Exploring Industry and Non-Profit Perspectives on Community Engagement and Energy Justice for Direct Air Capture (DAC) Carbon Removal Technologies

by

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ABSTRACT

This paper will explore the existing relationship between direct air capture (DAC) technology and energy justice (EJ) principles. As DAC is a nascent technology that is transitioning from the R&D phase to the deployment phase, a standard for typical scaling practices has not yet been established. Additionally, since the industry of DAC aims to capture at least 10 gigatonnes of carbon dioxide per year by 2050, and at least 20 Gt/yr by 2100, the scaling practices of this technology will have a significant impact on communities around the world. Therefore, in this thesis I argue that if DAC is not scaled equitably, it will negatively impact the communities hosting the technology, and would develop a negative reputation which could slow down the overall scaling process. On the flip side, if DAC is scaled equitably, then it could create a positive effect by being deployed in underserved and marginalized communities and providing an economic benefit. This could result in DAC having a positive reputation and scaling more rapidly. In order to understand how the field viewed the integration of EJ principles into the scaling process, I interviewed representatives from DAC companies, experts in energy justice from NGOs and academia, and local government officials. These interviews were semi-structured, open-ended and conducted anonymously. Through these interviews I was able to refine my arguments and put forward a set of guidelines that the industry could use to scale DAC with equity and justice as core principles.

TABLE OF CONTENTS

CHAPTERS Page

PREFACE

This thesis is intended to be the concluding document of my master's degree but it is also only the introductory document for my broader research scope. In this thesis I intend to introduce direct air capture technology and energy justice principles, and establish my stance on how these should be integrated into the larger climate mitigation plan. Additionally, I conducted some exploratory research into what representatives from DAC companies and energy justice experts from various NGOs and academic institutions were thinking about these topics. I gathered this information through interviews but my intention was not to be an objective interviewer, because while I wanted their unbiased thoughts, I also wanted their thoughts on the ideas that I will be proposing in this thesis. Through this thesis, you will see that sometimes the participants' view supports my own, and in other cases it does not. In both instances I will explain my thoughts, participants' feedback, and the justification for my proposal supported or opposed by their views. This thesis is not meant to be a scientific research paper on the objective views of the DAC industry. It is meant to establish my views on how to scale the DAC industry which are informed by the research I have done through my master's degree– and partially by the interviews conducted for this paper– while also providing some insight on how the broader field thinks about these same issues. I plan on continuing this research through a PhD at Arizona State University. The PhD will allow me to create a more detailed and robust framework on how to scale direct air capture with energy justice principles, while also giving me the time to test this framework to provide more scientific evidence either in support or opposition.

CHAPTER 1

CARBON REMOVAL AND DIRECT AIR CAPTURE

1.1. Climate Change and Carbon Management

Climate change is one of the most urgent issues that affects society today. Whether its national security, international politics, energy consumption, transportation, agriculture, fishing, or business, climate change is significantly changing the discussions and operations of these fields. The next few decades are going to be critical for the effort to mitigate climate change. We will either have to address the cause of climate change in some way, or we will have to face the consequences of an increasingly warmer global temperature. The consequences of ignoring climate change will be severe (IPCC, 2021).

Over the past 10,000 years, the Earth has seen an extremely consistent climate, a period known as the Holocene. The Holocene allowed for the development of human life and societies as we know it today because of the predictable seasons and weather patterns (Waggoner & Smith, 2011). However, over the last several hundred years, with the industrial revolution resulting in a significant increase in human-caused (or anthropogenic) emissions, this period of stable climate is starting to fade (Malhi, 2017).

Anthropogenic climate change is caused by the rapid increase of greenhouse gases (primarily carbon dioxide) in the atmosphere. Greenhouse gases are essential for retaining heat from the sun, and thereby providing a climate that has allowed for sustainable life on Earth (Burch & Harris, 2014, pg. 80-85). However, the rapid increase in atmospheric greenhouse gas levels since the industrial revolution has resulted in an increased amount of trapped heat, causing extreme weather conditions and rising sea levels (Burch & Harris, 2014, pg. 160-162). Additionally, as more carbon dioxide (CO_2) is released into the atmosphere, the surface ocean starts acting as a carbon sink, and also becomes more concentrated with CO_2. This causes the ocean to acidify, which, in combination with rising ocean temperatures due to global warming, is detrimental to ocean life and ecosystems (González-Delgado & Hernández, 2018). Not only does climate change pose a severe threat to Earth's environment and wildlife, but the variations in duration, frequency, and intensity of seasons and weather events result in very immediate and direct impacts on human lives and livelihoods. Extreme climate events and sea-level rise will displace many people and create climate refugees, long dry seasons will cause food and water insecurities, and intense rainy seasons and melting glaciers will cause flooding (Burch & Harris, 2014, pg. 160, 166, 183-187). These are just a few of the direct challenges that climate change will cause. As we continue to emit greenhouse gasses, these impacts will become more severe and harder to mitigate.

1.2. Carbon Dioxide Removal and the Role of Carbon Removal Pathways

The Intergovernmental Panel on Climate Change (IPCC) has concluded that we need to rapidly reduce anthropogenic greenhouse gas emissions and reach a net-zero economy as soon as possible in order to most effectively mitigate the impacts of climate change and address its causes (IPCC, 2021). Many of these technologies required for decarbonization are already being scaled like solar power, wind power, and electric vehicles.

However, even if anthropogenic emissions could be stopped immediately , a dangerous amount of greenhouse gases would still remain in the atmosphere

(MacDougall et al., 2020). Additionally, while there are a number of systems and processes which can be easily and feasibly transitioned to zero-emissions state, there are industrial sectors such as aviation, long-distance transport, heavy metal production, wastewater treatment, and agriculture which will be hard-pressed to make this transition (Bergman & Rinberg, 2021) (Davis et al., 2018). Therefore, in addition to decarbonization, we will have to also employ other tools to fully maximize our mitigation potential. The IPCC has identified carbon removal technologies as one of these other tools. Both carbon removal and decarbonization fall under a larger umbrella called carbon management. Carbon management is a strategy which treats CO_2 emissions as waste, and therefore uses a waste management strategy to address climate change (Lackner & Jospe, 2017).

Carbon removal is a portfolio of tools which remove carbon from the mobile carbon pool (Bergman & Rinberg, 2021). The mobile carbon pool includes the atmosphere, the surface oceans, and short-lived biomass. Carbon is constantly and relatively rapidly exchanged between separate areas of the mobile carbon pool. Removing carbon from the mobile carbon pool serves several essential purposes. Firstly, while we are still emitting greenhouse gases at high volumes, carbon removal will increase the amount of time we have to decarbonize our economy before reaching key markers such as a 1.5 degrees Celsius rise in global temperatures or atmospheric levels of approximately 450 CO_2 parts per million (ppm) (Paris Agreement, 2016) (IPCC, 2021). Secondly, carbon removal can be helpful in creating a net-zero economy by balancing out the hard-to-abate emissions(Bergman & Rinberg, 2021). Lastly, once we have reached net-zero, carbon removal can reduce the atmospheric CO_2 concentration back down to safe levels, around 350 ppm maximum (Hansen et al., 2008).

The goal of carbon removal is to either utilize CO_2 captured from the atmosphere to displace fossil-derived carbon, or sequester it in permanent storage. The utilization of carbon can take the form of fuels, cement, plastics, alcohol, or a number of other products. These are beneficial because carbon-neutral products can displace fossil fuels and create robust and diverse markets for carbon removal technologies (Psarras et al., 2021). Sequestering CO_2 in permanent storage is beneficial because it removes carbon from the mobile carbon pool and allows a technology to become net-negative (Hovorka & Keleman, 2021).

While there are many different types of carbon removal pathways, they can be broken down into three basic groups: Natural solutions, hybrid solutions, and engineered solutions. Natural carbon removal methods like reforestation or forest management involve enhancing or accelerating processes that already occur through the Earth systems. Hybrid solutions are methods which involve a combination of natural processes and technology (Sandalow et al., 2018). Biomass Energy Carbon Capture and Storage (BECCS) is an example of this because it involves growing biomass, a natural process, burning it to create energy, and then capturing and sequestering the CO_2 released from the energy production process, a technological process (Sandalow et al., 2018). Lastly, engineered methods are completely created by humans. An example of an engineered process is direct air capture (DAC) (Naimoli, 2021). DAC has been defined by Dr. Klaus Lackner as a method that removes CO_2 from the atmosphere without using photosynthesis.

All three of these groups have their own benefits and drawbacks, leading many experts to conclude that no one carbon removal method is going to be the silver bullet mitigating and reversing climate change (Minx et al., 2018). These methods are also at different stages of development. The metric by which this characteristic is measured is called the Technology Readiness Level (TRL) and is a scale from 1-9: 1 indicates technologies which are still conceptual but have the basic principles, and 9 indicates technologies which are ready to be deployed and operated in the field (Möllersten & Naqvi, 2022). Natural carbon removal methods like afforestation, reforestation, and forest management are most often rated with a very high TRL (7-9). Hybrid methods like BECCS and biochar are generally rated more in the middle of the scale but have more variance (5-9). Engineered methods like DAC, direct ocean capture, and carbon mineralization are rated lower on the TRL scale (4-6) (Möllersten & Naqvi, 2022). TRL is important because climate change mitigation needs to happen rapidly, and only technologies which have been developed to the appropriate level can be deployed in the near term.

According to the TRL system, engineered carbon removal methods are not considered ready to scale. Methods like afforestation, reforestation, forest management and other nature-based pathways are the cheapest and most immediately scalable. However, these natural methods do not have the capacity to remove the amount of carbon required to mitigate climate change on their own (Minx et al., 2018). Nature-based methods are often limited by the availability of natural resources. For example, afforestation is limited by the amount of land available to grow new forests (Minx et al., 2018). Additionally, land-dependent carbon removal methods are also limited by land demand for other uses (food, housing, etc.). Similarly, BECCS, a hybrid method, which uses dry biomass as a key source material, is also limited by the amount of land which can be used to grow the biomass for energy production (Sandalow et al., 2021). By contrast, the land demand for DAC is several orders of magnitude smaller than that of biomass based systems.

1.3. Direct Air Capture

DAC plus carbon sequestration (DACCS) is one of the carbon removal methods with the highest potential capacity for carbon removal (Sandalow et al., 2018). Unlike nature-based and hybrid carbon removal methods, DAC is not seriously limited by land availability because a simple calculation shows that all the CO2 currently emitted world wide could be collected in an area the size of Arizona by. Furthermore, if such a system were broken up into smaller units, the area demand would be even smaller. By contrast, the area required to collect the same amount of CO2 via biomass exceeds the current amount of agricultural land use (Lackner & Jospe, 2017). Additionally, DAC can be placed anywhere in the world and the carbon captured from DAC can be used for a variety of purposes since DAC produces concentrated CO_2 (Sandalow et al., 2018).

