

Self-Sustaining Light Post System Utilizing an Electromechanical Generator



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Abstract:

The amount of energy used during the night by the street lights is a huge impact on the Los Angeles environment and economy. Over 140,000 light poles are being used during night time. When it comes down to cost the city of Los Angeles pays about 15 million dollars for the light poles. The environmental effect of today's street light poles is the carbon dioxide release that leaves 110,000 metric tons of carbon dioxide¹. For this project, the main focus is the light poles of the city of Los Angeles. Thus, the idea proposed is an environmentally friendly outdoor light source that diminishes the amount of energy wasted and carbon emissions by relying only on renewable forms of energy. The goal is to reduce the amount of electrical lighting used by street lights and implement a light pole where renewable energy is used to power it. This idea will reduce city light costs, carbon dioxide, and overall help cities implement eco-friendly street light poles.

¹ Maddox, T. (2016, September 23). How LA is now saving \$9M a year with LED streetlights and converting them into EV charging stations.

Present Technology:

The technology that is being utilized to create the prototype consists of solar panels and LED lights that are efficient in the usage of energy. The LED lights will be powered by the energy provided by the generator gaining its momentum from the falling weight. In addition, a pulley system, weight, generator, and circuit will be used. A solar panel will be located on top of the lamp post, connected using wires to the pulley system to power the light or the pulley system in case of assistance. In other words (DC) or direct current takes place during this process. This will help us keep the cycle going by powering the motor. A motor, placed inside the top, will be used in order to produce electricity when the weight goes down. Ultimately, the device will convert potential energy into kinetic and power the LED light by gradually descending a weight to the bottom (kinetic potential energy).

Solar panels are one of the most recent upgrades there is in our society, revealing the process of sun rays converting into electricity. Then simplified systems that will allow our product to work by having ratios of gear systems that will help us keep the light-powered on for long. A limitation of the present technology that will be addressed in the project is the capturing of energy. Currently for the project, solar panels are being used to capture energy during daylight hours. Therefore, the main source of energy is the sun during the daylight which charges the solar panels to provide function and energy during the night, powering the LED lights. However this can present a problem if the amount of lumens decreases. Also to make the prototype work the correct ratio of speed, weight, consistency and torque for the prototype to work had to be found.

Moreover, there are starting to be seen similar ideas with kinetic energy being converted into electricity like the soon to come “Las Vegas downtown art district.”² The new technology is destined to convert pedestrians' footsteps into energy by placing kinetic pads that will charge a battery. Although the efficiency percentage is not the best with the pads, move over into the newly in progress “freeway” in China paved with solar panels.³ Cars running over the panels being charged every second can be a huge advantage to society. All said some limitations can be brought up like theft or even industrial espionage with solar panels being embedded into the streets.

For this project the main purpose is to reduce the amount of energy produced from excessive energy of electric power plants. Obtaining energy from a certain source is the limitation of present technology.

² Las Vegas Gambles With Pedestrian-Powered, Solar-Kinetic Streetlights - CityLab. (2020).

³ Free Power From Freeways? China Is Testing Roads Paved With Solar Panels. (2020).

History:

As the years pass the evolution of powered light sources and their efficiency being greater. However the amount of electricity being used has increased exponentially bringing effects to our atmosphere. According to Ghana the electricity has increased 12 percent every annum from 1999 to 2009⁴. In addition, the global energy development has increased since the 1980 to 2013, 14800 Twh. As it goes more in depth with the usage of energy, the distribution of energy around the world. In the year 1980 most of the electricity was more than 40% used in Europe. Light conservation has increased over the years. Also the amount of energy in every country has fluctuated. To add on, in Los Angeles alone they have used 550 million kWh. LA is one of the biggest economies in the nation of the United States and around the world. In recent years the energy consumption has increased yet the efficiency of reducing the negative effects have also increased using hydroelectric generators, wind turbines, and solar photovoltaic energy feeders. As shown there is still space in n improving our sources of light.

Future Technology:

In twenty years, the self-sustaining light post system (SLP) will rely solely on its own electricity to illuminate the night sky. Consequently, it will save the United States \$2 billion generated by current street lighting. Lamp posts used currently consume as much electricity as 1.9 million homes and the United States uses as much as 26 million streetlights⁵. As a self-sustaining device, the prototype light post will have no electricity costs and will provide huge cost savings to cities implementing this improved light post.

Not only will the device save the United States in electricity costs, but it will also incorporate recycled materials such as aluminum, steel, and plastic. In fact, most of America's landfill waste is sent off overseas to China where it accumulates in landfills or is incinerated. However, ever since China's ban in 2019, both waste and recyclable materials have been taken to incineration facilities⁶. This has contributed significantly to air pollution.

