Quantifying Carbon Removal via Enhanced Weathering and Mineralization

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Carbon180

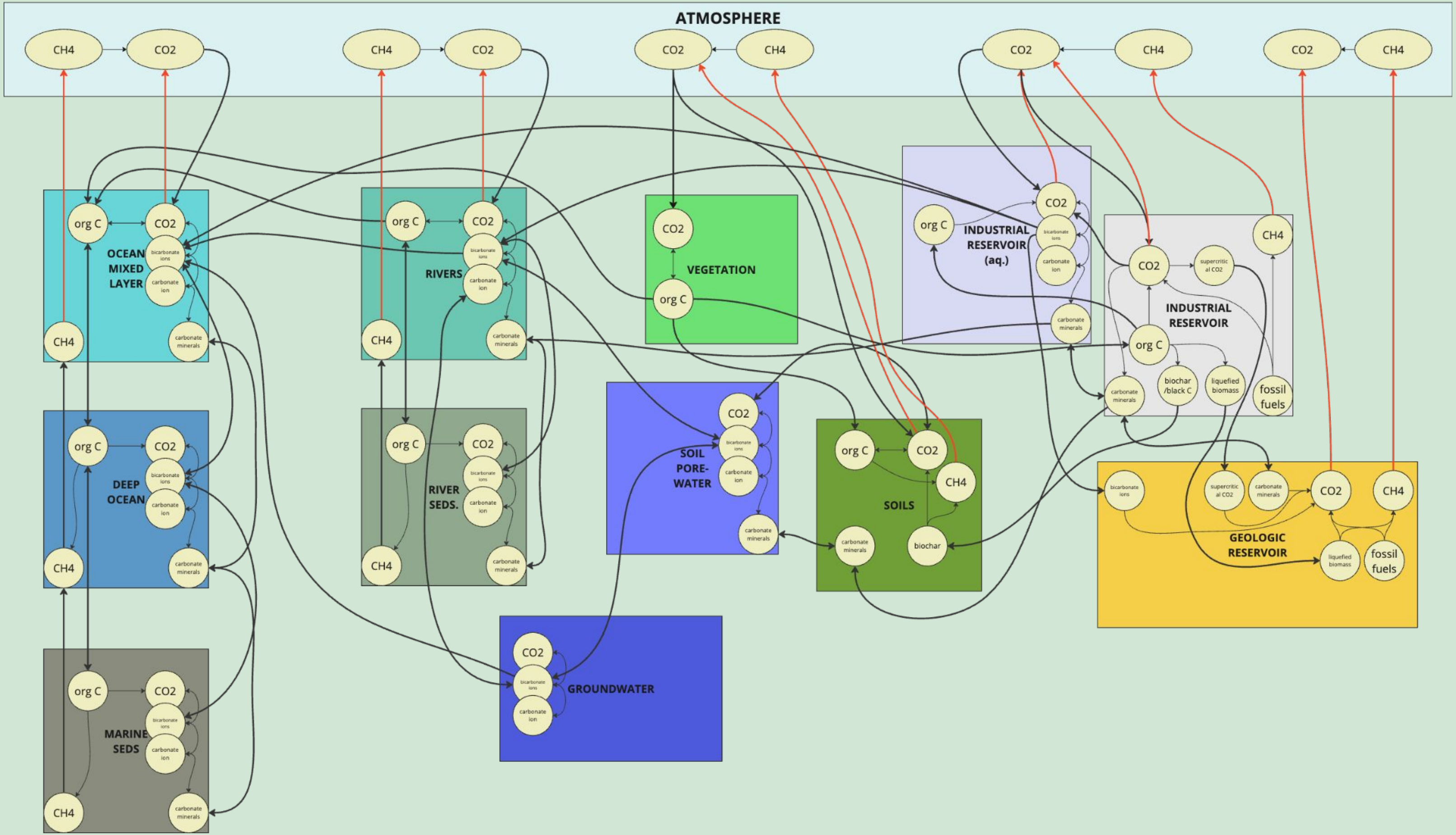
A preview of this presentation

1. Delineation of the sink to be estimated
    a. Enhanced weathering on agricultural lands
    b. Enhanced weathering in rivers (river liming)
    c. Ex situ mineralization
    d. Enhanced weathering using biogenic CO2 (wastewater alkalinity dosing)

