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The Socio-Economic Impact of Renewable Energy in Sub-Saharan Africa

A Ripple Effect Analysis of the ASYV Solar Power Plant in Rwanda

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Preface and acknowledgements

This thesis is written as a part of the double degree program between the Norwegian School of Economics and HEC Paris. The motivation behind the topic is based on our common interest for the intersection between the energy sectors and sustainable development – allowing us to combine and utilize knowledge obtained through both master degrees. Access to sustainable energy has emerged as an important topic on the global level, and it is often highlighted as essential for social and economic growth in developing countries. However, few researchers have investigated the relationship between electricity access and human development indicators in the Sub-Saharan African context. We thus wanted to shed light on this topic. Using a solar power plant located in Rwanda as a key input for our analysis allowed us to gain insight in the Sub-Saharan African power market, which display very different characteristics compared to the Nordic power market. The work was interesting, but also challenging in terms of data collection and establishing dialog with key stakeholders.

There are a number of people that have contributed and supported our work. Firstly, we would like to sincerely thank our supervisor, Stein Ivar Steinshamn, for constructive feedback throughout the writing process. He was always available with advice and provided us with guidance and direction along the way. Secondly, we would like to express our great appreciation to Caroline Sissener and Julie Hamre from Scatec Solar for invaluable insights into the company's operations. In this regard we would like to extend our gratitude to all 10 interviewees for their time and valuable input, which allowed us to incorporate first-hand insight into our thesis. Lastly, our gratitude goes to Rasmus Bøgh Holmen from Menon Economics for his time, patience and vast expertise when providing us with guidance on the typology for our economic impact analysis.

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Abstract

Socio-economic benefits are gaining prominence as a key driver for renewable energy deployment in Sub-Saharan Africa. However, analytical work and empirical evidence on these topics remains relatively limited. In an effort to contribute to this field of knowledge, this thesis conducts a comprehensive ripple effects analysis of the socio-economic impacts that stem from renewable energy deployment in the region. By conducting a case study of the ASYV solar power plant in Rwanda, developed and operated by the Norwegian company Scatec Solar, we identify local socio-economic ripple effects arising from Scatec Solar's procurement spending in Rwanda and the corresponding increased access to clean and reliable electricity for local households and businesses, and assess the value of these effects.

We find that a relatively low share of Scatec Solar's total value creation can be attributed to local suppliers in Rwanda. High dependency on imported products and foreign know-how in all segments of the project's value chain explains this finding. The ripple effects are, however, more substantial in terms of the creation of employment throughout the local value chain. Parallel to the expansion in electricity access, it will be crucial for the Rwandan Government to adapt the right policies in order to capture more of the value generated by foreign direct investments at the local level. Future efforts must be concentrated in sustaining technology transfers into the local economy, strengthening capabilities and promoting innovation in local economic sectors. Cross-cutting measures across all segments of the value chain will provide higher potential for local value creation.

In terms of ripple effects arising from electricity access, we also find that these effects remain modest in the short to medium-term, which contrasts the general belief that electricity is a key driver for socio-economic growth in developing countries. A number of country and region specific factors, like limited market exchange and high electricity tariffs, might explain this contradiction. Our findings suggest that electricity is not a criterion for development, but a facilitator, that in combination with possibilities for market exchange and a competitive electricity tariff can give rise to sustained growth in the long-term.

Abbreviations

AfDB	African Development Bank
ASYV	Agahozo Shalom Youth Village
CAPEX	Capital Expenditure
CDM	Clean Development Mechanism
CPA	Component Project Activity
DRC	Democratic Republic of Congo
EARP	Energy Access Rollout Programme
EBITDA	Earnings Before Interest, Taxes, Depreciation and Amortization
FiT	Feed-in Tariff
FDI	Foreign Direct Investment
IPP	Independent Power Producers
I-O	Input-Output
kV	Kilovolt
KWh	Kilowatt hour
MW	Megawatt
MWh	Megawatt hour
MWp	Megawatt-peak
OPEX	Operating Expense
PoA	Programmes of Activities
PPA	Power Purchase Agreement
PV	Photovoltaic
RE	Renewable Energy
REG	Rwanda Energy Group
RWF	Rwandan Franc
SSA	Sub-Saharan Africa
SWAp	Sector-wide Approach
SE4All	Sustainable Energy for All Initiative

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1. Introduction

Sub-Saharan Africa (SSA) has experienced high economic growth since the turn of the millennium. During the last fifteen years, the region's gross domestic product has more than doubled and the GDP per capita has nearly been tripled (Fjose, 2015). The economic boom of SSA has resulted in a rapidly growing demand for energy. Both residential and industrial demand for electricity is expected to increase further in the coming years in response to the estimated doubling of the region's population by 2040 (Castellano et al., 2015).

Investments in the African energy sector are, however, lagging behind, with almost 600 million people in SSA living without proper access to electricity (Fjose, 2015). The region's rural electrification rate is particularly low at only 17 percent (IEA, 2015). Consequently, solid biomass and kerosene remain the primary energy sources in most areas, accelerating deforestation and the prevalence of respiratory diseases. The hours spent collecting firewood also reduces productivity (Fjose, 2015). In electrified areas, the power supply is often insufficient and unstable. Use of polluting and ineffective diesel generators is therefore common, but raises energy expenses considerably. Castellano et al. (2015) report that the energy costs in SSA are higher than in any other emerging region of the world. This represents a major barrier for the region's business sector, hindering its competitiveness and ability to attract foreign investments.

Access to modern energy[1] is often highlighted as essential to a developing country's economic and human development. According to IEA (2016),

"*access to affordable and reliable energy services is fundamental to reducing poverty and improving health, increasing productivity, enhancing competitiveness and promoting economic growth*".

Existing literature on the socio-economic effects of electrification in developing countries outlines substantial impacts on education, health and income levels (Peters & Sievert, 2015;

[1] Access to modern energy is defined by household access to electricity and clean cooking facilities (OECD & IEA, 2010, p. 8).

Lenz et al., 2015). Furthermore, investing in modern energies creates jobs and improves energy security, while reducing the risk of climate change (SE4ALL, 2016). Energy investments in SSA are thus vital to fuel further growth and prosperity in the region.

Driven by this assessment, many countries are now seeking ways to obtain social and economic growth through the development of the renewable energy (RE) sector (IRENA & CEM, 2014). Through the initiative Sustainable Energy for All (SE4All), the United Nations aims for universal access to modern energy services and a doubling of the RE share in the global energy mix by 2030. This multi-stakeholder partnership brings together public, private and civil sectors to mobilize resources for RE deployment and electricity access programs (SE4ALL, 2016). However, the investment requirements to reach the goals of the SE4ALL initiative are difficult to achieve. Current annual investments in global energy access efforts are estimated at USD 13.1 billion, while the required annual amount is estimated at USD 49 billion in order to achieve universal energy access by 2030 (IEA, 2012). It is anticipated that more than 60 percent of the needed investment would have to be made in Sub-Saharan Africa (Angelou et al., 2013).

1.1 Study objective

The objective of this study is to examine the socio-economic ripple effects of investments in electrification and renewable energy in Sub-Saharan Africa. As indicated, such investments are projected to increase access to electricity, with potentially high impacts on economic and human development. With both the public and private sector committing to invest billions of dollars into electrification and RE deployment in developing countries, we believe that evaluating such investments and their socio-economic impacts is vital for making informed policy and investment decisions.

In spite of the significant investment required and the high number of different development programs related to electricity access and RE deployment, analytical work and empirical evidence on the socio-economic impacts of such efforts remains relatively limited. Only a few studies have evaluated the relationship between electrification access and human development indicators, and the vast majority of these have focused on Asian and Latin American countries (Lenz et al., 2015). Likewise, the impact of RE deployment in developing countries on domestic value creation has been assessed to a limited extent (IRENA & CEM, 2014). With this study we therefore intend to shed light on both the developmental effect of obtaining access to electricity and the local value creation generated through RE deployment. SSA is arguably the region facing the most pressing energy needs yet a region with little evidence on the topic. By focusing on the SSA region, we hope to bring a more comprehensive and empirical-based understanding of the socio-economic impacts of electrification and RE deployment in Sub-Saharan Africa.

1.2 Introducing the case study and its actualization

This study uses the Agahozo Shalom Youth Village (ASYV) solar power plant in Rwanda as a study case in order to analyze the socio-economic ripple effects that stems from RE investments in Sub-Saharan Africa. This approach helps us to limit the scope of our research. The focus on the Rwandan project will make our findings less comparable and transferable to similar projects in SSA. However, many social, political, and economic conditions are similar among countries in the region. This makes us believe that some general conclusions on the impact of RE deployment can be drawn for SSA as a whole by assessing the ASYV case.

There are several reasons why the ASYV solar power plant is a particularly interesting and relevant for this study. Firstly, the fact that it is a large-scale solar PV plant, the first of its kind in Eastern Africa, makes it a relevant case. Solar energy represents the largest primary energy source in SSA with a capacity potential of about 11 terawatts (Castellano et al., 2015). Furthermore, the cost level of solar PV panels and installation has dropped dramatically over the last few years. The significant environmental benefits, high capacity potential and lower costs have increased solar PV's attractiveness and competitiveness compared to conventional energy sources. As a result, scholars have suggested that solar PV will play a critical role in providing SSA with more sustainable energy in the coming years. It is therefore pertinent to focus on solar PV technology.

Secondly, the focus on Rwanda is also a good fit for our study objective. Rwanda reflects in many ways the general socio-economic situation of SSA: the country has strong economic progress, high population growth and is facing immense energy challenges. Combined, these three elements require a greater power generation capacity. Solar power stands out as an attractive energy source in Rwanda as the country relies heavily on diesel generation, which is considerably more expensive compared to solar power (Scatec Solar 2016 website). As late as in 2009, Rwanda had an electrification access rate of only 6 percent (World Bank, 2014). The same year, the Rwandan government launched its plans to multiply the country's power generation capacity and raise the electrification access rate to 70 percent by June 2018 (MININFRA, 2015B). Since then, large investments and good progress have been made. This provides a good base case for analyzing the ripple effects of electrification that can be associated with the investments in the ASYV plant.

The ASYV solar power plant is constructed and operated by the Norwegian solar power producer Scatec Solar in cooperation with Dutch-based Gigawatt Global. Thus, the project's link to Norway has been critical for establishing dialog with Scatec Solar and to access information regarding their operations in Rwanda. Lastly, the fact that the ASYV project was developed in partnership with governmental development finance institutions makes it an excellent example of the type of public-private partnerships that are currently being promoted by the United Nations and other intergovernmental development organizations.

1.3 Research question and clarifications

The research question of the thesis is tied to the case study of the ASYV solar power plant and Scatec Solar's business activities in Rwanda. Motivated by the overall objective of the thesis, where we aim to analyze the socio-economic ripple effects of RE investments in Sub-Saharan Africa, we want to answer the following research question:

What socio-economic ripple effects are generated by the ASYV solar power plant in Rwanda, and what is the value creation of these effects?

As we are focusing on the socio-economic ripple effects in our assessment of the solar power plant, we will also include effects of social and environmental character in our study. We therefore talk about value creation from a sustainable development perspective, which according to IRENA & CEM (2014),

"*goes beyond its traditional economic definition to include a vast array of socio-economic benefits to the society. These include job creation, improved health and education, reduced poverty and reduced negative environmental impacts*".

It is also important to note that we look at socio-economic ripple effects that are exclusive to Rwanda. Thus, any ripple effects that are being generated outside of the country will not be assessed in this study.

Based on the theoretical framework for analyzing socio-economic ripple effects, we will classify the identified effects into a framework of four main categories: direct, indirect, induced and catalytic effects. Scatec Solar's investment spending in Rwanda generates the first three groups of effects. These are all economic impacts, which can be captured by the flow of money that stems from the initial investment of the company. We will use an input-output model based on the Rwandan national accounts from 2011 in order to quantify these effects and the associated value creation within Scatec Solar's value chain in Rwanda.

Secondly, the ASYV solar power plant may generate important socio-economic effects, creating value through downstream activities enabled by the use of electricity. The Rwandan Government's ongoing Energy Access Rollout Program (EARP) is connecting thousands of new households, public institutions and businesses to the electrical grid each year. Thus, ASYV solar power plant is part of ensuring electricity access and supply to these newly connected entities. In the analysis we therefore aim to determine what socio-economic ripple effects are being created through improved access to electricity in Rwanda. Nevertheless, it is beyond the scope of this analysis to quantify the socio-economic value that stems from electricity access and supply in monetary terms; rather, we apply a qualitative assessment to estimate the value of these ripple effects.

1.4 Structure of the thesis

The following chapter will provide the necessary background and context for our research question. It will give a description of the socio-economic conditions in Rwanda, an overview of the Norwegian solar power producer Scatec Solar and the development of the ASYV project. Chapter 3 presents a literature review on the economic impact of foreign direct investments, opportunities for value creation in the renewable energy sector and the impact of electricity on human development indicators. Chapter 4 describes a review on the methodology of ripple effect analysis. We will present different methods that can be applied, and the reasons why we believe an input-output model is the best fit for our analysis. Strengths and weaknesses of our method will also be highlighted. Chapter 5 begins with a presentation of how we have gathered the quantitative and qualitative data, before our findings is presented. Chapter 6 discusses our findings in the light of the literature review, followed by a final conclusion in Chapter 7.

2. Case description

2.1 Rwanda

Rwanda is located in East-central Africa at approximately two degrees south of the Equator (The World Bank, 2016A). The country is landlocked, has an area of only 26 000 square meters and a population of almost 12 million people (UNdata, 2016). This makes Rwanda one of the most densely populated countries in Africa. The population is young and predominantly rural. As of 2012, more than half of its residents were under the age of 17 (Rwanda Data Portal, 2012). These younger generations represent an important source of employment. It further represents a great opportunity as well as a great challenge to create a sufficient number of productive jobs in the coming years.

Figure 2.1 Map of Rwanda (United Nations Geospatial Information Section, 2008).

2.1.1 Economic outlook

More than twenty years after the Rwandan genocide, the country has moved forward from conflict and fragility (World Bank, 2015). With support from the International Monetary

Fund and the World Bank, in addition to strong government commitment, Rwanda has been able to make robust progress on both economic and social indicators. Average annual growth exceeded 8 percent from 2000 to 2015, which was higher than both the world average and the average growth in the Sub-Saharan African region (World Bank, 2016B). Services are the largest contributor to growth, followed by agriculture and industry respectively. As illustrated in **figure 2.2** the growth is expected to be sustained in the coming years. Furthermore, the number of people completing primary school increased from a relatively low level of 50 percent in 2008 to almost 70 percent in 2013 (World Bank, 2016C). This positive trend is also reflected in the increase in youth literacy rate (population between 15-24 years) throughout the same time period (World Bank, 2016D).

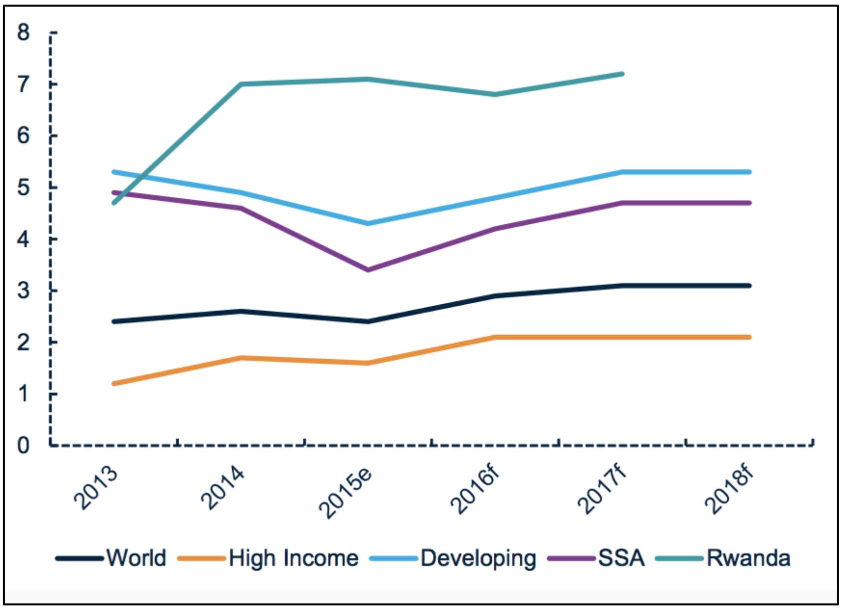

Figure 2.2 Rwanda's growth rate exceeds global and regional growth rates (%) (World Bank, 2016B).

The inflow of foreign aid into the country has been critical in fueling the recent economic and social growth. Financial aid from multiple international donors has amounted to a very high share (30-40 percent) of Rwanda's total budget (World Bank, 2016A). Even though the government has effectively been utilizing aid for development, the economy remains vulnerable to fluctuations in aid inflows. The Rwandan government has therefore been focusing on removing constraints to private sector investment coupled with increasing controls on corruption in order to attract private investors and reduce its dependency of foreign aid (Transparency International, 2014). These measures have resulted in a more favorable investment climate and caused a significant increase in foreign direct investment

(FDI). In 2014, the net inflows in FDI reached a record high of USD 292 million, almost triple the 2011 level (World Bank, 2016E). The government's commitment to attract FDI is also reflected in the country's strong performance in the Work Bank's *Doing Business Rankings* in recent years. In the latest report, Rwanda was ranked second best among the African countries in ease of doing business (World Bank, 2016F). Still, one of the areas in which the country scored notably poorly was access to reliable electricity.

In the last decade, Rwanda has experienced a persistent trade deficit (World Bank, 2016B). The country is a net importer of oil and energy imports account for a considerable share of the total imports. In 2015, trade deficits were reduced by 1.3 percent as declines in commodity prices reduced import spending by USD 67 million. This was largely due to the drop in oil prices, as the value of energy imports fell by USD 78 million, although the overall volume of energy imports increased by 11 percent throughout the same period of time (World Bank, 2016B).

2.1.2 Rwanda's employment landscape

World Bank's most recent report on *"Rwanda Economic Update"* devoted a whole chapter to the employment landscape of the country (World Bank, 2016B). According to the Bank, the total working force (15-64 years old) amounted to approximately 6.7 million Rwandans in 2014. Further data presented in the report is essentially derived from a comprehensive survey conducted by the National Institute of Statistics of Rwanda, which captured the labor dynamics of the year 2011 (NISR, 2011).

As of 2011, more than 70 percent of the employed labor force was engaged in agriculture, reflecting the country's heavy reliance on this sector. A small share of these workers earn a modest wage from cultivating other people's land, a practice referred to as "wage farming" in **figure 2.3**. The remaining share of the occupants work as "independent farmers" and cultivate their own or family land without a wage. The employment landscape therefore translates into remarkably low earnings for the majority of the population, which is reflected in the median annual earnings for all agricultural workers of USD 323. The remaining share of the workforce (30 percent) is either employed by the private or public business sectors (referred to as "non-farm wage employment" in **figure 2.3**) or engaged in independent non-farm related business activities. Common to both employment categories is the prevalence of informal positions.

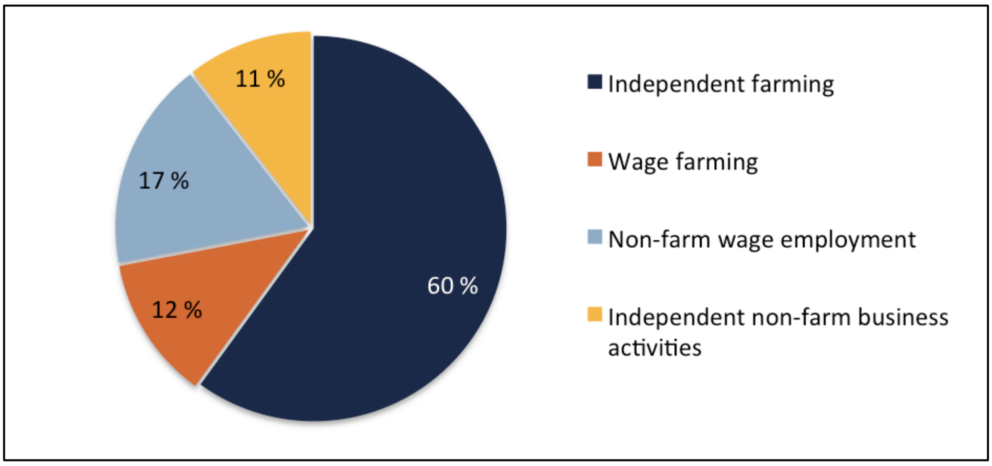

Figure 2.3 Proportion of workers by employment type (NISR, 2011).

Among the most evident trends in the Rwandan labor market are the rapid entry of young workers and the shift towards non-farm occupations. The latter trend can be attributed to the significant increase in the informal sector. Furthermore, underemployment[1] is a key feature of the labor market in Rwanda and has worsened in recent years. Also taking unemployed residents (1.7 percent) into account, close to 2 million Rwandans lack sufficient employment opportunities (World Bank, 2016B).

Rwanda will face great challenges linked to the creation of more productive jobs in the coming years. This is mainly due to the country's increasing population and the substantial move towards non-farm occupations. The rapid increase in the educational level of younger generations will further add pressure to this challenge. As the workforce continue to grow, the labor market will also be increasingly important in aligning overall growth with improvement in households' living standards. The economy will therefore need to transition from an agriculture -and commodity-based economy to that of a more modern and industrialized nation. In order to facilitate this shift a significant improvement in the electricity sector is needed.

[1]The labor statistics metadata handbook of Rwanda defines underemployment as the fraction of employed persons who work less than 35 hours a week, but would like to work more (NISR, 2014B).

2.1.3 Overview over the electricity sub-sector

The electricity sector in Rwanda remains highly underdeveloped and represents one of the major challenges for Rwanda's socio-economic development. According to the latest update from the Rwandan Ministry of Infrastructure, as much as 76 percent of the population is living without access to electricity (MININFRA, 2015B). At an average of 42 kWh per annum, Rwanda also has one of the lowest per capita electricity consumption rates in the world. In comparison, Norway consumed more than 23,000 kWh per capita in 2014 (World Bank, 2014A).

Introduction of the Energy Access Rollout Program

Despite these depressing numbers it is important to note that the electricity sector has made significant progress in the last 10 years. In 2009, The Energy Access Rollout Program (EARP) was launched and implemented by the national Rwanda Energy Group (REG) (World Bank, 2015). This is one of the largest and most comprehensive on-grid electrification programs in the world, and it intends to rapidly extend access to electricity for households, as well as for social and industrial infrastructure. So far, the electricity access rate has increased from 6 percent in 2009 to about 24 percent as of 2016 (The World Bank, 2014; J. B. Mugiraneza, personal communication, April 20, 2016).

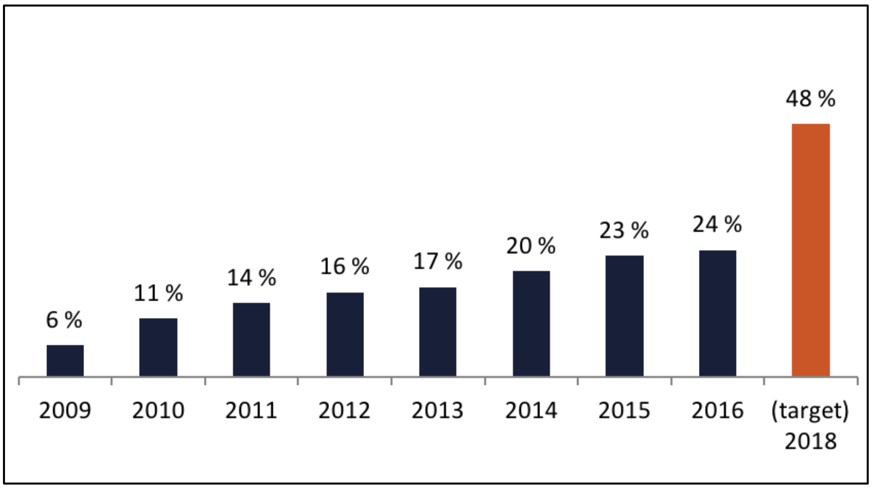

Figure 2.4 Growth in access rate between 2009-18 (%) (RURA Annual Reports 09/10-14/15; J. B. Mugiraneza, personal communication, April 20, 2016; MININFRA, 2015B).

The rapid scale-up of access was made possible due to support from international donors like the World Bank, AfDB and the Government of Netherlands (World Bank, 2015). The success is also a result of very effective governance, in which the Rwandan government implemented a Sector-wide Approach (SWAp) in the electricity sector. This approach coordinates development partners and other stakeholders in an effective manner (World Bank, 2014B).

The government has set ambitious targets for the year 2018. They intend to reach a national access rate of 70 percent, including 100 percent connection to all health centers, hospitals, administrative offices and schools (MININFRA, 2015B). The plan calls for 48 percent access through on-grid connections and the remaining 22 percent through off-grid connections, with the EARP solely focusing on the grid component. As indicated in **figure 2.5**, the targeted areas for grid electrification, the infrastructure will have to be expanded into more rural areas. This means that households living far below the official poverty line will be connected in the coming years. Although the total connection cost has decreased from over USD 1000 to around USD 550, the households only pay USD 72 to be connected to grid (Y. Semikolenova, personal communication, April 27, 2016). The rest is subsidized by the government. The repayment scheme is also designed in a way that allows households to pay the total connection fee in several installments. This makes it more achievable for poor households to connect to the national grid. However, the low consumption rates of these households will challenge the financial viability of the program in the coming years.

