Notes on Net Zero, Carbon Budget, and Negative Emission Technologies (NETs):

- Paris Agreement Objective: Sets an international legal objective for achieving a net-zero carbon future for the planet in the second half of the 21st century.
- Carbon Budget & Trajectory:
  - Emissions trajectories dictate how fast we reach the atmosphere's carbon budget.
  - Once the budget is reached, 100% of fossil fuel-related emissions must be prevented from entering the atmosphere (via CCS) or fully compensated.
- Unavoidable Emissions (Non-Energy Sector):
  - A quarter of greenhouse gas (GHG) emissions come from outside the energy sector, primarily agriculture (food cultivation, fertilizers, animal farming).
  - These activities generate methane and nitrous oxide, whose impact alone represents over a quarter of our carbon budget (when converted to CO_2 equivalents).
  - Crucially, these emissions cannot be reduced by renewable energy or energy efficiency alone.
- Necessity of Artificial Carbon Sinks / Negative Emission Technologies (NETs):
  - Reaching true "zero emissions" may be impossible without CCS or other NETs to compensate for these unavoidable agricultural and land-use emissions.
  - NETs are needed to replicate ecosystems' role in sequestering carbon.
  - The necessary scale of negative emissions for a 2°C target is extremely large (600-800 billion tonnes of CO_2 by century-end), equivalent to 15-20 years of current annual emissions.
  - The deployment of the 10 existing CDR methods at an industrial scale is currently unproven.
- Carbon Overshoot:
  - Most climate models that avoid breaching the 2°C limit include a "carbon overshoot" – a temporary state of excessive emissions.
  - This implies "going into debt" with the atmospheric carbon budget, requiring later "payback" via significant CO_2 removal (like opening a plug in a bath).
  - Early and deeper emission cuts can reduce overshoot and provide necessary compensation.
- Key Negative Emission Technologies (NETs):
  - BECCS (Bioenergy with Carbon Capture and Storage): Using biomass for energy, then capturing and storing the CO_2.
  - Direct Air Capture (DAC): Directly removing CO_2 from the atmosphere.
  - Important: In both BECCS and DAC, the captured CO_2 must be stored geologically (not in soil or temporary biomass like trees, as it could re-enter the atmosphere).
- Warnings & Trade-offs:

    - NETs are not a "silver bullet" and have important trade-offs (e.g., land use, biodiversity, water consumption, costs).
    - They are not an excuse for inaction: it's cheaper to reduce emissions at the source, and relying on NETs is a more expensive and potentially irreversible problem for future generations.

Notes on Negative Emission Technologies: BECCS and Direct Air Capture

I. Bioenergy with Carbon Capture and Storage (BECCS)

- Definition: A process that generates energy (e.g., electricity, liquid fuels, heat) from biomass, which is any material derived from biological sources.
- Carbon Cycling: Plants absorb atmospheric CO_2 during growth via photosynthesis. When this biomass is converted into an energy vector, the CO_2 released during conversion is captured.
- Carbon Balance (with CCS): When Carbon Capture and Storage (CCS) is integrated, the overall carbon balance becomes negative. This means CO_2 is actively removed from the atmosphere and permanently stored in geological formations, occurring during the conversion of primary biomass energy.
- Associated Emissions: Emissions are acknowledged from biomass cultivation (e.g., fertilizers, agricultural machinery fuel, land-use change) and transportation, although the net effect with CCS is carbon removal.
- Variability: Certain BECCS energy vectors (e.g., electricity, heat) can achieve greater carbon negativity compared to biofuels, where a fraction of carbon may re-enter the atmosphere upon end-user consumption.

II. Direct Air Capture (DAC)

- Definition: A technology designed to remove atmospheric carbon dioxide directly from ambient air.
- Operational Characteristics:
    - CO_2 is highly diluted in the atmosphere, requiring the processing of very large volumes of air.
    - This process is significantly energy intensive.
    - DAC is inherently more expensive than CO_2 capture from concentrated industrial point sources.
    - No energy vector is produced; its deployment is solely for the benefit of climate change mitigation.
- Process Outcome: Captured CO_2 is concentrated, then prepared for transport and permanent geological storage.

Citations:

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