2. For each sink
    a. Expected significance of activity
    b. Existing academic and commercial guidance on quantification
    c. Identification of overlap with and gaps in existing methodologies

Note on existing standards

Reservoir and Flux Framework - CO2 and CH4



Quantification Resource Database v1

Data | Automations | Interfaces | Help | Share

quantification standards v0.2 - fluxes no components | source document database v0.1 | flux database v0.1 | quantification standards v0.1 WAITING ROOM | 4 hidden tables | Extensions | Tools

Views | Grid view | 1 hidden field | Filter | Group | Sort | Color | Share and sync

	quantification standard	source document	flux(es)	pathway(s)	Used In
147	chemical dissolution rate laws and coefficients for basaltic glas...	Flaathen, Gislason, and Oelkers, 201	alkaline material CO2 exposure, alkaline material weathering	Enhanced Rock Weathering (ag)	Kelland et al., 2020 - In
148	total and composite aqueous alkalinity - ISO	ISO 9963-1:1994 - Water quality — I	soil porewater DIC to alkalinity transformation	Enhanced Rock Weathering (ag)	Isometric Enhanced We
149	aqueous dissolved anions by liquid chromatography - ISO	ISO 10304-1:2007 - Water quality —	soil porewater DIC to alkalinity transformation	Enhanced Rock Weathering (ag)	Isometric Enhanced We
150	water pH - ISO	ISO 10523:2008 - Water quality — D	soil porewater DIC to alkalinity transformation	Enhanced Rock Weathering (ag)	Isometric Enhanced We
151	soil carbonate content - calcimetry - ISO	ISO 10693:1995 - Soil quality — Det	pedogenic carbonate deposition, soil porewater carbonate	Enhanced Rock Weathering (ag)	Isometric Enhanced We
152	soil organic carbon - ISO	ISO 10694:1995 - Soil quality — Det	soil formation	Enhanced Rock Weathering (ag)	Isometric Enhanced We
153	total soil carbon - ISO	ISO 10694:1995 - Soil quality — Det	soil formation, pedogenic carbonate deposition	Enhanced Rock Weathering (ag)	Isometric Enhanced We
154	soil cation exchange capacity and base saturation - ISO	ISO 11260:2018 - Soil quality — Dete	soil porewater DIC to alkalinity transformation	Enhanced Rock Weathering (ag)	Isometric Enhanced We
155	measurement of aqueous elements via ICP-OES - ISO	ISO 11885:2007 - Water quality — D	soil porewater DIC to alkalinity transformation	Enhanced Rock Weathering (ag)	Isometric Enhanced We
156	soil nitrogen content by dry combustion - ISO	ISO 13878:1998 - Soil quality — Det	soil outgassing, soil porewater outgassing, soil porewater c	Enhanced Rock Weathering (ag)	Isometric Enhanced We
157	LCA - principles and framework - ISO	ISO 14040:2006 - Environmental ma	process or transportation emissions due to energy use, rele	Enhanced Rock Weathering (ag)	Isometric Enhanced We
158	LCA - requirements and guidelines - ISO	ISO 14044:2006 - Environmental ma	process or transportation emissions due to energy use, rele	Enhanced Rock Weathering (ag)	Isometric Enhanced We
159	quantification, monitoring, and reporting of GHG reductions or ...	ISO 14064-2: 2019 - Greenhouse Ga	process or transportation emissions due to energy use, rele	Enhanced Rock Weathering (ag)	Isometric Enhanced We
160	GHG statements - verification and validation - ISO	ISO 14064-3:2019 - Part 3: Specific	process or transportation emissions due to energy use, rele	Enhanced Rock Weathering (ag)	Isometric Enhanced We
161	measurement of aqueous elements via ICP-MS - ISO	ISO 17294-1:2024 - Water quality —	soil porewater DIC to alkalinity transformation	Enhanced Rock Weathering (ag)	Isometric Enhanced We
162	field-scale organic carbon and nitrogen	ISO 23400:2021 - Guidelines for the	soil formation, soil outgassing, soil porewater outgassing	Enhanced Rock Weathering (ag)	Isometric Enhanced We

