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FEASIBILITY STUDY OF RENEWABLE ENERGY SUPPLY FOR OUT DOOR CAMPUS UNIVERSITY OF SURABAYA, TRAWAS, INDONESIA

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Abstract:
This paper describes a feasibility study of different renewable energy supply systems for the Ubaya Training Center (UTC) in Indonesia. Various combinations of renewable energy sources and electrical loads have been compared in order to find the best financially viable solution. The potential of wind-, hydro- and solar energy has been assessed as possible sources of energy. None of the assessed system combinations reached payback within the assumed lifetime of 30 years. A solar powered, grid connected partial power supply for the UTC building complex and an off grid solar powered water pumping system show almost identical financial performance curves and also show best financial viability.

Keywords: renewable energy, electricity energy, ubaya training center, feasibility study

INTRODUCTION

Indonesia has many years of experience concerning renewable energy technology. In the past, mainly geothermal- and hydro systems have been used to harvest energy from renewable energy sources. Anyhow, statistics from the U.S. Energy Information Administration (EIA 2011) show, that even though according to the International Energy Office (IEA 2010) Indonesia has the highest total realizable potential for renewable among the ASEAN-6 countries (Indonesia, Malaysia, Singapore, Philippines, Thailand and Vietnam), only a small fraction of the total electricity consumption is covered by renewable sources of energy.

The Energy Policy Review of Indonesia (IEA 2008) proposes mainly 6 topics which need to be improved in order to increase the overall attractiveness of renewable energy systems in Indonesia. These cover the progressive reduction in fuel and electricity subsidies, better implementation of policy, improved clarity of the investment framework, helping the energy regulators do their job more effectively, and harnessing a sustainable development agenda, particularly renewable energy and energy efficiency (IEA 2008). One large step towards a market oriented prizing for electricity has been made as "*in September 2009, Indonesia has passed the law that ends electricity monopoly of the state utility PT PLN and allows regional governments to set up their own electricity rates*" (IEA 2010).

In 2008, a total of some 12 MW of solar photovoltaic systems have been installed as a result of some follow up programs to the previously mentioned programs. This also includes some 100,000 of originally 200,000 planned Solar Home Systems (IEA2008). Beside the technical performance (REINDERS 1999), also management and socioeconomic effects have been studied (DAUSELT 2002). As one of the major results, it can be said, that for a successful implementation of renewable energy supply systems not only the technology has to be provided but even more important, the users have to be trained and a solid maintenance and repair structure has to be established. The Ministry of Energy and Mineral Resources has established a Education and Training Center for Energy and Electricity. By installing one or different renewable energy systems at the Ubaya Training Center, the University of Surabaya might set a solid basis to become a strong partner institute for training and education of renewable energy technologies.

The buildings of the University of Surabaya are located on different Campuses in- or nearby the city of Surabaya in Indonesia. Campus III is located about 65 km south-west of Surabaya in a remote rural area near Mount Bromo. Campus III is also called Ubaya Training Center (UTC) and has been built to offer students the possibility to study in a rural and outdoor environment. The activities on the UTC are focused on teaching ecological systems and to perform social events for large groups mainly from universities and industry from the Surabaya region. The UTC is connected to the local electricity grid. By the end of 2008, a 800 Wp photovoltaic (PV) system has been installed to provide electricity to one of the cottages. For both, educational and environmental purposes, an additional and larger renewable energy system (RES) shall be installed.

The feasibility study shall focus on electrical energy from wind-, hydro- and solar systems. The resulting RES shall either cover the total or a well defined part load of the UTC. A financial analysis for the most promising system configurations shall provide information concerning total initial investment cost (IIC), the net present value (NPV) after the systems lifetime, the net present costs (NPC) and its discounted payback period (dPP). The four values will finally be used as a basis for decision which system configuration is the most feasible for this specific application. Solar thermal systems will not be considered in this feasibility study.

The Ubaya training center is connected to the electricity grid but is also willing to increase the fraction of renewable energy for the campus. Therefore the aim of the thesis work is to make a feasibility study and to design a “best fit” renewable energy supply system for the Ubaya training center in Trawas.

The objective of the feasibility study are to answer the following questions:

a) Would renewable energy sources adequately and reliably supply power?

