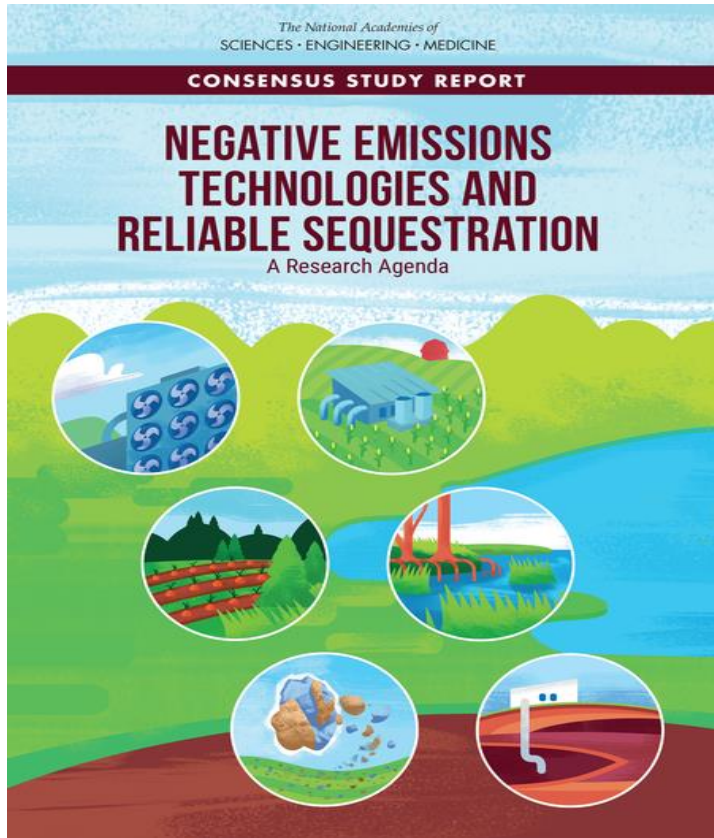


# Negative Emissions Technologies