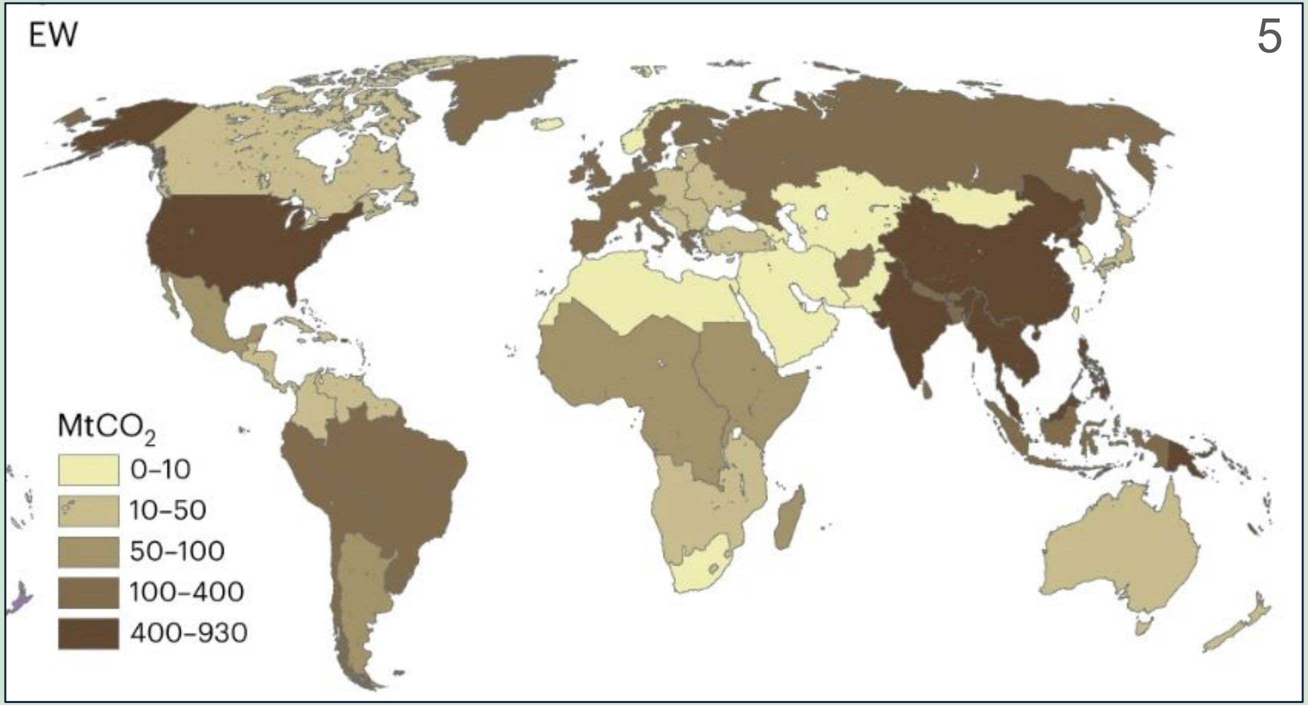
Enhanced Weathering: Agriculture

Expected Significance of Activities

- General consensus from top-down biogeochemical and techno-economic models of Gt scale potential
  - Removing 0.5 to 2 Gt/yr over 10-50% of global croplands[1]
  - Significant potential in the US, Brazil, India, China, Indonesia[1]
- Resilient to climate change and more effective in hot, humid environments[2]
- Potential climate impact from soil organic carbon storage[3]
- Can leverage existing industrial feedstock streams (mining, quarries)[4]

- **Limited data on field-scale deployments to validate models and assess environmental and agronomic impacts**

Expected Significance of Activities



Existing Guidance on Quantification

- 48 unique documents in our database:
  - academic papers,
  - academic reviews,
  - registry standards (e.g. Puro and Isometric),
  - supplier white papers (e.g. Eion),
  - ISO standards for specific measurement steps,
  - open-source models (e.g. SCEPTER).
- 96 unique quantification standards
- Limited data/information on uncertainty quantification