However, DAC is currently low on the TRL scale because of its high energy and water consumption and its high cost. In 2023, the CO_2 concentration sits at approximately 420.98 ppm (Scripps Institute of Oceanography, March 27, 2023). Therefore, while the concentration is considered dangerously high in climate change discussions, it is quite low in the context of carbon capture. For perspective, point source capture (PSC), which captures carbon dioxide from concentrated sources such as flue gas, is capturing CO_2

from a flue gas stream which has a CO_2 concentration of between 5% and 12% (Sandalow et al., 2018). PSC typically has a TRL of 8-9 (Möllersten & Naqvi, 2022). Therefore, to separate carbon dioxide from an inlet stream which has a CO_2 concentration of 0.042%, the energy requirements are higher, and more costly.

The standard design for DAC has been to use turbines to suck in ambient air from the atmosphere and funnel it into the air contactor. The air contactor is the place where the ambient air contacts a CO_2-attractive solvent or sorbent. As the air passes over or through the solvent or sorbent, the CO_2 gets stuck to the material, and the rest of the air flows back into the atmosphere. In order to get the sorbent/solvent to release the carbon dioxide molecules, a temperature, pressure, or moisture differential is applied. The captured CO_2 is funneled into a container, and the sorbent/solvent is cycled back for reuse (Sandalow et al., 2018). In order to further reduce the price of this process, there are several other methods in development. For example, there are some companies which are trying to implement a passive DAC approach, which involves using the wind to let the air passively flow over the sorbent instead of spending energy to push it into an air contactor (Ozkan et al., 2022).

Due to its large capture potential, DAC is going to be an important part of the carbon removal portfolio in the coming decades. However, due to the challenges discussed, most companies looking to scale DAC technology are at an early stage, and have not reached commercial scale. The ability to scale DAC would be limited if costs do not come down. However, many other technologies from wind and photovoltaic energy to automobiles, computers, and appliances have come down steep cost curves and there is no obvious reason why DAC would fail to do so (Lackner & Azarabadi, 2021). A recent very dramatic example of such cost reductions in an energy intensive industry is lifting mass into space. SpaceX has achieved lifting costs which are two orders of magnitude smaller than the previous industry standard.There are currently many start-up DAC companies which are exploring a variety of methods and processes to decrease the cost, energy, and water requirements for DAC. In the next section, I will discuss a few of these companies, their methods, and their scaling plans.

1.4. Status of DAC Technology

While there are many DAC companies which are in their early stages of research and design (R&D), there are a few companies which have risen past this stage and are building or have already built pilot and commercial scale plants. We will now discuss a few of these examples.

1.4.1. Carbon Engineering

Carbon Engineering is a DAC company based out of Canada. Their technology is an active DAC design which uses a liquid solvent to capture carbon dioxide and is powered by a natural gas power plant. Their design requires very high quality heat (700-900 $^\circ$C) to regenerate the solvent (Keith et al., 2018). Their design lends itself to non-modular large scale plants. They have their pilot-scale plant in Squamish, British Columbia, which captures one ton of CO_2 per year (https://carbonengineering.com/frequently-asked-questions, n.d.). Recently, they have partnered with Occidental Petroleum and OnePointFive to build a one megatonne capacity DAC plant in West Texas. The CO_2 captured by Carbon Engineering’s DAC plant in West Texas will be used for Enhanced Oil Recovery (EOR) by Occidental

Petroleum (Lust, 2022). EOR is a process which injects carbon dioxide into the ground in order to retrieve oil which would have been otherwise difficult to access.

1.4.2. Climeworks

Climeworks is a DAC company which is based out of Switzerland. They also have an active DAC design, but they use solid sorbents to capture the CO_2. The use of solid sorbents allows them to build a more modular design which requires lower temperatures of heat for regeneration. One unit of the DAC design captures up to 500 tonnes of CO2 per year. They currently have several small DAC plants running in Europe which capture on the order of tens to hundreds tonnes of CO_2 per year (Sandalow et al., 2018). Their largest capacity plant in operation, called Orca, is in Iceland, and can capture up to 4,000 tonnes of CO_2 per year (comprising 8 modular units) (https://climeworks.com/roadmap/orca, 2021). Orca is unique because it runs on renewable geothermal energy and sequesters the captured carbon underground through a process called mineralization (Pontecorvo, 2021). Climeworks is currently building a larger DAC plant called Mammoth, also located in Iceland, which will have the ability to capture up to 36,000 tonnes of carbon dioxide per year (https://climeworks.com/roadmap/mammoth, 2022). Climeworks is also looking to scale their technology in the US in the near future (https://www.businesswire.com/news/home/20221121005556/en/Gulf-Coast-Sequestration-and-Climeworks-Sign-MOU-to-Develop-First-Direct-Air-Capture-and-Storage-Hub-on-the-Gulf-Coast-in-Louisiana, 2022).

1.4.3. Heirloom

While Carbon Engineering and Climeworks were both founded in 2009, Heirloom was founded much more recently in 2020. Heirloom's approach to carbon removal is more unorthodox. They are using powdered CaO to capture CO_2 from the atmosphere. When combined with CO_2, CaO turns into $CaCO_3$, or limestone. This process which normally takes years, has been accelerated to to only take three days by using Heirloom's technology. The limestone is then heated in a renewable powered electric kiln to capture the CO_2 and reuse the CaO. Heirloom's technology is designed to be modular and eventually mass manufactured (https://www.heirloomcarbon.com /technology, n.d.). Recently, Heirloom partnered with CarbonCure, a carbon utilization company, to store carbon captured from the atmosphere into concrete. This is a milestone achievement because concrete production is typically a heavily carbon intensive process (CarbonCure Technologies, 2023). If carbon dioxide can affordably be stored in concrete, then this process can turn one of the world's largest industries from a carbon source into a carbon sink.

1.4.4 Carbon Capture

Carbon Capture, similar to Climeworks, is another DAC company which is using a modular active DAC design with a solid sorbent being used to capture the CO_2 (https://www.carbon capture.com/what-we-do, n.d.). Carbon Capture has recently started scaling Project Bison, a direct air capture and storage facility located in Wyoming which intends to capture and sequester five megatonnes of carbon dioxide per year by 2030. The DAC units will be renewable powered, and be adaptable to a number of different solid sorbents available in the field. In order to achieve this five megatonne goal by 2030, Project Bison intends to be able to capture and store 10,000 tonnes of CO_2 per year by 2024 (https://www.carboncapture.com/ project-bison, n.d.).

1.4.5. DAC Hubs

The companies listed above are four of the largest companies in the field. However, other engineered methods of capturing carbon from the atmosphere such as using passive DAC like Carbon Collect, electro-swing adsorption like Verdox, and DAC-to-fuels technology like Aircela, are still being developed and could soon be deployed as well. To accelerate the scaling of these DAC technologies, the US government passed the Bipartisan Infrastructure Bill in 2021, which allotted \$3.5 billion for building four regional DAC Hubs (Holness, 2022). These Hubs are required to capture one megaton of CO_2 per year by 2030. The round of application for the funding, which covers \$1.2 of \$3.5 billion allotted, was due on March 13th, 2023. The initial applications are encouraged to include more than one DAC technology provider, allowed to have EOR, and required to have community benefits plans (Holness, 2022). These DAC Hubs are the largest investment made by any government into DAC so far, and therefore, the US has become the center of the DAC industry for now.

While the DAC industry is still at an early stage, it is rapidly moving towards commercialization. We are motivated to research the implications of rapid scaling of DAC technologies because we start from the assumption that there is a high probability that DAC technologies will succeed in cost reduction. And if they do, they are uniquely positioned to take on a large part of a large CDR and carbon management in general.

As the field moves towards commercial scaling, it is going to be important to determine the challenges that are going to come with this new phase, and how to deal with them. As with any infrastructure, local communities are going to have an impact on how challenging this next phase will be. In the next section, I will introduce the concepts of energy justice and community engagement.

CHAPTER 2

CENTERING ENERGY JUSTICE

2.1. Climate Change and Justice

Climate change has been caused by humans, and more specifically caused by developed nations which primarily used fossil fuels to industrialize (Burch & Harris, 2014, pg. 94-97) (IPCC. 2021). While these countries have enjoyed the benefits of industrialization, all countries around the world will suffer the consequences of climate change. However, climate change will not affect each country equally, nor will it affect countries based on the amount they contributed to climate change. The most severe and intense consequences of climate change will affect the poorest countries. This is because these countries have the least amount of resources to guard against potential climate disasters, and recover after climate disasters. Additionally, these countries will be more vulnerable to climate impacts such as food shortages, disease, and sea-level rise (Burch & Harris, 2014, pg. 187-190).

These differences in equity, seen internationally, can also map onto regional and local circumstances as well. Affluent communities, who have historically emitted the most CO_2, are also the communities which will be most able to adapt, and underserved and marginalized communities will be the most vulnerable (Burch & Harris, 2014, pg. 187-190). As we are mitigating climate change, it is important that we do not harm the communities that have least contributed to and are yet most affected by climate change. Climate change mitigation technologies need to be scaled rapidly in order to avoid the most severe consequences, but I argue that it should not come at the cost of harming underserved and marginalized communities. Furthermore, stakeholders in the energy transition process should aim to create co-benefits for these underserved communities through the scaling of energy infrastructure.

2.2. Defining Energy Justice

These issues of equity are the focus of a field known as Energy Justice. Energy justice (EJ) is defined as a framework which, "evaluates where injustices emerge in the field of energy, determines the affected sections of society which are ignored, and works to reveal and reduce such injustices," (Jenkins et al., 2016). Energy Justice has four primary components:

1. **Distributional Justice** deals with the distribution of energy resources. More specifically, it examines where and by whom the energy is being produced, where and by whom the energy is being used, and who is being affected by the production and transportation of energy. Distributional justice says that benefits and costs of the energy production, transportation, and use should be equitably distributed among all parties involved (Jenkins et al., 2016). If one party is getting all or most of the advantages of the energy access while other parties are suffering all or most of the cost of the energy production and/or transportation, then it is a form of distributional injustice.
2. **Recognition-based justice** focuses on the injustices which are related to specific groups who are targeted based on their race, ethnicity, gender, or other identifying factors (Jenkins et al., 2016). For example, targeting native american tribal

communities to give up land in order to produce more energy, or exploiting their people as a workforce without providing appropriate compensation would be a form of recognition-based injustice.

