10th International Conference on Sustainable Solid Waste Management

Environmental evaluation of innovative biorefinery process

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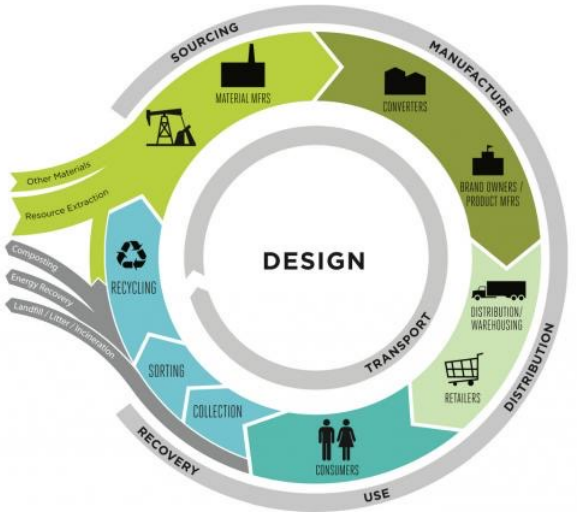
Summary

- ❑ BBCircle project
- ❑ Materials and method
  - Life Cycle Assessment
  - Goal and scope definition (G&S)
  - Life Cycle Inventory (LCI)
- ❑ Results and discussion - preliminary
  - Life Cycle Impact Assessment (LCIA)
- ❑ Conclusions



BBCircle project

The BBCircle project, funded by the Lazio Region (IT), is aimed at integrating different processes to produce biomaterials, biofuels, capturing CO_2 and promote circularity, in reference to the suitable and available substrates in the regional territory.
(2021-2023)

Link

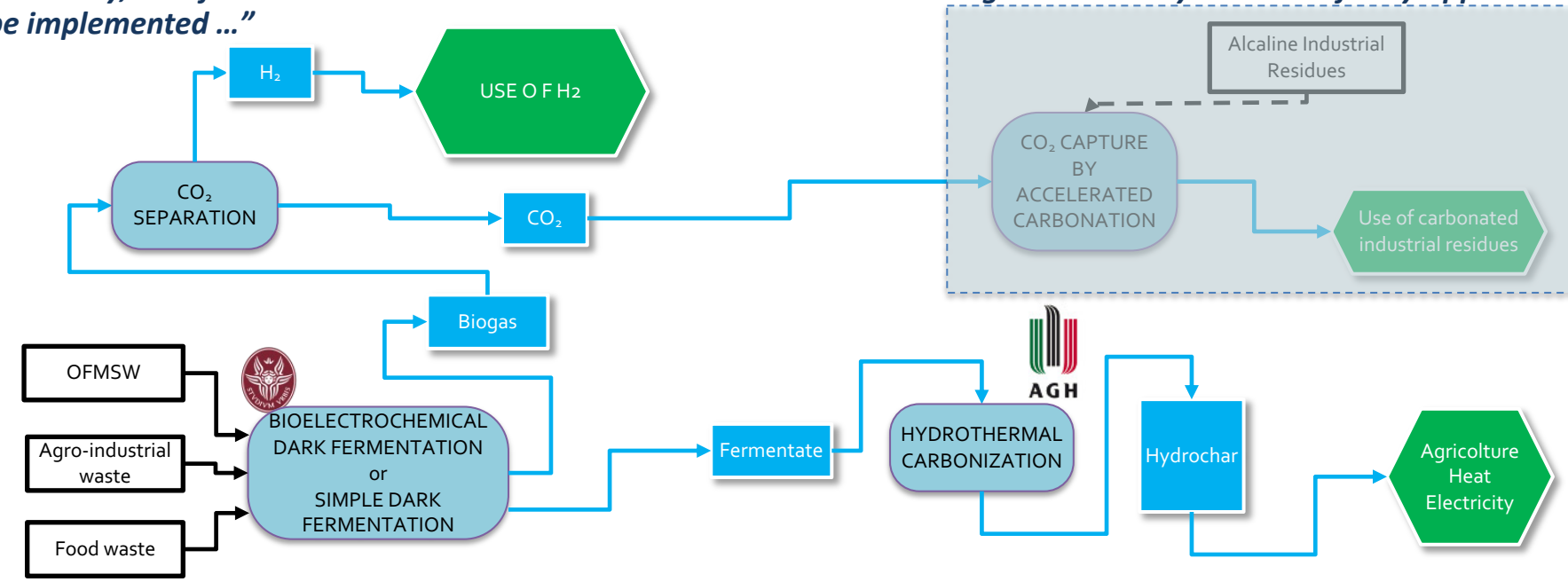
BBCircle – Biomaterials, Biofuels, CO2 sequestration and Circularity. A study about the possibility to implement Biorefineries in the Lazio Regione

Biomateriali, Biocombustibili, Sequestro della CO2 e Circolarità. Studio sull'implementabilità di Bioraffinerie nella Regione Lazio - Avviso Pubblico “Gruppi di Ricerca 2020” di cui alla Determinazione n. G08487 del 19/07/2020 U e modificato con Determinazione n. G10624 – POR FESR LAZIO 2014 – 2020 – Progetto n. A0375-2020-36701

