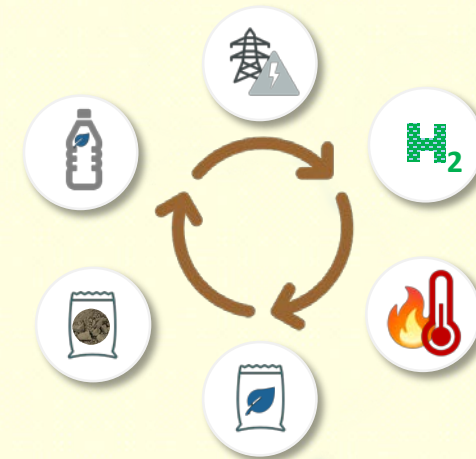


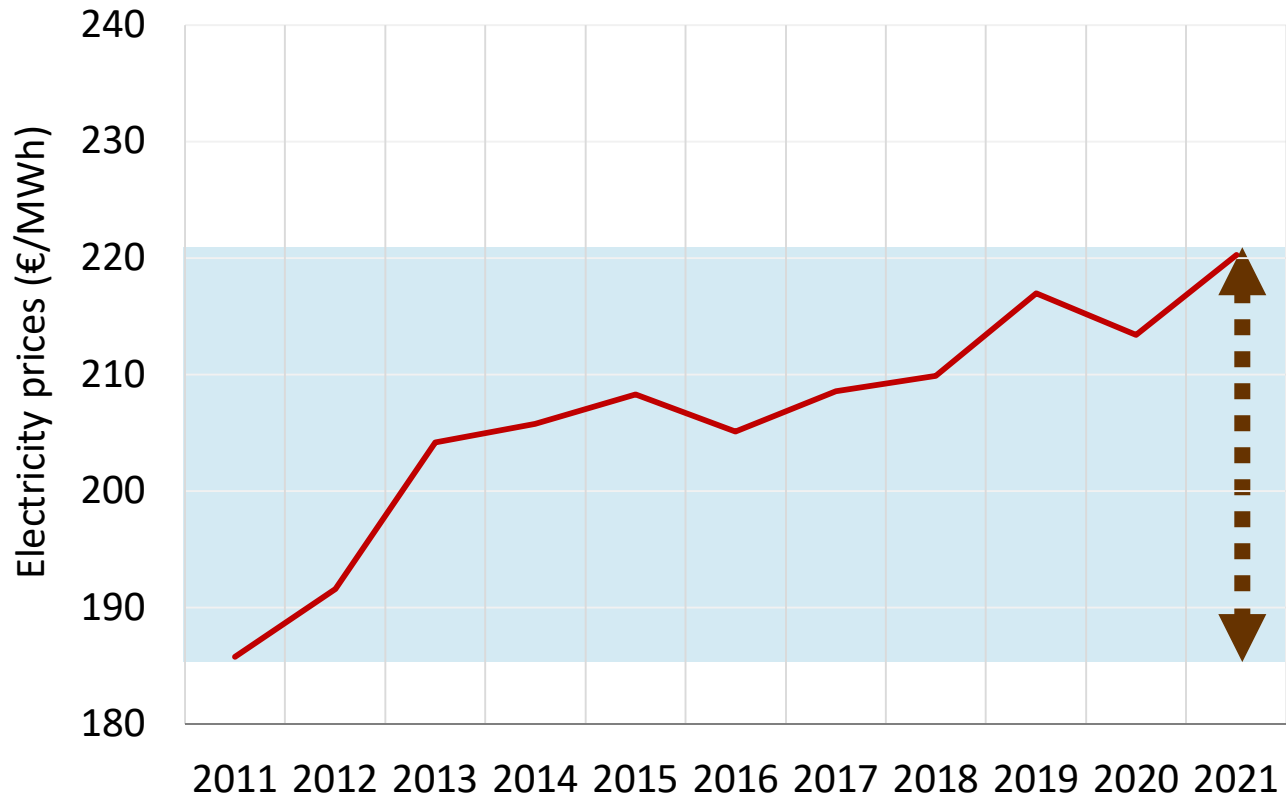
Dark fermentation as an environmental-sustainable win-win solution for bioenergy production

