Design and Development of Wireless Solar Powered Router for the Rural Area

Nor Azura Osman
Politeknik Sultan Azlan Shah, Perak
zurapsas@gmail.com

Shaiful Bahari Mohamad Norani
Politeknik Sultan Azlan Shah, Perak
shaifulpsas@gmail.com

Nor Faizah Md Sayuti
Politeknik Sultan Azlan Shah, Perak
norfaizahmdsayuti@gmail.com

Abstract
In Malaysia to form an e-governance administrative system, non-comprehensive internet access in the country is the factor to be considered. Some innovative service providers in other countries, especially in rural areas, are working to increase wireless networks by combining the solar system with cell towers to provide internet connectivity. The solar system is one of the renewable energy widely used in wireless communication systems, a challenge for future technologies. In addition, a wireless router is a less powerful device that is used to provide network access to a wireless internet connection. For continuous internet use, a wireless router can be used 24 hours and is ideal with solar systems. This study will also focus on Return On Investment (ROI) to identify the effectiveness of the use of solar energy compared to conventional electricity. The result show, the estimated operating cost for the production of this innovation can be reduced by 63% from the existing cost and the return on investment (ROI) can be obtained within 6 months. This innovative product is expected to help increase bandwidth facilities in rural areas and provide solutions to innovative green practices to save costs, energy and reduce greenhouse gas emissions.

Keywords: Solar, wireless, rural

1.0 Introduction

In the 21st century, most governments around the world are beginning to shift to a new paradigm through digitization technology to cater to the demands from the citizenry for more efficient, transparent and timely service. Malaysia began to move towards digitization technology through the implementation of e-governance. However, Malaysia faces some obstacles slowing down the implementation rate, among which is the gap between urban and rural bandwidth facilities is still high. To create an e-governance administrative system, computers and especially the internet must be comprehensive so that the dissemination of information can be fully communicated to the Malaysian community.

According to the International Telecommunication Union (ITU), in 2019, there will be about 72% of homes in urban areas around the world having internet access. Meanwhile, only 38% of households in rural areas have internet access. Geographical condition, poverty and lack of electricity coverage in rural areas are contributing factors to the low percentage of rural households with internet access. According to Borhanazad et al. (2013), Peninsular Malaysia has electricity coverage in rural areas around 79% compared to 99.62% in urban areas. Abd Rahim et al. (2010) stated that Peninsular Malaysia has high electrification rates with almost 100% compared to East Malaysia. For Sabah and Sarawak, electrification rates are lower, at 77% and 67% respectively. Meanwhile, Internet Users Survey 2020 done by Malaysian Communications and Multimedia Commision (MCMC) shows that 88.7% of the population in Malaysia are internet users distributed to urban areas with 75.6% and 24.4% for rural areas. The percentage is increase at 1.3% compared to the 2018 survey. The statistics of internet users in Malaysia are expected to increase over the years.

Therefore, in order to upgrade bandwidth facilities in rural areas, the use of renewable energy sources such as solar energy can be considered as one of the best alternatives to generate electricity. According to Borhanazad et al. (2013), Malaysia's solar energy potential is four times that of the world's fossil fuel resources. Malaysia benefits from its high average solar radiation, making it suitable in all areas. Electricity generation through solar energy can minimize greenhouse gas emissions especially those involving carbon dioxide, CO_2. Generally, greenhouse gas emissions generated during the burning of fossil materials can lead to global warming and climate change. Examples of this climate change are extreme weather events, rising sea surface temperatures, and ecosystem changes. As a result, it can affect the overall level of public health. Apart from that, the environment, animals and plants are also affected. Figure 1 shows the sources of CO_2 emissions by sector in Malaysia, where the electricity and heat production sector contributes 46% to greenhouse gas emissions compared to other sectors of lower value (Kazeem et al. 2019). In consistent with Malaysia's economy growth, the CO_2 emissions will also record continous increment. According to Begum et al. (2015), the implementation of solar energy can be regarded as one of alternatives to lessen the CO_2 emissions as the country strives its target to become a high-income economy by 2020.

