Thesis Project Portfolio

Synthesis of $LaNiO_{2-x}F_x$, an Oxyfluoride

(Technical Report)

The Technological Momentum of the Power Grid

(STS Research Paper)

An Undergraduate Thesis

Presented to the Faculty of the School of Engineering and Applied Science
University of Virginia • Charlottesville, Virginia

In Fulfillment of the Requirements for the Degree
Bachelor of Science, School of Engineering

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Sociotechnical Synthesis

The need for materials with advanced electronic capabilities grows and will continue to grow at an exceptional rate for many years to come. My group, working in the lab of and under the direction of Physics Department Chair Dr. Despina Louca, set out on a project this semester to synthesize a new material, LaNiOxF2-x, which falls into the category of being an oxyfluoride. Oxyfluorides are a versatile family of materials that have many uses due to their optical properties and high conductivity. We were ultimately unable to finish the syntheses due to a supplier's mix up sending us the wrong source material, but managed to develop and perfect our process for when we do have the correct materials. Though there is no direct connection between this project and my STS project, there is always a strong need for new materials in the field of energy production and distribution. My STS project draws attention to the sociotechnical issue that we face when our society relies on a century old electric grid that must be adopted for a new generation of electrification. As the electric grid ages, it becomes less capable of withstanding heavy load, while as society advances, the load put upon it continues to increase. Society is forced to live with this aged technology because with our long history of dependence on it, it has gained a momentum and sway on how we live our lives. Nearly every electric device that we use today is dependent on it. This is why, despite its failings and increasing blackouts, we have not sought any alternatives. The way out of this dilemma is not to cast aside this technology entirely. It would be a horrible waste of resources and be much too costly to replace. Instead, the electric grid needs augmentation to become more reliable, such as with microgrids. In this way, we will be able to turn a past technology that we are forced to adopt into one that benefits us greatly and suits today's needs.

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Spring, 2022
Technical Project Team Members
Jacob Flaherty
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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

Dr. Despina Louca, Department of Physics

Introduction

This semester I worked in the lab overseen by Physics Department Chair, Dr. Despina Louca. Her group specializes in the study of condensed matter physics and focuses on phase transitions in solids. Under Dr. Louca's guidance, postdoc John Schneeloch and I set out to complete a project which would involve synthesizing and characterizing a promising material, $LaNiO_{2-X}F_X$. This material would be considered an oxyfluoride, a classification of materials that have drawn attention due to their many technological applications, such as in light emitting diodes and as electrolytes in fuel cells and batteries and even possessing the possibility for superconductivity. With Dr. Louca's group having synthesized a similar material in 2015, we drew a significant amount of inspiration from their paper, "The Magnetic and Crystal Structures of $Sr_{1-d}FeO_{2-X}F_X$, a New Oxyfluoride"(PubMed ID: 26734691). Ultimately, however, we have yet to produce the desired product, likely due to the fact that one of our source materials was incorrect.

Experiment

Planned Procedure

The planned process for the experiment, devised by Dr. John Schneeloch, begins with creating solutions of $La(NO_3)_3 + 6H_2O$ and $Ni(NO_3)_2 + 6H_2O$ and combining them in a container with tetramethylammonium hydroxide (TMAH), then a precipitate is formed. We believe this is a base-catalyzed reaction, so the amount of TMAH added only influences the speed at which the reaction occurs. The more TMAH that is added, the faster it reacts. More distilled water is added until all components have reacted. Once the material has settled, it should then be filtered to remove the excess water. Following this, the resulting green clay-like substance is heated on a hotplate at 200 degrees Celsius until it turns dry and charcoal colored. This charcoal material is $LaNiO_3$. To make sure all the material has reacted we press pellets and put them through the tube furnace at 800 degrees Celsius for 24 hours for 3 cycles. Next, our goal is to reduce the sample to $LaNiO_2$ by combining with CaH_2 and heating in the furnace at 200 degrees Celsius for 3 days. This step is repeated for 3 cycles, adding CaH_2 between each cycle. The final step would be fluorination, which would be done by grinding our sample with polyvinylidene fluoride (PVDF), however at the time of writing this report we have yet to find a method for doing this.

