Eight Gardens, London, UK

Built with ECOPact with a 64% lower CO_2 footprint

CCUS – THE MINERALIZATION PATHWAY
FOR A NET-ZERO FUTURE

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BUILDING PROGRESS FOR
PEOPLE AND THE PLANET.

THE CEMENT AND CONCRETE INDUSTRY IN CANADA

14 Cement Plants

1,000 Ready mix concrete plants

58 Precast concrete plants

35 Concrete pipe plants

12 Insulated concrete form plants

35 Concrete masonry plants

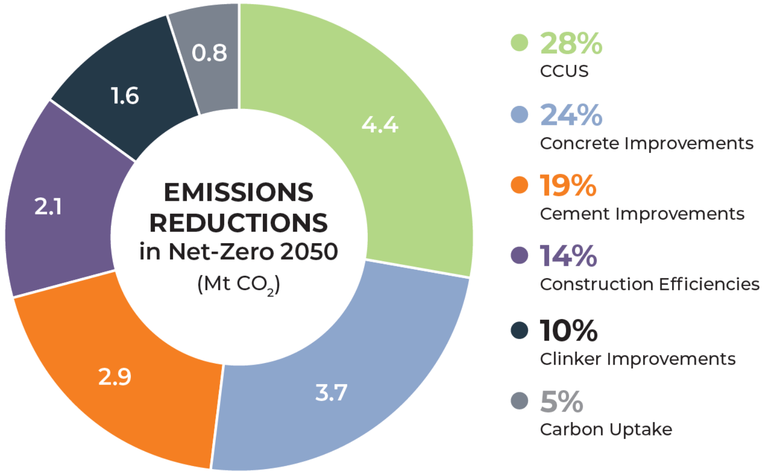
$79 Billion in Annual Economic Activity

40% Exports to US

158,000 Employees

13 million tonnes of Cement produced in Canada each year with emissions of 9.7 MT of CO_2 in 2020

Concrete Zero RoadMap



CONCRETE ZERO

Cement Association of Canada

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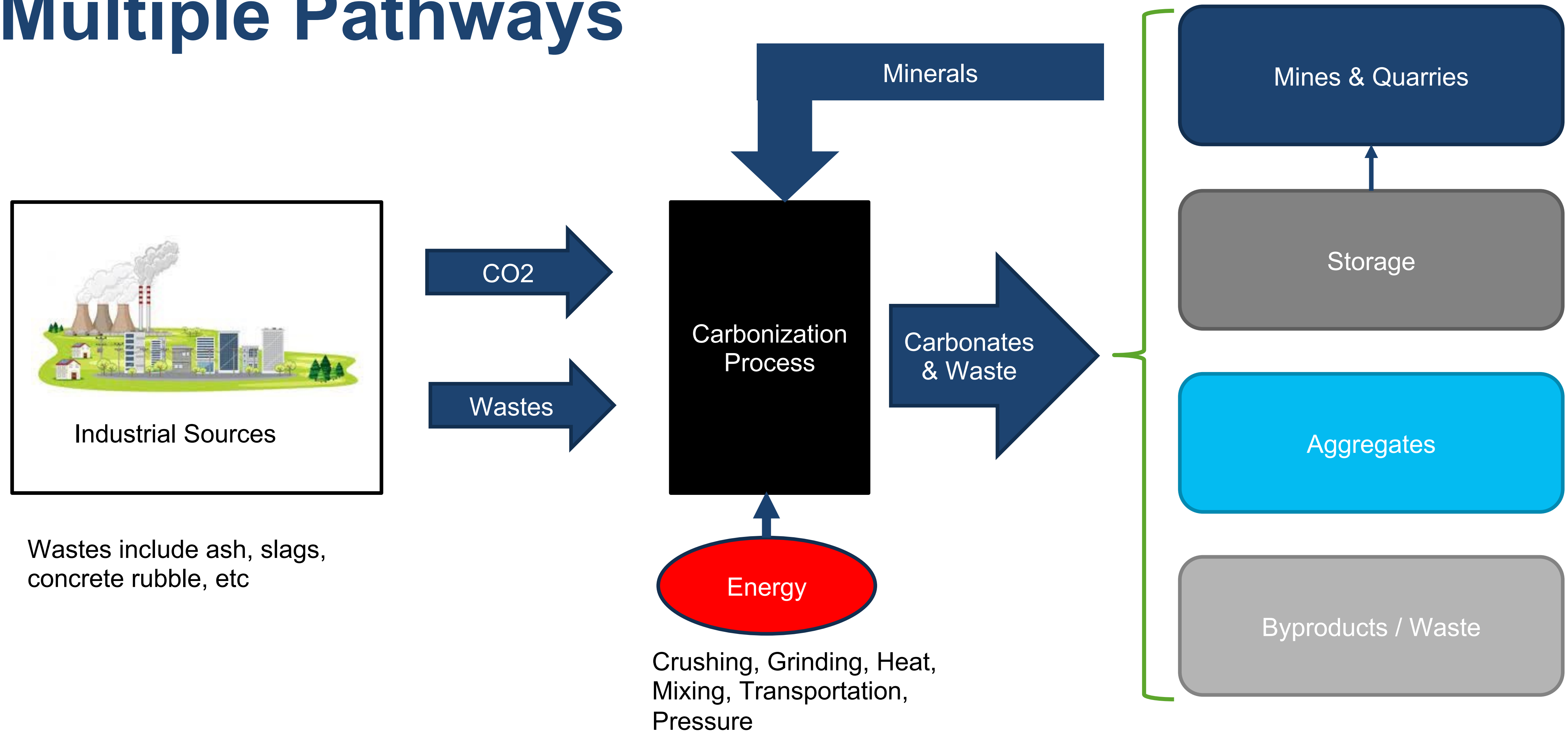
What is Mineralization?

