Modeling the Implications of Net Zero Emissions for Urban Renewal Projects

Renewable Energy Ethics: why have some green technologies been able to overcome tradeoffs and others have not?

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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 of Problem

Once a topic of focus for scientists, engineers and a small fringe of the world's population, climate change has become an omnipresent issue for everyone. All over the world, weather changes resulting from global warming have become increasingly undeniable. July of 2021 was the hottest month in history and natural disasters such as hurricanes have become more extreme and more prominent (NOAA 2021). The most critical consequence of climate change is global warming -- the actual measurable rise in average global temperature. The main source of global warming is when the heat generated by energy from the sun, infrared radiation, cannot properly leave the atmosphere at the rate it did in the preindustrial era, because it's trapped by an increased amount of greenhouse gasses (GHG) generated during the industrial era. In other words, "the global radiation and energy balances are 'off,'" according to Scott Doney, a UVA professor who specializes in the science, impacts, and solutions of climate change (Doney, 2021).

Recently, the public debate has shifted away from arguments about whether climate change is real, thanks to complete and undeniable scientific proof (including the most recent Intergovernmental Panel on Climate Change report (IPCC 2021)) that the world we live in is changing due to our behavior. The "Keeling Curve" measures the rate of increase of atmospheric carbon dioxide not because of natural processes, but because of human activities, see Figure 1.

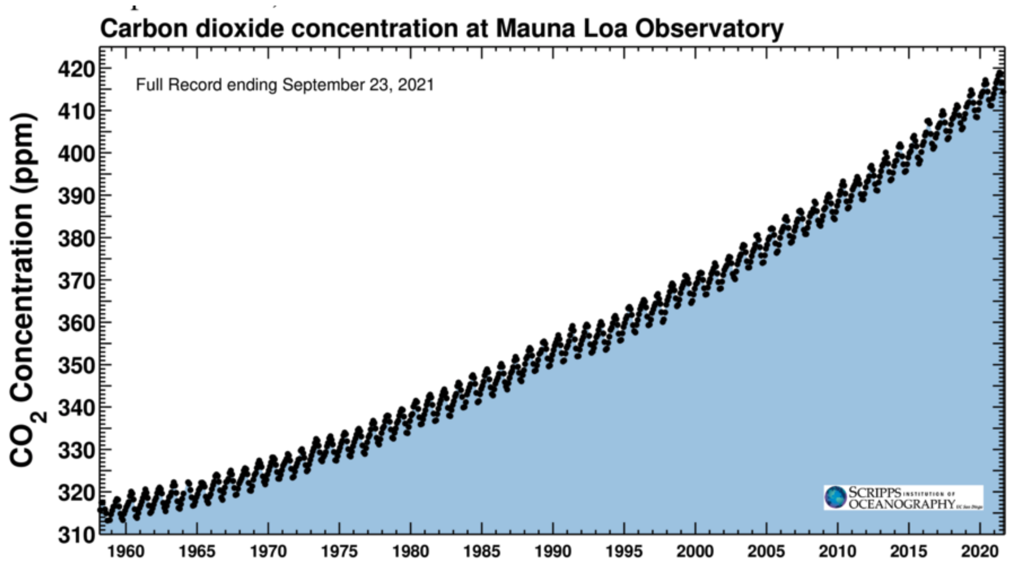

Figure 1. The Keeling Curve (Monroe, 2021)

Instead, the debate has shifted to the question of what to do about climate change, with a meaningful segment of the population appearing to embrace "doomism" – the view that the impacts of climate change cannot be effectively mitigated. According to one of the world's most influential climate scientists, Michael E. Mann, "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).

Regulatory action has largely proven ineffective for a variety of reasons, leading to efforts at the local governmental and individual levels. For example, the U.S. government has tried to act through initiatives like the Clean Air Act, the Clean Water Act, and the Endangered Species Act, but they've failed to use them properly to address climate change by looking at GHG emissions. Increasingly, innovators, engineers, political activists, and constituents have taken the lead at the individual, local, national and international levels. This can come in the form of changes in current practices, investments in more clean energy, electrification, building new and cleaner buildings (also known as green urban renewal), and more. For example, large companies have reacted to pressure from shareholders and have started to consider more heavily their environmental, social, and governance (ESG) footprint, including focusing on GHG emission reduction. At the governmental level, the state of Virginia has established goals expanding access to renewable energy and in support of clean energy jobs, including powering 30% of Virginia's electric system with renewable energy by 2030 and 100% by 2050 (Commonwealth of Virginia, 2021). The University of Virginia has established Ten Goals as part of its Sustainability Plan, including becoming net carbon neutral by 2030 and fossil fuel-free by 2050 (University of Virginia, 2021).

