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The Impact of Packaged Solar Installations and Infrastructural Repairs on Healthcare Utilization in Health Facilities in the Democratic Republic of Congo

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An abstract of
A thesis submitted to the Faculty of the
Rollins School of Public Health of Emory University
in partial fulfillment of the requirements for the degree of
Master of Public Health
in Global Health
2016

Abstract

Background/Introduction:

Given the Democratic Republic of Congo's (DRC) tumultuous economic and violent history, there is currently a lack of adequate health infrastructure particularly in terms of energy access at health facilities. Furthermore, there is a gap in existing literature on the impact and evaluation of improved energy access and its relationship to health service delivery and utilization. Finally, IMA World Health requires an assessment to determine the impact on health-seeking behavior from their investment in solar energy in the DRC through the ASSP Project.

Objective:

The purpose of this Master's thesis is to document any changes in utilization of health services at the health center level pre and post solar panel installations in order to measure the health impact of increasing access to solar energy at health facilities in the DRC.

Methods:

In order to assess the impact of solar installations on health service utilization in the pre-2006 re-classification provinces of Equateur, Province Orientale, Maniema and Kasai Occidental, a counterfactual analysis was conducted to measure the difference between utilization patterns at the health zone level. Seasonally adjusted trend extrapolations using a regression of historical utilization data was used as the counterfactual scenario (the absence of solar intervention) for each health zone. Using STATA software, a difference-in-difference analysis was employed in order to measure the statistical significance of any observable change.

Results:

The results of this analysis suggest an association exists between the implementation of the packaged solar installation/renovation intervention and health care utilization. Overall, the association appears to improve the average monthly health care utilization across all health zones analyzed.

Conclusion:

This evaluation has made headway in attempting to demystify the relationship between solar energy availability and healthcare utilization. Limited research and studies measuring the relationship between the two exist to date and this analysis, albeit limited, has made an attempt to quantify the relationship between solar energy installations and healthcare utilization.

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Table of Contents

CHAPTER 1: INTRODUCTION **1**
HISTORICAL CONTEXT 1
POPULATION HEALTH DEMOGRAPHICS 2
ENERGY PROVISION AT HEALTH FACILITIES 4
IMA WORLD HEALTH ASSP PROJECT OVERVIEW 4
PROBLEM STATEMENT 6
PURPOSE STATEMENT 7
RESEARCH QUESTION 7
SIGNIFICANCE 8

CHAPTER 2: LITERATURE REVIEW **9**
ENERGY AS NECESSARY INFRASTRUCTURE 9
PHOTOVOLTAIC (PV) SYSTEMS 10
EXISTING DATA COLLECTION TOOLS 11
CURRENT STATUS OF ENERGY COVERAGE IN HEALTH FACILITIES 12
RESEARCH LINKING INCREASED ENERGY ACCESS TO HEALTH OUTCOMES 14

CHAPTER 3: METHODS **17**
POPULATION AND SAMPLE 17
FIGURE 1: MAP OF ASSP PROGRAM PROVINCES, DEMOCRATIC REPUBLIC OF CONGO 18
RESEARCH DESIGN AND PROCEDURE 18
Table 1: List of ASSP Health Zones Analyzed by Province, Democratic Republic of Congo 18
LIMITATIONS 21

CHAPTER 4: RESULTS **23**
UTILIZATION TRENDS: ALL HEALTH ZONES 23
UTILIZATION TRENDS: ≥60% OF HEALTH ZONES RECEIVING INTERVENTION 24
Figure 2: Scenario Comparison of Utilization for Ndesha Health Zone, DRC 25
Figure 3: Scenario Comparison of Utilization for Muetshi Health Zone, DRC 25
Figure 4: Scenario Comparison of Utilization for Kakoka Health Zone, DRC 26
Figure 5: Scenario Comparison of Utilization for Bena Tshadi Health Zone, DRC 27
Figure 6: Scenario Comparison of Utilization for Tshikaji Health Zone, DRC 28
AVERAGE MONTHLY UTILIZATION: TWO SCENARIOS 29
Table 2: Average Monthly Utilization Before and After Packaged Solar Panel Installation and Renovation Intervention and Difference-in-Differences Impact 29
NET IMPACT: DIFFERENCE-IN-DIFFERENCES ANALYSIS 30
AVERAGE MONTHLY UTILIZATION: ACTUAL SCENARIO 31
Table 3: Actual Scenario Average Monthly Utilization Before and After Packaged Solar Panel Installation and Renovation Intervention 31

CHAPTER 5: DISCUSSION **33**

CHAPTER 6: RECOMMENDATIONS **37**

CONCLUSION **37**

REFERENCES: **41**

Chapter 1: Introduction

Historical Context

The Democratic Republic of Congo (DRC) is a Francophone country with vast mineral wealth located in central Africa. A former Belgian colony, the DRC gained its independence in 1960 but continues to experience political and social instability to date. After many years of ethnic strife and civil conflict, the Pretoria Accord was signed in 2002 in order to end fighting and establish a stable national government. A transitional government followed until the first free national elections took place in 2006. To date, the DRC continues to experience resurgent episodes of violence by various armed groups operating within the eastern part of the country. Instability is not limited to the eastern part of the country as displacement continues to occur in other parts of the country due to conflict and natural disasters. The next presidential election is scheduled for the end of 2016 but has been unofficially postponed and is likely to not occur (CIA, 2016).

The recent history of violent civil and political unrest experienced in the DRC has had many negative implications on the development of the country, exacerbating a weak infrastructure and stagnating economic growth. Many years of human rights abuses and widespread civilian suffering have led to high levels of population displacement and death due to fighting, disease, and malnutrition. Further, the development of a sustainable health infrastructure has not been a priority in the DRC until recent years; there is an insufficient number of health workers at all levels, lack of ongoing supervision, poor quality of care, and medical facilities remain severely limited with medical materials in short supply due to inconsistent supply of essential drugs and equipment (World Bank, 2005). As of 2013, total expenditure on health as a percentage of GDP remains very low between 3.5% – 3.9% with $26 per capita spent on health (WHO Global Health Observatory Data Depository, 2016; World Bank, 2016). The national health system focuses on primary health care and is heavily dependent on foreign aid with an estimated 70.2% of total health expenditure coming from external resources in 2014 (World Bank, 2016). In 2006 the government made headway by adopting a national strategy to strengthen the health system in order to improve the availability and use of quality healthcare by the Congolese population (DHS, 2014). Currently, the DRC ranks 176th out of 188 countries worldwide with a 2014 Human Development Index (HDI) of 0.433 indicating low human development. Despite a relatively low ranking and a decrease of 56.4% in Gross National Income (GNI) per capita since 1980, the DRC has experienced notable improvements since 1980; the HDI increased by 25.2%, life expectancy at birth increased by 12.3 years, mean years of schooling increased by 4.7 years and expected years of schooling increased by 2.5 years (UNDP, 2015).

