Why only Solar Power at the University of Virginia?

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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

The need to quickly move away from burning fossil fuels for energy to cleaner forms of energy production has never been higher due to climate change threatening the fragile ecosystems on Earth (London, 2020). Climate change is at the heart of problems like extreme weather, environmental issues for plants and animals, and rising ocean levels. In response to this, many institutions have adopted carbon neutral plans in order to start the transition to renewable energy and play their part in fossil fuel free plans in the future. The University of Virginia in particular, has pledged carbon neutrality by 2030 and fossil fuel free by 2050 (UVA Sustainability, Plans and Progress, n.d.). Carbon neutrality is achieved when the carbon emitted has a net zero effect on the environment. In short, carbon neutrality is reached by either decreasing the emissions from the energy sources they use or by increasing the carbon that the environment can absorb via carbon capture or planting trees. So far, the University of Virginia's renewable energy is mainly sourced from solar panels on grounds and solar facilities partnered with the University (UVA Sustainability, Energy, n.d.).

This paper explores the public's perception of differing types of renewable energy sources and how that might have influenced the University of Virginia to choose solar power as their sole source of renewable energy. While hydroelectric and wind power both produce more power than solar power globally, (Ritchie et al, 2023) there are social and political forces that may be negatively impacting these technologies while they are positively pushing for another technology. This is the theory that there are social and political forces behind any technology (Winner, 1980). The public's awareness and opinion of these renewable energy technologies may affect the Universities' stance on those technologies and therefore choose one over another. Along the same line, projects involving those same technologies that have succeeded and failed

may also play a part. As well as the environmental impact of some of these renewable energy sources. Following those points, the information that the public consumes in order to form their opinion on these matters may not be as straightforward as it seems. A study conducted in 2016 found that 62% of adults in America get their news from social media sources (Gottfried & Shearer, 2016), which are known to over exaggerate and cut out critical information to make their titles more captivating. Additionally, many other universities have also opted to utilize solar panels both on campus and from solar farms elsewhere in order to achieve their own carbon neutrality goals.

Theoretical Framework

In 1980, Langdon Winner wrote *Do Artifacts Have Politics?*, a paper supporting the idea that technology can have political properties. The definition of "politics" he uses refers to "arrangements of power and authority in human associates as well as the activities that take place within those arrangements," (Winner, 1980, p.123). For "technology" he refers to "all of modern practical artifice, but to avoid confusion I prefer to speak of technologies, smaller or larger pieces or systems of hardware of a specific kind," (Winner, 1980, p.123). The paper draws evidence from case studies on Long Island overpasses in New York, a pneumatic molding machine used by a factory, and a mechanical tomato harvester developed by the University of California. Showing the political forces influencing the designs, equipment, and conflict over those particular technologies and how they can be easily applied to many other technologies in the world around us.

Starting in the 1920s, Robert Moses, an urban planner and powerful figure at the time, had low-hanging overpasses built. These overpasses blocked out racial minority and lower income groups from going to places like Jones Beach, advertised as a public park, by being too low for public transportation to pass through. Furthermore, Moses was able to shoot down the proposal of extending the Long Island Railroad to the beach, yet another form of public

transportation. Another case in the 1880s involved Cyrus McCormick's manufacturing plant and his battle against the Union of Iron Molders. Instead of giving in to the Union formed by the skilled workers he needed, he instead opted for producing a lower quality product with unskilled labor manning a pneumatic molding machine while also costing more. By being able to continue producing products without the skilled workers, the Union they formed was then dissolved and the battle against them was won. Finally, in the 1940s, a mechanical tomato harvester produced by the University of California led to tens of thousands of jobs lost in the tomato industry. Since the University was a public institution funded by tax dollars, they were sued for spending those tax dollars on developing a product to line the pockets of private companies. The University argued that they would have to eliminate any research that may have any type of practical application if they were guilty of these charges. While unintentional, the tomato harvester had disastrous effects on smaller tomato farmers that could neither afford or efficiently use the technology.