My capstone team seeks to develop a modeling tool to enable more informed action at the state and local levels by both governmental and nongovernmental actors with respect to net zero urban renewal projects, with a case study of the UVA Net Zero plan. Building on this work, I intend to explore more deeply the ethics of the climate crisis outlined above with a focus on understanding why some proposed solutions have been able to overcome ethical barriers and some have not.

Technical Project

For our technical project, my team's goal is to identify a modeling approach to simplify decision-making for net zero for buildings that goes beyond what we are currently capable of – presumably because of cost or an area that no one has investigated yet (specifically within a building, in terms of the modeling itself, system errors, measurement errors, etc.). The urban building industry is responsible for nearly 30 percent of global emissions, making this a project with significant ramifications – every building in the world needs to be below net zero by 2050 to keep global warming below even 2 degrees Celsius, much less the UN's target of 1.5 degrees (World Building Council, 2020).

Within our process, we will consider the “embedded carbon, operational carbon, the transition of associated transportation and infrastructure systems and the opportunity to remove residual carbon emissions with nature-based solutions or direct carbon capture” (Clarens, 2021). We will consider factors like the carbon and circular economies, electrification, as well as offsets and negative emissions. In terms of reducing carbon footprints, an issue area is the use of different renewable energy sources. Innovations like solar, wind, renewable natural gas, blue and green hydrogen, and hydropower all have technical positives and social negatives.

We will 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 that seeks to solve “the environmental, health, and natural resource challenges that face our evolving world” (Integral Corp, 2021). Integral has nearly 20 years of experience with green building and has identified the predictions of operational carbon emissions as a pain point in their modeling process. We can continue to work with them to identify other pain points in the modeling of net zero building, and where our skills can be of use. According to Integral’s London team, if our capstone group “gets this right,” we can make the case for storage and reliability within a building and be more sophisticated in how building owners and decision makers account for carbon across a larger transformation of energy grids. This is a project already underway in Europe that we propose to bring into an American context.

One specific pain point we will focus on is the inability to measure methane leakages in buildings, which results in a gap in emissions reporting that comes from methane. According to the Environmental Protection Agency, “In 2015, more than 85% of the residential sector’s direct emissions were from on-site fossil fuel combustion. Most of the remainder resulted from leaks”

(EPA, 2020). Methane leakages vary from city to city. A research report on the U.S. natural gas industry collected the following data on leakage rates in cities around the US (The Gas Index, 2020):

