CO2 Filtration Device for Automobile Exhausts

Grant Proposal

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Author Note

If needed, write notes here with an indented first line. Be mindful, the text in your lit. review should be between 10-12 font size with a chosen font of Caibri, Times New Roman, or Arial. A Table of Contents is *optional*; however, you should format the section headers appropriately to have them show up in the TOC. Lines should be double-spaced.

Executive Summary

Transportation is one of the largest contributors to global CO_2 emissions, and gasoline-powered vehicles continue to release CO_2 directly into the atmosphere because catalytic converters cannot remove this stable combustion byproduct (EPA, 2023; Hamilton et al., 2023). As climate change intensifies, the need for accessible point-source carbon mitigation technologies grows increasingly urgent (IPCC, 2021). This project proposes the development of a CO_2 Filtration Device for Automobile Exhausts, an attachable, low-cost system that uses hydroxides to chemically convert CO_2 into stable carbonate before it exits the tailpipe. This project currently plans to use NaOH, which is well supported in carbon-capture literature for its fast reaction kinetics and strong absorption capacity (House et al., 2011; Stern et al., 2012). Preliminary impinger testing demonstrated approximately 75% CO_2 removal in under one minute. The goals of this project are to design a heat-resistant, high-surface-area NaOH filtration cartridge and to evaluate real-world CO_2 reduction during vehicle operation. By adapting principles from emerging mobile carbon capture research (Kim, 2024; Hadi, 2025) and distributed CO_2 removal technologies (Prats-Salvado et al., 2024; Li et al., 2024), this project aims to develop a first-of-its-kind, consumer-level, vehicle exhaust scrubbing device that enables individuals to directly reduce their carbon emissions during automobile transportation.

CO2 Filtration Device for Automobile Exhausts

Carbon dioxide (CO2) is the leading greenhouse gas emitted by humans, and transportation accounts for a major portion of those emissions (EPA, 2023). Gas-powered vehicles release CO_2 as an unavoidable byproduct of combustion, and because CO_2 is chemically stable, current exhaust systems, including catalytic converters, do not eliminate it (Hamilton et al., 2023). This means that even cars equipped with modern emissions control systems continue to emit significant quantities of CO_2 every time they operate.

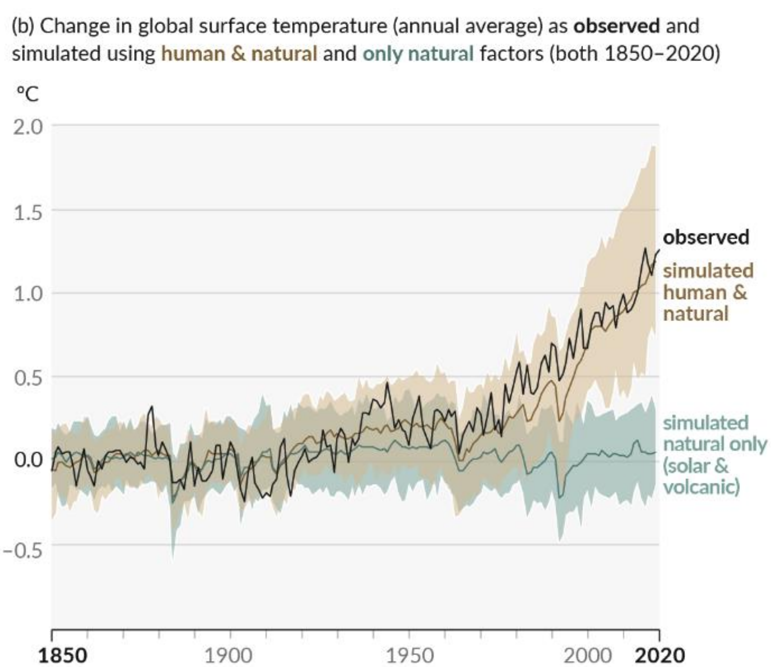

Figure 1: Changes in global surface temperature over the past 170 years (black line) relative to 1850–1900 and annually averaged, compared to Coupled Model Intercomparison Project Phase 6 (CMIP6) climate model simulations (see Box SPM.1) of the temperature response to both human and natural drivers (brown) and to only natural drivers (solar and volcanic activity, green). Solid colored lines show the multi-model average, and colored shades show the very likely range of simulations. (IPCC, 2021).