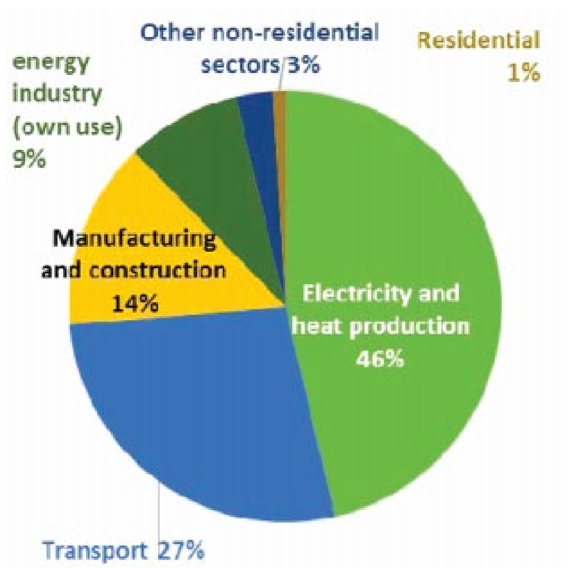

Figure 1: Sources of CO_2 emissions by sectors in Malaysia (IEA 2007)

The Sustainability Development Goals (SDGs) have been adopted by United Nations (UN) since January 1st, 2016. The main agenda of SDGs were meant to eradicate poverty, protect the planet, and to obtain the equal opportunity to all walks of life. Solar energy and the SDGs are closely linked. Currently, there are almost 789 million people still without electricity. SDG 7 under affordable and clean energy will ensure that the well-being of the people, economic development and poverty eradication can be achieved. According to the UNESCO Institute for Statistics (UIS) in May 2014, there are more than 90% of schools in Africa without electricity supply. Meanwhile, there are 188 million children globally attending school without electricity. By 2030, the main target of SDG 4 through the quality of education is to ensure that primary and secondary education is free and fair so that the relevant and good quality of learning outcomes are achieved. According to the International Renewable Energy Agency, almost 11.5 million people are already employed in the renewable energy sector interrelated to SDG 8 through decent work and economic growth. As for gender equality, women contributed 32% in the SDG 5. Final energy consumption at 17.1% comes from renewables in SDG 13 for climate action. The goals can be achieved by using solar as part of renewable energy. For example, by providing energy solar access to the community, especially in rural areas, life could be better for every home, school, clinic or healthcare center and for society itself.

With solar, it can reduce the demand for fossil fuels, limit greenhouse gas emissions, and shrink the carbon footprint. By installing a project such as Wireless Solar Powered Router using the solar energy system, a measurable effect can be obtained on the environment. Investment in infrastructure and innovation is one of 17 Global Goals that make up the 2030 Agenda for Sustainable Development. Investing in solar will improve productivity of energy. Clean and efficient energy can be achieved by upgrading the infrastructure and technology. This will drive economic growth and a better environment. The most important thing is the 2030 Agenda cannot be achieved without massive investment in Information and Communications Technology (ICT), especially in rural areas. Integrated efforts and support for the SDGs play a very important role in ensuring that access to ICT is improved and that all parties can enjoy affordable and good internet facilities, particularly for developing countries.

2.0 Literature Review

Access to internet facilities nowadays is a priority on the needs of human life. Therefore, the recommendation to upgrade the internet facilities to become the basic utility needs of the country is very much in line with the needs of human life today after the need for electricity and water supply. In developing countries, the broadband access penetration is at a moderate level. Many rural areas still do not receive good internet access due to geographical factors, economy, population and also the distance between the urban and rural areas. Most rural areas are also not provided with basic infrastructure facilities such as electricity and water supply. However, in this era of a borderless world, all these factors should not be taken into account. The gap between urban and rural areas needs to be eliminated and all citizens need to have equal internet access facility. (Ruiz & Esparcia, 2020).

In the third world, the socio-economic development of rural areas is very concerned with access to communication systems. The selection of communication technology that is appropriate to the ability and also the cost factor is very important in developing communication network infrastructure in rural areas. The selection of Wi-Fi technology (IEEE802.11) is very suitable because it is a high-potential technology and less expensive data centric broadband access (Raman & Chebrolu, 2007). As we known, the development of cable and fiber-based internet access infrastructure will cost a lot and is quite difficult to develop due to geographical factors and the distance between urban and rural areas, therefore the use of wireless communication such as Wi-Fi can be used to enhance the use of existing internet facilities. This method is also more cost effective because it is easier, less maintenance and more practical to connect rural areas. (Adithya, 2005).

