



LENFEST CENTER FOR
SUSTAINABLE ENERGY



COLUMBIA
UNIVERSITY

Towards Sustainable Energy: Tailored Synthesis of Carbon-Neutral Filler Materials during Carbon Mineral Sequestration

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Earth and Environmental Engineering & Chemical Engineering

Lenfest Center for Sustainable Energy

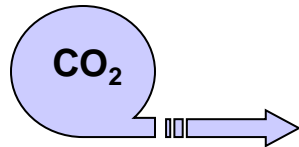
Columbia University

CO₂ Summit, Vail, Colorado

May 20th, 2010

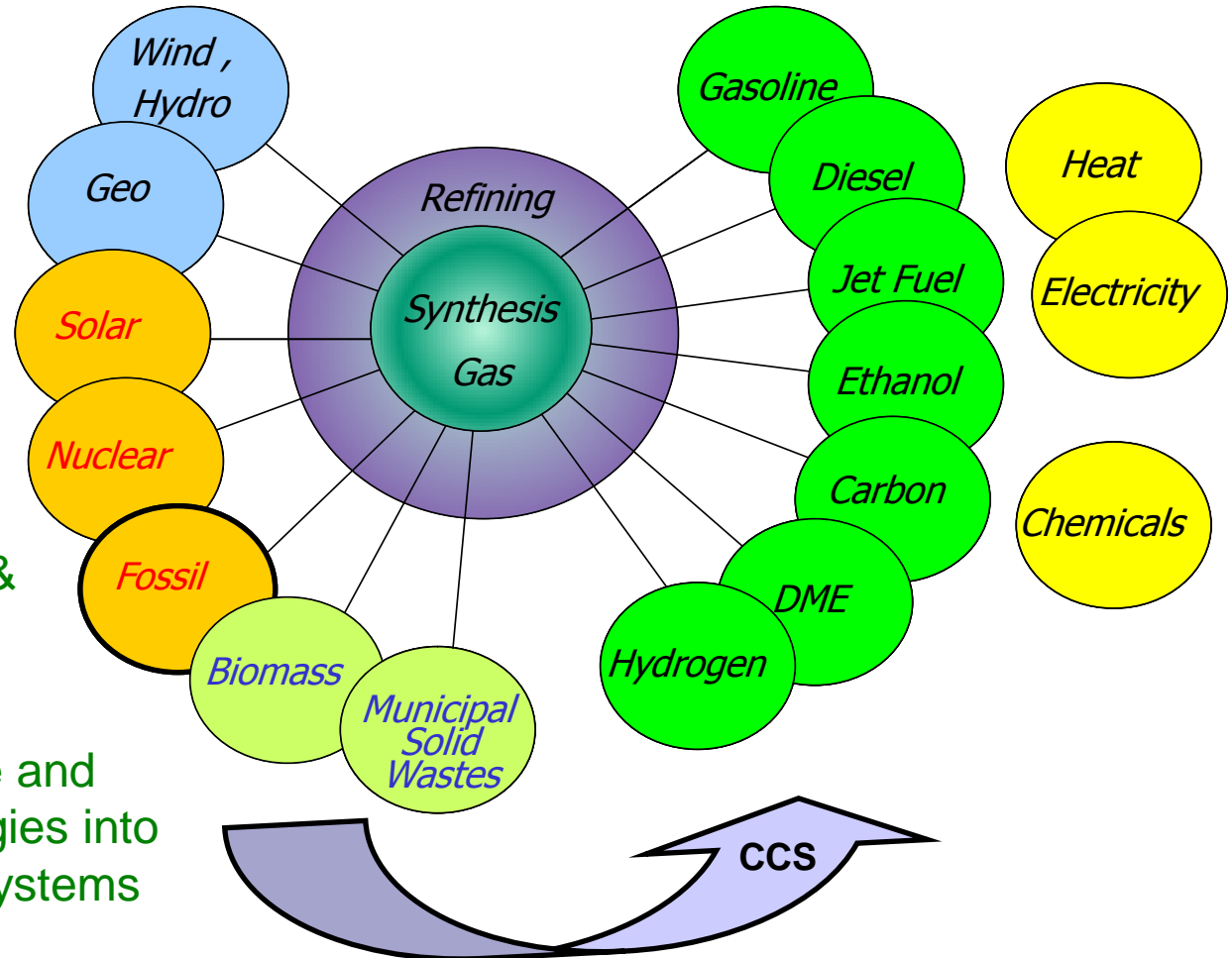
Our Research Goals

Use domestic energy sources to achieve energy independence with environmental sustainability

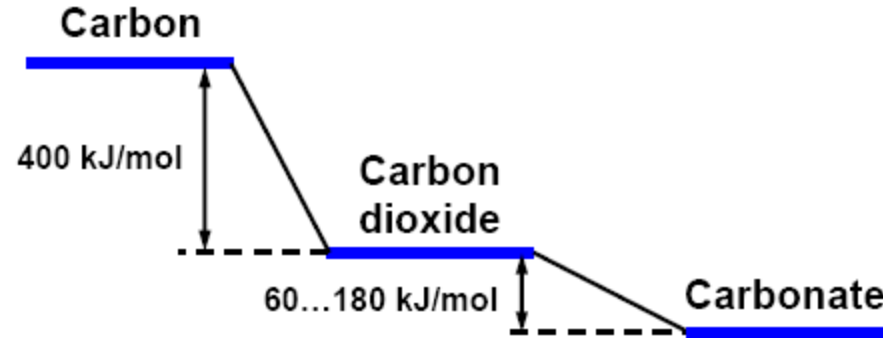


Use carbon neutral energy sources such as biomass & MSW

Integrate carbon capture and storage (CCS) technologies into the energy conversion systems



