Design of a Fan-Powered Face Mask with Advanced Filtering Capabilities
(Technical Paper)

An Analysis of Nuclear Energy and the Possible Solution to the Consequences of Burning Fossil Fuels
(STS Paper)

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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

Signed:  Date 07 May 2021

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Introduction

Well into the 21st Century, humans have had the best understanding of knowledge, science, and technology compared to any other lifeform, but what if I told you this vast comprehension of these fields is not always at the center of our decision making? At the end of the day, we are humans; perceived risk, doubt, and uncertainty remain non neglectable in everyday life. The effects of perceived risk are directly seen in the field of energy production. Overall, fossil fuel energy accounts for 60% of U.S. energy production; renewable sources such as wind, hydroelectric, and solar energy account for roughly 20%, leaving approximately 20% of energy produced in the United States by nuclear energy plants (EIA, 2020). Humans face the inevitable problem of greenhouse gases constantly emitting from fossil fuel-based energy plants, yet fear from past nuclear disasters as well as the dangerous nature of the fuel itself, may be inhibiting nuclear energy from being implemented to the extent necessary to prevent environmental consequences. Beyond the operation of a nuclear power plant, the support and supervision from government bodies also play a large role in successful implementation. Specifically, the public's trust in the government and their system regarding nuclear energy is paramount (Kerr, 2011).

While risk in the example of nuclear energy is may be seen as preventing the transition towards different energy production, precautionary measures can also drive the development of technology forward in other situations. So far in 2020, the COVID-19 pandemic has, in some way, affected the lives of everyone in the world, registering over 46 million cases and taking the lives of roughly 1.2 million people (Johns Hopkins, 2020). Throughout the year, scientists and other experts have continued to learn more about this virus, including how it spreads, how long

individuals remain contagious, and the best ways to slow down its spread. Relatively new discoveries regarding the Coronavirus, including airborne transmissions and asymptomatic cases, have instilled new levels of fear and risk in society, leading to more advanced developments of masks and other personal protection gear (PPE). The goal of the proposed Capstone project is to create fan powered mask system that effectively filters both the inhalation and exhalation of virus particles, as well as one that assists breathing and looks aesthetically pleasing.

Technical

From the beginning of the COVID-19 pandemic, virus mitigation efforts, including social distancing, mask wearing, and group size limitations, have been implemented around the world in order to slow the spread of the virus. Face masks, in particular, are some of the most effective protective measures against the spread of the coronavirus (Mayo Clinic Staff, 2020). The simplest form of face masks, made of cloth, are intended to trap water droplets from individuals in the event that they may be carrying the virus (Mayo Clinic Staff, 2020). While the material used in simple clinical face masks may increase the filtering capabilities of germs leaving an individual, the USFDA has yet to approve any surgical face mask for the protection against coronavirus (Mayo Clinic Staff, 2020). However, N95 masks are certified to block 95 percent of the particles during intake, resulting in the mask and the material itself to be one of the most common personal protection gear (PPE) technologies seen in the healthcare workplace upon passing a proper fit test (Mayo Clinic Staff, 2020).

As the material becomes more effective in filtering particles, it is noticeably harder to breathe through the masks (Mayo Clinic Staff, 2020). A solution to this restriction of breathing is including a powered fan within the mask to increase the flow of air to the individual. Devices

that integrate a powered fan, such as a Powered Air Purifying Respirator (PAPR), provide plenty of filtered air to the individual, but fail to filter the individual's exhalation (CDC, 2020). Together, the ability to filter inhalation and exhalation with certified materials and the ease of breathing in fan powered systems may result in an ideal user experience, while also protecting the general population.

The final technical deliverable of this project will be a powered mask system that filters both inhalation and exhalation. Current mask designs, such as half-face respirators or continuous positive airway pressure (CPAP) masks, will be repurposed to ensure that the final product's fit on the face of the individual meets current standards. In addition to these existing masks, 3D printed apparatus will be created and contain centrifugal blower fans and MERV-15 (minimum efficiency reporting value) material, a highly rated filter seen in heating, ventilation, and air conditioning (HVAC) systems. In addition to meeting health standards, the social perception of overall mask designs must be considered. Advanced half-face respirators, that in full resemble military-grade gas masks, are not incredibly expensive, yet these are rarely seen in public as a virus protection method. The fact that aesthetics matter greatly has led the group to put emphasis on color, size, sleekness, and compactness, in the overall design process. Additionally, the average mask removes facial expressions and lip reading from social interactions; choosing a clear CPAP mask as the base of our design is aimed to resolve this. The final design will be tested using computational fluid dynamics (CFD) software to analyze the flow of air within the mask along with self-testing both fit and ease of breathing by the group. The mock fit test will use Bitrex, a bitter spray that indicates the legitimacy of the face seal (OSHA, 2020), and the ease of breathing will be assessed by comparing the final deliverable to N95 masks and other reputable non-powered face masks. The design phase of possible prototypes is scheduled to

finish in the beginning of November, 2020, and the final deliverable is scheduled to be completed by the end of the month, with the final presentation being delivered on November 18, 2020.

