Feasibility Study Pairing Oxy-Combustion and Carbon Capture for Carbon Reduction in Aluminum Melt Furnaces

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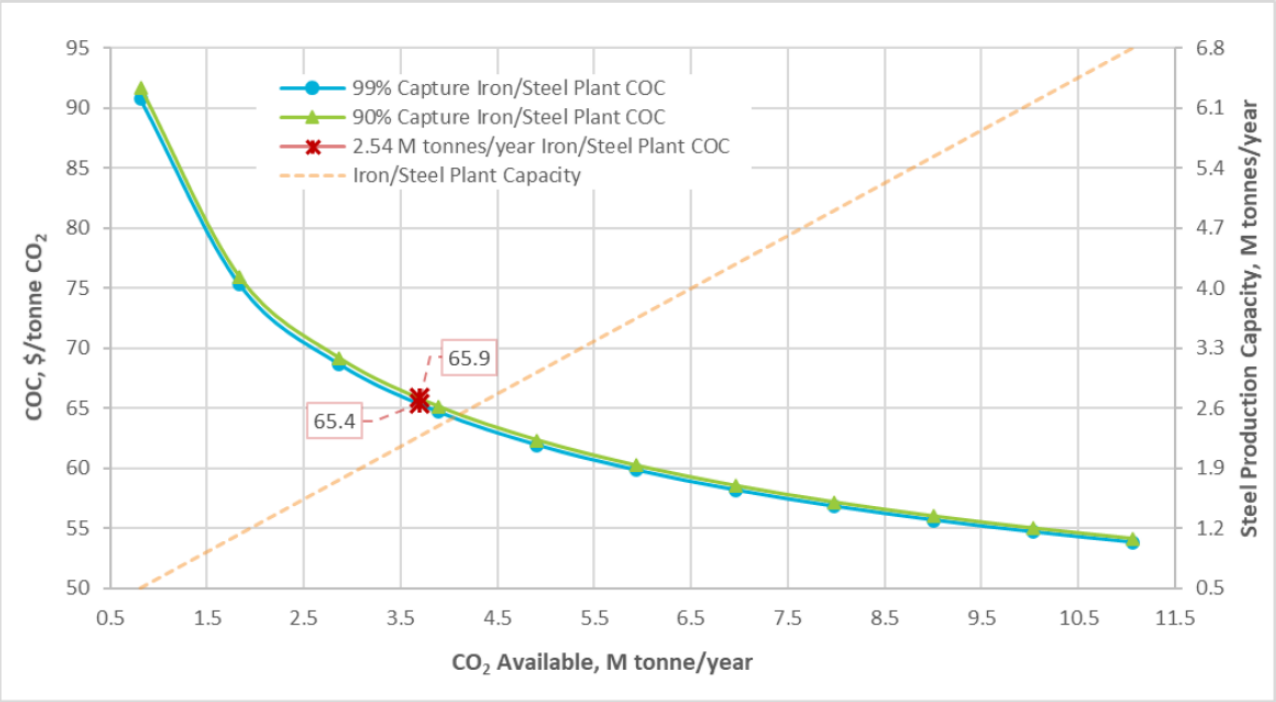
Agenda

- Problem statement and research question
- Project team and approach
- Preliminary technology screening and findings
- Market assessment and data analysis
- Next steps

Problem Statement and Research Question

- Mature post combustion carbon capture technology (amine solvent) favor very large economies of scale.
- A significant portion of industrial point-source emissions fall below the economic threshold for post-combustion capture
- **Research Questions:**
  - Can integrating oxy-combustion into industrial burner systems increase CO_2 concentration enough to reduce capture costs at smaller industrial scales?

