THE SUDD INSTITUTE
RESEARCH FOR A PEACEFUL, JUST AND PROSPEROUS SOUTH SUDAN
P. O. Box 34, Juba, South Sudan • Tel: +211 (0)956 305 780
Email: thesudd.institute@gmail.com • www.suddinstitute.org

Special Report

September 12, 2018

Transitioning to Renewable Energy: An Analysis of Energy Situation in Juba, South Sudan[1]

Nhial Tiitmamer
Jok Gai Anai

"We have this handy fusion reactor in the sky called the sun- you don't have to do anything, it just works." *Elon Musk, describing his Tesla PowerWall Home Battery*

[1] We thank Augustino Ting Mayai for his instrumental role throughout this research. Furthermore, we thank Nhial Deng Garang and Emmanuel Jok Dut for their research support. Last but not least, we thank CORDAID for its generous financial support for this research.

Table of Contents

Executive Summary

South Sudan faces a serious energy crisis due to a number of factors, including devastating conflicts (e.g. 1955-172, 1983-2005 & 2013–present) and reliance on the fossil fuel source. The country has the lowest energy consumption rate in Africa and the highest cost of producing energy (World Bank, 2016). Juba, the capital, has between 5,000 and 10,000 diesel powered generators that are inefficient and have detrimental impacts on people's health and environment (Ministry of Environment, 2014). South Sudan Electricity Corporation (SSEC) has an installed power capacity of 30 MW but most of it is not operational due to technical problems and fuel shortage.

This paper updates empirical evidence on energy access in Juba, with the view of informing a possible transition to renewable sources. We conducted a comprehensive literature review and a survey of 267 households and institutions in 4 administrative units of Juba. We selected the respondents randomly with the sampling technique based on Krejchie and Morgan's (1970) sampling frame.

Key findings

First, the number of households and institutions with access to electricity increased from 63% in 2013 to 67% in 2017 (Deng, 2013). However, 82.77% of these respondents are not satisfied with the available electricity source.

Second, following the shutdown of Juba power station in 2015, electricity in Juba has either been self-generated or supplied from neighboring households and independent power producers (IPPs). A little over forty-seven percent (47.57%) of the respondents generate their own power and 36.33% get power through the neighborhood mini-grids.

Third, a higher number of households in Juba have installed solar power than households who have installed diesel-powered generators. For example, solar installation has increased from 27% in 2013 to 34.33% in 2017 compared to the installation of diesel-powered generators which have decreased from 36% in 2013 to 30.85% in 2017. Increase in solar installation and a decrease in diesel-powered generators are attributed to the fuel crisis, which has forced households to resort to clean energy to save costs. In addition, more institutions use diesel-powered generators compared to households. For example, 52.46% of the institutions use diesel-powered generators compared to 16.39% who use the solar system.

Fourth, charcoal dominates as the leading cooking energy, with 95.52% of the households using it. Only 9.45% use cooking gas and 13.93% use firewood for cooking.

Last but not least, the driver of energy consumption is income. The higher the income, the higher the consumption. For example, the shutdown of the oil industry in 2012, which is the economic mainstay of the South Sudanese, decreased the acquisition of diesel-powered generators and solar system. Acquisition of the two sources of energy rose in 2013 following the re-opening of the oil industry but went down following the war in December 2013 (see figure 6 for details). Other factors include fuel shortage and high costs, which have forced a considerable number of households to shift to solar.

Policy recommendations

In response, we recommend the enactment of a micro-generation and decentralized grid policy supported with market-based incentives in the form of the feed-in-tariff program, implemented through a private-public partnership. This could be enforced through a legislation that encourages independent power producers to boost their production and supply of electricity to households and institutions in Juba and other localities across the country. Market-based incentives should be tailored toward meeting the needs of independent power producers to build local power grid networks. Finally, we recommend the provision of energy aid to poor neighborhoods.

1 Introduction

Energy is crucial in the fight against poverty, as it is among the greatest drivers of development. Ancient and modern civilizations rose on the back of energy (Nikiforuk, 2012). From captive humans to coal and oil, energy has played a central role in human progress, as it enables mass production of goods and services.[2] A paradigm shift in transitioning to a new form of energy defines human progress as well as its quality of civilization. However, a step in achieving this progression does not happen until a society fully recognizes the heavy economic, social and environmental costs arising from the energy form it is using. While oil and coal are far more efficient than rudimentary energy forms, they also come with bouts of economic, social, and environmental costs. When a society is not prepared for a change, that society can continue to stick with what it has and knows best. This is true of South Sudan, as it seems to stick to oil, a form of energy that is not able to meet its needs in an efficient and sustainable manner. The country must prepare as there is an opportunity for it to transition to an efficient and renewable energy, and this can happen when it fully recognizes the costs associated with the exploitation of fossil fuel and embarks on a full transition to renewable energy.

Partly due to the civil wars (e.g., 1955-1972, 1983-2005 & 2013-present), energy infrastructure remains very underdeveloped in South Sudan. Despite a peace agreement in 2015, which has been revitalized recently, conflict has impeded the country's effort in transitioning to renewable energy. Oil is currently the lead source of electricity in major towns. However, oil is not the right form of energy to meet South Sudan's rising energy demand due to (1) high costs (e.g. high costs of fuel and generator repair), (2) sporadic diesel fuel supply, (3) inefficiency and unsustainability and (4) detrimental health impacts on people and environment.

The country has a huge energy potential in form of hydro power, wind, and solar, which should be developed to meet its rising energy demand (Liu et al., 2013). The installed capacity based on different sources show that only 30 MW had been installed by 2010 (Whiting et al., 2015). Of the 30 MW, 22 MW was operational until 2015 when the 12 MW in Juba ceased to operate. However, this barely meets the basic need levels set by the United Nations, let alone advanced thresholds such as productive and modern society thresholds. Indeed, the country faces an energy crisis, as it is currently fronting constraints to generate adequate power to drive social and economic development. On average, for example, a threshold of 50-100 KWh is needed per a person a year to meet the basic energy needs of cooking, heating, lighting, communication, healthcare and education, which the country is not able to meet now (Whiting et al., 2015, UN, 2010). Advanced thresholds include 500 KWh per a person per a year to carry out agricultural work such as pumping water for irrigation, producing fertilizer, mechanizing farming, processing, and supporting transport and a 2000 KWh/person/year to operate more domestic

[2] See Andrew Nikiforuk's The Energy of Slaves. He talks about slaves as the first energy that drove civilizations from Ancient middle East to Mexico where these civilizations assembled slaves through conquest to build empires and perform mass irrigation work to enable mass production. American society was also founded on using the energy of slaves but this was abandoned because that society discovered it was inefficient and had to find a better energy form to perform work.

appliances for cooling, heating and private transportation (Whiting et al., 2015, UN 2010). These thresholds have been set to meet the UN's goal of universal access to modern form of energy by 2030 and they are important in guiding South Sudan's energy policy. Studies by Whiting et al., (2015), Liu et al., (2013), World Bank (2012, 2013), Deng (2013) and Ranganathan & Briceno–Garmendia, (2011) demonstrate a pitiful state of energy in South Sudan; however, little is empirically known currently of the condition of energy in Juba in particular and South Sudan in general following the war and economic crisis in the last 4 years.

Therefore, this paper provides an up-to-date empirical evidence by answering questions on (1) the sources of energy people use in Juba, (2) energy consumption level and demand, (3) whether households and businesses are satisfied with their current energy sources, (4) challenges associated with lack of access or satisfaction and (5) costs of accessing different sources of energy. The results are expected to inform energy policies that promote a clean and sustainable energy for all.

To inform our analysis, we conducted a literature review and used a structured survey, administered to households and institutions, both private and public. The survey covered four main Payams of Juba namely Juba, Munuki, Kator and Rajaf. Respondents were selected randomly following Krejchie and Morgan's (1970) sampling technique, obtaining a sample of 267 households and institutions.

