The Use of Direct Air Capture to Reduce Carbon Emissions for Process Plants

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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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STS Research Paper

Addressing Detrimental Climate Change Because of Carbon Emissions

In New York City, there is a clock that counts down the amount of time the Earth has before the detrimental changes due to global warming becomes irreversible (Moynihan, 2020). Without a planet to live on, the technological advancements of the future will be pointless. It is necessary to address the global carbon emissions problem in order to ensure the longevity of future generations. In the last century, the concentration of CO_2 in the atmosphere has risen by 100 ppm, from 300 ppm to 400 ppm. This increase in the concentration of has directly led to average temperature increases across the globe (Ritchie & Roser, 2020). As the world began to industrialize, the reliance on carbon emitting fossil fuels quickly spiraled out of control without any concern for the consequences of these technological advancements.

New research and technological advancements are being made every day in order to address the damage that society's reliance on fossil fuels has done to our planet and how to reverse it. However, the advancement of technology alone will not be enough to address global warming and climate change alone. Several economic, political, and societal factors heavily influence the slow transition away from fossil fuels and the slow adaptation of carbon-neutral practices. The question becomes, what can be done to push for a societal and political change in supporting new, green technology rather than relying on old methods that only perpetuate the problem of global warming? To address this question, an analysis Chevron's Carbon Capture and Storage project in Gorgon, Australia will be presented using Actor-Network Theory in order to understand what must be done to successfully integrate carbon capture in existing energy grids and storage technologies across the world.

Methods of Analysis

In order to analyze the project, news reports, research papers, studies, and surveys on the general public will be used and interpreted under the lens of Actor-Network Theory. Since this Chevron Project is a fairly recent project, not a lot of other methods are available currently. Chevron's company website offers some sources and fact sheet materials but no large comprehensive data sheets exist currently that can serve to contribute to this project in any capacity.

Background Information on Chevron's Carbon Capture and Storage Project

In order to analyze and understand the shortcomings of Chevron's novel Carbon Capture and Storage Project, context behind both the plant as well as the public image regarding the plant is needed. In 2009, Chevron Australia, in a joint venture with ExxonMobil and Shell, began construction on a natural gas plant on Barrow Island, off the coast of Australia. A radical part of this project was the CO_2 capture system, the largest that was to be implemented in the world (Gorgon CO2 Injection Project, n.d.). The main plant is a liquified natural gas plant, with the Carbon Capture and Storage (CCS) system injecting captured CO_2 back into a giant sandstone formation 2 km underneath the island. The CCS portion of the project was estimated to cost 2 billion dollars, and the Australian government invested 60 million into this project via the Low Emissions Technology Demonstrations Fund (Carbon Capture and Sequestration Technologies, n.d.).

The plant did not meet the five-year emissions reduction target set as the plant began operation. There has been backlash because of this failure to reach the target from the Australian Government (Morton, 2021). The main issue and subsequent problems occurred in January of

2021, when a problem with the pressure management system led to sand clogging the injection system for the CO_2 to reach the sandstone formation beneath the island (Cox, 2021). While the technical failures of the plant are a large contributing factor to why the project was not a success, it is also apparent that the other non-human actors like the Australian economy and certain tax policies, combined with negative media coverage both contributed to the general view that this project is a failure.

In terms of the economics, this project was very expensive and ran into trouble with regards to return on investment early on into the lifecycle of plant launch. In 2013 it was reported that the amount of money being invested into this project by Chevron and other contributing companies had increased by 2 billion dollars, more than the expected budget. These cost blowouts were reported as being caused by labor shortages and foreign exchange movements (Reuters, 2013). Many companies, as well as the Australian Government, had invested heavily into this plant, well above the original budget. Last year, when it was made public that the plant had not met the goals in terms of emissions reduction targets, climate campaigners called for the companies involved to be heavily fined. The public image of the plant was labeled a failure, and the economics of the plant created a foreboding sense of that even from the beginning before the plant was even running (Morton, 2021).

A Brief Introduction to Actor-Network Theory

In order to understand the analysis and connection between different technical, societal, and political factors, the method in which each of these factors are viewed from, the theory with which these perspectives are understood from, needs to be addressed. Actor-Network theory, which is usually associated with the authors Michel Callon, Bruno Latour and John Law, is a particular way to describe the ways in which society and technology influence one another. It

posits that different factors can serve as an individual actor of a larger network of relationships (Cressman, 2009). These factors can be both societal or technological, a living being or just an idea, or even just a piece of equipment or tool (Akrich, 1997). Within these networks, each actor can also be broken down as its own network, with its own actors that serve to build up its network.

