

CALiMERO

IMPROVING BIO-BASED INDUSTRIES LIFE CYCLE SUSTAINABILITY

Multi-objective optimization framework for bio-based processes with improved LCSA methodologies
– woodworking case study



**Funded by
the European Union**

Woodworking case study

Academic partner

Life cycle analysis
MOO tool application



+

Industrial partner

Primary data provision
Industrial expertise consultancy



Woodworking
company

Tabsal

EWP (Engineered Wood Products) family

Commercial name

lignum
strand

Generic name

Laminated Strand Lumber (LSL)



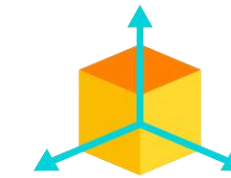
Location

Uharte Arakil (Navarra, Spain)



Production

One single product



Dimensions

L: 8.2 m H: 0.62 m W: 30-100 mm



Commercial applications

- o Technical doors
 - Fire resistant
 - Double climate resistant
 - Noise resistant
- o Bowling alleys
- o Construction
 - On-site construction houses
 - Prefabricated houses



Working life (durability)

50 years

Steps of the production process

1

Raw material extraction



2

Wood transportation to Tabsal



3

Lignumstrand production



- Spanish poplar forests two riverbanks
- Locally source product (~ 200 km)
- PEFC (Program for Endorsement of Forest Certification) **certification**

