

Carbon Capture's Role in Deep Decarbonization

MIT Climate Action Symposium

Howard Herzog
February 25, 2020

Carbon Dioxide Capture and Storage (CCS)

- CCS can eliminate or offset difficult-to-eliminate emissions by:
 - CCS at industrial plants
 - Production of “blue” hydrogen (steam methane reforming (SMR) with CCS)
 - Creating offsets through
 - » Direct Air Capture (DAC)
 - » Bioenergy with CCS (BECCS)

Industry

- Seven largest industries, including cement, iron & steel, and chemicals, account for ~20% of global CO₂ emissions
 - Predicted growth of 35% by 2050
- Significant percentage of CO₂ emissions from process, not energy
 - $\text{CaCO}_3 \rightarrow \text{CaO} + \text{CO}_2$
 - $\text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2$
- Limited options beyond CCS
 - Carbon-free fuels (e.g., hydrogen) and/or electrification
 - Alternative processes

Hydrogen

- Least cost pathway for hydrogen production today is Steam Methane Reforming (SMR) of natural gas
 - Cost very sensitive to natural gas price
 - In US today, electrolytic hydrogen costs ~4 times as much to produce as SMR hydrogen
- Least cost pathway to low-carbon hydrogen is SMR with CCS (“blue hydrogen”)
 - Demonstrated at the million ton CO₂ per year level at Air Products (Port Arthur, TX) and Shell Quest (Alberta, Canada)

Air Products SMR w/CCS



*Source: Air Products and Chemicals, Inc., <http://prphotorlibrary.airproducts.com/>
Howard Herzog / MIT Energy Initiative*

Direct Air Capture (DAC)

- DAC is a very seductive concept
- The question is not whether we can do it, but what is the cost
- I have been analyzing DAC for about 10 years and based on my analysis, I do not believe the lower cost numbers being floated today for DAC.
- My beliefs are detailed here:
 - House *et al.*, “Economic and Energetic Analysis of Capturing CO₂ from Ambient Air,” *Proceedings of the National Academy of Sciences* 108, no.51 (December 2011). <http://sequestration.mit.edu/pdf/1012253108full.pdf>

