Prospectus

# Noise Reduction of Wind Turbines Through Blade Design

**(Technical Paper)**

# Effects of Clean Energy on Appalachia

**(STS Research Paper)**

Presented to the Faculty of the School of Engineering and Applied Science

University of Virginia-Charlottesville, Virginia

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Bachelor of Science, School of Engineering

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On my honor as a student, I have neither given nor received any unauthorized aid on this assignment as defined by the Honor Guidelines for STS Papers

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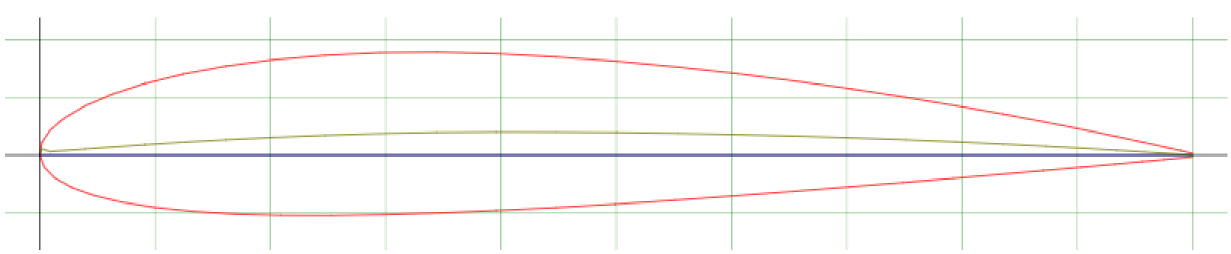
**Technical Introduction:**

Wind energy production is a massive technological innovation promising clean renewable energy effectively forever. However, the places on land where wind is best for turbine placement either already have residential populations in close proximity or are too far from the cities to be as beneficial as possible. If wind energy is to be implemented near cities, then the problems they cause, such as noise, will need to be addressed and rectified. The intent of this technical report is to show our progress on redesigning wind turbine blades to reduce the noise they produce.

**Technical Background:**

Public opinions of wind turbines are crucial to their acceptance to society. The ambient noise created from their operation can annoy, or in the worst case, negatively impact residents who live and work close to turbines. Wind turbines produce noise due to their methods of harvesting energy from nature. Pressure differences from wind flowing over the blades' edges cause turbulence. Additionally, problems with wind boundary layers staying close to the surface of the blades are main sources of noise. An unaltered turbine blade is to be used as a control group for comparison of sound levels and efficiency at harvesting energy. The shape of the control blade is not our innovation and is sourced from a NACA 2414 airfoil (airfoiltools.com, 2020). Figure 1 shows the profile of the NACA 2414 wing.

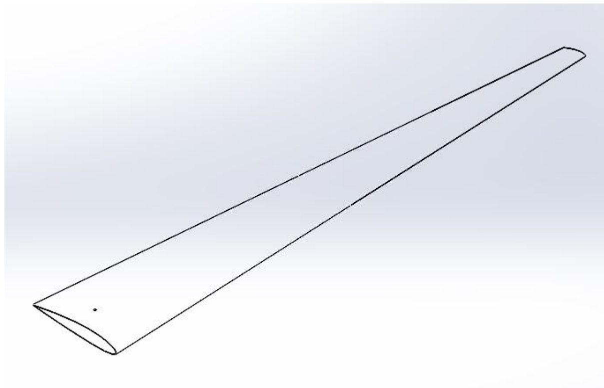
Figure 1: NACA 2414 airfoil (airfoiltools.com, 2020)