3. **Procedural Justice** focuses on the process of planning, designing, building and operating energy infrastructure. Procedural justice advocates for all communities and community members who may be affected by the infrastructure (Jenkins et al., 2016). If all affected parties do not have a voice in the decision-making process then it would be considered a form of procedural injustice.
4. **Intergenerational justice** focuses on the responsibility that the current generations of humans have to the future generations of humans who do not have a voice (Nguyen, 2020). This form of justice is mainly discussed in terms of processes and decisions which will have long-term impact, for instance, climate change. If we do not do all we can do to mitigate climate change, then we would be perpetuating a form of intergenerational injustice, because we would be causing a problem, and then leaving future generations to find a solution or suffer the consequences for our actions.

In an ideal world, all of these components of energy justice would have already been integrated into the design, development, and scaling of not just energy technologies, but all types of infrastructure. However, this has not happened for several reasons. Firstly, incorporating these principles into scaling practices requires time, effort, and money. In today's economy, speed and affordability are key components of a company's business plan, and oftentimes companies try to get by with putting in the minimum amount of time and effort required to pass through government regulations. Secondly, the government does not mandate the robust meaningful community engagement required to address the various components of EJ. Licensing and permitting processes often only require companies to engage with the landowners of the property the infrastructure will be located on early in the process, and notify the surrounding community once the permitting and siting process has finished. This process does not involve the community enough to be able to understand the community's needs and concerns and then work to address those throughout the process. I will delve deeper into this process in Section 6.

CHAPTER 3

CREATING A CONSTRUCTIVE RELATIONSHIP BETWEEN DAC AND EJ

Many energy technologies and infrastructures have had negative, or oppositional relationships with energy justice (Bosworth & Chua, 2021) (Weller et al., 2022) (Hsu, 2019) (Sankaran et al., 2022). As the technology scaled, communities and justice groups had issues with the technology's design, implementation, or negative externalities. Sometimes companies worked to engage the communities and resolve these issues with a compromise. But oftentimes, these issues were not resolved, or the company did not make a good faith effort to engage the community. Over time, industry grew to view the communities and justice groups as hurdles to overcome, and the communities started to become wary of companies that wanted to scale infrastructure near their land. It is also important to note the counterargument that there have been times when technology companies have engaged a community in good faith, but the community has dealt in bad faith due to false media narratives, politics, or bad prior experiences. However, despite these instances, there are real energy justice issues involved with scaling energy infrastructure which do need to be addressed through the community engagement process.

In this thesis, I will be arguing that companies developing and scaling DAC technology should not make this same mistake. DAC companies should meaningfully engage communities in the scaling and deployment of their technology. This meaningful engagement will serve multiple purposes. Firstly, if the company engages the community in good faith, with the goal of understanding the communities priorities, and needs, it will create a trust between the company and the community. This trust will be mutually beneficial to both parties because it will allow for free, honest, and consistent communication. Secondly, the company will benefit from the community's input throughout the deployment process because they will be able to adjust their plans and strategies to suit the communities preferences (within reason) and provide additional benefits to the community if and where possible. Thirdly, the community will benefit because they will be collaborating with a company who is invested in the community's success. The company will be interested in the community's growth and success because if the technology is integrated with the community's culture, workforce, and well-being, then as the community grows, so will the technology. Lastly, with meaningful engagement and collaboration, the community will be invested in the technology, so they will not slow down the scaling process with lawsuits and protests.

I will also argue that since the purpose of DAC is to mitigate climate impacts by removing CO_2 from the atmosphere, it would be counterproductive to scale DAC in ways that harm, or trouble the communities that least contributed to the problem. Therefore, community engagement should be an integral part of the scaling process for DAC. In fact, we should be scaling DAC in a way that not just limits the harm done to host communities, but actively aims to create positive benefits. As will be demonstrated through this thesis, there are plenty of ways for DAC technology to be deployed in ways that provide benefits to the host community.

However, this attitude will be difficult to instill in companies and parties across the field because it falls into the trap of the collective action problem. This problem occurs when each individual is incentivized to act in a certain way which only benefits themselves, but if enough individuals act in the interest of the collective, then everyone in the collective will benefit to a greater degree than if everyone acted in their own interest (Brechin, 2016). In order to get everyone to act in the interest of the collective, it takes a group with a particular focus on the long term, or a set of regulations. Otherwise, most individuals in a collective action problem end up choosing the option which does not benefit the collective. In this instance, the DAC companies have the option of continuing the status quo of community engagement, which would benefit themselves in the short term because they would be able to scale without putting in the extra effort of meaningfully engaging the community. If DAC companies choose this option, then there is no collective benefit. On the other hand, if all DAC companies choose to meaningfully engage communities prior to, and while scaling their technology, then DAC will develop a positive relationship with communities and this could increase the speed of the scaling of DAC overall as a field. However, since each company is incentivized to prioritize their own convenience, it will be difficult to convince a majority of the companies to act in this way to receive that collective benefit.

Given that it will be challenging to get the field to adopt a set of changes in standard practice, I argue that this is the best time to suggest and implement these changes. As mentioned previously, the field is at an early stage and most companies have not scaled commercial or pilot plants yet. Therefore, any implementation of new standard practices as it relates to community engagement will be much easier to adopt now, as opposed to when bad community engagement practices have already been institutionalized. Many of the other industries did not incorporate these principles into their scaling process from the beginning, and therefore it became much harder for them, as an industry, to unlearn their harmful practices and re-learn ones that promote justice and equity. Profits, habits, technology, and culture all have a part to play in this difficulty. However, in the case of DAC, all of these characteristics are still being formed, so it will be easier for this industry to incorporate meaningful community engagement into the scaling process now, than it will 10 years in the future.

Lastly, there is also clearly a moral argument to be made for the incorporation of meaningful community engagement into the DAC scaling process. As mentioned in 2.1, wealthy nations, communities and people are the groups who have contributed to climate change the most. As often happens, the wealthy groups do not want their areas to include energy infrastructure, and so it falls to the marginalized and underserved communities to host these technologies on their land. An example of this was shown in Memphis, where the Byhalia Connection was proposed. The route for this connection went through, "nearly all-Black neighborhoods on its planned route," and avoided most of the whiter, and wealthier neighborhoods where it could (Macaraeg, 2021.). When asked why the pipeline was going through front and back yards, and near elementary schools in an majority-Black neighborhood, "a supervising agent for the pipeline responded… describing the route as following 'a point of least resistance'," (Macaraeg, 2021.). This company understood that whiter, and wealthier communities would have the time, resources and influence to protest against a pipeline on their land. They also understood that communities of color, and underserved communities would not have these same resources to protest, and therefore building the pipeline through the majority-Black communities would be "the points of least resistance." This is the type of relationship with communities that the DAC industry should not create. DAC companies should not go looking for the points of least resistance to scale. They should instead willingly engage communities that they would like to scale their technologies in, and determine if the project would be a good fit for both the company and the community.

As the groups who contributed least to the problem of climate change, it is only right that we do not force them to bear the burden of hosting technologies which are being built to mitigate a problem which they did not cause. Community engagement needs to be an essential part of scaling DAC technologies to ensure that the communities that are hosting it are, at least, accepting, if not enthusiastic, about it being located there, and are sufficiently compensated.

Therefore, for the multitude of reasons listed, for the benefit of the company and community, meaningful community engagement should be a baseline principle that is incorporated into the DAC scaling process as soon as possible. In the next section, we will narrow the focus of this thesis onto three research questions.

CHAPTER 4

OBJECTIVES AND RESEARCH QUESTIONS

4.1. Objectives:

This thesis has the following objectives: First, to detail the process for scaling a DAC plant. Second, to describe what meaningful and effective community engagement looks like. Attaining these two objectives will show why DAC needs community engagement and where in the scaling process meaningful community engagement can fit. From this information, a standard can be proposed for DAC companies when it comes to community engagement during the scaling process. From this proposed standard will come a set of guidelines and tools outlining how the industry can transition from the current status quo to the proposed standard. The last objective is to describe the potential benefits for the carbon removal industry of applying such a standard..

4.2. Research Questions:

In order to achieve the objectives set above, the following three research questions will be answered:

1. How are DAC companies currently viewing community engagement in their scaling plans?
2. Do the design characteristics of particular DAC technologies affect how the company plans to conduct community engagement?

3. Can incorporating community engagement into the deployment process speed up the scaling of DAC technology?

The first research questions will determine the status quo, that is, where DAC companies currently stand when it comes to community engagement and acknowledging the energy justice responsibilities that DAC has. The second question is important because it will determine if there is a correlation between a certain type of technological characteristic or deployment style and increased or easier community engagement incorporation. If there is, then there can be an argument made that DAC with those specific characteristics could be technology to iterate and innovate on. The third and final research question is important because one of the key goals of DAC is to scale rapidly so that more CO_2 can be removed from the atmosphere sooner, resulting in less climate change harm. If there can be a strong argument made for meaningful community engagement increasing the speed of scaling as opposed to negatively or negligibly affecting it, then there is a high chance that it will be incorporated into the standard scaling process. In order to answer these questions, I had to use two different methods of research. These methods will be explored in section 5.

CHAPTER 5

METHODS

To answer the research questions proposed in 4.2, two main sources of information were used. Literature from the field was used to establish a background understanding of the fields of carbon removal, DAC, EJ, and community engagement. This background in carbon removal and DAC established the purpose of scaling direct air capture, the processes required to scale these technologies, and the various benefits and drawbacks this technology can have on a community scale. The background in EJ and community engagement showed how those principles are treated in the current energy infrastructure scaling practices, and the effect that they have on the technologies, and the communities.

Second, interviews were conducted with representatives from nine separate DAC companies, eight professionals who specialized in carbon removal and or energy justice, and one representative from a local government, for a total of eighteen interviews. The snowball sampling technique was used to recruit participants. I was first connected to several participants through my advisors and other lab members. From there, participants in the interview were able and willing to connect me to other people who they thought would be relevant for me to speak with and interview.

Each interview lasted for approximately one hour, and I was able to ask the participants a variety of questions on different topics, depending on their expertise. The interviews were semi-structured and open-ended so not every participant was asked the same set of questions (Appendix). Often the questions, and even the framing of the same questions would vary depending on the participants answers, and the direction of the conversation. These questions generally focused on understanding the benefits and drawbacks of DAC from a community perspective, the scaling philosophy for DAC companies, the role of community engagement in scaling technology, key design characteristics that might influence a company's view on community engagement, the potential long term impacts of incorporating community engagement into the scaling process, and strategies to encourage broad adoption of these strategies of DAC companies into their scaling process.

When analyzing the interview transcripts, I organized the relevant questions into an excel sheet and indicated the position taken by each participant (who was asked the question, or addressed the topic on their own). From this excel sheet I was able to determine whether an idea had broad support, mixed support, or no support. Additionally, during the discussions around community engagement, I took note not just of what each participant was saying, but also how they were speaking about the topic. I observed how comfortable they were with the subject, whether they brought up community engagement on their own, and how abstract or concretely they were able to speak about their views and experiences.

