The Analysis of the Integration of Sustainability in the Energy Industry

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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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1. Introduction

Renewable energy is energy produced from sources that do not deplete or can be replenished within a human's life time, such as solar, wind and hydropower. In the past decade, the United States has attempted to integrate renewable energy into the industrial and residential sects of society in many fashions, from carbon taxes to incentivized legislation on a statewide level (U.S. Department of Energy. November, 2019.). Continuing forward, the already-established systems and the sustainability legislation will hinder the future growth of renewable energy in the United States. Using the Social Construction of Technology (SCOT) framework to identify challenges within and surrounding the integration of renewable energy in future society.

The following paper will first detail the background of traditional energy consumption while identifying the initial emergence of renewables. This section will describe the current condition of the energy sector and how it has evolved to the present. This will set up an analysis of the three major challenges in integrating sustainable energy: policy and culture, homogeneity and renewable technologies, and the grid system. A succinct conclusion will then summarize the paper at the end. Historically, this paper will show how the energy sector has evolved, the current goals of energy activists and professionals, and the possibilities of sustainable energy moving forward. Logistically, the paper will outline obstacles to overcome, and structural and legislative changes that will be necessary to change for further sustainable integration.

2. Background

Evolution of Traditional Energy

Since the modernization of complete home electrification in the 1950s, the United States has dramatically increased the consumption of electricity – 335 billion kilowatt hours in 1950 to 4,117 billion kilowatt hours in 2019 (U.S. Department of Energy. March, 2020) . Electric utility companies, in turn, sought to discover and use more resources to match the increased population consumption. The most popular and largest resource served to be fossil fuels, especially those discovered in the Middle East. By 2007, coal and petroleum provided over 50% of the electric power to the United States (U.S. Department of Energy. March, 2020). The mass burning of fossil fuels was partnered with a developed system of factories, the modern electric grid and a general dependency on these fossil fuels to provide power for the population of the United States.

However, problems arose due to the exorbitant use of fossil fuels. These resources are nonrenewable, which means they are limited and cannot be replenished at a rate sustainable to which they are used. Further burning of fossil fuels, especially at its current amount, meant losing the main source of power for all of the United States and its citizens. Further, the main geographical location of excavation was the Middle East, in which there has been tension since the end of the second World War (NPR.). Realizing these growing concerns, politicians and leaders of the energy industry realized the need to find alternative fuel sources. These resources needed to be sustainable and easily obtainable by the United States in order to have long-term reliability in the industry and for its consumers. The paper, thus, focuses on solar energy, wind energy, and hydroelectric energy, since they are all domestically accessible, are renewable, and are a focal point of research and development amongst industry leaders in the United States and abroad.

Renewable Energy Movement

While there have been industrialists and scientists debating the use of oil and coal for decades, the first real movement to renewable energy began with the Clean Air Act of 1970 (Mason). This legislation was implemented in order to limit the amount of air pollution produced for the health and safety of the general public. While this was more related to health and pollution, it led to more intimate research in the consequences of modern energy consumption. Shortly thereafter was the rush of clean energy movements, the inception of Earth Day and the development of more sophisticated and safer technologies. In particular, there has been mass research on solar panels and storage, hydroelectric power generation and wind farms. The Federal Production Tax Credit (PTC), the Investment Tax Credit (ITC) and the Modified-Accelerated Cost—Recovery System (MACRS) are all federal forms of legislation that incentivize the use of renewable or "sustainable" energy. These policies were established in 1992, 2006, and 1981, respectively, but have been amended or renewed repeatedly since their conception. This ushered in a new era of cleaner, more sustainable energy (National Academic Press. 2010). Other policies have been implemented on a state-by-state basis – for example, the California Self-Generation Incentive Program (SGIP) is state level program organized between major utilities – Pacific Gas and Electric (PG&E), Southern California Edison (SCE), the Southern California Gas Company (SoCal Gas) and the Center for Sustainable Energy (CSE) – in order to provide solar production and storage initiatives for industry and residential use (PG&E. 2020). The passing of these policies has reduced the price of renewable energy technologies for the average homeowner as well as for the actual technology production. As of 2019, fossil fuel power consumption has decreased to 1,006 billion kilowatt hours from the 2,101 billion kilowatt hours in 2007 (U.S. Department of Energy. March, 2020).

