Thesis Project Portfolio

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

(Technical Report)

Investigation into the Social, Physical, and Political Factors that Influence the Success of Renewable Forms of Energy

(STS Research Paper)

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Sociotechnical Synthesis

Climate change is the salient existential threat facing modern civilization. Greenhouse gasses (GHG) have long been identified as key drivers of the climate change apparatus, engendering many nations to pass GHG neutrality goals and engage in international agreements to curtail GHG dispensation. Modern forms of infrastructure are heavily implicated in the push for GHG reduction, due to many production and manufacturing systems' reliance upon fossil fuels and other carbonized sources. Two quintessential instantiations of such infrastructure are contemporary means of livestock production and energy generation. Livestock, in particular cattle, production accounts for substantial releases of methane – a potent and long lasting GHG – originating from both the eructation and flatulence of cattle. The technical portion of this project explores genetic modification techniques to mitigate methane emissions from cattle, in an effort to limit its environmental impact. Energy generation modalities in many nations utilize carbonized sources of power, inciting intense GHG introduction into the atmosphere. Despite the availability of renewable sources of energy and their extensive commodification, there is notable resistance to their implementation seen disparately across different countries. The sociotechnical portion of this project investigates the sociopolitical factors that contribute to the variation among different countries in embracing renewable energy forms. Both components of this project aim to address and further understand a critical feature of GHG production, all to bolster the effort to combat climate change.

Livestock flatulence and eructation account for approximately 14.5% of all anthropogenic-related GHG emissions, much of which comes in the form of methane. Methane from these livestock is produced by methanogenic bacteria present in the cattle rumen that aid in food digestion and other bodily processes. Microbial engineering has emerged as a robust field

of study set on directly modifying the biochemical behavior of microorganisms to achieve biomedical and technological objectives. Because of the integrality of methanogens to ruminant health, genetic modulation of these bacteria could yield a multitude of unforeseen consequences to cattle wellbeing. This project, therefore, investigated the genetic modification of benign Escherichia coli (*E. coli*) bacteria to indiscriminately consume methane as an energy source. The modified *E. coli* would eventually be introduced into cattle feed to reach the gut and target methane emitted from native methanogens. To imbue methane consumption capabilities, three discrete viral vector plasmids were used to transfect *E. coli* plasmids with each individual subunit of the particulate methane monooxygenase (pMMO) gene. This gene, when expressed, synthesizes the pMMO protein complex which can oxidize methane into readily digestible byproducts for heterotrophic organisms. Following transfection of electrically competent *E. coli,* protein expression was confirmed via mass affinity SDS-PAGE, and methane reduction was observed in a comparative study between modified and unmodified *E. coli* samples. Growth kinetics were studied for all experimental groups, the results of which demonstrated relatively normal growth behavior across the groups.

The sociotechnical portion of this project identified and examined three major factors that contribute to the disparate implementation of renewable energy systems in different communities. Social identities such as race and gender, the access to critical natural resources of specific nations, and the political and legal landscapes constitute the identified factors and were studied via in depth literature review and statistical metrics. Racial and gender minorities, especially in nations with enduring traditions of vertically structured power systems, have experienced historical exclusion from these institutions. This inability to participate has extended into current demographic incongruities, where Black individuals and women are

underrepresented in the energy sector and in novel energy communities. Socially, there's a colloquial understanding by women that energy is a masculine affair and creates burdens on the implementation of renewable energy systems that seek democratic engagement from communities. Natural resources that are essential for distinct forms of renewable energy are distributed unevenly around the world. The unequal allocation makes it easier for certain countries and communities to adopt relevant energy forms and rely on these systems for larger shares of energy needs than others. Finally, legal and political structures are largely responsible for the mixed success of renewables. Countries with established lobbying practices or legal mechanisms that limit governmental or commercial ability to build renewable energy systems indeed suffer prolonged stasis of energetic innovation and reliance on fossil fuels. Moreover, public perception is heavily influenced by the politicization of issues like climate change that prematurely prevent community acceptance of any initiative to promote cleaner energy. The role of these recognized factors in affecting renewable energy success is further analyzed through the lens of social construction of technology, as a means of understanding how they themselves have evolved both because of and alongside the technological innovation of energy generation.

Though distinct, the simultaneous undertaking of both components of this project offered me a more complete understanding of the relationship between society and the environment. Energy and livestock production, though only two categories of environmentally taxing infrastructure, elucidate the breadth of the problem before us. Climate change and its preceding actors aren't restricted to one realm of technology or system, it's a sweeping issue that demands deliberate action. Furthermore, combining a technical area of research with one of sociotechnical focus reminds us as engineers of the scope of our work. The consequences extend beyond rigidly quantifiable metrics and often surpass the immediate problem of interest. The social and the

technical are perpetually inextricable; had it not been for the contemporaneous engagement in these two projects, I would hardly be able to appreciate that dogma.