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Hydropower as a Feasible Option of the University of Richmond

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Abstract

As the University of Richmond moves forward in achieving its sustainability goals, it made a decision to invest into a solar array in Spotsylvania, VA in order to offset their energy consumption with renewable energy. However, this solar array has been controversial for many of the residents in Spotsylvania. My senior seminar class has tasked itself with investigating all aspects of the University's decision to partner with sPower. This paper will analyze the potential alternative energy sources that the University can possible consider, in particular, hydropower; thereby, determining if hydropower is a potential viable option the University of Richmond can use to offset its energy consumption.

Introduction

As the University takes on the challenges of living up to it's sustainability initiative, it has decided to take a close look at its energy production and emissions. To uphold their commitment, the University of Richmond has an ambitious goal of complete carbon neutrality by 2050. Currently, the University of Richmond uses 41,000 MWh annually (Andrejewski, 2019). As a result, they have decided to invest into solar energy. In particular, contributing to a 20 MW solar array that is to be erected in Spotsylvania

County, Virginia which will be a part of sPower 500 MW facility. The Spider Solar project is expected to produce 41,000 MWh of solar energy. This will make the University the first higher education institution, in the southeast, to match 100% of its electricity demand with solar power (Andrejewski, 2019). Furthermore, this project is set to reduce emission by 60% lower than 2009 levels, negating 19,720 metric tons of carbon (Andrejewski, 2019). This array will not only serve a purpose in offsetting energy consumption of UR but will serve as living lab where students can travel to the site and learn about the intricacies of solar power.

However, though the solar array will provide many benefits to the community surrounding the University of Richmond and other stakeholders, it has been seen as controversial investment. Citizen of Spotsylvania have fought tirelessly to get site proposals rejected. Residents feel as if this solar facility is being forced upon them and will have negative effects economically, socially, and environmentally. Therefore, my group has been tasked with the job of analyzing feasibility of potential green alternative energy sources that the University can invest in that will still help meet their energy goals by 2050. This paper is taking a close look at the different forms of hydropower (micro, small, and hydro pump storage) as alternative source for the University of Richmond.

Literature Review

Any form of alteration regarding the environment, whether it is for construction or restoration, we are often familiarized with two concepts--land use and environmental impact. These two ideologies are the driving force for large companies in the decision making processes that sustains our lifestyle. Especially in this case, where my research group is in pursuit for the best alternative energy source that meets the University of Richmond energy needs. Constructing such structures, dams, will impact the immediate environment it is located in. Dams are renown for being the most devastating form of alternative energy, they require a great deal of land use and thus their environmental impact is severe (Huan Li, 2018). Dams cut a connected river and/or stream into two separate bodies of water, as a result, it creates two ecosystems. This can be problematic for previous existing ecosystem characteristics such as migrating fish which can interrupt their spawning habits.

Dams can cause sediment to build up,sediments are crucial in maintaining certain physical process and habitats downstream of dams. Moreover, the drastic transition from a free flowing river ecosystem to a man made reservoir can result in changes in chemical composition, temperature, and dissolved oxygen (Huan Li, 2018). These changes are not suitable for aquatic plants and animals that reside in a river ecosystem. Reservoirs contain non-native species that outcompete and undermine the river's natural communities. Land use is not only considered in the construction of the reservoir but also in the construction of access roads for project needs, powerlines, and the complete flooding of an area (Zema, 2016). Land use change is one of the biggest drivers of biodiversity loss. River systems are sensitive to such changes in their ecological makeup, which is why changes to their land use can be catastrophic to the environment. In conclusion, these two ideologies, land use and environmental impact, must be used when considering hydropower and all of its negative impacts.

Background

When discussing fossil fuel energy production, the first thought that pops in mind are its environmental impacts and land use controversy. Quickly, majority, of people would refuse for these facilities to be built near their homes or cities because of fear of pollution and other adverse effects. This the opposite public opinion when renewable energy is mentioned. Generally, people support the production and construction of alternative energy, until it is in their backyard. Any form of alteration regarding the environment, whether it is for construction or restoration, we are often familiarized with two concepts--land use and environmental impact. Similar devastating impacts that are often associated with fossil fuels can be linked with alternative energy, especially hydropower. On the other hand, hydropower is an effective clean and pollution-free form of renewable energy, thus, receiving substantial global attention while nonrenewable energy sources are facing depletion (Huan Li, 2018). As climate change becomes a serious threat to vulnerable populations, cleaner energy is necessary in combating anthropogenic climate change.