Winner wrote, "Rather than insist that we immediately reduce everything to the interplay of social forces, it suggests that we pay attention to the characteristics of technical objects and the meaning of those characteristics," (Winner, 1980, p.123). While technological determinism is the idea that the development of certain technologies is inevitable and will then change society and social determinism being the opposite, Winner proposes that both technology and society shape each other. Technology is not governed by society, or vice versa, but instead it is influenced by society while also having an influence on society as a result.

Later in the paper, Winner also writes about renewable technologies, "In my best estimation, however, the social consequences of building renewable energy systems will surely depend on the specific configurations of both hardware and the social institutions created to bring that energy to us," (Winner, 1980, p.135). While the advancement and increasing efficiency of the technology matters in its success, the rules and regulations put on them by legislation that are passed down to the energy providers may affect their decision to utilize this

technology or not. The technology can still be suppressed regardless of how sophisticated it is as long as there is enough political force against it to do so.

Public Awareness

How the public perceives a technology is important in its success in getting projects involving it approved. In 2022, a survey was conducted in Saudi Arabia assessing the public's view on renewable energy sources (Almulhim, 2022). For reference, most of the respondents had at least the equivalent of high school education and over half had been to college or above. One of the questions asked the responders which type of renewable energy can be used to produce power; solar was the most picked answer, wind second, water third, while biomass and geothermal in the last two spots by a wide margin. As shown by this one question, solar is seemingly the most popular, followed closely by wind and water.

Another survey published in 2008 asked engineering and economics university students in Canada, Romania, and Turkey questions gauging awareness and opinions (Ozil et al., 2008). A question had different types of renewable energy sources and asked the respondents to rank each one of them independently from very important to not important, or not sure. Hydro with a dam was the best performing type of renewable energy with about 80% of the respondents replying that it was very important or important with wind and photovoltaics with slightly worse results. Solar thermal, which is basically a bunch of panels directing the heat from the sunlight to a single point to produce steam and power a turbine, and geothermal were also good performers. Lesser-known forms of hydro power and biomass related forms of renewable energy had more unsure answers than the rest. Since this survey was directed at university students studying engineering and economics, it seems that they have more knowledge on the topic and know more about the different types of renewable resources and how they can be utilized for energy.

Renewable Energy Projects

Another factor affecting technology is how projects involving it in the past have turned out. The Cape Wind Project, first proposed in 2001, would've been America's first offshore wind farm, capitalizing on the superior winds near the coast and out of the way of major land masses. To be located in Nantucket Sound, the farm would house 130 turbines, producing 420 megawatts of energy at maximum capacity (Rodgers & Olmsted, 2008). However, after years of opposition from the residents near the coast concerned about their view and property value decreasing along with delays due to legislative changes, the project eventually failed due to failure to secure enough funding by 2015 and was later fully canceled in 2017 (Recker, 2023). This is a very interesting case study on how such a promising project failed essentially due to delays to the point that investors no longer believed in the project and pulled out. The groups opposing the project, namely the Alliance to Protect Nantucket Sound, had millions of dollars of funding from the 1% to run their campaign against the Cape Wind Project. Running ads in the area promoting their views and putting forth misleading images of the obstruction the final project would have on the horizon. Organizations that supported the project like Clean Energy Now were made up of the lower and middle class and had no chance with their limited funding potential.

The case of Cape Wind shows that the rich and powerful are willing to dump money into fueling a campaign against things they don't like. In this case they were ultimately successful in delaying the project enough for the project to be canceled and resulted in a huge blow against large scale renewable energy projects like this one. However, the world is beginning to realize the importance of converting to renewable energy and should in turn be more accepting of the projects that will serve as solutions.

Environmental Impact of Hydroelectric Dams

Hydropower as of 2022 produces 4,000 TWh, practically doubling that of wind and nearly quadrupling the energy generation from solar (Ritchie et al, 2023). The main source of hydropower comes from hydroelectric dams, trapping water from a river and directing it through a turbine in order to generate electricity when there is enough. Although there are other methods to generate electricity using the flow of water, namely diversions and pumped storage (Types of Hydropower Plants, n.d.), they are either less efficient or reliant on another system to power part of its functions. Hydroelectric dams are by far the most efficient form of hydropower, but that comes at a cost. These dams are also the cause of decreases in water quality in the area, emission of greenhouse gasses, and breaking down river ecosystems among other potentially negative effects on the environment (von Sperling, 2012).

