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PUBLIC PERCEPTION AND BUSINESS MODELS JOINT EVENT

Organised by the Carbon Capture, Utilisation
and Storage (CCUS) & Alternative Fuels
Horizon 2020/Horizon Europe CLUSTER projects

Supported by CINEA - European Climate,
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REPORT



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PUBLIC PERCEPTION AND BUSINESS MODELS JOINT EVENT

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Speakers

Case Study – C4U

Vincent de Gooyert

Case Study – ACCSESS

Jose Alberto Sanchez Berbegal

Case Study –ConsenCUS

Zoe Morrison

Case Study – CaLby2030

Jose L. Oviedo

Case Study – PilotSTRATEGY and HERCCULES

Elisabeth Duetschke

Case Study – eCOCO2

Linda Engelmann

Case study - MOF4Air

Spyros Karytsas

Case Study - Sun-To-X

Jonas Pigeon

Case study – 3D

Lolita Troilo

Case Study – NEGEM and AURORA

David Reiner

CO2SMOS

Imke Haverkämper

CO2Fokus

Adriana Díaz

DigiMon & BioNET

Danny Otto

Case study – C4U

Hannah Galbraith-Olive

Case study – GICO

Enrico Bocci

Case study – 3D

Paula Coussy

Case study - VIVALDI

Jorge Senan Salinas and Elvira Serra

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1 Executive Summary

A Joint Workshop on Public Perception and Business Models, hosted by the European Climate, Infrastructure and Environment Executive Agency (CINEA) and showcasing real-world insights on the role of these two crucial factors for CCUS and Alternative Fuels Cluster Projects, was held in Brussels on the 14th of November 2023.

The workshop has been organised within the CINEA's "Carbon Capture, Utilisation and Storage (CCUS) & Alternative Fuels Horizon 2020/ Horizon Europe Cluster projects" as a cluster priority for all the projects involved. In fact, public perception and business models were recognised by the cluster projects as a priority because they are key to enabling innovative technologies and guiding policy makers' decisions at national and European Commission levels.

The aim of the workshop was to bring together people from the cluster projects dealing with public perception and business models with external stakeholders. This connection aimed to produce a series of actionable recommendations on how EU projects, employers and policy makers can play a pivotal role in making CCUS and Alternative fuels social acceptance a structured topic through tailor-made information, in which business models pave the way for implementation leading both to diffused trust and gain commitment of policy makers and which can be governed by a dedicated regulatory framework.

To this aim, the workshop was structured in two parts, each serving specific objectives and namely:

- **Session 1 - Public perception:** In this segment, a carefully curated selection of speakers representing diverse facets of the CCUS and Alternative Fuels industry and academia attentively shared the case study of their project, highlighting the relative context, the methodology followed, the replicability conditions of the results obtained and likely take-away hints for policy makers. This session was tailored to tackle the differences of contexts, with a special focus on the need for commitment of policy makers, who, driven by business models, can develop a regulatory framework over which trust is being built
- **Session 2 - Business models:** Building upon the narratives presented in the first session, the focus shifted to a comprehensive analysis of business models, with attention paid to market and regulatory gaps affecting the economic rollout. Specifics were depicted, with contextual details as well, with an emphasis on potential market growth opportunities.

With 20 selected Horizon projects and more than 50 key stakeholders involved in the audience, this joint workshop has represented an extraordinary opportunity to strongly impact both on the activities still to be implemented by the ongoing projects and the design of new projects at higher TRL (close to commercial scale). In addition, it was an excellent networking opportunity to build relationships with policymakers, industry experts and project representatives, thus facilitating collaboration, knowledge sharing, and future partnerships.

The workshop started with a welcome and setting of the scene by the Organisers and by Maria MORAGUES CANOVAS, Project Officer of CINEA and the referent of the "Carbon Capture, Utilisation and Storage (CCUS) & Alternative Fuels Horizon 2020/ Horizon Europe Cluster projects". It was followed by seventeen 10/15 minutes presentations given by representatives from the Horizon Cluster projects. After Q&A sessions, emerging issues were discussed in open debate sessions, and they were followed by a short wrap-up session where actions and recommendations were formalised.

Operative organization has been carried out by the coordinators of the CLEANKER and eCOCO2 projects. The objective of this report is to summarise the key messages that emerged from the discussions that the participants had during the Q&A sessions and the open debate session.

