**Proceeding of International**
Conference on Science and Technology
Lembaga Penelitian Pengabdian kepada Masyarakat dan Dakwah Islamiyah, Universitas Islam Kuantan Singingi, Indonesia, November 10th 2022
DOI : https://doi.org/10.36378/internationalconferenceuniks.v0i0.2829
ISSN 2985-8739
**Page: 78-83**

# The House Project: A Sustainable Alternative For Rural Electrification

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***Abstract***

*In recent years there has been an outburst of interest in the use of renewable energy sources to reduce greenhouse gas emissions. These renewable energy sources are generally putting out dc power and hence some intermediate energy conversion to ac is essential for its use. Unfortunately, this much needed conversion yields not only extra cost to the system but also introduces power loss which consequently reduces system's efficiency. This DC House project aims to utilize the dc energy directly from renewable energy sources without the need for dc to ac conversion. Besides enhancing system's efficiency while reducing cost, the DC House's main use will be in locations where utility grid is out of reach or geographically inaccessible; hence, the opportunity to promote the use of renewable energy sources while providing electricity to those people who are less fortunate.*

*Keywords: DC House, Renewable Energy, Renewable Technology, Sustainable Energy, Rural Electrification*

## 1. Introduction

As of 2019, there were approximately 940 million people who do not have access to electricity [1]. This truly alarming statistic raises several questions about the impacts of globalization in many areas of the world. Despite the globalization of many technologies including advancements in industry, medicine, agriculture, and services, why is electrification still severely lacking?

Traditionally, transmission lines are necessary to transmit large amounts of power generated from large scale power plants to regions of high population density who can use it for commercial and residential applications. A large portion of those without electricity live in rural and remote areas, with a more dispersed population density. It becomes a problem of economics meaning that the high initial cost of the infrastructure (substations, transmission lines, transformers, etc.) is difficult to justify for a small village of a dispersed people. In essence, it is prohibitively expensive to bring the traditional electrical grid to remote areas of the world. This creates an opportunity for engineers to apply new technologies to fulfill these empty humanitarian gaps that still exist despite globalization and huge strides in the development of technology in the western world.

The current primary energy sources for the world come from fossil fuels: petroleum, coal, and natural gas. There are three problems that arise with the use of these resources for energy, and they are in the areas of sustainability, national security, and global warming.

Fossil fuels are a finite resource, this inherently makes them a non-sustainable energy source because they will eventually be completely consumed. There are concerns about the reserve levels of these fossil fuels, and there are many different takes on the remaining quantity. Estimating accurately the levels of fossil fuels is an extremely difficult task, because technology is constantly allowing new sources to be tapped. However it has been estimated that there are approximately 1.65 trillion barrels of proven oil reserves in the world as of 2016 [2]. The world has proven reserves equivalent to 46.6 times its annual consumption levels. This means it has about 47 years of oil left at current consumption levels. This is somewhat alarming, especially considering that the industrialization of high population countries such as China will increase the consumption rate of these fuels. There are a finite amount of fossil fuels remaining on planet earth, so finding alternative and renewable energy sources as well as effective and efficient systems to use them is key to achieving a sustainable future.

A disproportionate amount of the remaining fossil fuel reserves is located outside of the USA. The United States has about 2.13% of the world's petroleum reserves and must import 43% of its annually consumed petroleum from other countries [1]. This creates conflicts of interest for our nation to become reliant on other countries for purchasing fuels in the United States [3]. Figure 1 illustrates how much electricity is produced from hydro, nuclear, and fossil fuels. Renewables are extremely small but have been increasing over time.