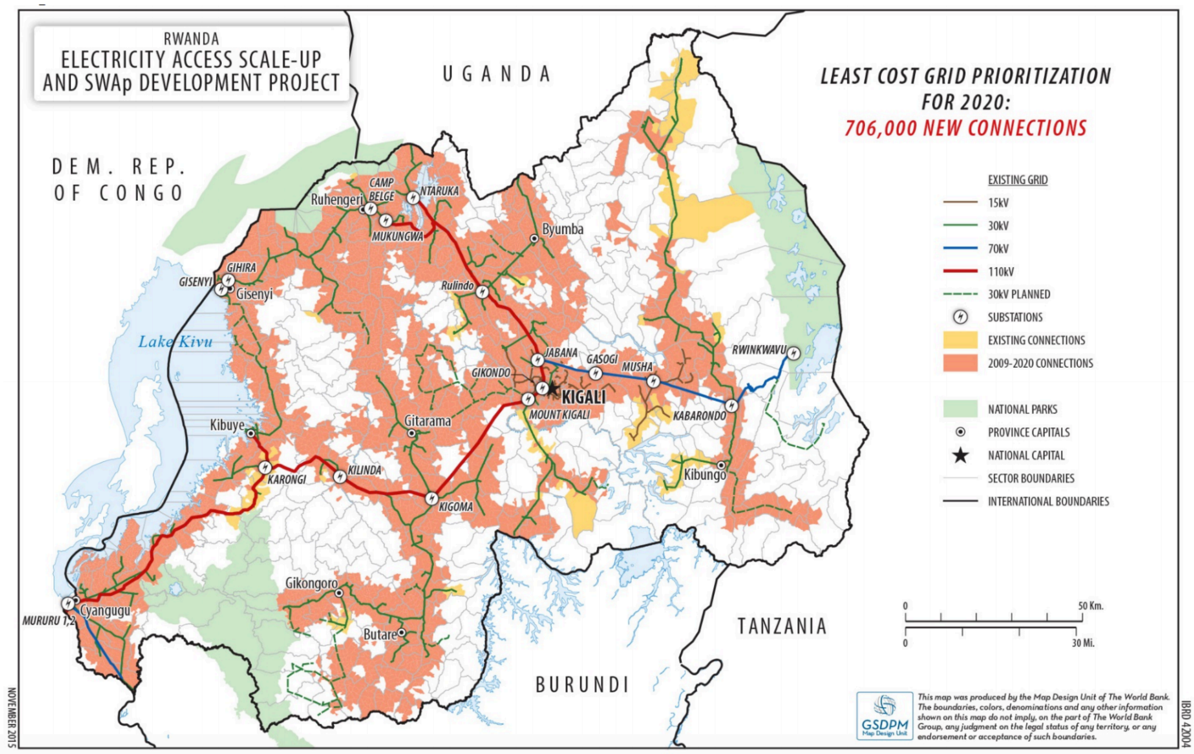

Figure 2.5 EARP electrification map (World Bank, 2015).

Parallel increase in generation capacity

With additional households connected to the grid, demand for electricity will rise and a parallel increase in generation capacity is needed. The government intends to increase total power production capacity from 186 MW in 2016 to more than 563 MW within 2018, supported by an upgrade of existing interconnections with neighboring countries (MININFRA, 2015B; J. B. Mugiraneza, personal communication, April 20, 2016). Rwanda is already an active member of the East African Power Pool and interconnections between Rwanda and DRC, Burundi, Ethiopia and Uganda are currently under construction (Batena, 2015). Rwanda also started to import electricity from Kenya in 2015 and intends to gradually increase imports in the coming years (Betena, 2015). The development of domestic power generation is currently dominated by Independent Power Producers (IPPs), in which private producers contracts with the Rwandan Utility through a long-term Power Purchase Agreements (MININFRA, 2015A). Acceleration in foreign investment has mainly been driven by attractive policies, including tax incentives and other guarantees offered by the Rwandan government (J. B. Mugiraneza, personal communication, April 20, 2016).

Since the mid-2000s, Rwanda has also imported expensive fossil fuel resources from neighboring countries in order to operate thermal power plants and close the gap between electricity supply and demand (MININFRA, 2015B). Given the landlocked nature of the country and the poor or even non-existing infrastructure, the transport costs of imports are extremely high (IRENA, 2014). The reliance on imported fuel products has been one of the key factors driving the high cost of electricity in Rwanda, and the country is currently facing one of the highest electricity tariffs in the world (AfDB, 2013). With an electricity tariff of around USD 0.21 per kWh, Rwandan households pay almost 10 times more than Norwegian consumers (Rwanda Development Board, 2015; SSB, 2016). With more than 60 percent of the population living below the global poverty line of USD 1.90 per day, most households cannot afford to finance high consumption rates (Y. Semikolenova, personal communication, April 27, 2016). AfDB argues that the high electricity tariffs constitute a bottleneck to the expansion of economic activities in Rwanda, which in particular affects the exporting business sectors who are exposed to regional competition (AfDB, 2013). Even though households and businesses are facing high tariffs in the commercial market, the prices remains highly subsidized by the Government as average cost of production in Rwanda is around USD 0.32 per kWh (Y. Semikolenova, personal communication, April 27, 2016). As of 2015, the government's annual electricity subsidies stood at approximately USD 37 million (Batena, 2015). Arguably, this considerable gap between generation and consumption tariffs is not be sustainable in the long run (Y. Semikolenova, personal communication, April 27, 2016).

The dependency on oil imports increases not only electricity prices in Rwanda, but it also represents a potential threat to the country's energy security and increases the likelihood of future geopolitical conflicts. As large parts of the imported petroleum products are transported from Mombasa in Kenya via pipelines and road transport to Rwanda, the supply is vulnerable to political instability in the region. As an example, the oil supply from Kenya was stopped completely in January 2008 due to post-election violence in the country (AfDB, 2013). This illustrates the importance of reducing dependency on oil-fired thermal power production.

Exploiting renewable resources

The government has over the last decade been focusing on developing domestic alternatives to diesel imports and increased investments in alternative energy sources. Renewable resources play a vital role in Rwanda's current energy mix, with 43 percent from hydro, 4 percent solar and 16 percent methane gas (RURA, 2015; J. B. Mugiraneza, personal communication, April 20, 2016). Although solar power only constitutes a modest share, it is gaining a stronger foothold in the generation mix. Rwanda is located close to the equator with abundant sunshine and monthly average radiation ranging from 4.2 to 5.3 kWh per square meter. Thus, solar energy has a considerable potential (Safari and Gasore, 2007). Favorable geographical features coupled with the accelerating cost reduction and innovation in solar technologies in recent years has made solar electricity systems a more competitive alternative to both hydro and thermal power. The future prospects of solar technology deployment in Rwanda face challenges given the large area requirements for solar plants and the country's hilly topographic profile. However, the hilly landscape and the size of the area required to build a large scale solar plant challenge the future prospects of solar technologies in Rwanda. Most of the available land area is used for agricultural production, thus increasing the alternative value of land in the areas suitable for solar parks. Still, a further exploitation of solar resources is believed to reduce Rwanda's reliance on imported fossil fuels and depress the high cost of electricity going forward (J. B. Mugiraneza, personal communication, April 20, 2016).

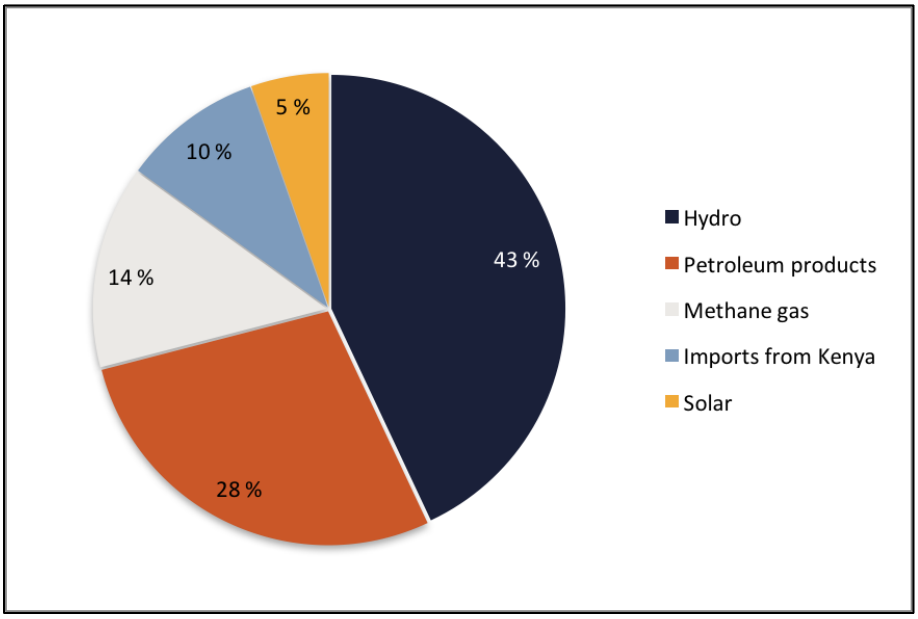

Figure 2.6 Total electricity generation by energy source (RURA, 2015; J. B. Mugiraneza, personal communication, April 20, 2016).

2.2 Scatec Solar and the ASYV project in Rwanda

Scatec Solar was founded by Alf Bjørseth in 2007 and is headquartered in Oslo, Norway. The company runs an integrated business model specialized in developing, constructing and operating photovoltaic (PV) systems. They are mainly exploring first mover opportunities in emerging PV markets by focusing on large, utility-scale solar PV installations. The company operates 426 MW of installed capacity in South Africa, Rwanda, Czech Republic, Jordan, Honduras and USA. Its project backlog and pipeline consists of more than 1.5 GW under development in the Americas, Africa, Asia and the Middle East (Scatec Solar, 2016C). All plants are considered large-scale, on-grid installations and produce electricity for sale under 20-25 year fixed priced power purchasing agreements (PPAs) or Feed-in-Tariff (FiT) schemes (Scatec Solar, 2016A).

Scatec Solar states that sustainability is an integral part of the business model and has identified three principal focus areas related to sustainability measures. One of these focuses is the company's social and economic contribution to local value creation in the communities where they are present (Scatec Solar, 2016A). Increasing access to electricity is highlighted by the company as its most significant contribution to local value creation. Scatec Solar also supports a variety of other development initiatives in local communities (Scatec Solar, 2015B). For instance, the company is committed to use local labor and suppliers as much as possible, exceeding what is included in local legislation. This contributes to reductions in unemployment rates and provides knowledge transfers to the local communities (Scatec Solar 2016A).

2.2.1 The ASYV project

The ASYV solar power plant is the first large-scale, grid-connected solar PV power plant in East Africa. Scatec Solar is the operator of the plant and owns it together with Norfund (the Norwegian Investment Fund for Developing Countries) and the Dutch-based renewable energy company Gigawatt Global. Scatec Solar is the majority owner and holds an ownership share of 57 percent in the project. It is located in the Rwamagana District, approximately 9 kilometers from the main Kigali-Kagitumba highway and about 60 km from Kigali (UNFCCC, 2015A). The solar power plant is located on the grounds of the Agahozo-Shalom Youth Village and the plant is therefore referred to as ASYV. The actual name of the project is Gigawatt Global Rwanda. However, throughout this study we refer to the power plant as the ASYV solar power plant or simply the ASYV project. The ASYV village is a residential and educational community for youth orphaned during and after the genocide in 1994 (Agahozo-Shalom Youth Village, 2016). The solar power plant consists of 28,360 solar PV modules, covering 17 hectares of land. Its peak output capacity is 8.5 MW_P (direct current) and the plant is designed to deliver 7.7 MW_{AC} (alternating current) to the grid. When the plant was commissioned in 2014, the added capacity of the ASYV project increased total generation capacity in Rwanda by 6 percent, sufficient to power more than 15,000 households with clean electricity (Gigawatt Global, 2015).

The ASYV project was initiated by the developer Gigawatt Global in 2012 and Scatec Solar entered the project in 2013. A power purchasing agreement (PPA) with the Rwandan utility company REG was signed in July 2013, and was guaranteed by the Government of Rwanda. Scatec Solar became responsible for the engineering, procurement and construction (EPC) activities after the financial close in February 2014. The plant was commissioned in late July 2014, and opened commercial production on 1 August, only 12 months after the signing of the PPA (C. Motzen, personal communication, March 3, 2016). The financing of the ASYV project was brought together by several international partners. Senior debt financing was made available by the Dutch development bank FMO and the Emerging Africa Infrastructure Fund (EAIF), and equity was provided by Scatec Solar, Norfund and KLP (Norfund, 2016). The project also received grants from public funds in Finland and the United States.

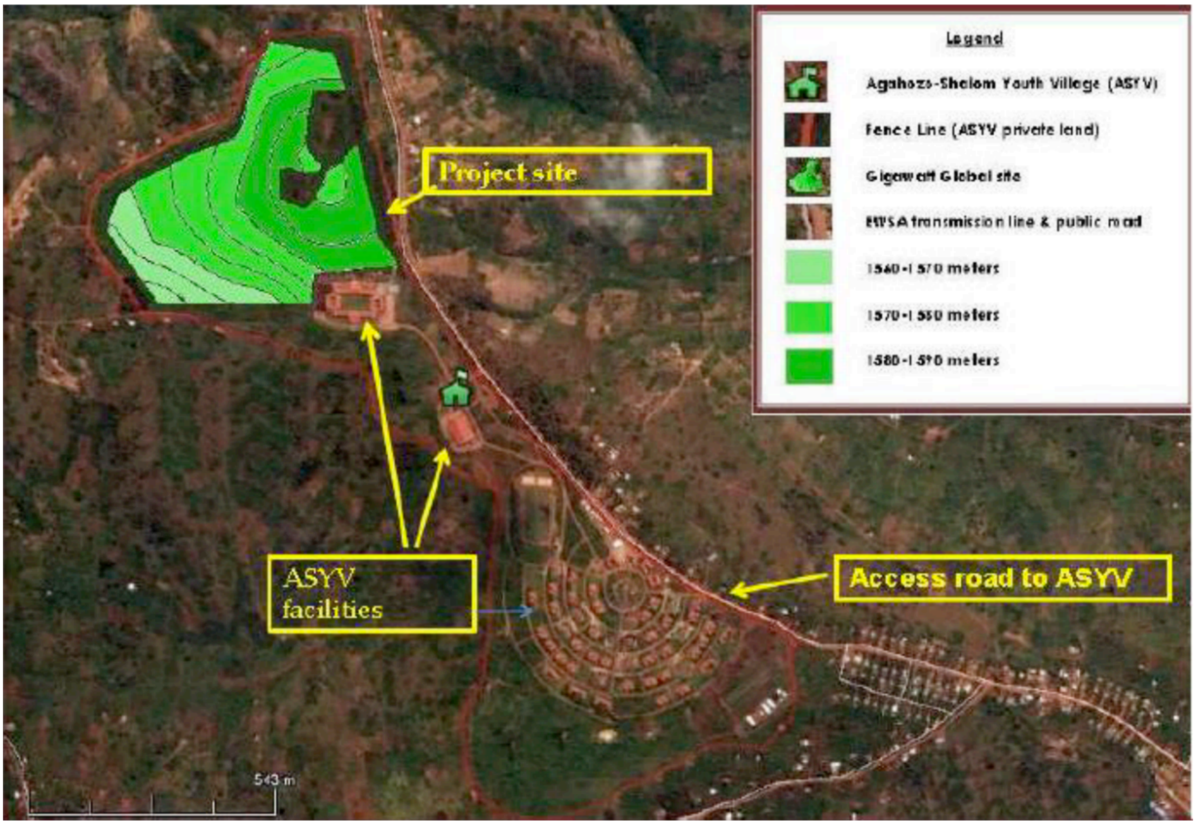

Figure 2.7: Site location of ASYV and the ASYV solar power plant (UNFCCC, 2015B).

The project is registered as a Component Project Activity (CPA) type 1 under UNFCCC's Clean Development Mechanism Program of Activities, meaning the power generation reduces CO2 emissions in the country by displacing electricity generated by fossil fuel powered plants (UNFCCC, 2015A). The annual production of 15,500 MWh reduces annually 8,000 tons of CO2 (Scatec Solar, 2016A). However, there is no criterion that the certified emission reduction credits coming out of the project would be transferred to the countries that provided the funding (UNFCCC, 2015A).

The ASYV project has received a wide range of international attention, both in the media and among international development donors and investors. The project has been highlighted as best practice of efficient and successful execution of an energy investment project in Sub-Saharan Africa. It is frequently used by the Rwandan Government as a showcase to attract foreign direct investments to the country (C. Motzen, personal communication, March 3, 2016). The solar power plant was opened by the Norwegian Prime Minister Erna Solberg, and has later on received several prominent visits, including the Irish musician and philanthropist Bono, and the former prime minister of the United Kingdom Tony Blair. Key stakeholders outline that apart from providing Rwanda with highly needed electricity, the legacy of the successful execution of the ASYV project and its transfers of know-how and technology to Rwanda are valuable contributions to the country's socio-economic development.

Construction phase

A large part of the total construction costs of the ASYV project is related to procurement spending on solar PV panels produced in China. Local procurement spending in Rwanda consisted of contracts with three individual subcontractors, which supported the installation, civil works and management of the project (C. Sissener, personal communication, March 3, 2016; T. Green, personal communication, April 11, 2016). The construction of the solar power plant imposed few adverse effects on its surroundings. Some existing vegetation on the site was cleared during the construction in order to enable optimal operation of the solar modules. Trees that were cut down were replanted in other areas and the cleared sections were landscaped with natural vegetation after the installation of the modules (UNFCCC, 2015A). Although the area around ASYV was already connected to the central grid by a 15 kV transmission line, a new 9 km long transmission line between the plant and the Musha substation was constructed by REG in order to minimize power losses due to transmission inefficiencies (UNFCCC, 2015A).

Scatec Solar reports that 380 temporary jobs were created in Rwanda during the 6-month construction period. Approximately 300 of these positions were employed by Rwandan nationals, most of them being unskilled (C. Sissener & C. Motzen, personal communication, March 3, 2016; T. Twagirimana, personal communication, March 21, 2016). All local employees were trained and received a diploma on completion of the project work, which describes the tasks performed. Scatec Solar reports that this diploma can later be used as documentation and as a reference for future job applications (Scatec Solar, 2015B). Chaim Motzen from Gigawatt Global also pointed out that the unskilled workers were paid more than the minimum wage and that the project covered health insurance during the time of employment.

Current operations

The ASYV solar power plant has an expected annual production of 15,500 MWh, and generated 13,817 MWh of electricity in 2015. All electricity produced is sold to the Rwandan utility company REG through the PPA. The PPA is guaranteed by the Government of Rwanda and ensures a stable and predictable return from the electricity generation. It was one of the first agreements to be negotiated with an independent power producer in Rwanda, and was the first to come into operations (C. Motzen, personal communication, March 3, 2016). The agreement has a duration of 25 years and involves an agreed upon tariff for each year of the agreement, adjusted by inflation in the given year. Due to the high confidentiality of the exact tariff levels in the PPA, this information was not disclosed by Scatec Solar. However, Scatec Solar expects annual revenues of NOK 23 million from the annual sales of 15,500 MWh (Scatec Solar, 2016D). Consequently, we can expect an average tariff of USD 0.18 per kWh over the total 25 years of the PPA contract. This estimate is based on the Norwegian central bank's USD-NOK average exchange rate of 2015 (1 USD = 8,0739 NOK; Norges Bank, 2016).

As the operator of the ASYV plant, Scatec Solar employs two full-time operators on-site, responsible for the operation and maintenance (O&M) activities on a day-to-day basis. In addition, approximately 5-10 local workers are employed on a needs-basis for different O&M tasks, such as cutting grass and cleaning of the modules. The solar plant also employs 9 security guards who work in double shifts throughout the day (C. Sissener, personal communication, March 3, 2016). The developers of the ASYV project point out that the training of local operators of the solar power plant is considered an important contribution to transfers of knowledge and state-of-the-art technology to Rwanda (UNFCCC, 2015A). Students at the youth village have also received training at the plant and the site is open for students coming from technical colleges all over Rwanda to learn more about the solar PV technology (T. Twagirimana, personal communication, March 21, 2016).

3. Literature Review

In this chapter we present relevant literature for our research question. The first part of the review is related to the economic impact of foreign direct investment (FDI) upon developing countries. This literature will support our analysis of the ripple effects generated by Scatec Solar's investment in Rwanda. The second part of the chapter reflects on the opportunities for value creation in the renewable energy (RE) sector. This will build on a comprehensive review on the topic conducted by the International Renewable Energy Agency and the Clean Energy Ministerial (IRENA & CEM, 2014). The third and last part of the chapter focuses on the socio-economic impacts of improved electricity access in developing countries and will support and supplement our analysis of the ripple effects that stems from electrification.

3.1 The economic impact of FDI in developing countries

Many Sub-Saharan countries lack adequate financial and technological resources to foster a sustained socio-economic development. Although international aid constitutes the largest contribution to external financial inflows into the African continent, attracting alternative finance is believed to be increasingly important in order to close the resource gap (UNCTAD, 2005; Ayanwale, 2007). The World Bank defines FDI as:

"*a category of cross-border investment associated with a resident in one economy having control or a significant degree of influence on the management of an enterprise that is resident in another economy*" (World Bank, 2016G).

Throughout the last three decades, the inflow of FDI into the African continent has grown dramatically in response to increasing economic globalization, higher capital mobility and integration of financial markets (UNCTAD, 2005). In recent years, slow global economic growth has also made the faster-growing African economies relatively more attractive.

In response to the rise in FDI and the expected benefits there has been an ongoing debate regarding the economic impact of FDI in developing countries. The effect is widely discussed in both the theoretical and empirical literature.

3.1.1 Endogenous innovation in neoclassical growth models

In theory, the Solow model suggests that FDI increases the capital stock and thereby stimulates growth in the host country (Brems, 1970). In neoclassical growth models with diminishing returns to capital, FDI only has a short-term effect on growth as the host economy moves towards a new steady state. In contrast, endogenous growth models assume that FDI introduce new technology in the production function of the host country (Borensztein et al., 1998). The entire production function therefore shifts outwards. The technological "spill-overs" thereby offset the effect of diminishing returns to scale and cause a long-run growth effect.

Introducing new knowledge and technology in physical infrastructure may also reduce what Romer (1993) refers to as "idea gaps" between developed and developing countries. From this perspective, FDI may boost productivity in all sectors, not just those receiving external investments. This is reflected in UNCTAD's latest World Investment Report, as the recent FDI inflows in the electricity sector in the Sub-Saharan African region has stimulated further FDI inflows in other sectors of the host economy (UNCTAD, 2015).

3.1.2 Empirical literature on FDI

The economic impact of FDI in developing countries remains more contentious in empirical than in theoretical studies (Adams, 2009). Among the empirical studies indicating that FDI has a strong positive effect on growth rates are Johnson (2006), Lumbila (2005) and Noorbakhsh et al. (2006). Johnson (2006) performed both a cross-sectional and panel data analysis on a dataset covering 90 countries during the period from 1980 to 2002. The results indicate that FDI has positive effects on economic growth through two different channels, namely capital inflow and technology spillovers. Likewise, Lumbila (2005) applied a panel data analysis on data from 47 African countries over the same two decades and found a positive effect on economic growth. The author concludes that FDI can represent a key contribution to economic development and in accordance with Johnson (2006); he attributes the effect to the spillover of technology. Thus, these results are perfectly in line with the endogenous growth theory presented above. Another comprehensive study by Noorbakhsh et al. (2006) focuses instead on the interaction between FDI and the human capital of the host country. The authors find evidence of FDI driving local employment through the creation of modern job opportunities.

Other empirical studies argue that the effect of FDI on economic growth is dependent on initial conditions in the host country. These conditions are believed to determine the country's *"ability to acquire, internalize and utilize"* the external technology that is made available to them via FDI (Habiyaremye and Ziesemer, 2006). For example, Borensztein et al. (1995) argue that a minimum threshold stock of educated workforce is needed for the host country to grasp the benefits from FDI. However, the authors also emphasize that the training required to prepare the labor force to work with new technologies suggests that there also exists a positive effect of FDI on human capital accumulation. Further, Prasad et al. (2003) find evidence of good institutional framework and high control of corruption being decisive for the extent to which a FDI can stimulate long-term growth.

A number of studies also indicate a non-significant or negative effect of FDI on economic growth. Akinlo (2004) investigates the impact of FDI on economic growth in Nigeria throughout the period 1970–2001 and finds that foreign capital has a small and insignificant effect on economic growth. These findings are supported by a more recent study by Ayanwale (2007). However, Akinlo points out that the bulk of FDI in Nigeria has been conducted in the primary industry (particularly in the oil sector), which is highly disconnected from the rest of the economy. His results further indicate that larger growth-effects can be expected from FDI placed in the manufacturing or service industry. Likewise, De Mello (1999) estimates the impact of FDI on factor productivity growth using a large sample of OECD and non-OECD countries in the period 1970-90. The results indicate a negative growth effect of FDI in non-OECD countries. He suggests that this effect may be linked to country-specific factors such as institutions and political regime, in which underdeveloped institutions inhibit the transfer of technology and knowledge.

Although the body of empirical literature indicate conflicting evidence regarding the impact of FDI on long-term economic growth in developing countries, the bulk of the evidence indicates a positive relationship. In line with the endogenous development theory, the empirical findings show that FDI allows the host economy to grasp advantages arising from capital inflow, cutting edge technological processes and employment possibilities that may not be available in the host market. Further, the impact of FDI is determined by country specific conditions such as basic network of infrastructure, institutions and level of corruption.

3.2 Opportunities for value creation in the renewable energy sector

In this section we outline in which areas opportunities for value creation of RE deployment exist. The IRENA report "*The Socio-economic Benefits of solar and Wind Energy*" (2014) written in cooperation with the Clean Energy Ministerial (CEM), presents a comprehensive review of how value can be created along the value chain of RE sectors. This section will thus build on the concepts presented in the report and further elaborate on the possibilities for value creation in the solar PV sector.

The RE industry is cross-sectional as it involves activities in various sectors of the economy. Thus, in their report, IRENA & CEM employ a so-called "value chain approach" to identify the opportunities for value creation in the different segments of the value chain of the RE sector. At each stage, value is added to the product by different sub-products and sub-processes, which are either conducted by the RE company itself or by its suppliers. Value creation can thus be generated in all parts of the value chain, by having all different agents contributing to the final product either directly or indirectly.

