INVESTIGATION OF SOCIAL BARRIERS TO CARBON CAPTURE VIA ACTOR NETWORK THEORY

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By

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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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As the world searches for ways to mitigate the consequences of climate change, there has been an increasing effort to develop new technologies and methods to limit the amount of carbon dioxide emitted into the atmosphere. Since the Industrial Revolution, humankind has increased the ambient concentration of carbon dioxide by 48%, which has led to a continuous increase in global temperatures explained by the greenhouse gas effect ("The cause of climate change," 2021). In 2015, the Paris Climate Agreement created international goals to limit global warming to below 2°C compared to pre-industrial global temperatures ("The Paris Agreement," 2021). With this goal, many scientists have argued that it is necessary to simultaneously reach net-zero carbon dioxide emissions and begin creating negative emission, lowering the concentration in the ambient atmosphere. The majority of carbon emissions come from the industrial (23%) and transportation (29%) sectors, which represent both point and nonpoint pollution ("Fun Facts on…," n.d.). The first application of carbon capture, carbon capture and sequestration, was used to capture point source emissions from industrial facilities and inject the carbon dioxide underground. Newer developments have increased the technology's capability by directly removing carbon dioxide from the ambient air through a process called direct air capture (DAC). Of all the applications, carbon capture and sequestration is the most successful and widely implemented type of carbon capture technology, with about 26 commercial-scale projects active ("Carbon Capture," 2020).

While the technology is developed, it is not used across all industries to lower emitted carbon dioxide. One of the most significant hurdles to carbon capture is the cost associated with equipment and energy requirements; therefore, research has been done to make the process less expensive by generating a higher-valued product to be sold or optimizing the systems. An example of this effort can be seen in the production of methanol, a highly efficient alternative

fuel that offers lower emissions compared to conventional petroleum. One issue with the traditional production processes involved the burning of syngas which contributes to 0.3 gigatonnes of carbon dioxide emissions per year (IRENA & Methanol Institute, 2021, p. 4). This creates both operational inefficiencies and environmental concerns as carbon dioxide, a greenhouse gas and a necessary feedstock to methanol production, is released into the environment.

The technical project seeks to solve both operational and environmental challenges by implementing a new process to produce methanol fuel in a carbon-neutral process. The technical project will focus primarily on the chemical processes and required equipment necessary to capture carbon dioxide from ambient air through a DAC process and synthesize fuel-grade methanol using the captured carbon dioxide as a feedstock. The goal of the technical research is two-fold: increase the economics of DAC processes by generating a higher-value product and create a carbon-neutral synthesis process for a fuel that is currently widely used. The research was completed with team members Lillian Huynh, Brian Lee, Alex Park, and Ciara Smith, with support from our faculty advisor, Eric Anderson.

While this technology and methodology are promising, it faces many barriers, including political turmoil, complex economics, and lack of public support. This technology is highly dependent on government subsidies, so the implementation has been deeply politicized with many actors in play, and development has been hindered. Hence, the STS research investigates the societal barriers to implementing carbon capture technology using the framework of Actor-Network Theory, developed by John Law, Bruno Latour, and Michel Callon, to determine the relevant actors and their motives (2007). The technical project and STS research topics are

tightly coupled as the technical research investigates a method to improve the economics of carbon capture technology, one of the largest societal barriers found in the STS research.

THROUGH THE LENS OF ACTOR NETWORK THEORY

The Actor Network Theory will be used as the primary conceptual framework for the STS research. Developed by Latour, Callon, and Law, the Actor Network Theory centers around the idea that the development of science and technology is inherently intertwined with social practices (Crawford, 2005). Both human and non-human actors are relevant in this framework as both play a role in developing networks. When analyzing the societal barriers that hinder carbon capture technology, many actors and interactions are considered. Prominent actors in this context include but are not limited to the government, the fossil fuel industry, and communities affected by air pollution. Uncovering the motivations and actions of relevant actors is necessary to understand their effects on the development of carbon capture technology. For these reasons, the main framework of this research will be the Actor Network Theory supported by specific case studies which illustrate the motivations of important actors.