2 Agenda

Session 1: Public Perception	
Chair: Martina Fantini	
9:40 – 9:50	Case Study - C4U <i>Speaker: Vincent de Gooyert</i>
9:50 – 10:00	Case Study - ACCSESS <i>Speaker: Sanchez Berbegal, Jose Alberto</i>
10:00 – 10:10	Case Study - ConsenCUS <i>Speaker: Zoe Morrison</i>
10:10 – 10:20	Case Study - Calby2030 <i>Speaker: Jose L. Oviedo</i>
10:20 – 10:35	Case Study – PilotSTRATEGY and HERCCULES <i>Speaker: Elisabeth Duetschke</i>
10.35 – 10.45	Case Study – eCOCO2 <i>Speaker: Linda Engelmann</i>
10:45 – 10:55	Case study - MOF4Air <i>Speaker: Spyros Karytsas</i>
10:55-11:30	Coffee break
11:30 – 11:40	Case Study - Sun-To-X <i>Speaker: Jonas Pigeon</i>
11:40 – 11:50	Case study – 3D <i>Speaker: Lolita Troilo</i>
11:50 – 12:05	Case Study – NEGEM and AURORA <i>Speaker: David Reiner</i>
12:05 – 12:15	Case Study – CO2SMOS <i>Speaker: Imke Haverkämper</i>
12:15 – 12:25	Case study - CO2Fokus <i>Speaker: Adriana Díaz</i>
12:25 – 12:40	Case Study – DigiMon & BioNET <i>Speaker: Danny Otto</i>
12:40 – 12:55	Q&A
Session 2: Business Models	
Chair: Jose Serra	
14:00 – 14:10	Case study – C4U <i>Speaker: Hannah Galbraith-Olive</i>
14:10 – 14:20	Case study – GICO <i>Speaker: Chiara Iurlaro</i>
14:20 – 14:30	Case study – 3D <i>Speaker: Paula Coussy</i>
14:30 – 14:40	Case study - VIVALDI <i>Speaker: Jorge Senan Salinas (BETA Technological Center) and Elvira Serra (Isle Utilities)</i>
14:40 – 14:55	Q&A
14:55 – 15:15	Shortt break
15:15 – 15:30	Summary of issues emerging in case studies for Session 1 <i>Rapporteurs: Elisabeth Duetschke</i>
15:30 – 15:45	Summary of issues emerging in case studies for Session 2 <i>Rapporteurs: Enrico Bocci</i>
15:45 – 16:00	Formalization/agreeing on the major challenges Rapporteur: Laura Almar
16:00 – 16:10	Concluding remarks and greeting Speaker: Jose Serra and Martina Fantini



Figure 1: Speakers and organizers of the event

3 Biographies and talks

3.1 VINCENT DE GOOYERT

Dr. Vincent de Gooyert is Associate Professor in System Dynamics at Radboud University.

His research and teaching revolve around increasing understanding of, as well as intervening in, societal transformations towards sustainability.

Vincent is trained both as an engineer and as a sociologist, and his work often aims to transcend disciplines, using and contributing to methods on

- *stakeholder engagement,*
- *system dynamics, and*
- *socio-technical transitions.*



It is through investing that societal readiness will develop

Although it is well known that CCS faces technological, economic and societal challenges, how these challenges interact has received relative scarce attention. The C4U project aimed to address that gap by looking at the dynamic interactions between technological, economic and societal aspects, with the aim of clarifying enablers for and barriers to the implementation of CCS in the North Sea Port (NSP) industrial cluster, spanning an area in Belgium

and the Netherlands. The analysis is based on literature, interviews and structured focus groups. Facilitated by researchers, the stakeholder dialogue helped mapping the structure of the socio-technical system of CCS implementation. C4U project brought together expert stakeholders from industry, government and NGOs to build a model of the system dynamics of the implementation of CCS in the NSP industrial cluster, finding that enablers and barriers, such as costs, government's decisiveness and public support, are strongly interrelated. Even public support plays a key role in understanding how policies and business cases develop over time. To realize successful CCS implementation in the NSP, such interdependencies of societal and techno-economical elements need to be acknowledged. To make progress, societal elements such as engagement and public support should be considered equal, instead of secondary to techno-economical elements by decisionmakers. Societal readiness and CCS implementation co-evolve. Industry and policymakers cannot 'wait' until societal readiness is high enough to start investing because it is through investing that societal readiness will develop.

3.2 JOSE ALBERTO SANCHEZ BERBEGAL



Jose Alberto Sanchez B. is a Fraunhofer IAO Research Assistant, involved in the Project ACCCESS on CCUS citizen's public perception.

His research field interests comprehend:

- *Computational linguistics;*
- *AI;*
- *Social media.*

His presentation provides a summary of the public opinion towards Carbon Capture, Utilization, and Storage (CCUS) based on a survey and social media

60% of respondents are in favor of CCUS, while 19% are not in favor and 21% have no opinion

analysis. This project was carried out within the framework of Horizon 2020 ACCCESS (Providing access to cost-efficient, replicable, safe and flexible CCUS). The presentation provides information about the respondents and the data collection methods used, as well as the project baseline. According to the survey, 60% of respondents are in favor of CCUS, while 19% are not in favor and 21% have no opinion. The most chosen benefit of CCUS is reducing the environmental impact of energy production, while the most chosen concern is greenwashing. The social media sentiment towards CCUS shows that 43% are in favor, 52% are not in favor, and 5% have no opinion. The most chosen benefit on social media is reducing climate change risks, while the most chosen concern is greenwashing.

3.3 ZOE MORRISON

*As a social scientist based in Aberdeen Business School, Robert Gordon University, Scotland, **Zoe Morrison** works to further the application of business and management studies to policy driven change programmes. Her work aims to inform leadership and human resource management theory through understanding individual experiences of change, including changing expectations of work, careers and employment, and adoption and implementation of technological innovation.*



Outreach activities using lay language and interesting formats are important for community participation

Zoe highlights the main facts through the following points:

- There is a low awareness of CCUS technologies amongst the lay public, even where there are plans to implement it at scale;
- More context and location specific information are needed for the public to take a position;
- Uncertainty is recognised within expert communities, but not adequately communicated in a comprehensible/ meaningful way to the lay public;
- Complex transparency, e.g., what information is disclosed to the public, how the EU funds are used: it is important to remain within the boundaries of the research i.e. focusing on CCUS.

Community members found it problematic that they were not informed about the development of CCUS facilities in their area and some advocated for more outreach activities from the involved companies and authorities.

