Conversion of *Escherichia coli* to Oxidize Methane for Reduction of Bovine Methane Pollution in Agriculture

(Technical Paper)

The Effects of Climate Legislation in the United States and Denmark on Communities Living in Poverty

(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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Introduction

The United States' reliance on cattle as a food source is destroying our planet at an alarming rate. A single cow produces between 154 to 264 pounds of methane gas per year. 1.5 billion cattle, raised specifically for meat production worldwide, emit at least 231 billion pounds of methane into the atmosphere each year (Environmental Protection Agency, 1). Despite the emission of methane from livestock, efforts to reduce cattle production have not been prioritized, so the technical team proposes to modify an *E. coli* strain to consume methane as a primary carbon source to reduce livestock methane emissions. Modifying an *E. coli* strain is an alternative to decreasing livestock numbers and shifting to a different food source in the U.S. The final technical deliverable the team aims to produce is the modified *E. coli* that produces a significant decrease in methane emissions. The research paper deliverable will be exploring the differences between the US's and Denmark's climate change policies and how these policies affect poor underserved populations and minorities. This research will identify which climate change policies protect the environment and minority groups.

On a different note the second proposed project in this prospectus investigates how climate change disproportionately affects underserved communities that are least capable of preparing for and recovering from events like flooding, heat waves, and other environmental impacts (Garfinkel, 1). Denmark was ranked as the country with the greatest climate protection based on the 2022 Climate Change Performance Index (Jaganmohan, 1). On the other hand, the US is rated very low for the GHG Emissions, Renewable Energy, and Energy Use categories, with a medium for Climate Policy according to this year's CCPI (CCPI, 1). The policies that

Denmark and the United States put in place differ drastically and indirectly affect the quality of life for poor underserved populations and minorities.

Technical

Livestock production accounts for 32% of anthropogenic greenhouse gas (GHG) emissions (Methane emissions are driving climate change. Here's how to reduce them, 1). Land clearing for grazing, feed production, manure production, and rumination, the process of digesting feed by fermentation, are causes of GHG emissions in livestock production. In the rumination process, methanogens in the rumen microbiome are responsible for methane production. Current mitigation measures to reduce rumination methane emissions include feed additives, formulations, or anti-methanogen vaccines (Kauffman, 3). However, rumen microbial species resist treatments, and mitigation methods are ineffective (Difford, 4). Genetic manipulation of organisms is becoming more cost-effective due to advances in genomic sequencing and Directed Evolution techniques. However, rumen methanogenic species cannot be manipulated to reduce methane production due to adverse effects on digestion. To this end, the research team proposes to modify an *E. coli* strain to consume methane as a primary carbon source to reduce livestock methane emissions.

We will use literature reviews and machine learning to define genetic targets in *E. coli* and determine which genes link to metabolism. Machine learning algorithms such as linear regression and random forest models to identify target genes with significant correlations to metabolic processes will be used. The team will determine unmodified *E. Coli* methane consumption in a closed environment with a Gas Chromatography (GC) machine to identify the need for improving upregulation of current methane consumption or genetic manipulation for novel methane consumption.

Then, we will modify *E. coli* strain to consume methane as a primary methane carbon source by using viral vectors to insert genetic mutation into target sites using ex vivo gene therapy. We will utilize proof-reading PCR (PR-PCR) to detect known mutations within genomic DNA in the *E. coli* strain through the amplification process to study isolated pieces of DNA.

We will then validate methane consumption by *E. Coli* by determining *E. coli* strain methane consumption by measuring the change in methane concentration in closed-environment air samples from *E. coli* consumption with a Gas Chromatography (GC) machine. While prior genetic engineering work has proven successful in modifying *E. coli* to utilize CO2 as a primary carbon source, can modified *E. coli be* successful at consuming methane (Ewen, 3)? This question is not solely critical in decreasing methane in livestock production, but in all other sectors that produce methane as an undesirable byproduct.

With both global food demands and the climate crisis intensifying, curtailing anthropogenic GHG production is more critical than ever. Methanogenic species in ruminating livestock are responsible for a significant portion of GHG emissions and present a need for investigation. Genomic sequencing and directed evolution of *E. coli* species to consume methane will provide a viable means of altering methane production in ruminating species while circumventing digestive complications in livestock. First, the identification of genetic targets before viral gene insertion will narrow the possibilities of random genetic mutation and home in on critical players in metabolism and byproduct formation. Moreover, gas chromatography techniques will measure the success of *E. coli* in reducing methane levels in a closed system. Our project is a continuation of previous work in modifying *E. coli* to decrease large-scale GHG emissions. Given the past success in creating CO_2-digestive *E. coli* strains, this work will demonstrate the broader applicability of microbial modulation in the context of GHG production.

Similarly, the avoidance of disturbing methanogenic bacteria yields a methodology that allays concerns of symbiotic perturbation and provides a better technique to reduce methane emissions compared to the mitigation methods.

