The climate challenge is a CO_2 challenge.

Deploying Versatile Carbon Capture Technologies and Storage at Scale

We present a vision for an MIT-wide Climate Grand Challenge flagship program dedicated to catalyzing rapid innovation and deployment strategies for CO_2 capture and sequestration (CCS). This effort addresses all manner of CO_2 emissions—positive and negative, and those from both point- and dispersed sources. Our research will address all stages of the TRL pipeline, from new concepts at early TRL stages to those technologically more mature. Our work also determines how multiple Gt/year of storage can be deployed in a safe, globally accessible, and socially acceptable way.

The climate challenge **is** a CO_2 challenge. We recognize that many other technological solutions will be needed. However, climate targets cannot be met without directly managing CO_2. It is no longer sufficient to capture today's CO_2 emissions—there is growing consensus that we will need to remove past CO_2 emissions from our air and oceans. CCS provides the only fail-safe mechanism to directly tackle all manner of emissions and must be a vital aspect of any credible plan to address climate change.

OBJECTIVES

Our core objective is to create an all-of-MIT, all-hands-on-deck research ecosystem dedicated to finding solutions for the capture, removal, and permanent storage of CO_2. We aim to accelerate the research of new ideas and measurably advance those already in development toward deployment for 2030, 2040, 2050, and beyond.

This effort aims to vigorously strengthen and advance the science, engineering, and technology basis for CCS. This proposal's core objectives are to make CO_2 capture:

- Less energy-intensive
- More energy-efficient
- More readily deployable
- Sufficiently versatile to accommodate emerging industrial demands for CCS
- Adaptive and responsive to varied societal needs
- Contributory and supportive toward different developmental trajectories across the globe

WHY IT MATTERS

Even with massive global efforts, we are likely to overshoot targets of containing warming to within 2°C. CCS is mature and can be deployed on a sub-decadal, rather than multi-decadal timeframe. Total reliance on other strategies is too risky; they may fail and many certainly will. CCS provides an insurance policy so that we are equipped to deal with climate change in all scenarios, especially failure of idealized ones. Additionally, net removal technologies present the only option to atone for past emissions and reverse warming in the likely scenario that temperatures overshoot. The IEA Sustainable Development Scenario (SDS) makes clear that CCS must do its part: capture and storage of 5-6 $GtCO_2$ are needed per year by 2050, and >10 $GtCO_2$ per year by 2070.

Today's carbon capture systems face many challenges. Deployment at scale requires that those challenges be mitigated for CCS technologies that are nearly mature. We also need to identify, design, and develop future systems that reconceive the basic operating principles of carbon capture and have potential to avoid many of these issues entirely.

WHY WE ARE UNIQUE

We have opted to focus our program on carbon capture and permanent storage at scale. Many of our peer institutions are already tackling other aspects of CO_2 including its utilization as feedstock for value-added chemicals and fuels. Our focus is instead on technologies that can serve as improvements or alternatives to today's amine chemisorption/thermal regeneration framework. Advanced concepts include:

1. Use of electrochemistry to modulate the capture environment for sorption/desorption of CO_2
2. Advanced materials for liquid and solid sorbents
3. New form factors and designs of carbon capture systems that are modular, versatile, and can even address emissions from mobile sources.

MIT has a strong track record in conceptualization and demonstration of advanced carbon capture technologies and this program will aim to strengthen and broaden this foundation.

OUR APPROACH

Our multi-PI, cross-MIT effort is structured around the following core research themes:

- Advanced Liquid/Solid Sorbents
- Design of Electrochemically Modulated Processes

- Membrane-Based Separations Processes
- Future CO_2 Capture System Designs for Versatility, Modularity, and Portability
- Negative Emissions Technologies (NETs) for Carbon Dioxide Removal (CDR)
- Technology Acceleration
- Geologic Storage at Scale
- Accelerating Mineralization
- Broader Societal, Policy, and Economic Impacts

By housing these efforts under one roof (metaphorically and physically), we will remove inefficiencies and hurdles common to a siloed research approach, accelerate learning, and catalyze new ideas at the intersection of disciplines.

TEAM COMPOSITION

This cross-Institute effort draws on team members' disciplinary and interdisciplinary expertise spanning MIT. Our team members bring expertise in chemistry, chemical engineering, electrochemistry, geology, geophysics, geomechanics, geochemistry, biology, bioengineering, materials science, mechanical engineering, physics, energy systems, policy, and economics. Research approaches span experimentation, engineering design at a device-to-system scale, modeling and simulation, policy, economics, and societal impacts of CCS.