ADVANCED CHEMICALS PRODUCTION FROM BIOGENIC CO_2 EMISSIONS

FOR CIRCULAR BIO-BASED INDUSTRIES

WP 1 – "Definition of the full value chain and process requirements"

D1.1 – "Design Thinking Session Manual and materials for CO2SMOS"

Organisation name of lead contractor for this deliverable: RINA Consulting S.p.A.

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Disclaimer

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Abbreviations and Acronyms

2,3-BDO	2,3- butanediol
BBI	Bio-Based Industries
BTEX	Bencene, Toluene, Ethilene, Xilene
CCU	Carbon Capture and Utilisation
CO_2	Carbon dioxide
CO2SMOS project	Advanced chemicals production from biogenic CO_2 emissions for circular bio-based industries
EU	European Union
GDPR	General Data Protection Regulation
HCA	Hydroxycarboxylic acids
LcDCAs	Long chain dicarboyxylic acids
mcl-PHA	Medium long chain polyhydroxyalcanoate
PHB	Polyhydroxybutyrate
PX	Para - xylene
R&D	Research and Development
RTO	Research and technology organisation
WP	Work Package

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Executive summary

This document represents the Deliverable D1.1 “Design Thinking Session Manual and materials for CO2SMOS”, the first deliverable of the CO2SMOS project, developed in WP1. It aims to **establish materials and approach** to facilitate collections of insights/feedback from potential end-users (both demonstrators and stakeholders) to drive CO2SMOS R&D Activities in terms of CO2SMOS process development and design.

Objective:

Development and presentation of the methodology to be used to define stakeholders’ and CO2SMOS user cases’ requirements and specifications and to characterize the industrial vision regarding circularity and regenerative capacity of the biogenic CO_2 emissions into added value-chemicals, to preliminiary estimate the circularity and regenerative capacity potential of the industrial value chains developed in CO2SMOS.

Target:

The target of the document is to engage both potential industries / BBI stakeholders / end-users and internal usercases of the consortium. The CO2SMOS user cases and all profiles identified as potential end-users or "key players" with interest in CO2SMOS results will be invited to participate in the webinars and surveys. The identification of these external stakeholders had already begun in the proposal phase of the CO2SMOS project and has been implemented in Section 1.2 of this document. This identification was made by CARTIF, supported by CO2VE as WP Dissemination leader.

Methodology:

First, an initial identification of stakeholders’ profiles was carried out to set the ground for the methodology development. it is important to target the audience to have the maximum return on the established activities.

Therefore, based on this, a first launch webinar will be organized at the beginning of September, where the CO2SMOS project, its objectives and industrial processes will be presented by the consortium. Through real-time pools, first opinions and feedback from the audience abour project objectives will be collected from the webinars attendees and they will be invited immediately afterwards to participate in a more structured online survey.

The first draft of this survey can be found in Section 1.1.6. It will be finalised focusing on the point of view of the stakeholders through the design thinking method. Questions are designed to identify the CO2SMOS platform of technologies features and characteristics and to understand its potential extrapolation to different industrial sectors and their CO_2 emissions. Most of them are single/multiple choice to facilitate quick yet detailed answers and to allow comparisons between industrial processes. The respondents will be able to attach documents for further information and/or clarifications.

In order to have a clear idea of the opinions of all the experts in the sector, a second questionnaire will be organized, which will be discussed through face-to-face interviews with the project end uses partners (NVMT, AVNT NADIR) via more structured questionnaires.

Finally, a final webinar will be organized in mid-October, where the results of the survey andof the questionnaire will be presented to be validated via again “Live polls”. The results will contribute to mapping the possible industrial sectors for CO2SMOS application.

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Distribution:

The webinars and the first survey will be forwarded online to external stakeholders, using the social channels of the individual project partners, waiting for the official social channels of the CO2SMOS project to be ready, or by contacting directly by email the networks/partners that eachconsortium members has. The aim is to involve the best respondents for each sector and ensure a good feedback ratio.

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1 Introduction

This report - Deliverable 1.1 "*Design Thinking Session Manual and materials for CO2SMOS*" - is a public document produced in the framework of the CO2SMOS project. It relates to work conducted under WP1 "*Definition of the full value chain and process requirements*", and more specifically under Task 1.1 "*Elicitation of stakeholders' requirements and market needs*". Part of the activities described in this D1.1, are also attributable to Task 1.6 "*Case studies definitions*". In this section, the aim of both the CO2SMOS project and this deliverable are sequentially presented in Sections 1.1.1 and 1.1.2, respectively.