Population Health Demographics

With a population estimated at 77.4 million people by the 2013-2014 Demographic Health Survey, the DRC remains under-populated and exceedingly rural with an approximate 24 people per square kilometer and 70% of the population living in rural areas. Health status of the Congolese has been directly affected by the decades of conflict - particularly illustrated by the low life expectancy of 51 years for men and 54 years for women. Further, the DRC's population is characterized by its youth - over half of the country's population (52%) is under 15 years and 61% under 20. This phenomenon is due to high fertility and high mortality and could potentially create significant challenges to the country's development, given the depressed economy and limited job market (DHS, 2014).

Females outnumber males in the DRC with a sex ratio of 93 males per 100 females yet only 46% of women participate in decisions regarding healthcare. DHS survey results indicate that despite experiencing one of the highest maternal mortality ratios in the world with 846 maternal deaths per 100,000 live births and more than half of women not receiving postnatal care, a high proportion of women (88%) received antenatal care provided by trained personnel and 80% of women reported giving birth at a health facility and under the assistance of a skilled provider (DHS, 2014). Similarly, under five mortality in the DRC remains alarmingly high at 104 deaths per 1,000 live births – 58 of which die before their first birthday. Further, vaccination coverage remains low at 45% of children aged 12-23 months receiving all recommended vaccines and of those children, only 41% were fully vaccinated before age one. The health status of women and children under five in the DRC is further characterized by high levels of chronic childhood malnutrition and chronic undernutrition in women – 43% of children under five are stunted of which the majority reside in rural areas and 14% of women have a BMI less than 18.5 (DHS, 2014). This double burden contributes to a low health status among these vulnerable populations. (DHS, 2014).

In an effort to show the degree of access to health care in the DRC, DHS results regarding health seeking behavior during the four weeks prior to the survey can be used. Overall, public health centers received the most outpatient visits among facilities in the DRC (29.7%) followed by private pharmacies (20.9%). Among the rural Congolese, the proportion seeking care at public health centers increases to 37% followed by public health posts at 17.3%. The survey results indicate that overall nearly half of the Congolese (49%) seek outpatient care in public facilities and that proportion increases to 60.9% amidst those residing in rural areas. Among women, the greatest barrier to accessing health services in the DRC is money for treatment (68.6%) followed by distance to the health facility (38.9%), having permission to seek treatment (32.6%), and not wanting to go alone (26.5%). All of these results were at least 26% higher among rural women than urban women with 82% of rural women citing at least one barrier to access compared to 66.4% of urban women (DHS, 2014). Given that political and economic insecurity have a negative impact on accessibility to health care, noting the existing barriers to treatment is important to understanding the effects that an unstable environment may have on utilization patterns.

Energy Provision at Health Facilities

Literature on the coverage of energy at health facilities in the DRC is limited. Most of the country's health facilities are located in rural areas and lack sufficient infrastructure including electricity. As a proxy measure, only one in seven households have electricity in the DRC, with coverage as low as 0.4% in rural areas where most of the population lives and consumes healthcare (DHS, 2014). Lack of energy access at health facilities has many negative implications on service delivery. Without energy, health facilities are forced to limit clinic hours, cannot store blood or necessary medicines and vaccines, have limited laboratory capacity, cannot provide night time deliveries, night time emergency care, and/or general emergency and/or obstetric care. All of these limitations in service severely undermine the provision of care in the DRC, which contributes to some of the worst health outcomes experienced by a country globally.

In recent years the United Nations has recognized the importance of energy in improving health services and established the Sustainable Energy for All (SE4All) initiative and designated Energy for Women's and Children's Health a "High-Impact Opportunity" which hopes to not only achieve universal access to energy by 2030 but also "improve availability and quality of essential maternal and child health care through the scale-up of energy access in health facilities (WHO, 2015)." Investments in energy provision in resource-constrained settings will lead to improved access to medical technologies and delivery of essential health services 24/7. Furthermore, it is possible that an increased access to energy at health facilities could also lead to higher levels of skilled health workers retention in rural areas and increased use of innovative technology, such as mobile and tele-medicine for the dissemination of public health information and education (WHO, 2015).

IMA World Health ASSP Project Overview

In an effort to improve access to health services, IMA World Health began working in the DRC in 2000. In 2012, IMA World Health received funding from the UK Department for

International Development (DFID) and the Swedish International Development Cooperation Agency (SIDA) to establish the Projet d'Acces aux Soins de Sante Primare / Access to Primary Health Care Project (ASSP) with the goal "to reduce morbidity and mortality in women and children under five by strengthening the national health system by providing integrated support to 56 health zones" (IMA World Health, 2015). The project timeframe extends from 2012 – 2018, operating with a budget of 283 Million USD, and includes several implementing partners. ASSP, focusing on health systems strengthening approach, works in conjunction with the Ministry of Health and the National Health Development Plan to improve coverage and access to primary care services across 56 health zones nationally, reaching an estimated population of 8.3 million people (IMA World Health, 2016). As part of ASSP, IMA World Health implemented a solar installation initiative in which about half of the estimated 900 ASSP sites have received solar panels for the provision of energy for lighting, refrigeration, and/or IT systems. Installations have taken place across 52 health zones in four provinces and continue to date.

Problem Statement

Given the DRC's tumultuous economic and violent history, there is currently a lack of adequate health infrastructure particularly in terms of energy access at health facilities. Furthermore, there is a gap in existing literature on the impact and evaluation of improved energy access and its relationship to health service delivery and utilization. Finally, IMA World Health requires an assessment to determine the impact on health-seeking behavior from their investment in solar energy in the DRC through the ASSP Project in an effort to provide lessons learned and justification for the investment in energy infrastructure at the health zone and heath facility level.

Purpose Statement

The purpose of this Master's thesis is to document any changes in utilization of health services at the health center level pre and post solar panel installations in order to measure the health impact of increasing access to solar energy at health facilities in the DRC.

Research Question

1. What is the relationship between the installation of solar panel technology and the health utilization rate (measured as the number of new cases seen in the health zone per person per month) in 43 health zones supported by the IMA World Health program in the pre-2006 provinces of Oriental, Kasai Occidental, Maniema and Equateur from April 2013 to June 2015?[1]

[1] The DRC re-classified its provinces from 11 to 26 as part of the 2005 Congolese Constitution which took effect in early 2006. This analysis will be using the 11 province system that was in place at the start of ASSP to refer to the provinces. The pre-2006 programmatic provinces listed equate to the post-2006 provinces of Tshopo, Kasai, Kasai Centrale, Maniema, and Nord Ubangi.

Significance

Through the assessment of ASSP’s solar panel installation initiative, efforts to establish a link between improved energy access and health outcomes in the DRC will be made. IMA World Health will use the results to understand programmatic successes, areas for improvement, feasibility of continuation and/or scale-up and funding implications. This analysis will also provide evidence to address the gap in literature on the relationship between improved energy access and health service delivery and utilization. Furthermore, this assessment can be used to inform policy surrounding the importance of investing in health infrastructure in the DRC to improve access to and demand for health services.

