Comprehensive Education of RES in Rural Karst Area: Sustainable Development of Solar Water Pumping System in Banyumeneng Village, Yogyakarta, Indonesia

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***Abstract*—Sustainability is the key issues in the development of Renewable Energy System (RES) in Indonesia. Some government's RE project just run for short-time period and then technically malfunctioned [1]. The main reason was a lack of local people's knowledge on RES and the absence of capability of local community in maintenance aspect. This paper presents an example of RE project in Banyumeneng Village namely Solar Water Pumping System (SWPS) which continuously runs over 7 years. By having a comprehensive knowledge transfer and adequate education program to the local people, the sustainability in this RE project can be achieved. This paper presents, its evaluation is done by using SWOT analysis to measure on effectiveness of knowledge transfers in this capacity building programme. Recommendations required to improve the educational method in sustaining RE project in Indonesia are presented.**

***Index Terms*—renewable energy system, sustainability, local education**

I. Introduction

By 2025, Indonesian population is projected to reach 285 million – an increase of 35 million compared to 2015. This number will lead to more energy demands. In 2014, most of the electricity in Indonesia was supplied by fossil fuels in which coal-fired and gas-fired power plants had the highest share, 50% (26 GW) and 23% (12 GW) respectively, followed by oil-fired power plants with a share of 14% (7.5 GW). At rest, renewables are predominated by geothermal power plants (3% or 1.3 GW) and hydropower (10% or 5.1 GW). In fact, renewable energy which is abundant in this country has potential to generate more than 200,000 MW. Based on National Energy Policy number 79 in 2014, the government sets a target to increase the contribution of renewable energy in national primary energy mix up to 23% in 2025 [2].

Sustainability is the key issue in the development of Renewable Energy (RE) system in Indonesia. Some government's RE projects just run for a short-time period and then technically malfunctioned [1]. Towards sustainable development in renewable energy systems, local people's education and sense of belonging to the systems are necessary to be considered. However, the challenge of low education people and economic levels, will be a main hurdle to educate people to understand about the renewable energy systems. Another challenge is a limited educational programme from government to local people and at last but not least is in improving their sense of belonging. As the result, rural people could only stay waiting on the local government action rather than fix the system by themselves.

Solar Water Pumping System (SWPS) in Banyumeneng Village is one of the renewable energy systems in Indonesia. This village is stood on the karst southern mountainous area in Gunung Kidul, Yogyakarta, Indonesia. This village has limited access to water supply due to its topography type, where karst could not reserve water to the ground. In summer, this village is one of hundreds villages who encounters the water scarcity. During the rainy season, they collect the rainwater in a collector tank and use it for daily needs. At most of the year, people had to walk downhill for 1.6 km to get water in the reservoir rather than spending at least IDR 150,000.00/month to buy water because of their average income is just around IDR 400,000.00/month [3].

Started in 2007, a pilot project of solar water pumping system was established by student unit called as Kamase, in collaboration with Curtin University. This was initiated by Kamase who granted as Mondialogo Engineering Award (MEA) winner. In 2009, featured by Students Community Service of Universitas Gadjah Mada (KKN-PPM UGM), Kamase started to establish the first SWPS project to pump water in Banyumeneng I with a capacity of 1200 Wp. This initiative then continued by the alumnae of Kamase who established a foundation called EnerBI by scaling up the SWPS up to 8000 Wp and establishing a new system for the neighboring village (Banyumeneng II) with a capacity of 2400 Wp. These projects were funded by Alstom foundation. In 2016,

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EnerBI again scaled up the SWPS for more households in Banyumeneng II with system's capacity 4000 Wp, funded by Indonesia Climate Change Trust Fund (ICCTF). As the result of today, the Solar Water Pumping Systems is able to fulfill the water needs for more than 200 households (500 people) in Banyumeneng I and Banyumeneng II. Over 7 years, this project has been active and sustain. This sustainability was underpinned by the integration of Kamase, EnerBI, KKN-PPM UGM, OPAKg, and Abimanyu.

