Direct Air Capture (DAC) and Carbon Sequestration in Building Materials

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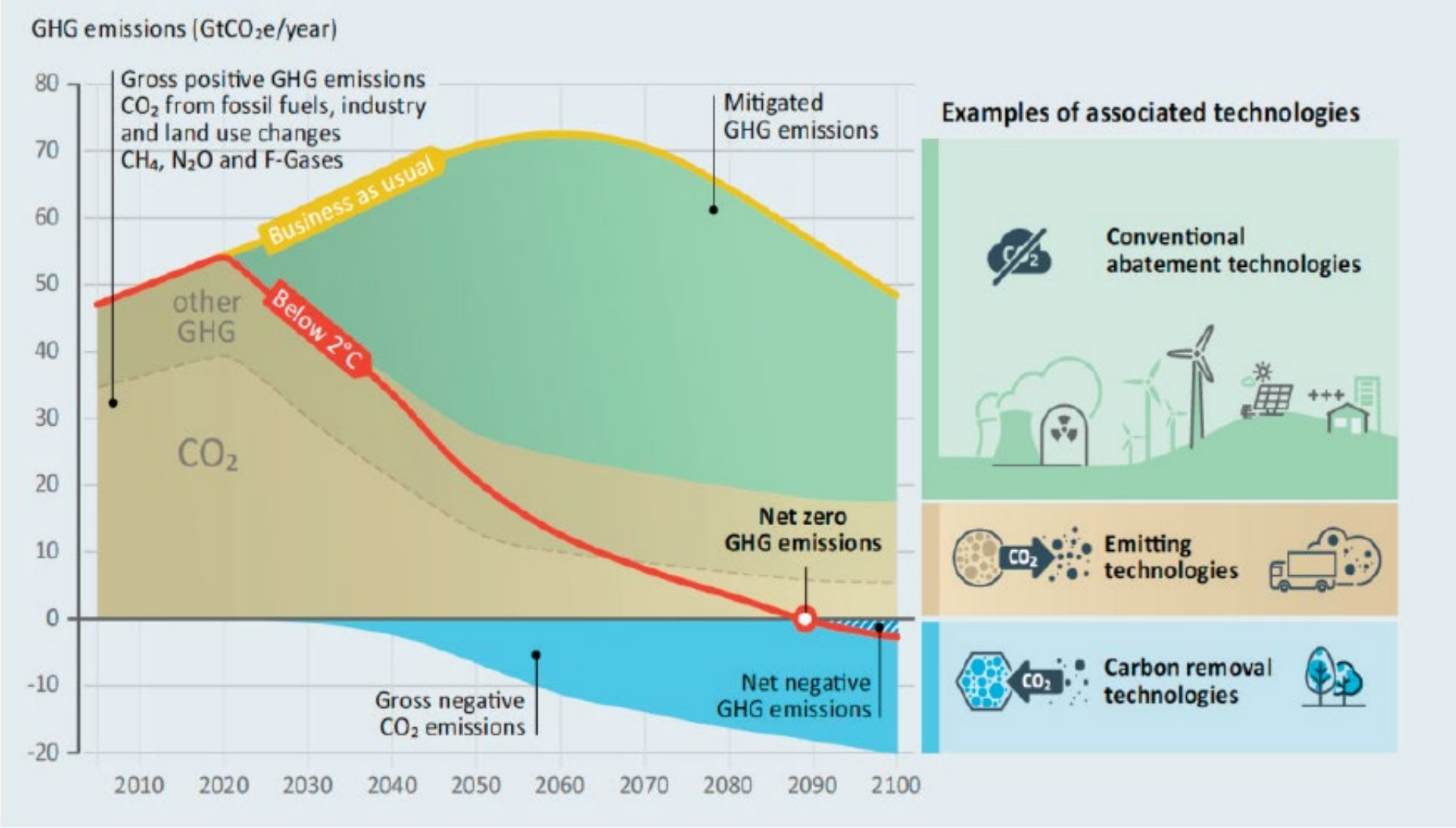
National Institute of Standards and Technology
U.S. Department of Commerce