3.2.1 Opportunities for domestic value creation along the value chain

A central question to the assessment of value creation in a RE sector is to what extent the value creation is being generated locally where the RE project is located, and how much of the value is a result of imported inputs. This depends on the maturity of the RE sector in the country where the project is being realized. Domestic economies that cannot supply the needed inputs to the value chain, must import either the needed material or expertise. In the following we present the opportunities for value creation in the different segments of the RE value chain, with emphasis on the solar PV sector. We will be looking at opportunities within the planning stage, manufacturing, installation, grid connection, operation and maintenance.

Planning: The project-planning phase includes activities within resource assessments, feasibility studies, and planning of infrastructure. Experienced and specialized personnel are required to conduct such activities. With many RE projects being developed in a country, the level of domestic know-how and expertise can be expected to be substantial, which places a large share of the value creation during the planning stage to the country. Where the RE sectors are less mature, it is more likely that foreign consultants are engaged in the planning. Enhancing education and training is thus important to bridge the gap of skills that exists in some cases, in order to retain the value creation at the local level. In the solar PV industry, the planning phase mainly consists of the planning and projecting of modules, which can be undertaken by the installer or a project developer.

Manufacturing: At the manufacturing stage, a certain degree of industrial capability in the country is necessary to generate value creation locally. If so, manufacturing can generate value in all its processes and offer large job creation potential depending on how technically advanced the different production processes are. A Japanese study on the employment potential related to manufacturing, construction, operation and maintenance of solar PV and wind power technologies shows that employment in manufacturing stands for approximately 70 percent of overall employment for both PV and wind (Matsumoto et al., 2011).

The manufacturing process in the solar PV sector includes the production of the PV modules, from silicon and components for the balance of system (inverters, mounting systems, combiner box and other electrical components) (IRENA, 2012). Manufacturing of PV cells and modules is mainly driven by technology innovation and economies of scale. Energy costs are also an important aspect for the development of a PV manufacturing industry, while labor costs play a less significant role as production is highly automated. In the recent years, the manufacturing of PV systems has been concentrated to Asia due to large investments made in production capacity in order to exploit the scale potential in the production (IEA, 2014).

Installation: The installation process relates to the construction and assembling of the renewable power plant, and the coherent infrastructure works. This phase includes labor-intensive civil engineering, infrastructure work including groundwork, foundations, channeling, water supply, buildings and roads, which are typically delivered by local companies. Complete system installations are more complicated to conduct when it involves imported equipment, which is often the case when installing solar PV modules. The manufacturers of the modules are therefore often involved in the installation activities with their own equipment and personnel. This leaves less work for local companies. Still, local companies can participate in delivering required services especially if the expertise already exists in the local area.

Grid connection: It is usually the local grid operator (TSO) that is responsible for the grid connection of a power plant. The task of grid connection includes planning work, such as developing a cabling and grid connection concept, and the following on-site construction and cabling work. Since these activities are conducted locally, usually by the local grid operator, the possibilities for domestic value creation are large. Furthermore, as the construction works includes ground works, cable production and installation, local companies can become involved in these tasks, by that creating jobs and local value. Lastly, value might also be generated as the grid is strengthened and expanded. This will increase the energy access and the security of supply.

Operation and maintenance: The operation and maintenance (O&M) segment involves long-term activities with high potential for value creation, especially in terms of jobs. Value is first of all generated for the power plant owners through the sale of electricity. The operational activities comprise day-to-day tasks such as monitoring the plant operation, responding to faulty events and coordinating with the utility. Maintenance activities include both scheduled services, such as periodic equipment inspections, and unscheduled services to repair components in case of failure (Walford, 2006). As all these activities more or less must be conducted on-site, O&M offers opportunities for domestic value creation for all countries, independently of their local RE manufacturing capabilities and degree of RE deployment. In the case of solar PV plants, regular maintenance is required, including the inspection of the electrical installations, structural repairs, check of the measuring, safety and transmission system, cleaning of the modules and keeping the site accessible. These activities are mainly conducted by local workers. However, the technical O&M activities might be required to be conducted by the manufacture or high-skilled technical staff.

Decommissioning is mentioned by IRENA & CEM (2014) as the last segment of the value chain, which comprises the disposal and recycling of materials. These processes also generate economic activities, which may contribute to local value creation depending on the skill level required for the management of these activities. We will, however, not elaborate further on this final segment of the value chain in our analysis.

Value creation in supporting processes: IRENA & CEM (2014) further elaborates on value creation in supporting processes to the value chain of RE projects. The mentioned supporting processes in the report are policy-making, financial services, education, research and development and consulting. Strengthening these processes may enable further value creation in the RE value chain.

Focus on policy-making is important to create an enabling environment for RE investments in a country. Hence, setting the right policies is considered a first step to facilitate RE investments and may boost value creation at an early stage. As there are high upfront costs associated with RE deployment, financial services that accommodate RE investments are vital to create an enabling environment for RE projects. Focus on education and training is needed in order to develop and operate RE projects successfully. Building a high skill level on RE technologies may further attract more investments in the RE sector, which increases the level of local value creation. Building up local research and development on RE technologies may not add much value creation initially, but has the potential to generate substantial value over time. Furthermore, transfer of know-how and technology could lead to positive externalities, which benefits the society as a whole. Lastly, as the RE sector in a country evolves, and education and skill levels improve, value creation can also be generated through consulting activities which are needed to support all segments of the value chain.

To sum up, the domestic value creation in the different segments of the RE value chain depends on the overall development level of a country's RE sector. Countries with a nascent RE sector have a medium to high potential for domestic value creation in activities such as O&M and grid connection, but have low potential in the other segments of the value chain. When the RE sector develops and if components are produced locally and not imported, opportunities for value creation increase along all segments of the value chain. In countries with a matured RE sector and many developed projects, value creation also improves through activities in economic sectors not directly associated with the RE value chain, such as in R&D and consulting. An overview of the potential for value creation along the different segments is presented in a summary table in the IRENA & CEM report, as shown in **table 3.1** below.

Table 3.1 Potential for domestic value creation on the stage of industry development (IRENA & CEM, 2014).

Potential for domestic value creation	Stage of development		
	Beginning of RE development	First projects realised, local industries suitable for participating	Many projects realised, national RE industries developing
Value chain segments			
Project planning	Low	Medium	High
Manufacturing	Low	Medium	Medium/High
Installation	Low	Medium	High
Grid connection	High	High	High
Operation & maintenance	Medium	High	High
Decommissioning	Low	Low	Medium
Supporting processes			
Policy-making	High	High	High
Financial services	Low/Medium	Medium	High
Research & development	Low	Low/Medium	Medium
Education and training	Low/Medium	Medium	Medium/High
Consulting	Low	Low	Medium

3.2.2 Further opportunities for value creation

In the same report, IRENA & CEM (2014) identifies a few other variables related to the deployment of renewable energies that generate opportunities for value creation. From this, we want to present the potential for value creation stemming from changes in trade balances, energy system related externalities and reduction of risks.

Starting with changes in trade balances, RE deployment may affect the trade of energy products in a country, such as fossil fuels, and the trade in goods and services related to RE. Especially for countries dependent on fossil fuel-imports, RE deployment can be a valuable alternative as it enables large economic savings. Spain and Germany are two countries that have invested heavily in renewable energies and annually save billions of USD on reduced fossil fuel imports. Furthermore, IRENA & CEM states that domestic RE sources could especially benefit countries with large trade balance deficits caused by high dependency on energy imports. It can also reduce pressure on government budgets in countries with subsidized fossil fuel consumption.

Policies that reduce imports of fossil fuels could in the same way make a country dependent on imports of RE equipment. In the worst case, this could lead to a zero or even negative effect on the trade balance. However, the imported RE technologies would allow for import reductions of fossil fuels for a considerable period of time, hence in the long run the effect on the trade balance is likely to be positive.

There are several positive externalities[1] associated with RE deployment; especially the environmental benefits related to RE deployment are considered valuable externalities. Other positive externalities can be related to technological spillovers, transfers of skills and know-how from the RE sector to other economic sectors in the country. This creates value for the society as a whole, something which is not fully reflected in the prices that the creating firms demand in the market (Mitchell et al., 2011). However, IRENA & CEM (2014) points at ways for decision makers to internalize such externalities as a means to support renewable energy deployment. Carbon pricing is one way of doing that.

RE deployment may generate risk reduction effects, which enable considerable value creation potential. IRENA highlights such risk reduction effects associated with RE deployment to reductions of accidents and environmental hazards, technical, geopolitical and financial risks. Although the potential of such risk reductions usually are not accounted for in RE projects, their contribution is highly valuable and may save the society for large costs. Firstly, RE deployment imposes low risks in terms of accidents and environmental disasters (oil spills, air pollution and hazardous waste) compared with other energy sources such as fossil fuels and nuclear power. It further reduces technical risks as RE systems are more decentralized in nature which lower the threat of supply disruptions. However, the intermittent nature of REs makes them not a fully reliable energy source. Geopolitical-related risks (also referred to as energy security risks) may also be lowered by RE deployment. This is largely related to countries importing large amounts of fossil fuels to cover their energy needs, as these become less dependent on imports from others. This can be important in order to avoid potential conflicts with energy exporters and possible supply disruptions. Lastly, financial risks are related to the price volatility of fossil fuels, which is

[1] OECD (1993) defines externalities as situations when the production or consumption activity of one party imposes costs or benefits on third parties that are unrelated to the activity.

relevant for both energy importing and exporting countries. RE deployment makes countries less vulnerable for such price fluctuations and introduces more predictable energy costs.

3.3 The relationship between electricity and socio-economic development

Access to electricity is widely believed to contribute to economic and social development (UN, 2010). The underlying assumption of this belief is that access to electricity can enhance quality of life at the household level and stimulate the economy at a broader level (Khandker et al. 2013). Intergovernmental organizations and financial institutions have therefore supported electrification program in many developing countries. In order to justify the international donor support, the impacts of rural electrification have received a lot of attention in the recent years. A number of studies have attempted to empirically test the relationship between rural electrification in developing countries and socio-economic indicators.

3.3.1 Empirical evidence from the developing world

The bulk of the existing literature is based upon evidence from Asia and Latin America; although some impact studies have also been conducted in Africa (Dinkelman, 2009; Jacobsen, 2006; Lenz et al., 2015). Researchers argue that electricity has a positive impact on development through the effect on the three components of the Human Development Index (HDI) and the environment. In the remaining part of this subchapter, we will present relevant evidence from a number of influential papers from the developing world.

Income is by far the most studied impact indicator throughout the body of literature. Papers examine how electrification affects household income through the usage of electrical appliances and engagement in non-farm activities that in turn, will stimulate business activity and improve productivity at the broader level. Two recently published studies from India found a strong positive relationship between electricity and firm and household earnings respectively. Rud (2012) found that electrification explains a significant proportion of the variation in manufacturing output across Indian states, while Van de Walle et al. (2013) found evidence of a significant increase in both the consumption and income level of households. Evidence of positive effects on household income is also found in Brazil (Lipscomp et al., 2012) and Vietnam (Khandker et al., 2013).

In the African context, studies on the effects of electricity on household income give conflicting results. Dinkelman (2011) found a substantial increase in female labor supply in the wake of electrification in South Africa. She ascribes this effect to the shift from using wood to the use of electric cooking and lighting. This allows women to save time on fuel collecting activities and can thus devote more time to productive work. On the contrary, Jacobsen (2006) found that electricity only supports economically productive activities to a very small extent in his study in Kenya. His results show that the central driver for electricity demand is the desire to use "connective appliances" such as television and telephones.

Educational performance is the second most studied impact indicator. Positive effects on enrollment rates and years of completed schooling are found in several studies from Asia and Latin America (Van de Walle et al, 2013; Khandker et al, 2013; Lipscomp et al, 2012). Furthermore, researchers have also examined how electrification effects the time children spend studying after school. Positive effects on the study time of children are found in two separate studies from Bangladesh (Khandker et al., 2013; Samad et al. 2013) and El Salvador (Barron and Torero, 2014).

Health indicators are analyzed to a much lesser extent, mostly due to lack of quantitative data (Peters and Sievert, 2015). There are, however, two papers analyzing the usage of kerosene lamps as a lightning source in Bangladesh and El Salvador respectively (Samad et al. 2013; Barron and Torero, 2014). Both studies found a substantial reduction in the use of kerosene in households with access to electricity. The latter further analyzed the indoor air quality and found a significant improvement in the concentration of harmful pollutants in connected households. The authors attribute this effect to the observed reduction in kerosene usage.

Although few papers address the relationship between electricity access and the environmental impacts, Heltberg (2004) found a strong link between electrification and the uptake of modern cooking fuels in eight different developing countries. The effect is strongest in urban areas and near major roads. The author argued that shifting from biomass fuel to modern energy has a significant environmental benefit through the reduction of forest degradation. In a comprehensive review from 2004, the World Bank supported this claim by concluding that electricity provision has a positive impact on wood fuel consumption in many African countries (ESMAP, 2001). Renewable electricity generation is also critical to address concerns about climate change issues and reduce emissions of greenhouse gases.

Thus, large amounts of emissions can be avoided through renewable energy deployment that replaces fossil electricity generation mainly from diesel generators (IRENA, 2015; Fjose, 2015).

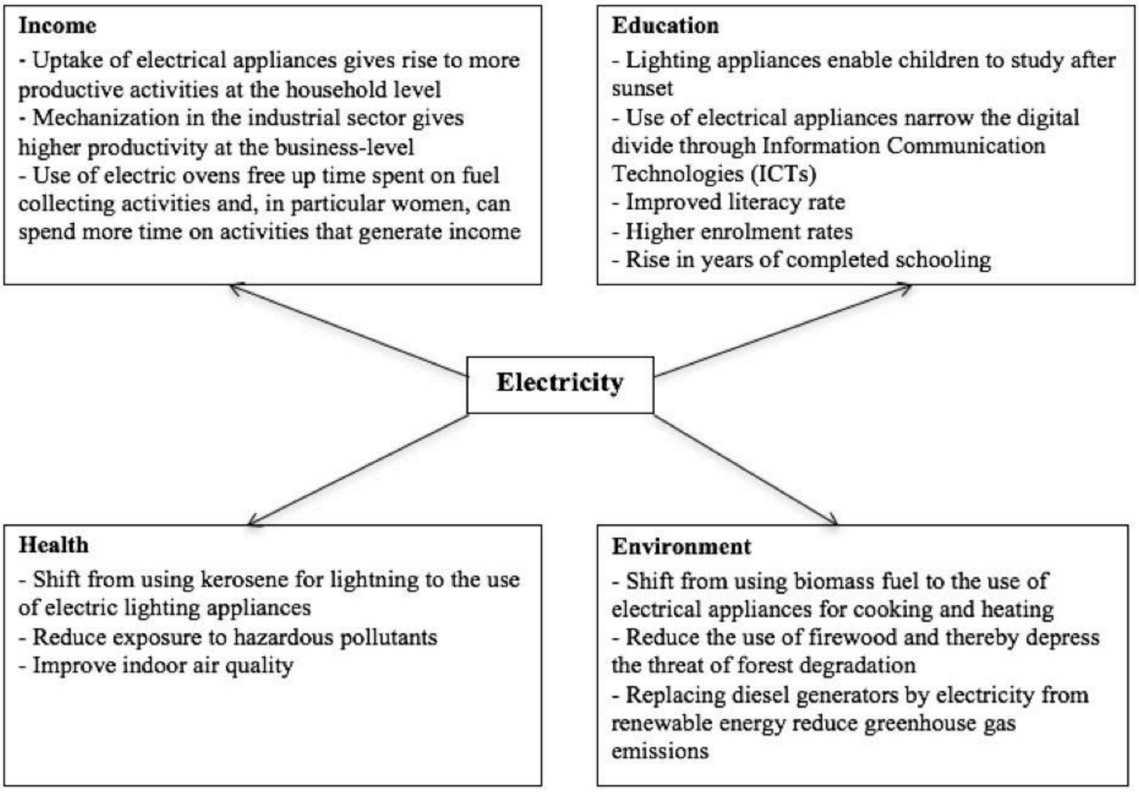

Figure 3.1 Summary of empirical evidence from developing countries (Source: Kanagawa and Nakata, 2008).

3.3.2 Evidence from Rwanda

In recent years, the Netherlands and the World Bank Group have initiated impact studies upon the Electricity Access Rollout Program (EARP) in Rwanda to evaluate and monitor the effects of their financial support to the program. The most recent and relevant study on the impact of rural electrification in Rwanda was published in 2015 (Lenz et al., 2015). This study was conducted by researchers at the German economic research center, Rheinisch-Westfälisches Institute (RWI), in cooperation with a local researcher from Rwanda.

Their analysis is based on both qualitative and quantitative surveys conducted between 2011 (baseline study) and 2014 (follow-up study). The researchers obtained a list of all communities that was scheduled to be electrified between 2011 and 2012 from the Rwanda Energy Group (REG). A proportion of 30 communities was drawn from this sample and included as the treatment group. 20 communities that were scheduled to receive electricity after the follow-up in 2014 served as a control group in the experiment. These communities are located in the same region as the ones in the treatment group and all 50 communities were included in EARP's target group. Hence, there is reason to believe that observed differences between the two groups are due to electrification and not due to other factors. The methodology used was a difference-in-difference approach, in which time-invariant differences between the control and treatment group were controlled for. The study includes the impact on households, schools, health centers and local SMEs. The study therefore gives a complete picture of the impact of rural electrification on all the beneficiary groups in the rural communities.

Welfare: Lenz et al. (2015) pointed out that the most immediate effect of electricity access in Rwanda comes through high-quality lightning, as all grid connected households use electricity as a lightning source. This increases the total time household members are awake during the day by 20 minutes on average. Furthermore, it allows people to change their daily routines as activities that were carried out during the day before, can now be conducted in the evening.

Apart from lighting, electrical appliances such as TV, radio, and mobile phones are more prevalent among electrified households compared to non-electrified households. These entertainment appliances free households from boredom and thus significantly increase their well-being. Lenz et al. (2015) also found that news is the most preferred program for TV owners and serve as the main source for information for electrified households. Moreover, the increase in mobile phone usage enables households to communicate with people outside the province. The two latter findings illustrate how electrification is links rural households to the outside world.

Income: The study also devotes a lot of attention to the impact of electrification on the income indicator. Income effects of electricity access are related to increased income levels among households and businesses. Electricity access allows people to use electric appliances and machinery to increase productivity and offer new products and services. On-grid electricity is also a cheaper energy source than kerosene, diesel, and other fossil fuels. Hence, households and businesses with access to electricity are able to consume energy at lower costs (per kWh).

In contrast to evidence from Asia and Latin America, there is only evidence of a modest to low effect on income among households and businesses in Rwanda. Lenz et al. (2015) found that very few households seem to adapt a productive use of electrical appliances. This observation can be explained by the low consumption levels among electrified households, as the authors find that connected households only consume 11 kWh per month, on average. The authors point at low household income as the most important obstacle for increased electricity consumption. Therefore, the majority of households do not generate enough income to support and sustain the amount of electricity needed to power more advanced electrical appliances. Their limited budget also limits the purchase of more expensive appliances. However, electricity seems to trigger a few income-generating activities that do not require a substantial amount of electricity. For example, households renting out mobile phones and the use of TVs and DVDs to operate small-scale cinemas.

Electricity access also seems to have moderate to low effects on the business environment. Lenz et al. (2015) found that enterprises like mills, hairdressing shops, welding shops and copy shops are more prevalent in connected communities compared to unconnected ones. Thus, the findings indicate that some enterprises emerge post-electrification. Common to all the emerging enterprises is the use of an electrical appliance in their daily operations. Access to grid-electricity enables these enterprises to operate at lower costs as it substitutes spending on fuels to run generators.

Electricity access also allows existing businesses to adapt to certain changes. The pathway in which these changes translate into higher income is illustrated in **figure 3.2** below. The availability of better lighting, and use of communication and entertainment devices enables existing enterprises to extend their operation hours, increase their range of offered products and services, and attract more customers. The use of electricity further implies savings in terms of money and time. The sum of these benefits cumulates into higher business productivity and profitability.

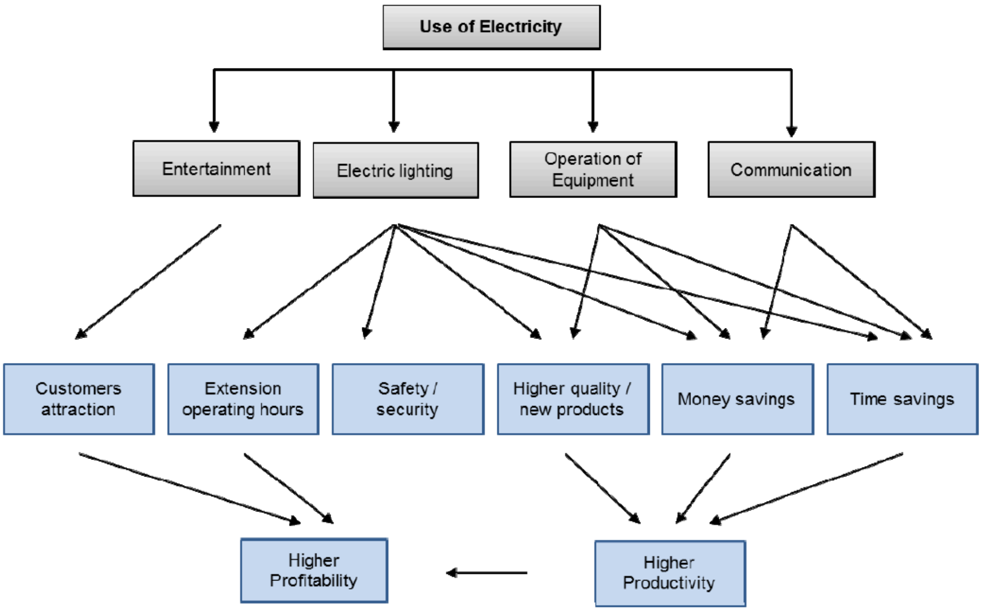

Figure 3.2 Pathways from electricity access to income in local SME's (Lenz et al., 2015).

Lenz et al. (2015) point out that the observed effects on existing businesses are most visible in communities that already had a vivid business center before electrification. This suggests that sufficient demand and a market size serve as vital conditions for increased income at the enterprise level.

Education: The adoption of high-quality electric light has a direct effect on a child's study time. Lenz et al. (2015) found that children in connected households study between 20 and 37 minutes longer after nightfall. The effect is present for both girls and boys. However, the total study time does not increase significantly. This suggests that children in connected households simply shift their study time from daytime to nighttime.

In contrast to evidence from Asia and Latin America, Lenz et al.'s (2015) estimates do not indicate an increase in school attendance among connected households. Qualitative interviews with teachers also supported this finding. However, there is evidence of connected schools having a higher availability of electrical appliances. For example, connected schools use computers for more administrative tasks and some also for educational purposes (computer classes). One third of the connected schools also offer classes after sunset, while none of the unconnected schools offer this.

Health: In terms of the impact on health at the household level, the authors examine the use of kerosene. The transmission channel here is that the use of kerosene leads to emissions of soot that is proven to be harmful for the people exposed (Chilcott, 2006). In their sample, the electrification treatment leads to a substantial reduction in the use of kerosene lamps. 40 percent of all connected households report that the air quality has improved the last two years. Most of these families ascribe this effect to the reduced use of kerosene lamps and the benefit of having electricity. On the other hand, households still use firewood and coal for cooking. Thus, access to electricity has not increased the prevalence of electric stoves in Rwanda in contrast to strong evidence from South Africa (Dinkelman, 2009).

In contrast to the rest of the literature, Lenz et al. (2015) also studied the impact of electrification on health centers. They found robust evidence of a reduction in energy expenditure as centers shift from generators and/or solar panels to grid electricity. However, the use of appliances is not significantly different between connected and unconnected centers. This is because all health centers included in the sample have access to electricity prior to grid connection, either by using a generator or distributed solar panels. The benefit of grid electricity comes through increased electricity capacity and convenience, allowing hospitals to use a range of appliances simultaneously. In addition, the qualitative health center surveys revealed that grid electricity attracts more qualified employees, which in turn increases the quality of services.

Environment: The authors also devoted some attention to the impacts on the environment. They found that connected households reduce their use of battery driven LED lamps. Batteries are usually not recycled and thus thrown in nature. This constitutes a potential hazard to the environment and eventually people's health. Although the usage of LED lamps in Rwanda is modest, the technology has made remarkable inroads into Sub-Saharan rural markets in recent years (Peters and Sievert, 2015). The expected shift from kerosene lamps to LED lamps among unconnected households represent a substantial environmental threat. Furthermore, Lenz et al. (2015) did not find any evidence of connected households shifting from biomass to electric ovens for cooking and heating purposes. This finding stands in contrast to what Heltberg (2004) found in his study. Thus, it is unlikely that electrification in Rwanda contributes to a reduction in deforestation. When it comes to impacts on GHG emissions, the RWI studies did not assess whether electrification reduces usage of diesel generators.

Figure 3.3 illustrates the main findings of the RWI studies. The most immediate effect of electrification is shown by the adaption of a range of electric appliances by the beneficiary groups. This gives rise to benefits in the form of time savings and energy cost reductions.

Furthermore, higher welfare on the household level and better income opportunities at the business level are shown as the short- and medium-term effects of the use of electrical appliances. The authors point out that the final impact on the components of HDI are ambiguous and impossible to measure given the limited period over which the study had been conducted.