3.4 JOSE L. OVIEDO



José L. Oviedo Pro is PhD in Economics and associate research professor at CSIC, where he does his research work at the Institute of Marine Sciences of Andalusia (ICMAN). His main research lines focus on the econometric analysis of methodological and applied aspects of stated preferences methods and the conceptual developments and applications of ecosystem accounting in both terrestrial and marine environments. He has published more than 30 scientific papers in peer-reviewed journals in the field

The expected results will elucidate and help to overcome current societal

The project CaLby2030 focuses on TRL6 demonstration of the pioneering Calcium Looping (CaL) CO₂ capture systems using the well-established Circulating Fluidised Bed (CFB) technology to a state ready for large-scale commercial deployment in key high-emitting industries by 2030. Three CFB-CaL pilot plants across Europe will be developed for demonstration in three industry sectors: steel, cement and waste-to-energy and combined heat and power applications. The above challenge will be approached from a technology as well as a social point of view. The project will assess the social acceptability and preferences towards of large-scale CCS deployment in the case study of the biomass-fired power plant of La Pereda (Asturias, Spain). To this end, a survey to the Spanish general population will be implemented to apply the methodology of choice experiments. The application of this method in a hypothetical scenario of large-scale deployment of the CaL-based CCUS technology in La Pereda will allow to: (i) identify social drivers and barriers for CCUS acceptability; (ii) assess trade-offs between these drivers and barriers; and (iii) evaluate whether global benefits would compensate local risks associated to the implementation of this technology. The expected results will elucidate and help to overcome current societal barriers for the implementation of CCUS that could be extrapolated to other case studies.

3.5 ELISABETH DUETSCHKE

Head of the Competence Center Energy Policy and Energy Markets, Coordinator of Business Unit Actors and Social Acceptance in the Transformation of the Energy System.

Elisabeth Duetschke, studied psychology, business administration and marketing and holds a PhD in social sciences. At Fraunhofer ISI she has coordinated several national and European research projects. Individual and societal perspectives on a changing energy system are the focus of her research. Currently she is one of the co-chairs of the working group on public perception of CCUS that was initiated by the EC.



Exploration, engagement, monitoring and reflection are integral components

engagement, monitoring and reflection are integral components. Exploration involves developing an understanding of regional perceptions of CCS pathways in order to identify potential challenges and opportunities. Appropriate engagement strategies are critical to building trust and tapping into regional knowledge to enable mutual learning. Ongoing monitoring helps to assess changing regional perceptions and adapt as necessary. Reflecting on the expectations of those involved in the project will help to develop a communication strategy - possibly making different roles visible. It is also important to recognise that local perceptions are influenced by a variety of factors, some of which are beyond the control of projects, including policy direction at regional, national and European level.

The EU-funded Strategy CCUS, PilotSTRATEGY and HERCCULES projects are currently attempting to develop CCS at a regional level. All projects have a strong component of social science research and societal engagement and participation. This presentation will outline the rationale for these activities. Exploration,

3.6 LINDA ENGELMANN



Linda Engelmann works at the Chair of Communication Science at RWTH Aachen University as a social scientist.

Her research focus is studying the perception and acceptance of renewable technologies, mainly in the area of public perception and acceptance of carbon removal and subsequent storage or utilization.

In the eCOCO₂ project (Direct electrocatalytic conversion of CO₂ into chemical energy carriers in a co-ionic membrane reactor) the focus of the social studies lies on empirically assessing societal perception and acceptance of the eCOCO₂ technology for CO₂ conversion. The study of acceptance and perception is a crucial part of technology development as a lack thereof can pose critical barriers to the deployment of a technology or product. Previous research on public perception of Carbon Capture and Utilization (CCU) indicates a rather positive perception of CCU, with the public perceiving both benefits and barriers in connection to CCU. For CO₂-based jet fuel, results are rather scarce, although singular studies indicate a positive perception of this specific CO₂-based product in comparison to others. To investigate among other things, which factors impact acceptance of the fuel, and how the production steps are perceived, that are necessary to produce CO₂-based fuel, qualitative (interviews) and quantitative methods (online surveys) were used to collect data from the public and technical experts. From these data we can conclude that there are national differences, e.g., for public acceptance and behavioral intention of CO₂-based jet fuel, as highest levels of acceptance were evident for Spanish participants, followed by German and Dutch people, with the lowest (but still positive) levels in case of Norwegians. When it comes to predictors of fuel acceptance, benefit perception was by far the biggest impacting factor, followed by risk perceptions and environmental awareness. For the perception of individual production steps, transport was found to be perceived the least positive, while separation, purification, and conversion were evaluated rather positively (with exception to costs). From a policy perspective we can conclude from these results that international differences in acceptance of CO₂-based jet fuels suggest a need for nationally or regionally tailored policies. **Emphasizing benefits and addressing risk perceptions is also vital to gain public trust and adoption.**

Emphasizing benefits and addressing risk perceptions is also vital to gain public trust and adoption

3.7 SPYROS KARYTSAS

***Dr. Spyridon Karytsas;** Economist, MSc in Sustainable Development, Ph.D. in Economics and Sustainable Development. Collaborating with the RES Division of the Center for Renewable Energy Sources and Saving (CRESS) since 2009 on the implementation of projects related to Renewable Energy Sources, CO2 Capture & Storage, and Circular Economy.*



MOF4AIR project explores the social acceptance of CCS infrastructure. In this respect, a quantitative social survey was performed on the general public (performed during January-February 2022; including 1775 participants from the seven MOF4AIR European countries).