The addition of a dam to a river slows down the flow of that river by trapping water upstream to be released on command. This effectively increases the temperature of the river due to the decreased flow of water along with producing still water at the site of the dam, which promotes the growth of bacteria that may harm the habitants of the river. Additionally, inland bodies of water already naturally produce some greenhouse gasses because of the decomposition of organic matter within that body of water. Reservoirs from hydroelectric dams do the same thing on a slightly larger scale. Therefore, hydroelectric power can be attributed to some greenhouse gas emissions due to the increase of gasses emitted from the site due to the installation of the dam (Tracking the Carbon Footprint of Hydropower, n.d.).

Hydroelectric dams also affect many species of fish, namely salmon in their migration journey upstream back to their birthplace in order to create their own spawn and start the cycle over again. This threatens the population of salmon due to the increased human obstacles the

salmon have to get through in order to reach their mating waters. Luckily, this was recognised and measures were taken to remedy this. In many rivers with fish migration, 'fish ladders' are the solution to this problem (What is a Fish Ladder?, n.d.).

All in all, while hydropower is a very prominent source of renewable energy in the world currently, it comes with many drawbacks in the form of harming the very environment that its core purpose is meant to save.

Misinformation on Renewable Energy

In the case of the Cape Wind Project, The Alliance was discussed as the main opposing force to the effort to install offshore wind turbines in federal waters within Nantucket Sound. According to them, the project planned to install '130 wind turbines, each 440 feet tall,' and even provided a simulated image of what visual effects the turbines would have on their coastline (Archives, 2021).

Fig. 1 Simulated View from Centerville/Osterville Bridge (Archives, 2021)

Fig. 2 Location above picture was taken from (Archives, 2021)

At first glance, it does look like the proposed project would greatly disrupt the view of the horizon. However, there is no proof that this would be the view after the project is finished. In order to find the true visual impact on the horizon, the location of this picture is simulated from and the distance from there to the first array of proposed turbines were supposed to be are needed. Utilizing google maps to find the exact location from street view, finding the shortest distance to the project perimeter to be around 6 miles, combining with the previous information that the turbines will be 440 feet tall the angular size the turbines would've actually taken up can be found. Plugging in the numbers into an online calculator (Size Calculator), the closest turbines wouldn't have taken more than 0.8 degrees above the horizon which would take up less space than a pinky finger held up horizontally to the horizon at an arm's length. For reference, degrees are used when measuring how much space something takes up in the sky. 1 degree is traditionally quickly measured by holding up one's pinky finger an arms length away (Hand Calibration, 2023). The space that the width of the finger covers up is roughly 1 degree and is

rather consistent due to the proportions of the human body. With that being said, this is an overestimation since some of the turbines would also be obscured further by the curvature of the Earth itself.

