Carbon Capture Machine (CCM)

DOE NETL/FECM Project Presentation DE-FE0032399

Biomass ash valorization by CO_2 capture for nanosized amorphous calcium carbonate production and use in lower carbon footprint cement

Kick-off Meeting

Raj Mosali
Principal Investigator

Lance A. Scott
Project Director

Revision: *January 9, 2024*

Carbon Capture Machine (CCM) Background

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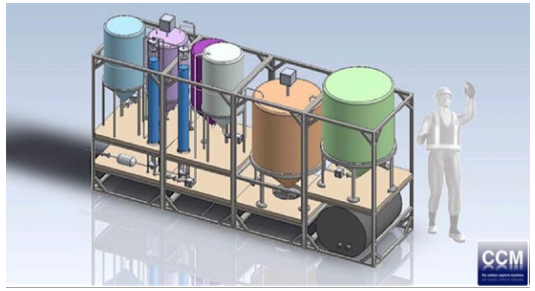

The company formed its roots at the University of Aberdeen, Scotland, as research "Team CCM" in the $20 million NRG COSIA Carbon XPRIZE competition.

- **September 27, 2017** – Carbon Capture Machine (UK) Ltd was founded by Dr. Mohammed Imbabi, Professor Fredrik Glasser and Professor Zoe Morrison.
- **April 9, 2018** – After a successful demonstration of a 200 kg CO_2/day XPRIZE pilot, CCM was selected as a Finalist and awarded $500,000 cash prize.
- **May 29, 2019** – A bipartisan delegation of U.S. Senators together with Paul Wheelhouse, Member of the Scottish Parliament (MSP), visited CCM (UK) Ltd as the sole European entrant to reach the finals of the NRG COSIA Carbon XPRIZE. The U.S. Senate delegation was led by Sen. Lisa Murkowski (R-AK), Chairman of the Senate Energy and Natural Resources Committee, and included Ranking Member Joe Manchin (D-WV), Senators Maria Cantwell (D-WA), John Barrasso (R-WY), and Sheldon Whitehouse (D-RI).
- **June 2019** – During an exploratory visit to SelectUSA Investment Summit in Washington, DC, Dr. Imbabi and Professor Morrison met with various potential collaboration partners including Lance Scott of Alliance Technologies, to discuss a planned capital raise, execution of the XPRIZE finalist competition, and further business development.
- **August 10, 2019** – After a brief illness, Dr. Imbabi sadly passed away, leaving the remaining team distraught and unable to complete the XPRIZE vision.
- **March 2020** – The COVID-19 pandemic forced the University of Aberdeen into a lockdown, and Alliance Technologies suffered a similarly tragic loss of a business partner and dear friend.
- **May 2022**, Lance Scott (Alliance Technologies) and Prof Paul Anastas (Yale University) acquire CCM. Prof. Fred Glasser remains on as a Founding Member.

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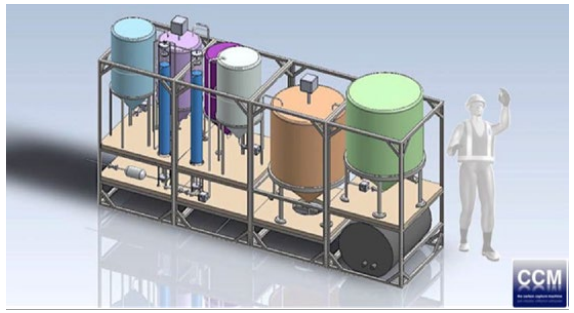

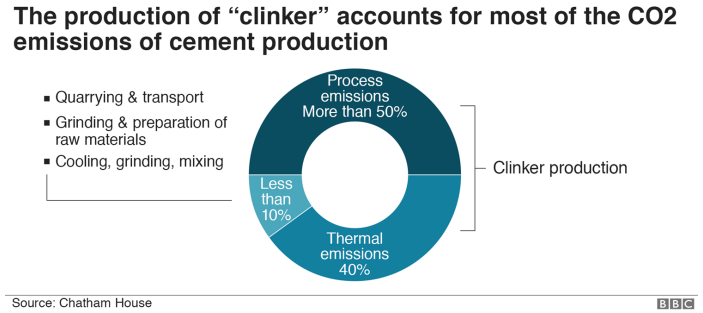

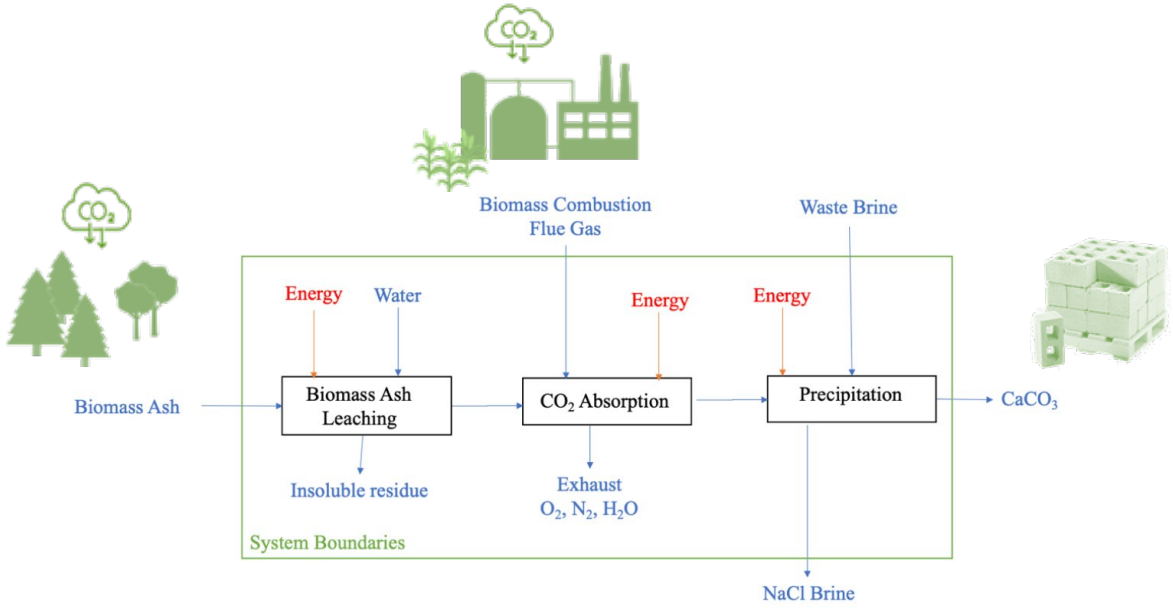

- Approximately 5 billon tons of cement are produced annually throughout the world for buildings, roads, dams, and other infrastructure.
- This large production comes with 8-9% contribution to global CO_2 emissions.
- This project promises to greatly reduce that footprint, with a carbon negative process at -329 to -381 kg CO_2 captured per ton calcium carbonate produced.
- The overall objectives of this proposed technology are to develop a 20 kg/day prototype process utilizing biomass ash and desalination brines for the capture of CO_2 yielding stabilized, amorphous calcium carbonate (ACC).
- The biomass ash will be leached to recover its alkalinity, which will then be used to capture CO_2 from the flue gas for conversion to selective mineral carbonates.
- ACC is a preferred form of calcium carbonate because it is chemically reactive when added to concrete, thereby strengthening it. In contrast, commercially available SCM is unreactive and acts only as a filler, thereby weakening cement.
- Consequently, ACC-containing cement is both superior in performance to cement currently in the market and has a lower carbon footprint.

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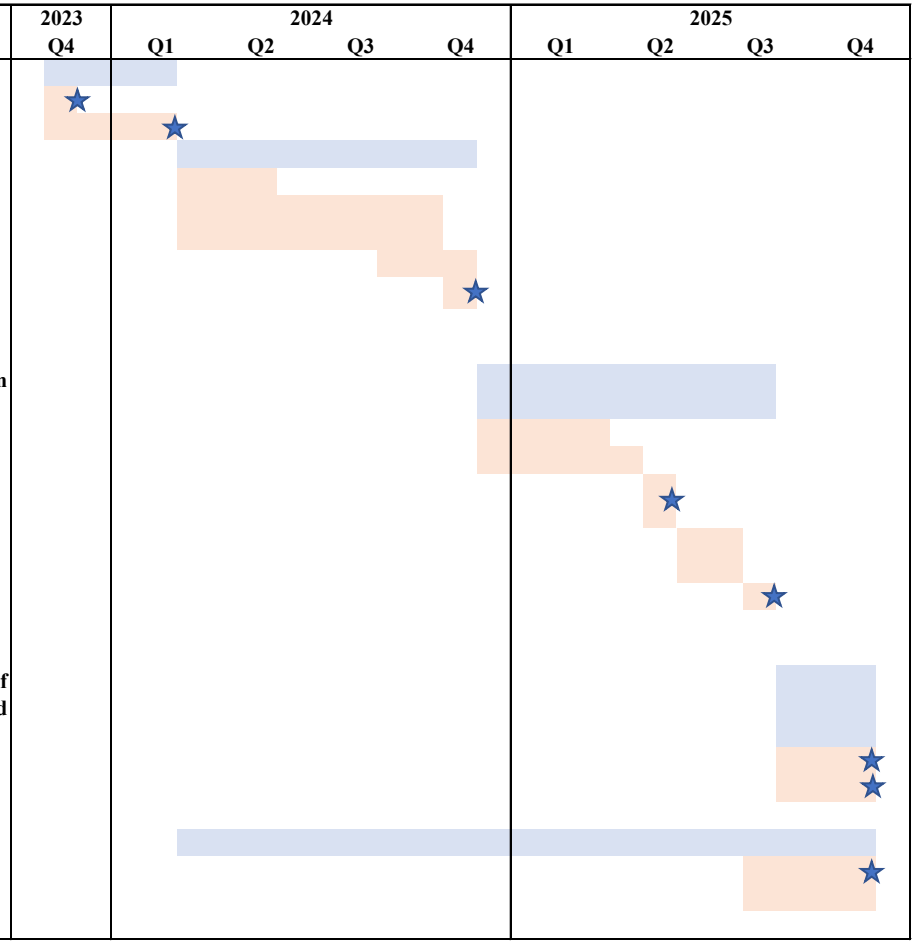
Task #	Subtask #	Task Name
1.0		**Project Management and Planning**
	1.1	Project Management Plan **Milestone**
	1.2	Technology Maturation Plan **Milestone**
2.0		**Design and Optimization of Biomass Ash Alkalinity Recovery Unit**
	2.1	Identification, Characterization, and multi-criteria informed decision on optimal waste sources
	2.2	Design, build, and proof of concept of flow extraction unit
	2.3	Optimization of flow extraction of Na_2O and K_2O
		Milestone: Continuous, selective. and efficient biomass ash alkalinity recovery
3.0		**Design and build integrated 20kg CO2/day prototype for amorphous calcium carbonate production from flue gas using biomass ash and desalination brines**
	3.1	Model and size separate and integrated units of alkalinity
	3.2	Source and build 20 kg CO2/day prototype
		Milestone: Continuous CO2 capture using biomass ash leachate and continuous synthesis of CaCO3 with 20 kg/day prototype
	3.3	Optimization of precipitation conditions for amorphous calcium carbonate stabilization and production of performant cement
	3.4	Optimize full CO2 capture and mineralization process
		Milestone: Production of performant cement with ACC
4.0		**Perform a detailed assessment of economic and environmental impacts of amorphous calcium carbonate production from flue gas using biomass ash and desalination brines**
	4.1	Techno-economic analysis (TEA) - **Final Milestone**
	4.2	Life Cycle Assessment (LCA) **Milestone**
5.0		**Community Engagement, Inclusion and Diversity**
	5.1	Environmental Justice Questionnaire **Milestone**
	5.2	Community and Stakeholder Survey



