The Geneva Challenge 2019

Renewable Energy as the Game Changer in Rural Health Crisis: Bringing Advancement in Community-Based Healthcare Facility in Remote Rural Areas of Indonesia

Hansol Jung1), Jihae Ko2), Chaiyoung Lee3)

Abstract

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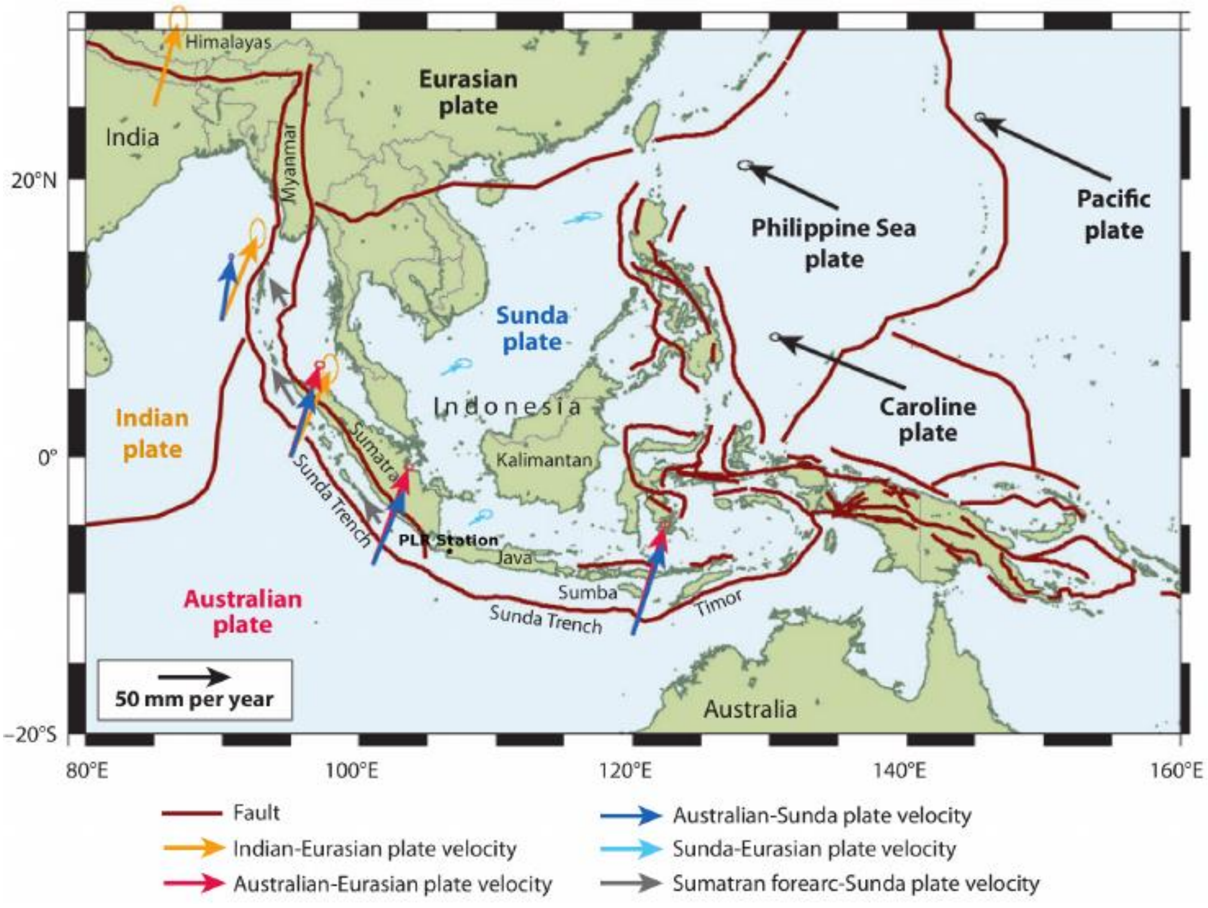
1. Introduction

A. Project Context

While being a country with a huge population, Indonesia is a geologically unstable country. As shown in Figure 1 (McCaffrey, 2009), it is located between two continental plates: the Eurasian Plate and the Australian Plate. Other tectonic plates including the Philippine Sea Plate and the Pacific Plate also meet under the Indonesian archipelago, forming a volcanic arc in western Indonesia. Powerful eruptions and earthquakes have been taking place due to the active seismic activities of the volcanoes.

Figure 1: The Tectonic Settings of Indonesia



The active seismic activities and the characteristic as an archipelago work as the main obstacles for extensive electricity service in Indonesia. According to ADB, 10.4 million people in Indonesia, mostly rural households, lived in the dark in 2016 (ADB, 2016).

Indonesia's primary source of electricity transmission is the grid connectivity. Indeed, there are many grids in Indonesia including the one for Java and Bali, and another for Sumatera areas. Electricity demand in the province of Bali is currently supplied by the electrical system in Java through a network of 150 kV submarine cable transmission with the capacity of 200 MW. It is also supplied by the existing plants in the province of Bali itself. Some small islands have their own grids too, but many other regions lack such connectivity at all. Due to poor grid connectivity among the islands, and with increased frequency of extreme weather events which hampers the functioning of regional grids, constant access to the electricity is limited from many regions.

The current alternatives are the utilization of diesel generators. The mini-grids in the smaller islands are usually more based on large diesel generators like those in Batam, Bintan, Lombok, and Sumba. These islands, although considered small, still have a population of around one million, and their sizes are larger than that of Singapore. Furthermore, even with the mini-grids, there are also communities with no access to electricity within these islands. Some communities may rent small diesel generators, but others still have not such access at all.

On the other side, Indonesia has a great potential in renewable energy projects, especially in geothermal with 28GW potential, and solar energy that is utilized only up to 24MW as of 2019 (Hamdi, 2019). Renewable energy accounts for around 28.2% of total primary energy supply (TPES) in 2016 (UN, 2016), but are only utilized to generate up to 5-6% of electricity supply in 2015 (Smiti, 2015).

B. Challenges in Rural Healthcare in Indonesia

Indonesia’s wide distribution of islands makes access to electricity a challenge, and this leads to the difficulties of delivering necessary health care. Healthcare facilities are very energy-intensive, as they operate 24/7 and entail different demands of power, including constant electric power, heating, and cooling.

In this sense, healthcare facilities in rural regions of Indonesia are prone to increased mortality. Especially the rural facilities in resource-constrained settings (i.e. small islands) suffer from unreliable energy networks that impedes health service provision. When there is a power outage, the critical operations of the healthcare facility during that time stop completely. In addition, unreliable access to electricity leads to vaccine spoilage, interruptions in the use of essential medical and diagnostic devices, and lack of even the most basic lighting and communications for maternal delivery and emergency procedures. Usually the healthcare facilities in the isolated regions are operated by diesel generators, using diesel fuels delivered from the main island by the ships. However, with the increased frequency of extreme weather events, diesel generators are no more reliable nor sustainable.

Furthermore, limited access to electricity not only hinders the operation of healthcare facilities, but also leads to the deterrence of healthy daily lives of the community. For example, an estimated 55% of Indonesian population (i.e. 128 million) rely on traditional biomass for cooking, as they cannot access nor utilize modern kitchen facilities without power connection. The families in Indonesia usually burn biomass fuel using traditional, inefficient stoves that waste potential fuel energy and emit health-damaging pollutants into the household environment (World Bank, 2013). Reliance on such a source of energy has the disadvantage that poor people in rural areas have little alternative but to collect timber for cooking, harming their health. Each year, about 165,000 premature deaths in Indonesia are attributed to household air pollution linked to traditional biomass cooking (Lim et al. 2012).

While it is clear many modern interventions cannot be delivered without electricity, few studies suggest or provide comprehensive explanation nor evidence of the links between the access to power of health facilities and the actual health outcomes of treatment.

C. Impact and Ramifications of the Challenges

Without stable and constant access to electricity, the healthcare facilities cannot operate properly. It translates into many lives that could otherwise have been saved being lost, due to the health challenges from the cause related to limited access to energy. Also, low access to electricity affects people's health negatively by exposing them to emissions from burning biomass. Considering these negative impacts of lacking electricity connectivity, it is evident that the government has to develop a more detailed understanding of challenges regarding access to electricity and provide the clearer matrix of solvency.

The solution for Indonesia comes from renewable energy. While accompanied by unstable seismic activities and climate, its location on the active volcanic arc provides Indonesia with great thermal energy. As a result, Indonesia has a great potential in renewable energy projects including that of geothermal and solar photovoltaics (PV). Accordingly, Indonesia has set a target of 23% of electricity generation from renewable sources by 2025 (Globeasia, 2017).