Figure 1 illustrates the relevant actors, depicted in red rectangles and blue ovals, and their interactions, shown as connecting lines, for this issue.

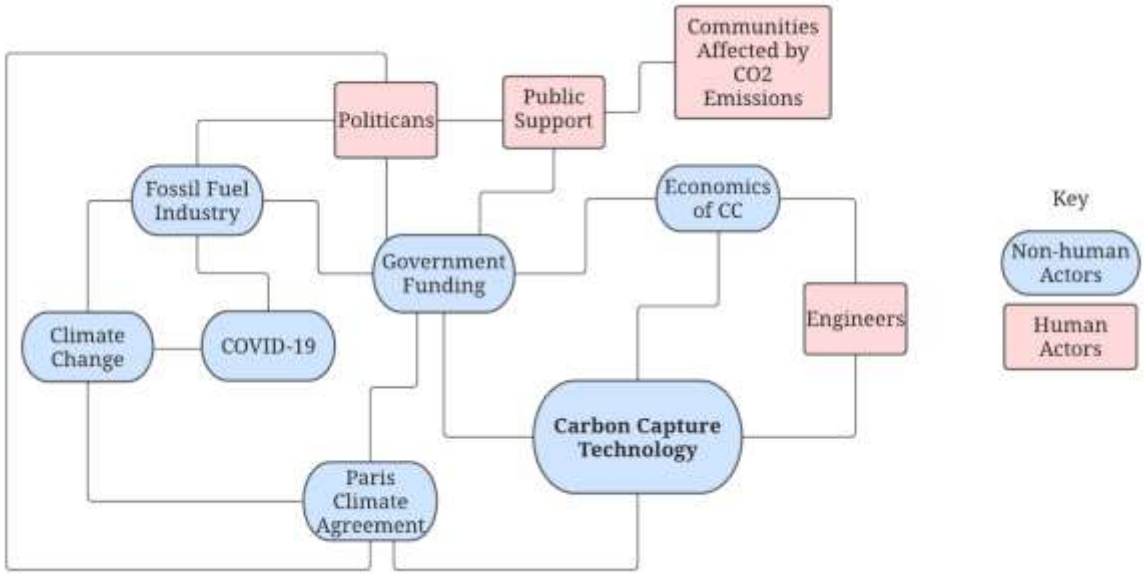

Figure 1. Actor Network Theory for carbon capture. Using Actor Network Theory to analyze actors, both human (red rectangles) and non-human (blue ovals), influencing the development of carbon capture technology (Brown, 2021).

As shown in Figure 1, many interactions are connected through one of the most influential actors, government funding. Being a new technology that has issues with profitability, government subsidies and funding are very influential. Politicians involved in policymaking, fossil fuel companies, the economic viability of carbon capture, and the public's support all indirectly influence the acceptance of carbon capture by influencing government funding. The motivations of each actor will be analyzed in later discussions. This analysis aims to understand the motivations of the actors that affect the government funding to understand why the technology has not been used widely. From this, recommendations can be made to create changes that would facilitate development and society's acceptance of the technology.

THE IMPACT OF POLITICS

Novel and developing technologies typically require monetary support to allow for growth beyond the research and development phase before the idea is proven. The United States government has a rich history of supporting emerging technology. Geospatial positioning systems, supercomputers, the Shale Gas Revolution, and the Human Genome Project are just a few examples of projects that relied on federal funding (Singer, 2014, p. 4-6). Likewise, carbon capture technology is in its early stages of development where there is sufficient research to support the theory, but scaling up the processes and implementation on a large scale is still out of reach. According to the National Academies of Sciences, Engineering, and Medicine, this significant reliance on government subsidies has been one of the major setbacks to the widespread implementation of carbon capture technologies (2019, p. 190).