Camacho, C.I., Estévez, S., Feijoo, G., **Moreira, M.T.**

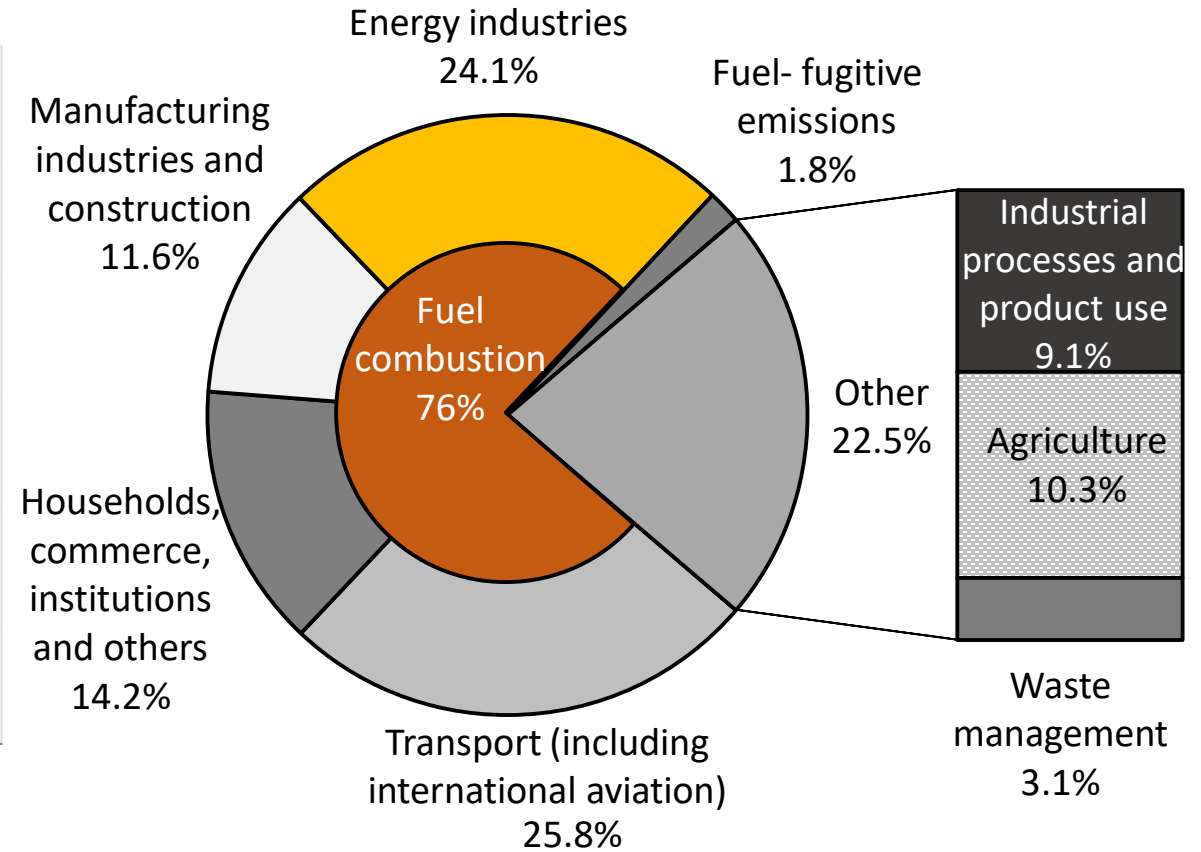


The energy problem in need of a solution

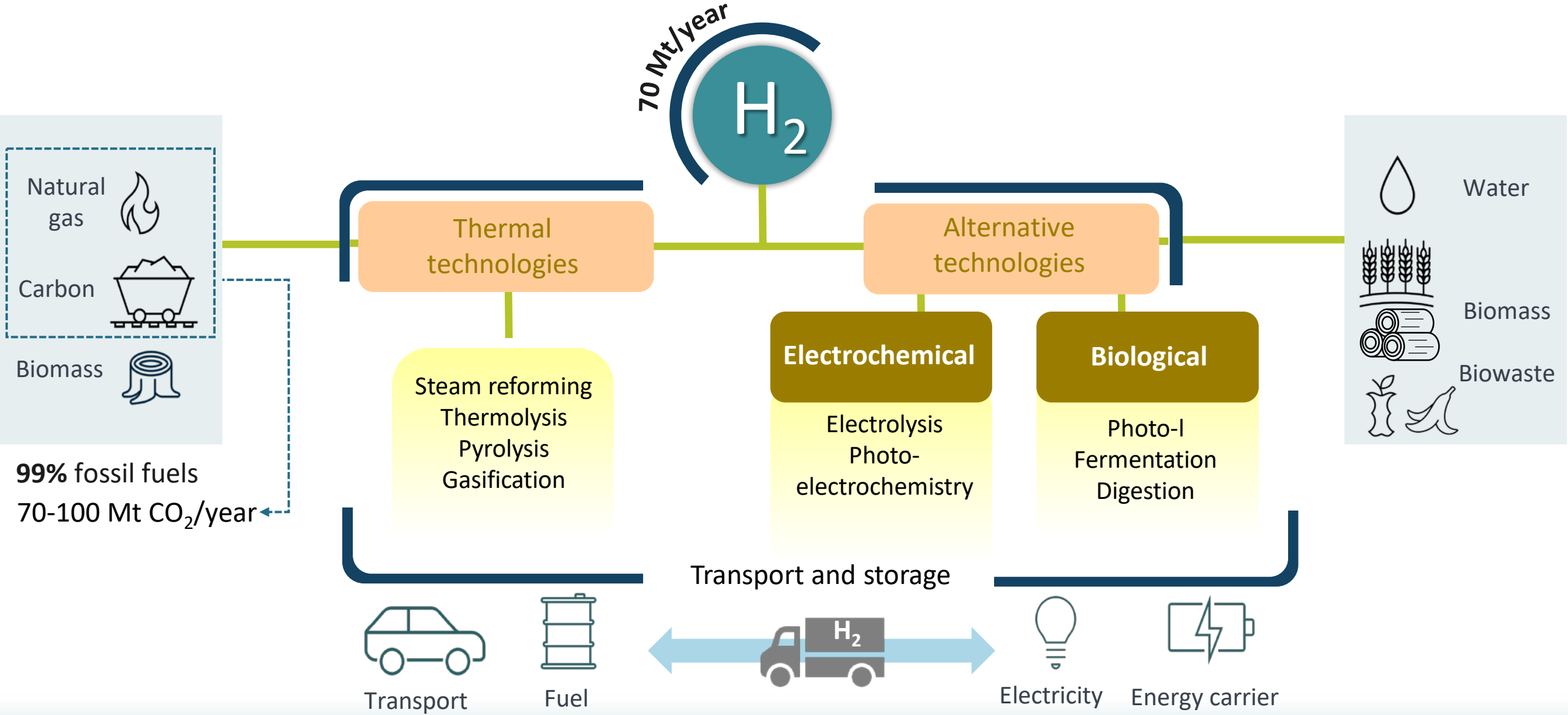