CCS knowledge is affected by environmental attitudes and demographics

CCS knowledge is statistically significantly affected mainly by sociodemographic characteristics and environmental attitude, while perceived acceptance is affected by sociodemographic characteristics; knowledge; perceived positive and negative impacts; trust of stakeholders and institutions; and procedural and distributional justice. In addition, a qualitative study was performed on CCS experts (performed during January-March 2022; including 25 experts from the seven MOF4AIR European countries). The scope of the

qualitative study was to provide a set of recommendations towards social acceptance of CCS projects, which -however - should be treated with caution, as the 25 interviewees do not represent a random or representative proportion neither of the general population nor of all CCS experts. The findings of the interviews include recommendations concerning stakeholder engagement (provision of information, collaboration with local communities, channels of communication, the role of public involvement), the provision of compensatory benefits to local communities, the identification of the main technical and safety specifications contributing to CCS projects' social acceptance, and the benefits that the utilization of captured CO₂ could offer to the social acceptance of CCS infrastructure.

3.8 JONAS PIGEON



Jonas Pigeon is a research engineer in social science at the ENGIE Lab CRIGEN since 2017. His work focuses on new energy technology techno-scientific promises & expectations, just transition, as well as on the implementation of new technological innovations in public spaces. Before working at ENGIE Lab CRIGEN he did a PhD in Spatial Planning on Techno-scientific promises of Carbon Capture & Storage in the Seine river valley.

Sun To X project combines Photo-electrocatalysis (PEC) and Hydrosil production to produce and store hydrogen effortlessly. All these technologies have a low TRL (3-4) and have yet to be demonstrated together, and the main goal of the project is to reach a TRL 5 for the combination of this technological system. Regarding this context of early-stage technology, managing a social acceptance survey induces an adaptation of the

methodological approach to collect relevant insights. Science and Technology Studies literature demonstrated that to consider and analyze the innovation process, researchers need to consider with the same analytical perspective the technological and socio-economic or political dimensions. Indeed, technologies and society are co-produced.

Regarding early-stage technological innovation, researchers from Science and Technologies Studies choose to consider Technological expectations they define as follows: "Technological expectations can more specifically be described as real-time representations of future technological situations and capabilities" , according to Borup et. Al, these expectations are performatives. In explaining what could be done in the future with a technological system, technology promoters both succeed in gathering funding and sketch relevant technological pathways and use cases. Expectations are expressed in discourses, roadmaps, or all communication supports. Therefore, analyzing these narratives is a relevant approach to characterize these expectations.

***Technological expectations
can more specifically be
described as real-time
representations of future
technological situations and
capabilities***

3.9 LOLITA TROILO

***Lolita Troïlo** is a Social Geographer specialized on social movements and debates surrounding oil and climate change.*

She has recently joined the Social R&D team at TotalEnergies in Paris-Saclay as a Social Engineer.



Her project seeks to identify stakeholders, analyze how local socio-economic context influences their perceptions, and assess how proposals from the Civil Exploration Committee (CEC) for public dialogue foster mutual understanding and acceptance of the project approach. A two-phased methodology is employed, involving stakeholder mapping/strategic recommendation and formation of the CEC - to co-

construct themes and dialogue modalities. Despite Dunkirk's historical favorability towards industrial projects, variations in stance among politicians, NGOs, and the public are observed, and opposition remains possible if negative impacts occur. The CEC has achieved notable success, demonstrating effectiveness in engagement and addressing diverse viewpoints, though a need for participant diversity is acknowledged. The 3D project enjoys general acceptance, with stakeholders expressing a desire for additional information on several aspects, including its integration into broader socio-economic and climate change contexts. Key recommendations encompass clarifying roles of project proponents, ensuring transparent communication of risks, promoting inclusive engagement, and maintaining dialogue to address debates on the legitimacy of CCS.

Key recommendations encompass clarifying roles of project proponents

3.10 DAVID REINER



David M. Reiner is Professor of Technology Policy at Judge Business School, University of Cambridge. He is also Assistant Director of the Energy Policy Research Group at Cambridge University. David serves on the CCUS Council, which is chaired by the UK Energy Minister and is also on the £210m Advisory Board of the UKRI Industrial Decarbonisation Challenge. His research focuses on the political economy of energy and climate change using both large-scale and small-scale public and stakeholder surveys, economic, policy and historical analysis.

Need for long-term certainty in regulatory frameworks, industrial clusters

Two European projects are described: Negem (Quantifying and Deploying Responsible Negative Emissions) funded under Horizon 2020 (1 June 2020–31 May 2024) and AURORA (Accelerated deployment of integrated CCUS chains based on solvent capture technology) funded under Horizon Europe (1 Jan 2023 – 30 June 2026). Cambridge University is leading the social science components of both projects using a variety of different approaches to better understand public and stakeholder considerations. Each project involves carbon capture and storage (CCS) in different ways – Negem focuses on negative emissions and so two of the main carbon dioxide removal options are bioenergy with carbon capture and storage (BECCS) and direct air capture and carbon storage (DACCS), which are examined alongside other CDR options using stakeholder interviews, focus groups, expert elicitations and representative public surveys in multiple EU member states. Negem benefits from industrial partners (Drax and Stockholm Exergi) and NGOs (Bellona and Carbon Market Watch) that have facilitated introductions and dissemination of surveys. The expert elicitations used to derive learning curves (expected cost reductions) for BECCS and DACCS can also be used by the modelling partners at PIK, VTT, ICL and ETHZ. The stakeholder interviews on the business case highlighted the need for long-term certainty in regulatory frameworks, industrial clusters & incentives for radical change, found significant differences in opinion across geography and sector and our workshops highlighted how the frames used to discuss NETPs can influence stakeholders' overall perceptions. Although AURORA has only just started, the project places social, political and economic considerations as key elements in exploring pathways to industrial decarbonisation particularly focused on those locations where the industrial partners' plants are located (Port of Antwerp and Greece).