- **Mineralization or mineral carbonation is the reaction of CO_2 with metal oxide bearing materials to form insoluble carbonates.**
    - Occurs naturally over millennia in a process called silicate weathering
    - Concrete will also carbonate over time
- **R_{CO2} is the ratio of the mass of mineral needed to the mass of CO_2 captured at 100% efficiency**
- **Chemistry $MO + CO_2 \rightarrow MCO_3 + Heat$**
    - M = divalent metals & alkaline earth metals (e.g. Ca, Mg, Fe)
    - Opposite of reactions in cement and lime production
    - Exothermic!
        - eg Wollastonite: $CaSiO_3 + CO_2 \rightarrow CaCO_3 + SiO_2 + 90$ kJ/mol CO_2

Multiple Pathways



The Case and the Challenges

Positive Features

- Chemical / permanent CO_2 fixation in products or CCS
- Exothermic chemistry
- Carbonate Sales
- Waste tipping fees
- Less (or no) flue gas clean up for mineral applications
- Basaltic & other mineral reserves exist in nature and in large quantities

Negative Features

- Significant tonnes of heavy oxide containing materials required
- Waste sources are limited and not globally available
- Sales of carbonates must compete with sales from depreciated assets producing lower cost products

Metal Oxide Sources

- Bivalent metals, alkaline earth metals
- Waste sources include: ash, slag, concrete rubble, CKD and so limit applicability
- Natural sources include: olivines, serpentine, enstatite, talc, and wollastonite

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Active Technology Developers

Developer	Process	Metal Oxide Source	Product	CO_2 / Oxide Exchange
Solidia	Production of calcium silicate product in kiln for use in concrete curing chamber with carbonic acid	Limestone or other calcium silicates (e.g. Wollastonite)	Concrete Products (brick, etc)	Aqueous
Carbfix	Injection of carbonic acid into underground basaltic formations, recover & recycle water	Natural subsurface basaltic formations	Geologic storage (CCS)	Aqueous
Fastcarb	Concrete rubble crushed / ground and mixed with flue gas	Demolition of built concrete structures	Beneficiated sand and gravel	Gas phase
Hyperion	Alkali metals mixed in wet process with hydroxide to produce carbonate precipitate and brine	Alkalis, wastes	Fine calcium carbonates, brine	Aqueous
Fortera	Calcine limestone and then combine with CO_2 to form a more reactive calcium carbonate	Limestone	Limestone additive to concrete	Gas phase
BluePlanet	Calcium oxide chemically extracted, precipitated, and mechanically formed	Waste, natural silicates	Aggregates	Aqueous
Carbon8	Waste residues are mixed with flue gases to produce carbonates	Waste (CKD, slag, ash)	Aggregates	Gas phase
Carbon Upcycling	Waste residues are ground in pressurized CO_2 rich gases with catalysts to produce reactive carbonates	Waste (ash, slag)	Supplementary cements, aggregates	Catalyzed gas phase