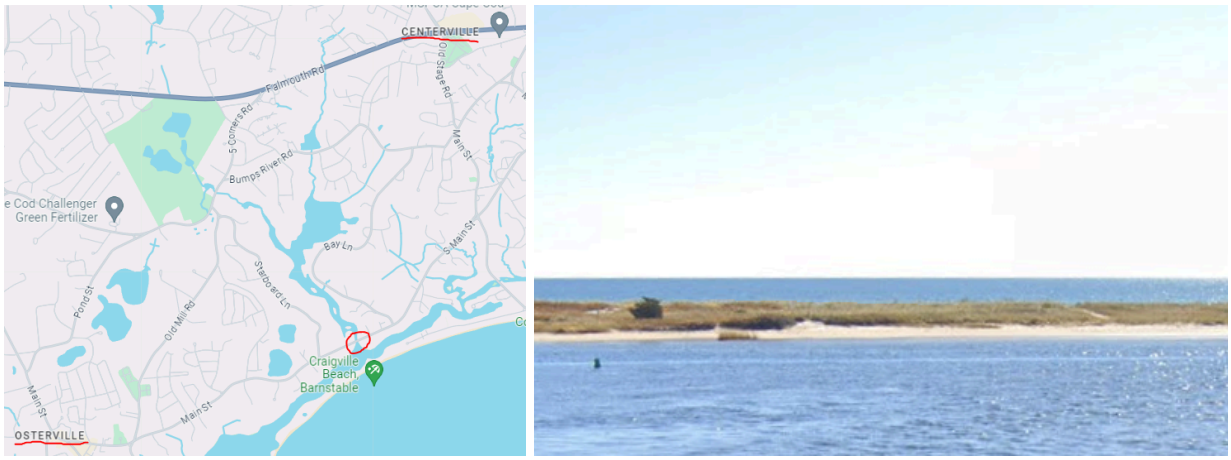

Fig. 3 - 4 Google Maps - Osterville/Centerville Bridge (Left), Street View from red circle (Right)

From these findings, it seems that the images provided by The Alliance are slightly exaggerated from what the final product would have yielded in terms of visual impacts. Additionally, the location of the simulated image is from an area rather close to the proposed project in relation to the surrounding areas in Martha's Vineyard or Nantucket. This is a very specific example of how misinformation is spread. Someone seeing this image wouldn't think much about double checking if it is true or not and jump to conclusions.

Very recently, misinformation has been spread that offshore wind is responsible for the death of whales. The parties with this mindset are mostly Anti-wind power groups who claim that the authorities examining the deceased whale corpses are either hiding information or not performing full-extensive investigations on the cause of death (Garza, 2023). While the truth is that it is hard for the authorities to determine the cause of death of whales that have died a few days in advance before washing ashore. Therefore the claim that offshore wind is the cause of these deaths is rather inconclusive, both the Bureau of Energy Management (BOEM) and the

National Oceanic and Atmospheric Administration (NOAA) have come forward and said that there is no evidence supporting the allegations that offshore wind farms are causing the death of these whales (Robles, 2023). Conspiracy backed up by the logic that if there is no evidence for my case, then evidence is being hidden from the public is completely ridiculous and terrible for the public (Garza, 2023). Media is consumed at such a rapid pace at this time that not many people bother to check sources or confirm the truthfulness of the dramatic titles thrown at them on a day to day basis, which leads to mass misinformation on topics such as renewable energy as a whole.

Two other bits of misinformation commonly associated with wind farms are that they are very loud and that they kill a large number of animals, namely birds and bats that get stuck by them. There is a video showing the sounds of a single turbine compared to the natural background noise from several distances away from the turbine itself, and finally from within the confines of a building (Arup, 2019). Another video, taken more recently, in front of an entire wind farm shows that the farm makes next to no noise (Advanced Power Alliance, 2020). As the technology improves, not only does the efficiency of the power conversion, but the noise production as well. Nowadays, smaller turbines produce less than 6 decibels (dB) of noise while larger ones produce 35-45 dB from 300 meters away on land (WINDExchange, n.d.). As for the turbines killing flying animals, a report was written on this exact topic, showing all the data and suggesting potential solutions (Rydell et al., 2012). The report reveals that a single turbine in Europe or North America kills on average 2.3 birds and 2.9 bats a year. However, this number is skewed upwards due to a small percentage of those turbines killing up to 60 birds and 70 bats in one year. Showing that a select few turbines have a higher rate than all others, and by fixing whatever causes those deaths would therefore drastically lower the average. The problem is not

with the turbines, but the location and the time they run. The study shows that accidents with bats occur during certain times of the day, making it very preventable. Birds on the other hand should be treated separately since no such patterns arose in their research. However, with this data areas that have high traffic of birds and bats alike can be avoided for wind turbine construction in order to reduce these numbers.