   The Ubaya training center is used for seminars and trainings not only for members of the University of Surabaya but also for external visitors. It will be used to demonstrate alternative and environmental friendly ways of living in the Indonesian environment. It is therefore essential to design an energy supply solution which is highly reliable and usable in this climate in order to convince people that conventional energy supply systems can be replaced by renewable energy supply systems with an even decreased risk of energy down time.

b) Which renewable energy resource is the most efficient and economical?

   Compared to the general costs of living, the costs for energy are comparably high in remote and rural areas. Not only to keep the costs for energy on a minimum level for the UTC, but also to show that renewable energy supply systems are affordable in similar applications, the resulting system shall be as efficient and economical as possible.

c) Which RES configuration provides the most economically viable solution?

   Based on the given boundary conditions such as available budget, subsidies for different types of RE technologies and even the availability of (maybe used) components, the different system options will be different economically viable. The viability of the final system design will be a strong argument whether or not to realize the project.

d) What is the payback time for the optimal RES configuration?

   Compared to conventional energy supply systems such as grid connection or energy supply based on a GenSet solution, the cost characteristic of renewable energy supply systems are increased initial investment costs but decreased running costs (e.g. for fuel, electricity from the grid or system maintenance). The payback period represents the breakeven point between cost for a conventional energy supply system (respectively the existing energy supply system) and a renewable energy supply system. The shorter the payback period and the longer the expected lifetime of the systems the more financial attractive the use of the RET system will become. As the payback period is one of the most common parameters which are used to decide whether or not to realize a project, it also will be calculated and used in the decision process for this project.

METHODS

The work was divided into a preparation and continued with three phases of work as shown in Fig 1. In a preparation phase, all available and necessary information was gathered. During phase 1 of the work all relevant technical and financial boundary conditions were clarified. Furthermore, a detailed assessment of the given load at Ubaya training center was done. Also in the first phase, an assessment of all locally available and potential energy sources were made. The result of the first phase shall be a framework of all relevant financial parameters, the user needs (e.g. load profile) and the available sources of energy. Within the resulting framework of phase 1, it will be possible to design different system options which all will fulfill the requirements. Therefore the aim of phase 2 will be to provide a set of different detailed designs for system options and to implement those in different system simulation tools such as HOMER or PVSyst. There are many different combinations of loads respectively sources. In some cases the load profile will not match the source profile concerning monthly or daily distribution. In a pre-selection round before the phase of detailed design, only the system combinations will be chosen were the load and the source profile fit to each other. Based on the result of the second phase a comparison between the different options will lead to best fit solution for this application in the third phase of the project.

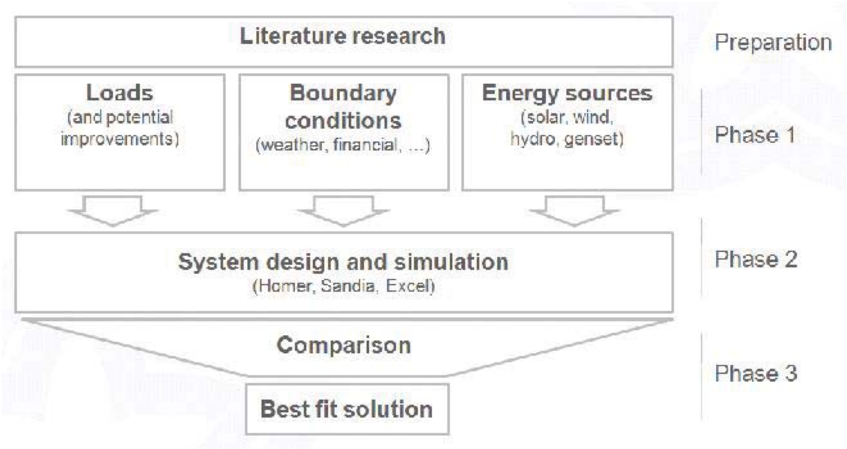

Fig. 1 Research method and phases

For the purpose of system design and system simulation, Sandia design sheets, HOMER (Version 2.68 beta), and PVSyst (Version 5.14) will be used. The Sandia design sheets have been developed by the Sandia National Laboratories (SANDIA 2011) in order to provide a tool for the dimensioning of PV based stand systems. HOMER (HOMER 2011) is an energy simulation system which can be used to design and simulate different lean or hybrid RES configurations. It is mainly designed to analyze the technical and financial performance of hybrid systems. PVSyst

(PVSYST 2011) is a design and simulation software for PV systems. It focuses on the grid connected, stand alone, solar water pumping or DC grid connected systems.