One of the interesting methods of analysis Actor-Network Theory (or ANT) uses is the incorporation of inanimate objects as actors that can affect and change social processes or other "alive" actors. An actor is defined to be "a source of action regardless of its status as human or non-human" (Cresswell, 2010). These actors must act in combination with other actors in order to have the possibility to "act," since Actor-Network Theory views reality as being actively performed by several various actors in specific locations and settings of time. Due to this specific assumption that Actor-Network Theory makes about reality, ANT views technology to be emerged from social interest like political or economic interests and therefore can shape social interactions, rather than being an outside force on society and social interactions. This lends itself well to the analysis of the Chevron Project due to the involvement of several non-human factors that can be viewed as actors.

Tracing the connections between actors in a network and how each network comes to reality or Actor-Network Theory is the core idea of Actor-Network Theory. What associations exist? How do they exist? How do these networks then affect reality because of those connections and associations? John Law, one of the aforementioned authors of Actor-Network Theory, provides an example that serves to illustrate the essence of ANT. A manager from a company can be analyzed as a network. In this network includes his computer, his phone, and even the large office itself. These three actors are connected to each other and to the network because these are items that provide the manager the means of which to do his job. Because of these connections,

the manager thus has power in the company. If the manager were to be studied in isolation, he is relatively powerless.

A drawback of ANT is that sometimes in reality, specific factors can, in isolation, have leverage or power in certain situations or networks. The assumption ANT makes about reality requiring various actors to be performing that said reality in tandem gives room for some fallacies, like when a reality could really be made up of only one singular factor. However, the flipside can hold true. When each of these actors are analyzed deep enough, it can be found that each actor also plays a role of a network, and thus this shortcoming of ANT can be worked around. In order to avoid situations like this in the analysis of the Chevron Project, proper thorough research of each actor and network is done in order to ensure that actors are connected and performing reality together in order to change and affect society.

How Can Sustainable Technologies be Supported by Society?

The main question being addressed is: what sociotechnical adjustments need to happen in order to support new, sustainable technologies? In order to answer this question, an analysis of Chevron's recent Carbon Capture and Storage (or CCS) Project in Gorgon, Australia is done below via documentary-style research, as well as discourse analysis surrounding both this project by Chevron as well as Carbon Capture and Storage technology itself. This is done by analyzing what specifically happened at Gorgon via news articles, the official Chevron Project website information, as well as other studies done about Carbon Capture and Storage technology. All of this is analyzed through the lens of Actor-Network Theory. The rest of this analysis goes over what exactly led to the failure of Chevron's project and find ways for a future sustainable project like this to be successful. Furthermore, an analysis of the public perception on CCS technology is done to see how crucial social acceptance and social awareness is with regards to a successful CCS

project. Finally, limitations of this research paper are addressed to identify what can be done moving forward for a more comprehensive view on what was analyzed, as well as next steps for said analysis.

Analysis of The Chevron Carbon Capture and Storage Project

Chevron's CCS Project in Gorgon, Australia had many actors that worked in tandem to shape and affect the societal and political climate surrounding the project. In the Chevron CCS Project Network, the key actors that led to its failure was the high-profile nature of the project, the technical delays and ultimately failures that came during operation and startup, and society's current knowledge and experience with CCS technologies. All the major companies involved with the Gorgon Project, like ExxonMobil and Shell, led to an increased attention of media, leading to scrutiny at every turn, so when the project ran into delays and initial problems at startup, it quickly became a lamb to the slaughter in the eyes of the media. Prior to stepping into the analysis, it is important to flesh out what certain phrases are in reference to as they are used later in the paper. The Gorgon Network is in reference to the network of actors that make up Chevron's Gorgon CCS Project. CCS, as mentioned before, refers to Carbon Capture and Storage.

Everything that went wrong with the Gorgon CCS project, from its high-profile nature to the technical failures are the exact opposite of what needs to be done in order to push social and political change into fully supporting new, green, sustainable technologies. Based on the research studies found about public perception of CCS technologies, the general public has an acceptance of greener, sustainable technologies, but the crucial missing cornerstone is the knowledge and experience with the technology, which ultimately leads to trust and positive perception (Seigo et al. 2014). Each of these actors will be analyzed and then the connections through the networks will be stated in order to clearly illustrate how the Chevron Project was affected.