II. Methodology

The Strength-Weakness-Opportunities-Threats (SWOT) analysis is the most suitable to evaluate and assess on how the local education could drive the project's sustainability as well as seeing on how much local people capability and awareness could be leveled up. SWOT is one of the simplest methodologies for assessing renewable energy system because of minimal data required. In addition, SWOT could be strong enough providing us later steps in planning to achieve the objectives. By using this methodology and circulating the questionnaire to some RE experts, this paper aims to create a recommendation framework on how to establish the sustainable renewable energy system in Indonesia.

SWOT analysis is a structured planning method used to evaluate the strengths, weaknesses, opportunities, and threats involved in a project or in a business venture. SWOT analysis could be elaborated by qualitative assessments in the form of expert interviews or general surveys to the objects/experts and quantitative data collection by comprehensive literature review [4]. In addition, by using SWOT analysis, the researchers are required to ask and answer questions that generate meaningful information for each category (strengths, weaknesses, opportunities, and threats) to make the analysis useful and find their competitive advantage. Another useful aspect of SWOT analysis is its scalability. SWOT analysis could evaluate by comparing the different cases in renewable energy sectors, as well as subsystems. The main result of SWOT analysis is very descriptive and qualitative [5].

Because of its simplicity, scalability and its capability to evaluate efficiently, SWOT analysis has broadly been used in the renewable energy sector. For example, SWOT Analysis is used to measure and to see the elements that could provide the advantages and disadvantages of renewable energy sources and energy efficiency potentials in Kleinregion Entwicklungsverband Tullnerfeld West, Austria. In Poland, the conducted SWOT analysis shows that the further development of renewable energy sector in Poland is strongly depended on the following: the act on renewable energy sources, simpler legal regulations, more effective financial support for new investments, introduction of guaranteed certificate prices, education of the public, as well as investors and decision-makers in the field of renewable energy sector development [6].

III. Result and Discussion

Solar Water Pumping System project in Banyumeneng Village has been started since 2009 with only 1200 Wp system to provide water at maximum of 30 households. Then it was scaled up to 16000 Wp to cover up water needs for more than 200 households. The project milestone of SWPS is figured in Fig. 1.

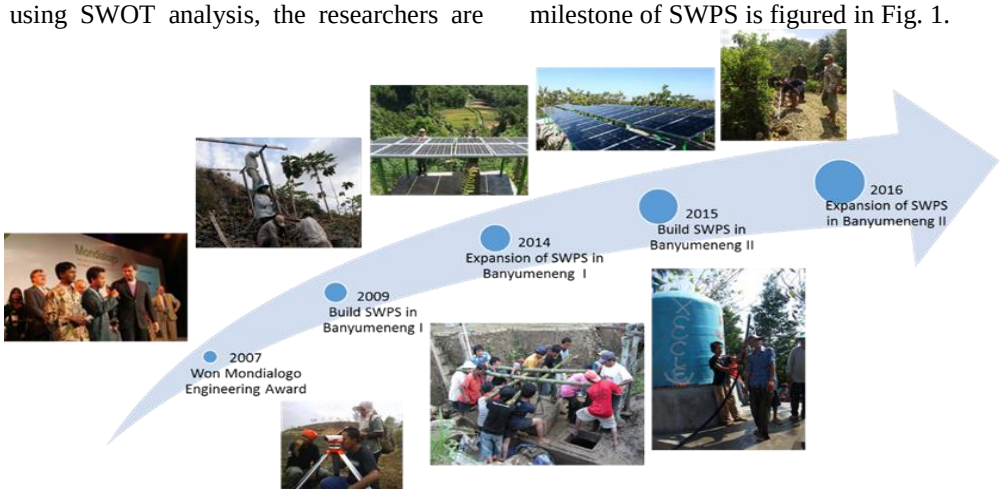

Figure 1. Project milestone of SWPS.

This sustainable development of renewable energy system can be achieved by performing a comprehensive knowledge transfer and adequate education involving intensive contributions of university students and experts for local people. The comprehensive education of SWPS was implemented through four phases.

