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FOSSIL FUELS IN DISGUISE: ENVIRONMENTAL ISSUES WITH CARBON CAPTURE STORAGE IN THE CENTRAL VALLEY

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Abstract

The California Air Resources Board's 2022 Scoping Plan supports the development of Carbon Capture Storage (CCS) facilities in order to meet California's climate goals. Most of the proposed fourteen sites will be located in the Central Valley. CCS may help achieve negative emissions but poses several environmental problems. Key among these issues are water depletion and contamination, excessive energy usage, air pollution, and the potential for CCS-induced seismic risk. Due to the Central Valley's disadvantaged and less-resourced background, this area is more at risk for environmental injustices with CCS implementation. By creating Geographic Information Systems (GIS) maps of factors related to CCS and conducting interviews with seismologists and environmental advocates, this project demonstrates that the CCS sites are concerningly close to environmental resources and human populations and that CCS still requires further research for safe implementation. Additionally, CCS can be used as a political strategy that fossil fuel industries employ to maintain the status quo and demonstrate false environmental commitments as a form of greenwashing rather than taking larger steps towards addressing climate change by eliminating the use of fossil fuels. Therefore, this thesis recommends alternative strategies such as land use changes and investment in renewable energy to achieve climate mitigation in California.

Keywords: Carbon Capture Storage (CCS)/Carbon Sequestration; Central Valley; Fossil Fuel Industry; Greenwashing; Just Transition; Energy and Environmental Justice

Note: All images are used for educational purposes. All maps are made by the author unless otherwise indicated.

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Introduction

On Halloween day of 2022, a CO_2 pipeline burst in Satartia, Mississippi, causing a mass poisoning that led to residents becoming severely ill (Zegart, 2021). A green fog encompassed the city, leaving people frothing at the mouth and wandering around dazed, nauseous, and unable to breathe. A first responder described the scene as “something you’d see in a zombie movie,” which is terrifying considering the expansion of pipelines and Carbon Capture Storage (CCS) projects in the United States (Zegart, 2021). Carbon Capture Storage refers to the process of capturing atmospheric CO_2 emissions produced by fossil fuel oil and gas factories, transporting the CO_2, and storing it in the ground. Fossil fuel industry leaders, state and federal government agencies, and some scientists are “techno-optimistic” and support CCS use as a necessary technology to fight against climate change (Bui et al., 2018), whereas environmental organizations and other scientists oppose CCS due to its environmental damage (Eldardiry & Habib, 2018; *CCS Air Pollution* 2020), ineffectiveness (Young, 2021; *Hydrogen's hidden emissions* 2022; Readfearn, 2022), and continual use of fossil fuels rather than a transition away from them (Gunderson et al., 2020). In the U.S., despite carbon sequestration failures such as Satartia, the Biden administration’s Build Back Better program aims to almost double the tax credits that companies can receive for employing CCS, and Biden’s 2021 Infrastructure Investment and Jobs Act also provides additional funding for CCS deployment (Douglas, 2022). In California, the California Air Resources Board (CARB) supports CCS use in its 2022 Scoping Plan. Thus, governmental sources are minimizing the risk of CCS instead of prioritizing it as an issue that must be acted upon in order to prevent tragedies like Satartia from happening again. When science fiction becomes reality, there is a cause for concern and a reason to act.

In October, I helped environmental groups develop a social media campaign to expose CCS as "Fossil Fuels in Disguise," employing Halloween themes of scariness, deception, and trickery. Working with the Center for Biological Diversity (CBD), Sunstone Environmental Solutions, The Asian Pacific Environmental Network (APEN), and California Environmental Justice Alliance (CEJA), we created over ten graphics for the mini-campaign, three of which I designed (Appendix 2). The first of my graphics showed CCS use as a "poison" hiding amongst a basket of treats or benefits (Figure A1). The second one demonstrated CCS facilities producing pollution in a haunted house as a metaphor of the danger this technology poses in California, cautioning against CCS (Figure A2). The last graphic showed a pair of glasses and a fake mustache on smokestacks as a metaphor for CCS use masking the continuation of the fossil fuel industry (Figure A3). CBD successfully led this effort and our social media campaign was retweeted several times by many environmental groups, including The Central Valley Air Quality Coalition and The Science & Environmental Health Network, and viewed over 500 times. Similar to the consequences of CO_2 exposure in Satartia, carbon sequestration through CCS is equally environmentally harmful as environmental groups have posited. We hoped our social media campaign, with its variety of eye-catching graphics and much-needed education through humor, would being to inform the public about the pitfalls of CCS and how it can negatively impact their communities. This social media campaign was part of a larger project that I joined in Fall 2022 as a partner to environmental organizations advocating against the 2022 CARB Scoping Plan that supports CCS implementation.

The Scoping Plan promotes CCS as a climate mitigation strategy, and this regulatory guidance will inform environmental changes in California that will last into 2045. It is imperative to take action on climate change in California because we are experiencing the worst wildfires, drought conditions, and extreme heat in recorded history. The Intergovernmental Panel on Climate Change (IPCC) has found that immediate and monumental changes are necessary to avoid the most significant impacts of climate change and keep global warming within 1.5-2°C. The CARB Scoping Plan aims to help the state achieve carbon neutrality and its climate targets by decarbonizing all sectors via efficient and equitable technological solutions, such as CCS.

Currently there are fourteen proposed CCS sites in California – twelve of which are located in the Central Valley – that are planned to be erected by the end of the decade. When various environmental groups, especially those based in the Central Valley, heard about CCS and BECCS permitting in the state, they joined forces to organize against CCS in their communities because of its various negative externalities. Because the Redford Conservancy at Pitzer College was involved in the communications efforts around this, Professor Susan Phillips recruited me to join the project as part of my thesis. The advocacy coalition included the Better World Group (BWG), the Center for Biological Diversity (CBD), the Asian Pacific Environmental Network (APEN), the California Environmental Justice Alliance, Food and Water Watch, Center for Energy Efficiency and Renewable Technologies (CEERT), the Sierra Club, Sunstone Environmental Solutions, and several others. In partnership, these groups co-wrote a letter of opposition to CARB stating the environmental issues with CCS, including the lack of fossil fuel phase-out, air pollution, underestimates of CO_2 storage, extreme energy and water use, groundwater contamination, accusations of greenwashing, and environmental injustices within CCS sites in the Central Valley. The coalition had gathered research and information on the negative impacts of CCS but needed additional quantitative data to back up their claims as well as assistance with sharing their message on social media to inform the public. The Redford Conservancy added to this effort through empirical research about potential water compromises as well as a special focus on earthquake risk. This work created an empirical platform for subsequent advocacy work and was distributed to partners.

This project examines the rhetoric around CCS and provides spatial analysis of the fourteen projected CCS sites in the state, ranging from Redding in Northern California to Bakersfield, located in the Central Valley. Eight out of the fourteen sites plan to use Bio-Energy with Carbon Capture and Storage (BECCS), which is the process of capturing bioenergy from biomass and thereby storing natural matter carbon (Fajardy & Pour, 2022), while the other five sites plan to use CCS to scrub or filter CO_2 emissions from existing fossil fuel plants smokestacks (Moseman, 2021). My role in the coalition was to investigate aquifer and earthquake risk due to CCS by analyzing research, creating GIS maps, and conducting interviews with seismologists and environmental advocates.

As an emerging technology, Carbon Capture Storage has developed in importance and will continue to grow in the next few years as fossil fuel companies and governments utilize this tactic to work toward carbon neutrality goals. However, several environmental problems arise from the implementation of CCS, including excessive water and energy use (Eldardiry & Habib, 2018), worsening air pollution (*CCS Air Pollution* 2020), and possibly an increased potential for earthquakes (Zoback & Gorelick, 2012). CCS is an environmental justice issue because most of the proposed sites are located in California's Central Valley, close to low-income, marginalized communities. In order to reach California's climate goals, the state must reimagine energy production via a just transition. A just energy transition strongly advocates for local, nature-based, and community-based climate solutions, such as the preservation of open and working lands, decrease in fossil fuel technologies, and integration of community voice to help

California achieve its environmental goals. Through my case study within California, specifically in the Central Valley, I examine the divisive discourse and ideologies around CCS and how these intersect with a just transition away from fossil fuels. Due to the harmful impacts of CCS, from energy costs to environmental justice detriments, California residents must become aware of the growing use of CCS facilities near them and be educated about other options for climate mitigation and adaptation, specifically Nature-based Solutions (NbS) to climate change and renewable energy. Exploring the environmental impacts of CCS on vulnerable populations through environmental and energy justice lenses demonstrates CCS' unsuitability for the Central Valley, its use as a greenwashing tactic and technofix with fossil fuel industry backing, and a technocratic approach to the climate crisis that perpetuates oppressive systems of extraction.

CCS Background

Carbon Capture Storage (CCS) is a technology that consists of separating carbon dioxide from high greenhouse gas (GHG) emitting point sources, transporting the carbon through pipelines and other transit, and eventually capturing it by injecting CO_2 deep into geological formations to store it, removing CO_2 from the atmosphere (CCUS, 2022; Carbon Storage Faqs, 2022; Hong, 2022). These sources include fossil fuel plants, biomass processing facilities, concrete factories, and energy and chemical production facilities (*2022 Scoping Plan For Achieving Carbon Neutrality* 2022). There are two main ways that CCS can be used to decarbonize the atmosphere. First, it can be used to capture or scrub carbon dioxide from industrial point sources as an attachment to smoke stacks that prevents GHGs from being emitted. Second, the carbon can be distilled directly from the atmosphere, also known as Direct Air Capture (DAC), providing negative emissions (Beck, 2019). The CO_2 that is captured can be stored directly under the facility responsible for carbon separation, most likely in California, or can be pipelined to other locations for storage, such as in the Midwest. The storage of this carbon dioxide is usually located in old oil and natural gas reservoirs, or saline formations, amongst other geological formations (*Carbon Storage Faqs*, 2022). Currently, in the United States, there are thirteen CCS facilities with a total yearly capture of more than 40 million tons (Mt) of CO_2 (Jones & Lawson, 2022).

CCS was introduced in the 1920s to separate the carbon dioxide and methane found in gas fields (Cherepovitsyn et al., 2020). The technology that drives CCS, called acid gas scrubbing, was developed two decades later and refined over time to separate CO_2 from a gas mixture (Nord & Bolland, 2020; Brandl et al., 2021). In 1972, the first instance of Carbon Capture Utilization and Storage (CCUS) occurred when Chevron pipelined CO_2 from Colorado to inject into an oilfield in Scurry County, Texas for Enhanced Oil Recovery (EOR) allowing for greater oil extraction (Ma et al., 2022). The difference between CCS and CCUS is that with CCUS, the resulting extra carbon can be repurposed into new products such as plastics, concrete, or biofuel (*What is CCS*, n.d.). Shortly after, in 1977, the concept of CCS was proposed by Physicist Cesare Marchetti as a geoengineering solution to collect, transport, and dispose of CO_2 (Brandl et al., 2021). In the 1980s, Steinberg explored a multitude of applications for CO2 capture processes and storage, authoring many reports on CCS use (Nord & Bolland, 2020; Brandl et al., 2021). By the 1990s, more techno-economic analyses of CCS were released by researchers Booras and Smelser (1991) and Herzog et al. (1991) and larger projects such as the 1996 Sleipner CCS project in Norway for offshore CCS and the 2000 Weyburn Project in Canada demonstrated successful CCS implementation (Ma et al., 2022).

Since its commercial deployment in the 1970s, CCS has been slow to be adopted due to its controversial nature, but is beginning to be used on a commercial scale for climate change mitigation. Some governments and academics support CCS use (Bui et al., 2018) as a necessary climate strategy while others caution against the risks of its implementation (Anderson, 2016). The former group considers CCS to be a beneficial long-term technological strategy to deal with carbon emissions, removing sizable amounts of CO_2 from the atmosphere. Studies have estimated that Carbon Capture Storage can lead to 80-90% CO_2 reductions (Rubin et al., 2005; Brandl et al., 2021). Additionally, reports by the International Energy Agency (IEA) and the Intergovernmental Panel on Climate Change (IPCC) continue to push for CCS use to achieve climate mitigation goals (Nord & Bolland, 2020). Thus, due to the intensification of climate change impacts and rising political pressure to act on climate change, CCS has already been implemented globally and nationally and is planned to be further used by governments and companies to achieve carbon neutrality goals. As of now, CCS is currently used in 35 facilities globally with an annual capture of approximately 45 Mt of CO_2 (Budinis et al., 2022). By 2050, the IEA predicts that CCS will contribute to 16.67% of CO_2 emissions reductions necessary to meet a 2 °C global warming target (Levina et al., 2013). This results in roughly 5.6 gigatonnes per annum of CO_2 that must be captured and stored using CCS (Martin-Roberts et al., 2021). Therefore, Carbon Capture Storage is being used and will continue to be adopted by states and companies to achieve negative emissions and carbon-neutral goals to demonstrate reducing their environmental impact. Given the rise of CCS, it will become more heavily relied upon by governments and industries as a leading climate mitigation strategy, especially in California, an environmental leader.

However, despite the current investment in CCS, there are some overarching issues with its deployment, such as its perpetuation of extractive systems, lack of research, and environmental issues. CCS is a political strategy that allows fossil fuel industries to maintain the status quo and simply install CCS facilities instead of taking drastic action against climate change. This has been proven by the disclosure records of fossil fuel companies that reveal exorbitant amounts of money going towards lobbying for pro-CCS actions and regulations. Utilizing CCS is easier for global fossil fuel industries and other companies to employ compared to investing in renewable energy to reach state and federal climate mandates. Fossil fuel interests and corporations market CCS as their way of contributing to the environment by achieving negative emissions, but are actually greenwashing a technology that only serves to keep their industry relevant in today’s world. They are overly confident, or techno-optimistic, about CCS and engage in risk minimization to keep up their beliefs. Risk minimization is fueled by the lack of comprehensive research on the full extent of its scientific capture capacity, environmental impacts, and social justice ramifications. Plus, when these CCS sites are proposed, there are very few spatial data visualizations of the CCS site locations, pipeline locations, and storage site locations. Additionally, California companies do not have to make their data publicly available (J. Avouac, Personal Communication, October 24, 2022), so there is not enough information to understand CCS' impacts on geological formations, natural resources, and frontline communities. Thus, it is critical to examine and research CCS' impacts before it is further codified for climate mitigation and deployed more frequently to capture carbon.

CCS poses severe environmental risks due to its high energy and water demands, release of air pollutants, the potential for pipeline leakage, possible increased seismic risk for earthquakes, and extension and continuation of fossil fuel infrastructure, which all lead to environmental justice impacts. CCS uses a large amount of water and energy resources and can contaminate the groundwater supply if CO_2 is leaked during the storage process (Eldardiry & Habib, 2018). Given California's history of drought (Diffenbaugh et al., 2015), CCS would further the negative impacts of climate change by depleting water resources. Installing CCS is predicted to create stress on water resources because adding CCS would increase a facility's water use by 55% (Rosa et al., 2021). Roughly 80-90% of the water for an electricity production facility is used for cooling and emission scrubbing in the capture and separation stages of carbon capture (Eldardiry & Habib, 2018). Similarly, for these stages, the energy demands also increase in a power plant with a CCS system by about 10–40% compared to its traditional counterpart (Eldardiry & Habib, 2018). This is because in the separation stage, removing carbon from the rest of the emissions stream requires high-intensity compression of CO_2 which is an energy intensive task (V. Tejeda, Personal Communication, March 8, 2023). Thus, CCS requires extensive water and energy resources which are scarce in California's Central Valley, the location of many proposed CCS sites. Also, the process of CCS leads to emissions of Particulate Matter (PM), Nitrogen Oxide (NOx), Sulphur Dioxide (SO2), and Ammonia (NH3), furthering the public health crisis in the Central Valley by causing the air quality to worsen (*CCS Air Pollution*, 2020; White, 2020). Additionally, CCS can potentially trigger earthquakes, worsening California's propensity to earthquakes. A study by Zoback and Gorelick (2012) states that there is a high probability that the injection of sizable quantities of CO_2 into continental land masses characterized by brittle rocks will trigger earthquakes. The increased potential for earthquakes due to CCS will disproportionately impact marginalized communities in the Central Valley because they have fewer resources to recover from disasters. Moreover, CCS is not just a method to trap carbon dioxide emissions; it can also help to produce hydrogen from natural gas, and be used for Enhanced Oil Recovery from depleted oil and gas reservoirs. About 75% of CCS sites in the United States are used for EOR, which is the process of extracting contaminated, deeper oil (Roberts, 2019), in order to further fossil fuel infrastructure and funding. Lastly, the process of CCS is expensive and can divert funds from other environmental practices. The IPCC Special Report on Carbon Capture and Storage found that CO_2 adds 44-87% to the original cost of a power plant and 42-81% to the original cost of electricity (Rubin et al., 2005). The environmental issues caused by CCS would heighten existing environmental injustices in the Central Valley, such as poor air quality and reduced access to natural resources.

Therefore, more people need to become fully educated about CCS' detrimental impacts on their communities, because although on the surface it may seem like a promising option, it has serious consequences. Although there are currently no active CCS sites in California, the

California Air Resources Board (CARB) is supporting CCS use in California to help meet California's climate goals despite CCS' environmental justice and greenwashing issues. Entities such as CARB prioritize easier to implement solutions that will receive adequate funding instead of working in partnership with community members to hear their concerns and find equitable, localized solutions. Due to these efforts by powerful corporations and governmental agencies, the rise of CCS is quickly approaching. The fourteen currently proposed CCS sites in California will be implemented by the end of the decade, yet not many people are aware of CCS use. This public education gap must be addressed to ensure that all Californians are aware of what is coming and know the effects of CCS use. Given the lack of rigorous academic study of CCS in both its scientific abilities and societal implications, my project and thesis on CCS facilities are new in the emerging field of Carbon Capture, Utilization, and Sequestration (CCUS). My targeted scope hones in on California, specifically information on the Central Valley's CCS sites. This includes the visualization of environmental and human factors, illuminating local state concerns with CCS adoption.

Literature Review

The debate surrounding CCS has significantly increased in the past few years as this technology has been increasingly deployed without sufficient research. Scholars and activists have different points of view on CCS based on their value systems and their populations of interest. Certain academics are techno-optimistic about the greater benefits of CCS to the planet and all people in reducing CO_2 emissions (Szulczewski et al., 2012; Bui et al., 2018; Beck, 2019), whereas other scholars focus on the local pollution and safety risks of CCS use that disproportionately impact marginalized communities and its use as a greenwashing tool (Eldardiry & Habib, 2018; Gunderson et al., 2020; Young, 2021). Below, I consider CCS within the context of the Environmental Justice movement and the theoretical frameworks of environmental and energy justice in order to truly understand the full range of its impacts. Without these theoretical underpinnings, fossil fuel greenwashing of CCS and CCS' negative impacts would go unchecked. Thus, utilizing energy justice concepts, a just transition must be achieved in order to combat the climate crisis in an equitable manner that uplifts all communities.

CCS Debate: The Pros and Cons in Academic Literature

Academics are on both sides of the CCS debate and have different scientific, political, and environmental reasons for their positions. Professor Howard Herzog at MIT and other academics demonstrate that there is enough underground storage for long-term carbon capture for at least 100 years (Szulczewski et al., 2012). Academics also make the case for the need for CCS deployment in order to achieve climate commitments (Bui et al., 2018). Other analyses show that from a political perspective, the United States is in an ideal position to lead commercial CCS use due to the country's resources, innovation, and energy economy (Beck, 2019). Many proponents of CCS acknowledge some of its risks but encourage the United States to advance CCS studies and deployment to improve the technology and begin storing carbon in order to keep planetary warming to between 1.5 and 2 degrees Celsius. Academics against CCS argue that fossil fuel companies are large supporters of it (Gunderson et al., 2020), that CCS is ineffective (Young, 2021; Hydrogen's hidden emissions 2022; Readfearn, 2022), and the CCS emissions benefits are offset by increased energy and water use upstream and downstream, as well as significant increases in air pollution (Eldardiry & Habib, 2018; CCS Air Pollution 2020).

Scientists also debate whether CCS has the potential to trigger earthquakes in California (Zoback & Gorelick, 2012). Due to the state's predisposition to earthquakes and prevalent environmental justice issues in areas with predominantly rural, lower-income, people of color (POC) residents, CCS can potentially lead to greater harm. These areas, such as the Central Valley, are of pressing concern due to the bigger environmental justice implications for rural communities that are linguistically isolated, have fewer resources, and generally have less support for environmental disaster recovery. Problems with CCS further reveal the serious consequences that disadvantaged communities face due to climate change, pollution exposure, and technological solutions that perpetuate reliance on fossil fuels and existing disparities.

Stanford Professor Mark Zoback has shown that there is a high chance that CCS will trigger earthquakes because even smaller earthquakes can threaten the seal of CO2 repositories (Zoback & Gorelick, 2012). His paper discourages large-scale adoption of CCS due to its geological risk and cost. Another study by Goebel et al. found that wastewater disposal can contribute to changes in pressure that ultimately result in earthquakes along active fault lines (Goebel et al., 2016). These scholars argue that induced seismicity may only be detected in

California with further analysis of these areas, which can also be true for CCS use. Another paper by Amos et al. (2014) notes that groundwater use in the Central Valley exceeds the replenishment of the aquifer, leading to the lowering of the valley floor. This may lead to peaks in the uplift of the Coast Ranges and reduce the normal stress on the San Andreas Fault, increasing the possibility of an earthquake. Given the environmental conditions of the region, CCS use could lead to a greater risk of fault failure.

Examining CCS requires an environmental justice framework in order to focus on the communities that will be disproportionately impacted by its negative externalities. Without this lens, CCS is seen as a neutral climate technology that can achieve negative emissions instead of what it really is – an extraction-based system perpetuating environmental and social harm. It is imperative that CCS is compared and contrasted to other climate mitigation options and their environmental justice impacts in order to understand that CCS is not the only solution or the best solution. Under a just transition, fossil fuel greenwashing will be replaced with Nature-based Solutions and regenerative systems that fortify California's sustainable energy development.

The Transition from Fossil Fuels

Many scholars have promoted the idea of energy justice (Heffron, 2022; David, 2018) for a just transition (McCauley & Heffron, 2018; Mascarenhas-Swan, 2017; Newell & Mulvaney, 2013; Healy & Barry, 2017; Hazrati, 2021) and noted obstacles to its implementation (York & Bell, 2019; Baker, 2020). Most of the literature on a just transition comes from political studies that deal with issues of energy, fossil fuel divestment, environmental resources, and justice (social, environmental, climate, and energy). These studies have become particularly pertinent as climate change has progressed and technological developments have encouraged the United

States to continue to significantly invest in fossil fuels and CCS techniques (Beck, 2019), rather than focusing on environmental justice through community-based, renewable energy-centered solutions. To further the theoretical discussion of a just transition in relation to CCS, I will discuss three themes in my literature review: environmental justice, energy justice via a just transition, and the fossil fuel industry's greenwashing.

United States Environmental Justice Movement

The United States Environmental Justice (EJ) movement began in the 1980s to primarily address issues of racialized environmental injustices that went unrecognized within the larger, predominantly white environmental movement from the previous decade. Following the larger Civil Rights Movement of the 1960s, alongside the United Farm Workers' protests in California and the Environmental Movement of the 1970s, environmental activists of color began to receive national attention for their identification of and resistance against disproportionately negative impacts of environmental issues in their neighborhoods. The term "environmental justice" was established following mobilization against disproportionate toxic waste dumping in low-income communities of color. One of the first recognized environmental justice protests was in Warren County, North Carolina in 1982 against Polychlorinated Biphenyl (PCB) landfills in a community of predominantly Black residents (McGurty, 2007). The proposed waste disposal site was planted in a low-income community of color, despite the availability of suitable alternative locations with fewer minorities: the quintessential environmental injustice (Mank, 2007). In 1983, Prominent sociologist Dr. Robert Bullard published an environmental racism study titled *Solid Waste Sites and the Black Houston Community*, a seminal piece considered to be the first of its kind to link structural racism with environmental issues. Bullard's study found that African

American neighborhoods in Houston had a disproportionate amount of garbage sites and landfills (Bullard, 1983). Bullard is also well-known for his work that revealed racially biased decision-making in the determination as shown through his influence in the rejection of a permit proposing the establishment of a nuclear waste facility in Louisiana (Cole & Foster, 2001). The initial protests against Warren County's development were led by Rev. Benjamin Chavis, head of the United Church of Christ Commission for Racial Justice, an organization that published a historic study in 1987 titled *Toxic Wastes and Race in the United States*. This report focused on the significant overarching trend of racial and socio-economic discrimination in toxic waste site placement within minority communities across the United States (United Church of Christ Commission for Racial Justice, 1987).