Existing IPCC Methodologies: Overlaps and Gaps

- Overlap - Volume 4 (AFOLU), Chapter 11 (CO2 Emissions from Lime)

EQUATION 11.12

ANNUAL CO_2 EMISSIONS FROM LIME APPLICATION

$$CO_2\text{–}C\ Emission = (M_{Limestone} \bullet EF_{Limestone}) + (M_{Dolomite} \bullet EF_{Dolomite})$$

Where:

CO_2–C Emission = annual C emissions from lime application, tonnes C yr^{-1}

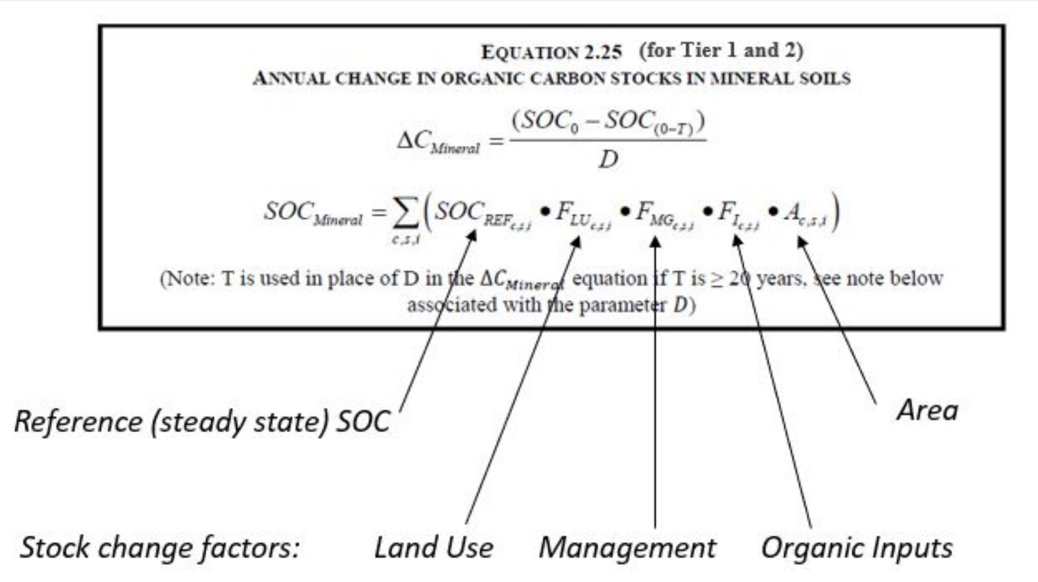
M = annual amount of calcic limestone ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$), tonnes yr^{-1}

EF = emission factor, tonne of C (tonne of limestone or dolomite)$^{-1}$

  - Tier 1 and US (EPA, USDA guidance) Tier 2 strictly source of CO2, but could have activity/region specific negative EF
  - Tier 3 – accounting for secondary precipitation and dissolved inorganic C transport – is similar to what VCM suppliers do today for EW crediting

Existing IPCC Methodologies: Overlaps and Gaps

- Model/analog - Volume 4 (AFOLU), Chapter 2 (Generic Methodologies), Section 3.3 (Change in Carbon Stocks in Soils)



