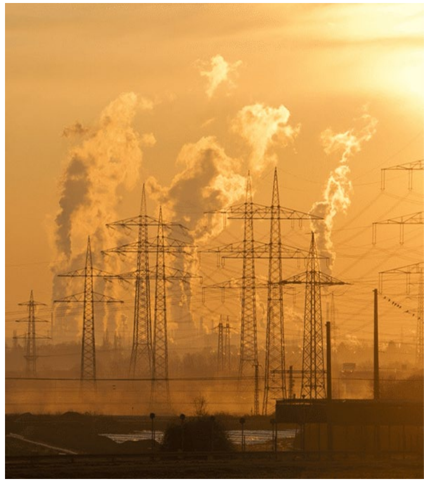
HARNESSING POTENTIAL OF BIOLOGICAL CO_2 CAPTURE FOR CIRCULAR ECONOMY

Enhancing the CO2 potential as a bioeconomy enabler



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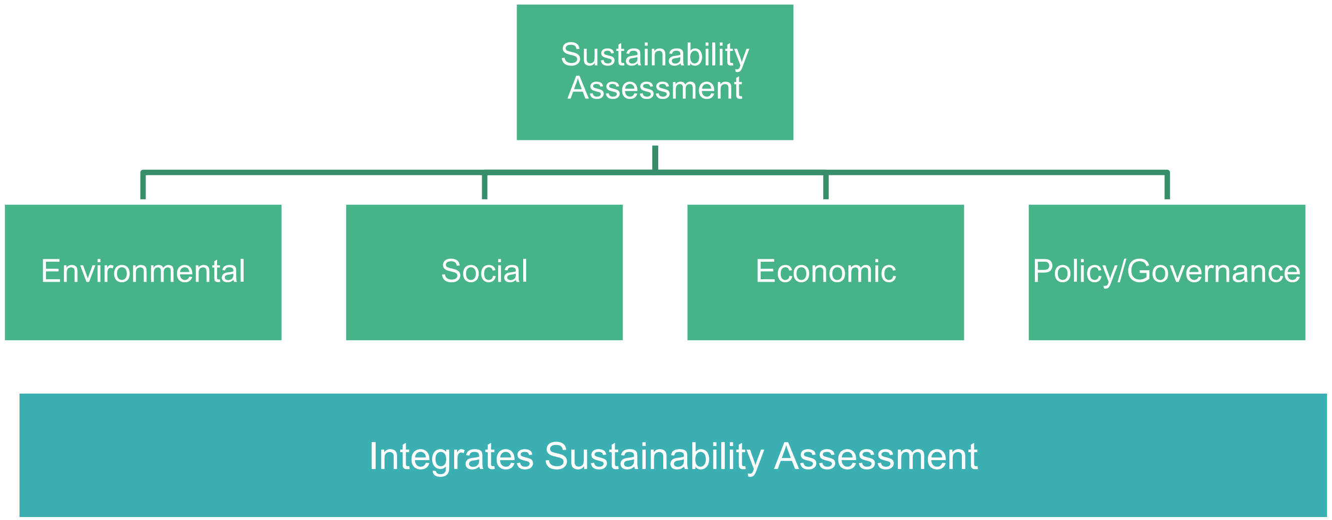
Outline

- To set robust basis of the bioeconomy, novel products obtained from renewable sources should be sustainable
- Biogenic CO2 is an underestimated renewable source to boost bioeconomy