Other Universities with Sustainability Goals

The Race to Zero site for Universities & Colleges (2023) provides a very extensive, though incomplete list of universities around that world that have either provided a plan to reach carbon neutrality or expressed their interest in doing so. Though that list is very extensive and long, only about half are committed with a plan. Additionally, only 9 universities in the United States have achieved their carbon neutrality goals (Wise, 2020). This list is made up of Colby College, Middlebury college, Bowdoin College, American University, Colgate University, University of San Francisco, Colorado College, Allegheny College, and Dickinson College. Colby College, with roughly 2,000 students, uses biomass and solar power along with buying offsets from places that are beyond carbon neutral (Colby College, n.d.). Middlebury college, a slightly larger college, also utilized biomass to reach carbon neutrality and is now looking to expand into solar power in order to reach their 100% renewable energy goal (Middlebury College, 2016 & 2021). Colgate University, a similarly sized college, worked on reducing their carbon emissions on campus while purchasing carbon offsets to make up for the rest (Colgate University, n.d.). American University, the first to reach carbon neutrality while also having a student population of over 11,000, sources half of their electricity from a solar farm and the other half from purchasing renewable energy credits (REC) (American University, 2018). Allegheny College, another small college, sources its energy from on-campus solar power and wind RECs

as well as heat from geothermal sources (Allegheny College, n.d.). The other colleges and universities on that list all use either a form of solar, geothermal heat, or also buy RECs in order to reach their carbon neutrality goals in conjunction with reducing their carbon emissions by recycling or composting along with other efforts.

Conclusion

With the current state of the world, drastic change in energy sectors to more renewable sources of energy is needed in order to avoid permanent change in our ecosystems and weather patterns. In response to this, the University of Virginia has pledged to be carbon neutral by 2030 and carbon free by 2050. So far, the University has only invested its resources into solar power, the least efficient of the three main forms of renewable energy forms: hydroelectric, wind power, and solar. After investigating the potential reasons for this decision in areas of public opinion, past conflicts around renewable energy projects, the advantages and disadvantages of hydroelectric dams, as well as the misinformation that is spread about different forms of renewable energy, I believe that the University made this decision to further their goals in sustainability with the least amount of resistance. Solar power is very versatile in that it can be installed virtually anywhere with ample sunlight exposure while other renewable technologies that may have higher efficiencies, are limited by geographical constraints and are also viewed in a more negative light in some cases. This is not to say that the University will never branch out and diversify their energy production inputs to include more forms of renewable energy in the future.

References

Advanced Power Alliance. (2020). *How Loud Are Wind Turbines*. https://www.youtube.com/watch?v=5gLMnf8Ki3g

Almulhim, A. I. (2022). Understanding public awareness and attitudes toward renewable energy resources in Saudi Arabia. *Renewable Energy*, *192*, 572–582. https://doi.org/10.1016/j.renene.2022.04.122

Archives (2021). *Save our Sound.* https://saveoursound.org/archives/

Arup. (2019). *The sound of wind farms*. https://www.youtube.com/watch?v=v-sUDSwsE_w

Carbon Neutrality | *Colgate University*. (n.d.). Retrieved February 7, 2024, from https://www.colgate.edu/about/sustainability/climate-action-planning

Carbon Neutrality is Now Reality at American University. (2018). *American University*. https://www.american.edu/media/news/20180425-carbon-neutrality.cfm

Carbon Neutrality and Solar Initiatives. (n.d.). *Colby College*. Retrieved February 7, 2024, from https://www.colby.edu/green-colby/green-campus/carbon-neutrality-and-solar-initiatives/

Energy | UVA Sustainability. (n.d.). *University of Virginia*. https://sustainability.virginia.edu/energy

Garza, A. (2023). *Whales Are Dying Along the East Coast. A Fight Is Surfacing Over Who's to Blame*. TIME. https://time.com/6254785/whale-deaths-offshore-wind-power/

Gottfried, J., & Shearer, E. (2016, May 26). News Use Across Social Media Platforms 2016. *Pew Research Center*. https://www.pewresearch.org/journalism/2016/05/26/news-use-across-social-media-platforms-2016/

Hand Calibration | *Exploratorium*. (2023, September 15). https://www.exploratorium.edu/never-lost/navigation/basics-wayfinding/hold-course-how-far/hand-calibration

Leal Filho, W., Sálvia, A. L., Paço, A. D., Anholon, R., Gonçalves Quelhas, O. L., Rampasso, I. S., Ng, A., Balogun, A.-L., Kondev, B., & Brandli, L. L. (2019). A comparative study of approaches towards energy efficiency and renewable energy use at higher education institutions. *Journal of Cleaner Production*, *237*, 117728. https://doi.org/10.1016/j.jclepro.2019.117728