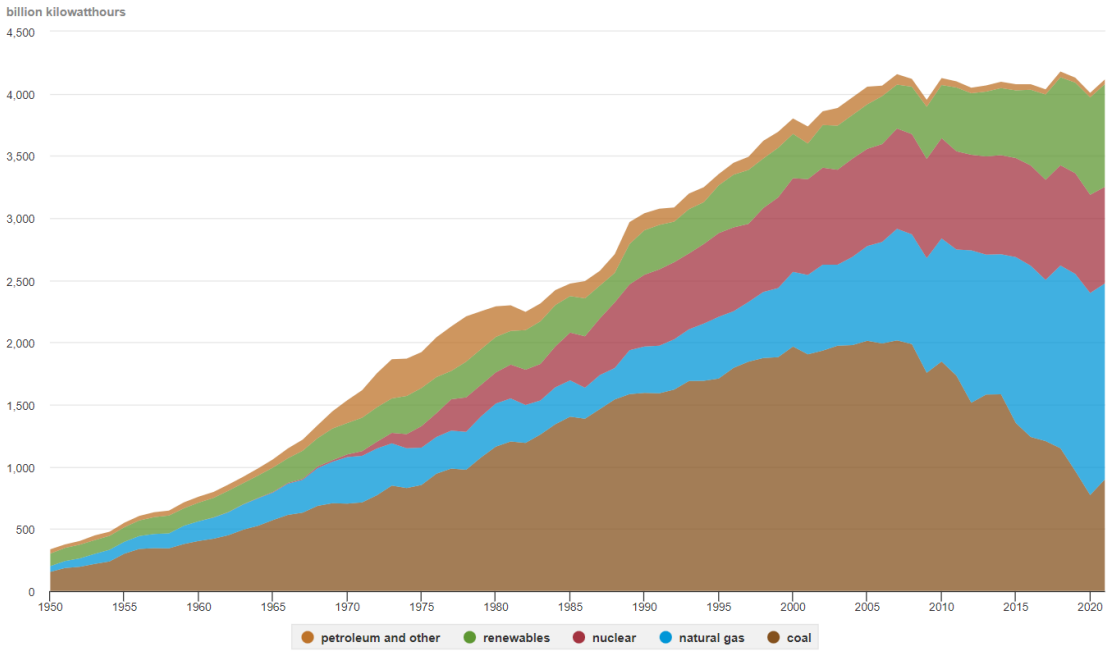

Figure 1. Electricity Production in the US over the past 70 Years

To aim for a more sustainable future in energy use, it is our responsibility to create systems that minimize future use of fossil fuel powered energy. One way to do this is to develop systems that utilize renewable energy sources to supplement and eventually to replace energy generated by fossil fuels. This will result in less reliance on other countries for energy needs, and thus globally creates a more stable future international political climate.

Global warming is a phenomenon where greenhouse gases produced from burning fossil fuels such as petroleum and coal warms the earth. This has been known to cause negative environmental effects which affect both human and non-human life on earth. Renewable energy sources, however, do not emit green-house gases, and hence can help stop this problem from getting worse. Development of technologies that promote the use of renewable energies will proliferate renewable energy use and will eventually replace fossil fuel-based energy.

## 2. Results and Discussions

### Making The Case For Dc

A DC powered electrical system is not a new and an uncommon concept. For example, the electronics in a car or RV are powered on a 12 V DC system with one or more batteries. The car's motor drives an alternator which produces AC voltage. The AC power is rectified to DC and the voltage level is regulated via a voltage regulator. The regulator feeds into the car battery. The regulator controls the power flow to the battery so that the battery is never overcharged. This system is used to power the on-board electronics and lighting in a car. The reason that the car uses DC is for several reasons. DC power is required for many onboard electronics such as the car stereo for example. DC also permits the use of a battery, which gives the car's power system some flexibility. This way, the car's motor doesn't have to be on and powering the car for the lights, radio, and electronics to work. This basic power system is very similar in motivation and function to a power system that incorporates renewable energy sources. It provides a voltage bus that supply DC powered loads, and via battery provides power to those loads when the energy source is inactive (cloudy weather for photovoltaic generation).

A primary weakness of renewable energy sources is that their operation is not guaranteed based on many things such as weather conditions and we need to deliver power to a home that will use the power at any given time. Using a DC system allows the incorporation of batteries to address the issue of uncertainty in renewable power generation. Additionally, because photovoltaics and other renewable power sources natively output DC power, they typically must be run through an inverter to power an AC load. As with any power device, there is an associated inefficiency with the inverter which can range from 95% to 97.5% depending on the manufacturer and type of inverter. The Enphase 230W D380 micro-inverter boasts a 95% CEC weighted average and the Eaton 250kW S-Max inverter has a 96.5% CEC weighted average efficiency. Although this is a relatively high efficiency, it is still significant enough to note especially on such a large scale. The more important problem with inverters isn't of efficiency but rather of lifetime.

