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Mini Review

Enhancement of Carbon Capture Through Nature-Based Technologies and Solutions. C-Sink Showcase-Part 1

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Abstract

C-SINK is a European project to boost large-scale atmospheric CO_2 removal (CDR) and help keep temperature rise below 2°C (ideally 1.5°C) through seven technologies (CDR T). The purpose of the C-SINK project is to deliver a complete package of proposals elaborated to support a new or modified European legal/regulatory framework to bring high quality CDRs to the market. That package will contain pre-standards (in CEN format) covering the requirements and methodologies for sampling, testing and QMS (ISO9000) on which to build monitoring, reporting and verification systems.

Keywords: CO_2 capture; carbon sinks; carbon market

Introduction

European Climate Law makes it possible to achieve the climate goal of reducing European Union (EU) emissions by at least 55% by 2030. EU member countries are working on new legislation to achieve this goal and ensure that the EU is climate neutral by 2050. The "Fit for 55" package [1] is a set of proposals aimed at reviewing and updating the EU legislation and launching new initiatives with the aim of:

a) Guarantee an equitable and socially just transition.

b) Maintain and strengthen the innovation and competitiveness of EU industry while ensuring a level playing field vis-à-vis economic operators from third countries.

c) Sustain the leadership position of the EU in the global fight against climate change.

Voluntary Carbon Market

There are two markets divided into regulated and voluntary. In regulated markets, the competent authority determines the emission limit in the affected sectors (for example, energy, industry, agriculture, livestock, and other land uses). Once determined, it issues a finite amount of emission rights and allows agents to exchange such rights or reduce emissions outside the system, through emission reduction projects, the so-called carbon credits. The main regulated market is the European Union Emissions Trading Scheme (EU ETS) [2] which covers around 40% of the EU greenhouse gas (GHG) emissions. Voluntary carbon markets bring together various initiatives where agents voluntarily participate in the generation or purchase and compensation of carbon credits. In order to guarantee a legitimate compensation of emissions, the projects that originate them must meet minimum requirements in terms of the standard that supports them, the technology that originates them, the vintage of the assets, referring to the year of issuance of the credits, the location of the project and its contribution to sustainable development and compliance with the United Nations Sustainable Development Goals.

Sustainable Carbon Cycles and Atmospheric Carbon Absorption Certification Framework

In December 2021, the European Commission (EC) adopted the Communication "Sustainable Carbon Cycles" [3], which sets out an action plan on how to develop sustainable solutions to increase carbon removals. This communication focuses on three pillars as follows:

a) Carbon farming: includes carbon sequestration practices from nature-based solutions including afforestation, reforestation, agroforestry, use of catch crops, cover crops, conservation tillage, and restoration of peatlands and wetlands.

b) Sustainable industrial carbon: carbon captured from industrial solutions is referred to as Carbon Capture and Storage (CCS) and Carbon Capture and Utilization (CCU). These practices involve capturing atmospheric carbon for use in other industrial processes or long-term storage.

c) Carbon removal certification framework: To encourage a robust and transparent voluntary carbon market, a certification framework is established to regulate removals from both nature-based and industrial solutions. The regulatory framework proposal published in November 2022 focuses on establishing four pillars that ensure the quality of removals based on the following criteria:

a) Quantification: credits will only be obtained from the net absorptions produced taking into account the baseline, project emissions and possible leaks.

b) Additionality: Carbon removals must be additional so that they meet the financial and jurisdictional additionality criteria.

c) Long-term storage: A carbon sequestration activity will aim to ensure long-term carbon storage.

d) Sustainability: A carbon sequestration activity will have a neutral impact or will generate co-benefits for different sustainability objectives.

The European C-Sink Project

C-SINK is a European project to boost large-scale atmospheric CO_2 removal (CDR) and help keep temperature rise below 2°C through seven technologies (CDR T). The C-SINK consortium includes organizations from 11 countries with complementary skills and experience in the different CDR technologies, CEN and ISO standard drafting, climate law, carbon trading and all relevant environmental and social issues. The purpose of the C-SINK project is to deliver to the EC a complete package of proposals elaborated to support a new or modified European legal/regulatory framework to bring high quality CDRs to the market. That package will contain pre-standards (in CEN format) covering the requirements and methodologies for sampling, testing and QMS (ISO9000) on which to build monitoring, reporting and verification systems. It will also include proposals to cover (a) environmental, social impact and governance issues, and (b) means of building trust in the market. This will encourage entrepreneurs to demonstrate safe and effective CDR projects to incentivize large investments, allowing the market to evolve to face the climate crisis.

