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 $MtCO_2$ per year (over the next 20 years with additional carbon removal till tress 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_2 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 $MtCO_2$ per year (NAS 2018)
      ii. Cost: relatively expensive
      iii. Technology readiness: Until a large-scale CO_2 pipeline network or biomass transportation infrastructure is available, BECCS will have to be limited to sites where biomass and suitable CO_2 storage are both available.
      iv. Scalability: limited by available waste and competing use for feedstock
      v. Permanence: the CO_2 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_2
    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_2 can be permanently sequestered
    vi. Benefits and co-benefits: ramping up CCUS infrastructure and CO_2 as feedstock for CO_2-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.

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