Recovery of Copper & Gold from Waste Electrical & Electronic Equipment

(Technical Paper)

Network Challenges in Advancing Energy Technology in the U.S.

(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

Introduction

Global energy use is projected to increase from 549 quadrillion British thermal units (BTU) in 2012, to 629 quadrillion BTU by 2020, to 813 quadrillion BTU by 2040. At the same time, greenhouse gas emissions are rising: CO_2 increased from approximately 280 ppm to over 400 ppm since the start of the Industrial Revolution (Chu et al., 2016). Thus, while modern society demands sustainable energy, it also requires technology that can meet its vast power consumption.

Energy consumption has not increased significantly in the last decade, as an increase in the number of energy users have been countered by increases in energy efficiency over several technologies (Today in Energy). Renewable energies are expected to become more widespread, but the extent to which they can be interweaved into society remains unclear. Myriad societal, political, and cultural forces, which often oppose one another in their goals, dictate development of environmentally benign and sustainable technologies.

One important component of our energy infrastructure is synthetic gas, or *syngas*. Syngas is a gas mixture used to generate energy and produce other chemicals, commonly generated using natural gas. The technical component of this capstone examines a method of producing syngas from waste. Though this process is desirable from an environmental perspective, it is less economically viable than using natural gas a feed source. Renewable energies tend to require higher initial capital costs and have a smaller market (Luthra, 2015). If new technologies are to be adopted by a broader base, then government agencies need to incentivize investment in renewable technology and provide educational opportunities to predispose consumers to renewables. Thus, technology alone is not enough to promote renewable energy. The STS component of this paper examines the societal, technological, political, and cultural forces that drive modern efforts in adopting sustainable energy. The technological component examines a potential system to convert waste to syngas and then into gasoline. Combined, this proposal seeks to probe how sustainable energy fits into our energy infrastructure to feasibly address the vast energy needs of the U.S.

Technical Topic

With increasing pressures towards addressing mounting waste in the US, scientists are turning towards new ways to utilize waste in energy-producing processes. Researchers from the International Telecommunication Union (ITU) estimate that about 44.7 million metric tons of electronic waste (e-waste) were generated worldwide in 2016. Only 20% of this amount was recycled through appropriate channels (Baldé et al., 2017). Developing a process to utilize productively e-waste is therefore highly desirable. E-waste is made up of a mixture of various metals; namely copper, aluminum, iron, and nickel, as well as various plastics, resins and ceramics (Flandinet et al., 2012, p. 485). We will research how to convert e-waste into synthesis gas (*syngas*) which can later be treated and converted into gasoline. Syngas is typically processed from natural gas; thus, this project has the environmental advantage of replacing a non-renewable feedstock with a non-degradable one, solving two issues in sustainability.

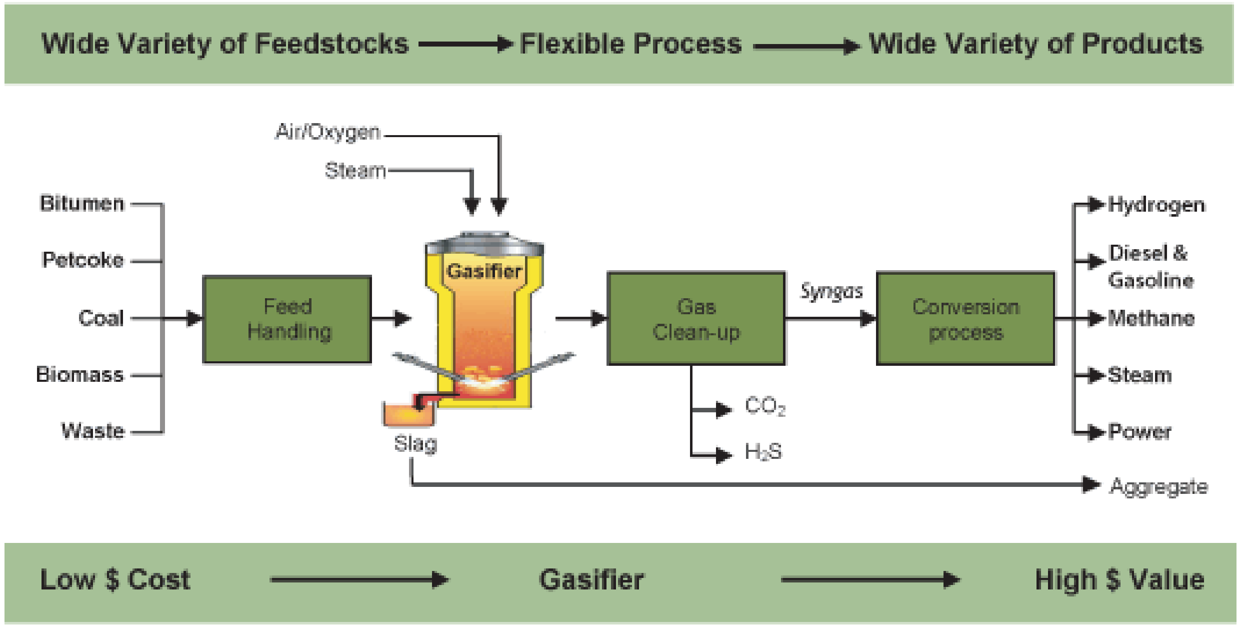

Figure 1. General process for producing syngas from gasification. (Bhat, N. 2016)