While the output from the solar photovoltaics sector is almost exclusively set aside for decentralized rural electrification, development of solar PV generation can lead to much stable and extensive access to electricity for rural areas. In 2019, only 24MW of solar, including solar rooftop units, are currently installed and dispatchable to the grid (Hamdi, 2019), leaving a great potential room for growth.

2. Project Backgrounds

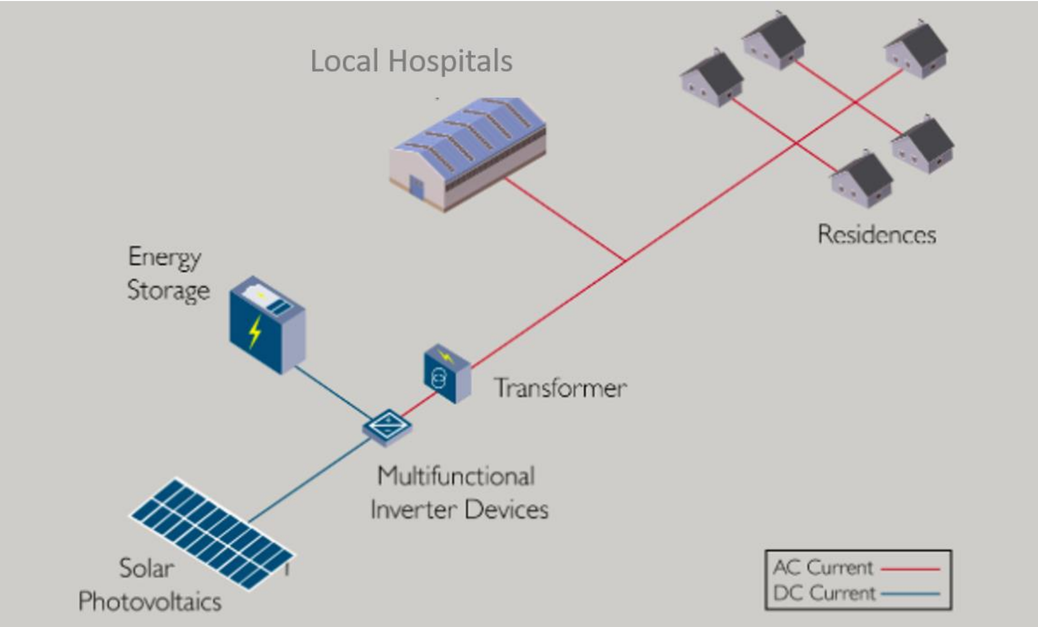
A. Overall Initiatives of the Project

The overall goal of our project is to provide a sustainable model of reference for the Indonesian government to advance on rural electrification and proper healthcare. Even after years of practices, there still remains a lot of questions as to whether there is a positive relationship between foreign developmental aids and improved public health. A knowledge gap between the community and the donors works as a barrier to directly address the challenges faced by the rural community, which grows the inefficiency of such projects. Moreover, many developmental aids are given in the form of a monetary supplement, lacking a thorough consideration on how to make the community livable.

To this end, this project aims to suggest a concrete model for the developmental aid for enhancing public health. In order to decrease discontinuity between developmental aid and the community, the project directly targets the local health needs by setting the government and the current state-run healthcare facilities as the main actors. To advance on the unreliable power system of the local healthcare facilities in Indonesia, therefore, we designed a model where a healthcare facility is fully operated by renewable energy, with additional public health space to provide a clean cooking solution to the local community. With the government and the local healthcare facility taking the first initiatives to launch the project, they will contribute to enhancing public health, not only by increasing the power system reliability of the facility, but also by significantly reducing the mortality induced by traditional biomass cooking.

Furthermore, the project will widen its scope by making the healthcare facility as a power generator, as depicted in Figure 2. The island population constantly suffers from the insufficient energy supply, as well as the high cost of energy, which is due to the geographical distance and isolation. The healthcare facility, incorporating a combination of electricity generation facilities and increasing the share of renewable energy in its power mix, will be able to deliver a model where the community end-users are supplied with on-site generated power for living.

Figure 2: Structure of the Stand-Alone System



B. Previous Cases of Reference

Grid outage in the operation of healthcare facilities is critical to function vital infrastructure for the patients. Realizing such importance, many healthcare facilities around the world have installed an independent electricity generator to prevent any critical accidents from happening. We listed several case studies where healthcare facilities are equipped with an on-site power system.

Case I: Mississippi Baptist Medical Center

Mississippi Baptist Medical Center is a 624-bed facility in Jackson, Mississippi. When the healthcare facility lost grid power for 52 hours in 2005 in the wake of Hurricane Katrina that caused extensive power outages, the Combined Heat and Power (CHP) system installed inside the healthcare facility allowed it to continue 100% operation. The CHP system provided power and thermal energy to the healthcare facility for more than four days after the storm, with no reliable grid power available. After the power grid stabilized, MBMC reconnected to the grid and resumed normal operation (U.S.DOE, 2015).

Case II: South Oaks Healthcare facility, Long Island

In the wake of Superstorm Sandy that hit the northeastern USA in 2012, a number of major New York City institutions were able to maintain power during the storm due to installed CHP systems. In particular, Long Island's South Oaks healthcare facility campus operated for five days on its CHP system when grid power was not accessible. It then operated for following 10 days even after the power was restored, upon the request of the crisis-besieged Long Island Power Authority (LIPA). Ultimately, South Oaks healthcare facility operated for 15 days isolated from the grid, supplying all necessary thermal and electric power to the 300,000 square foot facility (Health Care Without Harm, 2013).

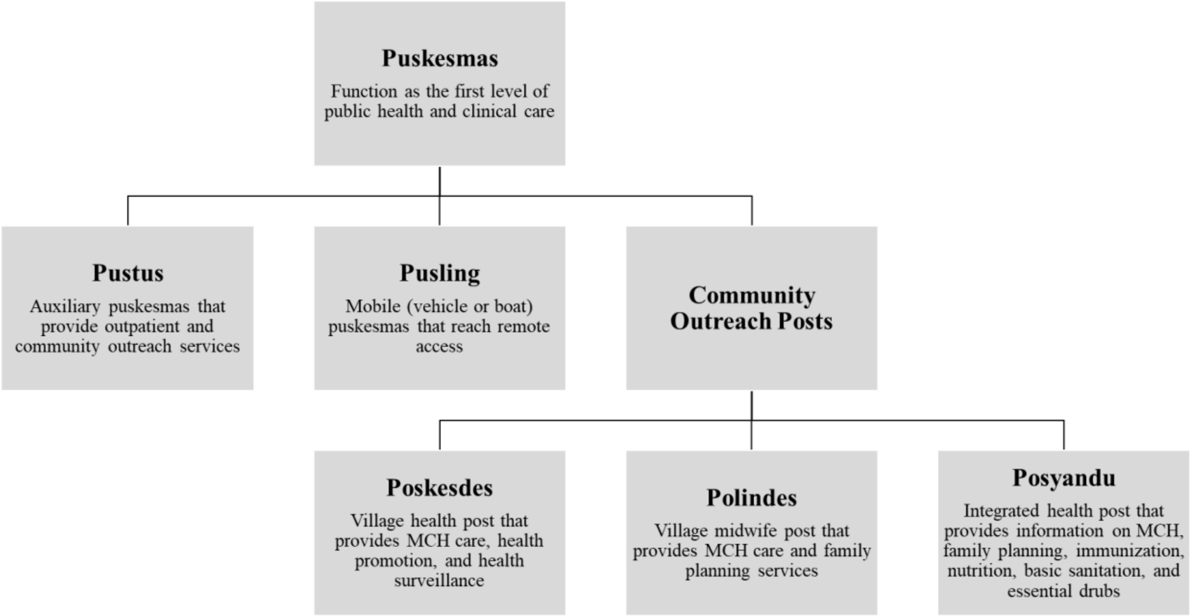
Case III: A Health Clinic and a Nursing School in Kalungi, Rwanda

Kalungi Hospital is located 125 kilometers south of Kampala, Uganda. The facility serves as both a health clinic and a nursing school; nurses who complete the Kalungi program are deployed into village healthcare facilities. To meet the electrification goal, a 1.6 kW solar array was installed at the healthcare facility to serve the electricity needs on-site. With the use of solar panels, the clinic hours have been extended; the nurses were able to continue study at night; able to sterilize and freeze medical instruments and materials. Additionally, the healthcare facility installed 2.6 kW solar array for the clean water provision for the village. This array powers a pump which pumps the water up a hill to a tank in the healthcare facility, and the water is then distributed to the community through the pipeline (USAID).