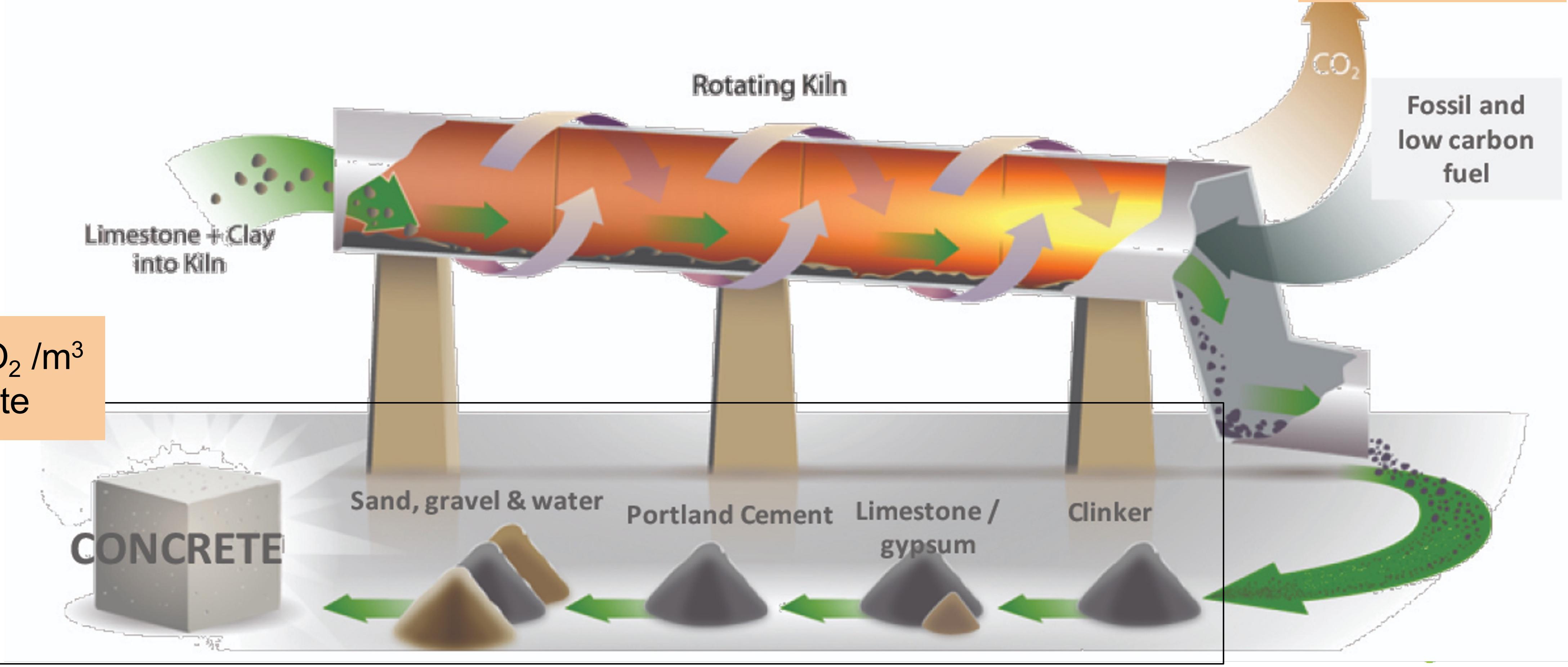
Mineralization is a good fit for the Concrete Sector