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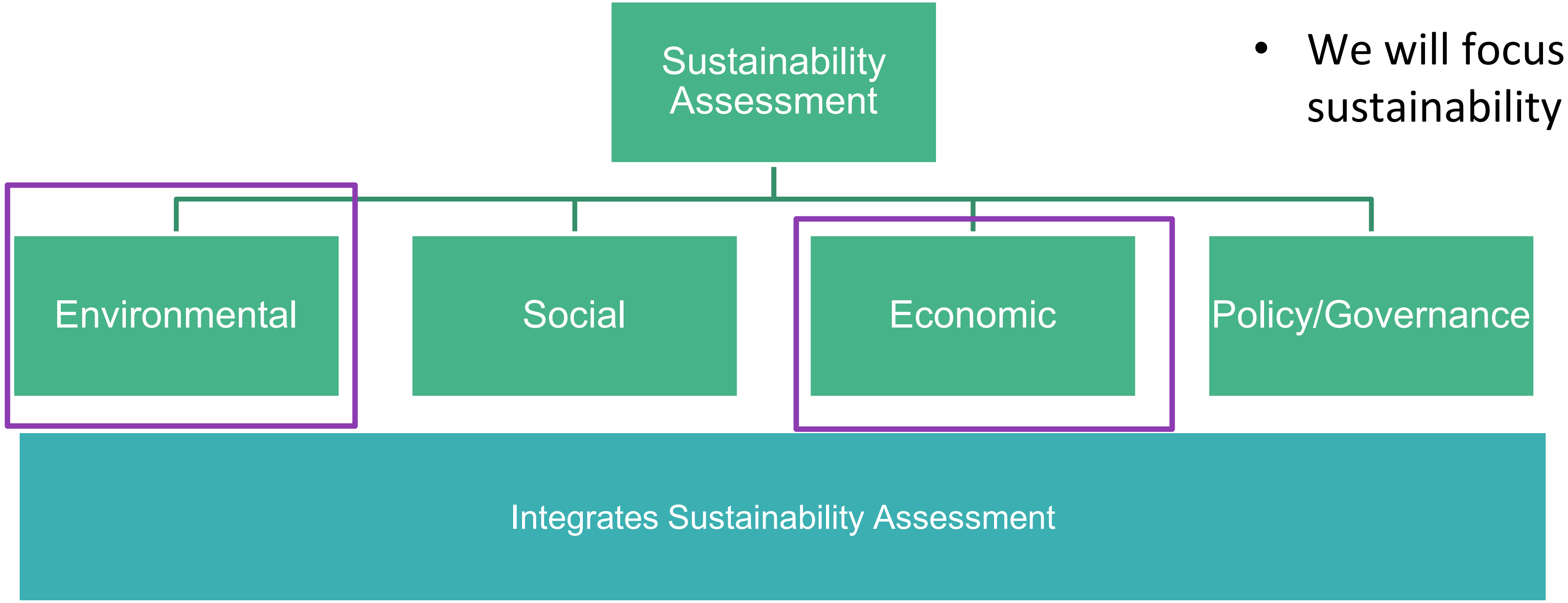
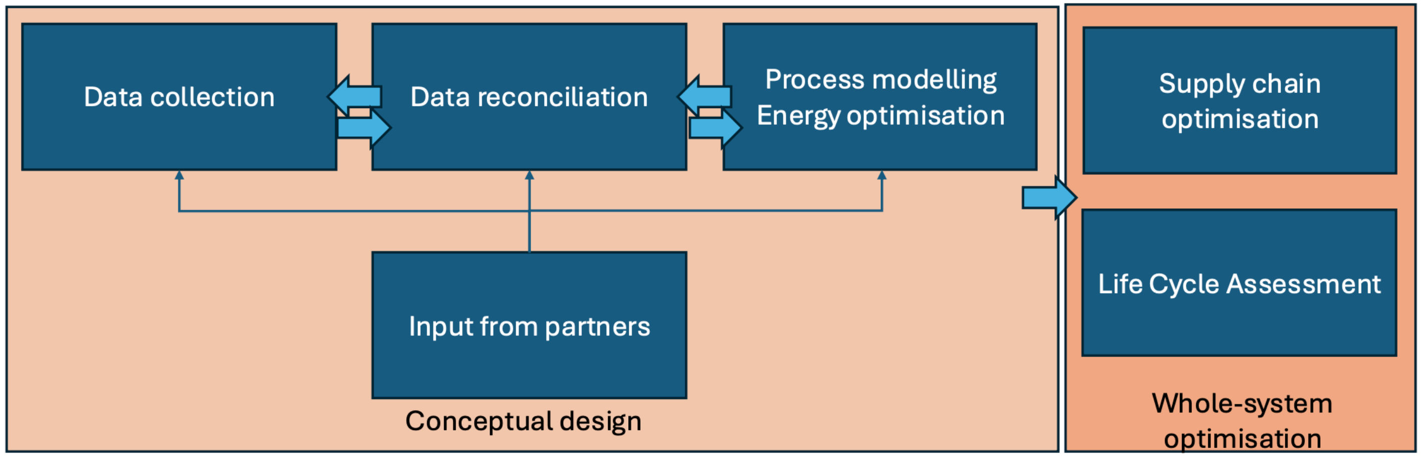


- We will focus on environmental and economic sustainability

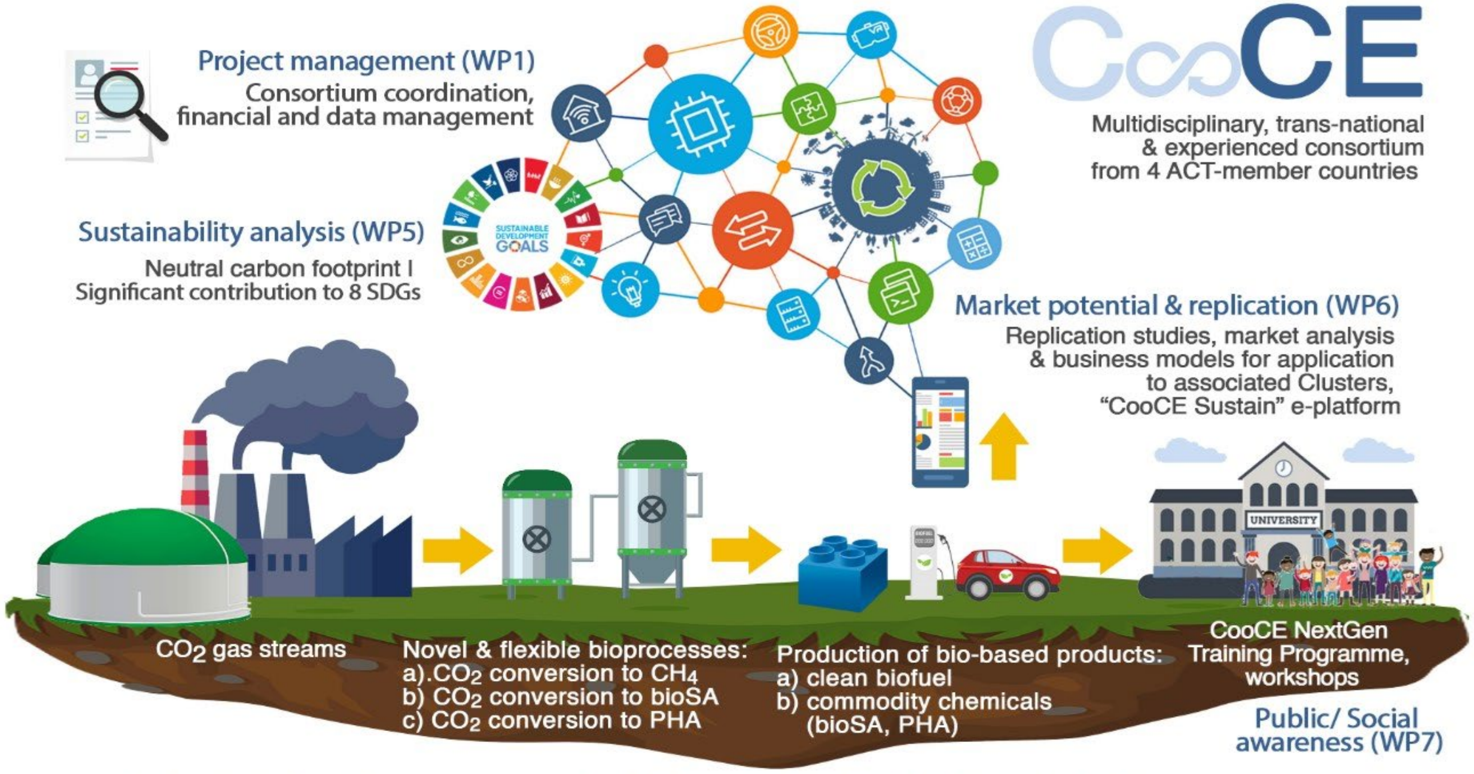


CooCE Concept & Main Objectives

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.



