5. Decarbonizing the global economy and society

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Key Concepts

Carbon or CO2 Pricing is the attribution of a cost applied to carbon emissions, which should act as an economic incentive for decarbonization.

Negative Emission Technologies for Carbon Dioxide Removal can be divided into different main categories as described below. The Safe Potential Rate of C02 removal comes from the National Academies of Science report and is expressed at current technology level.

1. **Bioenergy with Carbon Capture and Storage** (BECCSS) is the process of producing bioenergy (electricity, liquid fuels and/or heat) from plant biomass, combined with capture and sequestration of C02, thereby removing it from the atmosphere. Safe Potential Rate of CO2 Removal at <$100/tCO2: 3.5-5.2 (Gt/y CO2)

2. **Direct Air Carbon Capture and Storage** (DACCS) is the process that captures CO2 from the ambient air mostly through chemical processes an concentrates It so that It can be either for geological sequestration or utilization. Safe Potential Rate of CO2 Removal at <$100/tCO2: 0 (Gt/y CO2)

3. **Enhanced Weathering of Minerals** (EWM) is the process linked to carbon mineralization by which natural or artificially created minerals are dissolved using carbon dioxide from the atmosphere. Safe Potential Rate of CO2 Removal at <$100/tCO2: unknown

4. **Afforestation and Reforestation** (AR) is the process of planting trees in an area where there were none, or where they have been removed for other land uses. Safe Potential Rate of CO2 Removal at <$100/tCO2: 1 (Gt/y CO2)

5. **Manipulation of carbon uptake by the ocean**, can be done at the level of coastal ecosystems through “land use and management practices thatincrease the carbon stored in living plants or sediments in mangroves, tidal marshlands , seagrass beds, and other tidal or salt-water wetland” (‘blue carbon’) or in the deep ocean, through ocean fertilisation and alkanisation. For blue carbon, Safe Potential Rate of CO2 Removal at <$100/tCO2: 0,13 (Gt/y CO2)

6. **Altered agricultural practices** describes altered cultivating processes that enhance soil carbon storage. Safe Potential Rate of CO2 Removal at <$100/tCO2: 3 (Gt/y CO2)

Scientific Anticipatory Brief abstract

Current status

Developing a global strategy to ensure that atmospheric CO_2 levels do not increase above a critical level is a huge challenge that requires coordinated action across many communities. The scale of this problem, as well as its impact on the economy and on people's quality of life, poses challenging constraints on science and technology. Understanding these challenges and proposing a path forward that ensures global access to renewable energy, and ensures global participation with the right economic incentives, are key components of this challenge, to which GESDA can make a difference.

The Paris Agreement set out a global framework to limit global warming to between 1.5° and 2°C and, according to 2018 IPCC estimates, the remaining CO_2 budget to release in the atmosphere was 420 Gt and 1170 Gt at the end of 2017, respectively. The IPCC estimated, with a 66% likelihood, that if emissions continue at the current rate, these budgets will be used up in approximately 7 and 25 years respectively. Urgent action is therefore needed to match the 2°C limit to global warming. Looking into the longer term, this would require halving the CO_2 emissions every decade by 2030 until roughly 2060. Cutting emissions at this pace must be complemented by removing CO_2 from the atmosphere through nature-based solutions, eco-restoration and technical solutions via negative emissions technologies This requires adopting a portfolio approach combining economic incentives (**CO_2 pricing**), research, development and scaling-up of Negative Emission Technologies, and the transition into new energy systems. While some of those technologies appear ready for scale-up, future research and development is needed around synthetic fuels, non-carbon energy sources, chemistry, and materials science for direct removal of atmospheric CO_2 or new industrial processes enabling a circular economy. The convergence between digital technologies (AI, High Performance Computing), chemistry and materials sciences and life sciences (metabolic engineering and synthetic biology) will enable breakthroughs in the years to come. These breakthroughs combined with the economic and social incentives as well as the scaling-up of current technologies and approaches would allow humanity to limit the amount of CO_2 in the atmosphere. In short, the heterogeneity of technologies, their different levels of maturity and potential for upscaling require a "portfolio-based risk-management approach.

Not undoing but accelerating: The current situation around the COVID-19 pandemic provides the chance to pivot more rapidly on the long-term issues that humanity is facing. The big Issues of the coming years are to phase out our reliance on fossil fuels and keep on investing into a broad scale of technologies for energy, climate, water, food systems, health and planetary health, all in a very short time.

Trends at 5 years - Incremental improvement and deployment of Negative Emission Technologies and carbon pricing

With technological developments in sight reducing the price of carbon capture for selected Negative Emission Technologies below $100/tC02, the global C02 market starts becoming attractive for private actors. From a technology standpoint, experts do not expect game-changing developments at 5 years but rather incremental improvements to make those technologies more efficient and better integrated into the so-called circular economy. Also, cutting-edge technologies suffer from lack of experimentation at scale, which will be a focus at 5 and 10 years.

Trends at 10 years - Towards a genome project for material

Carbon pricing makes the removal of C02 from the atmosphere further commercially attractive, taking into account global and regional effects. Pioneering nations around a UN or a G20 framework could take the lead. At a technological level, new systems combining renewable energy and C02 extraction for the development of synthetic fuel, hydrogen energy, and as a source of carbon for the chemical industry. Finally, advances in computing and artificial intelligence would allow to accelerate the design of new materials and their deployments in real-world applications. This will in turn accelerate and unleash innovations in technologies required for Direct Air Carbon Capture, the conversation of C02 into synthetic fuels and further decarbonization techniques.

Trends at 25 years - Technology breakthrough and managing the energy transition

Breakthroughs in technologies for molecular separations allow applications at industrial scales allow direct C02 capture from the air for synthetic fuels Also, on the energy transition, in parallel and complementing developments around systems for hydrogen energy and other renewable, progress in the area of nuclear fusion reactors need to be considered.**extraction for the development of synthetic fuel, hydrogen energy, and as a source of carbon for the chemical industry. Finally, advances in computing and artificial intelligence would allow to accelerate the design of new materials and their deployments in real-world applications. This will in turn accelerate and unleash innovations in technologies required for Direct Air Carbon Capture, the conversation of C02 into synthetic fuels and further decarbonization techniques.**

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Example of breakthroughs

5 years

CO_2 Pricing

- CO_2 Pricing target is $40–80 per ton of CO_2, for reaching the 2-degree increase
- Progress in hydrogen energy research

Advanced materials

- Further progress in chemical separation technology
- Start of experimenting at scale
- Bio-based production of new materials and compounds

Negative Emission Technologies (NETs)

- Large scale demonstrators for commercially competitive NETs such as Bioenergy Carbon Capture and Storage (BECCS) driven by private investments.
- Progress in Direct Air Capture and Storage

10 years

CO_2 Pricing

- CO_2 Pricing target is $50–100 per ton of CO_2 in 2030, for reaching the 2-degree increase

Energy transition

- Mining the air instead of the ground by combining solar energy and CO_2 extraction to develop synthetic fuels and hydrogen energy
- Modular nuclear fission reactors

Advanced materials

- Advanced chemical compounds using new computing tools
- Towards a human genome for materials: advances in machine learning, artificial Intelligence and computing would allow to accelerate the design of new materials and their deployments in real-world settings

Negative Emission Technologies (NETs)

- Direct Air Capture and Storage large scale demonstrators

25 years

- Progress in fusion energy
- Direct C02 capture from the air for synthetic fuels: breakthroughs in technologies for molecular separations allow applications at Industrial scales
- Planetary scale deployment of Negative Emission Technologies