CCU and Bio-CCU technologies: social and economic sustainability

BIOCON-CO_2

BIOCON-CO_2 Final Symposium

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Laboratory of Steam Boilers and Thermal Plants, NTUA

- > 30 years Experience in power plant operations, energy conversion & industrial process analysis, modelling & optimization
- International collaborations with universities, major industrial partners
- > 100 Research Projects, total funding > 15 Million €
- Bilateral collaborations w. Greek industry for technical studies, measurements, licensing, environmental & economic feasibility studies

Role in BIOCON-CO_2:

- Process modelling
- Techno-economic assessment
- Environmental assessment
- Socioeconomic evaluation

} of the developed Bio-CCU concepts

- **WP8 Leader**

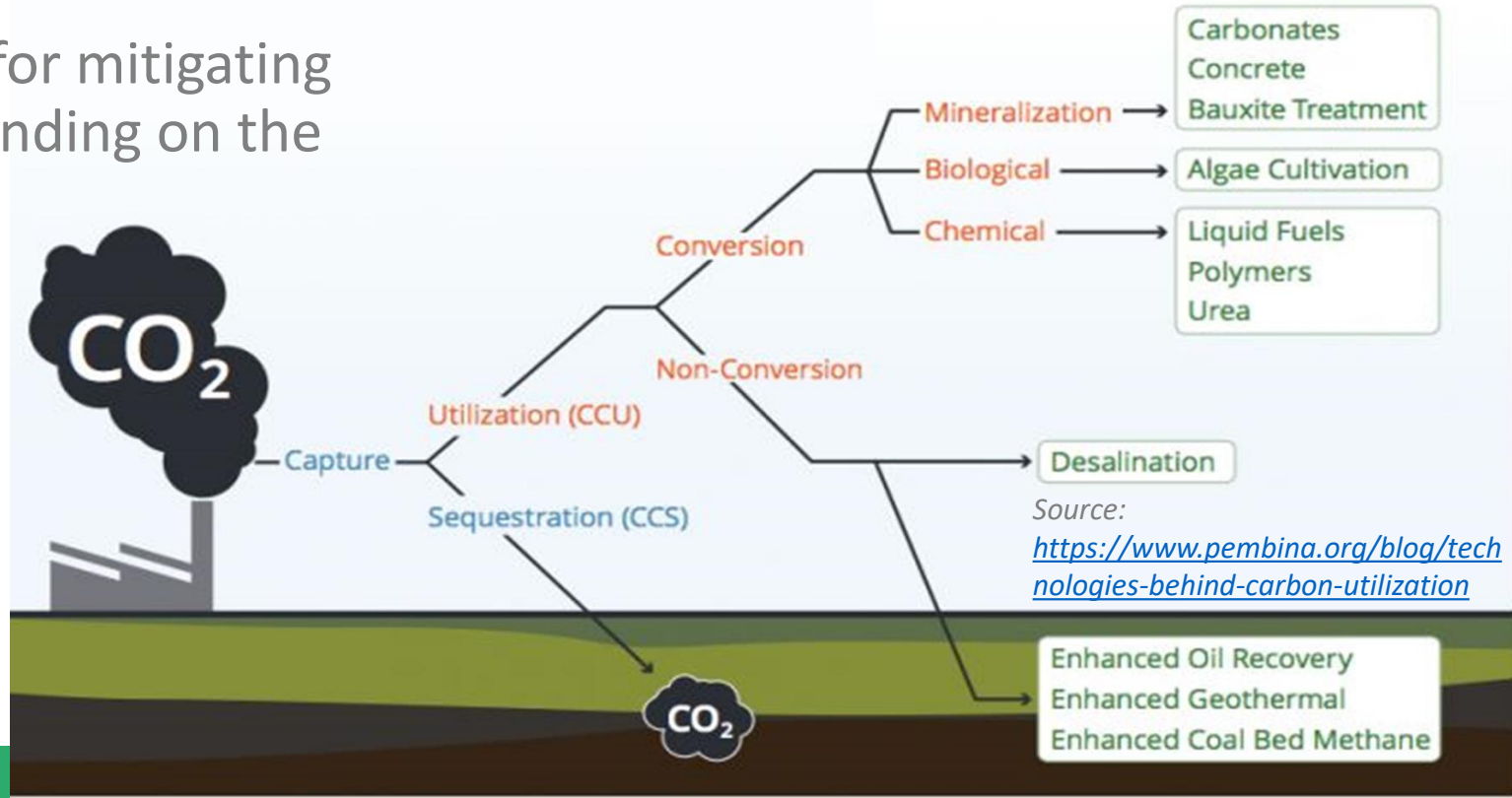
Contents

- Introduction
- Social sustainability aspects
- Economic sustainability assessment
- BIOCON-CO_2 expert survey

Introduction: main CCUS pathways

- EU climate law: target upgraded (12/2020) to **55% GHG emission decrease by 2030**
- A versatile toolkit is required to achieve this ambitious target – not one silver bullet exists!
- CCUS technologies will be required for mitigating **281-606 Mt of CO_2 until 2050**, depending on the scenario (IPCC 1.5°C report)
- CCS: permanently storing CO_2 to refrain it from re-entering the atmosphere
- CCU: converting **CO_2 from enemy into ally!**