A. Phase I

1) Giving renewable energy education and training by Kamase and EnerBI to students

Phase I aims to educate and encourage students to join the SWPS project as well as to enhance their awareness on local issues and renewable energy as the solution. EnerBI as the executor of SWPS project trained the academicians regarding solar water pumping system, technical strategy, and several aspects that have to be considered for running, monitoring, and maintaining SWPS through theoretical and practical training. Kamase as the mediator of the project supports EnerBI in conducting the training and assists the students in doing

field survey, educating the local people, and doing technical work.

2) Field survey

Students assisted by Kamase observed the location of SWPS in Banyumeneng to know the local renewable energy potential, field condition, water source, and the local people. The field study is divided into 3 activities which are:

- Seminar for local people

This seminar aims to introduce solar water pumping system project to local people, to raise their awareness on local issue particularly water scarcity, to know how much their water needs, and to know how much their acceptance to the project. In this activity, Kamase, EnerBI, and students' team tried to get closer to the local people by staying over there for several days and held a socialization forum with them.

- Feasibility study

The first feasibility study of SWPS in Banyumeneng I was done by Kamase and KKN-PPM UGM 2008. This feasibility study was done by doing potential, technical, social, and economic analysis. The second feasibility study was done by EnerBI to prepare the scaled up project for Banyumeneng I. Then, the third feasibility study was done by EnerBI collaborated with KKN-PPM UGM 2015 to prepare the pilot project of SWPS for Banyumeneng II. The last feasibility study was done by EnerBI to prepare the scaled up project for Banyumeneng II.

- Detailed Engineering Design (DED)

After conducting feasibility study, Detailed Engineering Design was made based on the potential and condition of local natural resources. Before and during the making of DED, KKN-PPM UGM team was trained to know the procedure and how to use some tools and software.

B. Phase II

Phase II aims to educate the local people regarding SWPS and to prepare its establishment. In order to start the project, KKN-PPM UGM team assisted by Kamase lived in Banyumeneng for two months to assimilate with local people. Education to local people is divided into 2 programs which are:

- Education for local people

Education of SWPS to local people is one of the important aspects to support its sustainability. KKN-PPM UGM team taught local people regarding water scarcity problem and renewable energy potential in Banyumeneng to raise their awareness on their local issue and to get their support in SWPS establishment. The education performed through seminar and interpersonal approach. The more we adjust with local people, the more they receive our education program. Local people had a high enthusiasm in taking part on the education program.

- Education for local communities

Local communities are required to be the people in charge to manage water distribution and maintain SWPS system. They consist of local people who have higher education level than the others thus they can be trained easily. The first local community established is OPAKg who is in charge for the pilot project of SWPS in Banyumeneng I. After scaling up and establishing new system for Banyumeneng II, another local community called Abimanyu is built whose job is same as OPAKg. These local communities are given a deeper knowledge than local people because they have responsibility to do administration and technical work for SWPS. Moreover, it also aims to make them become independent thus they can manage and develop SWPS by their selves. The education for OPAKg and Abimanyu is consisted of administration and technical lessons. Administration is important to manage money collected from local people. By establishing SWPS, local people do not need to buy water but they pay to OPAKg and Abimanyu instead. Before using water from SWPS, local people have to spend their money to buy water at least IDR 150,000.00/month (USD 11.00), but after establishing SWPS, they just have to pay IDR 10,000.00/month (USD 0.8) which is used to pay people in charge in OPAKg and Abimanyu and to pay if there is maintenance needs. Therefore, administration lesson is required to be given to OPAKg and Abimanyu which includes how to manage money flow, how to make fund raising proposal, and other general administrations. Technical lesson includes general explanation regarding SWPS system, photovoltaic modules, pumps, inverter, charge controller, how to do basic maintenance, and the maintenance procedure if there is a huge damage in the component by giving presentation and handbook.

C. Phase III

Phase III, called construction, is the important phase to keep the sustainability of SWPS. In this process, EnerBI who stands as executor worked together with local people and student's community service (KKN UGM) in piping excavation and installation, construct foundation, arranging PV framing, etc. The local people showed their high enthusiasm to participate in construction process which indicates their acceptance to this system. It shows that the education has been run successfully and local people have had the good understanding on the importance of this system. This participation also can build the sense of belonging among the local people to SWPS which is the most important part to keep the sustainability of the system.