3. Challenges in Policy and Culture

Moving forward, the United States policymakers and industry leaders have shown the willingness to integrate to renewable energies and provide a path to do so. However, long-term policy issues intended to help may actually hurt. The use of incentive programs has created an artificially low price of production and use for technology developers and residents has created an expectation and market unsustainable in the future. Other countries, like Mexico and South Africa, have used similar legislation policies, but bidders for projects consistently failed to pay contractors and other specialists once the incentive programs ended (Matsuo and Schmidt. 2019). In fact, in Mexico, many of the first-round projects did not begin production and failed to meet federal mandates on the terms of production due to failure of payment. In addition, the disappearance of the mandates has led to an equal disappearance of smaller businesses and local development within the countries. Large foreign companies that have the ability to accrue debt with other industries keeping them afloat have monopolized upstream project development. Similarly, many of the small and local businesses thriving during the current renewable energy market will struggle greatly once the incentive programs expire. In order to advance the renewable energy industry, the success of small businesses in niche industries is imperative as they lead all industries in the innovation and creation of new products (Greene. 2016).

Also written in the terms of many of the policies are performance-based incentives (PBIs). PBIs ensure that the owner of the renewable energy technology – whether industrial or residential – meet certain criteria to receive part of their incentive. The biggest issue with this would be with the policies and standards on continuous use. For example, the SGIP gives PBIs based on the duration and output of the solar battery being installed. It states that the incentive will cover only a percentage of the cost per megawatt/kilowatt for the specific hours of the battery. Using numbers for clarity, a homeowner buys a solar battery with a max duration of 8 hours and a maximum 10-kilowatt output. This means the maximum capacity is 80 kilowatt-hours (8 hours x 10-kilowatt output). Under the SGIP incentive rate, the program will cover one hundred percent of the cost of the output for hours one and two, fifty percent of the cost for hours three and four, twenty-five percent of the cost for hours five and six, then none of the cost after, all multiplied by the rate of coverage (i.e. fifty cents per kilowatt-hour) (SGIP Energy Storage Incentive Examples.). By implementing these criteria, the SGIP is, in essence, incentivizing battery companies and consumers alike to create and use short-term usage batteries. If the renewable energy sector is to evolve, homeowners and industries need the ability to rely on it throughout the entire day. By limiting the capabilities of the technologies being implemented throughout society as a whole, the evolution of the sector will also be limited. In general, the incentive programs' structure is too rigid and does not compensate for furthered innovation of renewable technologies currently being established in the industry.

Other issues in the United States can be attributed to the overall cultural lifestyle and structure compared to other countries. The United States is the largest consumer market of all countries, occupying 29% of the world's total consumer market (International Business. 2015). The general lifestyle of American citizens can be described as living above the means, or at least pushing the boundary. This mentality as it pertains to energy, means that much more power per individual will be required than in other nations with lifestyles more emphasis on sustainable and minimalism. In the same way, individualism is at the root of American decision-making, in the context of business and personal choice. Many other nations, especially those in Asia, make decisions with a team-oriented and consequential view. The derivative future decisions of individuals in foreign countries regarding energy will tend to be more based on its effects to nature, neighbors and other stakeholders. Americans, then, will make energy consumption decisions based on the needs of themselves, whether it be cost or immediate needs of power (i.e. without self-sacrifice). In order to integrate sustainable energy in a higher capacity, the mentality of the American citizens would need to mold to emphasize self-sacrifice and long-term effects.