Volatility of energy prices



Greenhouse gas emissions



H₂ production as an energy source

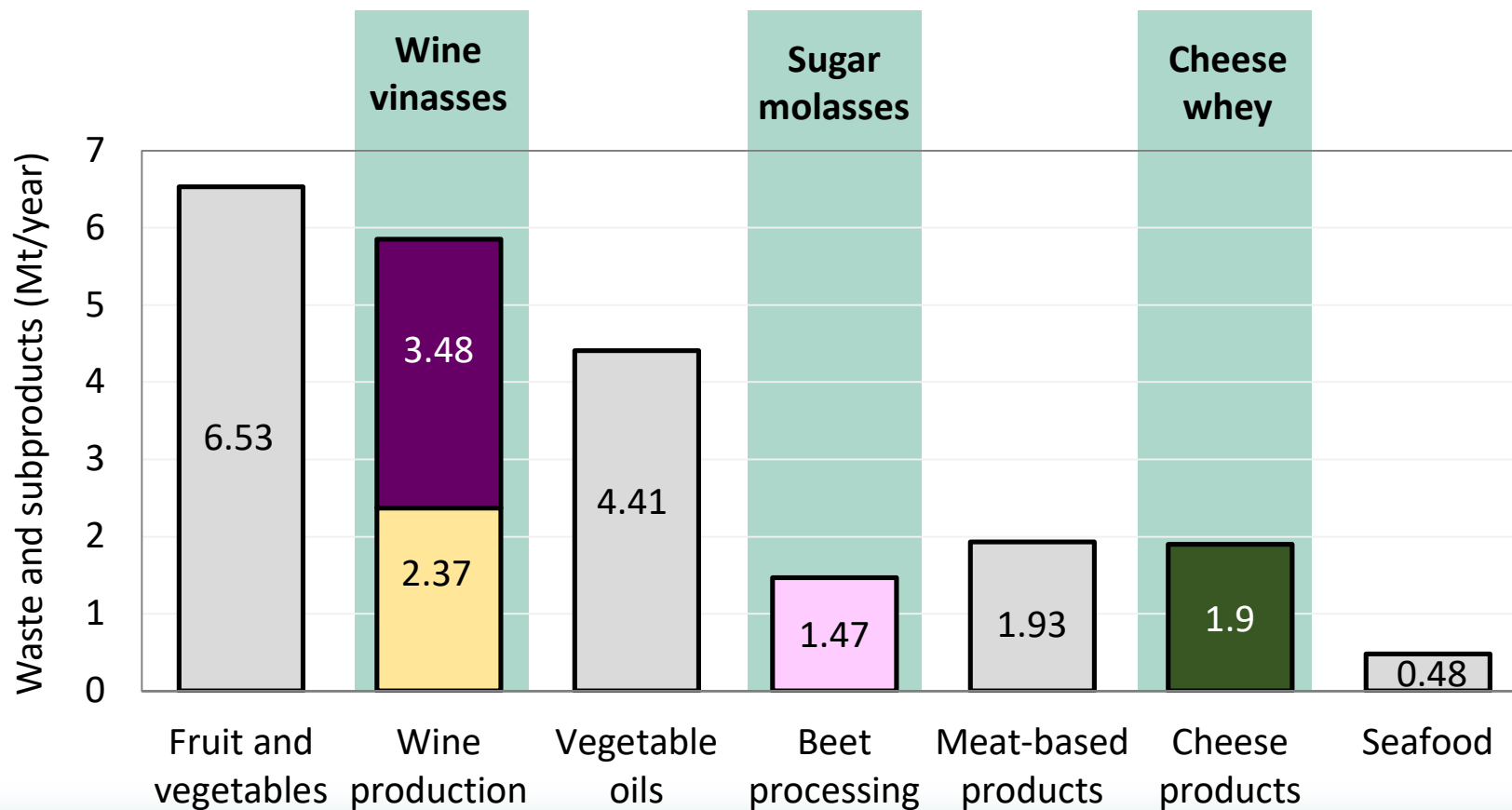


Biowaste in numbers

➤ Latest estimates suggest that around 931 million tons of food waste were generated in 2019

➤ Spain 

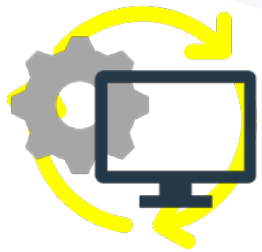
Waste and subproducts from food industry **23 Mt**