Methodologies and Technologies Included in C-SINK (CDR-T in C-SINK)

The C-SINK Consortium led by ICAMCYL FOUNDATION carried out an exhaustive review of the range of CDR-T available, based on external techno-economic reports, as well as laboratory-scale tests, pilot plants, research and own evaluations of Consortium partners. The technologies reviewed include Afforestation and Reforestation (AR), Biochar (BC), Soil Carbon Sequestration (SCS), Enhanced Weathering (EW), Ocean Fertilization (OF), Bioenergy with Carbon Capture and Storage (BECCS), Direct Airborne Carbon Capture and Storage (DACCS), among others. However, the Consortium agreed that there is high uncertainty around the CDR-T mainly due to:

a) The current level of technological understanding of CDR.

b) The adoption of CDR technologies in environmental policies and effective regulatory controls.

c) The ability to integrate CDR into commercially viable frameworks.

Based on a deep assessment C-SINK consortium will focus on seven CDR technologies:

Biological CO_2 fixation (BCO_2): Autotrophic bacteria synthesize all their constituent cells using CO_2 as a carbon source. However, recent studies report that heterotrophic microorganisms are more promising candidates, since CO_2 fixation is significant. These bacteria are capable of consuming CO_2 and incorporating it into their metabolisms during bioremediation and biofertilization processes. The occurrence of heterotrophic CO_2 fixation by soil microorganisms has been previously tested in various mineral and artificial soils. The results suggest that heterotrophic CO_2 fixation could be generalized, showing the importance of heterotrophic fixation and indicating a pathway to maximize carbon fixation that should be included in MRV related to soil, land and climate change management. land use.

Afforestation (AF): C-SINK will study the limits to high scaling and the best practices to reach the maximum storage potential, together with the maximum environmental benefits in terms of biodiversity and ecosystem services. In addition, it will focus on potential land use conflicts and review best practices for balancing and optimizing forestry, logging, and CDR. The development of MRV will take into account currently available standards, analyzing their weaknesses and threats. In addition, C-SINK will carry out an in-depth review of state-of-the-art monitoring techniques based on remote and satellite sensors, which are based on non-invasive measurements and will be tested in public and private areas in various case studies, including old areas and industrial/mining (now forested) sites.

Biochar (BC): The MRV system for BC in C-SINK will be tested in two real scenarios for BC production with different models.

Biochar with BECCS and CCS: Integrating biochar production with energy recovery from sustainable biomass sources with CCS appears to be a promising negative emissions technology. Furthermore, UED has shown that co-pyrolysis of biomass and wood ash increases carbon conversion efficiency, which reduces CO_2 abatement costs using BC. Wood ash is rich in potassium, which is known to catalyze the formation of BC, resulting in higher yields of sequestered carbon.

Artificial soils (AS): Soils constructed from a suitable set of materials can store large amounts of C over time and sequester additional C by encouraging biological activity (mainly vegetation growth) on marginal lands or vacant land.

Enhanced Weathering (EW) of Alkaline Silicate Rock Residues (ASWR) and Tailings: This research will focus on the mineralogical, geochemical, and morphological characterization of the tailings (ASWR). In addition, geochemical evaluation, and modelling of the potential implications of EW and mineral carbonation for (a) mine waste drainage characteristics and (b) end-use implications will be included. Besides this, the ASWR assessment will also cover (a) milling and pre-treatments, (b) situational variations, including the coincidence of ASWR and CO_2 availabilities, (c) the potential for geochemical permanence, and (d) the further extensive involvement of the CDRs in this sector.

C-SINK will explore several combinations or synergies between different CDR approaches and their MRV methodologies. The trials will cover three synergies already detected: (a) construction of artificial soils with/without BC (b) BC improved with the addition of wood ash; and (c) EW combined with BECCS through sorption Enhanced Gasification, a promising biomass conversion and CCS technology that can produce syngas along with on-site CO_2 capture.

Reforestation Project as Carbon Sinks

The calculation of CO_2 absorption is made based on the inventory data on reforestation in terms of species, area planted and year of planting of the specimens, as well as the treatments carried out on the ground. The estimation of GHG emissions associated with land use is carried out by quantifying the difference between the amount of carbon existing in the reservoirs at the end of the calculation year with respect to the initial amount of carbon that existed at the beginning of the calculation year. This estimate of emissions and removals follows the methodology of IPCC Volume 4 [4] which provides guidance for the preparation of annual GHG inventories in the Agriculture, Forestry and Other Land Use (AFOLU) sector. In particular, the chapter on Forest Land provides methods for estimating GHG emissions and removals due to changes in biomass, dead organic matter and soil organic carbon on Forest Land and Land Converted to Forest Land. These methods are based on the Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories [5] and the Good Practice Guide for Land Use, Land-Use Change and Forestry (GPG-LULUCF) [6]. These calculations will result in the net balance of GHG emissions and removals made by the afforestation technology, taking into account the baseline of stored carbon from which it starts, as well as possible leaks from the project.

Discussion

C-SINK project just started this year in June and will run for the next 4 years and the first results will be available in 2025. In addition, C-SINK will provide recommendations for such combinations between some CDR technologies as well as identify technology barriers and potential improvements.

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