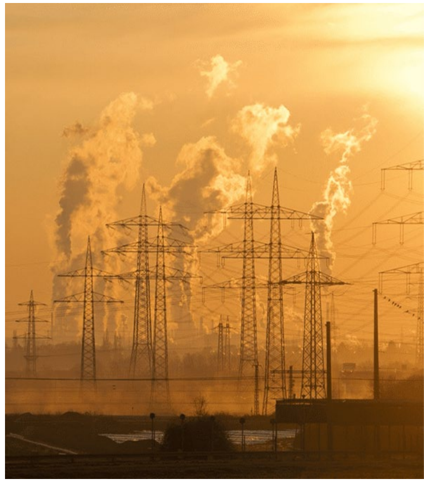
AIEE ASSOCIAZIONE ITALIANA ECONOMISTI DELL'ENERGIA

CooCE

HARNESSING POTENTIAL OF BIOLOGICAL CO_2 CAPTURE FOR CIRCULAR ECONOMY

Socio-economic assessment of CCUS for the expansion of the circular bioeconomy, the CooCE project

Padua, 28-30 November, 2024



Dr Rocio Diaz-Chavez
Centre for Environmental Policy
Imperial College London

Accelerating CCS Technologies   CooCE   IMPERIAL   Department for Energy Security & Net Zero

BTS   DTU   ELGO - DIMITRA   lemvigbiogas.com   IMPERIAL   EURONEWPACK global pack solutions   Qlab   pond

OUTLINE

- The CooCE project
- Socio-economic assessment methodology
- Results
- Conclusions

Accelerating CCS Technologies

CooCE

CooCE Partners

IMPERIAL

Università degli Studi di Padova

ELGO - DIMITRA
HELLENIC AGRICULTURAL ORGANIZATION - DIMITRA

DTU

IMPERIAL

BTS

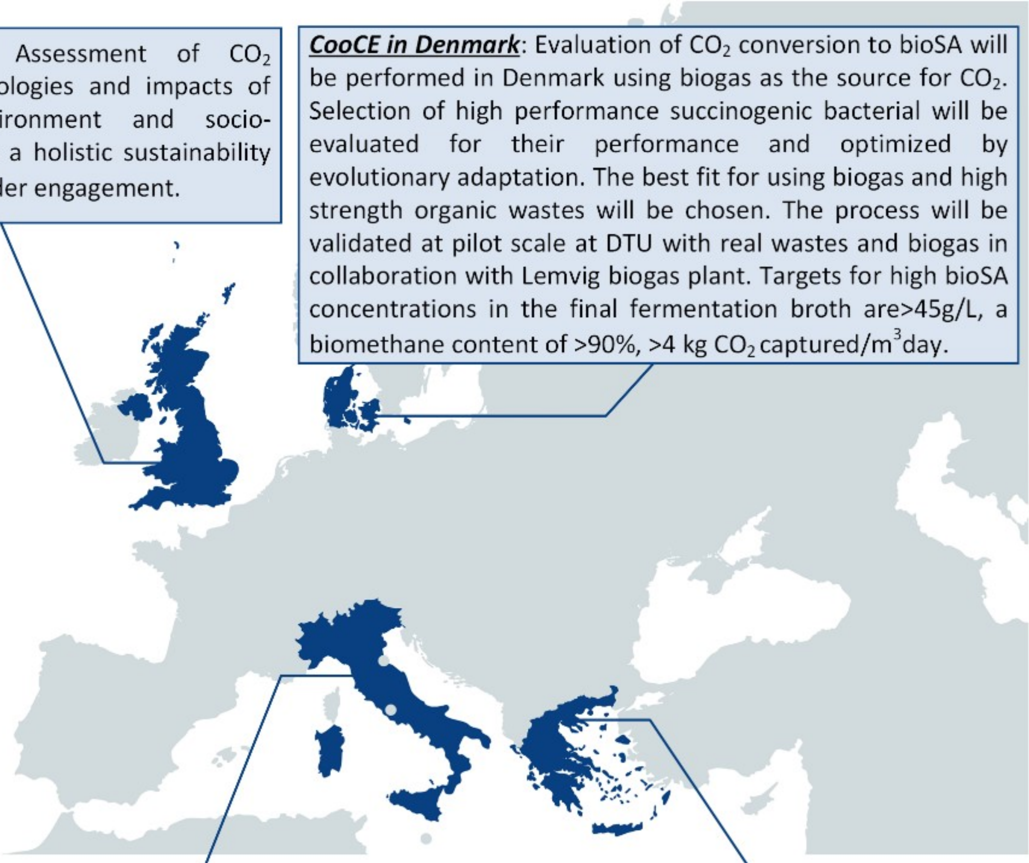
lemvigbiogas.com

EURONEWPACK
global pack solutions

Qlab
ANALYTICAL LABORATORY

pond

ECORESOURCES
RESEARCH • TECHNOLOGY • CONSULTANCY



CooCE in UK: Assessment of CO_2 conversion technologies and impacts of **CooCE** on environment and socio-economy through a holistic sustainability analysis, stakeholder engagement.

CooCE in Denmark: Evaluation of CO_2 conversion to bioSA will be performed in Denmark using biogas as the source for CO_2. Selection of high performance succinogenic bacterial will be evaluated for their performance and optimized by evolutionary adaptation. The best fit for using biogas and high strength organic wastes will be chosen. The process will be validated at pilot scale at DTU with real wastes and biogas in collaboration with Lemvig biogas plant. Targets for high bioSA concentrations in the final fermentation broth are>45g/L, a biomethane content of >90%, >4 kg CO_2 captured/m^3day.

CooCE in Italy: Evaluation of CO_2 conversion into PHA will be performed in Italy using emissions from BTS biogas s.r.l. Mainstream and alternative PHA producers will be tested to choose the best fit for the specific gaseous CO_2-rich streams (biogas) ensuring to use the best possible microbial strains. PHA produced will be further evaluated by ENP to pre-commercial phase by producing prototype bioplastic materials.