3.11 IMKE HAVERKAMPER

Imke Haverkämper is a research assistant at the Human-Computer Interaction Center at RWTH Aachen University who is pursuing a PhD in Communication Science. She specializes in the public's perception and acceptance of carbon capture and utilization/storage (CCU/CCS) technologies and resulting products.



A universal need for information underscores the importance of honest risk communication to build trust

The CO₂SMOS project aims to convert CO₂ emissions into added-valuable chemicals for sustainable bioproducts, utilizing biotechnological and electrochemical processes along with renewable sources. RWTH Aachen University assesses public perception and acceptance of these innovations. Carbon Capture and Utilization (CCU) technologies are often complex and unfamiliar to the public. Thus, it is

necessary to assess public perception early on in the development process, enabling the derivation of user-specific adoption guidelines. The research questions for this study include understanding the barriers and motivators related to CCU acceptance, examining how context-related factors influence consumer decisions regarding the usage of CCU-based products, and analyzing if consumers from different European countries differ in their acceptance assessments of CCU-based products. Thus, census-representative samples from Germany, Norway, Poland, and Spain are examined using a mixed-methods approach, combining an exploratory focus group study and a quantitative online survey. Key insights indicate that initial knowledge about CCU is low, but acceptance is generally high. Perceived CCU benefits include a positive environmental impact and fossil fuel conservation, though uncertainties regarding factual sustainability persist. Health compatibility is identified as the primary concern in acceptance decisions. While there are slight differences between product assessments, overall trends hold among the evaluated products. As the midway point of the project approaches, the derivation of adopter profiles and tailored communication strategies are still pending. However, a universal need for information underscores the importance of honest risk communication to build trust, especially considering country-specific differences.

3.12 ADRIANA DIAZ



Dr. Adriana Diaz holds Bachelor and MSc. degrees in Chemical Engineering from the Simón Bolívar University in Venezuela, and worked as a process engineer for the National oil Company (PDVSA), pharmaceutical and engineering firms in Venezuela. She holds a PhD in Environmental Engineering from Northeastern University (US). She worked as post-doctoral research fellow at the Material Systems Laboratory of the Massachusetts Institute of Technology, and as project assistant at the ETH Zurich. Since 2009 Dr. Díaz works at the ECODESIGN company, developing strategies for product improvements and ecodesign by means of Life Cycle Assessment of products and services.

The project CO₂Fokus is advancing CO₂ conversion, by developing a cutting-edge technology to directly convert industrial CO₂ into Dimethyl Ether (DME) by using 3D printed multichannel reactors and solid oxide electrolyzer in an industrial environment. DME is an added-value gas used in the chemical industry and in the energy sector, which can also be used as low emission and efficient fuel, especially for heavy duty vehicles. The social acceptance of a technology is usually assessed after its complete development or even long after its market rollout. In the CO₂Fokus project social acceptance is an integral component of technology development. This allows a timely understanding of public perceptions, to adequately prepare and steer information and communication strategies, and to support the creation of a strong value chain. In CO₂Fokus, a comprehensive literature review has been completed on the public perception of CCU, followed by with a customized survey completed by a large sample of 500 participants. The analysis of the responses, spontaneous thoughts, and concerns was clustered into themes, such as those related to health and safety, environmental impact and costs, which helped frame the communication, dissemination, and exploitation activities of the project. This study also enriches the information exchange with EU CCUS projects on current practices to assess societal acceptance of similar technologies.

The social acceptance of a technology is usually assessed after its complete development or even long after its market rollout.

3.13 DANNY OTTO

Dr. Danny Otto is a postdoctoral researcher at the Helmholtz Centre for Environmental Research, where he focuses on studying

- 1 public perceptions of negative emission technologies and CO2 storage,
- 2 as well as trust and environmental justice.



The research goal of this project is to develop a cost effective, human centred and smart digital monitoring system for CO2 storage projects. Public perception was relevant in this context in two ways:

In order to develop a human centred monitoring system it is important to understand needs, concerns and wishes of publics and stakeholders

1. It is so far unclear how CO2 storage monitoring and the public perception of CCS are related,
2. In order to develop a human centred monitoring system it is important to understand needs, concerns and wishes of publics and stakeholders. It is also shown how these questions were studied with an internationally comparative approach (Norway, Netherlands, Germany, Greece) and a mixed methods design (Interviews, surveys, workshops) . Therefore the most important take-aways and policy implications are summarized

The second part of the presentation is focused on the project BioNET-Multi-level assessment of bio-based negative emission technologies. Since many authoritative scientific assessments (e.g. IPCC) see Carbon dioxide removal (CDR) as crucial to achieve climate goals, the principal aim happens to be the contribution to a research gap by studying the regional implementation of negative emission technologies. Amongst these technologies is bioenergy with CCS. With a participatory and spatially explicit research approach, 3 focus regions in Germany are compared to understand challenges and benefits associated with BECCS. The most important policy implications relate to improving regulations for CDR (especially BECCS).

3.14 HANNAH GALBRAITH-OLIVE



Hannah Galbraith-Olive is a Consulting Senior Associate in the Sustainable Energy Solutions team at ERM. She works on a range of projects for public and private clients in the carbon capture utilization and storage (CCUS) and industrial decarbonization sectors. Before joining ERM, Hannah completed her PhD in Earth Sciences at the University of Cambridge and an MSci from Imperial College London in Geophysics.