As minority groups became empowered to protest racially targeted environmental degradation, they formed their own networks and organizations to continue to mobilize against these issues. In the 1990s, the First National People of Color Environmental Leadership Summit led to the establishment of the Indigenous Environmental Network, Asian Pacific Environmental Network (APEN), and National Black Environmental Justice Network (NBEJN), providing a forum for race-specific EJ conversation and shared organizing experience for marginalized communities (*Environmental Justice* 2022). By the 2000s, more EJ battles were won — such as the remediation of the PCB landfill — and a larger canon of EJ literature evolved as activists and scholars published more on the topic. As the movement grew, more people recognized and joined the intersectional fight for justice. Diversity increased with the addition of laborers, youth, and related organizations: such as public health, women's rights, and voting access groups. Environmental injustices continue to further existing inequalities faced by marginalized communities and trigger public health crises in addition to food and housing insecurities. Thus, the EJ movement remains focused on socially vulnerable groups, such as low-income, people of color, or otherwise disadvantaged people known as frontline communities, because these are the disproportionately impacted groups that require the most support from climate change solutions.

Energy Justice and a Just Transition

Environmental justice studies led to the conceptualization of climate and energy justice. Broadening the scope of environmental justice beyond the United States and first-world countries, climate justice focuses on long-term, globally just transitions and the repercussions of climate change on vulnerable groups mostly located in the Global South (McCauley & Heffron, 2018). On the other hand, energy justice focuses on current issues of resource distribution, specifically around energy production and access (McCauley & Heffron, 2018). The just transition grew from the intersection of climate, energy, and environmental (CEE) justice and has gained traction in recent years surrounding discussions of carbon reductions and climate planning (McCauley & Heffron, 2018; Newell & Mulvaney, 2013).

The *Energy Justice Workbook* was created by three lawyers of color who founded the Initiative for Energy Justice in 2018 to share their experiences fighting for a just transition and provide equity-based policy research and recommendations to policymakers. Since then, this report has become a well-cited document regarding the definition of energy justice and the energy justice scorecard. Energy justice is defined by the *Energy Justice Workbook* as the "goal of achieving equity in both the social and economic participation in the energy system, while also remediating social, economic, and health burdens on those historically harmed by the energy system ('frontline communities')" (Baker et al., 2019, p. 5). Since energy justice works to uplift marginalized communities, it inevitably aims to provide better access to clean, cost-effective energy for all communities (Baker et al., 2019). Energy justice can be achieved through five forms of justice: distributive, procedural, restorative, recognition, and cosmopolitan justice (Heffron, 2022). These forms of justice concern the distribution of benefits and costs from the energy sector, the legality and justice of processes followed in the energy system, the rectification of energy injustices, the recognition of the rights of BIPOC groups, and considerations of cross-border, global energy activities (Heffron, 2022). Another conceptualization of energy justice follows a framework of eight tenets for energy justice decision-making: availability, affordability, due process, transparency and accountability, sustainability, intra-generational equity, inter-generational equity, and responsibility (Sovacool et al., 2016) (Table 1). Through these pathways, energy justice provides an innovative, equitable perspective on energy systems and planning for a just transition.

Table 1

Energy Justice Decision-Making Framework

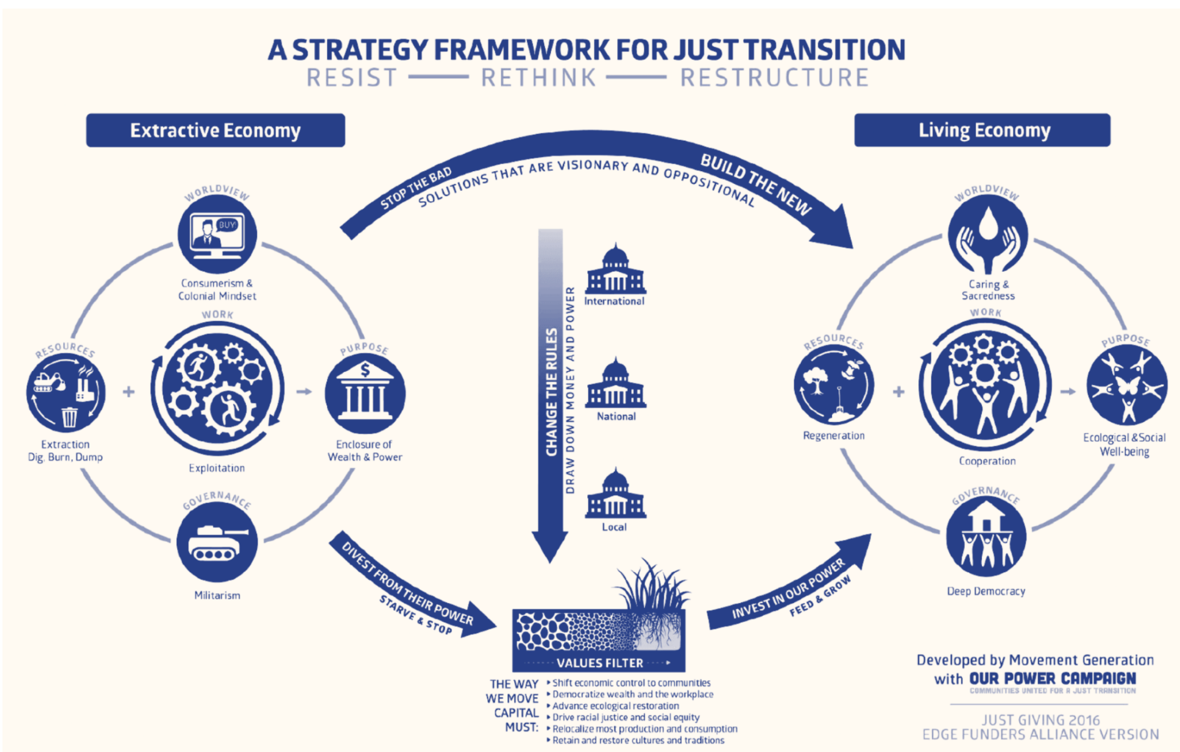
Principle	Description	Contemporary applications
Availability	People deserve sufficient energy resources of high quality	Investments in energy supply and energy efficiency; upgrades to infrastructure
Affordability	The provision of energy services should not become a financial burden for consumers, especially the poor	Fuel poverty eradication efforts; low-income assistance for weatherization efficiency improvements; retrofits to older buildings
Due process	Countries should respect due process and human rights in their production and use of energy	Social and environmental impact assessments; free, prior and informed consent
Transparency and accountability	All people should have access to high-quality information about energy and the environment, and fair, transparent and accountable forms of energy decision-making	The Extractive Industries Transparency Initiative; independent accountability mechanisms; international accounting standards for energy subsidies
Sustainability	Energy resources should not be depleted too quickly	Natural resource funds designed to save for future generations; system benefits charges
Intragenerational equity	All people have a right to fairly access energy services	The UN's Sustainable Energy for All initiative; Sustainable Development Goal 7
Intergenerational equity	Future generations have a right to enjoy a good life undisturbed by the damage that our energy systems inflict on the world today	Promoting environmentally friendly forms of low-carbon energy such as renewables or efficiency that can minimize externalities or prolong resource efficacy; implementing environmental bonds
Responsibility	All nations have a responsibility to protect the natural environment and reduce energy-related environmental threats	UN Framework Convention on Climate Change; the Green Climate Fund

Source: Sovacool et al., 2016

The just transition uses principles of energy justice to provide a framework for society to move away from fossil fuel dependence. The *Energy Justice Workbook* states that "energy justice … is integral to the just transition, as it addresses fairness and equity concerns within the current, extractive energy system" (Baker et al., 2019, p. 10). Additionally, energy justice furthers democracy, cooperation, regeneration, ecological and social well-being, and caring and sacredness which are all part of a just transition (Figure 1). Thus, a just transition can be defined as a fair and equitable process that draws from energy justice and prioritizes vulnerable communities in moving toward a post-carbon society, economy, and environment (Mascarenhas-Swan, 2017; McCauley & Heffron, 2018).

Figure 1

Movement Generation Just Transition Framework



Source: Baker et al., 2019

The term "just transition" was originally termed by the labor movement in the 1970s in response to increased military spending on nuclear energy for the Cold War. In a movement towards peace, Tony Mazzocchi, a leader of the Oil, Chemical, and Atomic Workers union, rallied trade unionists and advocated for those who would lose job security due to disarmament ("Just transition" – just what is it? 2016). The concept reemerged in the 1990s in light of Hansen's announcement of anthropogenic climate change, new environmental regulations, and the increased activism of the environmental movement. As a play on the establishment of the Superfund law for toxic clean-up, Mazzocchi redefined his work as a "superfund for workers" that aimed to support worker retraining and education as well as pushed for environmental reforms in the industrial sector (Henry et al., 2020). Historically, the just transition has been steeped in energy and social activism history which is the foundation of the current just transition.

Building on the history of the environmental justice movement, the just transition is now supported by environmental groups as part of the movement towards green jobs, better health conditions, and a moving away from fossil fuels (Mascarenhas-Swan, 2017; McCauley & Heffron, 2018). The just transition concept is beneficial because it prevents damage that would have otherwise occurred to the environment and disadvantaged groups via extractive measures (Mascarenhas-Swan, 2017; Heffron, 2022). In addition, the framework also provides a pathway towards sustainable energy solutions by not only divesting from fossil fuels, but also disrupting and redesigning current energy infrastructure and jobs to develop green ways of living (Healy & Barry, 2017). Thus, applying the just transition framework to CCS or other technologies is critical as the United States, and particularly California, increase their energy usage and expand renewable energy markets.

Energy justice and the just transition are ideal theoretical and practical frameworks for transitioning the country and California toward a more equitable, efficient, and safe energy future. However, the fossil fuel industry is resistant to change. In an effort to maintain status-quo operations, the fossil fuel industry uses CCS as a form of greenwashing to demonstrate false claims of sustainability and purported changes in their internal structure.

Greenwashing and the Fossil Fuel Industry

Greenwashing refers to when an organization deceptively markets products or initiatives as environmentally friendly even though they are not (Megura & Gunderson, 2022). The term greenwashing was coined in 1986 by Activist Jay Westerveld when he condemned the hotel industry for promoting towel reuse as an act to save the environment, when in reality, the primary intent was to reduce corporate expenses (de Freitas Netto et al., 2020; Nakamura, 2022), an act which Westerveld described as "greenwashing" (Becker-Olsen & Potucek, 2013). Since the term was coined, rampant increases in environmental disinformation have sparked consumer concern and wariness over corporate environmental claims, leading third-party groups such as Greenpeace and TerraChoice to monitor companies through research studies on greenwashing (Gatti et al., 2019). A 2009 study conducted by TerraChoice, an environmental marketing firm now acquired by the non-profit organization ULC Standards, found that out of 2,219 reviewed products, 98% were marketed using strategies that could be considered greenwashing (Lyon & Montgomery, 2015). Unfortunately, greenwashing is employed by a variety of powerful actors such as the fossil fuel industry, major companies, governments, research organizations, and nonprofit organizations, affecting many sectors (Nemes et al., 2022).

In a more nuanced definition, greenwashing includes faux promotion of an organization's environmental actions, regardless of the company's intent, or spending more money on advertising green business practices than on the actual practices themselves (Nemes et al., 2022). The main way greenwashing occurs is through spreading false or deceptive information regarding an organization's goals, strategies, and actions, which misleads customers about the organization's true practices and inflates positive opinions of the organization's environmental performance (Nemes et al., 2022). Although the company might be ignorant about environmental issues and regulations, or even of their own public relations, these reporting mechanisms should be strongly monitored and corrected to avoid accidental greenwashing. Thus, although greenwashing practices can range in severity and intent, they are inherently unethical because they promote false information to consumers (Nemes et al., 2022).

Well-known methods of greenwashing include false reporting and advertisement. A common method used to disguise actions via greenwashing is through incorrect reporting of data in sustainability reports such that claims are made based on singular attributes instead of comprehensive analysis (Megura & Gunderson, 2022). Additionally, the data may be collected in a biased manner or framed to suggest an outcome that is untrue. Another way to greenwash is to emphasize the expertise of the company, its scientists, and its technologies to improve the company's public image. This method appeals to a false sense of ethos and creates undue assurance in the company's mission (Megura & Gunderson, 2022). Since there are a variety of schemes a company can use to greenwash, utilizing a set of guidelines to determine if an action is greenwashing is beneficial for consumers and the public in general.

TerraChoice's "seven sins of greenwashing" and the Nemes et al. (2022) integrated framework help one determine if a claim made by a company is greenwashing or not. TerraChoice established "the seven sins of greenwashing" which include: hidden trade-offs (also known as selective disclosure), no proof, vagueness, worshipping false labels, irrelevance, lesser of two evils, and fibbing (*Sins of greenwashing*, n.d.). Nemes et al. built upon this list by creating a framework[1] to assess the type and extent that a claim greenwashes, with the addition of seven more categories, indicator questions, and more detail (2022). By sorting through the types of claims a company can make through this integrated framework, one can more easily discern whether a claim is greenwashing and to what extent it is greenwashing. This provides a much-needed standard across industries for determining whether an action is greenwashing.

In general, the fossil fuel industry uses multiple techniques to address the demand for sustainability while engaging in perverse commodity-based extraction through greenwashing tactics. In relation to CCS, techno-optimism and risk minimization are the most actively employed strategies used by oil and gas companies. Techno-optimism is the belief that innovative technologies alone, without social changes, can solve climate change as well as the promise to implement renewable energy in the future (Megura & Gunderson, 2022). This strategy most aligns with Carbon Capture Storage as companies believe if they provide this option, they can continue business as usual while sequestering carbon on the side to appease environmentalists. Additionally, risk minimization is a tactic that companies use to avoid disclosing predictions of potential environmental and societal risks, allowing them to continue their dependence upon unsustainable technological solutions and fossil fuels. Similar to previously mentioned tactics, withholding information is the first step toward a second-generation misinformation campaign. In conjunction with risk minimization, possibility

[1] See Nemes et. al (2022), Supplementary Materials, Table S1: Integrated Framework of Greenwashing

blindness is the refusal to envision a growing economy without the use of fossil fuels, and subsequently rejecting clean energy as a solution Megura & Gunderson, 2022). Thus, possibility blindness endangers a reimagined future that relies upon green energy and reduced emissions. This method of thinking implies that there is no need to change current or future emissions, enabling necessitarianism. Necessitarianism is the idea that the fossil fuel industry is a required system to provide current services. Since the fossil fuel system has been long established, compliance with new environmental standards, investments in environmental organizations, and sustainability initiatives greatly improve a company's public face by making the bare minimum amount of change look impressive compared to the previous status quo (Megura & Gunderson, 2022). Even though the status quo remains leagues behind in environmental protection, companies are applauded for these smaller countermeasures that essentially offset the company's dirty energy use for the public.

Since James Hansen's 1988 congressional testimony on climate change, fossil fuel corporations (e.g. ExxonMobil) have led efforts to deny climate change by discrediting scientists and spreading misinformation (Dunlap & McCright, 2015). Recent examples of fossil fuel industry greenwashing can be seen through the actions of high-profile companies such as BP, Chevron, ExxonMobil, and Shell. Although the European companies, BP and Shell, acknowledge climate science more than their American counterparts, Chevron and ExxonMobil, these companies continue to only implement smaller sustainability goals such as making simple pledges towards environmental causes or disclosing GHG emissions data (Li et al., 2022). Moreover, they are not even meeting minimal greenhouse emission reduction targets. Contrary to pledges, all four companies continue to support weakened environmental policies, redirect the responsibility of carbon reductions toward consumers, falsely advertise fossil fuels as green energy, and oversell their investment in clean energy (Li et al., 2022). Also, they all failed to show any divestment measures or quantifiable moves toward a just, clean energy transition as fossil fuels are still at the core of their business models (Li et al., 2022). Therefore, these companies continue to implement all of the above strategies for greenwashing.

The literature clearly shows the need for a just transition, especially in the face of the growing threats of climate change and the dangerous tactics of greenwashing employed by fossil fuel industries. Further investment in CCS will maintain the status quo, providing companies with a cop-out, instead of pushing them toward a low-carbon, clean energy future (Klein, 2015). More research is needed regarding how these industry tactics are furthered by geo-engineered climate solutions, such as CCS. For the remainder of this paper, I will be discussing the contribution of my thesis project to the research in this field.

Methodology

In this project, I was guided by environmental groups to support their advocacy work against the 2022 CARB Scoping Plan due to its reliance on CCS. To accomplish this, I utilized a mixed methods research approach that involved both spatial analysis and data visualization through GIS mapping, qualitative interviews with seismologists and CCS scholars, and discussions with environmental organizations. My project improved spatial understanding of proposed CCS facilities in California through data preparation and GIS mapping with the use of an original dataset I received from the Center for Biological Diversity. In partnership with these organizations, I spoke with representatives from these groups and helped map the concerns they were interested in visualizing by finding quantitative datasets on natural resources and human populations and proposing best-suited spatial analyses. Their CCS sites spreadsheet was fortified with this additional research and I began mapping these sites in relation to water concerns, earthquake risk, and human impact.

To understand the environmental effects of CCS, multiple GIS maps were created to explore the data. Maps were made with overlays of aquifer status, groundwater basin location and depth, and proximity to natural water sources in relation to CCS sites. Through spatial analyses, I demonstrated earthquake risk by including the proximity of fault lines to CCS sites, hot spot analysis to determine trends of high-confidence areas of earthquakes, and time series analyses of likely earthquake locations over the past few decades. Next, I mapped the 5-mile radius of census tracts and schools located near these proposed CCS sites layered with CalEnviro Screen 4.0 data to show environmental injustice issues. Finally, these layers were compiled and published in a public-facing ArcGIS Experience website with interactive features.

To spread awareness of CCS issues, I also helped the aforementioned environmental organizations with a "Fossil Fuels in Disguise" social media campaign for Halloween. Through these posts, we increased awareness of CCS issues and got re-tweeted several times by other environmental groups and politicians. I also collaborated with Professor Susan Phillips on a 8-page memo on CCS-based earthquake risk in California that included a summary of all my research, including academic sources on the CCS debate, GIS maps, and interviews with seismologists (Appendix 3). This memo was designed to inform Lucy Jones, a well-known, public-facing seismologist with a long tenure at the U.S. Geological Survey, on CCS-induced seismicity and environmental issues to receive her official input on the topic. It can also be used to educate the greater science community and the public on these issues.

Moreover, I interviewed stakeholders, including environmental organizations, academics, and other strong proponents and opponents of CCS to gain a better picture of the climate around current CCS discussions in California. The interviews with partner environmental groups allowed me to fully understand their background and passion for fighting against CCS use in California. The interviews with expert professors and seismologists expanded my knowledge of CCS-induced earthquake risk in California. Speaking with stakeholders who hold strong opinions on this topic will improve understanding of the various actors around California's CCS use and implementation. To contextualize these interviews in the greater literature, research was conducted on federal and state CCS policies in addition to studies on CCS use and its impacts on local communities and resources. Other components of the research include studying the Central Valley's physical and environmental justice characteristics and viable CCS alternatives for California.

Chapter 1. CCS Sites in the Central Valley of California

The Central Valley has a long history of racial and environmental injustices. Adding CCS to this area would deplete natural resources and has the potential to harm these communities due to CCS-induced seismic risk. Thus, CCS use in this area would only further existing environmental and structural issues, worsening living and working conditions in the area. Moving forward, a just transition framework would be ideal to prevent more environmental injustices and build community climate resilience through local and sustainable energy solutions.

Central Valley Background

CCS sites are placed near existing industrial plants which were disproportionately placed in the Central Valley due to the area's large quantities of petroleum and natural gas (Tikkanen, 2011). Since most of the planned CCS sites for California are located in the Central Valley, there is a need to focus on studying this area. The Central Valley has a history of environmental issues which CCS would further by depleting natural resources and increasing the environmental injustices faced by Central Valley residents. The environmental consequences of CCS use will disproportionately burden marginalized communities in the Central Valley.

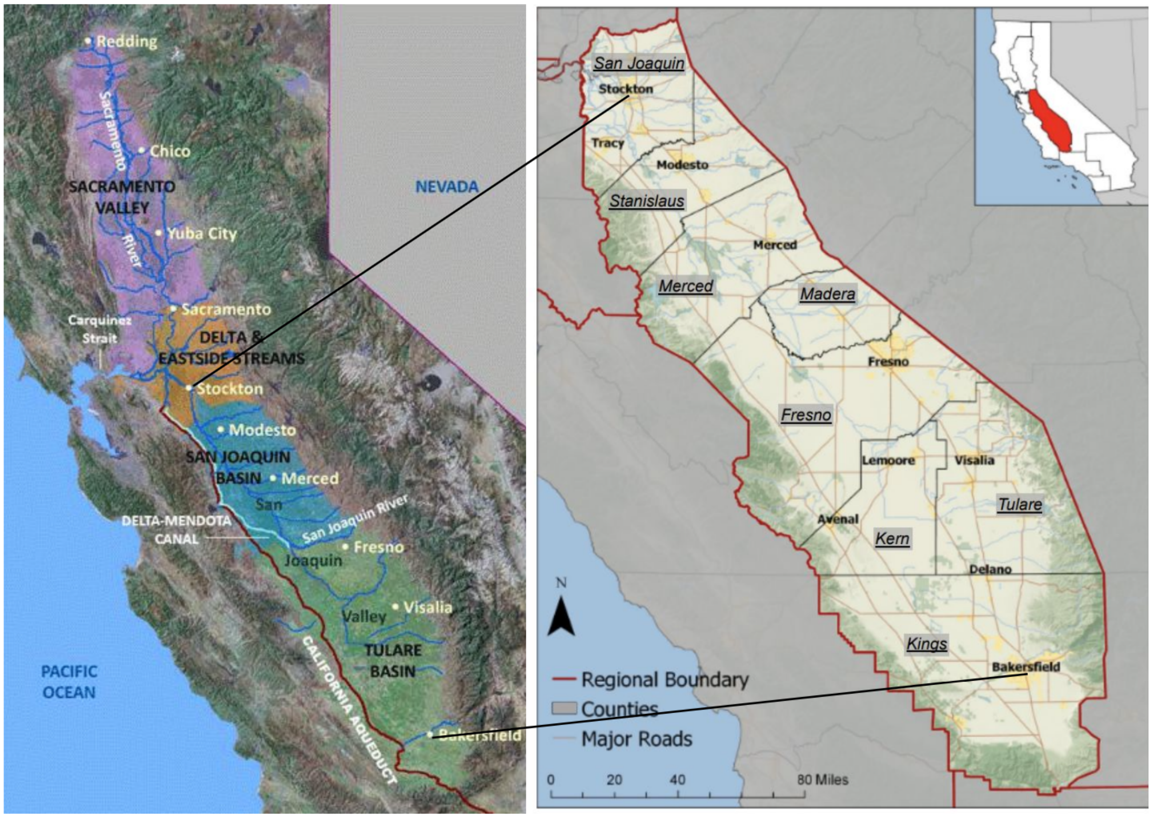
The Central Valley has experienced a long history of social injustice that led to the birth of the United Farm Workers Movement in the 1960s for agricultural workers' rights. In the 1900s, many low-income migrants moved to the San Joaquin Valley area due to the opportunity of fertile land and subsidized farming (London et al., 2018). However, they were systematically excluded from resources through redlining and violence, impoverishing minority communities of color (London et al., 2018). In 1962, the National Farm Workers Association (NFWA), now known as the United Farm Workers (UFW), was founded in Delano, California by Cesar Chávez, Dolores Huerta, and other Chicanx activists (*Latinx Resource Guide* n.d.). The group organized to support farmworker rights, such as pesticide protections (*Pesticides* n.d.), through nonviolent actions, such as marches, boycotts, and fasts, which received national attention. Eventually, their work led to renegotiated contracts with better wages and working conditions, including better hours, reduced pesticide exposure, and healthcare benefits. This led to the emergence of the Chicanx movement and fostered more inclusive activism (*Latinos In Twentieth Century California*). Unfortunately, social injustices continued in the Central Valley, leading to the further marginalization of Latinx populations.

These social injustices continue to impact current residents of the Central Valley. Decades after World War II, urban development preferentially prioritized urbanized, wealthier, and white communities, reducing investment in rural, people of color communities. This led to lower-income communities receiving fewer resources, making it harder for these areas to qualify for incorporation. As state policies formalized this injustice by overinvesting in urban areas and underinvesting in rural ones, land use designations were similarly used to keep agricultural areas rural (London et al., 2018). This model continues to be adopted in suburban growth through selective adoption of non-Disadvantaged Unincorporated Communities (DUCs) for new urban areas, depriving other communities of municipal services and leaving them at the mercy of unreliable state and federal funding (London et al., 2018). Thus, the Central Valley has been systematically underfunded and continues to be systematically disadvantaged.

