HARVESTING WIND ENERGY THROUGH TRIBOELECTRIC NANOGENERATORS

LOWER SNAKE RIVER DAMS: AND ECOLOGICAL FAILURE

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.

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Introduction

Renewable energy sources allow for a smooth transition towards an ecologically conscious global environment. However, there are challenges that restrict the sustainability of these innovative technologies. Renewable energy harvesting technologies should aim to have as little an ecological impact as possible in order to mitigate environmental impacts. After all, the overall goal of creating renewable energy systems is to mitigate ecological change caused by greenhouse gasses in the atmosphere, commonly known as climate change. Achieving this goal requires new technological devices and designs. A new method of converting mechanical energy to electrical energy is being developed through the interaction of charged materials, called triboelectric nanogenerators. I will adapt this new technology specifically for harnessing wind energy at low speeds and turbulent airflow, most common in urban areas. Both technical and social factors caused the failure of the Lower Snake River Dams, therefore it is necessary to understand how various factors influence the success or failure of a system. I will draw on Actor-Network Theory to examine how a lack of ecological concern created the failure of a renewable energy source, the LSRDs. If focus is only placed on building the structure, but does not account for ecological impacts, then a system meant to help fight climate change ends up causing more damage to the environment. Because the challenge of creating ecologically friendly renewable energy harvesting systems is sociotechnical in nature, it requires attending to both its technical and social aspects to accomplish successfully. In what follows, I set out two related research proposals: a technical project proposal for developing a new, non-invasive wind energy harvester and an STS project proposal for examining the ignorance of ecological impact and the tenacious goal of carbon neutrality in the ecological failure of the Lower Snake River Dams.

Technical Project

Wind turbines are a great use of natural resources to generate renewable energy, but these machines cannot be placed everywhere. The general restriction of wind turbines is the inability to work in wind speeds under 10 miles per hour. However, these low wind speeds are much more prevalent than high wind speeds needed for conventional wind turbines. This is especially true in urban areas, where winds are low and turbulence is high due to structures. Only 14 out of the 54 largest cities in America report average annual wind speeds over 10 miles per hour (Osborn, 2023). Wind turbines also are not adaptive to turbulence, which is a limiting factor when collecting wind energy. It can be shown that typical wind turbines need high speeds and low turbulence to operate; however, in order to make advances in renewable energy, these wind conditions must be harnessed for energy (Renewables First, n.d.).

There are two general types of wind turbines, horizontal axis wind turbines (HAWT) and vertical axis wind turbines (VAWT). The two most common VAWTs are the Savonius and Darrieus turbines. The Savonius rotors are best suited for low wind speeds while the Darrieus works in low wind speeds, but is best suited for moderate wind speeds. Images for these rotors are found in Figure 1. The traditional and most common image of a wind turbine is a tall HAWT placed in an empty field. This design works for the specific environment; however, there are many other geographies with the potential to harvest wind energy. Areas with low wind speeds have been considered for wind turbines and design modifications have been made to turbines to adapt them for low wind speed environments.

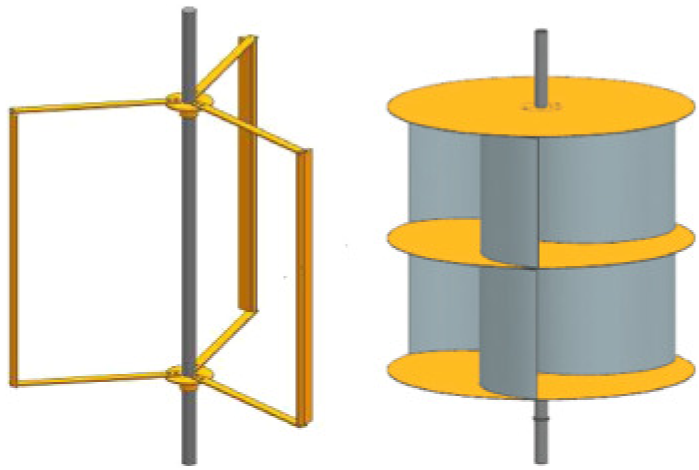

Fig 1. Common designs for Darrieus and Savonius rotors. (Wekesa et al., 2020)

For both HAWTs and VAWTs, the most common approach is optimization of blade design, materials, aerodynamic body, and rotor configurations for small scale turbines to determine the best model for low wind speed areas (Adeoye, 2023; Jaszczur et al., 2024; Letcher, 2010; Mayeed & Khalid, 2015; Robinson & Veers, 2002). Other ideas have been attempted, including creating taller towers for HAWTs in order to reach higher altitudes where larger wind speeds occur (Robinson & Veers, 2002), and combining different geometries of VAWTs to increase efficiency (Letcher, 2010). These designs have improved on the efficiency of wind turbines in low wind speed areas, however there are some flaws holding back these systems.

Unfortunately, these designs are restricted by limiting factors. For HAWTs, the largest limiting factor is cost. Larger blades, larger towers, and other increasing part sizes provide serious economical and logistical issues. Increased energy capture cannot come at the expense of increased cost, including manufacturing, construction,and transportation (Robinson & Veers, 2002). VAWTs generally have a lower efficiency than HAWTs. The largest problems stem from Savonius rotors' limitations to low wind speeds and Darrieus rotors' need for a starting force

(Letcher, 2010). Modifications can be done to help mitigate these issues, but the environment is also harmful to VAWTs. In urban areas, designers and constructors do not consider the interactions of the wind turbine with the surrounding constructions, including low wind speeds and high turbulence intensity caused by urban infrastructure and instigate issues with wind turbines (Jaszczur et al., 2024).

