Modeling the Implications of Net Zero Emissions for Urban Renewal Projects
(Technical Paper)

Power Politics in the Electric Utility Industry
(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

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I. Introduction

There has been a visible growth in attention and consideration for activities relating to environmental sustainability in our modern world, especially those activities in the built environment. According to the International Energy Agency (IEA), the built environment, including both building operations as well as the construction and materials sector, account for about 40% of global CO_2 emissions (Energy Information Administration, 2019). Reducing the level of emissions contributed by the built environment is paramount to transforming our society into a more environmentally conscious and sustainable state. In order to attain such a transformation, however, activities in the built environment must be analyzed and oftentimes reorganized such that new technologies and operations can be implemented to create a new design space for optimizing and reducing environmental impact. Our capstone team has taken on a particularly understudied, and unaccounted-for contributor to global warming in the built environment: fugitive natural gas emissions. In the United States, hundreds of natural gas pipeline systems account for over 300,000 miles of high-pressure transmission pipelines, often running across state boundaries, in order to supplement a yearly demand of around 30 trillion cubic feet of natural gas. Natural gas leaks are frequent throughout the United States natural gas infrastructure and they can be particularly harmful for the environment because of its predominant component, methane. Methane (CH_4) is estimated to be about 30 times more harmful than Carbon-Dioxide (CO_2), which is emitted in the combustion of methane as it is consumed (National Conference of State Legislatures, 2011). The final deliverable, a decision-making model, will help determine if a specified building, whether it be retrofitting or in the construction process, should replace their conventional natural gas systems with electrification technology, and how much fugitive emissions would be reduced if such a decision were made.

The model will first be applied to local buildings, such as in the UVA Engineering School and around UVA Grounds, and then adapted to analyze a broader set of the built environment and to be used by design decision makers.

Another staple industry of our technologically advanced society is the electrical utility industry. Much of the electric utility industry is actually powered by burning natural gas, up to 40% of all electric generation according to the EIA (EIA, 2021), however, the source of the electricity generation is much less important to the social and political ramifications brought about by the United States power grid. Since its inception, the electric utility industry has been characterized by an unrelenting entanglement between private and public control, with the average consumer getting very little consideration at the decision-making level. The United States electric utility industry is a fiercely competitive industry due to its widespread distribution and consumption. However, due to a varying level of reliance on electricity throughout its history, the infrastructure designed to support this industry come with a fair share of kinks and inequalities. The goal of this study will be to use proven STS research methods, including Policy Review, Literature Review, and Ethical Analysis to delineate a consequential relationship between public and private control in the history of the United States Power Grid. It will further speculate upon the future of the electric utility industry and how the public interest will be served by continued private control, or public control.

II. STS Topic

The long and complex history of power utility companies in the United States is characterized by an unceasing conflict between private and public interest in the electric power industry. It is especially an interesting topic of study given today's political climate which is often demanding of progressive measures to protect such things as the environment, people's civil rights, and United States business interests. Whether or not these variables have held the same magnitude of persuasion throughout the existence of the power grid, they have at different times been incredibly compelling for government and private sector decision-makers. These decision-makers—whether elected, appointed, or earned—have the ability to manipulate entire aspects of our livelihoods and our children's livelihoods without the slightest inclination towards their customers and constituents. When isolated, the impact of these legislators, speculators, and business executives on society, is enough alone to research and analyze. However, when it is paralleled with the development of a life-changing technology, such as generally accessible electricity at a low cost, those impacts become even more crucial and pertinent to today's political and technological climate.

Therefore, in this paper I will make an example out of the historical institution and contemporary dependence of the United States on the electrical power grid and use that to answer my fundamental research question:

"How does the history of the United States electric utility industry give insight into future decision-making and how can we use its lessons to guide further improvements in the grid system?"

By using policy and literature analysis from both primary and secondary sources, I will highlight the impacts of the early entrepreneurs whose guidance laid the foundation for a vertically integrated utilities industry, the legislators and lobbyists whose political and personal motivations created inconsistent and reactional measures to attempt to regulate the industry, and the countrymen whose desire for modern technology created the need and eventual dependence on electric utilities. The conclusions drawn from this historical framework will allow for analysis of today's context surrounding the power grid, its regulations, and the vision of the United States to become more sustainable and environmentally-benevolent. Finally, investigation into the consequential history of the United States electric utility industry will reveal STS themes of Technological Determinism as well as the Social Construction of Technology, which can be used to draw out cause and effect relationships to try to achieve a more accurate analysis of the electrical industry's past and where it could be headed in the future.