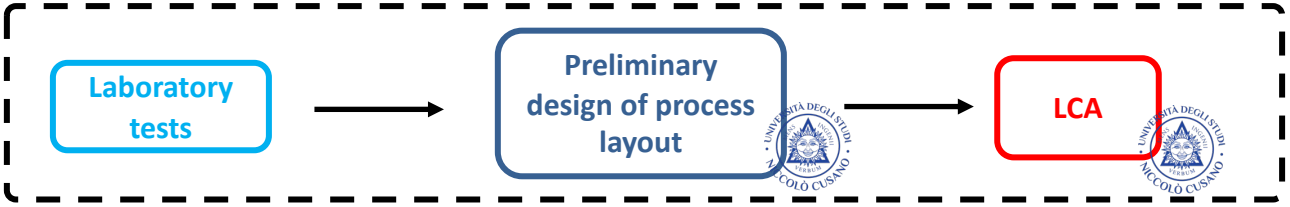
http://www.dicea.uniroma1.it/node/1220

BBCircle project – Biorefinery configuration

"…. is aimed at integrating different processes to produce biomaterials, biofuels, capturing CO_2 and promote circularity, in reference to the suitable and available substrates in the regional territory. The biorefinery approach will be implemented …"



Research pathway



BBCircle project – Cheese whey as substrate

Dairy industry

10%

Cheese

90%

Cheese whey

6%

Ricotta/Cottage Cheese

84%

Secondary cheese whey

- Dairy products in EU-28 area: 160 millions in 2020 (FAO)
- 9-10 L of CW per kg of cheese produced
- **CW organic load: 50-100 g_{COD}/L**

Environmental issue

- Eutrophication in waterbodies
- Toxicity to aquatic animals
- Decrease in crop yield

Huge opportunity to recover:

- Bioenergy
- Bioproducts

Management strategies

Past

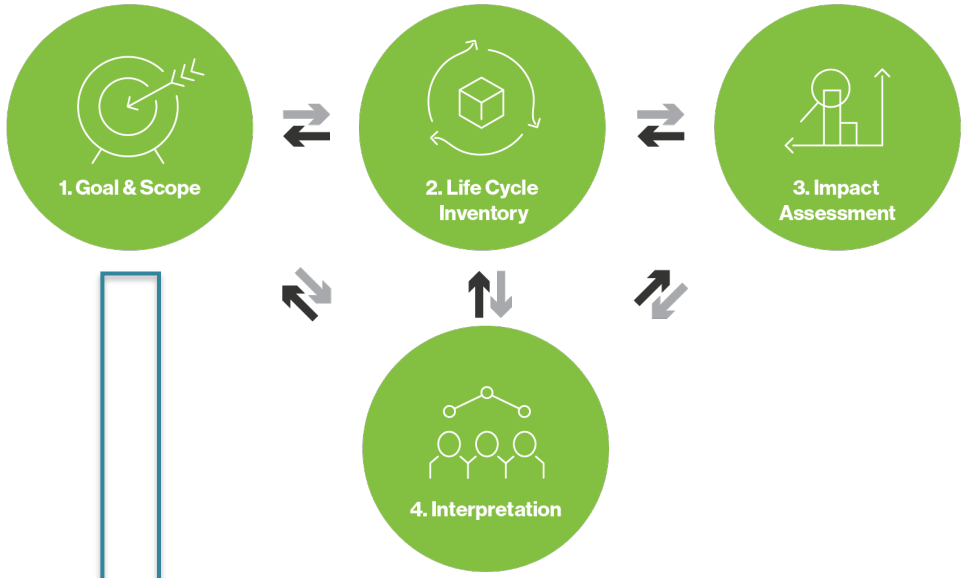
- Fertiliser
- Animal feed
- Disposed

Present & Future

- Extraction/separation processes → **Proteins**, **VFA**
- Anaerobic digestion → **CH_4-rich gas**
- Fermentative processes → **H_2-rich gas**, **PHA**, **EE**

Materials and method – Life Cycle Assessment

ISO 14044

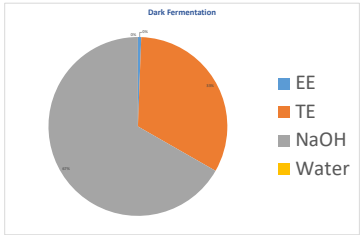


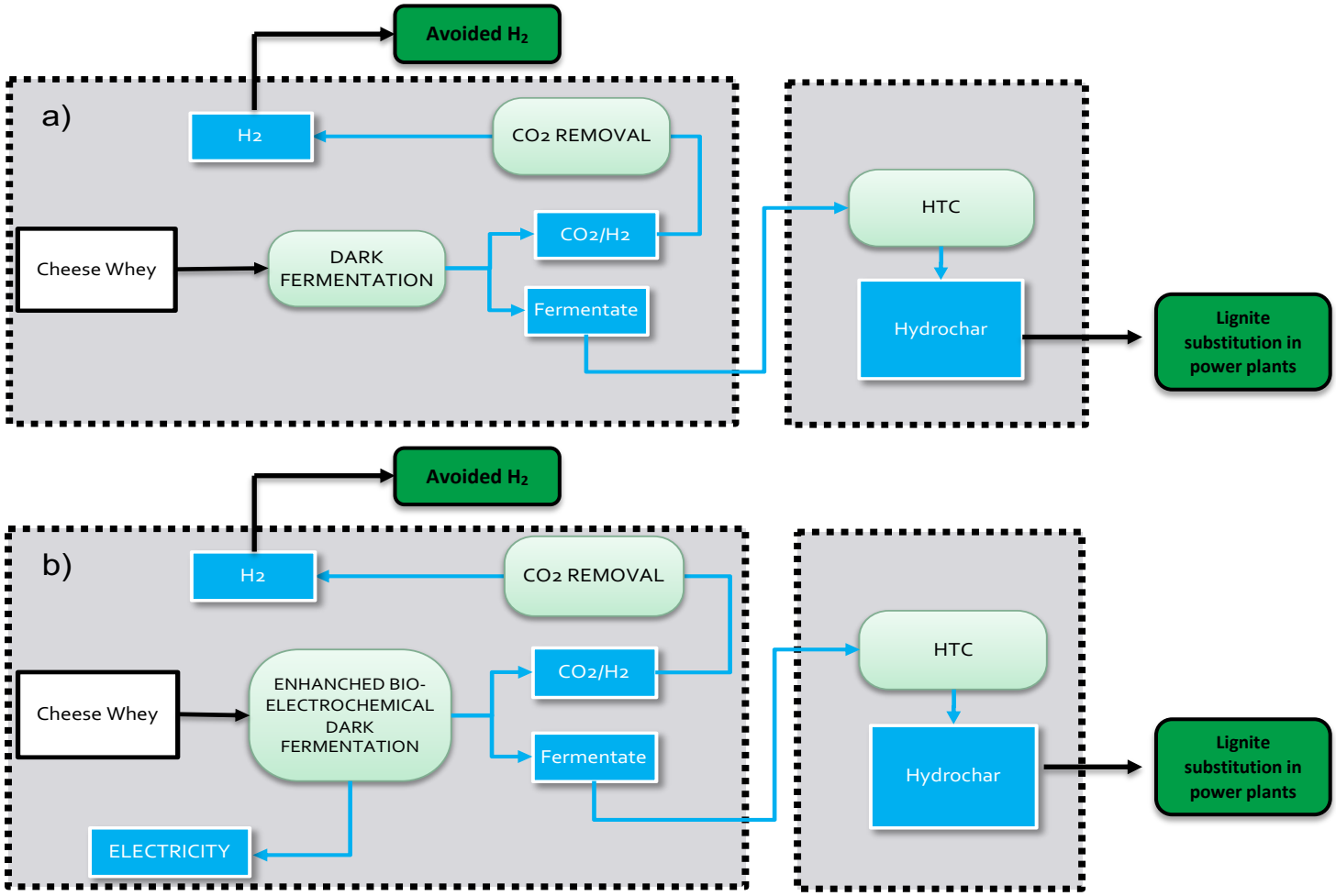
Goal & scope definition:

- **Evaluation of the sub-processes contribution**
- **Comparison of two alternative processes**

Goal & scope definition

Functional Unit: **1 t CW**



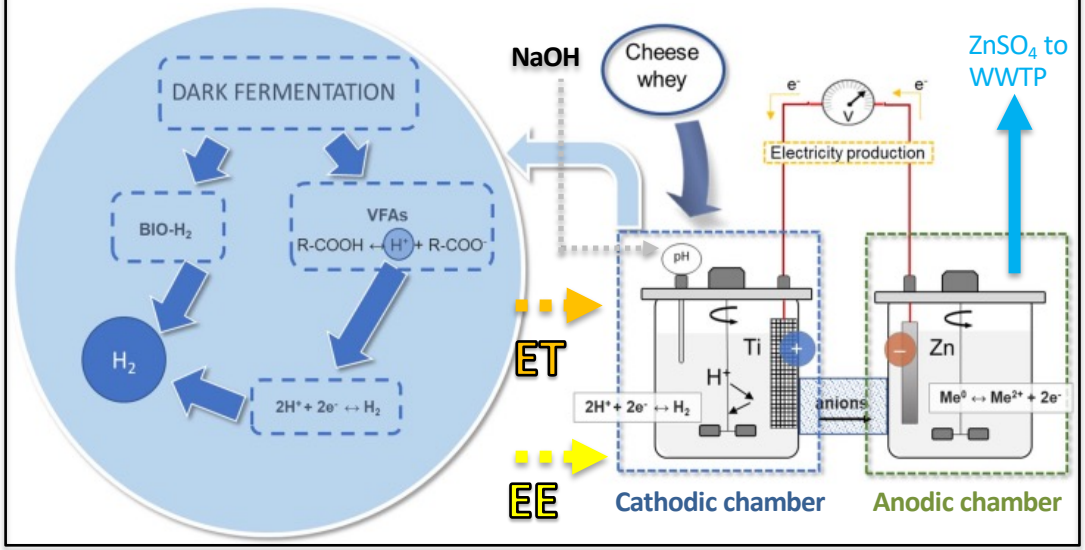


Goal & scope definition

Integrated Bio-Electrochemical System (IBES)

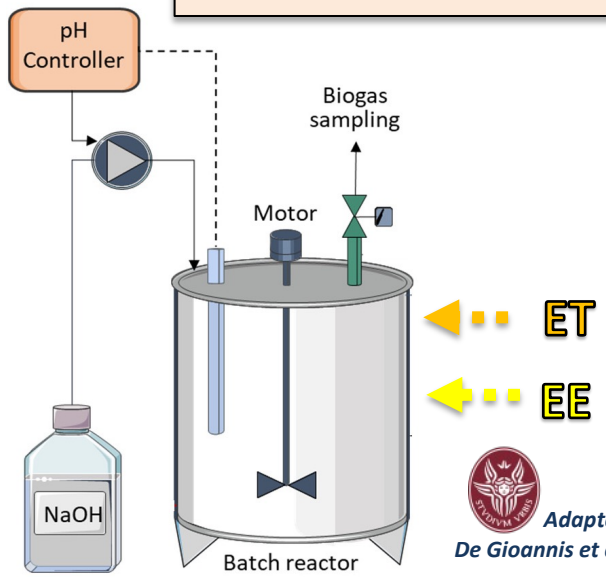
Adapted from:
De Gioannis et al., 2021

- Biogas yield: 3.6 kg/t CW
- Biogas composition (%vol.): 60 H_2-40 CO_2
- H_2 yield: 2.69 NL/kg CW
- Fermentate: 1.1 t/t CW
- EE prodotta: 0.08 kWh/t CW



Stand-alone dark fermentation

- Biogas yield: 13.5 kg/t CW
- Biogas composition (%vol.):50 H_2-50 CO_2
- H_2 yield: 6.57 NL/kg CW
- Fermentate: 1.3 t/t CW