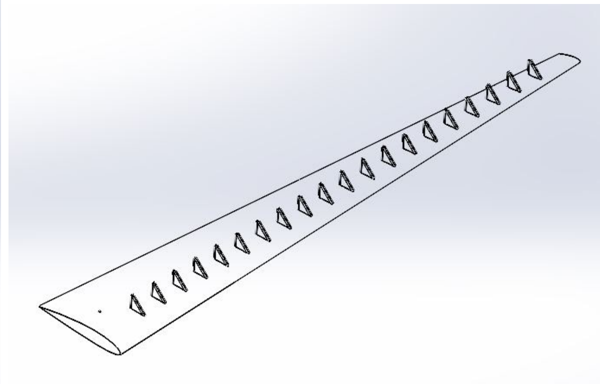
Aircraft have historically used winglets on the tips of their wings to change the vectors for the mixing pressure fields reducing the effect of noise produced by turbulence (Real Engineering, 2016). On the bio-inspired front, owls are known as the quietest flyers in the sky. They achieve this by using noded feathers on the lead edges of their wings and softer damping feathers on the trailing edges. The nodes work by breaking up the laminar air flow early causing mixing which keeps the boundary layers close to the wing surface, thus reducing turbulent vortices on the trailing edges. The addition of raised bumps on the leading edge of the turbine blade is hoped to have similar effect to the owl wing. The soft feathers on the trailing edge work by damping out turbulence, keeping laminar flow, and reducing noise (BBC Earth, 2016). The addition of a strip of serrated soft/rubbery plastic fixed to the trailing edge is hoped to have similar effect to the feathers of the owl and eliminating violent mixing of the differential pressured air flowing over the wing to a minimum.

Figure 2 shows the four designs in Solidworks.

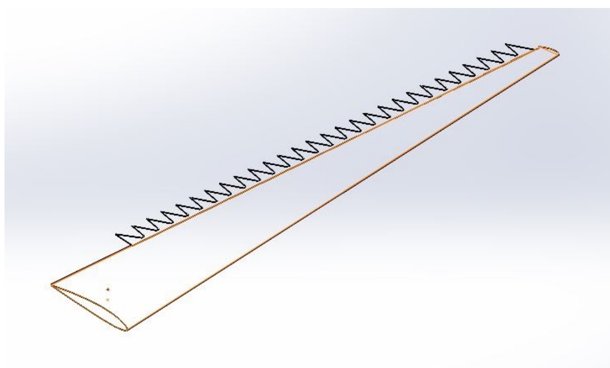
Figure 2: Various Wing Modifications



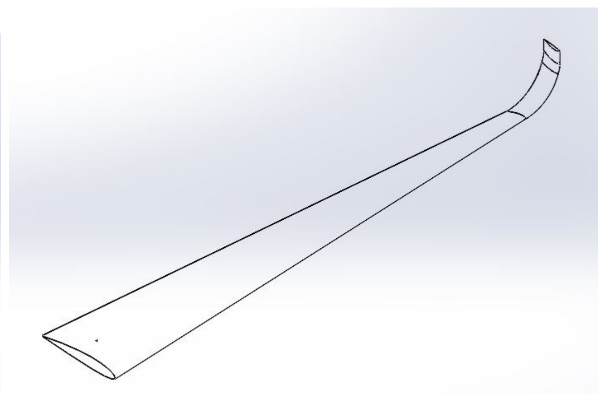
Standard



Noded



Serrated Trailing Edge



Winglet

**Technical Plan:**

Due to the present uncertainty caused by the novel coronavirus, there are unknown factors in our test procedures that may change as time progresses. We have designed three modified blades and designed a fourth as a control design for comparison based on a NACA 2414 airfoil.

Our present plan is to 3D print four blade designs and a turbine hub which will allow attachment to a generator and stand for testing efficiency, sound intensity, and performance. We propose to build an approximately two-foot diameter scale model to set up on a stand behind the university wind tunnels in the MEC building. Testing does not require perfectly laminar flows, and the semi-laminar exhaust produced by the wind tunnels will work well as a controlled source of wind for the experiments. Audio sampling will be performed by testing equipment and human hearing for comparison between the different designs.

Measuring the energy output from the generator will allow generation of relative efficiency numbers comparing the control to the sound reducing designs.

## STS Introduction:

Since the start of the second industrial revolution, the Appalachian Mountains have been a major source of coal for the rest of the nation. The residents of the mountains, an ethnocultural minority of the United States, have built their society from an agricultural based system into a resource based society to serve the main source for wealth creation in the region: the coal mines (Lasson, 1972). Public perception has shifted in the past few years, and greener energy sources are on the rise, supplanting coal power.