According to Reigadas et al. (2008), the factor of low population density in isolated rural areas, especially in developing countries is a major factor hindering the development of terrestrial telecommunication networks. In addition, electricity supply problems and also access to other basic facilities have obstructed the development of communication networks in rural areas. Usually rural areas do not have power supply, then the use of the solar system is very suitable for equatorial countries such as Malaysia where the rate of dependence on natural resources such as sunlight is very high. Therefore, the use of the solar system is very practical to be used as a power supply system for Wi-Fi modules. According to Khelifa and Jelassi (2018), the solar photovoltaic (PV) industry has been one of the fastest growing renewable energy industries, contributing to the reduction of greenhouse gas emissions. Solar PV systems work by absorbing sunlight through solar cells and converted it to direct current (DC) electricity. With the combination of these 2 main technologies; Wi-Fi and Solar PV systems, this project is more portable and easy to maintain even if it is used in rural areas. In urban areas as well, not all areas are able to receive good Wi-Fi access. There are also some spaces that are difficult to access and the cost of building a hotspot terminal also does not provide a good return. Therefore, this project can provide an optional solution to expand internet access in these areas, especially in higher usage of internet access such as higher education institutions.

Apart from that, this study will also focus on Return On Investment (ROI) to identify the effectiveness of the production of innovative products for a certain period of time is worthwhile or not. ROI can be calculated by using an Eq. 1 (Ozcan & Ersoz, 2019).

$$\text{ROI} = \frac{\text{Project Return (Income} - \text{Cost)}}{\text{Project Cost}} \text{ x } 100 \qquad \text{(Eq. 1)}$$

In the energy investment field, the method of investment refund time is an investment analysis technique that is widely used. The return time of an investment (payback period) in the Eq. 2 can be described as the time required for the repayment of the net investment.

$$\text{Payback Period} = \frac{\text{Investment Amount}}{\text{Annual Profit}} \qquad \text{(Eq. 2)}$$

According to Formica et al. (2017), the return on investment (ROI) analysis of a solar photovoltaic (PV) system will typically show an impact after 10 years used for residential usage (9.12kW) and according to Ozcan & Ersoz (2019), the photovoltaic investment in communication for Istanbul Tuzla provided a 63% return with the payback period in almost 7 years. Therefore, it is hoped that this innovative project can provide alternative solutions in the short term to ensure that rural and remote communities can enjoy internet access to facilitate their daily affairs.

3.0 Methodology

3.1 System Design

The proposed system design consists of two construction parts, which are a solar system and a wireless router as in Figure 2. Solar panels are used as renewable energy to replace conventional electrical energy to wireless routers. The solar controller is used to control the voltage of the battery and operate the regulated circuit. The Controller is used to protect batteries from overcharging or over discharging. Excessive charging can cause damage to the battery. Meanwhile, overcharge and over discharge can damage the installed router. The batteries are used to store electrical energy generated by solar panels for use by the router. The battery has the function of storing electrical energy and stabilizing voltage. It will be used as a backup at night or in cloudy weather. Meanwhile, wireless routers are used to provide internet connection to local users. A router is a device that propagates a Wi-Fi signal to a specific area, so that the Wi-Fi network can be used by all devices in its operating area. This design involves precise selection of solar panel measurements and battery capacity to obtain the amount of energy needed to operate the wireless router and charge the battery cell. The testing product was done by making the installation in the PSAS area which has a slow internet connection signal.