CooCE in Greece: Evaluation of CO_2 hydrogenation will be performed in lab and pilot scale conditions in Greece addressing the needs of the Greek Cluster of Raw Materials (www.grawmat.gr). The GRawMat cluster, led by EcoResources (member of the European Raw Materials Alliance), is comprised by the **top-10 Greek mining industries** (Mytilineos Group, Hellenic Gold, Stonegroup, Grecian Magnesites, North Aegean Slops, Mathios Refractories, GeoHellas, Aegean Perlites, Eco Efficiency, Ellimet.). The overall goal is to **demonstrate <u>for the first time</u>** an optimized bioprocess able to capture and transform **>5 kg CO_2/m^3reactor/day.**

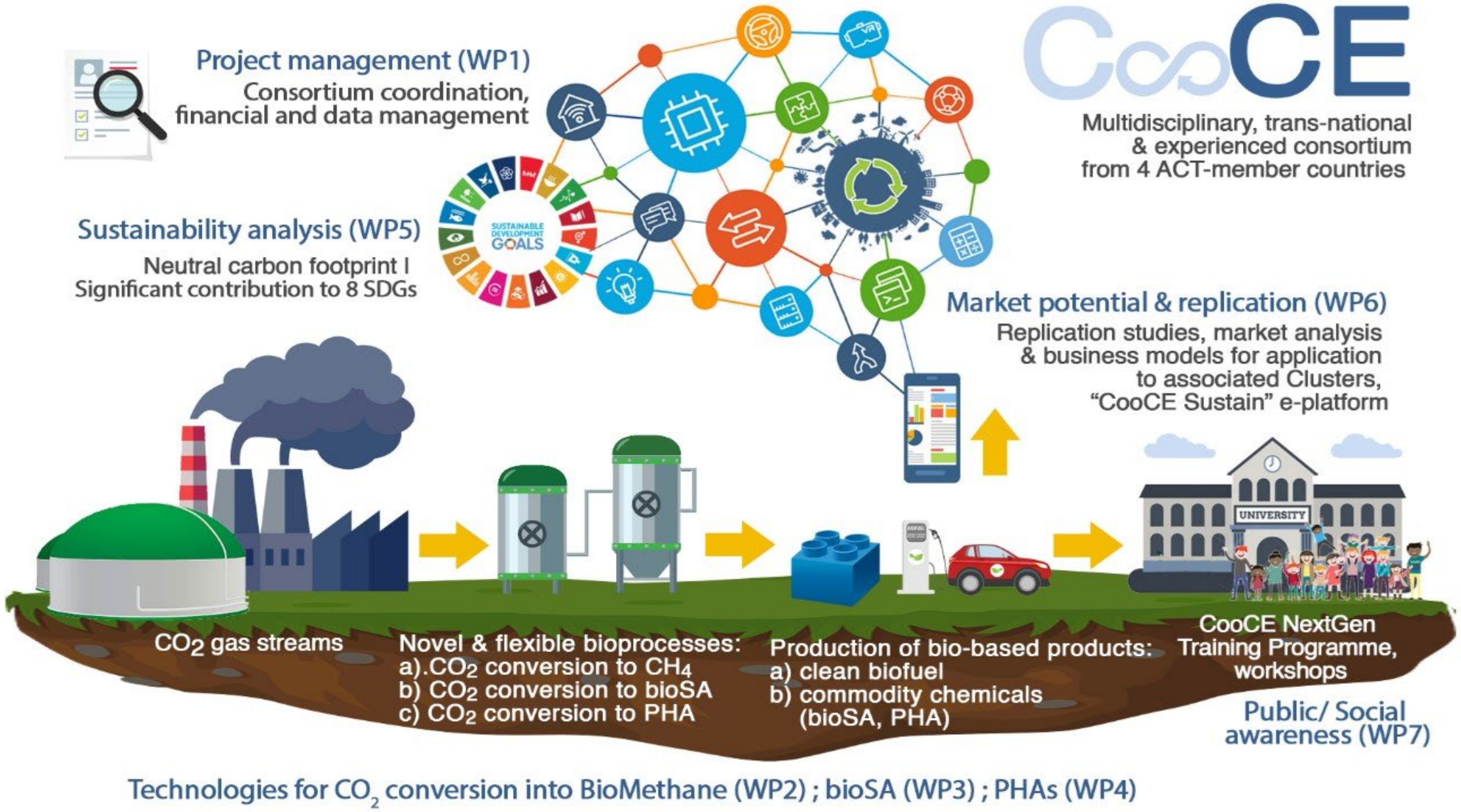
CooCE Concept & Main Objectives

IMPERIAL

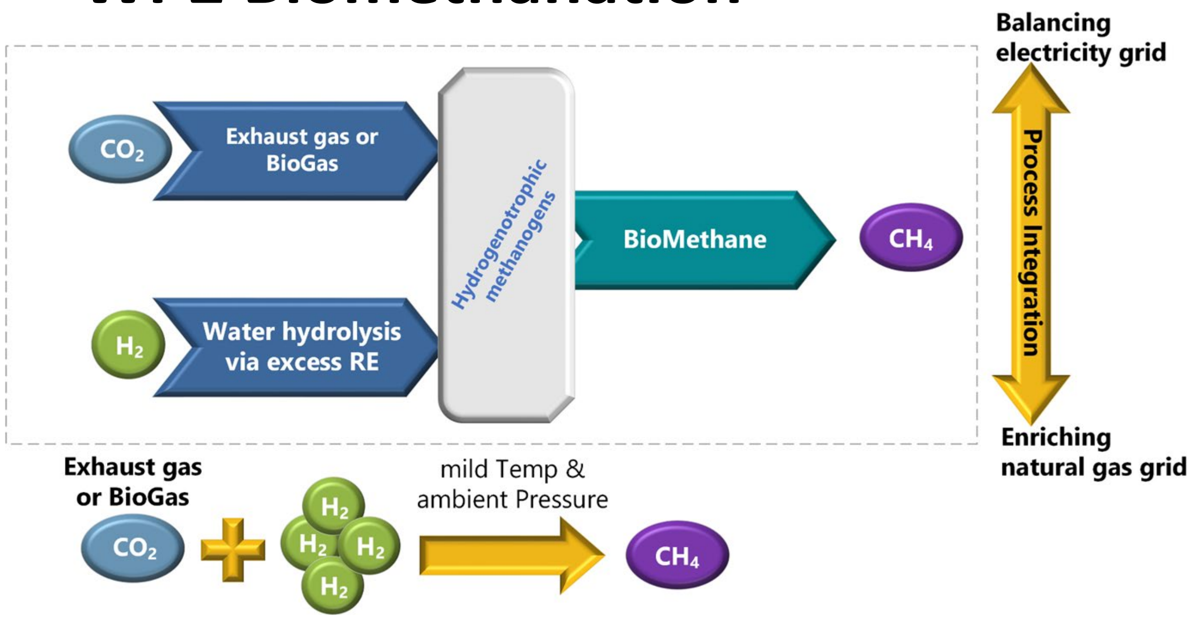
Industrial sectors currently account for 20% of global CO_2 emissions

CooCE targets to develop and demonstrate a novel biotechnological platform where **CO_2 from biogas or exhaust gasses** is converted into:

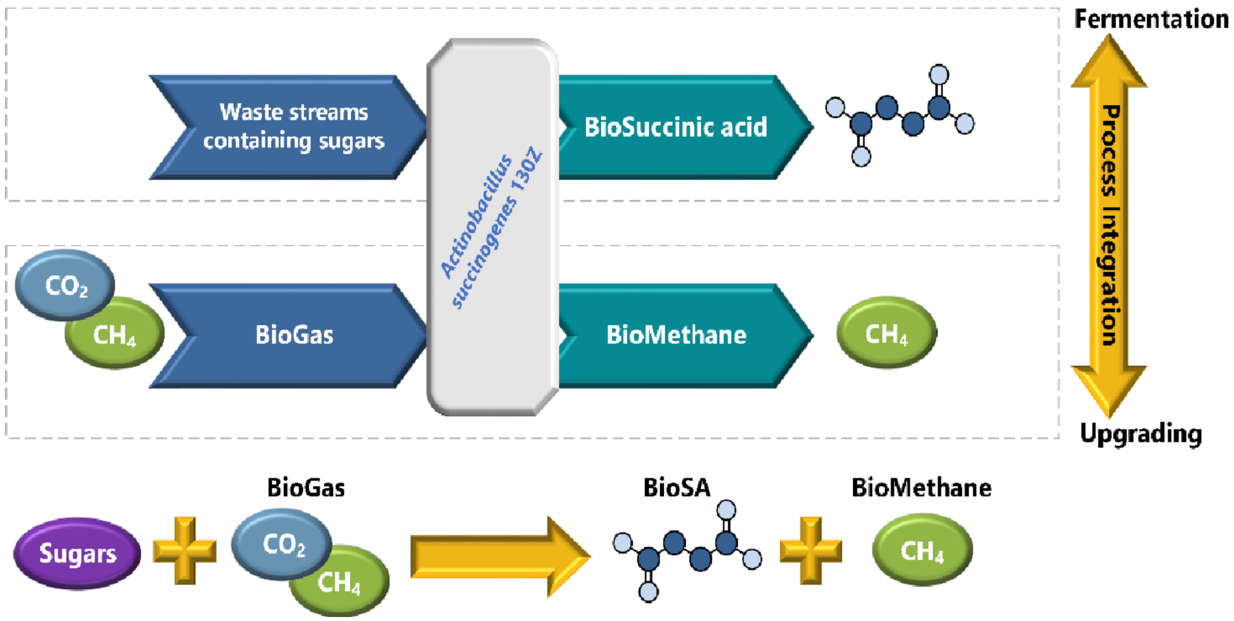
- **upgraded biofuels** for flexible on-site hybrid energy storage
- **high market value platform chemicals** forming the building blocks of various biopolymers and bioproducts.



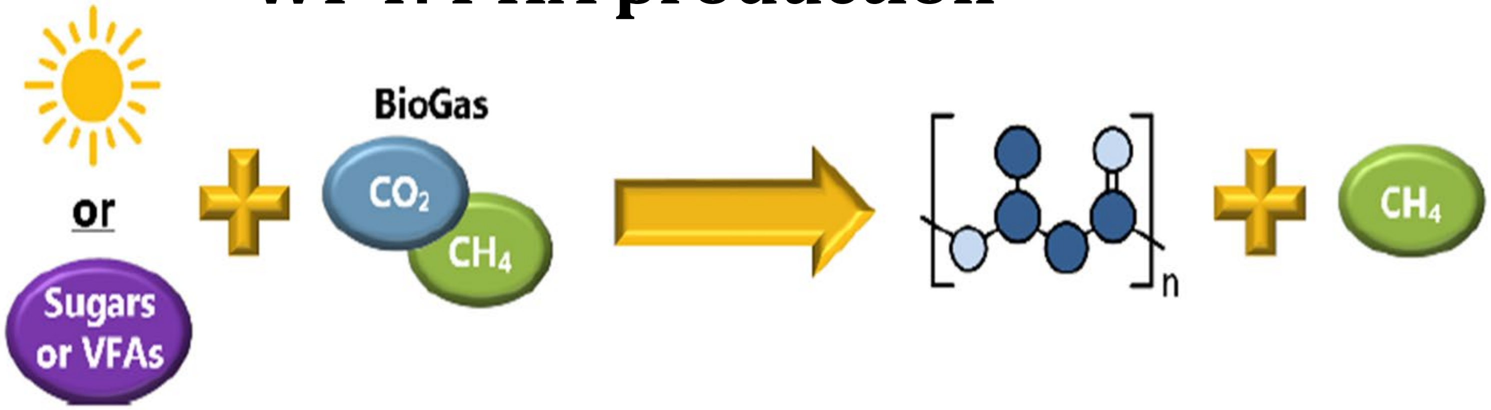
WP2 Biomethanation



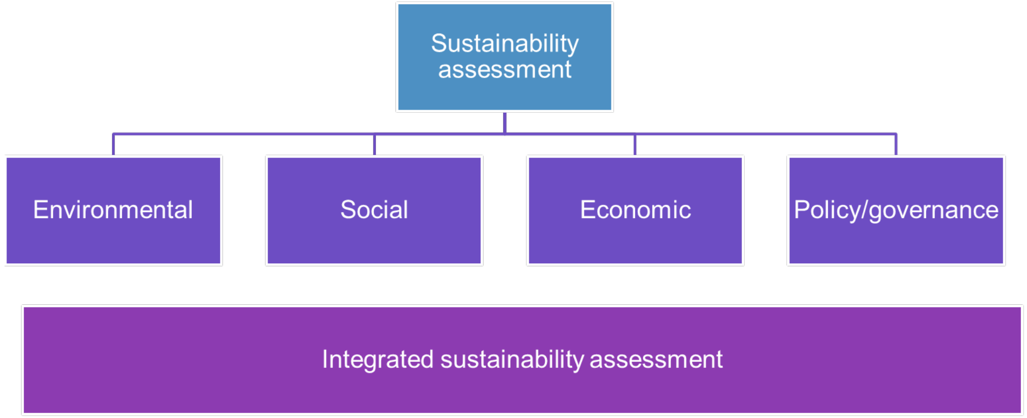
WP 3 Succinic acid production



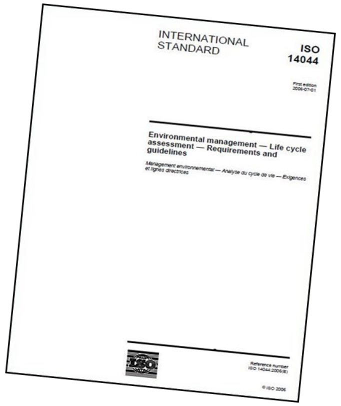
WP4: PHA production



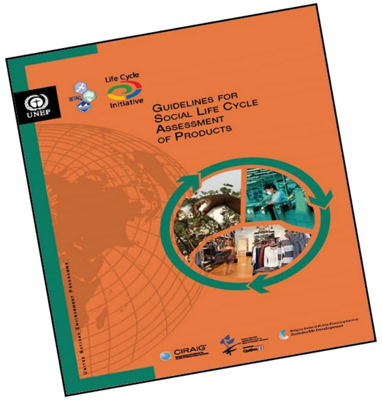
WP5 Sustainability assessment



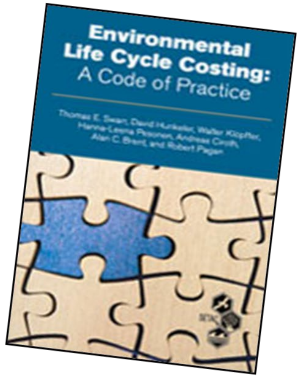
Life Cycle Assessment (LCA)