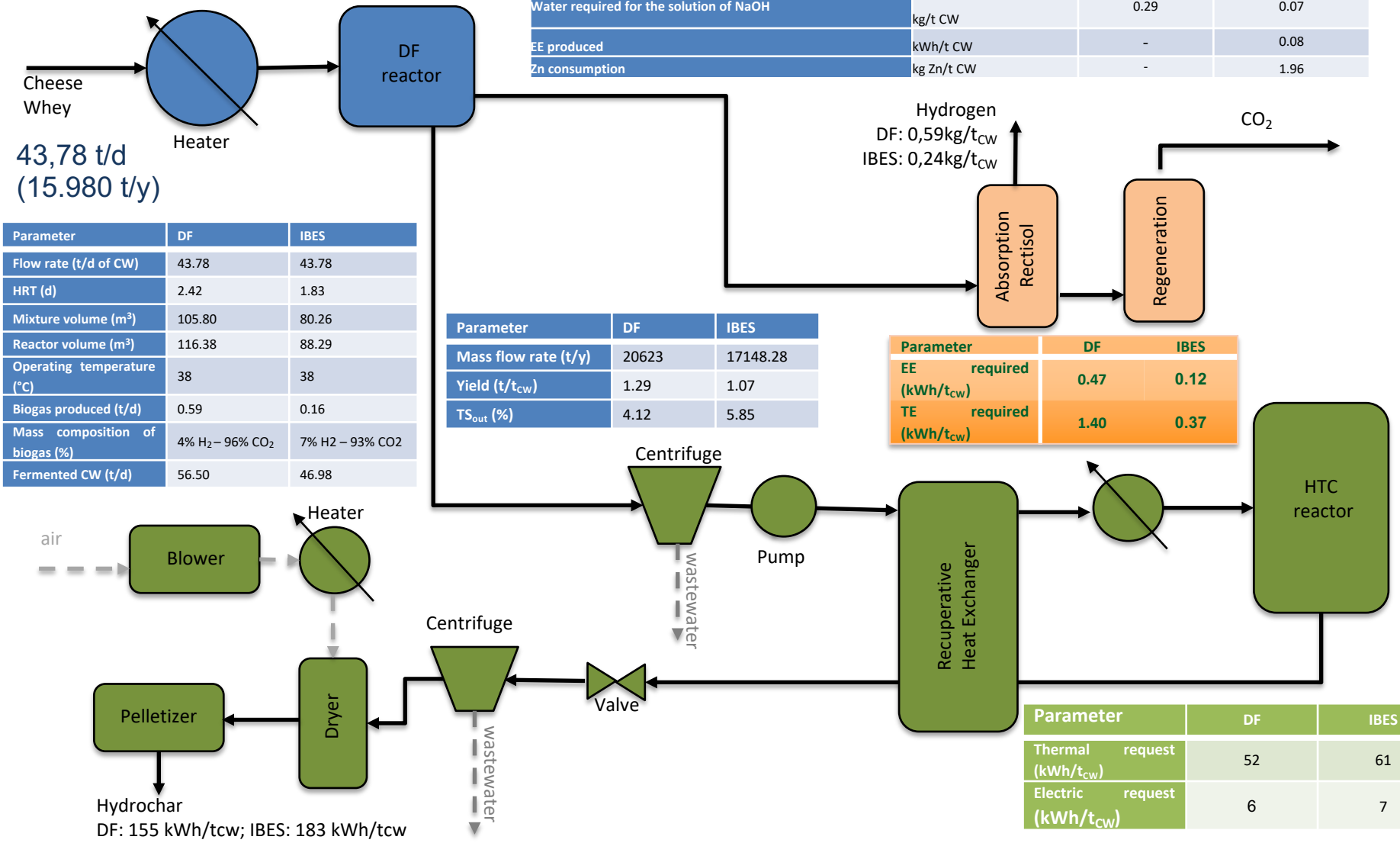
- ✓ Additional electrochemical generation of H_2
- ✓ EE generation
- ✓ No need to add buffering agent (NaOH) continuously
- X Consumption and replacement of zinc electrode
- X **Depletion of anode solution ($ZnSO_4$) and need to treat and replacement**

- ✓ Higher biogas yield
- ✓ Higher H_2 yield
- X Need to add buffering agent (NaOH) continuously

Substitution interval: once a day – once a year

Life Cycle Inventory

Parameter		DF	IBES
EE required	kWh/t CW	0.31	0.30
TE required	kWh/t CW	29.84	29.67
NaOH required	kg/t CW	17.43	5.85
Water required for the solution of NaOH	kg/t CW	0.29	0.07
EE produced	kWh/t CW	-	0.08
Zn consumption	kg Zn/t CW	-	1.96



Parameter	DF	IBES
Flow rate (t/d of CW)	43.78	43.78
HRT (d)	2.42	1.83
Mixture volume (m^3)	105.80	80.26
Reactor volume (m^3)	116.38	88.29
Operating temperature (°C)	38	38
Biogas produced (t/d)	0.59	0.16
Mass composition of biogas (%)	4% H_2 – 96% CO_2	7% H2 – 93% CO2
Fermented CW (t/d)	56.50	46.98