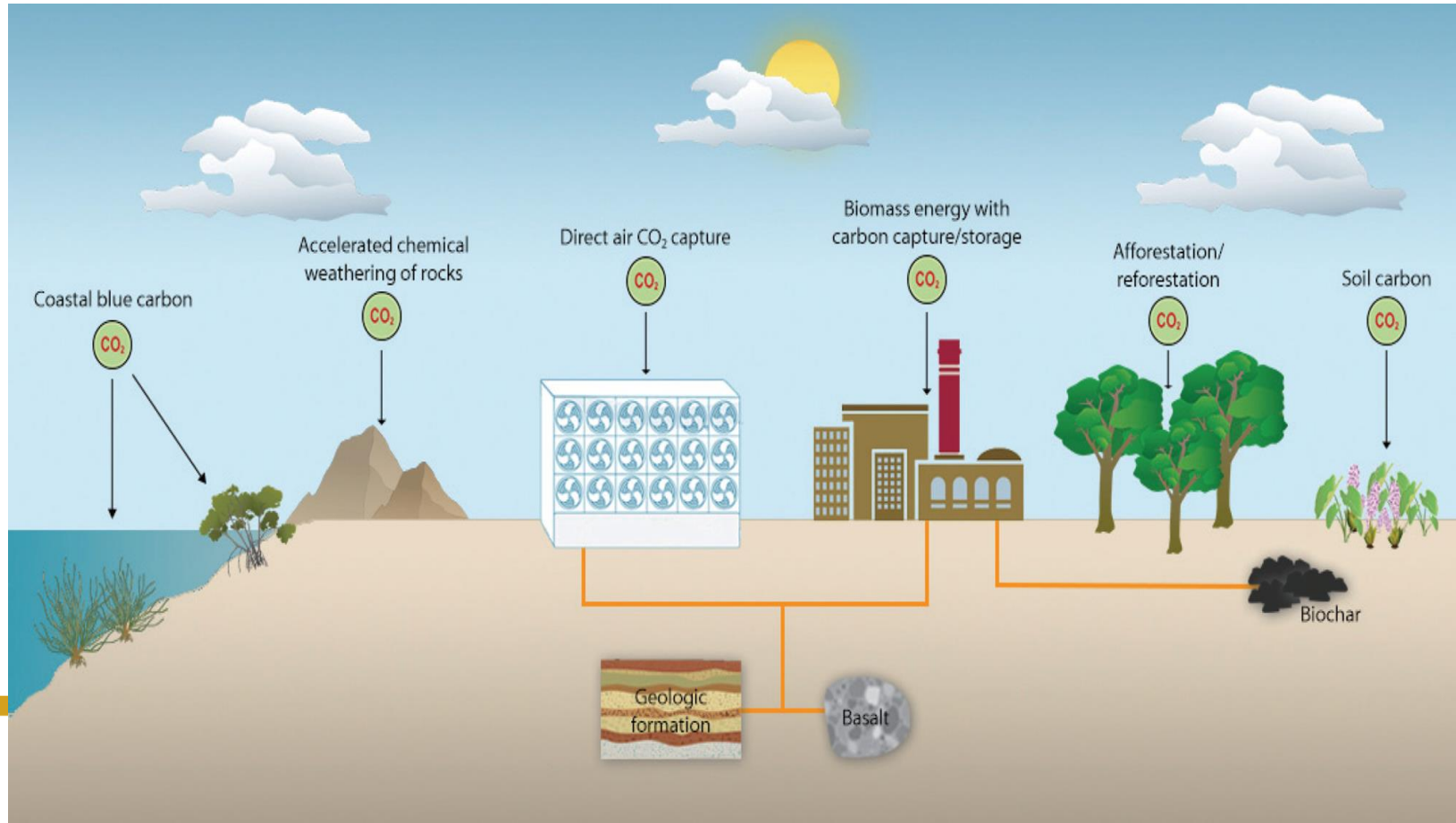
K John Holmes, National Academies  
18 October 2019