Global Climate Goals



Paris Agreement goal: Limit global temperature rise to < 2 °C

Difficult to decarbonize all sectors of the economy

Need net negative emissions technologies to meet climate goals

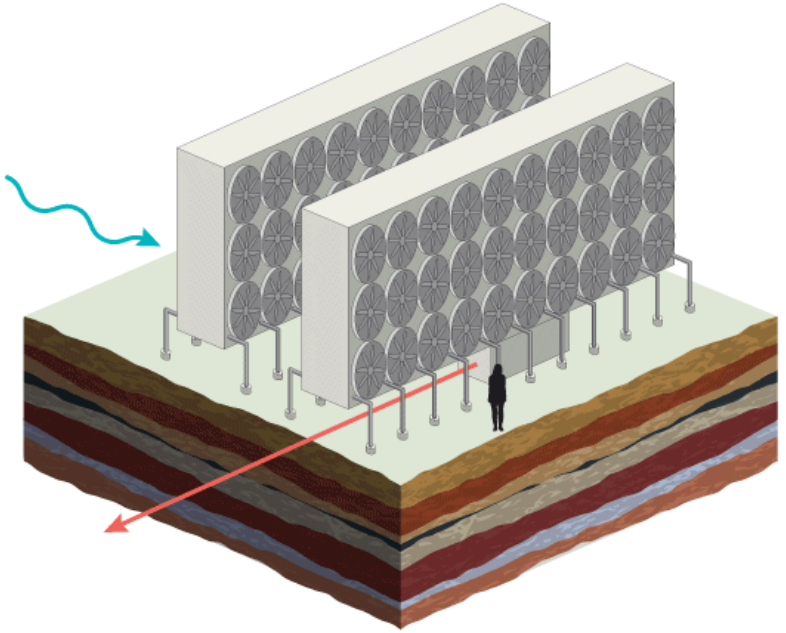
IPCC Special Report 2019; NASEM Negative Emissions Technologies… 2019; Energy Frontiers Initiative 2019

Why Direct Air Capture?

Negative Emission Technologies

Remove CO_2 from ambient air – permanently store CO_2

- 10's Gt/y globally
- Acceptable costs < \$100/t CO_2
- Achieve in climate relevant timeframe 2030-2050



Schematic-direct air capture
Washington Post, Feb 2016

Schematic-carbon sequestration
in geologic formation
Washington Post, Feb 2016

Direct Air Capture

- Chemical processes to remove CO_2
- High potential capture capacity and scalable

Direct Air Capture – Today

Climeworks & Carbfix – Iceland
4000 tons CO_2/year; Operational Sept 2021
Solid sorbent

Carbon Engineering – Canada & Texas
~400 tons CO_2/year
Liquid sorbent
DAC and **Air-to-Fuel**

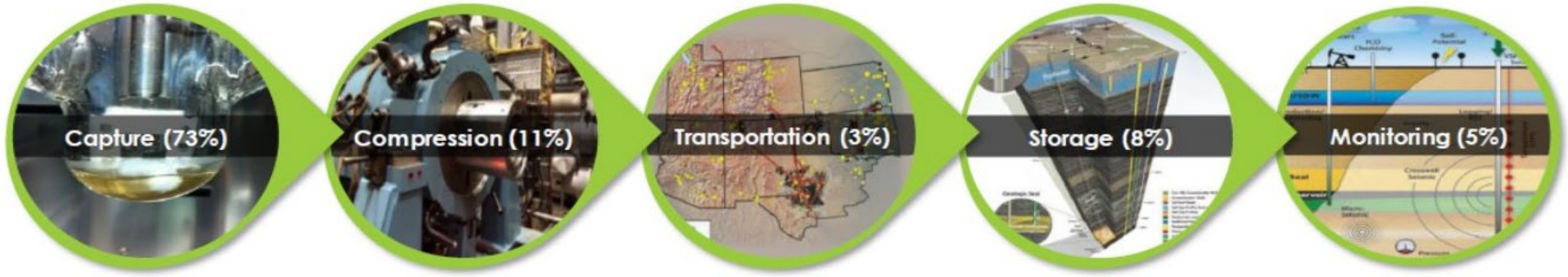
Klaus Lackner ASU & Silicon Kingdom Holdings Mechanical Tree Farm – Arizona
Passive collection – Moisture swing
Prototype Dec 2021

Why NIST?