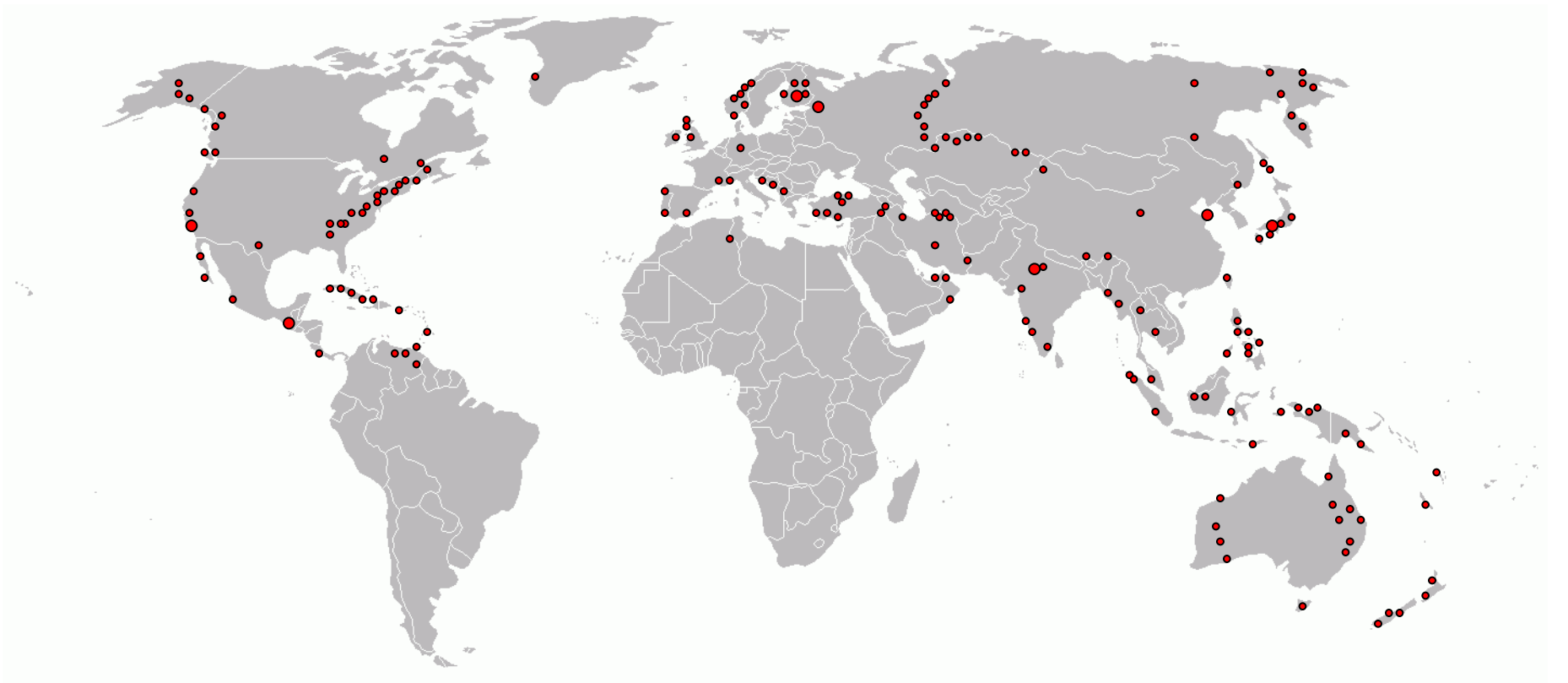
Mineral Sequestration of CO₂



- Mimics natural chemical transformation of CO₂

$$\text{MgO} + \text{CO}_2 \rightarrow \text{MgCO}_3$$
- Thermodynamically stable product
- Exothermic transformation
- Appropriate for long-term environmentally benign and unmonitored storage

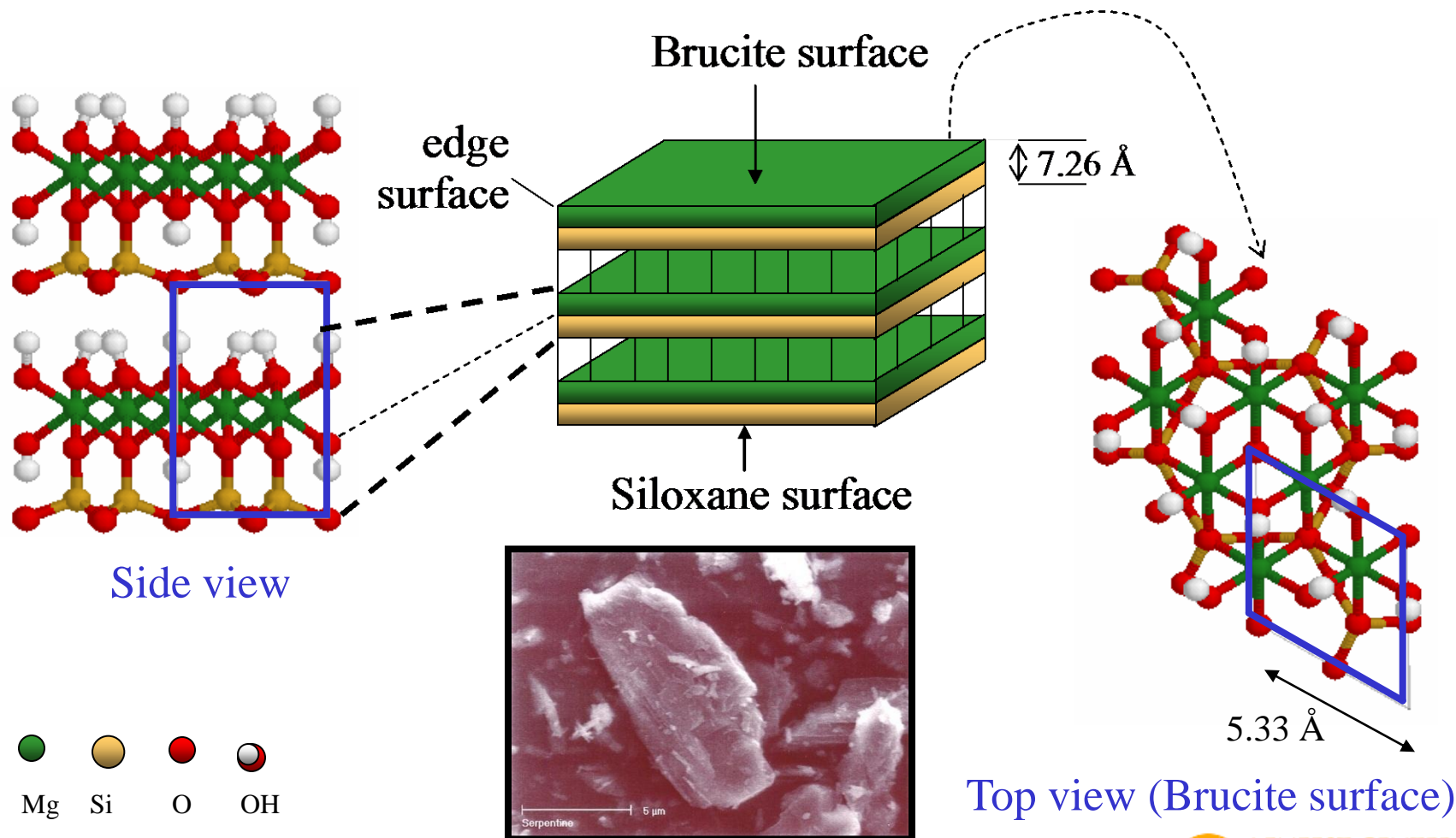
Availability of Minerals (Serpentine)