1.1 Aim

1.1.1 CO2SMOS Objectives

Global energy consumption has soared due to population growth and industrialization. In Europe, several green sources (biogas, bioethanol and other fermentation processes, solid biomass combustion) generate a significant amount of CO_2, estimated that 506.7 Mt/y biogenic CO_2 are currently produced, which is almost seven times the amount of current European industrial CO_2 demand.

In this context, the recycling and conversion of this CO_2 obtained from biobased processes using biomass as main feedstock in the production process is of strategic importance for the future of European bio-based industries (BBIs), as it offers a broad range of alternatives that will help transition from today´s fossil-based economy to a more resource efficient and resilient economy.

Biorefinery industries are in a unique position to lead the way in turning CO_2 emissions into added-value chemicals due to their intrinsic keenness towards innovation and their potential to transform their biogenic CO_2 waste streams into bio-based chemicals that can be integrated within their own processes in a circular way.

In this context, CO2SMOS aims to boost the development of a set of innovative cost competitive CO_2 conversion technologies (gas/liquid fermentation–biorefinery processes, intensified electrocatalytic processes and biobased/organic catalysed processes) to transform biogenic CO_2 emissions produced by bio-based industries (e.g., in fermentation processes) into a set a of high added-value chemicals with direct use as intermediates for bio-based products within the BBI's value chain.

The project will allow production of seven added-value chemicals and polymers (polyhydroxyalkanoates (mcl-PHA and PHB), 2,3-butanediol (2,3-BDO), long chain dicarboxylic acids C16-C18 (LcDCAs), BTEX and para-xylene (PX), cyclic carbonates and hydroxycarboxylic acids (HCAs)) from the primary conversion of CO_2 into two platform bulk chemicals (syngas and acetate).

These molecules will be validated as renewable CO_2 -based commodities for the formulation of high-performance biopolymers and renewable chemicals. The five breakthrough technologies involved in CO2SMOS will ensure low energy use (< 50 kWh/kg of CO_2 -based chemical), low production cost (< 1.75 €/kg), high product yield (up to 68% the ideal yield) and an outstanding GHG-abatement potential (avoiding of up to 10 additional kg of CO_2 per each

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kg used as feedstock), which will contribute to the sustainability and cost competitiveness of the integrated conversion processes. Integration of CO2SMOS concept in existing and emerging biorefineries (supported by Scale Up and Replication plans) will contribute to expand the business portfolio and strengthen the economic base of the sector.

The proposed technologies will be tested and validated from lab (TRL 3-4) to pilot scale (TRL 5), and the obtained molecules will be validated into final applications for the formulation of high-performance biopolymers renewable chemicals.

A campaign to assess social acceptance of CO2SMOS solutions and to promote awareness of their environmental, social and economic benefits is also foreseen. The consortium counts on academic, RTO and industrial partners with two major actors in the biorefinery sector.

1.1.2 Deliverable Objectives

This document aims to **establish materials and approach** to facilitate collections of insights/feedback from stakeholders and project end-users to drive CO2SMOS R&D Activities.

Furthermore, it also wants to collect the first information/feedback of CO2SMOS user cases, as a preparatory activity for Task 1.6.

As part of of Task 1.1, this methodology aims to perform the analysis and definition of the stakeholders' (technology providers, feedstock suppliers, refineries, fuel traders, final end-users, etc.) requirements and specifications has to be performed, emphasizing the expected benefits from the CO2SMOS CO_2-to-Chemicals Platform concept.

It also wants to pre-characterize the industrial vision regarding circularity and regenerative capacity of the biogenic CO_2 emissions into added value-chemicals. It is a preliminary activity within Task 1.6 to estimate the circularity and regenerative capacity potential of the industrial value chains developed in CO2SMOS. Inspired by current industrial use cases visions and EU policies, RINA and CARTIF will lead the definition of a procedure focused on the industrial vision and the Circularity and Regenerative capacity assessment.

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2 Elaboration of CO2SMOS approach

2.1 Preliminary Identification of Stakeholders Profiles

In order to achieve the established GHG reduction targets without risking competitiveness of the EU industry, it is essential to develop technologies that allow cost-effective CO_2 conversion into high-added value products, thus coupling environmental protection and economic growth.