Experiment Procedure and Results

Following our set plan, we began by adding 4.41 grams of $La(NO_3)_3 + 6H_2O$ and 3.21 grams of $Ni(NO_3)_2 + 6H_2O$ each into separate beakers with 50mL of water. The $La(NO_3)_3$ did not seem to completely dissolve and had a milky white appearance, while the $Ni(NO_3)_2$ appeared green. Putting the solutions together did not trigger any apparent reaction. Then we gradually added the TMAH, which was a 25 weight percent solution in water, using a pipet until a precipitate began to form. We put the resulting material through a coffee filter and rinsed it with distilled water and ethanol until we were left with a green substance with the consistency of clay. Putting this sample back into the beaker, we heated it on the hottest setting of our hotplate, which should be around 200 degrees Celsius. The sample then began to turn black on the bottom, so we periodically broke it up and mixed it with a stir rod until it was a dark charcoal color throughout, as can be seen below.

Fig 1: LaNiO3 on hot plate

Our original plan was to perform the fluorination step next. To make sure that all of the sample has reacted, forming $LaNiO_3$, pressed pellets were put in the tube furnace at 850 degrees Celsius for the duration of 24 hours with warm up and cool down periods at 10 degrees per minute. A steady stream of pure oxygen gas was applied through the furnace, with the gas exiting through a cup of vacuum pump oil to allow for the flow rate to be gauged by counting bubbles. After the first round of heating, we performed an x-ray diffraction measurement that showed that we had 80% of the desired phase, $LaNiO_3$, 11% La_2O_3, and 8% NiO, according to the Smartlab Studio II software. It seemed we had successfully synthesized the desired material, now through the next few rounds it hopefully would become more pure.

When performing the next round of heating, we ran into a problem where it seemed as though water vapor had contaminated and reacted with the sample to form $La(OH)_3$. We assume this is because during the second round we decided to use a cup of water as a flow gauge rather than the vacuum pump oil. To attempt to reverse this reaction, we repeated the heating cycle using the vacuum pump oil again instead of water to gauge the oxygen flow. This did not seem to remedy the problem and so we began a new batch of samples. Aside from this setback, the PVDF sample that we had was manufactured in small beads a few millimeters in diameter that we had not yet been able to find a method to grind, so we planned to make this the final step on the new batch, after calcification.

With our new batch fresh from the hot plate, we were ready to begin the calcification reduction step. We ground our sample and put it in the glove box. We performed this step in the glove box under an argon atmosphere because the reducer that we used, CaH_2, is very sensitive to oxygen and will oxidize exposed. After grinding together 0.5 grams of our sample and 0.2 grams of CaH_2 and putting it in a crucible, we placed the crucible in an open ampoule which was sealed with the finger of a glove in order to keep the argon atmosphere within until it could be vacuum sealed using the burner. We placed the sealed ampoule in the furnace and set it to 200 degrees Celsius for 3 days.

Once that round of reduction in the furnace was finished, we broke the ampoule, prepared a slide, and placed the slide in the x-ray diffractometer for a 10-minute scan. The data appeared very rough, so we checked on the sample and it appeared to have raised, forming a gas bubble within and hardening into a dome shape as seen below.

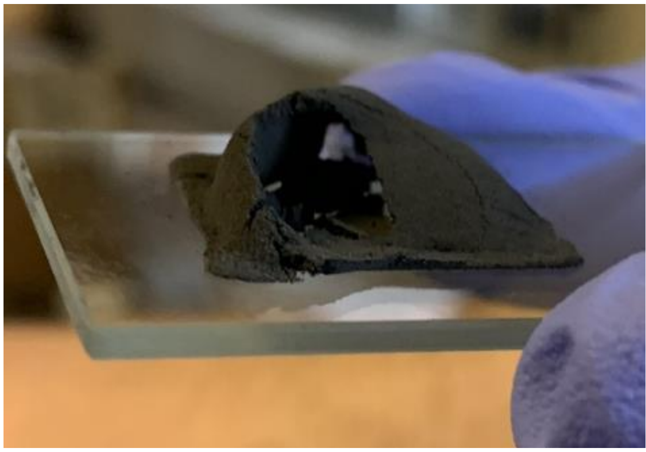

Fig 2: Domed sample after x-ray diffraction

We assumed that this reaction that happened in the x-ray diffractometer must have been due to the CaH2 oxidizing in the 15 minutes that it was exposed to air. We then brought the sample back into the glove box and repeated our process, adding another 0.2 grams of CaH2, sealing the sample in an ampoule, and putting it back in the furnace for a second round of heating for 3 days at 200 degrees Celsius. To prevent the CaH_2 from oxidizing again, we broke the ampoule and prepared slides all inside of the glove box. We sealed the slides by covering them in Kapton film, which we secured using scotch tape. Removing from the glove box and running a 10-minute scan, the software estimated the contents by molecular ratio: CaO (80%), CaH_2 (13%), La_2O_3 (4.4%), with trace amounts of NiO, $CaOH_2$, and $La_2(NiO_4)$, each under 1%. There was virtually none of the desired phase.

