Undergraduate Thesis Prospectus

# Use of Full Oxy-Fuel Combustion and Accelerated Carbonation Curing for Carbon Capture and Storage in Concrete Manufacturing

(technical research project in Chemical Engineering)

# The Lobbying Game: How Chemical Companies and Environmental Advocates Shape Policy

(sociotechnical research project)

by

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On my honor as a University student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments.
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**General Research Problem: Corporate involvement in federal law**

*How do American corporations seek to influence federal regulations in their interest?*

In *Citizens United v. Federal Election Commission* (2010), the U.S. Supreme Court ruled that corporations, like citizens, have a free speech right to contribute money to political campaigns. Corporations can seek to influence public policy by influencing the elections of the elected officials who shape it. In 2015, corporations spent about $2.6 billion on lobbying, much more than the U.S. government spends to fund the House and Senate ($2 billion) (Drutman, 2015). Corporations seek to influence public policy through public relations and through third parties such as think tanks (Cave, 2014). Since the Citizens United ruling, corporations have had greater opportunities to influence public policy.

**Use of full oxy-fuel combustion and accelerated carbonation curing for carbon dioxide emissions capture in concrete manufacturing**

*How can carbon dioxide emissions be captured in concrete manufacturing?*

This project will be worked on under the advising of professor Eric Anderson in the Chemical Engineering department. The project is a capstone project, that will be completed with three other chemical engineering students: Camille Cooper, Sarah Gill, and David Reed.

Concrete is the most widely used human-made material in existence. In terms of human consumption, it is second only to water (Rodgers, 2018). Unfortunately, cement, the principal component of concrete, leads to massive carbon dioxide ($CO_2$) emissions; in fact, approximately 2.2 billion tons of $CO_2$ per year, making up 8% of all global carbon emissions (Rodgers, 2018). This represents the second-largest single industrial process emitter after iron and steel production (Harvey, 2018). The cement industry is a promising opportunity for industrial sustainability due to its scope and worth. Market projections suggest that the cement market value will grow from $312.5B in 2018 to be worth $682.3B by 2025 (Grand View Research, 2018).

This prospectus will propose an alternative to the process of making cement as well as a production method for utilizing concrete as a Carbon Capture and Sequestration/Storage (CCS) technology. To meet the standards outlined in the 2015 Paris Agreement, it will require that global carbon emissions associated with cement production drop 16% by 2030 (Rodgers, 2018).

Over the last few decades, many advances have been made with regard to kiln and feedstock design in order to make the process more environmentally-friendly. However, only recent studies have explored the possibility of CCS and cement's role in this environmentally-sustainable technology. Additionally, the resulting designs of these studies face adverse market conditions. An economically-viable design will be necessary to garner the support needed to make a substantial shift toward sustainable cement production.

Ordinary Portland Cement (OPC) is the industry standard cement. OPC is produced when limestone, or another source of calcium carbonate, is crushed and mixed with other ingredients, such as clay, shale, or slag, and subsequently heated in a cylindrical, rotary kiln. The product of this kiln firing are small and circular pellets, called clinkers.

These hot molten pellets are sent through multiple coolers until they reach a cold enough temperature to be handled by humans. Then water can be added to the mixture to form concrete. In terms of cement produced, the de-carbonation of limestone in the kiln produces about 525 kg $CO_2$ per ton of product, and the fuel combustion step produces about 335 kg $CO_2$ per ton of cement (Bosoaga et al., 2009).

The two alterations to this design are oxy-fuel combustion and accelerated carbonation curing. Oxy-fuel combustion is a CCS technology. The process begins with an air separator, which produces a pure $O_2$ feed to the combustion process. The oxygen is then fed, in conjunction with a hydrocarbon fuel, to the boiler which facilitates combustion. $CO_2$ and $H_2O$ are the main products of this process and are taken off as flue gas. The stream then splits into two, one which recycles part of the flue gas back into the boiler, and one which leads to cooling, compressing, and dehydrating the stream to produce pure $CO_2$.

Part of what sets oxy-fuel combustion apart from other CCS technologies is that the process utilizes a pure $O_2$ stream and recycles flue gas back into the combustion process. This is as opposed to feeding air into the process, which presents inert nitrogen to dilute the $O_2$ in the boiler. Using flue gas to dilute oxygen instead allows for higher conversion to the products. The process is also one of the most viable and efficient CCS technologies available today.

Carbonation naturally occurs over time when cement paste and atmospheric $CO_2$ meet. However, this process can be accelerated for precast concrete to significantly increase carbon storage capacity, minimizing the cement-making process' overall carbon footprint. Accelerated carbonation occurs when $CO_2$ gas diffuses into the porous concrete. The solvation of gaseous $CO_2$ occurs before it is hydrated to $H_2CO_3$. Once $H_2CO_3$ forms it is then ionized. The newly formed $H^+$ ions cause the pH of the concrete to decrease. Finally, the nucleation of the $CaCO_3$ occurs, and C-S-H gel forms. Instead of hydrating, $CO_2$ could instead react with silicate phases, dicalcium silicate and tricalcium silicate, to dissolve exothermically and form stable calcium carbonates. The $CaCO_3$ then precipitates out of the solution to complete the carbonation curing process.