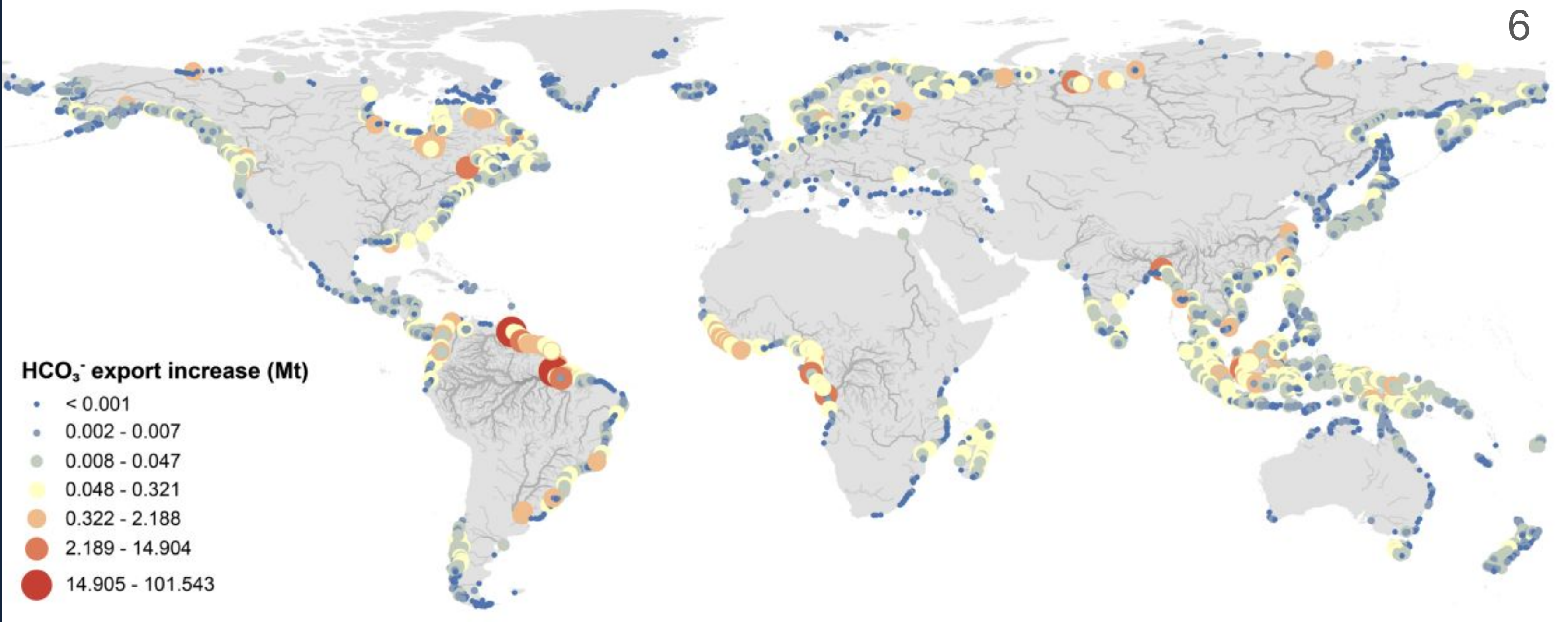
Enhanced Weathering: Rivers

Expected Significance of Activities

- No peer-reviewed estimates of global river liming CDR potential
  - One preprint suggests global potential of 100s of Mt[6]
- Case study of Amazon river plume: 0.07–0.1 Mt CO2 per month[7]
  - Focused on detectability limits, mouth of the river for OAE
- Model assessing river transport limitations on EW found 2.5–8.8 GtCO2 yr−1 river transport potential globally for accelerated carbonate weathering[8]

- **Anecdotal evidence of ecological benefits in acidified waters[9], but mixed evidence from systematic review[10]**

Expected Significance of Activities



Existing Guidance on Quantification

- 9 unique source documents
  - Many from the 1990s, focused on appropriate dosing for treatment of acidified streams
- 8 unique quantification standards
  - 1 source document provided rate parameters, not a quantification methodology
- Detectability at outflows is challenging
  - Signal-to-noise problem common across alkalinity management pathways