To gather information on the history of the electric utility industry I will be reviewing a multitude of secondary sources that have similar goals of tracing relationships in the key events of the power grid's institution. Three of these key texts include: *Electrifying America: Social Meanings of a New Technology,* by David Nye (Nye, 1992); *The Power Brokers: The Struggle to Shape and Control the Electric Power Industry,* by Jeremiah Lambert (Lambert, 2015); and *The Grid: The Fraying Wires Between America and Our Energy Future,* by Gretchen Bakke (Bakke, 2017). Several key players throughout this history have been identified, including Samuel Insull, Franklin Roosevelt, the Tennessee Valley Authority, and the FERC, just to name a few. These secondary sources will include contemporary history books, contemporary power grid books, as well as research articles from reliable sources. A few primary sources, including policy memos, newspaper reports, journal entries, and statistical summaries will be used to back up points and conclusions drawn from the secondary sources. I have organized these sources based on the events and themes that I am attributing to them and intend to convey their lessons to the reader.

III. Technical Prospectus

"Climate change" and "global warming" are terms many (if not most) people are familiar with, but don't know the actual meaning of. According to the United Nations' Paris Climate Agreement, supported by 196 countries to date, the rise in global temperatures needs to be limited to 1.5 degrees Celsius by the year 2050 in order to avoid “catastrophic” consequences in weather patterns, ecological systems, and the overall balance of the earth’s radiation and energy balances (United Nations, 2016). Research like the Keeling curve (see Appendix A) and the Intergovernmental Panel on Climate Change’s most recent report show the indisputable correlation between human emissions and global warming.

Many people aware of this correlation have begun to believe in “doomism.” According to Michael E. Mann, one of the world’s most influential climate scientists, “Inactivists know that if people believe there is nothing you can do, they are led down a path of disengagement. They unwittingly do the bidding of fossil fuel interests by giving up.” (Mann, 2021) Governments around the world have tried to take action against climate change, but have faced many barriers in politics and ethics. The US, in specific, has tried initiatives like the clean air act, the clean water act, and the endangered species act, but has failed to adequately address Greenhouse gas emissions thus far. So, climate change has become a problem that innovators, engineers, political activists, and students like ourselves have to take into our own hands.

Looking at the urban building industry, emissions from these building and development projects contribute nearly 30% of total emissions. A new report from the World Green Building Council states that every building on the planet must be net zero by 2050 in order to keep global warming below even 2 degrees Celsius, disregarding the UN’s target of 1.5 degrees (World Green Building Council, 2020). In order to move the world towards this target, the US and its urban areas need to be at the forefront of the transition to a net zero building industry.

That being said, the transition is much more complicated than we might think. To combat the impacts of climate change, we have chosen to look at a few key areas of the net zero urban renewal process: we will consider the embodied versus operational emissions associated with a building, with an eye towards circular economies, electrification, renewable energy, and features like offsets and negative emissions. Embodied emissions are the greenhouse gases emitted during the manufacturing, transportation, installation, maintenance, and disposal of all materials throughout the building process (Carbon Leadership Forum, 2020). The operational emissions include whatever is emitted during the normal use and upkeep of a building, depending on its purpose. Overall, we will have to look at the circular economy of the building process, including the transition to renewable energy, design of a system to mitigate waste and enable regeneration of natural systems.

IV. Goals and Objectives

Our ultimate goal is to provide some kind of a tool for project planners to model the path to net zero emissions, both in embodied and operational emissions. We can consider the policies and capabilities that surround any given project, as well as what tools have already been developed (and why they haven't been sufficient thus far). We are working with a sponsor, Integral Corporation, an engineering and consulting firm with the aim of solving "the environmental, health, and natural resource challenges that face our evolving world." (Integral Corp, 2021) Integral has a lot of experience with green building, and has identified the predictions of operational carbon emissions as a pain point of theirs in the modeling process. We can continue to work with them to identify other pain points in the process of net zero building, and where our skills can be of use. We plan to look at the UVA net zero plan and integrate it as a case study for whatever tool we decide to develop. We plan to specialize tool this in terms of fugitive emissions, and their impact on a building's life cycle carbon output. This tool will be a decision-making cost analysis tool that will be able to model tradeoffs and comparisons between conventional natural gas appliances and upgrading to electrified appliances.

