Call: Sustainable, secure and competitive energy supply (HORIZON-CL5-2021-D3-03)
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CRONUS

CAPTURE AND REUSE OF BIOGENIC GASES FOR NEGATIVE-EMISSION - SUSTAINABLE BIOFUELS

POLICY BRIEF

POLICY REVIEW RELATED TO CRONUS PROJECT

	Enabling policy environment	Barriers of the policy framework
	UNITED NATIONS	
Establishment of International Frameworks	The creation of the Intergovernmental Panel on Climate Change (IPCC) and the United Nations Framework Convention on Climate Change (UNFCCC) set a foundation for international climate cooperation and accountability, emphasizing the need for coordinated efforts to stabilize greenhouse gas emissions.	-
Legally Binding Agreements	The Kyoto Protocol introduced legally binding targets for GHG reductions, establishing mechanisms like the International Emissions Trading (IET) and the Clean Development Mechanism (CDM). These mechanisms create financial incentives for countries to invest in carbon saving technologies.	-
Paris Agreement Goals	The Paris Agreement sets ambitious temperature and emissions targets, urging countries to pursue efforts to limit global warming to 1.5°C. This commitment drives innovation and investment in technologies that can achieve significant emissions reductions.	-

EUROPEAN UNION		
European Green Deal	The European Green Deal aims to achieve carbon neutrality by 2050 and emphasizes the importance of decarbonizing the energy system, which accounts for more than 75% of the EU's greenhouse gas emissions.	-
European Climate Law	Makes it legally binding for the EU to achieve a balance between greenhouse gas emissions and removals by 2050, and to achieve negative emissions after 2050.	The binding targets for carbon neutrality, by prioritizing net-zero targets, lack of support for the negative emissions.
EU ETS (Directive 2003/87/EC)	The EU Emissions Trading System (EU ETS) is one of the largest of its kind in the world, covering around 40% of the EU27's greenhouse gas emissions and is considered to be the EU's most important climate policy instrument. The EU ETS has detailed rules for deploying CCS applications and is an example of a province that enables point source capture of fossil energy and industrial emissions.	Currently, emissions from biomass combustion are treated with a "zero-carbon rating," meaning they do not count against emissions targets under the ETS and the Carbon Removal Credits (CRCs). For that reason, EU ETS, does not currently allow negative emissions from bio-CCS or bio-CCU to be counted for compliance, potentially limiting the economic viability of BECCS.
Effort Sharing Regulation (ESR)	The ESR establishes binding annual GHG targets for EU MS, focusing on sectors such as domestic transport, buildings, agriculture, small industry, and waste which are sectors that are not covered by ETS.	Since the emissions from biomass are not considered in this regulation, the CCS(U) within the bioenergy sector are not supported
Directive 2009/31/EC On the on the geological storage of carbon dioxide	This directive establishes a legal framework for the environmentally safe geological storage of carbon dioxide. The geological storage is mentioned as "the injection and storage of CO_2 streams in underground geological formations".	The CCS can entail carbon removals with the BECCS or bio-CCS, called as technological removals. Since the Directive supports only the geological storage could create a restricting environment for other capture methods.
Commission proposal certification of carbon removals to help reach net zero emissions	This proposal boosts the innovative industrial carbon removal technologies, such as bioenergy with carbon capture and storage (BECCS) or direct air carbon capture and storage (DACCS). This proposal is the first initiative to include the industrial technologies such as BECCS and DACCS creating tailored certification methodologies for the different types of carbon removal activities.	As BECCUS is not mentioned, the utilization is not yet prioritized in this proposal.
DIRECTIVE (EU) 2018/2001, on the promotion of the use of energy from renewable sources. (RED II)	The RED II supports the use of biogas and biomethane for different sector and biomethane is no longer limited to the transport sector but is recognized across various applications, including electricity and heating, broadening the market potential.	The CRONUS functional prototypes that utilize the biogenic CO2 and upgrade it to biomethane, might face a difficulty with the proper identification and certification of biomethane produced from biogenic sources, since is not mentioned as a production system in ANNEX VI.

AIM of the project

To accelerate on the path to sustainable bioenergy and reach the UN SDGs by incorporating in the biofuels value chain carbon capture, utilisation and storage (CCUS) techniques promoting the decarbonisation of the EU economy in accordance to European Green Deal goals.

Impact of the project

Advancement of Bioenergy Technologies:

Development of innovative carbon capture, utilization, and storage (CCUS) technologies for biofuels production, enhancing efficiency and sustainability.

Support for EU Decarbonization Goals:

Aligns with the European Green Deal to facilitate the transition towards sustainable bioenergy, contributing to climate neutrality by 2050.

Development of Functional Prototypes:

Upscaling and validation of the technologies with real-world application (Functional Prototypes/FP).

Environmental and Socio-Economic Assessments:

Lfe-cycle assessments to evaluate the environmental and socio-economic impacts of new technologies.

Stakeholder Engagement:

Fosters collaboration among industry, academia, and civil society through Communities of Practice (CoPs) to address social values and tensions.

Promotion of Carbon-Negative Biofuels:

Aims to produce carbon-negative biofuels that significantly reduce greenhouse gas emissions.

