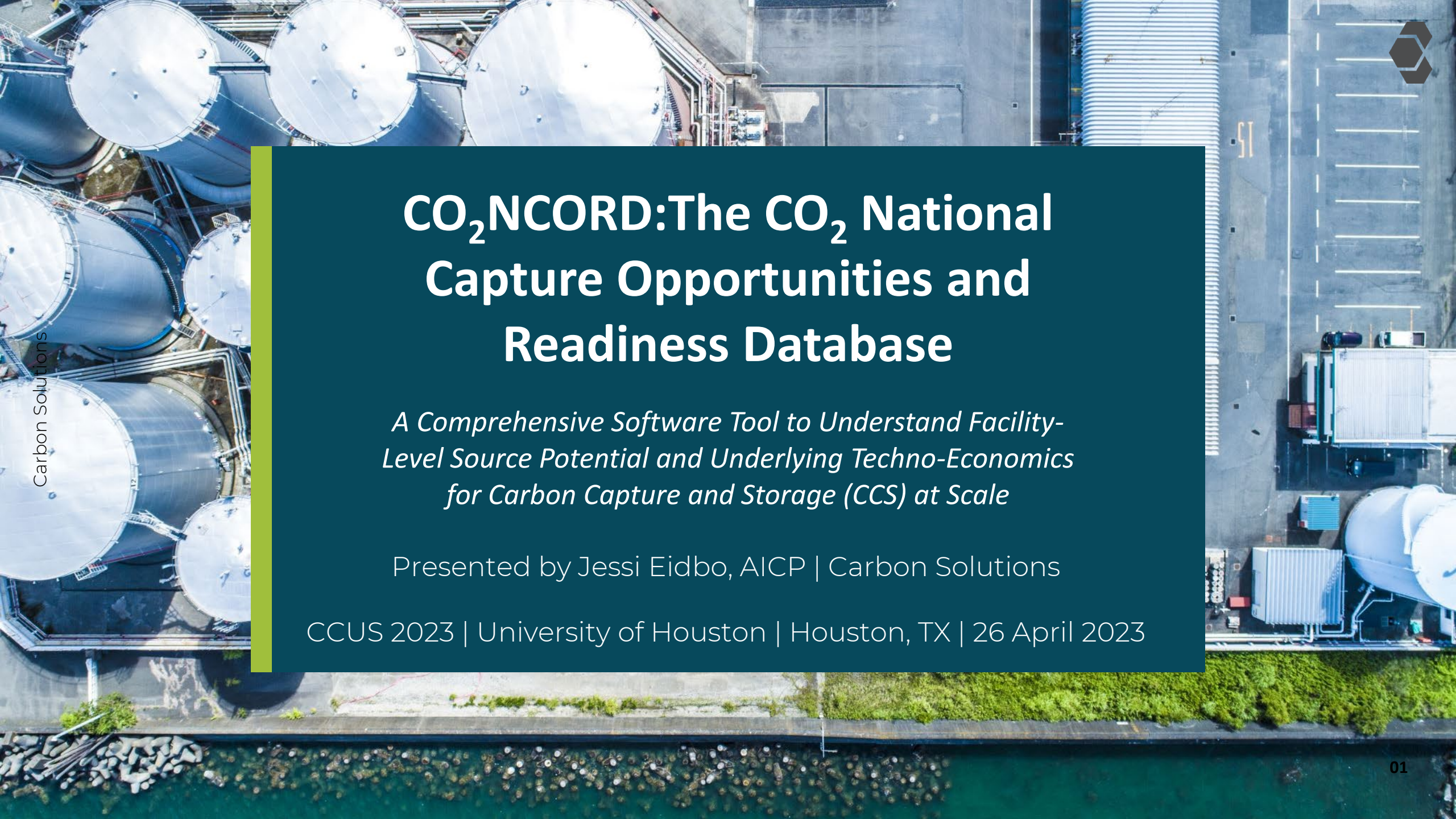


CO_2NCORD:The CO_2 National Capture Opportunities and Readiness Database

A Comprehensive Software Tool to Understand Facility-Level Source Potential and Underlying Techno-Economics for Carbon Capture and Storage (CCS) at Scale

Presented by Jessi Eidbo, AICP | Carbon Solutions

CCUS 2023 | University of Houston | Houston, TX | 26 April 2023

Carbon Solutions

CARBON SOLUTIONS

ABOUT US.

Mission-driven business

CARBON SOLUTIONS works with industry, government, non-profits, researchers, & other stakeholders to identify & implement real-world solutions for low-carbon energy challenges.