Two different



applications

Sales volume



Industrial applications

85 %

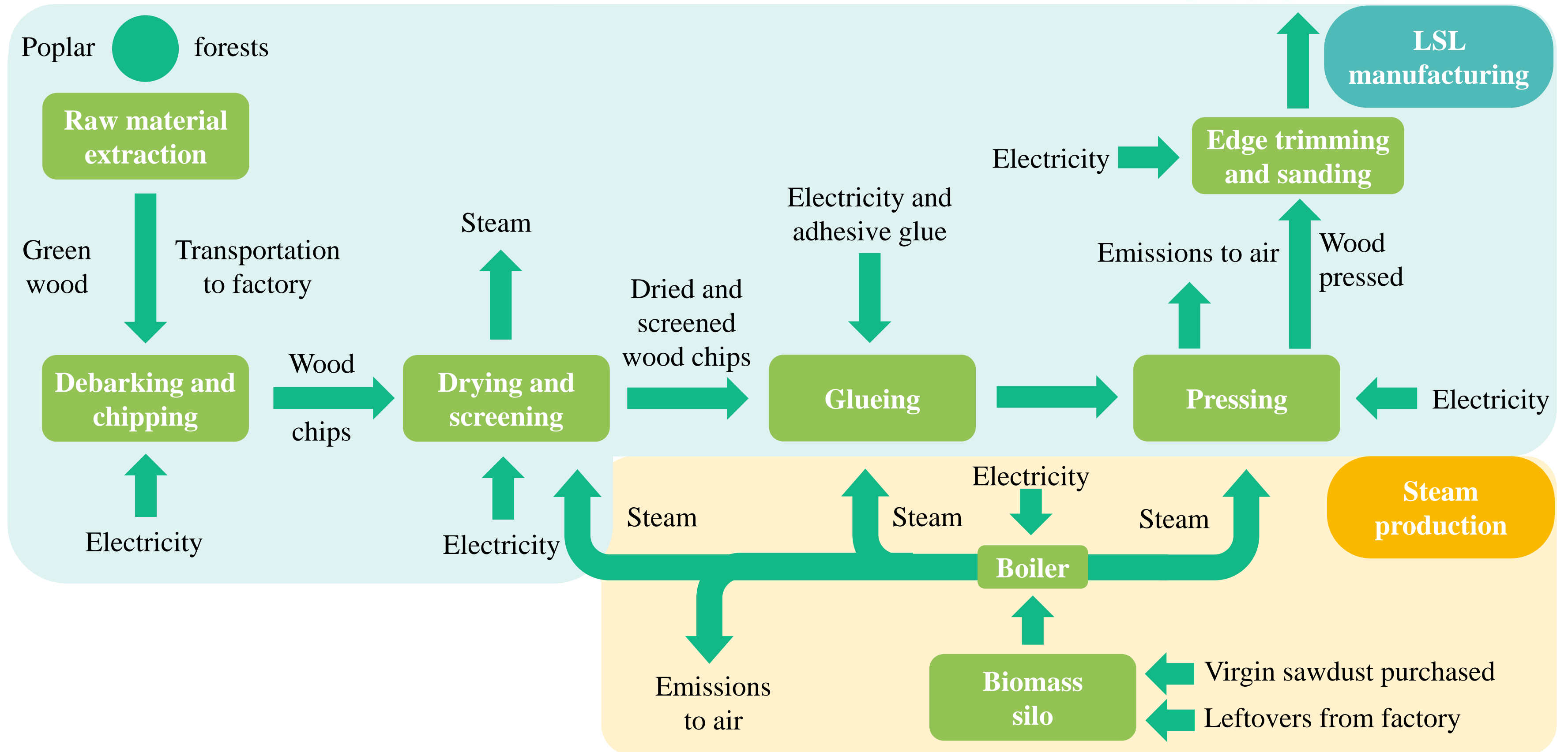
Structural applications

15 %



Directive 93/68/ECC

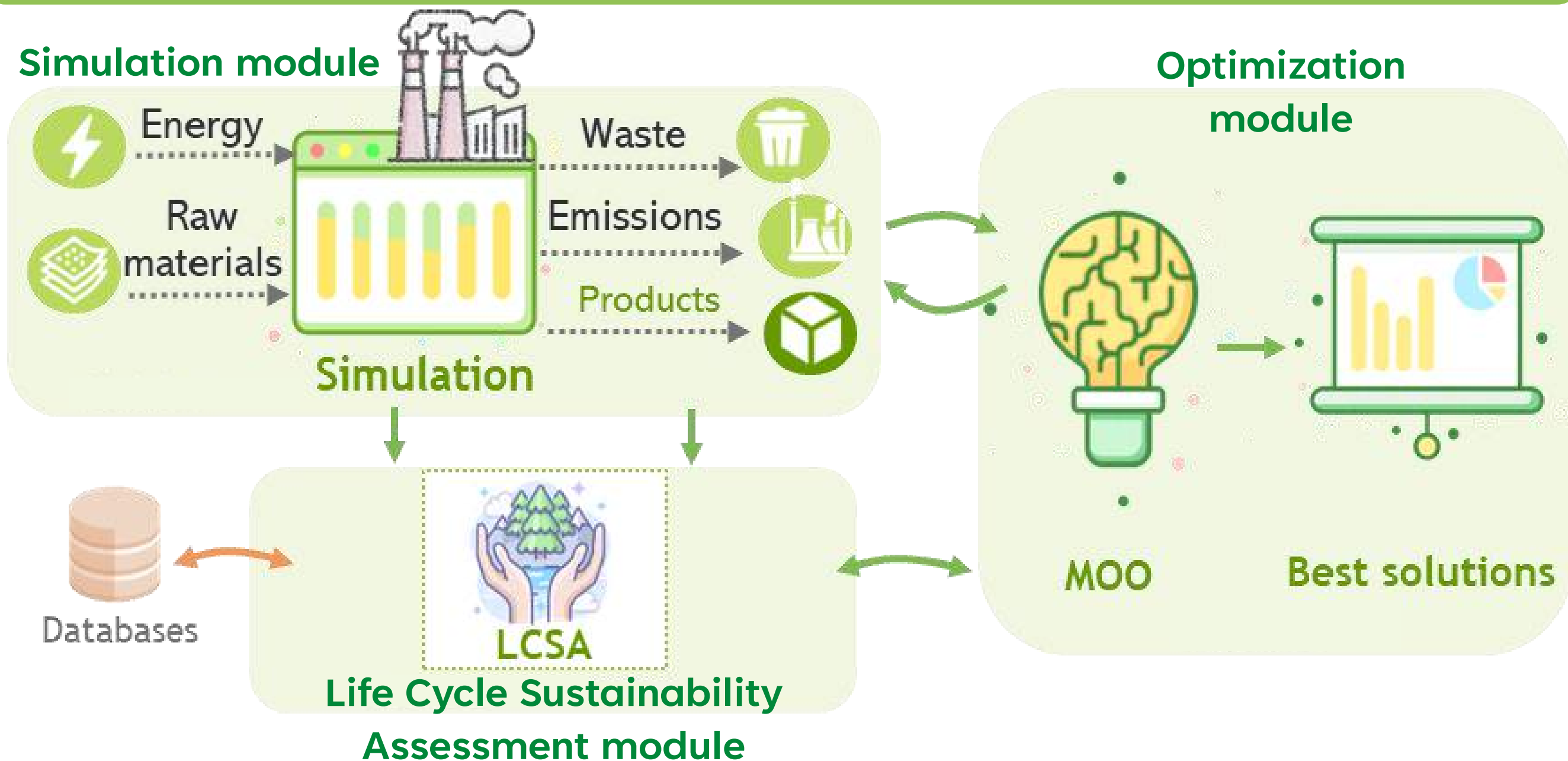
Diagram of the production process



Multi-Objective Optimization tool

General objective

To **identify** which production **process to optimize** for **improving** the **overall environmental sustainability** performance and **economical viability**