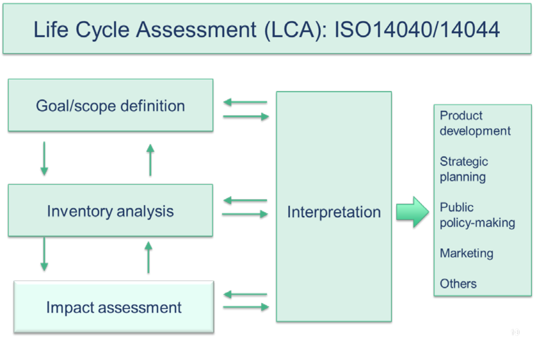


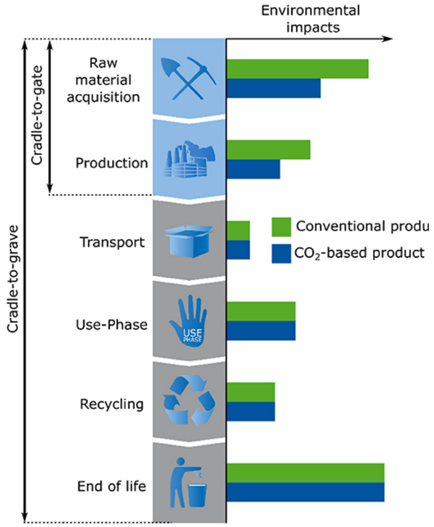
Social Life Cycle Assessment (SLCA)



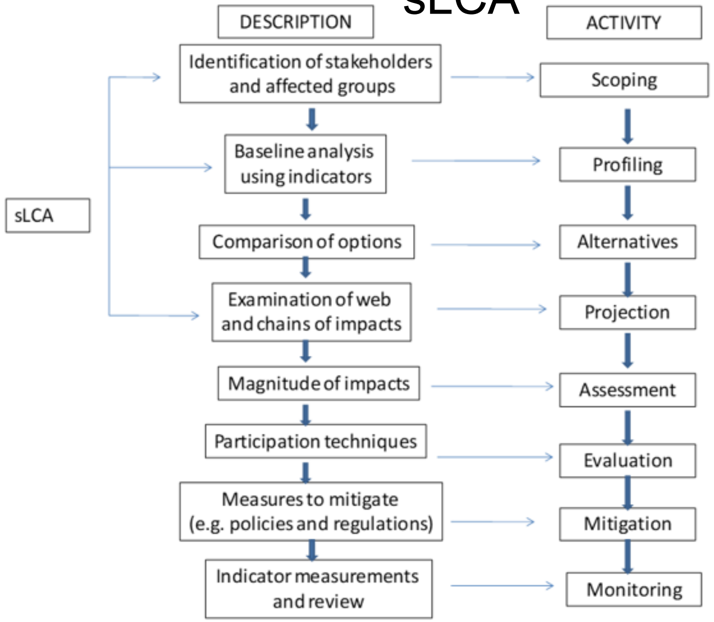
Environmental Life Cycle Costing (ELCC)







sLCA



Adapted SCLA and SIA (Diaz-Chavez, 2014; Diaz-Chavez et al., 2016)

LCC

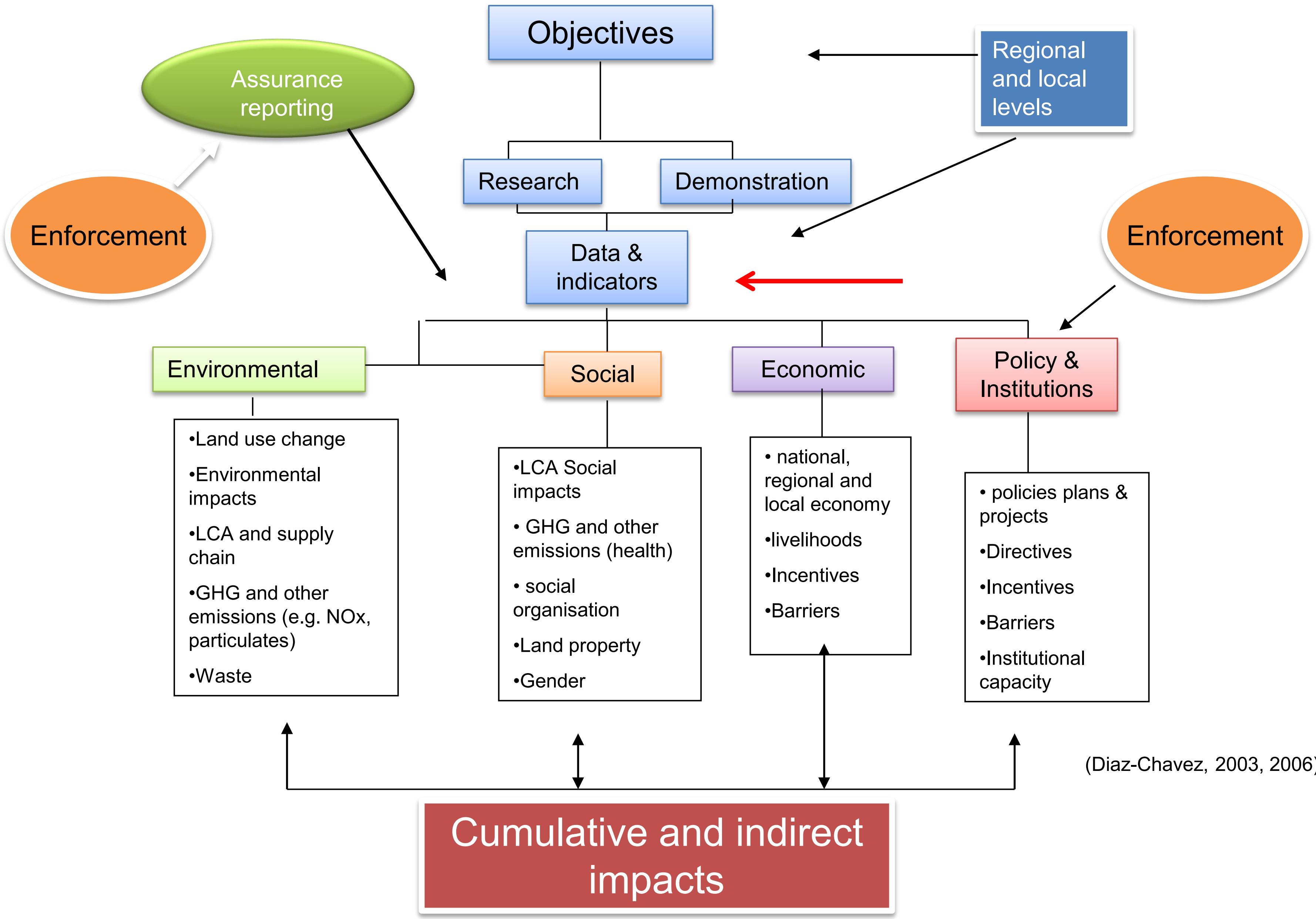
	Cost Type	Process
Biomethanation / bioSA / PHA	**Initial Cost**	*methanation unit*
		electrolysing unit
	Maintenance cost	-
	Operational costs	*Materials*
		labour
	Lifetime	

