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Experimental Comparison and Analysis of At-Home Urban Clean Energy Generation

Original Article

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Abstract: This study evaluates potential methods of harnessing sources of energy in everyday city life to generate electricity. By utilizing existing, underutilized (or non-utilized) sources of energy for electricity generation, use of hydrocarbons for power can be reduced. Specifically, natural light, artificial light, wind, and artificial water sources were evaluated. A series of tests to measure the efficacy of a solar panel in natural city light, a solar panel under different forms of artificial light, a wind turbine at average natural wind speeds, a hydroelectric turbine in the flow path of a sink, and a hydroelectric turbine in the flow path of a shower were conducted. After that, software was used to plot trends in the data to determine how factors like wind speed and lightbulb wattage affected electrical output. Overall, the wind turbine was by far the most efficient, generating 10 to 21 volts, followed by the solar panel under natural light, generating 2 to 5 volts during daylight hours. There were also other results of note, such as that water velocity affects the amount of electricity generated by a hydroelectric turbine more than water quantity does. While the results do not immediately suggest an alternative electricity generation system, they can be used to make use of current technology more effectively.

Keywords: renewable energy • solar power • wind turbine • hydroelectric

1. Introduction

Climate change is one of the foremost challenges facing the Earth, threatening the survival of most life with rising sea levels and increasing temperatures [1, 2]. Globally, byproducts of energy production are the single largest source of greenhouse gas emissions, which total 25% of all emissions, primarily in the form of carbon emissions [3]. Clean energy is a form of energy production that does not release greenhouse gasses [4, 5]. There are currently seven primary methods of generating clean energy: solar, biofuel, geothermal, wind, hydroelectric, tidal, and nuclear [6, 7]. Here, only photovoltaic (solar), wind, and hydroelectric systems are considered.

Solar energy is one of the most promising renewable energy sources, as it utilizes the sun's radiation, the initial source of most energy on earth [8, 9].

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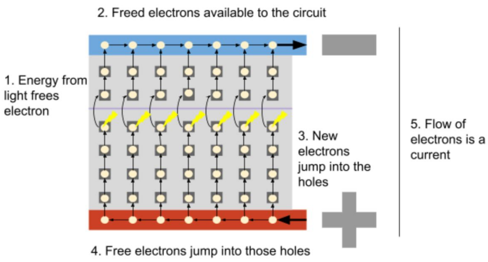

Figure 1. **Diagram showing how a photovoltaic cell works. Note that the electrons jump due to the photovoltaic effect.**

A photovoltaic system, or solar panel, utilizes the photovoltaic effect to generate electricity from sunlight [10]. In the photovoltaic effect, since each wave of light has an amount of energy inversely proportional to its wavelength, light striking an electron in matter may allow it to jump to another molecule [11, 12]. In a solar panel, sunlight strikes an electron in an n-type semiconductor layer, and causes it to jump over a junction to a p-type semiconductor layer [13–15]. This leads to an electron flow between the two layers of the solar panel, the flow of which is electricity (see Fig. 1). Another type of solar panel is a multijunction cell, which uses multiple solar panels stacked on top of each other to more efficiently use light [16, 17]. Unfortunately, solar energy systems tend to be large and costly in relation to the amount of energy they actually generate [18].

Wind energy, primarily wind turbines, use wind to turn a propeller, driving a generator [19]. This is one of the fastest growing types of renewable energy, soon expected to overtake hydroelectric and become the second largest source of clean energy [20, 21]. There are concerns over their effectiveness in less windy areas, especially near the equator where the Coriolis effect is weaker, as well as its impact on bird species and their migration patterns [22].

Hydroelectric uses water to generate electricity, and is the second largest source of clean energy [21, 23]. There are four main types that exist or are being developed: conventional hydroelectric, conventional tidal, pumped storage systems, and ocean thermal energy conversion [24]. Conventional hydroelectric uses a dam in a moving waterway to force water through a series of turbines [25, 26]. Similarly, conventional tidal also uses dams and turbines, but instead places them in a basin, using the tides to drive the turbines [24, 27]. Pumped storage systems place turbines in the path of water from higher to lower elevations, and then pump it back when there is excess electricity [28]. However, there are significant ecological concerns, as these divert the water's flow, potentially damaging many ecosystems [22]. Although still being developed, ocean thermal energy conversion is a promising method of electricity generation that uses the temperature and salinity gradient between ocean depths to generate electricity [27–29].