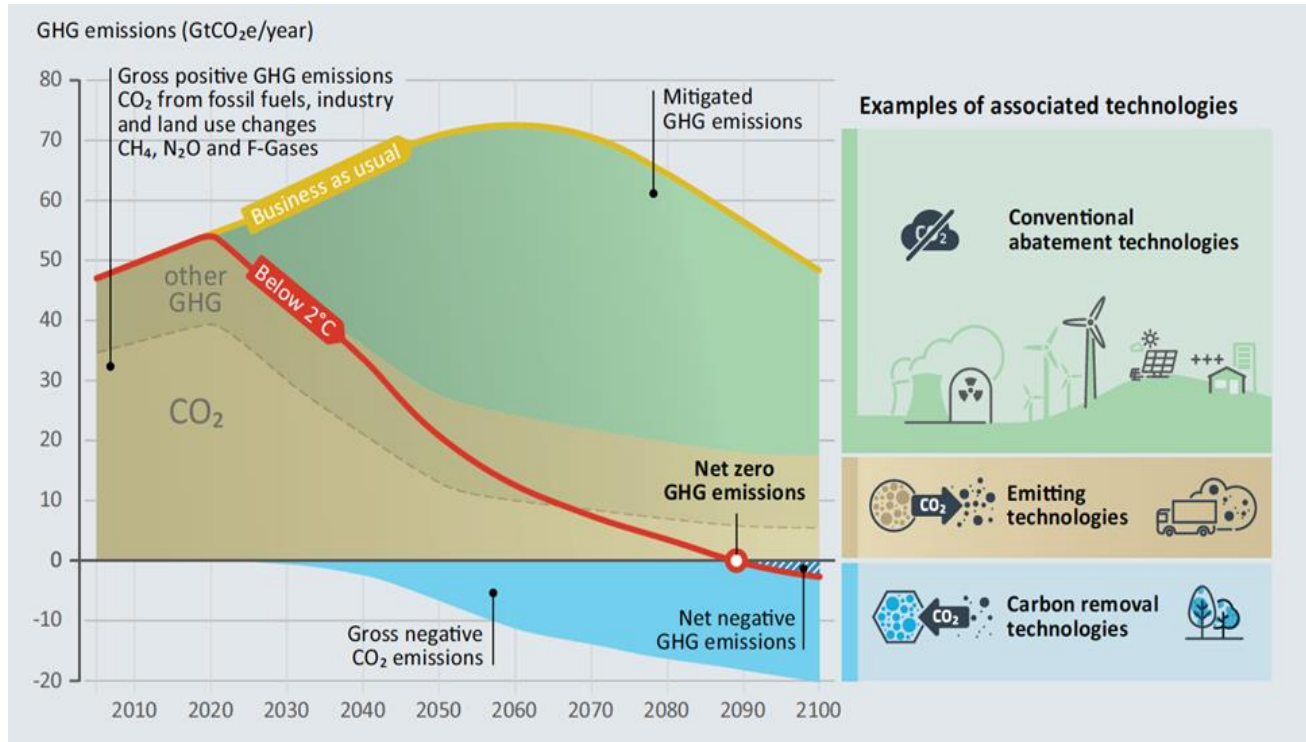
## Study Committee Task Statement

- 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

# Negative Emissions Technologies



# The role of NETs in emissions mitigation



~ 10 GtCO<sub>2</sub>/y  
globally by  
midcentury

~ 20 GtCO<sub>2</sub>/y  
globally by  
the century's  
end

SOURCE: UNEP (Smith et al. 2017)

# How much can NETs contribute to emissions reductions ?

| Negative Emissions Technology | Estimated Cost (\$/tCO <sub>2</sub> )<br>L = 0-20<br>M = 20-100<br>H = >100 | Upper Bound* for Safe* Potential Rate of CO <sub>2</sub> Removal Possible Given Current Technology and Understanding and at ≤\$100/tCO <sub>2</sub> (GtCO <sub>2</sub> /y) |                   |
|-------------------------------|---|--|-------------------|
|                               |   | US   | 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                         | M   | 0.5  | 3.5-5.2           |
| Direct air capture            | H   | 0  | 0                 |
| Carbon mineralization         | M to H  | unknown  | unknown           |
| <b>Total</b>                  |   | 1.02   | <b>9.13-10.83</b> |

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

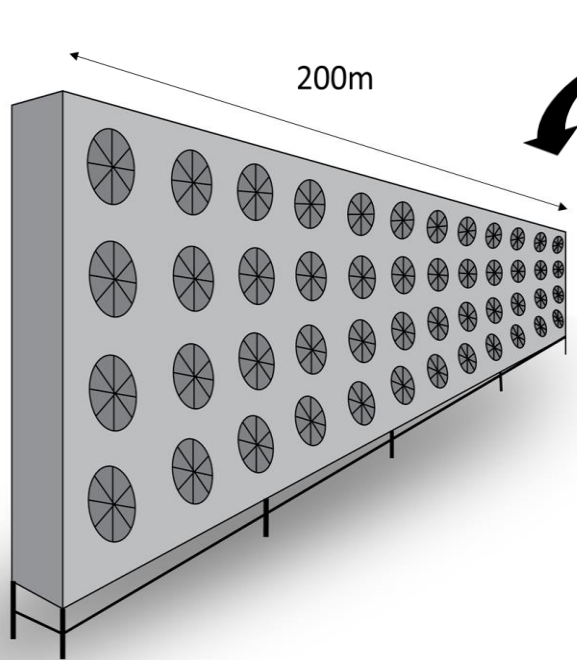
\*Safe means without without large-scale land-use change that could adversely affect food availability and biodiversity.