Generally, when thinking of hydropower a large scale hydro dam is pictured towering hundreds of feet in the air. However, due to technological innovation hydropower has become more advanced, efficient, and safer to humanity and the environment. For example, small hydropower station do not use reservoirs to produce energy. Small hydropower (SHP) works in as a ‘run-of-river system’, where water is drawn from a reservoir or stream and is directed down an incline to the powerhouse, where water flow drives the turbines (Harlan, 2018).Run-of-river systems plants have two sub categories ‘dam-type’ with reservoir storage, or ‘diversion-type’, the water is diverted from the stream into a canal without any reservoir storage (Harlan, 2018). More environmentally conscience areas create downstream cascading diversion-type dams that generate more energy. The water is diverted into the canal and flows from the primary plant to the next and so forth then is finally transferred back into the river (Harlan, 2018).

SHP possess the ability to generate stable electricity that provides local electricity and reduces emissions without the major ecological consequences of large dams (Harlan, 2018). Moreover, SHP has cheaper kilowatt-hour (kWh) construction and operating cost than solar PV or wind (Harlan, 2018). China has seen SHP as an energy source that has the potential to meet their energy needs and has switched SHP from a rural utility to a low-carbon industry (Harlan, 2018).

The true definition and what classifies a SHP facility changes in every country. Typically, SHP install capacity is <5MW (powering 3,300 homes), however, in China, SHP facilities can include plants up to 50 MW. This what makes SHP much more cost effective, on average, than either “mini” or “micro” hydro sites (Harlan, 2018). The smaller sites can only produce enough energy for a single household or block, and at current technology the installment cost oversees the returns from investing into the hydro facilities smaller than SHP. Though the capital cost of hydro instalments are high, operating and maintenance costs are low. The average cost to develop a ‘‘small’’ hydropower site is around $5,000 per kW but to be more competitive with fossil fuels this price must reduce to $2,000 per kW (Harlan, 2018).

Though SHP hydropower provides carbon free energy but many forms have significant environmental impact. SHP can cause some negative effects on the river ecosystem even while they satisfy the requirements of hydropower resource development and utilization, such as water volume reduction, vegetation destruction, and soil erosion (Huan Li, 2018). Diversion-type stations also reduce the water velocity, decreasing the water's capacity for holding pollutants, self-purification during the dry season (Harlan, 2018).

Micro hydropower (MHP) is very popular in rural areas and along neighborhoods. They have similar functionality of a SHP facility, by using the diversion-type run-of-river system to avoid unnecessary construction cost and environmental damages (Zema, 2016). MHP is considerably smaller than SHP, as a result, it has little impact on the surrounding ecology (Harlan, 2018). Due to MHP size, it is easily installed in many locations such as draining systems or irrigation system. Utilizing the most out of the available amenities, making the operation and maintenance cost miniscule (Harlan, 2018).

According to the National Hydro Association (NHA) MHP installment cost is $4,000-$6,000/kW. Further investments models have predictions on the techno-economic outcome of invest cost estimations between 1300 $/kW and 8000 $/kW for smaller projects (Cavazzini, 2016). MHP facilities range from 5kW to 100kW which can power between 5 and 100 homes, however, they can be as large as 1MW facility (Cavazzini, 2016).

Though MHP provides clean energy with low environmental cost it causes substantial financial geographic burdens. In order to take full advantage of the electrical potential of small streams, a suitable site is needed. Factors to consider are: distance from the power source to the location where energy is required, stream characteristics (flow rate and size etc.) and system components (transmission line, pipines, and batteries) (Cavazzini, 2016). Seasonal fluctuations in flow changes are especially impactful on MHP which have high sensitivity to flow. Additionally, “micro” projects are cost-ineffective, with over half of projects costing $50,000 per kW (Cavazzini, 2016).

Pump storage is becoming extremely popular in Virginia because it is able to take the excess energy production and store it in times of high energy demand. Pump-storage systems consist of an upper and lower reservoir (Poulain, 2018). Water is pumped from the lower to the upper reservoir during periods of low energy demands. During periods of high energy demand, water is released into the lower reservoir through turbines, producing electricity. The amount of energy production is dependent on the elevation difference between to the two reservoirs and water volume (Poulain, 2018). Many places around the world, especially Virginia, have taken measure to reduce environmental destruction when construction a pump storage system. Instead of digging into the ground and creating artificial reservoirs, companies have been interested in using abandoned mines or flooded quarries as storage reservoirs. They would serve as lower reservoirs saving cost (Poulain, 2018).

One of the strongest drawbacks of Pump-storage is it requires very large amounts of water and space. Furthermore, quarries and mines are not impervious reservoirs they are in close interaction with adjacent rock medium (Poulain, 2018). Therefore, pumping large volumes of water in a quarry or mine, within short intervals, will impact the surrounding groundwater table (Poulain, 2018). Water volumes exchanges during cycles may affect significantly the water levels in the quarry. The constant pumping can change the porosity of the rock media, causing water to leak out of the reservoir. This can contribute to water loss, making it the biggest threat to electricity production (Poulain, 2018).