Since then, the Central Valley has been a rural and agricultural area with lower-income, POC communities in the heart of California. The Central Valley is a large, flat region of roughly 20,000 square miles located in the middle of California with an average width of 50 miles and length of 400 miles from Redding to Bakersfield (*California's Central Valley*) (Figure 1). The Central Valley is surrounded by mountain ranges in all directions and is a land depression, making the area close to sea level. The Central Valley consists of four regions: the Sacramento Valley, Delta and Eastside Streams, the San Joaquin Basin, and the Tulare Basin, upon which all the proposed CCS sites are located (*California's Central Valley*). For the purpose of this thesis, the term "Central Valley" will be focused on the San Joaquin Valley which comprises the San Joaquin Basin and the Tulare Basin (Figure 2). This area consists of the following counties: San Joaquin, Stanislaus, Merced, Madera, Fresno, Tulare, Kings, and Kern (Fernandez-Bou et al., 2021). More than 90% of the land in the San Joaquin Valley is rural compared to roughly 10% of the U.S. population that lives in rural areas (Fernandez-Bou et al., 2021, p. 61). The San Joaquin Valley is home to roughly 4.3 million people (*QuickFacts: California* 2022), although these figures are inaccurate due to underestimates of the marginalized groups in this population, such as low-income African Americans, Latinx, Native Americans, and noncitizen minorities (Fernandez-Bou et al., 2021). 51% of the San Joaquin Valley's population is Latinx compared to 38% for the state as a whole (p. 61). Additionally, 55% of the population lives in census tracts that are disadvantaged and roughly a quarter of the population lives in poverty, which is 1.5 times more than the rate for the state of California (pp. 14, 60). Despite the area's poor economic standing, the Valley's average growth rate is 1.33%, resulting in a projection of 6.7 million people living in the San Joaquin Valley by 2050 (p. 14). The Central Valley's residents consist mostly of lower-income, POC communities who are employed in the agricultural sector.

Figure 2

Maps of the Central Valley and San Joaquin Valley



Sources: *California's Central Valley* and Fernandez-Bou et al., 2021

The Central Valley's communities are predominantly under-resourced Latinx agricultural workers facing worsening environmental conditions. The Valley is home to the largest number of rural, Disadvantaged Unincorporated Communities (DUCs) due to a majority of the population consisting of Latinx, migrant workers, and lower socio-economic people who work in the agricultural sector (Fernandez-Bou et al., 2021, p. 66). For instance, Kern County has one-fifth of the Valley's population but 42% of the population lives in DUCs (Flegal et al., 2013, p. 18). In the Valley, agricultural employment is one-sixth of all employment and half the state's agricultural employment, with roughly 200,000 people of whom the majority are Latinx, working in the agricultural sector (Fernandez-Bou et al., 2021, p. 60; *Agricultural Employment in California* 2021). Although the Central Valley produces 25% of the nation's food on 1% of its farmland, creating over $35 billion in farming, it continues to be one of the poorest areas in the

United States (*Our Valley* 2022; Fernandez-Bou et al., 2021). A farmworker's average annual wage was $43,613 in 2020 and almost half of the state's farmworkers had more than one job in 2016 (Fernandez-Bou et al., 2021; Martin et al., 2019). Additionally, these laborers have worsened health conditions due to long work hours, exposure to the physical elements, and limited access to healthcare facilities. Thus, they are most at risk from climate change, and implementing CCS in this area can lead to further racial and environmental justice concerns.

GIS Maps

To help with this effort as a senior thesis student embedded in this project, I researched and found data to create GIS maps to examine the relationship between the fourteen proposed CCS sites and environmental factors, including water resources, fault lines, and human population characteristics, such as census tracts and schools. Because the project was being run through the Redford Conservancy, Phillips and I together conducted online research and interviews with seismologists and environmental advocates to get their viewpoints about CCS risks and benefits, which informed the maps I made. I worked from an original dataset of CCS sites given to me by our partner environmental organizations. I added to this data by double-checking the locations on ArcGIS Pro to collect accurate addresses with coordinates. The fourteen CCS sites span the entire Central Valley from Redding in the North to Bakersfield in the South (Figure 3). I also retrieved the environmental datasets and human population datasets needed for the aforementioned analyses. Conducting spatial analyses on these sites allowed for a better understanding of CCS' impacts on environmental and societal factors in California.

Figure 3

Map of the fourteen CCS sites proposed to be built in California

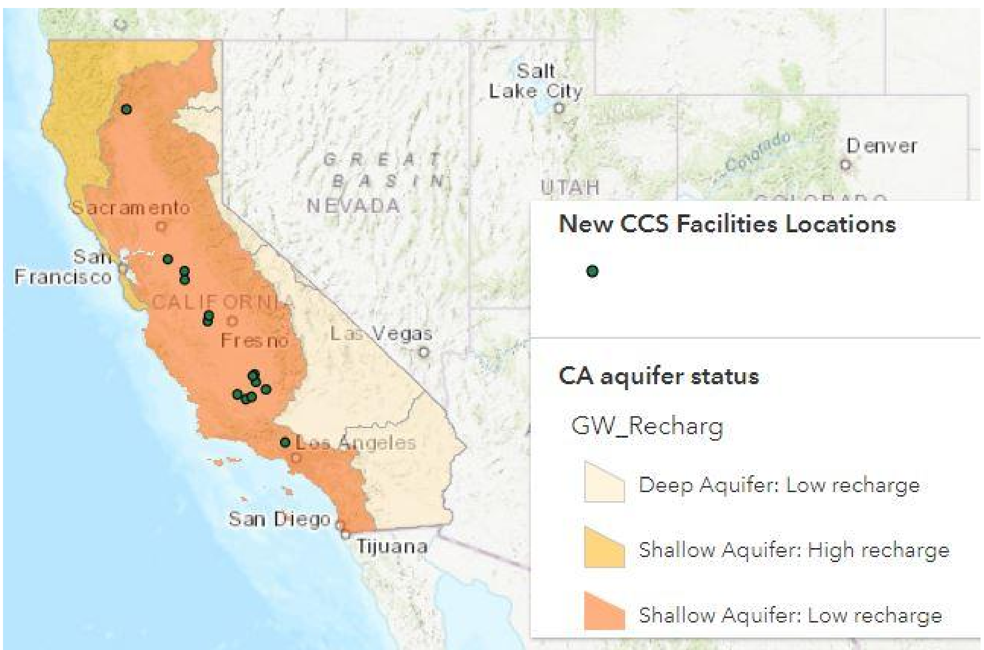
Data Source: Center for Biological Diversity, 2022

<u>Water Risk</u>

The first map I created overlaid CCS sites with aquifer status because I wanted to determine if CCS sites would endanger the existing water supply. The aquifer data consisted of three categories: deep aquifer with low recharge, shallow aquifer with high recharge, and shallow aquifer with low recharge. When mapping the CCS sites with the aquifer data, it was clear that all of the sites fell on shallow aquifers with low recharge (Figure 4). This means that because CCS requires extensive water resources to cool down CCS facilities, running CCS machines on low water levels will either maintain or further deplete the current water stores. Additionally, given California's challenges with drought and water shortage, as well as the Central Valley's low recharge aquifers, using CCS will increase the amount of time required for water levels to return to their original state. These findings are affirmed by a study that found that the Central Valley's groundwater depletion exceeds its aquifers' replenishment, causing the valley floor to lower in the process (Amos et al., 2014). Also, the 2022 IPCC report states that CCS should not be used in water scarce areas because it can increase a facility's water use by 55% (Caretta et al., 2022, p. 654; Rosa et al., 2020; Rosa et al., 2021). Thus, this map and the literature demonstrate that the Central Valley is not an ideal place for CCS due to its low water resources.

Figure 4

Map of Aquifer Status in California with CCS site locations

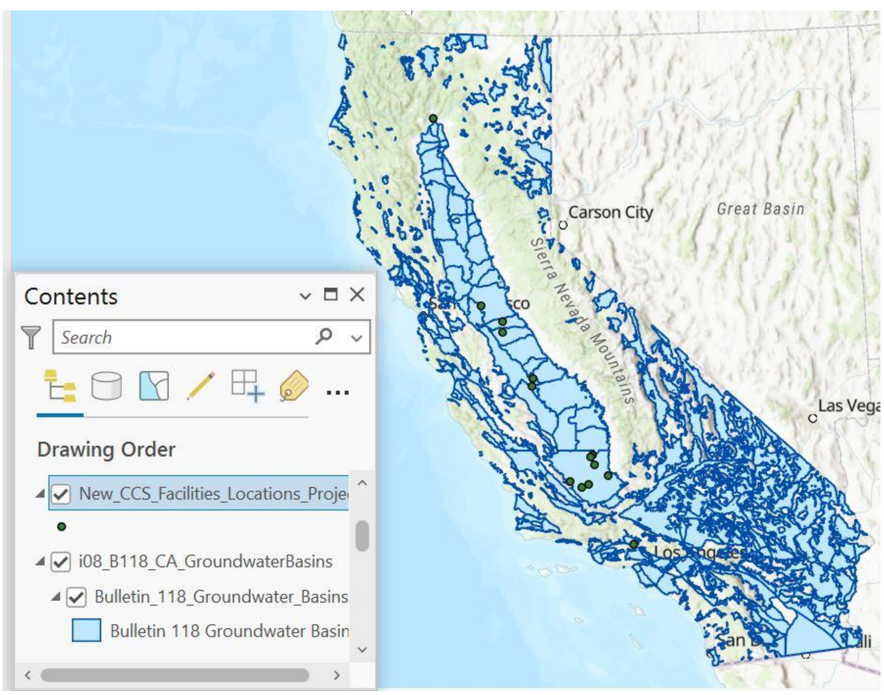


Data Source: The Nature Conservancy

Additionally, I added information about groundwater basins, groundwater well levels, and lakes to the maps, providing further information on water sources in relation to CCS sites. The groundwater basin data overlaid with CCS sites completely overlapped, meaning that all sites are located on groundwater basins (Figure 5). Figures 6 and 7 utilized my custom groundwater dataset and a California Lakes dataset and found that three projected CCS sites are located within a five-mile radius of a lake and one of these sites is also within five miles of a groundwater well (Figures 6 and 7). The placement of these sites on top of or near water sources could lead to CCS activities directly impacting groundwater quality. The aforementioned IPCC report also notes that deep injection of CO_2 into geologic formations carries the risk of polluting aquifers (Caretta et al., 2022). A study by Eldardiry & Habib (2018) confirms that accidental leakage of CO_2 during CCS' storage process could contaminate the groundwater supply (Eldardiry & Habib, 2018). These results in conjunction with the aquifer data suggest that there are minimal water resources for CCS facilities in the larger Central Valley and that there is a real risk of water depletion and contamination due to CCS use.

Figure 5

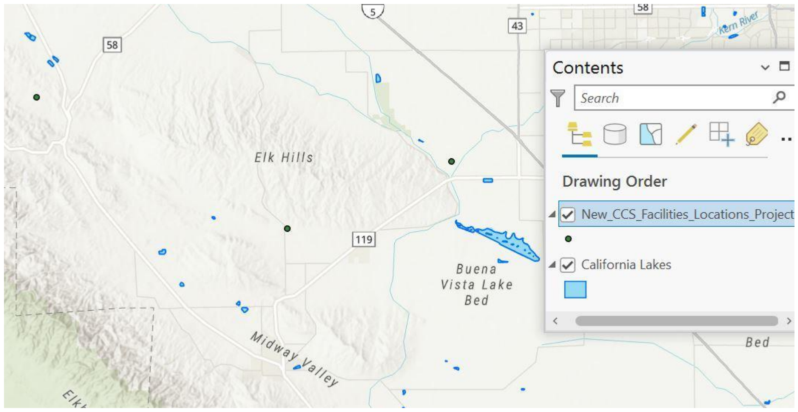
Map of groundwater basins in California with CCS site locations



Data Source: California Department of Water Resources

Figure 6

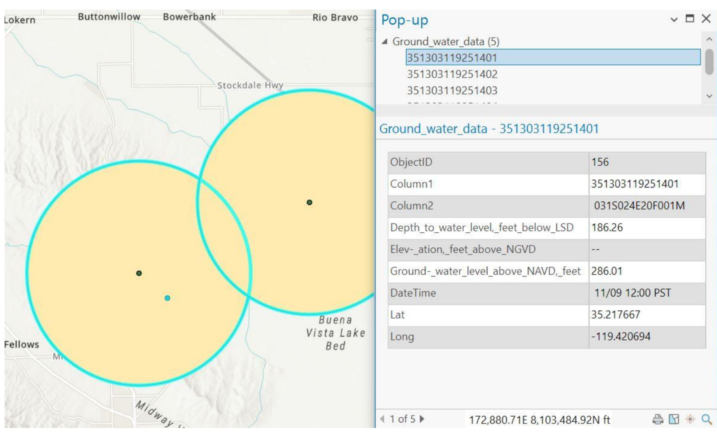
Zoomed-in map of three CCS sites within 5 miles of a lake



Data Source: California Department of Fish and Wildlife

Figure 7

Zoomed-in map of groundwater levels for site 3 with a 5-mile buffer for each CCS site



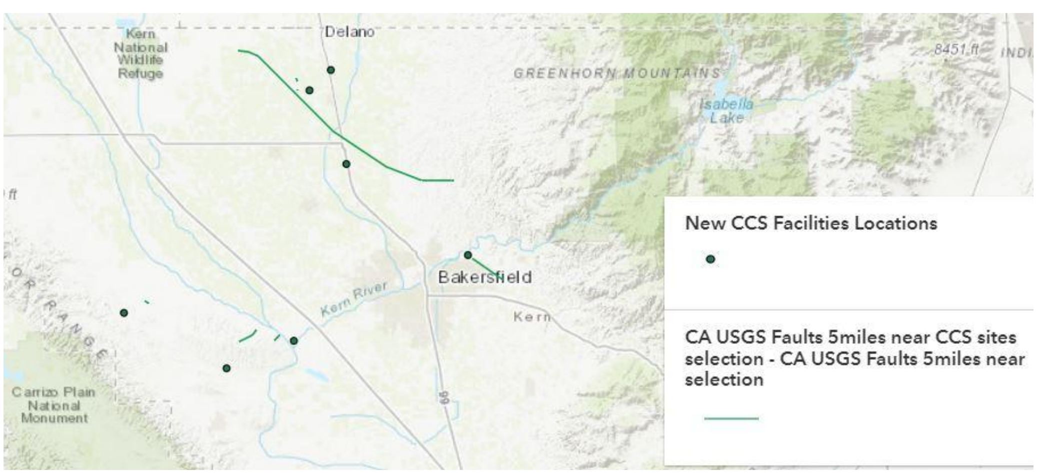
Data Source: U.S. Geological Survey

<u>Earthquake Risk</u>

The second set of maps I created overlaid CCS sites with earthquake fault lines to try to understand CCS-induced seismicity risk based on the proximity of fault lines to CCS sites. First, I found the distance of each CCS site to its nearest fault line and made a bar chart of my findings, from which Professor Susan Phillips and Professor David Robinson grouped the distances into three categories: less than one mile from a fault line, less than five miles from a fault line, and more than ten miles from a fault line. Because I had these categories and wanted to show the closest environmental impacts, I tried the one-mile radius and did not find any fault lines that close to CCS sites. Then, I moved up to the five-mile radius category and mapped CCS sites within a five mile radius of a fault line. There were eight sites near the South end of the Central Valley that had an earthquake fault line within a five mile radius of their location (Figure 8). A study by Verdon (2014) examined eleven case studies of injection-induced seismicity in the U.S. and found that the mean distance between the epicenter of the earthquake and the injection well was 5 km (or 3.11 miles) and that 99% of the induced events were within 20 km (or 12.4 miles). This study affirms induced seismicity risk and the search radius of five miles to determine this risk. These findings are corroborated by a well-known study by prominent Stanford University seismologist Mark Zoback that demonstrates a high chance that CCS will trigger earthquakes, leading to CCS-induced seismic risk (Zoback & Gorelick, 2012). The proximity of these sites to fault lines raises concern about the safety of the site placements. This map demonstrates the potential for earthquakes to occur in the Central Valley area due to CCS use.

Figure 8

Zoomed-in map of eight fault lines within 5-mile proximity of CCS sites



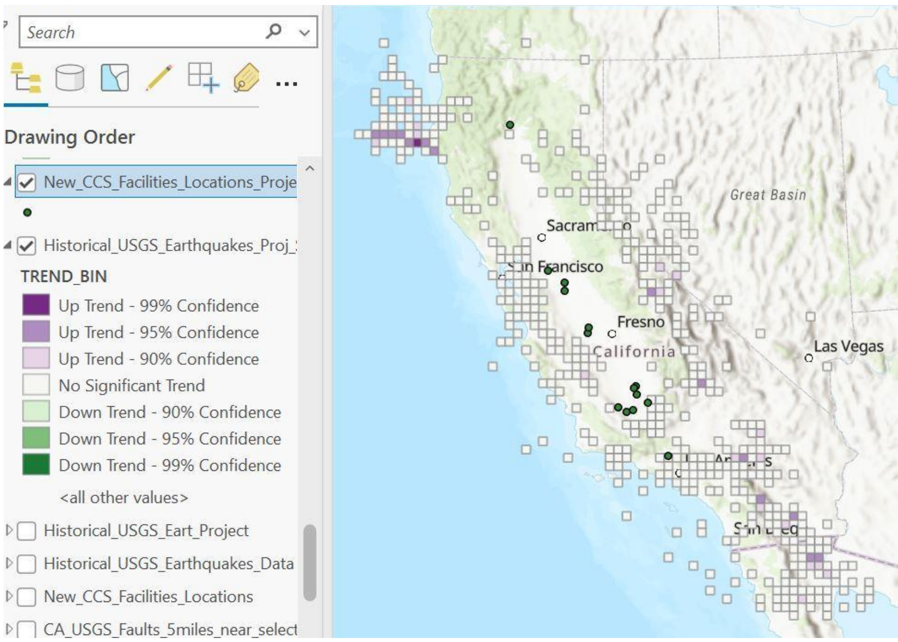
Data Source: U.S. Geological Survey

Next, I compiled a historical earthquake dataset and conducted spatial analyses to understand spatio-temporal trends of earthquakes in California. Using ArcGIS, I created a space-time cube of my data, which allows for time-series analyses that incorporate spatial and temporal patterns to create 2D and 3D visualizations. This cubic representation of my data allowed me to run a multitude of analyses, such as 2D and 3D Space Time Cube Visualizations (Figures 9 and 10), Emerging Hot Spot Analysis (Figure 11), Time Series Clustering (Figure 12), and Hot Spot Analysis (Figure 13), which provided insight into the prediction of future earthquake trends. The trend of increase from the 2D and 3D Space Time Cube visualizations shows that the Northwest, mid-East, and Southern California have had earthquake hot spots for the last few decades and will continue to have hot spots at a 99% confidence level (Figures 9 and 10). The mid-East hot spot is the closest to the CCS sites in the middle to end of the Central Valley. The Emerging Hot Spot Analysis demonstrates that the first two areas mentioned above have consecutive hot spots and all three areas have sporadic hot spots, which are also relevant to CCS sites located in the middle to end of the Central Valley (Figure 11). The Time Series Clustering reveals that there are clusters of 2-3 earthquakes completely surrounding the Central Valley and Southern California, demonstrating earthquake risk throughout the Central Valley (Figure 12). The regular Hot Spot Analysis shows hot spots in the Northwest and the Bay Area, close to CCS sites in the middle of the Central Valley (Figure 13). Based on these spatial analyses, most of the earthquakes tend to occur near the middle to the South end of the Central Valley, with general risk spread throughout the Central Valley. These predictive analyses also show future earthquakes in multiple areas of the Central Valley. Therefore, since the Central

Valley is already earthquake-prone, CCS use may have a higher chance of triggering earthquakes in this area.

Figure 9

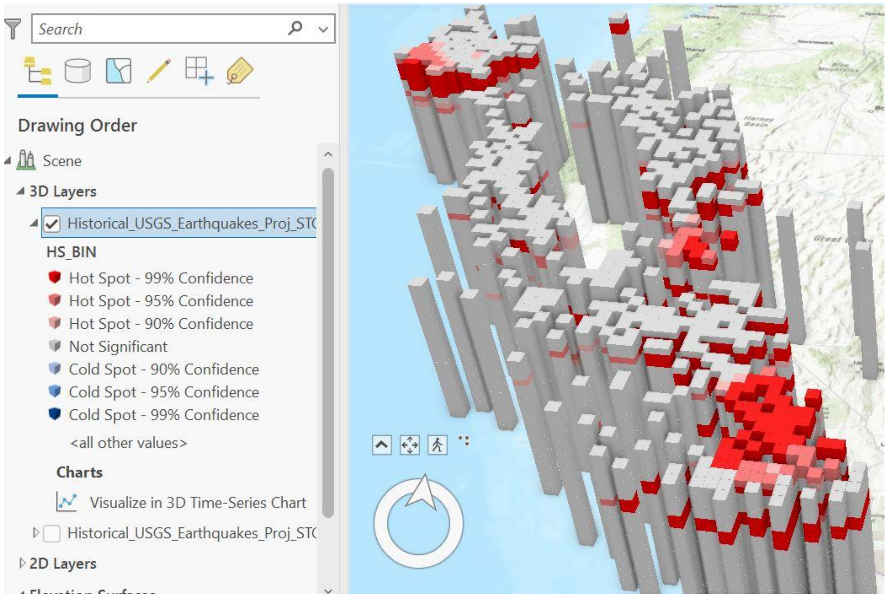
Map of Visualize Space Time Cube in 2D tool with up and down trends



Data Sources: California Department of Conservation and CalTech's Southern California Earthquake Data Center

Figure 10

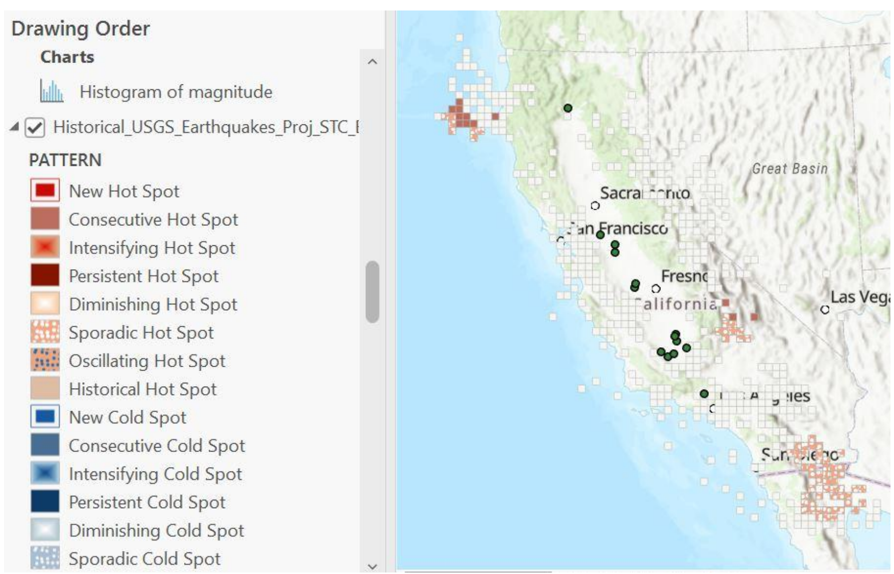
Map of Visualize Space Time Cube in 3D tool with hot and cold spot results



Data Sources: California Department of Conservation and CalTech's Southern California Earthquake Data Center