Exhibit 6-54. Iron/steel plant capacity sensitivity

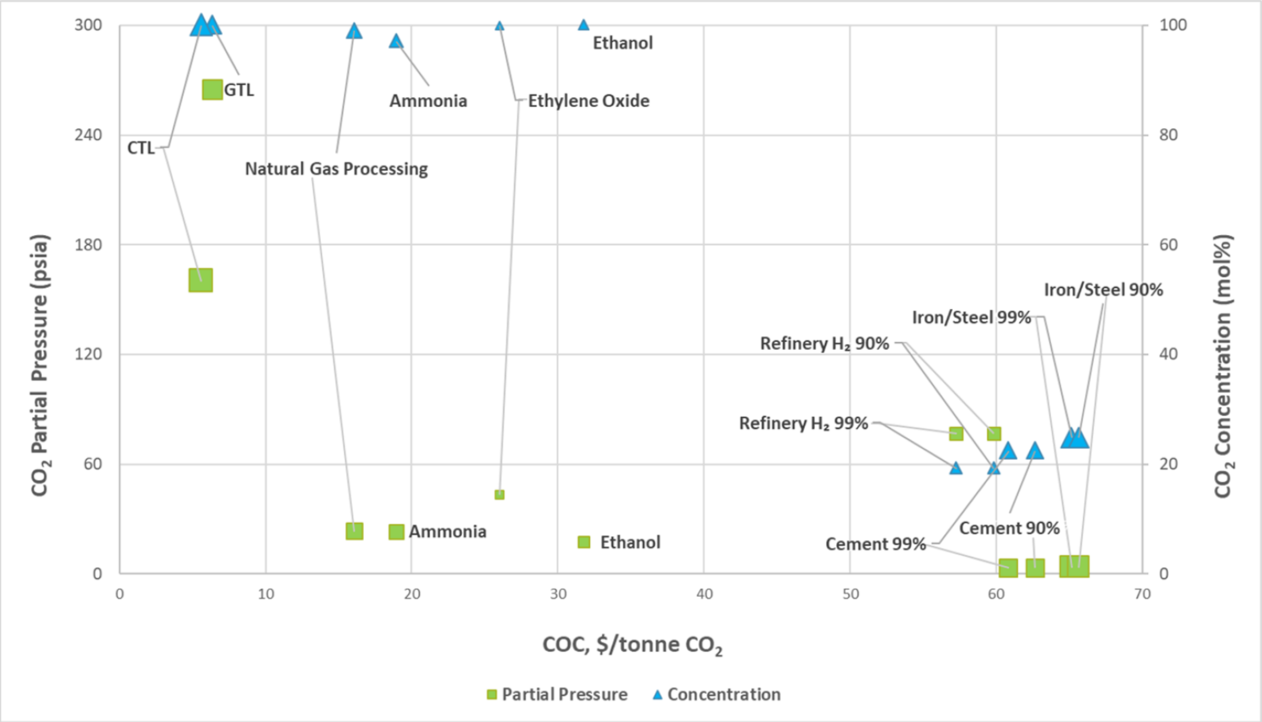


[TECHNICAL REPORT TEMPLATE AND USER GUIDE](https://netl.doe.gov/projects/files/CostofCapturingCO2fromIndustrialSources_071522.pdf)
:https://netl.doe.gov/projects/files/CostofCapturingCO2fromIndustrialSources_071522.pdf
NETL Report: COST OF CAPTURING CO2 FROM INDUSTRIAL SOURCES SYDNEY HUGHES, ALEXANDER ZOELLE

Economics of CO_2 Concentration and Carbon Capture

- Carbon capture costs decrease significantly as CO_2 concentration and partial pressure increase.
- Oxy-combustion can reduce fuel consumption per unit of useful heat while increasing CO_2 concentration.
- Hypothesis: The combined cost of oxy-combustion plus carbon capture may be lower than post-combustion capture alone for mid-scale industrial sources.

Exhibit ES-4. COC versus CO_2 partial pressure and CO_2 concentration



Note: Marker size is relatively indicative of CO_2 captured (tonnes/year).

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Project team and approach

Project team

- Project team
  - Aluminum producer
  - Oxy-combustion technology provider
  - Engineering firm
  - EPRI oversight
- Using flue gas data from aluminum melt furnace to feed oxy-combustion model.
  - Vary O_2 feed concentration to understand change CO_2 concentration in exhaust
  - Oxy-combustion technology also lowers fuel consumption thus estimating fuel consumption required at varying O_2 concentrations
- Based on exiting CO_2 concentration engineering firm is screening carbon capture technologies

Approach

- Use aluminum melt furnace flue-gas data as input to an oxy-combustion model.
- Vary O_2 feed concentration to quantify changes in exhaust CO_2 concentration
- Estimate fuel consumption at varying oxygen concentrations
- Screen carbon capture technologies based on resulting CO2 concentration, flowrates, and impurities.