The different renewable energy sources at the UTC, the electrical loads or part loads and the financial boundary conditions for the feasibility study are studied. All possible combinations of available energy sources and loads are shown, compared and the most promising system combinations are preselected. The result of the financial evaluation including a the result of a sensibility analysis for the most influencing financial parameters are studied.

RESULTS

Electrical Load for UTC

The Ubaya training center has two main connections respectively two independent electricity meters for the public grid electricity. One connection is exclusively used for the water pumping system which pumps water from a well to a primary water storage tank and from there to the secondary and final water tank on the top a mountain beside the UTC. The main UTC electricity supply covers all loads except the energy consumption from the water pumping system. The following estimation is based on the bills for electricity of the last 12 month, the occupation profile of the UTC and verbal statements about the monthly fuel consumption of the backup generator setup. The counter of the electricity meter is not being read always at the same day of the month. Therefore there might be a deviation between the real consumption and the consumption according to the bills for electricity for some month.

Especially after “hard rain”, mainly during the rainy season, the public grid is turned off due to short circuits, defects or overcharge events. In this situation, a GenSet which is located on the UTC area will supply the needed electricity for the UTC. The electricity which is produced by the GenSet is not measured from the electricity meter and does therefore also not appear in the above graph. Based on verbal statements of employees of the UTC, the GenSet has an average fuel consumption of 60 l/month. The following model has been used to take into account that the GenSet consumes more during rainy season and less during dry season.

There is no feed in tariff (FIT) program for PV systems in Indonesia. Therefore the system should be designed to provide not more than the minimum of the above load as an oversized system design will result in high initial system costs but no monetary gains during phases of overproduction.

The street lights of the UTC are switched on every night short before sunset and will stay turned on until short after sunrise. The resulting load is very predictable and stays constant throughout the whole night and also almost constant over the year. The time where the lights for the walkways of the UTC are turned on can be defined as the time between sunset and sunrise and additional 15 min in the evening and 15 min in the morning.

When designing a power supply system for the lights of the walkways, it also has to be considered that compact fluorescent lamp (CFL) will be used and that they need to be treated as capacitive loads during their start up phase. Before turning on a CFL, a build in capacitor has to be charged. In order to charge a capacitor, a high amount of current at the rated voltage is needed. As power is defined as the product of electrical current and voltage, the needed power to turn on the lamp will be significantly higher than the rated power of the lamp. Compact fluorescent lamps will need as much as 5 to 15 times of the rated power during the start up phase. The power supply system shall be designed large enough to be able to supply the needed power during the start up phase. Additionally it shall be considered not to turn on all lamps at the same time but in cluster of several lamps. This will reduce the needed size of the inverter and therefore also the total investment costs. Calculation shows the result of a cascaded turn on profile for the walkway lights. When using a cascaded turn on profile, a smaller and more cost effective inverter can be used. In Indonesia, especially during the rainy season, the grid turns off several times per day (resp. per night). Every on or off switch will reduce the lifetime of each of the used lamps. Therefore a solar driven power supply system for the walkways will not only save money due to a reduced electricity bill but also as the lifetime of the lamps will be increased.

Very similar to the walkway lights, the street lights will be turned on as soon as the sun sets and turned off as soon as the sun rises in the morning hours. However in contrast to the walkway lights, the street lights will be turned on every night whereas the walkway lights might not be turned on if there are no visitors are at the UTC. The calculation of the load for the street lights is very similar to the calculation of the load calculation for the lights of the walkway. The accumulative yearly energy consumption of the streetlights system equals 4939kWh /year.