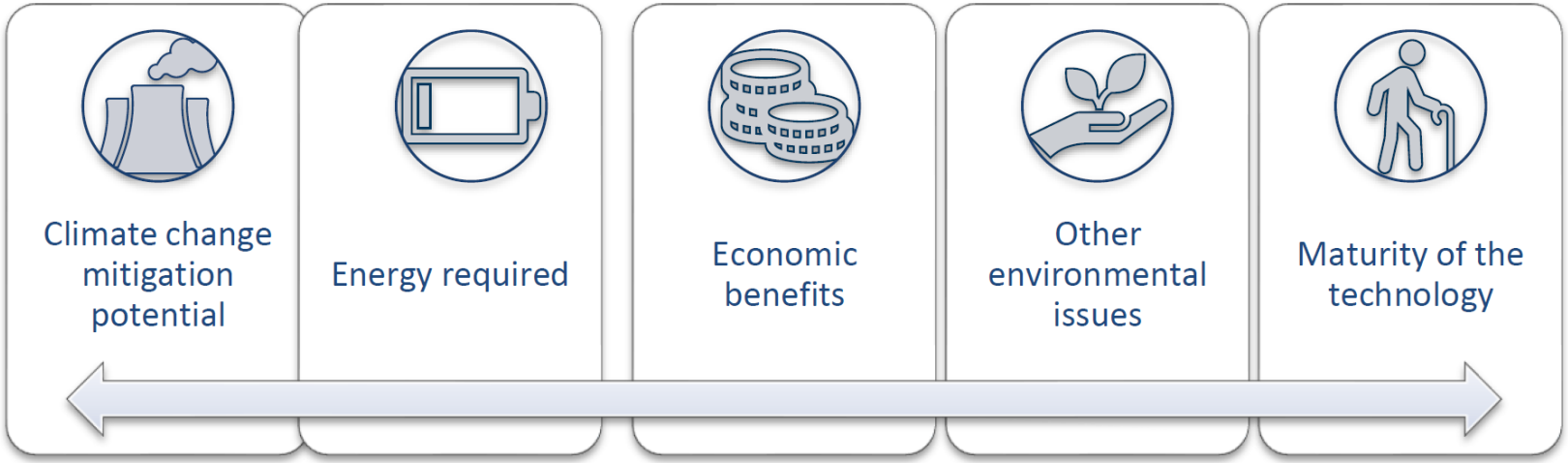
Source: https://theconversation.com/the-earth-needs-multiple-methods-for-removing-co2-from-the-air-to-avert-worst-of-climate-change-121479



Source: https://www.pembina.org/blog/technologies-behind-carbon-utilization

Sustainability criteria for CCU technologies

BIOCON-CO_2



Source: https://www.eccsel.org/news/eccselerate-reports/eccselerate-report-d13/

UN 2030 Sustainable Development Goals

(Source: https://sdgs.un.org/goals)

LSBTP

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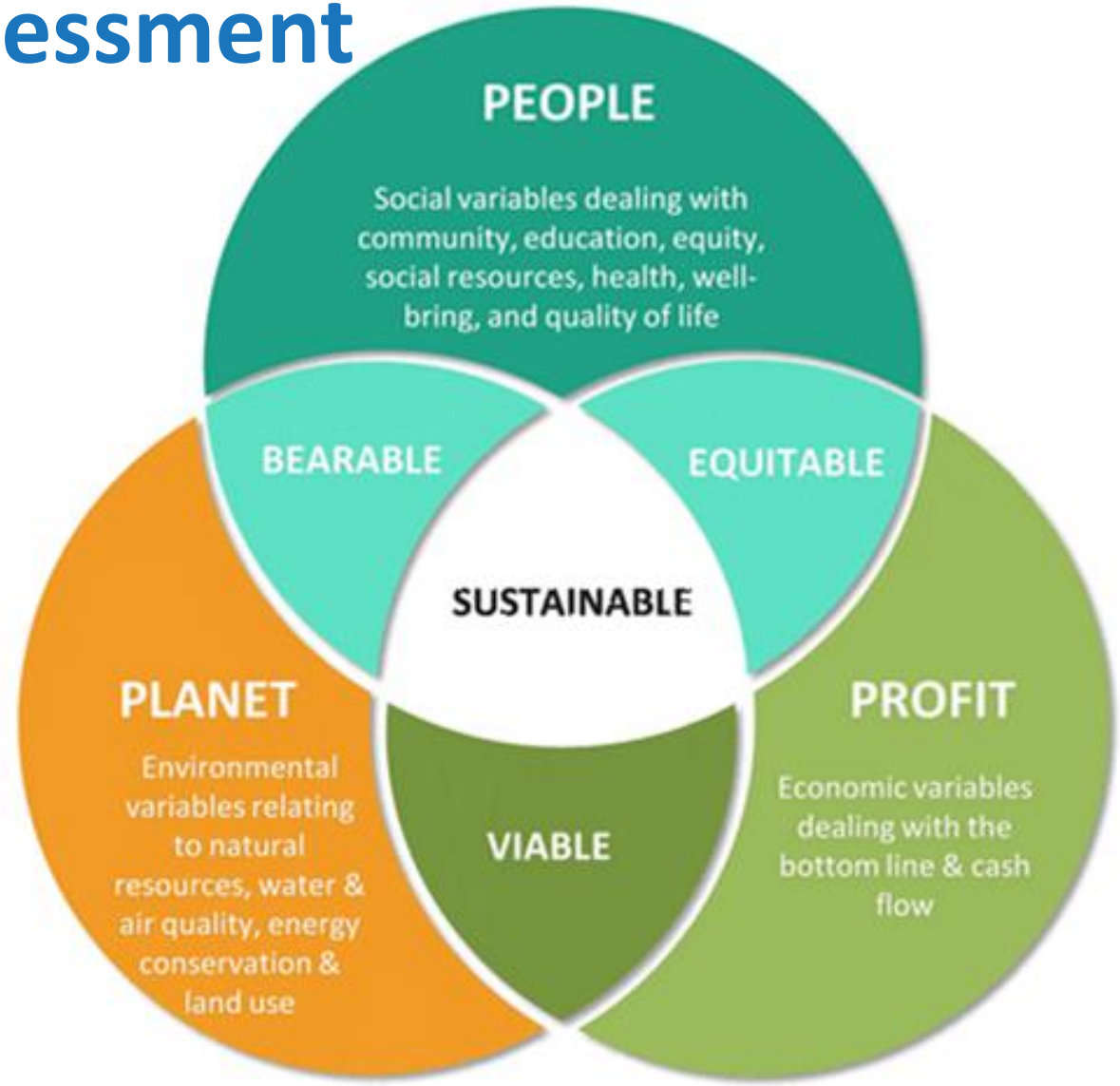
Integrated sustainability assessment



