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Isobutene production from wheat straw in a biorefinery perspective: A life cycle analysis

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PRIMA PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

Introduction

Climate Change

Food demand

Soil degradation

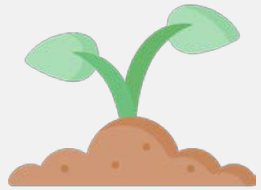
Wheat is one of the most important crops and plays a key role in food security.

It is estimated that 354 Mt of wheat straw are generated annually in the world (Li & Chen, 2020).

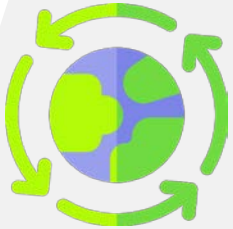
End-of-life management of wheat straw

Burned to reduce pests and weeds

Sold as feed or as bedding for livestock



Left in the field for soil amendment

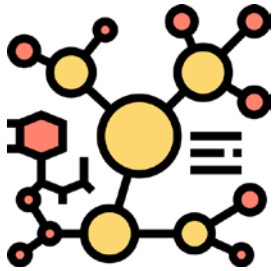


Raw material to obtain bio-products with high added value in a Circular Economy framework.

Li, S., Chen, G., 2020. J. Clean. Prod. 251, 119669

Introduction

Isobutene



converted into

Oligomer compounds found in automotive and aviation fuels

Polymers used in lubricants to plastics

In oil refineries it is obtained

- from naphtha steam cracking and fluidized catalytic cracking
- the energy-intensive catalytic dehydrogenation of isobutane

Berger et al. (2022). *Sustainable Production and Consumption*.

Aim of the study

Isobutene production from wheat straw valorisation using a biorefinery approach.