Through these two sources of information, as well as my own thoughts on the topic, I was able to answer each research question to a different degree, and create a set of guidelines to guide the industry moving forward.

CHAPTER 6

SCALING DIRECT AIR CAPTURE:

6.1. Process for scaling any energy infrastructure in the US

In order to create guidelines for incorporating community engagement into the process of scaling a new infrastructure, I need to first understand the community engagement practices that currently exist when scaling infrastructure. Broadly, the process for scaling infrastructure has various requirements for permits, siting, and impact assessments. These requirements tend to vary between technologies because of their different externalities. For the purpose of demonstrating a general example of the current standards for community engagement in scaling energy infrastructure, I will use natural gas pipelines.

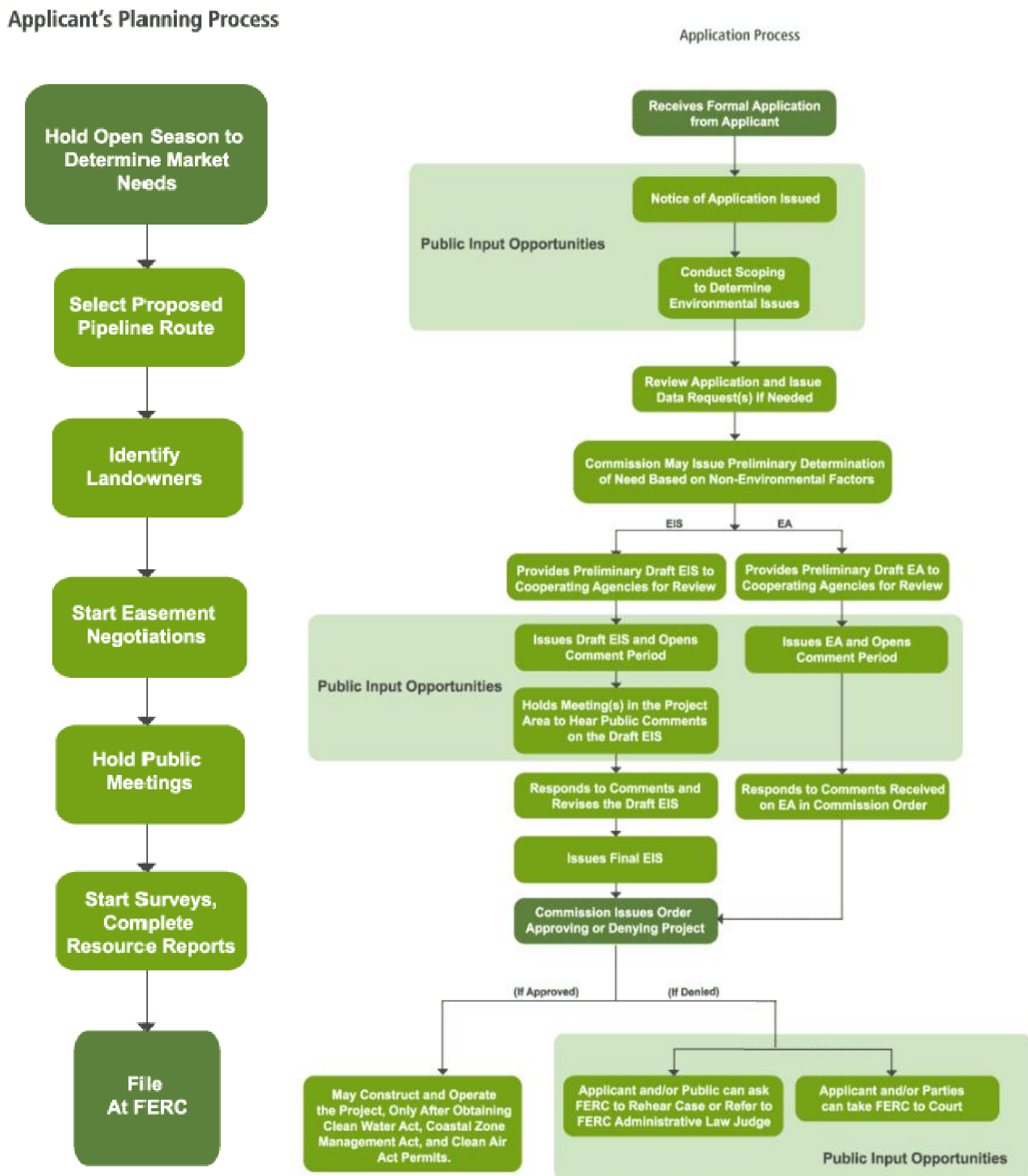

Figure 1: Processes for Natural Gas Certificates (https://www.ferc.gov/industries-data/resources/process)

The flow chart on the left shows the recommended planning process for companies that are trying to apply to the Federal Energy Regulatory Commission (FERC) for permits to build natural gas pipelines (https://www.ferc.gov/industries-data/resources/process, n.d.). The planning process chart shows that applicants should first select a pipeline route, identify the landowners on that route, and start easement negotiations with them. Only after this step does it indicate that the applicant's should hold any public meetings in the nearby communities, or start conducting surveys. In this process, it is clear to see that engaging the public to understand and adapt to their concerns is not a priority because the first engagement occurs after several big decisions, such as determining the pipeline route, are made..

The flowchart on the right shows the FERC application process, which comes after the "File At FERC" step in the planning process. Although the light green "Public Input Opportunities" bubble appears in the second step, this step only requires the company to notify the community. It does not require the company to hear the community's input, or ensure that the community is aware of the potential construction. As long as the company makes the effort to notify the community members, they have fulfilled their responsibility for this step. The second "Public Input Opportunity" is the first time they are required to hold public meetings to hear comments on the draft of the Environmental Impact Statement (EIS). This comes after the pipeline route has been chosen, the landowners have negotiated their settlement, FERC has received the company's application, and the EIS has been drafted.

This process for building natural gas pipelines, which is regulated by the federal government, includes community engagement in the process, but does not actively work to include the community into the decision making process. Instead, the company makes the decisions, and then consults the community afterwards, when it will be a more difficult process to include the community's input. It is this type of process which causes procedural, distributive, and recognition-based justice issues. When scaling DAC technology, it will be important to establish a different approach, one which more seamlessly integrates *meaningful* community engagement into the scaling and decision making process. Before delving into the question of how to do this, I will discuss a few of the important design considerations for DAC technology.

6.2. Design considerations for DAC

For DAC, there are a variety of design considerations which will affect both the scaling process and the host community. These considerations are important to note because they will affect how communities perceive DAC, what types of benefits they can receive, and how the technology can be scaled. The source of energy for powering a DAC plant is a key consideration. This source can be fossil-fuel or clean, isolated or connected to the grid, and modular or large scale (Sandalow et al., 2018). The end use of the captured carbon is also an important consideration. Whether the carbon is sequestered or utilized, whether the end use industry produces local jobs, and how much the end use contributes to climate change mitigation are important questions for the host community when thinking about scaling DAC. Additionally, the land, and water requirements will be important considerations because the DAC facility will likely be sharing the land and water resources with the local community (Sandalow et al., 2018). Lastly, the modularity of the DAC plant will also be a key consideration. This characteristic is important because it will be a key component in determining the flexibility of the company's deployment plan (Sandalow et al., 2018). Designs which are more modular will be able to quickly and incrementally add or remove units to the facility depending on theirs and the communities available resources and preferences (Dahlgren et al., 2013). Companies which have designed their DAC technology as a large scale plant will be less flexible over time in adjusting to changing circumstances.

All of these considerations will affect how a DAC company plans to deploy their technology, and how communities will perceive that technology. These characteristics are important to understand, because different communities will have different design characteristic preferences. Determining which communities prefer which characteristics could be a strategy to increase the speed of scaling.

6.3. Potential Positive and Negative Externalities of DAC

During the interview, one question which I asked nearly all of my participants was about what they thought the positive and negative externalities of DAC technology were from a community perspective. I wanted to understand what benefits they thought DAC could bring to a community, and what drawbacks they thought communities would be most wary of. When asked about benefits, most of the participants cited the same three things: local job creation & job training, attracting new industries, and opportunities for co-ownership. Job creation as a key benefit to scaling DAC facilities in communities was far and away the most common response, with one DAC company representative stating that DAC could provide, "a few economic benefits to the local population, [such as] the range of education training jobs, high skilled jobs, high paying jobs, and other activities." A few participants also pointed out that while job creation was often cited as a benefit to scaling DAC, the exact number of jobs that the industry would create in the short and long term were unclear since the field is still quite nascent. One benefit which was not disputed was the fact that scaling DAC facilities could attract other CO2 utilization industries (if the CO2 was not sequestered). The same participant stated that, “when you have these large [carbon capture facilities], you can expect that there will be other industries that will follow." Many of the other participants also made similar statements, citing value-add products and offtake agreements.

When asked about the potential negative externalities of DAC, the participants' responses were much less aligned. The most common responses referenced inconveniences during the construction process such as traffic and noise pollution, and the amount of land required by DAC. When speaking about the land requirements, participants specifically mentioned that a DAC facility itself would not need to take up much space, but any renewable power source would require a significant amount of land. A DAC company representative explained the issue, saying, “there's always a drawback when you're installing any new technology, because [the land] might be used for something else. It might be used to create a factory, it might be used to create a solar farm, which might be better on face value, it might create an income opportunity for these community members.” After these two issues, participants also listed energy requirements, water requirements, housing issues for local workers, and potential nervousness around carbon sequestration as other negative externalities.

Aside from these externalities that are a result of the physical presence of a DAC facility in a community, several participants referred to the moral hazard issue that DAC causes. This issue stems from the fact that many of the current efforts to mitigate climate change are rooted in decarbonization (Minx et al., 2018). As DAC scales and removes more emission from the atmosphere, there is a fear that this might result in many companies and governments using carbon removal as a crutch in order to continue emitting greenhouse gases and slow down the decarbonization process. While many in the DAC industry claim that DAC, and other carbon removal technologies should be used *in addition* to the existing portfolio of decarbonization technologies, it has also become clear that many in the fossil fuel industry are looking to use DAC in order to extend the lifetime of their own industry, as shown by Occidental Petroleum's partnership with Carbon Engineering (Bergman & Rinberg, 2021) (Lust, 2022). This moral hazard issue is an important externality to keep track of , because it will play a role in determining who the industry is supported by, and how much it contributes to climate change mitigation.