The fundamental aim of CO2SMOS Project is to contribute to reduce CO_2 emissions from the bio-based industries by developing breakthrough and cost-effective routes to produce high added value chemicals to develop an integrated process with zero or negative greenhouse gas emissions supporting the diversification and techno-economic sustainability of the base of bio-based industries, and its potential replicability to other sectors.

Before launching the webinars and the survey, it has been necessary to understand the existence and state of the art of the technologies involved in the project and the expected progress beyond the state of the art that will be achieved within the project. The technologies presented in CO2SMOS project are based in a circular bioeconomy concept to cover all the stages of the full value chain: from the biofeedstock suppliers and CO_2-emitter industry (i.e., bio-based industries that produce biogenic CO_2), to the industrial potential end-users, in particular renewable chemicals & biopolymer sectors. In this context specific technology developers (biotechnology, co-electrocatalysis and catalytic/electrochemical processes) have a key role in the project. A brief description of the CO2SMOS aimed technologies are described as follows:

- **Primary conversion technologies, from CO_2 to bulk chemicals:** CO2SMOS that includes two alternative technologies: gas fermentation of **CO_2 to bio-acetate** (**Tech #1**), and co-electrolysis of **CO_2 and water to syngas** (**Tech #2**).

- **Final conversion technologies from CO_2-based intermediates to end products, addressing:** thermocatalytic conversion of CO_2 to cyclic carbonates (**Tech #3**), liquid fermentation of acetate to PHA, PHB, LcDCAs and 2,3-BDO (**Tech #4**), gas fermentation of syngas to 2,3-BDO (**Tech #1.2**); and d) catalytic conversion of syngas BTEX and PX (**Tech #5**).

All the resources involved in these conversion technologies are renewable, including **biogenic CO_2**, **renewable electricity** (for Tech #2 and Tech #5), and **biomass by-products** for Tech #2.2, and Tech #3. In addition, the final products obtained using these technologies are valuable intermediates of the biopolymers and renewable chemicals sector.

Each of the technologies are explains as follows:

Technology #1 Advanced gas-fermentation process. Gas-fermentation technology is a disruptive technology that take advantage of the biotechnology and bioengineering tools to convert gaseous feedstocks such as carbon monoxide (CO), carbon dioxide (CO_2), syngas, methane (CH_4), or biogas, into platform chemicals.

CO2SMOS Project will develop the conversion of CO_2/H_2 and $CO_2/CO/H_2$ (green syngas) streams into acetate and other C4 key bulk-chemicals (2,3-BDO). These processes are further described as follows:

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I. Tech #1.1: ***Transformation of CO_2/H_2 into acetate***. *A. woodii* and *M. thermoacetica* will be used to convert **CO_2** as a carbon source and **H_2** as energy source into **bio-acetate** to the culture media. Thanks to engineering tools and metabolic models it is possible to develop robust engineered strains to produce acetate at industrial scale using CO_2 obtained from upgraded industrial biogenic CO_2 emissions produced directly by the BBIs and H_2 produced by water electrolysis (using HT-PEM). As important innovative point, the bio-acetate produced in this process will be used as a carbon source to replace conventional **sugars as a substrate for the fermentation processes** to obtain the aimed added-value bio-based chemicals (**Tech#4**).

II. Tech #1.2: ***Transformation of green syngas ($CO_2/CO/H_2$) into C2 and C4 compounds***. Syngas is key material/ennergy verctor that can be transformed into many different industrial compounds. In CO2SMOS Project, an innovative process is proposed base on gas-fermentation processes to produce added-value chemicals. In particular, the aim of this technology is to develop new engineered strain able to produce specifically **acetate** or **2,3-BDO using the green syngas** (10-30% CO_2, 40-60% CO and 20-30% H_2) **produced by electrochemical transformation of CO_2** (**Tech#2**).

Technology #2: Electrocatalytic conversion of CO_2/H_2O into green syngas and added-value chemicals. Two complementary approaches have been considered to research a develop two innovatives technologies base on co-electroysis technologies:

I. Tech# 2.1: ***Electrocatalytic reactor for direct syngas production from CO_2 and H_2O:*** *based on* Electrocatalytic reduction of CO_2 to syngas will be conducted in an intensified planar electrochemical membrane reactor.