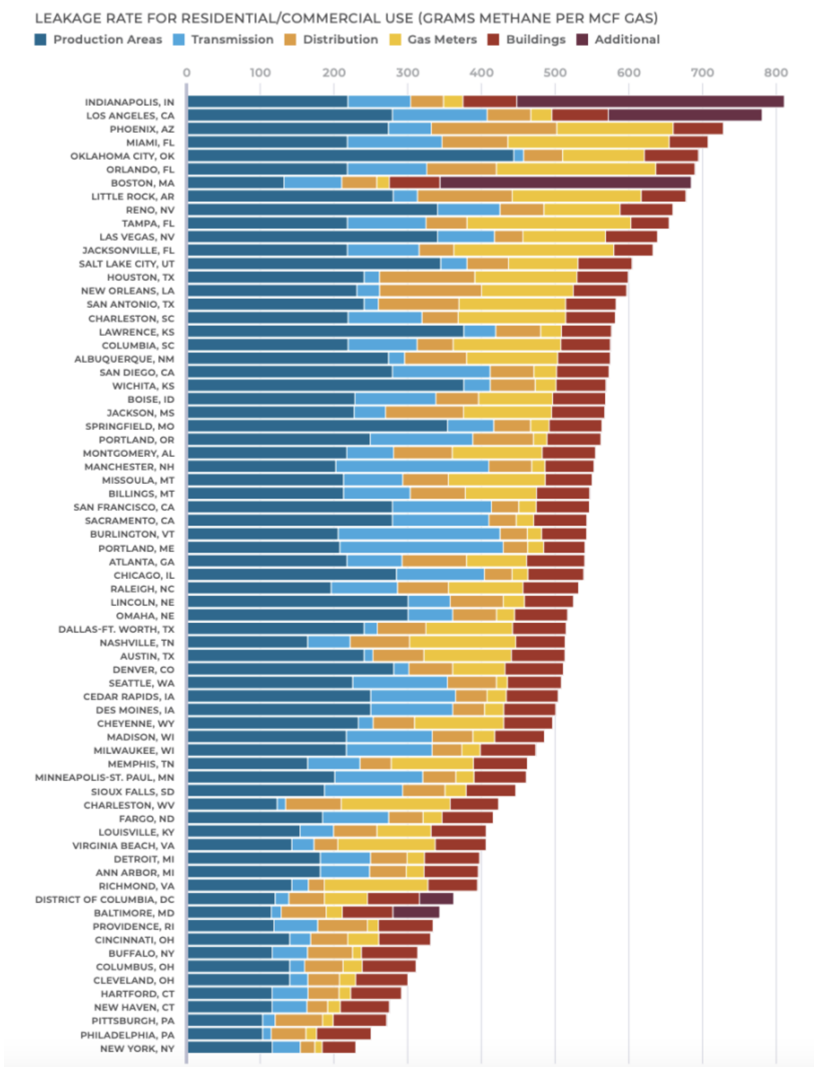

Figure 2. Leakage Rate for Residential/Commercial Use for Different U.S. Cities (Gas Index, 2021)

There is a vast difference between cities at the top (Indianapolis, LA) versus those are the bottom (Philadelphia, New York City), which is likely due to both operational and embodied emission leakage. So, we hope to develop a tool that is geographically explicit and can address this gap in reportability and therefore accountability.

In technical terms, this is a project that will yield a model for building decision makers to understand the implications of updating their infrastructure. It will account for both financial decisions and the time value of money as well as emission and policy-based decisions, with the added benefit of considering methane leakages for more accurate estimates. In a broader sense, however, we believe this project has significant societal implications – with the tool, users can investigate how to make renewable building more affordable. Educationally, the tool can make building owners more aware of the specific variables (and their cost) associated with "becoming net zero". We hope this research and tool will help break down a complex goal of "becoming net zero" into understandable and digestible components, thus helping reduce carbon footprints in urban areas around the world in a tactful way through empowerment.

Science, Technology, and Society

While my technical project focuses on the modeling of building emissions, I'm interested more generally in understanding what works and what doesn't work in addressing climate change, and why. I will be analyzing why some types of renewable energy technologies have been successful despite ethical setbacks on sociotechnical systems, why others have not, and whether we can learn from prior experience in ethically moving forward with the path to net zero emissions. In general, my hypothesis is that climate action is difficult to address, both attitude- and policy-wise, because of the ethical implications certain technologies can have on the societies they impact. Governments around the world have tried to act against climate change but have faced many barriers in politics and ethics. The Paris Agreement, the only widely-agreed-upon set of principles for climate action, still has many inconsistencies because of an inability to agree on necessary steps to reduce global warming.

According to Johan Rockstrom with the American Association for the Advancement of Science, the Paris Agreement's goals are "aligned with science," and can, in theory, be "technically and economically achieved," but there are still inconsistencies between science-based targets and national commitments (Rockstrom, 2017). Thus, it is necessary to understand on a more technical level reservations about certain engineered solutions as well as the stated and unstated reasons for those reservations. For example, some technologies such as solar power have been successfully implemented on smaller scales, but there is often a lack of international commitment to those same technologies. This begs the questions: *why* have some technologies been accepted while others have not, and are there ways to address reluctance to accept renewable energy technologies that are necessary to address climate change? Why have the conversations around these technologies been so politically charged, and how has that affected their integratio into society? If the goal of climate action is to achieve "efficiency without sacrifice" (ISECOECO, 2016), which sacrifices are deemed substantial enough to prevent that integration?

First, I plan to analyze a framework called *diffusion of innovation* (Rogers, 2003). that looks at the five main factors that influence the adoption of a technology into society:

- Relative Advantage – Is it better than other options?
- Compatibility – Is it consistent with values?
- Complexity – Is it easy to understand and use?
- Triability – Can it be tested or experienced before a commitment is made?
- Observability – Does it show tangible results?

Further, it looks briefly at inputs such as communication channels, the nature of social systems, and the extent of change agents' promotion efforts. The goal of analyzing a technology through this lens is to understand the social systems it inhabits and influences. A critic of this framework says the goal is to better include resources and social support as a factor in the success of a technology (Lamorte, 2019). I believe that an expansion on this framework that considers ethics and social support would be helpful to analyze the current state and future possibilities for renewable energy technologies and their integration into society.

Take solar, for example. It is successful in part because it can be easily adapted and scaled for different energy systems, from individual home use to an entire town based on a solar system. It doesn't require a total overhaul of existing networks, so it passes the relative advantage and compatibility components. It can be installed by professionals and integrated into regular home usage, so it passes complexity, as well. In terms of triability, it is usually sourced from solar companies and is therefore tested thoroughly before use. For observability, people can use metrics like their energy usage and costs. I hope to learn more about other renewable energy technologies and understand the implications of these five components on the successes of each.