Technologies for CO_2 conversion into BioMethane (WP2) ; bioSA (WP3) ; PHAs (WP4)

Three novel pathways

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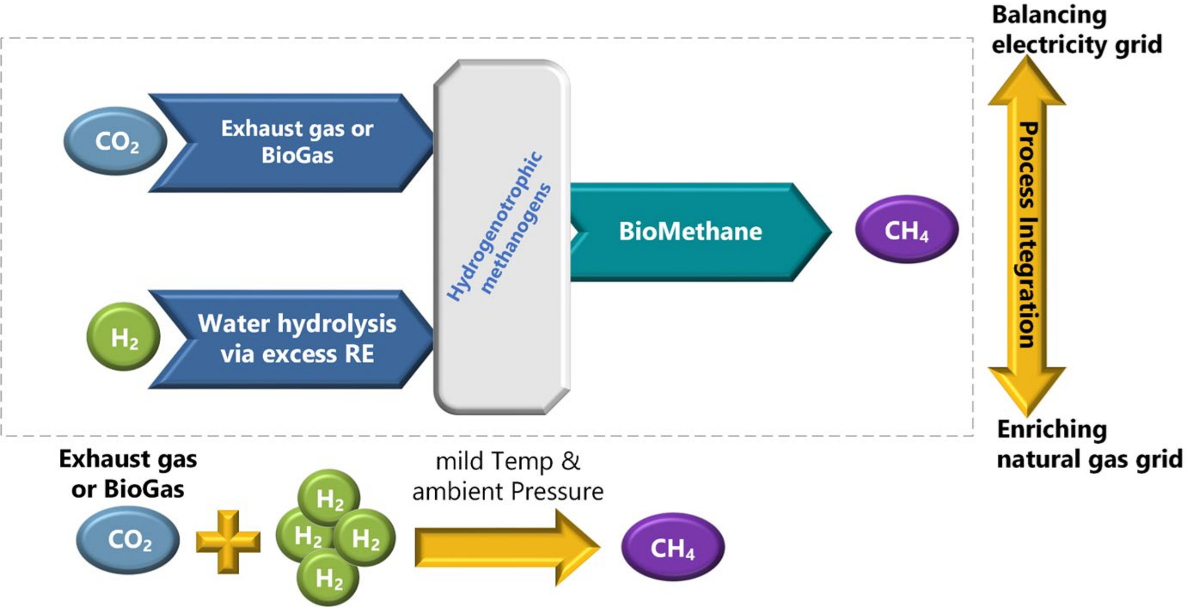
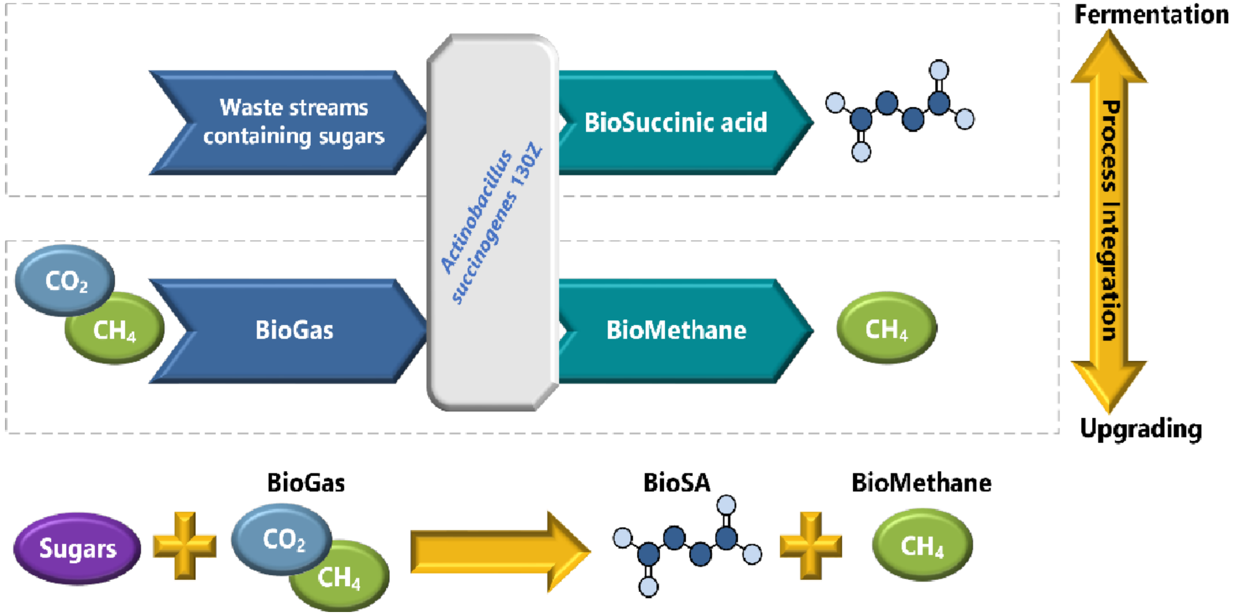
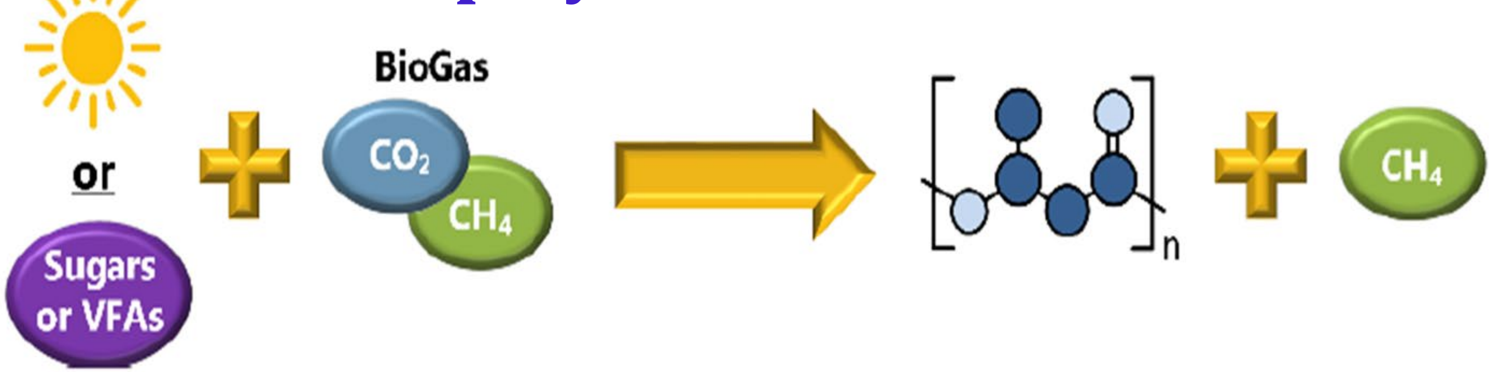
Biomethanation