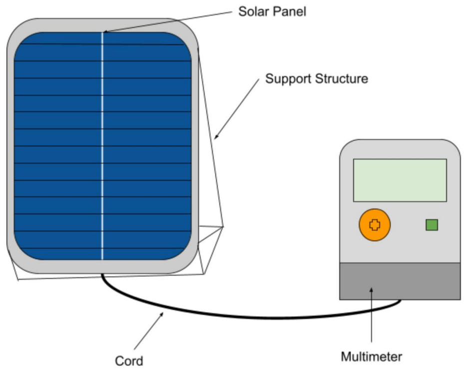

Figure 2. **Solar panel and multimeter.**

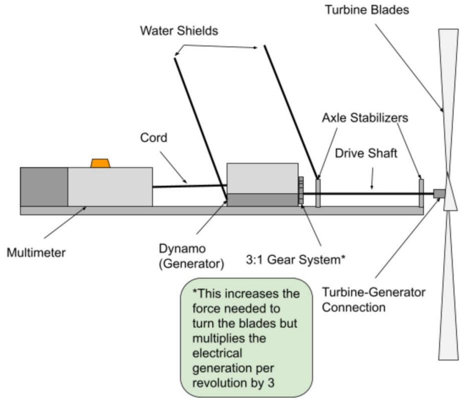

Figure 3. **Water turbine and multimeter.**

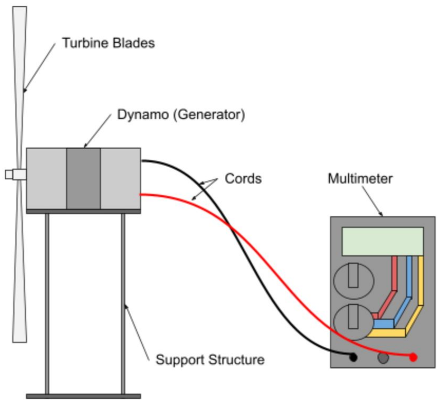

Figure 4. **Wind turbine and multimeter**

2. Methods

Six different types of tests were conducted: a solar panel under natural light, a solar panel under artificial light (light bulbs), a solar panel under a night light, a hydroelectric turbine under a sink, a hydroelectric turbine under a shower, and a wind turbine (see Figs. 2, 3, and 4). The solar panel under natural light experiment was conducted by placing a solar panel in the same spot on a windowsill in clear view of the sun, and its output (in voltage) was measured 13 times a day at specific intervals during the daylight hours for 5 days in a row (see Fig. 2). The solar panel under artificial light experiment was conducted by placing different light bulbs in the same light fixture with dark surroundings, placing the solar panel 3 feet away, and measuring the electrical output in volts at 10 times with equal intervals in between for 5 minutes, 10 minutes, and 15 minutes (see Fig. 2). The experiment with the solar panel under night light involved placing the solar panel 6 inches away from a night light in dark surroundings with various bulbs inside, and the same procedure for gathering data as in the solar panel under artificial light experiment (see Fig. 2). The experiment with the hydroelectric turbine in the flow of a sink was conducted by placing a hydroelectric turbine under the flow path of a sink under both concentrated and non-concentrated water flows, both with the same flow rate, and the electrical output in voltage was recorded using the same procedure as for the solar panel under artificial lighting (see Fig. 3). For the hydroelectric turbine under the flow of a shower experiment, the turbine was placed 6 inches away from the shower head under low, medium, and high flow concentrations, again with the same flow rate, and data was gathered every second for 15 seconds on each setting (see Fig. 3). In the wind turbine experiment, a wind turbine was placed on the roof of a car with no wind, driving at speeds calculated for first to third quartile average wind speeds at a height of one building story (calculated using a series of equations to scale average wind speeds to that height) (see Fig. 4) [30–32].

3. Results

Table 1. **Output for the turbine in concentrated vs. non-concentrated sink flow.**

Data Reading	Concentrated	Non-Concentrated
After 1 second	1.3 volts	2.2 volts
After 10 seconds	1.4 volts	2.0 volts
After 30 seconds	1.2 volts	1.8 volts
Average	1.3 volts	2.0 volts

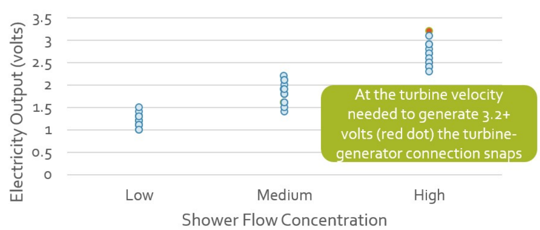

Figure 5. **Output for the turbine for different flow concentrations in the shower**