The impact findings from other developing countries, presented in **figure 3.1**, cannot directly be transferred to the Rwandan context. The evidence from Rwanda indicates that the welfare of households is the level that benefits the most from electrification. The impact evaluation reveals modest changes in income, and more substantial changes in educational and health indicators. The role of electricity is only modest in supporting economic activity at the enterprise level, although not insignificant. Limited market demand is pointed out as a major obstacle for businesses to reap the benefits offered by grid electricity. In terms of the impact on schools, the largest effect comes through an increase in the productive use of electrical appliances. Health Centers are able to attract more qualified staff, reduce the cost of energy, and use a range of appliances simultaneously. The environmental impact evaluation indicates a reduction in the use of battery-driven LED lamps among connected households.

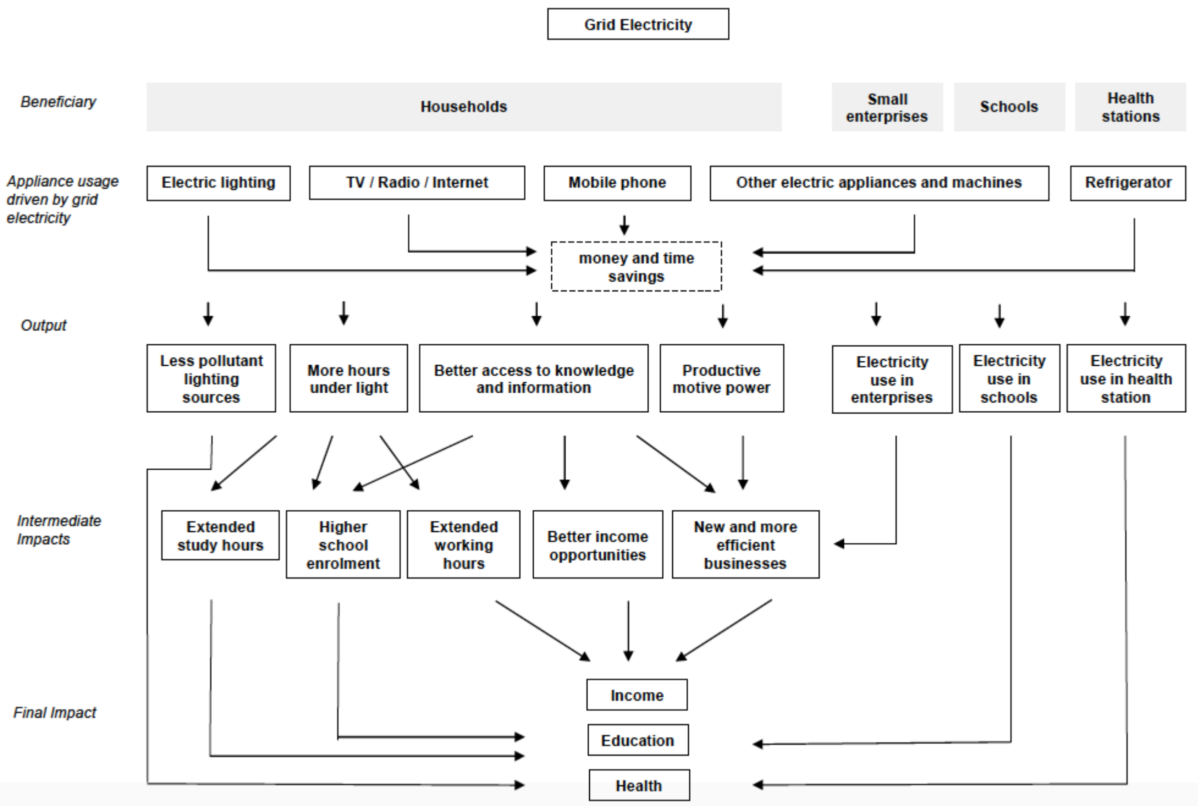

Figure 3.3 Pathways from electricity access to socio-economic impact (Lenz et al., 2015).

4. Methodology

The purpose of this chapter is to provide an introduction to ripple effect analysis and the quantitative economic methods that can be applied for this purpose. In the first subchapter we present a conceptual framework and coherent typology that can be used to identify and classify socio-economic ripple effects. The presented concepts are based on existing frameworks and models that have been employed in economic impact studies of energy-related industries. Among these, we particularly focus on concepts developed by Menon Economics (Fjose & Grünfeld, 2012; Holmen et al., 2015), Kjærland et al. (2009; 2010; 2012), and IRENA & CEM's (2014). In the second and third subchapters we present different analytical methods that can be applied in a ripple effect analysis. Here, we especially focus on the input-output (I-O) model, which is the quantitative economic model we apply in our ripple effect analysis of the ASYV solar power plant in Rwanda.

4.1 A theoretical framework for ripple effect analysis

In its simplicity, a ripple effect is a situation where ripples expand across water when throwing an object into it. The term is thus often used to describe how a single action affects other entities. The notion of ripple effects is multidisciplinary and its definition varies across disciplines. In economics, the term is often used to describe the impacts of a certain business activity, enterprise or industry on the economy. However, the literature does not give any clear definition of the term and scholars tend to define ripple effects in various ways (Kjærland et al., 2012). In this study, we base our understanding of ripple effects on Menon Economics' definition:

"*a ripple effect is an economic effect from an initial state or change in state that can be followed outwards in the economy from the initial shock or state incrementally"* (Holmen, 2014).

Identifying socio-economic ripple effects of economic activities is becoming increasingly common among organizations and enterprises. This is partly driven by more stringent reporting requirements on social accounting in various countries. The objective of such reporting is usually to showcase how enterprises contribute to increased demand in the economy, improving job creation and social welfare (Kjærland et al., 2012).

The scope of ripple effects varies throughout the different stages of an economic activity. Ripple effects from the construction period of a power plant will diminish once the construction is completed. Other, more long-term effects will be generated once the plant becomes operational (Henriksen & Sørnes, 2010). The generation and scope of ripple effects will also depend on local socio-economic conditions, such as the existence of local expertise and supplying industries (IRENA & CEM, 2014), as explained in subchapter 3.2.

4.1.1 Classifiying ripple effects

The total ripple effects of an economic activity can be divided into four different components: direct, indirect, induced and catalytic effects. Most ripple effect analyses use these components as categories in the assessment of the activity's overall impact on the economy (Fjose & Grünfeld, 2012; Kjærland et al., 2012).

Direct effects: The initial spending of the economic activity generates direct effects. This includes the activity's compensation of labor, tax payments and other operating expenses (Weisbrod & Weisbrod, 1997). The number of jobs created by the activity itself and its generated profits are also considered direct effects. These figures are regularly accounted for by enterprises, making it possible to determine the scope and value of the direct effects quite precisely (Kjærland et al., 2012).

Indirect effects: The direct effects from the initial spending generates a higher activity level in the supply chain of the activity being studied, which increases the level of transactions between supplying firms in the value chain. Thus, the indirect effects capture this additional business-to-business activity in the value chain (Weisbrod & Weisbrod, 1997). These effects can be measured by determining the scope and value of suppliers' additional spending on salaries, tax payments, etc. By estimating multipliers, indirect effects can be measured in an infinite number of stages back in the value chain (Fjose & Grünfeld, 2012).

Induced effects: Induced effects are generated when the direct and indirect effects increase the overall income level of the local economy. Increased activity levels in the value chain increase the income and subsequently the consumption of the workers employed in the value chain. In turn, this raises demand for goods and services in other business sectors of the local economy, which further generates more employment and output in the economy. Hence, induced effects capture the increase in household-to-business activity and can thus be described as a consumption effect (Weisbrod & Weisbrod, 1997).

In most economies, resources are scarce. It is therefore important to assess the alternative use of resources and the income level these alternatives may create. With this in mind, it is not certain whether a specific economic activity will create higher income levels in the local economy compared to other alternatives. Induced effects from the business activity will only be relevant if the value creation is superior to the alternatives, generating a higher income level in the economy (Fjose & Grünfeld, 2012). However, in most developing countries where unemployment and population growth are high, scarcity of human capital is less of a problem. This is true for Rwanda where large parts of the population are either self-employed in agriculture or unemployed.

Catalytic effects: In general, catalytic effects, sometimes also referred to as dynamic effects, are described as effects creating broader changes in the society over time, which ultimately increases income and welfare in the study area (Weisbrod & Weisbrod, 1997). Fjose & Grünfeld (2012) build on this view and define catalytic effects as "*changes of structural relationships in an economy"*. According to Cooper and Smith (2005), catalytic effects

"capture to which extent an activity contributes to an economy beyond any effects that are directly or indirectly associated with the activity itself".

Furthermore, several scholars place particular emphasis on economic spillover impacts in their definition of catalytic effects, in which the activities of the enterprise or industry in question generate positive externalities for other business sectors in the economy (Kjærland et al., 2012).

Drawing on these definitions, we can understand catalytic effects as economic, social and environmental effects that impact overall welfare levels in an area over time. The contribution of catalytic effects to the society as a whole can be large and highly valuable. However, these effects are rarely reported on in ripple effect analyses due to the difficulty of estimating the scope and value of such effects (Kjærland et al., 2012). The fact that catalytic effects occur over time makes it also necessary to apply a longer time perspective when analyzing such effects (Fjose & Grünfeld, 2012).

We can make a clear distinction between direct, indirect and induced effects on one side and catalytic effects on the other. The first three groups of effects are all considered demand-side effects that are created by the change in final demand generated by the activity being studied. Hence, these effects are all related to the revenue of the activity and capture how the monetary flow ripples through the rest of the economy. Catalytic effects, however, can be described as supply-side effects, which are generated by the output of the activity being studied (Kjærland et al., 2009). In the case of power production, electricity is the output generating supply-side effects in the economy. Below, **figure 4.1** illustrates the ripple effects of power production in the four categories and the relationships between them.

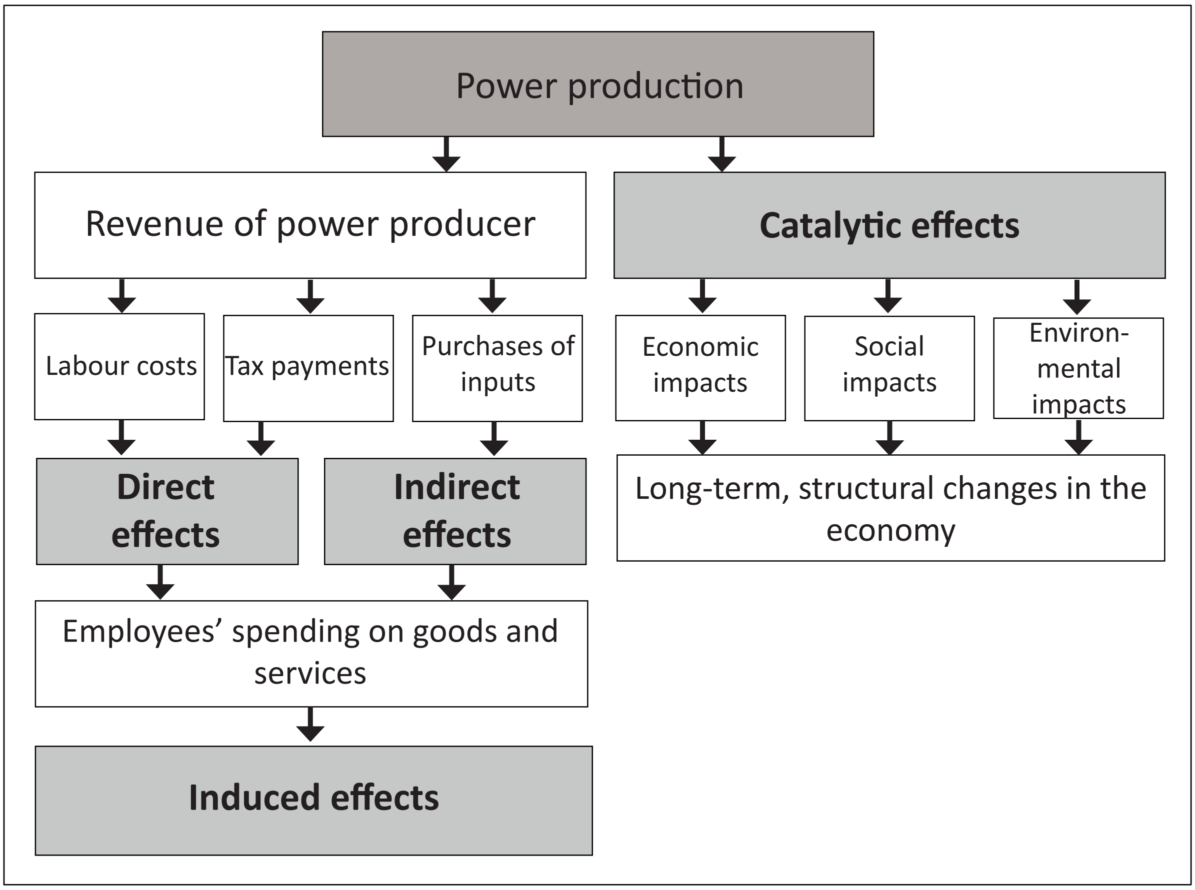

Figure 4.1 Ripple effects of power production (Source: Kjærland et al. 2009; Cooper & Smith, 2005).

4.1.2 Gross and net impact analyses

When conducting a ripple effect analysis it is important to determine whether to assess *gross* or *net* economic impacts (Weisbrod & Weisbrod, 1997). A gross economic impact analysis measures the economic contribution of a specific project, organization or industry to an economy, without taking into consideration possible effects on other sectors of the economy (IRENA & CEM, 2014). Gross economic analyses are commonly used to assess the impacts of existing activities at a specific point of time where the effects are assessed in terms of job and income generation. The net economic impact, on the other hand, addresses the impact of a project, organization or industry on the economy as a whole, taking into account possible negative and positive effects upon other sectors as well (IRENA & CEM, 2014). Thus, a net economic impact analysis considers also possible displacement effects[1] in an economy in order to capture all responses across the economy. Net economic impact analysis is therefore useful to measure the long-term impacts of an activity.

4.1.3 What should be measured in a ripple effect analysis?

In this study, we talk about an activity's impact in terms of value creation. Thus, the ripple effect analysis must identify relevant variables that capture in which areas value is being created (IRENA & CEM, 2014). This section presents selected variables pertaining to value creation in the value chain of an activity. These are value added, employment and income. Furthermore, we have defined value creation to also include various socio-economic benefits which necessarily cannot be measured in monetary terms. We thus include a welfare variable in order to address the social and environmental value created along the value chain.

Value added: IRENA & CEM (2014) define value added as the value of goods and services produced, less the value of consumption of intermediate inputs. The value added for a single firm is then the value of its sales less the cost of materials and services bought from supplying firms during the production process. Compensation of the firm's employees, revenue tax payments and dividend paid to owners is part of the firm's value added. The value added at each segment of the value chain will together add up to the total value added of the chain. Put simply, this can be explained as the difference between gross output and intermediate inputs, which reflects the total monetary value creation of the value chain and its contribution to GDP (IRENA & CEM, 2014).

Employment: The employment variable represents the total number of additional jobs that can be traced back to the activity being studied. It includes jobs created both directly and indirectly, and through induced effects that are created in the study area. When assessing employment effects in the RE sector, the jobs created by the RE firm itself are classified as direct, whereas jobs generated in supporting industries of the value chain are considered indirect. Jobs generated in other sectors that benefit from the activities of the RE firm and its supply chain are defined as induced. Limitations of the employment variable are, however,

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[1] Economic displacement arises when an expansion of economic activity in one location of the economy also has the effect of brining about some degree of reduction in economic activity elsewhere (Optimal Economics & TNS Research International, 2012).

that it does not reflect the quality of the jobs created, nor the costs of attracting these jobs if subsidies, tax reliefs or other public spending have been employed (Weisbrod & Weisbrod, 1997).

Income: The income variable refers to the compensation of employees in the value chain of the activity being studied. Hence, the total income effect equals the sum of total compensation of labor in the value chain. The share of income spent on consumption generates further activity in other sectors of the local economy, and we refer to this as a consumption effect, which illustrates the monetary value of the induced effects.

*Welfare***:** Lastly, the welfare variable refers to value creation in terms of impacts on people's well-being. This variable can be understood in a rather broad sense, to include both material well-being and more alternative measures related to social and environmental benefits. From the perspective of the RE sector, welfare effects can be generated in several ways. By increasing the access to modern energies, the possibly most important welfare effects of RE deployment are related to life-quality improvements. This includes effects on health, education, and amusement. However, it is a challenge to attribute quantifiable value to these measures as few quantitative methods have been developed to capture welfare effects. The assessment of welfare effects is thus limited to qualitative approaches (IRENA & CEM, 2014).

It is important to note that the variables address effects across the four effect categories of direct, indirect, induced and catalytic ripple effects. While the income variable solely relates to the induced effects, the value added and the employment variables describe both direct and indirect effects. Lastly, the welfare variable can arguably be used to address effects in all the effect categories. It is also important to note that the value creation identified by the variables overlap. For example, the value creation in the income effect is also part of the value added of the value chain. Consequently, Glen and Burton Weisbrod (1997) point out that the different measures cannot be added together when determining the total value creation of the ripple effects.

4.2 Analytic methods

In the following, we describe different analytical methods that can be used to quantify ripple effects in terms of value added, employment and income. Many studies use multiple methods in combination to determine the total scope of the ripple effects. It is, however, important to match the models with the conditions of the problem at hand. We will therefore elaborate on reasons for applying the input-output model in our ripple effect analysis.

4.2.1 Overview of methods

Several analytical tools are available to measure gross economic impacts of a project, enterprise or industry. **Inventory studies and surveys** are basic methods to assess the direct effects of an activity, such as figures on job creation and production output (ILO, 2013). **Employment factor studies** also estimate direct employment effects and identify in which segments of the value chain employment is created (ILO, 2013). For instance, in an impact analysis of the energy sector, employment effects can be expressed as the number of jobs created per MW of installed capacity (IRENA & CEM, 2014). **Supply chain analyses** assess where and how inputs are being mobilized throughout the supply chain in order to deliver the final products and services to end customers. Such assessments can be used to determine where employment and revenue is created in the supply chain and the scope of it (IRENA & CEM, 2014).

Input-output models: Input-output (I-O) models use multipliers to measure economic impacts of final demand changes in an economy. An I-O table, describing the flows of money between economic sectors within a region's economy, serves as the main analytical tool to calculate such multipliers (Oterhals & Hervik, 2006). Multipliers derived from the inter-industry relationships in the I-O table are used to calculate the total effect on demand generated by the spending on goods and services in a region (Weisbrod & Weisbrod, 1997).

Consequently, the I-O analysis provides a more comprehensive and thorough assessment of the economic value creation compared to the methods mentioned above. I-O models can be applied to measure value added, income and employment effects of the activity in question and its upstream activities. Thus, the models capture also indirect and induced effects, in addition to the direct effects of the activity. Since I-O models are more complex than the previously mentioned methods, they also require more resources and know-how for the model building, data processing and analysis of results. Available I-O tables or supply-use tables (SUTs) from a country's national accounts are fundamental in order to conduct an I-O analysis (IRENA & CEM, 2014).

As I-O tables are created for a given year, most methods using such tables will consider the economic structure of the country as static (IRENA & CEM, 2014). Thus, I-O models do not capture structural changes in an economy over time, such as changes in wage levels, prices, productivity of labor and capital, migration, etc. This means that I-O models first and foremost measure gross economic impacts.

Computable general equilibrium (CGE) models are considered to be ‘state-of-the-art’ in economic impact modeling. These models build on I-O tables and combine this with series of economic equations designed to capture the dynamic changes of an economy in a study area (ILO, 2013). CGE models measure net economic impacts and according to Glen and Burton Weisbrod (1997) they are able to determine

“*future changes in business costs, prices, wages, taxes, productivity and other aspects of business competitiveness, as well as shifts in population, employment and housing values*”.

Although CGE analyses are highly suitable for long-term assessments of economic impacts, developing CGE models is also highly resource intensive and requires use of detailed macroeconomic data employed in sophisticated computer programs (IRENA & CEM, 2014).

4.2.2 Choice of method

To assess the research question of the study, where we identify the socio-economic ripple effects of the ASYV solar power plant and evaluate the value creation of these effects, we find the I-O model as the most comprehensive and suitable method for this purpose. By employing the I-O model, we are able to calculate direct, indirect and induced effects that are generated by the ASYV project. This will make it possible to determine the total economic value creation of Scatec Solar’s activities in Rwanda.

The assessment of the economic ripple effects will be based on Scatec Solar’s financial figures on the ASYV project from 2014 and 2015, which includes the construction phase of the power plant (2014) and its first complete year of operations (2015). We consider Scatec Solar’s local expenditures in Rwanda during these two years as the initial shock of the project, which generates changes in final demand. Thus, it will be useful to employ a shock-tracking ripple effect model that measures the gross impact of the economic ripple effects. A gross input-output model is the most adequate method in order to capture the economic impacts of the power plant during this specific period of time.

The catalytic effects of the ASYV solar power plant, generated by the improved access and supply of electricity, cannot be captured in an I-O model. Optimally, a computable general equilibrium model would have been more appropriate to assess such long-term effects, which potentially cause structural changes to overall welfare levels in the society. However, the high requirements of resources, data and know-how to conduct a CGE analysis makes it more preferable to assess these effects in qualitative terms. We therefore build our assessment of the catalytic effects on interviews with key stakeholders to the ASYV solar power plant and to the EARP initiative in Rwanda. Furthermore, a CGE analysis would have been useful to capture potential displacement effects associated with the ASYV project. However, the fact that the project accounts for a relatively small investment in the overall economy of Rwanda, together with high unemployment rates and low income levels, we believe such displacement effects are very low.

4.3 Input-output model design

Many countries around the world have adapted the ISIC classification in their national accounts framework. This industry classification system was developed by the United Nations in 1948 and it combines industries according to their economic activity (OECD, 2006). The I-O table in **figure 4.2** is based on ISIC (shown in the first column and top row headings), and we will in the following refer to these industries as economic sectors.

		Recieving sectors								Final deliveries				
		Agriculture	Mining	Manufacturing	Construction	Trade	Transport	...	Sector n	Final household consumption	Final public consumption	Fixed Capital Formation	Exports	Total Output
Producing sectors	Agriculture	Z_{11}	Z_{12}	Z_{13}	Z_{14}	Z_{15}	Z_{16}	...	Z_{1n}	C_1	G_1	F_1	E_1	X_1
	Mining	Z_{21}	Z_{22}	Z_{23}	Z_{24}	Z_{25}	Z_{26}	...	Z_{2n}	C_2	G_2	F_2	E_2	X_2
	Manufacturing	Z_{31}	Z_{32}	Z_{33}	Z_{34}	Z_{35}	Z_{36}	...	Z_{3n}	C_3	G_3	F_3	E_3	X_3
	Construction	Z_{41}	Z_{42}	Z_{43}	Z_{44} A	Z_{45}	Z_{46}	...	Z_{4n}	C_4	G_4 C	F_4	E_4	X_4
	Trade	Z_{51}	Z_{52}	Z_{53}	Z_{54}	Z_{55}	Z_{56}	...	Z_{5n}	C_5	G_5	F_5	E_5	X_5
	Transport	Z_{61}	Z_{62}	Z_{63}	Z_{64}	Z_{65}	Z_{66}	...	Z_{6n}	C_6	G_6	F_6	E_6	X_6
	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	Sector n	Z_{n1}	Z_{n2}	Z_{n3}	Z_{n4}	Z_{n5}	Z_{n6}	...	Z_{nn}	C_n	G_n	F_n	E_n	X_n
Primary inputs	Imports	I_1	I_2	I_3	I_4	I_5	I_6	...	I_n	Gross Domestic Product (GDP)				I
	Gross value added	V_1	V_2	V_3	V_4 B	V_5	V_6	...	V_n					V
	Total Inputs	X_1	X_2	X_3	X_4	X_5	X_6	...	X_n	C	G	F	E	X

Figure 4.2 Structure of an input-output table (Source: Miller & Blair, 2009).

The table has four main components or quadrants. **Quadrant A** represents a transactional table and shows the monetary flows between different economic sectors. The column headings represent the receiving sectors, and the column values show the inputs needed from other sectors in order to produce the output from each sector (Thonstad, 1975). The sum of input factors required from other sectors is referred to as intermediate consumption. The row headings represent the supplying sectors. The row values show how the output from the supplying sectors is distributed to other sectors and used as input factors in the production process of these sectors. The rows in **Quadrant B** account for the other (non-industrial) inputs to production, such as labor costs, capital depreciation, government revenue, and imports (Miller and Blair, 2009). Adjusting for these input factors we get the gross production from each sector. The columns in **Quadrant C** record the monetary flows from each sector to their final market. Final demand is assumed to be exogenously given and includes private domestic consumption, government consumption and consumption by international consumers (exports) (Miller and Blair, 2009). Finally, the last quadrant illustrates the gross domestic product (GDP) of the analyzed economy.

In order to better understand the relationship between the I-O table and the national account, we can assess the aggregated information given in **figure 5.1**. From the last row we have that the total output in the economy is given by:

$$X = X_1 + X_2 + \ldots + X_n + C + G + F + E \qquad (4\text{-}1)$$

The **X_i-terms** denote output from each economic sector, while C, G and E represent total delivery to final markets and F denotes fixed capital formation[1].The total output is also expressed in the last column:

$$X = X_1 + X_2 + \ldots + X_n + I + V \qquad (4\text{-}2)$$

I denotes the total value of imports and *V* denotes value added. Substituting the left-hand side of equation (4-1) with equation (4-2) and subtracting the I-component from both sides gives us:

$$V = C + G + F + (E - I) \qquad (4\text{-}3)$$

[1] OECD (2001) defines fixed capital formation as the total value of acquisitions, less disposals, during the accounting period. It further includes changes in the value of non-produced assets, which is realized by the productive activity.

The left-hand side, value added, represents total factor payments (labor costs, profit, dividends, and government revenues) and can be derived from a country's National Account. The right-hand side represents the value of the aggregated output minus the intermediate inputs, i.e. the GDP.