C. Community-Based Healthcare Facilities in Indonesia – Puskesmas

In Indonesia, the government initiative has pushed the installment of the local clinic called "Puskesmas." Puskesmas is deployed all around the nation, reaching 9,825 entities as of 2018 (PHCPI, 2019). The primary role of Puskesmas is to provide preventive, promotive, and curative care at the sub-district level with a focus on the community. Puskesmas works as a hub for the implementation of primary care delivery strategy, with sub-level healthcare elements as shown in Figure 3.

Figure 3: The Healthcare Structure of Puskesmas, Indonesia



As they are deployed virtually everywhere within the nation, Puskesmas has a potential point to be central for new strategies and policies to enhance local healthcare. While the creation of the Puskesmas network increased geographic access to primary healthcare, mobilizing resources to fragmented islands still remains a challenge. Therefore, the government should prioritize the operation of Puskesmas system for enabling universal healthcare. In this project, therefore, we aim to provide a comprehensive roadmap for the delivery of the universal health coverage starting from Puskesmas.

D. Power Purchase Agreement

Power Purchase Agreement (PPA) in Indonesia takes monophonic structure, wherein Perusahaan Listrik Negara (PLN), the government’s national electricity provider, acts as the only off-taker of all the PPAs. Monophonic PPA, which usually lasts up to 20 to 30 years, has low flexibility in transitioning the main source of energy, because each retail seller has to meet all the regulatory standards set by the government and PLN. In addition, as sellers making contracts with PLN often wants to secure profits from the contract, the supply of electricity is often restricted to big cities that are already with grids and wirings to each household. Therefore, the current PPA structure works as a barrier to implement and expand the scope of community-specific power generation plans.

The solution of our project is to extend the concept of PPA in Indonesia to allow designated state-run health facilities to supply their own electricity and make supply contracts to individual consumers under humanitarian purpose. The goal of such an extension is to facilitate the utilization of renewable energy for rural healthcare. There are some empirical cases in North America and Europe, where the healthcare facilities themselves become partners of PPAs which enable on-site power generation. In such cases, energy utilities or other investors pay to construct and operate a CHP, wind or solar installation on the healthcare facility (WHO, 2014).

Our project proposes that Puskesmas that are spread across regions of Indonesia become the partners of PPAs to generate electricity of their own demand and to supply the surplus production to enhance the health and welfare of local people. As compared to the current monophonic PPA in Indonesia, independent PPA will increase power accessibility, stability, and flexibility.

As the objective of this project is to enhance public health, such a humanitarian initiative can provide enough rationale for the healthcare facilities to have an independent PPA. Furthermore, the recent proposal on solar photovoltaic purchase agreement by PLN on table 1 validates the feasibility of the project. Under the goal of securing solar power generation capacity of 5,000MW, Indonesian government planned to place gradual solar power project orders and announced a new MEMR Regulation No.19 of 2016 that specifies the required solar power generation capacity and the price payable for the electricity supplied. The selection of PV developers diverged from before in that not only energy sellers but any business entity in Indonesia could bid for the capacity quota offer on the first-come-first-served online registration.

Table 1: New Proposal of PV Power Purchase Agreement

Procedure for the purchase of PV power by PLN	
Pre-selection phase	(a) Call for registration (b) Registration process (c) Verification of documents
PV quota allocation phase	(a) Publication of the capacity quota plan (b) Communication of capacity quota offer (c) Application for capacity allocation (d) Verification of applications by EBTKE (e) Appointment & announcement of PV developers
Completion phase	(a) PPA signing: basic 20 year contract which can be extended through the negotiation with PLN (b) Financial Close: within the 6 months from the PPA contract (c) Obtention of IUPTL (d) COD

E. Target Setting

In this project, we have taken “Masalembu” as a target island. We utilized the demographic data of the Maselembu Island in order to apply our hypothetical ideas into the real settings. The data is summarized in the below Table 2.

Table 2: Summary of the Target Island

Target Island: Kepulauan Masalembu	
Province	East Java
Regency	Sumenep
Sub-district	Amsalem
Population	18,485 (2015) with 9,158 households
Total land area	23.86 square kilometers

Source: Statistics Indonesia, 2015; 2010 Population Census-Sumenep District

The island is selected due to its isolated location, where a 12-hour trip is required to reach the nearest main island. Patients on this island might not attain proper first-aid in case of any emergency without local healthcare. Not only that, the island falls within a sub-district of 3 small islands, which are Masalembu, Karamian and Masakambing. A government-subsidized pioneer ship service carries passengers and goods in and out of the island, although service interruptions happen occasionally. In this sub-district, there is only one Puskesmas run by the government, making it an ideal option for the transformation into a public healthcare hub.

As an only healthcare facility in the island, the Puskesmas serves as a primary pre-caring health center. In lack of sufficient information on this particular Puskesmas, we estimated the size and facilities of it based on the demographic data. According to WHO, Indonesian healthcare facilities have, in average, 12 beds per 10,000 population (WHO). If we assume that the Puskesmas serves all the 18,485 people living in the island, technically it should have 22 beds. Following the category of the healthcare facilities by USAID on Table 3, this facility should be under the category I, with only low-energy requirements including lightning, maintenance of cold chain, and utilizing the basic lab equipment. Table 4 below describes the estimated energy demand of the model Puskesmas in Masalembu.

Table 3: Description of Category I Healthcare Facilities

Category	**Description**
Category I low energy requirements	▪ Typically located in a remote setting with limited services and a small staff ▪ Approximately 0 - 60 beds

	▪ Electric power is required for: 1. lighting the facility during evening hours and to support limited surgical procedures (e.g. suturing) 2. maintain the cold chain for vaccines, blood, and other medical supplies - one or two refrigerators may be used 3. utilizing basic lab equipment - a centrifuge, hematology mixer, microscope, incubator, and hand-powered aspirator

Table 4: Estimation of the Category 1 Healthcare Facility Power Consumption

Category 1 Health Clinic Power and Energy consumption		**A**	**B**	**C=A*B**	**D**	**E=C*D**	**F=E/1000**
		Quantity	**Power (Watts)**	**Total Watts**	**On-Time (Watt hours/day)**	**Wattage (hours/ day)**	**kWh/day**
Description of Devices	**Vaccine Refrigerator**	1	60	60	24	1440.0	1.4
	Refrigerator (non-medical use)	1	200	200	24	4800.0	4.8
	Centrifuge	1	575	575	1.5	862.5	0.9
	Hematology Mixer	1	28	28	1.5	42.0	0.0
	Blood Chemical Analyzer	1	88	88	1.5	132.0	0.1
	CD4 Machine	1	200	200	1.5	300.0	0.3
	Microscope	1	15	15	4	60.0	0.1
	Desktop Computer	1	300	300	5	1500.0	1.5
	Lighting	2	10	20	10	200.0	0.2
	Incubator	1	400	400	12	4800.0	4.8
	Tube-Fluorescents	4	40	160	1.5	240.0	0.2
	Water Bath	1	1000	1000	2	2000.0	2.0
	Communiction via Radio	1	30	30	12	360.0	0.4
	Stand-by		2	0	12	0.0	0.0
	Transmitting		30	0	2	0.0	0.0
	Total			3076		16736.5	16.7