By incorporating recyclable materials to build self-sufficient street lights, the United States would drastically reduce the amount of waste contributing to air pollution and landfill waste. Furthermore, current tariffs placed on aluminum and steel imports overseas will

⁴ U.S. States - Search - U.S. Energy Information Administration (EIA). (2020).

⁵ Smalley, E. (2012, August 2). Streetlights: Changing our night sky, one lamppost at a time - The Boston Globe.

⁶ Milman, O. (2019, February 26). Since China's Ban, Recycling in the US Has Gone Up in Flames.

drastically inflate the price of domestic manufacturers⁷. By using recycled metals, the SLP can avoid such costs.

Being an off-the-grid device, the SLP can easily be fixed within 3 days regardless of background knowledge in engineering. Within those 3 days, the light post will begin to use its solar panels and thermoelectric device as backup sources of power. Moreover, the SLP will send out a signal to the monitoring system to notify that a repair is needed. This will provide more than enough time to fix the gearing. Therefore, the light post will greatly benefit underprivileged communities in third world countries lacking electricity to power their night skies.

Shown in Image 1, the light post will utilize a pulley system to lift a large weight within a duration of 13 hours. Once the weight reaches the top, the LED light will activate and remain active until the weight reaches the bottom. A DC motor will ensure the gears in the back work quickly to keep the LED from flickering.



Image 1. Light Post Prototype

On the other hand, the front gears will turn slowly to keep the LED running throughout the night. Image 2 shows the gearing system of the prototype. The main source of power will be the motor, where kinetic energy will be converted into electricity. Nevertheless, if the motor were to stop working, the light post will rely on its backup power source: a solar panel during the day and a thermoelectric device during the night.

⁷ Staub, C. (2018, March 6). Recycling industry could see variety of metals tariff impacts.



Image 2. Prototype' Gearing System

Furthermore, a light sensor will signal when the weight should be lifted or dropped. Once the light sensor detects a sufficient amount of lumens during sunrise, the weight will descend and the LED light will turn off. Similarly, when the light sensor detects a drop in lumens during sunset, the weight will begin to ascend.

Breakthroughs:

The most significant breakthroughs that present feasible components to designing the SLP are gravity lights, concrete pillars, and thermoelectric devices. Due to the fact that these breakthroughs were made recently, technology like the SLP that uses these components at a larger scale is yet to exist. For instance, outdoor lightings that incorporate thermoelectric devices do not exist due to a lack of development.

Modern gravity lights, shown in image 3, are not designed for the outdoors. Although gravity lights propose an optimal method of producing electricity using heavy objects with a DC motor, gravity lights are not durable enough to endure outdoor conditions. Therefore, gravity lights are still not suited to illuminate the dark skies.



Image 3. Gravity Light by Deciwatt

Likewise, concrete pillars, shown in image 4, are not economically efficient at the moment. While concrete pillars can store potential energy for later use, creating one cost millions of dollars⁸. The intention is to implement the device in large, populated communities that use large levels of electricity to light up the streets during the night. As a result, incorporating concrete pillars into Lumi's design is counterintuitive.



Image 4. Energy Vault stores potential energy for later use

There are several technologies that would need to be further developed to make the SLP a reality. These technologies include solar panels and thermoelectric devices. The SLP's primary source of power will be a DC generator to convert mechanical energy to direct current electricity. However, as backup sources of energy, the device will also rely on solar panels and radioactive cooling in the case that the primary source of power was to fail. Given that the process of converting radioactive cooling into electricity is still in development, there are not enough resources to generate enough power using this method alone⁹. Image 5 shows the large scale thermoelectric device that would serve as Lumi's secondary power source.

⁸ Grossman, D. (2019, October 14). Are Concrete Blocks the Next Batteries?

⁹ Ciaccia, C. (2019, September 20). Breakthrough device can generate electricity from the night sky.

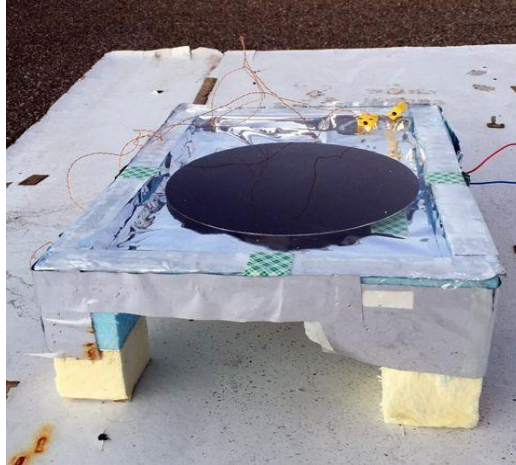


Image 5. Thermoelectric Device uses radioactive cooling

Current thermoelectric devices, as shown previously in image 5, do not generate enough electricity to power small LEDs, much less large lamp posts. Although thermoelectric devices employ a sustainable and renewable form of energy that is abundant at night, the technology itself cannot effectively convert radioactive cooling into electricity. .

