The National Academies of SCIENCES • ENGINEERING • MEDICINE

Negative Emissions Technologies

K John Holmes, National Academies 18 October 2019



Study Committee Task Statement

- Identify the most urgent unanswered scientific and technical questions needed to assess the benefits, risks, and sustainable scale potential for NETs
- Define the essential components of a research and development program and specific tasks required to answer these questions
- Estimate the costs and potential impacts of such a research and development program to the extent possible in the timeframe of the study

Privileged Draft - Do Not Distribute

Negative Emissions Technologies



The role of NETs in emissions mitigation

GHG emissions (GtCO₂e/year) Gross positive GHG emissions 80 -Mitigated CO2 from fossil fuels, industry Examples of associated technologies **GHG** emissions and land use changes 70 CH₄, N₂O and F-Gases 60 Conventional abatement technologies 50 40 30 CO2 20 Net zero **GHG** emissions • Emitting 10 technologies 0 The second second Carbon removal Ð -10 Net negative technologies Gross negative **GHG** emissions CO₂ emissions -20 2010 2020 2090 2100 2030 2040 2050 2060 2070 2080 SOURCE: UNEP (Smith et al. 2017

~10 GtCO₂/y globally by midcentury

~20 GtCO₂/y globally by the century's end

How much can NETs contribute to emissions reductions ?

Negative Emissions Technology	Estimated Cost (\$/tCO ₂) L = 0-20 M =20-100 H = >100	Upper Bound* for Rate of CO ₂ Remove Current Tech Understanding an (GtCC) US	Safe* Potential ral Possible Given inology and d at <u><</u> \$100/tCO ₂ O ₂ /y) Global					
Coastal blue carbon	L	0.02	0.13					
Afforestation/ Reforestation	L	0.15	1					
Forest management	L	0.1	1.5					
Agricultural soils	L to M	0.25	3					
BECCS	Μ	0.5	3.5-5.2					
Direct air capture	Н	0	0					
Carbon mineralization	M to H	unknown	unknown					
Total		1.02	9.13-10.83					

* Upper bound assumes full adoption of agricultural soil conservation practices, forestry management practices, and waste biomass capture.

*Safe means without without large-scale land-use change that could adversely affect food availability and biodiversity.

How much can NETs contribute to emissions reductions?

Finding: Existing options cannot provide amount of negative emissions needed (~10 GtCO2/y, global; 1-2 GtCO2/y, US) to help meet 2 degrees C goal without land use changes that could affect food availability & biodiversity

Recommendation: The nation should launch a substantial research initiative to advance negative emissions technologies as soon as practicable. One focus should be to make rapid progress on direct air capture and carbon mineralization technologies, which are underexplored but would have essentially unlimited capacity if high costs and many unknowns could be overcome

What does direct air capture look like at scale 10 of these to capture 1 MtCO₂ per year



<u>Solvents</u> rely on structured packing with solvent flow over the packing



<u>Solid sorbents</u> rely on a honey-comb structure with chemicals (amines) bound to structure



J. Wilcox, "Direct Air Capture", Workshop on Deep Decarbonization, National Academies 08/23/19

To Design a DAC Plant, you First Need to Design a Power Plant

- No matter which approach you choose, the heat required to recycle the material is **dominant** over the electricity required to drive the fans,
- To capture 1 MtCO₂/yr from air requires 300-500 MW of power!
- Choosing which energy resource to fuel the DAC plant will dictate the net CO_2 removed

J. Wilcox, "Direct Air Capture", Workshop on Deep Decarbonization, National Academies 08/23/19

Current NET Activities

NET Research

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Academies report produced a detailed and granular research agenda for NETs.

Current NET Activities

- Much interest in NETs nowadays judging by the number of publications in peer-reviewed journals and popular press
- Research agenda developed by the Academies committee being used by many NGOs and DOE to help set priorities
- First federal incentives to do carbon dioxide removal provides \$50/ton CO2 tax credit & California provides up to ~\$200/ton CO2
- Other proposed legislation to incentivize carbon capture and use