By looking at this from the SCOT framework, human-made policy structures and the culture of the general people direct the technologies that will and will not thrive. In the U.S., due to acts of individualism and convenience, it is difficult to bring effective change to the energy sector and implement sustainable technologies.

4. Challenges in Homogeneity and Renewable Technologies

One of the biggest challenges the United States faces in comparison to other countries that have successfully implemented an entirely sustainable energy grid is the heterogeneity of the country as a whole; it is a non-contiguous country with different variations of climate, terrain and people. Denmark, for example used solar and wind energy to produce half of its electricity in 2019 (Green Thinking.). They are able to change its systems in place and successfully achieve their goals of sustainability. However, their country is largely homogenized by geography, largely oceanic with a total of 16,573 square miles of land (not including Greenland) and a total population of 5.6 million. In comparison, the United States has vastly different terrain, 3.8 million square miles of land and a population of 327 million. The challenges facing the United States is the implementation of renewable energy in such diverse places. Hydroelectric power requires either a large amount of land and hilly terrain or a large river for a dam. In places with large populations, such as the northeast region, the implementation of a dam or a hydroelectric would ruin the ecology of the area, especially in port cities like New York or Boston. Much of the untouched land has national park protection as well, eliminating many other options.

Wind and solar farms would also require a large amount of land, and they are dependent on the weather. With very different climates across the United States, it would be difficultIn order to successfully implement the farms, one would need to choose location with consistent weather patterns in order to optimize the cost and effort to install them. One such option would be the Midwest, which has a large portion of agricultural land potentially available. Issues compile, though, when thinking of the sparsity of the population and seizing farmland for energy production. There will be challenges involved in moving the electricity long distances, which will be addressed later. In addition, seizing farmland could anger farmland and hurt the agricultural industry.

In addition to issues with the placement of renewable technologies, there are issues with the technologies themselves. When using solar and wind farms, all three technologies, including hydroelectric power, they all use large amounts of land and lack in efficiency. Dams and other hydroelectric power sources generate large amounts of energy through rushing water, but only 36%-44% is actually harnessed and used (2018 Standard Scenarios Report.). Dams have the luxury of flow fluctuation to change the amount of energy produced instantaneously, which is imperative during peak and non-peak hours of power usage. Unlike hydroelectric, solar and wind power source have limited capabilities in fluctuating energy output because of their dependence on weather factors. Wind farms lack efficiency in the same way that hydroelectric does, with a capacity factor (efficiency rating) of anywhere from 1%-80% (Andrew. 2014). The reason for the variance is the trade-off of costs of materials for individual farmers, with higher quality and lower quality eventually reaching the same return on investment. With this in mind, there is discrepancy on the types of materials, their effectiveness, and the disposal of the turbine materials after their lifecycle has ended. It is estimated that there will be 720,000 tons of disposed wind turbine material in the next 20 years, leading to more issues with the future development of wind power (Stella. 2019).

Solar panels have a capacity factor of 10%-25% (U.S. Department of Energy. April, 2020) making it, on aggregate, the least efficient of the three main renewable resources. Unlike the other two, however, it is very transferrable and can be used by individual homeowners or businesses. Solar energy has issues in this regard too, though. Despite being a personal commodity for homeowners, the typical peak hours of electricity use are at early evening and night, when the sun is down. In order to most optimally use solar power, the homeowner must buy a solar storage system. These can assist individuals with self-sufficiency, especially during power outages and extreme weather. In the same strand, the typical batteries used also lack in efficiency, just not to the extreme of the capacity factors of the energy technologies. Generally, solar batteries have an efficiency rate of about 85% per cycle (from charge to discharge), as is noted in the technical report. This means the total round-trip capacity factor from the solar panels to discharge is a maximum of about 21%. Solar energy has the most established grid system, with credit opportunities for using personal solar energy instead of that from the grid, but in total accounts for the smallest percentage of energy production amongst the three renewables (U.S. Department of Energy. March, 2020). In general, innovation within the technologies will take time, but there is promise with the implementation of any and all of these resources as long as there is creativity in design.