BIOCON-CO_2

- The “triple bottom line” approach

Socioeconomic impact: selection of indicators

- Overview of relevant literature & social impact assessment methodologies
- Selected indicators:

- Contribution to national GDP
- Job creation, income security
- Promotion of health and safety in workplaces
- Potential improvements in health and safety compared to both fossil-sourced and bio-based alternatives
- Potential for combination with bio-based production processes in integrated biorefineries

- Functionality and efficiency compared to both fossil-sourced and bio-based alternatives
- Reduction of dependency on non-renewable resource imports
- Avoidance of child labour
- Achieving labour equity
- Continuous education of workforce in areas affected by industry transitions
- Avoidance of international conflicts

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Economic sustainability aspects

- State of the art: operating or recently operated non-biological CO_2-to-alcohol pilot & demonstration plants

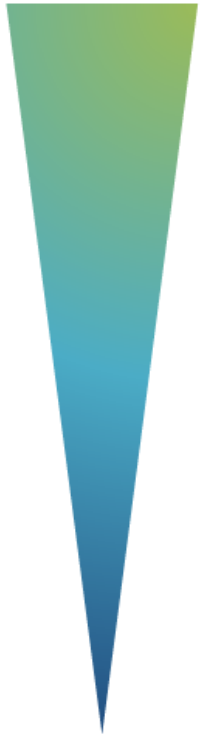
Organization	Location	Nameplate Capacity (tpa)	Temperature (°C)	Pressure (Psi)
Lurgi AG	Frankfurt, Germany	unpublished[a]	260	870
NIRE and RITE	Kyoto, Japan	18	250	725
CAMERE process	Seoul, South Korea	73	250	400
Mitsui Chemicals	Osaka, Japan	100	250	725
Carbon Recycling International	Grindavik, Iceland	4,000	225	725
Air Company	Brooklyn, NY, USA	32[b]	250	750

Source: Sarp et al., 2021 10.1016/j.joule.2020.11.005

- Bio-CCU: (indicative)
  - Steelanol: large scale demonstrator, capacity: 80 million L EtOH/year (operation starting in 2022) (BE)
  - Electrochaea: CO_2 to CH_4 conversion for biogas upgrading, 10,000 L bioreactor (DK)