To determine the costs of energy equipment over time, we converted currencies for which the energy equipment was bought into South Sudan Pound (SSP) using the official exchange rate regime between 2011 and 2017. To convert power KVA to Watts, we used the formula $W = 1000 \times kVA \times PF$, where PF always equals 0.8.

In the subsequent sections, we (1) review the energy literature regarding Juba in particular and South Sudan in general, to provide a better conceptual road map about the energy situation in the country, (2) review and discuss opportunities and policy tools that are usually deployed to promote sustainable energy development, with the view to informing which options best suit South Sudan's context, (3) analyze, present, and discuss the results of the survey and policy implications and (4) conclude with recommendations on the best options for delivering efficient and sustainable energy in South Sudan for both short and long terms.

2. An overview of the energy situation

2.1. Oil dependence

South Sudan owns the third largest oil reserves in Africa, valued at about 472 million Metric Tones (MT) while the continent's top two oil producers, Nigeria and Angola, have reserves estimated around 5,002.7 MT and 1,709.4 MT, respectively (World Energy Commission (WEC), 2017). The country's dependence on oil extends to all spheres of the economy. Oil accounts for about 72% of the 700 Ktoe total primary energy supply[3]. The country imports almost all of its oil products for transport and electricity generation, among others, due to the fact that there is no capacity at the moment to refine crude oil for domestic consumption (Mozersky and Kammen, 2018; Mai et al, 2016).

This dependence on oil for everything led to the protracted fuel shortage between 2015 and 2017. Factors responsible for the fuel shortage include hard currency shortage, unproductive fuel subsidies, inadequate downstream energy infrastructure (e.g. refineries, fuel storage depots, electricity infrastructure etc), energy inefficiency and reliance on oil for electricity production (Mai et al., 2016). Hard currency constraints have made it difficult for private investors to supply fuel. Similarly, most of these private suppliers were phased out from the market between 2015 and late 2017 as they could not afford to supply fuel and sell to make a profit. However, fuel market was partially liberalized in late 2017, allowing private fuel stations not owned by Nile Petroleum Corporation (Nilepet) to buy fuel and sell at market price (unsubsidized price). Subsidized fuel costs less in South Sudan than in Kenya where it is imported. A subsidized fuel costs a mere $0.14 or 22 SSP per liter in South Sudan. This is in contrast to a purchasing price of about $0.80 a liter in Kenya. This cost does not factor in the high tax rates and freight charges. Before liberalization, this forced the suppliers to hoard the fuel and sell it in the black market for profit, compounding the problem of energy access as families who operate generators were not able to afford fuel. South Sudan Electricity Corporation (SSEC), for example, was forced by the same circumstances to stop generating electricity between 2015 and 2018, leaving about 11,200 customers without electricity (see Table 4).[4]

The government has attempted to build refineries in Akon, Thiangrial and Bentiu but none has so far been completed due to the civil war, constraining the country to continue depending on neighboring countries for oil imports (Mai et al, 2016). In addition to supporting transport and electricity generation, oil generates revenues to finance 98% of the government budget (World Bank, 2013). Oil also accounts for about 60% of the country's growth domestic product (GDP) (Koffi & Soares da Gama, 2018). After the war in 2013, oil operations in former Unity State stopped except the oil fields in Northern Upper Nile State, which currently produces about 135,000 barrels per day. The 2013 war, together with other factors, resulted in a reduction of oil production from 165,000 barrels per a day in 2014 and from 350,000 barrels a day before the oil shutdown in 2012 (World Bank, 2016). By the time of finalization of this report, oil production in some oilfields in former Unity State was scheduled to resume in September 2018 and expected to add about 45,000 barrels per day.

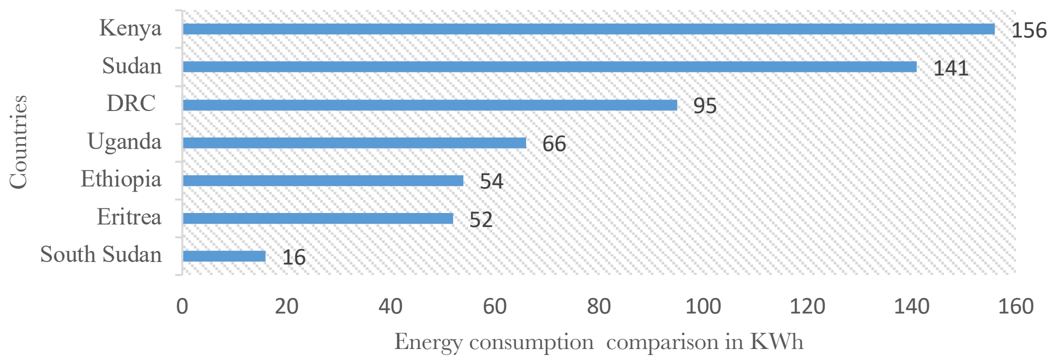
2.2. Energy consumption and demand

[3] See International Energy Agency's world key energy statistics

[4] Fuel shortage existed for almost two years until the private fuel suppliers were allowed to sell fuel at market rate, which, as of the time of finalizing this report, is between 210 and 220 SSP per a liter (an equivalent of between 95 cents and 99 cents). This is slightly below or the same as the price of fuel in Kenya and Uganda.

South Sudan has the lowest energy consumption per capita in Sub-Saharan Africa (World Bank, 2014). Electricity provision started in Juba in 1937 by the British colonists who used it to pump water to residential areas. During the 1983 -2005 war, Juba was supplied by a 5 MW power station, which increased to 12 MW following the signing of the Comprehensive Peace Agreement (CPA) in 2005.[5] After the CPA, the government bought new generators but these generators lasted for 3 years. New generators were bought again but they could not operate due to lack of spare parts and fuel, leading to the shutdown of 12 MW power station[6] in Juba in 2015.

Figure 1: South Sudan energy consumption comparison in KWh with neighboring countries (Source: World Bank, 2012)



About 5.1% of the population at the national level had access to electricity in 2013, with 12.3% of this portion located in urban and 3.5% in rural areas. When compared with neighbors, the country has the lowest access to electricity at national, urban and rural levels (see table 1 below). The situation is worse now than 2013 as access to electricity has now decreased with the shutdown in 2015 of some of the South Sudan Electricity Corporation's (SSEC) generators due to fuel availability and technical glitches.

Table 1: South Sudan's percentage of population with access to electricity at national, urban and rural levels in comparison with its neighbors (Source: World Bank, 2016).

Country	National	Urban	Rural
South Sudan	5.1	12.3	3.5
Sudan	32.6	62.1	17.8
Uganda	18.2	71.2	8.1
Kenya	23.0	58.2	6.7
Democratic Republic of Congo	16.4	36.3	5.8
Ethiopia	26.6	100.0	7.6
Central African Republic	10.8	14.9	8.2

[5] Remarks by Lawrence Loku Moyu delivered during the presentation of the preliminary findings at policy stakeholders' forum organized by the Sudd Institute in November 2017.
[6] The station remained inoperable for about 3 years and resumed just a few weeks before the finalization of this report. However, since it opened, it has supplied power only for some neighborhoods in Juba town and not all the areas in the whole city.

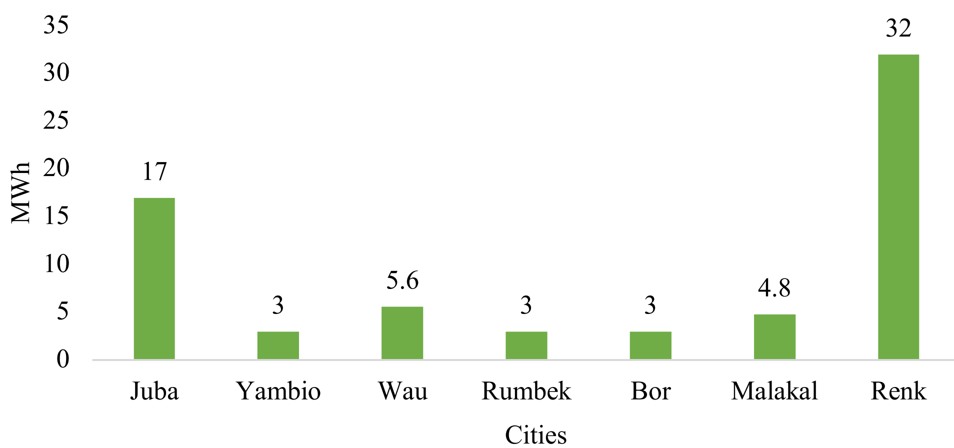
Since independence, electricity demand has been rising steadily (Liu et al., 2013). For example, installed capacity in Juba was 12 MW in 2010 while the demand was 32 MW, rising to 80 MW in 2012. See table 2 for details of energy demand and figure 2 for details of installed power capacity in seven South Sudan's cities.