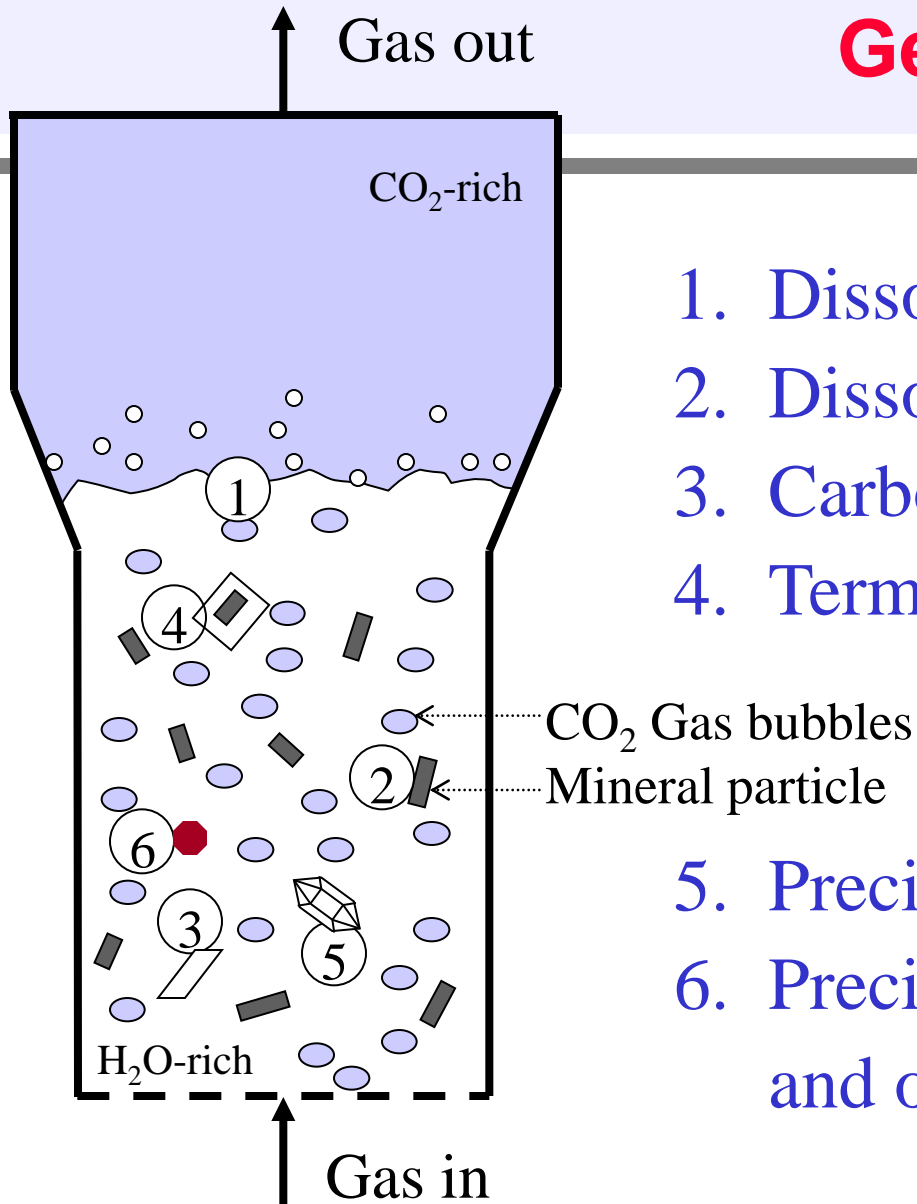
Worldwide distribution of magnesium-rich ultramafic rocks

(Adapted from Ziock et al., 2001)