This particular CCS project had attracted attention in the media from its conception due to the large, well-known companies that were involved with the project. Chevron, ExxonMobil, and Shell were all major oil and gas companies that were a part of this joint venture, along with Tokyo Gas, Osaka Gas, and Chubu Electric, all very famous companies in Japan, with Tokyo Gas being the biggest supplier of power and gas for Japan (Carbon Capture and Sequestration Technologies, n.d.). This high-profile nature can be viewed as a network itself, with each of these joint venturers can be seen as actors within this network. This high-profile nature is one of the most important actors in the Gorgon Network due to how much it affects the other key actors. The attention this project got amplified and exacerbated any delays or technical failures, as well as the social perception of the plant. In recent years companies like ExxonMobil, Shell, and BP have tried to change their public image by advertising their projects regarding sustainable technologies like algae-based fuels or other green technologies (ExxonMobil, 2018). However, that does little in changing the public perception of each of these actors in the Gorgon Project Network, the perception that is oil and gas giants that seemingly dominate the world's energy market with fossil fuels. Simply because of these actor's involvements with this project, it immediately brings attention, both good and bad, to the network due to the preconceived reputation of Chevron, ExxonMobil, and Shell. Analyzing this actor as a part of the Gorgon Network shows just how connected this project is in regard to the dynamic between technology and society. Social views and opinions have a strong voice when dealing with these large companies, and that ultimately affects the decisions made by said companies for projects like this one. Social actors like this particular one have a much more significant impact to technical factors of projects, and this is a very obvious case of just how the two can interact, which will be further analyzed as the technical failures actor is discussed.

In combination with this massive attention drawn to the Gorgon Network, another key actor was the delays and technical failures that arose as the plant was being built. When this actor is viewed as a network and broken down to its own key actors that contributed to the delays and technical failures, three main contributors for this network are revealed. The first is the ambition of the project. This project was very ambitious with its production and overall goals, because it was going to be the world's biggest carbon sequestration project at the time, with the original start date for carbon capture and storage to be in 2016 (Carbon Capture and Sequestration Technologies, n.d.). Due to the sheer size as well as the scope of the project, it led to many delays because of the difficulty in delivering on multiple different deadlines and progress points, which is common for larger scope projects. The ambition of this project can be interpreted as a social actor, an actor that stems from societal factors or decisions. While the delays of this project may at face value seems like the only factors to the failure of Gorgon, outside actors like the scope of this project will prove to also play a pivotal role in this network.

After all the delays and technical failures, the project finally began running in 2019 (Morton, 2019). Of those technical delays, the biggest came in the form of sand clogging the draining of water from the pipelines that would be used to inject CO_2 underground for storage. Any attempts to drain the water blocking the pipes were prevented due to the sand (Milne, 2021). This sparked a huge backlash from the general public, especially because the delay in the commencement of the CCS project was thought to have accounted for almost half of the increase in Australia's annual carbon emissions, since the natural gas plant continued operations even while the CCS project was not correctly operating (Cox, 2021). Another actor of the technical failure network involved a faulty design. There were compressors that incorrectly allowed water and CO_2 to mix streams, creating carbolic acid. This formation of carbolic acid would erode equipment

further downstream, which was detrimental as CO_2 was released back into the atmosphere as a result of the corrosion. Faulty design of these compressors required a redesign of the pipelines and valves for the injection of the CO_2 underneath Burrow Island, which caused significant delays (Milne, 2017).

As the technical failures of this project are addressed, a multitude of actors are revealed beyond just simple mechanical or engineering shortcomings. A major actor that can be identified in regard to the technical failures' "network" is the federal and Western Australian government. In a study done by Johnathan Paul Marshall from the University of Technology Sydney, the liability for any potential gas leaks in the long-term future was under the federal and Western Australian governments, with Chevron and the other contributors being liable for leaks only during the project's construction and the first 15 years after construction was complete (Marshall, 2022). This put both governments in between a rock and a hard place, as so much money was already invested into this project from the governments, and the taxpayer would ultimately be subsidizing this project. This government investment would paint the Gorgon Project in a bad light in the eyes of the public, which is not in the interests of the Australian government. When the Australian Government is analyzed as a network, a crucial actor that further played into the Gorgon Project's detriment is how friendly the tax regime was for fossil fuel companies. The tax credits for oil and gas companies in 2019 was at 324 billion Australian dollars (or AUD), which correlates to 324 billion AUD that these companies did not have to pay in taxes (Khadem, 2019). This specific actor gives motivation to companies like Chevron, or ExxonMobil, or Shell to continue with oil and gas ventures as it is the most profitable. From a business standpoint, it makes the most sense to emphasize the most profitable branch the most (Milne, 2021).