Existing IPCC Methodologies: Overlaps and Gaps

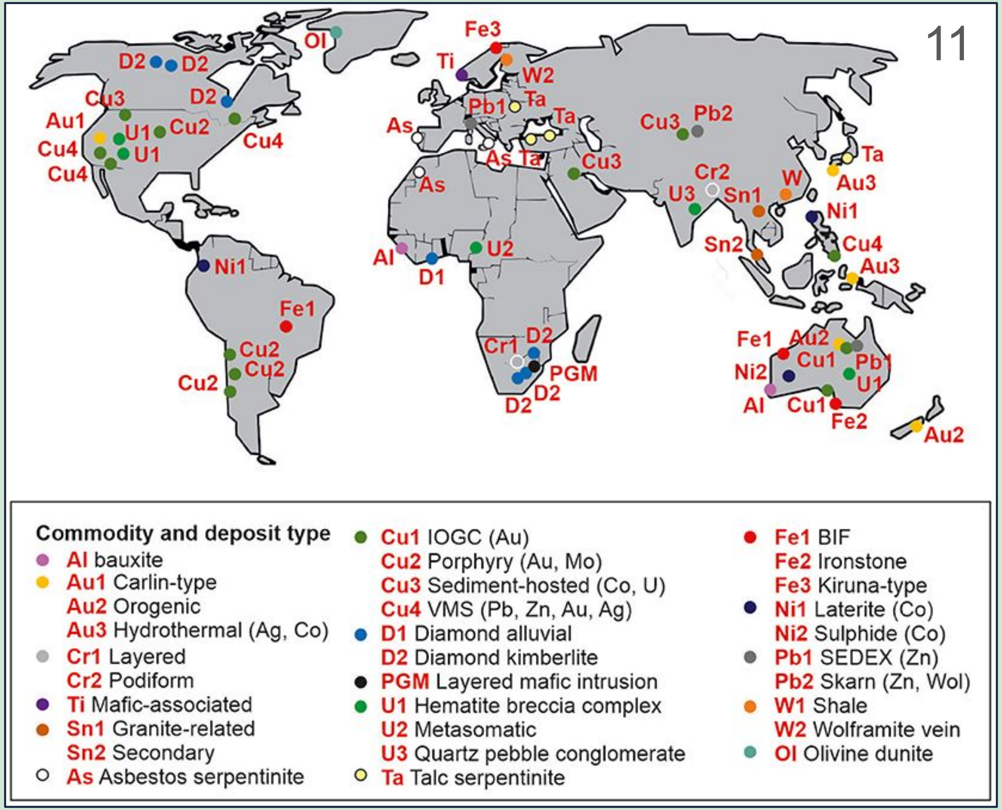
- Liming (as above)

Ex Situ Mineralization

Expected Significance of Activities

- Includes: steel slag, cement kiln dust, construction waste, coal ash, tailings
- 7 billion tons of alkaline materials produced annually as byproducts of industrial processes[4]
- Potential to capture 1.1-4.5Gt CO2 annually from mining wastes (silicate-hosted commodity minerals), or 31-125% of annual mining industry emissions, limited by dissolution rates over the next 50 years[11]
  - Potential depends on the removal potential per ton of processed mineral and annual total production of mineral, with copper-containing mines having the highest potential
- Some experimental work on CO2 uptake rate[12]

Expected Significance of Activities



Existing Guidance on Quantification

- 10 unique source documents
- 7 unique quantification standards (not all source documents are publicly available yet)
- Significant variation in uncertainty (containerized vs. open-air systems)