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Task/Subtask	Milestone Title & Description	Planned Completion Date	Verification Method
1.1	Updated Project Management plan	12/06/2023	Updated document provided to DOE
1.2	Technology Maturation Plan	2/10/2024	Document provided to DOE
2	Continuous, selective, and efficient biomass ash alkalinity recovery	11/10/2024	24 hours continuous flow of biomass ash leachate with pH > 12
3.1-3.2	Continuous CO_2 capture using biomass ash leachate and continuous synthesis of $CaCO_3$ with 20 kg/day prototype	05/10/2025	24 hours continuous CO_2 95% capture at 20kg/day flow and precipitation as $CaCO_3$
3.3	Production of performant cement with ACC	7/10/25	ASTM measurements at 28 days exceed Portland Cement control
4.1	Final TEA	10/10/2025	TEA results file and report file provided to DOE
4.2	LCA	10/10/2025	OpenLCA project file, LCA discussion report, LCA summary graphics, NETL CO2U OpenLCA Results tool file and report template file provided to DOE
5.1	Environmental Justice Questionnaire	10/31/2025	Document provided to DOE

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Section A - Budget Summary						
		Federal	**Cost Share**	**Total Costs**	**Cost Share %**	**Proposed Budget Period Dates**
	Budget Period 1	$622,259	$250,698	$872,957	28.72%	01 November 2023 - 31 October 2024
	Budget Period 2	$742,020	$101,765	$843,785	12.06%	01 November 2024 - 31 October 2025
	Budget Period 3	$0	$0	$0	0.00%	-
	Total	$1,364,279	$352,463	$1,716,742	20.53%	
Section B - Budget Categories						
CATEGORY	**Budget Period 1**	**Budget Period 2**	**Budget Period 3**	**Total Costs**	**% of Project**	**Comments** (as needed)
a. Personnel	$320,500	$386,050	$0	$706,550	41.16%	
b. Fringe Benefits	$66,728	$80,376	$0	$147,104	8.57%	
c. Travel	$6,875	$6,875	$0	$13,750	0.80%	
d. Equipment	$216,911	$112,966	$0	$329,877	19.22%	
e. Supplies	$13,533	$15,754	$0	$29,287	1.71%	
f. Contractual						
Sub-recipient	$0	$0	$0	$0	0.00%	
Vendor	$166,000	$166,000	$0	$332,000	19.34%	
FFRDC	$0	$0	$0	$0	0.00%	
Total Contractual	$166,000	$166,000	$0	$332,000	19.34%	
g. Construction	$0	$0	$0	$0	0.00%	
h. Other Direct Costs	$31,961	$36,571	$0	$68,532	3.99%	
Total Direct Costs	$822,508	$804,592	$0	$1,627,100	94.78%	
i. Indirect Charges	$50,449	$39,193	$0	$89,642	5.22%	
Total Costs	$872,957	$843,785	$0	$1,716,742	100.00%	

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SOPO Task #	Equipment Item	Qty	Unit Cost	Total Cost	Basis of Cost	Justification of need
Budget Period 1						
2	Furnace	1	$5,000	$5,000	Online pricing, KSL1200X-M	Testing of variability of biomass ash compisition with combustion conditions
2,3	Ion Chromatography Instrument	1	$127,424	$127,424	ThermoFisher Dionex Dual Channel ICS-6000 dual channel Quote	Testing of biomass ash alkalinity recovery selectivity and efficiency
2,3	Pump	2	$7,273	$14,546	Quote Magnatex 60 LPM pump	Biomass extraction flow reactor
2,3	Extraction Reactor	1	$3,500	$3,500	Rules of Thumb for Engineering practice, CEPCI, 609	Reactor for biomass ash alkalinity recovery
2,3	Particle size analyzer	1	$61,259	$61,259	Anton Paar, quote	Analysing ash and $CaCO_3$ particle size
2,3	pH meter	1	$5,182	$5,182	Orion Versa Star, online pricing	Assessment of biomass ash leaching conditions
	Budget Period 1 Total			$216,911		
Budget Period 2						
3	Crystallizer (with Filter)	1	$15,517	$15,517	Quote Buchiglass vessel 10L	Vessel for crystallization and filtration of $CaCO_3$
3	IR CO2/H2O detector	1	$5,760	$5,760	LI-COR quote, LI-850 instrument	In-line monitoring of CO_2 and gases at scrubber outlet
3	IR CO2 detector, % scale	1	$2,560	$2,560	Quantek 906, quote	In-line monitoring of CO_2 and gases at scrubber inlet
3	Packed column scrubber	1	$23,500	$23,500	Quote Buchiglass Scrubber 40 DN	Scrubber for CO_2 capture
3	Mixer	1	$2,566	$2,566	In-line static mixer 6 elements, online pricing	Mixer valve for $CaCO_3$ reaction
3	Pump	3	$7,273	$21,819	Quote Magnatex 60 LPM pump	prototype for 20 kg/day CO_2 capture and mineralization to $CaCO_3$
3	Vacuum Pump	1	$787	$787	Online Pricing	Filtering aid
3	Recirculating cooler	1	$2,790	$2,790	Online Pricing	Maintain optimal temperature at scrubber
3	Controls and Instrumentation	1	$32,485	$32,485	Calculated as 10% of capital cost of process	Required for prorotype operation
3	pH meter	1	$5,182	$5,182	Orion Versa Star, online pricing	Assessment of CO_2 capture
	Budget Period 2 Total			$112,966		

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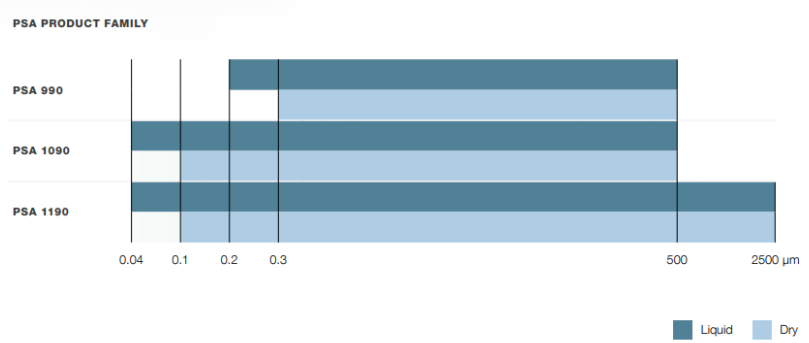
Thermo Scientific™
Dionex™ ICS-6000 Standard Bore and Microbore HPIC™ Systems
Catalog number: ICS6000-007
Related applications: Chromatography
Quotation #CPQ-00605464
September 15, 2023
$107k - $142k depending on final options, 6-8 weeks

Anton Paar USA, Inc.
PSA 990 L *(may need PSA 1090 for <100 nm)*
Laser diffraction instrument for highly reliable particle size
Size range: 200 nm to 500 µm
www.anton-paar.com
Quotation #820256542
January 3, 2024
$62,876, 4-5 weeks



AspenTech software (2-year license)
Aspen desktop quote Modeling and optimization of CCU process
August 18, 2023
$31,961 per year ($63,922 total)

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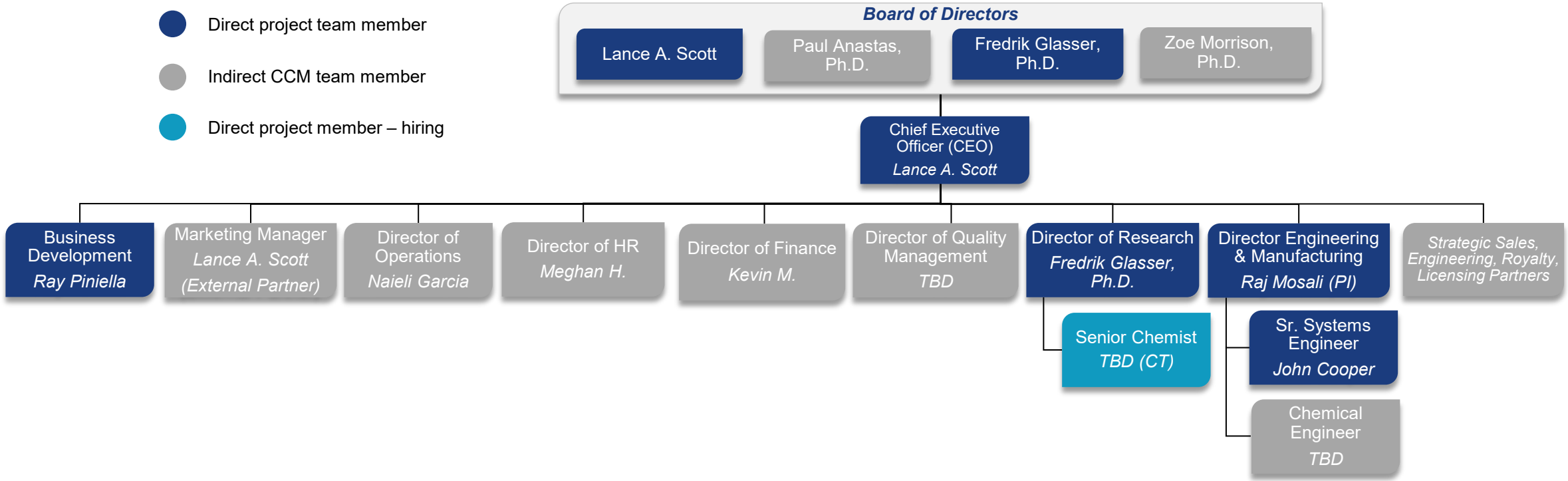
Biomass ash valorization by CO_2 capture for nanosized amorphous calcium carbonate production and use in lower carbon footprint cement