The main framework that will be used to analyse the situation of the Appalachians is SCOT: Social Construction of Technology. SCOT holds that a wide range of social factors ultimately decides whether a technology is embraced or discarded (encyclopedia.com, 2020). A technology is not merely created as inherently the best solution but must win the hearts and minds of the stakeholders to be the best technological innovation. The stakeholders are the groups who have a vested interest or are affected by an action, policy, or technological innovation. The citizens of the United States, the energy companies, the government; these groups are the stakeholders with vested interests, ideas, and the ability to influence a technology's development and usage. Besides the stakeholders, there are marginalized groups who are negatively affected or excluded by the technology. Examples of marginalized groups include blind people and touchscreen technology. While touch-interface technology has revolutionized cell phones, becoming the best option to the stakeholders, blind people are excluded from its direct benefits and therefore marginalized.

**STS Background:**

While usage of coal dates to before the founding of the United States, the widespread need for coal occurred in the nineteenth century spurred by the industrial revolution. Coal dug from mines in Pennsylvania to Alabama provided the power to turn iron into steel, power steam engines, and heat homes (Lasson, 1972). With electricity's allure in the eyes of the stakeholders, who were the people of the nation, the need for coal exploded, turning the forgotten hollows of the Appalachians into a source of wealth.

The Appalachians themselves are an ethno-cultural group who are descendants from farmers and hunters hidden away from the outside world by their impassable mountains. The difficulty in easy access for new peoples, technologies, and capital to penetrate the mountains allowed for a unified cultural identity to form separate from their respective states. With the coming of the industrial revolution, railroads and dynamite allowed the construction of roads into the mountains. Railroads to ship the coal out to the cities also allowed new technologies and organizational structures to flow into the mountains. Unification of the mines under large corporations like US Steel turned the miners into an almost slave labor force; unable to own property, unable to quit, and forced to use company money at company stores. Labor unions gave a voice to the miners and better representation allowed for a better standard of living. Coal mining jobs allowed the Appalachian communities to build schools, roads, hospitals, and attend universities. However, coal production peaked in 2007 in the US and has been on a steady decline ever since. Table 1 shows selected years of energy production data from the U.S. Energy Information Administration.

Table 1: USA energy production for select years by type in million kilowatt-hours

| Year | Coal | Oil | Natural Gas | Solar, Wind, Biomass, Waste |
|---|---|---|---|---|
| 1985 | 1,402,128 | 100,202 | 291,946 | 10,725 |
| 2007 | 2,016,456 | 65,739 | 896,590 | 105,238 |
| 2019 | 966,148 | 18,567 | 1,581,815 | 406,877 |

(EIA, 2020)

After the 1980s, the stakeholders identification of the "best" technology began to shift from cheap coal to sources that are renewable or at minimum cleaner burning than the black smoke often associated with the burning of coal. This shift drove the innovation, improvement, and implantation of different energy sources. Public pressure on lawmakers saw clean air ordinances, financial incentives to switch to natural gas, wind, solar, and an overall more diverse methodology for energy production. The changes in energy production left the coal mining community marginalized as the stakeholders took technological innovation in a new direction.

**STS Research Paper Plan:**

For the topic of the STS Research paper, the intent is to look at how the shift from coal to cleaner forms of power has been driven by the social factors and has overall negatively affected the Appalachian population. There is a large amount of data supplied by West Virginia, the US Department of Energy (DOE), and previous research on the topic that provides ample information and is the marker of the stakeholder's changing definition of best technology. The social construction of a new technology does not always mean everybody benefits, and some groups like the coal mining Appalachians are marginalized from the conversation, excluded, or left to fend for themselves. According to the West Virginia Policy group, which published that for southern West Virginia, the total population emmigration change in certain counties can be up to 17% in the post-coal era. (O'leary, 2019).

**Conclusion:**

The future of energy production in this country, and probably around the world, is trending towards cleaner energy technologies. The masses - whose monetary capital, voting power, and perception of the best technology - have shifted their priorities towards renewables and have marginalized and excluded the Appalachians miners from discussions. The miners who used to be participants in the construction of coal technology are being left behind as society moves to construct a new technology using clean energy. On the technical side: wind energy is a part of that new technology and will only be implemented if the stakeholders feel as though it is the best option. Noise pollution caused by wind turbines could cause delays in its embrace or abandonment for another technology, and subtle design changes such as noding, winglets, etc., could be the solution.

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Thank you