The aim is to develop a viable business model for industrial plants, focussing on revenue generation, ownership structures and capital financing

As part of the C4U Project, ERM is exploring a wide range of long-term business models for CCUS. Currently, there are not sufficient drivers for widespread CCS adoption for industrial plants across Europe and beyond. The context of our study is shortlisting and developing business models that could drive long-term integration of CCUS in industrial clusters, using the North Sea Port and the Iron & Steel sector as examples. The aim of this study is to develop a viable business model for industrial plants, focussing on revenue generation, ownership structures and capital financing. By testing each of these components against the levers and complexities which impact CCUS adoption, a short-list of viable CCUS business models will

be developed. This will identify the most critical barriers to CCUS adoption at both national and European level and highlight how policymakers and investors can best support long-term CCUS deployment.

3.15 ENRICO BOCCI

Enrico Bocci, researcher and associate professor at Marconi University of Rome, PhD in Gasification and Fuel Cells at Sapienza University of Rome.

Coordinator both of H2020 BLAZE Biomass Low cost Advanced Zero Emission gasifier-fuel cell and GICO Gasification Integrated with CO2 capture and conversion projects.



The GICO project targets to create an integrated system and, in parallel, tests materials and technologies that can be exploited also individually.

GICO aims at developing small to medium scale residual biomass multigeneration plants (2-20 t/day and 500-5.000 kWe) able to overcome the main barriers that prevent renewable energy technologies from forming the backbone of the energy system. GICO develops new materials (CO₂ capture sorbents; high temperature inorganic removal sorbents; catalytic filter candles; membranes for oxygen separation and methanol production) and technologies (Hydrothermal Carbonization; Sorption Enhanced Gasification; Hot Gas Conditioning; Carbon Capture, Storage and Use; power-to-gas via Plasma conversion). The GICO project targets to create an integrated system and, in parallel, tests materials and technologies that can be exploited also individually. GICO's main success factor is in

its modularity and simultaneous production of four energy carriers (bio-syngas, electricity, heat, bio-methanol) with reuse of waste CO₂, starting from low-cost residual biomass of local origin. The business plan methodology is centred on three points: identify competitors, identify technical advantages, translate it in price gap vs competition. Due to the changing market situation and the TRL level of GICO's technologies, particular attention needs to be done on the following critical assumptions: change of energy price, change of competitors prices, increase of competitor performances, lower GICO modules performances outcome vs expectations.

3.16 PAULA COUSSY



Paula Coussy, is a research scientist graduated of the Paris I Panthéon-Sorbonne University in Environmental Economics and Assistant Professor in economics of IFP School since 2000.

She is working on economic issues related to the use of energy and its impacts on the environment.

In particular, Paula Coussy has more than ten years of experience in European CCS projects (SOCECO2, ECCO, COCATE, CASTOR, DYNAMIS, Strategy CCUS, 3D) and is involved in many CCS platforms (Zero Emission).

The gap in legislation are on MRV methodology for the full CCS chain on regulatory and voluntary carbon markets, on CO2 transboundary regulation and the Art. 6 Paris Agreement.

The 3D project aims to prove that CO2 capture technology DMX™ can be operated in a steel plant and demonstrate technologies to TRL 7 in a complete value chain of Carbon Capture and Storage.

- The main economic risks are related to uncertainties on energy price, European Union Allowances (EUAs) forecasts, and the efficiency of the Cross Border Adjustment Mechanism (CBAM).
- The gaps in legislation are on MRV methodology for the full CCS chain on regulatory and voluntary carbon markets, on CO2 transboundary regulation and the Art. 6 Paris Agreement.
- DMX™ is designed to capture in Dunkirk 1 Mt/year of CO2 and 3 concepts of transport and offshore storage in North Sea is studying. The transport and storage are a service purchased by 3D project at 70€/ (purchased service)
- The EUAs long term forecast starts with 80€ in 2026 and ends at 184 €/tCO2 in 2046. The final cost estimation of 3D project (CAPEX and OPEX) is expected end 2024.
- The economic analysis is conducted with the Innovation Fund rules methodology - call 3 December 2022 and the time horizon validity of the study is 2025-2045
- At very first glance (need to be fixed in 2024): around 20% of total costs are due to capital expenditure, 80 % of total costs are due to operating costs. Impact of the Transport and storage operating costs of 3D CCS chain.
- The economics are highly impacted by : the Innovation Fund Grant rules, on the forecast prices (European inflation rate, energy price, transport and storage cost services, EUAs, and also the capability to add an additional premium price for decarbonated HRC (Hot Rolled Coil), the decline of the free allowances and the implementation of the Cross Border Adjustment Mechanism (from 2026).

3.17 JORGE SENAN SALINAS & ELVIRA SERRA BIGAS

Dr. Jorge Senán-Salinas has a PhD from the University of Alcalá with a thesis about the application of the Life Cycle Assessment in the transition to the Circular Economy of membrane technology. He is currently focused on the prospective sustainability analysis (techno-economic, environmental, and social) of emerging technologies in the context of transition to the Circular Economy at BETA Technology Centre involved in three European projects such as VIVALDI in which he is analysing Carbon Capture for Utilization (CCU) technologies at early stages.