Position Title	Pay Rate ($/Hr)	Project Total Hours	Project Total Dollars	Rate Basis
Sr. Chemical/Systems Engineer	$45.00	3590	$161,550	BLS, adjusted for seniority level
Director of Business Development (LCA expert)	$100.00	470	$47,000	Glassdoor average USA
Director of Research	$200.00	400	$80,000	Based on current company salaries
Project Director	$200.00	500	$100,000	Based on current company salaries
Sr. Chemist	$70.00	2400	$168,000	BLS, adjusted for seniority level
Principal Investigator (PI)	$75.00	2000	$150,000	Actual Salary
Total Personnel Costs		**9360**	**$706,550**	

- John Cooper
- Raymond Piniella
- Prof. Fred Glasser
- Lance A. Scott
- Hiring underway – 2nd interviews
- Raj Mosali

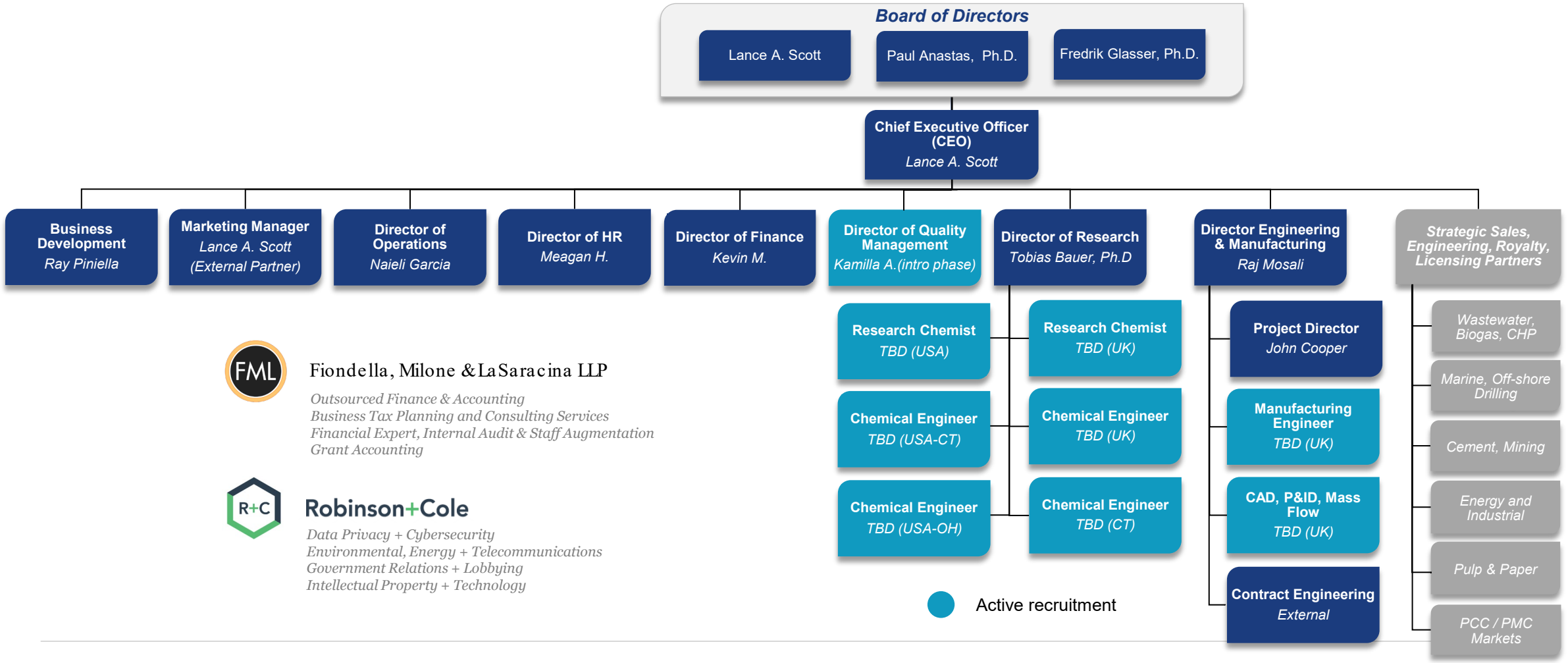
Project Team: DOE NETL Award DE-FE0032399

Biomass ash valorization by CO_2 capture for nanosized amorphous calcium carbonate production and use in lower carbon footprint cement



CCM Organizational Structure

Cross-functional International Matrix Organization with 'hands on' Board of Directors



Fiondella, Milone & LaSaracina LLP

Outsourced Finance & Accounting
Business Tax Planning and Consulting Services
Financial Expert, Internal Audit & Staff Augmentation
Grant Accounting

Robinson+Cole

Data Privacy + Cybersecurity
Environmental, Energy + Telecommunications
Government Relations + Lobbying
Intellectual Property + Technology

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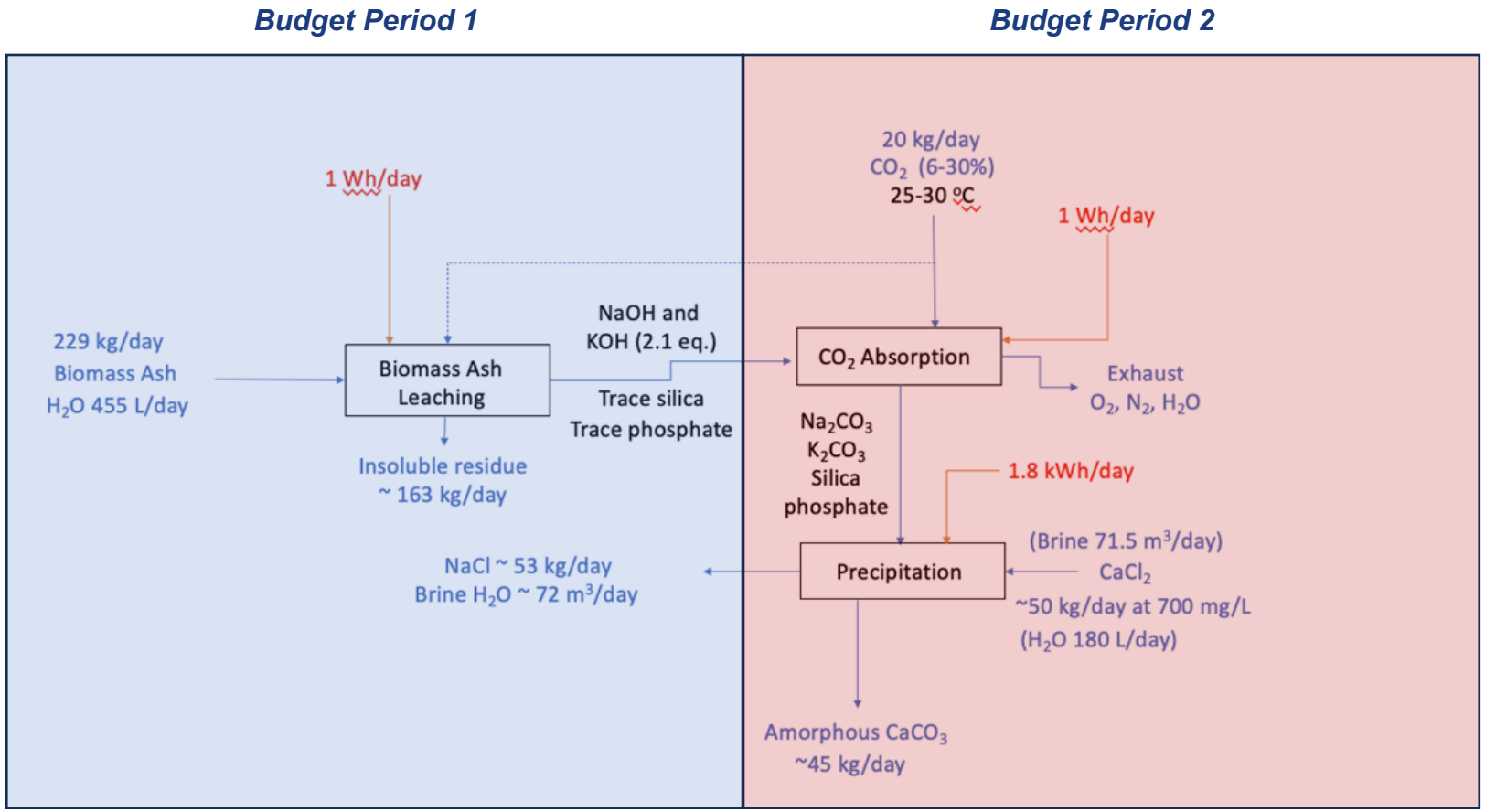