Electrolytic capacitors are a necessary component in most inverter topologies. Unfortunately, electrolytic capacitors are notorious for a short lifespan, and result in a typical lifespan of only 5 to 8 years. This necessitates the implementation of maintenance plans that can be costly and require power shutdown during replacements. Both reasons provide strong incentives for us to avoid AC power if possible.

The only final question is of whether a typical home's electrical needs can be fulfilled with DC powered devices. With recent breakthroughs and continued advancement in LED lighting, there is a huge opportunity to use LEDs to fulfil any lighting needs. Additionally, the existing RV and camper market has many DC home appliances available to fulfil any other home appliance needs.

**The Dc House Project**

To promote the use of renewable energy in a more sustainable way, one aspect relates to their energy conversion technology. Traditionally, due to the prevalent use of ac system, renewable energy sources used for off-grid application require conversion to ac power. This has been done despite the fact that the main renewable energy source (Photovoltaics) produces dc output power and internally most of appliances operate on dc power [3]. This in turn creates unnecessary extra power loss during the dc to ac conversion process. With advances in power conversion technology, it has become possible today to develop a purely dc system with dc-dc converter technology from dc sources with the promise of increased energy efficiency, and thus a more sustainable system.

For rural electrification such as remote villages or islands, it makes much more sense economically that distributed power is being implemented instead of its centralized counterpart. To do this, the most commonly used technology is that of portable generator set which runs on fossil-based fuels such as gasoline or diesel. This is indeed not a sustainable solution and thus better solution needs to be sought.

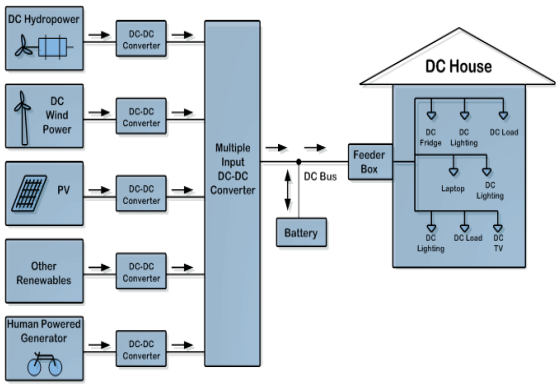


Figure 2. Basic Diagram of a DC House [4]

The DC House project aims to provide a solution for rural electrification by using a purely dc electrical system to allow optimum use of renewable energy and alternative energy sources. This in turns offers multiple benefits. First, DC House promotes a more sustainable solution by not using fossil-based fuels. Second since DC House is a new approach to solving rural electrification; hence, its development opens a whole range of possibilities in sustainable innovations to create key technologies in many different components of the DC House [4]-[7]. This paper focuses on such possibility by providing examples of key technologies currently being developed as well as planned.

**Dc House Components**

The DC-based electrical system goes back as far as the Edison's system. In the late 1880's, the DC system was the standard in the U.S. pioneered by its inventor, Thomas Alva Edison. So, historically speaking, DC system is not new. However, with the DC House project, the use of DC system is unique and offers new challenges due to its strong tie with renewable and sustainable energy sources as well as its implementation of latest and greatest technologies in dc devices. Hence, the door for ideas and innovations especially related to sustainability is now wide open. The following are just few examples.

**A. Energy Sources**

Referring to the block diagram of DC House (Figure 2), we can see that the system may incorporate multiple energy sources, mainly from renewables. Renewable energy for power generation is not new; however, renewable energy source for use in small-scale system is definitely unique. Many sustainable innovations may stem out from this component of the DC House. For example, the hydropower system is now below the range of what people have developed, and thus opportunity to develop new technology to generate power from water stream at power output between 50 to 500W is needed to eventually replace the commonly used diesel generators.

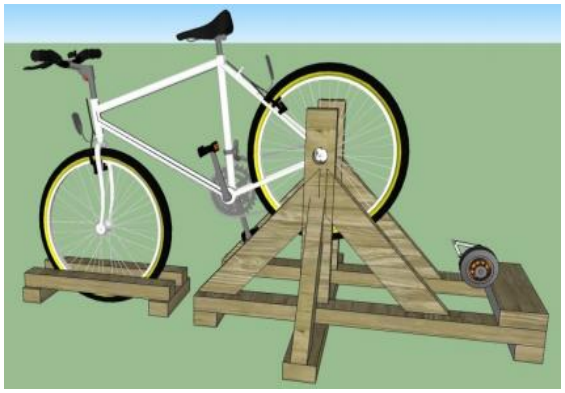

Figure 3. Bicycle human powered generator.

