2015. With an initial ratio of 1400 the Maternal Mortality Ratio has decreased to a ratio of 210 in 2015 as is illustrated below (Fig. 13).
The correlation coefficient between the development of access to electricity and the Maternal Mortality Ratio has a correlation value of -0.853 indicating a strong negative correlation. This means that increase in the access to electricity is strongly associated with a decrease in Maternal Mortality Ratio. The coefficient of determination ($R^2$) of 0.728 indicates that 73% of the variance in the dependant variable (MMR) can be explained by the independent variable (access to electricity).

A simple linear regression was calculated to predict the Maternal Mortality Ratio in Rwanda based on access to electricity (Fig 14). With a p-value of 0, a significant regression equation was found with a $R^2$ of 0.728. The regression can be formulated as illustrated in the figure below: $\hat{Y} = -60.672X + 1390.5$. This indicates that for every percent increase of access to electricity the Maternal Mortality Rate decreases by 60.672 deaths, if no other factors are taken into consideration.

Based on the regression results that every percent increase in access to electricity decreases the MMR by 60 deaths, future predictions of the MMR in Rwanda indicate that if the same pattern continues regardless of any other factor, a fulfilment of SDG 7 would mean that the MMR in Rwanda reaches a
value of 0. If the electrification rate would increase at the same rate the coming fifteen years as the past fifteen years, reaching an access rate of approx. 37%, the MMR in Rwanda would according to the regression equation still reach a value of 0%.

4.4. Symptoms of Acute Respiratory Infections among children under five.

The years of measurement for this indicator range from 2005 to 2015. With an initial value of 17.1 % of children under five with symptoms of Acute Respiratory Infection the value decreased down to 3.7 % and then increased up to 5.6 % in 2015 as is illustrated below (Fig. 15).

![Graph of ARI development](attachment:image)

**Fig. 15.** Illustration of the development of children under five with symptoms of Acute Respiratory Infections in Rwanda, 2005 – 2015. (NISR 2006; 2012; 2016)

The correlation coefficient between the development of access to electricity and Acute Respiratory Infections has a correlation value of -0.659 indicating a weak negative correlation. This means that increase in the access to electricity is to a smaller extent associated with a decrease in symptoms of acute respiratory infections among children under five. The coefficient of determination (R²) of 0.434 indicates that 43% of the variance in the dependant variable (ARI) can be explained by the independent variable (access to electricity).

A simple linear regression was calculated to predict the development of symptoms of Acute Respiratory Infections in Rwanda based on access to electricity (Fig 16). With a p-value of 0.027 a regression equation was found with a R² of 0.434. The regression can be formulated as illustrated in the figure below: Ŷ = -0.613X + 16.257. This indicates that for every percent increase of access to electricity the symptoms of Acute Respiratory Infections decreases by 0.613 percent.
As the correlation coefficient between Acute Respiratory Infections and access to electricity is found to be as low as 0.659 and an insufficient value of the coefficient of determination of 43%, the regression equation is not applicable to predict the future development of this indicator.

4.5. Female Literacy Rate, age 15-24

The years of measurement for this indicator range from 2005 to 2015. With an initial value of 79.6% female literacy rate of women in the age of 15-24 the value increased up to 88.9% in 2015 as is illustrated below (Fig. 17).

The correlation coefficient between the development of access to electricity and female literacy rate has a correlation value of 0.932 indicating a strong positive correlation. This means that increase in the access to electricity is strongly associated with an increase in the female literacy rate among women 15-24 years of age in Rwanda. The coefficient of determination ($R^2$) of 0.869 indicates that 87% of the
variance in the dependant variable (Female Literacy Rate) can be explained by the independent variable (access to electricity).