Objectives

1

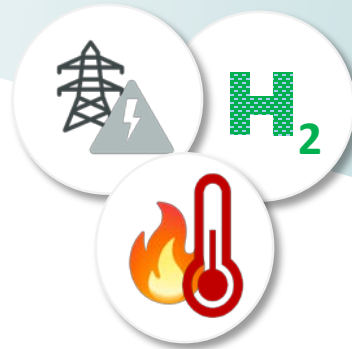
Valorization of food waste



Modelling & circular economy

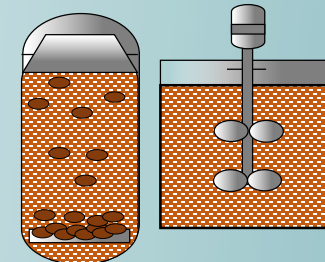
2

Production of energy



3

Environmental assessment of treatment technologies



Dark fermentation and anaerobic digestion

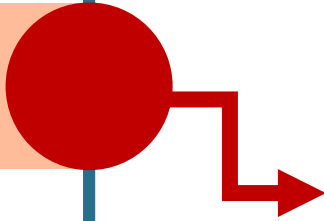
Stage 1.
Definition

Stage 2.
LCA
inventory

Stage 3.
Environmental
profile

Stage 4.
Interpretation
of results

Stage 1.
Definition



A life cycle approach

➤ **System function and functional unit**

OBJECTIVE

Environmental comparison of 3 food streams



Wine vinasses and sewage sludge

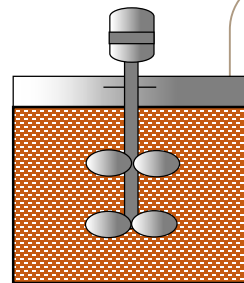


Sugar beet molasses



Cheese whey

SYSTEM FUNCTION

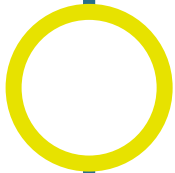


Bio-based hydrogen from dark fermentation

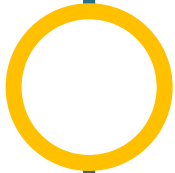
FUNCTIONAL UNIT

1 m³ of hydrogen (99% purity) in normal conditions

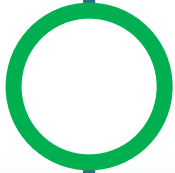