4.3.1 Transforming the I-O table into an operational model

In order to transform the statistical information presented in an I-O table into an operational input-output model, certain modifications need to be done. From **figure 4.2** we can see from the first column that the agriculture sector purchases inputs from the domestic sector Z_{11} to Z_{n1}, imports a quantity equal to I_1 and contributes to a value added of V_1.The first row illustrates that the agriculture sector delivers output to sector Z_{11} to Z_{1n}. It further delivers a quantity of C_1 to private consumers, G_1 for public consumption and E_1 to international consumers. F_1 adjusts from fixed capital formation. The production function of each individual sector in the economy with *n* different sectors is:

$$X_i = Z_{i1} + Z_{i2} + \dots + Z_{in} + Y_i \qquad (4\text{-}4)$$

$\boldsymbol{X_i}$ denotes the gross production from sector i, the **Z-terms** are derived from the transaction table (quadrant A) and denote the intermediate demands, and $\boldsymbol{Y_i}$ measures the sum of final demand for sector *i*'s product (shown in quadrant C).

Given that the ***n-1*** other sectors have similar production functions, the whole economy can be described with the following set of linear equations:

$$X_1 = Z_{11} + Z_{12} + \dots + Z_{1n} + Y_1$$

$$X_2 = Z_{21} + Z_{22} + \dots + Z_{2n} + Y_2$$

.

$$X_n = Z_{n1} + Z_{n2} + \dots + Z_{nn} + Y_n \qquad (4\text{-}5)$$

In order to normalize the **Z-terms**, we can transform the absolute values into shares of total output that are used as input in other sectors. Thus, we divide each cell in the transaction table by the gross output from each sector and calculate the following ratio:

$$a_{ij} = Z_{ij}/X_j \qquad (4\text{-}6)$$

The coefficient $\boldsymbol{a_{ij}}$ measures the relationship between the required input from sector *i* and the output from sector *j*. Hence, in order for sector *j* to produce one additional unit of output, it must use a_{ij} units from sector *i*. The coefficient is assumed to be fixed (see assumptions in **4.3.4**).

The set of equations in (4-5) can now be rewritten, replacing each Z_{ij} with $a_{ij}X_j$

$$X_1 = a_{11} X_1 + a_{12}X_2 + \ldots + a_{1n}X_n + Y_1$$

$$X_2 = a_{21} X_1 + a_{22}X_2 + \ldots + a_{2n}X_n + Y_2$$

.

$$X_n = a_{n1}X_1 + a_{n2}X_2 + \ldots + a_{nn}X_n + Y_n \qquad (4\text{-}7)$$

The set of equations in (4-7) expresses that the total output from the *n* sectors equals the intermediate output plus the final output. This equation system can be transformed into the fundamental matrix representation of an input-output analysis:

$$X = AX + Y \qquad (4\text{-}8)$$

The A component represents the matrix of the a_{ij} coefficients, while the X and the Y components denote the vectors of total output and final demand, respectively. This is illustrated below:

$$\mathbf{A} = \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{bmatrix}, \quad \mathbf{X} = \begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_n \end{bmatrix}, \quad \mathbf{Y} = \begin{bmatrix} Y_1 \\ Y_2 \\ \vdots \\ Y_n \end{bmatrix}$$

Equation 4-8 can further be transformed into:

$$X = (I - A)^{-1} Y \qquad (4\text{-}9)$$

where

$$(I - A)^{-1} = \begin{bmatrix} \alpha_{11} & \alpha_{12} & \cdots & \alpha_{1n} \\ \alpha_{21} & \alpha_{22} & \cdots & \alpha_{2n} \\ \vdots & \vdots & & \vdots \\ \alpha_{n1} & \alpha_{n2} & \cdots & \alpha_{nn} \end{bmatrix}$$

The $(\mathbf{I} - \mathbf{A})^{-1}$, known as the "Leontief Inverse", represents the share of deliveries between the different sectors in the analyzed economy (Miller and Blair, 2009). Each factor coefficient (α_{ij}) in this table indicate the proportion of inputs required from other economic sectors in order to produce one unit of output from a particular sector. The coefficients serve as multipliers, which can be used to determine the ripple effects of a certain economic activity (Ambargis & Bess, 2011).

4.3.2 Multipliers

We can further use the multipliers matrix to construct specific multipliers measuring the effects of an economic activity on value added, employment and income in the analyzed economy.

Value added: Total value added throughout the value chain of an activity is equivalent to the revenue generated from the sales of gross output to final markets. Thus, total value added can be derived from the financial reports of suppliers at the final stage, delivering goods and services to the final consumers (Holmen et al., 2015). The I-O table can be applied to identify the value added contribution of each economic sector in each individual stage of the value chain.

To construct a multiplier that estimates the value added contribution of a particular economic sector in a given stage of the value chain, we use the factor coefficient $\boldsymbol{\alpha_{ij}}$. By summing all the factor coefficients in the economic sector's column in the inverted matrix, we obtain the output multiplier for that sector:

$$Output\ multiplier\ for\ sector\ j = \sum_{j=1}^{n} \alpha_{ij}$$

Furthermore, we want our multiplier to estimate the change in value added of a one-unit increase in a sector's output. In order to do this, we need to define a ratio between gross output and value added for each sector. Since the I-O table contains details on the contribution to total value added and total gross output of each individual sector in the economy (see quadrant B in **figure 4.2**), this ratio can be calculated:

$$Value\ added\ ratio\ for\ sector\ j = \frac{V_j}{X_j}$$

$\boldsymbol{V_j}$ denotes the total value added contribution of sector j and $\boldsymbol{X_j}$ represents the gross output from sector j. For sector j, the value added multiplier can be calculated by multiplying the sum of the output multipliers for the sector with the coherent value added ratio:

$$Value\ added\ multipler\ for\ sector\ j = \sum_{j=1}^{n} \alpha_{ij} * \frac{V_j}{X_j}$$

To estimate the value added contribution of an economic sector in a particular stage of the value chain, the value added multiplier of that specific sector must be multiplied with the change in final demand output. The sum of all sectors' contribution to value added in each stage of the value chain corresponds to the total value added contribution generated by the initial change in final demand.

In most complex value chains, supplying firms also depend on imported products and services in order to produce its final output. A part of the value added throughout the total value chain is thus attributable to suppliers outside the analyzed economy (see 3.2.1). Applying the value added multiplier for the relevant economy allows us to isolate the share of total value added generated by the domestic value chain. In this case, adding the total value added by all respective domestic sectors will not add up to the sales of final output from the end sectors to final markets. This gap is captured by international suppliers (imports) and price distortions (Holmen et al., 2015).

Employment: The employment effect can be measured in terms of direct, indirect or induced effects. The direct effect is the change in employment directly caused by an activity being studied. In other words, this constitutes the change in employment in the business(es) which carry out the activity being studied. Thus, the direct employment effect can be identified through qualitative interviews with the business(es) in question[1] (Kjærland et al., 2009). To measure the indirect employment effects, employment multipliers can be constructed that measure the number of jobs created throughout the value chain per unit change in final demand.

In order to construct employment multipliers for the different economic sectors, we need to know the total number of workers employed in each sector. Since the I-O table does not

[1] This applies only when measuring ripple effects of an economic activity that is being/have been implemented.

include information on this, it has to be acquired from external sources. When obtained, we can calculate a labor coefficient for each economic sector by dividing the total number of workers employed in the specific sector with its gross output:

$$Labor\ coefficient\ for\ sector\ j = \frac{E_j}{X_j}$$

$\boldsymbol{E_j}$ denotes the number of employees in sector j while $\boldsymbol{X_j}$ represents the gross output from sector j. The labor coefficients measure the total number of workers per unit of gross output from each economic sector. The total gross output from the different economic sectors is available in the I-O table. The factor coefficients from the inverted matrix can now be applied in order to construct the final employment multipliers. This is done by multiplying the sum of the factor coefficients with the coherent labor coefficient of that sector:

$$Employment\ multiplier\ for\ sector\ j\ = \sum_{j=1}^{n} \alpha_{ij} * \frac{E_j}{X_j}$$

To estimate the change in employment in each economic sector, we simply multiply the employment multipliers with the change in final demand output. The total employment effect will then be the sum of all changes in employment for each economic sector, in each stage of the value chain.

Income: To estimate the income effects, the change in earnings of workers employed in the value chain, we do not necessarily need to construct income multipliers. In fact, the effect on income levels can be derived from the employment effect by multiplying the change in employment of each economic sector (ΔE_j) with the average wage level of the respective sectors. Thus, we can estimate the total change in income that follows the initial change in final demand in the following way:

$$Total\ income = \sum_{j=1}^{n} (\Delta E_j\ * Average\ wage\ of\ sector\ j)$$

When estimating the income effects, it is important to only include the compensation of workers who reside in the relevant economy. By utilizing an estimate for the average share of income spent on consumption in the economy, we can furthermore estimate the total consumption effect that arises from the initial changes in final demand. The effect is given by:

$$Total\ \Delta\ consumption = Total\ \Delta\ labor\ income * Average\ consumption\ rate$$

The increased consumption is an induced effect that generates further final demand changes in the economy. Thus, additional values and employment are created outside of the value chain being studied. It is, however, difficult to know the exact consumption patterns of end consumers in an economy. This makes it a complex task to adjust the I-O model for precise estimation of induced effects. To estimate induced effects, we therefore use a simplified approach which is explained in further detail in appendix D.

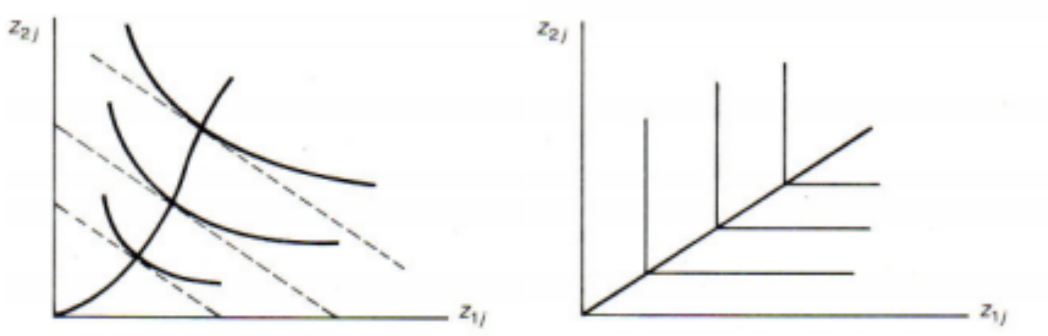
4.3.3 Assumptions in the input-output model

Most of the assumptions made in the I-O model are related to the production function of the economic sectors. The following assumptions should thus be considered when interpreting the direct, indirect and induced ripple effects.

A1. A fundamental assumption is that the model is based on a backward- linkage principle (Miller and Blair, 2009). This means that the inter-industry flows from sector i to sector j depends entirely on the total output of sector j. If sector j increases its production, the demand for sectors producing the intermediate inputs used in sector j will increase. Thus, sector i will need to increase its output accordingly.

A2. The coefficients in the "Leontief Inverse" matrix measure a fixed relationship between a sector's inputs and outputs (Miller and Blair, 2009). Thus, the system is based on constant returns to scale and ignores any economies or diseconomies of scale in production.

A3. The sectors are assumed to exhibit Leontief production functions, which differ from the classical production functions (Miller and Blair, 2009). The relationship between the two inputs factors in a Leontief function is constant and independent of the level of output: bij = Z1j / Z2j. The inputs are said to complement each other, meaning that it is not possible to substitute one input with another.



a) Classical Production Function b) Leontief Production Function

Figure 4.3 Production functions in input space **(**Miller and Blair, 2009)

A4. The assumption of a constant relationship between inputs also relates to labor. I-O models typically assume that changes in gross production will result in a proportional change in jobs. The model therefore assumes that unemployment exists in the economy and any additional demand for labor can be met by increasing the total number of employed workers (Briassoulis, 1991). If a sector can increase its output by extending the number of hours worked by existing employees the employment multiplier will overstate the actual increase in total employment.

A5. Finally, the model assumes that the described economy operates with spare capacity. This means that any increase in final demand can be met by an increase in sectorial output (Miller and Blair, 2009).

5. Ripple effect analysis of the ASYV project

In this chapter we will first give information about our data collection, followed by the presentation of findings from the ripple effect assessment of the ASYV project. Only ripple effects generated in Rwanda will be accounted for, including effects generated by Scatec Solar and its local value chain.

5.1 Data collection

Our analysis of the socio-economic impact of the ASYV solar power plant in Rwanda uses both quantitative and qualitative data. The quantitative data is gathered from the National Institute of Statistics of Rwanda while Scatec Solar provides the foundation for our assessment of direct, indirect and induced effects. The findings of the RWI studies (Lenz et al., 2015; Peters & Sievert, 2015) serve as a point of reference for our assessment of the catalytic effects. Furthermore, qualitative interviews with key stakeholders were conducted in order to verify and supplement the findings of the RWI institute. Detailed calculations and estimations are presented in appendices.

5.1.1 Quantitative data

The input-output (I-O) model is the main tool for the assessment of the economic ripple effects. We build our model by the principles of Menon Economics' *Total Effect Model* (TEM), which is based on Statistic Norway's input-output tables. By applying the model, we can generate multipliers for value added, employment and income for each economic sector and at each stage of the value chain. The model is normally derived from I-O tables for the economy being studied. However, there is no available I-O model nor tables for the Rwandan economy. We therefore constructed an I-O model by using a supply-use table for the year of 2011 (the most recently published). The table was derived from the Rwandan National Accounts. It provides detailed information about domestic production activities, supply and demand for goods and services, intermediate consumption, primary inputs and foreign trade. The 2011 supply-use table and the converted I-O table can be found in the appendices A and B respectively.

Furthermore, information on labor force and labor compensation are essential for estimating employment and income effects. We derive the number of workers employed in each economic sector from the Integrated Household Living Conditions Survey 3 (EICV 3). The survey was conducted by the National Institute of Statistics of Rwanda in 2011 and give detailed information about the distribution of the Rwandan labor force. Total employment in each economic sector is presented in appendix C. It is important to note that the employment numbers do not differentiate between full-time and part-time employment.

We derived data on labor compensation from a social accounting matrix. The matrix is based on the supply-use table from 2011 and gives a very detailed representation of the distribution of income in the Rwandan economy. It was published by the International Food Policy Research Institute (IFPRI) in 2014. See appendix C for the average wage level in the 12 economic sectors.

All numbers derived from the supply-use table and the social accounting matrix are converted from RWF to USD, using a 2011 average exchange rate from XE Currency Converter (1 USD = 595 RWF; XE Currency, 2016). We further use indices published by the World Bank (2016H) to adjust for inflation between 2011 and 2015 to make the numbers comparable to accounting numbers from 2015.

When running the I-O model, we introduce Scatec Solar's foreign investment as the initial shock that generates final demand changes in the Rwandan economy. The capital expenditure (CAPEX) represents the initial shock in the construction period while the operating expenses (OPEX) represent the initial shock in the operation period. The **Annual Report 2014** distinguishes between the project's total CAPEX and the share of the CAPEX directed to Rwandan suppliers. This information is essential in order to measure the local ripple effects during the construction. The ASYV project manager, Caroline Sissener, provided information on how the local purchases are split between three different subcontractors. All cost components are converted from NOK to USD, using a 2014 average currency exchange rate from the central bank of Norway (1 USD = 6,3019 NOK: Norges Bank, 2016). The numbers are then adjusted for inflation between 2014 and 2015 (1.8 percent) by using indices from the World Bank (2016H).

Information regarding the project's OPEX and revenue for the first year of operation is derived from Scatec Solar's **Annual Report 2015.** The report does not isolate the share of the OPEX directed to Rwandan suppliers. However, Caroline Sissener provided us with information regarding this share. We use an average currency exchange rate for 2015 from the Norwegian central bank (1 USD = 8,0739 NOK) in order to convert the figures from NOK to USD.

5.1.2 Qualitative data

Studies conducted by researchers from the German economic research institute, RWI, constitute a key component of the assessment of the catalytic effects. The main findings from these studies are presented in **figure 3.3**, and we refer to them throughout our assessment of the catalytic effects. In order to support and supplement the findings of the RWI studies, we conducted qualitative interviews with 10 different stakeholders of the ASYV project. We aimed at identifying key stakeholders that could provide us with relevant information, rather than a large number of respondents holding limited information.

First, we interviewed key personnel from Scatec Solar and Gigawatt Global. We interviewed Caroline Sissener and Chaim Motzen, the project managers from Scatec Solar and Gigawatt global respectively. We also interviewed Julie Hamre, who is a financial analyst at Scatec Solar. These respondents provided us with the shareholder's perception regarding the impact of their investments. Most of the information was concentrated around the construction phase of the project and therefore to some extent colored by ex-ante expectations regarding the socio-economic impact of the investments. Further, we interviewed Twaha Twagirmana and Jean Claude Nkulikiyimfura, the site manager and the village director of ASYV, respectively. These local stakeholders provided us with first-hand information regarding the impact of the investments upon economic and social indicators in the local community.

In order to gain insights from the utility side, we interviewed Jean Bosco Mugiraneza, CEO of the Rwandan Energy Group, and Niyibizi Mbanzabigwi, coordinator of EARP at the Rwandan Energy Group. Both work closely with the development of the electricity rollout program and provided us with information regarding the impact of electricity on newly connected households and businesses. They further held valuable information regarding the interdependency between the electricity program and the increase in generation capacity.

Lastly, we interviewed two researchers, one from the World Bank and one from RWI. The respondent from the World Bank, Yadviga Semikolenova, is a senior energy economist who is responsible for the institution's evaluation and follow-up process of EARP in Rwanda. The respondent from RWI, Jörg Peters, is one of the authors behind the recent and complete impact studies upon the electrification programs in Rwanda. Peters has also conducted research upon the effects of electricity in an array of African countries. He is currently involved in the third phase of data collection in Rwanda. The same households that were evaluated in 2011 and 2013 are again being surveyed in order to measure the effects of electricity in a 5-year perspective. The findings of this research have yet to be published. However, Peters provided us with some reflections regarding this ongoing research that give a valuable supplement to our analysis of the catalytic effects.

As outlined above, our selection of respondents presents various perspectives, and shed light on different aspects of the ASYV project and the effects of electricity. Due to practical obstacles like travel costs and lack of time we had to carry out the interviews using either Skype or mobile phone. A question sheet was sent to the respondents prior to the interview. The question sheet included standardized questions (for all interviewers) and specific questions tailored to each person. The questions were asked in an open manner in order to get the respondents to talk freely and not become colored by our opinions. The general question sheet is presented in appendix E. A list of all the stakeholders interviewed can be found in appendix F.

5.2 Measuring economic impact: direct, indirect and induced effects

The economic impact relates to the direct, indirect and induced effects of the ASYV project. Common for these effects is that they are all economic in nature, explaining how the value chain of the ASYV solar power plant impacts the Rwandan economy in terms of value added, employment and income. In the following assessment, we differentiate between the ripple effects being generated during the construction and the operations of the power plant. Furthermore, we differentiate between first order effects, second order effects and higher order effects. First order effects represent the direct effects generated by Scatec Solar in Rwanda. These figures have been derived directly from Scatec Solar's financial reports. Second and higher order effects illustrate the indirect effects, which are generated by the additional spending in Scatec Solar's local supply chain in Rwanda. We had access to financial information regarding Scatec Solar's subcontractors in Rwanda and this enabled us to make more precise calculations of the second order effects. The higher order effects are measured by using the multipliers from our I-O model for Rwanda. The model makes us able to estimate the value added and employment creation further down the local supply chain.

5.2.1 Construction

Total construction costs of the ASYV solar power plant amounted to USD 24,127,000 (in 2015 prices). Of this amount, USD 3,155,000 was spent on procurement in Rwanda. Thus, all ripple effects generated locally during the construction stems from this local procurement spending. The breakdown of the total construction costs in terms of local and international spending is illustrated in the chart on the left hand side in **figure 5.1** below. It is important to note that Scatec Solar did not employ any local workers during the construction period. All Scatec Solar employees that were involved during construction were non-Rwandans, residing abroad. This means that the labor compensation of Scatec Solar staff cannot be ascribed to the local value chain. We do not hold any information regarding tax payments from Scatec Solar to Rwanda during the construction. This means that our analysis fail to identify the direct effect of tax payments. All value added and employment effects in the local value chain during construction are thus to be considered as indirect effects. Consequently, no direct effects were generated in the local value chain during the construction period.

Value Added

By using the value added multipliers derived from the I-O model, we can break down the local procurement cost of USD 3,155,000 into four components: the local suppliers' contribution to value added of USD 1,860,000, imports of domestic suppliers of USD 1,004,000, net tax expenses of USD 20,000, and trade and transport margins of USD 241,000. This is illustrated in the chart to the left in **figure 5.1**. Value added by the domestic suppliers together with net tax expenses, a sum of USD 1,880,000, represent the total value added contribution of the local value chain. We choose to not count the value of trade and transport margins as contributions to domestic value added since our model does not break down the transportation and trade costs related to international or domestic purchases.

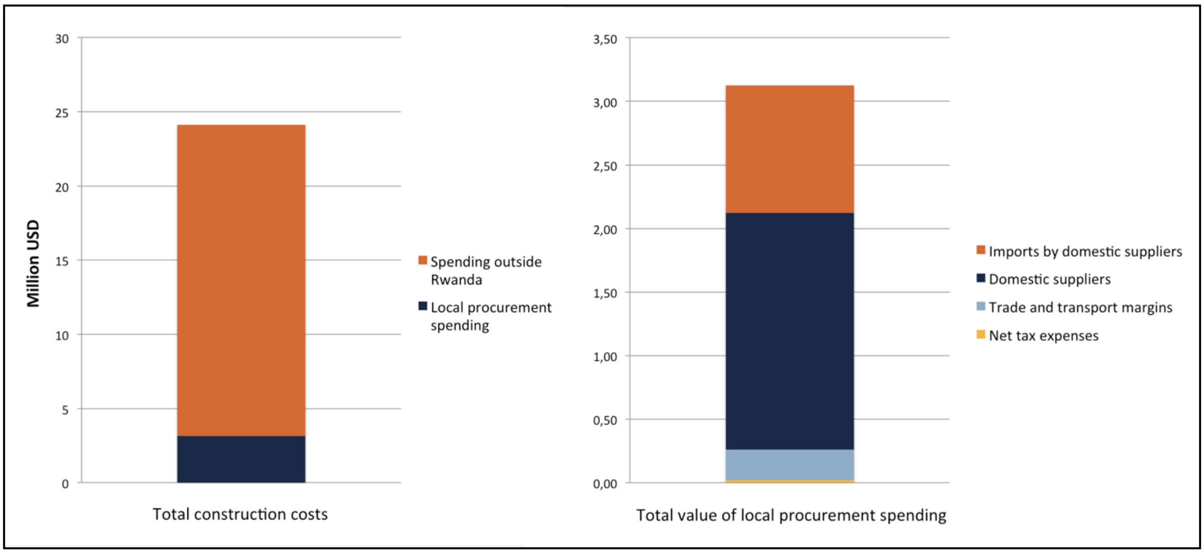


Figure 5.1 The breakdown of the total construction cost to the left and the further breakdown of the local procurement spending in Rwanda to the right.

The I-O model makes us able to determine the structure of domestic deliveries of intermediates and the share of imports by each sector in each stage of the local value chain. The imports of the local value chain can thus be explained by looking at these structures. The chart to the left in **figure 5.1** illustrates that the local value chain has been partly dependent on import in order to deliver the final outputs to the construction of the ASYV solar power plant. This is indicated by the share of imports by domestic suppliers. Scatec Solar's subcontractors in Rwanda (second order suppliers) produced most of its output from inputs produced by domestic suppliers. However, our I-O modeling reveals that the subcontractors purchased a substantial proportion of inputs from the manufacturing sector, which in turn imported more than half of its factor inputs from international suppliers. The manufacturing sector also exhibits a high proportion of internal purchases, which further increased import levels in our case. The sector accounted for more than 80 percent of total imports by domestic suppliers in the local value chain.

Furthermore, the I-O model enables us to identify the value added contribution of each different stage of the supply chain and the contribution of each economic sector. The contribution to value added by Scatec Solar's subcontractors (second order) constitutes USD 932,000, while higher order suppliers generate the remaining USD 948,000. This is illustrated in the left hand side chart of **figure 5.2**. The right hand side chart of **figure 5.2** illustrates the contributions to domestic value added by the different economic sectors. The utility, service and construction sectors generate the highest contribution to domestic value added. This reflects the fact that the direct subcontractors operate within these three sectors.

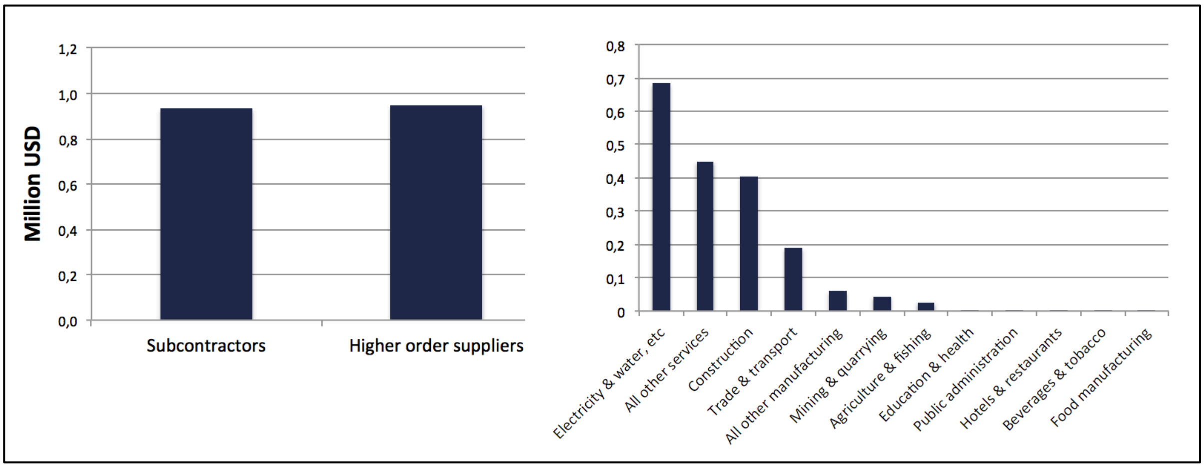


Figure 5.2 Domestic value added divided by subcontractors and higher order suppliers to the left and by economic sectors to the right.