Figure 11

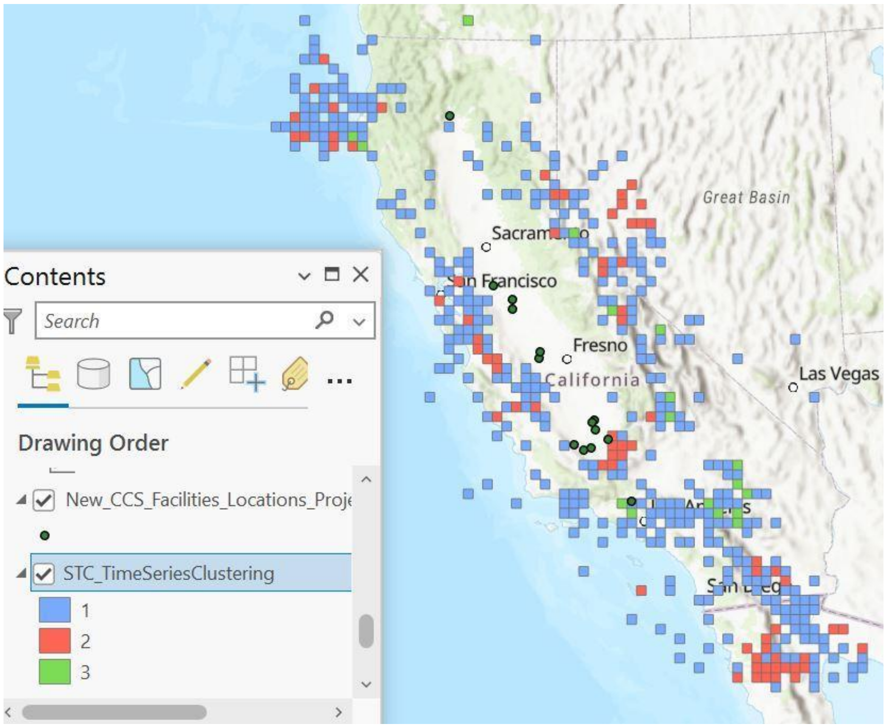
Map of Emerging Hot Spot Analysis with consecutive and sporadic hot spots



Data Sources: California Department of Conservation and CalTech's Southern California Earthquake Data Center

Figure 12

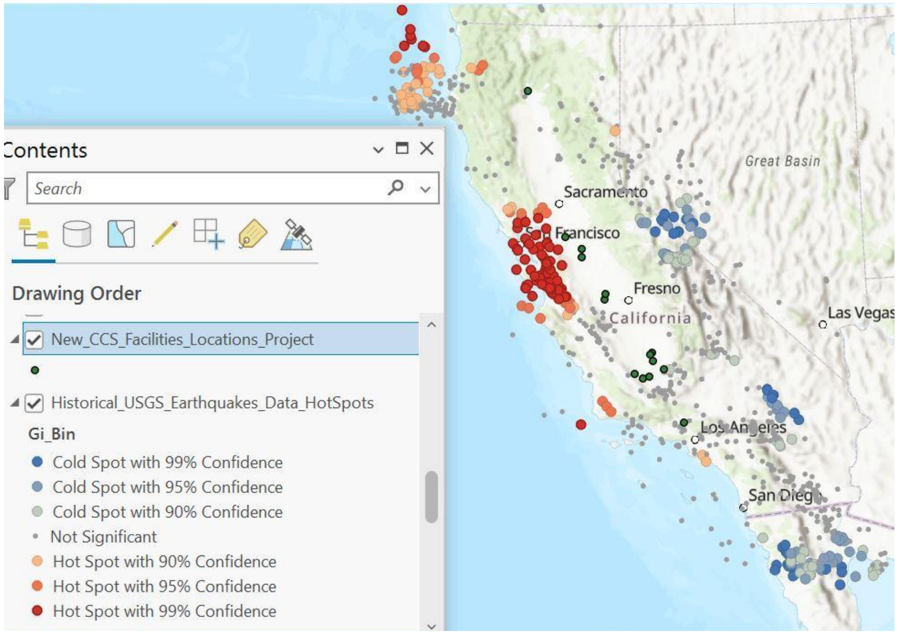
Map of Time Series Clustering with clusters of 2-3 earthquakes surrounding the Central Valley



Data Sources: California Department of Conservation and CalTech's Southern California Earthquake Data Center

Figure 13

Map of Hot Spot Analysis with hot and cold spots



Data Sources: California Department of Conservation and CalTech's Southern California Earthquake Data Center

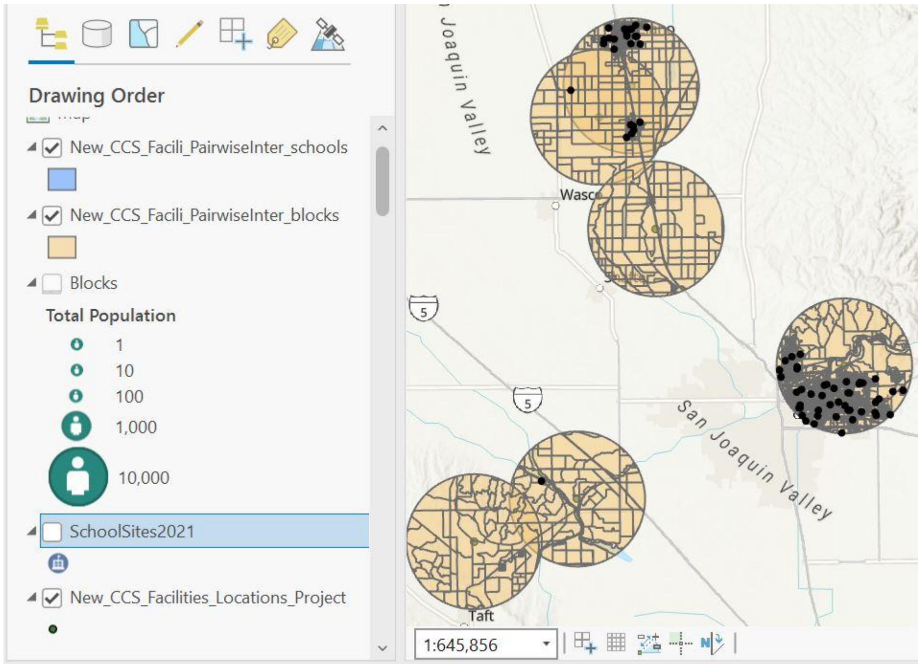
The potential for CCS technology to cause or be damaged by earthquakes is an understudied risk associated with CCS use. Given a lack of knowledge of underground fault line locations in California, in addition to minimal research on the seismic impacts of CCS, it is difficult to know how CCS-induced seismicity will occur and who it will impact. It is important to examine the earthquake risk of CCS in places like California, where earthquakes can damage CCS infrastructure, potentially leading to leaks, and where – similar to fracking – CO_2 injection can cause slippage in underground formations near fault lines. Further assessment of the correlation betweenCCS use and earthquake risk is paramount prior to increasing CCS usage in California. Lastly, low water levels increase earthquake risk, as the depletion of water lowers the Central Valley floor, consequently reducing normal stress on the San Andreas Fault and increasing the potential for an earthquake to occur (Amos et al., 2014). Thus, the combination of environmental risks in the Central Valley is compounded and can cause even more serious detriments.

Risk to Humans

Lastly, I mapped census tracts and schools in proximity to CCS sites to visualize the human populations at risk due to CCS implementation. I created buffers of a five-mile radius around each CCS site and intersected the buffer with 2020 census tract data and K-12 public school data. The results show that 12,674 census blocks live within a five-mile radius of CCS sites (Figure 14). In these communities, 283 schools intersect with the buffer, meaning that many children are within a five-mile radius of a proposed CCS site (Figure 14). Based on my research, there is a greater likelihood of people of color and low-income residents in these areas. Therefore, vulnerable populations of young children and marginalized communities are at higher risk of exposure to the environmental burdens caused by CCS use in their neighborhoods. One example of a CCS accident is a CO_2 leak from a CCS facility or its pipeline, which happened in Satartia, Mississippi. When the pipeline burst, local residents faced the most severe symptoms of CO_2 poisoning, such as nauseating dizziness, unresponsiveness, and fainting, and the community was ill-prepared to handle the disaster because they were not informed of this risk (Zegart, 2021). Ambulances and cars could not drive into the city to save people because of the lack of oxygen for fuel combustion in their vehicle's engines. The Central Valley communities that currently have fossil fuel facilities in their area are already impacted the hardest by air pollution concerns and environmental injustices, which would only be furthered with the use of CCS in their backyards.

Figure 14

Zoomed-in map of a 5-mile buffer for each CCS site with census tracts & school populations



Data Sources: U.S. Census Bureau and California Department of Education (CDE)

These maps demonstrated the tangible environmental risks of CCS use in the Central Valley and the disproportionately impacted communities it would harm. The water risk maps show the potential for CCS sites to deplete aquifers and contaminate groundwater since the sites are directly located on these water bodies or are in close proximity to them. The earthquake risk maps highlight eight CCS sites within five miles of a fault line, demonstrating the research-based and factual concern of CCS-induced seismicity in the Central Valley. The additional spatial analyses add to this finding by visualizing historical and future earthquake trends which cluster around the middle to the end of the Central Valley, narrowing the likely spatial scope of this threat. Since the environmental justice implications and environmental effects of CCS are largely undetermined, the creation of these GIS maps is one contribution to the environmental field that can educate both environmentalists and the general public about CCS-based environmental concerns.

Analysis: CCS as Environmental Injustice in the Central Valley

If the adverse effects of CCS — such as worsened air pollution, increased seismic risk, and reduced water levels — are not addressed, CCS implementation in the Central Valley will add to environmental injustice in the region. The U.S. Environmental Protection Agency (EPA) defines environmental justice as “the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies” (*Environmental Justice* 2023). CCS becomes an environmental justice concern in the Central Valley when considering the region’s disproportionately impacted communities that will only suffer more as a result of CCS implementation. Based on CalEnviroScreen 4.0, a percentile rating of environmental pollutants in California communities, the Central Valley composes a majority of the highest scores in the 80th-100th percentile (2022). Because the top 25% of worst scores indicate disadvantaged areas, this ranking indicates that the Central Valley is home to some of the state’s worst pollution and most disadvantaged communities. 55% of the Central Valley’s population lives in a disadvantaged community (Fernandez-Bou et al., 2021, p. 7). Thus, these communities are already facing environmental injustices that would only be exacerbated with CCS use.

One such injustice CCS will intensify is worsened public health for Central Valley communities. An article by White (2020) states that the public health crisis in the Central Valley is a high priority. As the valley traps smog, the physical and human-induced features of this area contribute to high levels of pollution and respiratory illnesses. Increased proximity to factories in the Central Valley, with the addition of CCS facilities, makes these communities more vulnerable to air pollution. Unfortunately, placing factories in rural, lower-income areas is often thought of as having a less severe impact on the state's overall population, disproportionately impacting disadvantaged communities. Thus, CCS will widen the health gap that disproportionately impacts rural, lower-income, and predominantly POC communities as opposed to urbanized, affluent, and white communities, in addition to furthering other environmental injustices (White, 2020).

The racially-determined factors that led to low-income, Latinx communities living in the Central Valley left these communities more vulnerable to environmental issues. The current locale of these communities is in part due to historically racist policies such as redlining and the current state-wide housing crisis that have already led to marginalized, low-income communities having to live close to polluting facilities (Tobias, 2022; Bell & Ebisu, 2012). This automatically increases their exposure to air pollutants and puts them at a higher seismic risk due to closer proximity to the CCS sites, from which they are not equipped to build back since they do not have access to many resources. A lack of affordable, safe housing, will further jeopardize these communities and exacerbate environmental risks. Additionally, a second outcome of these communities' predominately unincorporated status and location is that many of the residents are farmers, and water is a necessary component of their work in agriculture. Thus, reduced water access due to CCS could jeopardize their livelihoods. Due to the variety of environmental justice concerns, it is essential to ascertain the full extent of the environmental impacts of CCS on residents in the Central Valley, and to prevent these injustices from occurring.

An equitable path forward for the Central Valley would be the just transition. Through this framework, energy would be produced and distributed equitably and reparations would be made to communities that were previously harmed by environmental injustices, such as those in the Central Valley. Prioritizing a future without fossil fuels (McCauley & Heffron, 2018) and promoting equity requires stopping the implementation of CCS, especially in such close proximity to marginalized communities. As fossil fuel plants are phased out, the just transition also calls for green jobs with improved health conditions (Mascarenhas-Swan, 2017) which could be created by training workers to build sustainable energy infrastructure (Healy & Barry, 2017), such as solar panels. Implementing nature-based carbon capture, renewable energy, and localizing energy and sustainable solutions will improve environmental and societal health.

Chapter 2. Policy Analysis and Recommended Solutions

Analyzing the CARB Scoping Plan and SB 905 can provide insight into the concerns that environmental groups raise regarding CCS, and the legislative actions that would be necessary to address these concerns. Despite claims made by CARB, The CARB Scoping Plan clearly supports CCS and fails to address Nature-Based Solutions. Thus, the pipeline moratorium that resulted from SB 905 is an important example of policymaking that reflects community input and cautionary science. Environmental groups continue to advocate for Nature-Based Solutions, just renewable energy investment, and localized solutions.

CARB Scoping Plan and SB 905 Background and Analysis

After months of organizing and working to remove CCS reliance on the CARB Scoping Plan, Marie Choi from APEN summarized the wins and losses of their efforts. APEN got wins for goals to reduce VMT and invest more in mass transit and housing. However, when it came to CCS, the CARB did not budge on its Scoping Plan. Environmental groups were aware of the opposition against them, especially considering the senior staff person at CARB who was trying to reverse the pipeline moratorium and acted as an important author of the 2022 Scoping Plan. Instead, APEN took the Scoping Plan as an opportunity to build consensus among their communities and legislature against CCS use. Through their collective organizing, these environmental groups compelled the passing of the pipeline moratorium in 2022 and a ban on CCS for EOR in California, also known as SB 905.

2022 CARB Scoping Plan

The California Air Resources Board's (CARB) 2022 Scoping Plan is a roadmap for achieving carbon neutrality by 2045 and the state's climate targets through the utilization of technology in a cost-effective and equitable manner (*2022 Scoping Plan For Achieving Carbon Neutrality* 2022). The plan aims to decarbonize every sector via reducing fossil fuel dependence and enhancing natural and working lands (forests, shrublands/chaparral, croplands, wetlands, and other lands) as natural carbon sinks. However, the plan supports Carbon Capture Storage, a fossil fuel industry backed option, as a key climate mitigation strategy.

The Scoping Plan fully supports CCS implementation, contradictory to their claims to support Nature-Based Solutions. The Plan notes that California is "well-positioned" for CCS because there are only a few places on the West Coast for large scale geologic storage (*2022 Scoping Plan For Achieving Carbon Neutrality* 2022, p. 217). In particular, the Plan mentions that the Central Valley's deep sedimentary rock formations are "world-class" sites for CCS that have the potential to store at least 17 billion tons of CO2 (p. 85). It also calls for CCS to decarbonize petroleum refineries that will supply fuel for legacy vehicles and other applications. However, the plan admits that the modeling for the storage capacity and deployment of CCS facilities is uncertain due to the large size and complexity of California's refineries (p. 87). CARB also notes the overall model uncertainty due to the varied number of factors involved and calls for continued monitoring in order to determine whether projected reductions will be achieved which, based on historical case studies, will not occur. Additionally, the plan notes that CCS is the only option for cement facility emission reductions by 40% from 2019 levels in line with SB 596 instead of calling for alternative building materials or the phase out of concrete production (p. 86).

Particular to environmental and health impacts, the Scoping Plan notes these concerns and cites appropriate studies, but continues to support CCS deployment. The Environmental Justice Advisory Committee noted negative health and air quality impacts from CCS facilities that emit other greenhouse gasses, the potential for leaks, and questioned the viability of CCS (*2022 Scoping Plan For Achieving Carbon Neutrality* 2022, p. 89). The EJ Advisory Committee also brought up the need for CCS to not be used as a substitute for on-site carbon removal strategies and a delay tactic to postpone fossil fuel phase out. In response to these concerns, CARB claims to work with a varied group of stakeholders, including community residents, and hosted a CCS Symposium where they heard feedback, but does not mention how this was used to change the Scoping Plan, as it was not changed. The Plan also cites the Council of Environmental Quality (CEQ) as a source that has recommended further study of the air pollution impacts from CCS retrofits at industrial facilities, but does not address conducting a quantitative evaluation. Instead it counters the CEQ's study by citing a Stanford University study, which publishes the opposite results and concludes with the option to explore potential outcomes (p. 89). Though the Scoping Plan mentions the need to analyze criteria air pollutants associated with CCS, the report makes little mention of high water and energy demands or earthquake risk, which are the other environmental risks with CCS use. Instead, the end of the report concludes that CCS is a "safe and reliable tool" for carbon removal (p. 228).

The Scoping Plan aims to continue relying on CCS to achieve carbon neutrality, despite suggestions to wait, in line with ongoing funding for this technology. Many scientists and environmental advocates, such as those from APEN and CBD, suggest waiting to implement CCS until it is truly necessary and is safer to deploy (Robertson et al., 2022). Additionally, while Governor Newsom requested that CARB set a CO_2 sequestration target of 20 MMT for

2030 and 100 MMT for 2045, Newsom specifically prioritized sequestration in Natural and Working Lands which is not apparent in the Scoping Plan. According to the Plan, more than 50% of global CCS facilities are in the United States due to continued governmental assistance for manufacturing (*2022 Scoping Plan For Achieving Carbon Neutrality* 2022, p. 85) and this is only furthered by the federal 45Q tax credit for CCS. This credit was recently increased by the Inflation Reduction Act (IRA) to $85 per metric ton of CO_2 captured and stored in geologic formations with $180 per metric ton for Direct Air Capture (DAC). This support is also reflected in the previously passed legislation, namely the Infrastructure Investment and Jobs Act of 2021 which included $9 billion in CCS support. Additionally, the U.S. Department of Energy also provided financing for DAC in March 2020 and March 2021. Due to extensive funding for CCS, the need to research, recommend, and deploy CCS is increasing, especially through CARB's 2022 Scoping Plan.

The Plan even mentions other alternative choices with Nature-based Solutions, but concludes with a choice that relies on CCS. The draft Scoping Plan originally had four Natural and Working Lands (NWL) alternatives. The Plan mentions that in writing these alternatives "CARB staff aligned the scenarios with both the landscape types and actions identified in … Governor Newsom's Executive Order N-82-20 (e.g., California's Climate Smart Strategy and Pathways to 30x30)" (*2022 Scoping Plan For Achieving Carbon Neutrality* 2022, p. 67). However, this was not done to the furthest extent possible. The first alternative was the most environmentally friendly and least CCS dependent. Alternative 1 prioritized land management for forests and improved climate-smart agricultural practices (p. 44). This goal would be the most ideal for the Central Valley. For this choice, the Scoping Plan only modeled seven of the eight categories identified in California's Natural and Working Lands Climate Smart Strategy, excluding seagrasses and seaweeds. This is unfortunate as the ocean is a large natural carbon sink and choosing not to model this variable could have drastically reduced the amount of predicted natural CO_2 storage. The plan blatantly states that natural management options were only modeled if they were determined to be feasible by previous research conducted by the State of California. This stipulation clearly reduces the ability for new, innovative strategies to be included in the plan, even though the full potential of Nature-based Solutions has not yet been discovered (Fargione et al., 2018). The chosen alternative, Alternative 3, focuses on long-term restoration of ecosystems to improve climate resiliency by building up stable carbon stocks. In this scenario, stable solutions ironically include CCS. Thus, CARB is engaging in risk minimization because there is not enough research to support the claim for CCS' stability or to adequately quantify its impacts. Although Alternative 3 was demonstrated to sequester more carbon than Alternative 1, the Plan itself mentioned that if they had included additional climate smart management practices and land use change areas, more carbon could be stored through NWL, specifically in soils and oceans, beyond what they had modeled (*2022 Scoping Plan For Achieving Carbon Neutrality* 2022, pp. 68, 248). Thus, the model was not accurate, and actually underrepresented the natural storage capacity of NWL in California, biasing the selection towards Alternative 3. Another cited concern in the Scoping Plan with Alternative 1 was that it focused on short-term goals. However, Alternative 1 could have been implemented alongside another alternative, such as Alternative 3, in order to achieve both short and long term goals. And, if the concern with Alternative 1 was its short-term scope, then there is equal cause for concern with Alternative 3 as it is solely focused on long-term goals and would hinder action on current issues. Lastly, the Plan mentioned that during the future development of policies, CARB and partnering legislative bodies will continue to research the technologies and their costs before a more comprehensive evaluation is conducted with stakeholders, implying that the current research is incomplete (p. 98). Therefore, the CARB Scoping Plan selectively chooses Alternative 3 and tecno-optimistically prioritizes CCS implementation without adequate considerations, modeling, or information gathering.

SB 905

California Senate Bill 905 establishes development, evaluation, review, study, and consultation regarding multiple forms of carbon capture, including CCS (Caballero, 2022). It outlaws the use of CCS for Enhanced Oil Recovery and temporarily prohibits pipeline transfer of carbon in California until federal CO_2 pipeline safety requirements are updated by the U.S. Department of Transportation's Pipelines and Hazardous Materials Safety Administration (PHMSA). This bill has suspended currently proposed CCS projects, and encouraged facilities to inject CO_2 directly under their properties if geologically possible. SB 905 also requires project developers to create monitoring plans to mitigate adverse health and environmental impacts at the carbon capture site (*2022 Scoping Plan For Achieving Carbon Neutrality* 2022, p. 219), where the environmental risks include potential water pollution and seismic impacts.

SB 905 also lists provisions for the development of the Carbon Capture Removal, Utilization, and Storage Program in California. CARB's Industrial Strategies Division is the responsible for developing CCS regulations per SB 905. In particular, the main goal of SB 905 is to evaluate the safety and efficacy of CCS in general and specifically CO_2 transfer via pipelines for CCS (*2022 Scoping Plan For Achieving Carbon Neutrality* 2022, p. 218). The bill also requires a technology review of viable CCUS and Carbon Dioxide Reduction (CDR) methods to monitor and evaluate their safety and efficacy, the development of a unified permit application, and the establishment of reporting requirements (e.g. safety, financial security, etc.) (p. 218). Additionally, SB 905 mentions the need to create a public database for project statuses, which would be extremely beneficial for environmental groups and individuals interested in tracking project progress (p. 218). It also calls for the formation of a Geologic Carbon Sequestration Group to identify suitable well locations, monitor subsurface activity, and report potential hazards on-site to halt injection (Caballero, 2022). In addition to technological and geological review, the bill also works to ensure site safety and stability by requiring site-specific monitoring and reporting, acknowledging the differences present at each site that require varied studies and reporting. Lastly, the bill tasks the California Natural Resources Agency (CNRA) with providing a framework for the state that includes standards for the design, operation, siting, and maintenance of intrastate CO_2 pipelines to reduce public health and environmental risk (*2022 Scoping Plan For Achieving Carbon Neutrality* 2022, p. 219). Given the example of Satartia, it is crucial that California's state departments and agencies set a good precedent for CCS governance by taking the appropriate amount of time and conducting enough studies to develop and administer robust CO_2 pipeline safety standards.

Nature-Based Solutions (NbS)

Environmental groups organizing against the CARB Scoping Plan in the Fall of 2022 were working to push CARB towards Nature-Based Solutions instead of mechanical ones, such as CCS. This is especially relevant because Governor Newsom recently signed Executive Order N-82-20 in 2020 (*Executive Order N-82-20* 2020). This legislation expanded Nature-based Solutions and increased the restoration of landscapes in line with the state's climate and public service goals, leading to the development of the Natural and Working Lands Climate Smart

Strategy (*Natural And Working Lands Climate Smart Strategy* 2022). Additionally, N-82-20 led to the development of "Pathways to 30x30," which are targets designed by the CNRA to help California achieve a 30% conservation of state land and water sources (*Draft 30x30 Conservation Target* 2021). It was created to complement the Natural and Working Lands Climate Smart Strategy and focuses on the conservation goals of N-82-20. Thus, despite adequate state support for NbS and the preservation of natural lands, the CARB Scoping Plan failed to comprehensively include natural carbon capture in their plan. Environmental groups made efforts to bring attention to these weaknesses in CARB's Scoping Plan in hopes of aligning the Plan more towards their shared goals with the state for natural climate solutions.

Ironically the Implementation section of the Scoping Plan mentions that climate action in NWL sectors leads to many environmental benefits, without actually delineating how to implement these practices. The Plan even provides specific guidelines for the agricultural industry, and explores pathways for decreasing pesticide and fertilizer use in order to improve air quality and public health. Additionally, the Plan states that increasing healthy soil and organic agriculture "will require continued and sustained implementation by private industry and public agencies" (*2022 Scoping Plan For Achieving Carbon Neutrality* 2022, p. 99). Therefore, it is evident that CARB is aware of the climate action that needs to be taken, but chooses to propose greenwashed technological solutions (e.g., CCS and BECCS) instead.