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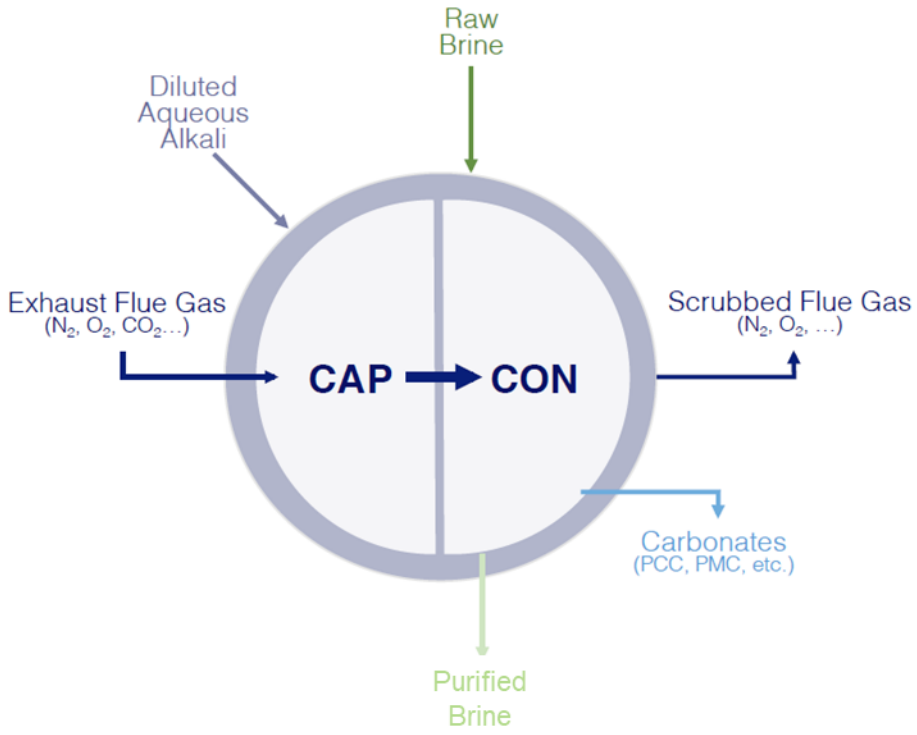
Carbon Capture Machine (CCM) technology and process methodology



- The CCM process is termed CAPCON because it CAPtures gaseous CO_2 from process flue gas and CONverts it to stable and insoluble mineral solids.
- The process operates at ambient temperature and pressure and does not require solvents other than water.
- The proprietary sequential precipitation process operates continuously to safely and efficiently yield valuable and saleable products.
- Purified brine, the third output, can be disposed of, re-injected to ground, or post-processed for other uses.
- The absorption of CO_2 in dilute aqueous alkali and precipitation of carbonates are well-understood processes that present no safety-related concerns
- A CCM differentiator is the benign source of Ca_2+ cations from brine, as opposed to CO_2-intensive, hazardous calcination of limestone.

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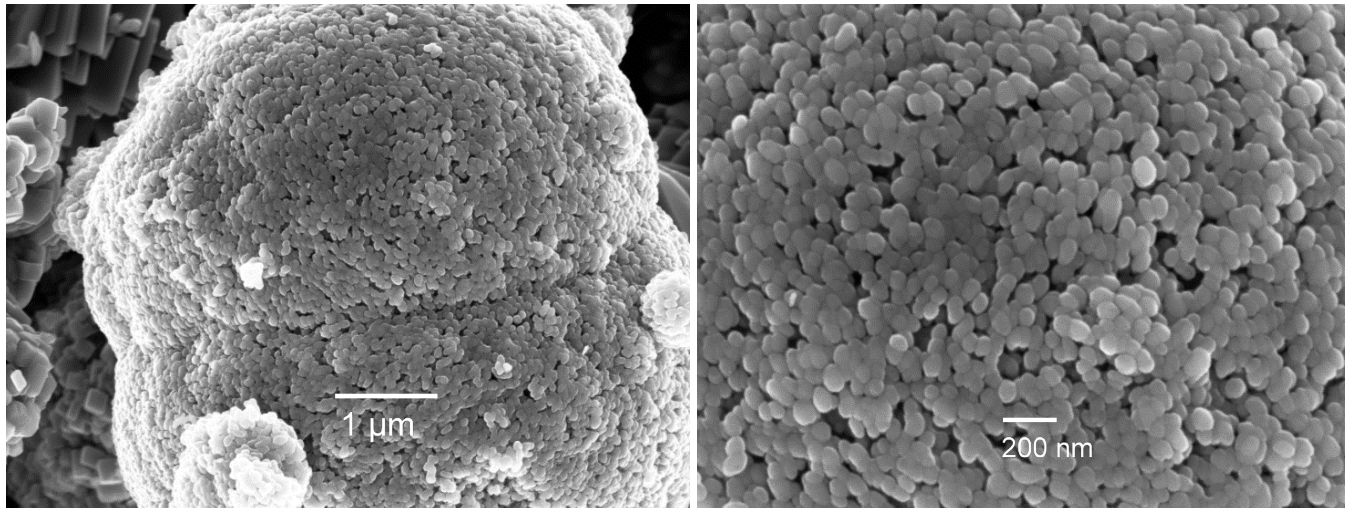
Carbon Capture Machine (CCM) technology and process methodology

Functional demonstration unit with SEM micrograph of amorphous calcium carbonate (ACC) formed with CCM proprietary processes



SEM micrograph of amorphous calcium carbonate formed by rapid precipitation and examined shortly after precipitation, ca 5 minutes.

Source: Formation of scawtite, $Ca_7(Si_6O_{18})CO_3 \cdot 2H_2O$, and tilleyite, $Ca_5Si_2O_7(CO_3)_2$, in Portland cements with lowered carbon footprint

L.J. McDonald, W. Afzal* and F.P. Glasser***
** University of Aberdeen, School of Engineering, Aberdeen, Scotland*
***CCM UK, 28 Albyn Place Aberdeen, Scotland, UK*

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Diversity, Equity, and Inclusion Plan

- For the proposed project, our public engagement strategy will include not only the economically active, but also members of underserved and disadvantaged communities (DAC) including individuals living in geographic proximity to the proposed project activity, geographically dispersed sets of individuals (such as migrant workers or Native Americans) where either type of group experiences common conditions, young adults, and the elderly. This engagement strategy will be guided by the principles of accountability, transparency, and collaboration, and we will endeavor to utilize the recently released Climate and Economic Justice Screening Tool (CEJST) BETA resource provided by the White House Council on Environmental Quality (CEQ) that aims to help identify DACs as part of the Justice40 Initiative.

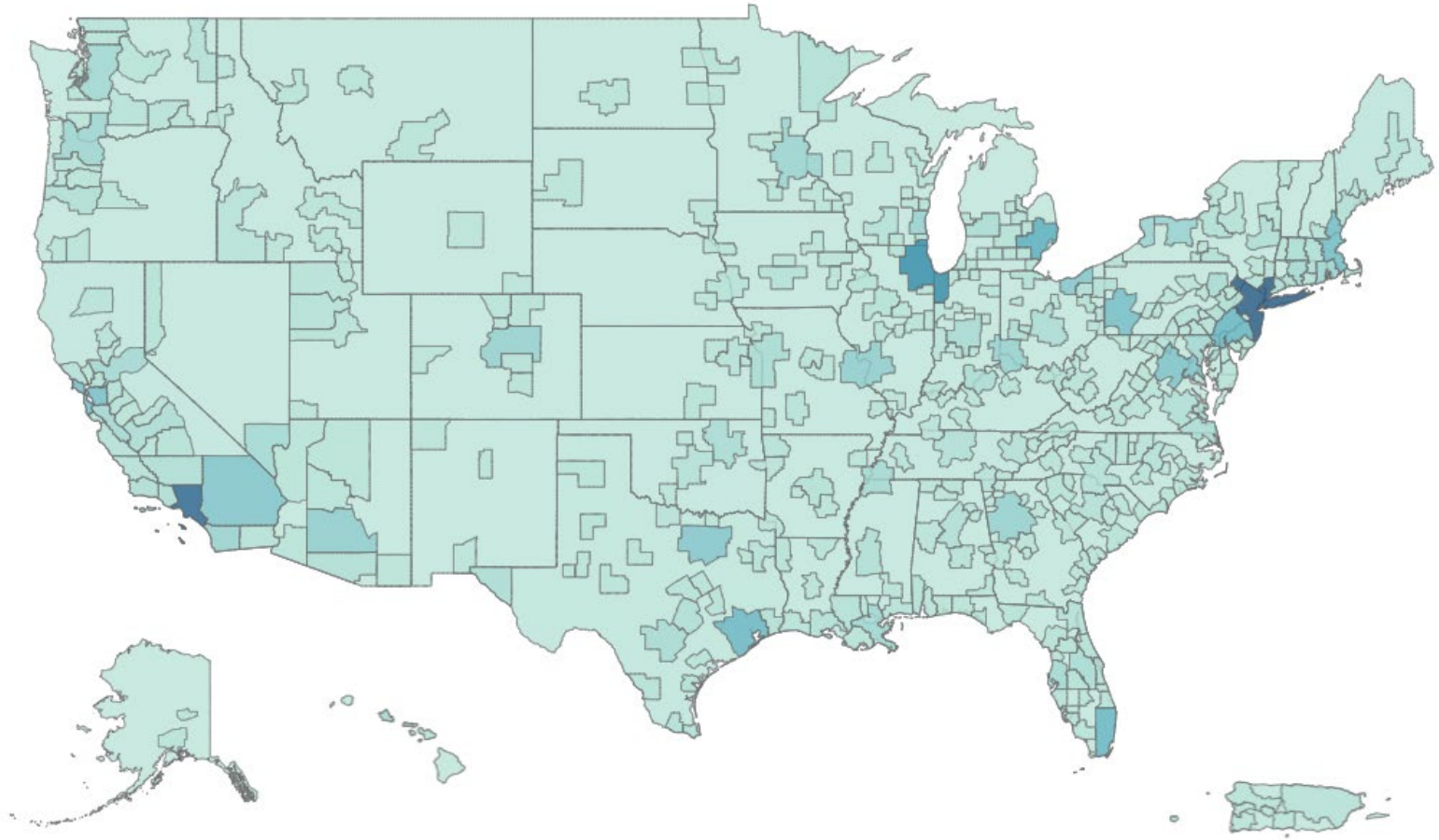
- Milestones in the project will be agreed with public engagement experts representing each of the project partners and local community representatives. Examples of engagement activities will include working with schools and community colleges, faith groups, and economic development agencies aiming to support indigenous populations and minority groups.