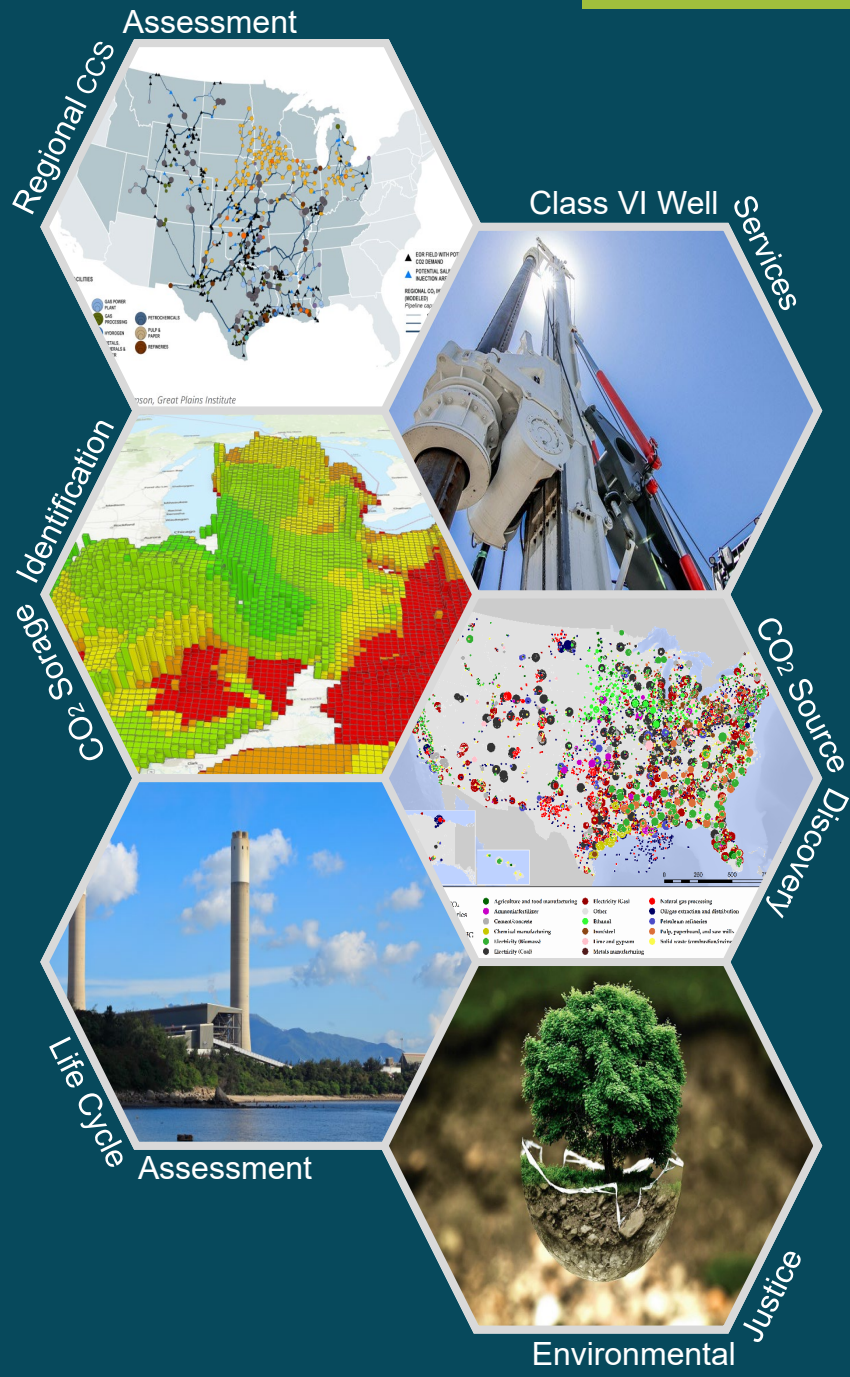
HISTORY: Launched in 2021 | 27 employees (12 PhD's)
FUNDING: 60% Fed. | 25% NGOs | 15% Industry.
FOUNDATION: Development of *SimCCS* and complementary software suite for system optimization.

Energy applications

CO_2 capture-transport-utilization-storage, hydrogen, direct air capture, geothermal, wind, energy storage, grid modeling, electric vehicles, energy equity, stakeholder facilitation, planning and siting.

Data analytics

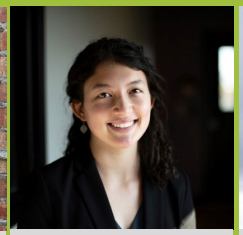
Optimization, reservoir simulation, ML/AI, LCA, TEA, econometrics, GIScience, and more.



MEET THE STAFF

Richard Middleton
CEO, Science Leader

Marie Abernathey
Design Marketing



Elizabeth Abramson
Visualization, Communication

Benjamin Adams
Mechanical Engineering

Jeff Bennett
Engineering, LCA, Software Development

Kyle Cox
Geology. GIScience

Juan C. Duque
Research Scientist

Jessi Eidbo
Policy, Planning, Software Development

Kevin Ellett
Geoscience, Reservoir Simulation

Michael Ford
Energy Economics/ TEA

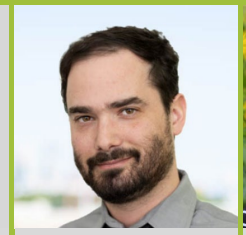
Sarah Henao
Data Science, Statistics, Optimization.

Monica Hernandez-Lara
Business Management

Nathan Holwerda
LCA, Energy Engineering

Amy Jordan
Hydrogeology, Software Development

Peter Johnson
Geoscience, Reservoir Simulation



Dane McFarlane
Policy Analysis, Climate

Erin Middleton
Energy Equity & Env. Justice

Marco Miranda
Infrastructure Optimization

Jonathan Ogland-Hand
Energy Systems, TEA, Software

Daniel Rodriguez
LCA, GIScience

Eric Schroeder
Finance & Administration

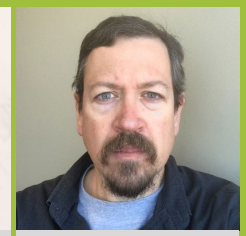
Kate Sale
Chemical Engineering

Kelsey Seals
Petroleum Engineering

Grace Selman
Marketing, Communications

Carl Talsma
Software Engineering

Anna Turnini
Hydrogeology, Geology, GIScience



Chris Upchurch
Transportation Planning, Optimization

MEET THE CO_2NCORD TEAM

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Jeff Bennett
Engineering, LCA, Software Development

Jessi Eidbo
Policy, Planning, Software Development

Michael Ford
Energy Economics/ TEA

Daniel Rodriguez
LCA, GIScience

Carl Talsma
Software Engineering

Kate Sale
Chemical Engineering

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TODAY'S AGENDA.

I. Context
II. CO_2NCORD Overview
III. Data and Methodology
IV. Application
V. Next Steps and Beyond

A *minimum* 0.9 GtCO2/yr of CO2 sequestration is required to transition the economy to net-zero by 2050.