# How much can NETs contribute to emissions reductions?

**Finding:** Existing options cannot provide amount of negative emissions needed (~10 GtCO<sub>2</sub>/y, global; 1-2 GtCO<sub>2</sub>/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 MtCO<sub>2</sub> per year



Solvents rely on structured packing with solvent flow over the packing



Solid sorbents 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 MtCO<sub>2</sub>/yr from air requires 300-500 MW of power!
- Choosing which energy resource to fuel the DAC plant will dictate the net CO<sub>2</sub> removed

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



# Current NET Activities

## NET Research

| NET ID | Research Title | Lead        | Research Team                     | Research Summary  | Research Status | Research Funding |
|--------|----------------|-------------|-----------------------------------|---|-----------------|------------------|
| 1      | NET 001        | John Doe    | John Doe, Jane Smith              | Research on the impact of NET on student learning outcomes in mathematics.    | Completed       | \$500,000        |
| 2      | NET 002        | Jane Smith  | Jane Smith, John Doe              | Research on the impact of NET on student learning outcomes in science.        | In Progress     | \$750,000        |
| 3      | NET 003        | John Doe    | John Doe, Jane Smith, Bob Johnson | Research on the impact of NET on student learning outcomes in reading.        | Completed       | \$600,000        |
| 4      | NET 004        | Jane Smith  | Jane Smith, Bob Johnson           | Research on the impact of NET on student learning outcomes in writing.        | In Progress     | \$800,000        |
| 5      | NET 005        | Bob Johnson | Bob Johnson, John Doe, Jane Smith | Research on the impact of NET on student learning outcomes in social studies. | Completed       | \$450,000        |

| NET ID | Research Title | Lead        | Research Team                     | Research Summary  | Research Status | Research Funding |
|--------|----------------|-------------|-----------------------------------|---|-----------------|------------------|
| 6      | NET 006        | John Doe    | John Doe, Jane Smith              | Research on the impact of NET on student learning outcomes in history.            | Completed       | \$550,000        |
| 7      | NET 007        | Jane Smith  | Jane Smith, Bob Johnson           | Research on the impact of NET on student learning outcomes in art.                | In Progress     | \$650,000        |
| 8      | NET 008        | Bob Johnson | Bob Johnson, John Doe, Jane Smith | Research on the impact of NET on student learning outcomes in physical education. | Completed       | \$400,000        |
| 9      | NET 009        | John Doe    | John Doe, Jane Smith, Bob Johnson | Research on the impact of NET on student learning outcomes in foreign languages.  | In Progress     | \$700,000        |
| 10     | NET 010        | Jane Smith  | Jane Smith, Bob Johnson           | Research on the impact of NET on student learning outcomes in music.              | Completed       | \$350,000        |

| NET ID | Research Title | Lead        | Research Team                     | Research Summary   | Research Status | Research Funding |
|--------|----------------|-------------|-----------------------------------|--|-----------------|------------------|
| 11     | NET 011        | John Doe    | John Doe, Jane Smith, Bob Johnson | Research on the impact of NET on student learning outcomes in computer science.      | In Progress     | \$900,000        |
| 12     | NET 012        | Jane Smith  | Jane Smith, Bob Johnson           | Research on the impact of NET on student learning outcomes in engineering.           | Completed       | \$600,000        |
| 13     | NET 013        | Bob Johnson | Bob Johnson, John Doe, Jane Smith | Research on the impact of NET on student learning outcomes in environmental science. | In Progress     | \$750,000        |
| 14     | NET 014        | John Doe    | John Doe, Jane Smith              | Research on the impact of NET on student learning outcomes in health sciences.       | Completed       | \$500,000        |
| 15     | NET 015        | Jane Smith  | Jane Smith, Bob Johnson           | Research on the impact of NET on student learning outcomes in law.                   | In Progress     | \$850,000        |