Stage 2.
LCA inventory



Stage 3.
Environmental profile

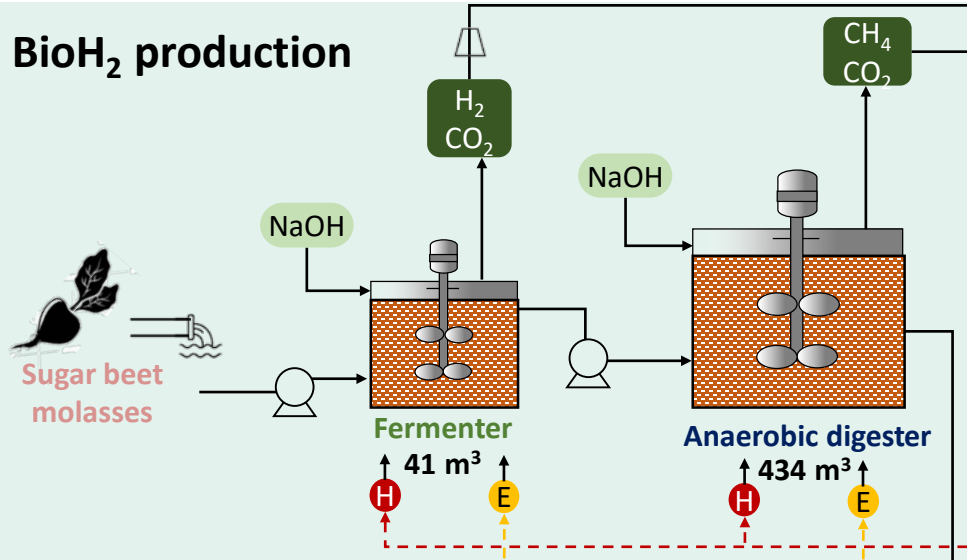


Stage 4.
Interpretation of results

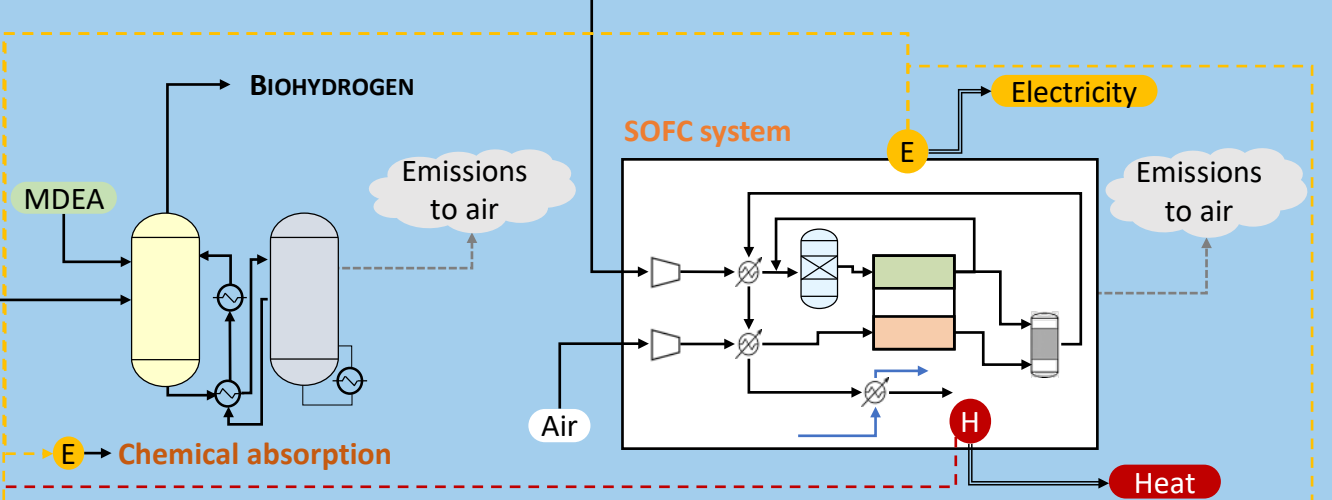


The process

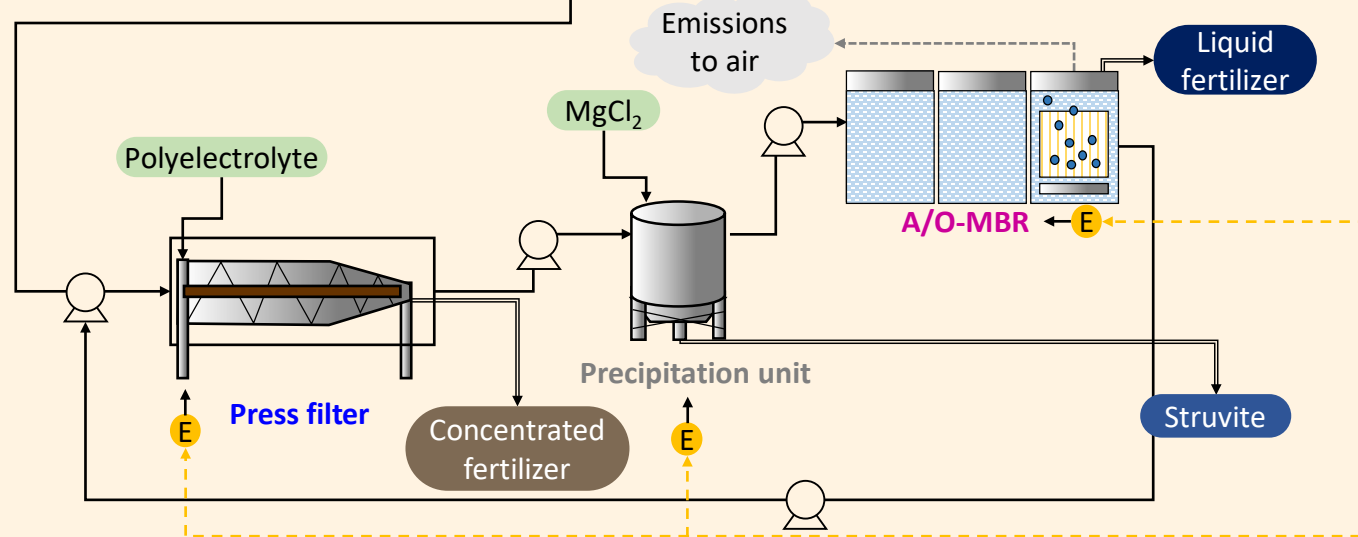
S1. BioH₂ production



S2. Energetic valorization



S3. Treatment of effluents

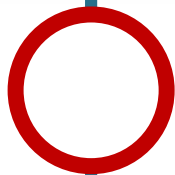


Data gathering

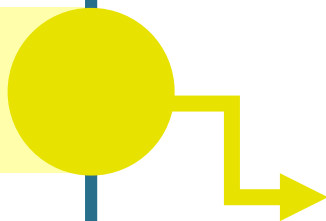
30 m³/d of Waste

	Electricity	Heat	Solid fertilizer & struvite	Liquid fertilizer	Hydrogen
Sugar beet molasses	3182.6	536.4	1385.7	20.9	298.0
Cheese whey	2727.5	27.9	526.7	0.0	92.9
Wine vinasses and sewage sludge	419.4	0.0	2038.6	27.8	34.0

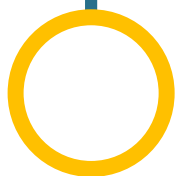
Stage 1.
Definition



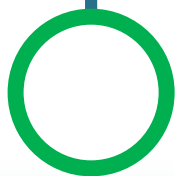
Stage 2.
LCA
inventory



Stage 3.
Environmental
profile



Stage 4.
Interpretation
of results



Life Cycle Impact Assessment

After system modelling and data gathering...