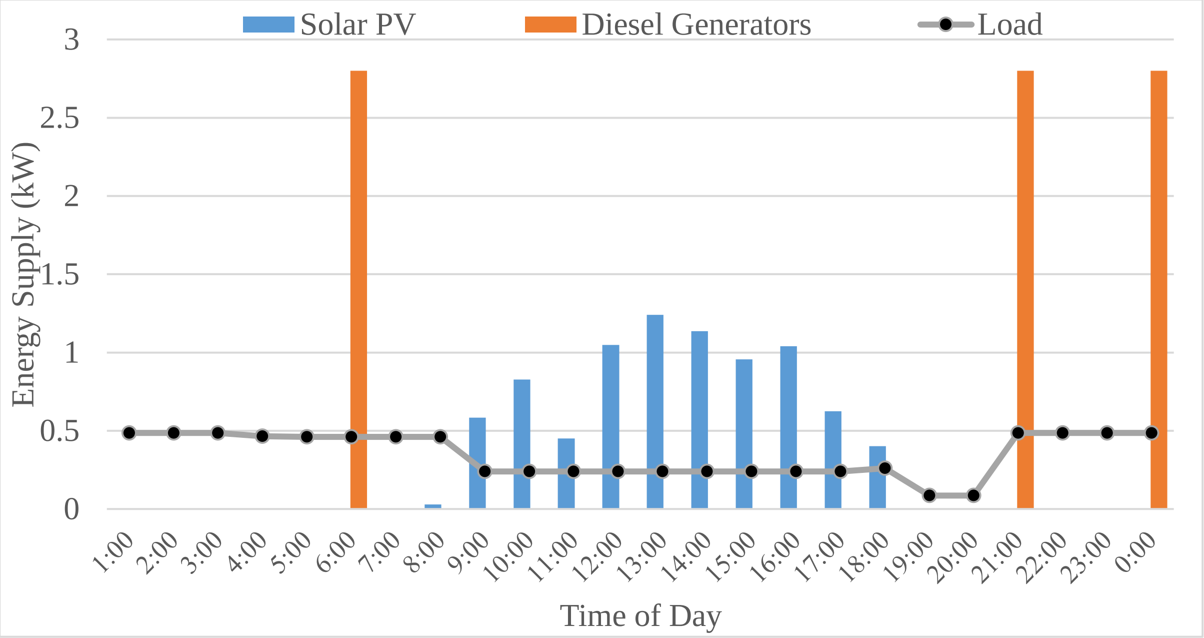
3. Project Overview and Stages

The goal of our project is to suggest a new model of reference that powers and enhances rural healthcare with renewable energy. We draw a masterplan for transition in the power mix of rural healthcare facilities from diesel to renewable energy. The masterplan comprises of 4 stages. In this part, each stage is described in detail in terms of demand, supply, and the resource mix of electricity.

A. Launching Solar Photovoltaics as Substitutional Source of Energy

We assume that the target healthcare facility, being remote to any grid access, is only fueled by the diesel generators at the beginning of the project. In this situation, we plan to launch the Solar Photovoltaic (PV) system as an alternative source of energy. At first, we plan to enable smoother energy transition by utilizing PV to partially power the facility's energy demands, primarily its vital equipment. Vital equipment indicates the facilities required for the basic operation of healthcare facility in-bed patients, or the devices that must operate constantly for medical emergency situations. Such vital equipment includes: vaccine refrigerator, desktop computer, lightning, incubator, and the radio for communication use.

Figure 4: The Daily Electricity Supply Distribution for the First Stage

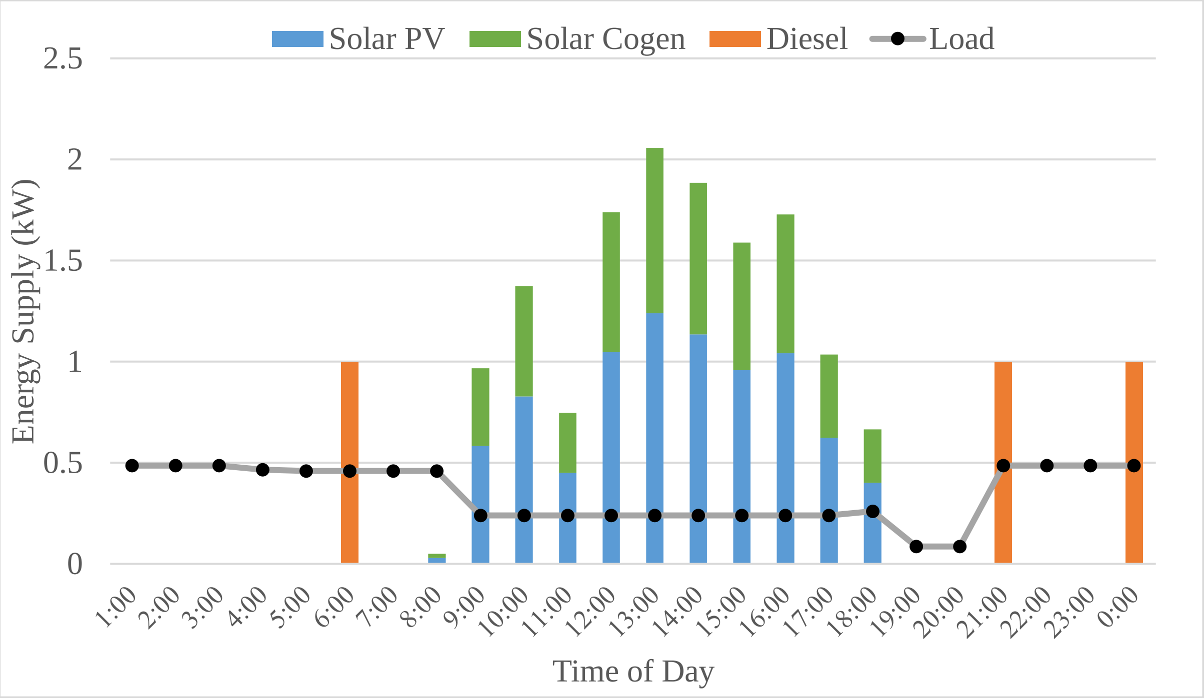


In Figure 4, the hourly load for running the equipment is shown in grey lines. The load is distributed evenly throughout the day, even the night time. To feed this load, a solar PV system with the capacity of 3kW will be installed beside the Puskesmas. Assuming that the average peak sun hours in Indonesia is around 2.8 hours, the daily electricity output of solar array will be 8.4kWh. Remaining 8.3kWh out of 16.7kWh total electricity demand of the Puskesmas will be generated by diesel generators already in place, 3 times a day. A virtual scenario of the combined set of electricity supply is presented in the figure below. The solar PV will mainly be generated during the daytime and will be stored with the use of Energy Storage System (ESS) to meet the electricity demands in the late night.

B. Introducing Combined Heat and Power System as On-Site Power Generation

The co-generation system, or in a different term, the hybrid concentrating solar co-generation plants have the ability to achieve high levels of energy efficiency. It captures the heat that is generated when a solar PV receives sunlight and produces energy, which would otherwise disappear into the air. These attributes make co-generation units well suited for district energy systems in remote off-grid areas (Prinsloo, 2016), which makes it highly compatible with our project. Many healthcare facilities also use co-generation plants as on-site generation system.

Figure 5: The Daily Electricity Supply Distribution for the Second Stage



As a pilot project, we introduce a couple of solar co-generation plants to the Puskesmas at this stage. The electricity generated by the co-generation plants will substitute the diesel generators, but not completely. According to a virtual scenario of the combined set of electricity generation presented in Figure 7, we install two solar co-generation units, with a total installed capacity of 2kW (1kW each). Assuming that the average peak sun hours in Indonesia is around

2.8 hours, we have in total 5.5kWh electricity generated with co-generation plants only. Here, solar energy, in combination with the 3kW solar PV array, produces around 82% of the total energy demand of the healthcare facility.

On the other hand, diesel generators will be used to power the remaining 18% of the energy demand. As was done in the previous stage, we assume diesel generators are used 3 times a day, producing 1kWh per each, 3kWh a day.

C. Advancing Puskesmas into an Inclusive Public Health Space

Our project, along with its principal goal of powering rural healthcare facilities with the independent generation, also builds on the objective of establishing an inclusive public health space for the village, the most representative usage of which would be that as a common kitchen. By bringing clean cooking to the community, the project addresses the public health in both clinical and daily manner, from a multi-dimensional approach.