Table 2: Energy demand forecast in GWH in the six cities under the SSEC's power plants between 2011 and 2013 (Source: SSEC).

City	2011	2012	2013
Juba	50.00	60.00	60.00
Yambio	30.00	30.00	30.00
Wau	30.00	30.00	30.00
Rumbek	10.00	10.00	10.00
Bor	8.00	10.00	10.00
Malakal	10.00	10.00	10.00
Renk	10.00	10.00	10.00
Total	148.00	160.00	160.00

.

Figure 2: South Sudan's installed power capacity by cities (source: SSEC)



Despite this increasing demand, installed power stations are barely operational. Renk is supplied with power through an agreement with the Sudan, which allows South Sudan to import about 32 MW, even though only about 3 MW has been imported due to a low demand in the border town. With an expected increase in population and development activities, energy demand is expected to reach 1400 MW in the year 2030 (Liu et al., 2013). Owing to a limited access to a reliable source of energy, majority of the people depend on biomass, mostly charcoals and firewood, to meet their pressing energy needs.

2.3. Electricity generation & distribution challenges

The story of electricity generation and distribution challenges in South Sudan can be well illustrated by highlighting the experience of the South Sudan Electricity Corporation (SSEC). The SSEC is supposedly a major power producer in South Sudan. It has three main generating stations in Juba, Wau and Malakal (Whiting et al., 2015). There are 8 diesel powered generators in Juba alone. However, these stations have not been effectively operating due to the reasons cited elsewhere in this work.

SSEC receives subsidies from the government. These subsidies accounted for 4% (54 million US dollars) of the government budget in 2011, which was expected to rise to 8% (133 million US dollars) by 2015 (World Bank, 2013). To produce a KWh, the government pays 0.54 US Dollars of the total generation cost of 0.70 US Dollars per KWh and selling the same KWh at 0.25 US Dollars. This is barely enough to cover the operation costs for the smooth running of the SSEC. In comparison with neighboring countries, South Sudan pays more for electricity (see table 3 below).

Table 3: Cost of electricity in South Sudan in comparison with its neighbors.

Country	Cost (USD/kWh)
South Sudan	38.8
Kenya	17.6
Central African Republic	11.0
Ethiopia	4.4
Uganda	22.7
DRC	11.5
Sudan	5.1

(Source: World Bank, 2014).

Owing to inadequate national grid networks and inefficiency in the transmission and distribution systems, the electricity sector incurs 30% of power loss. Besides, the electricity sector also incurs financial losses as a result of low revenue collected from customers, which in most cases are government agencies. Accordingly, SSEC stopped producing electricity in 2015, even as the average demand for electricity stood at 140 customers annually. This had deprived some15,474 customers of access to electricity. Table 4 below illustrates the number of customers that SSEC used to supply with electricity.

Table 4: Number of electricity customers by City between 2011 and 2013.

City	2011	2012	2013
Juba	9,567	10,966	11,200
Yambio	590	680	670
Wau	660	650	695
Rumbek	655	695	700
Bor	690	699	705
Malakal	800	850	854
Renk	550	605	650
Total customers	13,512	15,145	15,474

(Source: SSEC).

As a result, households and businesses have been forced to depend on personal diesel powered generators, many of which are costly to sustain, both financially and environmentally. Juba alone has between 5,000 and 10,000 generators owned by individuals and businesses (Ministry of Environment, 2014). Others who are fairly financially self-sufficient procure, install and maintain their own Solar PV Systems while those who can't afford modern forms of energy resort to charcoal and firewood. Charcoal and firewood burning is not sustainable as it contributes to environmental degradation, mostly through deforestation and pollution. Alternative sources of energy are required, as population growth and development compound this problem.

2.4. Existing national grid networks in South Sudan

A number of inefficient grid networks do exist in the country. Any serious investment for long term energy development must look into enhancing the existing grid networks and creating more grid interconnection systems to neighboring countries and within the country:

a. *Juba*

   The Juba Power grid network is old and needs a serious overhaul. It is not uncommon to see fallen wooden electrical poles along major roads within the city. The old Juba grid is small and has been overtaken by the rapid growth of the city. This has left many residential areas in the city, especially the newly established, unconnected. Recently, PowerChina, a Chinese engineering firm, has been contracted by SSEC to implement the Juba Power Rehabilitation Project starting initial implementation phase late 2017.

b. *Malakal*

   As one of the former three regional capitals, Malakal has benefited from concentration of regional resources, and therefore has a relatively well connected grid system and had the second highest number of SSEC customers by city from 2011 to 2013 (800, 850, 854) as shown in Table 4. By 2009, Malakal had 60 km of High Voltage and Low Voltage network covering about 40% of the town. Constructed by KANO[7], electricity was supplied from diesel powered generators. However, due to the 2013 civil war, this grid has been destroyed.

c. *Renk*

   Renk has one of the best grid interconnections, as it is connected to the Sudan grid network through a power interconnection sale agreement. In addition to the well-developed Renk town grid, Kano also constructed a 30 km Renk-Birka-Ajab Overhead Transmission Line in 2010, for the purpose of irrigating 35,000 fedans[8] at Geiger Agricultural Scheme.

[7] KANO for Trading & Investment Co. Ltd, a local engineering firm based in Juba, Malakal, Renk and Meluth

[8] Information provided by KANO for Trading & Investment Co. Ltd

Figure 3: Renk Substation. Photo by Jok Gai, September 2017

d. *Melut*

Melut has more than 40 km of grid network[9] within the town supplied from Paloch Oil Field Power Plant as a Community Development (CD) Project. As of 2017, a 3 km extension to Melut Secondary School and the neighboring village via a 500 kVA Power Distribution Transformer, is being undertaken.

Figure 4: During the commissioning of Melut Town Overhead Transmission Line in December 2017. Photo by KANO[10]

e. *Kodok*

Kodok Town has a 12 km grid network[11] supplied by diesel generators although it is not operational as a result of the conflict.

[9] KANO for Trading & Investment Co. Ltd (2013 – 2017)

[10] Permission for the use of this photo in the report was granted by management of KANO for Trading & Investment Co. Ltd

[11] Data were provided by KANO for Trading & Investment Co. Ltd

There are other local grid networks of unknown sizes in Yei, Yambio and Kapoeta built and run by NRECA International Ltd, an American Rural Electrification company. There are other isolated grids in Bor, Bentiu, Wau and Rumbek whose sizes were not known by the time of writing this report. Inadequate grid infrastructure in South Sudan complicates access to electricity. The one in Bentiu, like the ones in Malakal and Kodok, has been destroyed by the 2013 civil war.

2.5. Implications of inadequate energy access

The implications of an inadequate access to electricity by the population are multifaceted. First, inadequate power slows down development, as large scale production requires adequate power (Ranganathan and Briceno–Garmendia, 2011). For example, about 50% and 70% of large and small firms surveyed in 2011 indicated that lack of electricity is a serious impediment to doing business in South Sudan (Ranganathan and Briceno–Garmendia, 2011). Specifically, over 75% of firms surveyed in South Sudan complained that lack of energy hinders business operation. Second, lack of electricity drives up costs as businesses and families try to produce their own power, which is extremely expensive. Electricity prices in South Sudan are twice the prices of electricity in Africa and are five times the prices in other developing countries (Ranganathan and Briceno–Garmendia, 2011). As a resource rich country that needs to attract direct foreign investment, South Sudan definitely needs power to drive industrial development. When compared with resource rich countries that compete for the same investment opportunities, South Sudan has only installed a capacity of 25 MW while its peers have installed about 4,105 MW on average (Ranganathan and Briceno–Garmendia, 2011).