Hierarchy of biorefinery investment types

HIGHEST CAPEX



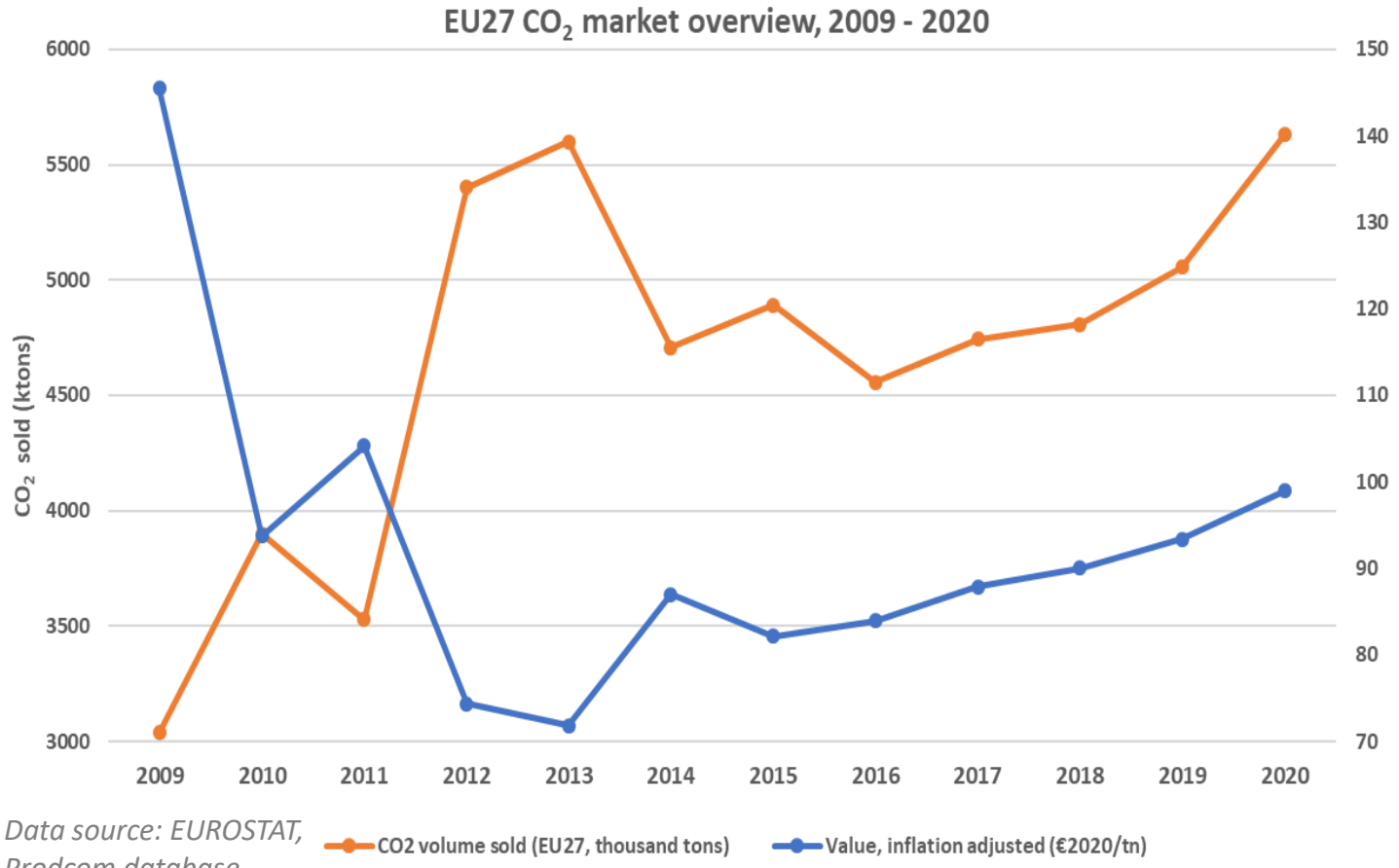
LOWEST CAPEX

- New greenfield biorefinery
- New biorefinery on a brownfield site (lower capex from shared services such as steam, water, power, storage, logistics etc…)
- Re-purposing/conversion of a plant on existing brownfield site (highly project dependent as equipment can only be partially reused)
- Expansion of a biorefinery on a brownfield site (e.g. valorising a side stream) – capacity increase often limited
- Debottlenecking (improving processes, revamping or new equipment) to increase the capacity of existing biorefineries - capacity increase is limited however
- Co-processing / re-focus of existing plants from fuels to chemicals (drop-in such as methanol)