Succinic acid



Biopolymers

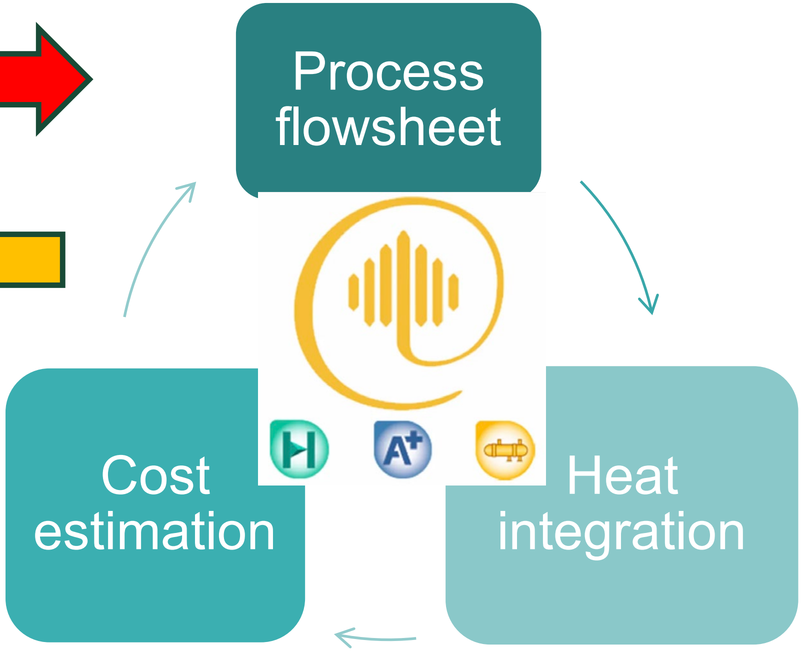


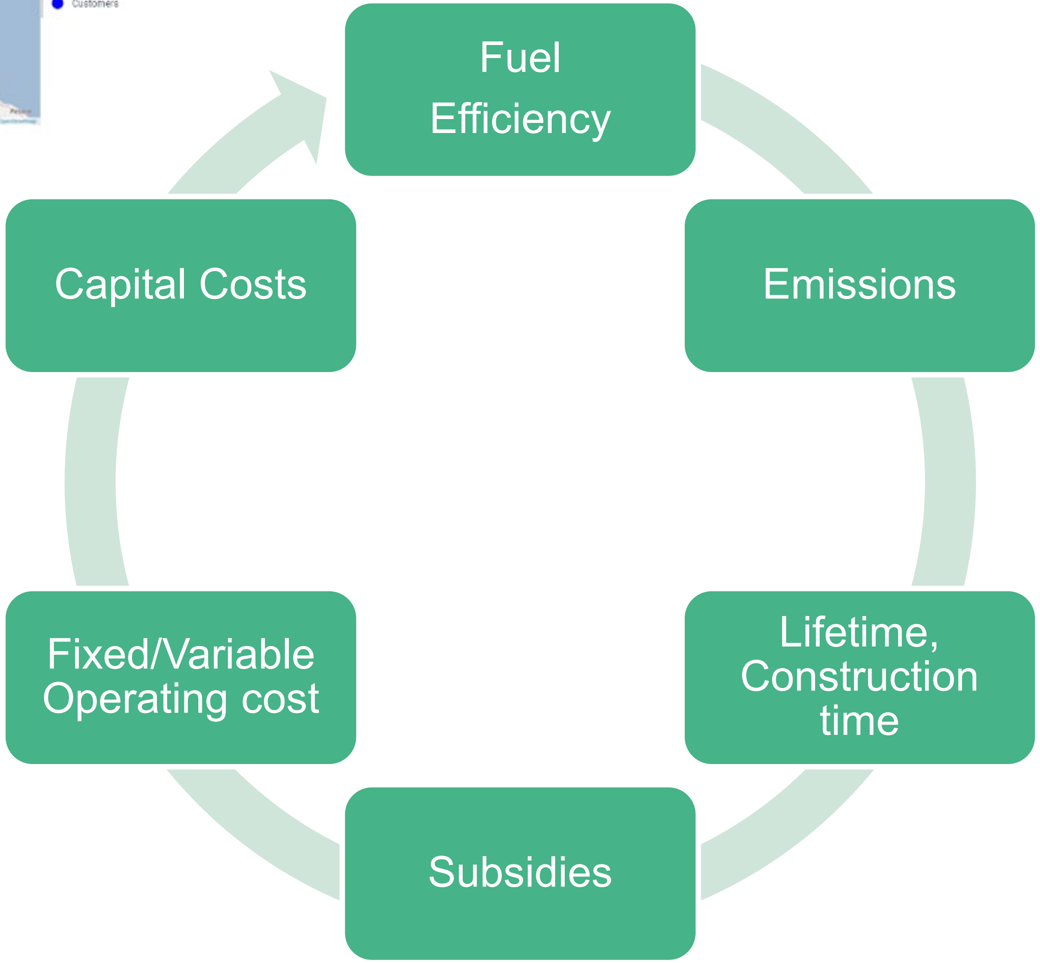
Economic Assessment: Methodology

- Case study approach (Greece, Denmark, Italy)
- Scenarios on the electricity supply