Syngas is a mixture of hydrogen, carbon monoxide, and carbon dioxide, typically produced using methane from large natural gas reserves. Syngas is used for a variety of processes, including diesel production, methanol production, and hydrogen synthesis, for the Haber-Bosch process used to irrigate most of the world's crops (Sartipi et al., 2013).

The first challenge in our process is breaking down e-waste into syngas. Gasification is a common method of converting organic waste into syngas; however, traditional gasification techniques may not handle the metals in e-waste without additional processing. Our process must be compatible with potential contaminants and produce high yields of clean syngas. Thus, we propose gasifying the e-waste using molten salt, which exhibits excellent heat transfer properties, a high operating temperature range, and does not require metal to be separated before gasification. Kinetic data for a eutectic mixture of lithium, sodium, potassium carbonates (LNK) molten salts reacting with e-waste has been published, supporting its viability in gasification (Salbidegoitia et al., 2015).

Once the e-waste converts into syngas, the syngas will be processed into gasoline. Historically, the Fischer-Tropsch process, pioneered in the 1920s, has been used to convert syngas into fuel. Recent developments in catalyst technology have improved the process' selectivity towards gasoline-grade hydrocarbons, reducing the need for hydrocracking (Sartipi, S., et al., 2013). Another mechanism converts the syngas into methanol, then into dimethyl ether, then into gasoline through a series of fluidized bed reactors (Primus Green Energy, 2019). Gasoline is a profitable product critical to society, and its production from waste may be an environmentally friendlier alternative to conventional petroleum extraction.

We will analyze our system through a collection of material and energy balances, while using MATLAB to solve the kinetic and thermodynamic equations that define our process. Our process will be simulated with *Aspen Plus V11*, which will guide our economic and unit operation analyses. We will determine if this process is energy-efficient. If the energy costs are high, then it may cost the environment more in burning fuel to run the process than it saves by recycling waste. The project will evaluate both the economic and environmental viability of producing gasoline from syngas generated from e-waste.

STS Topic

Increasing the use of sustainable energy sources while maintaining high power productivity is a worldwide phenomenon, and a looming issue for the United States. Luthra and others in 2015 identified a large number of factors that preclude adoption of sustainable energies in India, which included high costs, lack of financing mechanisms & market base, low development of technology, lack of customer awareness and public interest, insufficient R&D, geographic considerations, lack of government policies, and more. While these factors are not all seen in the U.S., the broad sources of these problems are expected to be shared by the U.S. at some tangible level. These factors can be distilled into broad aspects of society that affect energy consumption in the United States: policy, economy, technology, and culture.

To examine the complex connections that constitute today's energy landscape, I will use the STS framework of actor-network theory (ANT). ANT is a framework that examines the relationships between human and non-human elements, or, *actors*, in a conceptual framework. ANT focuses on the alliances between actors, especially the factors that enable these connections to endure. Successful application of ANT is predicated on identifying the most important actors.

In considering which factors most broadly present themselves in society (policy, economy, technology, and culture), actors corresponding to each category should be identified. The process of effecting policy is inherently the role of government legislators, who are not isolated actors; the Center for Responsive Politics estimates that lobbyist expenditures totaled over $125 million in 2018 solely for oil & gas, with another $122 million for electric utilities. Legislation is greatly affected by energy corporations – both by lobbying and by nature in responding to the actions of companies who produce the energy and technology used in today's power grid. These companies employ researchers, who are the driving force in innovating the energy landscape and are also employed by groups such as governments and universities. Finally, members of society beget cultural attitudes that influence how individuals and organizations consume energy. These actors are all consumers of energy: in 2018, 27% of energy was consumed directly in industrial and commercial processes, 28% in transportation, 7% residential, and 38% in other sources of electric power (which may have been used for industrial purposes) (U.S. Energy). ANT is limited in that it does not explicitly explain cause-and-effect, and fails to consider factors like actor history and human intentions that lead to multiplicities of roles actors play in multiple networks at multiple times (Cresswell 2010). To mitigate these shortcomings, I will consider examples of entities in each actor group and their context in the network, e.g. ExxonMobil as an energy company and its history with lawmakers.

Actors are linked to each other, and policy is deeply linked in connecting the actors. The government can provide economic incentives to using sustainable industrial methods, fund research into high-efficiency renewable technologies, and create public programs to address gaps in energy education. U.S. policymakers effect change through their interactions with other key members in the energy infrastructure: namely, energy companies, researchers, and members of society. The main actors of the network include the U.S. government, energy companies, lobbyists, researchers, energy technology, and energy consumers. The main network builder is the set of policymakers in the United States. The primary stakeholders include all people of the U.S. that utilize energy, or all members of society.