Structure of Serpentine



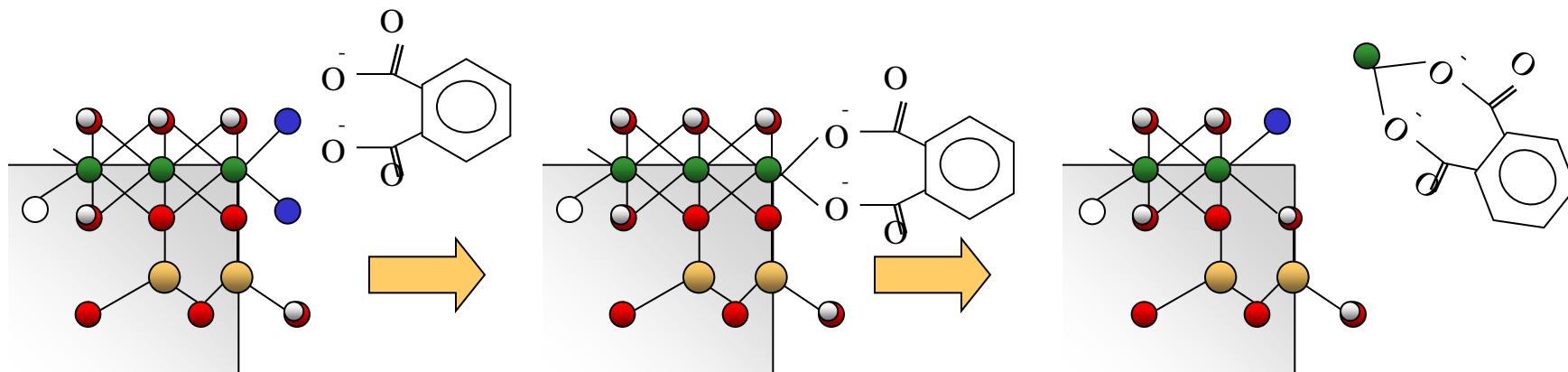
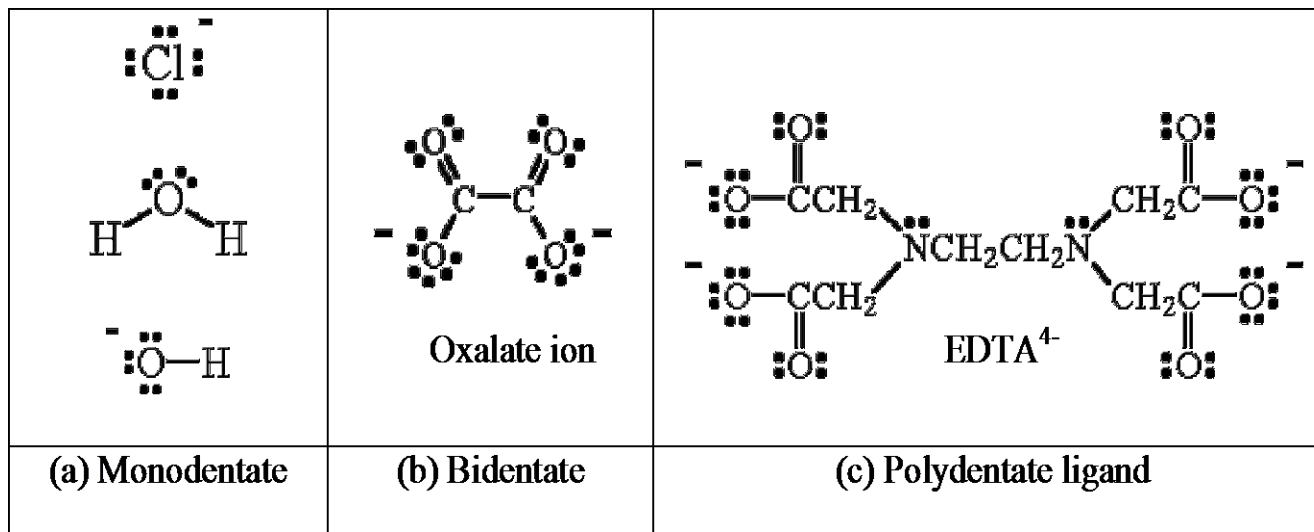
Geochemical Model



1. Dissolution of CO₂
2. Dissolution of mineral*
3. Carbonation/Precipitation
4. Termination of reaction
5. Precipitation of silica phases
6. Precipitation of phases of iron and other minor/trace elements

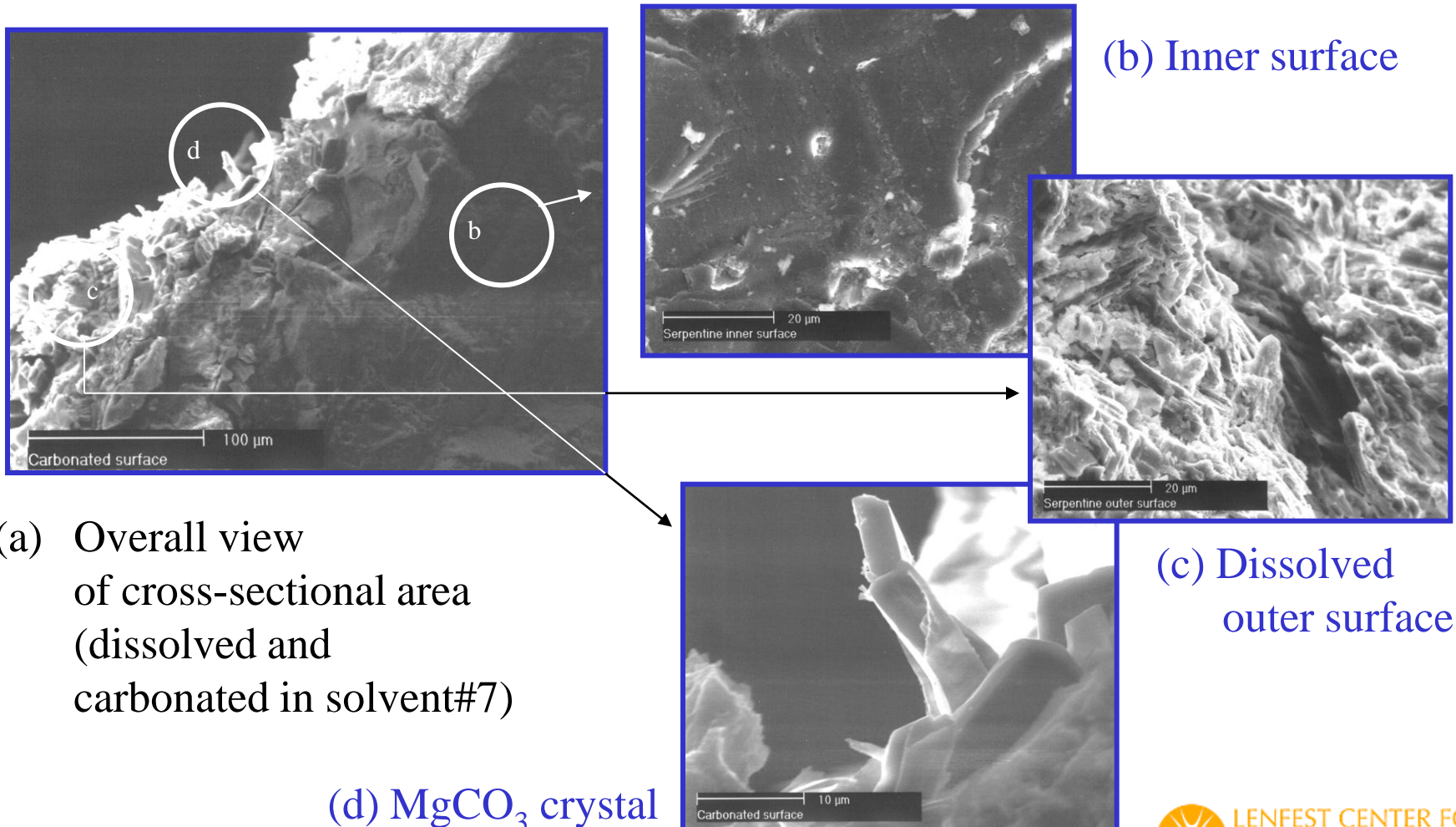
Chemically Enhanced Dissolution of Serpentine