Direct Air Capture Challenges

- Capture 400 ppm CO_2 from ambient air, energy intensive
- Understand fundamental physics & chemistry driving the processes
- New & multiple technologies, new materials, high costs
- Rapid scale-up - 4000 t now to 10 Gt CO_2/y by 2050

*NIST role - Develop benchmark materials, measurements, data, models, standards to **accelerate** innovation, validate performance, & enable commercialization*



NETL, Cost and Performance Baseline for Fossil Energy Plants, Revision 3, July 2015

Outreach and stakeholder engagement

Industry, academia, and Federal agencies

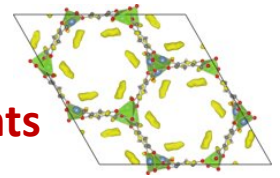
- Mini-workshops
- Seminars and NIST colloquia
- SME discussions
- Interagency working groups

Recommendations from stakeholders

Confirmed need for validation of:

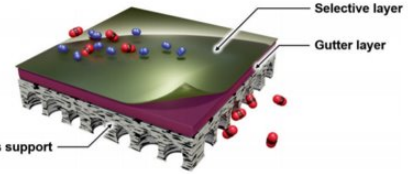
- New materials & technologies
- Scalable solutions
- Global carbon accounting

Solid Sorbents



CO_2 adsorption Mg-MOF74

Membranes



Mineralization

Carbonate content measurement

Expansion of sorbent characterization

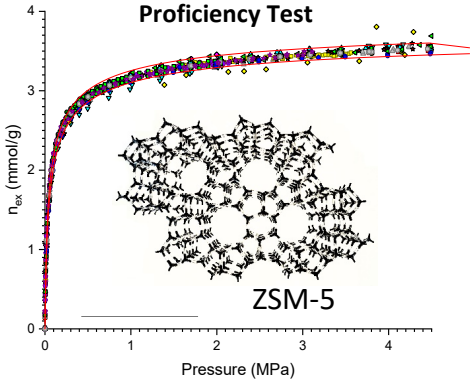
Facility for Adsorbent Characterization and Testing (FACT Lab)

- Quality-assured reference isotherms
- Interlaboratory studies

Binary gas adsorption measurements

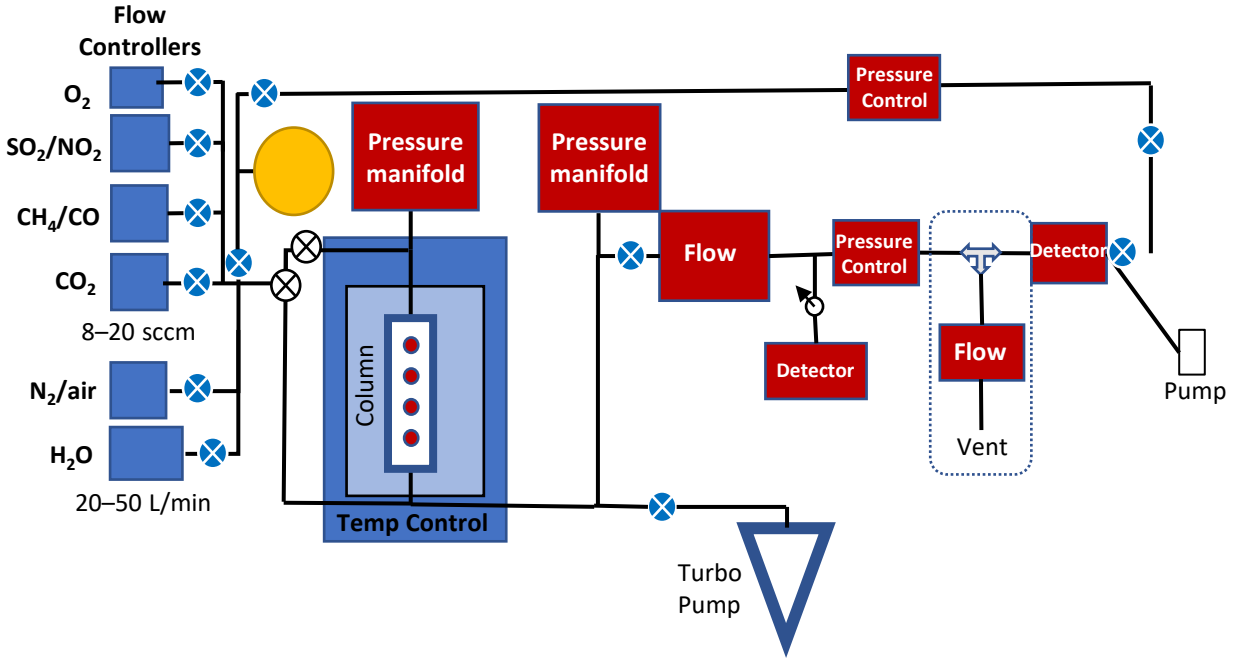
NIST Reference Material
8852
ZSM-5 zeolite