Third, reliance on oil for power generation and inadequate access to electricity have a lot of negative implications, including deforestation, health problems, and contribution to greenhouse gases, which cause climate change. In South Sudan, 96% of the families use biomass (firewood and charcoal) for their energy needs. Of this, 81.4% use firewood while about 14% use charcoal (NBS, 2012). This contributes to deforestation which the UN Environment Programme[12] estimates at 1.5% annually, from 0.84% a decade prior (UNEP, 2007). From 1990 to 2005, South Sudan lost 11.5% of its forest cover and if this continues unabated, the country may lose all of its forest cover in about 50 years (MoE, 2014). Loss of forest cover causes food insecurity via decreases in rainfalls and topsoil erosion.

Generation of electricity from oil emits pollutants that contaminate water, soil and air, which in return affect people's health and reducing soil productivity. Even though no study has been conducted to determine the rate of fuel pollutants in South Sudan, diesel has been found in many countries in Africa to contain a high rate of sulfur, which is very

---

[12] See charcoal trade leading to deforestation in South Sudan. This news report interviewed a UNEP official who estimated the annual rate of deforestation at 1.5%: http://www.gurtong.net/ECM/Editorial/tabid/124/ctl/ArticleView/mid/519/articleId/21051/categoryId/137/Charcoal-Trade-Leading-To-Deforestation-In-S-Sudan.aspx

detrimental to human and environmental health (Public Eye, 2016)[13]. In South Sudan, children exposed to biomass smoke are as twice as likely to suffer from pneumonia as do children from households that use clean energy for cooking (Abd-Elfaraga & Langoya, 2016). About 20% of children in South Sudan died of pneumonia in 2015 (WHO, 2015).

While emissions of greenhouse gases in South Sudan may be very small compared to other countries, reliance on fossil fuel for electricity will likely increase the emissions as the country aspires to achieve a middle income level by 2040. In fact, South Sudan can boast of producing and consuming electricity from completely carbon free sources, namely hydropower, solar and wind, which are of a huge potential. To-date, most of South Sudan's emissions come from fuel combustion for electricity and transport, which account for 30.6% and 65.3% of emissions of CO_2, respectively. Carbon dioxide emissions in 2012 and 2013 were estimated around 1,331 kt and 1,448.5 kt, respectively (World Bank, 2016). The country's ratio of CO_2 from primary energy supply was estimated at 2.17 CO_2/toe based on the World Bank's development indicators report in 2014. This is higher than the ratios of its neighbors, namely Ethiopia (0.19 CO2/toe), Kenya (0.52 CO2/toe), and Sudan (0.89 CO2/toe). These countries are relatively more industrialized but get most of their power from clean and carbon free sources. Thus, an immediate policy shift will certainly put the country on track of sustainable development.

3. Opportunities and policy tools

While the modern energy infrastructure is almost non-existent in South Sudan, the country is endowed with rich sources of sustainable energy. Hydropower capacity alone is estimated at 5,583 MW. Major sites of hydropower are located on the Nile, including Fula, Bedden, Lekki, and Shukoli (Liu et al., 2013). Table 5 below provides the sites with potential capacity and construction time.

Table 5: Hydropower sites on the White Nile with potential capacity and completion time.

Site	Capacity in Megawatts	Lead time
Fula	890 MW	5 years
Bedden	570 MW	5 years
Lekki	410 MW	5 years
Shukoli	230 MW	5 years

(Source: Liu et al., 2013).

The country also has about 18 minor hydropower sites distributed along the Nile and its various tributaries. Figure 5 below shows the distribution of major and minor hydropower sites.

[13] Details are in the report by Public Eye, a SWISS international public watchdog that conducted an investigation into content of pollutants in diesel sold at fuel pumps across a number of countries in Africa. We assume the same is happening in Juba and across other cities given low regulatory standards in South Sudan.

Figure 5: Major and minor electric sites in South Sudan

(Source: Liu et al., 2013).

South Sudan receives about 8 hours of sunshine daily, providing an estimated solar energy capacity of 436W/M^2/year (REEP, 2013). Similarly, wind energy density ranges between 285 and 380 W/M^2 (REEP, 2013). Both the solar sunshine duration and wind density meet the threshold required to produce high quality electricity. Therefore, even though these power sources have not yet been developed, their potential to contribute to a clean energy mix in South Sudan is very significant.

As shown in table 5 above, it would take at least 5 years to complete the development of any of the major hydropower sites. This means that if the development starts today, any of these sites can be completed by 2023. While the country has such an enormous energy resource, political instability, technical and financial constraints have stood in the way, making it nearly impossible to start and complete these projects since the feasibility studies were completed.

Constraints in developing mega hydro projects are intertwined with the challenges of developing a national power grid. For example, national grid also faces insecurity, potential violence that can destroy it, and potential unwillingness for the investors, particularly, the banks to lend money to finance it due to high risks associated with investing in a highly fragile place like South Sudan (Bazilian & Chattopadhyay, 2015). Distributed grid, which we call neighbor grid or micro-generation grid, is suitable in fragile contexts (Bazilian & Chattopadhyay, 2015). Distributed grid "also has the benefit of being able to be engineered to be compatible with the grid if or when it arrives" (Bazilian & Chattopadhyay, 2015, p.7). It does "not only spatially distribute the physical hardware, but also the risk of failure" (Bazilian & Chattopadhyay, 2015, p.7). In comparison, "large facilities that benefit from economies of scale are also vulnerable to attack and concentrate risk over a much smaller spatial domain" (Bazilian & Chattopadhyay, 2015, p.7). As a result, a national grid wouldn't be the option now as the country battles political instability.

To address the energy crisis, the country needs to explore a number of options: (1) getting power from the neighboring countries through bilateral interconnection agreements, (2) developing small hydro power projects, (3) developing thermal plants and (4) creating an enabling environment for businesses and individuals to develop power through a feed in tariff program to meet the short- to medium-terms energy needs.

These options face common constraints mentioned earlier, however. Buying from the neighbors requires installing a grid infrastructure to transmit electricity to South Sudan. While it is easy to connect the border towns such as Nimule and Renk, it can be difficult to extend these grids to distant places such as Juba, Malakal, Wau, and any other major population and economic centers in the interior.

In the short- to medium-term the country should focus on distributed grids. This does not mean that mega hydro projects are not important. It is to avoid the risks of destruction through any violence that may erupt as the country is still very fragile. Some small hydro sites that are secure and close to towns can be developed to also supply power through distributed grid. A feed in tariff program can help in incentivizing this process. While the micro-generation faces the same challenges as the national grid, it is relatively better than the other options in terms of generating power in the short- to medium-terms. As would be seen later in the results section, some households and businesses in Juba have been using micro-generation or neighborhood micro grid since SSEC stopped supplying electricity in 2015. In the region, Ethiopia and Kenya use this model to produce and distribute power.

What is a feed in tariff, how does it function and what is its main objective? Feed in tariff policy is a renewable energy production tool which puts a system in place to encourage people and businesses to produce power and get paid for extra power that they feed into the general electricity grid. In other words, it provides protection and incentives for individual and private renewable power generators to produce and supply power. Feed in tariff requires a law to protect people's investment, authorize, and make specifications about what amount of energy a firm or an individual can produce, should qualify for feeding into the grid, and a guaranteed amount or price the producer can get.

In the context of South Sudan, SSEC could build the grids or upgrade and expand its current grid systems in towns through which it can purchase power from individual firms and households and in turn sell it to those who are in need. It is a feasible option in this fragile South Sudanese context because it would be carried out in towns, which are secure and have some grid infrastructure. Feed in tariff program has been found effective in many countries, both developed and developing.