With this dependency, the issue of supporting carbon capture technology becomes politicized between the Democratic and Republican parties. Politicians are generally motivated by the needs of their constituents, and in areas where the fossil fuel industry employs a large portion of the community and funds political campaigns, it is unlikely for their representatives to support a project such as carbon capture. When communities depend on the wages from fossil fuel-based jobs, politicians have reason to avoid the issue. For example, senators, such as Floridian Rick Scott, have gone as far to acknowledge the issue of climate change yet will emphasize that investing in mitigative technologies is not advisable if “you’re killing the jobs” and that Republican voters are “more concerned with jobs than the environment” (Friedman & Davenport, 2021). In addition to these motivations, many politicians view the development of carbon capture as an admission of wrongdoing within the fossil fuel industry for allowing the emission of carbon dioxide. These sentiments are commonly threaded within the Republican

Party, a party that has a long-held relationship with the fossil fuel industry. In 2020, the fossil fuel industry donated $46 million to the GOP, signifying how influential the industry is in American politics (Friedman & Davenport, 2021). This dynamic network between the fossil fuel industry, politicians, and the public's support creates pushback to carbon capture implementation. This network is highly motivated by maintaining the status quo, which permits the fossil fuel industry to continue to block efforts of carbon capture development as a means of self-preservation.

LACK OF ECONOMIC INCENTIVE

Another reason politicians deny funding for carbon capture is the technology's lack of economic incentive, which can be explained by the technical processes required. The main objective of carbon capture is to separate carbon dioxide from some gas stream, whether that be a high-concentrated smokestack flue gas or low-concentrated ambient air of carbon dioxide. After the separation, the question is: what to do with this stream of carbon dioxide? In the scientific community, carbon dioxide is colloquially known as the 'garbage molecule of the universe' for good reason. Carbon dioxide is a waste molecule for many chemical processes, and the energy cost required to convert it into something more useful and less environmentally damaging outweighs the profit of the new molecule. This economic burden is unavoidable; there are ways to lower it, but it is easier to emit carbon dioxide into the atmosphere than it is to separate. To understand how economic incentive impacts the development of carbon capture, a case study, the shut down of Petra Nova will be analyzed ("Petra Nova…," n.d.).

Petra Nova: From Model to Failure

Most implemented forms of carbon capture involve injecting carbon dioxide underground for geological sequestration. This is environmentally beneficial as the carbon dioxide is stored

underground and does not enter the atmosphere; however, there is little financial incentive for this expensive process. Petra Nova was created to reverse this mindset. In 2010, the Department of Energy and NRG Energy Inc. came together to create the Petra Nova project, originally known as the W.A. Parish Post-Combustion CCS Sequestration project. Its goal was to demonstrate the capabilities of post-combustion carbon capture technology by retrofitting the technology onto an existing coal-fired power plant known ("Petra Nova…," n.d.). The captured carbon from Petra Nova was used for enhanced oil recovery, where captured carbon was injected into oil fields to increase the overall yield of crude oil. Figure 2. illustrates the effect the Petra Nova project had on the carbon dioxide emissions of the coal plant once it began to operate in 2017.