Figure 6. **Output for the solar panel for different types of night lights**

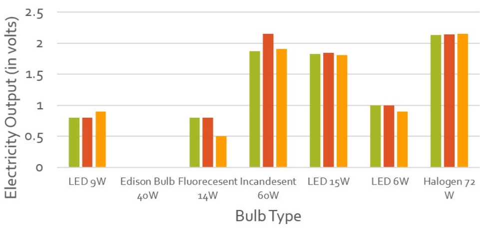

Figure 7. **Output for the solar panel for normal lights**

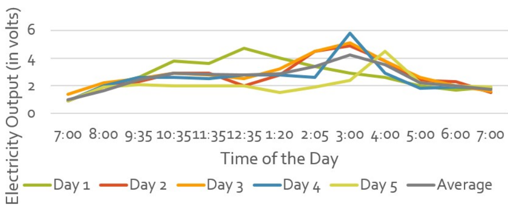

Figure 8. **Output for the solar panel in sunlight**

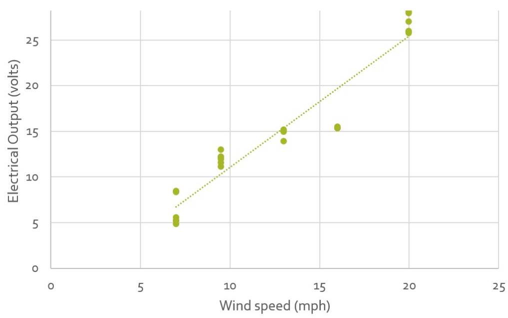

Figure 9. **Output for the wind turbine for different wind speeds**

Data was analyzed through the construction of the graphs (see Tab. 1 and Figs. 5-9). One particularly interesting trend noticed was that the less concentrated the water flow, the more electricity was generated by the hydroelectric turbine in the sink, but not for the shower (see Tab. 1). Another interesting trend is that LED lighting causes the solar panel to generate less electricity (see Fig. 6). An interesting lack of a trend was that there was no correlation between lightbulb wattage and the electrical output of the solar panel (see Fig. 7). Yet another interesting, yet expected, trend is that as wind speed increases linearly the amount of electricity generated by the wind turbine (see Fig. 9).

4. Discussion and Conclusions

Overall, the wind turbine was the most effective method of clean energy generation, followed by a solar panel in natural light. The wind turbine generated 10-21 volts, and the solar panel generated 2-5 volts. In addition, the amount of electricity generated by a wind turbine increases with increasing wind speed, and since wind speed increases with height, the amount of electricity that can be generated by a wind turbine would increase dramatically by being placed higher up (e.g., a skyscraper's roof), which could generate large amounts of energy (extrapolated to an estimated 2000 volts at average wind speeds for a 10-story building), and thus help fight climate change. The hydroelectric turbine under different sources of artificial running water and the solar panel under artificial lighting were less effective, generating 1-3 and 0-4 volts respectively (see Tab. 1 and Figs. 5 and 6).

However, this project did have some significant limitations, including a relatively small sample size and number of designs that were tested, as well as the limited situations it was tested in. A major benefit of this study is the novel nature of the generation methods tested. Previous literature focuses either on clean energy generation outside of households, conversion of households into smart homes, thus reducing the energy consumption, or the installation of large-scale rooftop or yard solar panels. This study adds on to that work, comparing solar panels to other methods of clean energy generation around the home, and utilizing the solar panel in different scenarios.

The next step in this project would be to test the wide variety of clean electricity generation methods that were not able to be tested because of the pandemic, such as testing an internally applied version of OTEC in AC and heating units to reduce net electricity consumption, or pressure plates as sidewalks. In addition, expanding the scope and scale of testing for the clean energy generation methods, such as testing these in a suburban setting or more varied apartments would help increase the significance of these results. Testing the efficacy of wind turbines at high heights, and seeing if they generate the predicted amount of energy, and seeing if the wind-tunnel effect could be used to cause the wind turbine to generate more electricity would also help increase the efficacy of home electricity generation, and hopefully cut down on the amount of greenhouse gasses emitted to power homes.

Conflict of Interest

Authors of this article declare that they have no conflict of interest.

Human Studies/Informed Consent

No human studies were carried out by the authors for this article.

Animal Studies

No animal studies were carried out by the authors for this article.

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