Another sustainable innovation from the source side of the DC House is what the author calls "Human Powered Generator". This method of creating power opens a plethora of creative ideas. The very commonly used method is pedalling a bicycle [8] or cranking a machine (Figure 3) and store the energy to battery. Other means of human-powered generators are the play park generators as shown in Figure 4 which promotes not only a sustainable way of generating electrical energy, but also health and fun.

Figure 4. Play Park Generators at Cal Poly State University [9]-[11].

Another idea to promote sustainability to power the DC House is on redesigning used and cheap machines for use as low-speed generator. Figure 5 shows the car alternator that has been retrofitted at Cal Poly to generate power at low speed.

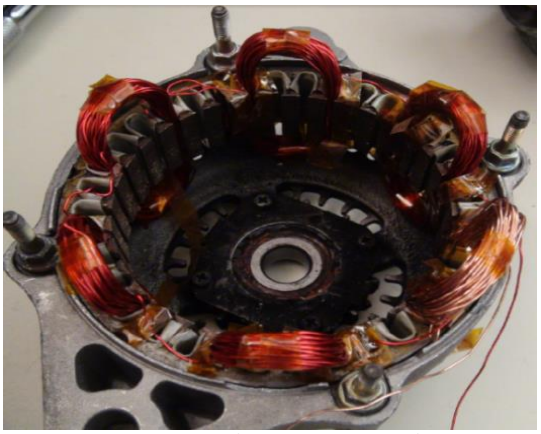

Figure 5. Retrofitted Car Alternator for Low-Speed Generation

### B. Dc-Dc Converter

Another component of the DC House is called Multiple Input Single Output (MISO) DC-DC converter. The DC House is designed such that it will have to use at least two or more renewable and/or sustainable energy sources to ensure continuous supply of energy. The multiple sources will interface with the main DC bus of the DC House through a converter that is able to take in multiple inputs while outputting only one output to the main DC bus of the DC House. The MISO converter offers a more efficient solution than using an individual converter for every source being used. MISO in turns reduces losses associated with dc-dc converter so that more energy can actually be used for the DC House; hence, a more sustainable energy conversion technology [13]-[15].

Figure 6. MISO Converter for DC House [16].

### C. DC Distribution

Moving further to right in Figure 2 we have the main DC bus with the rest of DC distribution system. As we are all aware AC electrical system is the predominant electrical system used to distribute electricity. The DC House is designed with sustainability in mind for its implementation. If a house has been constructed to operate with ac

system, then changing the system to DC should be a relatively smooth transition. In particular, the move to the DC system should incorporate the use of the same ac wiring system and lighting fixtures. This not only minimizes the cost of implementing DC House, but also promotes sustainability by reusing what has been used by the general population.

### D. DC Loads

Finally, at the end of the electrical system are the loads. For rural areas, the main residential load is the lightings. Additionally, refrigerator is also needed for the village not to store food, but rather for medicines in a health clinic. Again, there are quite a bit of ideas for sustainable innovation offered on the load side. One example which is currently being developed at Cal Poly is the development of dc lightings using the commonly used Edison's screw base. Recently, the development of dc lighting (using LED) for use in ac system has been progressing in an alarming rate [6][7] that many house appliance stores in the U.S. sell these "dc" light-bulbs. The main benefit of using LED or dc-based lighting is that they are very efficient, e.g. uses a fraction of energy for the same lumens provided by its ac light-bulb counterparts. This is in itself promoting a more sustainable use of energy.


Figure 7. Cal Poly's Dc Light Bulb [17].

### DC House Prototypes

Since its inception in 2010, the DC House project has attracted interest from many universities in Southeast Asia, mainly in Indonesia, Philippines, and Malaysia. To demonstrate the operation and feasibility of the DC House, and to promote DC House technology adoption, several DC House prototypes have been constructed in the US (Cal Poly State University), Indonesia (Universitas Padjadjaran), and Philippines (Technological Institute of Philippines). Figure 8 shows the three prototypes. The author invites other universities to develop and build the DC House prototype both for a demonstration site as well as for a living laboratory.