Another major actor in the technical failures network was a legal dispute between Chevron and the contracted construction company (Wiggins, 2020). This dispute was due to the CIMIC Group underquoting what the cost would be for this project to be built, and as costs increased due to the faulty designs mentioned earlier, tension grew between the two companies. It is worth noting that the issue of construction companies underquoting projects is a worldwide problem, and it inevitably leads to delays in construction. The last actor in the technical failure network that was critical is the oversight of safety during the construction of the Gorgon Project. Multiple pressure vessels that contained propane had been reported to have thousands of cracks by workers to the media. This oversight in the safety of the plant workers working with these pressure vessels sparked an investigation by the Department of Mines, Industry Regulation and Safety WorkSafe investigation (Milne, 2020). This ultimately led to several more delays as multiple vessels and other equipment like kettles needed to be replaced. When viewing all these non-technical actors in perspective with the technical failure network as a whole, it is clear that both political policies and societal factors impacted what seemingly feels like a purely technological component to the Gorgon Network. Everything from taxes to company oversights to even lawsuits caused or played a part in significant delays in this project. Society and technology are far more intertwined than what an initial eye test can perceive, and it is because of that intertwinement that this Gorgon Project has so far been considered a failure.

When viewing the Gorgon Project network from a broader perspective and analyzing the connections between the non-human network of technical failures and the high media exposure network/actor, it is obvious that while the technical delays and failures were a key component to the Gorgon Network's failure in its own right, the high-profile nature of the project only served to amplify and blow the project's shortcomings out of proportion. The Guardian articles referenced

earlier quotes multiple groups of the general public calling the project “a disaster from the start” or calling for the companies involved to be fined speaks volumes to the backlash of the Gorgon Project.

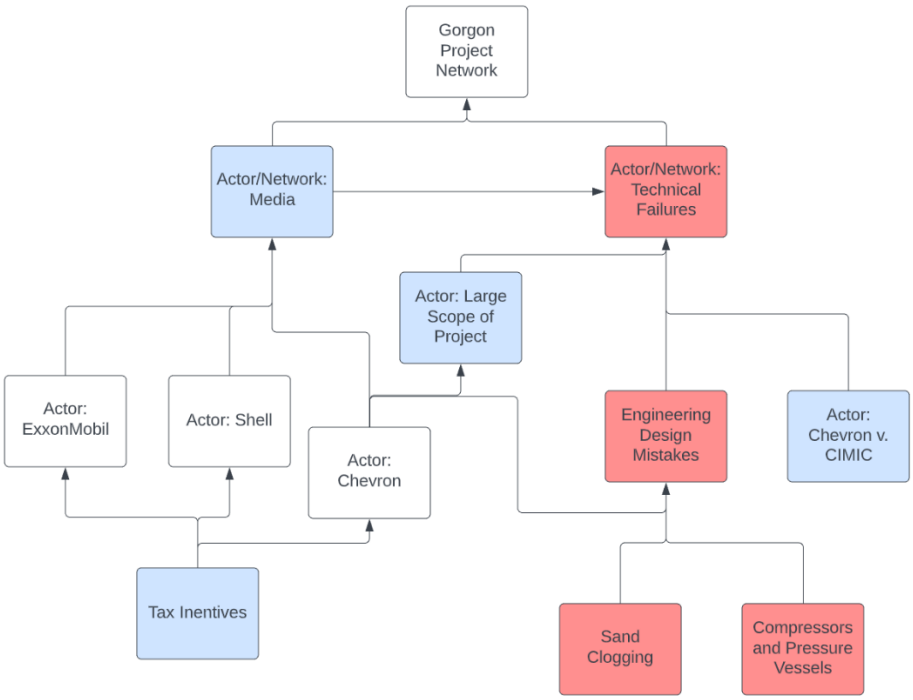

Figure 1. Flow Chart of the Gorgon Project Actor-Network (Park, 2022)