We decided to run the sample through the last round of reduction in the furnace, adding the same 0.5 grams of our sample to 0.2 grams of CaH_2 and following the same procedure used in the previous round to keep it protected from the atmosphere. The x-ray diffraction software estimated the contents to be CaO (85%), $La_2(NiO_4)$ (10%), and La_2O_3 (5%), with still no amount of the desired phase.

Discussion

Following the final x-ray diffraction measurement, we received notice from the supplier of one of our initial ingredients, $La_2(NO)_3$ $6H_2O$, that there was an error and we were actually sent La_2O_3. We are now currently waiting for the correct material to be delivered. This may explain why at the end of our CaH_2 reduction we still had none of the desired component. However, this theory is not well supported by the fact that in the first batch we did have 80% LaNiO3, the material to be reduced, prior to the hydration issue that forced us to restart. That is according to Smartlab Studio II, at least. This leaves us with a few theories. One, the software was mistaken on the first batch and we had not synthesized LaNiO3 or we were not able to make a pure enough sample, meaning that having the wrong source material did prove to be a roadblock. Or two, that the CaH_2 step failed, possibly due to the exposure to air or during another step of the process. Once the correct material arrives and we are able to create a third batch, our answer will be definitive. We will also be able to avoid exposure to air during the CaH_2 step.

Conclusion

While we may not have been able to produce the desired oxyfluoride, there is promise that we will be able to on the next round of synthesizing. Aside from having an incorrect source material, the first step in synthesizing $LaNiO_3$ did not have any hiccups. We also made many improvements when it came to finalizing that reaction and perfecting our setup with the tube furnace, making sure to use oil rather than water as a flow gauge. We made a few discoveries on the CaH_2 reduction step as well, realizing the extent of its sensitivity to air and how to work around that using Kapton film. For the final step, fluorination, there still remains the roadblock of finding a way to grind the PVDF beads down to a powder that can be blended with the sample. One option may be to use a source that provides PVDF already ground. Regardless of the reason that caused us to be unsuccessful in synthesizing the desired material, with the correct source material and the methods we've established for each step, we should be able to successfully synthesize $LaNiO_2$. By the time we have, hopefully we will have managed to obtain ground PVDF as well.

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Advisor

Elliott Travis, Department of Engineering and Society

Introduction

The power distribution network that we use today was originally constructed with the purpose of running electricity over long distances to power factories, as well as lights and other nonessential devices. Today, however, with the growing electrification of every device in the home—from climate control and cooking appliances to life support machines—the dependence on reliable electricity has grown substantially. Though the need for reliable energy has increased, the same power grid remains and its roots have dug deeper and deeper as time has gone on. If we continue to think of this technology as we did when it served the simpler goal of providing energy for auxiliary devices, then we will not be able to address how its role in our society has grown distant from our needs as users.

Intro of STS Framework

To attempt to understand the societal impact of complex technological issues, scholars have developed theoretical perspectives, or frameworks, that can be adjusted to fit certain circumstances. These frameworks allow them to break the problem down into its component parts or help to establish a narrative that clearly explains how a technology started, where it went wrong, how it influences society and how society influences it, and finally identify who the stakeholders are.

The framework that I believe will be best suited to help analyze the issue of an aging power grid is called Technological Momentum. Technological Momentum is a theory developed by Thomas Hughes which unites the conflicting views of the frameworks Technological Determinism and Social Determinism. Technological Determinism theorizes that technological development shapes how society functions and grows. Inversely, Social Determinism theorizes that the ways in which a technology is used and designed is heavily influenced by society and the needs of its users.