Employment

Figure 5.3 presents the number of jobs created throughout Scatec Solar's local value chain in Rwanda during the construction. A total of 632 jobs can be ascribed to the value chain as shown in the section on the left side of **figure 5.3** below. As mentioned, Scatec Solar did not employ any locals during the construction. Thus, all the 632 jobs created in the value chain are to be considered indirect employment effects. Scatec Solar reports that their subcontractors in Rwanda created about 380 jobs. Rwandan workers employed 300 of these jobs. Foreign workers, mainly African and European expats residing in Rwanda, employed the remaining 80 jobs. Thus, all the 380 jobs created can be ascribed to the local value chain. We further use the I-O model and the employment multipliers to estimate the job creation higher up in the supply chain. This gives us an estimate of 252 jobs created by higher order suppliers. We assume that Rwandan workers employed all positions.

As the construction of the ASYV plant took place in the first half of 2014, all jobs created by Scatec Solar's subcontractors in Rwanda were temporary positions. It is uncertain whether the jobs created higher up in the supply chain were temporary as well. We therefore consider all the 632 created jobs as temporary 6-month positions. The I-O model does not give us any information on the quality of the jobs created higher up in the supply chain, nor does it tell us whether the jobs were full-time or part-time positions.

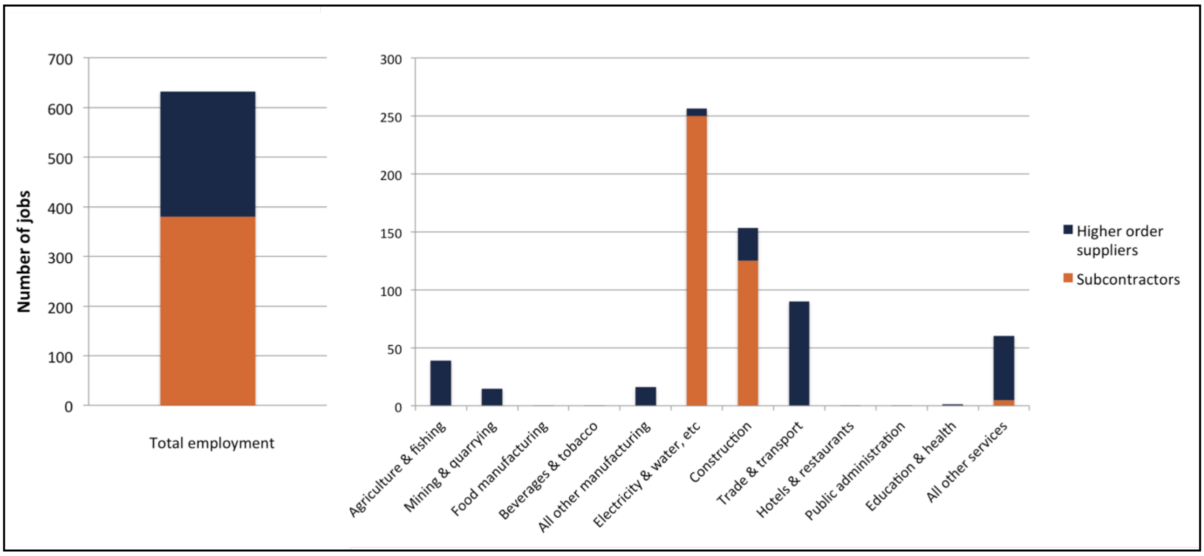


Figure 5.3: Total local employment by subcontractors and higher order suppliers, and employment by local economic sectors.

Based on employment numbers of the subcontractors and employment multipliers in the I-O model, we are able to estimate the number of jobs created by each stage of the value chain and by each economic sector. This is illustrated in the chart to the right in **figure 5.3**. Most jobs were created in the utility (electricity & water) and construction sector, as Scatec Solar's two largest subcontractors were engaged in these two sectors. Furthermore, we see that suppliers in the trade and transport sector created most jobs among the higher order suppliers (90 jobs created), followed by the sector for all other services (55) and the agriculture and fishing sector (39). As we saw above, the value added in the domestic economic sectors was highest in the sectors for utilities, construction, services and trade and transport. It is consequently not surprising that we see the highest job creation in these sectors. The agriculture and fishing sector contributed to a relatively low share of the value added in the local value chain. The reason why the number of jobs created in this sector still turned out to be relatively high is due to the high labor intensity in this sector. To a large extent, this also applies to the trade and transport sector, which is another highly labor intensive sector in Rwanda.

Income

Ripple effects in terms of income and consumption are related to the compensation of the employees in the value chain. We estimate that the 632 Rwandans employed in the local value chain were compensated by a total of USD 367,000 during the construction phase. This sum represents the total income effect during the construction phase of the ASYV project. The increased income levels of the employees give them the opportunity to consume more goods and services, which in turn increases the general demand in the local economy. This additional consumption therefore gives rise to induced ripple effects. We assume that the marginal propensity to save for an average Rwandan household is close to zero[1]. Thus, it is reasonable to believe that the employees spent their whole income on consumption (marginal propensity to consume is 1). This gives a consumption effect equal to the income effect of USD 367,000.

The increased consumption levels of USD 367,000 generated further induced effects in the Rwandan economy. In terms of employment, we estimate that approximately 260 jobs were created in the Rwandan economy due to the increased consumption levels. The calculation of the induced employment is explained in appendix D. The compensation of the 260 workers occupying these jobs will further increase consumption levels in the economy, and so on.

We do not know the exact consumption patterns of Rwandan households, which makes it difficult to measure the total scope of the induced effects with our I-O model. The estimated induced employment effect must therefore be considered as highly uncertain. In general, however, Rwandan households spend large shares of their income on food products, final goods and transport services. Thus, it is likely that most induced jobs and value have been created in the agriculture sector, manufacturing sectors and in the trade and transport sector.

Additional effects: Investments in transmission and distribution

As a result of the construction of the ASYV solar power plant, the Rwandan grid operator REG invested in a 9-kilometer long (medium voltage) grid line from its nearest sub-station to the construction site. In addition, transmission and distribution investments were made by REG following the completion of the ASYV solar power plant in order to improve connection of final users. We do not have access to financial figures regarding REG's investment, which makes us unable to measure the exact value creation of these investments. We also consider the investments as external to the local value chain of the ASYV project, and thus external to our economic impact assessment. However, assuming that REG engaged

[1] In Sub-Saharan Africa, low average income levels and a large share of the population living below the poverty line suggest that earnings are often insufficient to cover family needs. In turn, this limits the possibility of savings. Thus, the marginal propensity to save is at best close to zero (Hishamunda & Manning, 2002).

local suppliers in the on-site construction and cabling work, the investment generated additional value added, employment and income to the Rwandan economy.

5.2.2 Operations

Scatec Solar's total revenue from electricity sales in Rwanda amounts to USD 3,546,000 in the financial year of 2015. All generated electricity was sold to REG, which sold the electricity to final users in Rwanda. Thus, the revenue from electricity sales represents the total value creation of the ASYV value chain during operations in 2015. As illustrated in **figure 5.4** below**,** the revenue can be broken down into three components: OPEX in Rwanda of USD 216,000, OPEX outside Rwanda of USD 356,000, and EBITDA of USD 2,973,000. It is important to have in mind that the estimated ripple effects of the 2015 operations represent an annual contribution to the Rwandan economy. Thus, the estimate ripple effects are likely to sustain and further develop during the coming years of operations.

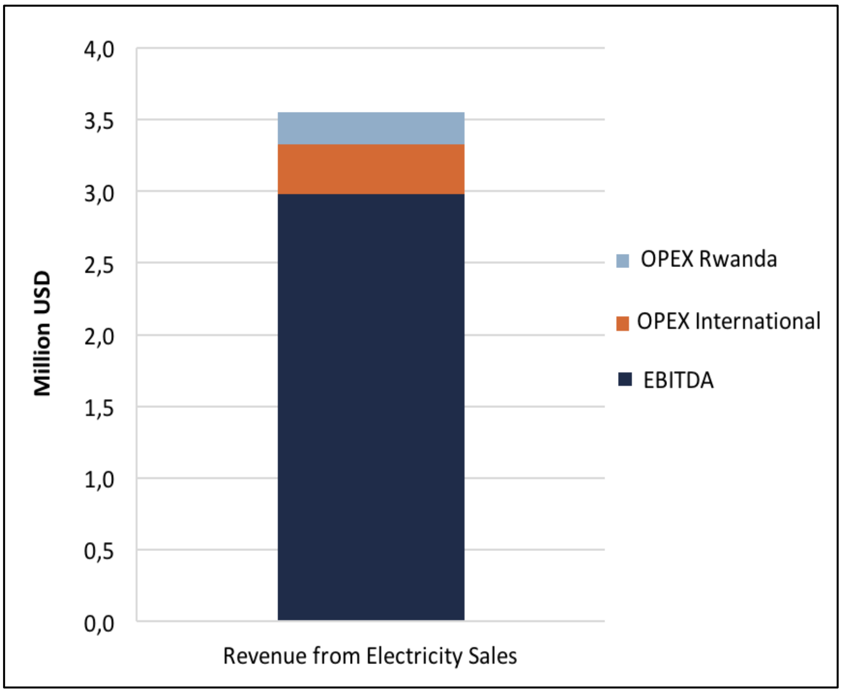


Figure 5.4 Breakdown of Scatec Solar's revenue by contribution to value added

Value added

Scatec Solar's EBITDA and the compensation of their local workers in Rwanda represent the direct value added contribution of Scatec Solar to their local value chain. However, Scatec Solar did not disclose the cost figures of local employment compensation. Thus, we are not able to determine the exact value of Scatec Solar's value added contribution and will rather use EBITDA as the direct value added effect of the 2015 operations.

To determine the local supply chain's contribution to value added (i.e. indirect value added effect), we need to look at Scatec Solar's operational expenses in Rwanda. By applying the value added multipliers from the I-O model, we can break down the local operation expenses into four components: domestic suppliers' contribution to value added of USD 174,000, imports by domestic suppliers of USD 39,000, net tax expenses of USD 7,000 and trade and transport margins of negative USD 5,000. This is illustrated in **figure 5.5**. Thus, the indirect value added effect corresponds to the value added contribution of domestic suppliers plus net tax expenses. This amounts to USD 182,000, which is 32 percent of Scatec Solar's total operational expenses and 84 percent of the local operational expenses.

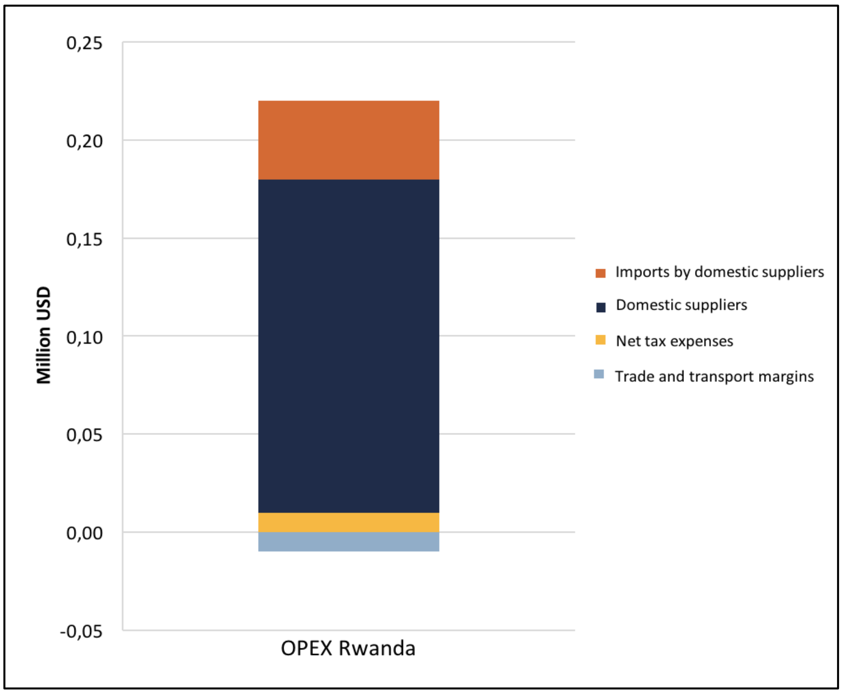


Figure 5.5 Breakdown of Scatec Solar's OPEX in Rwanda by contribution to value added

Furthermore, the I-O model allows us to identify the value added contribution of each different stage of the local supply chain and the contribution by each economic sector. Of the total value added contribution of the local supply chain, we find that second order subcontractors account for USD 126,000, while higher order suppliers account for USD 56,000. This is illustrated in the chart to the left of **figure 5.6** below. The chart to the right in **figure 5.6** illustrates the value added contributions of the different economic sectors in the Rwandan economy. The service sector is the biggest contributor to value added. The high value added contribution of the education sector is explained by an annual land lease fee of USD 100,000 paid by Scatec Solar to the ASYV School.

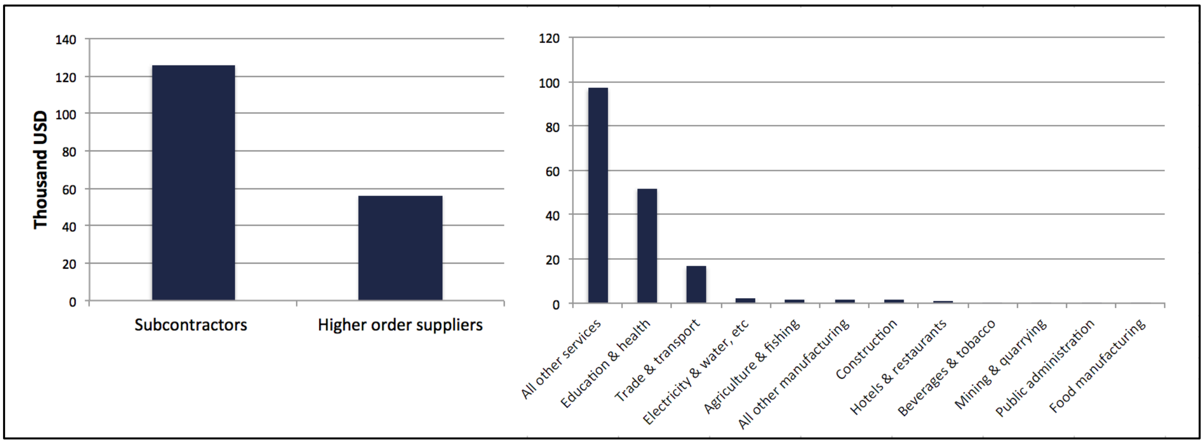


Figure 5.6 Domestic value added divided by subcontractors and higher order suppliers to the left and by economic sectors to the right

Employment

According to Scatec Solar, the company employed 2 full-time workers to operate the solar power plant, 9 security workers and 5 part-time workers on a daily basis. Thus, a total of 16 jobs were created directly by Scatec Solar. These jobs are also considered permanent and the jobs are likely to sustain over the coming years of operations. By applying the employment multipliers in our I-O model, we estimate that 47 local jobs were created in the value chain of Scatec Solar's operating activities in Rwanda. These 47 jobs represent the indirect employment effect. We also consider these jobs as permanent positions and assume that they were occupied by Rwandan workers. In total, we estimate that 63 permanent jobs were created in the local supply chain of the operations. The shares of direct and indirect employment are illustrated in the chart to the left in **figure 5.7**.

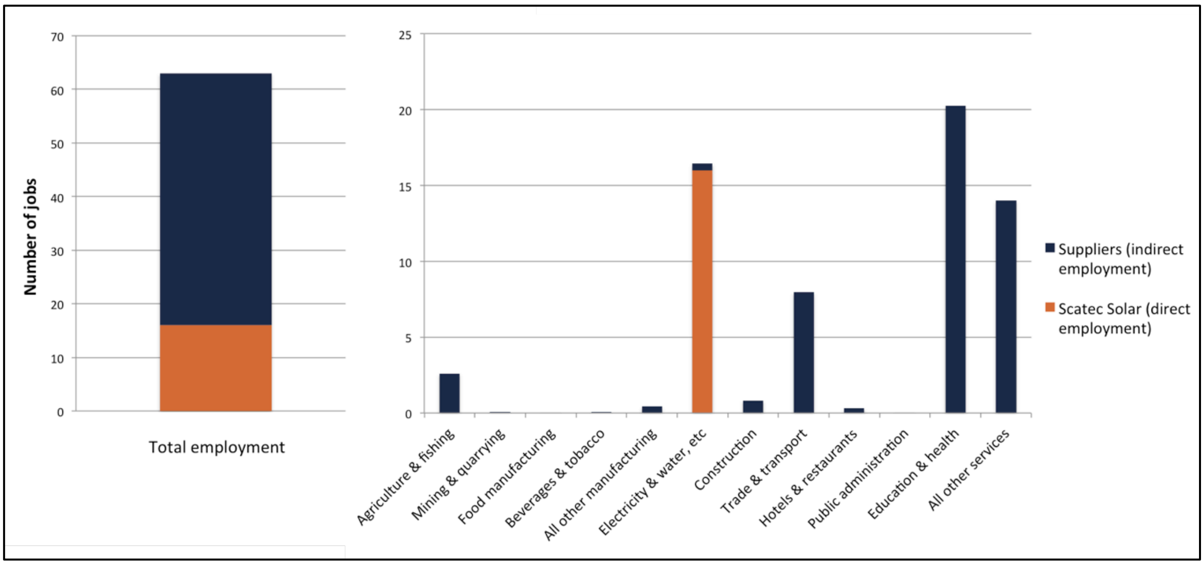


Figure 5.7 Total direct and indirect employment and employment by economic sectors.

Looking at local job creation by economic sectors in **figure 5.7** (right hand side), we see that most jobs were created in the education and health sector (20 jobs created), followed by the utility sector (16) and the service sector (14). Naturally, all direct jobs were created in the utility sector since Scatec Solar operates in this sector. The high indirect job creation in the education and health sector is again explained by the annual land lease expense of USD 100,000 to the ASYV School. However, the director of the ASYV, Mr. Nkulikiyimfura, indicated that the income from the land lease had not enabled the school to increase their activities and staff to any significant extent. Thus, the job creation in the education and health sector might be overestimated. We also see that a few jobs were created in the trade and transport sector (8) and for agriculture and fishing sector (3). Although these two sectors contribute to very little value added, the high labor intensity and low wage levels in the sectors still enable significant job creation here.

Income

We estimate that the compensation of the 63 employees in the local value chain amounted to USD 104,000. This suggests that the employees in the local economy spent USD 104,000 on additional consumption, generating additional demand for goods and services. We estimate that the increased spending will further generate 74 jobs in the local economy, mostly in the agriculture, manufacturing and trade and transport sectors (explained in subchapter 5.2.1). Thus, the induced effects of Scatec Solar's operational activities in Rwanda comprise an income/consumption effect of USD 104,000 and the creation of 74 jobs in the economy. Again, we underscore that this is a highly uncertain estimate, as our I-O model does not capture the exact scope of the induced ripple effects in the economy.

Additional effects: The alternative cost of electricity

The ASYV solar power plant produced 13,817 MWh of electricity in 2015 (Scatec Solar, 2015). As the total income in 2015 of USD 3,546,000 is attributable to the sales of electricity to the Rwandan utility, we estimate that Scatec Solar received USD 0.26 per kWh of produced electricity. We know, however, that the power tariffs in Rwanda are highly subsidized. In 2015, the average tariffs stood at USD 0.21 per kWh for residential customers[1] (low-voltage) and USD 0.18 per kWh for industrial customers (medium-voltage)

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[1] On the 1st of September 2015, the electricity tariff for residential customers in Rwanda increased from RWF 134 (USD 0.19) to RWF 182 (USD 0.25) (REG, 2015). This means that the electricity production of the ASYV solar power plant has been less subsidized from September 2015 and onwards.

(REG, 2015). Assuming all electricity generated by the ASYV solar power plant was sold to residential users, this implies that the Government subsidized every kWh produced by USD 0.05. This means that the total subsidy payment amounted to USD 691,000 in 2015. This raises the question whether alternative energy sources could generate electricity at a lower cost and thus contributing to higher value creation in the local economy.

However, a World Bank-estimate indicates that the average cost of power generation in Rwanda is USD 0.32 per kWh due to the high cost of fossil fuel imports for thermal power generation (Y. Semikolenova, personal communication, April 27, 2016). In fact, the cost of fossil fueled thermal power generation is consequently higher than the average generation cost of USD 0.32 per kWh. Given the severe shortage of domestic electricity supply in Rwanda, the short-term alternative to the solar powered electricity from ASYV would most likely have been through fossil fuelled thermal generation and diesel generators.

Based on Scatec Solar's expected annual production and revenues, we can expect an average PPA tariff of 0.18 USD over the 25-year-long contract with REG. With this in mind, it can be argued that the ASYV solar power plant in fact reduces the government spending on electricity subsidies by USD 2,170,000 annually. Our estimated value added contribution must therefore be considered as a minimum estimate, as we have not included the alternative cost of more expensive power generation. Nevertheless, it is important to keep in mind that Rwanda is investing in new domestic power generation and infrastructure. The country seeks to significantly increase power imports from neighboring countries, as explained in subchapter 2.1.3. Thus, the current average generation cost of USD 0.32 per kWh is likely to be reduced in the coming years. The ASYV project's contribution to lower power subsidy spending must therefore be considered as a highly uncertain estimate.

5.2.3 Summary table of direct, indirect and induced ripple effects

The main findings of the local ripple effects generated by the ASYV project are summarized in table 5.1 below. All figures are presented in USD, using 2015 prices. The direct effect contribution of Scatec Solar, in addition to second order indirect effects are based on reports and financial figures disclosed by the company itself. The remaining figures on indirect and induced effects are estimated by using the I-O model. Some uncertainty must therefore be associated with these figures. However, the summarized figures give us a good indication of the overall economic contribution of the ASYV solar power plant to the Rwandan economy.

Table 5.1 Summary of local direct, indirect and induced effects generated by the ASYV solar power plant during construction in 2014 and operations in 2015 (in USD).

	Direct effects	**Indirect effects**		**Induced effects**	**Total**
	First order	Second order	Higher order		
Construction					
Value Added	No value added contribution	932 000	948 000	NA	1 880 000
Employment	No local employment	380	252	260	892
Income	NA	NA		367 000	367 000
Operations					
Value Added	2 973 000[1]	126 000	56 000	NA	3 155 000
Employment	16	47		74	137
Income	NA	NA		104 000	104 000

5.3 Measuring social impact: catalytic effects

According to the literature, access to electricity gives rise to socio-economic effects on income, education, health and the environment. These effects have an important impact on people's welfare and can potentially generate structural changes in an economy over time. Thus, welfare impacts are to be considered catalytic ripple effects.

Scatec Solar states in their annual reports that the most significant contribution to local value creation is through increasing access to electricity in the countries they operate in. When the ASYV solar power plant was commissioned in 2014, it accounted for a 6 percent increase in Rwanda's power generation capacity. At the same time, thousands of households were connected to the national grid through EARP. This means that a great number of newly connected households were able to access clean electricity from the solar power plant. In the following, we will present how 10 different stakeholders believe access to electricity has impacted income, education, health, the environment, and other well-being factors in Rwanda. Their perspectives will be supplemented and compared to results from the RWI studies.

[1] The direct value added figure does not include the value added contribution of direct employment, as this information was not disclosed by Scatec Solar.

Income

The majority of interviewed stakeholders acknowledged electricity access as a vital contributor to household and enterprise income as it gives rise to more productive activities and lower energy costs. The CEO of REG further explains that access to electricity gives subsistence farmers a stronger incentive to substitute some of the hours spent in the field with activities that can generate a higher income for the household. However, the empirical evidence from the RWI studies indicates that the income effect remains modest to low in Rwanda. Neither income-generation in households or businesses in the data sample showed significant improvements after getting access to electricity. Jörg Peters could confirm that the changes in household and business consumption remained low in the new data sample from 2015. These findings suggest that even in the medium-term (after 5 years) the households do not seem to adapt any substantial benefits from electrification in terms of increased income.

Lenz et al. (2015) find that some small businesses are established when electricity access is being provided and that existing businesses increase opening hours and offer more products and services. The interviewed stakeholders living permanently in Rwanda confirmed these findings. The site manager of ASYV said that two local restaurants and three barbershops emerged in the community in the wake of electrification. The CEO of REG further pointed out that the observed increase in business activity contributed to the creation of more productive jobs. However, the Rwandan respondents also underlined that the scope of new business establishments is low and that it has little impact on overall income and consumption levels in communities.

Education

At the household level, the most significant effect of electrification access on education can be ascribed to changes in study hours. Lenz et al. (2015) find that children living in connected households study more at night, but that overall study time does not increase. This finding was also pointed out by several of the interviewed stakeholders as an important benefit, which makes it easier for children to do both their homework and help out at home. However, the RWI studies did not find any signs of increased school enrollments in connected villages. This was also confirmed by Jörg Peters in his interview.

Electricity access is further highlighted as important for the provision of schooling and educational services in Rwanda. Lenz et al. (2015) find that a considerable share of connected schools in the country have improved the curriculum and extended the offered services by the integration of appliances and electric lightning. Among schools that previously relied on electricity from a diesel generator or a solar panel, the connection to the central grid lowered energy costs and improved the power supply and reliability. Jörg Peters, the CEO of REG and the director of ASYV confirm these findings and underscore that electricity makes educative lessons and administrative tasks easier to conduct. The CEO of REG further believes that these effects strengthen the quality of the education as teachers can supplement and support the curriculum with online materials and exchange information with other schools. Jörg Peters and the director of ASYV are more conservative in ascribing positive impacts on school performance as an effect of increased electricity access. However, both of them underscore that electricity access is an important measure for attracting high-skilled teachers to work in rural schools.