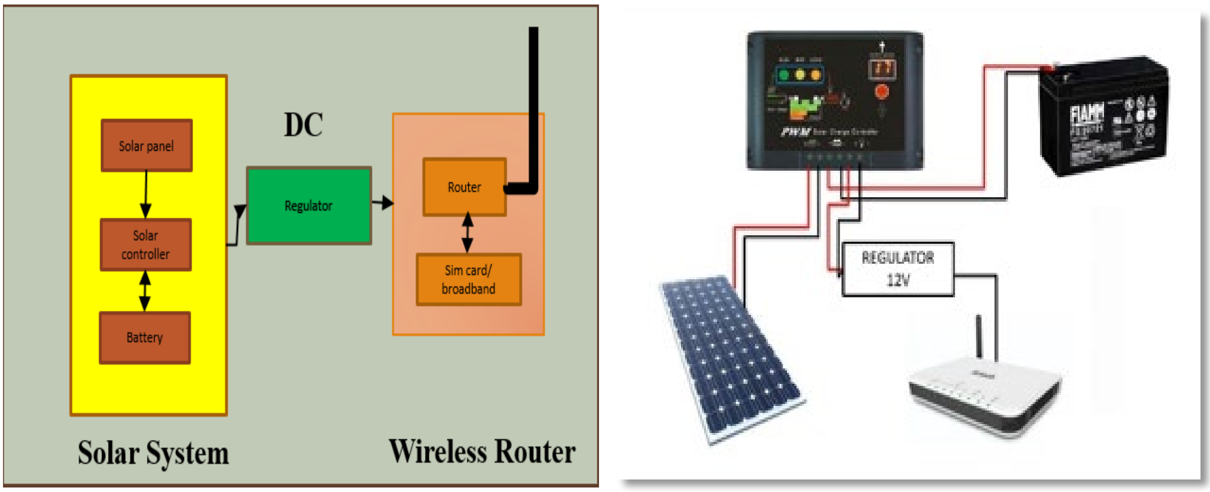

Figure 2: The proposed system design

3.2 Design of Solar System

There are two issues that need to be considered to design the project with a solar system, which are the size types of solar panel and the ability of the battery to maintain power over a period of time. The size of the solar panel used should be large enough to operate the router and capability to charge the battery for night or in cloudy weather. Table 1 shows the cost of solar panels per watt available on the market.

Table 1: Solar panel prices collected from online shopping websites

Watt	Monocrystalline (>18%) (RM)	Cost per Watt (RM)
20 W	70.00	3.50
30 W	110.00	3.60
50 W	138.00	2.76
80 W	199.00	2.48
100 W	238.00	2.38

Calculations for the initial estimate of power consumption in the system need to be calculated to resolve the two issues. First, to identify the maximum load of the router, the design of this system uses an Aztech router that has a maximum load of 5 watts. The estimated system conversion loss is 20% which is a loss factor from solar controller, cable and regulator circuit. The maximum power output required from solar energy to operate the system can be calculated using the formula:

$$\text{Solar Panel Output} = \text{Solar Array Area} \times \text{Conversion Efficiency} \times \text{Solar Radiation}$$

That is, $(5\ \text{Watt}) / (100\% - 20\%) = 6.25\ \text{Watt}$

The total power consumption to operate the router in 24 hours is;

$$6.25\ \text{Watt} \times 24\ \text{hour} = 150\ \text{Wh}$$

From the total power consumption obtained, the area surface measurements of the solar panel and the capacity of the battery to be used can be determined. The solar panel used should have a larger surface size to meet the power on the router and the charging capacity of the battery. The second step is to identify the average rate of solar radiation in Malaysia. According to Izadyar et al. (2016), the average monthly daily solar radiation in Malaysia was recorded as 4.5 KWh / m2. By using mono crystalline type solar panels with an efficiency of 18%, then the power required every day is;

$$4.5\ \text{kWh/m}^2\text{/day} \times 18\% = 0.81\ \text{kWh/m}^2\text{/day}$$

The required solar panel surface area is;

$$(150\ \text{Wh/day}) / (810.00\ \text{Wh/m}^2\text{/day}) = 0.2\ \text{m}^2$$

From the calculations, it shows the solar panel requires a size of at least 0.2 m^2 or 40 watts and above depending on the battery used to ensure the battery is always fully charged. Batteries used to store solar energy must exceed 150 Wh to maintain the number of days of operation.

3.3 Design of Wireless Router

The main design consideration of this system is the wireless router with lower power consumption. The less power an access point consumes, the longer it can connect a user to the internet when night. The wireless router is a device that performs the functions of a wireless access point, which broadcasts Wi-Fi signals for users to connect. All wireless routers feature has an interface controller. Some dual-band wireless routers can operate with 2 .4 GHz and 5 GHz bands. Wireless controllers support a part of the IEEE 802.11-standard family and many dual-band wireless routers that have data transfer rates exceeding to 300 Mbps (For 2.4 GHz band) and 450 Mbps (For 5 GHz band). Wireless routers have one or two USB ports that are used for connecting devices or mobile broadband modem, aside from connecting the wireless router to an Ethernet with DSL or a cable modem. A mobile broadband USB adapter are often connected to the router to share the mobile broadband internet connection through the wireless network.