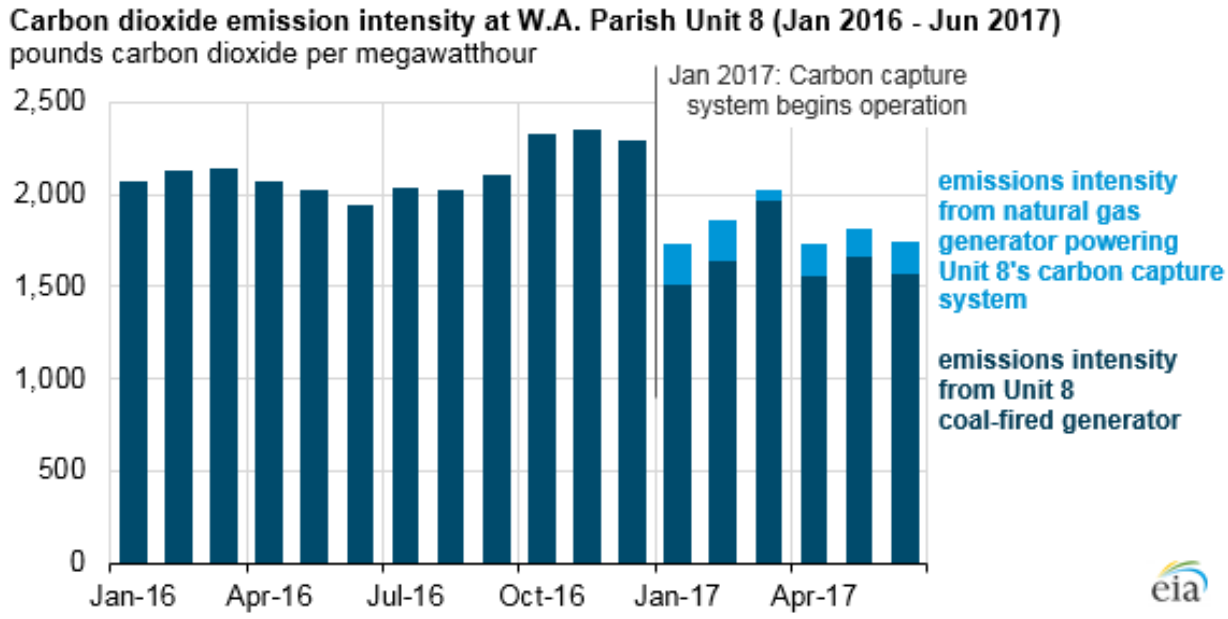

Figure 2. Impact of Petra Nova on facility's carbon dioxide emissions. Illustration shows the roughly 7% decrease of carbon dioxide once the operation of CCS began in Jan 2017. (Dubin, 2017).

As seen in Figure 2., the carbon dioxide emitted from the coal-fired power plant in W.A. Parish decreased by about 7% after the Petra Nova project was implemented. This illustrates that post-combustion carbon capture still requires substantial development to capture a more

significant portion of carbon released. Despite this, Petra Nova was celebrated during its years of operation and was touted as the most successful large-scale application of carbon capture. In many ways, Petra Nova became a symbol or proof of concept, proving that this technology could be successful, to some extent, and that there was potential in further applications.

In 2020, Petra Nova shut down as a result of oil price drops during the height of the COVID-19 pandemic (Hiller & Eaton, 2022). The $1 billion project was no longer economically viable to operate for enhanced oil recovery. This project illustrates the ethical dilemma of delineating who bears the risk and burden associated with mitigative technologies, an issue that surrounds almost every carbon capture application. This issue is discussed in an article entitled "Examining the role of carbon capture and storage through an ethical lens," written in 2013 before many carbon capture projects began. One of the most compelling arguments of this piece was the idea that failing to act on climate change now places more risk and burden onto future generations, yet acting hastily in the present, without considering the consequences of carbon capture, places unnecessary risk back on the population of the present (Medvecky, 2013). The shift of responsibility is one of the biggest motivations for the actors responsible for the development, or lack thereof, of carbon capture technology. Politicians, who control government funding, understand that this technology has risks associated with economics and could be beneficial to the environment in the long run. With "successful" projects such as Petra Nova failing after a few years, many politicians are unwilling to take on the economic risk of the technology despite the environmental benefits.

UNCERTAIN FUTURE OF CARBON CAPTURE

With many actors at play, the future of carbon capture is very uncertain. Even the act of supporting carbon capture technology has many nuances where the different applications have

varying implications. For example, the use of carbon capture and sequestration for enhanced oil recovery, such as the case with Petra Nova, is controversial in terms of whether the project is doing good for the environment. Projects like this are sparking debate within the scientific and political communities on whether or not to support the post-combustion carbon capture technology. Supporting this technology can be interpreted as enabling the fossil fuel industry to continue production, which diverts the allocation of resources away from developing renewable energy sources (Nisbet, 2019). This "business as usual" approach to carbon capture continues the reliance on fossil fuels and directs the attention away from developing new, cleaner technologies as replacements. Other applications of carbon capture, such as direct air capture, remove carbon dioxide from ambient air; however, the process is costly and proprietary to only a handful of companies. Direct air capture is considered the greenest carbon capture application as it has the potential to create negative emissions by lowering the overall concentration of carbon dioxide in the atmosphere. With no clear agenda, carbon capture technology is politicized, which can be seen in the study of Cancer Alley, a community fighting the fossil fuel industry from implementing carbon capture and sequestration in their "backyard."