Health

The most striking effect of electricity access in Rwanda on health is the substitution of kerosene as the main energy source for lightning. This has been extensively documented in the findings by Lenz et al. (2015). All the interviewees confirm that electric lightning to a large extent replaces use of kerosene in Rwanda. Lenz et al. (2015) do not find signs of reduction in the use of firewood for cooking and heating purposes. Thus, a large portion of indoor pollution is likely to prevail in Rwandan households. The interviewed stakeholders also believed that electrification is unlikely to reduce usage of firewood in the nearest future. Jörg Peters pointed out that the cost of buying and using an electric stove is too high and that the current grid capacity does not support the use of such power intensive appliances.

Most of the services conducted at health centers are dependent on electricity access. The RWI studies pointed out that most health centers already had access to electricity from a diesel generator or a solar panel prior to being connected to the grid. Hence, the uptake of new appliances is not very different after connection. However, getting access to on-grid electricity implies significant costs savings for connected health centers. It also increases the convenience of their services as it allows simultaneous use of more appliances, which in turn increase the quality of the services. In addition, the researcher from the World Bank pointed out that health centers are likely to be built in an area once it is provided with grid connection. This suggests that electricity access plays an enabling role in the provision of health services in Rwanda.

Environment

In Scatec Solar's annual report from 2015, it is reported that the ASYV plant contributes to a reduction of 8,000 tons of CO_2 per annum through the displacement of fossil fueled power generation. Although this number is incredibly small in the broader picture, it should still be acknowledged as a valuable contribution to GHG reductions in the Rwandan context. The CEO of REG further highlighted that the ASYV project has reduced the use of fossil fuels on two different levels. First, through lower dependence on thermal power plants. Second, through the reduction of distributed diesel generators. Businesses, schools and health centers that previously used generators to access electricity can instead use electricity from the national grid. The village director highlights that diesel generators are still used as a backup source in case of grid outages, but they no longer serve as the primary source of electricity. Jörg Peters points out that few businesses and almost none households were using diesel generators initially. Thus, the scope of the carbon savings associated with reduced usage can be assumed to be modest.

Lenz et al. (2015) also found that battery driven lamps are less prevalent among connected households. As batteries from these lamps are often disposed of in nature, they constitute a significant threat to the environment in the long-run. The CEO of REG confirmed that connected households tend switch from battery-driven lamps to electric lightning once electrified.

Other welfare effects

We define other welfare effects as measures that affect people's well-being and social conditions, but do not necessarily increase overall income levels of the economy. In Rwanda, the uptake of mobile phones, radio and television were among the most striking effects of increased electrification access. All the interviewed stakeholders highlighted the significant welfare benefits associated with increased uptake of such electric appliances. The CEO of REG stresses that mobile phones were prevalent before electrification, but easier access to charging has generated a substantial increase of telecommunication. Increased communication between households living in the same community and other regions of the country is pointed out as an important social benefit that arose from electrification by the majority of the respondents. Furthermore, the CEO believes that the information-inflow from appliances like TV and radio is an important contributor to the general knowledge level of both students and adults. Jörg Peters also highlight the welfare effect that follows the use of these appliances for entertainment. From this perspective, electricity provides households with the opportunity to escape boredom and stimulate a more positive state of mind.

The empirical findings suggest that access to high quality lighting significantly increases the number of hours people stay awake. This further provides households with the opportunity to rearrange their daily activities in more effective ways than before. Although the time savings do not translate into an increase in time spent on income-generating activities, Jörg Peters and the village director stresses that the increased flexibility that comes with electric lightning must be considered a valuable welfare gain. Outdoor lightning was also pointed out as a contributor to increased security in villages as people felt safer being outdoor after sunset.

5.3.1 Summary table of catalytic effects

A summary of the findings from the assessment of the catalytic effects can be found in **table 5.2**. Here we have weighted each welfare measure in terms of associated socio-economic benefits.

Table 5.2: Evaluation of the socio-economic impacts of electrification

Impact	Income	Education	Health	Environment	Well-being
	Low	Medium to low	Medium to high	High	High

We consider the impact of electricity access on enterprise and household income as low. The findings of the RWI studies did not find any difference in overall income levels between connected and unconnected households and businesses. However, the RWI findings, supported by our interviewees, show that some small-scale businesses are established in the wake of electrification.

The impacts of electrification on education are considered medium to low. The empirical findings from Rwanda do not suggest that school enrollment or years of completed schooling increase in connected areas, nor that children study more. Thus, electricity itself is not vital for the provision of educative services. However, electric lighting makes it possible to study after nightfall and the use of electric appliances improves the services and the curriculum of schools.

Furthermore, we find that electric lightning substitute kerosene usage and that electricity is an enabling factor for the provision of health services in Rwanda. Still, the uptake of electrical appliances for cooking and heating purposes are limited, restricting health benefits in this area. In total, we therefore consider the health impact of electricity access as medium to high.

The benefits of the environmental impacts are considered high as the electricity generated from the ASYV solar power plant is 100 percent renewable. This constitutes a symbolically important contribution towards reducing GHG emissions of power generation in Rwanda.

Lastly, the impacts of electricity access on direct well-being measures are many and generate valuable welfare benefits for most people, such as entertainment, access to information and knowledge, time savings and security. This suggests that electricity access has a high impact on well-being measures, such as people's convenience and flexibility.

It is important to note that the assessment of the catalytic effects on welfare measures is based on short- to mid-term evidence. Although several of the identified impacts seem modest, the long-term effects might be more significant. Following the logic of **figure 3.4** in subchapter 3.3.2, many of the identified effects can be described as mid-term impacts. In the long run, these effects may generate more significant socio-economic impacts on income, health and education levels that create structural changes in the economy.

6. Discussion

This study examines how the ASYV solar power plant generates socio-economic ripple effects in Rwanda. The findings from the ripple effect assessment indicate that local economic impacts of the ASYV project are relatively modest while certain social impacts seem more significant, at least in the short to medium term. In this discussion we will address four topics. First, we will elaborate on the reasons why local value creation seems low in the case of the ASYV project in Rwanda, and how the country can be better able to transfer foreign investments into local value creation. Second, we will elaborate on the ASYV project's contribution to increased electricity access in Rwanda and why our findings are somewhat different from the assumptions found in literature. Third, we will discuss the future viability of solar power deployment in Rwanda and whether our findings can help us draw some general conclusions for the Sub-Saharan African region as a whole. Lastly, we will highlight some limitations of our study.

6.1 Enabling further local value creation in the value chain

Our findings suggest that the value chain of the ASYV project has low value creation in Rwanda. During construction, the share of the domestic value added accounts for only 7.8 percent of the total construction cost of the ASYV project. This is a result of high dependency on imported inputs and foreign know-how during all segments of the project's value chain. Our finding is supported by the literature, saying that little value can be expected to be created domestically in countries with an underdeveloped RE industry in planning, manufacturing and installation activities (cf. subchapter 3.2.1). We further find that the utility, service and construction sectors generate the highest contribution to domestic value added during construction. This aligns with the literature presented in subchapter 3.2.1, in that water supply, groundwork and channeling are typically delivered by local companies, making opportunities for local value creation high for such activities. We also find that Rwandan suppliers are less dependent on imports during operations. 84 percent of Scatec Solar's operational expenses are captured as value creation by local suppliers. This also corresponds to the theory (cf. 3.2.1) in that the potential for local value creation is high for maintenance activities. Still, there are relatively small expenses linked to the operation and maintenance of a solar power plant which limits the value creation potential.

With this in mind it is therefore relevant to ask: How can Rwanda capture more of the value being created throughout the ASYV value chain and similar foreign investment projects, and how can the nation ensure that these capital transfers contribute to sustainable economic growth?

Driven by ambitious plans to increase power generation and access throughout the country, the Government of Rwanda has succeeded to a large extent in implementing policy instruments that promote RE deployment. Feed-in tariffs for small-scale hydro plants and PPAs employed in RE projects (such as ASYV) are proof of this. The Government of Rwanda has also been highly successful in attracting foreign investment from public and private investors into various development projects in the country. The involvement of development finance institutions has been crucial in attracting private investors, significantly aiding the inflow of FDI into the nation. Moreover, low levels of corruption and effective and supportive government infrastructure have smoothened the flow of money into Rwanda.

However, more supporting policies are necessary in order to maximize the benefits of FDI inflow. From our findings it is clear that little to no value is being created domestically in several segments of the ASYV project's value chain. Thus, the challenge is to ensure that local products and services can meet the demand in all segments of the project's value chain, enabling IPPs to choose local contractors over foreign ones.

Integrating local content requirements is suggested by IRENA and CEM (2014, p. 51) as one way of strengthening local value creation along the value chain of a RE project in developing countries. Such policies are often tied to deployment of supporting policies, such as FiTs and PPAs, and obligate the project developer to acquire a certain amount of inputs from local suppliers. This enables the government to capture specific socio-economic measures in order to reach national development targets. Local content requirements can also be useful to ensure value creation in segments that were previously not generating value in the domestic economy, such as in the planning and manufacturing segments of the ASYV value chain.

However, empowering local agents to capture larger shares of the value creation is not possible without strengthening firm-level capabilities, and educating and training the workforce. This is also highlighted in the FDI literature, which suggests that foreign investments induce economic growth through the spillover of technology and know-how.

Foreign investments thus play an important role in helping the host country to enhance value creation with respect to knowledge acquisition and capability upgrades along the value chain of different RE sectors. Consequently, improving Rwandan industry ability to absorb such technology transfers and use it to enhance capabilities is crucial to helping local firms better compete with foreign contractors and thereby capture larger shares of the value creation in RE value chains. We therefore argue that Rwanda should develop policies that support an environment conducive to innovation and capacity building.

In the case of the ASYV project, we found that domestic suppliers added the largest share of value during the construction period, although it raised activity levels in the economy only for a limited period of time. However, the technological transfers during this period induced a valuable contribution of skills enhancement for workers. This could create further ripple effects in the economy if the knowledge gained is preserved and utilized to strengthen the capabilities of workers and firms. It is worth noting that the scope of this effect will depend on the interaction between the educated workforce and the Rwandan workers, and the ability of locals to absorb the new knowledge.

Nevertheless, there are several impediments to enhancing the capability level of domestic industries in Rwanda. First, the market potential for RE deployment in Rwanda is limited. The country is small, possessing few resources. Although the energy demand is high, the low consumption levels of electricity do not speak in favor of building many large solar power plants, at least not in the near future. This makes it questionable whether the development of a domestic industry, such as in manufacturing components for the solar PV industry, is realistic. There might, however, be sufficient market potential at the regional level to develop a sustainable manufacturing sector in Rwanda. We know that many countries in SSA are in high need of increasing power generation capacity and have launched ambitious plans to meet their energy needs with solar and other renewable sources. Learning from the ASYV project, the first large-scale grid connected solar PV project in East Africa, can thus be an important mean to gain first mover advantages in this market on a broader, regional level.

6.2 The contribution of electricity access

Access to electricity is widely believed to be a key component to set economic gears in motion within developing countries. The most direct transmission channel is the perceived impact on the income level of both households and businesses. In contrast to strong evidence from Asia and Latin America, our results do not indicate a significant effect of electricity on income and productivity levels. Thus, our findings challenge the transferability of this evidence to Sub-Saharan Africa. What are the underlying mechanisms explaining this observation?

On the household level, income is often too low to finance the upfront cost associated with new electrical appliances uptake. High commercial electricity tariffs also partially explain why households cannot afford to consume high levels of electricity. The combination of expensive upfront costs and high consumption rates associated with the use of electrical appliances represents a substantial barrier for low-income households to take full advantage of the opportunities offered by electricity. On the community level, severely underdeveloped physical infrastructure coupled with low household income culminates in limited markets. Poor domestic connectivity inhibits trade between different community clusters, and the production by economic sectors is therefore only distributed to the local market. Furthermore, Rwanda is a landlocked country with poor connectivity to neighboring countries, also reducing the potential for exports of products and services to the region. In contrast, countries in Asia and Latin America have a much larger potential for exports, both domestically and regionally. This gives businesses greater incentives to invest in electrical appliances in order to harvest productivity and enhanced quality gains.

Reflection on the underlying factors explaining why the income level remains unchanged in the wake of electrification indicates that electricity is not a criterion for economic development; it is more of a facilitator. Furthermore, this suggests that other political measures must be conducted in parallel to the expansion of electricity infrastructure and access in order to enhance the scope of the ripple effects of electricity access. The Government of Rwanda therefore needs to implement measures and policies that can stimulate economic activity, reduce extreme poverty and raise the consumption levels of the masses of the Rwandan population.

Moreover, the low electricity consumption patterns among households and businesses raise the question of whether the commercial electricity tariff is too high. Lowering electricity prices and improving electric appliances availability in the market would enable people to better capitalize on opportunities offered by electrical machinery and harvest associated productivity gains. The economic sectors would then produce more output from inputs and encourage new business establishments. This would in turn generate higher demands for products and services from both economic sectors and final consumers.

In addition, the government needs to improve internal and external transport infrastructure in parallel to measures focusing on increasing resident's purchasing power. Increasing the potential for domestic and regional exports would give businesses greater incentives to utilize electric machinery in order to increase output and harvest productivity gains. The importance of efficient infrastructure is reflected in Lenz et al. (2015), as they found a significant correlation between communities located close to major roads or larger community clusters, and income level among residents in these communities. Further investment in infrastructure will increase the opportunities for value creation throughout the whole value chain and possibly justify government usage of higher subsidies in the long-run.

In spite of limited effects on income in the short to medium term, our findings indicate that electricity has a positive impact on both educational and health indicators. In terms of education, electricity has improved the lighting conditions at schools and for home studying. It has also improved the curriculum at electrified schools, although enrollment rates and years of completed schooling remain unchanged. Lenz et al. (2015) did not address educational performance, and the true impact on education might be more uncertain. Still, we find it reasonable to believe that electricity access will improve the provision of educational services in Rwanda. Furthermore, the observed impact on health indicators suggests that electricity access reduces respiratory diseases and increases access to high-quality health services. A healthier and more educated population can in the long term be expected to increase labor productivity and thereby cause structural changes in the Rwandan economy and strengthen the scope of the ripple effects associated with electrification. Economic sectors can produce more output from its inputs and new businesses can emerge, which in turn can fuel socio-economic growth. A general increase in economic activities can further encourage younger generations to enter the educational system and complete more years of schooling. Thus, in the long term, Rwanda may experience increased enrollment rates and years of completed schooling, as observed in a number of countries in Asia and Latin America.

Positive impacts on well-being are perhaps the most prominent contribution of improved access to electricity in Rwanda, at least in the short to medium term. Increased access to entertainment, information and communication, and possibilities to restructure daily activities definitely affect people's mindset. The bulk of young generations might therefore adapt to these opportunities and form a stronger belief in future development. Although hard to measure in monetary terms, the positive impacts on household welfare must be acknowledged as an important effect of electricity access. This is also emphasized in conclusions made by Lenz et al. (2015) and in the interview with Jörg Peters. Alternations in people's mentality might change habits and consumption patterns. Moreover, greater access to information and communication channels can translate into higher school enrollment rates as people learn about existing opportunities and become more exposed to urban lifestyles. The aggregation of behavioral changes that arises from higher well-being can also translate into structural changes in the economy over time.

Lastly, one must also acknowledge the positive environmental impact of the ASYV solar plant's supply of renewable energy into the Rwandan grid. Even though the plant's contribution of 8000 tons of CO_2 reduction annually is small in the broader picture, it still should be noted as an important symbolic contribution to the world's reduced reliance on fossil fuel resources. Developing countries have been severely hit by global climate change, and Rwanda's heavy reliance on agricultural food production makes it vulnerable to extreme events like drought and floods. Such events have a dramatic effect on the national economy of Rwanda, further emphasizing the importance of investments into the renewable sector.

Furthermore, we do not find evidence of any increase in uptake of ovens for cooking and heating purposes. This can be explained by the associated high electricity consumption of ovens and the grid's inability to support a widespread use of this appliance. This finding further suggests that electricity do not have the same positive impact on deforestation in Rwanda as found in many other developing countries (Heltberg, 2004). We do not believe it is realistic to expect Rwandans to adapt electric ovens in the near future, meaning that the country will miss out on a potential environmental ripple effect.

6.3 The long-term viability of solar power generation in Rwanda

Several stakeholders highlight the success of the ASYV project. It figures as a template for how the region can tackle its energy challenges. The project stands out as an example of how quickly and seamlessly a solar PV plant can be installed in a developing country, a point that is important to showcase for investors in order to attract future investment into the Rwandan economy. In our assessment, we have addressed the viability of solar power generation in

Rwanda in a short to medium term perspective. The long-term perspective, however, is more complex and difficult to assess due to constantly changing market conditions.

Thus far we have been looking at the ripple effects that can be identified by tracing the capital flow of the ASYV project, or by addressing the socio-economic impacts of access to electricity. In the long-term, however, there are also other benefits arising, which are not always accounted for when assessing the value creation of RE projects. Reduction of risks associated with fossil fueled power generation is one of such benefits. As Rwanda is a net importer of petroleum products, the solar powered electricity is valuable also in terms of reduction of risks associated with energy security and geopolitical issues. Furthermore, environmental risks reductions constitute an important contribution to climate change mitigation efforts, although the symbolic value is arguably more significant than the amount of reduced GHG emissions. Lastly, the ASYV solar power plant also has a positive impact on financial risks related to trade balances and governmental spending on energy subsidies. Compared to the current average power generation costs in Rwanda, the solar powered electricity from ASYV enables significant savings on energy subsidies, and one can argue that it is an important step towards reducing the dependency on fossil fuel imports.

Still, it is important to note that a large share of the equipment and material needed to construct and operate the ASYV solar power plant needs to be imported. This may suggest that Rwanda only substitutes fossil fuel imports with imports of solar PV technology and that the final effects on trade balances are less significant. Nevertheless, the imported solar PV equipment would allow for reductions of fossil fuels imports throughout the whole lifetime of the power plant, making the long-term impact on trade balances likely positive. Again, this illustrates the importance of developing local capabilities so that larger shares of the value creation in the solar PV value chain can be attributed to local content.

As we have seen, one of the challenges to really reap the benefits of renewable electricity is to make electricity consumption reasonably affordable for the larger masses of the Rwandan population. Currently, increasing subsidies would be the most effective way to lower electricity tariffs. However, it is not sustainable to rely on subsidies in the long run. Rwanda is a poor country that relies heavily on official development aid, limiting its capacity to use subsidies. Rwanda therefore needs to deploy energy sources that can bring generation costs down. As a result, the Rwandan government has set ambitious plans to further increase its power generation capacity by deploying other energy sources. A methane gas power plant on the Kivu Lake was recently connected to the central grid, and there are several small and medium-sized hydropower projects being developed. Looking at the average generation costs of these energy sources on a global level, power production from these sources will presumably have a lower generation cost per kWh compared to the solar power from the ASYV plant. This will enable reductions of production costs, which subsequently may lower electricity tariffs and subsidy spending.

In light of solar PV requiring large imports of technical equipment and foreign know-how, investments conducted in other energy sources could arguably generate higher domestic value creation. For example, building a hydropower dam is less technology intensive and also requires large investments in construction and civil works activities, which are more likely to be contracted to domestic suppliers. One can therefore argue that ripple effects in terms of domestic value added, employment creation, and subsequently increased income and consumption levels in the local economy, are likely to be larger in the case of a hydropower project.

Furthermore, electricity imports from neighboring countries will also be scaled up in order to bring the electricity tariffs in Rwanda further down. The fall in oil and coal prices has also made fossil fueled thermal power generation more affordable, which may have a positive impact on final electricity tariffs in the country. Still, high transportation costs are likely to prevail and the current low price level of petroleum products might not be sustained in the long run.

In sum, these tendencies question the viability of further solar PV deployment in Rwanda. This may indicate that the PPA between Scatec Solar and the Rwandan utility company REG is not beneficial for the country in the long run given that cheaper power sources are implemented in the Rwandan power mix. Consequently, the positive contributions to subsidy savings may instead translate into increased governmental spending in the long run. However, it is uncertain if the PPA tariff of 2015 is representative for the coming years of production as the details of the PPA has not been disclosed by Scatec Solar for this analysis. Still, it is worth noting that the Rwandan government has not initiated any other large-scale solar power developments after the installation of the ASYV solar plant. This may indicate that the negotiated PPA between REG and Scatec Solar is not sustainable for future developments in Rwanda. The project was the first of its kind in the entire region of East

Africa and it is assumable the Rwandan Government had little experience negotiating on RE deployment agreements.

However, the solar PV industry has experienced dramatic cost reductions, which are likely to continue in coming years. This indicates that solar PV technology is becoming increasingly competitive and could figure as a more sustainable solution in the future, creating important ripple effects in society. Still, regardless of which energy source generates the most socio-economic ripple effects in Rwanda, the intermittent nature of renewable energies, solar in particular, makes it unfeasible to solely focus deployment on one single energy source. Thus, it is essential that a diversified energy mix is developed, in which the different risks and weaknesses of the different energy sources are mitigated. This will result in a more effective and sustainable energy supply that ensures sustained socio-economic ripple effects from energy investments and increased electricity access.

6.4 Transferability to the Sub-Saharan African context

Many of the findings from the assessment of the ASYV project in Rwanda are assumably similar to what we can expect to find in other countries in Sub-Saharan Africa (SSA). High energy needs and low electricity access coupled with underdeveloped and ineffective business sectors are highly prevalent conditions in most countries of the region. This suggests that RE deployment most likely will remain dependent on import of foreign expertise and material, limiting opportunities for local value creation. In many nations across the region, the workforce is dominated by low-skilled workers, particularly in the agricultural sector. Thus, the discussion on capability enhancement in Rwanda will be crucial in most countries in order to strengthen socio-economic ripple effects at the local level.

We have discussed that RE deployment can constitute a valuable contribution in terms of reduced imports of fossil fuels and increased energy security. Several countries in the region have, however, vast oil and gas resources that may be the most cost effective energy system to increase power generation. Thus, it is not certain whether RE deployment will have positive impacts on trade balances in such countries. Increased investment in RE deployment could also initiate negative depreciation effects if reduction of local value creation and job losses in conventional energy systems are greater than the value creation of the RE sector. Still, high energy needs combined with a large share of the workforce being low-paid and unskilled workers suggests that negative depreciation effects are unlikely in most parts of the Sub-Saharan African region. Although dominated by international corporations, the oil and gas industry in resource rich countries might also induce technology spillovers to the RE sector and take advantage of existing local capabilities. Consequently, countries with a developed oil and gas industry in SSA may capture larger shares of value creation in RE value chains.

Low electricity consumption amongst connected households and low uptake of electric appliances is also highly relevant for SSA as a whole. With an average GNI per capita at USD 1,638 (World Bank, 2014C), large portions of the population in SSA are considered poor and without the ability to consume large amounts of electricity. Furthermore, the region's average electricity tariff at USD 0.13 per kWh is much higher than tariffs in most developing parts of the world where average tariffs fall in the range of USD 0.04-0.08 (World Bank, 2013). This restricts the opportunity for socio-economic ripple effects of increased electricity access all over the region.

The findings of Lenz et al. (2015) from Rwanda suggest that lack of market access and the resulting limited demand for labor is a major reason why most people do not find it reasonable to use electricity for productive purposes. However, some countries are better positioned to develop internal markets due to the size of the country (market potential) and the potential of exports, e.g. access to seaports, low trade tariffs, etc. which reduces transport and transaction costs. Furthermore, Rwanda is a country with relatively few natural resources, so there is little potential to develop exporting industries that can benefit from the higher availability of electricity. Other countries in the region, however, are more resource rich, both in terms of minerals and fertile soils that can be used for agricultural industry. This suggests that electricity availability in other countries might generate larger impacts on income and economic growth. As a landlocked country, Rwanda is not well positioned to be a major regional trading hub, which does not help the development of manufacturing industries or raw material processing industries. Again, countries that have more favorable geographical conditions for trading purposes are likely to have a higher potential to exploit the productive benefits of electricity.

A well-functioning state and an enabling business environment that contain easy access to finance and investment incentives have been among the major reasons why Rwanda has been able to increase electricity access and generation capacity to such a large extent. Good governance and transparency is thus vital to be able to harvest the benefits of RE deployment. Many countries in SSA are not in the same position as Rwanda and face tremendous challenges in order to accomplish political stability. This might suggest that positive socio-economic ripple effects are less likely to arise in countries with high corruption levels and political instability.

6.5 Scope and Limitations of the analysis

Lastly, we would like to draw the attention to the scope and limitations of our study, especially those that are related to the use of I-O modeling. Note that the assumptions in the input-output (I-O) model, presented in subchapter 4.3.4 also provide a source of uncertainty for our results.

Structural changes in the Rwandan economy: Our assessment of the direct, indirect and induced effects builds upon the I-O model. This model captures the static relationships between inter-industry demand and deliveries for the year 2011. Using financial data for the years 2014 and 2015, our results build upon the assumption that no notable structural changes have occurred in the Rwandan economy between 2011 and 2014/15. There has, however, been a transfer of labor force from agricultural activities to non-farm activities the recent years coupled with high economic growth. These trends might have caused some structural changes in the economy. The extent to which structural changes have been present are further elaborated on in the discussion.

Displacement effects: Our assessment of the ripple effects is a gross analysis in the sense that it does not take displacement of inputs into account. Alternative usage of the labor force is therefore not considered. Rwanda displayed a fairly low unemployment rate in 2011 at 1.7 percent, mostly explained by the inclusion of subsistence farming into the share of total employed labor force. This means that workers employed throughout Scatec Solar's local value chain might have alternative usages. Given that 70 percent of Rwanda's population is engaged in agricultural activities with modest income generation, the labor inputs can be assumed to have substantial lower alternative usages with lower factor return, on average, outside Scatec Solar's local value chain. From this perspective, our estimate of the value creation per labor input will not be much lower than the net value creation per labor input.