Various Chelating Agents

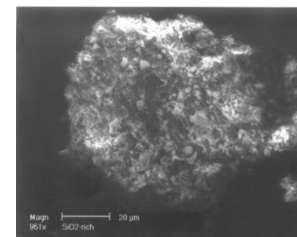
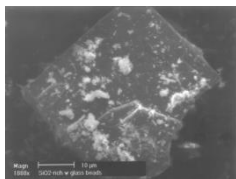
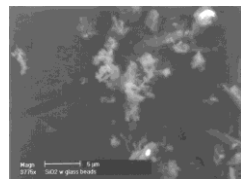
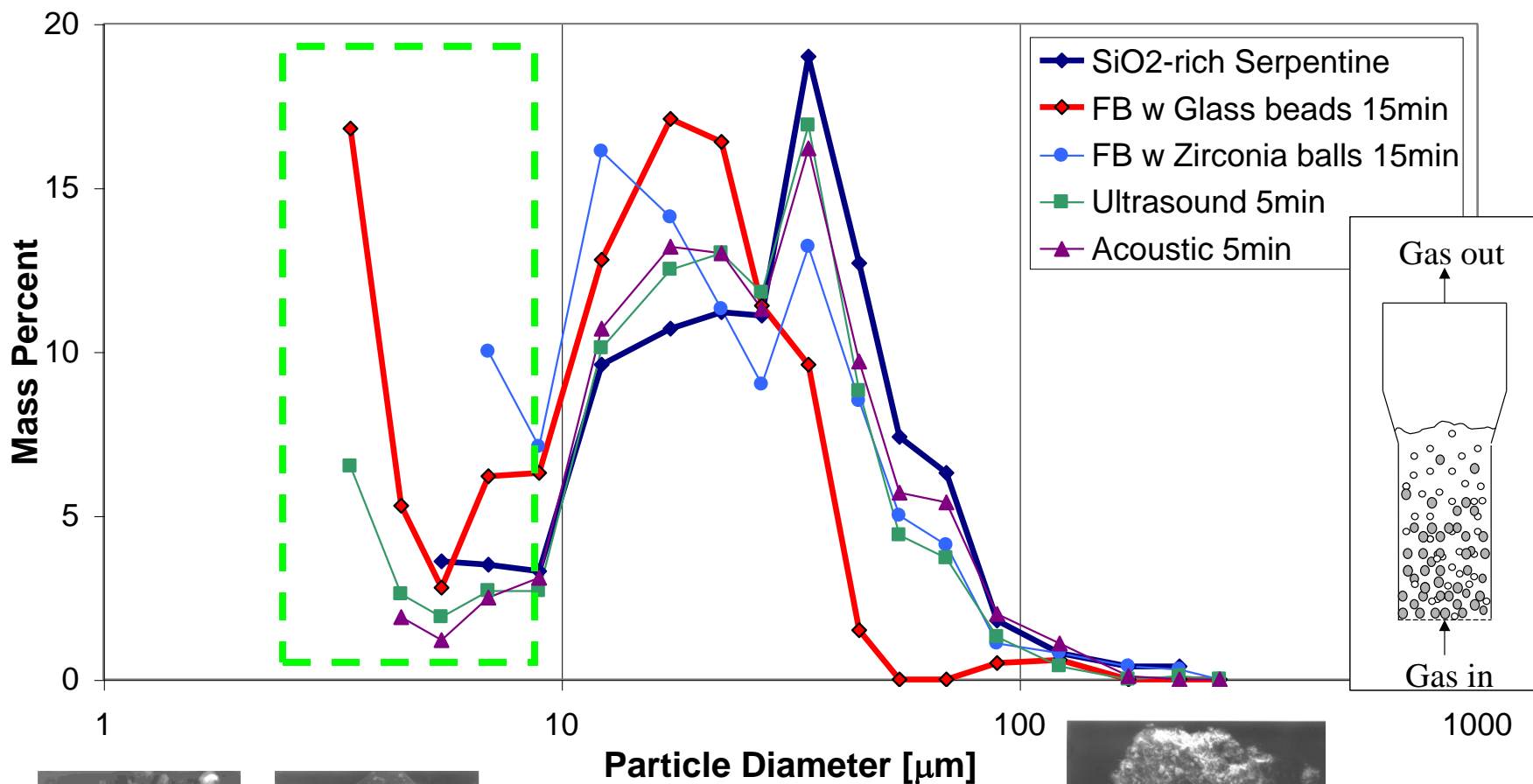