Absorber Size

Coal-Fired Flue Gas vs. DAC



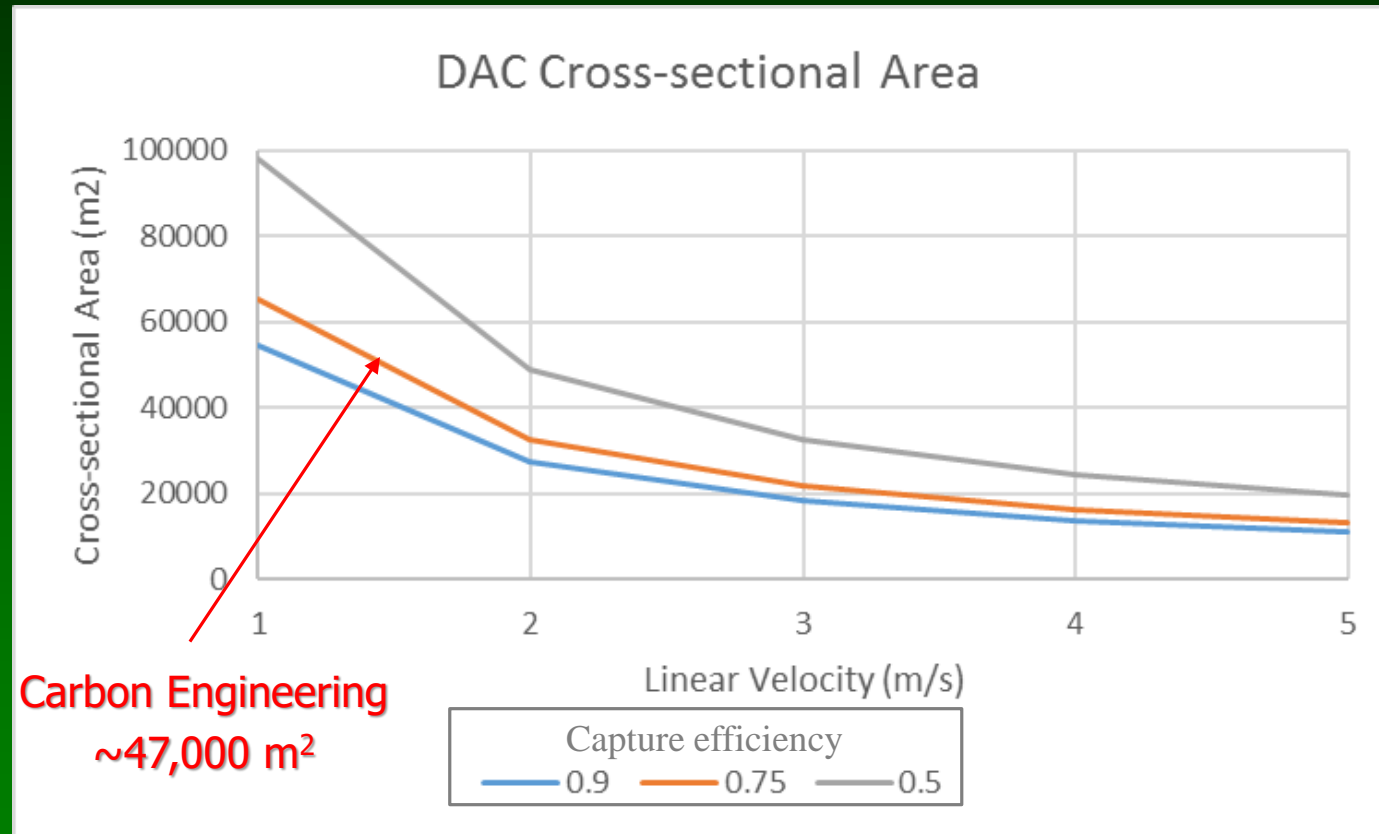
Climeworks DAC unit
900 tCO₂/year.



Petra Nova capture plant
1,600,000 tCO₂/year.

DAC Cross-Sectional Area

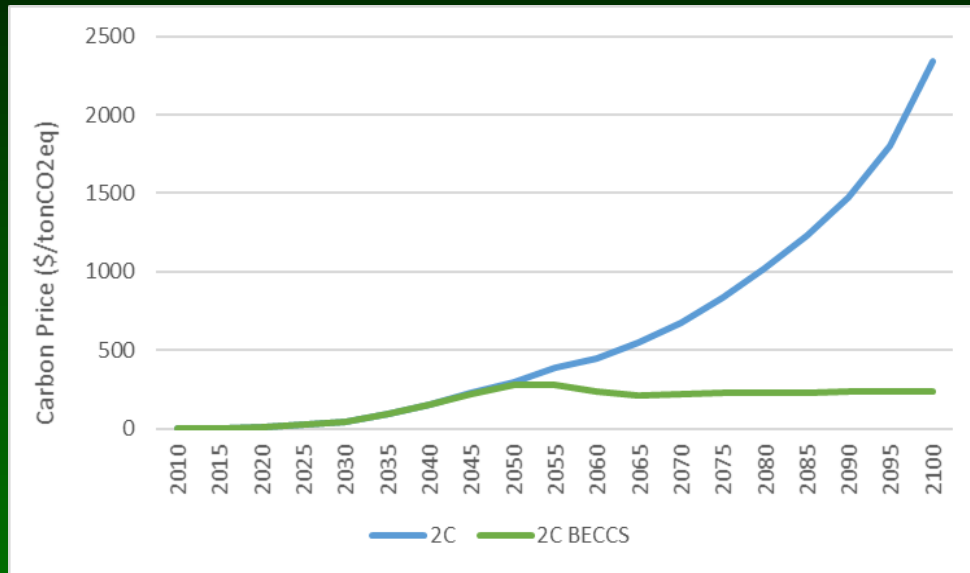
1 Mt/yr



BECCS

- Biomass removes CO₂ from the air - no absorbers or adsorbers needed
- Biomass provides the energy required for CCS and produces electricity as a by-product
- Uses the same capture technology that has been demonstrated at coal-fired power plants
- Requires a sustainable supply of biomass