Environmental groups argue for nature-based carbon capture and storage through land use changes, which is a healthier alternative to CCS that is much easier to implement. Avoiding using land for construction and industrial warehouses and instead prioritizing natural landscapes full of native plants, trees, and wetlands acts as a natural carbon sink and improves ecosystem biodiversity. The CNRA states on its website that California's lands are "a critical yet underutilized sector" to sequester carbon (*Expanding Nature-Based Solutions* 2022). Transforming our landscape from the ground up will protect society by increasing ecosystem and community resiliency in the face of the worsening impacts of climate change. For example, climate smart management of wetlands, riparian areas, and forests reduces risks of flooding, soil erosion, and wildfires, thus better protecting vulnerable communities and increasing the number of green jobs to restore these lands (*Natural And Working Lands Climate Smart Strategy* 2022). Additionally, these practices restore these areas back to their historic environments, support cultural Indigenous traditions, and provide increased access to green space. In comparison, the current urban landscape consists of large building developments and facilities, leading to the release of more greenhouse gases, contributing to economic and health inequities, and increasing vulnerability to the risks of climate change.

To bring these benefits to California, Governor Newsom signed EO N-82-20 which led to the creation of the Natural and Working Lands Climate Smart Strategy (*Natural And Working Lands Climate Smart Strategy* 2022). This strategy will support climate action in natural and working lands by outlining how management of these lands can be improved by identifying higher priority solutions and understanding regional natural solutions. Through these measures, these solutions can be scaled to meet California's needs. The plan divides California into eight types of natural resources with specific recommendations for each land type: Forests, Shrublands & Chaparral, Developed Lands, Wetlands, Seagrasses & Seaweeds, Croplands, Grasslands, And Sparsely Vegetated Lands (*Natural And Working Lands Climate Smart Strategy* 2022). The strategy also summarizes eight unique climatic regions, details the land use of these areas, and demonstrates how community input can shape regional solutions. In relation to the San Joaquin Valley region, a majority of the land is cropland. The recommendations for cropland include better soil health practices, improved nutrient and water use efficiency, and repurposing unused land to provide environmental and climate resiliency benefits such as flood control (*Natural And Working Lands Climate Smart Strategy* 2022). Specifically, because water is a limited resource in this area, the strategy focuses on increasing management of groundwater recharge and capturing rain and storm runoff to increase aquifer levels and maintain drought resilience. In regards to farming, the plan proposes regenerative agricultural practices to reduce waste, planting local, cultural foods, and improving sustainable integrated pest management (*Natural And Working Lands Climate Smart Strategy* 2022). These practices would remedy some of the environmental issues currently faced in the Central Valley that would be exacerbated by the deployment of CCS, such as reduced groundwater levels, groundwater contamination, increased GHG emissions, and excessive energy use. Therefore, policies and plans such as these will benefit California's climate and population more quickly, efficiently, and sustainably using fewer resources when compared to mechanical solutions such as CCS.

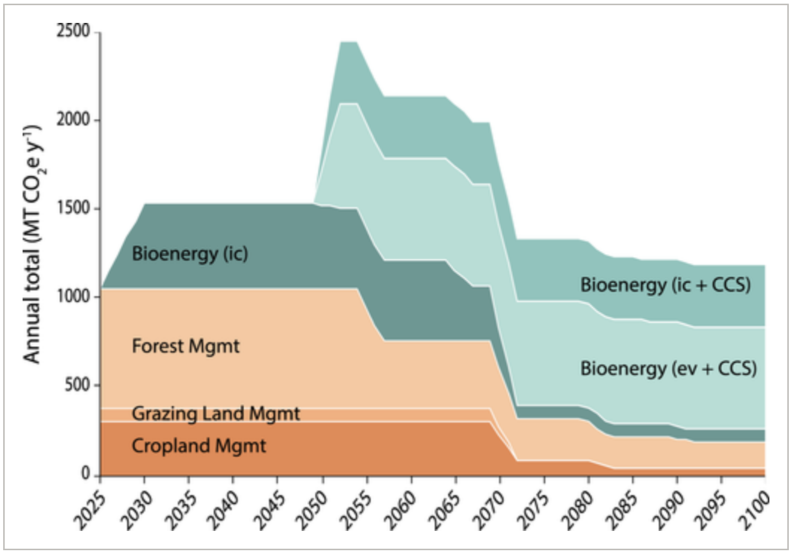
Additional studies have shown the immediate effectiveness of land-based mitigation compared to bioenergy and CCS and the nature-based co-benefits of these options. Gvein et al. conducted a study on the climate change mitigation potential of the largest Carbon Dioxide Reduction (CDR) measures: Bioenergy with CCS (BECCS), Afforestation (AF), and Natural Vegetation Regrowth (NR) (2023). They found that aside from reducing fossil fuel emissions, the most cost-effective option with the greatest benefits to nature for climate change mitigation was regrowth of natural vegetation and that afforestation can also help when appropriately implemented. The study concluded that a greater investment in infrastructure and transformative technological progress would be needed to achieve greater mitigation through BECCS. Another study by Han & Chen (2022) shows that Nature-based Solutions can completely offset the impacts of land urbanization, and that it is critical to employ region-specific NbS. This study confirms the Gvein et al. study by affirming the benefits of reforestation as the most effective NbS. Additionally, the IPCC also notes the importance of land use changes to reduce the impacts of climate change. The IPCC Special Report on Climate Change and Land modeled pathways for limiting global warming under 1.5º- 2°C and found with high confidence that all options require land-based mitigation and land-use change, such as reforestation, afforestation, reduced deforestation, and bioenergy (Shukla et al., 2019). However, later in this section, the report counters its claim on the reliance on bioenergy by stating that "the inclusion of additional response options in models could reduce the projected need for bioenergy or CDR that increases the demand for land" (p. 23). Therefore, improved models that incorporate other natural solutions would reduce the need for bioenergy in supporting climate mitigation. The report also determined that land-related responses, such as the ones listed above, provide additional benefits, including mitigating desertification and land degradation while strengthening food security and reversing the negative effects of climate change. Therefore, sustainable, natural solutions such as land use changes are a superior alternative to CCS due to their reliability, cost-effectiveness, extra benefits, and ability to time-sensitively address climate change.

The largest counter argument to Nature-based Solutions is that they have limits and cannot achieve the necessary reductions. To the first point, it is true that natural carbon sinks have limits, but the capacities of these sources have not yet been filled. A study by Robertson et al. (2022) focused on cropland, grazing land, and forest management as NbS for climate mitigation and emphasizes the greater value of combining natural and BECCS/CCS solutions. In regards to annual mitigation potentials, the aforementioned nature-based categories sequester larger amounts of carbon and greenhouse gases compared to bioenergy and CCS up till at least

2050, at which point the study assumes CCS would be available for implementation (Robertson et al., 2022) (Figure 15). Scientists are unsure when natural sinks would become fully saturated, although they would approach this stage in a more gradual manner than in Figure 15 and would take at least until 2100 (Robertson et al., 2022). This shows that our focus should be on natural sequestration as it is most viable and effective at this time, especially since the current status of bioenergy and CCS can pose significant environmental risks (Robertson et al., 2022). Another study by Fargione et al. found a maximum potential for Natural Climate Solutions (NCS) to sequester 1.2 (0.9 to 1.6) Pg CO_2e year^{-1}, which is roughly one-fifth of current net annual emissions of the United States (2018). They looked at 21 NCS categories and found that increased plant biomass carbon sequestration (63%), soil carbon sequestration (29%), and avoiding CH_4 and N_2O emissions (7%) are the best natural strategies for climate mitigation. At the price point of $100 per Mg CO_2e, 1.1 Pg CO_2e year^{-1} are available, meeting the United States' Nationally Determined Contribution under the Paris Agreement (Fargione et al., 2018). Essentially, through NCS alone, the U.S. can meet our climate promises and reduce GHG emissions by 26 to 28% compared to 2005 levels. Therefore, there is no current need to rely on non-natural climate solutions to mitigate climate change because existing NCS can provide adequate carbon sequestration to meet the country's climate goals.

Figure 15

Annual mitigation potentials till 2100 for different Nature-based Solutions and mechanical solutions



Source: Robertson et al., 2022

Just Renewable Energy Investment

In terms of policy changes, sweeping strides can be made at the gubernatorial level to support the transition to clean, renewable energy (Newell & Mulvaney, 2013). For example, California's influential pro-environment voter population and policymaker preferences alongside funded research has led to the state becoming a leader in climate change and energy policies (Mazmanian et al., 2019). The passage of AB 32 in 2006 became and still is the only state-level mandate for a thorough, economy-wide reduction of GHG emissions and regulated transition to renewable energy production (Mazmanian et al., 2019). Over time, these policies have become more ambitious, with SB100 in 2018 increasing California's Renewable Portfolio Standard (RPS) to 100% renewable electricity generation by 2045 and Executive Order N-79-20 in 2020 making 100% of in-state sales of new passenger cars and trucks zero-emission by 2035 (Mazmanian et al., 2019; Executive Order N-79-20, 2020). Therefore, California is a great place to implement the just transition and innovative energy reductions, as the state continues to pass progressive environmental regulations.

A just transition would provide clean energy to the grid (Healy & Barry, 2017), diversify energy production and resiliency (Wang & Lo, 2021; Fedorova et al., 2019), and create green jobs in the process of reducing emissions (Mascarenhas-Swan, 2017; Healy & Barry, 2017). On the other hand, CCS would put a tremendous strain on the energy grid due to its exorbitant energy use, which is estimated to require over one-third of current energy production in the state (Mahone et al., 2020). Thus, to ensure sustainable energy and a just transition, the state of California needs to invest more resources into renewable energy development and deployment for all communities. It is important that justice is considered in this process in order to relieve the extra burdens that frontline communities face due to an increasingly expensive energy system. Low-income, marginalized households should receive a stipend or subsidy to support their transition to renewable energy (e.g., increased access to electric vehicles (EV) or home solar panels). Increasing community access to clean energy helps alleviate the consequences of historically extractive practices. Additionally, the decentralization of energy production and storage will diversify the energy grid and reduce the number and duration of state-wide blackouts, thereby increasing energy resilience in California. Lastly, to truly encourage residents to make the switch to clean cars and sustainable energy systems, the state of California needs to set an example by making sizeable investments in green infrastructure. This infrastructure refers not only to physical contributions such as EV charging stations and subsidies for solar panel installations on homes, but also social infrastructure or training to help workers transition into green jobs. The process of reaching California's climate goals and rebuilding our energy system will be laborious and is estimated to create one million new jobs from 2021-2030 (*Equitable*

Transition n.d.). Therefore, the state should invest in creating low-cost training programs that will prepare individuals who want to transition to or start a new career in the clean energy industry. Through these steps, California can forge a path towards a sustainable energy future and uplift marginalized communities along the way.

Achieving a just transition has not been a priority in the state's energy plans, such as the 2022 CARB Scoping Plan. As the country and state transition their energy production and supply, they must also consider that alongside a just transition, measures must be taken to reduce energy usage and improve current energy systems. Part of a just transition includes a timeline for reductions in overall energy usage and emissions (York & Bell, 2019). This requires identifying feasible reduction actions in each sector and working with industry leaders to ensure that this transition occurs over time. While working towards the desired final outcome of a just transition to a clean energy world, two other stages of justice can be implemented in today's fossil fuel-based economy (Hazrati, 2021). The first step consists of applying energy justice to identify and reduce injustices caused by the oil and gas industry. The second phase involves beginning fair energy transitions toward a just transition, as mentioned earlier. In this way, efforts to achieve energy justice can begin sooner rather than later and become standardized within the energy industry as a just transition is enacted.

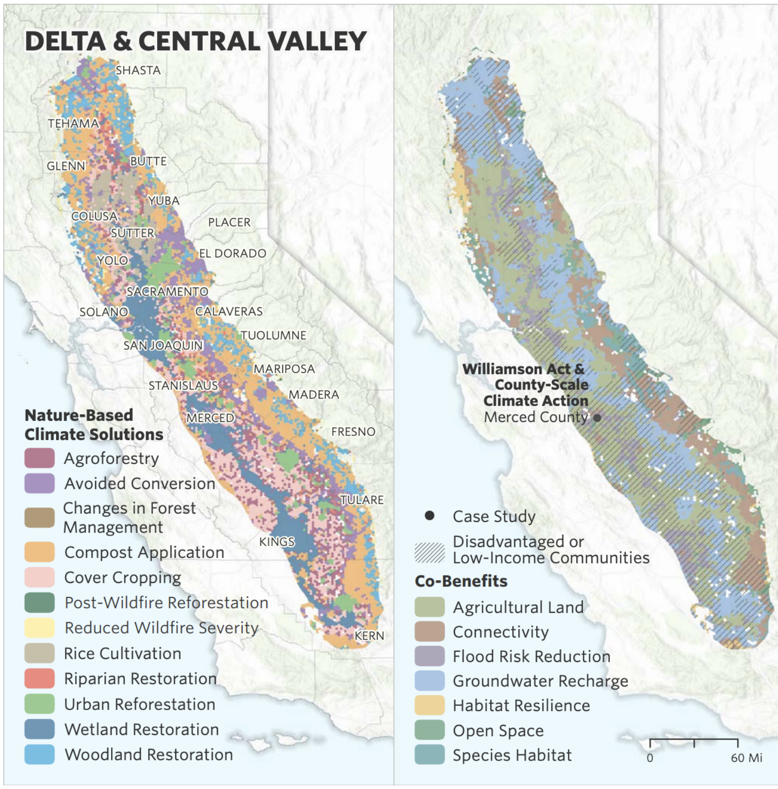
Local Solutions

Building on the idea of Nature-based Solutions, it is also critical that these solutions are localized and adapted to the Central Valley. As mentioned, the Central Valley is an agricultural powerhouse, so solutions that support the environment and the people's livelihoods as farmers and agricultural workers would provide the best benefits. Investment in regional sustainable practices must ensure that environmental justice and community leadership are prioritized in the process of implementing NbS and local renewable energy, such as decentralized energy storage and agrovoltaics.

The Central Valley is an ideal and effective place to implement local, nature-based carbon sequestration methods. The Nature Conservancy's report, titled "Nature-Based Climate Solutions: A Roadmap to Accelerate Action in California," demonstrates the versatility of natural environmental actions that need to occur in the Delta and Central Valley region in order to mitigate climate change (Figure 16). Since the area is an agricultural leader, climate smart agricultural practices — such as more efficient agroforestry, cover cropping, compost application, nitrogen management, and rice cultivation — will provide locally beneficial solutions (Chamberlin et al., 2020, p. 38). These practices increase soil carbon, enhance water quality and availability, improve nutrient availability and crop fertility, and advance yield production (*Natural And Working Lands Climate Smart Strategy* 2022, p. 8). The ecosystem resources provided by nurtured land raise water storage levels for flood and drought resilience, boost food security, improve drinking water and air quality, support biodiversity, reduce wildfire risk on grasslands, and benefit the economy (p. 8). By using local, Nature-based Solutions, these measures will ensure environmentally appropriate carbon sequestration, which will repair the land, subsequently improving environmental justice efforts through the enhancement of people's living and working conditions. Figure 17 adds to Figure 16 to demonstrate that the Delta and Central Valley region identified above has the largest potential for generative land use change at roughly 13 million suitable acres for nature-based climate solutions in California. Therefore, it is critical to implement these changes, as they would support the environment and local communities while transforming a large part of California's land use.

Figure 16

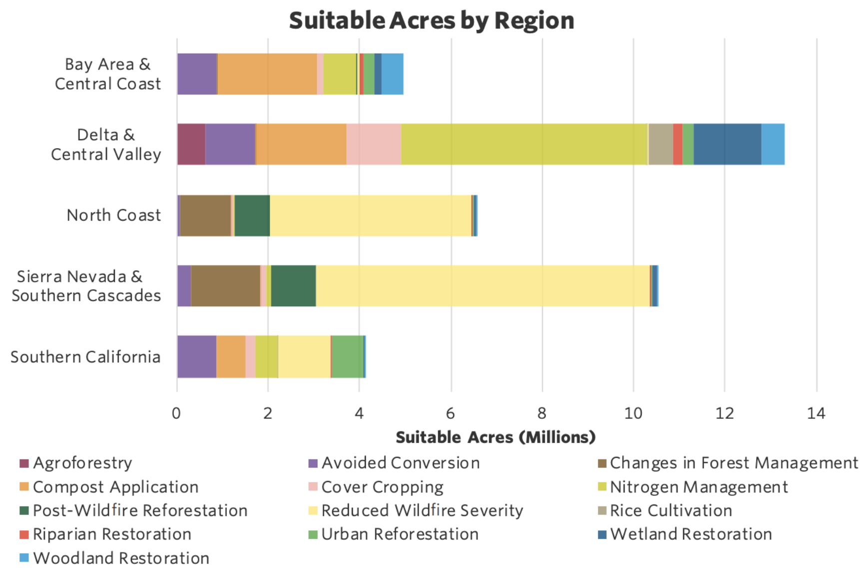
Nature-Based Climate Solutions by viable location for the Delta and Central Valley



Source: Chamberlin et al., 2020

Figure 17

Suitable acres by region for Nature-based Solutions



Source: Chamberlin et al., 2020

In terms of localizing renewable energy solutions, there are a few methods that could improve their implementation in the Central Valley. Since the Central Valley has great exposure to sunlight, solar panels would be an optimal path for renewable energy in this area. However, one of the biggest obstacles to installing solar panels on a household scale is the financial barrier of its cost. Therefore, financial incentives specifically catered to DUCs and advertised to Central Valley residents and solar panel manufacturers and installers would improve local solar energy production. These incentives should also include support for a battery in order to store energy at home, thereby improving energy autonomy. Additionally, subsidies for farmers and agricultural workers to receive solar panels on their homes might increase the likelihood of its installation in the Central Valley. Lastly, particularly for the farms themselves, agrovoltaics provides a newer solution to a common solar panel issue of needing large amounts of empty space. Agrivoltaics is an innovative approach to agricultural land use that allows for crop growth and renewable energy generation on the same plot of land (Dinesh & Pearce, 2016). Solar panels would be installed roughly 12 feet high with a tilt angle of 25° for maximized solar output, and crops that require shade, such as lettuce, could be grown underneath (Dinesh & Pearce, 2016). Agrovoltaics provide high efficiency solar energy production (Proctor et al., 2020), improved water efficiency, regulated climate and lower soil temperatures to prevent soil erosion (Rodriguez, 2021), increased yield and profits, and could lengthen the harvest season (Dinesh & Pearce, 2016).

Chapter 3. Interviews and Analysis

In an effort to better understand the organizing efforts of these environmental organizations against CCS, I conducted interviews with environmental advocates from the Asian Pacific Environmental Network (APEN) and the Center for Biodiversity (CBD). I also spoke with many insightful, expert seismologists in the field to better grasp CCS-induced earthquake risk.

Environmental Advocates

Marie Choi, Communications Director at APEN

Marie became involved in this work when she began organizing the environmental justice groups around demanding the removal of Carbon Capture Storage from the CARB Scoping Plan last year. APEN saw that CARB's Scoping Plan clearly highlighted that CCS was a leading strategy in their pathway to reduce greenhouse gas emissions from oil refineries and wanted to fight against this with partner organizations such as CBE and CRPE. In particular, the Central Valley environmental groups became concerned about BECCS as permitting applications increased for these projects in their area.

Through this work, Marie highlighted that although the technology has existed for a while, it's only recently been lobbied for by fossil fuel companies, specifically by the Carbon Capture Coalition in California that is funded by Chevron. It is a fossil fuel industry group that works to increase the influence of CCS in California and is made up of oil and gas companies. Oil and gas lobbyists, such as this coalition, continue pushing for public subsidies for CCS in California to propagate their industry, instead of creating pathways toward the full decommissioning of defunct fossil fuel infrastructure and cleanup and repurposing of refinery lands. Last year, disclosure records indicated that fossil fuel companies spent close to $20 million on lobbying for bills related to CCUS and the CARB Scoping Plan.

Marie said that most of the oil refineries in California are concentrated in the Contra Costa refinery corridor in the Eastern Bay Area or in Southern California near Los Angeles and Kern Counties. APEN has been fighting against the oil refineries in the former area and joined the fight against development in the latter area, where most of the projected geologic storage sites for CCS are located within the Central Valley. She highlighted that the problems with CCS include: having to put carbon capture machinery on each of the one to two hundred smokestacks of an oil refinery, using large amounts of energy to run the machines, the air pollution from the processing, pipelining the CO_2 from Northern regions through earthquake prone areas to the Central Valley, and dumping CO_2 underground in frontline communities in the San Joaquin Valley.

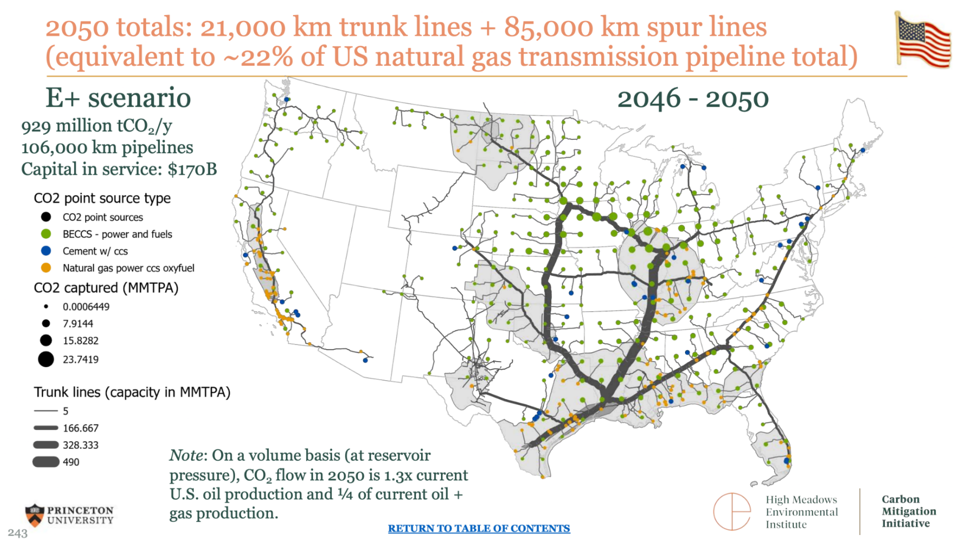
Marie also spoke about how pipeline leaks disproportionately endanger lower-income communities of color in the Central Valley and, specifically CO_2 leaks, can cause severe sickness to local residents, like in Satartia, Mississippi. When APEN heard of this incident, it was a real wake up call to continue fighting on this issue because hearing the 911 calls from Satartia were “reminiscent of industrial disasters that [they’ve] seen in Richmond over the years.” She recounted horrible tragedies of large fires and chemical spills that sent thousands of people to the hospital in Richmond and Chicago – tragedies that have shown local residents that a company’s safety promise is not guaranteed to hold true. Now, in response to the push for CCS deployment, Marie said “the risks feel really real around CCS too.”

Currently, the primary reason some CCS facilities have not progressed further is that the current pipeline moratorium in California prevents them from building transportation infrastructure for moving carbon (Phillis, 2023). But this is being pushed against from the fossil fuel industry and a senior staff member at CARB's Industrial Strategies Division.

Although there is currently a moratorium on pipeline construction for CCS, Marie noted that the plans to build pipelines in the future are concerning due to lack of staff and the increased radius for risk. She shared that the U.S. Department of Transportation's Pipelines and Hazardous Materials Safety Administration, the entity that is responsible for pipeline regulation in the U.S., is understaffed and ill-equipped to effectively monitor and regulate pipeline infrastructure. Moreover, beyond the specific locations of the proposed CCS facilities, the addition of pipelines will increase the area for CO_2 leaking risks. Due to these conditions, Marie warned against further plans to build CCS infrastructure through pipelining which is, unfortunately, the current case. Some possible pipeline routes are shown below (Figures 18, 19, and 20). Marie shared that CCUS in California will require hundreds of miles of CO_2 pipelines through various CCS sites located in Contra Costa County, South Los Angeles, Kern County and throughout the Central Valley. In these areas, CCS will have serious environmental (low water access, high earthquake risk, increased air pollution) and societal impacts (fewer resources to build back from disasters) on local working class, POC populations. Thus, there are staffing, scientific, and societal reasons that CCS and its pipelines should not be implemented in the Central Valley region.