Chapter 2: Literature Review

Energy as Necessary Infrastructure

Availability of electricity is often assumed when designing and implementing health interventions worldwide. In reality, many rural health facilities in resource-constrained countries lack access to efficient and reliable energy, impeding their ability to provide an adequate range of services. Much of the necessary medical equipment required to provide basic and emergency services require electricity. For example, refrigerators, sterilizers, lighting, cookers, suction machines for deliveries, incubators, microscopes, centrifuges, mixers, X-Ray viewers, and equipment used for infection control all depend on reliable electricity (EC, 2006). With the advent of the post 2015 development agenda and sustainable development goals, energy as a universal right has gained momentum. In 2011, the UN established the "Sustainable Energy for ALL" (SE4All) initiative, which included as a main objective the assurance of universal access to modern energy services by 2030 (WHO SE4ALL, 2015). With newfound attention geared towards increasing access to energy worldwide, evidence-based interventions are needed to support investments in this programmatic area.

A 2006 report by the European Commission identified relationships between energy poverty and unattained health sector objectives and their resulting implications. Institutional level problems found in the report included poor storage for vaccines and medicines, poor sterilization of medical tools, poor lighting for operations, inability to provide clinical services after dark, difficulty in deploying health officers in remote/rural areas, inability to power diagnostic laboratory equipment, and poor ability to communicate with specialists or transport to a specialized health facility. The report also found an indirect relationship between energy access and the ability to attract and retain health workers to live in rural areas (EC, 2006). Practical Action's 2014 Poor People's Energy Outlook approximates that one billion people worldwide are serviced by health facilities without electricity indicating that electricity is an important component of health infrastructure necessary to support health interventions worldwide and that a lack of access to energy is a major barrier to receiving adequate healthcare (PA, 2014). Restricted access to energy can thus have a negative impact on health-seeking behavior at health facilities among populations and can also discourage health providers from staying in rural areas.

Photovoltaic (PV) Systems

Photovoltaic (PV) systems utilize sunlight collected by solar panels and stored in batteries to generate electricity. Solar energy may therefore be most effective in a setting like Africa where there is a longer period of peak sunlight per day (USAID, 2014). Solar energy is quiet and does not produce emissions when compared to generators. Further, the panels have an estimated lifetime of 20-30 years. Solar energy generally have higher capital and initial costs but overall lower operating costs when compared to other options; USAID estimated the cost of $8 -$12 per watt produced in addition to the expenses related to transport, installation, and maintenance. These systems require regular maintenance in order to remain reliable, which is oftentimes not accounted for in the budget or operations of donor-funded PV systems. (USAID, 2014). This could lead to some potential drawbacks to solar technology such as non-operating solar systems installed at health facilities due to the lack of trained technicians and high costs associated with regular maintenance. Further, it is important to note that some of the rural markets in which solar systems are installed may not have access to the parts needed or the technicians required to make necessary repairs.

Existing Data Collection Tools

Existing national data collection initiatives that include measures regarding energy access include the Service Provision Assessment (SPA) survey implemented under the MEASURE DHS program, the Service Availability Mapping (SAM) WHO tool, and the joint WHO-USAID tool Service Ability and Readiness Assessment (SARA). The DRC currently uses the SARA assessment tool to report on service delivery, availability of basic equipment and amenities, essential medicines, diagnostic capacities, and health facility readiness to provide basic health-care interventions in the domain areas of family planning, child health services, basic and comprehensive emergency obstetric are, HIV, TB, malaria, and non-communicable diseases (WHO Service Availability and Readiness Assessment, 2016). Currently, the DRC's SARA questionnaire specifically asks about energy sources for electricity under the infrastructure section. The questionnaire asks whether the health facility is equipped with electricity, how the electricity is used, what the main source of electricity (including solar energy) is, whether the facility has a secondary or emergency source of electricity, whether electricity has been continuously available during clinic hours over the last seven days, and whether the solar energy system is currently functioning (WHO, 2014). The 2014 DRC SARA report found that 9% of health facilities nationwide had an energy source (26% of urban facilities and 5% or rural facilities) and included permanent and continuous availability of electricity and water in all health facilities as one their main recommendations (WHO, 2014).

Current Status of Energy Coverage in Health Facilities

Although the increased importance of energy as an essential requirement in health facilities worldwide is now readily accepted, the actual provision and availability of energy in health care facilities worldwide remains low. The 2014 Poor People's Energy Outlook estimated that electrification rates in health facilities are particularly low in Sub-Saharan Africa - an estimated 30% of health facilities which service approximately 225 million people without electricity (PA, 2014). The WHO commissioned a study to determine the access to electricity across health facilities in eleven Sub-Saharan African countries and similarly found an average of 26% of facilities with no electricity access. Of those eleven countries, only four included solar energy as a type of electricity access. They conducted a sub-analysis of these four countries (Namibia, Kenya, Sierra Leone and Uganda) and found that solar energy sources are growing in popularity with over one-third of facilities receiving some power from solar sources (Adair-Rohani et al, 2013).

Oftentimes, energy availability is unreliable which can negatively impact emergency, childbirth, and nighttime services as well as storage temperatures for vaccines, blood, and medicines (PA, 2014). Adair-Rohani et al found that only 28% of the facilities included in their analysis reported having reliable access to electricity – 34% in hospitals and 26% in other health facilities. The results were even lower for facilities that relied on generators for electricity – 10%-29% reported having functioning generators with fuel available (2013).

Most of the literature and tools currently used to evaluate the availability of energy in health facilities focus on generators and/or grid connection rather than solar energy even though renewable energy such as solar energy provides a reliable and affordable alternative for rural facilities that are far from accessing the electrical grid (PA, 2014). The declining costs of renewable energy and the increasing costs of oil make solar energy favorable to generators and cheaper over time making them better suited for highly resource-constrained settings (Adair-Rohani et al, 2013). A Liberian case study that looked at electricity availability in public facilities nationwide over two years included in the Adair-Rohani analysis concluded that the increase in electricity access across all facilities was primarily due to the procurement of either generators or solar systems. Further, more facilities reported using solar systems as their primary energy source at the health clinic level for the second year of data collection and suggested a higher level of reliable electricity. The authors concluded that albeit many potential confounding factors, these findings suggest that solar power might be more reliable than generators as an electricity source in remote health facilities (2013).

Prioritizing improved energy coverage at the national level is oftentimes overlooked or heavily dependent on the private sector. For example, a 2006 European Commission Report reviewed the national strategies for poverty reduction of Kenya, Tanzania, and Uganda and found that although the three countries did identify improvements in energy access as a role in meeting poverty reduction targets in their PRSPs, they lacked explicit budgetary allocations for energy improvements and displayed a low emphasis on the linkages between energy and education, gender, equality, and health (EC, 2006).

Research Linking Increased Energy Access to Health Outcomes

Despite the fact that access to energy worldwide is inadequate and that it is generally accepted that improved access to energy can improve health care delivery, evidence that links access to electricity in resource-constrained countries to health outcomes is under-studied. The relationship between energy access at the health facility level and health outcomes is subject to many confounding factors and therefore difficult to measure. Some potential confounding factors affecting both energy access and utilization include, but are not limited to geographic and infrastructural barriers to accessing health facilities, governmental policies, temporal/seasonal factors, and the efficacy of the health facilities themselves. A comprehensive literature review conducted by the Global Village Energy Partnership (GVEP International) as part of a Powering Health Sector report for DFID found that there were few studies available which provided empirical evidence of the link between electricity access and health indicators of interest. They were able to identify two papers that directly link electricity to health outcomes (GVEP, 2013).