Scientific assessments have shown that atmospheric CO_2 concentrations continue to climb, accelerating warming and increasing the severity of climate-related disasters (See Figure 1). While electric vehicles, hydrogen-powered systems, and renewable energy technologies are growing rapidly, internal combustion engines remain widespread, and millions of gas-powered vehicles are expected to remain on the road for decades. This creates a pressing need for transitional technologies that can mitigate emissions from existing vehicles.

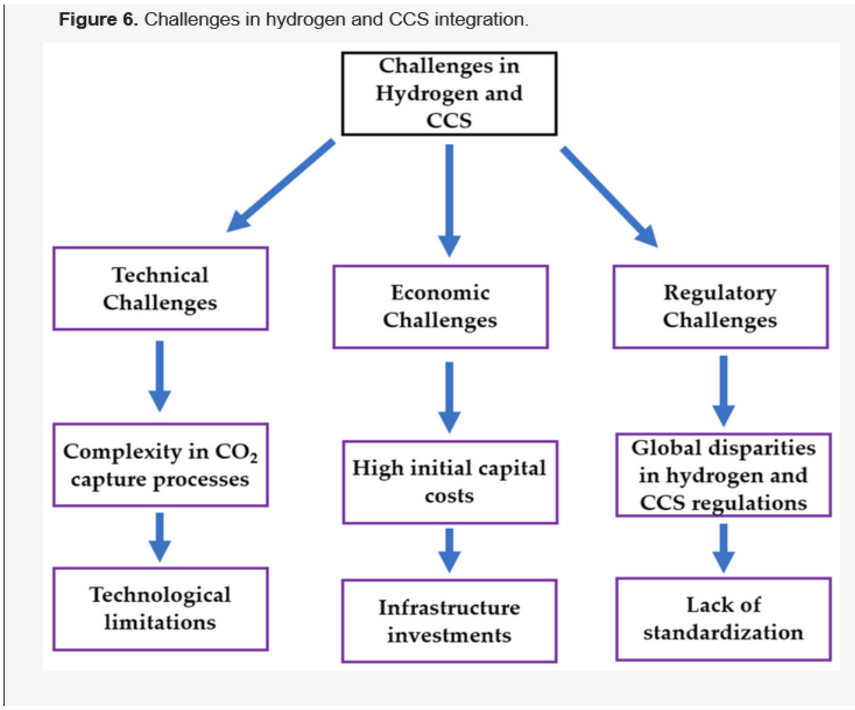

Figure 2: Challenges in Hydrogen and Carbon Capture System integration. (Alizadeh et al., 2024)

Carbon capture technologies have traditionally focused on industrial smokestacks or large-scale direct air capture (**DAC**) systems. These systems often require significant infrastructure, energy inputs, and investment (See Figure 2). However, emerging research has expanded into mobile carbon capture designs, systems built to operate on moving platforms such as long-haul trucks and heavy-duty machinery (Hamilton et al., 2023; Kim, 2024). These advancements demonstrate growing interest in distributed, decentralized forms of carbon capture that do not rely on stationary facilities.

Chemical absorption remains one of the most effective CO_2 removal pathways for small-scale systems. Sodium hydroxide (NaOH) is particularly notable due to its rapid reaction with CO_2, high absorption capacity, affordability, and compatibility with porous substrates that increase surface area (Stern et al., 2012; House et al., 2011).

The reaction converts CO_2 into sodium carbonate (Na_2CO_3), a stable solid that remains safely inside the filter until disposal. This makes NaOH a compelling scrubbing medium for an exhaust-mounted device; however, the process would be the same with other hydroxides.

Recent studies in DAC and solar-assisted CO_2 capture highlight the growing scientific interest in small, flexible, and renewable carbon removal approaches (Prats-Salvado et al., 2024; Li et al., 2024). By adapting similar chemical principles into an exhaust-mounted system, this project aims to capture CO_2 at the exact moment it is generated, making it one of the first prototypes to explore personal-scale point-source carbon capture.

This project integrates chemistry, engineering and environmental science to create a practical CO_2 filtration device that everyday drivers could eventually use, contributing directly to emissions reduction at the individual level.

Section II: Specific Aims

This proposal's objective is to design, prototype, and evaluate a CO_2 Filtration Device for Automobile Exhausts that uses hydroxide-based chemical scrubbing to remove CO_2 directly from vehicle emissions. My long-term goal is to contribute to the development of scalable, consumer-friendly carbon mitigation technologies that can help reduce emissions from existing gasoline vehicles. The central hypothesis is that a porous, hydroxide-coated filtration module can achieve meaningful CO_2 removal under real exhaust conditions if designed to balance chemical reactivity, heat resistance, and airflow.