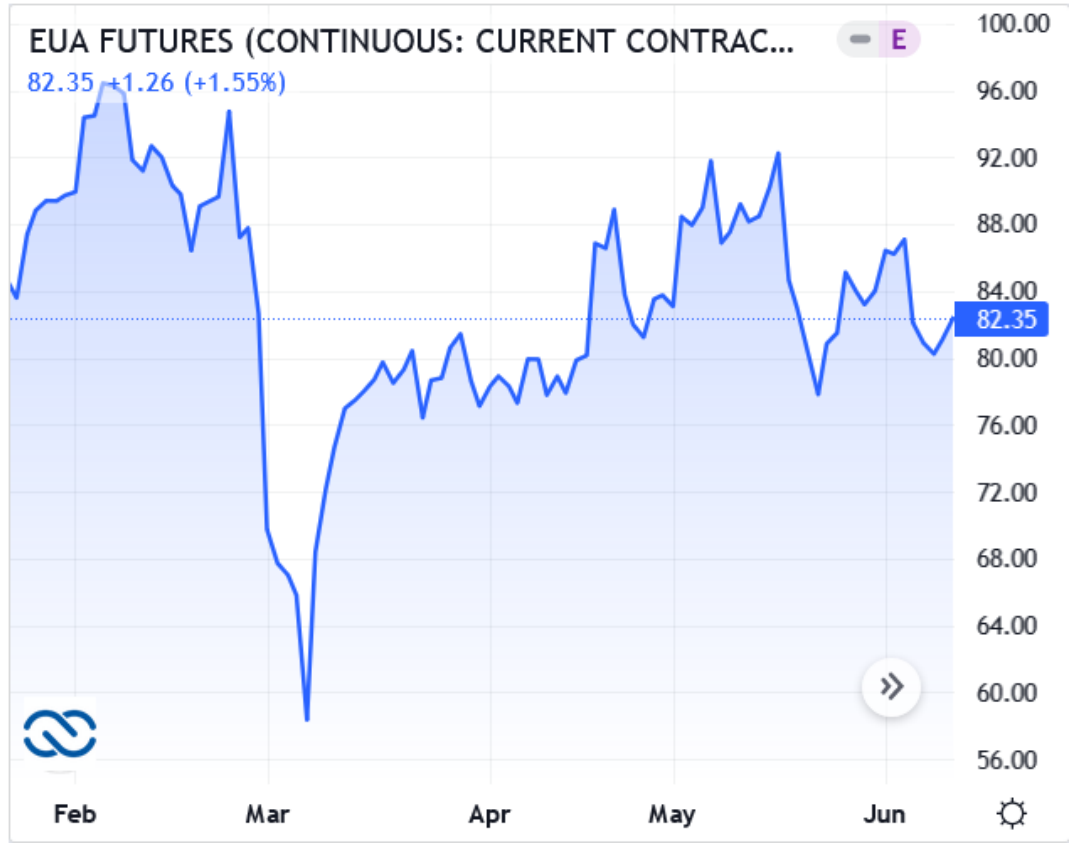
Source: EU Biorefinery Outlook to 2030

Economic assessment of CCU technologies

- Selection of appropriate basis for evaluation & comparison of alternative solutions



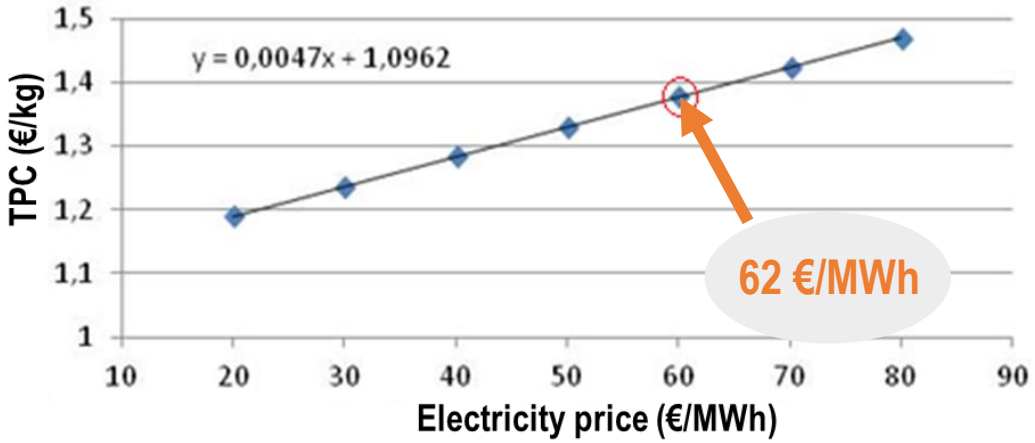
Data source: EUROSTAT, Prodcom database

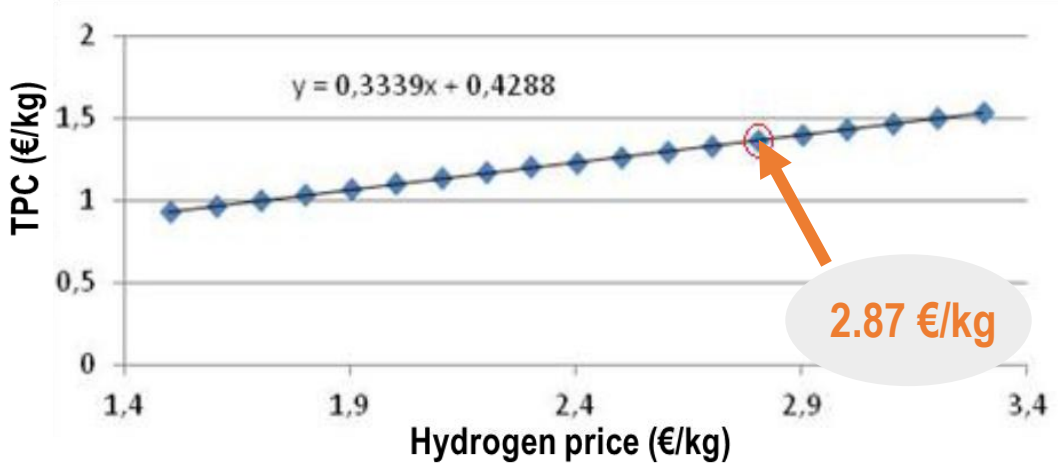


Source: https://carboncredits.com/carbon-prices-today/ (Visited on 12.06.22)

BIOCON-CO_2: Economic sustainability

- Case study: MCF #1 - mixed alcohols (BuOH, HeOH mix as reference products)
- Overall capacity: approx. 590 ktons/year
- main cost drivers: **equipment CAPEX, hydrogen, electricity**





- Industry expert calculations: the deployment of BIOCON-CO_2 systems demonstrates the potential to generate **20 billion €** turnover, create **4,200** direct jobs in the chemical industry, **25,000** indirect jobs & **16,800** construction jobs **across Europe**