Figure 8. DC House Prototypes

## 4. Conclusion

The DC House project is a humanitarian effort aimed to increase rural electrification while promoting the use of renewable energy sources. The project is a long-term project consisting of short-term goals and initiated at Cal Poly State University, USA where a DC House prototype currently resides. It is our hope that DC House will be tested and implemented in many countries around the world in the near future. For details, the author has established a website dedicated for the DC House project at dchouse.calpoly.edu.

There are a lot more to be done and explored to make the DC House project the most viable solution to the world's need of electrification especially in rural and remote areas. The authors

therefore welcome more collaborations and ideas from academia, industry, as well as government agencies.

## Reference


[1]. H. Ritchie and M. Roser, “Access to Energy”, https://ourworldindata.org/energy-access

[2]. World Oil Reserves, https://www.worldometers.info/oil/

[3]. Engelen, K.; Leung Shun, E.; Vermeyen, P.; Pardon, I.; D'hulst, R.; Driesen, J.; Belmans, R.; , "The Feasibility of Small-Scale Residential DC Distribution Systems," IEEE Industrial Electronics, IECON 2006 - 32nd Annual Conference on , vol., no., pp.2618-2623, 6-10 Nov. 2006.

[4]. Taufik, “The DC House Project: An Alternate Solution for Rural Electrification”, IEEE Global Humanitarian Technology Conference, October 2014.

[5]. Taufik, "Research Experience on the DC House Project for Rural Electrification", Proc. of International Conference on Computational Science and Computational Intelligence - Symposium on Education, December 2017.

[6]. Taufik, "Rural Electrification: The DC House Solution", The Economist, Power Up: Perspectives on Indonesia's Energy Future, January 2014.

[7]. Soeprapto, Taufik, S. Sidopekso, M. Taufik, "The DC House Project for Sustainable Rural Electrification", Proc. of 2012 International Conference on Sustainable Energy Engineering and Applications, November 2012.

[8]. Natarajan, V.; Baxi, A.; Padmanabhan, R.; Mageshkumar, V.; “Low-Cost Bio-Mechanical Energy Generator for Off-grid Users”, 2011 IEEE Global Humanitarian Technology Conference, 2011, Page(s): 253 – 256.

[9]. J. Avelar, J. Galindo, J. Ramos, “Swing Human Powered Generator: For the DC House Project”, Senior Project Report, Cal Poly State University, 2013.

[10]. S. Ashe and S. Navarro, “Merry-Go-Round Human Powered Generator”, Senior Project Report, Cal Poly State University, 2014.

[11]. W. Varsh and J. Healy, “Human Powered Generation - Seesaw: A DC House Project”, Senior Project Report, Cal Poly State University, 2012.

[12]. Y. Carillo, “Retrofitting a Car Alternator for Low-Speed Power Generation”, Senior Project Report, Cal Poly State University, 2012.

[13]. T. Taufik, K. Htoo and G. Larson, "Multiple-input bridge converter for connecting multiple renewable energy sources to a DC system," 2016 Future Technologies Conference (FTC), 2016, pp. 444-449, doi: 10.1109/FTC.2016.7821646.

[14]. M. Taufik, T. Taufik and T. Wong, "Multiple-Input Single-Output converter for renewable energy sources," 2012 IEEE Symposium on Industrial Electronics and Applications, 2012, pp. 130-135, doi: 10.1109/ISIEA.2012.6496614.

[15]. K. Chan, Taufik, R. N. Hasanah, Suprapto, M. P. Jati and A. Nasuha, "Multiple Input Single Output Converter with Uneven Load Sharing Control for Improved Efficiency," 2021 IEEE Conference on Energy Conversion (CENCON), 2021, pp. 46-51, doi: 10.1109/CENCON51869.2021.9627255.

[16]. A. Gallardo, “Design and Construction of 1800W Modular Multiple Input Single Output Non-Isolated DC-DC Converters”, Master’s Thesis, Cal Poly State University, 2017.

[17]. Taufik, K. Liang, and M. Taufik, "Design and Simulation of DC Light Bulb for DC House", Proc. of 2013 PIPS, May 2013.