Cancer Alley: Response to Carbon Capture and Sequestration

St. James Parish, also known as Cancer Alley, is a corridor located in southern Louisiana where the population is greatly affected by the carbon dioxide emissions of local industrial facilities. With about 150 oil refineries, plastics plants, and chemical facilities along the Mississippi River, the residents of Cancer Alley suffer from higher rates of cancer and respiratory diseases than the national average ("Environmental racism…", 2021). Of the residents in the region, people from Black communities are disproportionately affected. According to UN News, African American residents' risk of cancer is about 104 to 105 cases per

million, but the risk is 60 to 75 cases per million in districts of predominantly white residents (2021). Additionally, Cancer Alley has been deemed an environmental sacrifice zone which is defined as a “fence-line” area that is close in proximity to polluting facilities and is usually inhabited by low-income families and people of color (“Let’s talk about…”, 2021). This is illustrated in Figure 3 below, showing the sites of the industrial facilities surrounding the Mississippi

River.

Figure 3. Industrial sites in Cancer Alley. Illustration of polluting sources surrounding the Mississippi River in “Cancer Alley” with each red dot representing an industrial facility (Harris, 2020).

Figure 3 provides a visualization of the magnitude of polluting industrial facilities and sheds light on the harsh reality of being a resident of the area. Despite the pushback from the residents of Cancer Alley, the many facilities in the area are there to stay.

Carbon capture and sequestration have been utilized by Louisiana facilities, with the support of state legislation, continuing the reliance on fossil fuels in the region. As a response, there has been pushback from affected communities and environmental groups hoping to change the focus of legislation from supporting carbon capture to increasing public health measures. As a result of years of excessive pollution and governmental prioritization of industry, residents lack trust in their government and reject the development of the technology outright. Residents of the community reject the implementation of carbon capture and sequestration as it is not seen as a "viable climate solution" ("Carbon Capture and Storage…," 2021). Ultimately while these communities have made clear their disapproval, carbon capture for sequestration has been implemented in the region, signifying the power imbalance between the affected communities, politicians, and the fossil fuel industry.

FUTURE OF CARBON CAPTURE

This analysis has demonstrated the impact of actors such as politicians, the fossil fuel industry, and fence-line communities on the development of carbon capture technologies. Motivated by the needs of their constituents, many Republican politicians make decisions based on preserving economic security instead of allowing government funding for carbon capture. It becomes difficult for actors such as Republican politicians to justify the economic burden of investing in carbon capture if model projects such as Petra Nova fail just years after startup. The ethical dilemma of deciding which generation must deal with the consequences of climate change will continue to be at the center of the development of new mitigative technologies. Residents from Cancer Alley have proven that showing public disapproval of the industry's disregard for carbon emissions is not enough for politicians to break ties with the fossil fuel industry. The government is the most influential actor in this network, where other actors are

motivated to change how funding is divided. The power imbalance between those who support carbon capture and those who deny it allows for business to proceed as usual and continues the reliance on fossil fuels.

Recommendations Moving Forward

After analyzing the typical actors preventing carbon capture technology from widespread implementation, it is clear that reducing the economic burden of development will help facilitate implementation. Currently, the Biden administration has increased the monetary credits given to companies that capture carbon through the Clean Air Task Force (Valdmanis, 2021). This type of effort from the government will be essential to the success of carbon capture, either for sequestration or direct air capture. Another route is to increase the economic potential of carbon capture by using carbon dioxide as a feedstock for other chemical processes to incentivize industry leaders, politicians, and communities to support its development. This is the technical research topic, but further studies should be done to understand precisely how incentivizing this process alters the perception of carbon capture and if support would be changed.

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