The first of the two studies identified by GVEP used a survey to identify factors related to maternal and newborn health in Uganda. The study found availability of electricity at the health facility to have a protective effect on maternal health – with a significant reduction in the odds of maternal complications when women delivered in facilities with electricity compared to no electricity (Mbonye et al, 2007). The second study focused on an impact evaluation of rural telemedicine in the amazon region of Peru in which health posts were outfitted with solar energy systems for communication and referral purposes. The authors found that the use of the solar systems significantly reduced the time for referrals and that in 25% of emergency cases it had led to the saving of a life. The communication system saw the greatest benefit in obstetric emergencies followed by complicated cases of malaria (Martinez et al, 2004).

Since limited studies have looked specifically at electricity as a catalyst for heath provision, we can use different proxy measures to assess the impact the lack of electricity has on health services. A study conducted in 2011 aimed to assess the different key barriers to the provision of emergency and surgical care in Sub-Saharan Africa found that none of the five countries assessed had sufficient infrastructure available to provide the minimal standard of care as per WHO standards. The authors found that less than 65% of all hospitals had reliable sources of water and electricity and that 7%-35% of clinics also did not. These findings indicate that without basic infrastructure, comprehensive emergency services could not be carried out (Hsia et al, 2011). Furthermore, a study conducted in 2015 focusing on district hospitals in the DRC using the WHO Tool of Situational Analysis to Assess Emergency and Essential Surgical Care found that only 42% of the hospitals had uninterrupted electricity and 16% had no electricity at all contributing to the overall inability of facilities to provide 21% of lifesaving surgical interventions (Sion et al, 2015). Similarly, one of the major challenges in vaccine provision in resource-constrained settings is the maintenance of ideal temperatures in the distribution and storage of vaccines and its adverse effects on vaccine efficacy. Therefore, cold-chain integrity remains important and is oftentimes compromised by a lack of sufficient refrigeration infrastructures in certain areas (Hill et al, 2016).

The WHO analysis of electricity access in health facilities across Sub-Saharan Africa made it clear that there is a lack of clear and universal indicators to assess electricity access in health facilities (Adair-Rohani et al, 2013). As a result, WHO expanded the questions pertaining to electricity within the SARA in order to capture a broader range of electricity sources and their reliability. There remains a need for a more comprehensive and standardized tracking system of energy access in order to adequately monitor progress, measure impacts on health, and better allocate resources (Adair-Rohani et al, 2013).

Chapter 3: Methods

In order to assess the impact of solar installations on health service utilization in the pre-2006 provinces of Equateur, Province Orientale, Maniema and Kasai Occidental, a counterfactual analysis was conducted to measure the difference between utilization patterns at the health zone level. Seasonally adjusted trend extrapolations using a regression of historical utilization data was used as the counterfactual scenario (the absence of solar intervention) for each health zone. Using STATA software, a difference-in-differences analysis was employed in order to measure the statistical significance of any observable change.

Population and Sample

This analysis uses data on solar installations and service utilization collected in the DRC as part of the ASSP Project by IMA World Health. Although installations remain ongoing, the solar installation data collected to date spans the years 2012 – 2015 for 52 health zones and the utilization data collected spans the years April 2013 - June 2015 for 56 health zones. For the purpose of this analysis the pre-2006 provinces were used and all health zones included in the datasets were located in the former provinces of Equateur, Orientale, Maniema, and Kasai Occidental. Equateur and Orientale both lie in the northern part of the country, bordering South Sudan, Central African Republic, the Republic of the Congo and Uganda. Maniema is a smaller landlocked province, and Kasai Occidental borders Angola in the south. Solar installation data is provided on the health facility level and includes health centers, reference health centers, hospitals, regional distribution centers, and health zone central offices.

Figure 1: Map of ASSP Program Provinces, Democratic Republic of Congo

Source: http://upload.wikimedia.org/wikipedia/commons/1/13/DRCongo_provinces_named.png
**Map consists of pre-2006 Provinces*

Research Design and Procedure

Of the data provided by IMA World Health, a final dataset of 43 health zones in the four aforementioned provinces was used. For this analysis, data cleaning included dropping health facilities with missing or inadequate solar installation and/or utilization data and dropping health facilities who did not receive a solar installation during the calendar year 2012 in order to obtain a restricted sample of health facilities with full information and breadth to adequately measure change. Further, the analysis only looked at solar installations used for refrigeration and lighting. Data concluded that installations spanned January-July 2014 and which 120 health facilities received a solar installation for refrigeration only, 217 for lighting only, and 61 for both. ASSP data provided by IMA World Health was used to define and measure utilization and in an effort to remain consistent with IMA World Health measurements, the same formula was used. Utilization was measured by summing the number of new cases seen at the health centers and hospitals in the health zone divided by the health zone population. The health facilities identified in the solar installation dataset as having received a lighting and/or refrigeration installation during the 2014 calendar year were then matched to their corresponding health zones in the ASSP dataset for the purpose of measuring utilization. The final breakdown of health zones per province are displayed in the table below:

Table 1: List of ASSP Health Zones Analyzed by Province, Democratic Republic of Congo

Equateur ***(11)***	**Kasai Occidental** ***(25)***		**Maniema** ***(4)***	**Orientale** ***(3)***
Abuzi	Banga-Lubaka	Lukonga	Ferekeni	Banalia
Bili	Bena Leka	Muetshi	Lubutu	Bengamisa
Bosobolo	Bena Tshiadi	Mikope	Obokote	Ubundu
Businga	Demba	Musheng	Punia	
Gbadolite	Ilebo	Mutena		
Karawa	Kakenge	Mutoto		
Loko	Kalonda-Ouest	Mweka		
Mobay-Mbongo	Kamonia	Ndesha		
Wapinda	Kanzala	Ndjoko-Punda		
Wasolo	Katende	Nyanga		
Yakoma	Katoka	Tshikaji		
	Kitangwa	Tshikapa		
	Luebo			

*Note: Pre-2006 provinces used

Utilization was then calculated for each of the 43 health zones using new cases and population per month starting in April 2013 and ending in June 2015 in an effort to provide enough pre and post data for analysis. Utilization data was then adjusted for seasonality using short time series methodology and assuming that seasonal fluctuations are constant for the series. A straight-line trend of the data was estimated using a regression analysis with Excel and then a residual difference was calculated between the original series and the trend. Seasonal factors were calculated using the average of the residuals for a given month and finally, to get the seasonally adjusted series, the seasonal factor was subtracted from the original series. In order to establish the counterfactual scenario, a straight-line trend of the pre-installation monthly data was estimated using a regression analysis with Excel. That trend was then extrapolated through the end point of June 2015. This method was replicated for all health zones in each province and resulted in two scenario trend lines per health zone.