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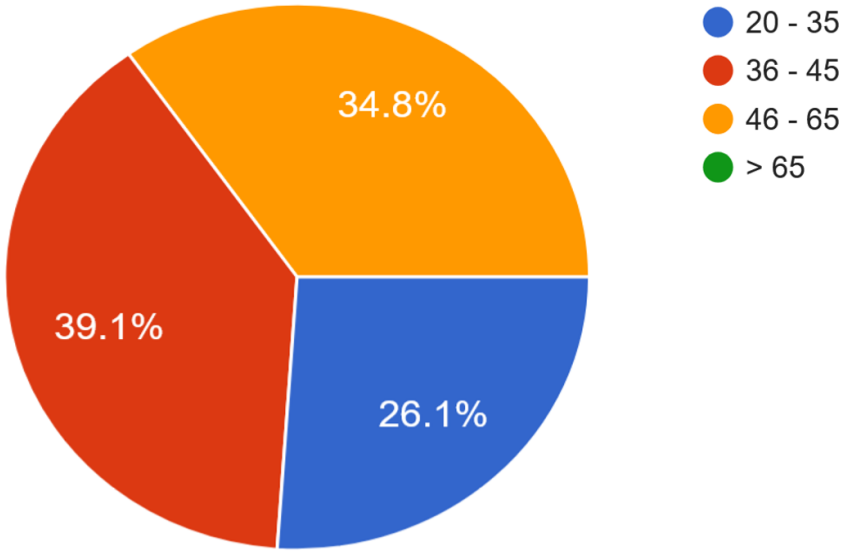
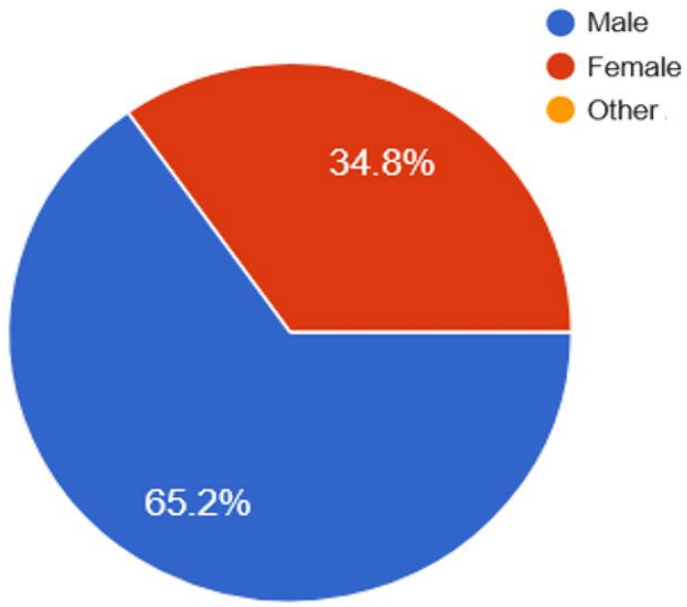
BIOCON-CO_2 expert survey

- Methodology:
- Targeted sampling, questionnaire-based interviews, experts reached through consortium & *CO_2oling the Earth* mailing list - 87 experts contacted between March - April 2022
- Participants: 23 experts from 7 countries