Data gathered from different sources: In order to convert the SUT table into an operational I-O model and to calculate the multipliers, we had to gather data from both the national SAM table and the EICV surveys 3 and 4. Combining data from three distinct sources might reduce the validity of the results, although all data corresponds to 2011 variables.

Limited time horizon: In our assessment of the catalytic effects, we analyze the effect of electrification on different social and economic variables. Most of the electrified households have not been connected for a long time. Therefore, our results might not capture the long-term effects of electricity. We thus believe more research is needed in the coming years to fully grasp the dynamic effects.

7. Conclusion

In this study we have identified the socio-economic ripple effects that stems from Scatec Solar's investment in the ASYV project and estimated the coherent value of these effects. When it comes to the economic impacts, our findings indicate that a relatively low share of Scatec Solar's value creation throughout the value chain of the ASYV project can be attributed to local suppliers in Rwanda. This finding is applicable to both the construction and the operational period of the project. Nevertheless, it is important to note that the local ripple effects identified in the operational year of 2015 may be assumed to give a realistic picture of the annual contribution to local value creation for the future years of the operation of the solar plant.

We have further reflected on several mechanisms that may explain the limited scope of the local ripple effects in Rwanda. The most prominent explanatory factor is the high dependency on imported inputs and foreign know-hows during all segments of the project's value chain. This can partly be seen as a consequence of the severely underdeveloped economic sectors in Rwanda coupled with the project's demand for advanced technological products and services. In line with theory on the formation of renewable power plants, the bulk of local value added is concentrated to activities typically delivered by local companies in the segments of construction, grid connection and O&M. In the segments of planning and manufacturing, where most of the value creation in the value chain takes place, the share of local value creation is close to non-existing.

In spite the limited scope of local value added, one should still acknowledge the notable increase in local employment that arise from Scatec Solar's investment. The I-O model does not address the quality nor duration of these positions, but the general trends in the Rwandan labor market suggests that these positions can be attributed to low-skilled employment in the informal sectors. The high creation of employment is a reflection of the general low wage levels in Rwanda. This essentially also explains why employment is especially prominent in low-wage professions within the retail and service sectors higher up in the value chain.

Furthermore, the findings from our assessment of the catalytic effects indicate that also the socio-economic ripple effects arising from access to electricity remains modest. This observation contrasts the general belief that electricity is a key driver for socio-economic growth in developing countries. A number of country and region specific factors may, however, explain this contradiction. Rwandan residents face one of the highest electricity prices in the world coupled with severely underdeveloped infrastructure which restricts the market exchange. Economic sectors thus lack the ability and opportunity to increase output and harvest productivity gains provided by electricity. This further indicates that electricity is not a criterion for socio-economic development, more a facilitator, explaining why the income levels of both households and businesses remain unchanged in the wake of electrification.

Although our findings do not support the link between electrification and classical development indicators, such as poverty reduction, electrification has significant impacts on people's well-being. Softer welfare impacts related to the convenience and flexibility of people's daily life is the most prominent effect of electrification in Rwanda. This effect might give rise to broader structural changes in the Rwandan economy in the long run, although this possibility is not identified and captured in the existing literature. Also the positive effects of electrification on health and educational indicators may translate into a more healthy and educated labor force, which in turn might enhance the income levels of Rwandan residents over time. It thus remains to see how the scope of the ripple effects associated with electrification unfolds in the long-run.

Parallel to the expansion in electricity capacity and access, the Government of Rwanda needs to further adopt the right policies in order to maximize value creation that stems from foreign direct investments in the RE sector. The country has already come a long way on establishing a good policy mix to stimulate RE deployment and financial incentives to attract investments. Further efforts must be concentrated in sustaining technology transfers into the local economy, strengthening capabilities and promoting innovation in local industry sectors so that domestic firms can capture larger shares of value creation domestically. These cross-cutting measures along all segments of the value chain will generate higher potential for local value creation. The Rwandan Government further needs to find the right incentives to reduce power generation cost so that electricity tariffs can be made affordable for the greater majority. It is unknown whether solar PV can maximize domestic value creation and socio-economic ripple effects. Nevertheless, solar PV technology is likely to play a vital role in solving the energy challenges in Rwanda and in Sub-Saharan Africa as a whole. Further technology advancements will eventually be a key factor determining future deployment.

Comparing the socio-economic impacts of the ASYV project with potential impacts of other energy sources and alternative electricity dissemination systems (e.g. off-grid electrification) is beyond the scope of this study. However, we see this as a highly relevant area for future research and an important contribution in the debate on whether investment into solar PV deployment and on-grid electrification can be justified compared to alternative solutions.

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Appendices

Appendix A: Supply-use tables from Rwanda (2011)

Supply Use Table A
Production accounts 2011
(in billion Frw)

Activity description	ISIC Rev.4Code	Total output at basic prices	Input output ratio	Inter-mediate consumption	Groos value added
Gross domestic product (GDP) at market prices					**3,846**
ALL ACTIVITIES at basic prices	**Total**	**6,032**	41%	**2,444**	**3,588**
AGRICULTURE, FORESTRY & FISHING	**A**	**1,327**	**6%**	**83**	**1,244**
Food crops	AA	895	6%	50	845
Export crops	AB	88	11%	9	79
Livestock & livestock products	AC	128	5%	7	122
Forestry	AD	199	7%	14	185
Fishing	AE	17	19%	3	14
INDUSTRY	**B-F**	**1,734**	**68%**	**1,179**	**554**
Mining & quarrying	B	117	37%	44	74
TOTAL MANUFACTURING	C	824	75%	620	204
Manufacturing of food	*CA*	*277*	*82%*	*227*	*50*
Manufacturing of beverages & tobacco	*CB*	*298*	*67%*	*199*	*99*
Manufacturing of textiles, clothing & leather goods	*CC*	*36*	*78%*	*28*	*8*
Manufacturing of wood & paper; printing	*CD*	*62*	*78%*	*48*	*14*
Manufacturing of chemicals, rubber & plastic products	*CE*	*41*	*78%*	*32*	*9*
Manufacturing of non-metalic mineral products	*CF*	*28*	*69%*	*19*	*9*
Manufacturing of metal products, machinery & equipment	*CG*	*50*	*83%*	*41*	*9*
Furniture & other manufacturing	*CH*	*33*	*77%*	*25*	*8*
Electricity	D	56	80%	45	11
Water & waste management	E	24	44%	11	14
Construction	F	711	65%	460	251
SERVICES	**G-T**	**2,971**	**40%**	**1,182**	**1,790**
TRADE &TRANSPORT	G-H	857	31%	265	592
Maintenance & repair of motor vehicles	GA	40	54%	22	19
Wholesale & retail trade	GB	566	18%	100	466
Transport services	H	251	57%	144	107
OTHER SERVICES	I-T	2,115	43%	917	1,198
Hotels & restaurants	I	311	68%	211	100
Information & communication	J	148	37%	56	93
Financial services	K	162	33%	54	108
Real estate activities	L	311	8%	25	286
Professional, scientific & technical activities	M	137	29%	40	97
Administrative & support service activities	N	148	31%	46	102
Public administration & defence; compulsory social security	O	379	70%	264	115
Education	P	190	36%	68	122
Human health & social work activities	Q	132	71%	94	39
Cultural, domestic & other services	R-T	196	30%	60	137
Taxes less subsidies on products					**258**

Source: National Institute of Statistics of Rwanda

Supply Use Table B

Commodity flow accounts 2011

(in billion Frw)

Supply Use Table B

Commodity flow accounts 2011

(in billion Frw)

Product description	ISIC Rev.4Code	Imports of goods & services	Total output at basic prices	Margins	Taxes on products less subsidies	TOTAL SUPPLY TOTAL USE	Inter-mediate demand	Final househld cons-umption	Final govt & NGO cons-umption	Capital formation	Exports of goods & services	ISIC Rev.4Code	Product description
ALL ACTIVITIES at basic prices		**1,139**	**6,032**		**258**	**7,429**	**2,444**	**2,938**	**616**	**905**	**525**		**ALL ACTIVITIES at basic prices**
AGRICULTURAL & FISHING PRODUCTS	**A**	**52**	**1,327**	**72**	**2**	**1,453**	**415**	**908**		**53**	**78**	**A**	**AGRICULTURAL & FISHING PRODUCTS**
Food crops	A1	44	895	46	1	986	294	666		15	11	A1	Food crops
Export crpos	A2	4	88	6	0	98	31	7		14	46	A2	Export crpos
Livestock & livestock products	A3	4	128	8	0	140	62	36		22	19	A3	Livestock & livestock products
Forestry	A4	1	199	11	0	210	27	182		1	0	A4	Forestry
Fishing	A5	0	17	1	0	19	1	17			1	A5	Fishing
INDUSTRIAL PRODUCTS	**B-F**	**946**	**1,734**	**481**	**237**	**3,398**	**1,188**	**1,173**		**840**	**196**	**B-F**	**INDUSTRIAL PRODUCTS**
Mining & quarry products	B0	5	117	36	1	159	59			0	100	B0	Mining & quarry products
Manufactured food products	C1	113	277	39	21	451	57	335		7	52	C1	Manufactured food products
Beverages & tobacco	C2	15	298	27	63	402	119	280			4	C2	Beverages & tobacco
Textiles, clothing & leather goods	C3	42	36	97	12	187	32	149			6	C3	Textiles, clothing & leather goods
Wood, paper & printing products	C4	26	62	14	5	108	66	41			1	C4	Wood, paper & printing products
Petroleum products	C51	172	0	45	53	271	189	71			11	C51	Petroleum products
Chemicals, rubber & plastic products	C5X	148	41	54	14	257	188	65			4	C5X	Chemicals, rubber & plastic products
Non-metalic mineral products	C6	56	28	21	8	113	109	0			3	C6	Non-metalic mineral products
Metal products, machinery & equipment	C7	335	50	136	51	571	268	98		190	14	C7	Metal products, machinery & equipment
Furniture & other manufactured products	C8	28	33	12	4	77	3	34		38	2	C8	Furniture & other manufactured products
Electricy	D0	3	47		-6	44	33	11			0	D0	Electricy
Water & waste management	E0		24		0	24	7	17				E0	Water & waste management
Construction	F0	2	721		11	734	57	73		605		F0	Construction
TRADE & TRANSPORT SERVICES	**G-H**	**-2**	**856**	**-556**	**-25**	**273**	**151**	**91**			**30**	**G-H**	**TRADE & TRANSPORT SERVICES**
Maintenance & repair of motor vehicles	G1		40		2	43	32	10				G1	Maintenance & repair of motor vehicles
Wholesale & retail trade	G2		566	-556		10	10					G2	Wholesale & retail trade
Transport services	H	-2	250		-27	220	109	81			30	H	Transport services
OTHER SERVICES	**I-T**	**79**	**2,116**	**2**	**44**	**2,241**	**643**	**946**	**616**	**12**	**24**	**I-T**	**OTHER SERVICES**
Hotels & restaurants	I0		311		9	320	48	272				I0	Hotels & restaurants
Publishing & broadcasting services	J1	9	9	2	1	21	10	11			0	J1	Publishing & broadcasting services
Telecommunication	J2	21	117		22	159	82	57			20	J2	Telecommunication
Information technology services	J3		23		1	24	12	1		11		J3	Information technology services
Financial services	K0	4	162		6	172	93	67	11		1	K0	Financial services
Real estate	L0		311		0	311	58	253				L0	Real estate
Professional, scientific & technical services	M0	44	137		2	184	177	6		1	0	M0	Professional, scientific & technical services
Administrative & support services	N0		148		2	150	125	22			3	N0	Administrative & support services
Public administration & defence	O0		379			379	11	4	364			O0	Public administration & defence
Education	P0		191		0	191	21	86	84			P0	Education
Human health & social work	Q0		132		0	133		38	94			Q0	Human health & social work
Arts, entertainment & recreation	R0	0	14		0	14	4	10			0	R0	Arts, entertainment & recreation
Other personal & community services	S0	0	131		1	132	1	67	63		-0	S0	Other personal & community services
Domestic services	T0		52		0	52		52				T0	Domestic services
Travel debits & credits	**V**	**64**				**64**	**48**	**-181**			**196**	**V**	**Travel debits & credits**
Spending by residents abroad	V1	64				64	48	16				V1	Spending by residents abroad
Spending by non-residents in Rwanda	V2							-196			196	V2	Spending by non-residents in Rwanda

Source: National Institute of Statistics of Rwanda

Source: National Institute of Statistics of Rwanda

Supply Use Table C

Intermediate consumption matrix 2011

(in billion Frw)

Supply Use Table C
Intermediate consumption matrix 2011
(in billion Frw)

Product description	Code based on ISIC Rev.4	Inter-mediate demand	Agriculture & fishing A	Mining & quarrying B	Food manufacturing CA	Beverages & tobacco CB	All other manufacturing CX	Electricity, water, etc D,E	Construction F	Trade & transport G,H	Hotels & restaurants I	Public administration O	Education & health P,Q	All other services X
ALL ACTIVITIES at basic prices		**2,444**	**83**	**44**	**227**	**199**	**194**	**56**	**460**	**265**	**211**	**264**	**161**	**281**
Food crops	A1	294	24		94	139	6				30			
Export crpos	A2	31	6		23						0	2	0	0
Livestock & livestock products	A3	62	2		58						2			
Forestry	A4	27			2	0	21			0	3	0	1	0
Fishing	A5	1									1			
Mining & quarry products	B0	59					2		57					
Manufactured food products	C1	57	1		25	14					16			
Beverages & tobacco	C2	119				7					111			
Textiles, clothing & leather goods	C3	32	1				22			0		2	0	7
Wood, paper & printing products	C4	66		0	0	1	26	0	17	1	3	7	5	5
Petroleum products	C51	189	10	5	2	9	8	28	21	78	7	5	3	13
Chemicals, rubber & plastic products	C5X	188	26	5	2	9	37	2	28	17	1	3	53	5
Non-metalic mineral products	C6	109		3		2	4	1	92	5	0		0	2
Metal products, machinery & equipment	C7	268	2	19	2	4	40	4	119	22	2	2	5	49
Furniture & other manufactured products	C8	3		-0	-0	-0	-1	-0	-1	-1	-0	8	4	-6
Electricy	D0	33		0	3	3	6	3	1	2	4	5	2	6
Water & waste management	E0	7			2	1	0	0	0	1	1		1	1
Construction	F0	57		1	0	0	1	5		3	1	18	3	25
Maintenance & repair of motor vehicles	G1	32	3	1	1	1	1	1	6	10	2	1	1	5
Wholesale & retail trade	G2	10												10
Transport services	H	109		1	4	0	2	0	3	63	1	14	4	17
Hotels & restaurants	I0	48			0	1	0	0	0	2	2	32	5	5
Publishing & broadcasting services	J1	10		-0	-0	-0	-0	0	-0	-0	-0	4	6	0
Telecommunication	J2	82	7	1	1	2	3	8	8	11	2	4	7	29
Information technology services	J3	12	0	0	1	1	1	0	3	1	1	1	0	2
Financial services	K0	93		2	1	1	3	0	15	13	12	4	12	31
Real estate	L0	58		1	0	0	3	0	2	10	4	7	4	26
Professional, scientific & technical services	M0	177	0	1	1	3	2	1	43	3	0	86	21	15
Administrative & support services	N0	125			2	0	3	2	42	6	4	54	1	11
Public administration & defence	O0	11	0	0	1	1	1	0	2	1	1		0	2
Education	P0	21			0		1	0	0	2	0		8	10
Human health & social work	Q0													
Arts, entertainment & recreation	R0	4									-0	4	0	
Other personal & community services	S0	1		1			0							0
Spending by residents abroad	V1	48		2	0	0	2			16	0		15	12

Source: National Institute of Statistics of Rwanda

Source: National Institute of Statistics of Rwanda

Appendix B: Input-output table of Rwanda

Input-Output Table Rwanda 2011 (in million USD)

NACE group	Code based on ISIC Rev.4	Agriculture & fishing A	Mining & quarrying B	Food manufacturing CA	Beverages & tobacco CB	All other manufacturing CX	Electricity & water D, E	Construction F	Trade & transport G, H	Hotels & restaurants I	Public administration O	Education & health P, Q	All other services X	Total	Final household consumption	Final public consumption	Capital formation	Exports of Goods & services	Total use
Agriculture & fishing	A	53,78	0,00	297,48	233,61	45,38	0,00	0,00	0,00	60,50	3,36	1,68	0,00	697,48	1526,05	0,00	89,08	131,09	2443,70
Mining & quarrying	B	0,00	0,00	0,00	0,00	3,36	0,00	95,80	0,00	0,00	0,00	0,00	0,00	99,16	0,00	0,00	0,00	168,07	267,23
Food manufacturing	CA	1,68	0,00	42,02	23,53	0,00	0,00	0,00	0,00	26,89	0,00	0,00	0,00	95,80	563,03	0,00	11,76	87,39	757,98
Beverages & tobacco	CB	0,00	0,00	0,00	11,76	0,00	0,00	0,00	0,00	186,55	0,00	0,00	0,00	200,00	470,59	0,00	0,00	6,72	677,31
All other manufacturing	CX	65,55	53,78	10,08	42,02	228,57	58,82	463,87	205,04	21,85	45,38	117,65	126,05	1438,66	769,75	0,00	383,19	68,91	2660,50
Electricity & water	D, E	0,00	0,00	8,40	6,72	10,08	5,04	1,68	5,04	8,40	8,40	5,04	11,76	67,23	47,06	0,00	0,00	0,00	114,29
Construction	F	0,00	1,68	0,00	0,00	1,68	8,40	0,00	5,04	1,68	30,25	5,04	42,02	95,80	122,69	0,00	1016,81	0,00	1235,29
Trade & transport	G, H	5,04	3,36	8,40	1,68	5,04	1,68	15,13	122,69	5,04	25,21	8,40	53,78	253,78	152,94	0,00	0,00	50,42	457,14
Hotels & restaurants	I	0,00	0,00	0,00	1,68	0,00	0,00	0,00	3,36	3,36	53,78	8,40	8,40	80,67	457,14	0,00	0,00	0,00	537,82
Public administration	O	0,00	0,00	1,68	1,68	1,68	0,00	3,36	1,68	1,68	0,00	0,00	3,36	18,49	6,72	611,76	0,00	0,00	636,97
Education & health	P, Q		0,00	0,00	0,00	1,68	0,00	0,00	3,36	0,00	0,00	13,45	16,81	35,29	208,40	299,16	0,00	0,00	542,86
All other services	X	11,76	13,45	10,08	11,76	28,57	18,49	189,92	100,84	38,66	275,63	110,92	211,76	1026,89	615,13	124,37	20,17	369,75	2156,30
Total intermediate consumption		139,50	73,95	381,51	334,45	326,05	94,12	773,11	445,38	354,62	443,70	270,59	472,27						
Total use of imported products		87,39	8,40	189,92	25,21	1356,30	5,04	3,36	-3,36	0,00	0,00	0,00	238,66						
Taxes less subsidies on products		3,36	1,68	35,29	105,88	247,06	-10,08	18,49	-42,02	15,13	0,00	0,00	58,82						
Margins		121,01	60,50	65,55	45,38	636,97	0,00	0,00	-934,45	0,00	0,00	0,00	3,36						
Total intermediate consumption adjusted		351,26	144,54	672,27	510,92	2566,39	89,08	794,96	-534,45	369,75	443,70	270,59	773,11						
Value added at basic prices		2090,76	124,37	84,03	166,39	95,80	42,02	421,85	994,96	168,07	205,04	270,59	1383,19						
Total supply total use		2442,02	268,91	756,30	677,31	2662,18	131,09	1216,81	460,50	537,82	648,74	541,18	2156,30						

Appendix C: Total employment and average annual wage

Total employment in each economic sector

The calculations of total employment in each economic sector are based on the Integrated Household Living Conditions Survey 3 (EICV 3). This survey was conducted in the year of 2011, and is thus compatible with the supply use table that was conducted the same year. We derive the number of workers employed in "agriculture & fishing", "mining & quarrying", "electricity & water", "trade & transport" and "all other services" directly from EICV 3.

The dataset does not, however, provide a clear representation of the number of workers in the remaining seven sectors. We therefore derive information regarding these sectors from the most recent household survey, EICV 4 (2014). As illustrated below, the share of workers employed in each of the seven sectors (data from EICV 4) is multiplied with the total labor force (data from EICV 3).

$$Employment\ in\ sector\ j = \frac{Employment\ in\ sector\ j,\ EIVC\ 4}{Total\ labor\ force,\ EICV\ 4} * Total\ labor\ force,\ EICV\ 3$$

Where j = {"food manufacturing"; "beverages & tobacco"; "all other manufacturing"; "construction"; "hotels & restaurant"; "public administration"; and "education & health"}.

The calculations are based on the assumption that the distribution of the Rwandan labor force remained relatively constant between 2011 and 2014. Given that there has been a shift of workers from agricultural activities to non-agricultural activities the last years, the calculated number of workers in the six sector might be overestimated. Still, there is only three years between the two surveys were conducted and we thus believe the information provided by EICV 4 is representative. Total employment in each of the 12 economic sectors is presented in the table below.

Average annual wage in each economic sector

We derive data on labor compensation from a social accounting matrix from Rwanda. The matrix is based on the supply-use table from 2011 and gives a very detailed representation of the distribution of income in the Rwandan economy. It distinguishes between total compensation given to four different labor inputs: "labor – agriculture", "labor – unskilled", "labor – low skill" and "labor – high skill". Total labor compensation for each economic sector is calculated by summing the compensation given to the different labor inputs that is employed in the respective sectors. We then obtain total labor compensation in each sector. This can further be divided by total employment in the coherent sectors (see calculations above), which gives us the average wage level in each sector. The average annual wage in each economic sector is presented in the table below.

	Agriculture & fishing	Mining & quarrying	Food manufacturing	Beverages & tobacco	All other manufacturing	Electricity & water
Total employment	3 596 000	48 000	49 491	33 325	29 184	10 000
Average annual wage (in USD)	312	929	1 646	1 646	1 646	882

	Construction	Trade & transport	Hotels & restaurants	Public administration	Education & health	All other services
Total employment	253 011	535 000	57 727	39 688	119 964	225 000
Average annual wage (in USD)	1 438	1 282	1 246	9 837	3 162	1 855

Appendix D: Estimating induced employment effect

We have used a simplified method to calculate the induced employment effect that can be explained in three different steps. First, we use a ratio between total labor compensation and total output. Total labor compensation is derived from the social accounting table in Rwanda (see appendix C) and total output is derived from our I-O model. Second, we multiply this ratio by the consumption effect to find the additional value added that is spent on labor compensation. Lastly, we divide the labor compensation by the Rwandan median wage in order to find the number of jobs created. The median annual wage, USD 367 (218 100 RWF), is derived from World Bank's most recent report on *"Rwanda Economic Update"* (World Bank, 2016B). We believe the median wage is more representative compared to the average wage. In general, Rwandan households spend most of their income on food products and transport services. It is thus more likely that most induces jobs have been created in these sectors. Using an average wage would possible have underestimated the induced employment effect, as the wage levels in the utility and public sector are much higher than in more labor intensive sectors such as food manufacturing and transportation.

Appendix E: General Interview Guide

1. ELECTRICITY ACCESS ROLLOUT PROGRAM (EARP)	
Q1a	How important is increased power generation for the progress of the EARP agenda?
Q1b	What are the main reasons why some households choose to/not to connect to the grid?
Q1c	To what extent are the low consumption levels of electricity among newly connected households a challenge for the financial viability of the program?
Q1d	How dependent has the progress of the EARP initiative been on inflows of official development assistance and other types of international aid support?
2. OFF GRID VERSUS ON-GRID SOLUTION	
Q2a	How do you evaluate the importance of off-grid solutions in the coming years?
Q2b	Are solar home systems, LED lamps and batteries feasible solutions to access modern energies for households located far away from existing energy infrastructure?
Q2c	Do you see any difference in the socio-economic benefits of households powered by either off-grid or on-grid solutions?
3. HUMAN DEVELOPMENT INDICATORS	
Q3a	In your opinion, what are the major benefits of being connected to the central grid?
Q3b	How does rural electrification affect private households?
Q3c	Do you see changes in the daily routines of newly connected households?
Q3d	What is the impact of electrification upon local enterprises?
Q3e	What barrier do enterprises face when deciding whether they should invest in electrical appliances in order to increase productivity?
Q3f	How do you think electricity access impacts students, teachers and school performance in Rwanda?
Q3g	What is the impact of electrification upon the quality of health services?
Q3h	To what extent do households/people switch from kerosene to electric light when they get access to electricity?
4. THE ENVIRONMENT	
Q4a	To what extent does grid electricity substitute for the use of distributed diesel generators?
Q4b	To what extent do people substitute battery-driven lamps with electric lightning?

* Note that the questionnaire template was to some extent modified to fit the specific position and background of the different interviewees.

Appendix F: Summary of Key Stakeholders Interviewed

Name of Stakeholder	Position	Date of interview
Julie Hamre	Financial Analyst at Scatec Solar	09.02.2016
Caroline Sissener	Project Manager Scatec Solar	03.03.2016
Chaim Motzen	Project Manager Gigawatt Global	03.03.2016
Jean Bosco Mugiraneza	CEO of Rwanda Energy Group (REG)	01.04.2016
Niyibizi Mbanzabigwi	EARP Ag Coordinator	01.04.2016
Twaha Twagirimana	Site Manager, ASYV	21.03.2016
Jean Claude Nkulikiyimfura	Village Directer of ASYV	20.04.2016
Yadviga Semikolenova	Senior Energy Economist at the World Bank	27.04.2016
Norah Kipwola	Senior Energy Specialist at the Word Bank	27.04.2016
Jörg Peters	Researcher at RWI	05.05.2016