Potassium acid phthalate KH_2PO_4

SEM of cross-sectional view of *serpentine* aggregate



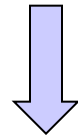
Removal of SiO₂ layer



pH swing

(Park and Fan, Patent publication # 20050180910)

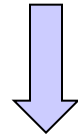
Grind Serpentine



Serpentine + Acid + chelating agent

at higher T

pH 2



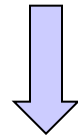
SiO₂



Mg- and Fe-rich solution

at room T

pH 8.6



Precipitated iron oxide

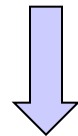


High P
CO₂ (SO₂)

Mg-rich solution

at room T

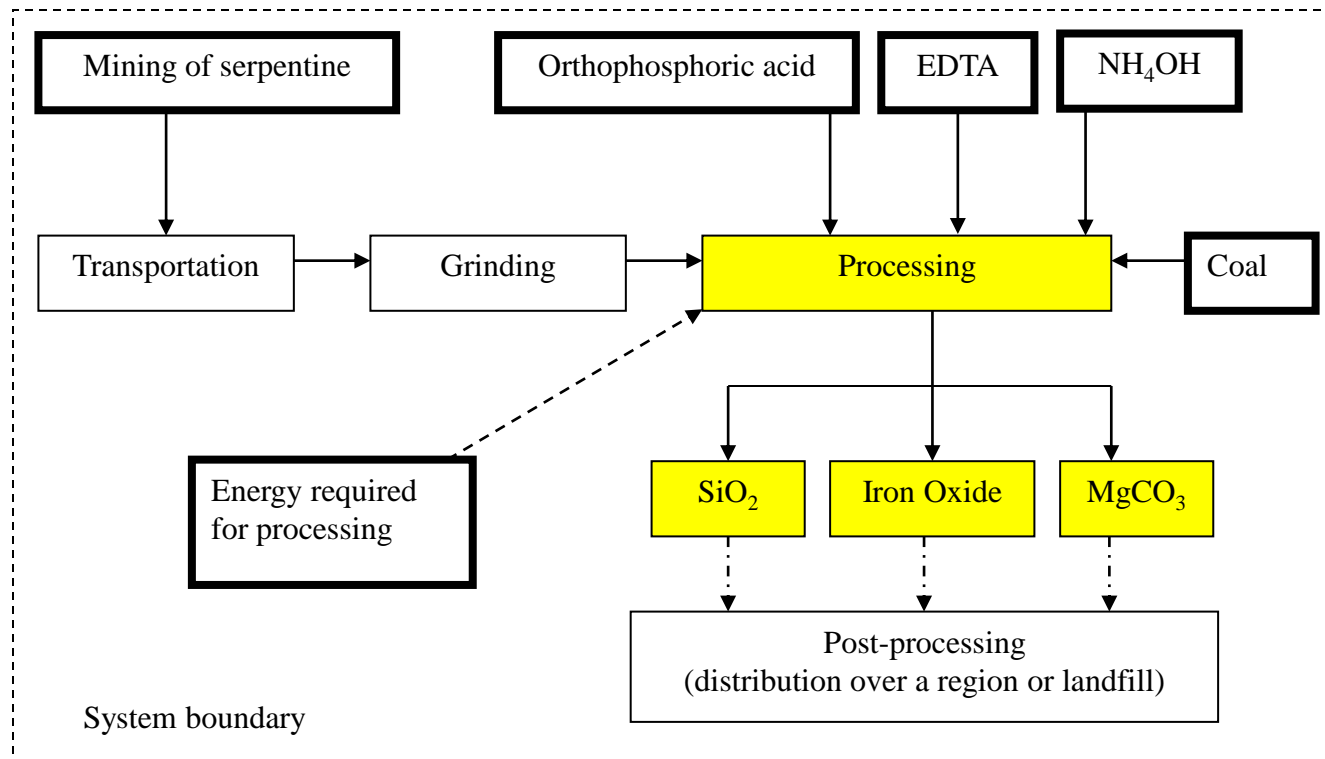
pH 9.5



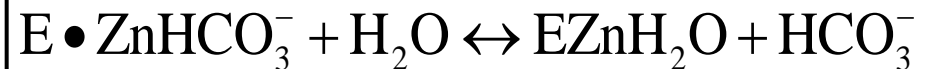
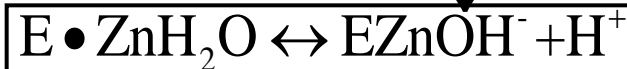
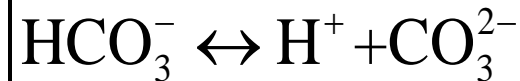
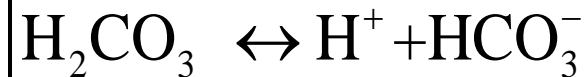
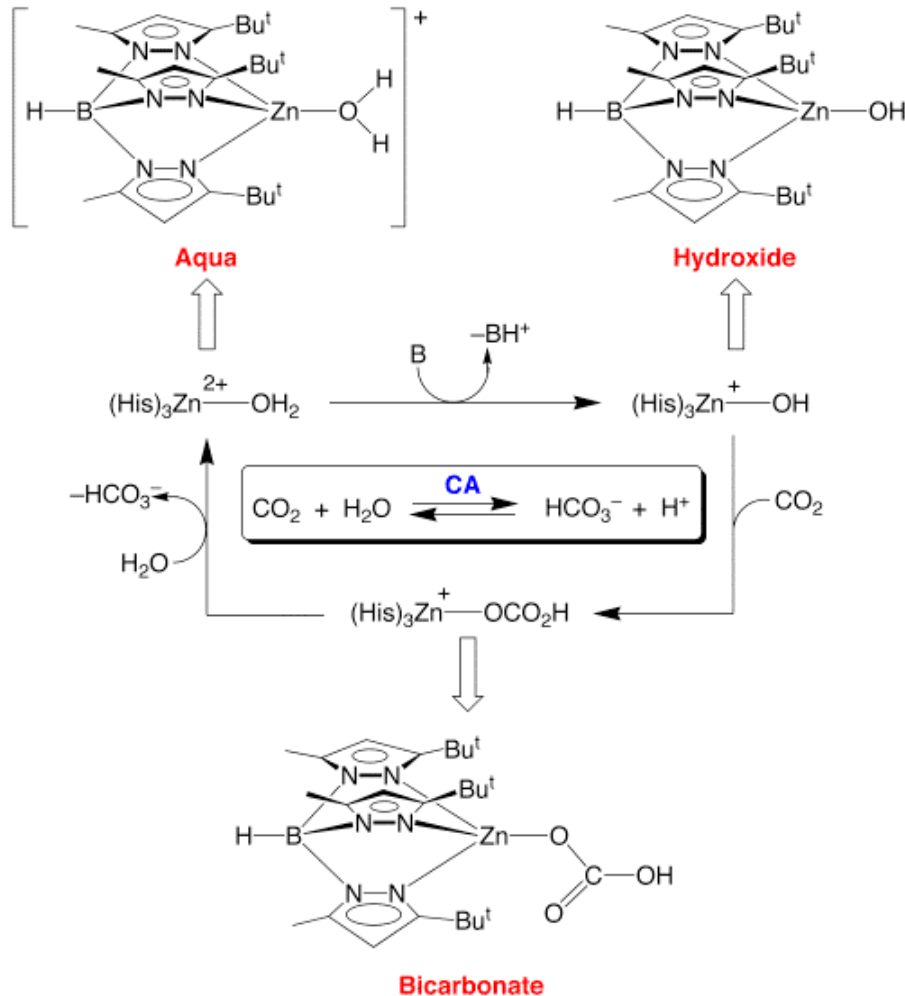
Precipitated MgCO₃