STS Topic

Human activities, including fossil fuel combustion, emit roughly 35 billion metric tons of carbon dioxide into the atmosphere, annually (Perera, 2017). According to proposed carbon budgets, total emissions must be reduced to roughly 1,170 to 1,500 billion metric tons in order to limit the Earth's warming to two degrees Celsius, which represents about 28 to 36 years based on current emissions (Mooney, 2019). In addition to carbon dioxide, the burning of fossil fuels results in pollutants, including but not limited to methane, black carbons, polycyclic aromatic hydrocarbons, and nitrogen and sulfur dioxide, which are even more effective in trapping heat in the atmosphere (Perera, 2017). Moreover, according to the World Health Organization (WHO), "urban air pollution causes seven million deaths annually or about one in eight total deaths," (Wilkerson, 2016). Head to head, coal and natural gas power plants produce 820 and 490 grams of carbon dioxide per kilowatt hour, respectively. Coal, the most common fossil fuel burned, is phasing out in energy production; however, the burning of natural gas still produces carbon dioxide and pollutant levels worth noting.

Nuclear energy production involves harvesting the energy released from splitting atoms in nuclear fission. This radiation is captured in the form of boiling water, which then acts as the heat source for a traditional steam power system (Office of Nuclear Energy, 2020). As a result, nuclear plants do not directly release carbon dioxide gases as would a typical coal power plant (EIA, 2020). However, nuclear energy is certainly not risk free. The nature of nuclear fuel,

Uranium-235, is radioactive; meaning the material is actively emitting harmful gamma radiation to its immediate surrounding when not properly contained (Wilkerson, 2016). Additionally, this material remains radioactive years after it's decommissioned, creating a problem of how to effectively store nuclear waste (Jacoby, 2020). While these foreseeable challenges, such as material containment, may be safely addressed, the unforeseeable mishaps of nuclear energy can be devastating. When any component of the primary reactor system is compromised, the nuclear reaction that occurs within the reactors may no longer be controllable. In 2011, an earthquake and a tsunami near Japan resulted in the Fukushima Nuclear Disaster (Wilkerson, 2016). Generators responsible for cooling the reactors of the plant failed, which caused the components of the reactor cores to melt, and as a result of this malfunction, radioactive material were released into the environment (Wilkerson, 2016).

In order to reduce the danger in nuclear energy, the nuclear engineers are constantly developing new technologies and protocols in an effort to make these plants failsafe. For example, some newer reactor generations, referred to as pebble-bed reactors, are designed to prevent uncontrollable fission and meltdowns in the event a component of the reactor system is compromised (Wilkerson, 2016). The nuclear industry is also very involved with the political systems when establishing safety regulations and determining proper waste storage locations. The United States Nuclear Regulatory Commission is an organization that regulates nuclear power plants and encourages a positive nuclear safety culture, a culture that includes but is not limited to personal accountability, continuous learning, effective communication, problem identification, and a questioning attitude (NRC, 2011). In the end, the nuclear industry values the safety of plants and their personnel, as well as the safety of the general public and how it is perceived by society.

When working with materials that are innately hazardous in an industry that has a history of disastrous accidents, risk is everywhere. More importantly, the perception of this risk by the general public has great significance, for action in a situation with risk may no longer be decided solely by experts (Beck, 2006). Invented by German sociologist Ulrich Beck, the risk analysis framework defines risk as a "systemic way of dealing with hazards and insecurities induced and introduced by modernization," (Beck, 2006). The use of risk analysis will be applied to the subject of nuclear energy because there are benefits to nuclear energy when compared to fossil fuel plants, yet there are also less obvious forces that have prevented it from replacing coal and natural gas energy production, for established risk "suggests what should not be done, not what should be done," (Beck, 2006, p. 218).

Methodologies

Researching and analyzing risk in the nuclear industry will help answer the following research question: "how significant is the influence of perceived risk of nuclear energy and its inherently political nature on its implementation into the energy field?" Important key words and research points to look for include but are not limited to public attitude, awareness, and perception. This research paper will investigate the extent of cooperation between environmental activists and politicians in the past, as well as how interest groups quantify risk in order to make financial decisions and protect funding. Research will be conducted to determine how individuals construct cost-benefit analyses comparing two energy platforms. On the subject of environmental policy, this research paper will reference Wicked Problems in general and how plausible environmental action may actually be. For every engineering solution, problems may be redirected elsewhere, and the subject of nuclear energy will show that.

Conclusion

Perceived risk in society directly impacts the direction which technologies advance. The COVID-19 pandemic has led my Capstone group to create a fan powered mask that is designed to successfully filter coronavirus particles in both directions, assist the breathing for the individual, and be aesthetically pleasing, all in an effort to provide a solution to the spread of the virus. The deliverable of this project is creating a working prototype that solves the problems mentioned regarding the mask industry and appeals to the average user enough to use it as personal protective equipment (PPE). Independently, the STS research project will find an answer to what has prevented nuclear energy from solving the environmental concerns of fossil fuel energy. Using background information on risk and wicked problems frameworks, this research paper will analyze the public perception of nuclear and fossil fuel energy, the continuous regulation of the industries, and the process of juxtaposing the two platforms on economic and political levels in order to understand all of the factors that influence the direction of the energy industry.

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