In order to measure the significance of the observable difference between the two scenarios, a difference-in-differences analysis using STATA was employed. Health zone utilization data was categorized as pre or post installation dependent on the month of installation (for health zones with more than one installation month, the average was used) and Welch's t-tests were conducted to measure the significance of the differences in means before and after installation.

Limitations

Given the nature of the setting and type of data collected, this analysis is subject to many limitations. Particularly, data collection methodology was not infallible due to the resource-constrained setting. The installation protocol was not consistent and record keeping was deficient. Further, assumptions were made regarding the validity of the data provided by IMA World Health. Consistency of data was also a challenge; utilization data was provided at the health zone level whereas solar installation data was provided at the health facility level limiting the ability of the analysis to measure an impact of solar installations at the health facility level. Thus, the utilization data used for the actual scenario and the extrapolated counterfactual scenario both include health facilities that did not receive installations along with those that did due to inability to differentiate utilization data by health facility. The online DHIS2 database was explored for supplemental data at the health facility level but the data available was not consistent or complete and therefore not valid for the purposes of this analysis.

During the data cleaning process all facilities that received any other form of solar installation aside from lighting and refrigeration were dropped but some of those facilities remained in the final dataset because they also received either a lighting or refrigeration installation leading to some potential confounding. Further, data for all provinces were not distributed equally – due to either being outside of the inclusion criteria for analysis purposes or outside IMA World Health's programmatic area. The differences in number of health zones per province is notable with more than half of the dataset's health zones belonging to Kasai Occidental. Additionally, specific installation dates were unavailable for the province of Equateur so the midpoint month (June 2014) was used. Similarly, when performing the regression analysis a few health zones had more than one month recorded for installation so the midpoint month was used.

Another major limitation of this analysis is in regards to tandem infrastructure repairs and solar panel upkeep. None or not enough data was available to specify whether a facility received an infrastructural repair in tandem to the solar installation. Further, no follow-up data was available to discern whether solar energy remained uninterrupted or in need of upkeep/repair. The inability to create inclusion criteria for facilities that experienced uninterrupted solar energy could lead to variability in solar energy and potentially undermines some of the conclusions of this analysis. The lack of data that delineates whether or not repairs to the health facilities were performed in tandem to the solar installation has the potential to undermine the conclusions drawn from this analysis. IMA World Health has confirmed that oftentimes these two were performed during the same visit therefore for the purpose of this analysis we make the assumption that health facilities received a packaged intervention of health infrastructure repairs and solar installations at the time installation was recorded.

Chapter 4: Results

Utilization Trends: All Health Zones

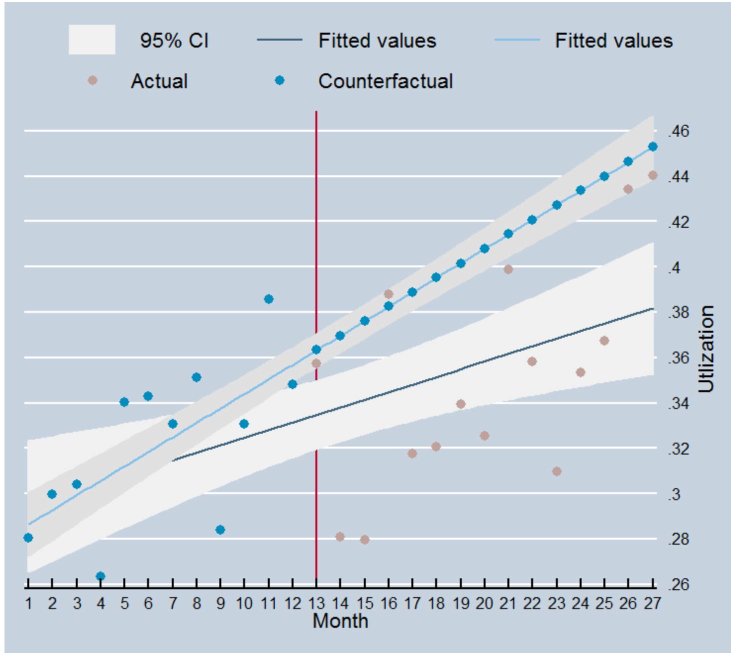
When comparing the utilization trends by scenarios for all health zones, 43.1% (19) indicated an improved trend in the presence of the packaged intervention. All three health zones in Oriental experienced a decline in overall utilization for both scenarios, although it appears that the intervention slowed the decline since all three health zones had a comparatively improved utilization trend for the intervention scenario. Contextual information provided by IMA World Health suggests that the pre-existing decline occurred due to a phase-out of a pre-existing project in 20 health zones within the province which paid facility staff salaries and provided free care. Further, IMA was not active in all health zones in this province during the year 2013 and therefore not all services were available in all health facilities until 2014. In the province of Maniema, three of the four health zones experienced a decline in overall utilization for both scenarios. The impact of the intervention was mixed in this province; two health zones had lower utilization trends compared to the counterfactual, one clearly improved, and one comparatively improved although still declining. For the province of Equateur, 81.8% (9) of health zones experienced an overall increase in utilization and the rest a slight decline. In terms of observable differences between the two scenarios, 45.5% (5) experienced an improved trend line for the intervention scenario with one of the heath zones experiencing a very slight increase. In Kasai Occidental 80% (20) of health zones experienced an overall increase in utilization for both scenarios, with only one experiencing an increase in the actual intervention scenario and a decrease in the counterfactual (absence of intervention). 12% (3) of health zones experienced an overall decline in utilization but all of them had an improved trend when compared to the counterfactual. Further, one health zone appeared to have a stable utilization trend for both scenarios although better for the intervention scenario. Again, this can imply the intervention may be mitigating the pre-existing downward trend in utilization in these health zones.

Utilization Trends: ≥60% of Health Zones Receiving Intervention

Since utilization data was aggregated at the health zone level and the intervention took place at the health area level, a closer look was taken at health zones in which 60% or more of the health areas in a given health zone received the solar panel/renovation packaged intervention. Due to the nature of the data, that limited results to five health zones (Ndesha, Katoka, Muetshi, Tshikai, and Bena Tishada) all located within the Kasai Occidental province. All except one of these health zones experienced an overall increase in utilization for both scenarios. Figures 2-6 are scatterplots of the five chosen health zones comparing utilization among the two scenarios, indicating the intervention month with the red vertical line and 95% confidence intervals around the line of best fit.