- Underserved communities have been unfairly impacted by climate change and the environmental consequences of industry. For example, petrochemical industries, power plants, landfills, or otherwise environmentally destructive industries are often located in areas of underserved, low-income communities, making residents more susceptible to poor air quality and negative health disparities. Furthermore, sociodemographic factors contribute to worsening health disparities from air pollution in low-income communities.

- CCM's project proposes to dramatically reduce air and landfill pollution from biomass or waste combustion sources or from cement kilns. Specifically, the use of a scrubber will prevent the release of carbon dioxide, as well as SOx, NOx, and particulate emissions from combustion and incineration sources. Furthermore, the prevention of a fraction of biomass ash from reaching landfills will mitigate the possibility of ash components from entering soil and water sources. Poor families and people of color are also more likely to be impacted by the global impacts of climate change, such as more frequent extreme weather events, increased food and water prices due to droughts, or rising sea levels. By mitigating carbon emissions, the proposed project works to indirectly mitigate impacts most severely felt by disadvantaged communities.

Community Investment Explorer 2.0: Data Tool

Community Funding by Metropolitan Area



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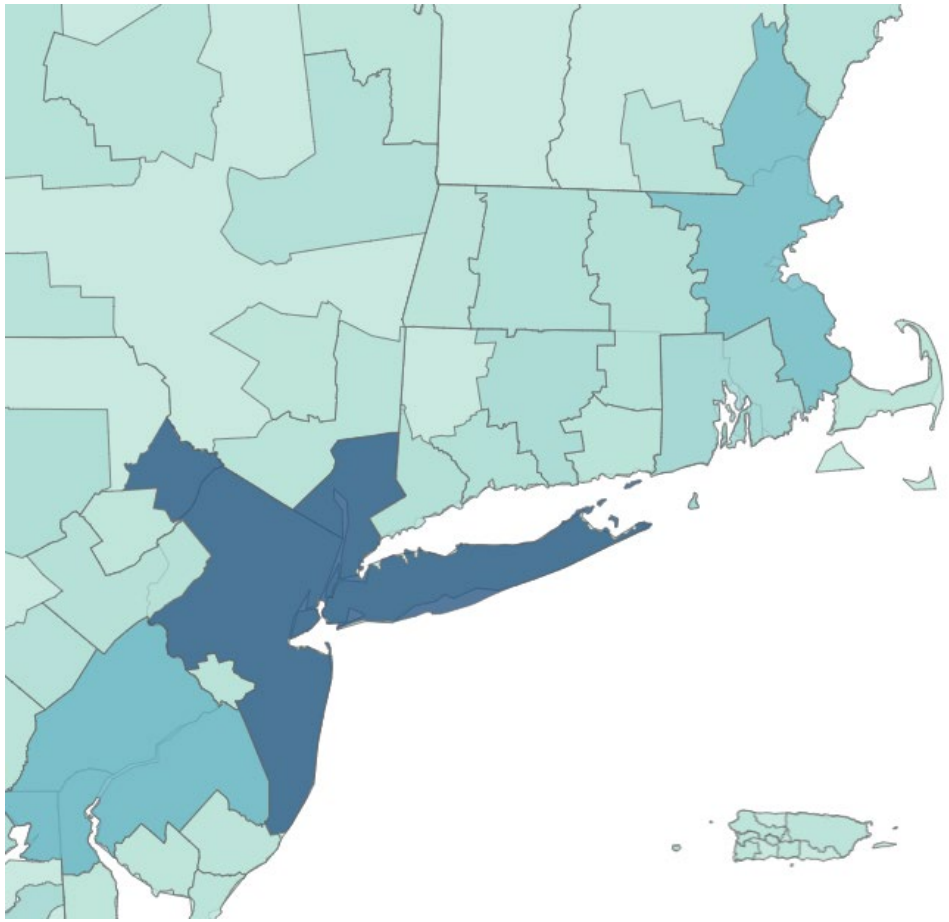
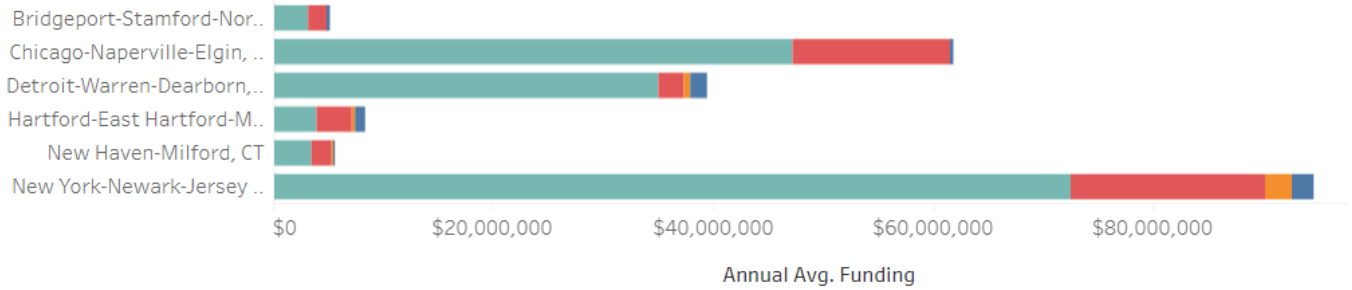
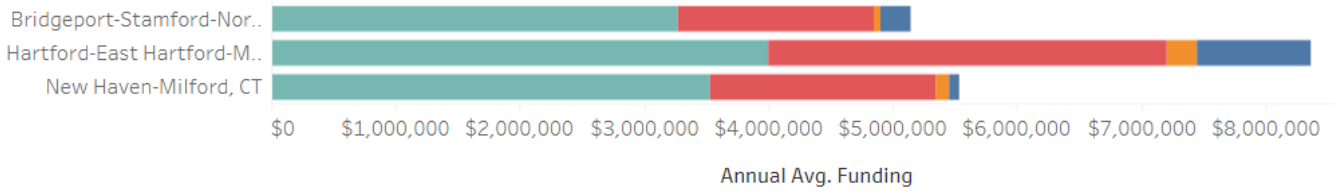
Community Investment Explorer 2.0: Data Tool

Community Funding by Metropolitan Area





Bridgeport is underrepresented within Connecticut



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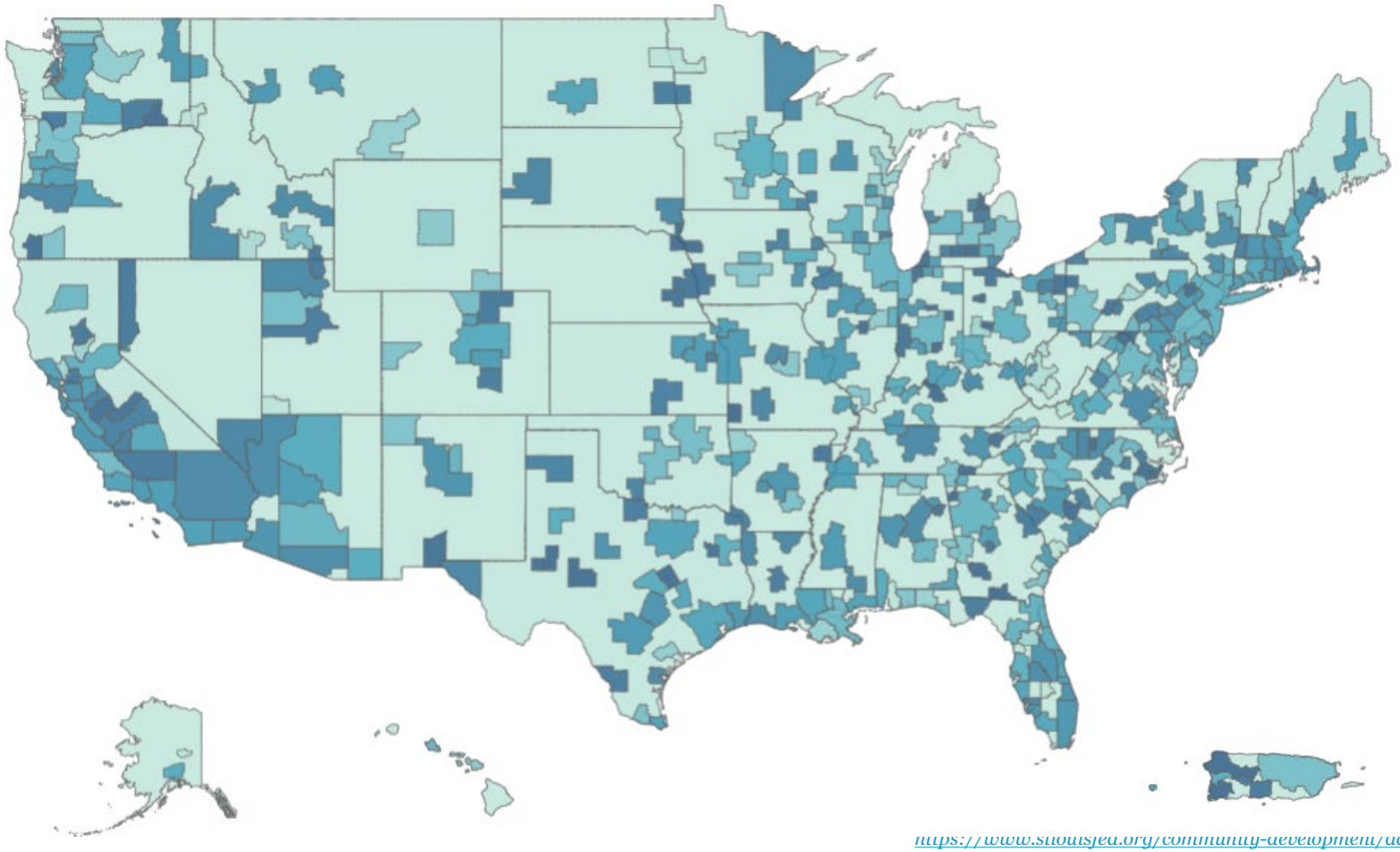
Community Investment Explorer 2.0: Data Tool