Technological Momentum, on the other hand, introduces the idea that while a technology is in its infancy, it is highly controlled by societal choices. Its purpose is shaped by society's needs. As the technology ages, it becomes more widely used and gains a “momentum” that grants it a heavy influence on how society is built alongside it. The technology then has more of an ability to shape society’s values, practices, and power relations.

Links between STS framework The Power Grid

In its infancy, the power grid wasn’t initially a grid at all, but rather it began as small distinct stations specifically built for the purpose of supplying energy to industrial factories. At that point, its design was heavily influenced by societal needs. As the needs expanded, so did the power lines. More generators were built and connected to local stores in order to provide lighting. Then over the next few years, they were able to build long range transmission lines operating on high voltage AC and DC power distribution. These advancements made it possible for an interconnected system to be established to transmit power to many locations over long distances.

Today, we have inherited this system of fraying wires and use it far beyond what was imagined by its creators. In 2020, the United States consumed 3.8 Trillion kWh of electricity, which is 13 times the amount consumed in 1950. Though the grid began construction in the late 1800s, this shows a glimpse of the amount that the demand for electricity has grown. With only 4% of that power being produced and consumed on site, 96% of the electricity consumed in 2020 was produced and sold by distributors that rely on the power grid(Energy Explained - Use of electricity 2022). This increase can be attributed to many different outlets which use electricity and rely on the grid. With a power grid in place, it made for a very streamlined transition into an electrified world. In addition to the initial industrial machinery and lighting, society has been enabled to invent climate control systems and other high consumption appliances such as refrigerators, washers, dryers, and flat screen TVs for every household or business. It has even enabled a social and cultural shift into the information age with almost every person in the country having some form of connection to the internet. This transition has increased quality of life manyfold, but now we have established a strong dependence on a not so dependable power grid. Considering the change in direction of influence between the power grid and society, analysis of this complex problem is made much easier to sort through when it is looked at from the angle of the Technological Momentum framework.

Background

In 2020, the average time that consumers in the US were without power due to an issue with the public power distribution system was 8 hours . Twenty-five percent of that time occurred without any major incident causing the outage. This is more than double the averages for 2013 to 2016, which shows that the problem is still increasing. Today, the average age of power plants in the US is over 30 years old. Some parts of the distribution network range to over a century old (Infographic: Understanding the grid 2014). This aging network is bound to experience issues, causing users to be without power.

The electric grid is an interconnected system of power generators, transmission and distribution lines, and users. A power blackout occurs when there is some form of interruption between the generation of power and its delivery to the user, leaving the user with a complete loss of electricity. They can last for only a few moments or , under severe conditions, even weeks. Some common causes of power outages include extreme weather, system failures, or even attacks on infrastructure (What causes electrical blackouts?).

In the late 1800s, when the electric grid was first being connected, Texans began wiring electricity from the excess produced in local ice making factories. As the grid expanded, however, Texas decided that it preferred to keep its energy infrastructure separate from the national network so that they could avoid federal regulations (Hampton, Feb 2021). Today, Texans rely on a power grid that, like the national power grid, is old and fraying. This issue finally caught up with Texans in February of 2021.

In February of 2021, 70% of Texans relying on the state's main power grid lost power for an average of 42 hours (Bohra, March 2021). This led many citizens to turn to gas stoves, grills, and vehicles for warmth in order to avoid hypothermia, which resulted in many carbon-monoxide related deaths. In January 2022, the state of Texas officially announced that there were 246 winter storm related deaths as a direct result of this incident (News Updates 2022).

Analysis by STS framework

The catastrophe that occurred in Texas in 2020 should serve to illustrate that our reliance on electricity has evolved from considering it a convenience for uses in manufacturing and production to a life or death necessity. In the late 1800s, as the power grid was being established, 90 percent of the common people in the United States were living in rural areas, with about 50% of the workforce being in agriculture (The story of U.S. Agricultural Estimates 1973). They were self reliant, producing, preserving, and cooking their own food. They heated their homes with a fireplace, they lit their homes and businesses with lanterns or candles, and they traveled by either walking, horse, or train if they needed to go long distances. Society didn’t have a strong need for electricity because they had been living without it up until then. This is why when power production plants were being connected to their consumers, there was less attention dedicated to making it 100% reliable, but rather to making it economical. The energy producers knew that if their system failed, the consequence would be that customers would simply revert to their old methods of getting by until the problem was fixed.