The rationale is grounded in extensive literature demonstrating hydroxides' strong CO_2 absorption capability (Stern et al., 2012), the feasibility of mobile carbon capture systems (Hamilton et al., 2023; Kim, 2024), and the growing need for accessible climate technologies (IPCC, 2021; Alizadeh et al., 2024). The work proposed will create and test a functional prototype, generating foundational data on filtration efficiency, device durability, and real-world viability.

Specific Aim 1: Test and analyze 4 different hydroxides for efficiency of chemical scrubbing of CO2 in a controlled environment at low CO2 concentration.

Specific Aim 2: Select the most efficient hydroxide, then test said hydroxide at higher CO2 concentrations to more accurately determine effectiveness in an automobile exhaust application.

Specific Aim 3: Design and construct the filtration device (the actual exhaust cap) using the determined hydroxide. Then complete and analyze real world experimentation with the device.

Expected Outcome:

A functional CO_2 scrubbing prototype that demonstrates measurable CO_2 reduction and lays the groundwork for future mobile carbon capture research and consumer-level deployment.

Section III: Project Goals and Methodology

Relevance/Significance

With transportation contributing heavily to global CO_2 emissions and no existing exhaust systems designed to eliminate CO_2, this project fills a crucial technological gap (EPA, 2023). As millions of gasoline vehicles continue to operate worldwide, point-source carbon capture offers an important transition strategy until carbon-neutral transportation becomes universal (IPCC, 2021). Developing a compact, low-cost CO_2 filtration device for personal vehicles could empower individuals to reduce their carbon footprint directly.

Innovation

This device will be the first commercially available exhaust-mounted NaOH chemical scrubbing device. It moves beyond catalytic converters to address CO_2, the pollutant currently left untreated. It also uses chemical transformation, not mechanical filtration, for higher efficiency. The device Incorporates research from mobile carbon capture studies (Hamilton et al., 2023; Kim, 2024), and bridges stationary DAC concepts with consumer-scale devices (Prats-Salvado et al., 2024; Li et al., 2024).

Methodology

Specific Aim #1: Test and analyze 4 different hydroxides for efficiency of chemical scrubbing of CO2 in a controlled environment at low CO2 concentration.

The objective is to run CO2 gas through different hydroxides and analyze the change in concentration over time after filtration. This will determine the most effective hydroxide for chemical scrubbing at the current concentration of CO2.

Justification and Feasibility. This test is necessary because it will allow for more efficient filtration due to a higher absorption rate on the hydroxide, therefore needing less of one hydroxide during use. This test will save both time and money and allow for better filtration later on. It is a feasible method because it uses very few resources, the testing is quick, and there is little danger to the testers.

Summary of Preliminary Data

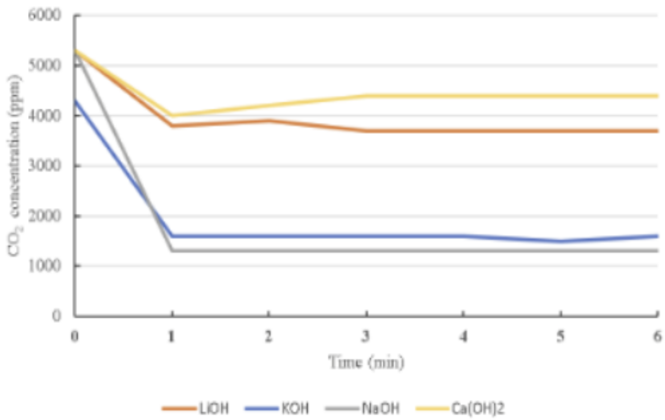

Figure 2: Concentration of CO2 in outlet gas after passing through various hydroxides. 30 g of each hydroxide was taken in the impinger and nitrogen-CO2 mixture was passed through the impinger at 1 L/ min. The carbon dioxide concentration of outlet gas was measured at one-minute intervals for six consecutive minutes.

The data shows the reduction of CO2 concentrations, over a span of 6 minutes, between the 4 different hydroxides (LiOH, KOH, NaOH, and Ca(OH)2). Ca(OH)2 showed an average reduction of 24.5% CO2, LiOH showed an average reduction of 28% CO2, KOH showed an average reduction of 62% CO2, and NaOH showed an average reduction of 75% CO2. Thus, at this lower concentration, NaOH filtered the most effectively.

Expected Outcomes. The overall outcome of this aim is to determine the most efficient hydroxide at chemically scrubbing CO2 at a low concentration. This knowledge will be used to then test that same hydroxide at higher concentrations.