Production process to be optimized: pressing

Bottleneck

- Time-consuming
- Energy-demanding

Wood entering

Poplar wood processed + adhesive

1,800 kg poplar wood·m⁻³ LSL

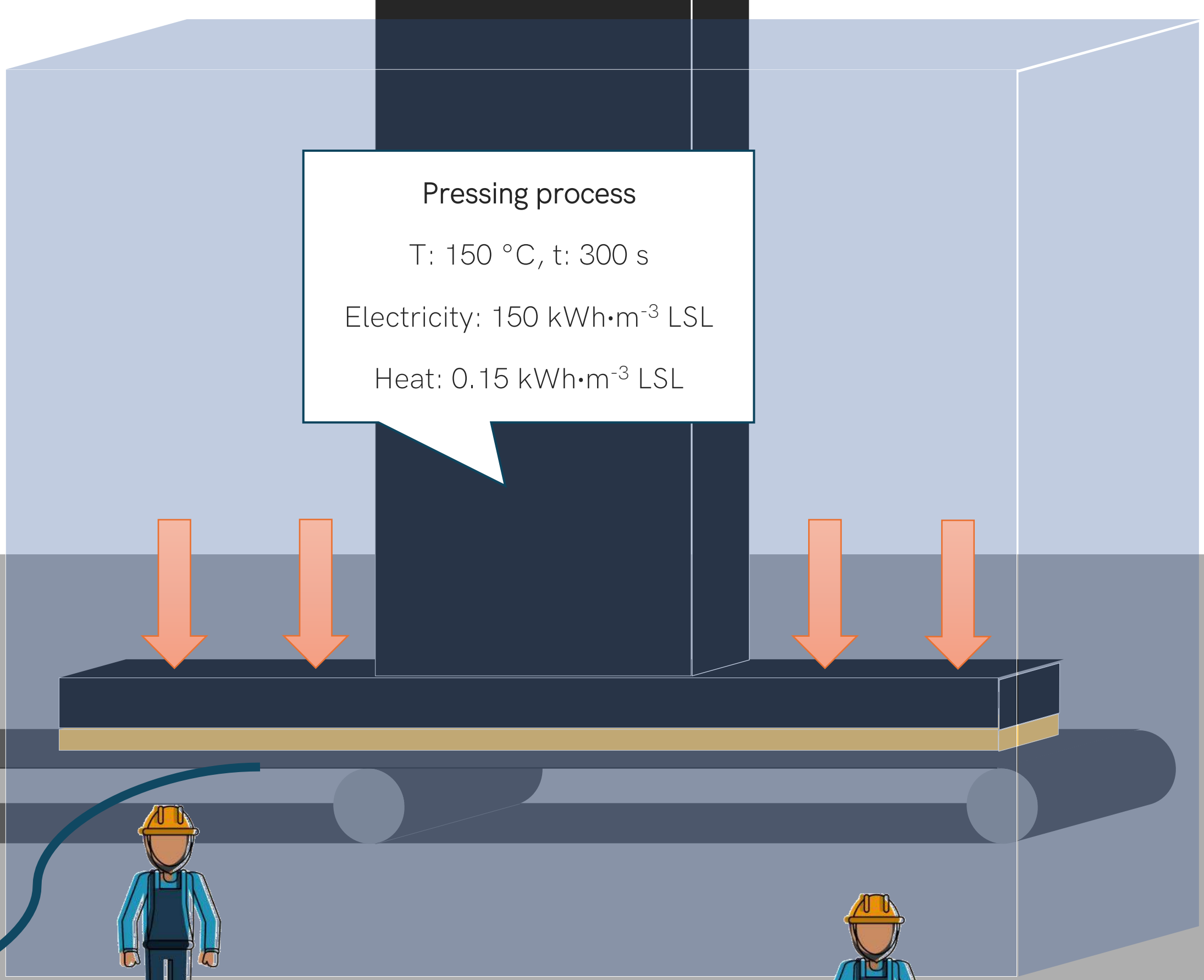
35 kg pMDI·m⁻³ LSL

Pressing process

T: 150 °C, t: 300 s

Electricity: 150 kWh·m⁻³ LSL

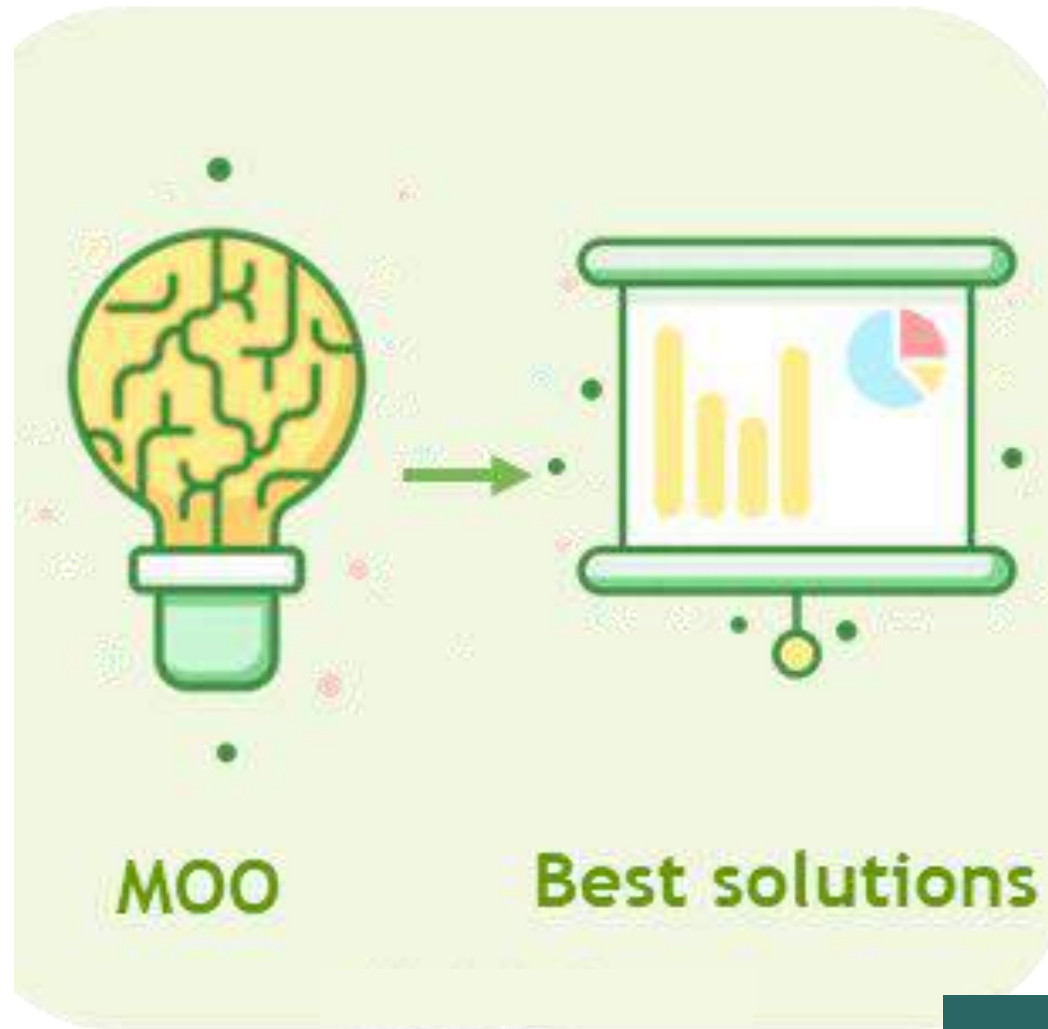
Heat: 0.15 kWh·m⁻³ LSL



Emissions from the fossil-based adhesive

pMDI emissions	Propionic Acid
Formic Acid	Formaldehyde
Butyric Acid	Methanol
	Acetic Acid

Optimization module



Objective

To **identify** which **operational variables** are editable, **apart from the objectives to be further optimized**

Marketable technical features of the wood boards to be produced