Regardless, an experiment can be simulated using a solar panel and a DC motor to resemble a DC generator. Using the solar panel and motor, a prototype can be tested and built out of aluminum, gears, and string. With the experiment, the lifespan of an LED in terms of time in seconds can be measured as well as the intensity of the light in lumens. The claim that will be tested is that the prototype will provide its own sufficient energy to power the LED for longer than one minute. The data that would be collected from the experiment would be time as the independent variable and lumens as the dependent variable. The solar panel would power the system and the DC motor would allow the pulley system to activate.

Design Process

Before creating any designs and identifying the problem the team used the ability of empathizing towards the community. Living in a suburb of Los Angeles there's at least 215,000 street lights and each light pole wastes from 35 watts to 250 watts. Remember that the energy that is used to power the light poles are non-renewable, meaning that they do not come back. Since light poles use a lot of energy a problem statement was derived. The problem that was identified was how can electricity be generated self-sufficiently without depending on non-renewable energy to power street light poles. After identifying the problem, a total of three designs were brainstormed that were possible solutions to the problem. The only criteria was to not use non-renewable energy to power the light pole.

The first design consisted of using electroluminescent technology. Electroluminescent is a semiconductor that is able to produce light by electrical current or electrical field. The features that made this technology possible were the low wattage, longer life span and no external circulatory system is needed. Image 6 shows how electroluminescent works.

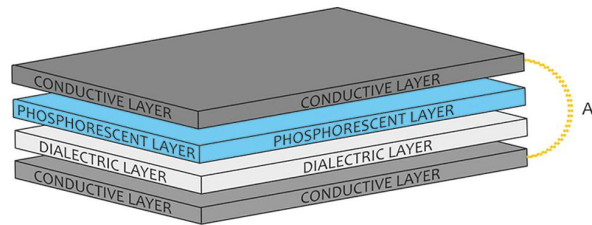


Image 6: Electroluminescent layers

Electroluminescent feature of low wattage was good to conserve more battery life span, but this was also a weakness for a street light pole. The amount of light produced by lumen is very low per watt. In other words to place a light pole with electroluminescent will not be enough to light streets for people to see when walking. Therefore the idea was rejected.

The second alternative idea was to only use solar panels to store energy for the street light pole. A good feature of using a solar panel is that during the day the energy collected by the sun can be stored. Then at night that energy can be used to power the street light poles. Secondly, solar energy is a renewable energy which is good ,as the goal is to reduce the amount of non-renewable energy consumption. One of the weaknesses found in using solar panels is the change of weather. If there is no sun then the light poles wont get any solar energy and at night they won't be any light source. Nextly, to produce enough light the size of the solar panel increases. Image 7 shows the number of watts produced by a large solar panel. This is a weakness because placing a big solar panel into a street light pole will take a lot of space. Therefore the design was rejected.

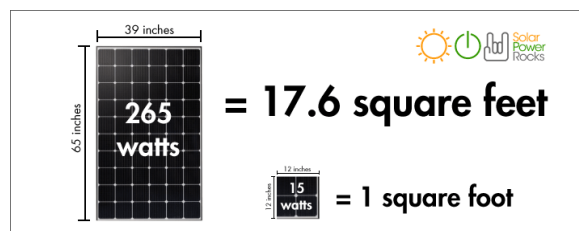


Image 7: Size of a solar panel to produce Power (W)

The third design was to implement a motion sensor into the street light poles. Having a motion sensor will allow to conserve the amount of energy being used in a light pole. The features of the motion sensor is that it uses heat and light to detect the motion. The motion sensor will only be turned on when it detects human body heat. It will remain on until no body heat is detected. The weakness of using a motion sensor is that if the weather is below 35 °C the motion sensor won't work. The prototype will have to be reliable in any type of weather. Therefore using a motion sensor would not be as efficient.

After generating possible solutions and identifying the flaw of each idea the fourth idea was the one. The final solution was inspired from a “gravity light”. Image 8 depicts how the gravity light works and a sketch on Image 9 of how it will be implemented into a street light pole.