II. Tech #2.2 ***PCEC for simultaneous polyols oxidation and CO_2/H_2O conversion into syngas and HCAs*:** CO2SMOS also proposes a novel paired electrolysis process to generate value-added chemicals at both electrodes: the co-reduction of CO_2 and H_2O evolution at the cathode produces syngas and, simultaneously, a selective oxidation of bio-based glycols to the value-added HCAs in the anode.

Technology #3: Chemical conversion of CO2 by organic/bio catalysts into cyclic carbonates. This technology is based on heterogeneous and reusable organic catalysts that permits to obtain 100% bio-based cyclic carbonates. In this sense, aliphatic polycarbonates have gained importance as "green and more ecologycal" polymers due to their good biodegradability and biocompatibility. In addition, CO_2 can be used as an interesting bio-based building block in preparing aliphatic polycarbonates with low carbon footprints.

Technology #4: Advanced aerobic liquid-fermentation for synthesis of high-added value chemicals. Following up with the results of gas fermentation technology (***Tech#1***), the CO_2-derived bio-acetate can be used as carbon source by many microorganisms and so that, becoming a cost-competitive process with traditional carbon sources (glucose, sucrose, starch) for industrial fermentations. In conclusión, CO_2-based bio-acetate can be considered as a **key substrate or "building block"** for a biotechnological platform to produce a significant list of valuable intermediates and commodities widely used in the chemical industry (fine chemical, polymer, etc.) and also in food or other BBIs. CO2SMOS proposes the use of CO_2-derived acetate as a key-starting material to be transformed in a **second stage** by means of **aerobic liquid-phase fermentations** into high added-value chemicals.

Technology #5: CMR for syngas conversion to BTEX and PX. One-step conversion of syngas into BTEX and PX is propose by means of catalytic-membrane-reactor (CMR) combining catalytic conversion of syngas to BTEX with a ceramic membrane-based separation, combining metallic

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oxides to produce specific intermediates from syngas with a zeolite to *in-situ* transform, via acid catalysis, the intermediates into aromatics.

As a summary, the CO2SMOS project aims to develop a breakthrough route to produce high added value chemicals from bio-based industrial CO_2 emissions and renewable resources, through a disruptive technology combining intensified chemical conversions (electrocatalytic and membrane reactors) and innovative biotechnological processes (cascade fermentations and organic/biocatalysts).

These targeted molecules will be used as renewable commodity materials for the processes and applications selected by the bio-based industries in CO2SMOS consortium (Novamont, Avantium & Nadir), with a view to displace their current fossil-derived commodities in end-products and applications in i**ntermediate products** for the formulation of **high-performance biopolymers and renewable chemicals**.

Last, CO2SMOS project aims to optimize the performance of the CO_2 conversion processes and the purity of high added-value chemicals studying yield and costs in relevant industrial pilot plants. Industrial partners will be also involved in a market analysis and business plans for the developed products.

New business models will be introduced covering the whole value chain, from the targeted CO_2 emitters –focused on bio-based industries- to the potential end users allocated in the bio-based sector, aimed at renewable chemicals/polymers and bio-based products manufacturers, in general.

This analysis was preliminarily made in the phase of the CO2SMOS proposal, and a first result can be found in the Grant Agreement.

The analysis was fundamental to profile the industrial processes of interest for the project and consequently to outline some specific profiles as potential end-users or "key players" with interest in CO2SMOS results.

A detailed a list of **profiles** identified as potential **end-users or "key players"** is below:

- Potential applications and supply of biogenic CO_2 as a carbon source for CO2SMOS technologies
- Potential applications and supply of bio-feedstock as a raw material for CO2SMOS bio-based processes and products
- Biotechnological solutions for converting CO_2 into added-value chemicals
- Electrochemical solutions for converting CO_2 into added-value chemicals
- Organic-catalyst based solutions for converting CO_2 into added-value chemicals
- Full value chain integration and overall business models development from CO_2-to-end user bioproductos and applications in Renewable Chemicals/Biopolymers sector
- Full value chain integration and overall business models development from CO_2-to-end user bioproductos and applications in Agro-food sector
- Full value chain integration and overall business models development from CO_2-to-end user bioproductos and applications in Food & Beverage sector
- Full value chain integration and overall business models development from CO_2-to-end user bioproductos and applications in Personal care and Cosmetic sector

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Instead, the short list below is meant to identify the **potential industries** / **BBI's end-users**:

- Biogenic CO_2 producer with potential applications as a carbon source for CO2SMOS technologies
- Bio-feedstock supplier as a raw material for bio-based processes and products
- Bio-based industry focused on bioproducts development and as end-user of CO2SMOS technologies

All the profiles listed above will be the main guests and actors of the metophology described in the following Section 2.2.