Barriers to implementing a CCS process in concrete production are mostly in the oxy-fuel combustion component. High combustion temperatures and costs associated with using oxy-fuel combustion (more fuel, energy to increase temperature) are issues associated with our design that should be taken into account. The introduction of a pure $O_2$ stream to the kiln, instead of an air stream, also increases the partial pressure of $CO_2$ in the kiln, and changes the reaction from a gradual to a threshold reaction (threatening re-carbonation of lime to limestone, and making the reaction much more sensitive) (Zeman, 2009). The whole process will be designed using Aspen Plus software. If, successful, our group will have a fully designed process for cleaner manufacturing of cement.

## The Struggle over Regulation of Chemical Industries in the U.S.: Safety, Sustainability, and Productivity

*How do U.S. chemical companies, environmental advocates, and others compete to influence federal legislation in their favor?*

Though American chemical companies have welcomed many regulations, they have opposed many others. Primarily, however, chemical companies do not so much strive to thwart regulation as to influence it in their favor. But in so doing they compete with environmental advocacies, which often demand stricter regulations. Chemical companies exercise their influence through lobbying. Between 2011 and 2014, “the chemical companies and their industry trade group gave more than $2.2 million to members of the House and Senate committees that initiate new chemical reform legislative proposals” (Green, 2015).

Many researchers have examined the extent of chemicals companies’ involvement by analyzing their expenditures on lobbying. For example, almost all of the largest chemical companies have increased spending on lobbying between 2008 and 2014 (fig. 1).

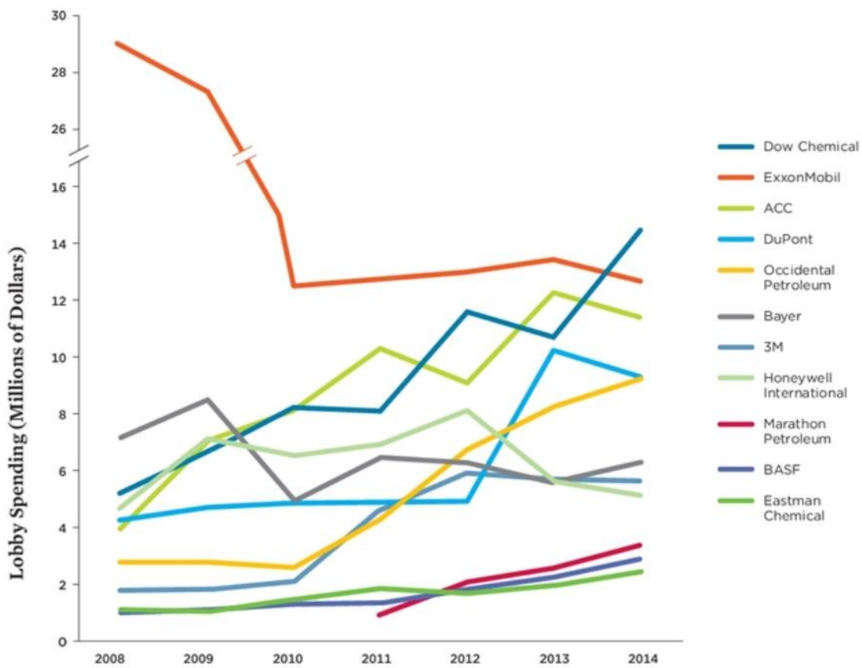

Figure 1. Lobbying Spending by the American Chemistry Council and Select Member Companies

(Goldman et al., 2015)

Other researchers have examined environmental policymaking. Chepesiuk (1994) examined trade associations, nonprofit interest groups, and scientific research organizations, finding that the industrial sector has the most resources at its disposal. However, in the case of the Chemical Facilities Act of 2008, environmental groups formed a coalition to lobby for stricter safety regulation at chemical planta, while industry opposed the measures, claiming they required “expensive innovation” (Smoot, 2008).

Chemical companies, environmental advocacies, and citizens’ groups are engaged; they seek to exercise influence through lawmakers and through scientific research. Chemical companies aim to roll back federal regulations by funding candidates who will likely support bills with rollbacks. In 2016, ExxonMobil spent about $11.8 million on lobbying for deregulation of chemical companies (Center for Responsive Politics, 2018). Environmental advocacies have long condemned chemical corporations’ policy influence. For example, Pesticide Action Network is committed to “shining a light on the undue influence of the pesticide industry on decisions made by regulators in Washington, D.C” (PAN, 2019).

Congress has historically sided with these chemical companies in the past 6 years. In November 2017, Congress passed a bill to revoke the Stream Protection Rule, which prevented coal mining companies from dumping debris into local streams (Federal Register, 2017). Many people have become victims of toxic chemical exposure and have fought to prevent chemical companies from releasing harmful chemicals into the environment. One such person, named Wendy Rash, was diagnosed with a thyroid disorder, and doctors could not explain her sudden failing health. Her family then became victims of various types of cancers. They eventually found out that a nearby chemical plant contaminated their drinking water with PFAS, a toxic chemical known to cause health defects (Cloud, 2020). Scientific researchers aim to analyze environmental issues by advancing scientific understanding. Since most Congressional members do not have the expertise nor the time to thoroughly investigate complex issues such as environmental impact, scientists serve as an independent and impartial voice (Bohlen, 1990).

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