Existing IPCC Methodologies: Overlaps and Gaps

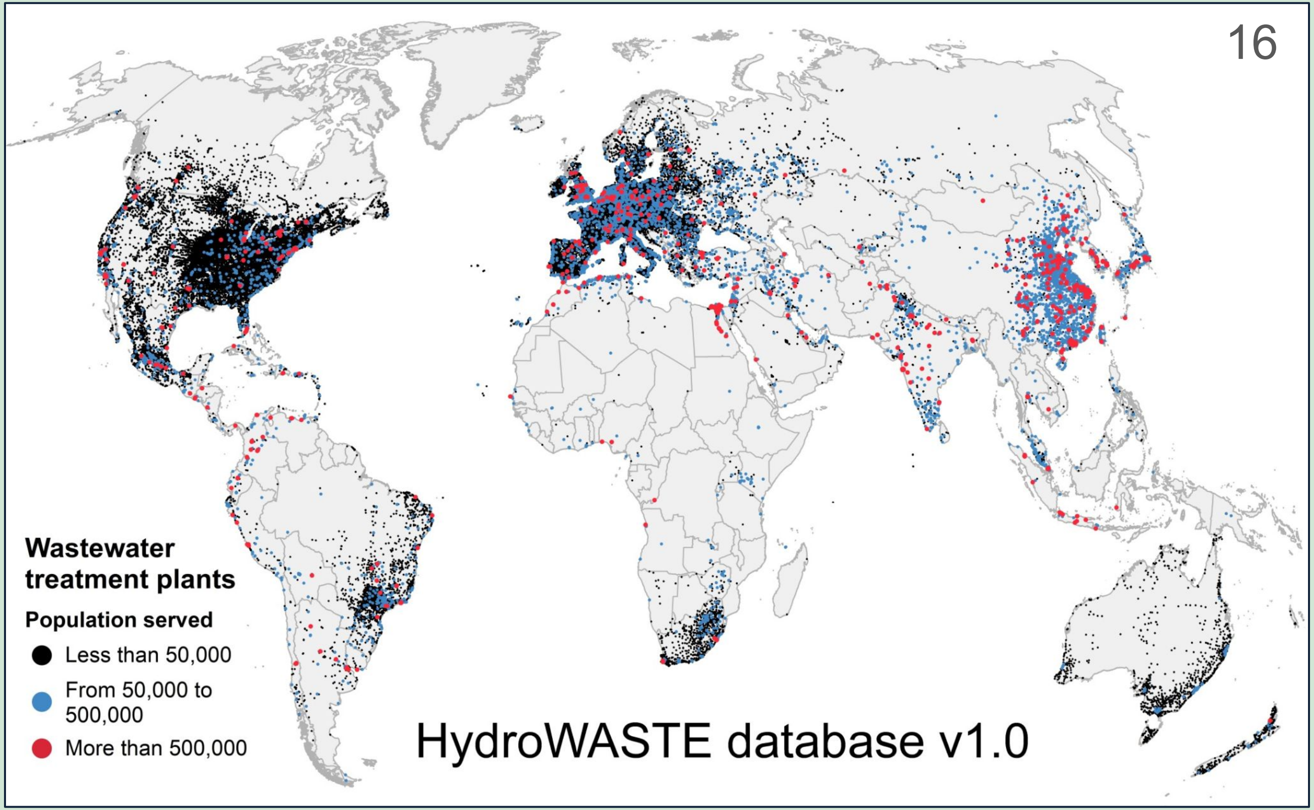
- Mentioned in Volume 2 (Energy), Chapter 5 (Carbon Dioxide Transport, Injection, and Geologic Storage): *"With the exception of the* ***mineral carbonation of certain waste materials****, these technologies are at the research stage rather than the demonstration or later stages of technological development."*

Enhanced Weathering: Biogenic C

Expected Significance of Activities

- No published estimates of global CDR potential from conversion of biogenic C to bicarbonate in wastewater treatment facilities
  - Wastewater treatment contributes 1-2% of GHG emissions annually; EW represents opportunity for significant sectoral emissions reductions[13]
- One perspective piece considers wastewater effluent for OAE because of its low pH and high pCO_2, but does not quantify total potential[14]
  - 300 km^3 of wastewater discharged from municipal facilities annually
- Opportunities for integration with phosphorus and nitrogen management[15]
  - Additional processing steps generate effluent with different chemistry, that maybe more or less efficient at carbon removal

Expected Significance of Activities



Existing Guidance on Quantification

- 8 unique source documents
  - All from CDR suppliers
  - No published academic or commercial quantification methodologies
- Considerable gaps in existing standards
  - No resource for counterfactual pH management of wastewater, likely from outside the CDR sector

Existing IPCC Methodologies: Overlaps and Gaps

- Overlap with Volume 5 (Waste), Chapter 6 (Wastewater Treatment and Discharge)
  - CO_2 emissions are not counted
  - Alkalinity dosing could be considered a treatment system (generating, for example, treatment-specific correction factors to the CH_4 emission factor)
- Analogy to BECCS in Volume 2 (Energy), Chapter 2 (Stationary Combustion)
  - *"Negative emissions may arise from the capture and compression system if CO_2 generated by biomass combustion is captured. This is a correct procedure and negative emissions should be reported as such."*

Resources

- Citation list for this presentation (Google Sheet)
- Link for this presentation (PDF)
- Carbon Reservoir and Flux Framework (EW pathways)
- Quantification Resources Database (all pathways)*

** Please ask Anu for access. A public version will be available in late July.*