Note: technical/non-human actors/networks are shown in red, societal/political/economic actors that may have humans involved shown in blue

To clearly review the different actors and networks and how they intertwine with each other, figure 1 outlines how each actor connects with the different networks, with blue boxes representing social actors and red boxes representing technical actors. The failures of the Gorgon Project gives clear answers to how society can be pushed towards sustainable, green technology. The first and foremost is to address social perceptions of projects as they progress. It was unfortunate that the Gorgon Project had so much spotlight in the media, but Chevron’s own secrecy

surrounding current the project's progress as well as current injections and reductions in emissions was their own undoing (Cox, 2021). The company emphasized its future projections for emissions reductions and injection volumes, but with the delays of the project already hindering the view society had on it, Chevron was an actor in its own Gorgon Network failure. Companies need to be transparent not only with current progress on projects such as these, but also with the technology that they are developing. Advertising, and thus making the public aware of, what the technology does and how it works even at a rudimentary level is the first step in pushing our world towards a transition to sustainable technology. In the public perception study done by Seigo et al, it was found that while most people who were surveyed generally accepted carbon capture and storage technology, a vast majority of them lacked positive affect or a proper understanding of the knowledge around carbon capture and storage technology (Seigo et al. 2014). They described positive affect as positive feelings towards CCS technology. In both the qualitative and the quantitative surveys done and analyzed by the study, a majority did not have positive affects towards CCS. Positive feelings from the society are crucial if a transition to sustainable energy is to be completed by governments across the globe, from Australia to the U.S.

Furthermore, the current government policies regarding tax incentives, both for oil and gas and for sustainable technology and energy. In addition to Australia's oil and gas policies, the U.S. oil and gas policies also incentivize oil and gas, as it is still the most dominant source of energy across the world (American Petroleum Institute, n.d.). When viewing the world's energy market as a network, the actor of government tax policies is a key factor, as it motivates businesses to continue being in that business. Society cannot progress and transition into sustainable technology when businesses that affect public opinion and supply the energy needs of their taxpayers are incentivized to continue in oil and gas as their most profitable market.

Now that all of the important actors and networks are identified, the connections and collaborations that ultimately promoted the downfall of the Gorgon Project must be observed. First and foremost, all of the different networks and actors are connected by one common factor: the media. Through the network that is the media and press coverage surrounding the Gorgon Project, the technical failures, the economic situations and tax situations, and even the lawsuit all were able to work in tandem with each other due to the media coverage in order to act on the sociotechnical climate of the project. The tax incentives acted in collaboration with the different famous companies involved in order to create a lower desire in society's other large, well-known companies to pursue investing in more sustainable technologies like CCS. The large scope of the project, the technical failures, and the lawsuit that is occurring between Chevron and the CIMIC construction company all participated together to create an opportunity for the media to paint the project in a very bad light and were connected to each other because of this media coverage. The media coverage is the glue that allows all of these different actors to work in tandem with each other and ultimately affect the Gorgon Project the way that each actor did.

Although these suggestions offer insights on how to learn from the shortcomings of the Gorgon Project, there were a few limitations to this research. First and foremost, the Gorgon Project is currently still in progress, and while there have been significant delays, as stated in this paper, much can still transpire during the next few years. In addition, because of the novelty of carbon capture and storage technology, there is not a significant amount of public surveys and published papers about CCS. In the future, other CCS projects should be incorporated into the analysis across the globe to have a bigger sample size in terms of perspective on CCS projects and add in successful examples.

Final Thoughts

In order to push society to a transition into sustainable technology, both political and societal factors need to push technological advancements. With the current societal and political environment surrounding the energy market network, the biggest actors that need to come through is governmental policies incentivizing sustainable technology like carbon capture and storage, as well as addressing media coverage and proper transparency with regards to a project's progress and capabilities. It is now obvious that the mishandling of media coverage and information transparency to society, particularly one on a large scale with major companies involved like in the case of the Gorgon Project, will propagate and exacerbate a project's delay or technical failures. At the end of the day, society and technology both serve as actors to each other's network, and in order for our world to progress and become more environmentally friendly to ensure the safety of our future generations, they must work in tandem to push a shift to sustainable technology.

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