❖ 100% renewable, 100 % grid, mixed

Conceptual design

Experimental data





Supply Chain Optimisation

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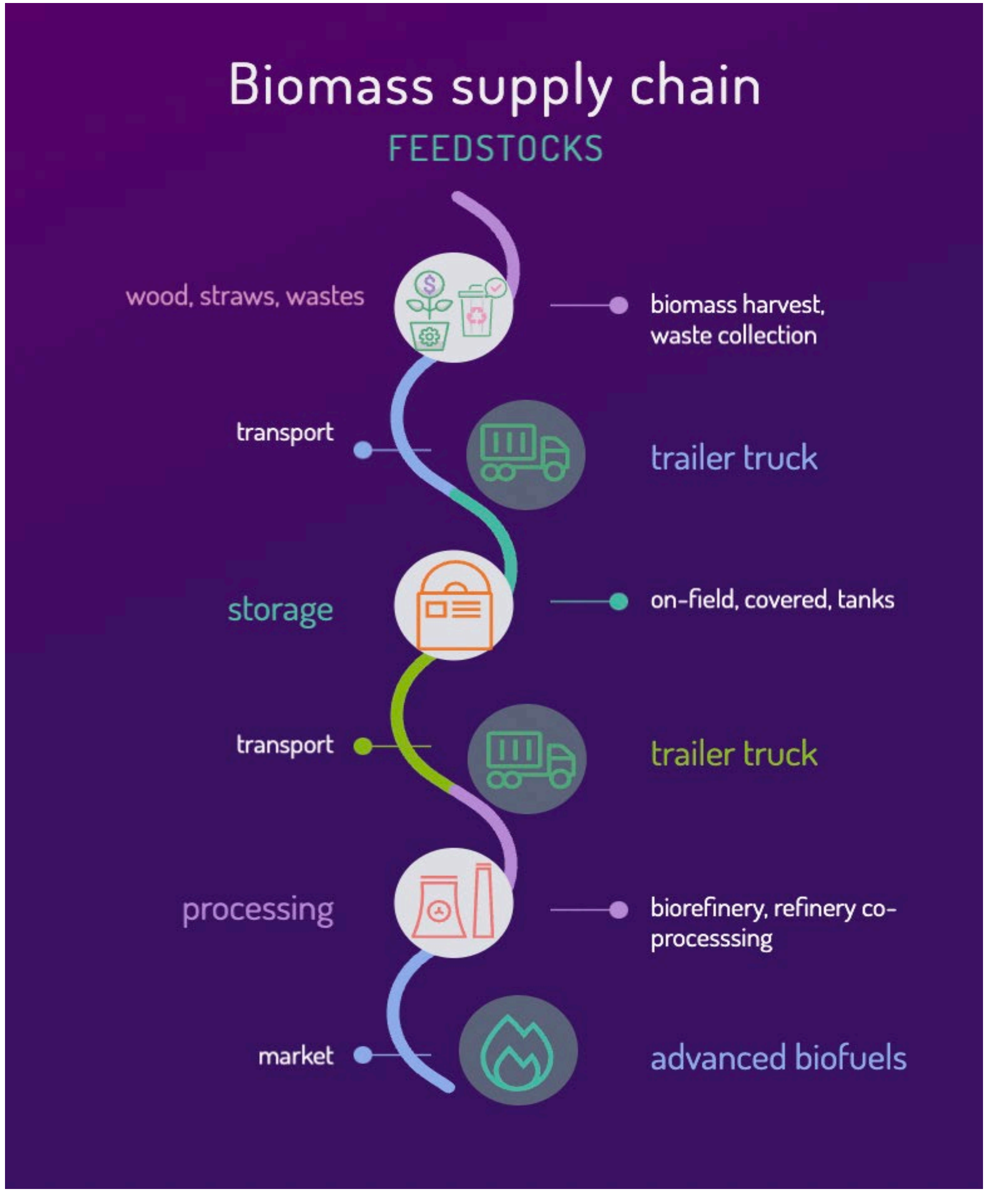
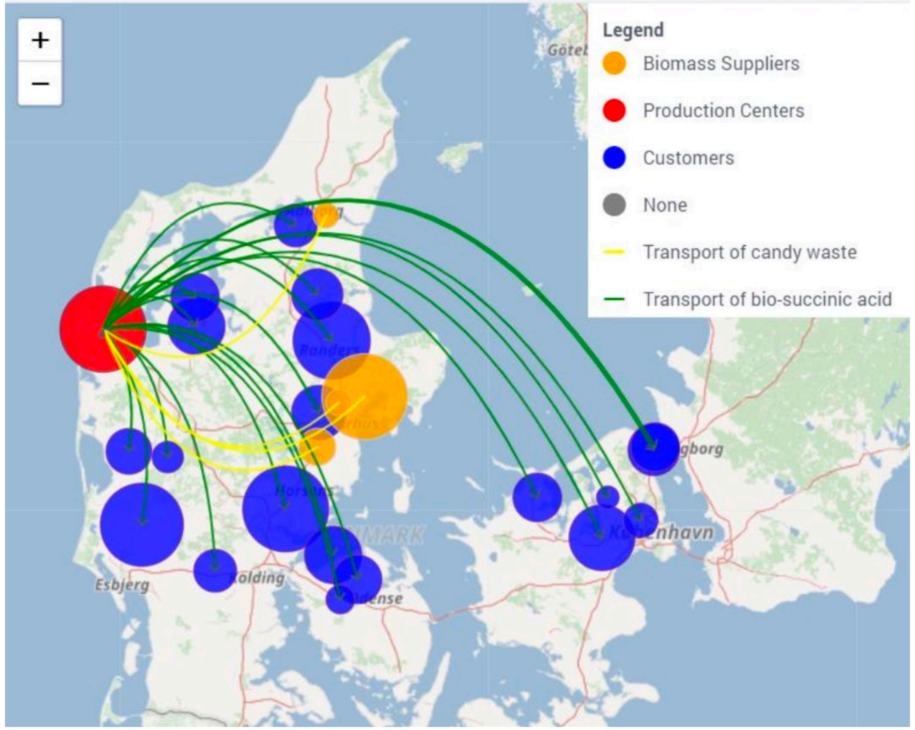