2.2 Methodology development

In order to achieve the goal of the deliverable, it was decided to identify an agile and collaborative method, in order to collect the industrial vision, past experiences and requirements from stakeholders and opinions/key points regarding the circularity and the CO2SMOS Project technologies and processes.

To this end, RINA, in collaboration with CARTIF and the consortium, will organize two webinars and two surveys:

- **a launch webinar event**
- **a survey for external stakeholders**
- **a guided questionnaire with face-to-face meetings with the project partner user cases**
- **a final webinar event**

During the launch webinar, the consortium will be pleased to present the CO2SMOS project to the audience, detailing the objectives and processes that will be considered for the production of the seven added-value molecules. The audience will be actively involved and will be asked to participate through simple real-time polls (based on a Design Thinking approach), thus leaving them room to launch keywords and opinions. Thanks to this, the first interesting feedbacks and industrial requirements will be collected.

This event is titled "**CO2SMOS: Biogenic CO2 emissions in innovative chemicals for bio-based industries**" and will be organized on September 15, 2021. It will last about an hour and will start at 9:00 CEST.

The agenda is the following:

TABLE 2.1 AGENDA FOR CO2SMOS LAUNCH WEBINAR EVENT

Agenda		
9 – 9.05	Introduction	Fabiola Raccataglia, RINA Consulting S.p.A.
9.05 – 9.15	Driver of the project: CO_2 valorisation and EU policy framework and perspective	Anastasios Perimenis, CO_2 Value Europe
9.15 – 9.30	Presentation of the project	Raúl Piñero, CARTIF Center of Technology
9.30 – 9.40	Presentation of one of our demosite	Novamont S.p.A / Avantium BV
9.40 – 9.50	Presentation of stakeholders' activities and survey	Miriam Lorenzo, HERA Fabiola Roccataglia, RINA Consulting S.p.A.
9.50 – 10	Final discussion and Q&A	

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The agenda was defined in cooperation with the event' speakers and HERA, WP1 Leader.

The link to register and then join the webinar is the following:

https://register.gotowebinar.com/register/3735733009027457803?source=mass+mailing

Supported by CO2VE, Dissemination Leader, this launch event will be disseminated thanks to a communication campaign. CO2VE will send the invitation email to all its members (78 members including large companies, SMEs, Universities and RTOs involved in CCU) and to its newsletter distribution list, which includes a much larger reach. All CO2SMOS partners will send the invitation emails to their potentially interested contacts/stakeholders. Moreover, banners have also been prepared for Twitter and LinkedIn. The banners will be published along a short text explaining the objective of the event and the registration link.

FIGURE 2.1 LINDEKIN BANNER FOR CO2SMOS LAUNCH WEBINAR

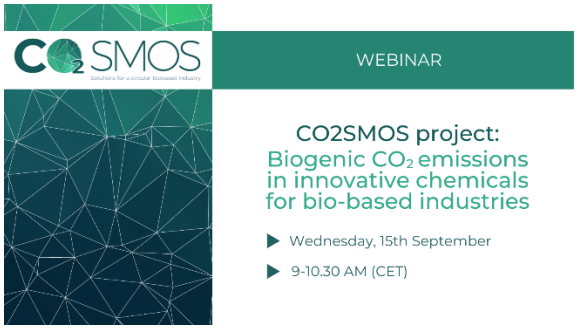

FIGURE 2.2 TWITTER BANNER FOR CO2SMOS LAUNCH WEBINAR

After this first event, a survey will be published online for external stakeholders, both for those who will have the opportunity to be part of the audience of the first webinar, and for those who will be interested to the project. In Section 1.1.6, it is possible to find a first draft of the survey, which will be finalized on the basis of the answers/feedback that will be collected during the first webinar.

The general objective of the survey will be to profile the industrial processes currently existing on the market, to identify the requirements and potential solutions that can solve the barriers and to understand how the industrial processes involved in CO2SMOS can be exploited.