A simple linear regression was calculated to predict the female literacy rate in Rwanda based on access to electricity (Fig 18). With a p-value of 0, a significant regression equation was found with a 0.869. The regression can be formulated as illustrated in the figure below: Ŷ = 0.584X + 76.609. This indicates that for every percent of increase in access to electricity the percentage of female literacy in the age-group 15-24 increases by 0.584 %, if no other factors are taken into consideration.

\[ y = 0.584x + 76.609 \]
\[ R^2 = 0.8688 \]

Based on the regression results that every percent increase in access to electricity increases the female literacy rate of women aged 15-24 by 0.58%, future predictions of this indicator indicate that if the same pattern continues regardless of any other factor, a fulfilment of SDG 7 would mean that the female literacy rate of women aged 15-24 reaches 100%. If the electrification rate would increase at the same rate the coming fifteen years as the past fifteen years, reaching an access rate of approx. 37%, the female literacy rate of women aged 15-24 in Rwanda would according to the regression equation still reach 100%.

5. Discussion

This chapter is divided into two sections. The first section (5.1) discusses the results from the literature review and the second section (5.2) discusses the results from the statistical analysis.

5.1. Literature review

As previously presented in the results chapter the range of indicators that has been linked to access to electricity in previous research ranges over all aspects of sustainable development, although with less environmental indicators represented. The literature review acknowledged economic indicators as having a prominent role in the previous research within the field of study. An explanation to why economic indicators has been highly represented in previous research may be due to the advantages in measurement, as poverty, productivity, growth and employments rates use well established units of
measurement, enabling the researcher to perform studies on the development of these indicators. These units of measurements such as GDP growth and poverty rate has additionally been used for measurement for a relatively long time, which further enables researchers to study longer periods of data. The representation might also be explained by an actual change in these indicators leading to more research being performed as means for identifying why and how these developments occur. As research is naturally cumulative, identification of relevance of studying economic indicators in relation to electrification generates further research in the same field of study.

The reason to why poverty and electrification to a lesser extent than the other economic indicators was represented in previous research may be due to poverty being portrayed as the end result while growth, employment and productivity are directly affected by electrification measures, which in turn can have an impact on poverty. However poverty has been identified in previous research as linked to electricity access which may be due to poverty being one of the major goals set by the international community and posing as one of the most commonly used measurement for human socio-economic development, hence an interest of identifying this particular relation.

Similar to the economic indicators, social indicators are highly represented in previous research. Although in contrast to the economic indicators, social indicators have generally less established units for measurements. Dealing with social indicators therefore often involves more qualitative aspects of measurements and data collection which can have implications on their use in statistical analysis. Among the social indicators identified, security is an example of an indicator problematic to quantitatively measure as it alludes to people’s feelings and perceptions.

However, the complications of dealing with people’s perceptions is relatively limited when assessing the social development indicators found in the previous research, as many of them explore more quantitative ways of measuring social development. This may be explained by their strong representation in health related issues, since health indicators often have a more quantitative approach of measurement. As health related indicators are generally measurable they are also to a high extent represented as SDG indicators which may also be a factor to why more research is done on these issues. Attendance of skilled health staff at delivery, Maternal Mortality Ratio, symptoms of ARI and female literacy rate all represent social indicators of which statistical data is available and measurable, which might be a reason to why they are represented in previous research. In addition to the ability to quantitatively measure health related social indicators as being a factor to why they are represented in previous research, their evident relation to electrification can be considered as a strong determinant.

Previous research on how environmental development indicators are affected by the rate of access to electricity, is scarce. This can possibly be explained by the fact that electricity access in itself have little evident environmental impacts, rather the form of energy generating the electricity used. The environmental impact depend highly on the energy source as e.g. fossil fuel dependant energy production often is considered as having a negative environmental impact in contrast to renewable alternatives. Possibly more research is performed on the issue on source of energy rather than the environmental impact of gaining access to electricity.

The only environmental indicator identified in previous studies can be found within the issue of deforestation. Even within the research of this development indicator’s relation to electrification, there is uncertainty of whether or not a link can be found. Due to the inconclusive relation between access to electricity and deforestation ant that no other indicators could be identified, no environmental indicators were used in the statistical analysis of the development in Rwanda.