It will be important for DAC companies to understand how the various design choices they have made will affect the communities that they scale their technology in. They should also understand what benefits they can offer to the communities and what drawbacks they should be trying to minimize. Additionally, through the engagement process companies should be trying to understand how the communities are viewing these same design characteristics, what benefits they would like, and what drawbacks the communities would like to see minimized. If the company can understand these preferences from the community's perspective, then they can have a collaborative scaling process, and also increase the likelihood that the community is invested in the success of the DAC facility. However, in order to have this relationship, DAC companies will have to use an engagement approach that involves communities in a meaningful way, as opposed to one which is done to overcome an obstacle. In the next section, we will define what meaningful community engagement looks like, and how it addresses the energy justice issues caused by scaling energy infrastructure.

CHAPTER 7

DEFINING MEANINGFUL COMMUNITY ENGAGEMENT:

7.1. What is meaningful community engagement?

In order to make the community engagement process meaningful, there are a number of criteria that need to be met. By doing a literature survey of over 80 journal papers, Luyet et al identified a minimum of five key principles for "successful participation." Firstly, it is highly important to have experienced moderators present at the engagement events (Luyet et al., 2012). Even if all of the other criteria are met, if the engagement is not conducted properly, then it won't be nearly as valuable.

Second, the engagement should start early in the scaling process (Luyet et al., 2012). In the natural gas pipeline example given in 6.1, the first sign of engagement is only after the pipeline route has been chosen, and the easement negotiations have begun. Engaging communities earlier in the process, prior to even concretely deciding if a facility will be located in the community, will allow the community to have a greater voice in the early stage decisions like size and location of the facility. Having this influence will also allow the community to feel a greater sense of ownership over the project (Jami & Walsh, 2017). Early engagement activities can also be beneficial for the DAC company because they will be able to easily learn local knowledge from the community which might help them make better informed decisions earlier in the process (instead of having to make the difficult decision to change course at a later stage).

Third, all of the stakeholders in the community should be engaged (Luyet et al., 2012). This means that the company may have to put in additional effort to reach those stakeholders in the community who are not as engaged, have less time to attend engagement activities, or are more wary of participating in engagement activities. Engaging all the stakeholders groups in the community is important because oftentimes the groups that are harder to reach are the ones who are the marginalized and underserved groups in the community. They will often have a different perspective, and set of concerns from those groups who are easiest to engage.

Fourth, adequate resources are required to effectively conduct meaningful community engagement (Luyet et al., 2012). This fourth point further emphasizes the third criteria because without adequate resources, it becomes very difficult to engage the groups in the community which are the hardest to reach. Companies will need enough time, money, and people to conduct meaningful community engagement.

Lastly, Luyet et al states that a "fair, equal, and transparent process," is required in order to "promote equity, learning, trust, and respect," between the community and the company. This last point is important because if the process to engage with the community is not fair and transparent then regardless of the company's intentions, the community will have a level of wariness and distance. This set of criteria established is part of a conceptual framework, but can be the foundation of a more practical framework if used and refined.

If put into practice properly, this definition of meaningful community engagement could ensure that the various components of energy justice (aside from intergenerational justice which is indirectly addressed through furthering climate change mitigation goals) are directly addressed. Procedural justice is addressed by engaging the community early, and making sure that their voices are heard and their concerns are addressed throughout the scaling process. Distributive justice is addressed by ensuring that the community is satisfied with the compensation that they are receiving for the burdens that they will face in hosting the DAC technology. Lastly, recognition-based justice is addressed by making sure that all the stakeholders (of all races, ethnicities, and backgrounds) in the community are consulted and included in the engagement process, and a single or select few groups are not targeted to bear the brunt of the burden.

When I asked the participants what meaningful community engagement looked like, I heard many of the same criteria as the definition above, along with a few other criteria which were tangentially addressed by Luyet et al, but described more in detail by the participants. Several of the participants, including both DAC company representatives and EJ experts, listed two-way communication as a key criteria for meaningful community engagement. One participant described its significance, “it's really important to meet communities where they're at, with the knowledge that they do have, because they're experts and their lived experience." Several participants also mentioned the community’s lived experience and local knowledge as big reasons for why companies should be interested in meaningful two-way communication. This two-way communication is hinted at in the fifth criteria defined by Luyet et al, when they mention promoting learning between community and company.

Other additional criteria I heard mentioned frequently were sustained and iterative engagement. One participant emphasized that companies needed to engage the community often, and then,” continually iterate based on what they have to say.” Practicing sustained and iterative engagement is something else that is reliant on having adequate time and resources, because if a company does not have time and resources, then it will not be able to conduct an extended period of community engagement or iterating on the feedback.

Lastly, two participants mentioned accessibility, with one saying that it is important, “that there is a structure in place that not only has the project developers leading– but also brings the community into leadership roles and compensates them for their time, providing childcare, and different language and accessibility things such as allowing a sign language speaker." Both of these participants who brought up accommodations like child care and sign language speakers were EJ experts, while none of the DAC company representatives mentioned these points. This last point is extremely important for the criteria of integrating all of the stakeholder groups in the community. It is likely that there will be times where a company has to offer specific services in order to engage a group of people who have kids and cannot pay for childcare, or do not have transportation to come to the engagement activity. Child care is also just one example. There will be groups in communities which will need some particular compensation in order to attend and participate in engagement activities. In these situations, it is the responsibility of the group conducting the engagement to ensure that those circumstances are met, at least a few times if not consistently. Based on the interviews that I conducted, two-way communication, and sustained, iterative, and accessible community engagement are all essential criteria for the engagement to be meaningful.

The criteria established by Luyet et al, along with the additional criteria from the participants should be the standard for community engagement for the DAC industry. Most of the participants who were asked to define meaningful community engagement listed at least several of the factors listed in this section. Therefore, it is fairly evident that setting community engagement based on the previously discussed criteria should be an appropriately high standard to scale DAC facilities with equity and justice as core principles.

7.2. What are the major questions remaining around community engagement?

However, even though meaningful community engagement is fairly well defined through the literature, and directly by the interview participants, several interview participants acknowledged that the question of “who” should be doing the community engagement in order to be most effective was still ambiguous. One participant directly stated, “the bigger question is not what [community engagement] should look like, I feel like that's pretty well established, but who should be doing it? And that's something that the community of research and practice is having challenges with.”

Till this point in the thesis, the operating assumption has been that the DAC companies would be the ones engaging the communities that they would like to scale their technology in. This makes sense because if the company is the one that is interested in scaling their technology, then they should be the ones to put in the work to engage the community. However, there are few valid reasons why DAC companies might not be the best ones to conduct the engagement. Firstly, if a DAC company engages a community, there is a chance that the community will become immediately wary of a company providing biased information in order to scale their technology quickly instead of engaging them in good faith. Secondly, the company could be biased, even implicitly, when engaging a community with the purpose of scaling their technology. And lastly, the company could have a lack of resources or lack of experience when trying to conduct meaningful engagement, leading the engagement activities to be less effective. Would the field be better served by other organizations such as NGOs, local governments, or academic institutions conducting this engagement instead?

When I posed this question in my interviews, I received a variety of answers. The most straightforward answer I received was, “I think it has to be a collaborative effort across the board.” Another participant agreed, but took it a step further saying, “Everyone needs to be involved. As for who actually serves as kind of a central convener-- that depends on the [community’s preference].” One of the EJ experts said that their preferred model would be to have, “a company develop a partnership with some local NGOs and local municipalities and then dedicate funds for them to design and do the engagement.” However, after a brief pause, they continued, “even though that would be a nice model, it's not a particularly realistic one," because there would be very few companies willing to take on the risk of funding a community engagement process, only to have the community respond negatively.

Only one DAC company representative had a concrete answer for this question, responding, “So the model that we've looked at is: Let's say, you assume that you have a community that's interested, and it works based on your engineering needs. Then for our plan, we're gonna hire somebody locally in that community, who is knowledgeable and respected and can do/ lead a lot of that work on the ground.” This company determined that the most effective way to conduct meaningful community engagement was to hire someone from within the community itself. The drawback here is that any company following this plan will have to hire a different local resident for each community that they are scaling in. For an earlier stage start-up this plan could be quite costly. However, the benefit of this plan would be that local community engagement leads would already know each of the important groups in the community and how to reach them. Additionally, most people in the community would already be comfortable around them, and therefore the engagement process could happen at a quicker pace compared to an outsider who would have to come in and learn and understand the community first.

There does not seem to be a consensus on the best actor to lead the community engagement process for DAC yet. However, as the field continues to scale and grow, more engagement strategies will be tried by a variety of actors, and this process will become more standardized. If the actors doing the engagement are able to follow the standards established in 7.1, then it is possible for the standardized method to also be a very effective one. Now that a theoretical standard for meaningful community engagement has been established, it is important to understand how the companies in the field are thinking about community engagement.

CHAPTER 8

FINDINGS

8.1. How are DAC companies thinking about community engagement?

I interviewed nine DAC companies about their thoughts on community engagement. To parse their responses while maintaining a level of anonymity, the companies were separated into four groups. To create these groupings I considered what the company representative said, how thoughtfully they spoke about community engagement, and what engagement the company has done.

The companies in Group A indicated that community engagement and energy justice principles have a high value, but do not think that the field of DAC should be doing anything beyond the current status quo as far as community engagement. Their preferred approach is to push energy justice progress as an entire larger movement, instead of trying to lead the progress with one field (namely DAC in this case). I have placed one company in Group A. This company did not want to be quoted.

The companies in Group B indicated that DAC should be doing more community engagement than the current status quo requires. However, since they are at such an early stage, these companies have not thought about their community engagement plan a lot and therefore were not able to expand on any potential community engagement plans. I have placed two companies in Group B. A representative from one of these companies said, “we have to first demonstrate what [scaling DAC] looks like, what type of scale it can achieve, what are the economic impacts, and what are the job opportunities that it drives and so on. But once we've gone through that phase, I would expect that it won't be us going out actively trying to find sites that will support us [but rather] a two way street of people and communications who believe they have the right infrastructure or conditions available, looking to have these types of activities within their communities."

The companies in Group C have already done some community engagement, or are planning on doing some in the near future. These companies have thought a considerable amount about how to incorporate community engagement into their process, but either have not been able to implement much of their plan yet, or were not willing to discuss the intricacies of their plan during the interview. I have also placed two companies in Group C. A representative from one of these companies said, "So rather than conducting community engagement before we start selling our technology to communities– we intend to sell our technology to communities, and that will be the cornerstone of our, of our community engagement." The same representative later expanded on this point saying that exposing the target communities to their modular DAC technology was their initial plan for the engagement. Once the community had been exposed, they could then conduct focus groups and other engagement activities to receive feedback. The representative from the other company said, "we haven't had a ton of conversations with communities. And I'm not going to share specifically conversations we've had." However, they also acknowledged that, "it's impossible to define what those benefits and risks are properly without understanding the community's perspective, " and "if you're not engaged in the community, there's a good chance that your project will fail." From these comments it is clear that both of these companies understand the significant role that community engagement does and should play in the scaling of technology, but neither of them were able to demonstrate examples of conducting meaningful engagement in the past, or plans to do it moving forward.