Methodological framework

Wheat cultivation

Farm stage Inventory: Wheat straw

Simulation at Industrial scale

Mass and Energy balance

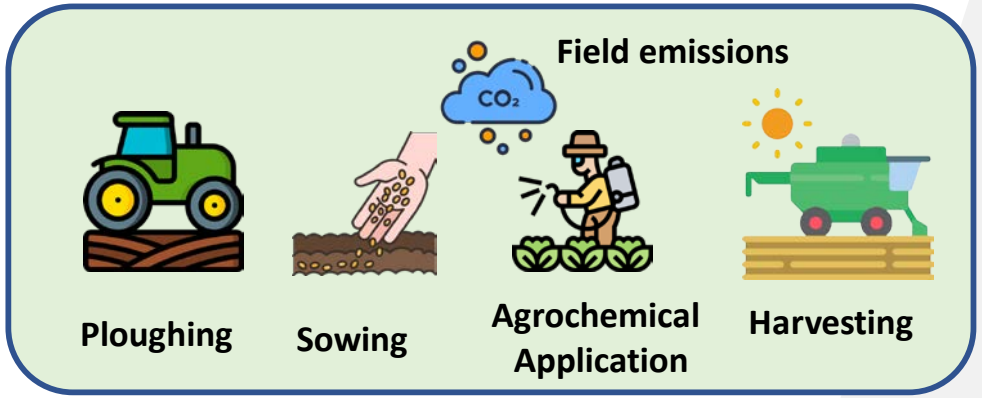
Life Cycle Assessment

Environmental profile

Interpretation and Improvement strategies

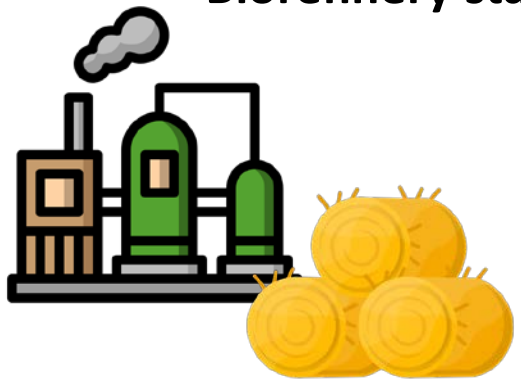
Methodology

Farm stage



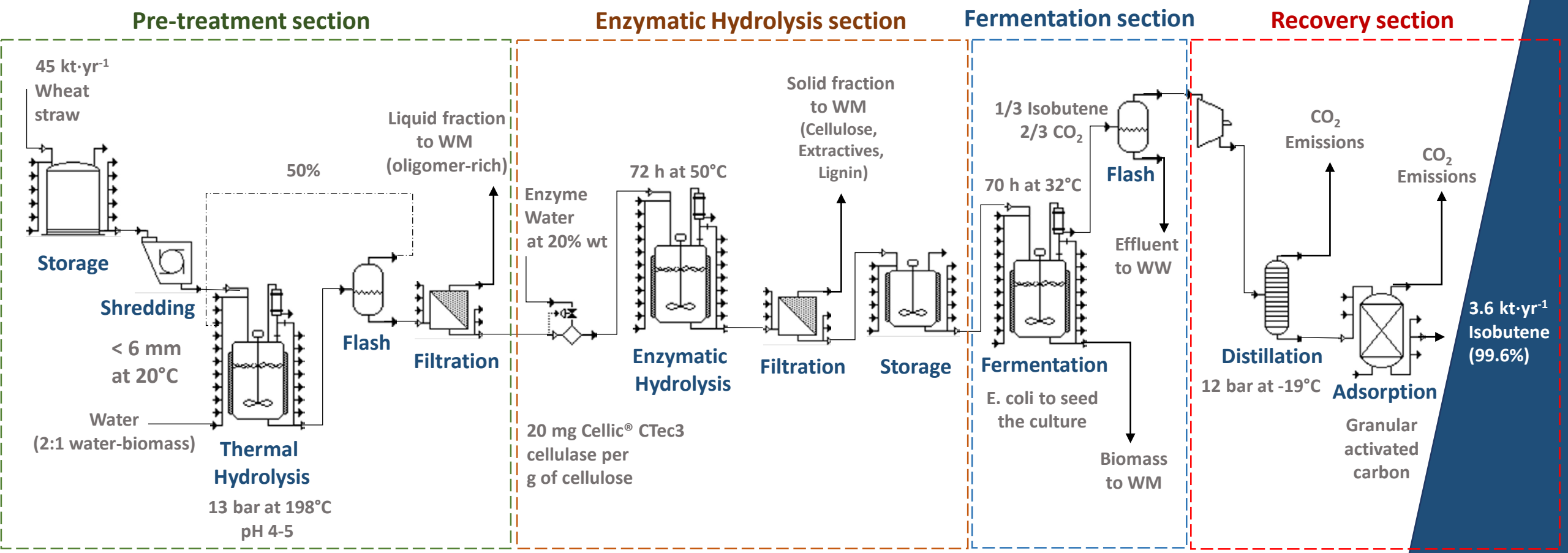
- Inventory data from durum wheat cultivation in Foggia, Italy
- Economic allocation (grain and straw)

Biorefinery stage



- A biorefinery platform with a capacity of 45 $kt \cdot yr^{-1}$ of wheat straw was considered for process modelling.
- The valorisation of this resource will imply the management of the straw generated in 10% of the area with available potential in the province of Foggia, Puglia, Italy.