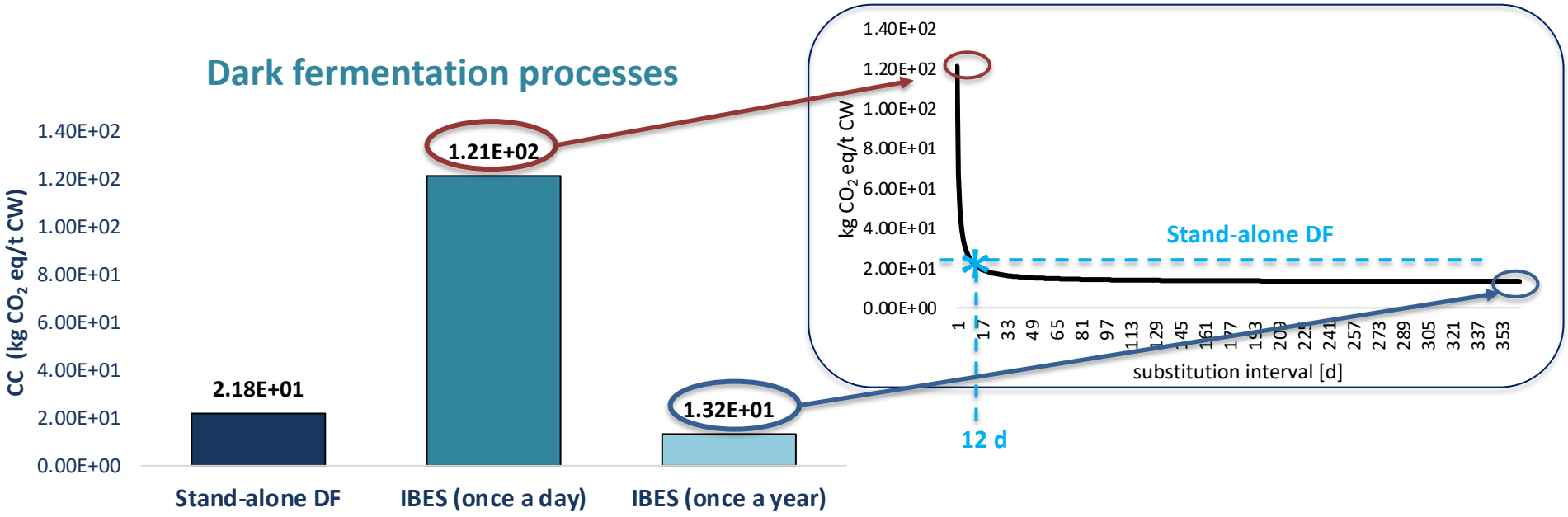
Parameter	DF	IBES
Mass flow rate (t/y)	20623	17148.28
Yield (t/t$_{CW}$)	1.29	1.07
TS_{out} (%)	4.12	5.85

Parameter	DF	IBES
EE required (kWh/t$_{CW}$)	0.47	0.12
TE required (kWh/t$_{CW}$)	1.40	0.37

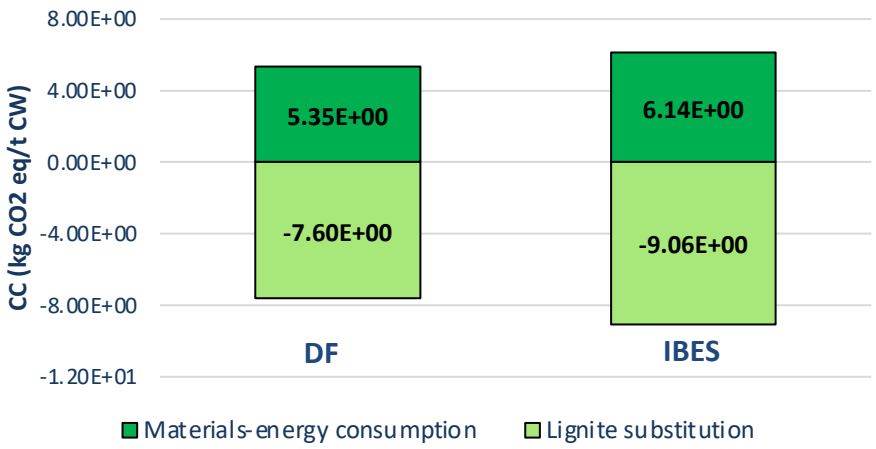
Parameter	DF	IBES
Thermal request (kWh/t$_{CW}$)	52	61
Electric request (kWh/t$_{CW}$)	6	7

Results and discussion – Impact Assessment (CC)