Feed in tariff can be combined with other incentives to promote rapid deployment of renewable energy in the short- to medium-terms or until the country stabilizes whenever it will. Other incentives include tax exemption, deductions, credits, subsidies, grants, and preferential loans ((Tupy, 2009, Menz and Vachon, 2006). For example, a tax exemption can be used on renewable energy technologies imports. Subsidies have been crucial in the development of any energy sources, including oil and coal in the early stages of development. So, removing subsidies particularly on fuel for generators would level the investment ground for solar and wind energy in South Sudan. Subsidizing diesel makes investing in diesel powered generators cheaper, threatening the environment and development of clean sources of energy. The government should lift subsidies from diesel fuel and invest this money in generating renewable energy. While the economic crisis may make it difficult to provide tax and financial incentives, the country can take the opportunities provided through Global Environment Facility (GEF), which finances green development to reduce emissions of greenhouse gases. Implementing this energy supply model would require enacting a micro-generation and feed in tariff act that can be administered by the Ministry of Electricity and Dams and regulated by the Electricity Regulation Authority. Additional tools include Peace Renewable Energy Credit, which the Energy for Peace Partners (an international NGO based in the USA) is currently developing for conflict affected countries like South Sudan. While this is still in development stage, it is worth mentioning, as South Sudan is their focus.

4. Results

This section presents and discusses results from the survey. As mentioned in the introduction, our objectives were to (1) determine sources of energy accessed by surveyed households and institutions, (2) determine how many of the surveyed folks use hybrid system, (3) find out the number of people who are satisfied with their current energy, (4) compare the number of surveyed households and institutions who consume electricity from diesel powered generators and solar, (5) establish the proportion of the population that owns or generates their own electricity, and (6) determine a cost comparison between solar and diesel powered generators. We present the results in the subsequent sub-sections, beginning with the demographic information of the surveyed population.

4.1. Sample characteristics

In total, we surveyed 267 households, public, and private institutions located in four Payams of Juba City, namely Juba, Munuki, Kator and Rajaf. Public institutions include government ministries and any other institutions under the government while private institutions include businesses (e.g. companies, shops) and non-governmental organizations. Households form the majority of the respondents (200), followed by private institutions (62) and then public institutions (5). Our target was to interview between 200 and 300 households, which the current sample meets. Table 6 below provides details of our sample.

Table 6: Sample characteristics of the surveyed population

Respondent	Number surveyed	Percentage (%)
Public Institutions	5	1.87
Private Institutions	62	23.22
Households	200	74.91

Total	267	100

4.2. Sources of energy in Juba

In this section, we determine different energy sources households and institutions have access to, namely solar system, diesel powered generators, charcoal, and cooking gas. We find that Juba city's households and institutions use different sources of energy at varying levels. Accordingly, 29.96% of those interviewed use solar, 37.08% use diesel powered generators, and 32.58% do not have access to electricity. Put differently, 67.04% of the households & institutions have access to any source of electricity, compared to 32.58% who do not have access to electricity.

Of those who use electricity, 1.5% of the respondents say they have access to hybrid power, which is a combination of solar system and diesel powered generator. This low percentage demonstrates that it is costly to maintain a hybrid system. In other words, less people are willing to spend money to maintain two energy systems. Instead, households prefer to either own a solar system or a diesel powered generator.

In Juba, 74.16% of the total respondents use charcoal, 7.49% use cooking gas and 10.49% use firewood for cooking. When we look at access by households which form the bulk of the respondents, 34.33% of them use solar, 30.85% use diesel powered generators and only 1.5% use a hybrid system. In addition, 95.52% of the households use charcoal, 9.45% use cooking gas and 13.93% use firewood for cooking. It can be deduced that households have more access to solar than diesel powered generators which may be a result of fuel crisis therefore forcing people to resort to clean energy to reduce costs. When analyzing energy access by private institutions, we found 52.46% use diesel powered generator, 16.39% use solar system and 19.67% have no access to electricity.

When asked which source of electricity they would prefer to switch to, most of the respondents prefer any electricity source that is available and reliable (62.14%), followed by solar (19.75%). The least preferred source of electricity is diesel powered generators, which was not surprising given expensive repairing and fuel costs, coupled with pollution (see figure 7 and table 9). In Tables 7, 8, 9, 10, and figures 6 and 7 below, we provide the breakdown of the results.

Table 7: All sources of energy and their accessibility by Juba's households and institutions

Sources of Energy used in Juba	Access by Respondent	Access %
Solar	80	29.96
Diesel-Powered Generator	99	37.08
Hydro	0	0.00
Wind	0	0.00

Hybrid	4	1.50
Charcoal	198	74.16
Cooking Gas	20	7.49
Firewood	28	10.49
No Electricity Access	87	32.58

Table 8: Energy sources accessed by households in Juba

Energy source	# of Respondents	Percentage
Diesel powered generator	62	30.85
Solar	69	34.33
Hybrid	1	0.50
Charcoal	192	95.52
Cooking gas	19	9.45
Hydro	0	0.00
Wind	0	0.00
Firewood	28	13.93

Table 9: Electricity source preference by households & institutions in Juba

Electricity choice	% preferring to switch
Any available & reliable source	62.14%
Solar	19.75%
Juba City Power	13.58%
Hydro Power	3.70%
Hybrid power	0.41%
Diesel powered generator	0.41%

Figure 6: Acquisition of solar power versus diesel generated power in Juba, 1999 - 2017

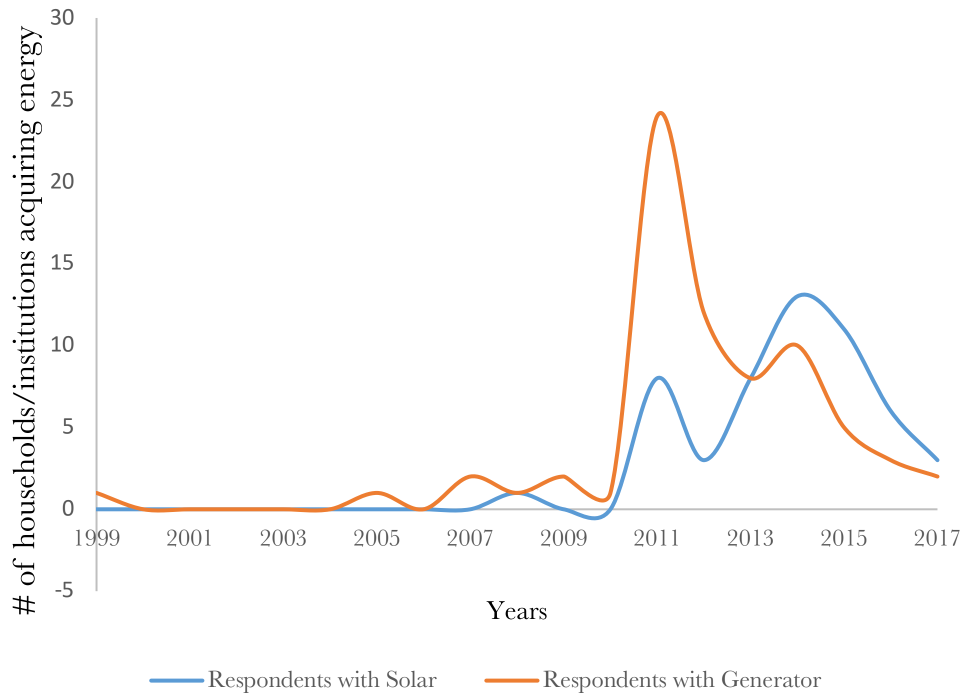


Figure 7: Electricity source preference by households & institutions in Juba, 2017