Simulation stage



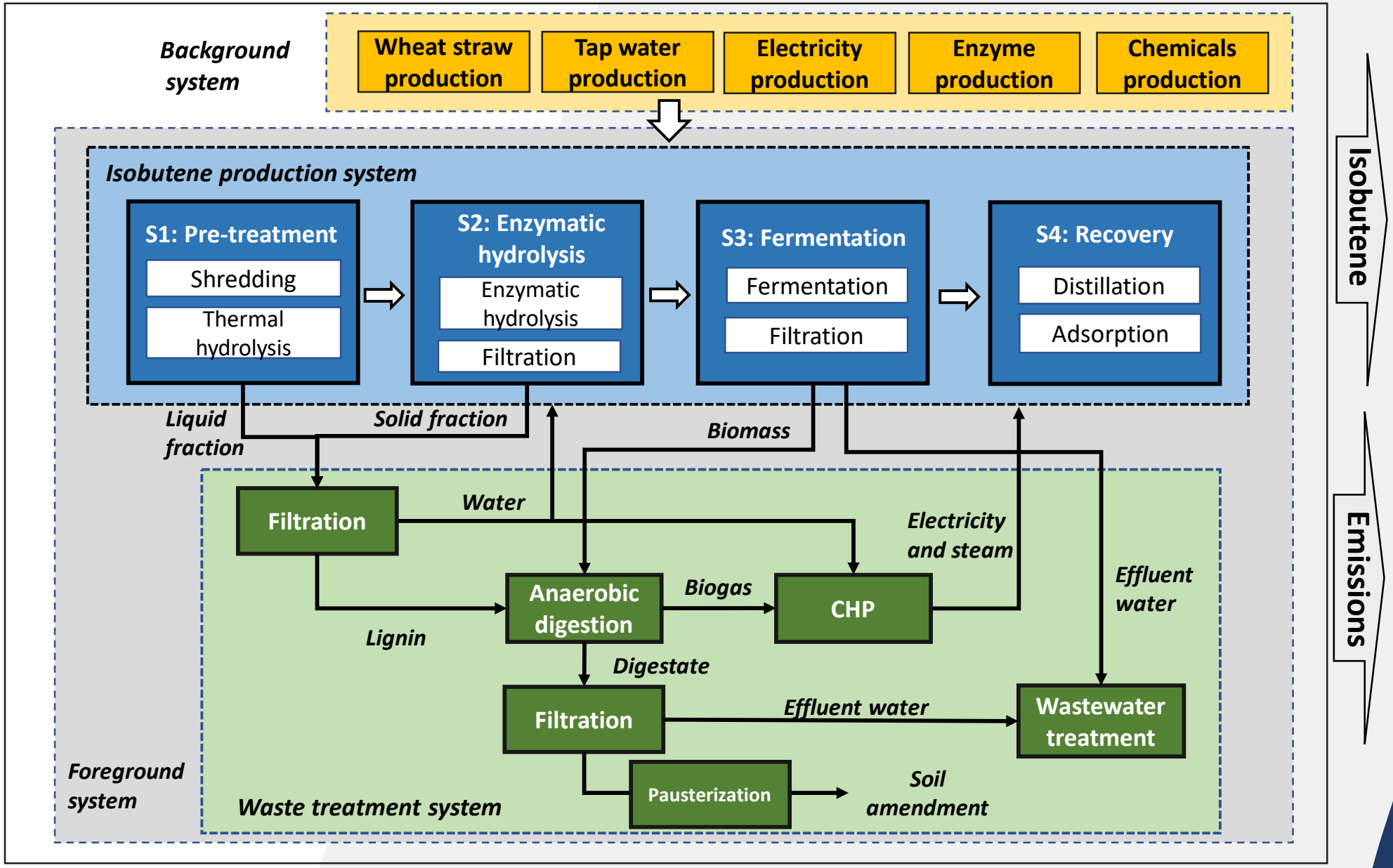
Summarized modelling process

WM: Waste management section
WW: Wastewater treatment

Biogas produced

70% to electricity production
30% to HP steam production

Life Cycle Assessment



Life Cycle Assessment

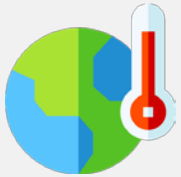
System boundary
Cradle-to-gate

Functional Unit
1 kg of Isobutene from wheat straw

Impact Assessment
ReCipe 2016 v1.06: ▪ Midpoint World (H) ▪ Endpoint (H) World (2010) H/A

SimaPro

Impact categories


Global Warming (GW)


Particulate Matter (PM)


Freshwater Eutrophication (FE)


Marine Eutrophication (ME)


Terrestrial Acidification (TA)


Human Toxicity (HT)

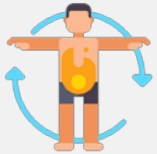

Land Use (LU)


Fossil Resource Scarcity (FRS)