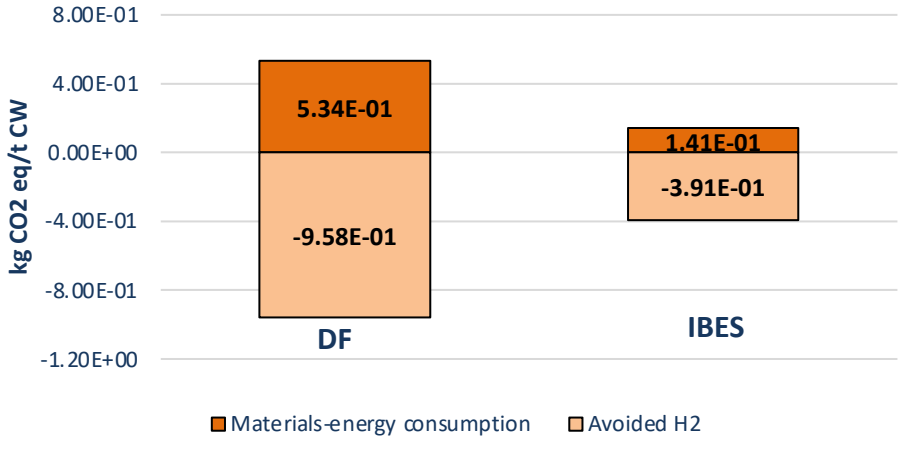
Dark fermentation processes



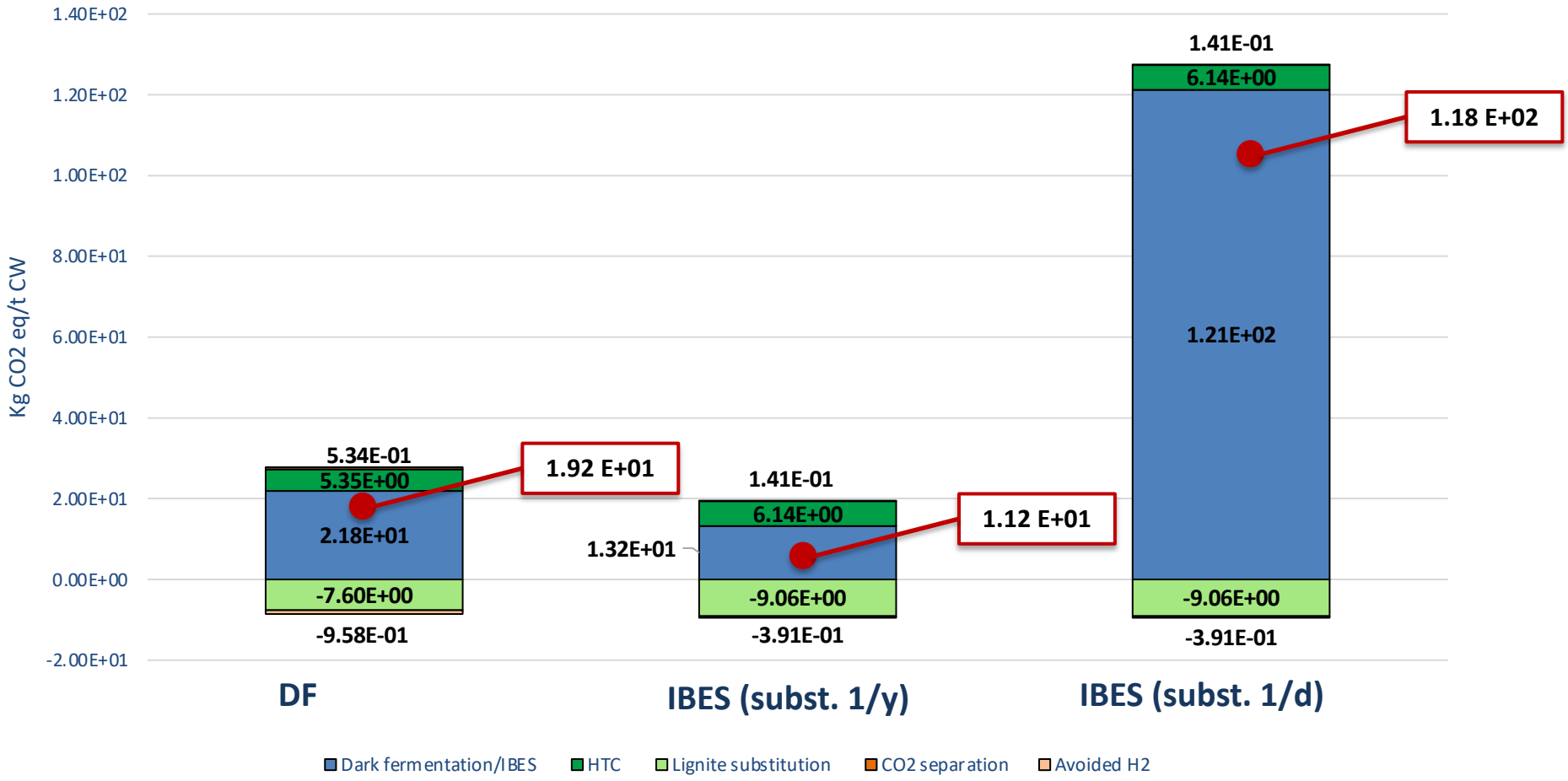
HTC process



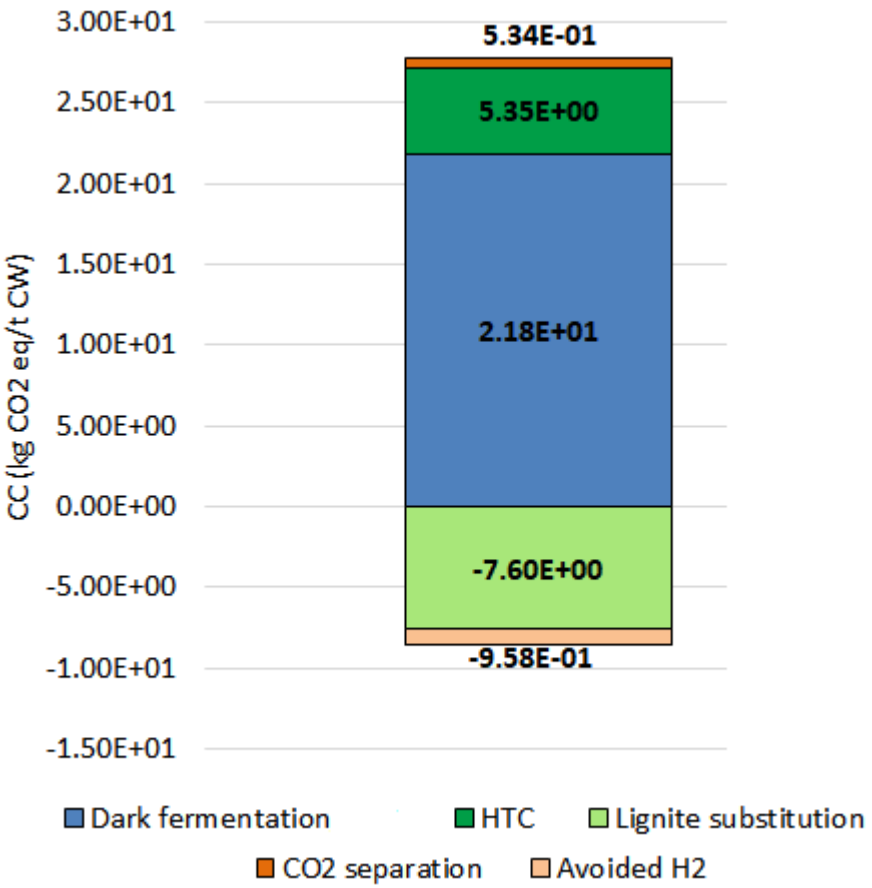
CO2 separation/H2 production



Results and discussion – Impact Assessment (CC)



