

# CARBON DIOXIDE REMOVAL: ALTERNATIVE PATHWAYS AND POLICY NEEDS

## Executive Summary (1 page)

### Carbon dioxide removal in a net-zero future (2-3 pages): the case, the need, the role

1. Given the strong likelihood of continued emissions from hard-to-decarbonize sectors, carbon dioxide removal (CDR) methods will be needed to produce the “negative emissions” required to achieve economy-wide carbon neutrality.
2. Scaling up CDR in a timely fashion requires a fuller understanding of the economic, social, and environmental ramifications of alternative approaches and the policies needed to advance them.
3. Carbon removal is not a substitute for cutting emissions. Accelerating efforts to decarbonize the economy by reducing emissions remains an urgent priority.

### Key criteria for evaluating CDR solutions (1 page)

(Mapping out the evaluation matrix and the scale/scope of different criteria)

1. Technical potential
2. Cost
3. Readiness
4. Scalability
5. Permanence
6. Benefits and co-benefits
7. Challenges

### CDR Solutions (4-6 pages)

1. Nature-based Solutions and enhanced natural processes (2-3 pages)
  - a. Afforestation, reforestation, coastal habitat restoration
    - i. Potential: 180-360 MtCO<sub>2</sub> per year (over the next 20 years with additional carbon removal till trees reach maturity) (Fargione et al. 2018)

- ii. Cost: relatively low-cost options
- iii. Readiness: nature-based solutions offer the advantage of being deployed at scale sooner than the technological ones (where things are now)
- iv. Scalability: deployment-ready at scale, but with concerns about how saturation can limit scalability
- v. Permanence: the climate benefits are reversible through degradation of forests
- vi. Benefits and co-benefits: The positive environmental impacts of replacing cropland or degraded land with forests (e.g., improved soil quality, reduced flooding and erosion)
- vii. Challenges: The concerns over biodiversity, impermanence, impacts on food supply, leakage, lifecycle impacts, and additionality

*b. Biochar, enhanced mineralization*

- i. Potential: enhanced mineralization can sequester larger amounts of CO<sub>2</sub> than biochar or other nature-based solutions
- ii. Cost: it's more expensive than other nature-based solutions
- iii. Readiness: large-scale field trials are needed to refine estimates of the potential and side effects
- iv. Scalability: will take longer time to scale up
- v. Permanence: the climate benefits are reversible through degradation of soils
- vi. Benefits and co-benefits: protecting biodiversity, providing ecosystem services
- vii. Challenges: competition with BECCS for biomass inputs

*2. Technological solutions (2-3 pages)*

*a. BECCS*

- i. Technical potential: large carbon removal potentials of BECCS, ~ 180 MtCO<sub>2</sub> per year (NAS 2018)
- ii. Cost: relatively expensive
- iii. Technology readiness: Until a large-scale CO<sub>2</sub> pipeline network or biomass transportation infrastructure is available, BECCS will have to be limited to sites where biomass and suitable CO<sub>2</sub> storage are both available.
- iv. Scalability: limited by available waste and competing use for feedstock
- v. Permanence: the CO<sub>2</sub> yield can be permanently stored
- vi. Benefits and co-benefits: could help reduce lifecycle carbon footprint of biofuels and ramp up CCUS infrastructure

- vii. Challenges: Purpose-grown biomass and the fuel vs food dispute, combining a mature technology, bioenergy from biomass, with CCS that is largely at the demonstration stage, ensuring secure geologic storage.
- b. Direct Air Capture
  - i. Technical potential: may be able to sequester extremely large amounts of CO<sub>2</sub>
  - ii. Cost: the very high cost is the main barrier for deployment
  - iii. Technology readiness: one-off pilot or demonstration stage
  - iv. Scalability: scalable to demand at a given location, it needs longer time to scale
  - v. Permanence: the captured CO<sub>2</sub> can be permanently sequestered
  - vi. Benefits and co-benefits: ramping up CCUS infrastructure and CO<sub>2</sub> as feedstock for CO<sub>2</sub>-sequestering products, small land footprint of DAC facilities (with a concern over the large land footprint of the associated RE sources)
  - vii. Challenges: high costs in the absence of a natural economic driver (a cost on carbon) and depend heavily on abundant low-carbon energy sources, ensuring secure geologic storage.

**Redacted - First Amendment**