3.4 Prototype Project

Figure 3 shows the prototype of the project that was developed. The project has been developed within 4 months and has been tested for its functionality. The prototype design consists of 3 solar panels with 60 W, 2 batteries 12 V with 14.4 Ah, solar controller, regulator circuit and router.

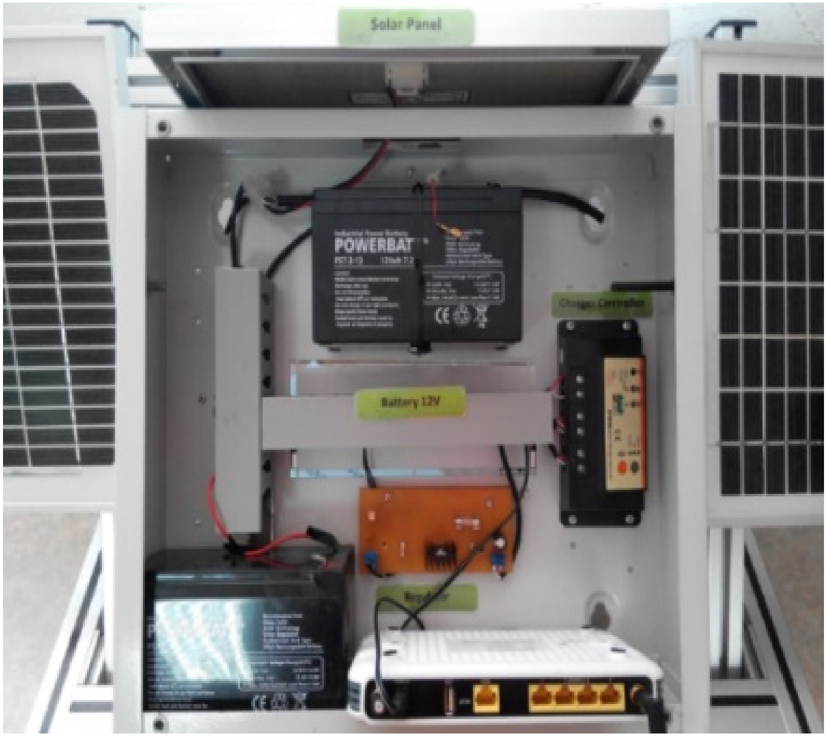

Figure 3: The Prototype of solar powered wireless router

3.4.1 Solar Panel

Three solar panels as in the figure 4(a), valued at 60 W, were used for this project. The 60 W solar panel was chosen because it is suitable for supplying power to the system and is most effective in output cost per watt to powered the router. A solar controller such as Figure 4(b) is used to control the voltage on the battery. In Figure 4(c) shown two 12 V battery units with 14.4 Ah are used to store the energy generated from the solar panel. The battery has a wide range of advantages and a cheap price. Determining the capacity of the battery used allows the use of the internet connection to be done for at least 1 day without the use of solar energy.

Figure 4(a)

Figure 4(b)

Figure 4(c)

Figure 4: Devices used in this system (a) The solar panel that generated the electricity system (b) The solar controller is used to control the voltage on the battery (c) The battery 12 V with a 14.4 Ah to store electrical energy

3.4.2 Aluminium Casing Box

Aluminium casing box is one of the factors to be considered in implementing this project. The casing box is used to store all devices and not being exposed to the outside weather. The physical characteristics of the casing box shall consist of a waterproof, strong and durable material. The size of the casing box should be suitable to house the solar controller, wireless router, regulator and DC battery as shown in Figure 5. Solar panels are installed at the top of the casing box to protect the box from liquids and weather that can cause rust. The dimensions of the casing box used are 60 cm X 40 cm X 14 cm with stainless steel material.

Figure 5: Stainless steel casing

3.5 Equipment Cost

The total cost of equipment (refer to Table 2) is RM 450.00, excluding installation costs. The monthly plan of the broadband network used for the test is 20 Mbps for one-month use.