CO_2 ZMS-5 isotherm
Proficiency Test

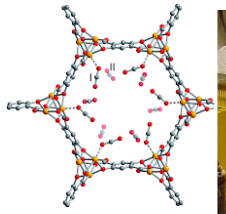


Developing customized capabilities

- Breakthrough measurements under real-world DAC conditions



Leveraging NIST expertise

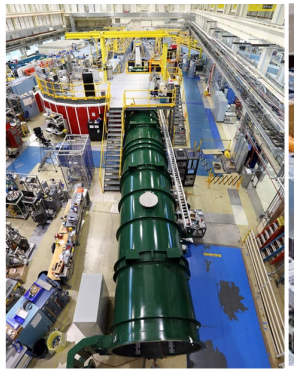


Locating CO_2 in MOFs

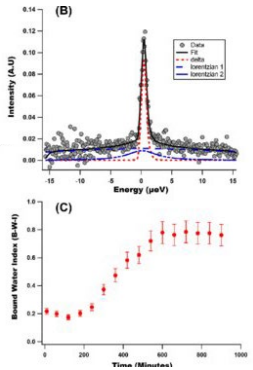
Structure

<0.1 nm

1 – 2000 nm

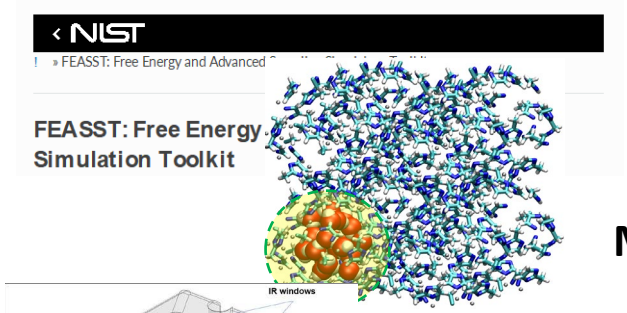


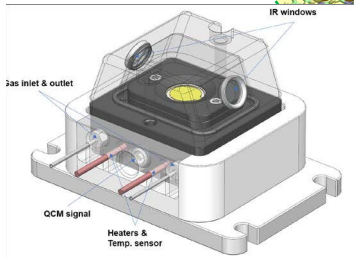
Nanosecond dynamics



Water dynamics when curing cements

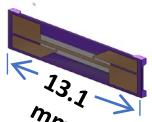