V. Technical Approach

Currently, we are in the process of outscoping to understand the needs of stakeholders in green building processes, both at UVA and abroad (with Integral clients). At UVA, we've been in touch with the UVA Delta Force and Green Labs team (within the UVA Sustainability Department) and the facilities management team for both UVA Engineering and the broader UVA community. Essentially, they hope to get a new lens from us as students that their current engineers can't offer: a closer focus in terms of systems analysis on things like energy efficiency within a building, how to manage the different inputs (and outputs) to a building and its energy use, such as air circulation, division of tenants within a building, the materials used in a building, as well as on the other side, things like billing and restrictions on usage. With the Integral team, we hope to use the knowledge we gain by looking at UVA buildings to help understand pathways from embodied carbon to modeling operational carbon emissions. According to the Integral London team, if we "get this right," we can make the case for storage and reliability within a building and be more sophisticated in how we account for carbon across a larger transformation of energy grids. This is a project already underway in Europe that we can help bring into an American context.

Applying our specialization on fugitive emissions, our team is hoping that our efforts will share impacts around the globe. Our tool will shed light on the importance and potential impact of fugitive emission analysis especially when approached from a local context. While understanding and improving large-scale production and distribution of natural gas remains a priority of reducing global fugitive emissions, approaching the problem from a local perspective can give helpful insight into future initiatives that could make large impacts, such as electrification of building utilities. Local actors tend to have a lot more control over important decisions and improvements can be manifested much sooner than on a governmental level like with the larger scale generation and distribution by large regulated utility companies.

The process of outscoping has brought a lot of potential for our skills to be put to use -- we can go as broad as a full life cycle consumption model for a building, but we'll need to note the overall complexity of any system. Our team has discussed looking specifically at one type of building (such as lab space, classrooms, hospital space, or retail buildings), and looking to understand both the carbon intensity of materials but also the space carbon intensity of actually using and operating a building. Our immediate next step is continuing research on lifecycle carbon analysis and green engineering, as well as continuing to understand what tools exist across the world and where any "holes" in their use might be.

In terms of timing and deliverables, the UVA Net Zero plan is due in January, so we can plan to work alongside that team for our case study based on their timeline. We can continue talking to UVA stakeholders like Paul Zmick and Bob Brimmer to specify in the next few weeks where exactly our direction will be for the case study, and soon after that define a concrete plan for a modeling tool to help Integral's work.

VI. Conclusion

This paper looks at an alternative method to reducing carbon emissions in the built environment in order to bring our structures and communities closer to net-zero. Through project outscoping and review of previous methodologies, our team is poised to create a cost and environmental analysis tool for decision-makers that will model operational conditions using natural gas infrastructure compared to more contemporary electrified infrastructure, with a focus on the impact of fugitive emissions on the life cycle carbon output of a project. This tool will likely be in the form of a plugin on a popularly used building software such as Autodesk Revit, however, the team is still in the process of making decisions on the final objectives of our technical project deliverable. An optimistic goal is to create a usable tool that can be built upon and eventually improved to a level of functionality that could legitimately benefit decision makers in the built environment.

A further goal of this paper is to explore another public utility: electricity. Using STS fundamentals, a detailed investigation will be conducted into the history of the United States electric utility industry in order to gather understandable and actionable conclusions for the contemporary electric utility environment. We will see that by applying policy and literary review techniques to with STS methodologies, such as Technological Determinism and Social Construction of Technology, that valuable lessons can be extracted from the events and actors that took part in organizing and reorganizing our electric utility system. The goal of this analysis will be to delineate several key events throughout the history of the electric utility industry and connect them based on STS themes of determinism, SCOT, as well as power politics, and then will go a step further to show how these events foreshadow future regulatory legislation and industry decision-making. These conclusions could be helpful for incorporating in environmental and industrial models in the future, including my technical team's fugitive emissions decision-making tool. Our tool will have to incorporate a variety of environmental, cost, and policy factors in order to estimate impacts of infrastructure tradeoffs multiple years into the future. Some of the lessons learned from the history of the United States power grid will make very helpful additions into our model for predicting possible policy decisions multiple years into the future.

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