-Princeton Net Zero America Study (Dr. Eric Larson, Andlinger Center for Energy+Environment)

A *minimum* 0.9 GtCO2/yr of CO2 sequestration is required to transition the economy to net-zero by 2050.

-Princeton Net Zero America Study (Dr. Eric Larson, Andlinger Center for Energy + Environment)

There will be an **$330–500 billion** invested in CCS projects in the US by midcentury, and a fair portion will be spent on profiling capturable CO_2 streams from emitters.

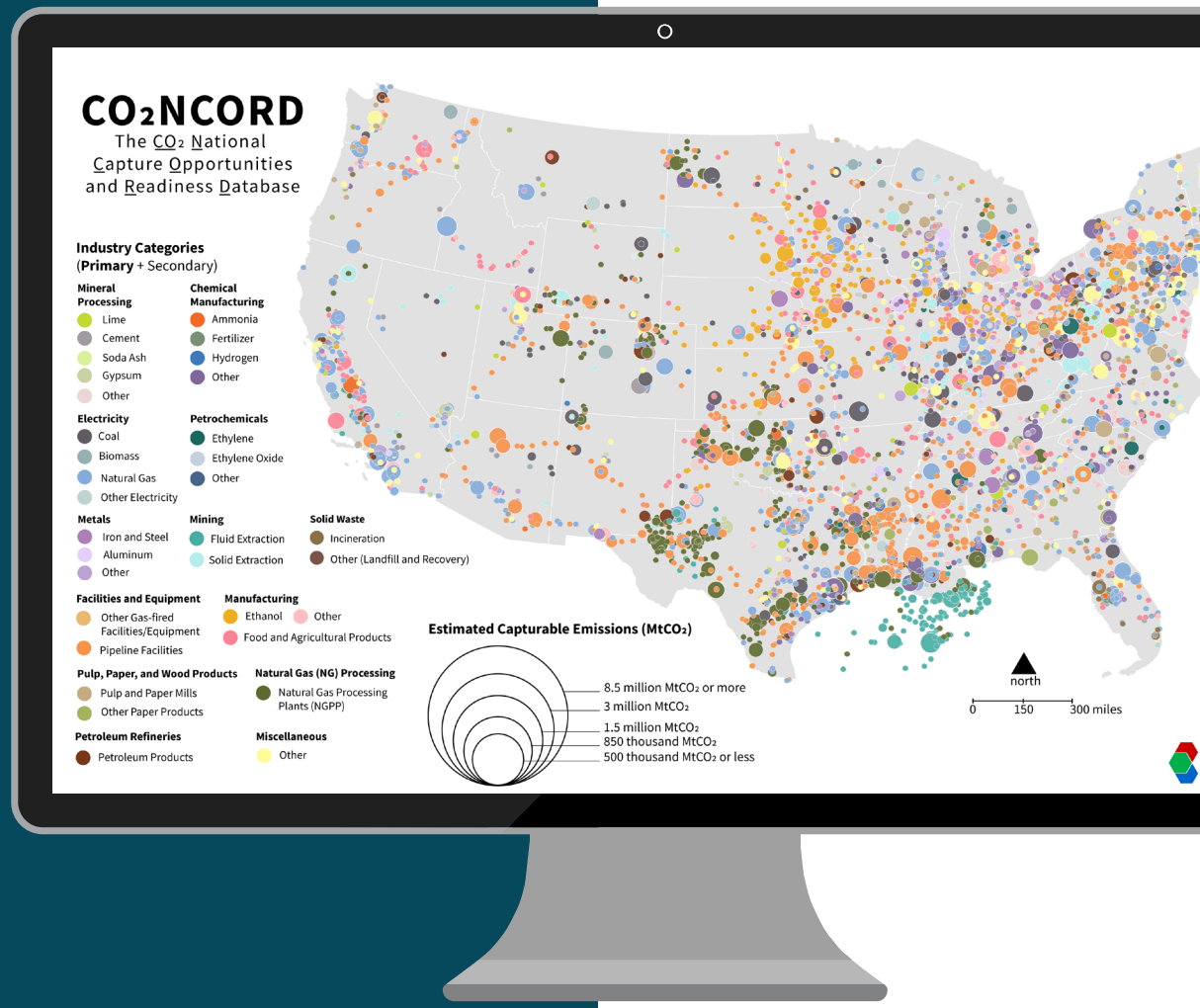
-The Rhodium Group, 2022 CCUS Analysis

CO_2NCORD

- Enables users to identify sub-facility sources of CO_2 for profitable CCS development.

- Provides critical, unique project-specific insights, including:
  - Breakeven CO_2 capture cost,
  - technology readiness level (TRL),
  - lifecycle CO_2 emissions

  ...for any prospective CCS project across the country.



USER CAPABILITIES.

Filter by Industry

Output any combination of 33 industry sub-categories for source opportunities unique to the user.

Filter by AOI or User-Defined Geography

Users can upload a shapefile to output capture opportunities in an AOI

Filter by Industry-Specific Parameters

Limit outputs by facility age, min. capturable emissions potential, cost parameters, and more.

Primary Industry	Secondary Industry Category
Mineral Processing	Cement
	Gypsum
	Lime
	Other
	Soda Ash
Electricity	Biomass
	Coal
	Natural Gas
	Other electricity
Petrochemicals	Ethylene
	Ethylene Oxide
	Other
Facilities and Equipment	Other gas-fired facilities/equipment
	Pipeline facilities
Mining	Fluid Extraction
	Solid Extraction
Chemical Manufacturing	Ammonia
	Fertilizer
	Hydrogen
	Other
Petroleum Refineries	Petroleum Products
Natural Gas (NG) Processing	Natural Gas Processing Plants (NGPP)
Metals	Iron and Steel
	Aluminum
	Other
Manufacturing	Other Manufacturing
	Food and Agricultural Products
	Ethanol
Pulp, Paper, and Wood Processing	Pulp and Paper Mills
	Other Pulp, Paper, and Wood Products
Solid Waste	Incineration
	Other

INDUSTRY CLASSIFICATION.