Dr. Elvira Serra-Bigas has a PhD in Industrial Engineering from the University of Girona. She is Principal Consultant in Isle Utilities (ISLE), an independent technology and innovation consultancy with a specific focus to accelerate innovation in the water sector and beyond. She is involved in different European funded projects where ISLE acts as Innovation Partner. In the VIVALDI project she is leading the work on exploitation, market assessment and development of business strategies including post-project roadmaps and time to market strategies to facilitate rapid market access of the solutions demonstrated during the project.



VIVALDI proposes an integrated novel solution for the conversion of biogenic CO₂ into four added-value organic acids (OAs) which can re-enter the biorefinery value chains. CO₂ is first captured and converted to methanol or formic acid (C1 products) through electrochemical technologies. Then, target OAs are bio-produced with the C1 products and the nutrients, also recovered from industrial wastewater. After downstream processing, OAs will be industrially validated to ensure that they meet the requirements of the end-users. The VIVALDI consortium is formed by 16 partners, including the main actors along the value chain of the project: biobased industries, technology developers, end-users and knowledge hubs with specific expertise in policy, sustainability and market adoption of innovations.

The presentation focuses on the approach that the VIVALDI project has taken to assess prospectively the techno-economic feasibility of the VIVALDI solutions considering the circular, environmental, economic, and social dimensions as well as market opportunities.

Prospective analysis of the VIVALDI solutions takes into consideration several criteria such as the business models designed for the project, potential industrial symbiosis opportunities and existing and upcoming policy frameworks. LCC results allowed the definition of potential business models as well as the role of the CO₂ Capture at early stages of the research. Furthermore, CO₂ status (waste or co-product) influences LCA methodologies and the final sustainability of the VIVALDI solutions. Finally, the presentation concludes with a summary of the opportunities and barriers identified at the project's current stage for the market adoption of VIVALDI solutions.

The social acceptance of a technology is usually assessed after its complete development or even after its market rollout.

4 Key messages

This section provides a summary and highlights the key messages extracted from the speaker's speeches and the subsequent discussions taken place during the final stage of the workshop among all the participants, with the main purpose of exchanging insights on best practices and proposing actionable measures to advance progress within their organizations, EU projects, among policy makers and in society at large.

- Throughout all the sessions, one of the subjects that generated a lot of interest was the enabling strategy to provide the most consistent amount of groups with details and information **in order to create knowledge and trust**. Some technologies, such as those related to CCUS, need to be deeply explained to the public and the policy makers to be highly prioritized on the social and political agenda. Presentations showed that there are no significant advancements in terms of societal debate or financial mechanisms to enable technological adoption. All of the findings indicate that the situation is still unclear and that a sizable portion of society is not participating in the discussions. The audience discussed and agreed on the fact that effective stakeholder communication can boost public confidence, particularly when the message is perceived as being in line with the interests of those involved.
- Some researchers have also looked into how past attitudes affect the way the public perceives CCUS and alternative fuel technologies and approaches, even though the connections between these elements have not been proven. These findings emphasize how crucial it is to consider the different factors that influence people's perceptions.
- Policymakers and industry stakeholders could benefit from the dialogue with the public to learn about their goals and concerns in order to support effective public engagement initiatives.
- **Business models** can represent a relevant tool in awareness-building since the social acceptance of a technology is usually assessed after its complete development or even long after its market rollout.
- An additional reflective insight gleaned from the speakers' discussions that we consider important takeaways from the workshop is related to the **legal and regulatory framework**. This is particularly relevant for the CCUS worldwide, which will require the creation of strong legal and regulatory frameworks that offer efficient CCUS activity stewardship and oversight. The regulatory frameworks that currently govern industrial activities, such as those pertaining to oil and gas, waste management, industrial site health, safety, environmental considerations, property rights, and transportation, will frequently cover issues relating to CO₂ capture, transport, and use. In contrast to CO₂ storage, these areas might only need minor or no changes to current frameworks; however, governments should review and remove any potential obstacles to the deployment of CCUS by reviewing and revising current domestic and international frameworks. The primary goal of these frameworks will be to guarantee the long-term, safe, and secure storage of CO₂ in deep geological formations. In addition, CCUS laws and regulations need to define the rights and obligations of CCUS stakeholders, protect the environment and public health, and establish a legal framework for creating, using, and managing CO₂ storage resources.

In conclusion, innovative technologies need the support of public opinion and strong business models, factors that are of utmost importance for national and European Commission policymakers' decisions and that give concrete support for regulatory and legal issues.

5 Conclusions, recommendations, and learnings

For the first time, representatives of “Carbon Capture, Utilisation and Storage (CCUS) & Alternative Fuels Horizon 2020/ Horizon Europe Cluster projects” in different regions and Members States, together with project coordinators, policy makers, exploitation experts and relevant stakeholders gathered to discuss and explore concrete synergies and actions to be implemented to advance knowledge and trust in the field of CCUS and alternative fuels.

The talks and the discussion highlighted several issues responsible for the misperception of CCUS technologies. Building from the discussion in the workshop, we have tried to identify practical recommendations adoptable by all types of institutions to facilitate awareness and social acceptance. Some of the main elements recognised are listed below:

Barriers

- Lack of lay language information
- Perception of CCUS as not linked to the context
- Absence of a structured and univoque regulatory framework
- Absence of a structured and univoque methodology
- Lack of proper communication channels
- Lack of synergic cross-cutting working groups

Enablers

- Networking
- Building knowledge and trust through communication and dissemination
- Workshop sectorization
- Take-away key messages