Funding in Low to Moderate Income (LMI) Communities



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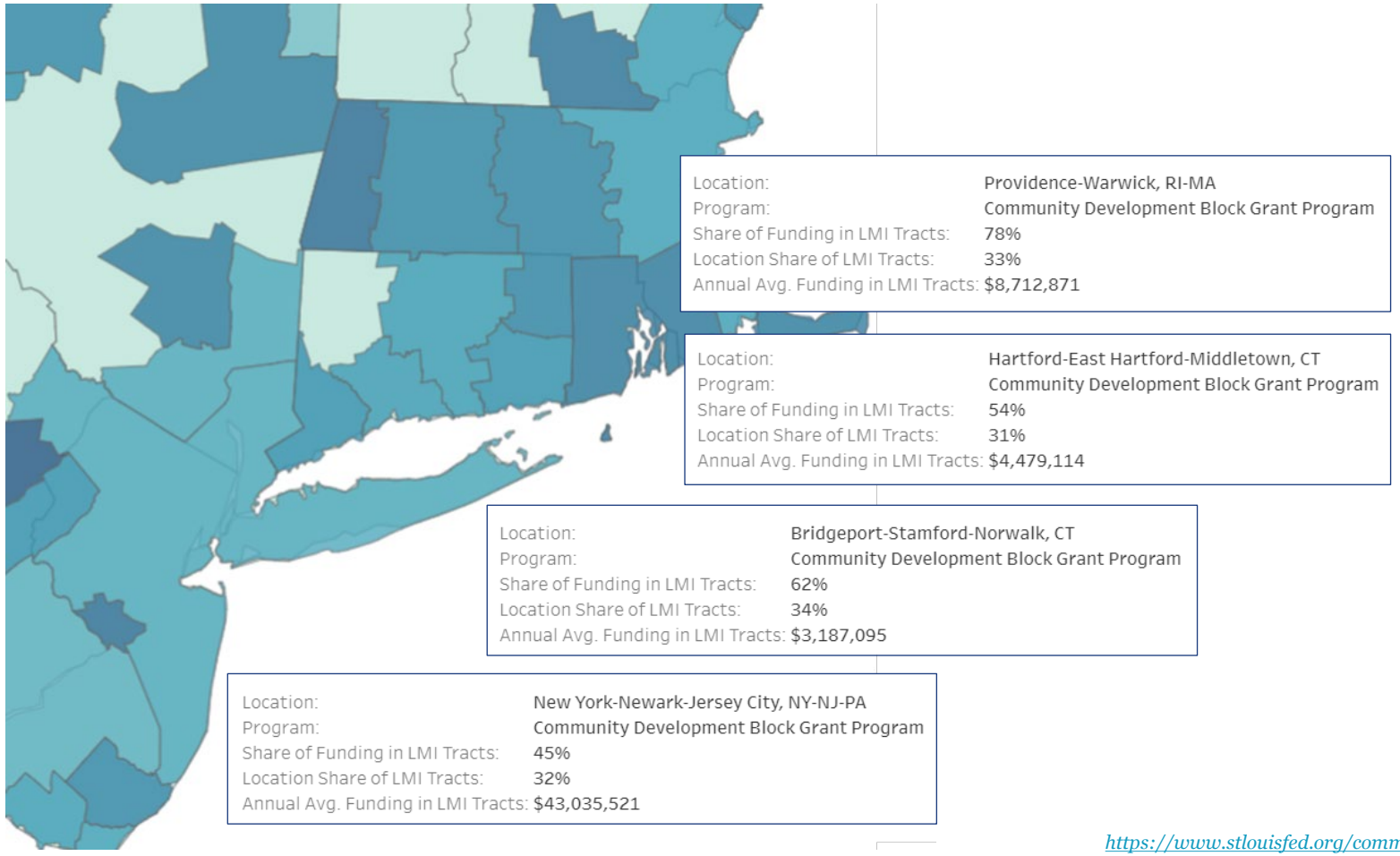
Funding in Low to Moderate Income (LMI) Communities



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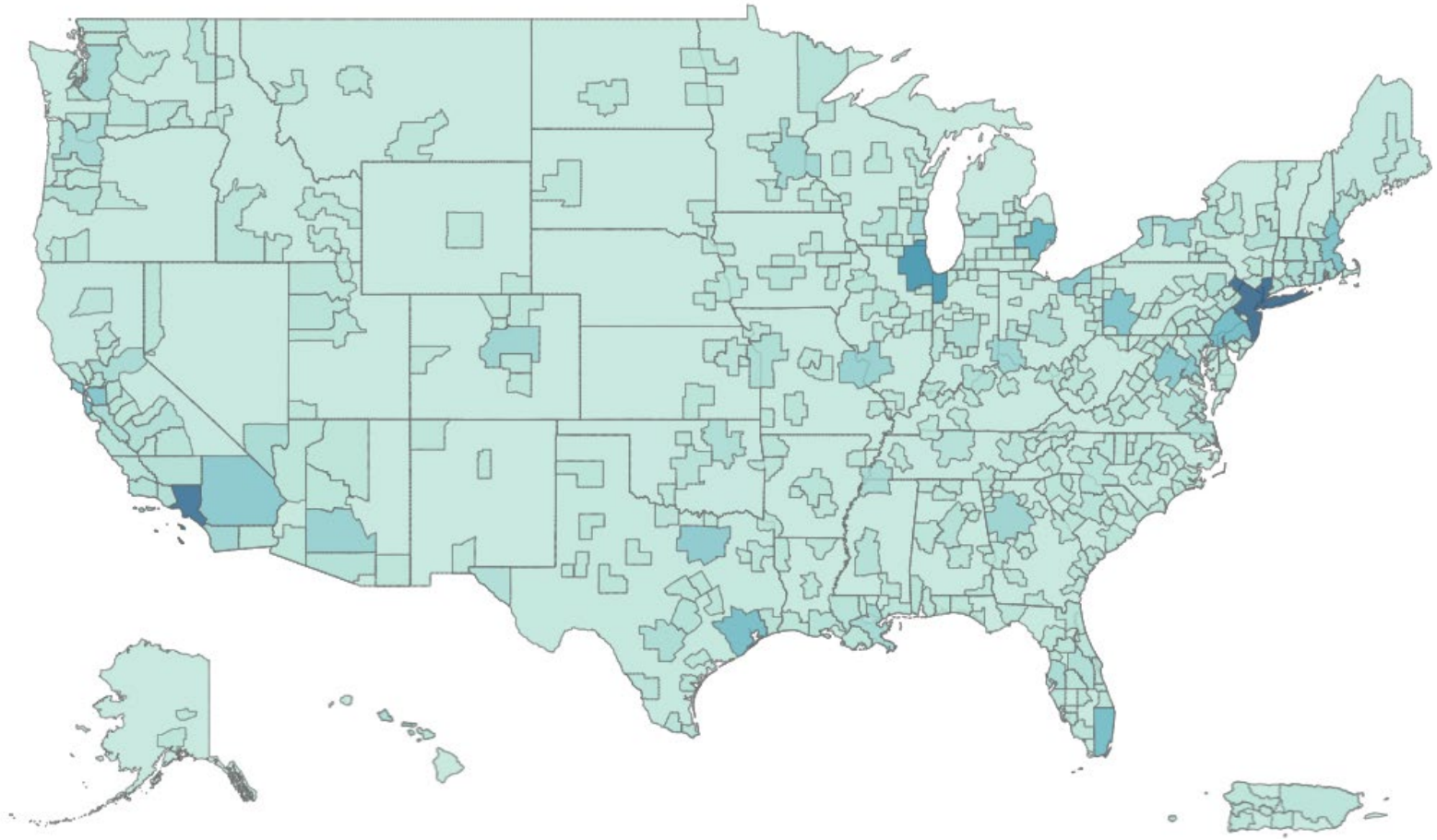
Community Investment Explorer 2.0: Data Tool

Funding in Communities of Color



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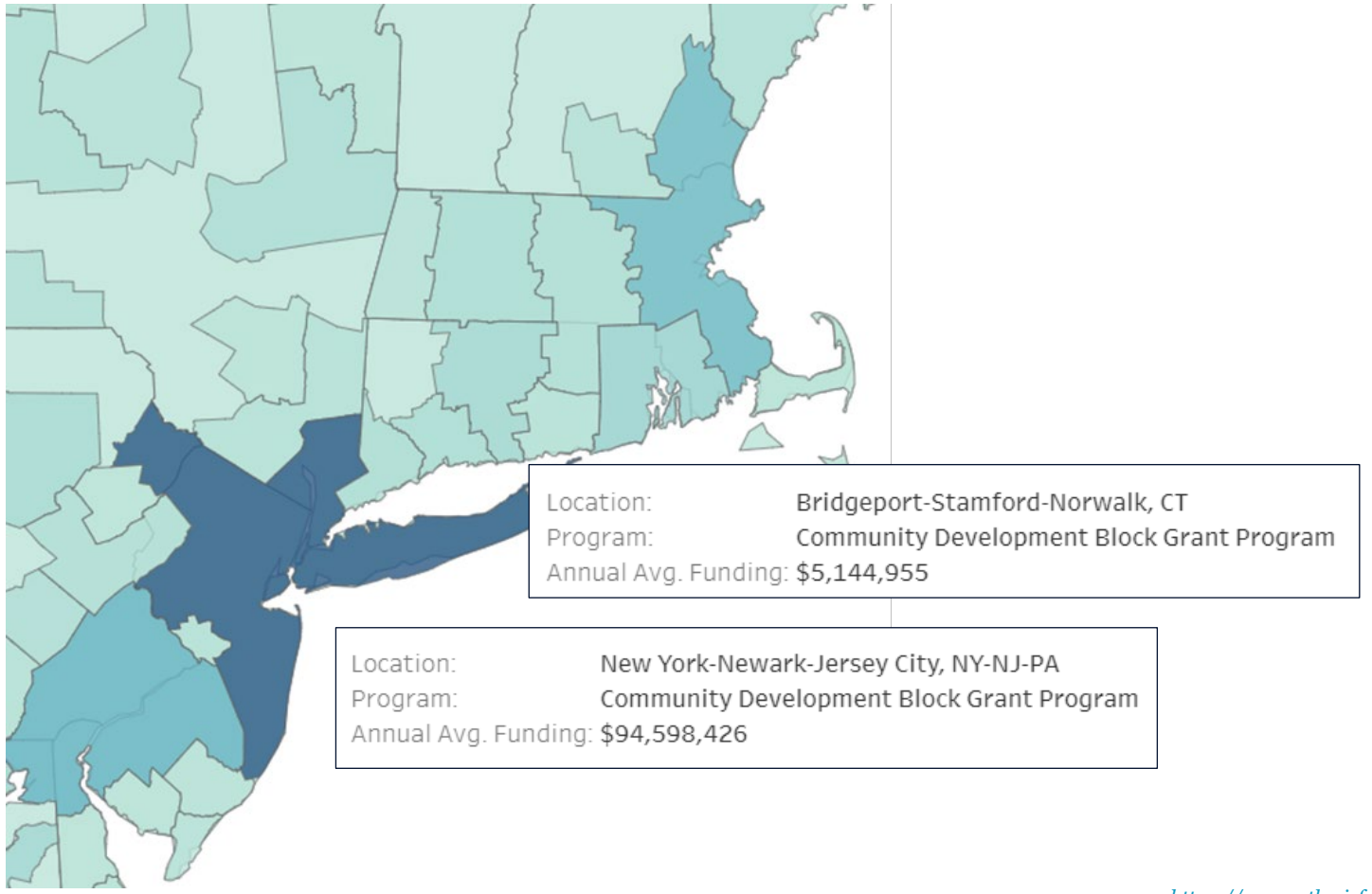
Funding in Communities of Color