5.2. Statistical analysis

5.2.1. Poverty rates
In the case of poverty and extreme poverty rate, a very strong correlation was found which indicates that the development of the poverty rates and electrification rate has developed in a co-integrated
fashion. As the $r^2$ value indicates, 87% of the change in poverty rate and 89% of the change in the extreme poverty rate can be explained due to the change in the rate of access to electricity. In the case of poverty rates it can be very controversial to position the poverty rates as being the dependant variables in this scenario as it might as well be the rate of access to electricity that is affected by the poverty rates as decreased poverty enable communities and households to afford to gain access to electricity. Sometimes that might be the case, and the two variables might even develop simultaneously in a co-dependant relation. However, as the purpose of this study was to investigate how electrification measures may affect other development indicators and the fact that previous studies has identified electrification to affect poverty rates, this relation has been investigated although not proclaiming that a causal relation is present.

According to the results from the statistical analysis the poverty rate in Rwanda is decreasing by 1.47% for every percent of increase in access to electricity, while extreme poverty rate decrease by 1.68%. As the previous literature examined does not provide any statistical data of this sort, these results may extend the current understanding of the relation between the indicators in a theoretical sense. In the study by Fan et al. (2005) the main outcome of their research was that the probability of living in poverty increased when there was no access to electricity, while the results from this study provide some indication that access to electricity can have a decreasing effect on poverty which corroborates more with the study by NORAD (2013).

The results from the regression equations on poverty and extreme poverty indicate that if SDG 7 is reached by 2030 in delivering universal access to electricity poverty and extreme poverty in Rwanda should be eradicated. In the case of poverty rate this is highly unlikely, since very few places have completely eradicated poverty even though they have 100% access to electricity since several other factors have an effect on poverty. Unpredictable events such as natural disasters, financial crises or political instability may impact the poverty rate and interfere with the relation between access to electricity and poverty.

The rate of extreme poverty has in the 14 years of analysis decreased by more than half from 40 to 16% which suggest that the probability of eradicating extreme poverty in Rwanda might be plausible, even without taking into consideration a universal access to electricity. When adding the estimated effect of electrification on extreme poverty rate to the goal of gained universal access to electricity, an eradication of extreme poverty in Rwanda may be reached.

Although the results do not provide any applied value, they can provide value in a theoretical sense as they can be useful in combination with other calculations of other indicators. In order to provide more valuable insight on the relation between access to electricity and poverty rates, several other indicators should be implemented into the calculations to provide a more elaborate and comprehensive understanding of the relation. The conclusion that can be drawn from the results is that increased rates of access to electricity suggests an effect in poverty rates in general, although the regression results does not provide valid indication for predicting future development of poverty rates. In order to make any assumptions based on the statistical results, additional indicators should be implemented into the analysis.

### 5.2.2. Attendance of skilled health staff at delivery

The second development indicator selected for the statistical analysis was the percentage of attendance of skilled health staff at delivery. As previous research has recognised access to electricity as having such a significant impact on the development of this indicator, the assumption of the causal direction of this indicator is more valid. In contrast to the case of poverty rates, there is a more apparent relation between these indicators as the probability of the percentage of attendance of skilled health staff at delivery affecting the rate of access to electricity in Rwanda being highly unlikely. The fact that the percentage of this indicator has shown such significant increase since the year 2000 reaching up to
over 90% in 2015 indicates that there probably are other factors affecting this development other than the rate of access to electricity as the electrification rate has not had the same development.

A very strong positive correlation was found for the relation of the indicators which in combination with its recognition in previous research as being affected by access to electricity, further strengthens the indication of electricity as an enabler of increased attendance of skilled health staff at delivery. According to the regression result, the percentage of attendance of skilled health staff at delivery increase by approx. 4 % by every percent increased access to electricity in Rwanda. This result corroborates with the report by the World Bank and World Health Organisation (2014) as well as the report by Voluntary Service Overseas (2012) as both reported on access to electricity as a crucial factor in the fast development of the attendance of skilled health staff at delivery. Further, the results from this study extends to the understanding of the relation by providing the specific increase of the attendance of skilled health staff that can be expected as a result from electrification. These numbers could be applied to national development strategies in other countries as indicative measurement of their development. Although the same relation of the indicator can’t be expected outside the context of Rwanda, the results provide some indication of expected outcomes from electrification measures.