Accelerating CCS Technologies
CooCE

SDGs 2016

IMPERIAL

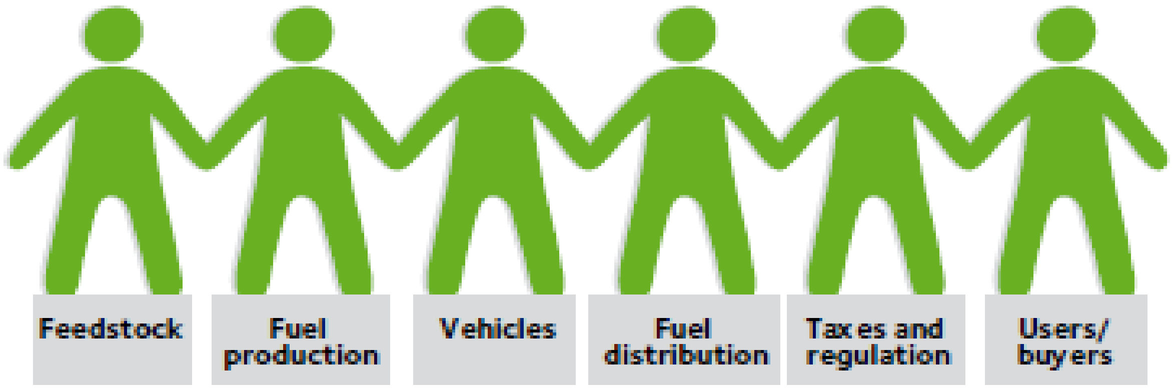
FRAMEWORK



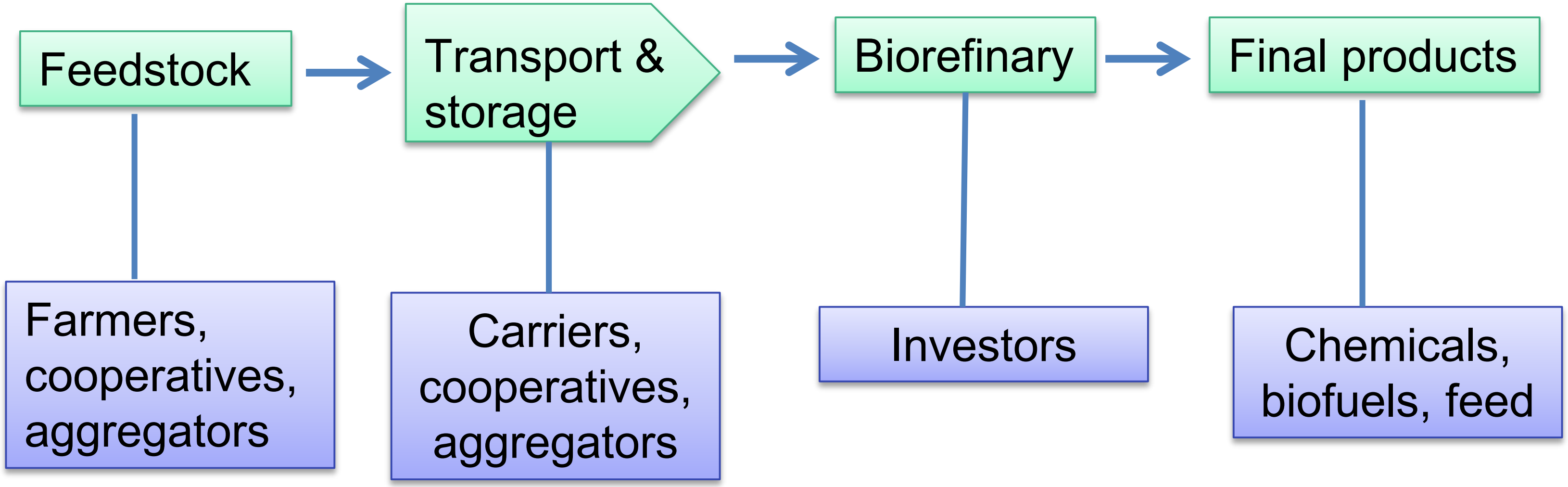
(Diaz-Chavez, 2003, 2006)