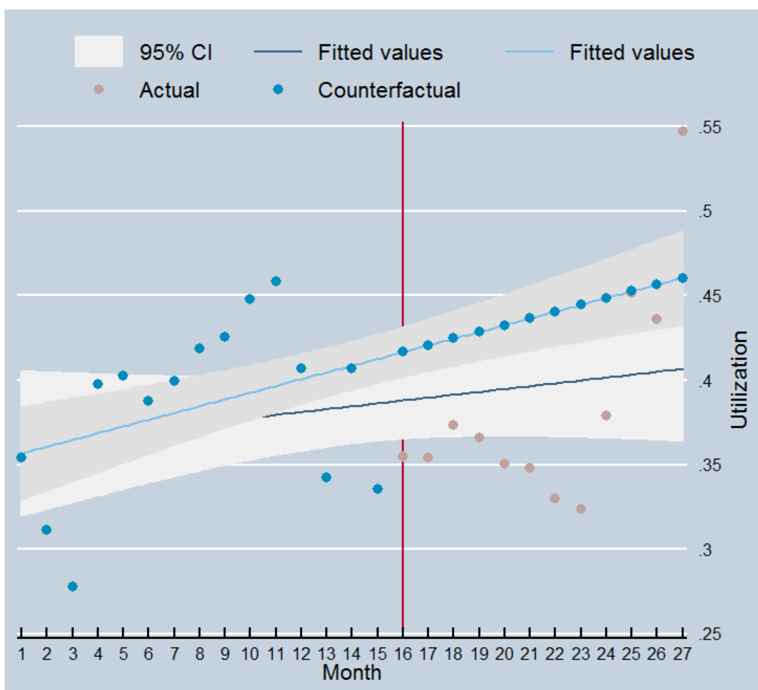
In Figures 2 and 3 below, the counterfactual scenario projected a higher utilization trend than that of the intervention scenario.

Figure 2: Scenario Comparison of Utilization for Ndesha Health Zone, Democratic Republic of Congo



*Utilization calculated as number of new cases per person per month

Figure 3: Scenario Comparison of Utilization for Muetshi Health Zone, Democratic Republic of Congo

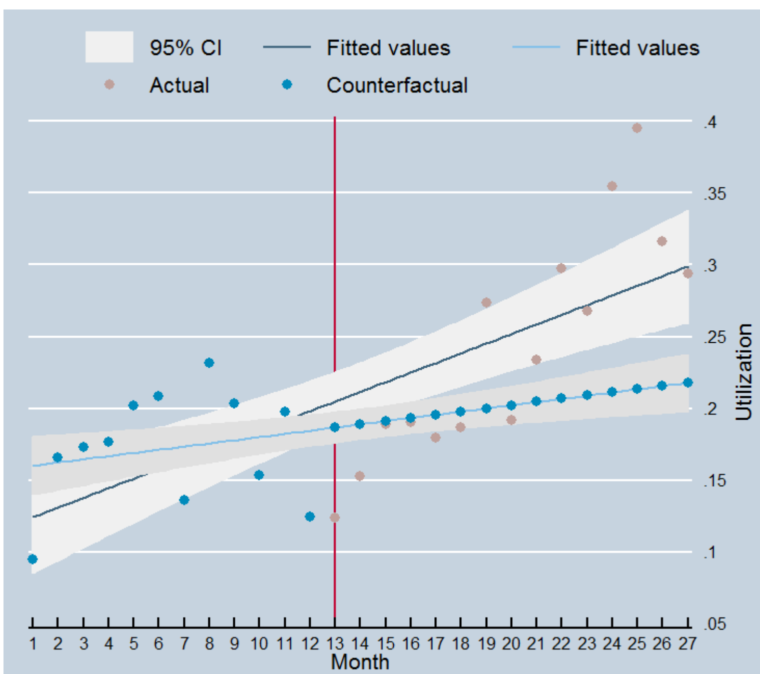


*Utilization calculated as number of new cases per person per month

The effect appears more profound in the Ndesha health zone than in the Muetshi Health zone, although positive for both. The intervention start date should be taken into consideration when comparing these two figures. Figure 2 has 12 months of pre-intervention data compared to 15 months in Figure 3. Since the counterfactual scenario uses an extrapolated trend based on pre-intervention data, Figure 3 would have a slightly more accurate projection.

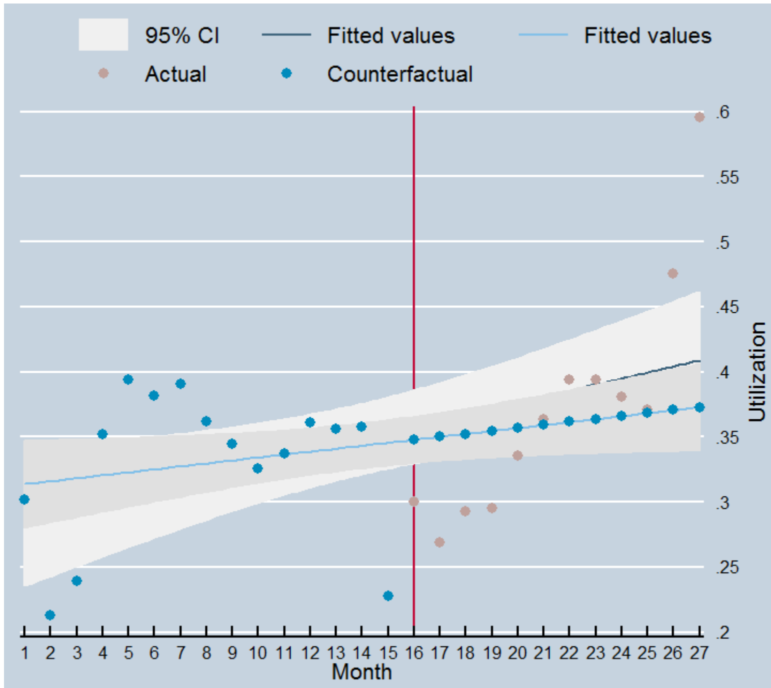
In Figures 4 and 5 below, the intervention scenario experienced an improved utilization trend compared to the counterfactual.

Figure 4: Scenario Comparison of Utilization for Kakoka Health Zone, Democratic Republic of Congo



*Utilization calculated as number of new cases per person per month

Figure 5: Scenario Comparison of Utilization for Bena Tshadi Health Zone, Democratic Republic of Congo

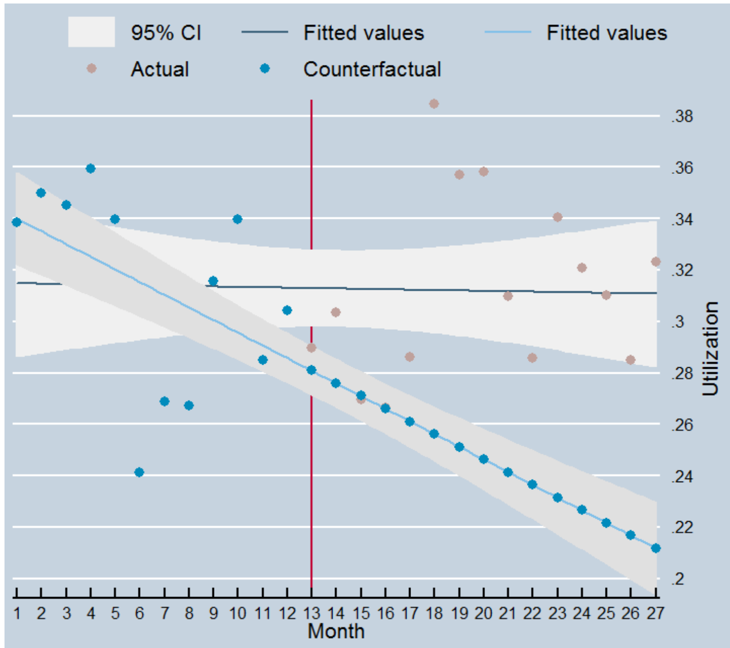


*Utilization calculated as number of new cases per person per month

The difference in trends between the two scenarios was substantially smaller in the Bena Tshadi health zone than in the Kakoka health zone. Again, the intervention start dates differ between these two Figures and similar to what we saw in Figures 2 and 3, the effect appears to be more impactful in the health zone with less pre-intervention data.