Within an individual facility, CO_2NCORD can extract stream-level opportunity:

- characterizing capturable emissions for specific equipment,
- stream-specific cost estimates

EMISSIONS STREAM CLASSIFICATION.

Example iron/steel mill shows how **multiple opportunities for capture exist for each unique facility stream.**

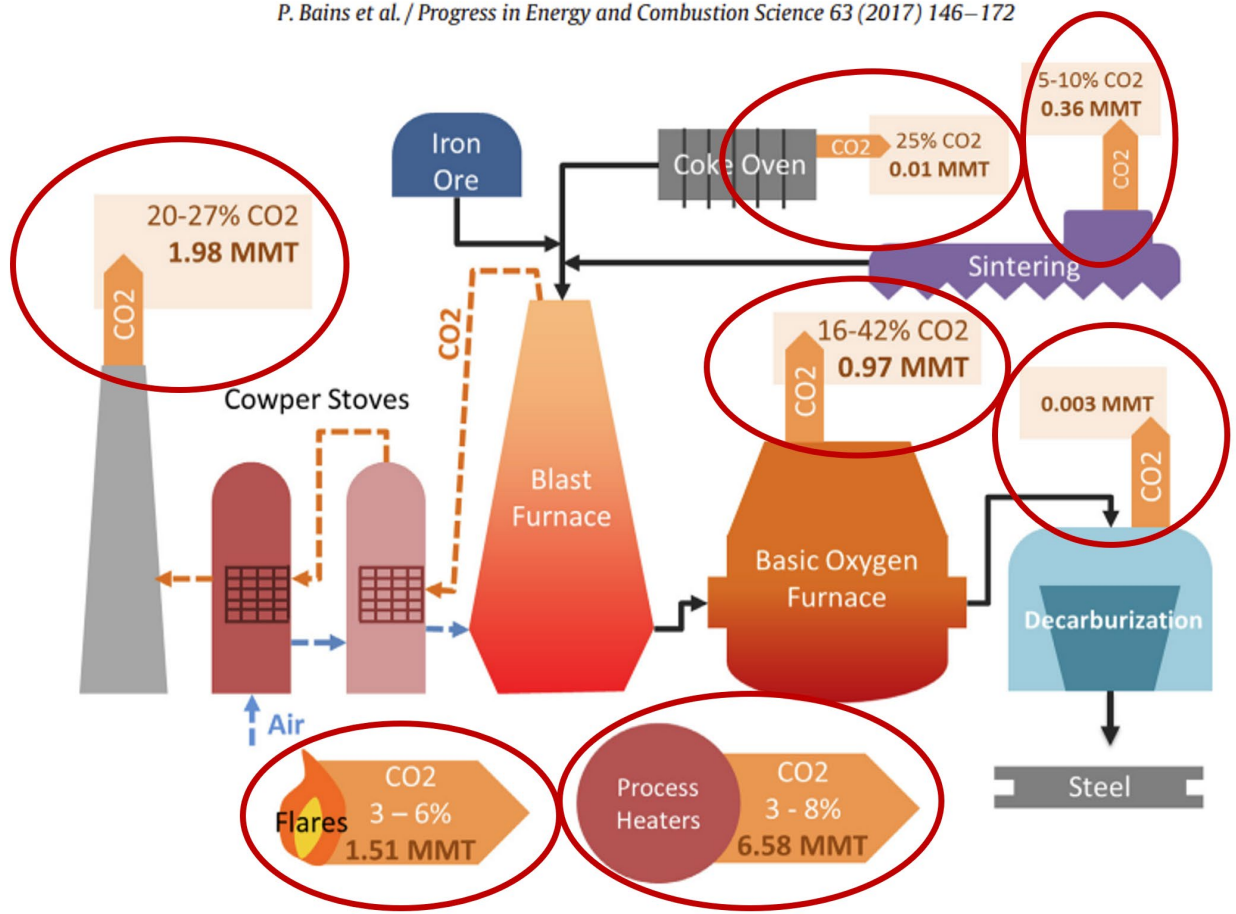


Fig. 10. Process diagram for blast furnace and basic oxygen furnace primary iron and steel production. 2014 emission numbers taken from U.S. GHGRP for U.S. Steel Corps plant in Gary, IN.

CAPTURE COST ESTIMATES.

Dual Estimation Methodology:

(1) Industry-specific (foundation in NETL methodology) + (2) Itemized to account for economies of scale, regional energy, & local labor.

Highest-degree of cost specificity possible without conducting a full FEED study.

CHARACTERIZE INTRA-FACILITY EMISSIONS COMPOSITION PROFILES.