GIS integration



$$\textbf{maximize } TP = \sum_{s \in S} [Prob_s(RV_s - OC_s)] - CC \quad (4)$$

subject to

$$\sum_{c \in C} x_{c,k,g,t,s} \leq F_k \cdot y_{k,g}, \ \forall\ k \in K, g \in G, t \in T, s \in S \quad (5)$$

$$\sum_{k \in K} y_{k,g} \leq 1, \ \forall\ g \in G \quad (6)$$

$$x_{c,k,g,t,s} \geq 0, \ \forall\ c \in C, k \in K, g \in G, t \in T, s \in S \quad (7)$$

$$y_{k,g} \in \{0,1\}, \ \forall\ k \in K, g \in G \quad (8)$$

Economic Assessment: Capital Cost Breakdown

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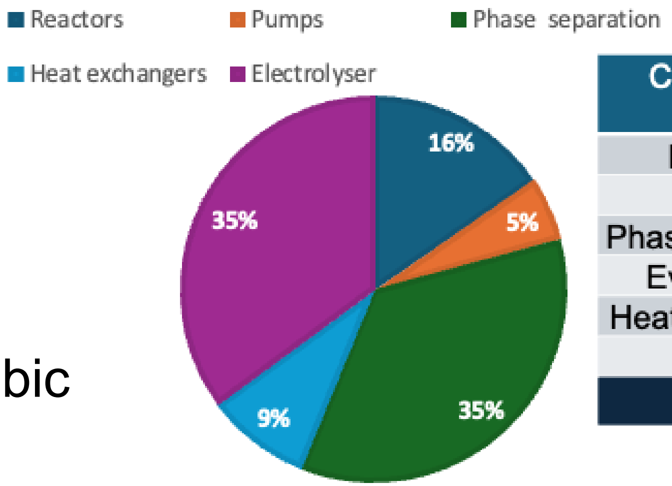
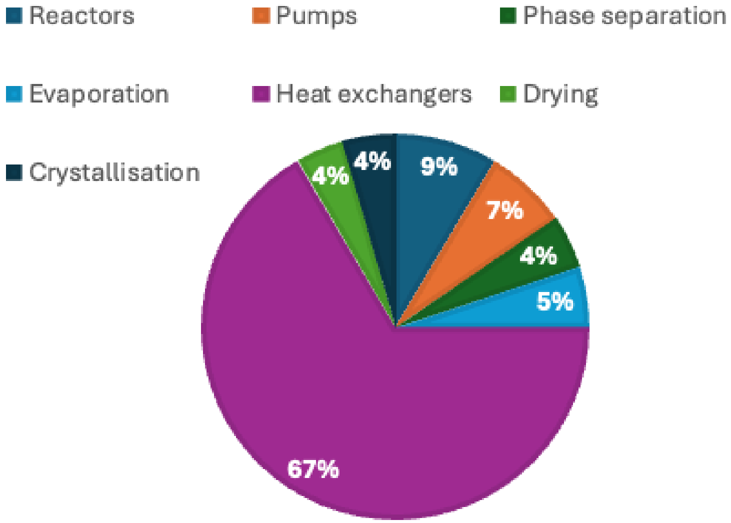
Component Name	Component Cost
Reactors	4945
Pumps	1702
Phase separation	11294
Heat exchangers	2801
Electrolyser	11224
Total	31966



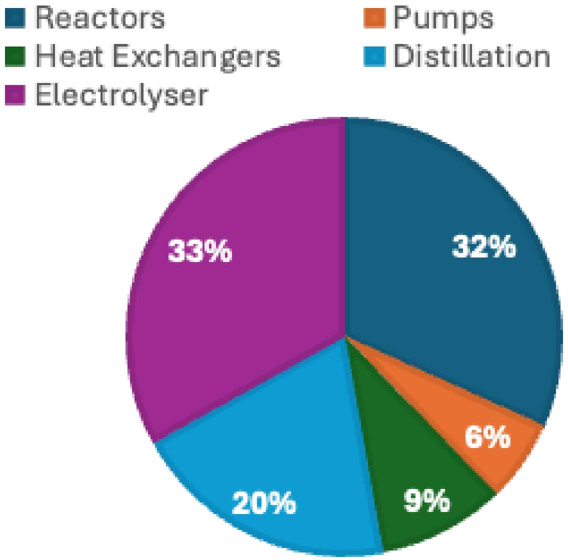
Biomethane (incl. Anaerobic Digestion)