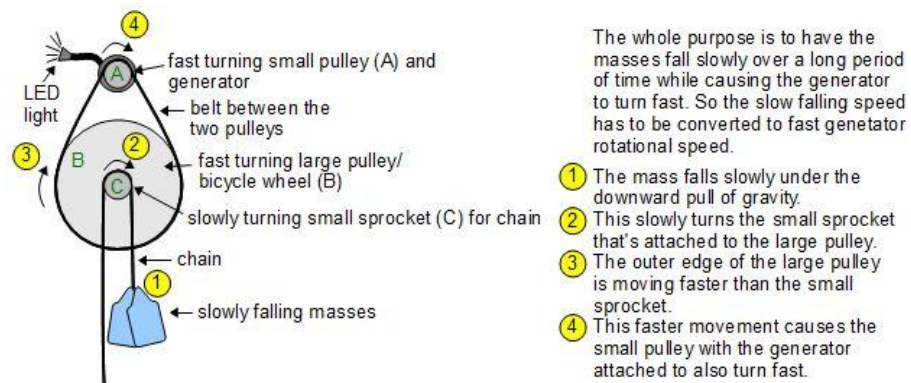


Image 8. How gravity light works

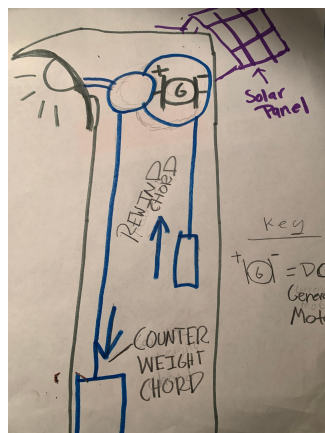


Image 9: Quick sketch of brainstorm idea

The features that made this idea better than our previous designs is the implementation of solely using gravitational energy to produce light. By having a mass attached to a string it will

slowly be pulled down by gravity. Then the gearing system will spin the DC motor which is connected to the LED lights. The main feature of this design is using gravitational energy, the gearing system and the mass to produce energy. Most importantly it will not rely on non-renewable energy. At the moment the prototype is under construction and testing the fourth step of the Design Process. Image 10 shows the the SLP prototype.



Image 10: Construction of Prototype

Using the Design Process help the team finalize the new solution the Self-sustaining Light Post System Utilizing an Electromechanical Generator. The Design Process has helped find a solution to the problem statement. In the future the City of Los Angeles will save more money as there is no need to use any power plant to install the light poles. All the energy will be created by mechanical energy.

Consequences:

Like any other design, there are pros and cons that come along, but there are more pros than cons that make this project an eco-friendly alternative. It would be a drastic improvement from the light posts used today. Pros that come along with this product are the lack of electricity costs given the light post system is self-sufficient. Electricity produced from outside sources would not be needed since the electricity will be produced using the pulley system and the DC motor. Therefore, this will save millions of dollars spent on electricity used for streetlighting. The prototype is an off grid lamp post. Having an off grid lamp post will reduce a \$15 million cost of energy which can go towards other city needs. The city of Los Angeles made some changes making their light poles be composed of LED lights and as of now it has saved over 9 million dollars indicating that with the idea of a gravity light post prototype the total annual cost can be

reduced¹⁰. In addition, the light street post will conserve a total of 30 million barrels of oil annually here in the U.S. As of now, the U.S wastes about 2 billion dollars for street lighting annually and 8.2 tons of coal to provide lighting at night.¹¹

To add on, there are about 304-352 street lights, showing that not all countries have street lighting provided. With this project idea, light can be provided for third world countries who can't afford the cost. Many countries are uniting to conserve energy by becoming part of a LED street lighting project where energy will be conserved, cost will lower, and light posts will have a long lifespan. Even though the goal of energy conservation is emphasized with the LED project the cost countries have to invest is a total of \$53.7 billion dollars in which many third world countries can't afford.¹² The energy conservation light post project won't be of high cost for these third world countries because of the off grid and easy installation. Lastly, when it comes to the mechanics of the prototype mechanical failures with the gearing or pulley system can come forward. For this reason a backup battery will be installed storing energy from a solar panel. If at any time of the light post lifespan there is a mechanical failure the backup battery will provide enough energy for at least three days so any mechanical failure can be fixed. In general the prototype shouldn't have any major complications or failures instead it will be an energy conserving and cost saving light post.

¹⁰ Maddox, T. (2016, September 23). How LA is now saving \$9M a year with LED streetlights and converting them into EV charging stations.

¹¹ Eric Vandernoot, F. (2020). Light Pollution Wastes Money and Energy. Retrieved 10 February 2020,

¹² Pnewswire.com. (2020). *Global LED & Smart Street Lighting Market (2015-2025)*.

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