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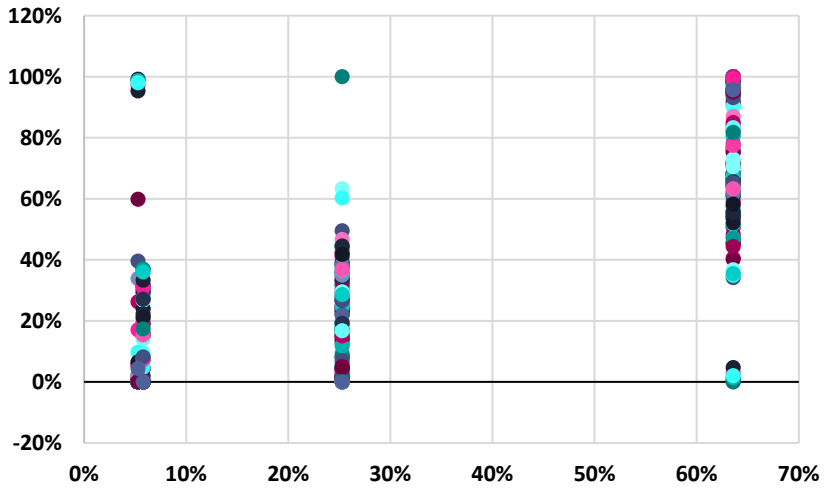
Sector	Top 3 Emitting Facilities for Each Industry (of Study Industries)	Total CO_2 emissions	**Stream 1** % of Total Emissions	**Stream 2** % of Total Emissions	**Stream 3** % of Total Emissions	**Stream 4** % of Total Emissions
Petroleum Refineries	Chevron Pascagoula Refinery	4,298,251	8%	4%	6%	83%
	CHEVRON PRODS.CO. RICHMOND REFY	4,124,414	8%	4%	6%	83%
	Flint Hills Resources Pine Bend Refinery	3,963,509	8%	4%	6%	83%



Petroleum Refineries - Petroleum Products				
	FCC + SCU	process heaters	PSA unit tail gas	Balance
	Petroleum refining	Stationary Combustion	Hydrogen Production	
	BX	AZ	BJ	C-BX-AZ-BJ
Literature	*25.3%*	*63.6%*	5.8%	5.3%

Actual				
25th Percentile	0.8%	55.8%	0.0%	0.0%
Mean	17.8%	71.8%	5.6%	4.2%
75th Percentile	29.9%	95.7%	4.6%	0.0%

CAPTURE COST ESTIMATES.

Dynamic functionality allows user to customize financial estimates.

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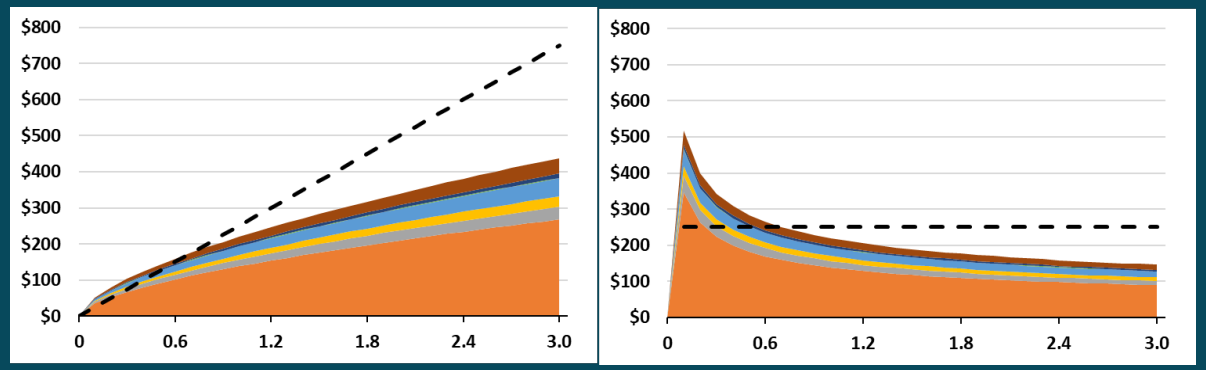
Overnight capital costs

Total ($ millions) | **Unit ($/tCO$_2$ captured)**

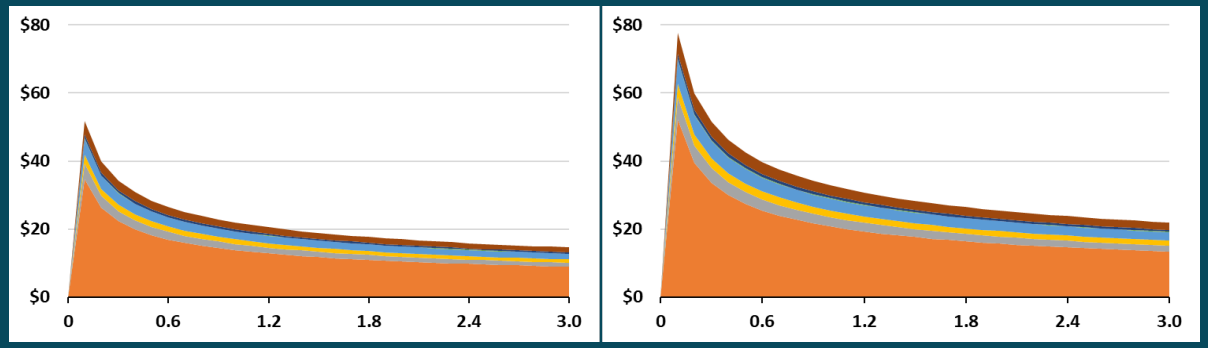


MMtCO$_2$ captured

Balance-of-plant
After-Cooler
Pre-Cooler
Cooling water system
Low-pressure boiler
CO_2 compressor
CO_2 removal system

Amortized capital costs ($/tCO$_2$ captured per annum)

10% CRF | **15% CRF**



MMtCO$_2$ captured

Financial assumptions

- Exponents unique to MDEA, compressor, and other capital equipment – leads to economies of scale (top graphs).
- **CRF matters**. 10% vs. 15% in bottom graphs.

CAPTURE COST ESTIMATES.

Dynamic functionality allows user to customize financial estimates.