Results and discussion – Impact Assessment (CC)

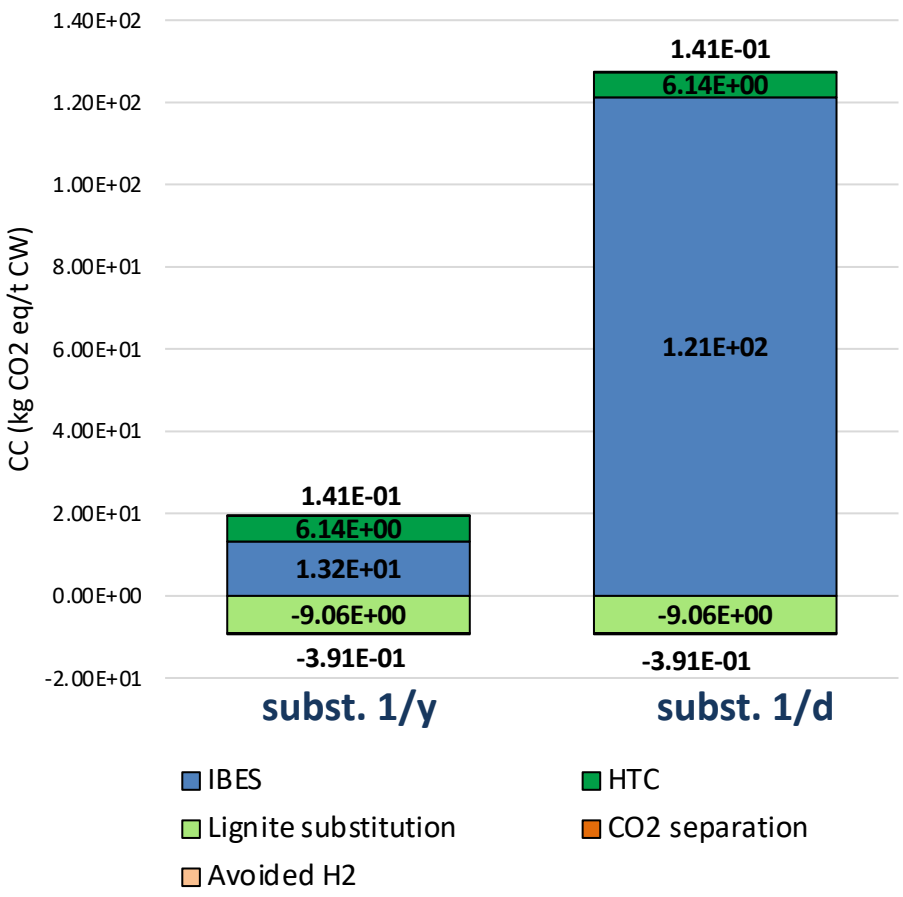


DARK FERMENTATION	
	kg CO2 eq
EE	0.130768
TE	7.137116
NaOH	14.58
Water	9.7E-05

HTC	
	kg CO2 eq
DW	1.250339
HTC REACTOR	2.585074
CENTRIFUGATION	0.314037
DRYING	0.366746
PELLETTIZING	0.83597
LIGNITE SUBSTITUTION	-7.6048

CO2 SEPARATION	
	kg CO2 eq
EE	0.199524
TE	0.334882
Avoided H2	-0.95765

Results and discussion – Impact Assessment (CC)



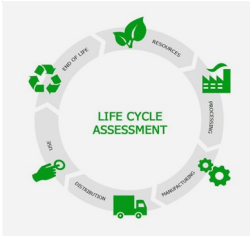
IBES		
	kg CO2 eq	
Substitution	once a year	once a day
EE	1.29E-01	1.29E-01
TE	7.10E+00	7.10E+00
NaOH	4.89E+00	4.89E+00
Zn	8.65E-01	8.65E-01
EE produced	-3.38E-02	-3.38E-02
Anodic solution to WWTP	1.81E-03	6.60E-01
ZnSO4	2.93E-01	1.07E+02
Water	1.68E-03	6.12E-01

HTC	
	kg CO2 eq
DW	1.314386
HTC REACTOR	3.034049
CENTRIFUGATION	0.371434
DRYING	0.434188
PELLETTISING	0.989699
LIGNITE SUBSTITUTION	-9.05924

CO2 SEPARATION	
	kg CO2 eq
EE	0.052518
TE	0.088146
Avoided H2	-0.39146

Conclusions

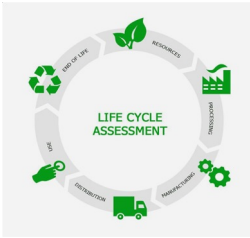
- Introducing the IBES process in place of DF reduces a lot the impact of NaOH use
- But uncertainty remains on the degradation of the $ZnSO_4$ solution
- To be competitive the $ZnSO_4$ solution should last at least 12 days
- Environmental credits are not able to balance the consumptions impacts of biorefinery system
- The main environmental credits come from hydrochar use
- Biorefinery results are promising: further aspects need to be investigated and further efforts must be invested in the experimental verification → **LCA can support this process**
- Other processes and other substrates are under investigation



Life-cycle thinking

SUSTAINABLE CIRCULAR ECONOMY

Thank You!