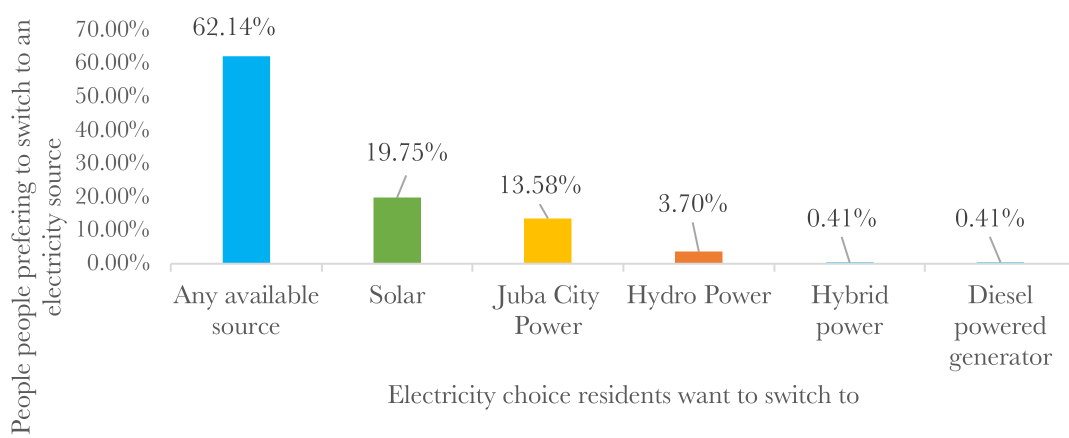


Table 10: Energy sources accessed by private institutions in Juba

Energy source	# of Respondents	Percentage
Diesel Powered Generator	32	52.46
Solar	10	16.39
Hybrid	0	0.00

Charcoal	6	9.84
Cooking Gas	1	1.64
Hydro	0	0.00
Wind	0	0.00
Firewood	0	0.00
No Access to energy	12	19.67

4.3. Energy consumption patterns, generation and satisfaction

We find that households and institutions in Juba consume on average a total of 2.2 MWh of electricity per day. This figure appears high for a daily average consumption because it has been skewed by big institutional consumers such as ministries and businesses. We find that 47.57% of the households and institutions in Juba generate their own power, 36.33% get their power from micro-grid (neighborhood grid), 1.87% get power from Juba Power (up to 2015) and 14.23% get their power from unspecified sources (see table 11).

Starting in 2011, the number of people acquiring diesel powered generators was higher than the number of those acquiring solar (see figure 6). This could be explained by higher income and the fact that diesel fuel was abundantly available. Around 2014, the annual number of households acquiring solar system rose above the number of those acquiring generators. While both started to go down as can be seen in figure 6, the number of respondents acquiring solar system per year continued to be higher. The drop in the number of respondents acquiring energy sources could be explained by far-reaching economic downturn which started to intensify in 2014. Perhaps the reason keeping the number of those acquiring solar higher is that fuel became largely unavailable at the petrol stations at some points. For example, we found out that people who owned diesel powered generators stopped operating them in 2015 due to fuel shortage. They cited being denied access to procure fuel using containers at petrol stations as the main reason they switched off their generators. Only cars were allowed to fuel. Some of the households switched to taking power from neighbors or stopped having power at all. The SSEC run Juba Power Station also stopped production in 2015 due to fuel crisis and inoperable machines.

A whopping 82.77% of the respondents say they are not satisfied with the energy sources they have. Factors responsible for this include high demand and incredibly low power supply. Power is available to some households in the evening only, especially from 7:30pm to around 10:30pm. Businesses, particularly from Konyokonyo market reported to us that power is available to them from 9am until 5pm and they use it for lighting and cooling. Other factors responsible for lack of power satisfaction include the maintenance cost of generators and the intermittent functioning of low capacity solar PV system when the weather is cloudy.

Households said they use power for lighting in order for their school going kids to study at night and sell basic commodities in the shops. They say they would want to increase their current consumption level if the power was available and cheaper.

Due to inadequate power, we found that some businesses are not able to operate or do business because of power. For example, one pharmacy that sells veterinary medicines, particularly vaccines that need cooling said they are no longer keeping these vaccines for sale due to lack of power. They only bring them on request and store them overnight at the Manager's home, which has power. This has greatly affected the quality of health service delivery.

Table 11: Energy Source Ownership

Energy source ownership	No. of respondents	Percentage ownership %
Owner	127	47.57
Juba Power	5	1.87
Micro grid (IPP)	97	36.33
Other	38	14.23

4.4. Cost of accessing energy sources

Cost is a very important factor in the choice of an energy source. From 2011 – 2017, there has been a transition from Juba Power to individual ownership of energy sources as SSEC could no longer afford to buy fuel and spare parts for generators. Due to 2013 and 2016 wars, which compounded the fuel crisis, Juba's residents transitioned from personal generators to microgrids (IPP). This is a cost driven transition. The following table shows an accumulative cost breakdown for a number of energy sources.

Table 12: Estimate of households' total annual spending on energy sources, 2011–2017 in a hundred thousand (US Dollars equivalent)

Year	Generator Repairs (USD)	Fuel Cost (USD)	Cooking Gas (USD)	Charcoal (USD)	Microgrid (USD)
2011	703	15326	18	120	83
2012	1369	17457	16	130	105
2013	2009	19501	25	212	155
2014	2670	21915	38	350	290
2015	3354	24260	70	457	496
2016	289	1188	8	63	64
2017	148	565	8	187	57

The table above shows an estimate of total costs households and institutions in Juba said they incurred as a result of using a specific energy source in Juba from 2011 to 2017. It shows spending patterns on various energy supplies over the seven-year study period. A number of messages can be gleaned from the table. First, spending on energy sources increase over time until it peaked in 2015 and went down (see figures 8 & 9). Second, spending on charcoal rose in 2016 and has been rising while cooking gas spending remained flat throughout. Third, spending on micro-grid or neighborhood power sources has often remain low throughout with the exception of a small insignificant rise in 2015. Fourth, the driver of energy consumption in South Sudan is income. The higher the income, the higher the consumption.

Two factors led to the fall in spending in the last quarter of 2015. First, the spending fell due to falling incomes. Second, fuel shortage also reduced spending on energy sources in 2015 as sustained fuel shortage started in the last quarter of 2015. Due to the fact that people could not find fuel to buy, many stopped buying fuel and because there was no fuel to operate generators, households also stopped spending on repairing generators. Drop in consumption of charcoal and gas could be attributed mainly to drop in income level. In fact, as mentioned elsewhere in this report, some households started to buy firewood for cooking, even though estimated spending on this category has not been factored in. Therefore, income and availability of a particular source of power and its efficiency are some of the factors policymakers and partners should take note of going forward.

Figure 8: Annual spending by Juba's households on charcoal & cooking gas, 2011 -2017