Potential Pitfalls and Alternative Strategies. I expect that experimentation might be difficult, especially adjusting the CO2 concentration, and creating reliable data. This means I will likely need to re-test.

Specific Aim #2: Select the most efficient hydroxide, then test said hydroxide at higher CO2 concentrations to more accurately determine effectiveness in an automobile exhaust application.

The objective is to re-test the most efficient hydroxide at higher concentrations of CO2 and analyze the change in concentration after filtration. This will determine the usability of the hydroxide for CO2 filtration at higher concentrations.

Justification and Feasibility. This test is justified because it is necessary to determine the usability of the hydroxide in a controlled setting prior to attempting use in a real-world environment. Without doing so, much more time and resources could be wasted. It is feasible because little materials and time are used, and it does not danger the tester.

Summary of Preliminary Data

	Concentration of CO_2 in the outlet gas after 'x' minutes (%)					
Concentration of CO_2 in the inlet (%)	1	2	3	4	5	6
5.07	0.38	0.37	0.36	0.34	0.33	0.31
9.85	2.65	3.93	5.12	6.23	6.37	6.49
14.87	8.25	11.56	12.80	13.52	13.75	14.02

Table 1: CO2 absorption capacity of solid sodium hydroxide pellets at higher concentrations of CO2 when placed in an impinger. Inlet gas with varying CO2 concentration was passed through NaOH pellets to observe the CO2 absorption capacity of NaOH at higher levels of CO2. This experiment was conducted to check the suitability of NaOH as a CO2 scrubber for industrv effluents or automobile exhaust.

The data shows NaOH filtration (using the same methods as the last experiment) of CO2 at 3 different concentrations: 5.07%, 9.85%, and 14.87%. 92% decrease in concentration at 5.07% inlet concentration after the first minute, and a 96% decrease after 6 minutes. Then a 73% decrease in concentration at 9.85% inlet concentration after the first minute, but then it decreased to only 34.2% after 6 minutes. Lastly, a 42% decrease in concentration at 14.87% inlet concentration after the first minute, but then it decreased to 12% after 6 minutes, showing a similar pattern to the previous test.

Expected Outcome. The overall outcome is to determine if sodium hydroxide is an appropriate filtration method to use in an automobile exhaust application. This knowledge will then be used to determine whether further testing is necessary, and if not, it will be used in the design and construction of the exhaust device itself.

Potential Pitfalls and Alternative Strategies. I expect that experimentation may show unsatisfactory results. This means that further testing and reconsideration of processes and methodology may be necessary.

Section IV: Resources/Equipment

- Sodium Hydroxide (NaOH) pellets or solution
- Lithium Hydroxide (LiOH) pellets or solution
- Potassium Hydroxide (KOH) pellets or solution
- Calcium Hydroxide (Ca(OH)2) pellets or solution
- Porous filter matrix (ceramic, metal foam, or mesh)
- Exhaust-mountable metal housing (cylindrical and rectangular)
- CO2 gas detector / analyzer
  - determines concentration of CO2
- Impinger testing apparatus
  - houses hydroxide and is the location of filtration in testing
- Air pump / CO_2 gas pump
- Stainless steel clamps and mounting hardware
- Heat-resistant gloves
- Safety goggles
- Lab glassware and tubing

Section V: Ethical Considerations

Caustic Material:
NaOH is highly caustic and can cause chemical burns. Gloves and goggles are mandatory. (OSHA, 2022)

High Exhaust Temperatures:
Exhaust gases may exceed 400°C. Components must be heat-resistant; handling requires protective equipment.

Pressure and Backflow:
Improper design could restrict airflow, so pressure monitoring during testing is crucial.

Chemical Saturation:
Once NaOH becomes sodium carbonate, CO_2 capture stops. Used filters must be disposed of appropriately.

Section VI: Timeline

August	September	October	November	December	January

Completed some of the General Research	September 21th: Complete Carbon Capture Research	October 4: Start collecting Preliminary data Also check for feasibility	November 1: Look into gathering materials	December 1: Finalize and Analyze Data	January: After fair, evaluate necessary changes
	September 28th: Complete all general research (can research more later if needed)	October 18: Develop Experiment/Testing Methods Also check for feasibility.	November 10th: Begin constructing & testing prototype	December 8: Create conclusion/ presentation	Possibly do more research
		October (whole): Do More research where applicable	November 20: Begin collecting official data.	Rest of December: Make changes and edits where applicable	

Section VII: Appendix

Section VIII: References

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