An explanation to why this indicator has developed at a rate much faster that the increased rate of access to electricity could be that health facilities in some cases are prioritized in the electrification process. As rural communities gain access to electricity, the health care facilities are often prioritized due to their importance to the community (WB 2017). Additionally, communities with health care facilities are often prioritized over communities without health care facilities in electrification project. As urban areas often hosts health care facilities to a larger extent than rural areas while also gaining access to electricity at a faster rate, health care facilities might in general experience electrification at a faster rate than Rwanda in general.

As the development of this indicator has increased from 30 to over 90% during the 15 years of analysis the development suggests that 100% might be reached by 2030 even without taking a reach of SDG 7 into consideration. Since the regression results indicate that every percent increase of electricity lead to an increase of this indicator by 4% the probability of reaching close to 100% attendance of skilled health staff at delivery strengthens as this suggests that less than 3% increase of access to electricity should be required.

The key conclusions to be drawn from the analysis of this indicator was that there is a rather significant relation between access to electricity and the percentage of attendance of skilled health staff at delivery in Rwanda which can provide some explanatory value to the impact of electrification. In order to strengthen the understanding of the relation, surveys similar to the one initially prepared to be utilized in this study could provide deeper understanding of the specific changes in the health care facility conditions experienced in recently electrified facilities.

5.2.3. Maternal Mortality Ratio

As portrayed in the literature review, the Maternal Mortality Ratio is closely related to both access to electricity and the attendance of skilled health staff at delivery which makes it additionally interesting for this study. A critique on implementing this indicator into the analysis might be that it is too closely related to the attendance of skilled health staff, although as recognised by both the WHO & WB (2014) and USAID (2014) the attendance of skilled health staff is merely one of many health care facility factors affected by access to electricity which all together have an impact on the decreasing MMR. In other words, access to electricity has a larger impact on the MMR than on the percentage of attendance of skilled health staff at delivery according to the previous studies.

The considerable impact of electrification presented by previous studies evidently isn’t as strong in the statistical analysis of this study as the correlation coefficient end up on a negative correlation of approx. -85. Statistically speaking this is a strong negative correlation, although in comparison to the
correlations of the indicators presented above and its recognition in previous studies it is significantly weaker. This can probably be explained by the high MMR during the first five years of the analysis as the MMR during those years dropped from 1400 deaths to 750 deaths and from 750 deaths to 210 deaths in the following 10 years which result in a large deviation from the regression line during the first five years. Due to these large initial values of the MMR and substantial reduction from 1400 deaths to 210 deaths over the time frame of analysis, the interpretation of the relation to the development of access to electricity is significantly hampered.

The relatively large number of the MMR is also represented in the regression results as they suggest that for every percent increase in access to electricity the MMR drops by 60 deaths per 100,000 live births. Considering that universal access to electricity is reached by 2030, the results from the regression equation indicates that the MMR in Rwanda should have reached lowest possible values. Taking into consideration the dramatic decrease of MMR seen in the past 15 years, this might be a possible outcome.

The conclusion to be drawn from the statistical analysis of this indicator was that electrification to some extent can have an impact on the MMR, although the relatively weak correlation found suggests that additional investigation of the relation is required to find the more specific effects of electrification of MMR in Rwanda. As suggested for the previous indicator, implementing additional forms of data would enable deeper analysis of what specifically is causing the MMR to decrease which would provide further understanding of the impact of access to electricity.

5.2.4. Symptoms of acute respiratory infections among children under five

Among the development indicators selected for the statistical analysis, the development of symptoms of acute respiratory infections among children under five represents the only indicator which has not steadily increased or decreased during the time span for analysis. During the first six years a decrease was reported although the following years reported an increase. As this differs significantly from the development of the rate of access to electricity, the correlation between the indicators result in a weak negative correlation. As the coefficient of determination indicate a value under 50% the regression equation has to be valued as insignificant and not be used to analyse the relation between the indicators.