Potential damages


Resources

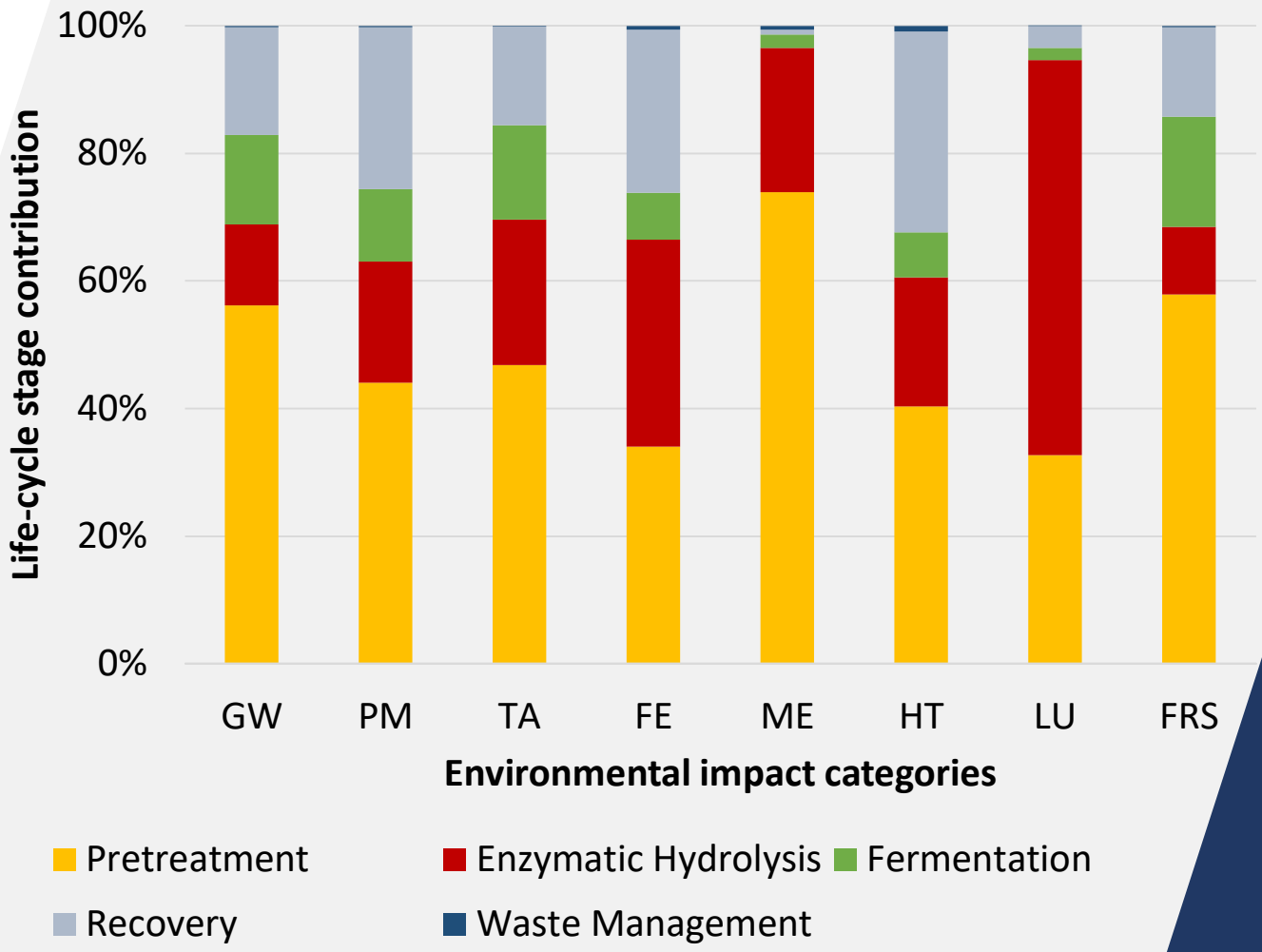

Ecosystem


Human health

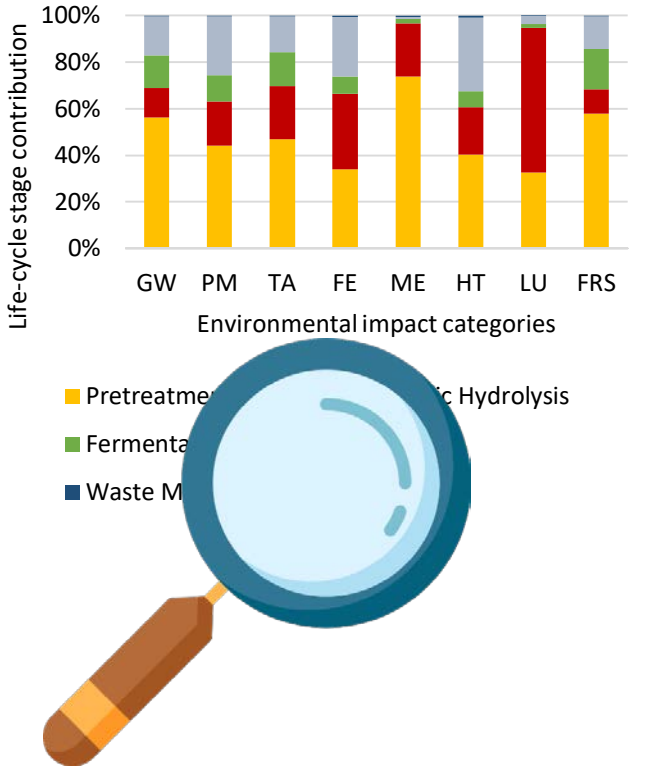
Results - Midpoint

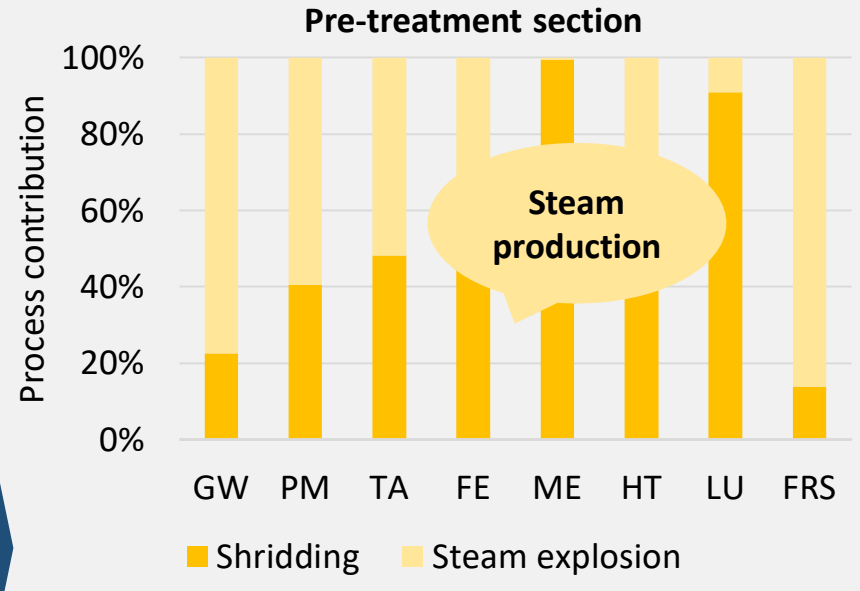
Environmental profile (FU: 1 kg Isobutene)