1.4 % of Canada's GHG Emissions

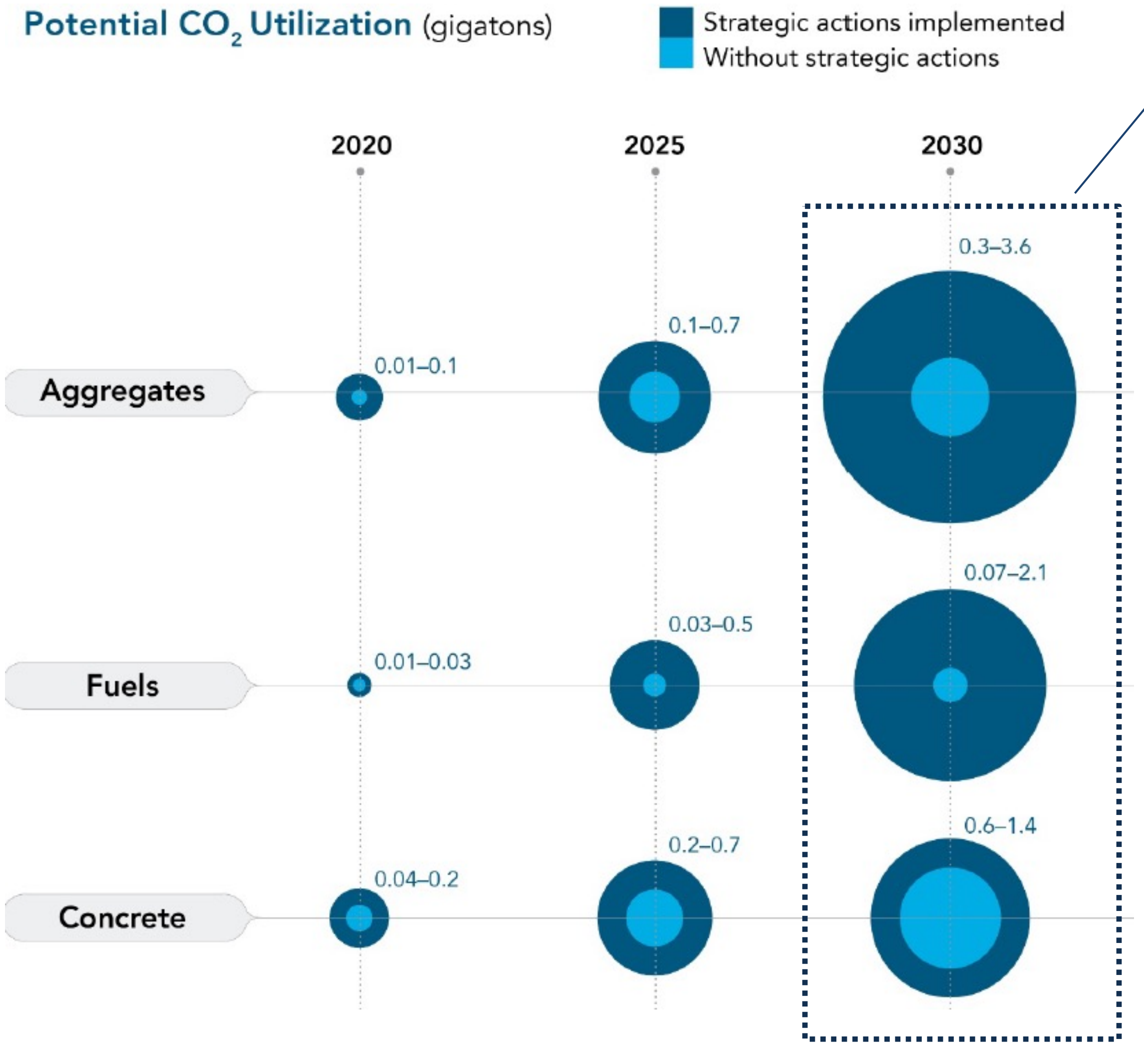
Cement is the essential ingredient in **concrete**. It is a fine powder that acts as the glue that holds concrete together when mixed with water, sand and aggregates