The insignificant result might be explained by the continued use of traditional sources of energy for cooking and heating even though a household has been electrified. As recognised in the report by the World Bank (2010) and used in the argumentation for a non-relation between electrification and reforestation by Bensel (2008) and Mazimpaka (2014) recently gained access to electricity rarely result in a decrease in use of fuelwood for cooking and heating. This implies that even if universal access to electricity is reached in Rwanda by 2030, it might not have an impact on symptoms of acute respiratory infections. What is necessary for the improvement of this indicator is that electricity is used in a way that improves the living conditions by replacing traditional, polluting fuels like fuelwood, kerosene and charcoal in households. So rather than simply electrifying people with Tier 1 (22 kWh/hh/year) the reliability and quantity of supply is required to increase so as to support electric stoves in order for the electrification measures to have an impact on this indicator.

The over-all development of the indicator show that even if there has not been a stable development, a significant decrease has been reported when comparing the first years of measurement with the last, which corroborates with the results presented by Barron and Torero (2014) as they reported a decrease of ARI of 37 to 44% among electrified households. This may be explained by that a share of the electrified households has reached a level of access to electricity higher than tier 1, leading to a transition to cleaner methods for cooking.
The shift from decreasing to increasing numbers of reported symptoms of ARI in 2011 further contradicts the presumed impact of electricity access on ARI since the rate on access to electricity in Rwanda increased at a faster rate from 2011 onwards. In addition to the suggested dependency of higher levels of access to electricity needed to impact ARI, an additional factor such as an epidemic might have been affecting young children’s ability to withstand infections causing the number of reported cases to increase in the later years. By further analysing the development of ARI in a broader context, taking into consideration additional factors such as the general health status of children and other household conditions better understanding of the development of ARI in Rwanda could be reached.

5.2.5. Female literacy rate, age 15-24

The final indicator chosen for statistical analysis was the development of the rate of female literacy of women 15-24 years of age. Similar results could be seen in the analysis of this indicator as found in the percentage of attendance of skilled health staff at delivery at birth. A positive correlation coefficient of 0.93 indicates a very strong correlation which is further strengthen by a coefficient of determination of 87%. The strong correlation to the rate of access to electricity may be explained by the amount of electricity that is needed for electricity access to have an impact on this indicator. As presented in the study by Daka and Ballet (2011) the indoor lighting made possible when households gain access to electricity impact girls ability to study at home after dark. Since indoor task lighting is made available when households reach tier 1 of electrification, the majority of electrified households can attain the circumstances needed for causing a change in the female literacy rate.

As identified in the previous research on the subject, increased abilities by schools to provide quality education due to gained access to electricity might be an additional factor to the increasing female literacy rate. In contrast to the electricity level required to enable indoor lighting in households, improved educational circumstances in schools often involves implementation of modern educational tools, such as televisions and computers which generally are made available at tier two and three.

If universal access to electricity is reached in Rwanda by 2030, all households and schools are enabled to provide sufficient lighting for girls to perform schoolwork at home, although the possibility of schools to provide modern educational tools is uncertain, depending on the level of access to electricity gained. The results from the regression analysis indicate that universal access to electricity by 2030 should imply a 100% female literacy rate since every percent of increased access to electricity the female literacy rate, age 15-24 increases by 0.6%. Since the female literacy rate already has reached to a level of 89% this is a probability, and according to the previous research in combination to the strong relation identified in the statistical analysis, this may be partially caused by the increasing rate of access to electricity in Rwanda.

6. Summary & Conclusion

As of today 1.1 billion people in the world lack access to modern energy services primarily electricity. This is most prominent in Sub-Saharan Africa where 600 million people (2 out of 3) do not have access to electricity and moderns cooking fuels. Electricity pose as a crucial part of modern society as it is implemented on almost everything we do and need, in terms of services. Without electricity the modern society would fail to support its demand for housing, food production, education and health care as it is based on a continuous and reliable access to electricity.

In recent years there has been considerate advancements in electrification on a global scale as the electricity deficit has declined from 1.3 billion to 1.1 billion while the electrification rate has increased from 77 to 85% globally. Sub-Saharan Africa has reported an increase from 27 to 38% since 2000
although the fast population growth in the region has inflated the number of people lacking access to electricity which is rising (Kanagawa & Nakata 2008; WB 2017).