Due to its size, pump-storage is very costly. It can cost up to $200 million on initial estimate but can quickly balloon to $600 million (Poulain, 2018). However, The price of a storage reservoir varies significantly depending on the local geography quoted numbers lie between 1 and 20$/kW h for storage capacity and 600-1000$/kW for the turbine. Pump-storage has a wide range of energy production from a few hundred to kW to more than 10 MW (Poulain, 2018).

Results

Cost Effectiveness

When making large investments the first and most important thing to consider is whether or not the project is cost-effective. Cost effectiveness must be center ideology in the making decisions process, a project may look great on paper, however, if it fails to bring returns that are required to meet goals, offsetting 100% of the University's energy consumption, then the project must be excluded. In the case of the University of

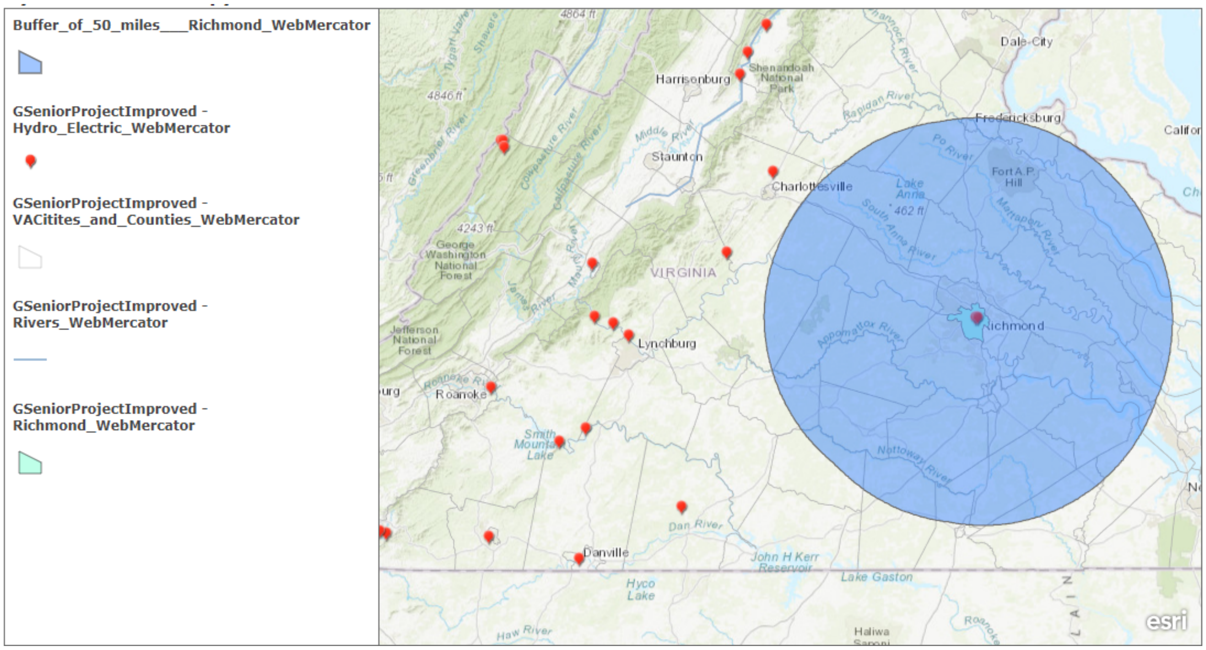
Richmond, the least cost effective hydro project to invest into is MHP. To meet the University requirement of offsetting 47,000 MWh, it would require 47,000 1MW MHP plants. Moreover, it would cost the University about $2.35 billion, about the size of its endowment (see Fig.1). While on the other hand SHP and pump-storage has less of a financial burden.

SHP is cost less on the margin to construct than MHP, making SHP more cost-effective than its counterpart. The amount of energy that a SHP can generate compared to a MHP is significantly greater. The $5,000 per kWh makes the invest more difficult because it is cheaper to continue to use fossil fuels. However, technology for SHP is evolving and becoming more cheaper. Investing into a portion of a pump-storage facility provides the most amount of energy for its investment cost. A 3,003 MW facility powers nearly a million homes, therefore, investing into a similar project would prove the most cost-effective for the University.

Feasibility

The feasibility of a hydropower must be consider next. The University of Richmond is located in a “hydropower desert”. There are only two hydroelectric dams in a 50 mile radius that are solely dedicated to the generation of electricity (see Figure 1). Even with the lack of hydropower facilities in close proximity of the University of Richmond, there is a possibility a project can be constructed with the utilization of the James River. Something that poses as a problem is finding a location for the most cost-effective hydro investment, pump storage. Since it this kind of project requires large hills and space, makes it difficult to produce such infrastructure in the piedmont area.