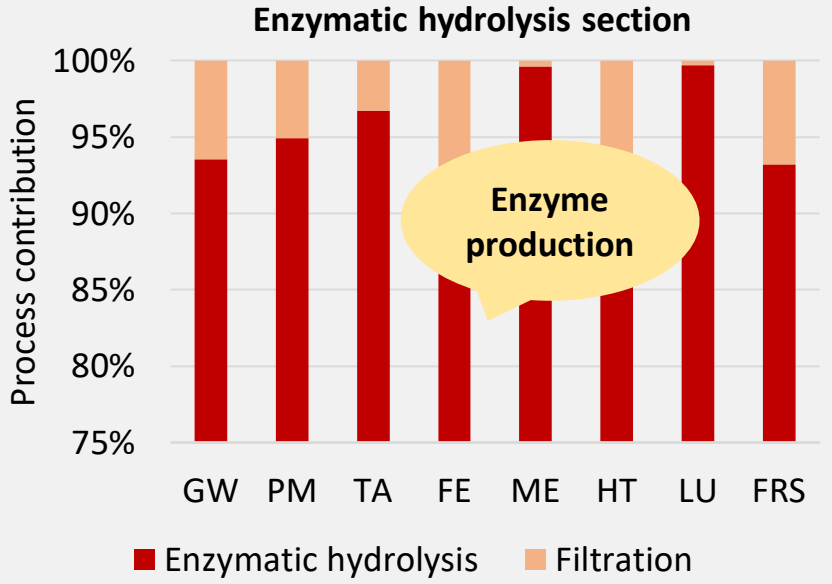
Impact category	Unit	Value
GW	kg CO_2 eq	8.16
PM	g $PM_{2.5}$ eq	10.9
TA	g SO_2 eq	35.4
FE	g P eq	2.74
ME	g N eq	5.75
HT	g 1,4-DCB	139
LU	m^2a crop eq	0.97
FRS	kg oil eq	2.7