According to prominent actors within the field of electrification and development the levels and the quality of health services, education, gender equality, indoor environment, and daily activities like lighting, heating, cooking and transportation, as well as business, agricultural, infrastructure and telecommunications sectors may all be linked to access to modern energy services in forms of electricity (IEA 2017; SE4ALL 2016; UN 2016). The United Nations agreed on the 17 Sustainable development Goals (SDGs) with the aim to stimulate action over the next fifteen years in areas of critical importance for ending poverty, protect the planet and ensure prosperity for all. Each one of the goals with its specific targets to be achieved by 2030.

The aim of this study was to gain deeper understanding of the relation between access to electricity and a number of selected development indicators, which has been selected based on their relevance within the field of study according to previous studies. In order to sort out which indicators that can be of importance a literature review has been performed. The indicators selected has then been statistically analysed within a fitting country, Rwanda, in order to gain understanding of how electrification strategies affect development in currently unserved areas.

The literature review of previous research on the subject has found that economic and social indicators were represented to a larger extent than environmental indicators in previous research. As the aim of the thesis was to identify which development indicators that can be of relevance when estimating the impact of access to electricity, the conclusion from the literature review identified the following five indicators as most relevant according to previous research:

- Poverty and extreme poverty rate
- The percentage of attendance of skilled health staff at delivery of birth
- Maternal Mortality Ratio
- Symptoms of Acute Respiratory Infections among children under five
- Female literacy rate among women of 15-24 years of age

The results from the statistical analysis indicated that the increased rate of access to electricity in Rwanda has had an impact on development to some extent. In the case of poverty rates, the estimations of an eventual impact is hampered by the uncertainty of the causal direction between the indicators. Although an evident co-variance could be found which in combination with the previous studies proclaiming electrification to have an impact on poverty, provide some indication of electrification as an enabler of poverty reduction.

In the case of the percentage of skilled health staff at delivery of birth, a strong correlation could be found which corroborates with previous studies and strengthens the assumption of electricity access as an enabler of this indicator. Further conclusions could be made from the results that health care facilities seem to gain access to electricity at a faster rate than Rwanda in general, which could play as an important factor to the significant increase of the percentage of skilled health staff at delivery of birth in Rwanda. If this assumption could be further strengthen through additional research it could provide sufficient incitements for policy makers to promote electrification measurement towards health care facilities as means for reaching SDG 7 and SDG 4.

As MMR has been recognized as being closely related to the development of both access to electricity and the percentage of skilled health staff at delivery, a strong correlation was expected, although according to the statistical analysis results a relatively weak correlation could be found. The weak correlation could possibly be explained by the high initial values of the MMR decreasing from 1400 deaths to 210 deaths over the time frame of analysis. The conclusion suggests that investigation of additional factors affecting the relation is required to find more specific effects of electrification on MMR in Rwanda.

The analysis of the development of ARI indicates that investigating the level of electricity access should provide better understanding of the development due to the large amounts of electricity
required to change the household conditions affecting air quality and ARI. However, the reported numbers of ARI has significantly decreased when assessing the total development during the time period, which indicates that electrification might have had an impact. By further analysing the development of ARI in a broader context, taking into consideration additional factors such as the general health status of children and other household conditions, better understanding of the development of ARI in Rwanda could be reached.

The development of female literacy rate among women age 15-24 indicate a strong relation to access to electricity which could be explained by the low amount of electricity required to have an impact as indoor task lighting is made available for the majority of electrified households. Simultaneously, increasing the access level in schools enabled higher quality of education, identified in previous studies as having an impact. This indicates that increasing the number of electrified households while increasing the level of access for schools should have the largest impact on female literacy rate.

The general conclusion from the analysis is that access to electricity can be related to all of the identified indicators to some extent, although further assessment of the relation is required in order to provide stronger indication of to what degree access to electricity has an impact. Further, reaching SDG 7 by providing 100% access to electricity in Rwanda would have a significant impact on all indicators, which should have positive effects on policy-makers engagement of promoting electrification measurements in favour of advancing the development of the identified indicators.