Component Name	Component Cost (k€)
Reactors	346
Pumps	283
Phase separation	180
Evaporation	203
Heat exchangers	2,694
Drying	165
Total	4,048



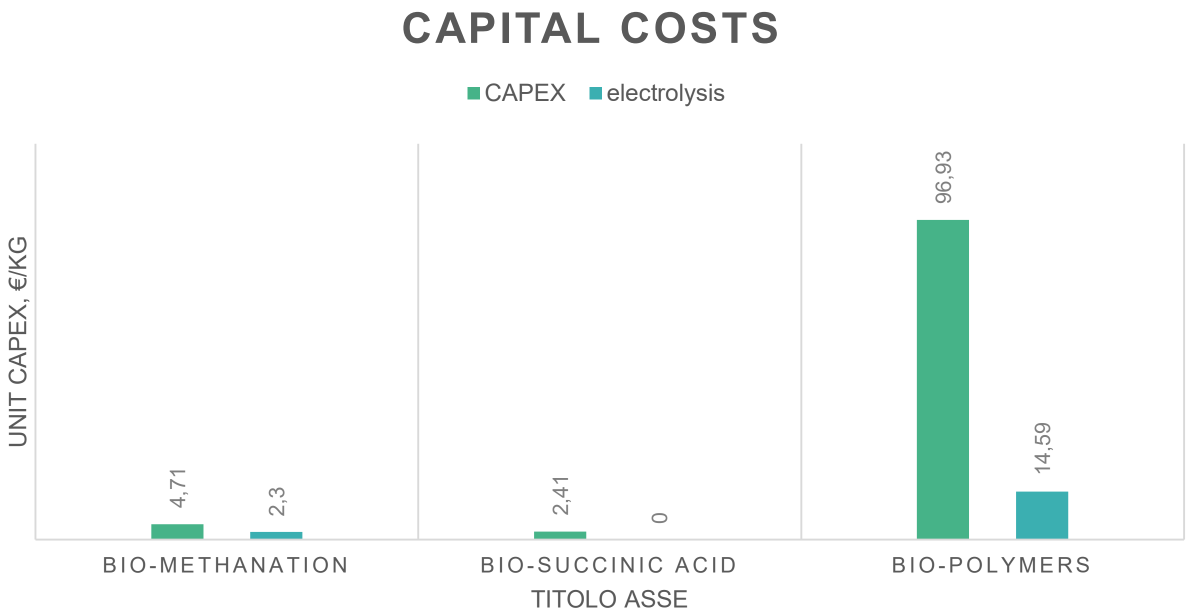
Bio-succinic Acid

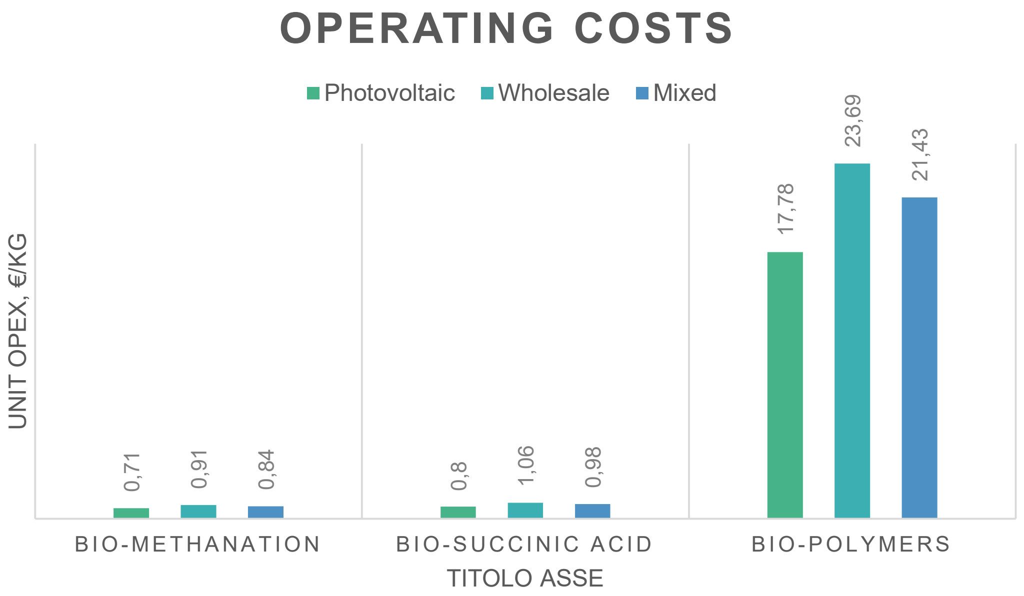
Component Name	Component Cost (k€)
Reactors	1,469
Pumps	285
Heat exchangers	435
Distillation	918
Electrolyser	1,534
Total	4,641



Biopolymers

Economic Assessment: cost metrics





- Electrolysis are an important contributions to the increase in costs
- Biopolymers have important needs of reaction and purification

- Electricity consumption affects the overall costs, especially in presence of electrolysis
- Biopolymers performance are negatively affected by the high energy requirements, the high demand of solvents, the hydrogen needs, and the low yields

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Economic assessment: minimum selling price

Biomethane

Feedstock	Unit, € / MWh	Reference from literature
Biogas methanation	82 - 118	Our work
Fermentation of different feedstocks	55 - 110	European Biomass Association
Fermentation of grass silage	62.75 – 136.25	Other literature