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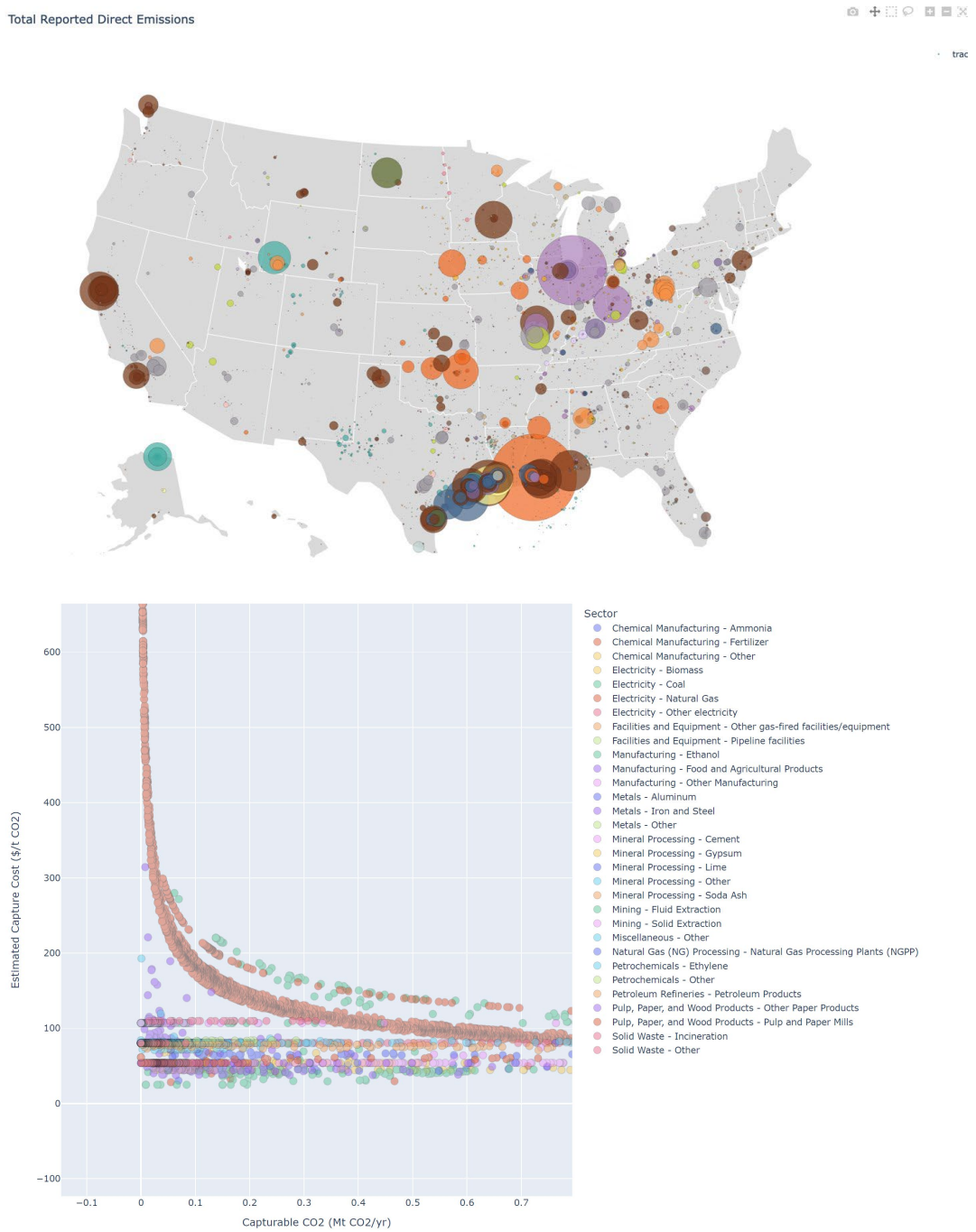
USER CAN FURTHER CUSTOMIZE:

- Power source (i.e., external vs. parasitic)
- Minimum captured
- Max train capacity
- Project economic life
- Capital Recovery Factor
- Oldest allowable plant
- Cooling system
- Project type
- Retrofit factor
- Capture rate



Multi-Scenario Functionality.

Flexible User Outputs

- Data outputs adaptive to user needs
- Range from simplified to unit-level, aggregated to include suite of information within CO_2NCORD
- Outputs both graphical and geospatial results summary

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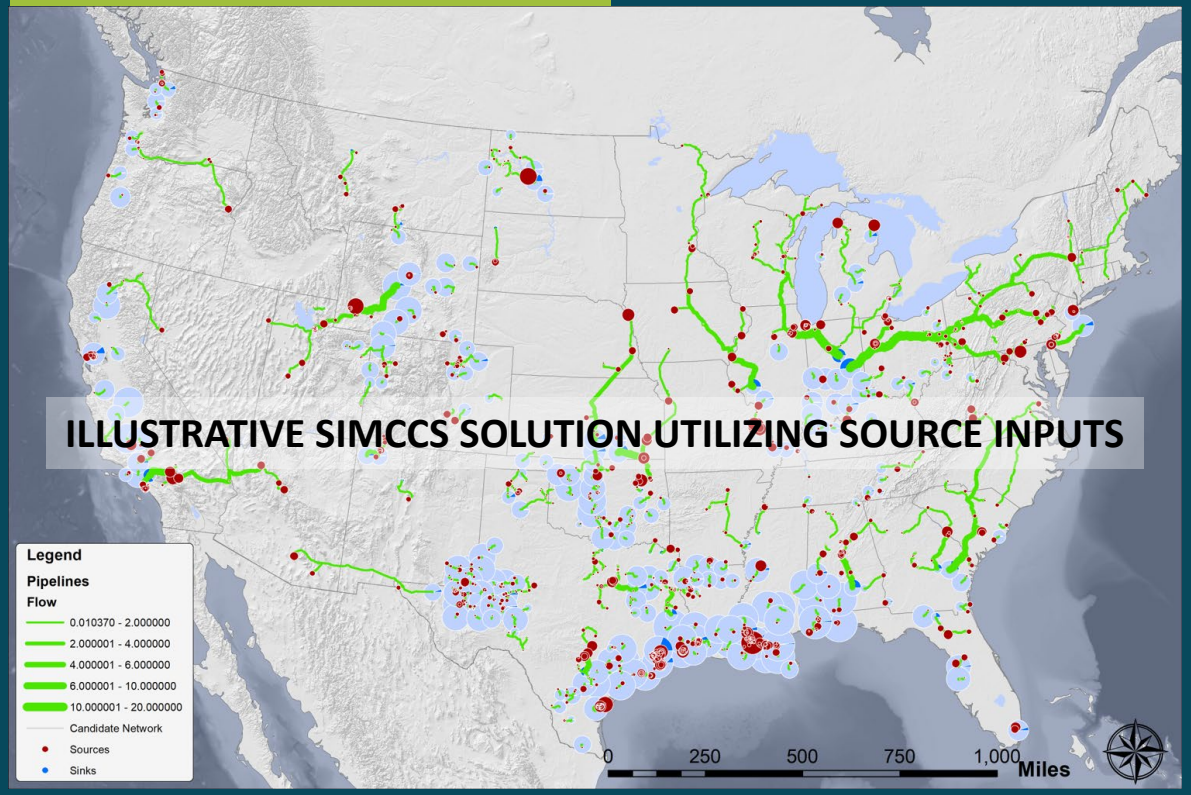
IMMEDIATE INTEGRATION WITH *SIMCCS*^{PRO} SOFTWARE + CARBON SOLUTIONS OPTIMIZATION SUITE