The companies in the final group, Group D, have done, or are planning in the near future to do the “meaningful” community engagement discussed in 7.1. They have or are planning to engage communities prior to the start of scaling commercial DAC plants, and are invested in creating a two-way communication between themselves and the community. I have placed four companies in Group D. One of the representatives from these companies stated, “it is it is quite literally the centerpiece of how we run the business,” before expanding on topic, “in each of those [target] markets, we're spending a lot of time talking to stakeholders that can really inform and transform not just like the deployment and the siting of the direct air capture plant, but also just how we think about being a neighbor in that community.” While the companies in Groups B and C seemed to understand the importance of community engagement, none of them were able to verbalize their commitment to it like this. Another DAC company representative in this group said, “We have weekly or bi weekly meetings on this, about how we can make sure that the community aspect of our machine is taken into consideration by our engineering and design team. When you talk to the community members who are going to be most impacted by technology, they usually come up with brilliant solutions.” They went on to describe an energy management problem that the community helped solve by recommending a load management strategy. This anecdote showed the experience this company had with collaborating with the host community to find solutions.

Six out of the nine companies that were interviewed were placed in Groups C or D which means, at minimum, that they showed that they have thought a considerable amount about how to engage communities meaningfully when scaling their technology.

8.2. Does a company's DAC design heavily impact its view of community engagement?

My hypothesis is that modular DAC designs naturally lend themselves more to increased community engagement because of their flexibility, which has been referenced as a strength of modular DAC by several interview participants. The increased flexibility will allow these companies to scale at a more incremental place if necessary compared to a non-modular large scale facility which is an all or nothing proposition for the communities. The modularity will allow for communities to host one or a few modules to understand how the DAC plant works in practice, before deciding whether or not to scale up to a larger capacity plant. Additionally, the requirements for the DAC plant will also be more flexible and adaptable based on the resources (land, electricity, water) available in the community. A larger capacity plant would not have the ability to increase capacity as the resources in the host community increased (or scale down if necessary, if resources decrease). Lastly, the modularity of the DAC design will allow for greater variations in size, and distribution of the facility (Dahlgren et al., 2013). Depending on the design, the company (and community) could have the option of locating all of the modules in one location, spreading them out across a larger area, or even integrating them within the existing community infrastructure.

However, my hypothesis is not supported by the findings from section 8.1. While there are several modular DAC companies in Groups C and D, there are also modular

DAC companies that are in Groups A and B. Similarly, while there are some non-modular DAC companies in Groups A and B, there are also non-modular DAC companies in Groups C and D.

Additionally, during my interviews, I was able to ask the representatives from modular DAC companies, as well as EJ experts whether they thought that the characteristics of technology could affect a company's approach to community engagement. The EJ experts weren't sure, but they tended to lean towards the technology not playing too big of a role, with one EJ expert saying, "that feels hard for me to say, but no." The representatives from DAC companies however seemed fairly firm that it was not the technology, but rather their leadership and company values that set a focus on incorporating meaningful community engagement methods. One participant even went so far as to say that, "Yes, [our community engagement focus is] certainly founder driven, but I'd say it's much bigger than the founder, because what you need is your product engineers, your warehouse designer, that's working in an r&d facility, mission aligned. I think part of being mission aligned is not just like, 'oh, the climate is warming,' but actually getting people who are motivated to do things right, and do things well. That's the type of hiring that we do." This representative credited the founders for setting the values, but also claimed that they aim to grow this culture by hiring people who also have the same EJ values and priorities.

Although neither of these factors supports my initial hypothesis, neither of them disprove it either. First, while nine companies is not an irrelevant sample size, there are still a dozen or so companies which I have not spoken to which could have different views on engagement. Second, and more importantly, most of these companies are very early stage and there is still a chance that as these companies grow and start deploying commercial fleets, the more modular DAC companies will be able to exercise their flexibility, and the non-modular companies will start to find their options narrowing, leading to less robust engagement tactics (or a shift in technology to a modular design).

However, based on the participant responses to this question, it is clear that one of the most significant factors in determining the robustness of a company's community engagement plan is the intentionality of their leadership group. At least during the early stages of DAC design and pilot-testing, these interviews have shown that any DAC company, regardless of technological characteristics, can create and conduct a meaningful community engagement strategy. Additionally, if the leadership group maintains this value as the company grows and hires more employees, then this value will spread through the company, as shown by the previous quote at the top of page 43. However, despite the majority of the companies that were interviewed expressing support for integrating meaningful community engagement into the scaling process, I have heard arguments through my interviews, as well as other conversations, for why the DAC industry should not try to push the boundaries of the current energy justice status quo while scaling.

8.3 Common Arguments and Responses

These arguments have come from representatives of DAC companies, DAC subject-matter experts, and influential voices in the industry. I will present their arguments and then provide my counterarguments explaining why DAC should still use meaningful community engagement. These arguments are important to discuss because if they go unaddressed then they can cause confusion where there shouldn't be, or make an unresolved issue look conclusive.

8.3.1.

Argument 1: Since DAC does not have many negative externalities, companies should focus on informing communities about DAC from an educational perspective, as opposed to engaging in higher degrees of community engagement.

Response: I will first reject the premise that DAC does not have many negative externalities. As one of the EJ experts said, “"I don't think that there are no potential negative externalities or impacts, I think there's lots of possible impacts, the risks around air quality, traffic, others.. there's lots of potential harms.” And without scaling the technology first, there is no way to be certain that there are no significant negative externalities. With this doubt in mind, it follows that community engagement is necessary because there is a chance that the community could raise issues that the company might not have thought of. Secondly, as one of my participants said, there are several factors that are required for DAC technologies to scale which can potentially be negative externalities, “totally depending on the technology and the implementation.” For example, DAC requires high amounts of energy, and if the DAC plant takes the energy from the electricity grid, then the nearby communities might have a lack of energy. Similarly, some DAC technologies require large quantities of water, which, if drawn from nearby water sources, could put an undue burden on the nearby communities. If the standard is set that DAC does not need to engage in meaningful community engagement then companies, regardless of their technology or implementation method, will not see the need to conduct community engagement. Thirdly, given the sheer scale the DAC is attempting to reach (gigatonnes of removal per year), even the smallest negative externalities will be amplified by the size of the industry. Lastly, even when DAC is still a small industry, it can benefit from community engagement. If DAC companies can use meaningful community engagement throughout the early stages of scaling the technology, then the industry can develop a reputation for being accommodating to communities. Moreover, if the technology succeeds and communities are able to benefit from its success, then DAC will become a technology which communities want to have near them. This type of reputation will only help the field scale quicker, which will benefit all companies.

8.3.2.

Argument 2: Community engagement is not feasible because it will be a drain on the company's resources (time, money, human).

Response: I argue that a company's benefit from conducting meaningful community engagement will outweigh the negative effects of the drained resources. From the perspective of time, many of the interview candidates have denied the statement that incorporating community engagement into the scaling process will lengthen the time it takes to scale a DAC plant. One of the representatives from a DAC company in Group D said, "it's happening in parallel, the whole time. So it's not, it's not actually adding [time], in fact, it's probably actually saving us time, in the long run." And while community engagement does have some financial requirements, the company will have the opportunity to save money in the long run through saving on lawyers from avoiding litigation, and by utilizing the local knowledge of the land to their advantage (Jenkins et al., 2016). Additionally, having a good reputation with the community will also help the

DAC company in the long run if they plan on expanding the size of the existing DAC plant by already having created a bond of trust with the community. Additionally, the same representative said, “I could see how it could be a drain on resources, if you're not planning for it in the first place. But I think that companies should be planning-- any developers should be planning for that in the first place.” They are arguing that the company should not think about community engagement as a drain on their resources because they should have budgeted for that from the beginning with each round funding, and each accepted grant.

8.3.3.

Argument 3: Energy justice organizations are influencing communities to deal in bad faith with DAC companies by not seriously considering the technology.

Response: It is true that there are several energy justice organizations which have decided to oppose DAC as a concept because of the moral hazard issue discussed earlier. They do not want to support any technologies which could possibly increase the lifetime of fossil fuel technologies. As DAC has the potential to increase the lifetime of fossil fuel technologies by offsetting fossil fuel emissions and making them carbon-neutral, these energy justice organizations do not want DAC to scale at any cost. Additionally, these organizations sometimes have some influence on communities and can sway them to not want to even engage with DAC companies. I argue that the best step forward for both the DAC company and the field overall is to not force the issue. If the DAC company is seen forcing the issue of scaling a DAC plant in a community that does not want it (for whatever reason) then no matter the circumstance, the likelihood is that the company (and potentially industry) will get portrayed in a negative light. On the other hand, if the DAC company is able to scale in another community which is willing to engage with the company in good faith, then this will firstly allow for a greater chance for success, and secondly portray the company in a positive light. Then, if the project has succeeded, the DAC company will be able to point to this development as an example of success, which might more successfully persuade skeptical communities than preliminary sketches or design plans. It is important to note here that it is the community's perspective that matters here, not the view of the energy justice organization, and regardless of how the community responds, and what motivation they might have, it is in the best interest of the field to respect their values. A representative from another DAC company from Group D said, “there's a chance that communities might not want to engage, so being prepared for that to be a possible outcome [is important].“ They are arguing that DAC companies should understand that this is a realistic possibility when going in to engage a community, and therefore should not necessarily be surprised, while still doing all they can to facilitate a productive conversation. Additionally, DAC companies can proactively also attempt to engage with energy justice organizations to try and create a more productive and mutually beneficial relationship. I will also argue here that the more modular technologies, which have the ability to operate at any scale, can be more successful in engaging skeptical communities because they do not always have to scale megaton or kiloton capacity. They can scale at an extremely small scale in these skeptical communities to provide examples of success within the community itself.

8.3.4.

Argument 4: DAC, as an industry, should not follow different community engagement and energy justice guidelines than other energy and climate change industries because that could be harmful to the progress of energy justice values. We should be working on pushing energy justice and community engagement values forward in all fields simultaneously instead of using DAC as a leader.

Response: It would not harm energy justice principles to be pushed forward by the field of DAC. In a regulatory form I would agree that it would be unfair for the field of DAC to be treated differently than other fields, because it would firstly set a bad precedent that all fields do not have to follow the same basic practices of community engagement. But, if companies, organizations, partnerships, or coalitions decided to change the way that DAC is scaled and it proved to be a more successful method than just following the regulations then it would firstly help other industries follow similar guidelines to DAC, and secondly it would also help get regulations passed through government in an easier fashion. Additionally, one of the EJ experts offered a strong rebuttal to this statement, arguing, “We're creating a really large industry and I think that we have a responsibility to apply the new ways that we're looking at the world and society right now, with a big eye to justice as, like those need to be built in.” This argument falls in line with the stance that I have been advocating for throughout this thesis, which is that DAC, as a new industry, has the opportunity to try a new scaling process which incorporates energy justice. This participant however, argues that this is not just an opportunity for the DAC industry, but a responsibility.