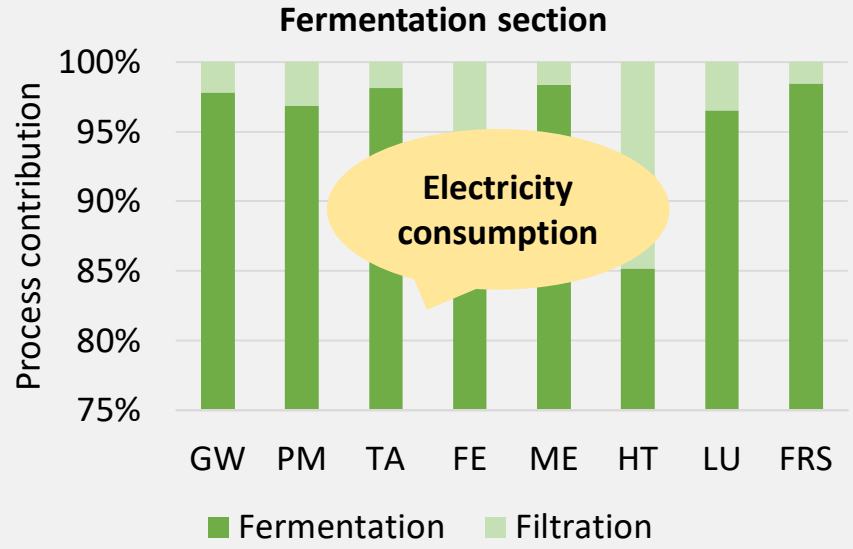


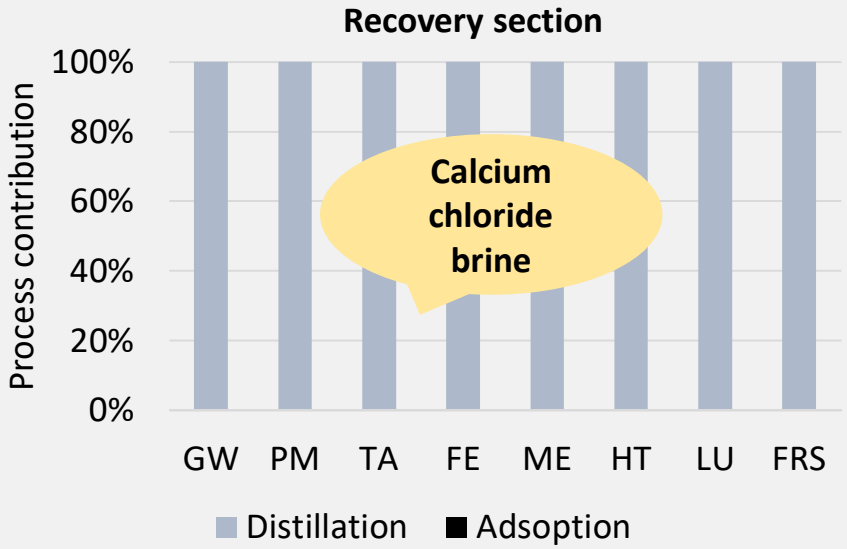
Results - Midpoint



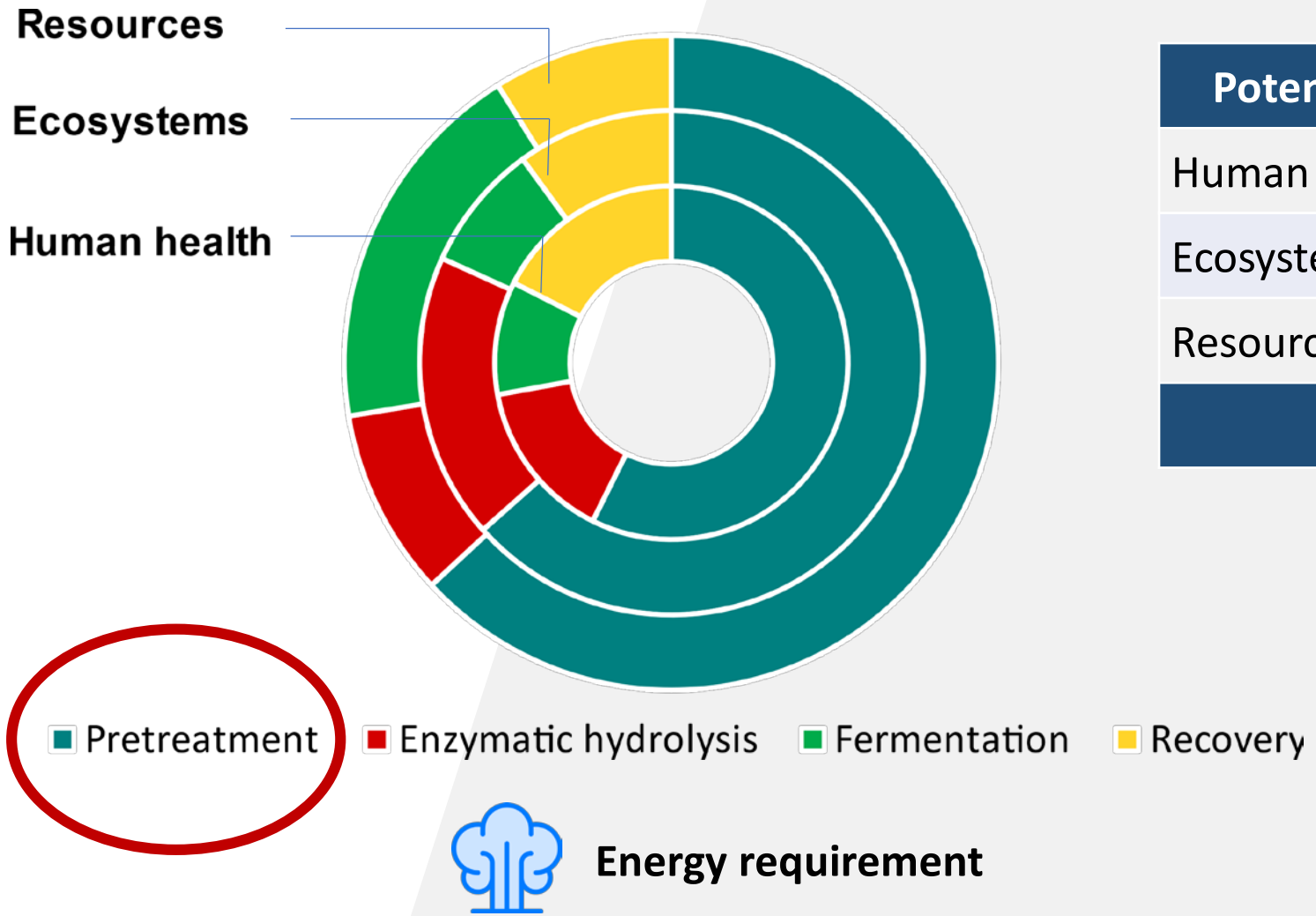








Results - Endpoint

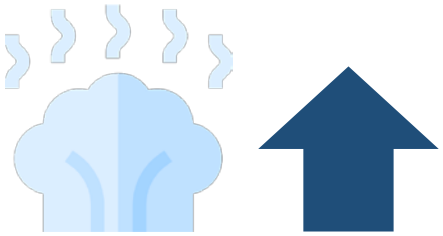


Potential damage	Total (mPt)
Human health	27.40
Ecosystems	1.51
Resources	0.50
Total	**29.40**