What to consider

IMPERIAL

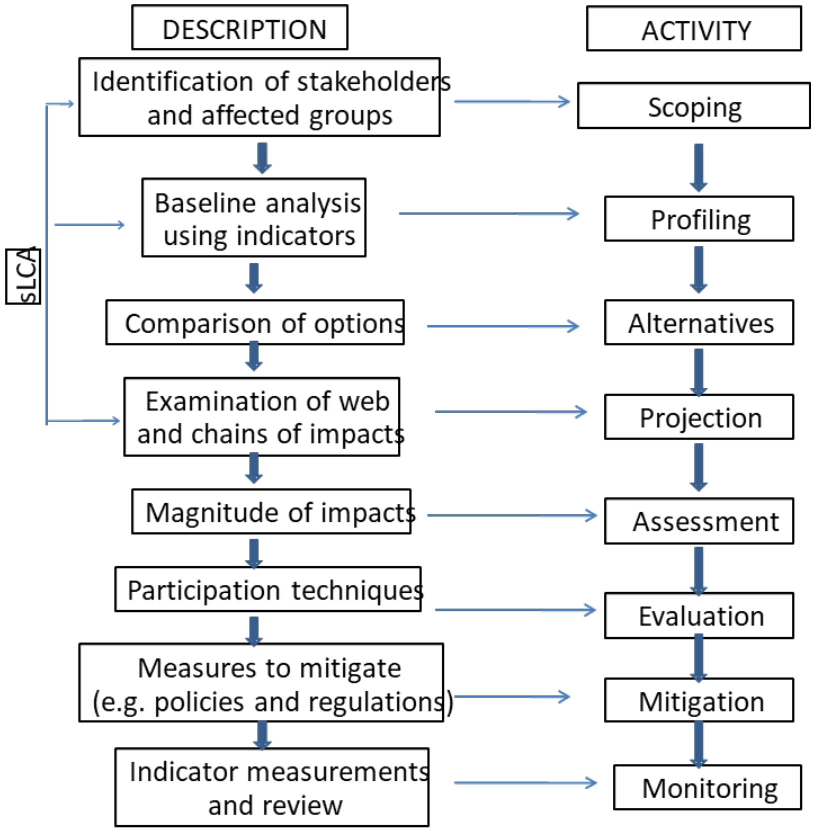


Supply chain



Socio-economic and policy assessment

Adapted social impact assessment to sLCA

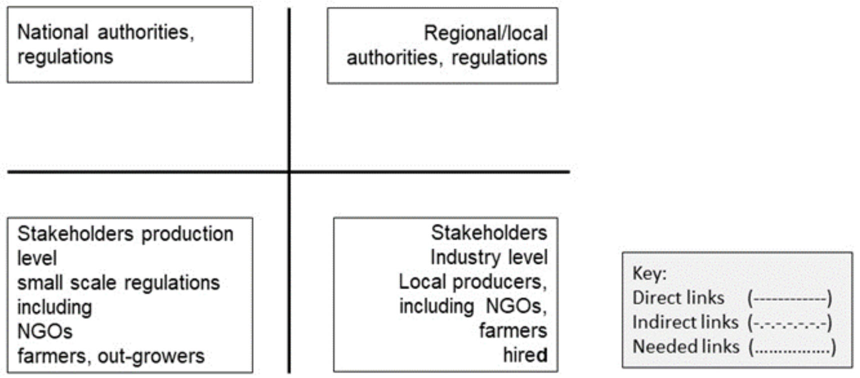


(Diaz-Chavez, 2012)

The mapping of stakeholders uses a quadrat for sorting the stakeholders.

Stakeholders in crops and agriculture are identified first. Next are stakeholders at the production level, encompassing farmers, NGOs (and other civil organisations), and the industry sector (including also farmers with different forms of participation, such as out-growers).These are followed by stakeholders from local government, national government, NGOs (and other civil organisations) and industry. These last two quadrats may include also farmers, but at different levels of organisation.

The links between these different bodies and stakeholders are expressed depicted through lines, as direct, indirect or needed. The closer they are, the closer the relationship is or should be.



Source: Diaz-Chavez et al. (2010)

(Diaz-Chavez, 2012)

Accelerating CCS Technologies CooCE

IMPERIAL

Key variables and sustainability indicators

- **Production and availability of feedstock**
  - Biomass surplus
  - Willingness to shift cropping patterns
  - Role of panchayat in deciding cropping patterns
- **Employment**
  - Limitation to employment opportunity
  - Openness in exploring and taking non-agricultural activities
  - Working conditions in the competing industry
  - Willingness to work in bio-refinery
  - Strength of labour union
  - Child labour issues; etc
- **Health, environment and food security**
  - Health impacts due to working conditions in competing industries
  - Impacts on food security due to presence of a bio-refinery
  - Environmental, water related, land related stress in the area related to industrial activities; etc.
- **Rural development**
  - Improvement in physical infrastructure due to industrialization
  - Would bio-refinery improve infrastructure
- **Research and development**
  - Extent to which investments in R&D activities in clean/bioenergy is needed
  - Extent to which R&D activities have happened in clean/bioenergy
- **Other issues related to political, legal and economic barriers**
  - Current barriers in terms of political and administrative hurdles in setting up of a new bio-refinery
  - Creation of new economic opportunities for the locals

Stakeholder assessment and engagement

Workshop in Bologna with stakeholders EUBCE, June 2023

Organisers
Imperial College
Dr Diaz-Chavez,
Dr Evans and Dr
Giarola
Coordinator
CooCe:
Dr Tomas
Morisoto

Advantages	Challenges
CooCE Concept	***Concept/CCUS***
Addresses policy agendas for lowering emissions	Competing uses for renewable energy
Carbon negative	Complex market for biogas producers
CO_2 as feedstock	Costly investment
Circularity	Energy requirements
Decentralised approach	Lack of funding mechanisms
Diversified applications	Little known yet
Favoured by net zero emissions mandates	Multitude of stakeholders
Suitable across industries/sectors	Own CO_2 emissions
Potentially profitable	Potential shortage of CO_2
Revenue pathway for biogas producers	Public perception
Techno-process	Scalability
Biodigestion	Slow market expansion in EU
Bioreaction	***Techno-process***
Biomethane upgrade	Bacteria use/storage/platform purification
Gases purification	Biogas transportation
Integrated System	H_2 production
System easy to operate	Large-scale growth of microorganisms
Product	Potential CO_2 leakage
Biogas from CO_2 upgrade	Reactor configuration
Chemicals platform	***Product***
Diversified range of outputs	Quality standards for commercial use
Fuels from CO_2 with H_2	***Policy/Regulation***
High Purity bio-CH_4	Lack of consistency in EU regulations
Bioplastics (rising demand)	Lack of policies for CCUS/its bioproducts

No	Parameter	Characteristics/ Criteria	Assessment Level	Supply chain stage	Data type and source
1	Trade of feedstock	Incentives and barriers	EU/National	Feedstock	Qualitative Quantitative
2	Identification of stakeholders along the supply chain	Associations Authorities/regulators Businesses CO2 emitters Investors Researchers Etc	National Local	All	Qualitative
3	Policies and regulations	International National Regional Local	National International	All	Qualitative Quantitative
4	CO^2 point source	Availability of feedstock (CO_2)	Local	Feedstock	Qualitative
5	Land (N/A)	• Availability in EU • Ownership and rights	National		
6	Community participation	Community acceptance of: • feedstocks, processes, products • other involvement	National Local	All	Quantitative Qualitative
7	Quality of life N/A	Improvement of quality of life (longitudinal data needed)	National Local	N/A	Quantitative
8	Rural development and Infrastructure	• Roads • Sanitation • Water	National Local	All	Qualitative
9	Job creation and wages	• Labour conditions • Job creation • Wage regulations	National Local	All	Qualitative Quantitative
10	Gender equity	Inclusion of women	National	All	Qualitative Quantitative
11	Labour conditions	ILO conventions and human rights including: • Child labour • Right to organise • Forced labour	National	All	Qualitative Quantitative
12	Health and safety	Compliance with health and safety regulations	National Local	All	Qualitative Quantitative
13	Competition with other sectors	Competition and negative impacts on other industries and sectors	National Local	All	Qualitative Quantitative

Source: Adapted from Diaz-Chavez (2014) Key: N/A= Not applicable

Social Sustainability Assessment

IMPERIAL

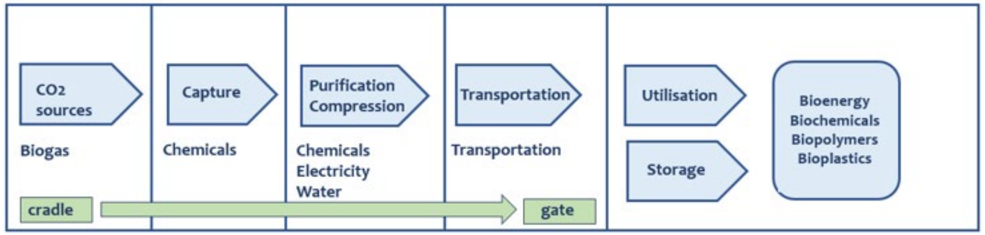
Methodological Approach (Composite)