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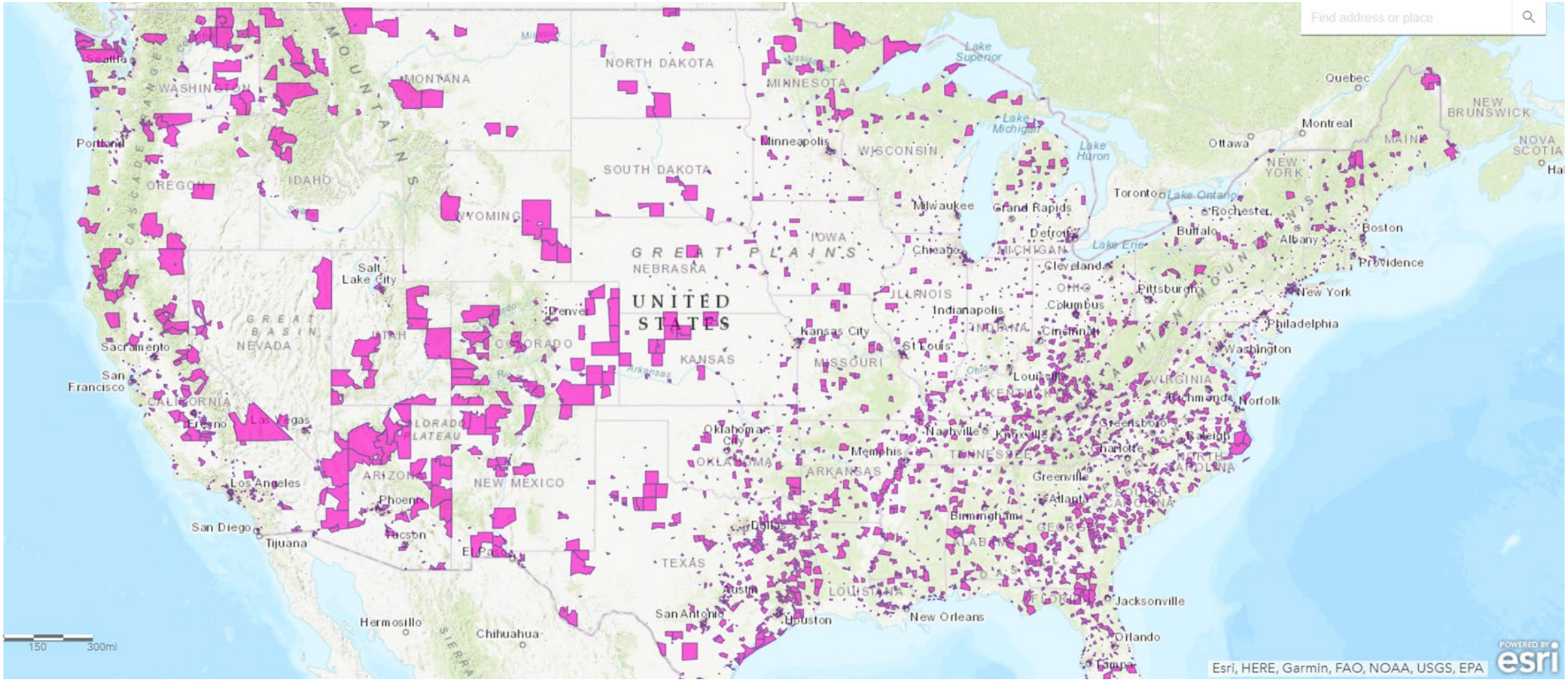
Diversity, Equity, and Inclusion Plan – U.S. Opportunity Zones

https://opportunityzones.hud.gov/resources/map



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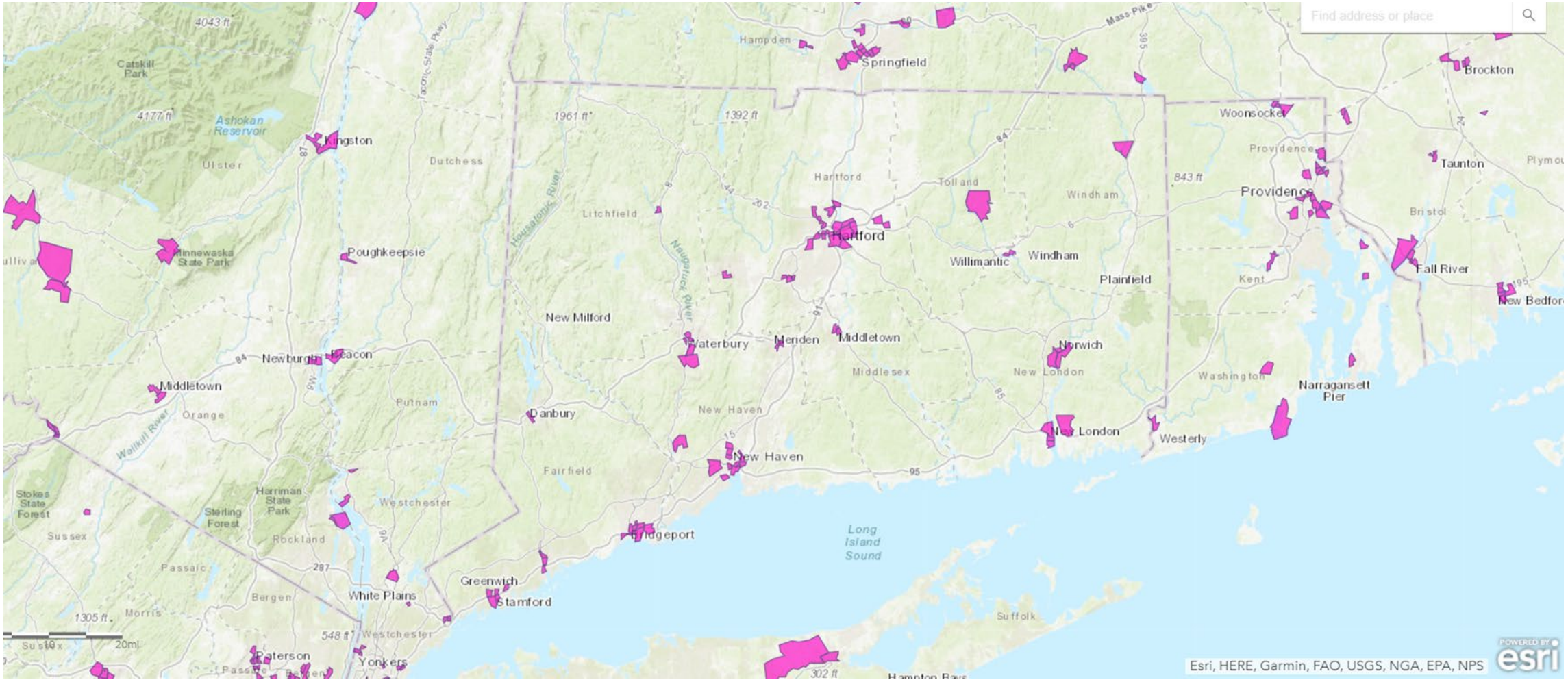
Diversity, Equity, and Inclusion Plan – Connecticut Opportunity Zones

https://opportunityzones.hud.gov/resources/map



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Diversity, Equity, and Inclusion Plan

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Diversity, Equity, and Inclusion Plan

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Diversity, Equity, and Inclusion Plan

1. **Water Pollution Control Authority (WPCA)** operates two wastewater treatment facilities and maintains the sewer system in the City of Bridgeport

2. 

Bridgeport Regional Aquaculture Science and Technology Education Center serves a community of diverse students with a broad range of social, economic, cultural and ethnic backgrounds.

3. **O&G Industries, Inc.** is a leading provider of construction services and products in the Northeast, with cement manufacturing and asphalt production at this Bridgeport site.

4. The **Wheelabrator** waste-to-energy plant in Bridgeport is one of several incinerators that sends waste ash to a landfill in Putnam

5. 
Bridgeport Harbor Station 3 –PSEG. Decommissioned coal plant.

6. 
Bridgeport Harbor Station 5 – 500 MW highly efficient combined cycle generating station that Generation Bridge II acquired from PSEG in February 2022.
.

7. **Goodwin University** Celebrated the opening of a "Manufacturing Epicenter" on University of Bridgeport Campus in October 2023.

8. **UB**'s 56-acre campus is home to 14 schools, colleges and institutes.The College of Engineering, Business, and Education provides comprehensive professional, education, and research opportunities to a diverse community in engineering, sciences, technology, computing, business, management, entrepreneurship, finance, analytics, accounting, education, teacher preparation, and educational administration..

9. 
Bassick High School and Bridgeport Military Academy – New 205,000 sqft facility with 48 classrooms, labs, trade programs, Advanced Manufacturing, Aeronautical Tech.