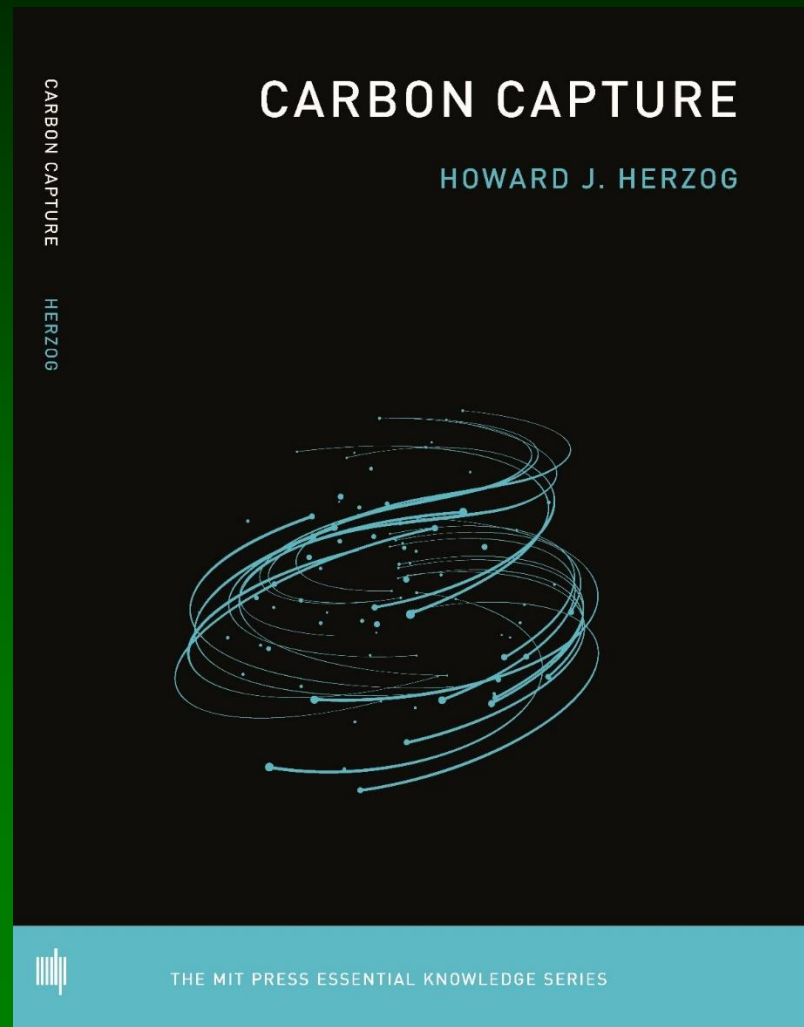
Model Results



- Biomass used: 30 EJ in 2050, 320 EJ in 2100
- Negative emissions: 21 GtCO₂ in 2100
- Impact on food prices: ~5% increase

Ecosystem impacts and social acceptability were not modeled and could limit deployment

Further Reading



Howard Herzog / MIT Energy Initiative

Contact Information



Howard Herzog
Senior Research Engineer

Massachusetts Institute of Technology (MIT)
Energy Initiative
Room E19-370L
Cambridge, MA 02139

Phone: 617-253-0688

E-mail: hjherzog@mit.edu

Web Site: sequestration.mit.edu