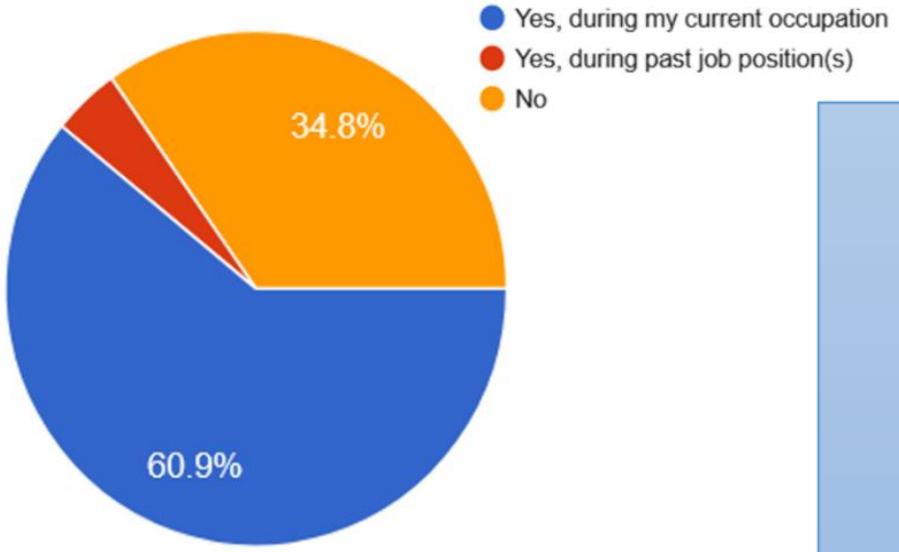


Age distribution of participants

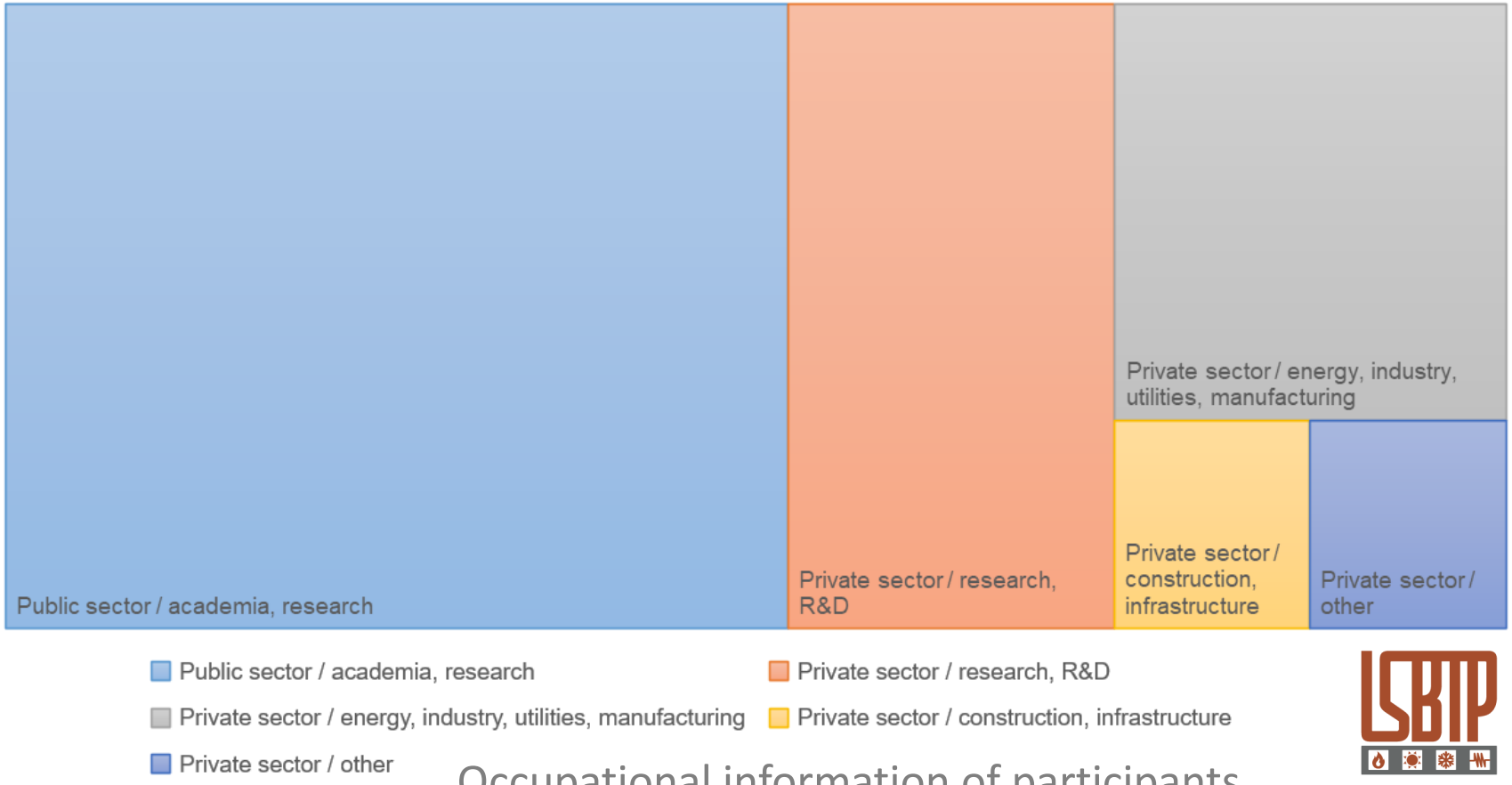


Gender distribution of participants

BIOCON-CO_2 expert survey (cont'd)



Participation in CCU-related R&I projects



Occupational information of participants

BIOCON-CO_2 expert survey (cont'd)

Relevance of existing legislation & standards for evaluation of biological CCU products and value chains (%)	Not relevant	Somewhat relevant	Relevant	Very relevant	Cannot answer
1. RED II - revised Renewable Energy Directive 2018 and its subsequent revisions on renewable fuels of non-biological origin (RFNBO) and recycled carbon fuels (RCF)	4.35	8.70	21.74	43.48	21.74
2. EN 16751 - Bio-based products - Sustainability criteria	4.35	0	47.83	21.74	26.09
3. EU Taxonomy for sustainable activities - Regulation (EU) 2020/852	13.04	13.04	17.39	26.09	30.43
4. ISO 13065:2015 - Sustainability criteria for bioenergy	0	13.04	30.43	26.09	30.43
5. EC Communication on Sustainable Carbon Cycles (2021)	4.35	4.35	26.09	39.13	26.09
6. Circular Carbon Economy (CCE) Index and tools	4.35	4.35	26.09	34.78	30.43
7. Platform for Accelerating the Circular Economy (PACE)	8.70	8.70	21.74	30.43	30.43

BIOCON-CO_2 expert survey (cont'd)

Relevance of existing legislation & standards for evaluation of biological CCU products and value chains (%)	Not relevant	Somewhat relevant	Relevant	Very relevant	Cannot answer
8. BS 8001:2017 - Framework for implementing the principles of circular economy in organizations	4.35	17.39	21.74	17.39	39.13
9. EU Green Deal	4.35	21.74	17.39	43.48	13.04
10. Ecodesign directive (EU)	0	26.09	26.09	17.39	30.43
11. Registration, Evaluation, Authorisation and Restriction of Chemicals Regulation (REACH)	4.35	26.09	26.09	26.09	17.39
12. Waste Framework Directive (EU)	4.35	21.74	17.39	39.13	17.39
13. EU Circular Economy Action Plan	0	17.39	26.09	43.48	13.04
14. UN 2030 Agenda, SDGs and social transformation framework	4.35	17.39	26.09	30.43	21.74
15. Product Environmental Footprint (PEF) framework	4.35	8.70	30.43	34.78	21.74