Each VIP cottage on the Ubaya Training Center is equipped with several electrical consumers such as refrigerator, toaster, television and small electrical water cooker. Assuming certain on and off times for each consumer, an overall daily load profile can be estimated. Furthermore, it can be assumed, that not all customers turn off and on their devices simultaneously. Therefore to estimate the total load of all 4 cottages, the result of a rolling average (ROLAV) calculation will be used. There are load peak in the morning and evening hours in each cottage . This is mainly due to the lights which are turned on during this time. In addition to the lights, it has to be considered that the TV is turned on in the afternoon / evening hours. It also can be found, that the fridge represents a constant load and is turned on even during night. The above shown daily load profile is valid only if the cottage is occupied. In case of no occupation, the energy consumption decreases The average daily energy consumption for both cottages was found in the range of 5.5 kWh/day and 6.4 kWh/day. The peak load in this case will be defined as the electrical load if all electrical consumers are turned on. Therefore the peak load for the VIP cottages equals 1736 W/cottage.

The water pumping system has its own connection to the main grid and therefore also its own electricity meter. The measured energy consumption can be treated as the total load for this application. Daily average energy consumption for the pumping system was found to be varies between 178 kWh/day in May and 313 kWh/day in January. Anyhow, as the occupation of the UTC varies greatly between weekday and weekend, also the real energy consumption can differ significantly from the averaged value. The water pumping system basically consists of a well, a primary pump, a primary storage tank, a second pump and a secondary water storage tank. The vertical distance between the well and the primary storage tank equals 69 m and the vertical distance between the primary water storage tank and the secondary storage tank equals 75 m.

In order to increase the amount of renewable energy for the UTC, it could also be considered to design a solar water pumping system which does not cover the total but a fraction of the total water need of the UTC. In order to avoid overproduction during times of low occupation, the partial water supply system shall cover not more than the base water needs of the UTC.

DISCUSSION

The feasibility study has been made as the Ubaya training center is willing to increase their fraction of renewable energy in the total energy consumption. There are both, different sources of renewable energy as well as different ways of using the gained energy from renewable energy sources. For the feasibility study the potential of the different sources of renewable energy has been assessed as well as different ways of using the gained energy for the Ubaya training center. The potential sources are wind, hydro and solar energy. Other potential sources such as geothermal have not been assessed as required time for an assessment would exceed the time limitation of this feasibility study.

Measurements at the Ubaya training center as well as data from different online data bases show that the velocity of the wind is mostly below 3.5 m/sec (at a height of 10m above ground) and therefore too low for a useful application at this location.

The use of hydro energy could be considered for future applications. A micro hydro plant in the near surrounding of Trawas shows that this form of energy is a relatively cheap and reliable way of converting energy from renewable energy resources. The water in the surrounding mountains of Trawas is being used since long time for irrigation of the nearby rice fields. Therefore numerous water channels along the mountain lines already exist and can partly be used for energy conversion. However, due to the fact that Trawas is located in an area with a lot of rain during rainy season and almost no rain during dry season, the potential of hydro energy varies significantly over the year.

The two potential sources of hydro energy which have been assessed during this feasibility study have a theoretical capacity of 21.2 kWh/day respectively 71.2 kWh/day (April 2011). This is significantly less than the total daily energy consumption of the UTC building complex, which is between 100 kWh/day and 310 kWh/day or the water pumping system which is in the range of 180 kWh/day to 345 kWh/day. Therefore the hydro energy could be used to cover part loads of the total consumption. In this feasibility study, no application for the potential hydro energy sources has been proposed mainly due to the uncertainties concerning the potential of the river over the period of one year.

Despite the fact that there is a rainy season and dry season in Trawas, there is a relatively uniform distribution of the available solar energy over the year. However, especially during the rainy season, there might be several days of consecutive rainfall with low solar irradiance. The yearly average daily solar irradiation equals 5.17 kWh/(m^2 day). Therefore, solar energy has high potential to be used as a renewable form of energy for the Ubaya training center.

Based on that, the first two questions of the description of the feasibility study can be answered:

Would renewable energy sources adequately and reliably supply power?

None of the assessed forms of renewable energy sources has enough potential to cover the total electrical load of the UTC with adequate financial investment effort. However, solar and hydro energy provide a relatively constant and reliable form of renewable energy which can be used to supply electrical power to part loads of the Ubaya training center.

Which renewable energy resource is most efficient and economical?

Generally spoken, micro hydro systems have great potential to be most efficient and economical in mountain areas. In this specific application, the river, which could be used for a micro hydro system has only limited capacity, presumably a large difference in its usable energy between rainy and dry season and is located relatively far away from the UTC. The energy which could be gained from wind can be neglected at this location. Therefore solar energy seems to have the highest potential to be most efficient and economical.