Life-cycle thinking

SUSTAINABLE CIRCULAR ECONOMY

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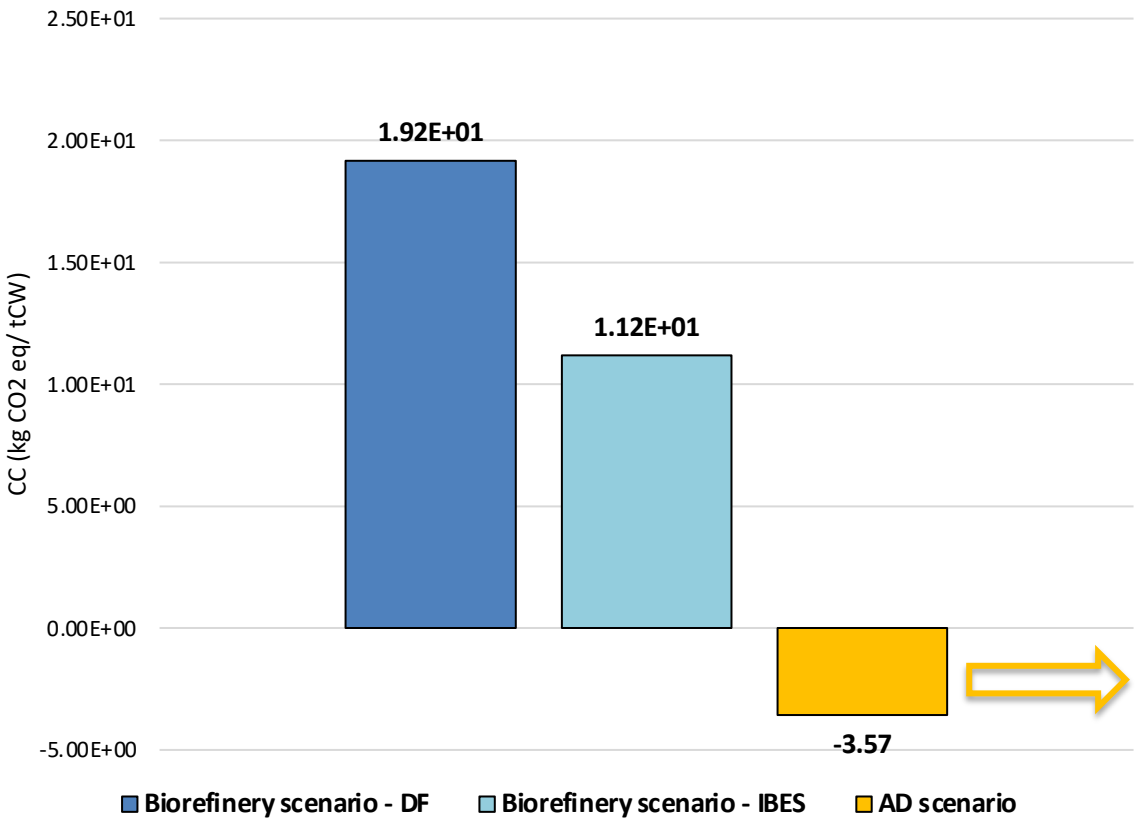
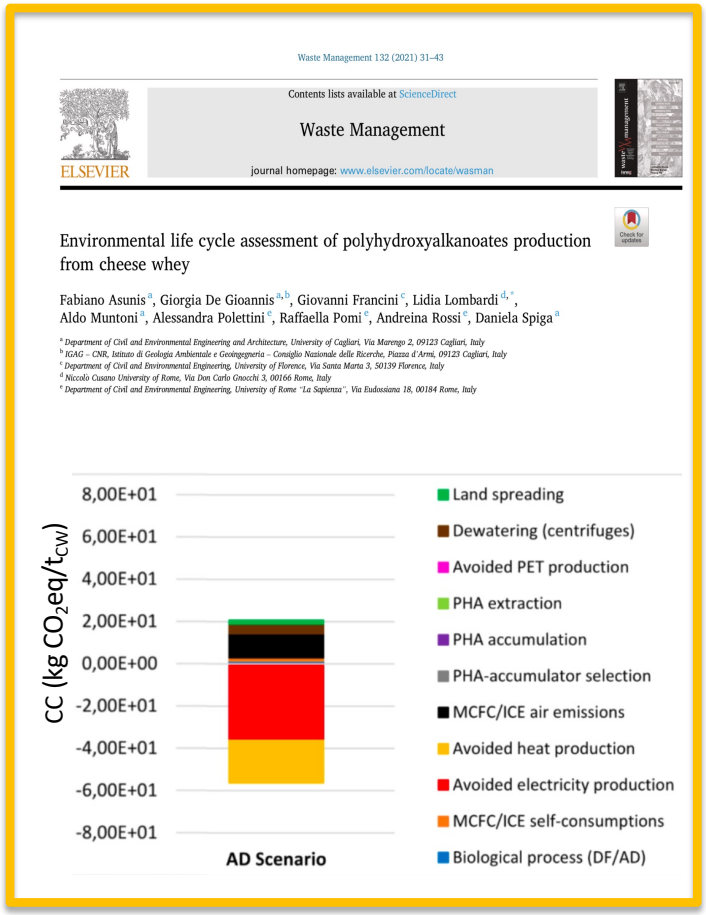
Results and discussion – Impact Assessment (CC)

LCIA method: Environmental Footprint ⇨ **Climate change (kg CO2 eq/t CW)**





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Environmental life cycle assessment of polyhydroxyalkanoates production from cheese whey

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