Preliminary Technology Screening and Findings

Preliminary Screening of Carbon Capture Technologies

Screening Criteria

- What is technically feasible with commercial technology
- What has potential to scale down more economically
- What are potential contaminates that might affect operations
- How does technology integrate with site operations or constraints
- **Key takeaway:** Increasing CO_2 partial pressure expands the range of commercially viable capture technologies and reduces reliance on post-combustion amine systems.

Technology Analysis

CO_2 Partial Pressure in Feed Gas	Default / Incumbent Technology	TRL of Incumbent	Potential Alternate Technologies & Key Advantages
< ~10 kPa	Amines (or similar chemical solvents) developed for post-combustion capture (PCC)	TRL 8–9 (High for general applications and PCC)	Limited alternatives: Non-amine chemical solvents, solid sorbents, and low-temperature ("cryogenic") approaches proposed, but performance deteriorates significantly at low partial pressure and data are more limited than for amines.
~10 – 40 kPa	Amines (or similar chemical solvents) developed for PCC	TRL 8–9 (High for general applications and PCC)	Non-amine chemical solvents (e.g., promoted carbonate, ammonia): potential lower cost and lower contaminant sensitivity (best above ~20 kPa). Membranes (PCC): lower energy, minimal chemical handling, modular footprint. Solid sorbents (PCC): lower energy, no volatile emissions. Low-temperature (cryogenic): lower energy, reduced contaminant sensitivity.
~40 – 90 kPa	Not clear	N/A	Commercial gas treating technologies with compression; commercial gas treating amines (e.g., LNG AGRU units); low-temperature (cryogenic) processes, membranes, solid sorbents; PCC amines technically effective but potentially sub-optimal; hybrid processes (e.g., PSA + cryogenic separation).
> ~90 kPa (high-purity CO_2 stream)	CO_2 compression + dehydration + trace contaminant removal; CO_2 liquefaction + distillation + trace contaminant removal	TRL 9+ (Commercial)	None identified; technology selection depends on CO_2 purity, impurities, and product specification. Does not represent bulk CO_2 separation at this level.
> 200 – 300 kPa (requires flue-gas compression in PCC)	Commercial CO_2 removal technologies used in NG processing and NH_3 production (Benfield 'Hot Pot', MDEA, membranes, Rectisol, Selexol)	TRL 9+ (Commercial)	None identified; generally considered only when flue-gas CO_2 concentration is high (> ~50 vol%). Applicability of flue-gas compression not evaluated.

Preliminary findings

- Increasing O_2 concentration has a strong, predictable impact on exhaust CO_2 concentration.
- At ~93% O_2, CO_2 concentration reaches approximately 85%.
- On-site PSA-based oxygen production may reduce oxygen supply costs by 40–60% relative to bulk liquid delivery.
- Current break point with liquefaction distillation seems to be around a 90% CO_2 concentration
- Preliminary screening indicates liquefaction distillation becomes favorable above ~90% CO_2 concentration
- Liquefaction distillation current leading technology but potential for physical solvents to play.

Market Assessment

Emissions Profile

- **Rule of thumb:** Post-combustion carbon capture is often uneconomical below ~300,000 tonnes CO_2/year
- A significant portion of point source emissions fall below the 300,000 tonne per year mark
- Nearly 40% of non-power industrial emissions fall below this threshold.