Table 2: The equipment cost of system design

Items	Price (RM)
60 W solar panels (for 3 panel)	210
12V/14.4AH battery	80
Regulator	10
Solar controller	70
Casing	40
Cable Connector	40
Total	450

4.0 Results and Discussion

4.1 The result of distance and speed test

Table 3 shows the results of experiments conducted on the developed project involving speed and distance on the user device. The system was tested using a broadband modem connected to the router for 20 Mbps data capacity and the standard used was 802.11a with a maximum reach of 54 Mbps.

Table 3: Results of distance and speed test

Distance (m)	Speed (Mbps)	Internet connectivity
0	52	Good
1	44	Good
5	39	Good
10	30	Good
20	36	Good
30	40	Good
40	28	Good
50	27	Moderate
60	25	Moderate
70	22	Moderate
80	No speed	Signal loss

The results show that the internet speed does not depend on the strength of the Wi-Fi used but instead depends on the router with a subscribed value of 20 Mbps. The findings also show that when the device is placed next to the router, it is found that the tested speed reaches up to 54 Mbps full. The farther it moves, the speed decreases to 40 Mbps. Upon encountering a thick wall, the speed is getting lower, 25 Mbps. The distance and number of resistances can affect the signal strength required. The conclusion shows that if the subscribed internet speed capacity is 20 Mbps, the internet can only use a maximum of 20 Mbps even if the device shows a high Mbps value. According to Ali et.al (2015), it is stated that IEEE 802.11a router has a maximum speed rate of 20 Mbps and better performance. However, it uses more energy and a larger solar battery unit. The results of these findings resemble the theory of using conventional systems although experiments were performed on solar systems. This shows that by using a solar system, the router can be used properly without any problems.

4. 2 Return of Investment – ROI

The main objective of this project is to produce low cost solar powered routers in rural areas, the comparison cost has been made to compare between the cost of installing TNB cables and the cost of installing this project. This system is very suitable to be installed in outdoor areas that require internet coverage as well as in rural areas that are difficult to receive electricity. Below are the calculations of ROI:

Estimate the cost of existing operations using electrical energy

= (Three-phase distribution line installation price (wages and TNB) + (electricity consumption for 24 hours x 30 days x 12 months)

= RM1200.00 + RM29.44

= RM1229.44

Wireless Solar powered router Saving

= RM1229.44 - RM450.00

= RM779.44 (63.4%)

Return on Investment (ROI)

= Installation Cost / Cost savings

= RM450.00 / RM779.44

= 0.6 years

The results show that the operating costs for the production of this project can be reduced by 63% of the existing costs and return on investment (ROI) can be obtained within 6 months. This finding is supported by Ozcan & Ersoz (2019) who found that the implementation of the solar system in Turkey shows that the return on investment would recover within 7 years. However, solar energy savings also depend on geographical factors and the type of system to be installed.

4.3 Emission of CO_2

The conventional electricity system through the burning of fossil fuels will increase carbon dioxide, CO_2 concentration in the atmosphere and thus induces global warming commonly referred to as the greenhouse effect. The use of solar renewable energy can reduce CO_2 emissions in the atmosphere. Below is the calculation of CO_2 emission for one-year duration.

Estimated Emission Factor (EF)in energy saving measures for one year is 0.667 (Anonymous, CDM Electricity Baseline for Malaysia, 2017)

= Power consumption of the innovation with one year operate x Emission Factor (EF)
= 150 Wh x 30 days x 12 months x 0.667
= 54 kWh x 0.667
= 36.018 kg CO_2

From the result show, the total of CO_2 emission for one year is 36.018kg for one project. S. Suja and T. Sathish (2013) stated, using renewable energy resources in communication system can reduce the CO_2 emissions and mitigate the effect of global warming. If this project is installed in larger quantities in areas that receive less electricity and internet supply, such as rural areas, the rate of CO_2 emissions will be further reduced more.

5.0 Conclusion

Solar-powered wireless routers were developed to provide internet connectivity to users in remote areas, especially in rural areas. The main advantages of this design are easy installation and less maintenance, especially in those remote areas and locations. According to Wong et, al. (2020), by using solar-powered internet access, low-cost infrastructure can be built in remote areas. By using solar energy, electricity costs are reduced and Return Of Investment (ROI) can be achieved in less than 1 year. In addition, the application of solar in this project also enables a level of environmental sustainability to be achieved through the elimination of CO_2 emissions compared to the previous use of fossil-based electricity. With the implementation of this project, it is hoped to help improve broadband facilities in rural areas and provide solutions to innovative green practices in saving costs and energy. The impact of this project can also be linked to the Sustainable Development Goals where the goal of SDG 12 is to ensure good use of resources, improves energy efficiency, sustainable infrastructure, and provides access to basic services by ensuring better quality of life for all.