10. **Housatonic Community College** is a Connecticut State Community College with an Advanced Manufacturing Technology Center for training future leaders of CT's manufacturing workforce and placing students into jobs after graduation.

11. **The Mary & Eliza Freeman Center** – Mission to restore, preserve, and ensure the viability of the Freeman Houses and Little Liberia; teach the history of Connecticut Blacks.

12. **Metro-North Railroad** connects Bridgeport to surrounding Northeast locations, including New York City's Grand Central Station. Six new express trains were recently were added with travel time of 1 hour 22 minutes.

13. With over 132 years of service, **The Bridgeport & Port Jefferson Steamboat Company** is an institution within both the Long Island and Southern Connecticut communities.

DOE NETL Award DE-FE0032399

Diversity, Equity, and Inclusion Plan

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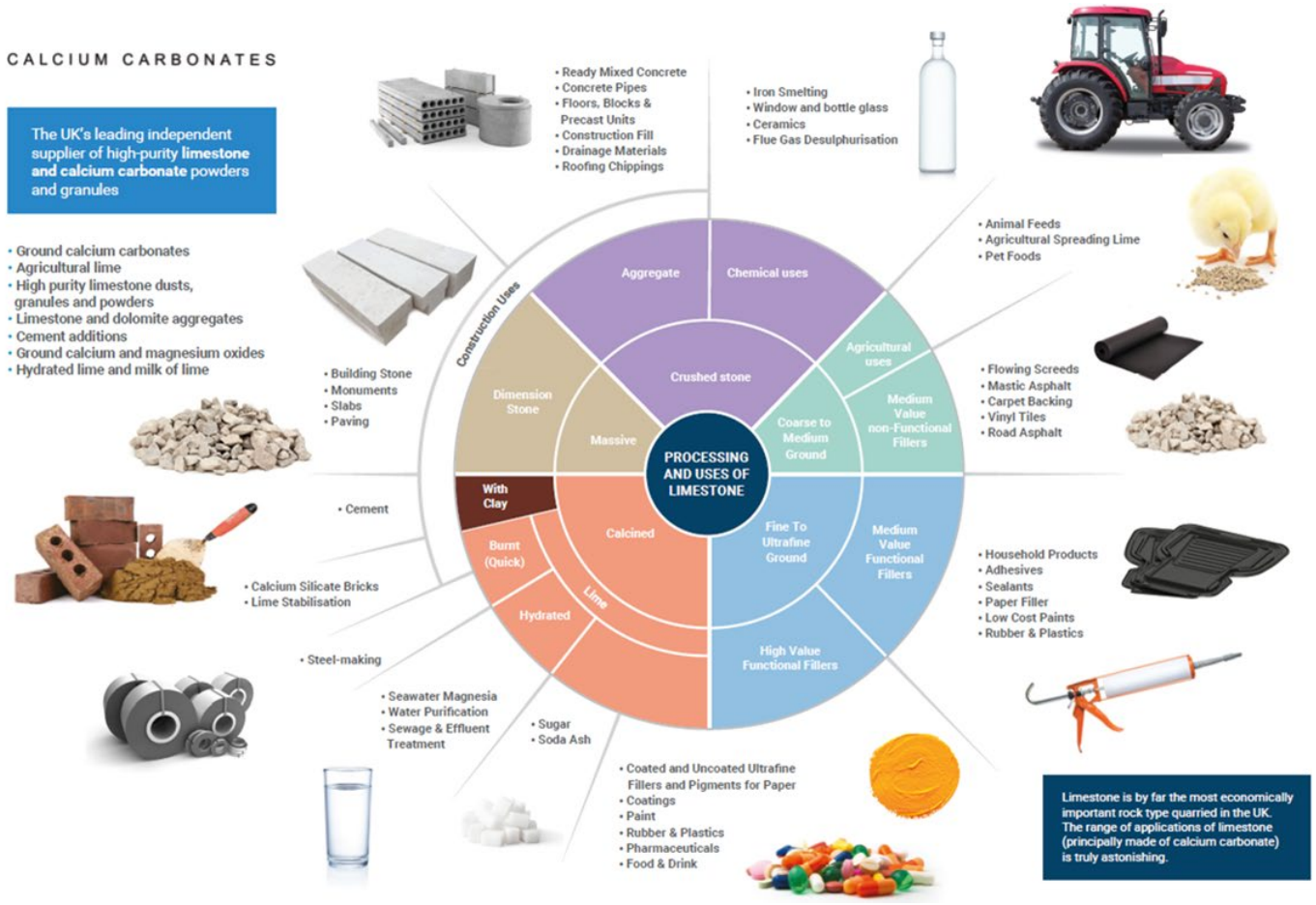
Diversity, Equity, and Inclusion Plan

Carbon Capture Machine (CCM) “eco-PCC”

CCM’s lightweight cementized eco-PCC and eco-PMC offer a new range of *carbon negative*, *sustainable*, *cost-effective* building materials



Sales and Marketing Approach

Key market segments for core CCUS technology

Natural Gas Power Plants

Coal Power Plants

Petroleum Refineries

Waste-to-heat, Wastewater

Agriculture, Biodiesel, BECCU

Cement & Concrete Production

Iron & Steel Production

Paper & Forest Products

Glass & Ceramic Production

Chemical Production

Mining & Construction

Other Industrial

Brewing, Baking, Distilling

Offshore Drilling

Marine & Transportation

Sales and Marketing Approach

Key Markets – Precipitated Calcium Carbonate (eco-PCC) and (eco-PMC) Byproducts

Iron and Steel
Precipitated calcium carbonate (PCC)

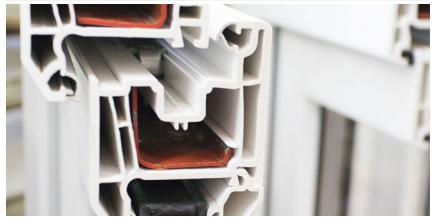
Agriculture
Precipitated calcium carbonate (PCC)

Paints and Inks
Precipitated calcium carbonate (PCC)

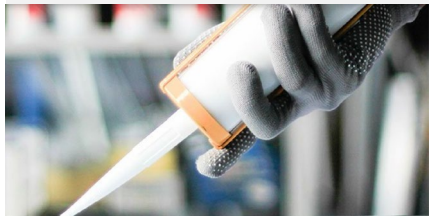
Paper
Precipitated calcium carbonate (PCC)

Cement
Precipitated calcium carbonate (PCC)

Plastics
Precipitated calcium carbonate (PCC)



Adhesives, Sealants
Precipitated calcium carbonate (PCC)



Food, Cosmetics
Precipitated calcium carbonate (PCC)

Pharmaceuticals
Precipitated calcium carbonate (PCC)

Glass
Precipitated calcium carbonate (PCC)

Ceramics
Precipitated calcium carbonate (PCC)

Building Stone
Precipitated calcium carbonate (PCC)

Water Purification
Precipitated calcium carbonate (PCC)

Vinyl Tiles
Precipitated calcium carbonate (PCC)

Animal Feed
Precipitated calcium carbonate (PCC)

Carbon Capture Machine (CCM)

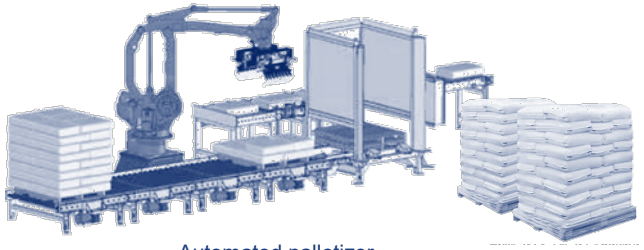
Modular and scalable CCU solution for a wide range of applications

Chemical storage

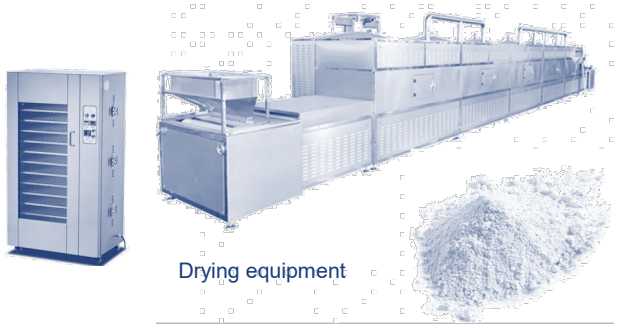
Carbon Capture Machine (CCM)

- Scalable containerized design for a wide range of engine/furnace sizes
- Emission “agnostic” – natural gas, biogas, diesel, coal, etc.
- Produces a wide range of $CaCO_3$ or $MgCO_3$ carbonates for a variety of applications
- Purified NaCl brine output is desirable for numerous industrial applications

Bulk bag fillers



Automated palletizer



Drying equipment

Carbon Capture Machine (CCM)

Site Selection – Connecticut / New York (USA)

Yale University

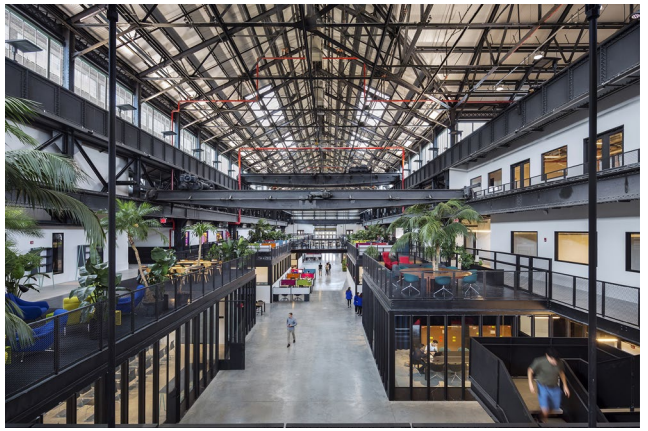
Center for Green Chemistry & Green Engineering

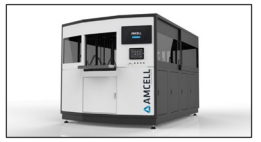
Greeley Memorial Laboratory

Sacred Heart UNIVERSITY

JACK WELCH COLLEGE OF BUSINESS & TECHNOLOGY

NEWLAB





Thank you for your consideration…