Software

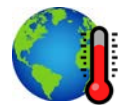


Method



➤ Indicators

- *Midpoint (H)-Impact indicators*
- *Endpoint (H/H)- Damage indicators*



Climate change



Acidification



Freshwater eutrophication



Marine eutrophication



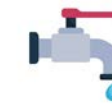
Terrestrial ecotoxicity



Land use

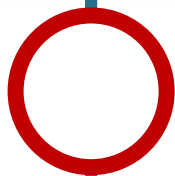


Fossil resource scarcity

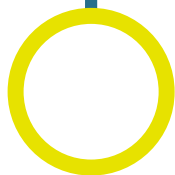


Water consumption scarcity

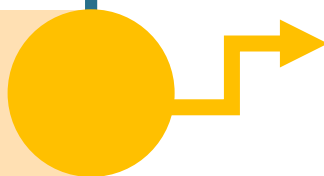
Stage 1.
Definition



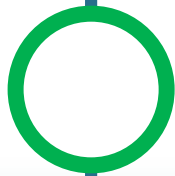
Stage 2.
LCA
inventory



Stage 3.
Environmental
profile

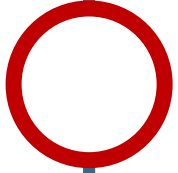


Stage 4.
Interpretation
of results

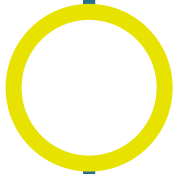


Analysis of results

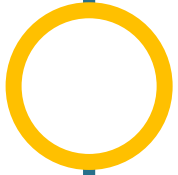
Stage 1.
Definition



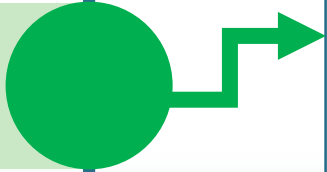
Stage 2.
LCA
inventory



Stage 3.
Environmental
profile



Stage 4.
Interpretation
of results



**Midpoint
analysis**
Benchmark of
environmental
impacts



**Endpoint
analysis**
Single score
comparison



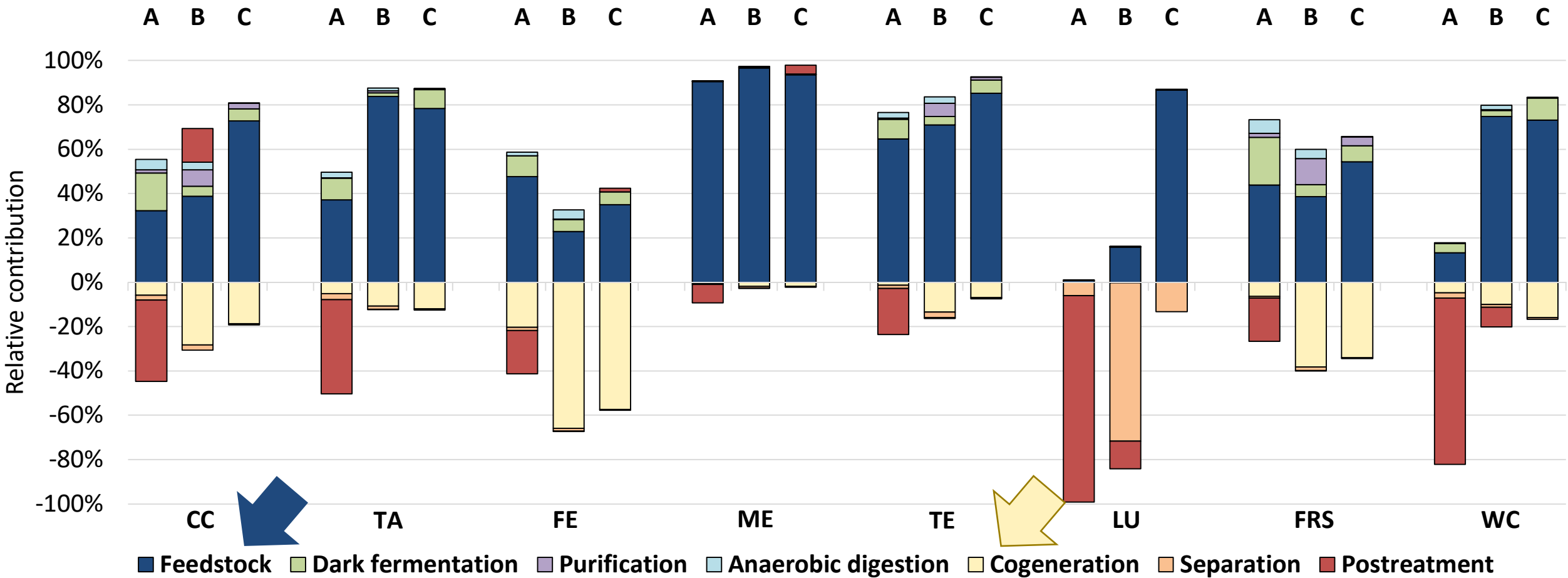
**Energy
balance**
Process
sustainability