Variable name	Unit	Range
Pressing time	s	[260, 300]
Operating temperature	°C	[150, 210]
Adhesive concentration	%	[4.8, 5.2]

Operational objectives to be optimized

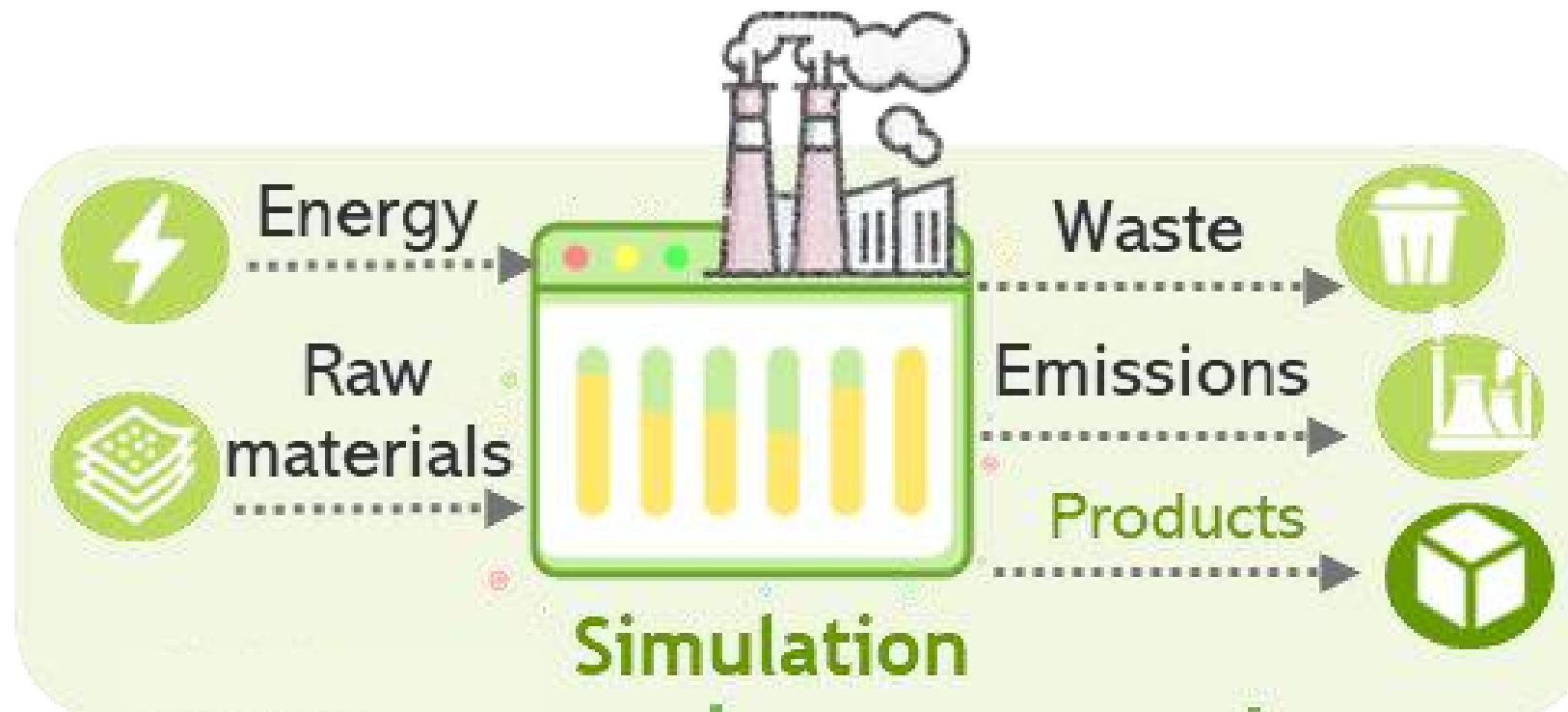
Deliverable 1.2

Most impactful bio-based industrial processes

Objective name	Unit	Scope	Aim
Climate Change	kg CO2-Eq.	cradle-to-gate	minimize
Human Toxicity: Non-Carcinogenic	CTUh	Pressing process	minimize
Human Toxicity: Carcinogenic	CTUh	Pressing process	minimize
Ecotoxicity: Freshwater	CTUe	Pressing process	minimize
Not relevant impacts single score sum (from PEF method)	Pt	cradle-to-gate	minimize
OPEX	€	energy (electricity and heat) + virgin wood chips + adhesive + transport	minimize