Figure 18

Proposed CCS pipeline infrastructure for the United States



Source: Princeton University (Larson et al., 2020)

Figure 19

Proposed CCS geologic storage and pipeline routes in California

Source: Stanford University (*An Action Plan for Carbon Capture and Storage in California: Opportunities, Challenges, and Solutions* 2020)

Figure 20

Proposed CO_2 trunk pipeline in California

Figure 60. *Map of potential CO_2 trunk pipeline. California counties are shown with existing major natural gas pipelines in orange. Approximate proposed CO_2 storage areas are marked with purple ovals. The base case CO_2 pipeline is shown in red. This route follows major natural gas pipelines and passes through our studied storage sites in the central valley, and a potential geothermal-powered direct air capture plant near the Salton Sea.*

Source: Lawrence Livermore National Laboratory (Baker et al., 2020)

Marie also shared that CCS does not work based on previous pilot projects and actual emission reductions. Out of almost 40 attempted Carbon Capture Utilization and Storage projects in the U.S., over 80% have not been successful (Luderer et al., 2021). Despite fossil fuel lobbyists' claims that CCS will reduce emissions by 90%, CCS demonstration projects have delivered less than 40% emissions reductions. For projects that did open, not one met its projected emissions reductions. One example she provided was the Petra Nova CCS project in Texas, one of the largest CCS plants in the world, with a reported capture rate of 33% (Young, 2021). Another project in Canada, called the Shell Quest project, only captured 48 percent of carbon emissions (*Hydrogen's hidden emissions* 2022).

In addition to the drastically decreased capacity of CO_2 capture, Marie astutely noted that accounting for upstream and downstream emissions increases CCS' predicted energy usage. To begin with, CCS puts a lot of pressure on the electric grid and would likely increase energy costs in California. A study by Psarras et al. (2020) found that adding CCS to a gas-fired plant could increase the energy costs by up to 61%. CARB's "Achieving Carbon Neutrality Report" states that in their high carbon dioxide removal scenario, 80 Million Metric Tons (MMT) of carbon dioxide would need to be captured annually in California by 2045, and there are further projections for beyond 2045 (Mahone et al., 2020). 80 MMT requires 100 Terawatt hours of energy which is more than 33% of the total electricity produced in California in 2021. When observing both the energy needed to run the machines that capture carbon and the usage of carbon dioxide as a conduit to further extractive practices such as EOR in order to gain the hardest to reach and dirtiest oil; Marie made it clear that CCS uses too much energy and that companies are unable to meet their promises.

As California is working towards phasing out fossil fuels and finished petroleum products by 2045 according to the CARB Scoping Plan, reducing transportation, refining, and oil production could cut the state's emissions in half. Marie noted that reducing both the use and production of fossil fuels is the core strategy for reducing emissions at the scale needed to stabilize our climate. As she said "the oil era in California is coming to an end."

Moving forward, Marie emphasized that we need to employ Nature-based Solutions first before even considering carbon capture storage for reaching net zero emissions. When I asked her about strategies other than CCS for achieving 100% carbon neutrality, she said "I don't think they're alternative strategies. I think those are actually the core strategies that we need." She made the salient point that CCS only supports reaching the last 5-10% of emission reductions necessary to reach a full 100% reduction. In the meantime, she says, we need to use direct emissions reduction strategies to actually reduce emissions by 80-90%. In our discussion, she made it clear that getting to our climate goals is not dependent on CCS, but is more reliant on our ability to phase out fossil fuels. Marie highlighted that the Environmental Justice Advisory Committee (EJAC) has outlined many strategies towards equitable and nature-based climate solutions, but that these have not been prioritized in the CARB Scoping Plan.

EJAC's strategies to reduce emissions and improve environmental and societal health are similar to the goals APEN has suggested, such as, electrification via clean, renewable energy, energy efficiency, building decarbonization, investments in clean transit systems, and more. In particular, during the interview, Marie focused on electrifying transportation, reducing Vehicle Miles Traveled (VMT), and reducing commute distances through anti-displacement measures and affordable housing. In line with Governor Newsom's Executive Order N-79-20 that aims to have all new cars and passenger trucks sold in California be zero-emission vehicles by 2035, there is a rulemaking process currently under way for advanced clean fleets which would require that all heavy duty trucks also be zero-emissions by 2035. She also explained the dire need and desire for mass public transit that works for everyone by being a faster, cheaper, and more convenient option for moving and commuting. Through this transformation of transit, she explained that VMT would be reduced as efficient paths for transport are utilized and commutes are shortened. In hand with transportation, better housing is also a climate strategy she recommended that would address the waves of displacement California has witnessed in recent years with rising home prices and the fallout of extreme natural disasters. In addition, climate resilient housing and more affordable options closer to peoples workplaces would also cut emissions.

To complement the changes in demands, Marie said that on the supply side, the state needs to play an active role in ramping down oil production. Otherwise, if this is not enforced, Marie predicts that oil companies will see declines in national sales and choose to build their market globally to continue exporting oil or replace oil production with other fuels produced by burning fossil fuels, such as hydrogen. Even though hydrogen is seen as a cleaner fuel, over 95% of the hydrogen produced today is from burning fracked gas. In the most ideal scenario, Marie would like to see refineries close down because consumers are no longer interested in dirty products, but even this option has social and environmental pitfalls. She said that refineries should not close overnight because it cuts jobs, reduces funding for public services, and removes accountability for cleaning up environmental damages.

The transition away from oil is already under way. Marie recounted how in Contra Costa County, two refineries closed during the pandemic and reopened as biofuel refineries. Without clear pathways and procedures for decommissioning, cleanup, and repurposing of refinery lands, Marie said that polluters will simply replace one polluting facility with another if for no other reason than to avoid paying for cleanup. Additionally, CARB's projections show that 80%

of California's refinery capacity will no longer be needed by 2045. Thus, regulation needs to be developed to support decommissioning fossil fuel plants.

Lastly, Marie emphasized that building pipelines and further investing in CCS infrastructure is a last ditch attempt by the fossil fuel industry to keep their companies afloat and generate profits. She said many people in the climate space consider CCS as a delay tactic that companies can use to prevent discussing fossil fuel phase out. She added that if CCS is the first solution that governments employ to address climate change, then it keeps the industry running for longer. Her estimate is that CCS could sustain the industry for another 50 to 100 years as the technology increases investment into oil and gas infrastructure. This is why fossil fuel companies are interested in carbon capture. She warned that if governments are not intentional about the transition away from fossil fuels, then it is easy to revert to this system and extend the life of fossil fuel infrastructure.

Marie sees this fight continuing with the leadership of the Central Valley environmental groups in legal courts and policy battles. And it is not just CCS that they will be fighting against, but also hydrogen, biofuels, and future refineries. She also emphasized the need to plan for a large-scale transition from extractive systems towards just energy production.

She left a few questions for consideration as communities continue to organize against CCS deployment in their neighborhoods:

1. What is the actual function and purpose of CCS?
2. What is CCS going to mean for communities?
3. What do communities and workers need as we navigate this [energy] transition period?

Victoria Bogdan Tejeda, Staff Attorney at the Center for Biological Diversity

Victoria got involved in working against CCS deployment when she joined the Center for Biological Diversity (CBD) in 2021. CBD had heard from their partner environmental justice groups that CCS projects were being proposed in California, so Victoria began researching and submitting Public Record Act requests to federal and state agencies to get ahead of the situation before the permits became public. CCS projects can request federal permits from the EPA for a Class VI Well for Geologic Sequestration of Carbon Dioxide, land permits for the area for the facility, water permits for cooling down CCS facilities, and other permits. That is when she learned that most proposed CCS sites planned to use BECCS and that all of them were located in the Central Valley, posing an environmental justice concern for their partner organizations and raising further questions about the permitting process.

Her research found that there are huge regulatory gaps for CCS because it has not been deployed at scale yet. Thus, she said it was important to see how the Scoping Plan proposed to reduce California's emissions by heavily relying on CCS. Victoria's work focused on debunking myths in the Plan, specifically around carbon capture estimates. Most of the modeling assumptions claimed a 90% capture rate on paper, but this was not the reality (Mahone et al., 2022).

Based on what she learned, Victoria and the Center for Biological Diversity do not support CCS implementation for a few reasons. First, she said that CCS is not a solution to the climate crisis because it has "historically over-promised and under-delivered." The epitome of this concept is the West Australian Gorgon Gas, Carbon Capture and Storage Project which promised to capture 80% of CO_2 emissions but only ended up caturing 40% (Morton, 2021). This five year project for a fossil fuel fired powerplant used taxpayer money and was subsidized by the government, but failed to reach its goals. This and other examples have shown Victoria that it is unreasonable to believe that the continuation of the fossil fuel industry to remove carbon will work as a climate solution. She added that in all scenarios, since facilities cannot currently promise a 100% rate of capture, there will always be extra emissions that still have to be addressed. Additionally, she said that even if these goals were achieved, the energy penalty of compressing carbon for capture is roughly 25%, which is the added electricity required to run the CCS equipment per unit of energy produced by the powerplant (Jacobson, 2019). Victoria explained that the energy penalty reduces a projected capture rate of 80% to 55%. She also noted that CCS produces co-pollutants, worsening air quality, and is a harmful system for local communities. Because these numbers do not add up to being an effective climate strategy, Victoria concluded that fossil fuel industries sell CCS as a climate solution or technofix because it maintains the status-quo and keeps operations afloat.

Another CCS myth that Victoria and other activists note is that we need CCS to reach the Paris Climate target of 1.5°C. Environmental groups we worked with indicated that this was not true. Although the IPCC has modeled many scenarios that require CCS use for meeting climate targets, Victoria showed me a scenario in the IPCC's 2022 Climate Mitigation Report that has little to no reliance on engineered carbon capture storage. Instead, this scenario focuses more on natural carbon sequestration through working lands and ratcheting down fossil fuel production to achieve 1.5°C (Shukla et al., 2022). This set of pathways are called C1 and limit global warming to 1.5°C with no or limited overshoot to achieve rapid, deep, and immediate reductions by transitioning away from fossil fuels and CCS, to renewable energy (Shukla et al., 2022). In fact, the main C1 pathway had the highest likelihood of maintaining peak global warming below the given percentage goal. Victoria made it clear that CCS is not the silver bullet technology that many hoped it would be.

Lastly, Victoria noted that environmental justice concerns arise because community groups see CCS as industrial justification for continued pollution and the creation of a CO_2 dumping ground. The example of Satartia was brought up and she noted that it was not even close to the scale of industrial CCS projects. She also shared how residents are still feeling the after effects of the CO_2 leak, which was something that could have been prevented. Because of situations like this, environmental justice groups are fighting against CCS not only because it worsens air quality, but because "the carbon could potentially asphyxiate and kill us." Appalachia and Gulf South communities echo this sentiment of CCS as environmental racism, a practice that devalues marginalized communities and land.

Particularly for the Central Valley, Victoria agreed that climate conditions and community input do not work in favor of CCS. The Central Valley is a very hot, dry area with low access to water resources that is already inadequate for agricultural production in the area. The lack of water leads to high levels of dust and is home to some of the worst air pollution in the country. Victoria mentioned that environmental groups have been working really hard to clean the air by trying to work with the Air Quality Districts and the State of California, and cannot take any more direct air pollution from CCS. Studies that Victoria sent my way demonstrate this issue of BECCS and CCS contributing to higher levels of air pollution (Wang et al., 2020; Young et al., 2019). Victoria noted that there are many migrant workers, linguistically isolated individuals, and vulnerable populations in the Central Valley that are against CCS in California or elsewhere because they know air pollution transgresses boundaries and they understand the problems of being overburdened by industrial processes.

Despite these conditions, a common argument for CCS in the Central Valley, is that it is home to the most suitable geology for CO_2 injection and has a lot of emptied oil fields that have been drained which allow for the storage of CO_2. However, Victoria said that there are huge problems with this statement. In all the applications to the EPA for CCS in the Central Valley, Victoria saw that there were high levels of uncertainty regarding fault line locations and a blatant ignorance of the issue by the companies that decided to inject carbon in these areas anyway. This is a concern because CCS-induced seismicity can trigger earthquakes in these regions that are not well studied. Instead of being preventative, Victoria said that the companies' attitude is to deal with problems as they occur. She said that this is not good enough because carbon can migrate and resurface and displace other gases and fluids already stored underground, similar to how currently abandoned oil and gas wells have been leaking methane. Plus, it is a big waste of federal funding for projects that do not work. In one shocking case of a Class VI well application Victoria looked at, she saw that the company's area of review, or modeling of where the CO_2 plume will migrate underground after injection, predicted that CO_2 would migrate 10 miles north during the lifetime of the project. In response, the EPA required the company to map vulnerable populations in a 10-mile radius of the proposed site, which included a whole town of residents with many houses, hospitals, and schools in its vicinity. These cases demonstrate real public health risk in case of a leak. Therefore, despite having advantageous rock layers, Victoria explained the variety of existing and predicted problems with carbon storage in the Central Valley.

Regarding pipelines for the proposed CCS projects, because of the current pipeline moratorium, Victoria shared that some of the California sites plan to store carbon directly under their site. She informed me that the Mendota and San Joaquin Renewables projects said they would inject CO_2 directly under their property with the potential for the Elk Hills project to follow suit. She predicts that because the state is a big proponent of CCS, the pipeline moratorium may be lifted in the near future.

She showed me the Pipeline Safety Trust's report on the safety of CO_2 pipelines for CCUS, which is alarming. It describes CO_2 as a gas that is both an asphyxiant and intoxicant, that, because of its odorless and colorless characteristics, make it difficult to observe and circumvent. The report states that CO_2 is different from materials moved in other pipelines because a CO_2 pipeline rupture would impact a larger number of people compared to hydrocarbon transmission rupture and that the former has "a greater potential to endanger the public" (Kuprewicz, 2022, p. 8). However, federal regulations do not delineate these differences which would need to change in order to account for the severity of CO_2 pipeline leak effects.

Victoria noted that there are a lot of problems with mitigating CCS' many risks. One of the overarching issues is that the risks throughout the CCS lifecycle are the responsibility of a variety of agencies. She also pointed out that not all the risks are regulated nor are the solutions enforced. Victoria brought up the idea of monitoring, and questioned who is in charge of ensuring companies capture their projected numbers. She said it is unclear how and by whom CCS will be regulated. Another issue she shared is that the recent federal 45Q tax credit and the IRA encourage companies to do CCS, building a subsidized market for CO_2 capture and changing business models. With these incentives, CCS will be pushed towards deployment faster than it should be implemented. For Victoria, the funding brought up questions regarding who is in charge of the tax credit and how they are verifying CO_2 capture. She shared that the IRS or whoever else has tax authority would check with the EPA, which only has a voluntary reporting program that can easily be manipulated. This leads to fraud that goes undetected due to a lack of enforcement mechanisms. One example she provided was that in 2020, there was a report about this fraud and it found that 7 out of 10 companies audited were illegally claiming the 45Q tax credit through self-reporting. In terms of safety, Victoria mentioned that the Pipeline Safety Trust said at a CCS Symopsium last year that even with the best pipeline regulations, there is no way to completely eliminate the risk of CO_2 leakage from pipelines. This brought up additional questions for Victoria regarding who has the authority to shut down a pipeline when it suddenly leaks or who is monitoring the potential underground leaks before they become big disasters. These are good questions that the state has not addressed yet, but are concerns for local residents. Aside from the theoretical concerns about management, Victoria reiterated that people are even more concerned about the real public health and environmental impacts of CCS on their neighborhoods, impacts that can never be fully eliminated. She emphasized that the real problem with mitigating CCS' impacts is that there is very little public understanding of how these projects will be run, monitored, and evaluated, and that better regulations will never fully absolve these concerns.

Instead of CCS, Victoria supports further investment into renewable energy, especially distributed, small scale projects. For solar, she mentioned that large solar farms can use up natural resources when typically placed in desert settings and harm wildlife migration. Thus, Victoria suggests a decentralized system that is community-run with smaller solar projects to strengthen local climate resilience. She also mentioned wind power as a good alternative but that it may also have negative impacts, particularly with off-shore wind. Even though biomass sometimes is lumped into renewable energy, Victoria was clear that CBD rejects it as a good climate strategy because of its harms. Lastly, she also supports the idea of natural carbon sequestration through the restoration of landscapes as natural carbon sinks.

Victoria's bottomline was that the costs of CCS outweigh the potential benefits. She raised a lot of questions throughout the interview about the location of fault lines, projections of CO_2 plume movement, impacts of CCS on groundwater aquifers, and the injection of CO_2 into saline formations. Because of these unknowns, it is very difficult to quantify CCS' impacts and adds to the many known reasons why CCS should not be deployed in the Central Valley.

Summary of Environmental Advocates

From Marie and Victoria, I learned a lot about how anti-CCS community organzing began 1-2 years ago and the different roadblocks that have come up along the way. Victoria said that CCS infrastructure makes communities feel like they are a CO_2 dumping ground and Marie added that CCS reminds APEN of previous battles they have fought against oil refineries. They both do not think CCS is suitable for the Central Valley for a variety of reasons. They emphasized the ineffectiveness of CCS based on past projects that modeled CO_2 storage capabilities that companies have severely failed to meet. Additionally, Marie and Victoria highlighted the various environmental issues with CCS, including air pollution and public health, excessive water and energy use, and pipeline leakage, and their negative environmental justice implications. Even though there is currently a pipeline moratorium, Marie also focused on the potential plans for pipeline infrastructure in California that have been drafted by various universities, which unfortunately map out the entire state in pipelines and would further the risks of CCS. Victoria added that because of this roadblock, companies are electing to store CO_2 directly under their properties. Victoria also helped debunk common myths, such as the need for CCS to achieve climate targets which is untrue because the IPCC has climate mitigation scenarios that do not rely on CCS. Another statement she falsified was the argument that CCS should be used in the Central Valley because it has the best geologic storage. She mentioned that in the CCS permitting applications submitted to the EPA that she has looked over, most companies were uncertain of where fault lines existed and where the CO_2 would migrate underground after injection, which could harm communities over 10 miles away from the injection site. Thus, there is not enough geologic knowledge or planning to safely conduct CCS in the Central Valley. Marie also shared more about the fossil fuel industry's backing of CCS and how it is a greenwashing tool and both of them noted that CCS furthers oil and gas infrastructure and funding to try to keep the sector relevant in an energy transition that is already underway. Victoria also cautioned against CCS because federal and state agencies are not effectively regulating the technology. Both of them called for stricter pipeline regulations and reinforced that Nature-based Solutions are key to climate mitigation and that CCS should not be considered at this time. Marie added that the government needs to support the just transition by phasing out fossil fuels at the state level.

Seismologists

In the memo I wrote about earthquake risks due to CCS use, I synthezised interviews with five seismologists to gain a better understanding of the body of knowledge regarding injection-induced seismic risk and how this can be applied to CCS. I spoke with Professor Avouac from CalTech, Professor Dvory from the University of Utah, Seismologist Jake Walter from the University of Oklahoma, Professor Herzog from MIT, and Professor Goebel from the University of Memphis. The following are shortened interview analyses with these esteemed seismologists.

Jean-Phillipe Avouac, Professor of Geology and Mechanical and Civil Engineering at CalTech

Seismologist Jean-Philippe Avouac was enthusiastic about CCS as a carbon capture technology and stressed its importance for decarbonization. He disclosed that he works directly with CCS companies. In terms of earthquake risk, Avouac indicated that CCS could lead to groundwater reductions and that if earthquake concerns are substantive enough, they can shut down facilities. Avouac encourages the companies he works with to do case studies for CCS use prior to the installation of facilities. However, since that is an out-of-pocket cost, they are often unlikely to volunteer to pay for additional research. He said that studying areas outside the Central Valley (such as Canada) would provide data on CCS because California does not mandate its collection. Avouac indicated that California might actually be better suited to deal with any increased seismicity from CCS since the state is already familiar with earthquakes and thus somewhat prepared for them. Avouac contended that earthquakes that were induced by CCS would likely have occurred anyway in those locations – just at different times. He also mentioned that, as oil and gas fields are depleted, carbon injection might help to stabilize geological formations – essentially taking the place of the oil and gas. Avouac mentioned that the state should be cautious in furthering CCS too rapidly and should maximize study and data gathering. He indicated that companies would welcome this data and could partner with other industry leaders while benefiting from regulatory supervision so they are not liable for CCS. He indicated that government research and agencies are not up to this level yet. Therefore, it is crucial that CCS be studied further.

No'am Zach Dvory, Research Assistant Professor for the Civil and Environmental Engineering Department at the University of Utah

Professor Dvory was a student of Mark Zobak at Stanford and expressed interest in CCS as a key climate solution. In terms of earthquake risk, he recommended that we look at the history of earthquakes in the area, specifically active faults and tectonic stresses, because, in these areas, a small amount of pressure can induce a slip. He mentioned that the total volume of injection and how pressure propagates in the sub-surface layer is more important than the distance of CCS facilities to fault lines. So, it is critical to understand the proposed amount of injected carbon and extend CCS research before starting up CCS sites with unknown geological repercussions.

Jake Walter, State Seismologist for the Oklahoma Geological Survey and faculty of the University of Oklahoma's School of Geosciences

Jake Walter considered that CCS as a climate solution carried risks; he expressed certitude regarding linkages to increased seismicity. He described CCS injection as similar to fracking, which has increased seismicity in locations that were not normally earthquake-prone. Walter shared that any kind of injection into the ground would produce earthquakes. Given that CCS relies on the injection process, he considered it inevitable that CCS would lead to earthquakes that would not have otherwise happened at this time and in magnitude. Also, based on wastewater and other stresses, scientists would be able to demonstrate CCS-caused earthquakes that would not otherwise have occurred. Walter explained that CCS injections and wastewater storage underground can create stresses in the rocks that are felt many kilometers away by critically stressed tectonic faults, which expedite sub-surface failure. Essentially, a small impact could trigger a smaller earthquake further away which could eventually lead to a larger earthquake. Walter noted that it would be very difficult to attribute the latter earthquake to the former. Walter clearly advised that CCS could lead to earthquakes and this could produce additional hazards for California residents.

Professor Howard Herzog (MIT Energy Initiative) Senior Research Engineer

Howard Herzog emphasized that CCS should be conducted properly with precaution in order to achieve necessary CO_2 emissions reductions. In response to Professor Zoback's work at Stanford, Professor Herzog wrote a letter stating that Zoback's article was too extreme and that microseismicity is inevitable when it comes to any type of subsurface injection. He mentioned that fluids are safely injected all the time, but faulted areas should be avoided for CCS. Also, Herzog mentioned that when CCS is done correctly with proper pressure management, it should not lead to additional problems. He said the risks with CCS are not out of line compared to the risks with current industrial practices. When it comes to implementation, Herzog explained that CCS is deployed where existing oil and gas operations are located, which in California's case is mostly in the Central Valley. For this area, he recommended listening to local experts who are aware of the specific geography and fault lines, and said that it is likely that there are reasonable places for CCS in the Central Valley.

Herzog estimates that there currently exists about 5000 miles of pipelines for CO_2 transportation to storage fields. He said that whether a pipeline will be built is based on the type of project and its storage capacity estimates, with the economic incentive for pipelines beginning at one million tons of CO_2 storage. Herzog also noted that CO_2 pipelines are very safe and would not explode. In the rare case that it does, as it occurred in Satartia, Mississippi, there would have to be a perfect storm of factors to cause immense damage, such as mass asphyxiation. Professor Herzog explained the incident in Satartia as the fallout of the combination of Hydrogen Sulfide (H_2S) with CO_2, where H_2S is toxic in smaller quantities, and strongly recommends against combining these gasses in a pipeline.

Herzog considers any strategy to reduce CO_2 emissions as a positive approach and pushes for implementing as many as possible to achieve the highest percentage of emissions reduction. He mentioned that renewable energies such as wind, water, and solar power are important but these alone cannot reach 100% of our energy needs, so other strategies have to be employed to make up the difference. He said we don't have the option to discard technologies at this point, including nuclear energy.

Herzog said that the method for capturing CO_2 is very sensitive to air pollution so to conduct CCS, the pollutants SO_2 and NO_x would have to be reduced more than air permits require, improving environmental justice. And in response to the suggestion of Nature-based Solutions, he said that although there is some potential, there is not enough regulation to make it effective due to greenwashing and inaccurate carbon crediting systems. Another issue he brought up is the idea of a lack of permanence for long-term CO_2 storage in natural carbon sinks. Lastly, Professor Herzog reiterated that when technology works to lower CO_2 in the atmosphere and meets environmental regulations, it should not be qualified as a good or bad technology. Instead, it should simply be implemented to do its job. Therefore, he supports the use of CCS for climate mitigation.