While the feasibility of pump-storage is in question, MHP and SHP can be incorporated into the water system surrounding the University of Richmond. MHP, in particular, can be built right here on campus there are many locations in the Richmond community where this is possible.



Discussion

The Solar array in Spotsylvania County is going to be the biggest such area east of the Rocky Mountains. The University has thought of both feasibility and cost effectiveness when making the final decision to further pursue this project. Bringing hydropower into the discussion helps compare the two simultaneously. Though, hydropower is proven to be cheaper in construction and operating cost than solar, the biggest shortcoming is location. As mentioned above, there are only two operating hydroelectric dams within 50 miles of the University of Richmond which is about the same distant the solar array is from the University. Instead of expanding existed projects there would have to be construction of new facilities. Permitting and finding locations for these SHP or MHP takes years and their will be citizen resistance to the project sites. Furthermore, MHP is simply not an effective energy source for the University to invest into. The dams lack the energy productivity the University would need to meet its goal by 2020 and there is too much variability when energy production is heavily impacted during seasonal fluctuations. The cost of a project to meet the energy requirements is absurd and not practical.

SHP and pump-storage, more so pump-storage, is the more practical choice if the University were to invest in hydropower. Both could meet the energy needs of the University, there has been success stories of SHP in China were it switched from being a rural energy source to supplying energy on the industrial leve. The effectiveness of pump-storage has been seen here in VA where it has supplied energy to nearly a million homes. The more cost-effective project would be pump-storage because of its low kWh rate. Virtually, the University would be paying renewable energy that is far cheaper than fossil fuel. The location of the new pump-storage facility will be in Wise, Virginia about 357.9 miles from Richmond. Posing as potential challenges for energy distribution, suggesting there would be a pipeline system that would have to be erected to transport the energy from SW Virginia to Richmond. With pipeline having a negative connotation in the public lately, makes moving forward with this project very difficult. A major issue that must be noted is that {ump-storage is only sustainable if the energy source used for pumping is renewable and it is difficult to track this with the grid system. Additionally, the environmental impacts from pump-storage would be the most significant out of the all three options. There has to be proper assessment of endangered species and what are the threats to the local ecology because of the reservoir.

Conclusion

In conclusion, at current technology and location of the University, I do not believe that hydropower is the best option to offset the campus energy consumption. There are too many obstacles that prevent hydropower from being a practical and realistic investment. Pump-storage, the best hydro option, is not feasible to construct a large enough facility close to University. Furthermore, erected powerlines hundreds of miles adds on to the difficulty and cost. The other hydro options simply cost too much and are not nearly productive, MHP, enough to reach the University's goal. The Spotsylvania solar array is the best renewable option for the University because of its productivity and proximity.

Though it is controversial to the citizens of Spotsylvania the solar array is the better option at our current technological advancements. On the other hand, to really change our environmental impact and GHG emissions the University must change it's consumption habitats. It is nice to invest in clean energy that offsets pollution but the same amount of pollution is going into the atmosphere. The University is not reducing it's emissions but just covering it up by matching it with clean energy. For change to really happen, the culture around the University energy consumption must be addressed and look into technology that will help reduce their emissions.

References

Bath county pumped storage station | dominion energy. (n.d.). Retrieved May 2, 2019, from https://www.dominionenergy.com/company/making-energy/renewable-generation/water/bath-county-pumped-storage-station

Dominion energy pursues sites for pumped hydroelectric storage facility in coalfield region. (n.d.). Retrieved May 2, 2019, from Dominion Energy MediaRoom website: https://news.dominionenergy.com/2017-09-07-Dominion-Energy-Pursues-Sites-for-Pumped-Hydroelectric-Storage-Facility-in-Coalfield-Region

Harlan, T. (2018). Rural utility to low-carbon industry: Small hydropower and the industrialization of renewable energy in China. Geoforum, 95, 59–69. https://doi.org/10.1016/j.geoforum.2018.06.025

Li, H., Zhao, W., Tang, X., Li, Q., Guo, W., & Gong, D. (2018). Entrainment effects of a small-scale diversion-type hydropower station on phytoplankton. Ecological Engineering, 116, 45–51. https://doi.org/10.1016/j.ecoleng.2018.02.030

Poulain, A., de Dreuzy, J.-R., & Goderniaux, P. (2018). Pump Hydro Energy Storage systems (Phes) in groundwater flooded quarries. Journal of Hydrology, 559, 1002–1012. https://doi.org/10.1016/j.jhydrol.2018.02.025

Zema, D. A., Nicotra, A., Tamburino, V., & Zimbone, S. M. (2016). A simple method to evaluate the technical and economic feasibility of micro hydro power plants in existing irrigation systems. Renewable Energy, 85, 498–506. https://doi.org/10.1016/j.renene.2015.06.066