Alignment with UN Sustainable Development Goals (SDGs):

Supports multiple SDGs, particularly those related to clean energy, climate action, and sustainable industry.

Facilitation of Policy Development:

Creates policy recommendations for sustainable biofuels and carbon management practices based on project findings.

FUNCTIONAL PROTOTYPES

FP1-Athens, Greece

This prototype, focuses on utilizing biogenic CO_2 emissions from an integrated biorefinery that processes 1 ton of biowaste daily to produce biodiesel, bioethanol, biogas, and digestate. It captures CO_2 from drying, fermentation, and anaerobic digestion, dissolves it into water using enzymatic capture, and uses it to cultivate algae in raceway ponds. The algae, harvested via low-cost sedimentation, are further processed to maximize biofuel production and extract carbonic anhydrase enzymes to enhance CO_2 absorption and algae growth. The project aims to improve biofuel sustainability and achieve negative carbon emissions.

FP2-Thessaloniki, Greece

The demonstration setup in Northern Greece produces high-grade biomethane with over 95% methane content by converting carbon dioxide and green hydrogen. The hydrogen, generated through water electrolysis powered by surplus renewable energy, is combined with CO_2 from a biogas reactor in a Trickle Bed Reactor, creating an optimal environment for microbial growth and efficient methane production.

FP3-Copenhagen, Denmark

FP3 produces natural-gas-grade biomethane by converting the organic fraction of anaerobic sludge from biogas plants. The process combines thermochemical pyrolysis, which transforms sludge into bio-syngas and biochar, with biological syngas biomethanation. Bio-syngas is upgraded with hydrogen for full methanation of biogenic CO_2 and fed into a trickle bed reactor, where microorganisms efficiently convert it into high-quality biomethane.

FP4-Montpelier, France

FP4 converts biomass into biochar and energy-rich bio-fuel gases through pyrolysis at high temperatures in the absence of oxygen. The biochar, a carbon-rich porous solid, enhances soil and plant interactions and offers potential for carbon sequestration. The reactor, with a 70 L/day capacity, is optimized for various biomass types and equipped to produce biochar and combust gases. The gaseous co-products (CO_2, CO, CH_4, and H_2) are collected and analyzed to achieve mass and energy balance.

FP5-Boecillo, Spain

FP5 integrates a microbial electrolysis cell with a two-phase anaerobic digestion system to enhance biogas production and reduce CO_2 in biogas. Anaerobic digestion breaks down organic matter into methane and CO_2, while the microbial electrolysis cell uses microorganisms to produce H_2 that is converted with CO_2 into methane through hydrogenotrophic methanogens (if this is to detailed maybe microbial community). The system includes a homogenization unit, and a methanogenic reactor, where the microbial electrolysis cell is integrated to improve process stability, and maximize methane output.

EXPECTED OUTCOMES OF FUNCTIONAL PROTOTYPES

FP1 (Algal Cultivation and Enzymatic CO_2 Capture):

Key Outcomes:

- 85% enzymatic CO_2 capture efficiency in the bed reactor.
- Nearly 100% of captured CO_2 utilized as a substrate for algae growth.
- Algal cultivation enables production of 10–20 g/m^2/day of dry biomass with a 22% increase in biomass resource utilization.
- Energy-efficient operation with minimal input for CO_2 capture and mixing (5–15 Wh/m^2).
- Production of Carbonic Anhydrase (CA) enzymes from algae biomass reduces external inputs and enhances biofuels production.

FP2 (Biological Biogas Upgrading with Hydrogen):

Key Outcomes:

- 95% efficiency in converting CO_2 to methane via biological hydrogenation with no additional energy inputs (powered by renewables).
- All carbon from anaerobic digestion feedstock is converted to fuel gas, significantly increasing biomass carbon utilization.
- Produces carbon-negative biofuels by utilizing carbon that would otherwise remain unconverted in conventional systems.
- Energy efficiency improves by 63% for energy output relative to initial feedstock (BE2).

FP3 (Syngas Biomethanation):

Key Outcomes:

- 90% conversion efficiency of pyrolysis bio-syngas to methane.
- Biomethanation process requires limited additional energy.
- Biomass resource utilization improves by ~17%, and energy efficiency increases by 64%.
- Produces carbon-negative biofuels powered by renewable energy.

FP4 (Biochar Production from Pyrolysis):

Key Outcomes:

- Produces biochar as the primary carbon-based product, capturing and storing 23 kg of carbon per 100 kg feedstock.
- Optimized pyrolysis enhances biochar properties (e.g., high surface area for soil and agronomic benefits).
- Energy efficiency increases by 23% (BE1) and 20% (BE2) while achieving effective carbon storage.

FP5 (Microbial Electrolysis Cell Integration in Anaerobic Digestion):

Key Outcomes:

- Reduces CO_2 in biogas by 20–50% and increases methane production by >20%.
- Total energy output doubles compared to anaerobic digestion alone, with a 400% increase in energy output relative to MEC energy input.
- Enhances COD removal by >10%, improving overall process efficiency and stability.
- Achieves a 25–30% reduction in CO_2 content in biogas output compared to conventional systems.