D. Phase IV

In order to keep the sustainability of SWPS, the local people are also taught how to build the network with the relevant government. This network will involve some parties to participate in maintaining system and also invite them to support this system, including Ministry of Public Work and regional government. They will support the availability of some SWPS components if there are problems or damages in the components, like pipes and water storages. Then, the local water community that involved is PAM-MASKARTA who is a community who manages the distribution of drinking water in Special Region of Yogyakarta. In SWPS project, PAM-MASKARTA assists both Abimanyu and OpaKg in managerial aspects, thus they are able to have good

management continuously. PAM-MASKARTA also helps them to communicate with government when they need the government's assistance in maintaining SWPS.

E. SWOT Analysis

Renewable energy system education which had been performed is required to be evaluated to know how effective the education, how much their local capability in solving future problems regarding sustainability of the system, and what recommendation needed to improve the education method for renewable energy system. The evaluation is done using SWOT analysis based on expert interview. The experts came from EnerBI as the initiator and executor of SWPS project in Banyumeneng.

1) Strength

Education of RES can raise the local people awareness on local issues, renewable energy potential, and knowledge of technology. Participation of local people in the construction of SWPS can build the sense of belonging to the system which is important to support the sustainability of SWPS. Moreover, the establishment of OPAKg and Abimanyu raise their capability of maintaining SWPS independently.

2) Weakness

Education of technical aspect is given only to certain people who are in charge of OPAKg and Abimanyu due to the limitation of comprehension ability of local people. Knowledge transfer from academicians to local communities is limited based on their needs and abilities.

3) Weakness

Renewable energy system particularly SWPS has life time for 25 years. Therefore, OPAKg and Abimanyu will require a regeneration for the next following years. Regeneration can provide opportunity of knowledge transfer from current staff to the next generation. In addition, the implementation of Phase IV gives opportunity to OPAKg and Abimanyu to collaborate with other communities and institutions in Yogyakarta in the form of knowledge transfer or giving support to each other.

4) Threats

The education level of the local people is still low so it is difficult for them to understand engineering terms. Therefore, we have to select people in charge of OPAKg and Abimanyu who have a higher level of background education than the others. Besides that, comprehension level of each person is different, therefore, academicians should be patient and be hard work in performing the education program.

IV. Conclusion

As the result, the comprehensive education of Renewable Energy System (RES) which is done with appropriate procedure can support sustainable development of RES. It also proves that RES education to society is not an impossible matter to be realized as long as there is a high commitment in both educator and local society. This kind of procedure can be a role model to the other renewable energy systems in any locations with some adjustments based on the local wisdom.

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References

[1] D. P. Aloysius, R. S. Fiki, W. Suci, and S. Nur, "Gradual development & socio-economic evaluation for sustainable renewable energy system: Solar water pumping system in Rural Karst Area, Banyumeneng Village, Yogyakarta," Presented at the 3rd Asia Future Conference, 2016.

[2] *Indonesia Energy Outlook*, Agency for the Assessment and Application of Technology, Jakarta, 2014.

[3] S. W. Nur, W. Suci, W. Ellena, and S. P. Didit, "Integrated communities for the sustainability of renewable energy application: Solar water pumping system in Banyumeneng Village Gunung Kidul D. I. Yogyakarta," *Energy Procedia*, 2015.

[4] G. Oliver, "A SWOT analysis for renewable energy sources and energy efficiency in the kleinregion entwicklungsverband tullnerfeld west," Research Report, Center of Excellence for Renewable Energy, Energy Efficiency and Environment, 2012.

[5] Schienke. (2015). Renewable energy and non-market eneterprise. [Online]. Available: https://www.e-education.psu.edu/eme805/node/2

[6] I. Bartlomiej, P. Grzegorz, I. Anna, C. Marcin, and B. Roman. (2015). The study on the SWOT analysis of renewable energy sector on the example of the Pomorskie Voivodeship (Poland). [Online]. Available: https://www.researchgate.net/publication

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