NCNR

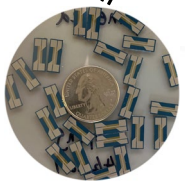




Phase-modulated IR with mass

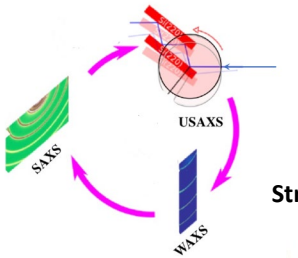
Nanocalorimetry



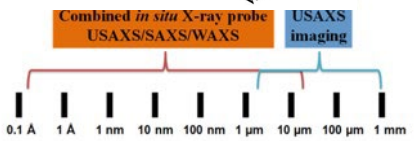


MML

Candidate Reference Materials

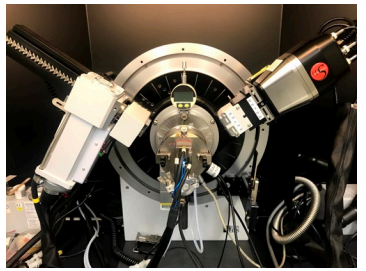


Structure/microstructure characterization



EL

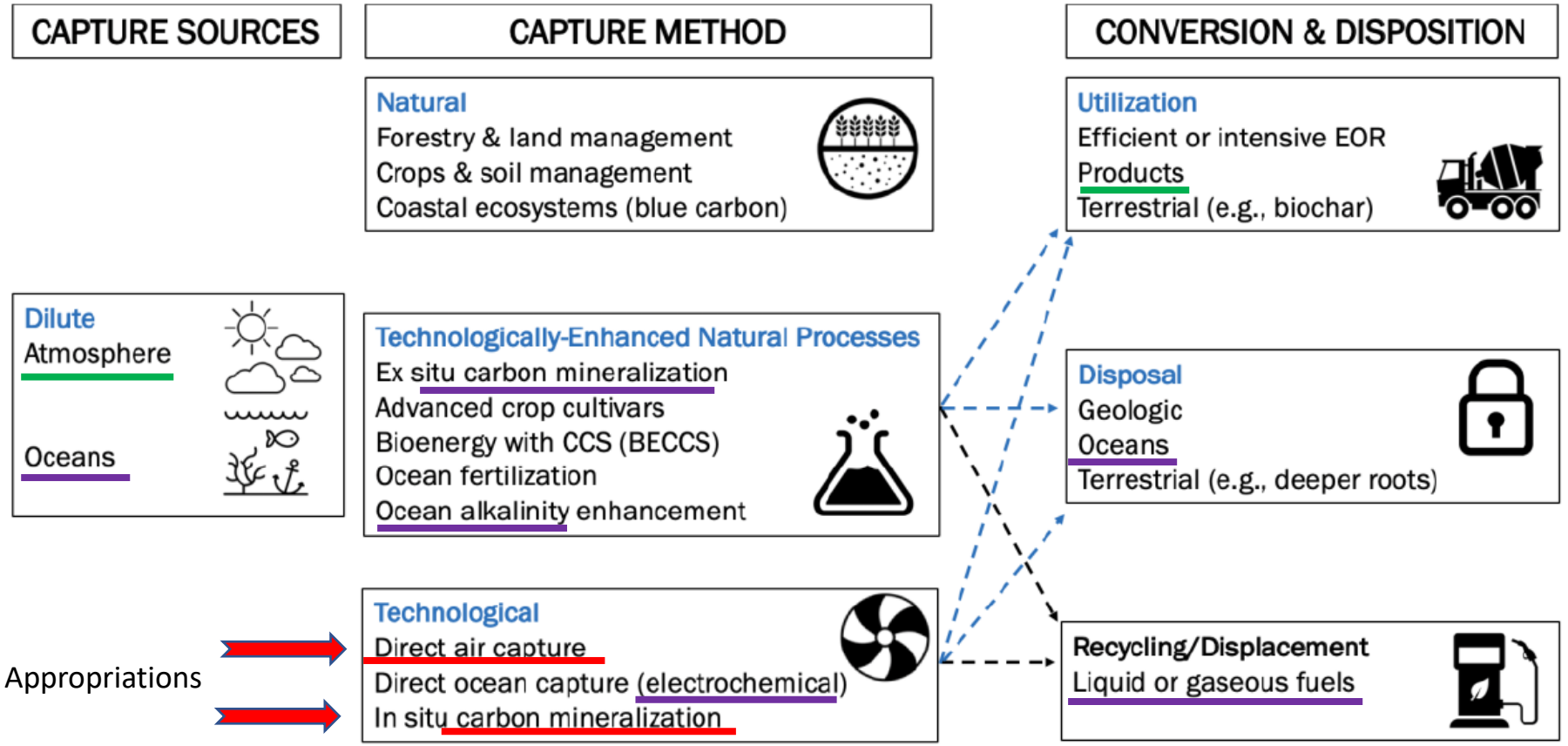
Crystal Structure



Strength, creep & fracture

Elemental Mapping

Carbon Capture, Use, and Storage



FY21 NIST Appropriations

Energy Futures Initiative, 2019