			Number of point sources
With power plants	Above 300k	2,012,618,826	1233
	Below 300k	370,221,592.33	5238
	total	2,382,840,418	6471
	Percent of total emisison below 300k (with power)	**16%**	
Without power plants	Above 300k	626,264,511	555
	Below 300k	370,221,592	5120
	total	996,486,103	5675
	Percent of total emisison below 300k (without power)	**37%**	

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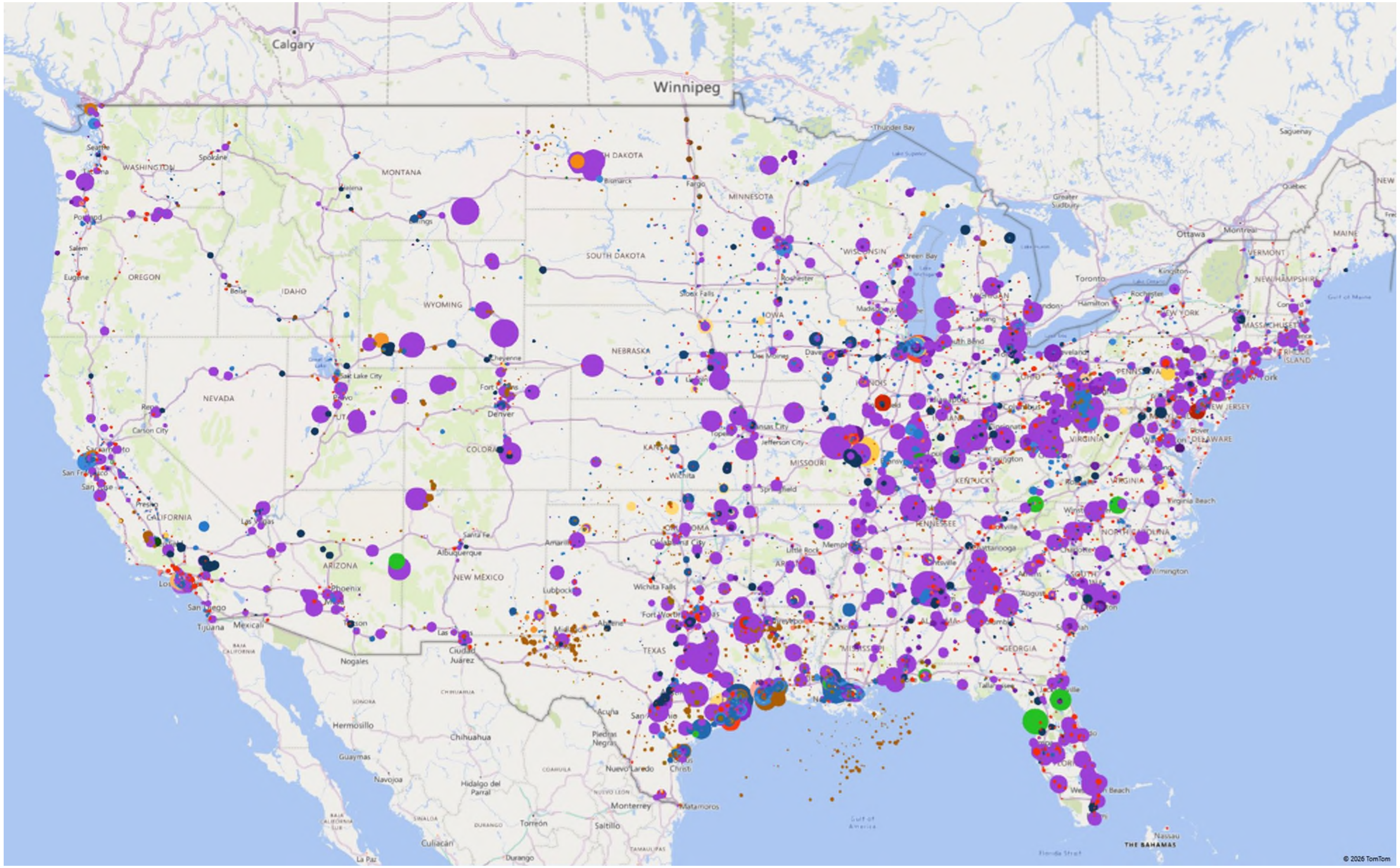
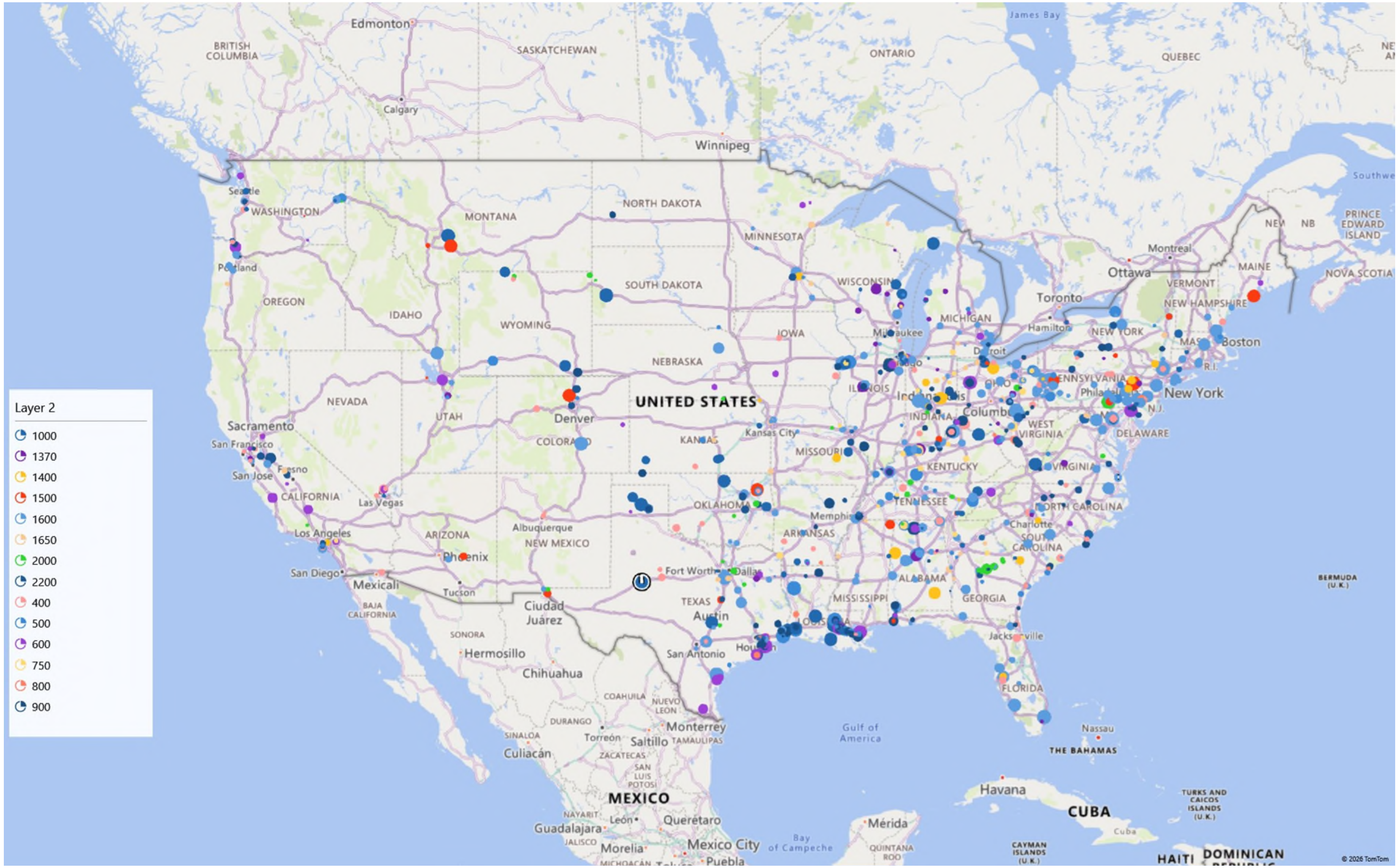
All Emissions

- Each circle represents a point source; size is proportional to annual CO_2 emissions.
- Power plants shown in purple



Below 300K (without power production)



Future work

Future work

- Complete feasibility study and refine cost estimates
- Quantify carbon reduction potential
- Advance to demonstration phase pending favorable economics
- Conduct oxy-combustion trial at an aluminum melt furnace
- Collect emissions and trace contaminant data (with focus on NOx impacts)
- Refine capture and contaminant treatment requirements.
- Complete market assessment and Identify regional clusters that could share oxy-combustion infrastructure.

Questions

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