To get a complete overview, a second internal survey will be organized for CO2SMOS' user cases. They will be managed personally by RINA together with CARTIF with dedicated face-to-face interviews. From these interested comparisons with them, RINA will be able to complete the survey on behalf of the partners, who will be asked to verify the answers already filled in and validate them.

Finally, the final webinar will be launched in the first half of October 2021, where the consortium will be happy to publicly present the consolidated data of the survey and ask the audience if they agree with these. Also in this event, the Design Thinking approach and the use

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of real-time polls will be used to collect audience feedback. This latest webinair will be key to validating the survey results.

This agile process will be held between September and October 2021 so that all results will be integrated into D1.2, led by CARTIF.

2.2.1 Design Thinking Approach

As anticipated in the previous section, the consortium will collect insights/feedback from the audience during the lanch and the final webinars. For this, the consortium will want to apply a Design Thinking Approach.

The common challenges that will be addressed during the sessions are described by the next questions:

"In order to emphas the expected benefits from the CO2SMOS CO2-to-Chemicals Platform concept, which are the industrial stakeholders' requirements and specifications?"

"In order to preliminary estimate the circularity and regenerative capacity potential of the industrial value chains developed in CO2SMOS, how could the CO2SMOS innovative cost competitive CO_2 conversion technologies be integrated into existing industrial processes?"

Design thinking is a methodology that puts people, or the targeted stakeholder, in the centre of the problem that is intended to be solved. In this sense, the methodology proposes, colloquially speaking, that designers put themselves on the stakeholder's shoes in order to focus on understanding the real-life situations and the problem complexities that stakeholders face on a daily basis, and that probably are not the same circumstances that designers used to be involved on. By going in deep and defining complex problems, the Design Thinking methodology is a proven approach to generate innovative solutions that are a consequence of that complex understanding. The methodology is an iterative process composed by five stages: Empathize, Define, Ideate, Prototype and Test.

FIGURE 2.3 DESIGN THINKING APPROCH[1]

Due to COVID-19, unfortunately it will not be possible to use this methodology as it is in physical meetings, but the approach will be used by implementing real-time polling sessions.

[1] https://www.psycheatwork.com/il-design-thinking-2/

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The interesting things and the focal points that will emerge during the webinar sessions will be integrated to finalise the questions of the next phase of the methodology, the online survey for the external stakeholders.

As a result, the key parts and topics that defined the CO2SMOS project will be presented and covered. Also, better comprehension will be achieved about the point of view of the audience. The role-playing exercise will allow the consortium to better comprehend the needs and priorities of the stakeholders and, therefore, facilitated the design of the straightforward yet detailed set of inquiries.

2.3 CO2SMOS's survey for external stakeholders

2.3.1 Survey Purpose

This survey aims at supporting the analysis, within the CO2SMOS EU project, of the end users' requirements in order to identify the features and characteristics of CO2SMOS platform technologies, and to understand its potential extrapolation to different industrial sectors and their CO2 emissions. The goal is to collect specific information about the most interesting industries to identify a list of sectors, processes and stakeholders with potential interest in **CO2 emission valorisation**, as well as a list of challenges, requirements and potential solutions that can solve those barriers.

The results of this survey will contribute mapping the possible manufacturing sectors for CO2SMOS application in order to understand the exploitation and replication possibilities. The requirements will be measurable and will be expressed as relevant KPIs in the Task 1.4.

2.3.2 Data Protection

This Survey was developed with **MICROSOFT FORM**.

Microsoft Form processes Personal Data according to the following privacy policy: https://docs.microsoft.com/it-it/legal/gdpr

Microsoft Forms, part of the Office 365 Suite, is GDPR-compliant. Microsoft goal is to help global business customers manage compliance and avoid risk. Microsoft Forms allows users to quickly and easily create custom quizzes, surveys, questionnaires, registration forms, and more. The content in these forms, as well as end user information, remains in the direct control of administrators and end users. Microsoft processes data on behalf of customers to provide the requested service as set forth in Microsoft Online Services Terms.

In the PRIVACY AND CONFIDENTIALITY POLICY that will be included in the survey, it will explain how CO2SMOS Consortium handles your personal data and information collected through this questionnaire. Personal data is any information relating to an identified or identifiable person (e.g., name, surname, e-mail address or phone number). Information are your answer to the questionnaire.