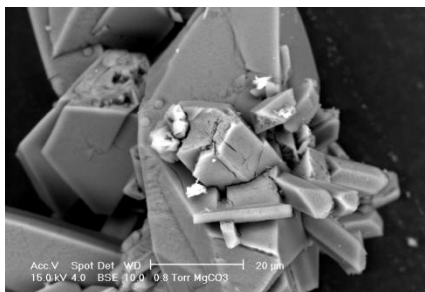
Life Cycle Assessment



Carbonic Anhydrase

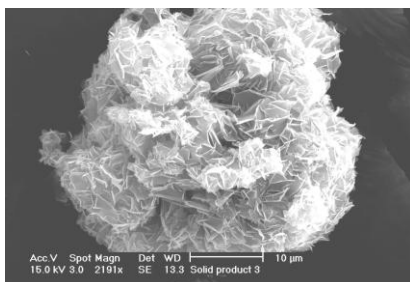


Controlled Precipitation of $MgCO_3$



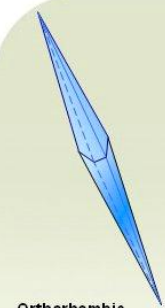
PMC w/o chelating agents

Vs.



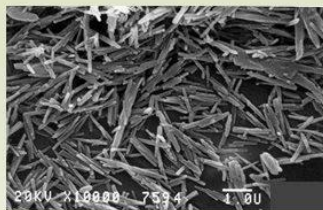
PMC w/ chelating agents

Examples of Precipitated Calcium Carbonate (PCC) Morphologies

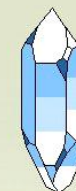


Orthorhombic
Aragonite PCC

OPACARB® PCC

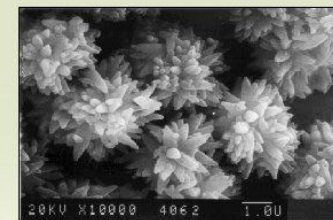


Median Particle Size: 0.4-2.0 µm
Surface Area: 6-12 m²/g



Scalenohedral
Calcite PCC

ALBACAR® PCC

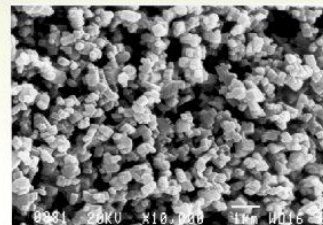


Median Particle Size: 0.9-2.2 µm
Surface Area: 6-25 m²/g



Rhombohedral
Calcite PCC

ULTRAPAQUE™ PCC

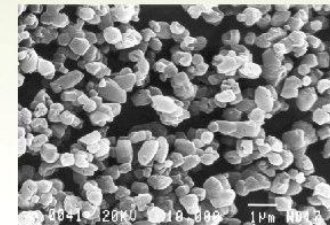


Median Particle Size: 0.3 µm
Surface Area: 7.5 m²/g



Prismatic
Calcite PCC

ALBAFIL® PCC



Median Particle Size: 0.6-2.2 µm
Surface Area: 4-12 m²/g

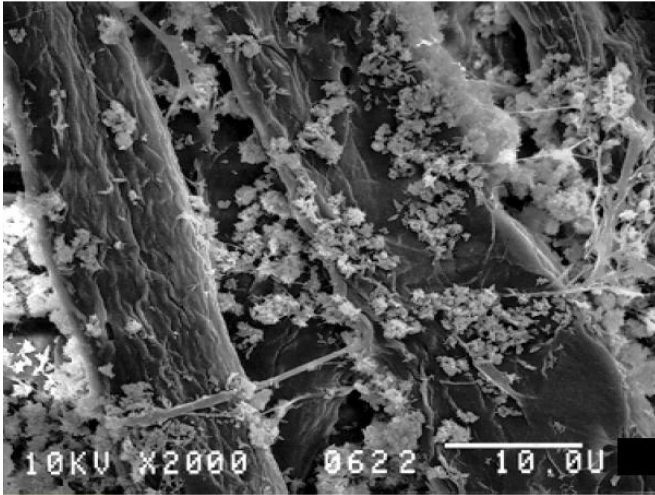


making paper making better



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Controlled Precipitation of $MgCO_3$