Finally, Figure 6 below indicates that there was not much variation in the trend line for the actual intervention scenario in the Tshikaji health zone. Although not indicating an overall increase in utilization over time, the actual scenario appears to be mitigating the pre-existing downward trend extrapolated by the counterfactual scenario.

Figure 6: Scenario Comparison of Utilization for Tshikaji Health Zone, Democratic Republic of Congo



*Utilization calculated as number of new cases per person per month

It is important to note that in Figures 2-6 the 95% confidence intervals surrounding the best-fit trend lines for the actual scenario is noticeably wide. The wideness of the shaded area among the actual intervention scenario in all the figures indicates that there is a high level of variability in the existing utilization data. Although the data was adjusted for some variability during the analysis, clearly there is an underlying factor causing much of the variability seen in these figures. Considering that these 5 health zones have the highest proportion of health areas receiving the intervention and therefore among the most accurate and complete comparisons available in our analysis, data quality seems to be an important issue to address in future analyses.

Average Monthly Utilization: Two Scenarios

Table 2 below summarizes the difference in mean monthly utilization in both scenarios, their difference, and net impact measured using a difference-in-differences. Utilization rate was calculation as the number of new cases in a health zone during a given month over the health zone catchment population of that same month.

Table 2: Average Monthly Utilization Before and After Packaged Solar Panel Installation and Renovation Intervention and Difference-in-Differences Impact

Province	Before	After	Difference	D-in-D
All Provinces	0.2944528	0.313057	0.0186042**	0.0419727***
≥ 60% with Intervention	0.3090604	0.3269717	0.0179113*	0.0036428
Kasai Occidental	0.3000406	0.3421336	0.042093***	0.0358354*
Equateur	0.2315246	0.3456174	0.1140928***	-0.0324148
Maniema	0.2853295	0.268812	-0.1165175***	0.341358
Oriental	0.4275755	0.0657654	-0.3618101***	0.3050305***

Notes: Statistical analysis was conducted using STATA software. The adjusted Difference-in-Differences analysis was conducted using the counterfactual scenario as the control group.
* indicates a p-value ≤ .05
** indicates a p-value ≤ .01
*** indicates a p-value ≤ .001

Table 2 shows that overall, among all the health zones analyzed, utilization improved from a monthly average of .29 new cases per person per month to .31 after the intervention start date. When looking only at the health zones in which ≥60% of the health areas received the intervention, the difference is slight smaller than that of all health zones (.017 compared to .018) and the statistical significance slightly weaker (p-value of 0.0435 compared to 0.0017). The province of Equateur saw the highest increase in average monthly utilization after the installations/renovation (difference of .11) and the province of Oriental saw the lowest decrease post intervention (-.36 difference). For the provinces experiencing a decline in average monthly utilization, 14.3% of the health zones included in those provinces did experience an increase. It should be noted that Maniema and Oriental combined only account for 16.3% of the total health zones evaluated and therefore the effect in these sub-samples may be overestimated.

Net Impact: Difference-in-Differences Analysis

The net impact of the difference-in-differences analysis is used to measure the differential effect of the actual intervention scenario versus the counterfactual (no intervention) scenario. The net impact, or effect, of the intervention on monthly utilization is listed in the last column. The largest impact is observed in the province of Maniema but the impact was not statistically significant (p-value of 0.283). The impact was also found to not be statistically significant for the health zones within Equateur (p-value of .088) and the health zones in which ≥60% of the health areas received the intervention (p-value of .862). The province of Oriental experienced the largest impact among the provinces in which the results were statistically significant (p-value of 0.00). When comparing the difference-in-differences between all health zones and those in which ≥60% of the health areas received the intervention, all health zones had a larger impact (.042 compared to .004) and more statistically significant than the health zones in which ≥60% of the health areas received the intervention (p-value of 0.001 compared to 0.862).

Average Monthly Utilization: Actual Scenario

Table 3 below summarizes the difference in monthly utilization before and after the intervention only among the health zones receiving the intervention. This table represents the actual scenario and therefore includes none of the extrapolated data.

Table 3: Actual Scenario Average Monthly Utilization Before and After Packaged Solar Panel Installation and Renovation Intervention

Province	Before	After	Difference
All Provinces	0.2944528	0.3340434	0.0395905***
≥ 60% with Intervention	0.3090604	0.3287931	0.0197327
Kasai Occidental	0.3000406	0.3600513	0.0600107***
Equateur	0.2315246	0.32941	0.0978854***
Maniema	0.2853295	0.2858799	-0.0994496***
Oriental	0.4275755	0.2182806	-0.2092948***

Notes: Statistical analysis was conducted using STATA software.
* indicates a p-value ≤ .05
** indicates a p-value ≤ .01
*** indicates a p-value ≤ .001

The average monthly utilization post-intervention in Table 2 is higher among all provinces except Equateur when compared to Table 3. Overall, all health zones experienced an increase of .04 in average monthly utilization between the pre and post intervention period. When looking only at health zones in which ≥60% of the health areas received the intervention, the difference was smaller (.02) and not statistically significant when compared to the difference of all the health zones (p-value of 0.0836 compared to 0.00). The largest difference is observed in the province or Oriental where monthly utilization rate decreased from .43 new cases per person per month to .21 post intervention and the smallest difference was observed in the province of Kasai Occidental where monthly average utilization increased from .30 new cases per person per month to .36.

Chapter 5: Discussion

The DRC continues to require high need of humanitarian assistance due to high levels of insecurity, violence, and population displacement. Further, the United States government reissued a disaster declaration for the complex emergency in the DRC for the fiscal year 2016, which categorizes the DRC as a complex emergency country (USAID 2016). The Inter Agency Standard Committee officially defines a complex emergency as “a humanitarian crisis in a country, region or society where there is total or considerable breakdown of authority resulting from internal or external conflict and which requires an international response that goes beyond the mandate or capacity of any single agency and/or the ongoing United Nations country program” (IACS, 1994). This type of context and a deteriorated security situation in certain areas of the country creates additional barriers to the delivery of health care. More specifically, it can interrupt or cause sluggish supply chains that have a negative impact on the factors studied in this analysis. In 1997, the Sphere Project was launched in order to develop globally accepted minimum standards for program indicators and behaviors in core areas of humanitarian assistance. The Sphere Project recommends that among stable rural and dispersed populations, health care utilization should be at least 1 new case per person per year (Sphere Project, 2011). This recommendation averages to .08 new cases per person per month. Results from this analysis will be compared to Sphere standards to assess the overall performance of this indicator according to global humanitarian standards.