CO2SMOS Consortium collects answers to this questionnaire and other relevant information voluntarily disclosed in the framework of WP1 to collect wishes and needs of the consortium

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partners. Data and information will be stored in an internal confidential repository and will be included in project reports in anonymized way. We aim to protect the personal and confidential data. CO2SMOS Consortium uses a variety of commercially available security technologies to protect your data.

CO2SMOS will not provide your personal data and information to any third party outside the consortium without your prior consent. Furthermore, any information collected via this questionnaire will be used only for CO2SMOS project purpose.

The respondent may opt out of the collection and processing of your personal data/collected information at any time. In addition, the respondent has the right to correct or delete data/information we hold about their institution.

You have the right to withdraw from the survey at any stage up to the point at which you click the submit button. At this point, your data will be collated with that of other participants.

The information you provide may contribute to research reports, research publications and/or conference presentations delivered by the CO2SMOS project team.

2.3.3 Draft of the Survey

*** Which type of organization do you belong to?**

- ○ Manufacturing sector/energy intensive industry
- ○ Energy service provider or energy related company
- ○ Technology provider
- ○ Standardization and certification body
- ○ Chemical and bio-chemical
- ○ Polymers and bio-polymers
- ○ Refinery and bio-refinery
- ○ Academia/R&D sector
- ○ Public authority
- ○ Bio-based industry: potential biogenic CO2 emitter
- ○ Bio-based industry: forestry pulp and paper
- ○ Bio-based industry: food and beverages
- ○ Bio-based industry: agriculture and agrofood
- ○ Waste management & valorization
- ○ Biomass provider and/or primary conversion industry (biofuel/bioenergy)
- ○ Other

  Please specify if “Other”

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* In which country is your organization located?

* What is the size of your organization?

- Small/Medium Enterprise
- Large Company
- RTOs
- Academia
- NGOs
- Public bodies

* What is your role in your organization?

- Technical department staff
- Top management
- Manufacturing Production Manager
- Energy Manager
- Finance Manager
- Sales Manager
- Researcher
- Data analyst
- Other

Please specify if “Other”

* In which sense CO_2 emissions affects your production/process/industry?

- Mainly from an environmental/image point of view
- Mainly from an economic point of view (carbon tax)
- Both from an environmental/image and economic point of view (Carbon tax)
- Other

Please specify if “Other”

* In your opinion, what are the barriers and constraints preventing your organisation to implement and deploy carbon capture and utilisation (CCU) solutions (multiple choice)

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- ☐ Lack of knowledge on the technology
- ☐ Technical difficulties to integrate CCU process in the overall industrial process
- ☐ Economic reasons (high CAPEX to implement CCU systems)
- ☐ Economic reasons (high OPEX in running CCU systems, e.g., cost of renewable energy and material)
- ☐ No local value chain for exploitation of the produced CO_2 based products
- ☐ No local availability of renewable energy
- ☐ CO_2 concentration of flue gas is too low
- ☐ Other

Please specify if "Other"

*** Do you have any on-going/planned investment on CCU?**

- ○ Yes
- ○ No

Please describe if YES

*** Do you have any on-going/planned investment on the production of bio-based products?**

- ○ Yes
- ○ No

Please describe if YES

CO2SMOS will develop a set a of high added-value chemicals with direct use as intermediates for bio-based products. The result is a toolbox combining intensified chemical conversions (electrocatalytic and membrane reactors) and innovative biotechnological solutions based on gas/liquid combined fermentation processes and organic/green-catalysts reaction processes, which allow versatile production, depending on the available resources and the targeted value chains, of seven different bio-based chemicals. How much are you aware/confident about…

(rate each choice from 1, not aware/confident at all, to 5, very much aware/confident)

*** possibilility to use bio-technoloical solutions in your process for CO_2 valorisation?**
1 to 5

*** possibilility to use catalytic solutions in your process for CO_2 valorisation?**
1 to 5

*** possibilility to use electro-catalytic solutions in your process for CO_2 valorisation?**
1 to 5

*** possibilility to use membrane-based solutions in your process for CO_2 capture and then valorisation?**
1 to 5

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*** What would you expect from a CCU process for your industrial process? To provide a relevant solution to...(put in order of priority)**