STS Topic

If the growth of greenhouse emission continues at the current rate, there will be a global warming of about 1.5 degrees Celsius by 2050, leading to extreme weather conditions and degradation of food systems (Climate Change in 2050, 1). The policies put in place by countries' leaders have the potential to either mitigate the effects of climate change or allow the climate to continue to increase at an alarming rate. Denmark and the United States have taken contrasting stances on climate change, resulting in immensely different ratings in the climate change performance index (CCPI) The CCPI is an independent monitoring tool for tracking the climate protection performance of countries to enhance transparency in international climate policies. (Climate Change Performance Index, 1). Denmark was ranked as the country with the greatest climate protection based on the 2022 Climate Change Performance Index (Jaganmohan, 1). On the other hand, the US is rated very low for the GHG Emissions, Renewable Energy, and Energy Use categories, with a medium for Climate Policy according to this year's CCPI (CCPI, 1).

In 2020, Denmark passed a substantive Climate Change Act (CCA), which defines legally binding targets and has laid down a solid foundation for continued and ambitious climate actions. One of the near-term targets of Denmark's CCA is reducing total greenhouse gas emissions by 70% by 2030. This is one of the most ambitious CCA's a country has passed as it requires efforts made not only by the Danish Government and Parliament, but also by the Danish society with active roles for individuals, municipalities, trade unions, civil society, and the business community (Climate Programme 2020, 6).

As for the United States, the Inflation Reduction Act, which was passed in August 2022, which includes $364.75 billion in clean energy and climate investments (Bell, 1). This act aims to create good-paying union jobs that will help reduce emissions across every sector of the economy. This massive budget package to fight climate change also includes other funds like a $40 billion fund that will be used toward environmental justice (The United States Government, 1). A major difference between Denmark's and the US's policies on climate change is the level of involvement of citizens themselves and the lower-level government sector.

The climate change policies these two countries pass not only have an effect on the environment, but also impact poor and underrepresented communities. Climate change disproportionately affects those who suffer from socioeconomic inequalities, including a lot of people of color. When the government fails to combat climate change effectively, the ones that suffer the most are those most vulnerable. Most people living close to hazardous waste are people of color and poor communities, making them vulnerable to dying from environmental causes from climate change and pollution (Patnaik, 2). More than one million African Americans live within a half mile from natural gas facilities, putting them at a greater risk of cancer and other health effects than most rich, white communities. An analysis of Denmark's and the USA's climate change policies will advance the comprehension of how these policies affect poor underserved populations and minorities.

Technological momentum is a theory developed by Thomas P. Hughes about the relationship between technology and society over time. This theory unites Technological Determinism, which states that society is shaped by technology, and Social Determinism, which states that technology is shaped by society. Hughes states that in the infancy of a technology, society controls the technology heavily, but as this technology grows, it gains momentum that

allows the technology to influence society (Hughes, 101). Critiques of technological momentum argue that it is similar to technological determinism since the theory revolves around technology. Technological determinism has been perceived as oversimplified claims on how technology and society interact (Adler, 1). However, Hughes argues that society and technology influence each other equally. This theory will be used to understand how climate change policies are used as technology, and how these policies as a technology have the power to influence technology.

Methodologies

Research Question: How do the differences in climate change policies in the United States compared to Denmark affect poor underserved populations and minorities?

To answer my research question, I will use the theory of technological momentum developed by Thomas P. Hughes. This theory will help explain how climate change policies are used as technology and how they affect society. There is a link between climate change policies and the treatment of poor, underserved communities that will be proved through the application of this theory.

The sources that are being collected to conduct this research include policy documentation from both countries, statistics of poverty rate and living conditions for the lower class, and also amount of emissions reductions achieved post implementation of different climate change policies. Climate change policy documentation will show the differences in the urgency and approach between the two countries. To determine how effective each policy in both the U.S. and Denmark is, sources that include climate change indicators, such as emission rates and the Climate Change Performance Index will be used. The statistics before and after the policy is implemented will show the success or shortcoming the policy had in reducing climate change

effects. Using sources with statistics of poverty rate and living conditions for the lower class before and after implementation of policies will be used to prove that climate change policies affect poor, underserved populations and in what way.

Understanding how the United States' and Denmark's climate change policies affect poor underserved populations and minorities will pave the path for how countries should resolve the unfair treatment of these groups when it comes to environmental effects. This research question will allow countries to comprehend how to better fight climate change while protecting vulnerable populations and bring awareness to how certain policies are failing citizens.

Conclusion

This paper outlines plans for two projects, one with a technical deliverable and one with a research paper deliverable. The technical aspect will be combating the greenhouse gas (GHG) emissions from livestock production, as livestock production accounts for 32% of GHG emissions (Methane emissions are driving climate change. Here's how to reduce them, 1). The technical deliverable will be a modified *E. coli* strain that consumes methane as a primary carbon source to reduce livestock methane emissions. The team expects the modified *E. coli* will consume methane in its environment, leading to a significant reduction in methane levels.

The research paper deliverable will be exploring the differences between the US's and Denmark's climate change policies and how these policies affect poor underserved populations and minorities. It is expected that the country with the most thorough and extensive policies will have the best living conditions and treatment for these underserved groups. This research will identify which climate change policies protect the environment and minority groups.

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