I would also contend that Argument 4 creates a false dichotomy. There is no reason why energy justice principles and policies cannot be advanced through legislation while the field of DAC establishes an appropriately high standard for itself. In fact, if both happened simultaneously, then it is possible that they might even be able to increase the speed of progress in both areas.

8.3.5.

Argument 5: We can not treat DAC as a completely new industry because it has parts of many industries which are already highly regulated.

Response: It is true that the current design of many large capacity DAC plants uses many parts of existing industries. However, it is very possible that the DAC devices which are used in the future will not look like this. For example, one of the first cars that was designed to look like an engine pulling a carriage (imagine an engine in the place of a horse in a horse drawn carriage). It was designed like this because that was the standard design for small capacity transportation. However, through innovation and practice, the modern internal combustion engine vehicle looks much different. This example can be used to show that DAC plants have a reasonable, if not high chance, of looking much different in fifty years than they do now. Additionally, strictly thinking about DAC as a technology composed of parts of other technologies creates artificial boundaries when thinking about how to improve and innovate the technology.

Secondly, as mentioned previously, DAC technology, and more broadly the field of carbon removal was established to mitigate the harms caused by climate change by removing the CO_2 from the atmosphere. These new technologies lead to new ways of thinking about climate change mitigation, so DAC is not just a technology which is composed of parts of other existing technologies, it is also helping create a new way of thinking about the challenges that we face and how to solve them. I argue that it is not incorrect to think about treating this as a completely new industry, because it has created a new way of conceptualizing the problem of climate change. Therefore, I also do not think that it is a mistake to start thinking about new ways to scale the technology more equitably.

8.3.6

All of the arguments presented take the perspective that meaningful and effective community engagement can slow down, undermine, or be too costly to incorporate into the scaling process for DAC plants. On the contrary, I will argue that there are actually several arguments to be made that incorporating meaningful and effective community engagement into the scaling process can actually increase the speed of scaling up DAC plants. This additional benefit of community engagement would be important because the more rapid scaling of DAC plants will result in a lower atmospheric CO_2 concentration peak, and less severe impacts of climate change.

8.4. Can Effective Community Engagement Increase the Speed of Scaling DAC?

We have already shown that, according to experts, community engagement, if done meaningfully and properly, will not slow down the DAC scaling process. I am arguing that it could actually increase the scaling of DAC in the medium to long term.

If DAC companies conduct good faith community engagement with communities early in the process, in an accessible way, and iterate on the community's feedback, then the communities hosting the DAC plant will be actively engaged and interested in the scaling and success of the DAC plant. Through this collaboration they will also receive a set of benefits which they negotiated and therefore will appreciate. This collaborative process will result in the success of the DAC plant, and the growth of the community being tied together, and therefore the company and the community will be working in collaboration to ensure the success of both. If this positive relationship occurs repeatedly across multiple communities and is facilitated by a majority of the companies, then DAC will develop a positive reputation. Companies will be able to point to past successes when attempting to scale new plants, and potential host communities will want, or show enthusiasm about DAC plants scaling near their land because they will be able to see the growth of other communities as the DAC plants develop. Over time, if DAC develops that positive reputation of succeeding along with the surrounding community, then more communities will start to proactively put forward plans for scaling DAC, and welcome companies with a positive track record instead of immediately feeling threatened. When I shared this line of reasoning with my participants, I was given a resounding positive response from almost all of them. One participant said, "I agree with everything that you said [referring to the reasoning above]. I think it's sound logic." Another participant who also agreed expanded on my point, saying, ""If communities are working together with developers very early on, then I think that that sets a good precedent for DAC that can kind of help its reputation on the large scale in order to help it scale up. If more people can point to this specific example of how a community and a DAC developer work together to create what that community believes is a successful model, then that's likely to also happen in a neighboring community." While this vision may seem idealistic, it is not one that is wholly unachievable, with one caveat.

In order for DAC to develop a positive reputation, all or most of the field must participate in some form of this meaningful and effective community engagement. This issue falls into the collective action problem discussed in Section 3. That is, each individual (at least in the short term), is incentivized to put in less work, and less resources to maintain the status quo with community engagement, and do the bare minimum in order to scale their technology. This would involve going through the normal permitting, notification, and impact assessment process, without actually engaging the community early, hearing their concerns, and working to address them. However, this individualistic choice would result in a small resource gain for the company in the short term, maintaining the status quo, and DAC being treated similar to other existing energy infrastructures, with the added complication of the moral hazard issue. However, if all or most companies acted in the interest of the “collective” by conducting meaningful and effective community engagement prior to any significant scaling endeavor, then DAC could develop the positive reputation mentioned in the previous paragraph, leading to an increase in enthusiasm around DAC, and an increase in the speed of scaling. This positive feedback loop would take a significant amount of time to create, but I do believe that it will have a compounding effect as time goes on. But as mentioned previously, in order to have the chance of occurring, it would need a large number of DAC companies to participate in this effort.

During my interviews, I asked several of my participants what they thought would be required in order for all or most of the field to adopt the stance of incorporating meaningful community engagement into their scaling plans. Many of the participants I asked mentioned government intervention being the primary or most likely method by which this could happen. As an overall representation of the responses, one of the participants said, “as somebody who wants to see a change in the industry, I would say the government has to enforce this... Whatever technology is out there that the government is buying credits from, they should only buy the credits from them if they can verify that the community engagement aspect is as true as what the company's saying it to be." I agree with the participants that the most likely course of action to affect the entire field would be government action. However, going back to Argument 4 in the previous section, I argued that government regulation for community engagement solely focused on the industry of DAC would be unfair. Additionally, one of the base premises for this thesis is that the field of DAC cannot wait for an appropriately high energy justice standard to pass through Congress to start conducting meaningful and effective community engagement. Therefore, despite the recommendation of the interview participants, I am arguing that the field needs to look beyond government for a solution to effectively incorporate community engagement into the scaling process. The organizations that makeup the DAC industry need to understand the long term issue of climate change in more than an academic sense, and determine the long term goals in order to guide their near term actions. Additionally, there are tools which can be built and used by the DAC industry to intelligently incentivize and simplify the community engagement integration process.

8.5. Tools for Incorporating Community Engagement into the DAC Scaling Process:

8.5.1. Anticipatory Engagement:

The first tool I want to discuss is anticipatory engagement. I am defining anticipatory engagement as community engagement that is done in an area prior to any concrete projects, or even proposals that have expressed an interest in scaling that area. This type of engagement is usually conducted by a third-party like an NGO, academic institution or consulting firm. There are several benefits to anticipatory engagement. Firstly, the community has the opportunity to develop an understanding of the general technology as well as its benefits and drawbacks. Secondly, the community will get to provide its feedback prior to being engaged by a company, so the implicit bias provided by the engager will likely be much lower. Additionally, the community will not have the pressure of trying to determine whether they do or do not want to participate in a particular project with bounds set by a company. Instead, they will have the ability to legitimately consider what is best for their community in a void and then act based on that information. From the community perspective, anticipatory engagement can be somewhat dangerous because there is no company backing the engagement. This means that even if the community decides that they do want to host a DAC plant on their land, there is not necessarily going to be an immediate avenue available to pursue that goal.

In my opinion, there is a gap here for an organization, or a set of organizations, to conduct anticipatory engagement in interested communities across the US. These engagements can range from learning whether communities are interested in scaling any climate technology, to creating a plan or set of guidelines which outline the characteristics of DAC technology that a community is looking for. It can also include the benefits they would like to receive, and the drawbacks they would like to avoid. If a wide variety of communities were engaged, and put forward guidelines, then it is likely that there would be a variety of preferences in characteristics (scale, capacity, distribution, end use, energy source, etc…). Based on these plans, DAC companies would be able to find communities which would be interested in hosting their particular technology. This model provides several benefits. Firstly, the communities will have their voice heard, and get to create a base plan without any company intervention. Secondly, the companies do not have to spend as many of their resources starting engagement and determining the baseline characteristics of the community. Thirdly, when the company approaches the community, the relationship starts from a position of mutual interest and understanding. I argue that this would also result in more rapid scaling and a higher success rate from both the community and company's side.

When I pitched this idea to several of my participants, I received a broadly positive response for the idea from DAC companies as well as social science experts. One DAC company representative went as far as to call it, "a beautiful idea." However, several of those same participants also did voice some concerns that they had about its implementation. One participant asked, "who is going to pay for it," while another mentioned that they, "just don't know how to do what [I] said, unless we get multi-sector buy into that idea, because it can't just be the corporate sector advancing it." Lastly, one of the EJ experts pointed out, "the challenges of working in the abstract mode and convincing people it's worth their time to talk about things in the abstract." So while anticipatory engagement is a nice concept, putting it into practice will require more research and significant problem solving.

8.5.2. Community/ Co-ownership Models:

Another set of tools that I recommend the industry explore are community ownership and co-ownership models. Community ownership models are instances where the community, or a portion of it, owns the DAC plant. This would result in the community owning the captured CO_2 that the DAC plant produces and getting to decide how to dispose of the captured CO_2. Co-ownership models would result in the community and company each owning parts of the DAC plant. This shared ownership would be a more collaborative relationship between company and community. Both of these models are beneficial for promoting meaningful and effective community engagement because both of these result in the community having a financial stake in the DAC plant. Firstly, this means that the community will inherently need to understand the technology and its benefits and drawbacks before agreeing to have a financial stake in the plant. Secondly, this means that both company and community have an interest in both the DAC plant and the community growing together. I argue that if there is a scenario in which both the company and the community are working towards the same goal, it will lead to a more productive relationship than a scenario in which their interests are either unrelated or in direct opposition to each other.

I asked my participants about their thoughts on the co-ownership and community ownership models and while many of them were enthusiastic about the idea, none could concretely describe how this would look in practice. This is because, as one participant explained, “we're still very much in the kind of proof of concept stage. So it seems unreasonable to ask a community or the public to take that kind of risk based on the landscape right now." However, when asked to envision DAC technology ten to twenty years in the future, several participants bring up the concept of community ownership. One of the participants described his dream scenario as, “a group of people in a community, buying our technology, and setting it up on their own land powering it with their own solar panels that they have bought. [With this] they create a source of income for themselves which empowers these people.” Another participant who works for a modular DAC company mentioned that he, “imagines a sort of carbon value chain that includes manufacturing units, installing panels, operating the system, the end use, and then the business consequences of having readily available [carbon dioxide] at reasonable prices, it can keep all of the value generated by that system within a certain community"

One of the EJ experts that I interviewed took this concept a step further. Instead of just scaling a DAC plan through community or co-ownership, she wanted to expand this idea to the entire local economy.