Cradle-to-gate benchmark

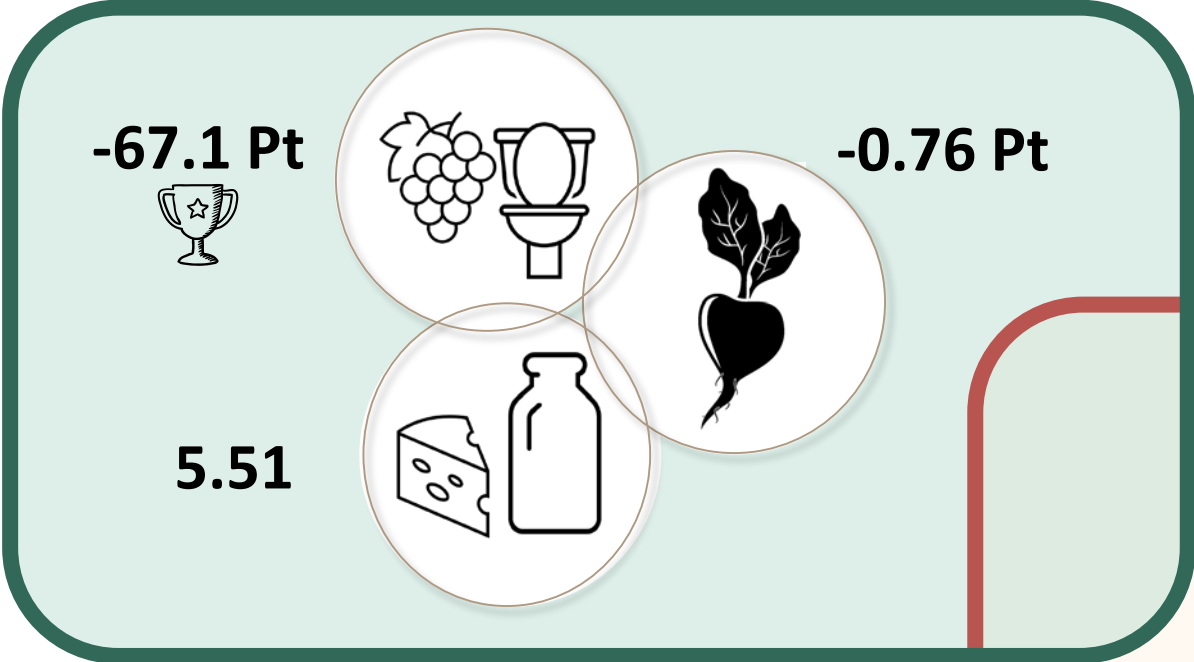


- A** Wine vinasses and sludge
- B** Sugar beet molasses
- C** Cheese Whey



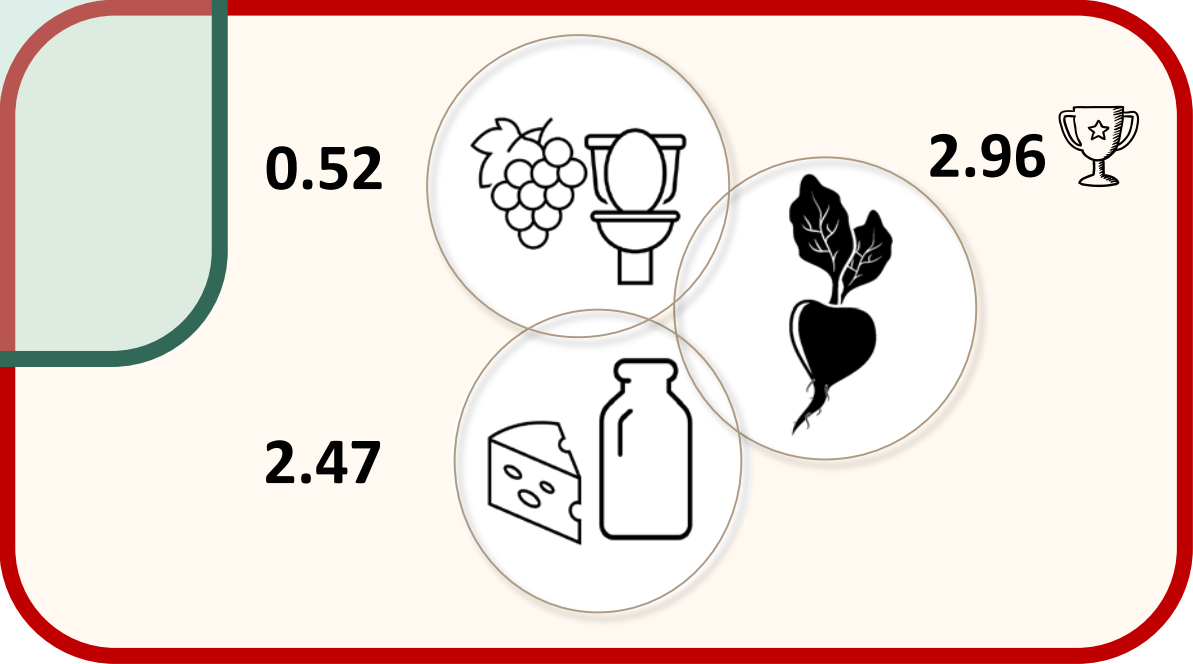
■ Feedstock
 ■ Dark fermentation
 ■ Purification
 ■ Anaerobic digestion
 ■ Cogeneration
 ■ Separation
 ■ Posttreatment

Single score benchmark



Environment

Energy



Conclusions

The relevancy of the feedstock

1

Valorization of waste from the food industry



Sustainable process

Energy self-efficient

2

Production of energy

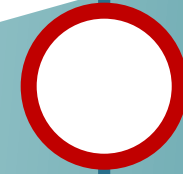
3

Environmental assessment of treatment technologies

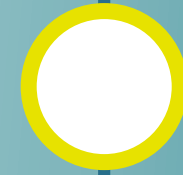


Sustainable process

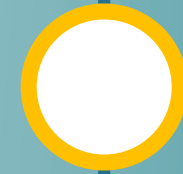
Environmentally friendly



Stage 1.
Definition



Stage 2.
LCA
inventory



Stage 3.
Environmental
profile



Stage 4.
Interpretation
of results

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