Participants' opinion on the importance of selected social indicators (%)	Not important	Somewhat important	Important	Very important	Cannot answer	Neutral
1. Contribution to national GDP	4.35	17.39	21.74	43.48	8.70	4.35
2. Job creation, income security	4.35	17.39	30.43	34.78	0	13.04
3. Promotion of health and safety in workplaces	4.35	30.43	39.13	17.39	0	8.70
4. Potential improvements in health and safety compared to both fossil-sourced and bio-based alternatives	0	4.35	43.48	47.83	0	4.35
5. Potential for combination with bio-based production processes in integrated biorefineries	0	8.70	39.13	43.48	0	8.70
6. Functionality and efficiency compared to both fossil-sourced and bio-based alternatives	0	4.35	26.09	56.52	0	13.04
7. Reduction of dependency on non-renewable resource imports	0	4.35	17.39	65.22	0	13.04
8. Avoidance of child labour	0	4.35	21.74	34.78	13.04	26.09
9. Achieving labour equity	0	8.70	30.43	30.43	8.70	21.74
10. Continuous education of workforce in areas affected by industry transitions	4.35	13.04	43.48	34.78	0	4.35
11. Avoidance of international conflicts	0	13.04	26.09	39.13	8.70	13.04

BIOCON-CO_2 expert survey (cont'd)

Participants' view on the future performance of CO_2-based products (%)	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Don't know
1. Waste streams from industrial or waste treatment sectors should be free of environmental burdens for use in downstream processing.	8.70	17.39	17.39	30.43	21.74	4.35
2. Waste streams from industrial or waste treatment sectors should be free of economic burdens for use in downstream processing (i.e. the producer should pay for transport to repurposing facility).	0	13.04	34.78	43.48	8.70	0
3. Waste streams from industrial or waste treatment sectors should be free of environmental AND economic burdens in the case of downstream utilisation.	0	13.04	21.74	39.13	17.39	8.70
4. Incentives based on financial instruments must be provided at national and EU level, both for new CO_2-based industries and for the transformation of conventional industries.	0	4.35	8.70	47.83	34.78	4.35
5. Incentives based on financial instruments must be provided at national and EU level, mainly focusing on new CO_2-based industries.	0	8.70	21.74	30.43	34.78	4.35
6. Clear certification schemes and comprehensive labelling regulations will accelerate market uptake of biologically produced CO_2-based products.	0	0	8.70	56.52	34.78	0
7. CO_2-based chemicals produced from biological processes must be treated as equal to their bio-based counterparts.	0	30.43	13.04	21.74	30.43	4.35

Participants' view on the future performance of CO2-based products (%)	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Don't know
8. CO2-based chemicals produced from biological processes must be given priority compared to bio-based counterparts, due to their specific benefits - e.g. lower impacts on biodiversity.	0	8.70	21.74	26.09	34.78	8.70
9. CO2-based chemicals produced from biological processes must be treated as inferior to their bio-based counterparts, since carbon sourcing might be insufficiently reported.	4.35	52.17	26.09	0	8.70	8.70
10. The formation and regular update of a toolkit / knowledge transfer system, along with certification and labelling frameworks, will further assist private firms in assessing their potential for implementing biological CCU processes.	0	0	17.39	60.87	21.74	0
11. Carbon removals and increases in CO2 capture and conversion efficiency of all CCU processes must be reported in detail using the same framework, to ensure comparability.	0	0	17.39	56.52	26.09	0
12. The implementation of biological CCU systems in conventional industries will prolong the consumption of fossil fuels.	4.35	39.13	30.43	13.04	4.35	8.70
13. The implementation of biological CCU systems in conventional industries will lead to an increase in the consumption of non-renewable resources.	13.04	34.78	39.13	4.35	4.35	4.35

Participants' view on the future performance of CO2-based products (%)	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree	Don't know
14. The implementation of biological CCU systems in conventional industries will lead to a decrease in the consumption of non-renewable resources.	0	4.35	56.52	26.09	8.70	4.35
15. CO2-based chemicals may achieve improved environmental, economic and social performance than their bio-based counterparts.	0	4.35	47.83	39.13	4.35	4.35
16. CO2-based chemicals may achieve poorer environmental, economic and social performance than their bio-based counterparts.	4.35	34.78	43.48	13.04	4.35	0
17. CO2-based chemicals are expected to demonstrate similar environmental, economic and social performance as their bio-based counterparts.	4.35	4.35	52.17	34.78	0	4.35
18. The development of biological CCU systems for producing CO2-based chemicals may negatively impact the development of other CCU processes and hinder climate change mitigation efforts.	13.04	47.83	21.74	4.35	4.35	8.70
19. The development of biological CCU systems for producing CO2-based chemicals will complement the development of other CCU processes, forming a versatile CCU toolkit to address complex site-specific issues.	0	4.35	4.35	65.22	17.39	8.70

Conclusions

- Economic performance greatly depends on the opportunities for lowering CAPEX and energy costs – integration with existing infrastructure offers great flexibility, but is **case specific**
- Carbon removals and increases in CO_2 capture and conversion efficiency of all CCU processes must be reported in detail using the same framework, to ensure comparability & consistency
- The formation & regular update of a toolkit / knowledge transfer system, along with certification & labelling frameworks, is expected to further assist private firms in assessing their potential for implementing biological CCU processes.
- With respect to the provision of **incentives** at national and EU level, experts agreed that these must be provided both to new CO_2-based industries and for the transformation of existing conventional industries.

Thank you

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