8.5.3. Scaling DAC by creating partnerships to scale the entire local economy:

This participant said, “If you just engage on the particulars of a technology or a project, you're missing the conversation about why we need this. The conversation needs to be a lot broader. It has to be about what this energy system looks like in 50 years.” They are arguing for not just thinking about DAC, but about scaling energy systems as a whole in a community. They continue, “for that, you need to be able to talk about the power sector, and also transport options and industrial decarbonization, and all of these different things that you're not going to have the right people there to talk about those systems if you're just focusing on one technology or this project. So it really does need to be part of broader energy, decarbonization roadmapping.” They ended the explanation by stating that this conversation becomes about energy planning, in which DAC is a smaller part. These larger scale planning and roadmapping processes can transform a community much more than a single DAC plant because there is just a lot more flexibility and weight behind the entire system. I thought that this idea was really interesting but I was concerned about the feasibility. While it was clear through the interviews that meaningful community engagement done correctly would not slow down the scaling process of DAC, I thought that creating extensive large scale partnerships and systems planning would. While it would allow for more flexibility in how the community energy system is designed, it would be a much slower process. When I spoke with other participants I found out that some thought it was brilliant, with one DAC company representative saying, “I couldn't agree more. That's the version of equitable climate change mitigation--scaling the economy.” On the flip side, there were also other participants who thought the costs were too high to use it as a standard scaling model. They said, “ The cost is so important to this, because we are so up against the wall. If some state or a group of municipalities step forward and they're willing [to scale with this model] then that's awesome. But it just can't be a thing where it elongates [timelines] and puts extra cost and uncertainty on projects for developers, because that's just going to slow us down.” I also found out that not many other people were even thinking along these lines because it typically took a long explanation of the idea for most of the participants to understand what I was asking about. While this idea about scaling DAC within a larger framework seems very interesting and intriguing, I do not think it will be a feasible solution for incorporating community engagement into the larger scaling process for most DAC companies. However, in specific communities which have the right set of organizations, this method (after more testing) could be an extremely effective method for scaling DAC with community engagement through a larger transition period in the community.

8.5.4. Making scaling with community engagement the standard, instead of the luxury:

Through these methods, the ultimate goal will be to incorporate meaningful community engagement methods seamlessly into the scaling process until it becomes the regular standard instead of a luxury (or worse, an unwanted cost). One of the participants in the interview put it best when I asked him why they decided to conduct community engagement so early in their process. He said, “Our business model is built on the fact that one of our customers are the community members. So we never did anything else. This was what we started with.... for us, our timeline includes this, because that's what we're building our business model around.” If the industry can reach the stage where community engagement and equitable scaling processes are “what we’re building our business model around,” which admittedly will take some time, then I maintain that the industry will be able to reap the benefits of an increase in the speed of scaling. In this situation, the “additional costs” of community engagement would just be factored into the price of running a DAC company and deploying the technology in an equitable manner.

CHAPTER 9

PROPOSED GUIDELINES FOR SCALING DAC WITH ROBUST, MEANINGFUL COMMUNITY ENGAGEMENT

The guidelines presented in this section are the culmination of the information learned through the literature reviews and the interviews that I conducted. These recommendations are not just for DAC companies in particular, but the entire field including academia and non-profits as well.

Guidelines:

1. Organizations should be created that can conduct anticipatory engagement in communities and collaborate with DAC companies to assist on early-stage engagement.
2. DAC companies should create strong partnerships with local governments and community advisory organizations in communities where they would like to scale along with energy providers and offtake agreement parties.
3. DAC companies should hire, at an early stage, a full or part-time energy justice expert or social scientist to start thinking about community engagement so that it seamlessly integrates into the scaling process once it starts.
4. DAC companies should create a culture inside their company that prioritizes community benefits alongside rapid scaling of DAC. This can start from the company leadership, and spread through good hiring practices. This can also be documented by an internal memo or policy document.

5. Interfaces should be created to publicize and market successful partnerships between DAC companies and communities that were created through robust community engagement.
6. All actors in the field should start or continue trying to communicate and constructively work with energy justice organizations that are willing to collaborate.

As I continue my research, these guidelines will continue to evolve as I learn new information. For the sake of this thesis, these guidelines represent the best practices that I can recommend based on my research till date.

CHAPTER 10

CONCLUSION

10.1. Conclusion:

While I understand that many of the ideas and guidelines put forward in this thesis are quite idealistic, I would like to point out that they are not unrealistic. A majority of the DAC companies that I interviewed showed a sizable internal motivation to conduct meaningful community engagement when scaling their DAC plants. Several were not ready to scale, and others were not sure exactly how to do the engagement effectively, but the motivation was there. If we as a field can employ some of the strategies discussed in this thesis, as well as others suggested by other experts, then there is a realistic opportunity for the field of DAC to succeed in reaching gigaton scale by conducting robust, meaningful community engagement to create a system where the success of the DAC plant and the growth of the host community are directly connected. Also, as shown in section 8.4, a logical argument can be made for integrating meaningful community engagement into the DAC scaling process leading to an increase in the speed of scaling over the medium to long term.

I wanted to use this thesis to show that while following the current standards for community engagement, and waiting for the federal government to pass legislation, raising the standard for scaling procedures might be the most likely option for the field moving forward, it is not necessarily the only one or even the safest one. Without meaningful community engagement, DAC could find itself with a bad reputation, making it difficult to scale rapidly due to protests and lawsuits. There are feasible options which include incorporating meaningful community engagement that result in taking on more risk and work in the short term, but could also result in a much bigger benefit in the long term.

However, as seen throughout this thesis, the findings from this work are anything but conclusive, and there is more work which needs to be done in order to support and calibrate the ideas put forward in this thesis.

10.2. Future Plans:

First, there are more people in and around the industry that I can talk to and interview about these topics. As mentioned previously, there are a dozen or so more DAC companies who I have not reached out to, and it would be important to get their input as well. Additionally, for this thesis I was only able to speak to a representative from one local government. Their perspective was extremely insightful and I know for sure that there are two more local government officials who are interested in scaling DAC in their communities who are willing to speak with me. Given more time, I can even conduct a wider and more thorough search. Through this process I have also been connected with several professionals who are experts at the intersection of energy justice and carbon removal. Speaking with more of these professionals to learn about their work, and what strategies they have seen applied and succeed will be very useful, especially as this field continues to grow and learn. Lastly, I was able to touch on this briefly in the introduction, but I would like to speak to more individuals who have worked to scale other nascent technologies in the past to learn from their experience and create analogies between DAC and other industries. Creating these analogies could be a guide for the field on what to do, and what not to do when scaling with community engagement.

Second, I would like to take the guidelines that I have proposed in this thesis (and the ones which I will create based off of future interviews) and go through them with community members. Conducting focus groups in communities which are interested in scaling DAC (or other engineered CDR methods) will be able to give me insight into the shortcomings of the guidelines proposed in this thesis. In these focus groups I will conduct a more structured form of engagement compared to the interviews conducted for this thesis. Through focus groups with community members, I will be able to refine my suggestions to be more realistic, helpful and applicable for communities, companies, governments, and third-parties.

Lastly, I would like to figure out ways to implement the suggestions that I have proposed (and will refine). I don’t want to simply suggest broad and potentially radical changes to the status quo, and then leave it to other parties to figure out how to implement the changes. Whether through working with DAC companies, engaging energy justice organizations, or creating an organization to conduct early and/or anticipatory engagement, I would like to work on practical methods to implement the changes proposed to create real change in the field.

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APPENDIX A

[RELEVANT INTERVIEW QUESTIONS]

These questions are listed in no particular order, and are not word-for-word how they were phrased during the interview. Additionally, all participants were not asked every question on this list. Due to the semi-structured and open-ended nature of the interviews, some questions were more deeply explored with some participants while I focused on different questions with others.

1. Do you consider your DAC technology design to be modular or large-scale (non-modular)?
2. What are the benefits and drawbacks of [your] DAC technology from a community perspective?
3. What is the role of community engagement in scaling DAC [energy infrastructure]?
4. How do you define meaningful community engagement?
5. Who should be doing the community engagement in order for it to be most effective [DAC companies, NGOs, local governments, or academic institutions]?
6. How does your company think about incorporating community engagement into the scaling of your technology?
7. Does the modular [or large scale] nature of your technology affect your view of community engagement?
8. If DAC has little to no negative externalities then why should companies conduct meaningful community engagement?
9. Will incorporating community engagement in the scaling process for DAC affect the timeline?

10. Have you had any experiences with communities dealing in bad faith when you are trying to engage them?
11. Should DAC be incorporating more energy justice principles into the scaling process compared to other industries?
12. Can the use of meaningful community engagement in the scaling process for DAC lead to an increase in the scaling of the field in the long term?
13. What are the steps that need to [can be] taken in order to get broad adoption of meaningful community engagement practices by the DAC industry?
14. Should DAC companies try to scale independently as quickly as possible, or try and partner with other organizations within a community to scale as a local economy [instead of a single technology]?
15. What is the role of anticipatory engagement in the scaling of DAC?
16. Are there opportunities for [broad adoption of] Community or Co-ownership models for DAC?

APPENDIX B

[IRB APPROVAL]

ASU Knowledge Enterprise Development

EXEMPTION GRANTED

Clark Miller
CGF: Future of Innovation in Society, School for the (SFIS)
480/965-1778
Clark.Miller@asu.edu

Dear Clark Miller:

On 12/28/2022 the ASU IRB reviewed the following protocol:

Type of Review:	Initial Study
Title:	Exploring Industry, City, and Non-Profit Perspectives on Community Engagement and Energy Justice for Direct Air Capture (DAC) Carbon Removal Technologies
Investigator:	Clark Miller
IRB ID:	STUDY00017191
Funding:	None
Grant Title:	None
Grant ID:	None
Documents Reviewed:	• IRB Wizard Determination - Miller Sriramprasad.pdf, Category: IRB Protocol;

The IRB determined that the protocol is considered exempt pursuant to Federal Regulations 45CFR46 (2)(i) Tests, surveys, interviews, or observation (non-identifiable) on 12/28/2022.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

If any changes are made to the study, the IRB must be notified at research.integrity@asu.edu to determine if additional reviews/approvals are required. Changes may include but not limited to revisions to data collection, survey and/or interview questions, and vulnerable populations, etc.

Sincerely,

IRB Administrator

cc: Vishrudh Sriramprasad
Clark Miller
Klaus Lackner
Vishrudh Sriramprasad