When examining the health zones combining both scenarios, all but one province experienced an average utilization rate well above the .08 new cases per person per month recommendation. The province of Oriental had an average post-intervention utilization rate of .07 new cases per person per month for all its health zones, slightly below the minimum requirement. When examining data only among the actual intervention scenario, the average monthly utilization rate was higher than the recommended standard indicating that overall, the health zones included in IMA's programmatic area is doing well in regards to meeting the Sphere Project's minimum standard recommendation. More contextual information is needed to verify if this estimate is accurate, as over-estimation may be possible due to specific public health problems or an overall under-estimation of the population.

Further, the high levels of variation seen in the utilization data across all health zones challenge the validity of this level of analysis. The confidence intervals from the utilization trend lines in the previous section indicate that even after controlling for seasonality the observable variation in the data remains large. Some of this variation is expected due to the context in which this program is operating. The DRC has a relatively new health infrastructure and lacks political and societal stability meaning that any and all data collected may not be of the best quality. Given the nature of the program setting, many potential confounding variables exist that could affect utilization trends. They could include the political and societal context of the DRC, geographic and infrastructural barriers to accessing health facilities, tandem government or other NGO-sponsored campaigns, and the staffing, services and efficacy of the health facilities themselves. Further, since tandem renovations were not recorded and the reliability of the energy not measured, it is difficult to ascertain if the increase in average monthly utilization was due to the solar installation itself or another factor.

The results of this analysis suggest an association exists between the implementation of the packaged solar installation/renovation intervention and health care utilization. Overall, the association appears to improve the average monthly health care utilization across all health zones analyzed. Similar to the overall average across all health zones, when stratified by province, the health zones located in the provinces of Equateur and Kasai-Occidental appear to experience an improved average monthly utilization in association with the intervention. The association, although still statistically significant, appears to decrease the average monthly health care utilization among the health zones located in the provinces of Maniema and Oriental. The smaller sample size (7 health zones) may be the reason and therefore a larger sample of health zones for these provinces is needed in order to assess if the average is representative of those provinces. Further, the proximity of these two provinces to the unstable and violent eastern part of the country may account for the decline in average monthly utilization for those health zones.

Due to the lack of a true non-experimental control, a causal relationship cannot be established. When looking at the aggregate level of all the health zones included in this analysis, the increase in average monthly utilization post intervention was found to be statistically significant. Underlying trends were controlled for during this analysis but not outside factors that may be responsible for trends due to the lack of a non-experimental control. In order to mitigate this, future research could examine the context and other outside factors that have the possibility of impacting utilization trends. Further, if a true control group cannot be established, future research can implement a step wedge design in order to evaluate the effect of time on the intervention and address the logistical difficulties of implementing the intervention at once across all sites and therefore more effectively implement and evaluate the program.

This analysis has made headway in attempting to demystify the relationship between solar energy availability and healthcare utilization. Limited research and studies measuring the relationship between the two exist to date and this analysis, albeit limited, has made an attempt to quantify the relationship between solar energy installations and healthcare utilization.

Chapter 6: Recommendations

Understanding the association between solar energy availability and healthcare utilization has great potential to impact health status, by improving access to health services in resource-constrained settings worldwide. The DRC, in particular, currently experiences some of the worst health outcomes worldwide - some of which could be mitigated by the availability of solar energy in health facilities across the country. Existing literature in this domain has established that providing solar energy in health facilities can lead to extended operating hours, proper storage of medicines, blood, and vaccines, and increase the availability of night time deliveries and emergency care. The results from this preliminary analysis may inform these indicators through findings that seem to show that higher monthly utilization rates are associated with solar panel installations. These following recommendations are meant to help facilitate future positive public health implications in relation to the provision of solar energy as well as better inform any future studies conducted that seek to examine the relationship between health and solar energy.

First, although this assessment initially set out to establish a causal relationship between the packaged intervention and healthcare utilization, lack of sufficient data made this impractical. Therefore, future investments in solar energy interventions need to include adequate and specific monitoring and evaluation processes and metrics in order to capture the appropriate data to establish a causal link. Specific to the program run by IMA World Health, a more systematic data collection process should begin to ensure standardization of data collected and make data points comparable across sites. Utilization metrics should also be developed to include sex, ethnic groups, and age sub-categories in order to capture important trends in these sub-populations. Further, if possible, a standardized installation schedule should be implemented in order to establish clear pre and post periods and facilitate the evaluation of utilization changes over time and across sites. Tandem renovations to the health facilities should also be explicitly and standardly documented across all sites or implemented on a different programmatic schedule in order to mitigate the potential confounding of this secondary intervention on the effect of the solar panel installations. Most importantly, follow-up should be conducted at the installation sites in order to establish whether the solar panels are being used and still functioning adequately. This kind of follow-up data would be able to capture whether facilities experienced uninterrupted solar energy since installation, allowing for better measurement of the effect of the intervention.

Next, due to the specific context of the DRC, qualitative analysis should be conducted on a sample of the health zones receiving the intervention in order to supplement the quantitative findings of this analysis. Further, a difference-in-differences analysis, like the one used in this analysis, has the potential to either over or under estimate the effect of the intervention making specific regional contextual insight produced by a qualitative analysis invaluable. Data across all health facilities may not be comparable given certain contextual factors, so a qualitative component to this analysis may help in establishing a better control group. Qualitative interviews at the health facility level would also be beneficial to the evaluation because they could provide a better idea of the incentives and barriers behind healthcare seeking behavior at the facility level.

Further, once the proper monitoring and evaluation mechanisms are put in place, continuation of this intervention should be strongly considered by IMA World Health and policy makers in the DRC. Since the majority of the country's health facilities are located in rural areas where only 0.4% of the population has access to electricity, installing solar panels in health facilities could help mitigate the lack of access to electricity experienced by most of the country's population. An investment in increasing the availability of solar energy at health facilities has the potential to lead to improved health outcomes associated emergency care, vaccination, and deliveries as facilities are better equipped to provide a full range of services and people consume more healthcare.

Finally, newly collected data at the health area level was made available to the researcher and further analysis should be conducted in order to establish a more granular level understanding of the association between the packaged intervention and healthcare utilization. Comparisons can be made between the health area and health zone levels and the effect of the intervention can be better evaluated. It would be interesting to see if the effects of the intervention seen in utilization rates at the health area level translate into the patterns we observed at the health zone level with this analysis.

Conclusion

Through this assessment we were able to observe an association between healthcare utilization and a packaged intervention of solar panel installations and health facility renovations. We were able to establish several significant changes in average monthly utilization before and after the intervention and across the different scenarios and provinces evaluated. This assessment is a first step in the understanding and measurement of the relationship between solar energy and healthcare utilization. Although widely accepted to improve health outcomes, a clear and causal link between availability of solar energy and improved healthcare utilization remains to be determined. Only once this causal link is established will we be able to measure the exact effect of solar energy on health and subsequently work to improve existing health infrastructures to improve health outcomes in resource-constrained settings worldwide using innovative solar technology.

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