838 kg CO_2/t clinker produced

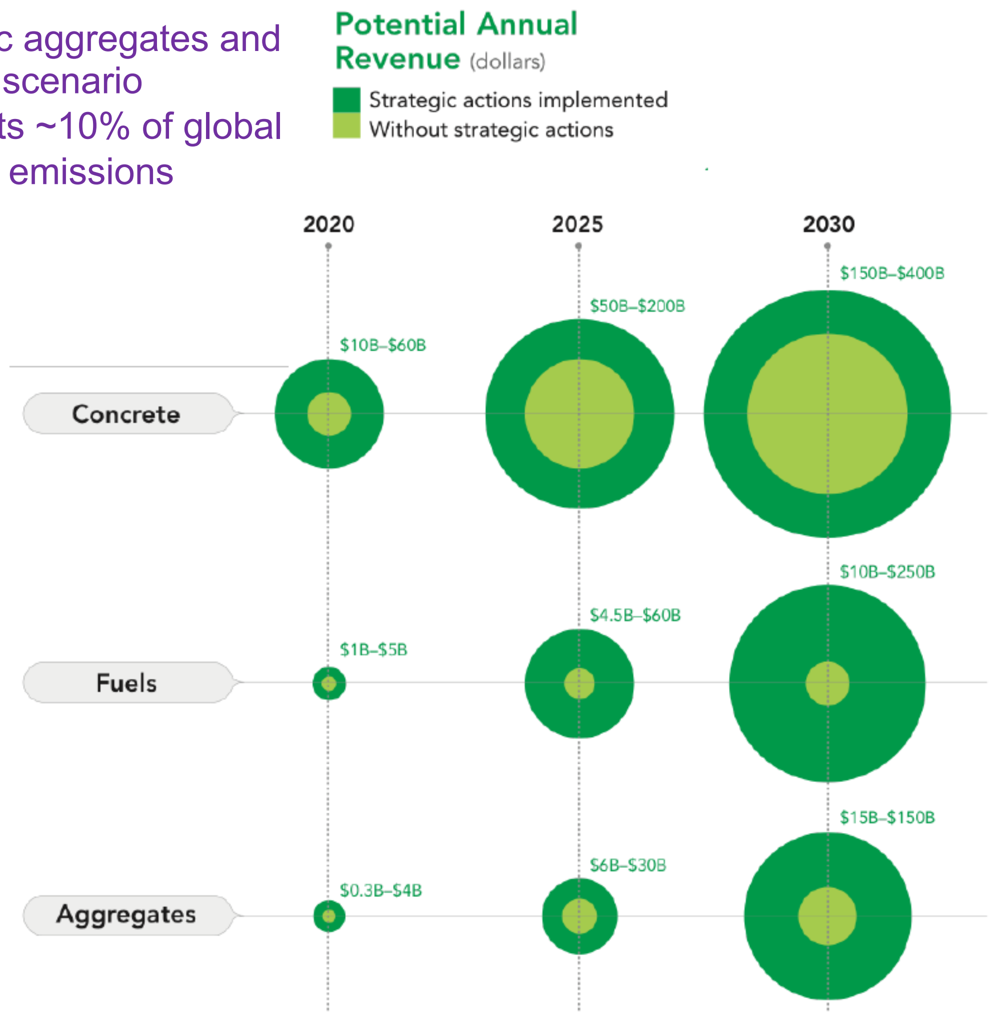
246 kg CO_2 /m^3 concrete



Mineralization Potential – Global CO2 Initiative at the University of Michigan



Optimistic aggregates and concrete scenario represents ~10% of global industrial emissions



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Resources

- **IPCC, Carbon Dioxide Capture and Storage (SRCCS)**
  - Chapter 7, Mineral Carbonation and Industrial Uses of CO_2
  - Available at https://archive.ipcc.ch/report/srccs/
- **Global CO2 Initiative at the University of Michigan, Global Roadmap for Implementing CO_2 Utilization, November 2016**
- **Carbon mineralization pathways for carbon capture, storage, and utilization, Greeshma Gadikota, Communications Chemistry**
- **Towards a business case for CO_2 mineralization in the cement industry, Till Strunge et al, Communications Chemistry**