CO_2NCORD is built for immediate compatibility with Carbon Solutions suite of optimization and energy research software tools, notably including *SIMCCS*^{PRO}

COMPREHENSIVE, OPEN-SOURCE DATA INPUTS.

- ✓ EPA-FLIGHT – locations, stream emissions
- ✓ EPA-EGRID – locations, unit emissions (for power plants)
- ✓ Renewable Fuels Association
- ✓ International Energy Association (IEA)
- ✓ IRENA
- ✓ National Hydrogen Database
- ✓ Extensive review of published literature
- ✓ Inflation from BEA – GNP-IPD.
- ✓ Independent stream characterization and evaluation.
- ✓ Cost formulae from DOE-NETL
- ✓ Inflation: BLS (PPI, CQEW)
- ✓ Co-pollutants: EIA-923
- ✓ Heat/Power needs: GPI, 2020
- ✓ Heat/Power prices/regions: EIA AEO2022 + EMM regions

EXAMPLE APPLICATION:

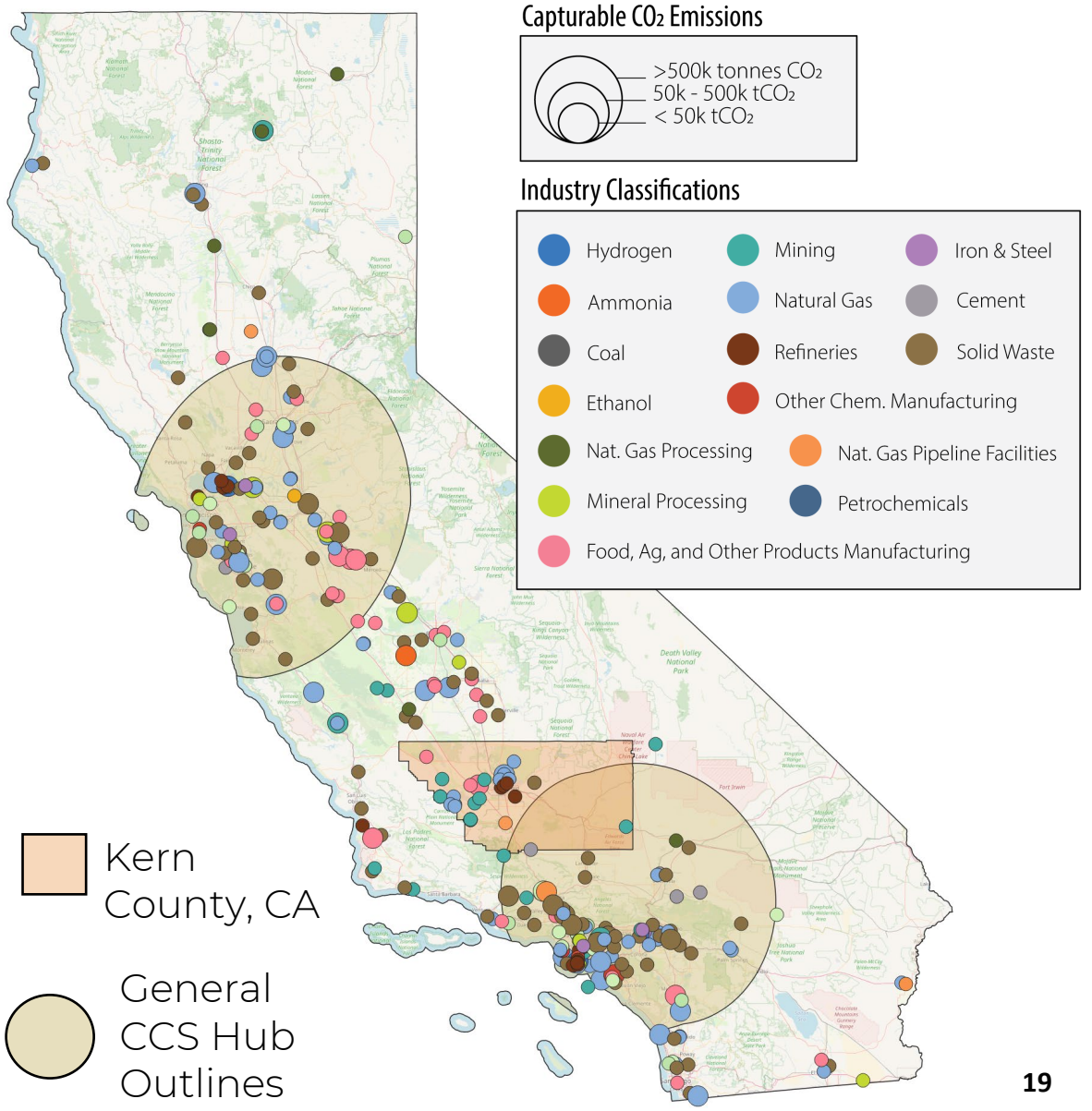
CUSP Focused Project: Laying the Cornerstones of a Regional Storage Hub in California