Aims: Identify CooCe's potential societal impacts and risks

Focus on CooCE Countries: Denmark, Italy, Greece, UK

- Social Impact Assessment (indicators)
- Social Life Cyle Assessment (indicators)
- Mapping of stakeholders
- Stakeholders' workshop and online survey
- Social Hotspot Database (indicators)
- Policy review (documents)

CooCE Product System



Social Hotspot Index for Gas

Social Sustainability Assessment of CooCE: Results for selected

Parameter	Criteria	Risk	Benefit	Observations, Issues and Mitigation
Gender equity	Inclusion of women	M	H	**Issue**: men are generally more economically active than women in all CooCE countries, although gender employment and pay gaps have been narrowing **Mitigation**: ensure gender equality of opportunity or enhanced opportunity for women to access resources and services for participating in the implementation of CooCE (e.g.jobs, business ownership, supporting services, etc)
Labour conditions	Conventions on child labour, forced labour, right to organise	M	H	**Observation**: CooCE countries are signatories of most ILO conventions **Issues**: medium risk of lack of enforcement of labour laws and conventions in four sectors in all countries; high risk of excessive working time and of forced labour in Greece in all CooCE sectors; very high risk for migrant workers in Greece, Italy and the UK across all sectors **Mitigation**: monitor enforcement of legislation for labour protection to prevent excessive working time and exploitation of migrant workers
Health and safety	Compliance with health and safety regulations for each stage of the value chain	H	H	**Observation**: all CooCE countries have legislation in place for health and safety at the workplace and are long-standing signatories of the Labour Inspection Convention **Issues**: very high occupational and health risks in all four CooCE countries and sectors; medium overall risk of lack of access to health care **Mitigation**: monitor enforcement of legislation for health and safety at the workplace and at public spaces (i.e. roads) to minimise risk of occupational injuries and hazards and public health hazards
Community participation	Involvement/acceptance (feedstocks, technologies, products)	M	H	**Issues**: NIMBY syndrome; poor knowledge about CCUS and biodegradability of products; concerns about impacts on human health and the environment **Mitigation**: ensure engagement of local stakeholders in CooCE implementation; understake awareness-raising campagins on CCUS safety and environmental impacts (e.g. CO_2 leakages; use of water and chemicals; biodegradability)

Key: M= Medium; H=High

CooCE

Policy Assessment

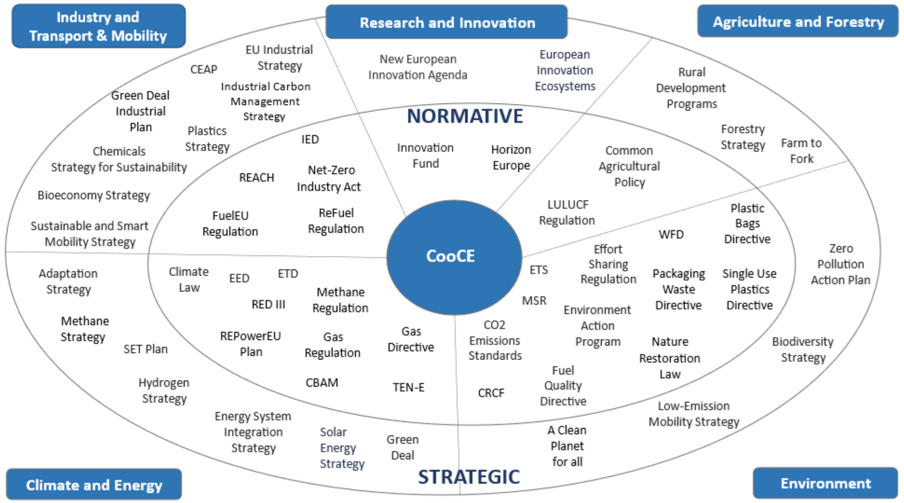
Assessment of EU and UK Policies relevant to CooCE (general/and pathways)

Aims: identify enablers and barriers to the implementation of CooCE in

- the EU (Denmark, Italy, Greece)
- the UK

Method:

- Description and critical review of policies
- recommendations for addressing challenges



IMPERIAL

Example of Assessment: Gas Directive (EU Directive 2024/1788)

Assessment: This instrument is highly relevant to CooCE's renewable gas (biomethane) produced from upgrading CO_2 from biogenic sources, as it is likely to expand and strengthen the gas market where CooCE's biomethane is traded and consumed. The non-discriminatory access to gas infrastructure for renewable gas producers creates new opportunities for biogas producers to integrate their products into the EU gas grid, supporting the transition away from fossil fuels. Clearer rules on grid connections will simplify the process for biogas producers, making market participation easier. The introduction of a certification system for renewable gases will require biogas production to comply with the directive's sustainability and emissions standards aimed at reducing greenhouse gases. Additionally, the EU's investment in repurposing natural gas infrastructure to accommodate renewable gases should lower costs for biogas producers and facilitate wider distribution. The phase-out of long-term contracts for unabated fossil gas by 2049 is likely to boost demand for renewable alternatives, creating a growing market for biogas. Overall, the directive may help establish a more favorable regulatory framework, supporting market expansion, enhancing energy security, and promoting sustainability.

Example of Challenges in Overarching EU Policy Instruments

Challenge: There is currently no unified or comprehensive EU regulatory framework for CCUS. Instead, CCUS is governed by various pieces of legislation, each focusing on different aspects such as emissions reduction, environmental protection, innovation, and infrastructure. Key legislations include the *ETS-I*, the *TEN-E Regulation*, the proposed *CRCF*, and the *Innovation Fund*. These directives, regulations, and funding programs cover aspects of CCUS but lack an integrated approach.

Recommendations: Create a comprehensive legal framework that includes specific policies for all aspects of CCUS and aligns cross-sector regulations to ensure consistency and coherence for projects such as CooCE.