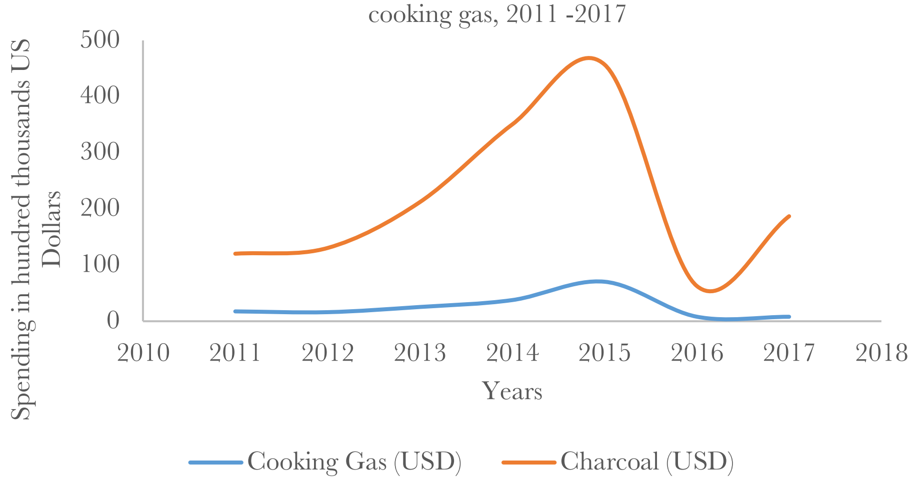
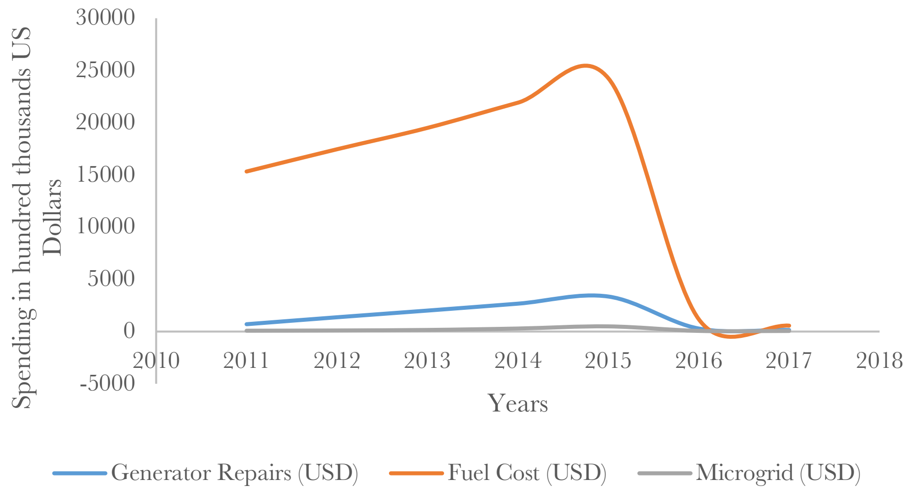


Figure 9: Respondents' spending on energy sources, 2011 - 2017



In addition to spending estimates from 2010 to 2017, we calculated the costs of acquiring or accessing energy. Table 13 illustrates the costs for installing solar, diesel powered generator, average cost of charcoal and cooking gas per a household per a year. From the results in Table 13, it appears more expensive to buy a watt of solar than a watt of diesel powered generator but if you add the cost of grid extension, repairs and fuel, it can become self-evident as to why the residents of Juba have shifted to solar and neighborhood micro grids as previously mentioned. Besides, it is cheaper for a household to use cooking gas than to use to charcoal.

Table 13: Average cost of energy source in Juba

Energy source	Cost in USD
Average initial cost of solar	$4.81 per Watt
Diesel powered generator installation	$1.99 per Watt (without grid extension)
Average cost of charcoal	$812.23 per year
Average cost of cooking gas	$98.07 per year

5. Discussion

There are a number of lessons to be learned from this analysis. First, the trend in the number of people who have access to electricity in Juba increased from 63% in 2013 to 67.04% in 2017, despite the economic crisis (Deng, 2013).[14] However, this increase does not mean the households and institutions are satisfied with the electricity access as about

[14] Deng, a Master's student from the University of Nairobi, in his 2013 study, established that 63% of households in Juba have access to electricity based on a survey he conducted for his Master's thesis.

82.77% of these expressed being unsatisfied. This dissatisfaction explains also why 74.16% of the households still use charcoal.

Second is the shift in the number of people generating their own power. This transition is driven by three factors, namely income, irregularity and the eventual shutdown of the Juba Power, and the diesel fuel shortage. Third, those who own generators tend to move to a new source that is better because of the maintenance and fuel costs. In addition, taking electricity from IPP or neighborhood grid also has costs of monthly tariffs, making solar a better option.

Fourth, the need for neighborhood grid, independent power producers, and suppliers is imperative. We find a new mechanism in Juba where a shop owner or a hotel or a rich household install power and supplies the rest in the neighborhood with power. We are calling this a "neighbourhood grid." Hotels or households install their own power to meet their own needs first and then sell surplus power to meet the needs of their neighbors while independent power producers (IPP) install power for the purpose of supplying others with power. This is the case with 5 IPPs supplying Konyokonyo shops and are collecting fees daily. This opportunity can be built on by establishing a micro generation policy with tangible incentives to encourage more IPPs and neighborhood energy suppliers to invest more in neighborhood grids. As mentioned in the opportunities and policy tools sections, this potential can be developed using feed in tariff and subsidies to incentivize the production of electricity by these emerging groups of producers. What is needed is a law that establishes standards and regulates this energy sector.

Fifth, the fact that majority of the households use charcoal is a bad sign for continued air pollution which is responsible for respiratory illnesses such as pneumonia which is a leading killer of children in South Sudan. The continued use of charcoal also means continuous deforestation, which has a lot of negative implications for food security as highlighted early in the review section. It means contributions to greenhouse gas emissions as deforestation reduces the capacity of South Sudan's carbon sink. This challenge can be overcome by tapping into GEF funding to support the production of renewable energy and sustainable fuel technologies to reduce pollution and greenhouse gas emissions.

Development of South Sudan will start from the households, particularly if their productive capacity is enhanced through electricity and other modern forms of power. We found from the surveys that households prioritize basic energy needs.

Given the population of South Sudan standing at approximately 12 million, majority of it being rural folks surviving on subsistence farming and animal husbandry, a case may be made that this country is in a better position to let go of fossil fuels in favor of hydro, wind and solar energy. In 2016, two days before the fighting broke out at State House, locally known as J One, a 55kW[15] Solar system was installed at the Ministry of Health's Blood Bank and Public Health Labs. This solar system, operating 24/7 was able to save

[15] This Solar PV System was procured, installed and maintained by Bomatek Electric Ltd located at 397 KonyoKonyo Port Road, Juba
Website: www.bomatekelectric.com; E-mail: enquiries@bomatekelectric.com

lives by preserving blood samples from going bad as there would have been no one to fuel the generators during the crisis. Since the Solar systems run very much on their own after installation, a blood sample disaster was averted. It is for reasons like this that it is crucial to transition from fossil fuel sources to renewable sources of energy, particularly during fragility such as the one we are in.

In short, what are the policy implications? First, the trend of the number of people having a tendency to acquire their own power can be built on by creating micro generation policy that establishes feed in tariff program to incentivize people and businesses to generate their own renewable energy electricity. Mozersky and Kammen (2018) call for a humanitarian led transition to renewable energy which they want to focus on education, health, and displaced camps and non-governmental organizations' compounds. Such a humanitarian led effort can complement government and private sector efforts which we are recommending in encouraging individuals and firms to provide renewable energy in the short to medium term. The government can shift the current subsidies being given to fossil fuel suppliers to individual power producers and private firms to level the playing field and reduce costs. These subsidies should be productive instead of being used to only encourage consumption as it has been the case with fuel subsidies. This means anybody who intends to install power should be given incentives through feed in tariff policy that guarantees payments for power produced and fed into the grid.

5.1. Conclusion and recommendations

In this analysis, we have assessed energy sources, dissatisfaction, cost and consumption patterns in Juba. We found (1) an increase in number of households with access to electricity yet still dissatisfied with available source, (2) electricity has been either self-generated or supplied from neighborhoods, which can be strengthened through a feed in tariff policy, (3) more households have installed solar power than diesel-powered generators, (4) most households prefer solar and any available reliable source, and (5) the driver of energy consumption is income.

We recommend that in the short to medium terms, the government should establish an incentivized electricity micro-generation policy through a feed in tariff policy across the nation. Such a policy should culminate in a Micro-Generation Act that is able to (1) provide producers with certainty and legally guaranteed returns, (2) set and specify safety and environmental standards for the producers, (3) provide tax exemption and depreciation allowance on renewable energy equipment, and (4) remove subsidies on diesel fuel and redirect them toward renewable sources.

To carry out a feed-in-tariff program, a number of options can be considered. First, since the SSEC has a grid, it can buy the power from the IPP, individual producing households, and institutions at a legally guaranteed rate and resell it to those in need. Or the IPP, individual households, and institutions can sell their surplus power directly to customers in the neighborhoods. We prefer the later option.