In addition to the assessment of the different energy sources, an assessment of different possibilities to use the gained renewable energy has been made. As mentioned previously, none of the available renewable energy sources provides enough energy to cover the total electrical load of the UTC within a reasonable cost framework. Therefore, the following different part loads have been defined.

a) Power supply system for the walkway lights
b) Power supply system for the streetlight system
c) Grid independent water pumping system
d) Grid independent supporting water pumping system
e) Power supply system for a small electro scooter fleet
f) Grid connected partial power supply for the UTC
g) Power supply for the VIP cottages.

Both, the average and daily load profile have been compared with the profile of the different sources of energy. Best fit between source and load profile could be found for configurataion b), d) and f). For each of the three options, a more detailed concept has been designed and simulated in PVSyst or HOMER. Based on the results of the technical simulation a financial evaluation has been made. The result of the financial evaluation is described in chapter **Error! Reference source not found.** Based on that the last two questions description of the feasibility study can be answered.

Which RES configuration (grid-only, grid/RES hybrid, RES-only) provides the most economically viable solution, using net present cost (NPC) as the basis of comparison? The small water pumping system (RES-only/offgrid) and the grid connected partial power supply for the UTC (grid/RES hybrid) provide the most economically viable solution. There is no significant difference in the financial performance between the two solutions. Applying a sensibility analysis with best case parameter settings the grid connected system will get the highest (positive) net present value (NPV) the lowest net present costs (NPC) and the shortest discounted payback period (dPP). Therefore, assuming best case conditions, the grid connected partial power supply for the UTC complex provides the most economical viable solution.

What is the payback time for the optimal RES configuration?
Based on the financial assumptions the benefits due to saved energy from the grid are not large enough to cover the system costs. Therefore there is no payback within the assumed lifetime of the system. Applying a sensibility analysis with best case parameter settings the large grid connected system will have a discounted payback period of 23 years.

In 2008 the UTC purchased a photovoltaic system to realize an off grid power supply for one of the cottages. Currently the photovoltaic system is not in use as the performance is below the expectations. This system could be used for either the realization of one of the first grid connected photovoltaic systems in Indonesia or for educational purposes. For a grid connection only a relatively cheap, additional inverter would be needed to complete the needed equipment. For the use for educational purposes, the solar array needed to be mounted to a location where the students have direct access to study the system by doing measurements, variations or improvements. A third possible option would be to use the system as power supply system for a low energy cottage. Currently, the UTC building complex is about to be extended by several new cottages. One of the cottages could be designed to be a low energy cottage with optimized electrical consumers such as small and high efficient fridge or low consumption lights and the existing photovoltaic system could be used to realize a grid independent power supply solution for this cottage.

It would be very beneficial if the University of Surabaya would purchase and install a weather station which is able to measure and log the most important weather data such as air temperature, wind velocity and solar irradiation. This would be beneficial, not only in the field of renewable energy development but also in all future activities in the fields of general meteorology.

CONCLUSION

The government of Indonesia currently provides a cash program for geothermal- and hydro energy systems and a feed in tariff for electricity produced from geothermal sources systems (IEA 2010). Apart from this, there are no subsidies or other financial aids for renewable energy systems. Furthermore, fuel for combustion engines is subsidized and electricity is even subsidized below the level of production (TWB 2010). These are the two main reasons why it is currently not financially attractive to invest into renewable energy systems in Indonesia. However, Indonesia seems to be willing to follow the suggestions from The World Bank, AUSAid (TWB2010) and the International Energy Agency (IEA 2008) to reduce the subsidies for fuel and electricity and increase the subsidies and other financial aids for renewable energy systems in the upcoming years. This will lead to a more equalized market where the use of renewable energy will become more and more financially attractive.

For the specific application of renewable energy systems at the Ubaya Training Center, the feasibility analysis shows, that it is most viable to install either a grid connected partial power supply for the UTC building complex or to install a solar powered off grid water pumping system. Both configurations show a similar financial performance curve and both system can be scaled to meet the maximum initial investment costs what the UTC is able and willing to spend. Taking into account the result of the sensibility analysis, the grid connected partial power supply becomes more attractive as for the same initial investment costs more electricity will be produced and therefore more direct financial benefits will lead to a shorter payback period.

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