- ☐ ...reduce carbon emissions (and then taxes) for my processes
- ☐ ...improve the self-sustainability of the process valorising CO_2 for new products that could become raw material for my processes
- ☐ ... improve the competitiveness of the process valorising CO_2 for new products to be sold
- ☐ ...improve the social reputation of the manufacturing company and/or its products
- ☐ ...improve the company competitiveness
- ☐ Other

  Please specify if “Other”

*** Which could be the barriers for the CO2SMOS CCU installation? (multiple choices)**

- ☐ Carbon tax does not yet represent a big share of the manufacturing costs
- ☐ CAPEX/OPEX of such implementation and use
- ☐ Our products are not carbon intensive
- ☐ Lack of environmental sensibility of the company
- ☐ Health and Safety aspects that can prevent to install electro-chemical/chemicaò/bio-technological processes in the industrial area
- ☐ Interoperability with the existing process
- ☐ Staff not sufficiently trained to manage a new solution
- ☐ Commercial CCU technologies do not meet the parameters of efficiency, scalability and/or economical feasibility required to tackle a possible investment at large scale
- ☐ Other

  Please specify if “Other”

*** Who are, in your opinion, the most relevant industrial sectors/processes to be targeted by CO2SMOS Solutions? (multiple choice)**

- ☐ Oil and Gas and Refinery
- ☐ Chemical
- ☐ Waste inceneration plant and fossil-based power plant
- ☐ Pharma
- ☐ Ferilizers
- ☐ Feed and food

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☐ Other

Please specify if "Other"

If you wish, please provide any other further detail that you think can help us to improve our analysis.

2.4 CO2SMOS's questionnaire inside the Consortium

The following qauestionnaire is the techno-economic template will be used to collect the information from user cases in the CO2SMOS project for the analysis of the current plant and future potential business cases related to local CO2 production.

2.4.1 Description of the plant

In the first section of the questionnaire, RINA and CARTIF will kindly ask to the user cases to present their plant, providing also pictures and/or diagrams.

Please describe shortly your plant – please emphasize what are the CO2 emission points (combustion exhaust composition, CO2 produced by biomethane upgrade, CO2 produced by chemical processes etc.) and what is their source.
Please describe how you're targeting circularity and sustainability in your industry
Please describe which type of biogenic wastes (and a rough estimation) you're producing and how you're handling such wastes, maybe promoting strategies for valorisation of biogenic residues etc.
Please describe past actions you performed towards a reduction of CO2 emission of your plant.
Please include here a rough estimation of yearly CO2 produced by your plant.
Please include here a rough estimation of CO2 composition produced by your plant.

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Does your plant already treat and/or capture CO2? How? Please describe.
Which type of chemicals and fuels are you using in your industrial process? Can you provide a rough estimation per year?

2.4.2 End users experiences useful for CO2SMOS scope

According to the user cases experience, in this section we will kindly ask to present why they looked/are looking at CCU solutions.

Please describe here where/how you think you could valorise the bio-based products produced by the CO2SMOS project? (.....etc.)
Please describe if and where you have enough and adequate space to install an eventual upscaled CO2SMOS prototype as well as potential regulatory constraints you have to face there
Describe the potential that your plant would have by enhancing the CO2 emitted and by deploying CCU solutions.
Please describe the replication potential of the CO2SMOS system in your company (in other sites etc.) and potentially for the industrial sector of your industrial process
Please describe if in your country/region there are any incentives to use CCU solutions or to biogenic waste valorisation

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3 Next steps

The methodology described will be implemented between September 2021 and October 2021, in order to guarantee the correct collection of information to be included in D1.2 with deadline M6.

RINA will organize the two webinars on the GotoWebinar platform. The launch webinar will be held on September 15th, 2021. The date on which the second webinair will take place is still to be defined.

The survey for external stakeholder will be launched at the end of the first webinar and will be online for one month. After that, it will be closed to allow the analysis of the data. The results of the survey will be presented during the second webinair.

In parallel to the survey and before the second webinar, RINA with the support of CARTIF will interview the CO2SMOS user cases, in order to collect details and useful information to answer the questions of the questionnaire that was intended for them.

The outputs will be gathered during these activites will be an important starting point for the next Tasks, mainly Task 1.4 in which measurable requirements will be expressed as relevant KPIs and Task 1.6 in which the circularity and regenerative capacity potential of the industrial value chains developed in CO2SMOS will be further estimated.

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