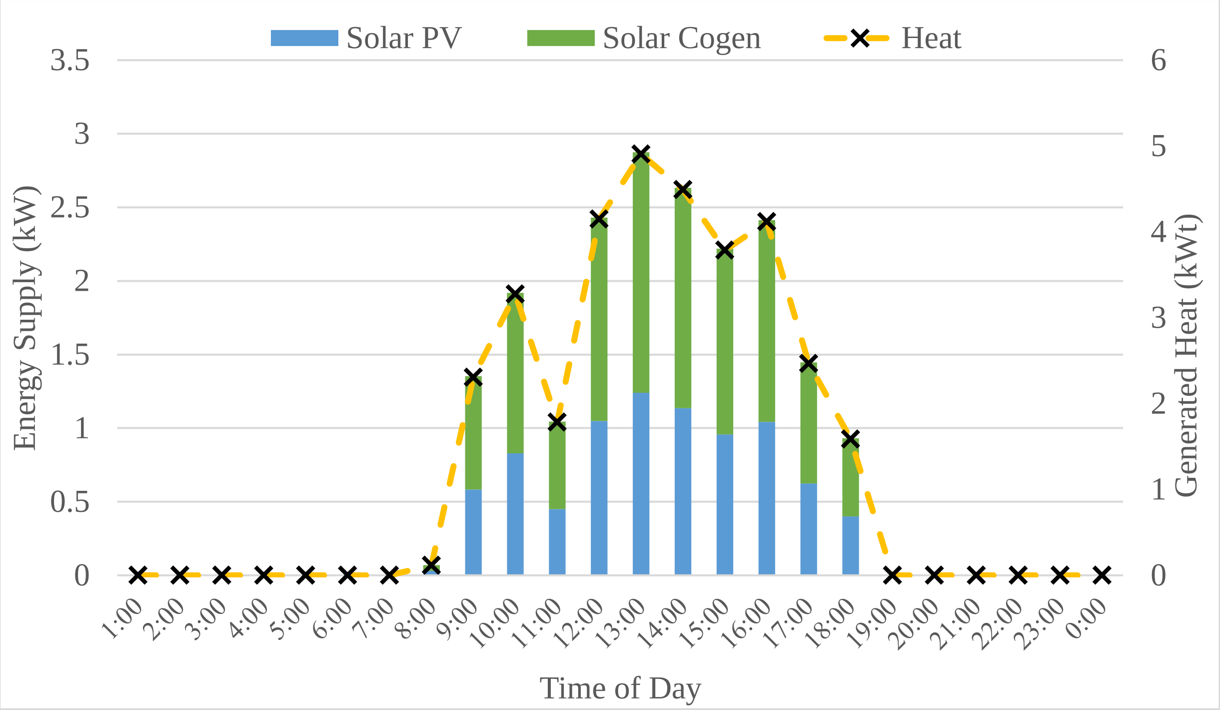
Figure 6: Clean Cooking Project initiated by Tata Trusts in rural region of India

Many Indonesian rural households currently use rudimentary three-stone stoves commonly made of mud, cement, stone, scrap metal, or recycled oil drums. These stoves are quite energy inefficient and emit significant amounts of toxic smoke (World Bank, 2013). If the healthcare facility opens the public common kitchen with electric stoves, the villagers could utilize the space for cooking, saving their respiratory health in the long run. Out of similar motivations, Tata Trusts initiated a project to provide clean cooking environment in India as shown in Figure 8 (Tata Trusts, 2017).

In our model, the heat generated as a by-product of the co-generation power plant could be utilized to heat the stoves in the common kitchen. At this stage, we assume that the healthcare center is powered 100% by the renewable energy. In order to do that, we install 2 additional solar co-generation power plants in the lot. Applying the same set of assumptions as in previous discussions, the total electricity generated by the solar PV system, combined with

4 solar co-generation plants will be 19.3 kWh with 2.75 solar peak hours. With each kilowatt produced by the solar co-generation plants comes the by-produced heat of 3kWh. Therefore, the heat generated at this stage with 4 co-generation plants will be 33kWh. The heat energy generated every hour is presented in yellow dashed lines in the Figure 7. All this heat could be transmitted to the common kitchen, where it will be used to heat the electric stoves.

Figure 7: The Daily Electricity Supply Distribution for the Third Stage



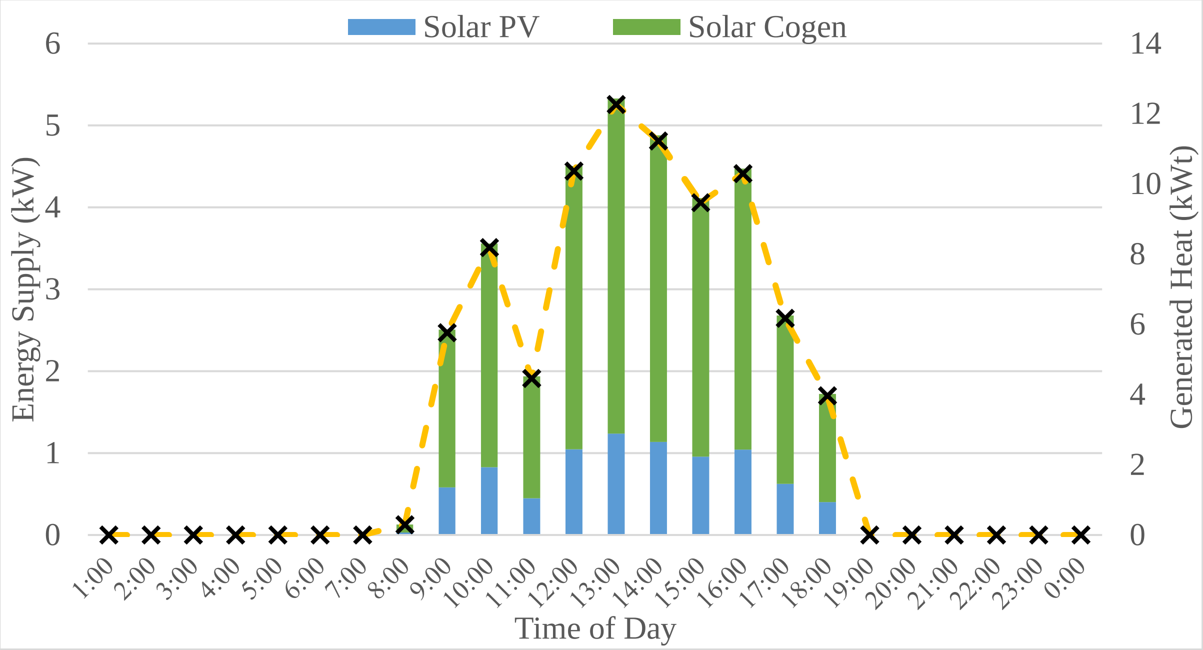
The average monthly energy consumption level for rural households in Southeast Asia is assumed to be 56.73kWh (Foysal, 2012). If we assume that 50% of this energy is used for cooking (Lloyd & Cowan, 2004), 0.9kWh heat energy will be needed every day to provide the daily energy for cooking purposes. 33kWh of the heat generated with the solar co-generation plants will easily supply enough energy to feed 36 households.

Currently, the commercial market for biomass stoves is quite limited. Households in Indonesia rather construct than purchase their own stoves, and usually own more than one. Therefore, those for the common kitchen in Puskesmas are evaluated to cost the highest of $2,800 (Watson) in our model, considering the big size of common stoves and the costs of shipping from outside. Despite the high initial cost accompanied with installing stoves, we can expect a significant reduce of health cost as the mortality rate due to biomass cooking will be reduced. As of now, 55% of the Indonesian population still cooks with traditional biomass fuels. With the common kitchen, less people will suffer from diseases related to inhaling toxics.

D. Powering Remote Households with Mini-Grids

In order to improve the rural living standards, increasing access to electricity is very important. The prior steps of the project focused on generating electricity with renewable energy so as to increase the power independency of the healthcare facility and its relevant healthcare activities. At the final stage, we expand our scope to turn the healthcare facility into an electricity provider to the rural community, so that relatively remote households in the local area can also access electricity to pursue a healthier lifestyle.

Figure 8: The Daily Electricity Supply Distribution for the Fourth Stage



In Figure 8, we suggest installing 6 additional solar co-generation plants that will generate 35.7kWh a day on top of the previously installed 4 solar co-generation plants and solar PV system. Out of total 35.7kWh, 16.7kWh will be used to operate the healthcare facility 24 hours. The remaining 19.1kWh could be delivered to rural households. An average household in an isolated rural area uses 1.9 kWh a day (Foysal, 2012), which means that the electricity dispersed to the community will at least serve 10 key households.

In order to deliver electricity generated by the healthcare facility, a mini-grid that connects each household with the generator should be installed first. The mini-grid transmits electricity generated by the Puskesmas, on the path of creating an energy-independent community powered by the on-site generation.

Also, the thermal energy created by 10 solar co-generation power plants will add up to 82.5 kWh. Even if we exclude the amount used to run the common kitchen inside the Puskesmas, a significant amount of heat could be delivered to each of the houses for water heating purposes. To this end, a set of pipes for district heating and cooling can also be installed in the community with optimized energy use. In this paper, however, we focus only on providing electricity to the community, as pictured in Figure 9 below.