Simulation module



Partner(s)

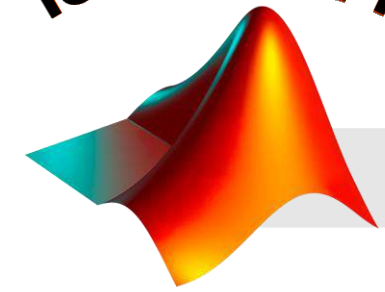
DTU

cesefor

Objective

To **simulate** the **emissions generated** during the **pressing process** of the wood panels manufacturing

Matlab regression learner app



MATLAB

Input variables (predictors)

- * Pressing temperature
- * Pressing time
- * Adhesive content
- * Moisture content
- * Board density

Output variables (emissions of interest)

- * pMDI emissions
- * Formic Acid
- * Butyric Acid
- * Propionic Acid
- * Formaldehyde
- * Methanol
- * Acetic acid

Set of data-driven models



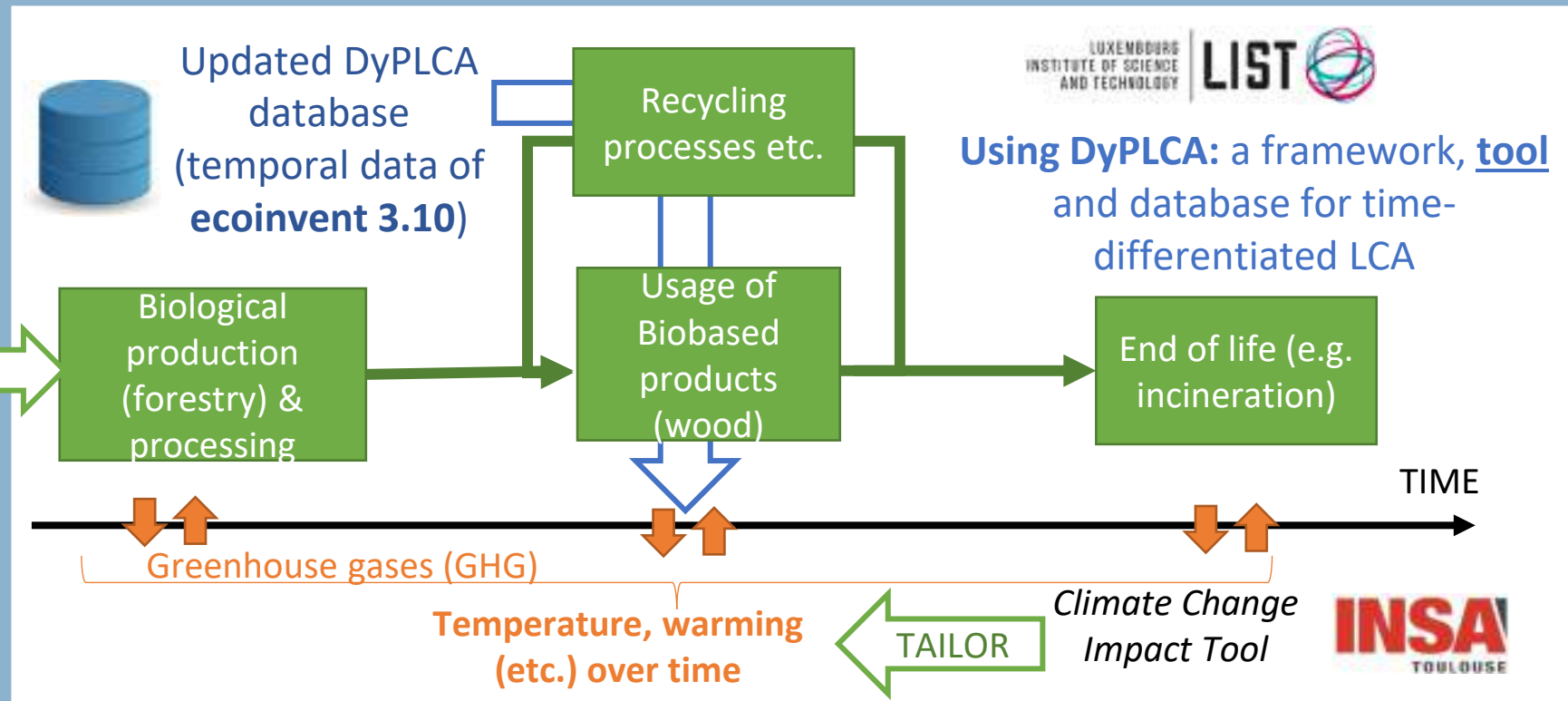
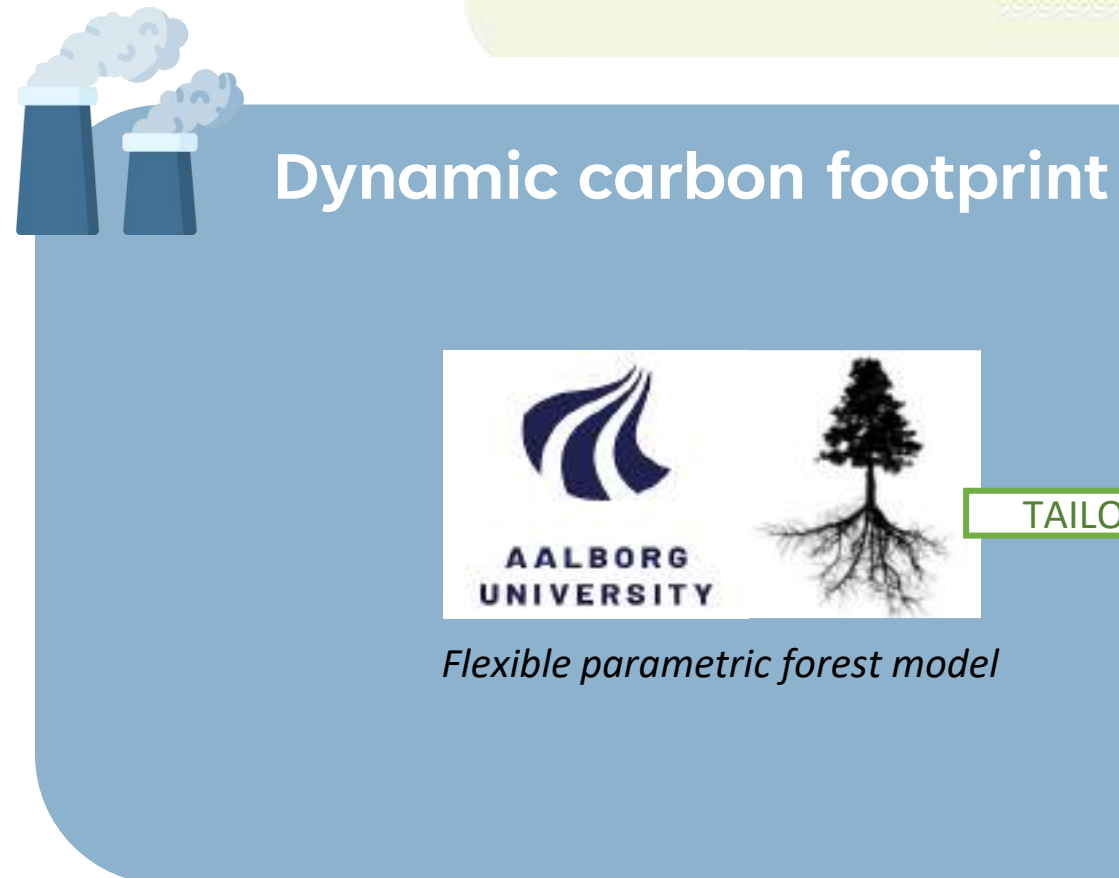
Excel spreadsheet