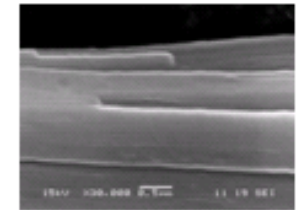
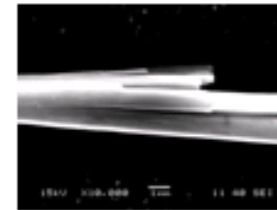
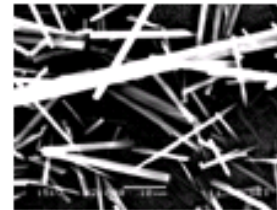


Desired particle characteristics:

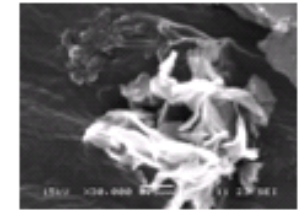
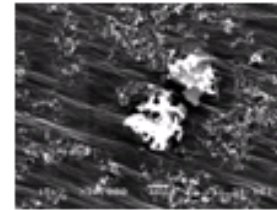
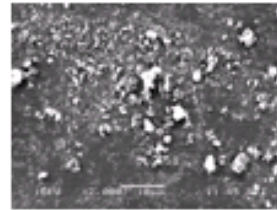
- ~2 μm , narrow PSD
- High Reflectivity
- Uniform Spherical/rosette shape

Effect of Temperature

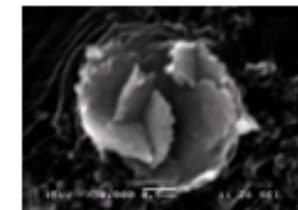
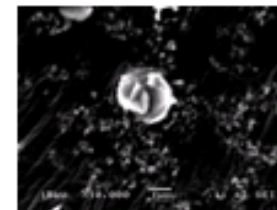
42 °C



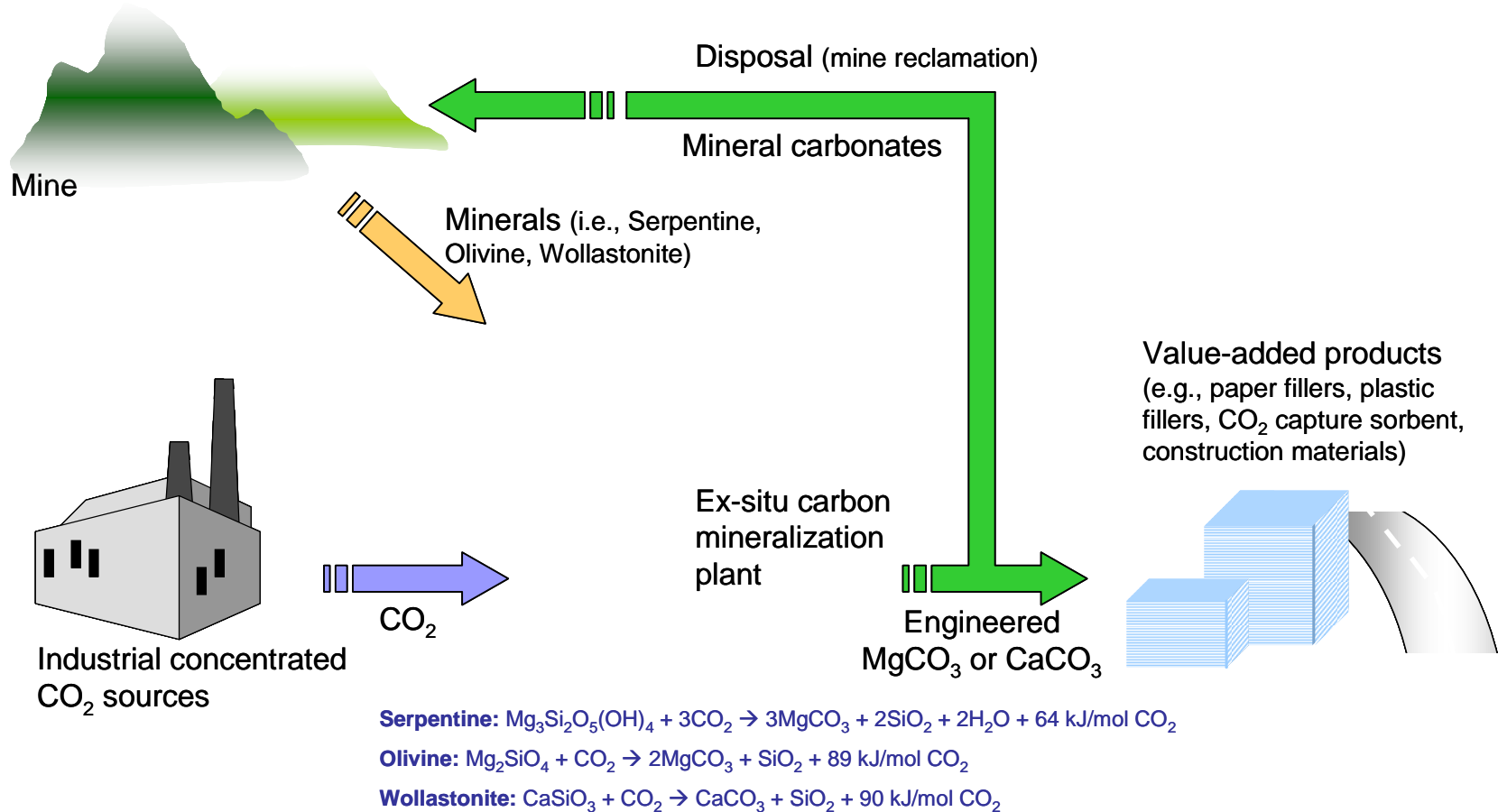
67 °C



92 °C



Ex-Situ Carbon Mineral Sequestration



Carbon Capture

Carbon Mineralization

Re-use / Disposal