As consumers began to increase their demand for electricity, utility companies began to connect their lines with other companies so that they could share the load when peak consumption times occurred. This also helped to build a more resilient system since if one plant couldn’t handle the demands, others would pick up the slack rather than the consumers losing power (How electricity is delivered to consumers 2021). This is a fine solution for the production side of the system, but does not protect consumers if their local distribution infrastructure breaks down. In this case, there is no relief for consumers who cannot produce their own power. While this issue benefits producers of at home solar providers, it leaves those who either cannot afford solar or live in an area where they cannot access consistent sunlight, such as the city, in the dark.

The cost of a typical home solar installation in 2021, ranged from around $16,000 to $21,000, which is a substantial decrease from the $50,000 that it would have cost a decade ago (Cost of solar in 2021 2021). However, the cost of materials and installation of solar panels proves to still be too much with less than 4% of US homes having rooftop solar. That leaves the majority of customers to fend for themselves. Even if the price of personal solar continues to drop at such an accelerated rate, there are many people in the US who will still not have access to it due to geographic location or to the fact that they rent their property, with only 65% of citizens owning their home on average (U.S. homeownership rate in the United States from 1990 to 2021 2022).

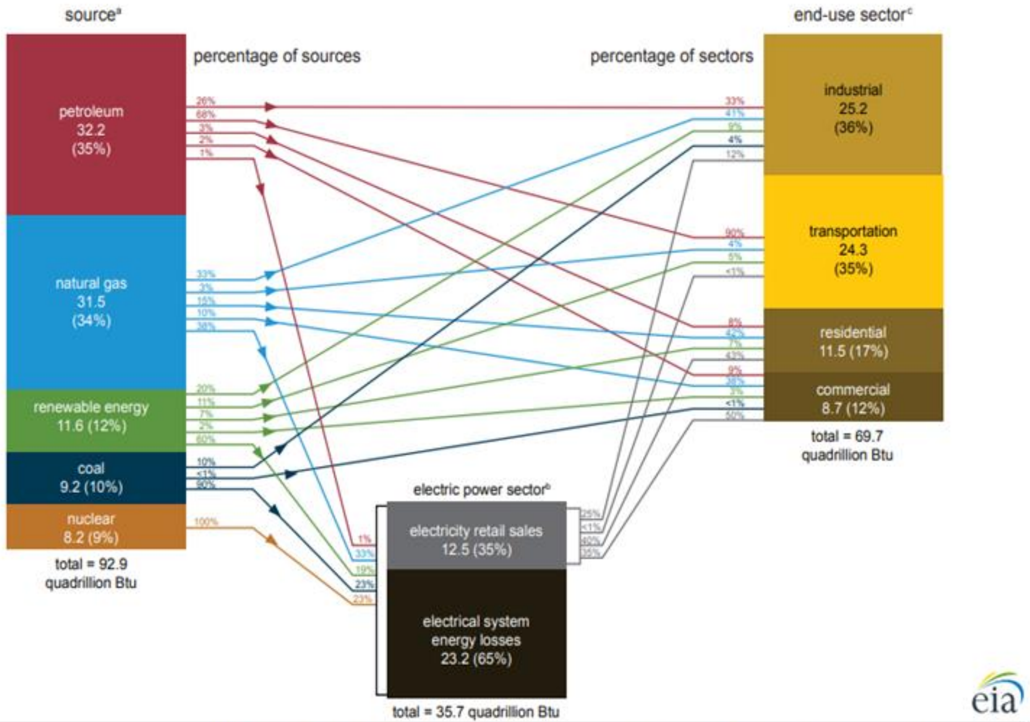
With no solution to the issue of unreliable electricity, the majority of Americans are still at risk of losing power whenever the grid in their area has failed. This may have been acceptable back when the grid was first being built, but it is not acceptable today. Only 41% of homes built in 2018 included a fireplace, and that number is steadily decreasing (Emrath, 2019). The consequences of this disparity was very evident in the Texas power outage. This trend continues when considering pumping water, cooking, and preserving food. Homes today aren't built in preparation for being off of the power grid, especially homes that are built in or around cities, which makes them completely reliant on the system since they don't have access to natural resources.