Figure 9: Structure of Mini-Grids

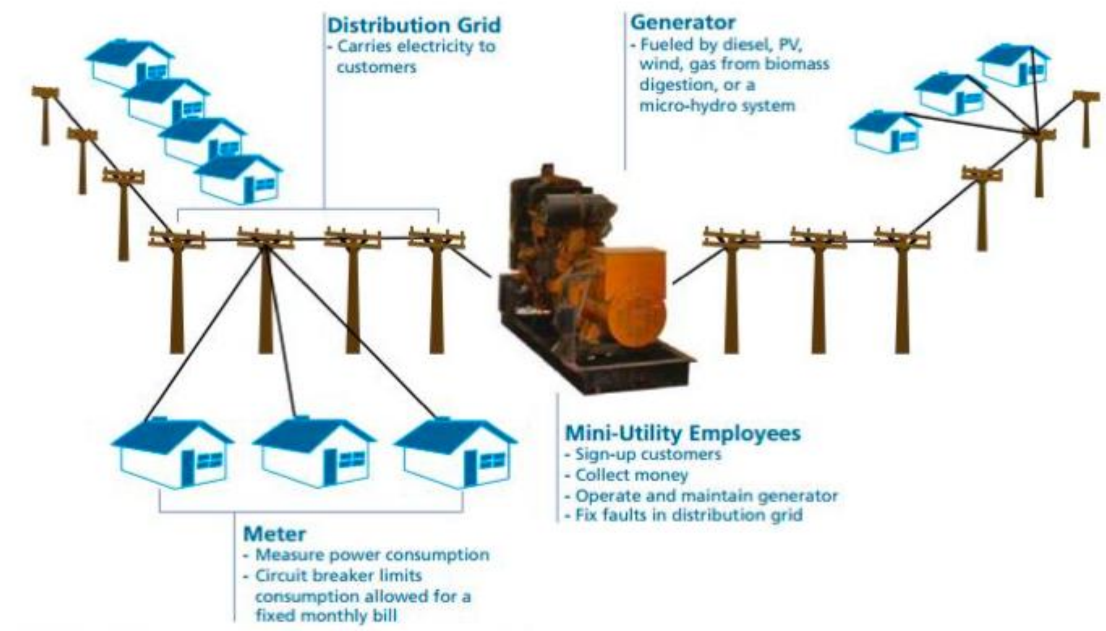
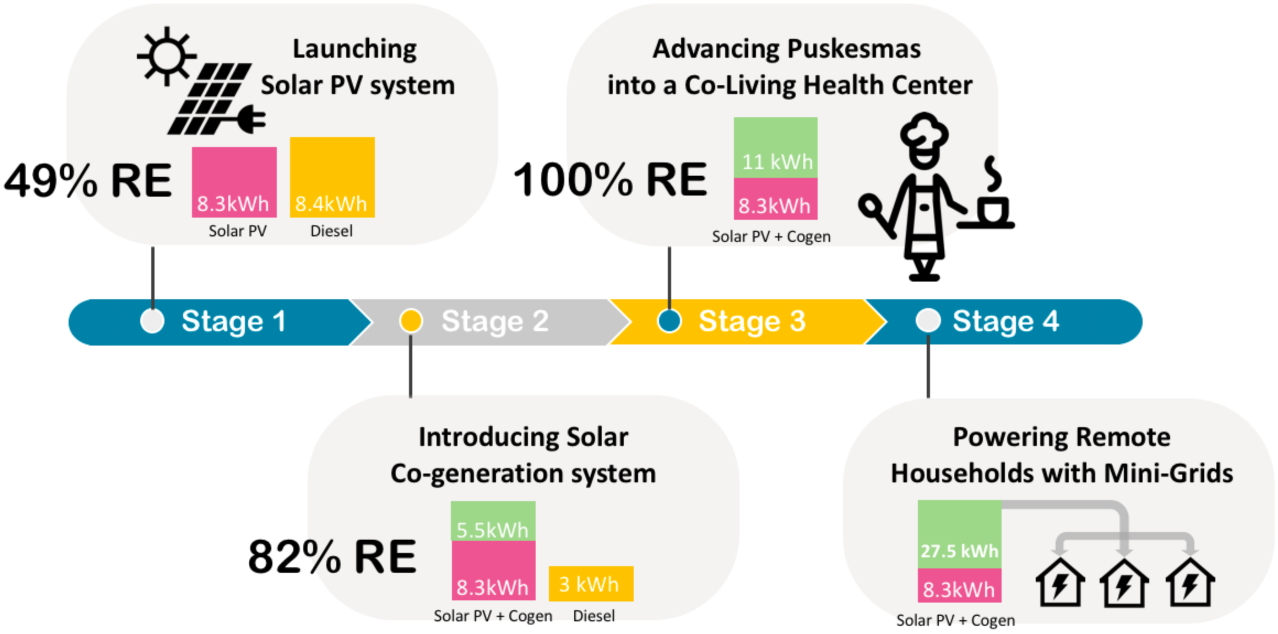


FIGURE 3.15: Generalized mini-utility operating model
Source: IFC analysis.

E. Summary of Project Milestones

Figure 10: Project Roadmap and Milestones



(a) Stage 1 (Year 0 ~ Year 2)

At stage 1, we install renewable energy generators to cover for the vital operation of the Puskesmas, as a back-up source to the traditional diesel generators. This will supply around 49% of the total demand, creating a soft landing for the energy transition. The milestone of this stage is to make the healthcare facility functional with the solar PV and the accompanying storage system. Therefore, capacity building and training for the local personnel is needed to facilitate the distributed use of stored solar energy.

(b) Stage 2 (Year 3 ~ Year 5)

Before the onset of stage 2, it is critical to make sure that the Puskesmas has successfully incorporated the solar PV system into the daily operation of the facility. The next step is to increase the portion of solar energy in the total energy mix by adding solar co-generation power plants to the healthcare facility. The solar co-generation unit is expensive and not yet widely available, so we need to see if it is applicable to our target. To that end, as for a pilot project, we install 2 solar co-generation units, which will supply 82% of the daily electricity demand.

(c) Stage 3 (Year 6 ~ Year 8)

Before the onset of stage 3, we check whether the two types of solar generators are running properly. Then, we have two milestones at this stage. The first milestone is to make the Puskesmas fully functioning with renewable energy only. In order to increase the share of renewable energy, we install 2 additional solar co-generators. Naturally, it follows that the diesel generators will not be used anymore. The second milestone is to build a public space for cooking, which is open to rural households. This is to prevent the mortality induced from biomass-based cooking. The common kitchen will be built inside the healthcare facility, and the heat needed to cook the food will be transmitted from the co-generators. When local people spend time inside the building, cooking and sharing food, the place turns into a central hub for community activities.

(d) Stage 4 (Year 9 ~ Year 12)

With the Puskesmas fully functioning with on-site generated energy, we propose an energy-independent community where all the electricity demand of the community is met by the power generated by the central healthcare facility. This is to enhance the living standards of off-grid households with more access to electricity. The milestone at this stage is to build a community-scale mini-grid to connect to 10 households. The electricity and heat generated by the healthcare facility will be sold to the community at cheaper costs than the average cost in Indonesia, with subsidies from the government. The ultimate goal of this stage after the initial four years of launching with 10 households is to build a sustainable model for comprehensive rural electrification and healthcare, with the Puskesmas being at the center. The successful case can be shared to other regions of Indonesia and to other developing countries, improving public health condition.

4. Verification of the Project

A. Key Datapoints

To summarize and project the comprehensive cash and energy flows of the entire project timespan, further data needs to be organized into reference points. (a) The cost of installation and operation of each heat and electricity generator, (b) the price of electricity in Indonesia, (c) the cost of installing the common kitchen in Puskesmas, (d) the cost of connecting mini-grids to households, and (e) the external subsidies from Indonesian government and non-government organizations are all considered, as they are the new components in the projection of launching and implementing the new project of energy transition. However, other numbers including the operation costs or the sales of Puskesmas are not considered, as they are out of topic in our project.

(a) The cost of installation and operation of each heat and electricity generator

The diesel powered generators are the primary source of energy for small islands like Batam, Bintan, Lombok, Sumba, and the smaller. In Indonesia, the system cost of diesel generator is estimated to be 650 USD/kW, with the operation and maintenance cost of 0.05 USD/kW per an hour (Keeley · Managi, 2019). However, additional fuel costs are required for running a diesel generator, along with shipping costs of the fuels. The smallest diesel generator under 20 kW capacity consumes 1.6 gallons of diesel per hour when it is fully loaded to the capacity (Worldwide Power Products, 2019), and the diesel price in Indonesia has been around 0.88 USD per litter and 3.324 USD per gallon in year 2019 (Global Petrol Prices, 2019).