References

Abd Rahim, Nasrudin & Islam, Mohammad & Rahman, Saidur. (2010). Rural Electrification in Malaysia. *Psychology International Conference "Innovations for Renewable Energy" Hanoi, Vietnam.* Retrieved from https://www.researchgate.net/publication/280808028_RURAL_ELECTRIFICATION_IN_MALAYSIA

Adithya.,R. (2005). The Economic Advantage of Wireless Infrastructure for Development. *Sustainable Development Department Technical Papers Series. Washington, D.C.* https://publications.iadb.org/publications/english/document/The-Economic-Advantage-of-Wireless-Infrastructure-for-Development.pdf

Ali, Qutaiba & Jalal.K. (2015). Practical Design of Solar-Powered IEEE 802.11 Backhaul Wireless Repeater. *Proceedings - 6th International Conference on Multimedia, Computer Graphics and Broadcasting, MulGraB 2014*. 9-12. 10.1109/MulGraB.2014.9.

Anonymous. (2017). CDM Electricity Baseline For Malaysia. Malaysian Green Technology Corporation.

Begum, Rawshan & Sohag, Kazi & Syed Abdullah, Sharifah & Jaafar, Mokhtar. (2015). CO2 emissions, energy consumption, economic and population growth in Malaysia. *Renewable and Sustainable Energy Reviews*. 41. 594–601. 10.1016/j.rser.2014.07.205.

Borhanazad, Hanieh & Mekhilef, Saad & Rahman, Saidur & Boroumandjazi, G. (2013). Potential application of renewable energy for rural electrication in Malaysia. *Renewable Energy*. 59. 210–219. 10.1016/j.renene.2013.03.039.

Formica, T. J., Khan, H. A., & Pecht, M.G. (2017). The Effect of Inverter Failures on the Return on Investment of Solar Photovoltaic Systems. *IEEE Access*, Vol.5, 21336–21343.

Izadyar, Nima & Ong, Hwai Chyuan & Chong, Wen Tong & Mojumder, Juwel & Leong, Kin Yuen. (2016). Investigation of potential hybrid renewable energy at various rural areas in Malaysia. *Journal of Cleaner Production*. 139. 10.1016/j.jclepro.2016.07.167.

Kazeem Alasinrin, Fathin Faizah Said, Nor Ghani Md Nor. (2019). Reducing Carbon Dioxide Emissions from Malaysian Power Sector: Current Issues and Future Directions. *Jurnal Kejuruteraan SI* 1(6) 2018: 59-69. http://dx.doi.org/10.17576/jkukm-2018-si

Khelifa, R.F., & Jelassi, K. (2018). A Smart Control System For Solar Photovoltaic Power Supply in Rural Africa. *International Journal of Renewable Energy Research*, 8(3), 1718–1728.

Ozcan, O., & Ersoz, F. (2019). Project And Cost-Based Evaluation Of Solar Energy Performance In Three Different Geographical Regions Of Turkey: Investment Analysis Application. *International Journal of Engineering Science and Technology*, 22(4), 1098–1106. https://doi.org/10.1016/j.jestch.2019.04.001

Raman, B., & Chebrolu, K. (2007). Experiences in Using Wi-Fi for Rural Internet in India. *IEEE Communications Magazine*, 45(3) 104–110.

Reigadas, F. J. S., Fernandez, A. M., Garcia, P. O., & Pascual, J. S. (2008). The Design Of A Wireless Solar-Powered Router For Rural

Environments Isolated From Health Facilities. *IEEE Communications Magazine*, 15(3), 24–30.

Ruiz M.I., Esparcia, J. (2020). Internet Access in Rural Areas: Brake or Stimulus as Post-Covid-19 Opportunity? *Sustainability 2020*, 12, 9619.
https://doi.org/10.3390/su12229619

Suja, S. and Sathish Kumar, T. (2013). Solar based wireless power transfer system, *2013 International Conference on Computation of Power, Energy, Information and Communication (ICCPEIC)*, pp. 93-99, doi: 10.1109/ICCPEIC.2013.6778505.