Biopolymers

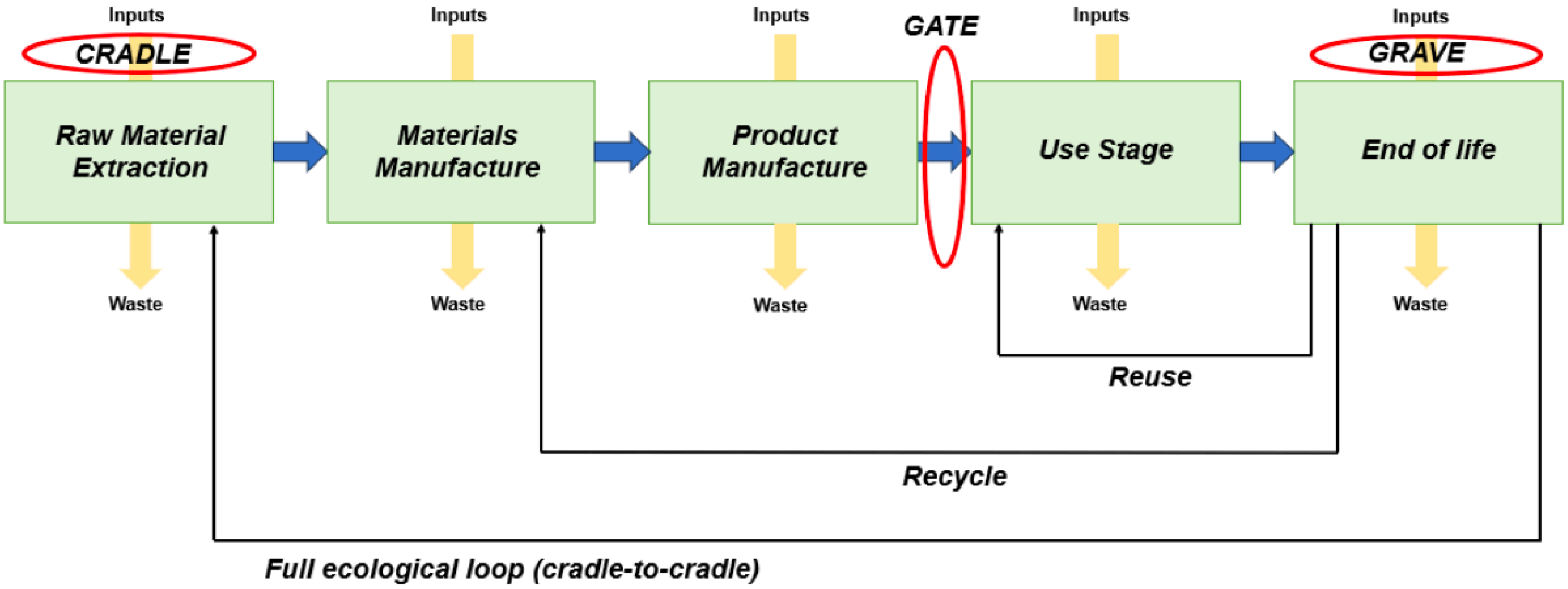
Feedstock	Unit, € (2024)/ kg	Reference from literature
Biogas	40 – 51	Our study
n.a.	4	Other literature

Biosuccinic acid

Feedstock	Unit, € (2024)/ kg	Reference from literature
Biogas and candy waste	1.34 – 1.94	Fermentation (our study)
Municipal biowaste	2.75	electrochemical membrane bioreactor
Bagasse	2.5 – 4.23	fermentation
Fossil	2.3 (up to 9)	maleic anhydride

The minimum selling price reflects the readiness of the technologies
Biomethane and biosuccinic acid are in line with other evidence from the literature
Biopolymers have higher selling price showing needs to further process optimisation

Environmental Assessment: Methodology



CO_2 emissions are evaluated with a cradle-to-gate approach

Environmental Assessment: CO_2 emissions

		Biomethane	Bio-succinic acid	Bio-polymer s
Raw material		0.394	0.053	39.264
Electricity		0.19	0.087	8.548
Natural Gas	Photovoltaics	0	0.085	0.253
Total (w/o credit)		0.584	0.225	48.065
Total (with credit)		-2.166	-0.148	46.05

		Biomethane	Bio-succinic acid	Bio-polymer s
Raw material		0.394	0.053	39.264
Electricity		1.39	0.64	62.644
Natural Gas	Mixed	0	0.253	0.253
Total (w/o credit)		1.784	0.778	102.161
Total (with credit)		-0.966	0.405	100.146

		Biomethane	Bio-succinic acid	Bio-polymer s
Raw material		0.394	0.053	39.264
Electricity		1.991	0.916	89.707
Natural Gas	Wholesale	0	0.253	0.253
Total (w/o credit)		2.385	1.054	129.224
Total (with credit)		-0.365	0.681	127.209
Fossil	**Energy mix**	**0.07 – 0.8 (natural gas)**	**1.94**	**1.8**

- The source of electricity and the renewable share is crucial to determine the emissions.
- The reuse of CO_2 within the product synthesis could be assigned a credit compared to the fossils.
- The temporary CO_2 presence in the product cannot be considered as a form of storage.

Environmental assessment: energy and waste

	Case	Biomethane	Biosuccinic acid	Biopolymer
Electricity, kWh / kg of product	Photovoltaics, Grid, Mixed	4.663	4.342	256.306
Waste, kg / kg of product		17.52	46.2	81.23

- Electricity and waste generation are estimated at a process level
- All the technologies show a high energy consumption, with biopolymers reaching the highest levels
- Wastes are of various nature and contain a different mix of liquid and solids depending on the technologies. Further data will be needed to evaluate how these can be recovered or processed.

Final considerations

- The biomethane process shows the highest readiness level. Improvements at a process level targeting a reduction in the use of energy, the dependency on hydrogen as well as the improvements in yields could lower the minimum selling price, making it a more valuable alternative to natural gas.

- The biosuccinic acid shows concerns in the uses of electricity and the amount of waste produced. However, the technology environmental performance are generally promising. Although the selling price calculated could be underestimated, the technology economics align with the fossil route.

- The biopolymer production require bigger efforts in terms of scale-up compared to the other two routes. Advances in the processes would come from process optimisation targeting an increase in yields which would reduce the use of resources and of energy in the process.

CooCE

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Thank you!

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