Life Cycle Sustainability Assessment module



Objective

To conduct an **improved life cycle** study in comparison with the **PEF standard**



Life Cycle Sustainability Assessment module



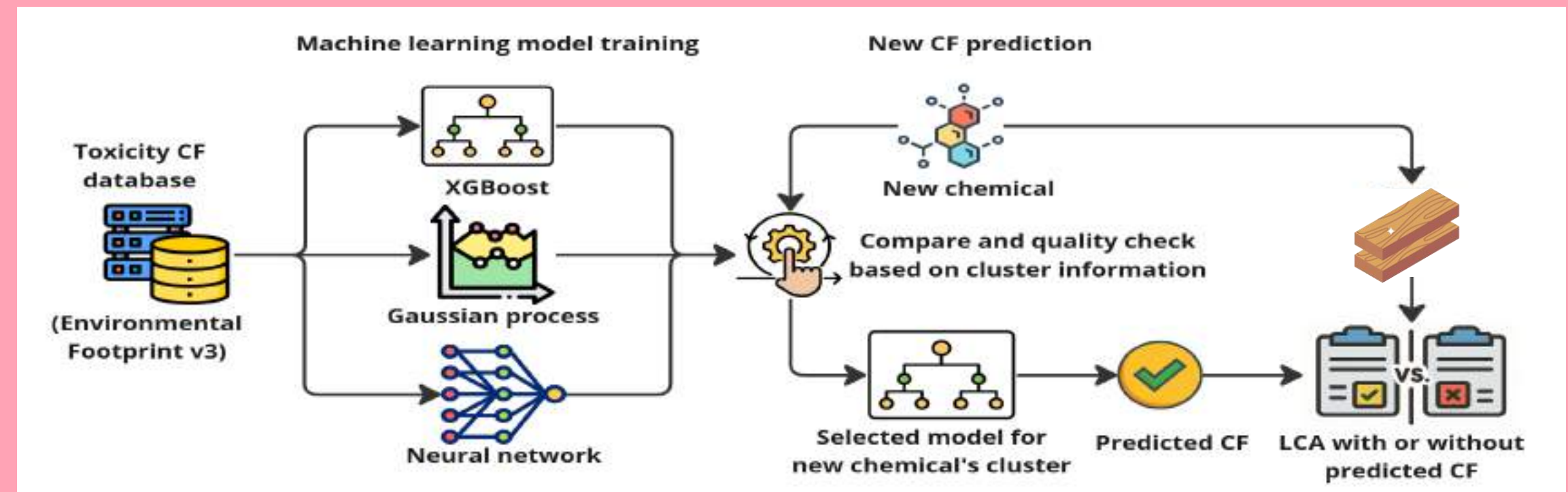
Objective

To conduct an **improved life cycle** study in comparison with the **PEF standard**



Novel toxicity characterization factors

Air emissions from acids such as butyric, formic or propionic, among other substances