For solar photovoltaics, there is a wide range of prices depending on the cost structure of the manufacturer, market features and module efficiency in reality. The LCOE, or levelized cost of energy, is a term which describes the cost of the power produced by unit generator over a period of time. The basic management and utility costs are included in LCOE to construct price receivables of the generated electricity. According to Table 5 of the LCOE trend, the global price of solar PV has kept declining with more competition and technological advancement.

Table 5: LCOE of Solar Photovoltaic Projects

LCOE of Solar PV Projects (USD/kW)			
Year	**5th percentile**	**95th percentile**	**Weighted average**
2010	0.183	0.511	0.370
2011	0.161	0.485	0.287
2012	0.135	0.398	0.221
2013	0.120	0.362	0.175
2014	0.101	0.363	0.165

2015	0.082	0.289	0.133
2016	0.080	0.267	0.119
2017	0.060	0.230	0.097
2018	0.057	0.218	0.085

The project assumes the solar PV cost of year 2018 in Indonesia to be the fixed cost of reference for the projection, assuming a long-term contract. Based on the data from IRENA publication (IRENA, 2019) adjusted in Table 6, solar PV entails 919.12 installation cost per kW capacity and 272.51 operation cost per kW throughout the project period. At the first year of the project (stage 1), solar PV units of 8.3 kWh capacity is installed with 7628.66 installation cost and 2261.79 operation cost.

Table 6: Cost Components of Utility-Scale Solar Photovoltaics

Cost components of utility-scale solar photovoltaics (USD/kW, 2018)		
Category	**Cost Component**	**Indonesia**
Module and inverter hardware	Modules	589
	Inverters	37.334
BoS hardware	Racking and mounting	94.079
	Grid connection	71.1
	Cabling/ wiring	42.444
	Safety and security	27.034
	Monitoring and control	20.276
Installation	Mechanical installation	19.195
	Electrical installation	13.517
	Inspection	5.137
Total installation costs		919.116
Soft costs	Margin	107.055
	Financing costs	49.743
	System design	30.819
	Permitting	44.877
	Incentive application	27.305
	Costumer acquisition	12.706
Total operation year costs		272.505
Total initial costs		1191.621

At the following years and stages, combined heat and power generators including solar photovoltaics are installed instead of the pure solar PV units. For utilizing combined heat and power system for the cogeneration, new CHP units are installed at the respective beginning of stage 2 and 3 of the project. Based on a reference (Mundada, 2016), The cost for the unit CHP is calculated as 7,950 USD, as the sum value of the cost of solar PV, the cost of batteries, and the cost of installation. The annual operation cost is approximated to be a double of the operation cost of solar PV, reaching 545.01 USD.

At the year 3 of the project (stage 2), 2 CHP units are installed and at the year 6 of the project (stage 3), 2 additional CHP units are installed. At the year 9 of the project (stage 4), 6 additional CHP unites are installed to make the total number of CHP units to 10. These numbers of units are multipliers to calculate the CHP installation costs that are 15,900 USD, 15,900 USD, 47,700 USD, respectively. Operation costs are calculated with the multipliers of capacity that are 5.5kWh, 11kWh, 27.49kWh at each stage, yielding 2,996.79 USD, 5,993.59 USD, 14,983.97 USD.

(b) The price of electricity in Indonesia

PLN is an Indonesian state-owned corporation which has a monopoly on electricity distribution in Indonesia and generates the majority of the country's electricity. It links the price of electricity to the floating price of international price of oil, changing it on a regular basis. Under Law No. 30/2009 (the 2009 Electricity Law), the electricity tariffs no longer need to be uniform throughout Indonesia, but may differ between operating areas. Tariffs are differentiated depending on the end user group, taking into account the customer’s purchasing power and the installed power capacity. The tariffs for low income households are heavily subsidized, with a price more than three times lower than the average supply cost (PwC, 2017).

The average price of electricity in Indonesia is 0.1 USD per kWh as of March 2019, while the average price of electricity in the world for that period is 0.15 USD per kWh (Global Petrol Prices, 2019). The cost of electricity supply to the target area is estimated to be a third of this average cost with the help of state subsidies, considering the capacity and income level of the area. The project assumes that the subsidies would also be granted to the installment and operation of power generators with renewable energy, so that local people can benefit from the stand-alone electricity generation and pursue a healthier lifestyle.

(c) The cost of installing the common kitchen in Puskesmas

The costs entailed to creating a new public health space in Puskesmas are estimated to the minimum, assuming the utilization of all the existing space and facilities but new electric stoves that would be powered by the saved heat from CHP units.

The heat generated with 4 co-generation plants reaches 33kWh. Considering that half of the average monthly energy consumption for rural households in Southeast Asia, 56.73kWh, is used for cooking, 0.9kWh is required for daily cooking with electricity per rural household. The heat from CHP units alone can afford up to around 37 households at stage 3.

The electric stoves costs 650 USD to 2,800 USD across the world (Watson, 2012), but the best ranges can also be attained at less than 1,000 USD (Consumer Reports, 2018). Considering that the commercial market for stoves is currently quite limited in rural Indonesia, electric stoves for the common kitchen in Puskesmas are evaluated at the highest cost of $2,800. It is also reasonable considering the size of public electric stoves and the transportation costs to remote areas in Indonesian archipelago.

The energy use of an electric stove top varies; smaller units use 1kW, while a larger heating element will go up to 3kW (Energy Use Calculator, 2019). Assuming 2 shifts of cooking sessions at the common kitchen, 5 electric stoves with larger size of 3kW wattage consumption can be installed.

(d) The cost of connecting mini-grids to households

At the final stage of transforming the Puskesmas into a healthy energy hub that provides necessary power for the rural community, relatively remote households that cannot make a daily trip to Puskesmas for cooking should also be guaranteed with their access to electricity and healthier lifestyle. Installing 6 additional solar co-generation plants, the project supplies electricity to at least 10 households of 1.9 kWh average wattage consumption.

While the cost component of mini-grid projects are divided into many hard cost and soft cost categories as shown by Table 7, the cost of generation, and of storage and powerhouse can be disregarded at the stage, as those were already included in the previous stages of installing solar photovoltaics and solar co-generation plants.

Table 7: Cost Components of Mini-Grids

Hard Cost Category	Unit
1. Generation	
PV modules (including spare parts)	kWp
PV modules Structure	kWp
Charge regulators & protections - DC coupling or Solar Inverter & protection - AC coupling	kWp
2. Storage and powerhouse	
Lead acid (incl.cells, cabling, protection)	kWp
Lithium ion (incl.cells, cabling, protection)	kWp
Monitoring and control system	unit
Powerhouse (building, cabinet, container, incl. fence)	m²
3. Conversion	
Battery inverter incl. cabling	kVA
EMS (Energy Management System)	unit
Backup Diesel generator	kVA
4. Distribution and Consumption	
LV gird (incl. poles, cabling and protections)	km
LV distribution poles	km
Street lighting (if applicable)	n. customers or km
Smart meters and service connections	n. customers or km
5. Customer systems (without installation)	
End user indoor wiring (cabling, sockets and protections) if applicable	n. customers
End user appliances (if applicable)	n. customers

Soft Cost Category	Unit
6. Project development	
Management and engineering	% overall hard costs or kW (AC service)
Capacity building and training (of local operators)	
7. Logistics	
International shipping costs (maritime), incl. customers	% overall hard costs or kW (AC service)
Local transportatio costs (road)	
Storage of equilpment	
Insurance	

Taking a look into recent mini-grid projects across the world on Table 8 provides an approximate reference of the capital expenditure on fixed assets (CAPEX) of mini-grids. While neither the continent variable nor the number of customers has any significant correlation with the CAPEX, mini-grid projects with private utility service as service management agent and multi-mini-grids over single grid tends to show lower CAPEX per kW. The cells with shades highlight the projects of reference which are similar to the size, location, and environment with our project in Indonesia. The CAPEX per kW for such projects ranges from 6,500 to 8,500 considering all the cost components. Since our project is small size multi-mini-grids but ran by community management, the reference for the costs can be set on the median values.