Professor Thomas Goebel, Assistant Professor at the University of Memphis

One of Professor Goebel's studies focused on the LA Basin, Ventura, and the San Joaquin Valley to determine background earthquake rates because no one had previously studied the hydrocarbon environment in this area. This is calculated by isolating the primary earthquake shocks that occur by removing aftershocks to determine the rate of earthquakes over a certain timescale. Comparing this number to tectonic stresses, the speed of plates moving past each other, and fault slip rates can elucidate whether an earthquake was potentially caused by human activity. This is most noticeable through pressure changes that come with high rates of artificial injection. So when looking at changing background rates, one can notice induced activity. His overall findings indicated that the background rate was stable which leads to two interpretations. Either there is little to no induced activity or the induced activity is very masked due to a generally high level of tectonic earthquakes. The latter conclusion was determined based on zooming in on a smaller scale to a handful of areas that did show a significant spatiotemporal correlation between injection rates and the number of earthquakes. One of these areas was in the Central Valley near Bakersfield in the Tejon Oil Field. There, his team detected a higher level of injection activity starting around 2004-2005 which resulted in earthquake magnitudes reaching 4-4.5 on the Richter scale which is when people can feel the tremors. The study determined a long-term correlation between seismicity and injection rates within the Bakersfield area, but the earthquakes were smaller, landing at 2-2.5 on the Richter scale. Another study he conducted in the Salinas Basin also found a long-term relationship between earthquakes and the injection of wastewater for disposal in the area. Although Professor Goebel was looking at wastewater disposal, the mechanism for CO_2 injection is quite similar when storing it underground and can cause similar side effects, such as fault line slippage and earthquakes. He noted that his study is unique because this area and topic are not well studied, so even though there is little evidence of notable induced earthquakes in the Central Valley, that does not mean it does not exist.

Professor Goebel described a variety of issues that make it difficult to figure out the probability of inducing an earthquake in an area due to human activity. One issue is that the faults within oil or other reservoirs have some pre-existing tectonic stress from extractive practices, and they might already be quite close to failure. Thus, a small perturbation can have a significant effect on triggering an earthquake, whether or not it would have eventually happened naturally. Another issue with determining seismicity rates in California is that there is no recorded seismic history before any anthropogenic activity which started in the 1900s. In comparison, his other study in Oklahoma clearly showed that human influence led to an exponential growth in seismic activity and that these earthquakes cause subsequent earthquakes. Additionally, when fluids are injected into a thick sedimentary rock column, the fluids do not reach the deeper faults in the basement of the rock as easily, reducing the chances of a large earthquake. The Central Valley also has a significant sedimentary rock column which could be part of the reason that these induced earthquakes are not as visible.

Specifically, for the proposed CCS sites, Professor Goebel mentioned that using old oil and gas reservoirs means that the reservoir pressure had dropped due to extraction and can handle higher fluid pressure which is a good thing for CCS. This is because the cap rock is still intact and can shield the CO_2 keeping it in place under the surface. In this way, using emptied reservoirs can mitigate the seismic hazard. In general, Goebel noted that monitoring the areas of potential injection and being aware of the previously identified hazardous faults and earthquakes will help reduce induced seismicity.

Summary of Seismologists

All of the seismologists we interviewed agreed that CCS is not studied well enough to understand its full impacts on earthquake risk, efficiency, or other risks. Jean-Phillipe Avouac said that research is not conducted because there is no data in California, since fewer regulations mandate data reporting. No'am Zach Dvory and Howard Herzog mentioned that proper management is necessary to reduce the adverse effects of CCS, but that CCS could be done safely. Jake Walter explained that scientists do not fully understand how the magnitude of an earthquake would change based on stressors since it is hard to know the full extent of conditions in the geological system. And Professor Goebel echoed this sentiment and added that there are currently more induced seismicity studies in geothermal than hydrocarbon, so this area requires further research.

Seismologists continue to have varied viewpoints on CCS and its seismic impact. One of the biggest points of contention is that some seismologists thought that CCS-induced earthquakes would have happened naturally versus being able to prevent or reduce the magnitude of these earthquakes by reducing anthropogenic injection. Another key difference was that the interviewees differed in their confidence in CCS and its viable application in California, nationally, and globally.

Analysis of the CCS Divide

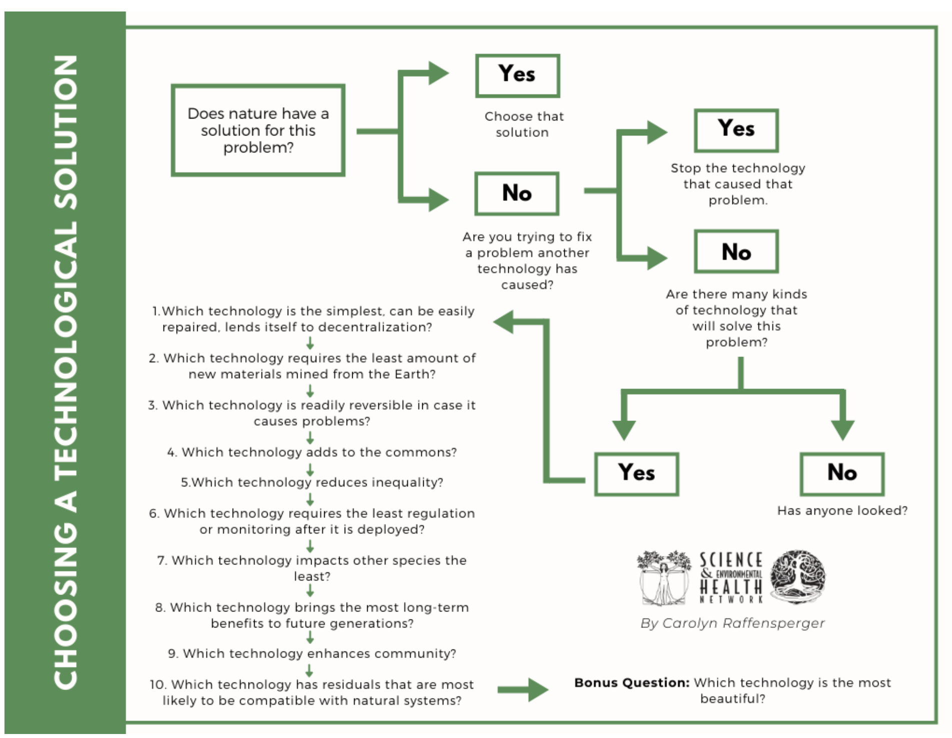
Although both proponents and opponents of CCS are aware of the issue at hand – that global warming is reaching a tipping point of 1.5-2°C – and agree on the need to act on climate change, their approaches differ based on their value systems. To find solutions, environmental advocates prioritize communities and Nature-based Solutions, whereas pro-CCS academics and professionals focus on theoretical research and techno-positive solutions.

Environmental advocates use the concept of fossil fuel greenwashing, track funding patterns, and follow the framework of a just transition to condemn CCS use. Given the historic environmental justice impacts of fossil fuel infrastructure on local communities, APEN was aware that CCS is a continuation of this industry and its oppression of frontline communities. Environmental advocates call out the fossil fuel industry for greenwashing CCS because they claim this technofix does not effectively capture carbon; instead, it furthers environmental harm by increasing air pollution and seismic risk, reducing natural resource reserves, and increasing funding for fossil fuel technological solutions. Via a just transition, CCS use would be rendered obsolete. Energy justice under a just transition would allow communities to become empowered to run their own decentralized, renewable energy. This new way of energy production and distribution would increase good, green jobs and support a sustainable economy. By putting their communities first, environmental advocates look at how a solution impacts their neighbors and facilitates community decision-making to work against harm and towards sustainable, equitable, and just solutions.

The Science & Environmental Health Network (SEHN) published a Decision Tree for Technological Solutions framework that explores nature and community-based approaches versus technological solutions (Raffensperger, 2021) (Figure 21). This framework can be used to theorize pathways of potential solutions to the ongoing climate crisis. The first question ("Does nature have a solution for this problem?") reveals the existence of Nature-based Solutions, such as land use changes in the form of natural carbon sinks that naturally capture carbon. Thus, the framework tells us to select this option over a technological solution such as CCS. If instead, one selects that there is no natural solution to the problem, the framework asks if the problem being fixed is caused by technology; this answer is true, as evidenced from over 150 years of industrial production. These technologies have created and continue to worsen the problems of CO_2 emissions and global warming. The framework then tells us to stop using the technology that instigated our current climate problems, which would mean decommissioning fossil fuel plants and industrial facilities whose existence would only be prolonged by the adoption of CCS. Lastly, if the answer of "No" is chosen at every decision point in the framework, the framework will still continue to encourage the choice of natural solutions. The last main question ("Are there many kinds of technology that will solve this problem?") reveals that aside from mechanical CCS, nature-based carbon capture and renewable energy are great options. Going through the list of ten questions at the end of the framework makes clear that a simple solution with the least amount of extraction would be nature-based, could benefit the commons, and be reversible if damage occurred. In all scenarios, the framework returns to a sustainable, nature-based option for carbon capture. Responding with the choice of CCS leads to an answer of "No" several times throughout the framework, reflecting its unnatural manner of capturing CO_2.

Figure 21

The Science & Environmental Health Network's Decision Tree for Technological Solutions framework



Source: Raffensperger, 2021

The role of power plays an incredible role in the relationships between fossil fuel industries, federal and state legislators, and communities because despite community objections and past precedent of CCS failure, fossil fuel lobbyists and government officials are partnering to deploy a harmful technology. These authority figures tend to listen to the voices of academia and lobbyists, whether or not they are backed by fossil fuels and money, because they are valued greater than community members. Thus, published research, even if incorrect, is given more serious consideration than the stories of lived experiences. Both Marie and Victoria noted that the fossil fuel industry's reclamation of power and relevance due to CCS use would have naturally phased out without this technofix.

On the other hand, some academics encourage CCS use due to researched modeling predictions, and in conjunction with fossil fuel companies and government officials, focus on technological necessity and techno-optimism to address the impacts of climate change. Utilizing a technocratic decision making framework, these groups pursue technological solutions and rely upon researched predictions to justify their conclusions. Since the scientific models demonstrate CCS' ability to adequately capture carbon, companies and governments blindly fall into techno-optimism and put the solution of CCS first due to its quantifiable impact. Even after modeling predictions have been demonstrated to be incorrect, these numbers, such as a 90% carbon capture rate (Mahone et al., 2022; Brandl et al., 2021; Rubin et al., 2005), are still hailed by industry and state officials as a remarkable capacity for CO_2 capture. This prioritization of technology to solve climate issues and the willingness to continue funding its research works toward ensuring that CCS can eventually reach its original targets. Additionally, the practice of risk minimization is heavily utilized to downplay environmental risks that stem from the lack of

CCS data in California and minimal knowledge of fault line locations in the Central Valley. On the other hand, these groups weaponize possibility blindness and fossil fuel industry necessitarianism to avoid turning to Nature-based Solutions (Megura & Gunderson, 2022).

Additionally, some academic supporters of CCS ignore the historical origins of racial and social oppression that come with technological solutions. Technology can never be fully neutral due to its original intent and history of impact. Oil and gas companies have a legacy with linkages to environmental injustices and racial and social oppression through the continuation of extractive systems, such as fracking and low-wage labor. Thus, CCS inherently embodies these technocratic and oppressive values, especially as they are promoted by fossil fuel interests. Therefore, proponents of CCS value technocratic ideologies and put solutions such as CCS first due to their trust in technology and minimization of its environmental, racial, and social impacts.

Discussion: Future Directions

There are many directions this research can be taken in the future. On the policy side, analyzing the CCS sites' Notices of Preparation (NOPs) and waiting on the companies and the state to publish Environmental Impact Reports (EIRs) for further study would be one way to track projects' alignment with the California Environmental Quality Act. In the minimal documentation that exists, the NOPs have already listed potentially significant impacts of CCS projects in multiple environmental variable categories. For example, in the Carbon TerraVault 1 NOP, the supervising planner found that this proposed project "may have a significant effect on the environment, and an Environmental Impact Report is required," so evaluating the final EIR when it is published will be critical for furthering this work (Hoover, 2022, p. 16).

Also, as this year progressed, more CCS sites are being submitted for permit approval by the state and federal government. Thus, on the data side, including these sites in further GIS map analyses to determine current CCS impacts would be helpful. A next step in the mapping part of this project would be to develop a database that can automatically refresh after a certain time period and update existing maps with this new information. Additionally, further analyses of potential CO_2 pipeline placement in relation to the proposed CCS sites would be interesting.

Lastly, as weather conditions have been changing due to climate change, it is important to begin asking new questions about CCS use in California. In particular, the past winter and spring of 2023 brought an onslaught of water into California through severe rainstorms. Thus, even though this thesis has focused on California's history of drought and a lack of water resources, it is now important to ask the reverse: how do floods impact CO_2 storage and pipelining?

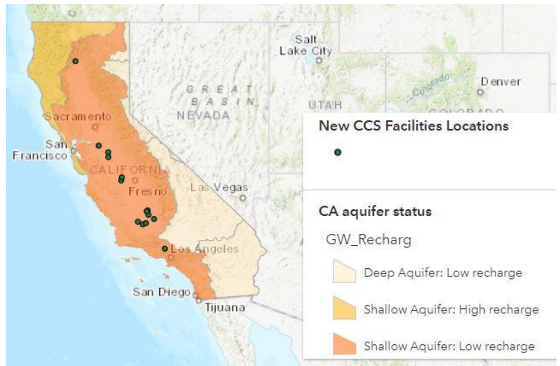
Conclusion

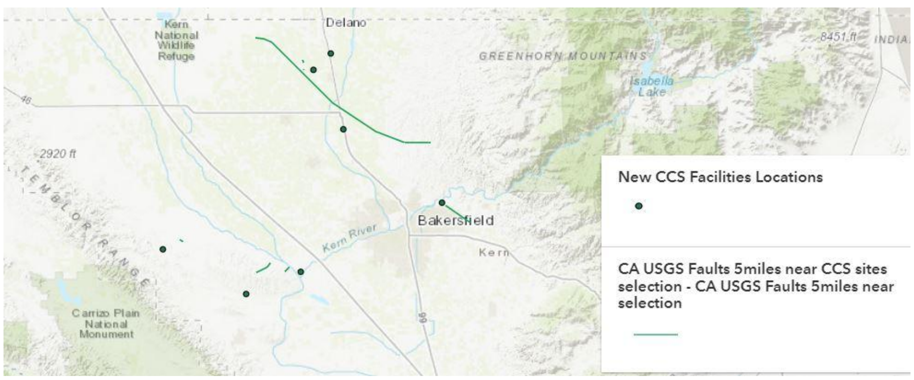
While Carbon Capture Storage can be a tool for carbon drawdown and supporting climate mitigation, it leads to significant natural resource and human risks, has high upstream and downstream costs, as well as an unproven track record of success. CCS relies upon high levels of water and energy, contributes to air pollution, and has the potential to trigger earthquakes. In particular, the Central Valley is at greater environmental risk from CCS due to its low groundwater levels, fewer resources (i.e. energy and money), and poor air quality. CCS-induced earthquake risk is probable and needs to be studied further to better understand its implications for vulnerable populations that live in close proximity to proposed CCS sites. Given that the Central Valley is an underserved and underrepresented area, CCS also poses an environmental injustice to Central Valley residents. Ultimately, carbon storage must be environmentally sustainable and just in order to be effective, which is not currently the case. It is imperative that emissions reductions are truly achieved through sustainable practices and that CCS is not greenwashed in the process. In fact, the IPCC has found that even in the best case scenario, carbon removal technologies (like BECCS and CCS) would not be able to make meaningful CO_2 reductions to achieve negative emissions until 2050 or later (*Unmasking clear warnings* 2022; *Carbon removal through BECCS and DACS 2030-2100* 2022), meaning that CCS is not a solution to today's climate crisis. Therefore, the Central Valley should employ alternative climate mitigation strategies, such as nature-based carbon storage methods through land use changes, as well as renewable energy investments. Unfortunately, as CCS becomes deployed more frequently in the Central Valley and elsewhere, further research needs to be conducted to understand CCS' implications for the region and ensure geologically and societally safe CCS use. Thus, it is critical for policymakers – in California and any other region considering CCS – to acknowledge the concerns surrounding CCS and to make environmentally informed decisions that will lead towards a sustainable energy future.

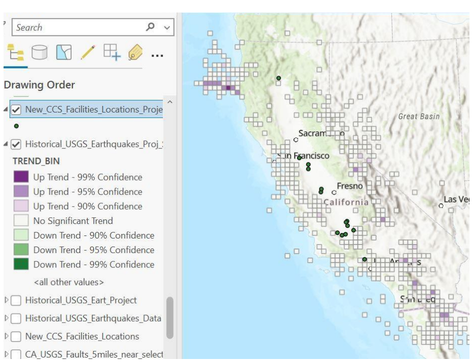
Appendix 1: GIS Maps

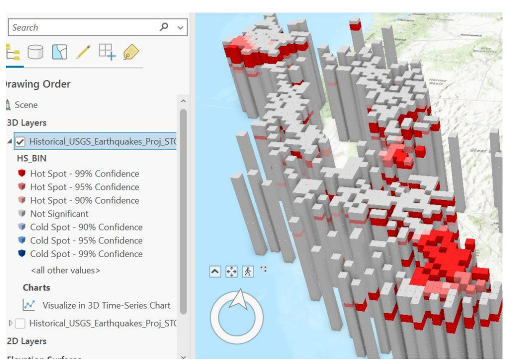
To interact with these maps and further understand project findings, please visit this website:

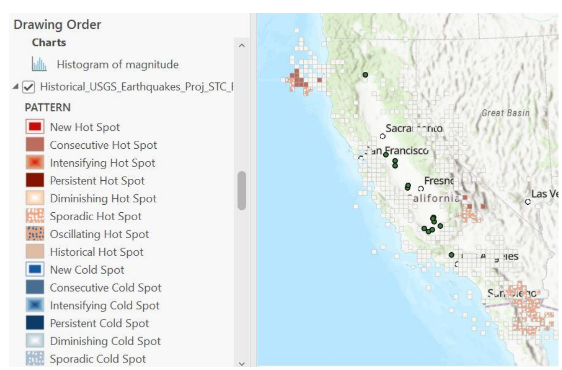
https://experience.arcgis.com/experience/5b0267fa0ad64d8db700e1fb7c4a87fd

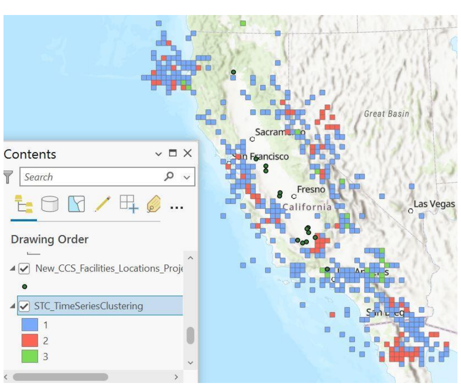


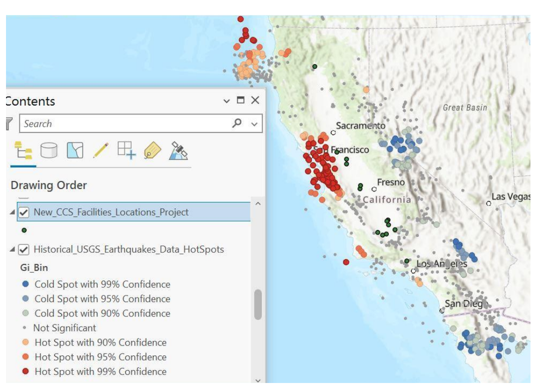


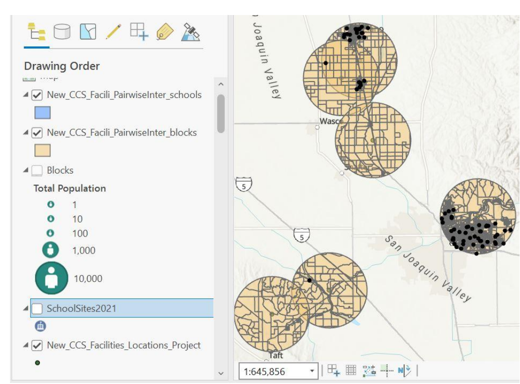












Appendix 2: Fossil Fuels in Disguise Social Media Campaign

Fossil Fuels in Disguise Twitter Campaign:

https://twitter.com/hashtag/FossilFuelsInDisguise?f=video

Link to video version of the Haunted House graphic:

https://drive.google.com/file/d/1wW6gf8I70BK9RyD-rImyBirqNGXNHY9b/view?usp=sharing

A1

A2

A3

Appendix 3: CCS-Induced Earthquake Risk Memo

Environmental Risks Associated with Carbon Capture Storage in California: Special Focus on Earthquakes

By Medha Gelli and Susan Phillips

April 2023

Key Question: Is earthquake risk associated with Carbon Capture Storage in California?

What is CCS?

Carbon Capture Storage (CCS) is a technology that separates carbon dioxide from high greenhouse gas (GHG) emitting point sources, such as fossil fuel plants, biomass processing facilities, concrete factories, etc. (Beck, 2019). The carbon is captured at the smokestacks as it leaves the emitting facility and then is compressed before being injected underground into geological formations to store it, removing CO_2 from the atmosphere. In addition to being stored directly beneath carbon-emitting facilities, CO_2 may also be transported through pipelines and other transit to more distant locations in order to capture it (*CCUS*, 2022; *Carbon Storage Faqs*, 2022; Hong, 2022). The storage of carbon dioxide can be located in saline formations and old oil and natural gas reservoirs (*Carbon Storage Faqs*, 2022). Currently, in the United States, there are 13 CCS facilities with a total yearly capture of more than 40 million metric tons (Jones & Lawson, 2022). Over half of CCS sites globally are in the United States, which currently has 13 operational sites and another 80 in development.

CCS is not just a method to trap carbon dioxide emissions; it can also help to produce hydrogen from natural gas, and be used for enhanced oil recovery from depleted oil and gas reservoirs. About 75% of CCS sites in the United States are used for enhanced oil recovery (Roberts, 2019). Since its development roughly half a century ago, CCS has been used internationally and is promoted by fossil fuel interests and corporations as a negative emissions strategy. However, CCS poses environmental risks due to the extension and continuation of fossil fuel infrastructure, the potential for pipeline leakage, high energy and water demands, and increases in local pollution emissions that lead to environmental justice impacts. The potential for CCS technology to cause, or be damaged by, earthquakes is an understudied risk associated with CCS use. It is important to examine the earthquake risk of CCS in places like California, where earthquakes can damage CCS infrastructure, potentially leading to leaks, and where–similar to fracking–CO_2 injection can cause slippage in underground formations near fault lines. Further assessment of the relationship of CCS to earthquake risk is paramount prior to increasing CCS use in California.

Methods

In addition to surveying the academic literature and select CCS policies, summarized below, memo co-author Gelli utilized GIS to create multiple maps of CCS sites in relation to environmental factors. The maps include aquifer status, proximity to water bodies, proximity to earthquake faults, and proximity to human resources (schools, neighborhoods, and so on). Additionally, we interviewed five expert seismologists and two environmental advocates about the topic of CCS and earthquake risk.

Relevant CCS Policy-Making Bodies and Legislation in Brief

- **IPCC**. The Sixth Intergovernmental Panel on Climate Change (IPCC) places "fossil fuels with CCS" alongside key renewable energy strategies in order to limit planetary warming to under 2 degrees celsius. In their 2022 report, the IPCC indicates that CCS sites "are best deployed in locations which are not water scarce" (Rosa et al., 2020) because CCS can increase water usage by 50-80%. Further, the IPCC report mentions that deep injection of CO2 carries the risk of polluting aquifers. There is no mention of CCS's potential risk from earthquakes.
- **IRA**. In the US, the 2022 Inflation Reduction Act (IRA) enhances the 45Q tax credit for CCS, increasing the tax credit from $50 to $85 per ton of sequestered carbon. The IRA is anticipated to increase the deployment of CCS by 13-fold by 2030 (Tiseo, 2023).
- **CARB**. The California Air Resources Board's (CARB) 2022 Scoping Plan supports Carbon Capture Storage as a key climate mitigation strategy. The Scoping Plan describes the Central Valley's deep sedimentary rock formations as "world-class" sites for CCS that have the potential to store at least 17 billion tons of CO_2–although the plan admits that the modeling for this number is uncertain (p 87). Though the Scoping Plan mentions the need to analyze criteria air pollutants associated with CCS, the report makes little mention of high water and energy demands or earthquake risk, concluding that CCS is a "safe and reliable tool" for carbon removal (p 228).

- **SB 905**. California's SB 905 establishes development, evaluation, review, study, and consultation regarding multiple forms of Carbon Capture, including CCS. SB 905 outlaws the use of CCS for enhanced oil recovery and temporarily prohibits pipeline transfer of carbon in California until federal CO_2 pipeline safety requirements are updated. SB 905 considers potential water pollution as well as the minimization of seismic impacts.