MOO framework

Linking between three modules
Inputs-outputs



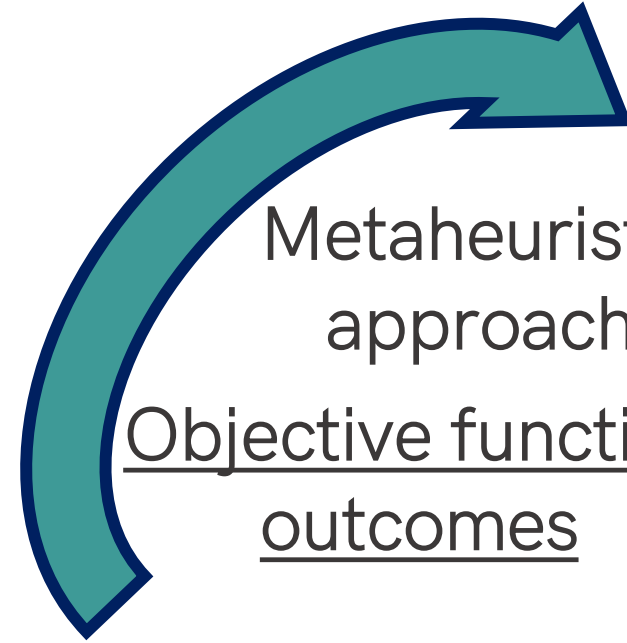
Black box model reruns until
the optimal value is obtained

SimaPro



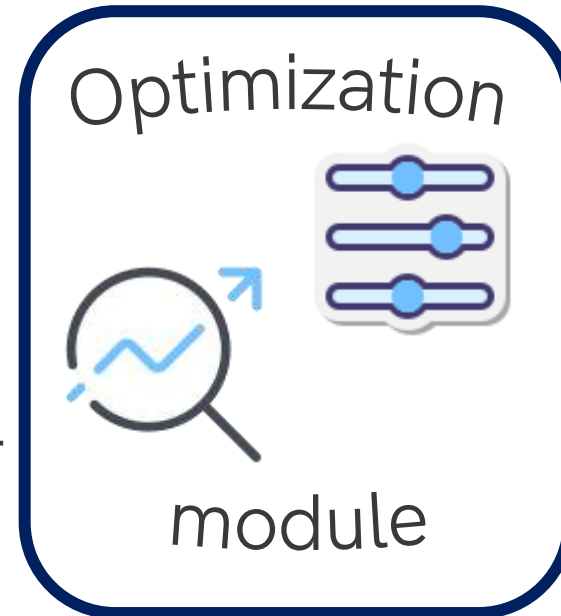
Brightway

Foreground
inventory
system



Metaheuristic
approach

Objective function
outcomes

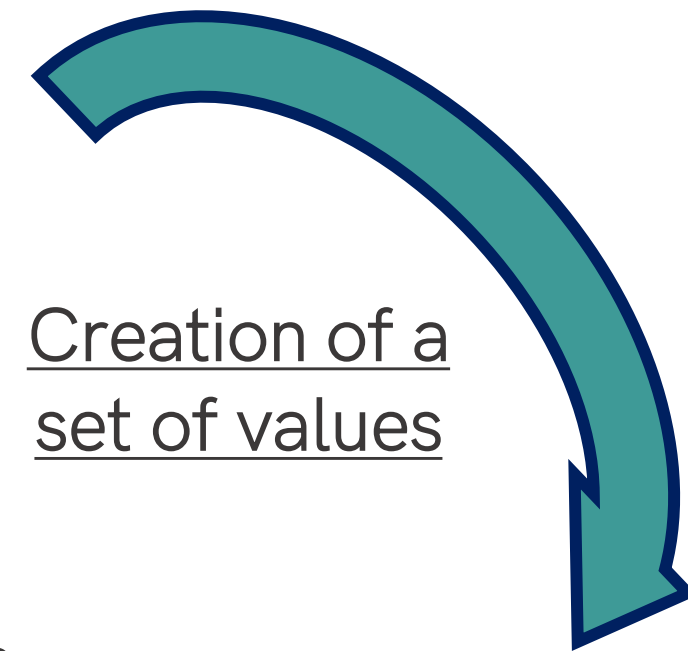


Optimization

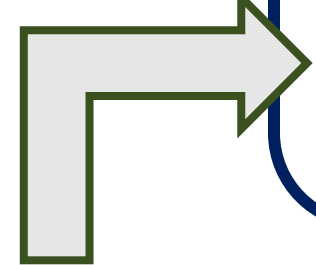
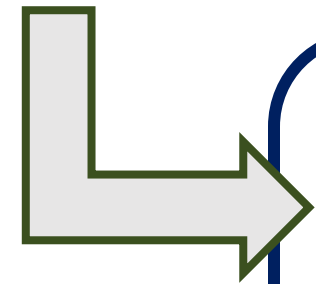