Objectives:

- Investigate storage volumes and dynamic storage capacity in targeted saline formation
- Forge a pathway to deploy a regional storage hub in the Southern San Joaquin Basin

Project Lead: Stanford University

Partners: Sentinel Peak Resources (SPR), Carbon Solutions, Montana State University

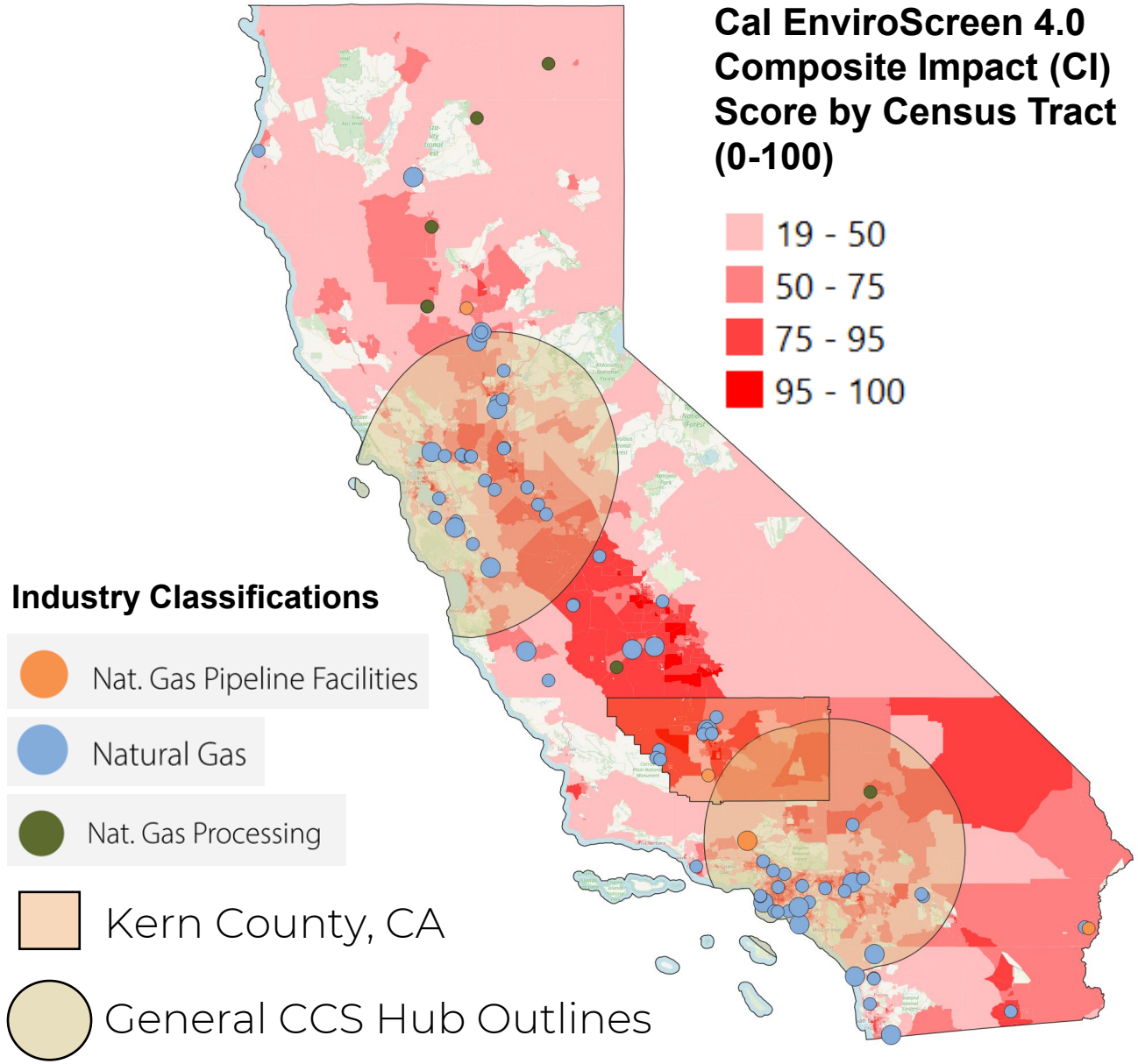


EXAMPLE APPLICATION:

CUSP Focused Project: Laying the Cornerstones of a Regional Storage Hub in California

Current Research Priorities

- Understand the extent of capturable potential across state industries, with focus on natural gas
- Contextualize potential for centralized storage hub, including the economics of a combined capture (CO2NCORD), transport (CostMAP^{PRO} + SimCCS^{PRO}), and storage (CUSP)
- Consider impact of environmental justice on siting infrastructure



FORTHCOMING

01. Additional functionality to address user customization needs

02. Advance techno-economics for facility-specific impacts to stream(s) & validate estimates

03. Streamline GUI to run CO_2NCORD, as well as integrate with SimCCS^{PRO} + optimization software suite

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QUESTIONS?

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