Overall recommendations for policy issues

- Design policies specific for CCUS (feedstocks, techno-processes, products, bioproducts)
- Improve existing regulatory frameworks relevant to elements of CCUS to account and recognise the contribution of captured carbon bioproducts to energy targets and the CE
- Provide funding and investment mechanisms for developing CCUS biotechnologies

CooCE

Integrated Sustainability Assessment

Assessment of CooCE Pathways for

- Pathway 1: Biomethane

Methodological Overview

- Integrated Approach: combines results from individual assessments and SWOT analysis
- Key Tool => Multi-Criteria Evaluation: 'traffic light' scoring system that identifies positive, neutral, or negative impacts based on selected indicators for each pathway; it enables structured comparisons of sustainability performance across pathways
- Scope: 'cradle-to-gate' (lifecycle)
- Aim: identify the most sustainable pathways for implementing CooCE technologies and products

Traffic Light Scoring System

	Very positive	Positive	Neutral	Negative	Very negative
Impact	++	+	0	-	--
Risk Level	Very low	Low	Moderate	High	Very High

Theme	Indicators	Pathway 1:	Pathway 2:	Pathway 3:	Assessment Outcome
Technological	1. CO_2 Storage	0	+	++	3
	2. Barriers to Commercialisation	0	0	--	1,2
	3. Electricity Source Reliance	-	-	--	1,2
	4. Hydrogen Reliance	-	0	--	2
	1. Process Scalability	++	0	--	1
	2. Regulatory Frameworks	+	-	--	1
	3. TRL Development	++	+	--	1
Environmental	4. CO_2 Capture Rate	++	+	+	1
	5. CO_2 Emissions	++	+	--	1
	6. Energy Consumption	0	0	--	1,2
	11. Waste Generation	-	--	--	1
	12. Water Usage	+	+	--	1,2
Economic	13. Energy Sourcing	0	0	--	1,2
	14. Location	-	++	+	2
	15. Market Price	-	+	--	2
	16. Potential for Circularity	+	++	+	2
	17. Product Demand	+	++	+	2
	18. Product Volume	+	-	--	1
	19. Revenue Potential	+	++	--	2
Social	20. Job Creation	+	++	0	2
	21. Health and Safety	-	--	-	1,3
	22. Gender Equity	+	++	0	2
	23. Labour	+	++	0	2
Legal	24. Policy Instruments	+	-	--	1

ISA Matrix highlights the potential of Pathways 1 and 2 as sustainable options for CooCE implementation

Observation:

Outcomes do not necessarily imply that an impact or risk is inherently sustainable; rather it suggests that the identified pathway may be preferable to the alternatives

For example:

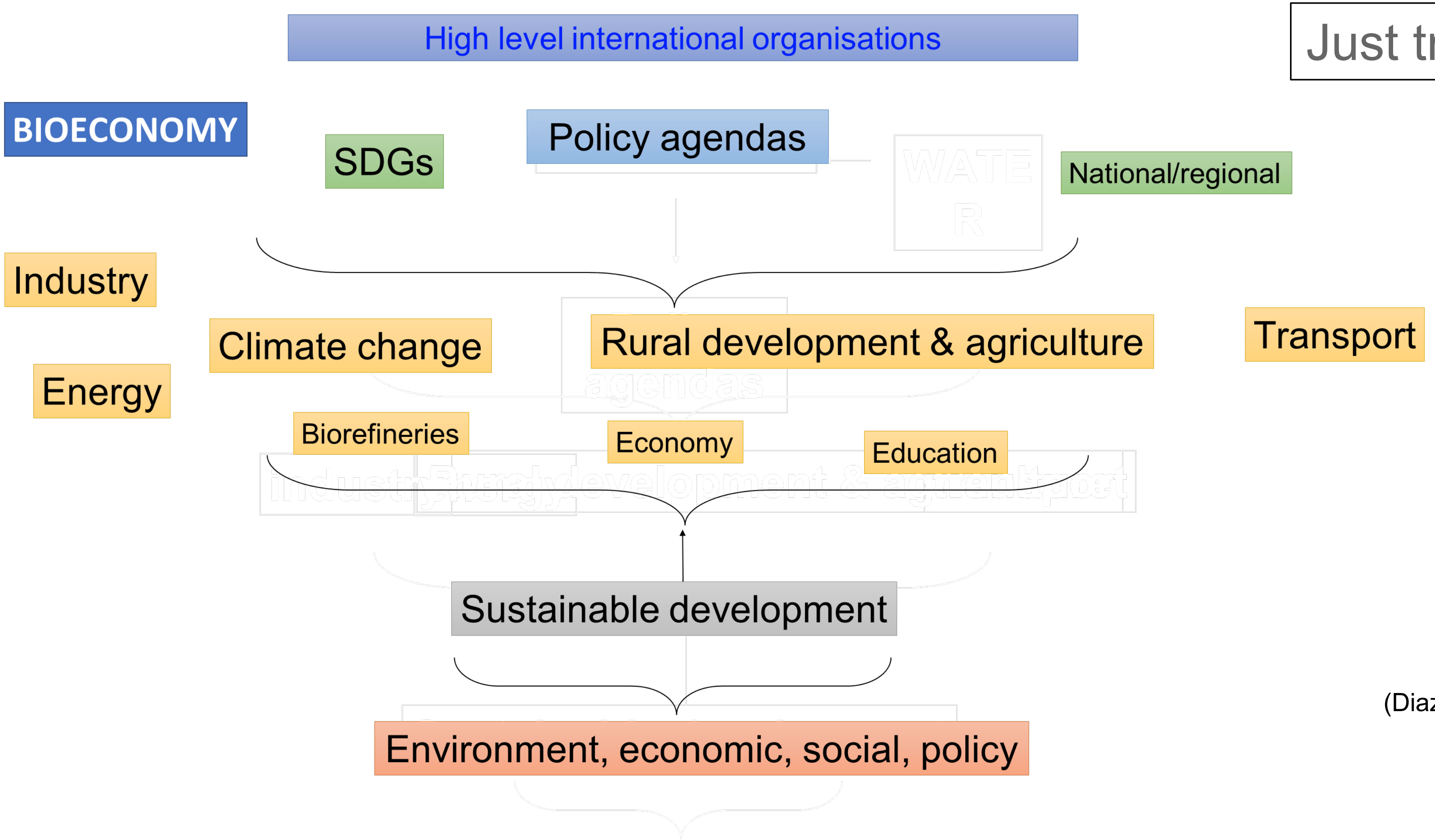
- Electricity Source Reliance
- Waste Generation
- Health and Safety

Indicators that exhibit **negative impacts** across all **three pathways**; these will require mitigation regardless of the pathway chosen

Links to bioeconomy and circular economy

- Consider stakeholders along supply chains
- Enough data on biomass potential
- Origin/production of H2
- Financial issues for scaling upAssessment, uncertainty & subjectivity
- Mitigation and Monitoring
- Sustainable development main issues are related to public participation and engagement
- Consider other env management tools such as SEA

Strategic view for a renewal of the sector



Just transitions

(Diaz-Chavez, 2003, 2006)

Thank you!

Dr Rocio Diaz-Chavez
Centre for Environmental Policy
Imperial College London
r.diaz-chavez@imperial.ac.uk

https://www.imperial.ac.uk/people/r.diaz-chavez
https://www.researchgate.net/profile/Rocio-Diaz-Chavez
https://www.linkedin.com/in/rocio-diaz-chavez-43569713/?originalSubdomain=uk

Projects

HARNESSING POTENTIAL OF BIOLOGICAL CO_2 CAPTURE FOR CIRCULAR ECONOMY

This project is part of the ACT ERA-NET Co-fund under the European Union's Horizon 2020 Research and Innovation Programme (Project No 327331 CooCE)
In the UK by the Department of Energy Security and Net Zero