For change to occur in society, we need to consider the conversations we have around climate change. Jonathan Pickering introduced a concept called *moral language* – '"moral language may be used to generate and communicate prescriptions for action on climate change, namely through: (i) characterizing the problem of climate change and identifying solutions to the problem; and (ii) motivating people to take action in response to climate change" (Pickering, 2016). He discusses the difference between the analytical role and motivational role of words. He implies that moral language can trigger emotions in people that can overcome feelings like doomism and strong political determinism.

The Paris Agreement and other international climate change discussions are backed in science, but not backed in ethical framework and emotional arguments for people to act. John

Rawls outlines what is called *ideal theory* for climate change – principles that would apply if every nation complied with international goals for emission mitigation and adaptation (Leif, 2021). However, we unfortunately live in a non-ideal world. Caney outlines strategies to approach international climate action, which he calls *nonideal theory*. He points out that often, not everyone will be pleased, so we must understand which sacrifices are worth the benefits received from mitigating global warming. "The extra (unjust) disadvantage that compliers bear is less than the extra (unjust) disadvantage that would be borne by many victims of climate change. … Dangerous climate change will lead to the death of many and for this reason, as well as for others, imposes irreversible harm." (Caney, 2016). Beyond that, there are economic implications for why we need to act against climate change. Innovation in clean technologies will reduce the cost of mitigation of global warming by as much as 50 percent (Brant, 2014). Looking at this stance in coordination with the diffusion of innovation, for a technology to reach the standard of compatibility, it needs to be carefully integrated into societies on a local level.

Research Question and Methods

Every type of energy production has some sort of tradeoff. Consider the following: Hydroelectric energy, one of the US's most prominent sources of renewable energy, can displace people from their land and homes due to the large swaths of land needed (Kumar, 2019). Solar fields could have a similar impact. Hydraulic fracturing (also known as fracking) can cause health problems in surrounding communities. Biofuels, an alternative to fossil fuels, have been socially opposed because of religious and moral concerns about genetic modification, and ethically opposed because of the magnitude of water consumption that may deprive others of clean drinking water. Nuclear energy can have catastrophic failures, which introduces significant compliance costs and societal concerns for safety in order to provide an adequate amount of energy for a completely clean energy grid. Wind power causes concerns in violations of natural beauty and proper use of space (Caney, 2016). These all demonstrate that there will always be tradeoffs in introducing new technologies to an area, and I believe that an understudied area is the ethical tradeoffs in renewable energy technologies. So, the question I hope to tackle is: *What are the ethical implications of different types of renewable energy technologies that tie into whether a particular technology is successful as a large-scale solution on the path to net zero, and can we learn from this to make technologies more likely to be adopted?*

There are good reasons for this investigation beyond simply addressing climate change. The solar industry is not only becoming increasingly affordable as an energy source, but it also provides jobs for 3.4 million people in the United States (Tierney and Bird, 2020). Helping to scale renewable energy technologies may help to address one well-known tradeoff to a move away from carbon-based energy sources – job loss. Can similarly cheap technologies like battery storage or wind power help to mitigate job loss associated with a transition to clean energy?

Throughout my research, I hope to use a more detailed analysis of the solar industry as a "base case" for analyzing the potential of other technologies. I intend to interview individuals who work in solar sales, as well as wind energy, and more niche energy technologies like renewable natural gas. I have already reached out to a contact who works in solar sales in Virginia Beach, and one who works with wind energy policy in the U.S. These would help me to understand the personal side of why some people are opposed to investing in these technologies, and steps that are being taken to address that. I would also like to interview engineers and coordinators at UVA involved in the purchase and installation of solar energy, to further understand the effects of underlying systems on investment in clean energy. Lastly, I will speak to a few of my bosses for next year who work in sustainable finance, who can help me break down numerical reasoning behind these decisions. On a larger scale, I want to investigate public speeches and arguments that have been made about different types of energy and the language that backs them up, to see if I can apply the combination of Pickering's theory on moral language and the diffusion of innovation framework to analyze sentiment on these technologies.

Conclusion

To tackle climate change before consequences become more disastrous than they already are, we all need to act both individually and collectively. It's exciting to be able to work on two sides of this problem at once: technical research that can help building owners reduce emissions by making individual decisions more effectively through use of a widely available tool, and ethical research that can potentially help those seeking to influence collective action do so in a more effective way. For the technical research, we hope to develop a working model that helps building owners make informed decisions about the implications of different systems on the path to net zero, with a value-add of focusing on methane leakages. For my ethical/sociotechnical research, I intend to analyze successes and failures of renewable energy technologies to date using the *diffusion of innovation* framework and hope to glean insight into how to better position renewable energy technologies for widespread adoption.

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