To this effect, the SCOT framework holds that the actions of humans shape technology. By choosing where to live, only specific renewables can become effective resources, thus limiting and eliminating the evolution of certain technologies in their region.

5. Challenges with the Grid System

The modernization of electrification developed an intricate system in which the majority of Americans receive their home and commercial electricity. Called the electrical grid, it is a serious of power lines and transformers that move electricity from the energy factory or farm to the homes and buildings in its precinct. As of now, there are localized factories all across the United States, owned by different utility companies that serve this purpose. However, with the intent of integrating more renewable technologies, the grid serves a challenge on transporting the electricity or for transforming the modern system as it is.

Beginning with transporting electricity, there are currently over 360,000 miles of transmission lines in the United States with over 7,000 power plants meant to convert the output to a more sustainable voltage for homes and businesses (United States Industry Primer.). As it stands, there are localized plants and factories in which to produce electricity using fossil fuels or natural gas, but a generally long distance is still required to transport the electricity to every home and business in its precinct. With the transportation of such a large voltage (69 to 765 kV) over a longer transmission line, power loss occurs and is exaggerated as either the distance or voltage is increased (United States Industry Primer.). Translating this to renewable energy, an established and very powerful wind or solar farm would need a large amount of land in order to power a large population. This means it would be required to be located in a remote area. Sending out all of the power from one or a handful of locations would lead to more power loss than in the current state of the market. In order to send the electricity across great distances, a higher voltage is required, thus exponentiating the power loss. With renewables being a generally inefficient source of energy, a plant even more massive than originally thought would be necessary to meet the needs of all consumers.

This points to an even greater problem that may require a solution in the near future. The grid system is currently rigid, well-established, and needed for the general population. It is currently a centralized grid, meaning that it is interconnected and power is pooled from a single energy source to multiple users, much how older landline phones would work. This means if that single energy source cannot provide power, all users will be without grid power for any amount of time. With renewable energy being unreliable in a given day, it is extremely difficult to use the current system with a single renewable power source to provide electricity for a small population. There are already some self-sufficient homes that can power their own home with solar and other alternative energy sources.

Moving forward, the United States Department of Energy could look at implementing more self-sufficient or decentralized structures, or even complete privatization of electricity, that utilizes smaller-scale electricity transportation such as residential solar farms in sunny climates. The issues that arise with this are again in part due to the current grid system in place. The rigidity of the structures – figuratively and literally – make adjustments difficult. The current power lines would become obsolete in a renewable energy-style structure. The removal and possible repurposing of the power lines would take a long time and cost a lot of money. The liability of removing them is very high as well as the difficulty of redirecting the power from homes to localized plants would be tricky without shutting off the power of a community for a significant amount of time. Moving forward, either the grid system or the implementation of renewable technologies must evolve in order to work with each other.

By interpreting this challenge with the SCOT framework, it is easy to understand the evolution of the grid system to its current system. With no long-term vision, the American conglomerate innovated the grid system to become problematic in the future. However, because of what was universally accepted and convenient system, the grid survived for years, with new technologies being created only to connect and optimize with it.

6. Conclusion

With fossil fuels becoming limited across the world, the United States has begun to develop more sustainable practices with renewable energy. These developments have in some ways hindered long-term growth, such as an artificial renewable energy industry due to price-lowering incentives. Along with the heterogeneity of the United States and the limitations of the renewable technologies, there will be challenges moving forward on implementing these technologies on a larger scale in the future – particularly involving policy and culture, homogeneity, and with the current grid infrastructure. The current grid system has affected the ability to transport and conserve electricity, favoring instantaneous power-output systems like the fossil fuels still being used today. In order to combat this, difficult changes and decision must be made to the centralized United States grid. All of these factors add up, highlighting the Social Construction of Technology that has developed the current system, and how the United States must evolve moving forward.

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