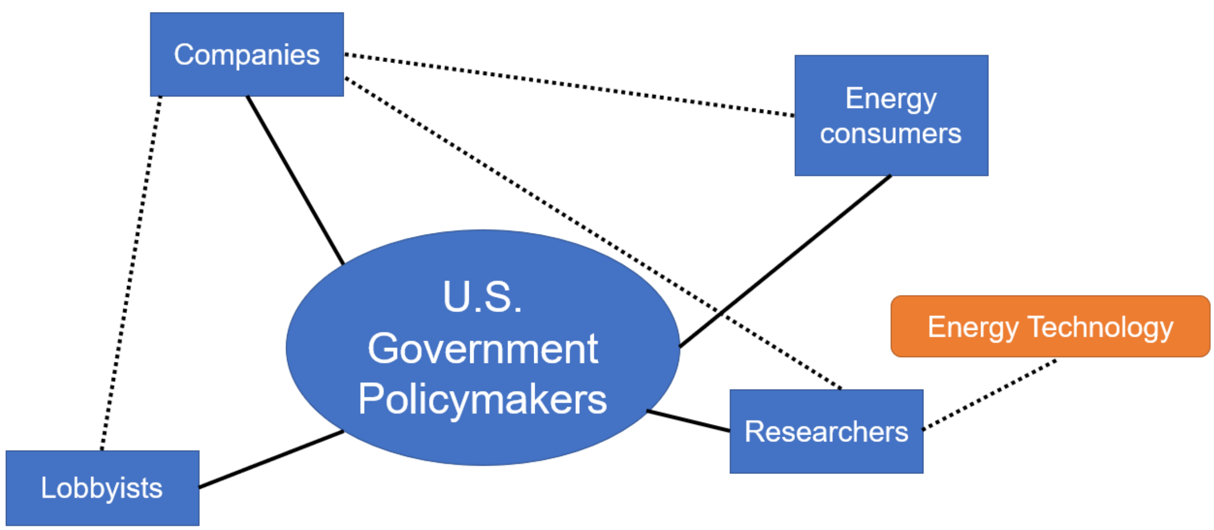

Figure 2. Network of actors in the U.S. energy infrastructure. Blue shapes represent human actors and orange represents non-human actors; shape type corresponds to nodal distance from the network builder.

These actors may pull each other in contrasting directions. For instance, a societal push to develop more renewable energy is at odds with companies' motives to maximize profits using well-developed natural gas systems rather than inchoate expensive technologies. Simultaneously, people are influenced by their local communities. A recent paper in Nature Human Behavior concludes that "second-order normative beliefs—the belief that community members think that saving energy helps the environment—play in curbing energy use" (Jachimowicz et al., 2018). Therefore, the beliefs of society affect how individuals behave in terms of selecting sustainable energies. These beliefs are further influenced by larger forces such as advertising pushed by corporations and incentives provided by government organizations. The network is therefore intrinsically subject to perturbations that threaten its stability. The government can help stabilize some of these disruptions, but since resources are limited it is impossible to appease all relevant actors through laws alone. Finally, we must consider that the government itself is a divided entity, whose actions may contradict one another and are affected by lobbyists and party ideologies.

Research Question and Methods

The network of actors who affect energy usage in the U.S. is perturbed by conflicting goals which threaten the network's longevity. The network is further threatened by the challenge in adopting sustainable energy to decrease greenhouse gas emissions and reduce environmental waste while simultaneously addressing our growing, massive energy needs. How can the energy network of the United States succeed through fair policy enacted by legislators and negotiated among governments, lobbyists, lawmakers, researchers, and energy consumers?

This discussion cannot be completed without examining the policies that have been enacted by legislators to mediate energy production and usage. Since an actor-network theory framework is the main lens through which energy is being probed, network analysis will be the main method in examining literature. Literature may include energy consumption and production statistics published by the U.S. DOE, renewable energy regulations like renewable portfolio standards, and national energy agreements such as the Paris Agreement. Finally, studies into reported difficulties in adopting sustainable energies, along with research into upcoming green technologies, will be examined through academic literature. Thus, policy analysis, network analysis, and documentary analysis are the main methods that will be used.

Conclusion

The technical component of this proposal will produce an industrial process to create syngas and then gasoline using waste instead of natural gas. The STS component will examine which actors and connections play a role in the current energy landscape, and will make recommendations for the future of sustainable technology. Combined, these two components can illuminate potential solutions in replacing current highly-efficient (though environmentally damaging) energy-related processes with more efficacious sustainable technologies and sensible policies. In exploring how actors influence energy consumption, this paper will investigate the feasibility of sustainable technology in the future, and suggest changes that would be needed to continue meaningful development of renewable energies.

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