Modern wind turbines are unable to effectively harness energy in low wind speed environments with high turbulence. Additionally, their obtrusive size and noise levels make them unsuitable for residential areas. If these problems are not addressed, the high potential of available clean energy will continue being wasted.

This technical project aims to design and develop a wind energy harvester using triboelectric nanogenerators to capture energy in underutilized spaces. With a modular and adaptable design, our device will integrate seamlessly into urban landscapes, reducing visual impact and maximizing efficiency in space-constrained areas. Triboelectric nanogenerators (TENGs) are an emerging technology effective for converting ambient mechanical energy, such as motion, friction, and contact, into electrical power, unlocking new energy collection possibilities. When two different triboelectric materials rub against each other, they exchange electrons, creating a small electrical charge that can be captured and turned into usable energy (Yang, 2021). The generator will contain an array of flexible structures overlaid with triboelectric material. Gusts of wind and turbulence will induce rubbing and contact within the structures, generating electricity.

Engineering knowledge in a variety of disciplines is required for this project. A thorough understanding of fluid mechanics and turbulent flow will reveal how the device responds in specific conditions. The material and triboelectric properties of blade components will be analyzed to balance cost, electricity generation, and performance. Machine design and fatigue analysis will be used to predict the product's lifetime. Computer-Aided Design (CAD) modeling will play a crucial role in our design process, enabling us to optimize the design through multiple iterations. We will produce detailed technical drawings for each component of our design, as well as an assembly drawing of the entire product, complete with precise tolerancing and dimensioning.

Initial design data for the product will be obtained from scholarly articles on the triboelectric effect and existing systems utilizing TENGs. Power output data will be the primary metric collected and analyzed to refine our design and demonstrate its value. Each iteration will undergo analysis for both peak power output and average sustained power generation.
In the final development stages, tests will be conducted to optimize durability, aesthetics, and manufacturability.

STS Project

In the 1960s and 1970s, four dams were built in the Snake River, the largest tributary of the Columbia River, in eastern Washington state. The Lower Snake River Dams consist of four dams which span the lower section of the river: Ice Harbor, Lower Monumental, Little Goose, and Lower Granite. These dams were built by and are currently maintained by the Army Corps of Engineers to provide transportation and hydroelectric power. Unfortunately, these dams foster ecologically disturbing environments due to the lack of water flow and water heating (US Army Corps of Engineers, n.d.). These harmful ecological effects include: lack of sediment deposits in the river, community damage of local riverside plant species, and endangerment of 13 species of salmon and orcas which all need a healthy river to sustain themselves (Fragiacomo, 2023;

Hilbert-Wolf & Gerlak, 2021). These dams are still up and running, but many consider them a failure due to the harmful ecological impacts they cause.

Some proponents of this project argue that the dams are an important part of the local economy and infrastructure and therefore not a failure. The renewable source of energy produced by the dams are a large reason they are still up. The dams provide economic value to the energy, agriculture, and transportation industries (Storch et al., 2022). These are the groups who are arguing to keep the dams up. Climate change is best attacked by renewable energy sources and proponents of the dams believe that keeping them up will be beneficial to fight climate change. There was an effort to help fish migration patterns through the dams in the 2010s, which proponents of the dams cite to aid their argument (US Army Corps of Engineers, n.d.).

While it is true that there is economic benefit, sustainability, and an effort to create ecological stability, these views overlook the factors that others have proposed. These include examples of ecosystem restoration post dam removal (Fragiacomo, 2023). Studies have been performed on the Lower Snake River Dams to determine if ecosystem restoration is possible by dam removal, and they have determined that dam removal does restore the ecology of the areas (Storch et al., 2022).

Changes in climate will affect almost every ecosystem on the earth, and it has been shown that nature based solutions to fight climate change are as helpful or more helpful compared to human engineered solutions. Nature based solutions for ecological restoration and sustaining strong ecosystems are important ways to create resilience to global climate change if these ecosystems are threatened in the future (Pearce, 2022). When ecological impact is ignored in order to achieve renewable energy goals and economical development, the dams are considered a success. However, this is not what happened, as these factors need to be considered to understand why this project is actually a failure. I argue that ignorance of ecological harm in conjunction with the tenacious goal of creating renewable energy and urge for economic development caused the Lower Snake River Dams to be considered a failure. More specifically, the combination of these factors caused the creation of these dams without consideration of the local environment and its effects on the ecology and economy.

My argument draws upon the framework of Actor-Network Theory (ANT) developed by scholars such as Michel Callon, Bruno Latour and John Law. ANT examines interactions among human and non-human 'actors' within the network that a network builder creates; these actors and their connections between other actors influence the overall system. The interactions between the different actors within the network is what is analyzed to determine why a network succeeds or fails (Cressman, 2009). To support my argument, I will analyze evidence from scientific articles, such as "A review of potential conservation and fisheries benefits of breaching four dams in the Lower Snake River (Washington, USA)" in order to display the science-backed arguments that support the ecological restoration. I will also analyze opinion pieces and analyses of conflict summaries which provide different viewpoints on the removal of the dams.

Conclusion

Both the Technical and STS projects I have presented contribute to maintaining a goal of advancement in renewable energy while simultaneously being ecologically mindful. The technical project achieves this by creating a wind energy harvester that will be courteous of ecological impacts. The STS project presents an understanding of ecological impacts of renewable energy sources through the case study of the Lower Snake River Dams. The insights provided by the sociotechnical research of the LSRDs will allow me to design a product that considers the social factors in this case study and assure I will not make the same errors when creating a renewable energy harvester.

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