Table 8: Recent Mini-Grid Project CAPEX across the World

Site, Country	Continent	n. of customers	Power (AC) output kW	Solar fraction	Management Model	CAPEX with Installation USD	CAPEX per kW
Manikgonj, Bangladesh	Aisa	1099	228	87.50%	Private utility	1,090,211	4607.456
Mombou, Chad	Africa	133	40	100%	Community	296,529	6917.575
Volta Lake, Ghana	Africa	157	50	93%	Public utility	364,922	6782.22
Talek, narok, Kenya	Africa	120	40	94%	Public utility	304,409	7347.975
Tanzania	Africa	63	30	100%	Private utility	265,312	8075.2
Kutubdia, Bangladesh	Asia	360	100	85%	Private utility	973,177	7622.38
Tunga Jika, Nigeria	Africa	290	100	100%	Private utility	639,212	5822.98
Lengbamah, Lofa, Liberia	Africa	156	23	100%	Private utility	151,969	5758

Segbwema, Kailahun, Sierra Leone	Africa	204	128	100%	Private utility	400,703	2867.586
Samfya, Luapula, Zambia	Africa	480	60	100%	Public utility	602,757	9183.617
Saithway, Myanmar	Asia	130	10	100%	Public utility	88,591	8504.9
Bihar, India	Asia	95	30	90%	Private utility	96,214	2953.067
Kakpin, Ivory Coast	Africa	150	36	100%	Community	385,081	9805.306
Dubung, Tanahun, Nepal	Asia	112	20.4	100%	PPP-(Private utility)	154,166	7105.931
West Bank, Palestine	Asia	39	29	100%	Community	169,524	5433.69
Bambadinca, Gunea Bissau	Africa	1421	200	98%	Community	3,262,754	11874.77

With the median value as reference, the cost benchmarks of mini-grids are described on Table 9. At the final stage of utilizing mini-grids, the surplus 19.1kWh electricity from Puskesmas is delivered to the rural households. We disregard the cost of generation and of storage and powerhouse. We assume 10-hour supply of electricity and direct current circuits where kVA is equal to kW. In conclusion, the overall cost of the mini-grids for the project accounts for 21,118.9 USD with project unit multipliers.

Table 9: Cost Breakdown of Mini-Grids

Cost benchmarks	**Median Value, CAPEX per unit**	**Project Unit**	**Project Cost**
Generation	1485 USD/kWp	1.24	1841.4
Conversion	844 USD/KVA	1.91	1612.0
Customer Systems	47 USD/customer	10 households	470.0
Logistics	470 USD/kW	1.91	897.7
Storage and Powerhouse	220 USD/kWh	19.1	4202.0
Distribution	331 USD/customer	50 people	16550.0
Project Development	832 USD/kW	1.91	1589.1

(e) The subsidies from Indonesian government and non-government organizations

At the moment there are few subsidies for the local autonomous electricity generation out of renewable energy. Some government entities would tender electrification projects, but they are not usually very effective without concrete project models. Other projects rely on funding from non-government organizations or international grants. Meanwhile, multilateral development banks usually only deal with projects if they exceed certain sizes, around or over 1 million dollars, which are quite difficult for rural electrification to arrange.

Therefore, our project urges that the government should take initiatives in renewable energy projects following the proposed project flow, diverting their capacity and subsidies from previous electrification projects to the new transition project of Puskesmas into healthy energy hub. The budget of funding and subsidies would be the function of costs expected to be required throughout the project timespan by Puskesmas, taking its advantage of being a state-run institution. No credit financing would be made with Puskesmas as the debtor, but external funding from non-government organizations for humanitarian purpose is assumed to account for a third of the any cost related to energy transition project, which is about half an amount of the government funding.

B. Projection of Future Cash and Energy Flows

The comprehensive projection of cash flows of the project by different stages are shown in the following Figure 11.

Figure 11: Future Cost and Energy Projection

Masalembu Puskesmas	**Stage 1**			**Stage 2**			**Stage 3**			**Stage 4**			
	Year 0	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**	**Year 11**	**Year 12**
Total Project Costs (USD)	9902.77	2274.11	2274.11	21162.98	5262.98	5262.98	38155.38	8255.38	8255.38	86064.62	19732.58	19732.58	19732.58
Solar PV Installation	7628.66												
Solar PV Operation	2261.79	2261.79	2261.79	2261.79	2261.79	2261.79	2261.79	2261.79	2261.79	2261.79	2261.79	2261.79	2261.79
Diesel Generator Operation (excl. shipping)	12.31	12.31	12.31	4.40	4.40	4.40							
Solar Cogeneration Installation				15900.00			15900.00			47700.00			
Solar Cogeneration Operation				2996.79	2996.79	2996.79	5993.59	5993.59	5993.59	14983.97	14983.97	14983.97	14983.97
Electric Stove Installation							14000.00						
Mini-Grids Installation										18632.04			
Mini-Grids Operation										2486.82	2486.82	2486.82	2486.82
Total Project Income (USD)	9902.77	2274.11	2274.11	21163	5263	5263	38155.7	8255.7	8255.7	86069.63	19737.59	19737.59	19737.59
State Funding	6605.95	1520.17	1520.17	14110.12	3510.12	3510.12	25436.92	5503.59	5503.59	57376.41	13155.05	13155.05	13155.05
External Subsidies from NGOs	3296.82	753.93	753.93	7052.86	1752.86	1752.86	12718.46	2751.79	2751.79	28688.21	6577.53	6577.53	6577.53
Sales of Electricity	0.00	0.00	0.00	0.01	0.01	0.01	0.32	0.32	0.32	5.01	5.01	5.01	5.01
Total Electricity Demand (kWh)	16.70	16.70	16.70	16.70	16.70	16.70	16.70	16.70	16.70	16.70	16.70	16.70	16.70
Total Electricity Production (kWh)	16.74	16.74	16.74	16.84	16.84	16.84	52.33	52.33	52.33	118.31	118.31	118.31	118.31
Solar PV	8.34	8.34	8.34	8.34	8.34	8.34	8.34	8.34	8.34	8.34	8.34	8.34	8.34
Solar Cogeneration				5.50	5.50	5.50	11.00	11.00	11.00	27.49	27.49	27.49	27.49
Diesel	8.40	8.40	8.40	3.00	3.00	3.00							
Heat							32.99	32.99	32.99	82.48	82.48	82.48	82.48
Total Surplus of Electricity before Additional Activities (kWh)	0.04	0.04	0.04	0.14	0.14	0.14	35.63	35.63	35.63	101.61	101.61	101.61	101.61
Consumption at Common Kitchen (kWh)							32.40	32.40	32.40	32.40	32.40	32.40	32.40
Consumption at Remote Households (kWh)										19.13	19.13	19.13	19.13
Total Surplus of Electricity after Additional Activities (kWh)	0.04	0.04	0.04	0.14	0.14	0.14	3.23	3.23	3.23	50.08	50.08	50.08	50.08

5. Conclusion

Indonesian archipelago is highly dispersed from one another. Due to its geographic characteristic, and with the increased frequency of extreme weather events, operation of healthcare facilities in rural islands is faced with a challenge. Increasing the access to the electricity for the rural community, therefore, could be the way to enhance public health. In realization of such needs, we developed a new model with the emphasis on sustainability, a self-sustaining healthcare center that could operate on its own with financial viability.

Our masterplan to advance on rural health building up on Puskesmas, a local unit for national primary care delivery strategy. Our masterplan considers the incorporation of renewable energy into the operation of the healthcare facility, with a combined power generation of solar PV and solar co-generation plants. In addition, our plan aims to achieve inclusive healthcare for the village through clean cooking. The common kitchen will be open to the public, and the heat generated from the solar CHP plant will be used to heat up the stoves. The final milestone for the project is to build a mini-grid that connects the households to provide electricity.

We presented a thorough validation for each stage of the project roadmap to prove the viability and rigorousness of the proposal. Utilizing the projection of future cash and energy flows, the total project costs and the total project income were matched, and we figured out how much subsidies would be needed at each year to make such ends meet. While the financial cost at the initiation of the project is distributed to the exterior funding and subsidy from the government and multilateral non-government organizations, such initiatives are vital to achieving the long-term goal to advance on public health, and would be compensated with the growing surplus of power generation that is already shown in the projection, and the sales from it.

In this paper, we explained how building a grid-independent healthcare facility could benefit public health and on the development of the local community, with financial reasoning for the project. The project holds huge implications for powering isolated islands suffering from the frequent power outage. The model designed for this project will contribute to achieving both SDG 3: Good health and well-being, and SDG 7: Affordable and clean energy. Of course, aside from maintaining reliable power supply, we also need to focus on improving the general facilities and services provided in Puskesmas. The successful implementation of the project will build a healthy rural community and move forward in addressing the global health crisis.

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