Environmental and EJ Costs of CCS

Fourteen CCS sites in California, mostly located in the Central Valley, are planned to be operational by the end of the decade. Utilizing CCS is easier for fossil fuel industries and other companies to employ in reaching state and federal climate mandates. However, the process of Carbon Capture Storage also comes with significant environmental costs and social justice issues–only some of which are considered in the policy reports and legislation above. CCS uses significant water and energy resources and can contaminate the groundwater supply if CO_2 is leaked during the storage process (Eldardiry & Habib, 2018). CCS is predicted to create stress on water resources, as large amounts of water are used for cooling and emission scrubbing in the capture and separation stages of carbon capture (Eldardiry & Habib, 2018). Similarly, energy demands also increase in a power plant with a CCS system by about 10–40% compared to its traditional counterpart (Eldardiry & Habib, 2018). Also, the process of CCS leads to emissions of Particulate matter (PM), Nitrogen oxide (NOx), Sulphur dioxide (SO2), and Ammonia (NH3), furthering the public health crisis in the Central Valley by worsening the air quality (*CCS Air Pollution* 2020; White, 2020). Lastly, the increased potential for earthquakes due to CCS disproportionately impacts marginalized communities in the Central Valley which have fewer resources to build back from disaster.

Academic Literature in Brief

Academics are on both sides of the CCS debate and have different scientific, political, and environmental reasons for their positions. Professor Howard Herzog at MIT and other academics demonstrate that there is enough underground storage for long-term carbon capture for at least 100 years (Szulczewski et al., 2012). Academics also make the case for the need for CCS deployment in order to achieve climate commitments (Bui et al., 2018). Other analyses show that from a non-technical, political perspective, the United States is in an ideal position to lead commercial CCS use due to the country's resources, innovation, and energy economy (Beck, 2019). Many proponents of CCS acknowledge some of its risks but encourage the United States to advance CCS studies and deployment to improve the technology and begin storing carbon in order to keep planetary warming to between 1.5 and 2 degrees Celsius. Academics against CCS argue that fossil fuel companies are large supporters of it (Gunderson et al., 2020), that CCS is ineffective (Young, 2021; *Hydrogen's hidden emissions* 2022; Readfearn, 2022), and the CCS emissions benefits are offset by increased energy and water use upstream and downstream, as well as significant increases in air pollution (Eldardiry & Habib, 2018; *CCS Air Pollution* 2020).

Academic Literature: Earthquake Risk

Scientists also debate whether CCS has the potential to trigger earthquakes in California (Zoback & Gorelick, 2012). Due to the state's predisposition to earthquakes and prevalent environmental justice issues in areas with predominantly rural, lower-income, people of color residents, CCS can potentially lead to greater harm. These areas, such as the Central Valley, are of pressing concern due to the bigger environmental justice implications for rural communities that are linguistically isolated, have fewer resources, and generally have less support for environmental disaster recovery. Problems with CCS further reveal the serious consequences that disadvantaged communities face due to climate change, pollution exposure, and technological solutions that perpetuate reliance on fossil fuels and existing disparities.

Stanford Professor Mark Zoback has shown that there is a high chance that CCS will trigger earthquakes because even smaller earthquakes can threaten the seal of CO_2 repositories (Zoback & Gorelick, 2012). His paper discourages large-scale adoption of CCS due to its geological risk and cost. Another study by Goebel et al. found that wastewater disposal can contribute to changes in pressure that ultimately result in earthquakes along active fault lines (Goebel et al., 2016). These scholars argue that induced seismicity may only be detected in California with further analysis of these areas, which can also be true for CCS use. Another paper by Amos et al. (2014) notes that groundwater use in the Central Valley exceeds the replenishment of the aquifer, leading to the lowering of the valley floor. This may lead to peaks in the uplift of the Coast Ranges and reduce the normal stress on the San Andreas Fault, increasing the possibility of an earthquake. Given the environmental conditions of the region, CCS use could lead to a greater risk of fault failure.

Data and Findings: CCS Mapping

The following maps and graphics demonstrate the proximity of the fault lines to the Central Valley's proposed CCS sites. Six sites in the area are within five miles of a fault line and two are within 0.75 miles of a fault line. Due to the sites' proximity to fault lines, there are higher chances of CCS facilities triggering earthquakes. The rest of the sites are located within 10 to 25 miles of a fault line. Despite this distance, impacts upon the water table in areas with shallow aquifers and low recharge may lead to the lowering of the Valley floor, impacting larger and more distant fault lines such as the San Andreas. Future pipelines that carry carbon dioxide to another location for storage would also increase the radius of earthquake risk and make CCS infrastructure vulnerable to seismicity and thus leakage or storage failures. These data are provided for the purposes of expert interpretation.

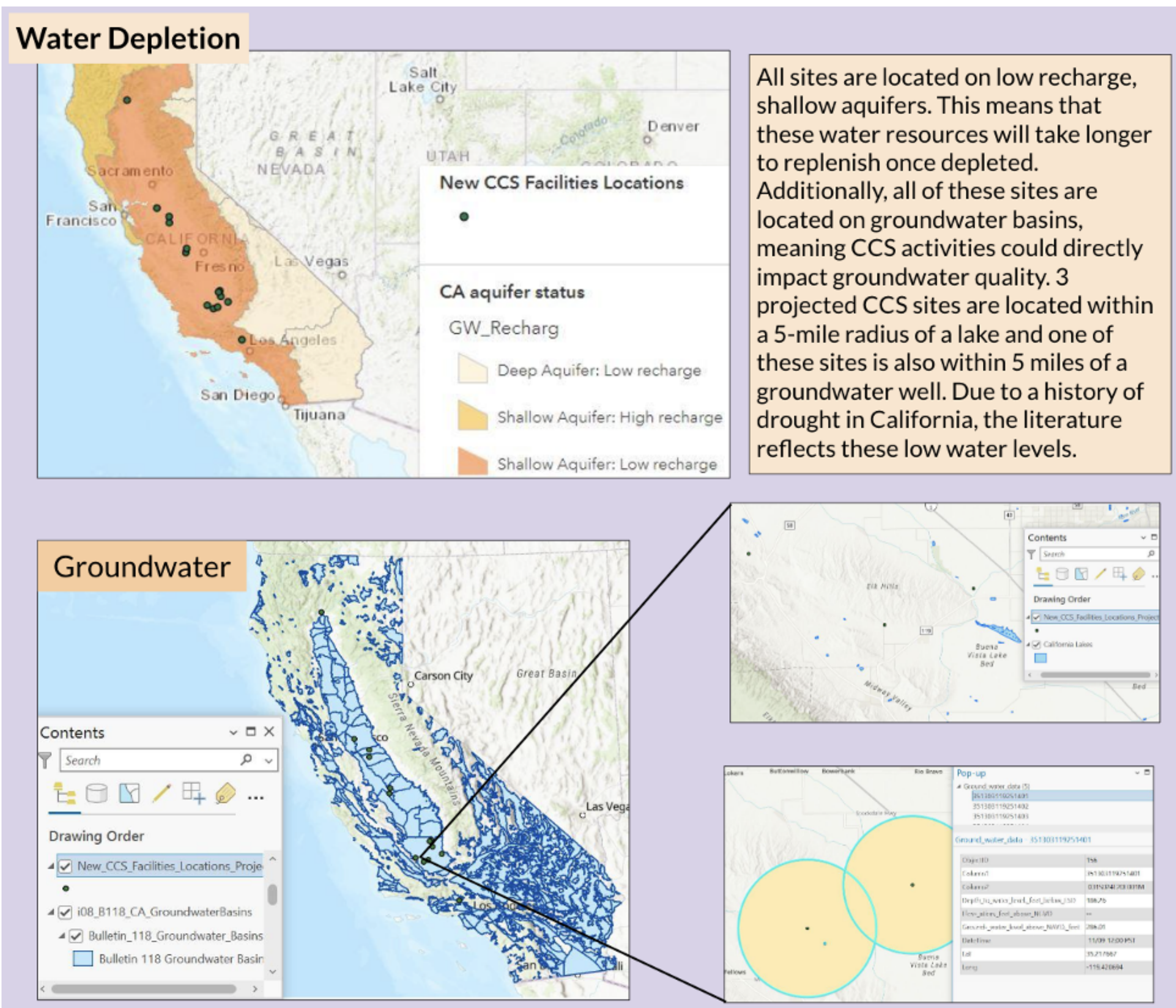
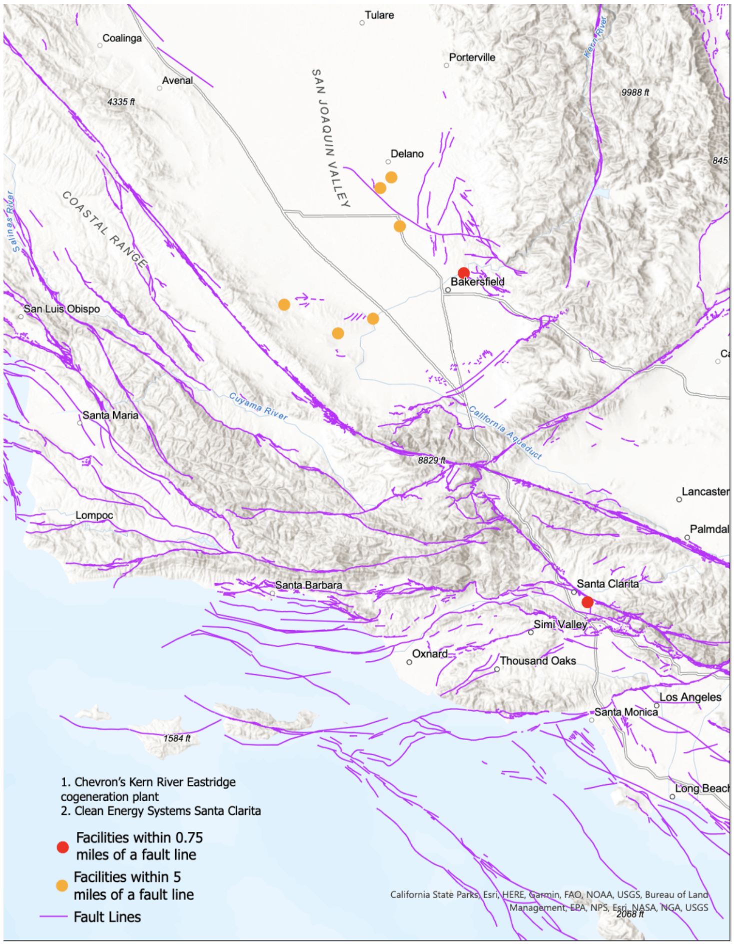
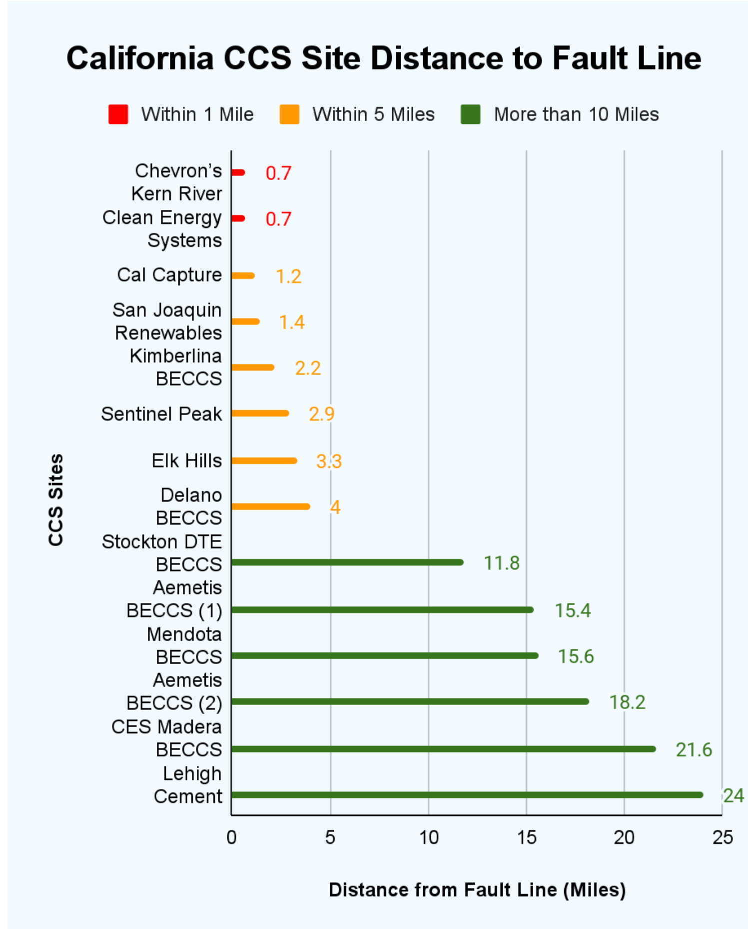
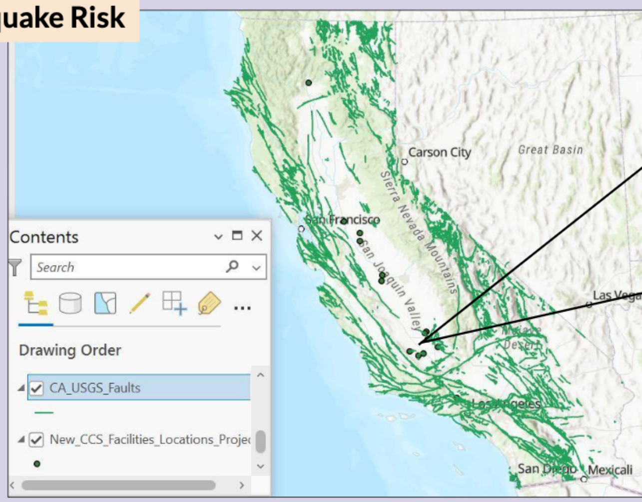


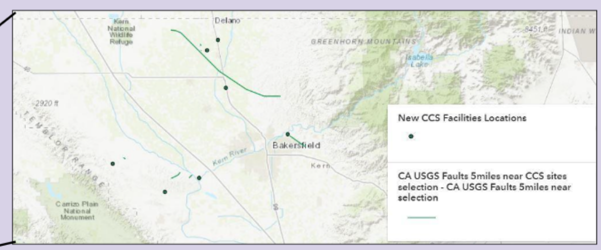
Figure 1. Maps demonstrating planned CCS sites in areas with depleted and significant groundwater resources.





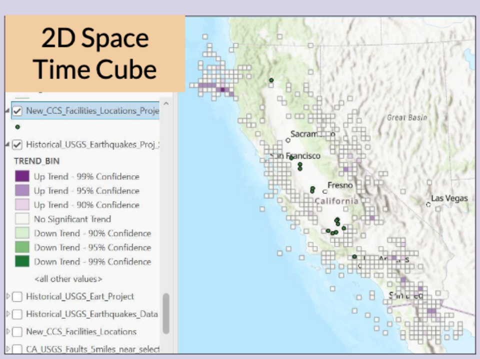
Earthquake Risk



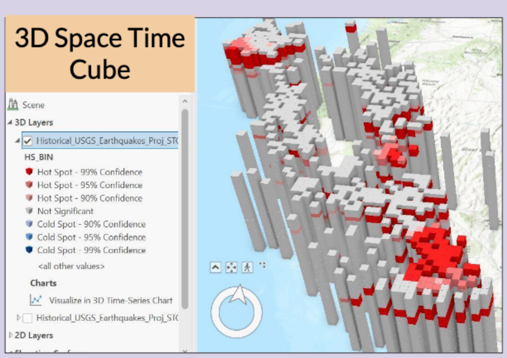


CCS has the potential to trigger earthquakes due to carbon injection into geological formations. These maps show that there are 8 earthquake faults within a 5-mile radius of proposed CCS sites.

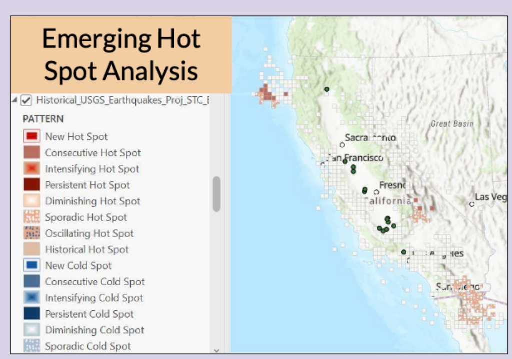
2D Space Time Cube



3D Space Time Cube



Emerging Hot Spot Analysis



Trend of increase from the 2D and 3D Space Time Cube visualizations show that the Northwest, mid-East and Southern California have had earthquake hot spots for the last few decades and will continue to have these hot spots with over 99% confidence. The Emerging Hot Spot Analysis determined that the first two areas mentioned above have consecutive hot spots and all three areas have sporadic hot spots. Therefore, CCS use in these areas is may lead to earthquakes.

Data and Findings: Seismologists Talk about CCS

Jake Walter, State Seismologist for the Oklahoma Geological Survey and faculty of the University of Oklahoma's School of Geosciences: Jake Walter considered that CCS as a climate solution carried risks; he expressed certitude regarding linkages to increased seismicity. He described CCS injection as similar to fracking, which has increased seismicity in locations that were not normally earthquake-prone. Walter shared that any kind of injection into the ground would produce earthquakes. Given that CCS relies on the injection process, he considered it inevitable that CCS would lead to earthquakes that would not have otherwise happened at this time and in magnitude. Also, based on wastewater and other stresses, scientists would be able to demonstrate CCS-caused earthquakes that would not otherwise have occurred. Walter explained that CCS injections and wastewater storage underground can create stresses in the rocks that are felt many kilometers away by critically stressed tectonic faults, which expedite sub-surface failure. Essentially, a small impact could trigger a smaller earthquake further away which could eventually lead to a larger earthquake. Walter noted that it would be very difficult to attribute the latter earthquake to the former. Walter clearly advised that CCS could lead to earthquakes and this could produce additional hazards for California residents.

No'am Zach Dvory, Research Assistant Professor for the Civil and Environmental Engineering Department at the University of Utah: Professor Dvory was a student of Mark Zobak at Stanford and expressed interest in CCS as a key climate solution. In terms of earthquake risk, he recommended that we look at the history of earthquakes in the area, specifically active faults and tectonic stresses, because, in these areas, a small amount of pressure can induce a slip. He mentioned that the total volume of injection and how pressure propagates in the sub-surface layer is more important than the distance of CCS facilities to fault lines. So, it is critical to understand the proposed amount of injected carbon and extend CCS research before starting up CCS sites with unknown geological repercussions.

Jean-Philippe Avouac, Professor of Geology and Mechanical and Civil Engineering at CalTech: Seismologist Jean-Philippe Avouac was enthusiastic about CCS as a carbon capture technology and stressed its importance for decarbonization. He disclosed that he works directly with CCS companies. In terms of earthquake risk, Avouac indicated that CCS could lead to groundwater reductions and that if earthquake concerns are substantive enough, they can shut down facilities. Avouac encourages the companies he works with to do case studies for CCS use prior to the installation of facilities. However, since that is an out-of-pocket cost, they are often unlikely to volunteer to pay for additional research. He said that studying areas outside the Central Valley (such as Canada) would provide data on CCS because California does not mandate its collection. Avouac indicated that California might actually be better suited to deal with any increased seismicity from CCS since the state is already familiar with earthquakes and thus somewhat prepared for them. Avouac contended that earthquakes that were induced by CCS would likely have occurred anyway in those locations–just at different times. He also mentioned that, as oil and gas fields are depleted, carbon injection might help to stabilize geological formations–essentially taking the place of the oil and gas. Avouac mentioned that the state should be cautious in furthering CCS too rapidly and should maximize study and data gathering. He indicated that companies would welcome this data and could partner with other industry leaders while benefiting from regulatory supervision so they are not liable for CCS. He indicated that government research and agencies are not up to this level yet. Therefore, it is crucial that CCS be studied further.

Howard Herzog, Senior Research Engineer and Professor at MIT (MIT Energy Initiative):

Howard Herzog emphasized that CCS should be conducted properly with precaution in order to achieve necessary CO_2 emissions reductions. In response to Professor Zoback's work at Stanford, Professor Herzog wrote a letter stating that Zoback's article was too extreme and that microseismicity is inevitable when it comes to any type of subsurface injection (Juanes et al., 2012). He mentioned that fluids are safely injected all the time, but faulted areas should be avoided for CCS. Also, Herzog mentioned that when CCS is done correctly with proper pressure management, it should not lead to additional problems. He said the risks with CCS are not out of line compared to the risks with current industrial practices. When it comes to implementation, Herzog explained that CCS is deployed where existing oil and gas operations are located, which in California's case is mostly in the Central Valley. For this area, he recommended listening to local experts who are aware of the specific geography and fault lines, and said that it is likely that there are reasonable places for CCS in the Central Valley.

Professor Thomas Goebel, Assistant Professor at the University of Memphis:

Professor Goebel clarified that injections can lead to earthquakes, especially near California's active plate boundaries, but multiple factors make it difficult to prove the probability and magnitude of injection-induced seismicity. One of his studies focused on the Central Valley showed that injection kept earthquake rates stable, which either means that there is no impact or a masked impact due to a generally high level of tectonic activity in the region (Goebel et al., 2016). At the Tejon Oil Field near Bakersfield, he found that there is a significant spatiotemporal correlation between injection rates and the number of earthquakes, suggesting the masked impact hypothesis is a better answer. Professor Goebel also shared a variety of reasons that it can be difficult to determine induced seismicity risk, such as unknown pre-existing tectonic stress conditions, a lack of pre-injection earthquake data in California, and the thick sedimentary rock column in the Central Valley that prevents fluids from reaching deeper faults. Although Professor Goebel was looking at wastewater disposal, the mechanism for CO_2 injection is similar when storing carbon underground and can cause similar side effects, such as fault line slippage and earthquakes. He noted that his study is unique because this area and topic are not well studied, so even though there is little evidence of notable induced earthquakes in the Central Valley, that does not mean it does not exist. Goebel understood Avouac's comment regarding extra earthquake preparedness in California but thought this would be a nonstarter with California residents. Goebel indicated that using old oil and gas reservoirs for carbon storage means that the reservoir pressure had dropped due to prior extraction and can handle higher fluid pressure. This a good thing for CCS, because the cap rock is still intact and can keep CO_2 in place under the surface. In this way, using emptied reservoirs can mitigate seismic hazards. In general, Goebel noted that monitoring areas of potential injection and being aware of the previously identified hazardous faults and earthquakes will help reduce the effects of induced seismicity.

Summary of Seismologists

All of the seismologists we interviewed agreed that CCS is not studied well enough to understand its full impacts on earthquake risk, efficiency, or other risks. Jean-Phillipe Avouac said that research is not conducted because there is no data in California, since fewer regulations mandate data reporting. No'am Zach Dvory and Howard Herzog mentioned that proper management is necessary to reduce the adverse effects of CCS, but that CCS could be done safely. Jake Walter explained that scientists do not fully understand how the magnitude of an earthquake would change based on stressors since it is hard to know the full extent of conditions in the geological system. And Professor Goebel echoed this sentiment and added that there are currently more induced seismicity studies in geothermal than hydrocarbon, so this area does require further research.

Seismologists continue to have varied viewpoints on CCS and its seismic impact. One of the biggest points of contention is that some seismologists thought that CCS-induced earthquakes would have happened naturally anyway versus being able to prevent or reduce the magnitude of these earthquakes by reducing anthropogenic injection. Another key difference was that the interviewees differed in their confidence in CCS and its viable application in California, nationally, and globally.

Conclusion

Carbon Capture Storage in California's Central Valley requires further study to understand its implications for the region. CCS technology can capture carbon, but the technology also produces carbon as well as posing numerous environmental risks, most of which are understudied. Environmental groups consider CCS to be a greenwashing tool that allows for the perpetuation of fossil fuel technologies at a time when we should be weaning ourselves from carbon-intensive processes. Even if seismic risk is deemed minimal with further study, the

Central Valley may still not be a suitable location for CCS due to drought, low groundwater levels, flood risk, fewer resources (i.e. energy and money), and already poor air quality. The earthquake risk in the Central Valley only adds to an existing list of issues that need to be considered and weighed alongside Nature-based Solutions. More independent research needs to be done to ensure safe CCS use as well as its efficacy. CCS use in drought-ridden California entails quadruple risk–it goes against the IPCC recommendation not to utilize CCS in water-scarce areas, it risks polluting aquifers, and carries an unknown probability of increased seismicity, as well as increasing environmental impacts and energy use.

Many factors remain unconsidered regarding the use and placement of CCS. Increased whiplash patterns of extreme weather, labor, health, biodiversity, bioproductive land use, and equity concerns need to be considered holistically. Assessing the ability of technologies work with or against natural systems under stress will be pivotal during the next decades. How CCS technologies interface with stressors such as drought, water, air, fire, flood, and earthquake should be integrated into a broader cost-benefit analysis that harnesses diverse scientific, equity-based, and environmental expertise into a holistic accounting of CCS technology as a climate strategy.

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