Aside from relying on electricity today for our comfort and survival, there are incredibly strong ties between the power grid and how society now functions. Our daily lives look very different from how they did a century ago. Today, over 90% of people in the US have access to the internet, which they use to work, communicate, go to school, and entertain themselves in general (Johnson, 2022). Nearly everyone uses the internet in some form for work. Whether it be communicating with customers, coworkers, or suppliers, the internet plays an integral role in business around the country and around the world. In addition to these uses, there has been a significant spike in the amount of people who solely work from home via the internet, and this trend is likely to continue. All of this has only been made possible through a steady connection to power. When that connection goes down, people lose access to communication and their ability to work.

A helpful analogy might be to think of a building with a foundation. Each floor of the building represents another reliance on the foundation, which represents the power grid. There is a floor for taking care of the household with heating, cooling, and common appliances. There is a floor for storing, sending, and receiving data via the internet, as well as to run the computing equipment. There is even a floor today for transportation now that we have electric trains, cars, and public transport. All of these floors have been built with the same old foundation in place that was only designed to support the weight of manufacturing plants and simple lighting, and even those sectors have increased their weight by many fold.

Discussion

Below is a figure from the US Energy Information Administration (EIA) describing the amount of energy that is produced by each source with realistic size proportions given to each. As can be seen, 35.7 of the 92.9 quadrillion BTU produced in 2020 went directly toward producing electricity. That 38.4% of energy goes straight onto the electrical grid in order to be delivered to its end users (U.S. energy facts explained - consumption and production 2021). This already huge amount of electricity is bound for a substantial increase in the coming years due to the US' goals for electrification. First, note that 65% of that electric energy is lost due to unavoidable inefficiencies of converting from heat at the power plant and transmission of the electricity to the users through the power grid. This leaves us with an electrical output of only 12.5 quadrillion BTU. To consider transportation alone, if the US were to transfer the 90% of transportation energy that gasoline powered vehicles use into being electrically powered, that would require an additional output of 21.9 quadrillion BTU (Use of energy for transportation 2021). That is a 275% increase of the amount of electricity produced and transmitted using our same aging power grid, and that is only considering the electrification of one sector.



U.S. energy consumption by source and sector, 2020

quadrillion British thermal units (Btu)

Sources: U.S. Energy Information Administration (EIA), *Monthly Energy Review* (April 2021), Tables 1.3 and 2.1-2.6.

Note: Sum of components may not equal total due to independent rounding. All source and end-use sector consumption data include other energy losses from energy use, not separately identified. See "Extended Chart Notes" on next page.

[a] Primary energy consumption. Each energy source is measured in different physical units and converted to common British thermal units (Btu). See EIA's *Monthly Energy Review* (MER), Appendix A. Noncombustible renewable energy sources are converted to Btu using the "Fossil Fuel Equivalency Approach", see MER Appendix E.

[b] The electric power sector includes electricity-only and combined-heat-and-power (CHP) plants whose primary business is to sell electricity, or electricity and heat, to the public. Energy consumed reflects the approximate heat rates for electricity in MER Appendix A. The total includes electricity net imports, not shown separately. Electrical system energy losses are calculated as the primary energy consumed by the electric power sector minus the heat content of electricity retail sales. See Note 1, "Electrical System Energy Losses," at the end of MER Section 2.

[c] End-use sector consumption of primary energy and electricity retail sales, excluding electrical system energy losses from electricity retail sales. Industrial and commercial sectors consumption includes primary energy consumption by CHP and electricity-only plants contained within the sector.

It would stand to argue if the electricity did not need to be transmitted as far, less would be lost to the inefficiency of transmission. According to the EIA, however, the average losses in the transmission and distribution networks from 2016 to 2020 equaled only about 5% of what was produced (Frequently asked questions 2021). Though producing electricity near the end use may not prevent losses as much, it would make for less infrastructure to fail between generation and use, making the system more resilient. This resilience would be even more essential once nearly the entire transportation sector rests on the shoulders of this system, adding another floor to this same foundation.

Nearly 25% of the annual $950/customer cost of electricity goes into maintaining the transmission and distribution network. While we have already discussed the promise of household rooftop solar for increasing resilience, this money might be better spent investing in a more efficient and dependable public infrastructure. One example of a more reliable infrastructure is the concept of microgrids. A microgrid is a local, community scale energy grid which can operate autonomously from the traditional grid (Use of energy for transportation 2021). While most of the time, the microgrid would be connected to the traditional grid, it can be disconnected and used to provide constant power when portions of the traditional grid are being repaired. Not only do microgrids provide backup power, but they can use local energy sources to supplement the traditional grid, decreasing the load. Microgrids are a well rounded solution because they not only can be powered using renewable energy, but they serve in tandem with the already existing infrastructure. Rather than replacing what we have, this concept will support it and make it into a more well rounded and sustainable system.