Second, an international or national organization should sponsor an Energy Aid program to supply power to neighborhoods that may not afford it. There should be a pilot program to test this proposed Energy Aid program in one of the suburbs of Juba such as Gumbo or Gurei.

Third, the government can build on the fact that Juba's households and institutions are already shifting towards owning their own Solar PV Systems, as shown in this study. This success can be expanded by removing fuel subsidies and giving them to independent private producers to encourage direct investment in renewable energy. The government can also encourage the IPP, individual households and institutions by providing tax exemption on solar and depreciation allowance on renewable energy equipment.

Given the current fragility that threatens development of national grid and mega hydro projects, the government in partnership with private investors should lay decentralized grid networks supported by incentives, public-private partnership and supplied by a mix of solar, small hydro and thermal power generated by independent power producers, households, and institutions so that the country is able to access considerable electricity for basic, productive, and other needs.

References

Abd-Elfaraga, Gasim, and Charles Langoya. (2016). Household air pollution and pneumonia in South Sudan: will clean cooking stoves reduce the incidence and mortality. South Sudan Medical Journal.

AFREC. 2015. Key Energy Statistics (2015). Algiers: Africa Energy Commission (AFREC) of the African Union.

African Development Bank (AfDB). (2013). South Sudan: An infrastructure action plan. Tunis: African Development Bank AfDB.

Bazilian, M. and Chattopadhyay, D. 2015. Considering power system planning in fragile and conflict states. Cambridge Working Papers in Economics.

Daly. H. (1996). Beyond Growth: The Economics of Sustainable Development.

Deng, J.M. (2013). Energy Status in South Sudan. Master's Degree Dissertation, University of Nairobi, Nairobi, Kenya.

IEA. (N.D). Key World Energy Statistics. Paris: International Energy Agency (IEA).

James, S. (2009). Incentives and Investments: Evidence and Policy Implications. Investment Climate Advisory Services of the World Bank Group.

Koffi, Y. G and Soares Da Gama, F. (2018). 2018 African economic outlook country note. African Development Bank. Retrieved from https://www.afdb.org/fileadmin/uploads/afdb/Documents/Generic-Documents/country_notes/South_Sudan_country_note.pdf

Liu, H., D. Masera, and L., Esser. (2013). World Small Hydropower Devleopment Report 2013 - South Sudan. United Nations Industrial Development Organization (UNIDO) and International Center, Link: http://www.smallhydroworld.org/fileadmin/user_upload/pdf/Africa_Eastern/WSHPDR_2013_South_Sudan.pdf.

MacNeill, J. (1989). Strategies for Sustainable Development. Scientific American 261(3):154–165.

Mai, N.J.H. Mai, Mayai, A.T., and Tiitmamer, N. (2016). Sporadic Fuel Crisis in South Sudan: Causes, Impacts and Solutions. Sudd Institute, Juba, South Sudan.
Menz, F.C, and Vachon, S. (2006). The effectiveness of different policy regimes for promoting wind power: experiences from the states. Energy Policy, 34: 1786 -1796.
Ministry of Environment and Forestry. (2014). The National Environment Protection and Sustainable Development Policy, 2014-2024. Juba:Republic of South Sudan, 72.
Mozersky, D. and Kammen, D.M. (2018). South Sudan's renewable energy potential: A building block for peace. Special Report; Washington DC: United States Institute of Peace.
NBS. (2012). National Baseline Household Survey 2009 Report. Juba: National Bureau of Statistics (NBS), Republic of South Sudan, 173.
Nikiforuk, A. (2012). The Energy of Slaves. Canada.
Public Eye. (2016). Dirty fuel: How Swiss traders flood Africa with toxic fuels. A Public Eye Investigation. Retrieved from https://www.publiceye.ch/fileadmin/files/documents/2016_DirtyDiesel_A-Public-Eye-Investigation_final.pdf
Ranganathan, R. and Briceño-Garmendia, C.M. (2011). South Sudan's Infrastructure a Continental Perspective. Policy Research Working Paper 5814, Sustainable Development Unit, Africa Region, World Bank.
Solow, Robert M. (1993). Sustainability: An economist's perspective. In R. Dorfman and N. Dorfman (eds.), Economics of the environment: Selected readings, pp. 179–187. New York: W.W. Norton and Company.
Tupy, T. (2009). The Importance of the Legal and Regulatory Framework for the Development of Renewable Energy. 10th Baku International Congress – "Energy, Ecology, Economy", Baku, 23rd September 2009 on behalf of the OSCE Office in Baku.
UN. (April 2010). Energy for a sustainable future: Report and recommendations. The Secretary General's Advisory Group on Energy and Climate Change, New York, USA.
UNDP. (2012). Environmental Impacts, Risks and Opportunities Assessment Natural resources management and climate change in South Sudan. Juba: Ministry of Environment (MOE), Republic of South Sudan and United Nations Development Programme (UNDP), 91.
UNEP. (2007). Sudan. Post conflict environmental assessment. Nairobi: United Nations Environment Programme (UNEP).
UNSD. (2017). United Nations Statistics Division (UNSD). February 5. http://data.un.org/CountryProfile.aspx?crName=South%20sudan.
Wani, James. (2015). Energy needs in a humanitarian setting. The South Sudan experience. Juba: Clean Energy Solutions. https://cleanenergysolutions.org/sites/default/files/documents/james_wani-energy_in_the_context_of_crisis.pdf.
Whiting, K., Amogpai, A., Carmona, L.G. and Esser, L.J. (2015). South Sudan: A review of the development of sustainable energy policy and practices. Investigación ambiental 7(1).
WHO. (2015). Countdown to 2015. The 2015 report. Geneva: Countdown to 2015 Secretariat,WHO.

WHO. (2016). Pneumonia fact sheet. World Health Organisation (WHO). January 29. http://www.who.int/mediacentre/factsheets/fs331/en/.
World Bank. (2017). Taming the tides of high inflation: Policy options for South Sudan. Washington, D.C: World Bank.
World Bank. (2013). Energy sector support note. Washington, D.C: World Bank.
World Bank. (2014). Analysis of Juba distribution network and capacity building needs in the electricity sector. Report No ACS84995-SS. Washington DC: The World Bank.
World Bank. (2016). World Development Indicators 2016. Washington D.C: World Bank.
World Energy Council (WEC). (2017). World Energy Resources 2016. London:WEC. https://www.worldenergy.org/data/resources/country/south-sudan/.

About The Sudd Institute

The Sudd Institute is an independent research organization that conducts and facilitates policy relevant research and training to inform public policy and practice, to create opportunities for discussion and debate, and to improve analytical capacity in South Sudan. The Sudd Institute's intention is to significantly improve the quality, impact, and accountability of local, national, and international policy- and decision-making in South Sudan in order to promote a more peaceful, just and prosperous society.

About the Authors

Nhial Tiitmamer is Programme Manager for environmental, energy and natural resources research and as well the Institute's Focal Point on Building Resilience and Adaptation to Climate Extremes and Disasters (BRACED), a climate change resilience programme being implemented in South Sudan by a consortium composed of The Sudd Institute and other international organizations. Nhial holds a Bachelor of Arts Degree and a Master of Science in Environmental Studies and Sustainable Energy from the Universities of Alberta and Calgary in Canada where he spent stints as an environmental consultant and research associate in environmental studies. Nhial is the co-founder of the NewSudanVision.com and has extensively commented and written on issues about South Sudan.

Jok Gai Anai is a visiting researcher at the Sudd Institute. He holds a Bachelor of Engineering in Electrical Engineering from the University of Victoria, British Columbia, Canada. Jok has spent 11 years working in areas of High Voltage Power Transmission Networks & Distribution for Infrastructure and Oil & Gas Projects, Hydro, Renewable Energy, and Entrepreneurship and is also interested in researching the role of energy in development of post conflict states, the case of South Sudan. He is Founder and CEO of Bomatek Electric Ltd (www.bomatekengineering.com), a local engineering firm operating in South Sudan since 2012.