module

Evolutionary optimization
algorithm



Creation of a
set of values



LCSA



module

parameterization process to transform simulation



parameters into life cycle inventory results

Simulation



123

module

ecoinvent

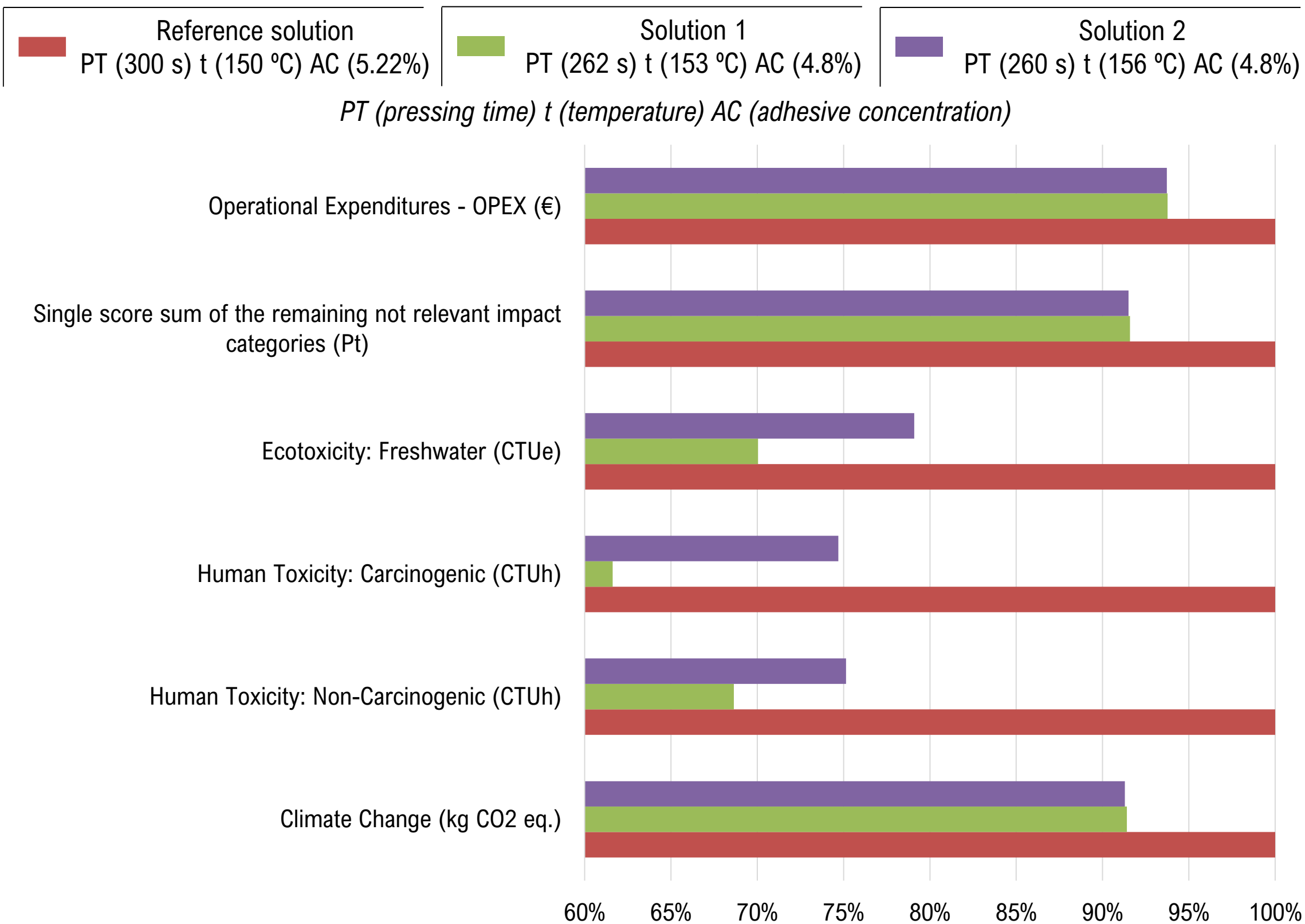
Background
data

Results interpretation – Found solutions*

	Variables	Solution 1	Solution 2	Reference solution
	Pressing time (s)	262	260	300
	Temperature (°C)	153	156	150
Objectives	Adhesive Concentration (%)	4.80	4.80	5.22
	Climate Change (kg CO ₂ eq.)	170.67	170.44	186.71
	Human Toxicity: Non-Carcinogenic (CTUh)	5.98·10 ⁻⁹	6.54·10 ⁻⁹	8.71·10 ⁻⁹
	Human Toxicity: Carcinogenic (CTUh)	3.70·10 ⁻¹⁰	4.48·10 ⁻¹⁰	6.00·10 ⁻¹⁰
	Ecotoxicity: Freshwater (CTUe)	2.76·10 ⁻¹	3.12·10 ⁻¹	3.95·10 ⁻¹
	Not relevant impacts single score sum (Pt)	1.334·10 ⁻²	1.333·10 ⁻²	1.457·10 ⁻²
	OPEX (€)	31.04	31.02	33.10

* Impacts calculated for 1 m³ of LSL board

Results interpretation – Key conclusions



Reference Solution (RS)

Significant room for improvement in view of the identified solutions

Solution 1 vs RS

↓ PT (s) ↓↓ t (°C) = higher reduction in the toxicity impact categories

Solution 2 vs Solution 1

↓↓ PT (s) ↑ t (°C) = lower GHG emissions, overall environmental performance and OPEX

Main conclusions

- ✓ The **MOO tool** applied involves **balancing** environmental responsibility, economic viability, and operational efficiency—representing addressing three **critical pillars of sustainable production at the same time**.
- ✓ One of the key **takeaways** is that **sustainability-driven industrial optimization** cannot rely on a one-size-fits-all approach. Each sector presents unique challenges, thus requiring tailored solutions. However, by integrating industrial process simulations, optimization algorithms and life cycle approaches can make more **informed, strategic decisions**.
- ✓ **Further research** should be focused on integrating additional S-LCA approaches, apart from advancing on diversifying the portfolio of practical approaches tailored to individual cases.

Thank you for your attention!

*Contact us in case you need more
information or if you want to know
how to participate*

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