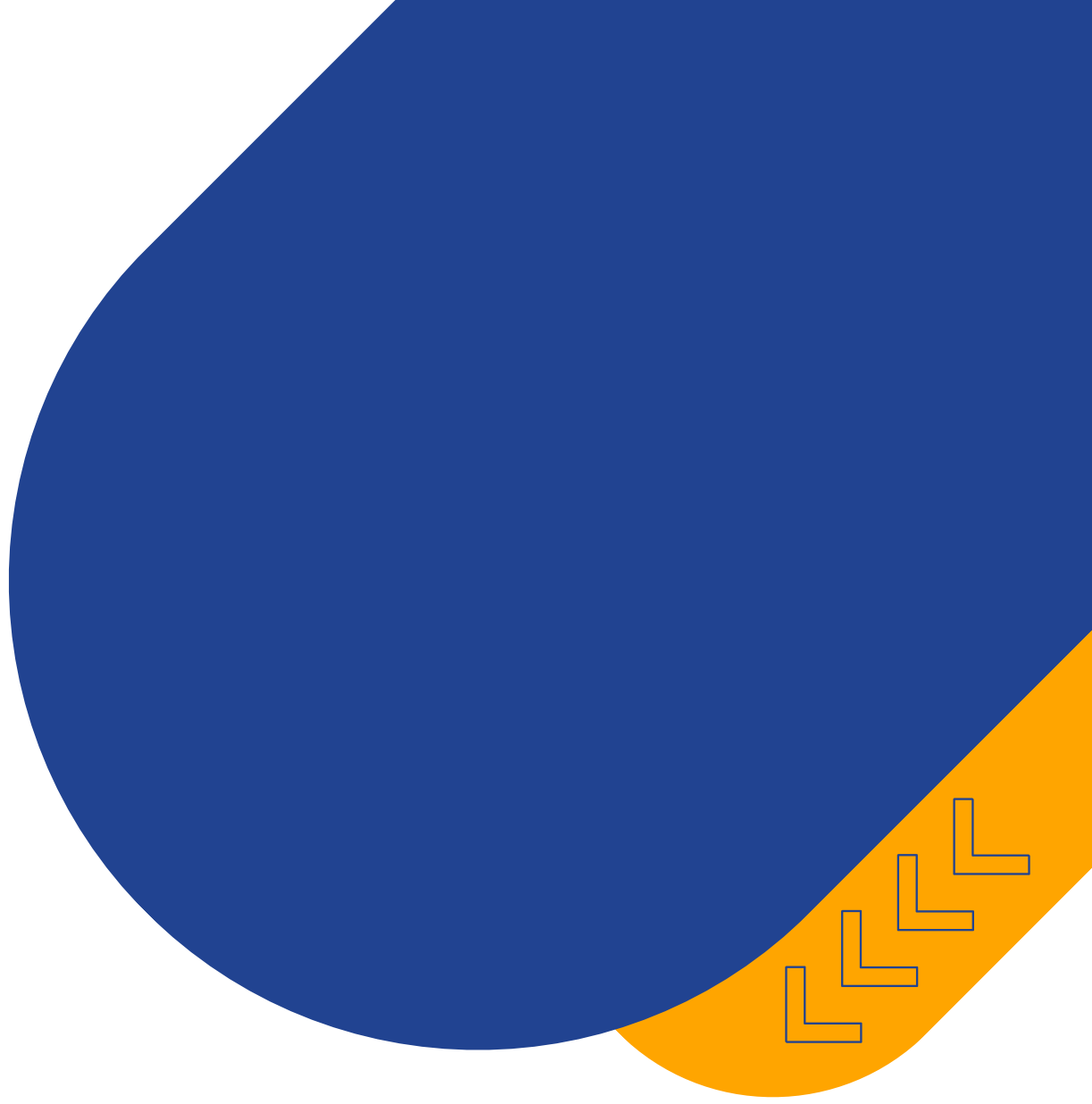
In the table below, we have listed some suggestions, highlighting in which areas we think they can benefit.

RECOMMENDATION	ENABLER	BARRIER
Making communication and dissemination as open and as transparent as possible following open access practices. E.g. developing games (cards) for different target groups with guidelines to be replicated in different environments.	Building knowledge and trust through communication and dissemination And Take-away key messages	Lack of lay language information Lack of proper communication channels
Networking among the projects joining the same call with the aim of working together to get robust conclusions to avoid any bias in methodology and analysis	Networking	Absence of a structured and univoque regulatory framework
When organizing conferences and all kinds of events, think about dedicated sessions on Public perception and Business Models that make clear assumptions, methodology followed, and results gained. Working group parallel sessions could be implemented.	Workshop sectorization	Absence of a structured and univoque methodology
Re-launch SPiCC Wiki for Social Perception in Carbon Capture Project developed by RWTH-Aachen. The platform is formed by different pages related to CCUS projects with the aim of exchanging and expand existing knowledge	Networking and dissemination	Lack of synergic cross-cutting working groups
Elisabeth DUETSCHKE (from Fraunhofer) is deeply involved in several networking activities	Networking and dissemination	Lack of synergic cross-cutting working groups

on public perception, and she invited the projects to contact her to be involved in the loop.		
Position paper on business models	Take-away key messages	Perception of CCUS as not linked to the context and Absence of a structured and univoque regulatory framework

Participants expressed interest in other workshops in the autumn of 2024 to discuss the current state and plan ahead. The next format could be a 2-days workshop, one dedicated to public perception and the second one on business models also integrating legal and regulatory aspects.

Action on this will be discussed in the coming "Carbon Capture, Utilisation and Storage (CCUS) & Alternative Fuels Horizon 2020/ Horizon Europe Cluster projects" internal meeting, making use of bullet point surveys.



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