Conclusion

The problem that the aging electrical grid poses to society seems to be a very complex one, but it is one that needs to be addressed. By identifying the key properties in the Technological Momentum framework, which are that when a technology is first introduced, its development is highly influenced by societal needs, and as the technology ages it gains more sway over the way in which society functions and grows, I hope that a clear connection has been made to aid in understanding how the power grid’s direction of influence has changed over time. The grid was initially built simply to increase the efficiency of industrial processes, as well as provide light for streets and businesses. Today, however, the grid has become a lifeline that we rely on dearly for business, transportation, and taking care of our daily needs. The grid’s duties have multiplied substantially, yet we are left with the same piece of equipment and it is not meeting our needs. The solution today is not to throw out the old system, though, but to help it become better through augmenting with microgrids, which can help reduce the load and supply users with energy even when the grid has failed.

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Small Scale Mechanical Energy Storage

(Technical Paper)

Unstable Energy Accessibility Due to Aging Infrastructure

(STS Paper)

A Thesis Prospectus Submitted to the
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Jacob Michael Flaherty

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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

A Sociotechnical Issue In 2016, the average time that consumers were without power due to an issue with the public power distribution system was 4 hours ("Average Frequency," 2018). Nearly half of that time occurred without any major incident causing the outage. The average age of power plants in the US is over 30 years old. Some parts of the distribution network range to over a century old ("Understanding the Grid," 2014). This aging network is bound to experience issues, causing users to be without power. Sustainable energy sources such as solar and wind not only reduce the amount of carbon released into the atmosphere and increase our national energy independence, but they do so now at a comparable price to fossil fuels. Most relevantly, however, solar panels allow consumers to produce power on site at a single household scale. A problem arises because solar and wind are volatile and unpredictable as energy sources, so in order for them to be considered viable, there must be a way to store the energy so that it can be used when it is not being generated.

Currently, the issue of sporadic power generation from home solar panels is solved by primarily relying on the public power grid to provide consistent power. The use of solar panels is then left only as an auxiliary to lessen the load consumed from the grid. The main issue with relying mainly on the public power grid is that the grid is not always reliable. This can lead to dangerous repercussions when the public loses access to power in hazardous weather conditions such as what was experienced in Texas in February of 2021. Another issue with this solution is that the public power grid is supplied using 60% fossil fuels ("Electricity Explained," 2021), which are known to release greenhouse gases that contribute to climate change and destruction of ecosystems ("The Sources and Solutions"). Though it is known that the electric grid is in need of replacing, doing so is difficult because there is already an immeasurable amount of infrastructure, equipment, and practices that go into keeping it running. There are many people who rely on the power grid for jobs as well. The task of moving away from centralized power and toward microgrids or dispersed power will not be completed unless both the technical and social aspects are taken into consideration.

The instability of power that is delivered to users is socio-technical in nature and therefore requires a solution that addresses both its technical and social aspects. In order to solve the technical issues, I will propose an updated strategy for storing energy on a smaller scale to avoid reliance on long range transmission. In order to address the social factors causing the issue, I hope to provide a better understanding of how technological momentum has caused us to rely on an ancient and ever-aging electrical grid.

Technical Project: Small Scale Mechanical Energy Storage

Renewable energy such as from solar and wind has been on the rise for decades now, but the issue with their inconsistent power supply has remained. The solution is commonly known to be to develop better modes of storing the energy ("Energy Storage," 2012). Today, renewables are mainly used to supplement fossil fuels because fossil fuels are controllable and can be utilized at any time. Current methods of storing energy derived from solar and wind that are commonly used include hydroelectric dams and larger batteries. As of 2018, there existed 25.2GW of US energy storage capacity, with 94% being in the form of pumped hydroelectric energy storage. The remaining 6% was split between thermal, battery, compressed air, and flywheels ("Energy Storage").