7. Recommendations for future research

In order to gain further understanding of which indicators that are of relevance when assessing the impact of access to electricity a broader and more comprehensive review of literature should be implemented. Literature reviews are always to some extent limited to the interpretation of the researcher, so by conducting similar literature reviews the conclusions made in this study could be further recognised or falsified depending on the outcome.

Due to the limitations in performing a statistical analysis on social indicators using a simple linear regression analysis, inserting additional indicators could improve the results and contribute to an increased use of the results. As the results from the analysis of poverty rates provided very limited understanding of their relation to electricity access, due to the complex interaction of poverty and other development indicators, additional indicators could strengthen the analysis. By cross-referencing additional economic indicators such as income or employment rates with poverty rates, better understanding of how poverty relates to access to electricity could be reached.

In order to test the accuracy of the conclusions made from the statistical analysis and reach more generalizable results, the same indicators should be analysed within several other countries to assess how the indicators have developed in other settings. If similar developments of the indicators can be identified in other countries or regions, the assumptions would gain stronger evidence. If no similarities can be found, the research could be used to more effectively falsify the assumptions drawn from this study.

Additionally, other forms of research would significantly add value to the research. By conducting a mixture of research methods such as geospatial analysis, survey data analysis and interview, a deeper understanding of the development of the indicators would be able to be reached. The results from this study could be used in such research as a contributor of statistical data specifically for Rwanda, which could be deeper analysed or used as comparison to similar research in other countries.
8. Acknowledgements

First of all I would like to thank Professor Mark Howells for undertaking the supervision of my Master thesis. In addition I would like to thank Dimitrios Mentis for providing me with much useful information and guidance as the evaluator of this thesis.

Moreover, I am very grateful and lucky to have had Alexandros Korkovelos as an additional supervisor during this whole process guiding me through every step of the thesis and being a crucial part of bringing it all together.

In addition I would like to thank everyone at Uppsala University engaged in process of finalizing this thesis, especially Åsa Frisk, Amanda Johnson, Patrik Rönnbäck and Maria Andersson.

I would also like to thank my former colleagues at the Swedish International Development Cooperation Agency for inspiring me to dwell deeper into the field of electrification and development and all the knowledge gained from them.

The support and help from my family has been carrying me through some of the most difficult times during the process, to which I’m ever grateful.

Finally, I would like to express my deepest gratitude to Boonlai Korboon for supporting me during all of these years through my studies. This is for you.
Reference list


Appendices

Regression Results

SUMMARY OUTPUT
Poverty

<table>
<thead>
<tr>
<th>Regression Statistics</th>
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<tbody>
<tr>
<td>Multiple-R</td>
</tr>
<tr>
<td>R-Square</td>
</tr>
<tr>
<td>Adj R-Square</td>
</tr>
<tr>
<td>St Error</td>
</tr>
<tr>
<td>Observations</td>
</tr>
</tbody>
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ANOVA

<table>
<thead>
<tr>
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Coefficients

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Summary output of regression calculations for poverty.

SUMMARY OUTPUT
Extreme poverty

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<td>Observations</td>
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ANOVA

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Coefficients

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Summary output of regression calculations for extreme poverty.
SUMMARY OUTPUT
attendance of skilled health staff at delivery

**Regression Statistics**
- Multiple-R: 0.958
- R-Square: 0.917
- Adj R-Square: 0.911
- St Error: 6.298
- Observations: 16

**ANOVA**

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*Summary output of regression calculations for attendance of skilled health staff at delivery.*

SUMMARY OUTPUT
Maternal Mortality Ratio

**Regression Statistics**
- Multiple-R: 0.853
- R-Square: 0.728
- Adj R-Square: 0.708
- St Error: 196,842
- Observations: 16

**ANOVA**

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*Summary output of regression calculations for Maternal Mortality Ratio.*
### SUMMARY OUTPUT

#### Acute Respiratory Infections

**Regression Statistics**

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*Summary output of regression calculations for symptoms of Acute Respiratory Infections.*

---

### SUMMARY OUTPUT

#### female literacy rate, age 15-24

**Regression Statistics**

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*Summary output of regression calculations for female literacy rate, age 15-24.*