London, M. (2020). *The Effects of Climate Change*. ABDO Publishing Company. http://ebookcentral.proquest.com/lib/uva/detail.action?docID=28295971

Middlebury Reaches 2016 Carbon Neutrality Goal | *Middlebury News and Announcements*. (2016, December 8). https://www.middlebury.edu/announcements/news/2016/12/middlebury-reaches-2016-carbon-neutrality-goal

Ozil, E., Ugursal, V. I., Akbulut, U., & Ozpinar, A. (2008). Renewable Energy and Environmental Awareness and Opinions: A Survey of University Students in Canada,

Romania, and Turkey. *International Journal of Green Energy*, *5*(3), 174–188. https://doi.org/10.1080/15435070802107025

Plans & Progress | UVA Sustainability. (2023) *University of Virginia*. https://sustainability.virginia.edu/plans-progress

Recker, M. (2023). An Analysis of the Rise and Fall of Cape Wind and its Implications in Environmental Policy. *Trinity College.* https://digitalrepository.trincoll.edu/theses/1051/

Ritchie, H., Rosado, P., & Roser, M. (2023). Fossil Fuels. *Our World in Data*. https://ourworldindata.org/fossil-fuels

Ritchie, H., Roser, M., & Rosado, P. (2023). Renewable Energy. *Our World in Data*. https://ourworldindata.org/renewable-energy

Robles, J. (2023). *Addressing Misinformation on Offshore Wind Farms and Recent Whale Mortalities*. Energy.Gov. Retrieved April 8, 2024, from https://www.energy.gov/articles/addressing-misinformation-offshore-wind-farms-and-recent-whale-mortalities

Rodgers, M., & Olmsted, C. (2008). The Cape Wind Project in Context. *Leadership and Management in Engineering*, *8*(3), 102–112. https://doi.org/10.1061/(ASCE)1532-6748(2008)8:3(102)

Rydell, J., Engström, H., Hedenström, A., Kyed Larsen, J., Pettersson, J., & Green, M. (2012). *The effect of wind power on birds and bats: A synthesis*. Naturvårdsverket. https://urn.kb.se/resolve?urn=urn:nbn:se:naturvardsverket:diva-9270

Size Calculator. (n.d.). Retrieved April 8, 2024, from http://sizecalc.com/

Solar Project Brings Middlebury College Closer to 100 Percent Renewable Energy Goal | *Middlebury News and Announcements*. (2021, October 12). https://www.middlebury.edu/announcements/news/2021/10/solar-project-brings-middlebury-college-closer-100-percent-renewable-energy-goal

Sustainability | *Allegheny College*. (n.d.). Allegheny.Edu. Retrieved February 7, 2024, from https://sites.allegheny.edu/sustainability/energy/

The Alliance for Sustainability Leadership in Education. (2023). *Current Signatories for Race to Zero for Universities and Colleges*. https://www.educationracetozero.org/current-signatories

Tracking the Carbon Footprint of Hydropower. (n.d.). Energy.Gov. Retrieved April 19, 2024, from https://www.energy.gov/eere/water/tracking-carbon-footprint-hydropower

Types of Hydropower Plants. (n.d.). Energy.Gov. Retrieved April 19, 2024, from https://www.energy.gov/eere/water/types-hydropower-plants

von Sperling, E. (2012). Hydropower in Brazil: Overview of Positive and Negative Environmental Aspects. *Energy Procedia*, *18*, 110–118. https://doi.org/10.1016/j.egypro.2012.05.023

What is a fish ladder? US Department of Commerce, N. O. and A. A. (n.d.). Retrieved April 19, 2024, from https://oceanservice.noaa.gov/facts/fish-ladder.html

WINDExchange | *Wind Turbine Sound*. (n.d) Retrieved April 8, 2024 from https://windexchange.energy.gov/projects/sound

Winner, L. (1980). Do Artifacts Have Politics? *Daedalus*, *109*(1), 121–136. http://www.jstor.org/stable/20024652?origin=JSTOR-pdf

Wise, M. (2020, September 16). *Carbon Neutral Universities in the United States*. Second Nature. https://secondnature.org/media/carbon-neutral-universities-in-the-united-states/