Aside from the fact that use of fossil fuels is damaging to the environment and limited, the energy produced is centralized at a power plant, making it rely on a public transmission network. Hydroelectric dams are long lasting, able to store vast amounts of energy, and convert it with 80%

efficiency (“Fact Sheet: Energy Storage”). However, these huge and expensive structures are limited to locations with large bodies of water. Additionally, they do not solve the problem of possible failures in the electrical grid because they still rely on the public network to distribute the stored energy. Large batteries on the other hand can store energy at the home, creating a reliable power source even when the public grid has failed. The issue lies with their capacity, price, and longevity. Batteries quickly increase in size as their energy storage capacity increases. They are also made using rare metals, which decreases the practicality when considering scaling to where every home has a battery of substantial size. Finally, batteries degrade over time, leading to them needing to be recycled and replaced. Lithium-ion batteries, the most popular type used, typically last between 1,000 and 10,000 cycles (“Fact Sheet: Energy Storage”).

By leaving this problem unresolved, the US will continue to face power outages that take away from the comfort and safety of the public. I claim that the solution to the problem lies in an energy storage system that is placed at the home so that it will have 100% accessibility in the event of public power failure. I propose a device that stores excess power in the form of mechanical energy. To be more specific, a device that uses the potential energy of a large mass by raising it when energy is in excess and lowering when energy is needed.

In order to prove this design, I will analyze the cost and practicality of having such a device installed at every home. To demonstrate the value of a new design, I will draw on data regarding the number of homes that have gone without power due to failures within the power grid. I will also address the feasibility of small scale gravitational potential energy storage using information about standard energy usage in the United States combined with estimations of the capabilities for such a device.

STS Project: Technological Momentum of The Electrical Grid

In the late 1800s, when the electric grid was first being connected, Texans began wiring electricity from the excess produced in local ice making factories. As the grid expanded, however, Texas decided that it preferred to keep its energy infrastructure separate from the national network so that they could avoid federal regulations (Hampton, Feb 2021). Today, Texans rely on a power grid that, like the national power grid, is old and fraying. This issue finally caught up with them in February of 2021.

In February of 2021, 70% of Texans relying on the states main power grid lost power for an average of 42 hours (Bohra, March 2021). This led many citizens to turn to gas stoves, grills, and vehicles for warmth, resulting in many carbon-monoxide related deaths. As of July 2021, the state of Texas has officially announced 210 winter storm related deaths ("Winter Storm Related Deaths," July 2021).

The power distribution network that we use today was originally constructed with the purpose of running electricity over long distances to power factories, as well as lights and nonessential devices. Today, however, with the growing electrification of every device in the home —from climate control and cooking devices to life support machines—the dependance on reliable electricity has grown substantially. Though the need for reliable energy has increased, the same power grid has dug its roots deeper and deeper as time goes on. If we continue to think of this technology as we did when it served the simpler goal of providing energy for auxiliary devices, then we will not be able to address how its role in our society has grown distant from our needs as users.

Although our nation’s power grid was originally designed to electrify simple machines for the sake of industrialization over the wide expanse that is the United States, over time it has gained momentum because it has been developed so heavily. There are many jobs supporting its use and an immense amount of infrastructure keeping it running.

To attempt to understand the social impact of the electric grid, I will analyze it using Thomas Hughes’ theory of Technological Momentum. Hughes’ theory unites the conflicting views of Technological Determinism, which states that society is shaped by technology, and Social Determinism, which states that technology is shaped by society. He does this by introducing the idea that in its infancy, a technology is highly controlled by societal choices, but as the technology develops it gains a “momentum” that grants it a heavy influence on how society is built along side it. To support my argument, I will analyze evidence from news interviews and historical publishing which will provide information about how the power grid was originally designed and intended compared to how it has evolved into what it is today.

Conclusion

In order to combat the instability that users face due to centralized power generation because of aging infrastructure and natural disasters, I hope to deliver a device that allows energy to be stored on the site of each household. This device will operate using a mechanical energy storage system that, unlike batteries, will not degrade over time or require rare and limited materials to function. For this new device to be accepted universally, I hope to give my readers a better understanding of how social aspects affect the development of technology using the framework of Technological Momentum. With the introduction of a reliable, consistent, and affordable method of storing energy on a small scale, there is no need to rip up the deep roots that the current electrical grid has grown. Rather, with an understanding of the technological momentum that the grid possesses, the process of incorporating the small scale storage will make for a more stable system altogether.

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