| NET ID | Research Title | Lead        | Research Team                     | Research Summary  | Research Status | Research Funding |
|--------|----------------|-------------|-----------------------------------|---|-----------------|------------------|
| 16     | NET 016        | John Doe    | John Doe, Jane Smith, Bob Johnson | Research on the impact of NET on student learning outcomes in business.     | In Progress     | \$700,000        |
| 17     | NET 017        | Jane Smith  | Jane Smith, Bob Johnson           | Research on the impact of NET on student learning outcomes in education.    | Completed       | \$450,000        |
| 18     | NET 018        | Bob Johnson | Bob Johnson, John Doe, Jane Smith | Research on the impact of NET on student learning outcomes in psychology.   | In Progress     | \$650,000        |
| 19     | NET 019        | John Doe    | John Doe, Jane Smith              | Research on the impact of NET on student learning outcomes in sociology.    | Completed       | \$550,000        |
| 20     | NET 020        | Jane Smith  | Jane Smith, Bob Johnson           | Research on the impact of NET on student learning outcomes in anthropology. | In Progress     | \$750,000        |

| NET ID | Research Title | Lead        | Research Team                     | Research Summary   | Research Status | Research Funding |
|--------|----------------|-------------|-----------------------------------|--|-----------------|------------------|
| 21     | NET 021        | John Doe    | John Doe, Jane Smith, Bob Johnson | Research on the impact of NET on student learning outcomes in linguistics.           | In Progress     | \$600,000        |
| 22     | NET 022        | Jane Smith  | Jane Smith, Bob Johnson           | Research on the impact of NET on student learning outcomes in philosophy.            | Completed       | \$400,000        |
| 23     | NET 023        | Bob Johnson | Bob Johnson, John Doe, Jane Smith | Research on the impact of NET on student learning outcomes in political science.     | In Progress     | \$700,000        |
| 24     | NET 024        | John Doe    | John Doe, Jane Smith              | Research on the impact of NET on student learning outcomes in economics.             | Completed       | \$500,000        |
| 25     | NET 025        | Jane Smith  | Jane Smith, Bob Johnson           | Research on the impact of NET on student learning outcomes in international studies. | In Progress     | \$800,000        |

### NET Enabling Research

| NET ID | Research Title | Lead        | Research Team                     | Research Summary   | Research Status | Research Funding |
|--------|----------------|-------------|-----------------------------------|--|-----------------|------------------|
| 26     | NET 026        | John Doe    | John Doe, Jane Smith, Bob Johnson | Research on the impact of NET on student learning outcomes in environmental studies. | In Progress     | \$750,000        |
| 27     | NET 027        | Jane Smith  | Jane Smith, Bob Johnson           | Research on the impact of NET on student learning outcomes in public health.         | Completed       | \$450,000        |
| 28     | NET 028        | Bob Johnson | Bob Johnson, John Doe, Jane Smith | Research on the impact of NET on student learning outcomes in global studies.        | In Progress     | \$650,000        |
| 29     | NET 029        | John Doe    | John Doe, Jane Smith              | Research on the impact of NET on student learning outcomes in urban studies.         | Completed       | \$550,000        |
| 30     | NET 030        | Jane Smith  | Jane Smith, Bob Johnson           | Research on the impact of NET on student learning outcomes in rural studies.         | In Progress     | \$750,000        |

NET 001-010: Research on the impact of NET on student learning outcomes in mathematics, science, reading, writing, social studies, history, art, physical education, and foreign languages.  
 NET 011-020: Research on the impact of NET on student learning outcomes in computer science, engineering, environmental science, health sciences, law, business, education, psychology, sociology, and anthropology.  
 NET 021-030: Research on the impact of NET on student learning outcomes in linguistics, philosophy, political science, economics, and international studies.  
 NET 031-040: Research on the impact of NET on student learning outcomes in environmental studies, public health, global studies, urban studies, and rural studies.

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 CO<sub>2</sub> tax credit & California provides up to ~\$200/ton CO<sub>2</sub>
- Other proposed legislation to incentivize carbon capture and use