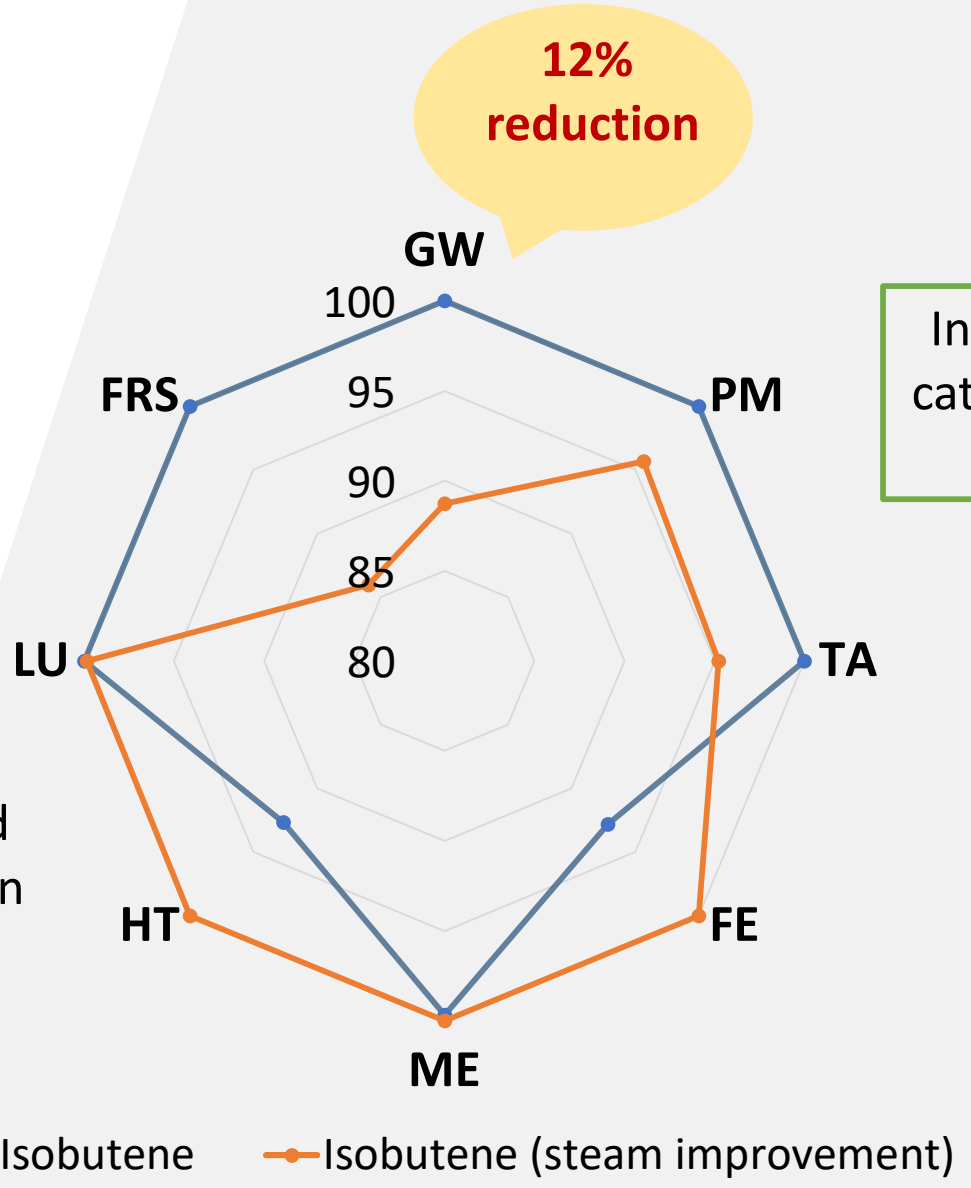
Energy requirement

Results

Improvement strategy:



Almost all the biogas (90%) obtained from the Waste Management section is used to produce steam.

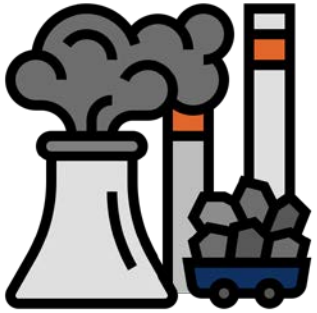


Increase in other impact categories due to a higher electricity demand

Results

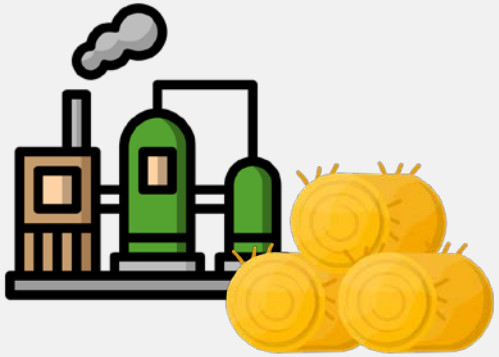
OPTISOCHEM project evaluated a life-cycle analysis of three fossil isobutene routes based on literature data, considering a mass allocation approach and the CML 2001 method, focusing only in GW category

Fossil based production



Scenarios	GW impact (kg CO_2 eq)
TBA dehydration	2.14 - 2.99
MTBE decomposition	1.92 - 2.36
Isobutane dehydrogenation	2.51

Bio-based production

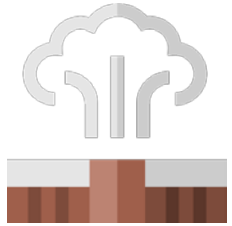


6.69 kg CO_2 eq

This study

Conclusions

The pre-treatment section is the main contributor in the mid-point and end-point perspectives.



The need for energy (i.e. steam production) is primarily responsible for impacts

Reducing CO_2eq emissions requires a focus on strategies to reduce energy needs.

Further research is needed to optimise energy demand and improve production efficiency.

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