Techno-economic and environmental sustainability assessment of poly(butylene succinate) production process from sugar beet pulp through biorefinery development

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STAR ProBio
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Selected case studies

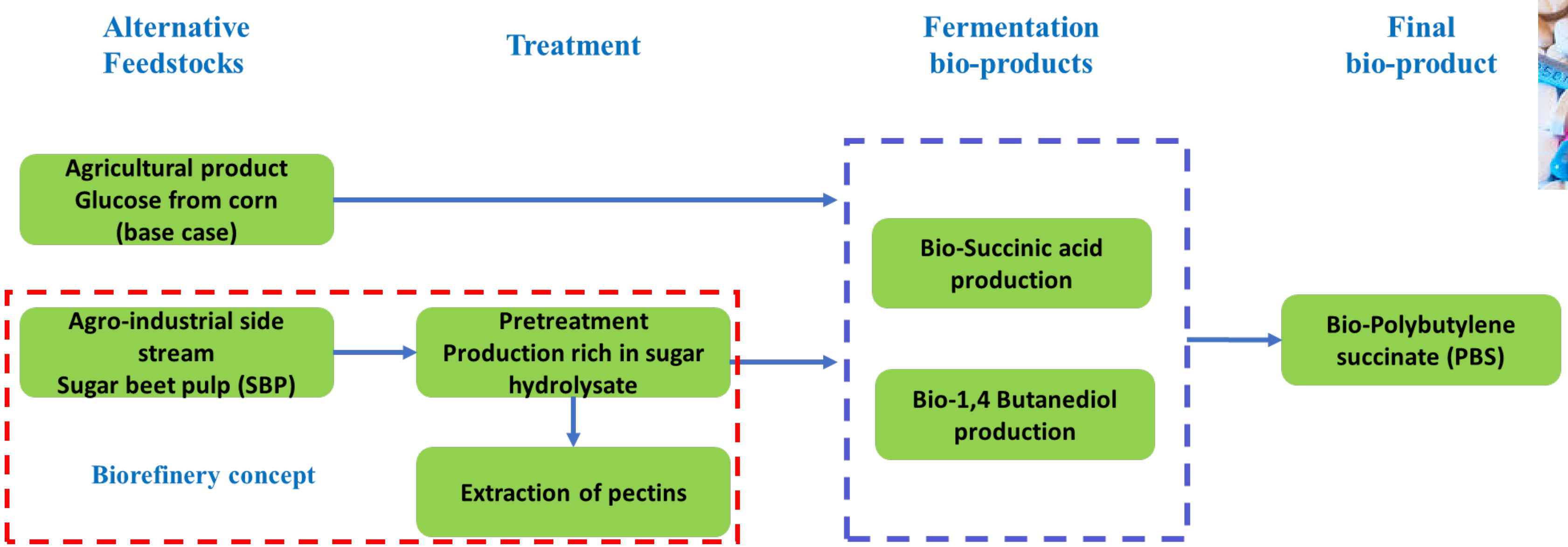
Sugar beet pulp (SBP)*

- ✓ Promising industrial side stream from the sugar production industry using sugar beet
- ✓ Suitable for biorefinery development
- ✓ Sufficient quantities are available in several EU-28 countries
- ✓ High carbohydrate content
- ✓ High pectin content

* considering that SBP contains 70% water content;
Drying and pelletisation have not been considered

Poly(butylene succinate) – PBS

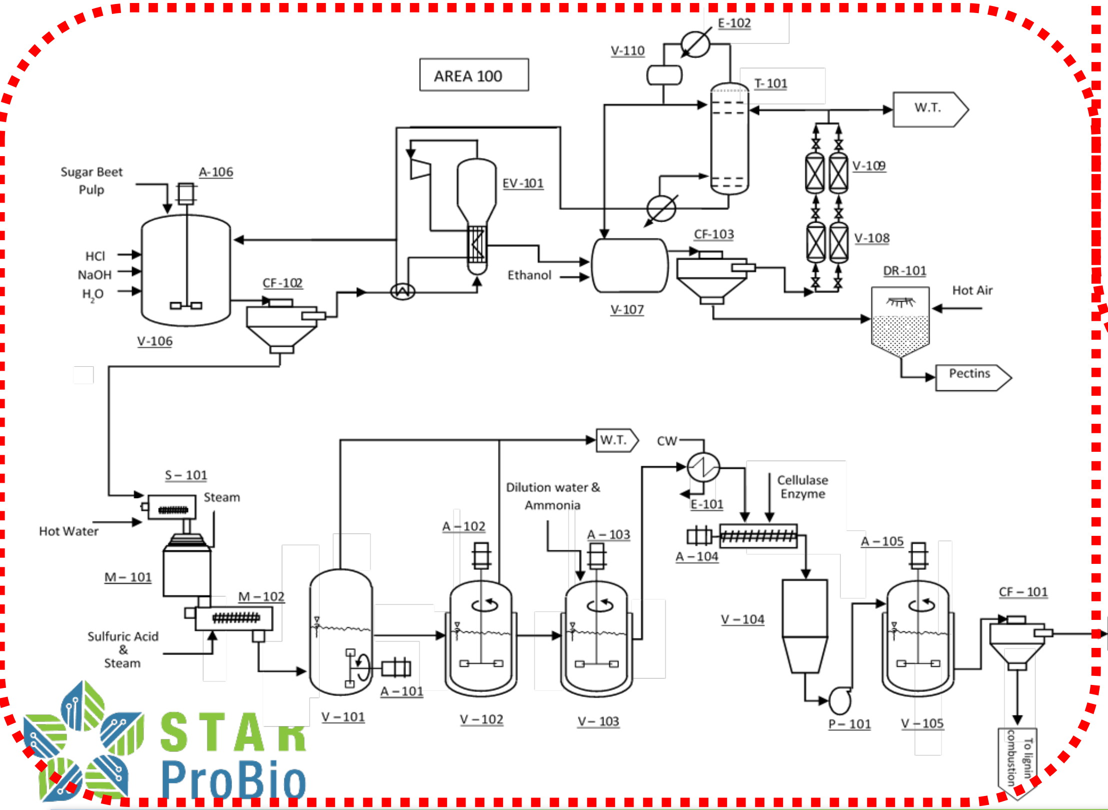
Monomers: bio-based succinic acid and 1,4-butanediol
Replacement for: general purpose polystyrene (GPPS)



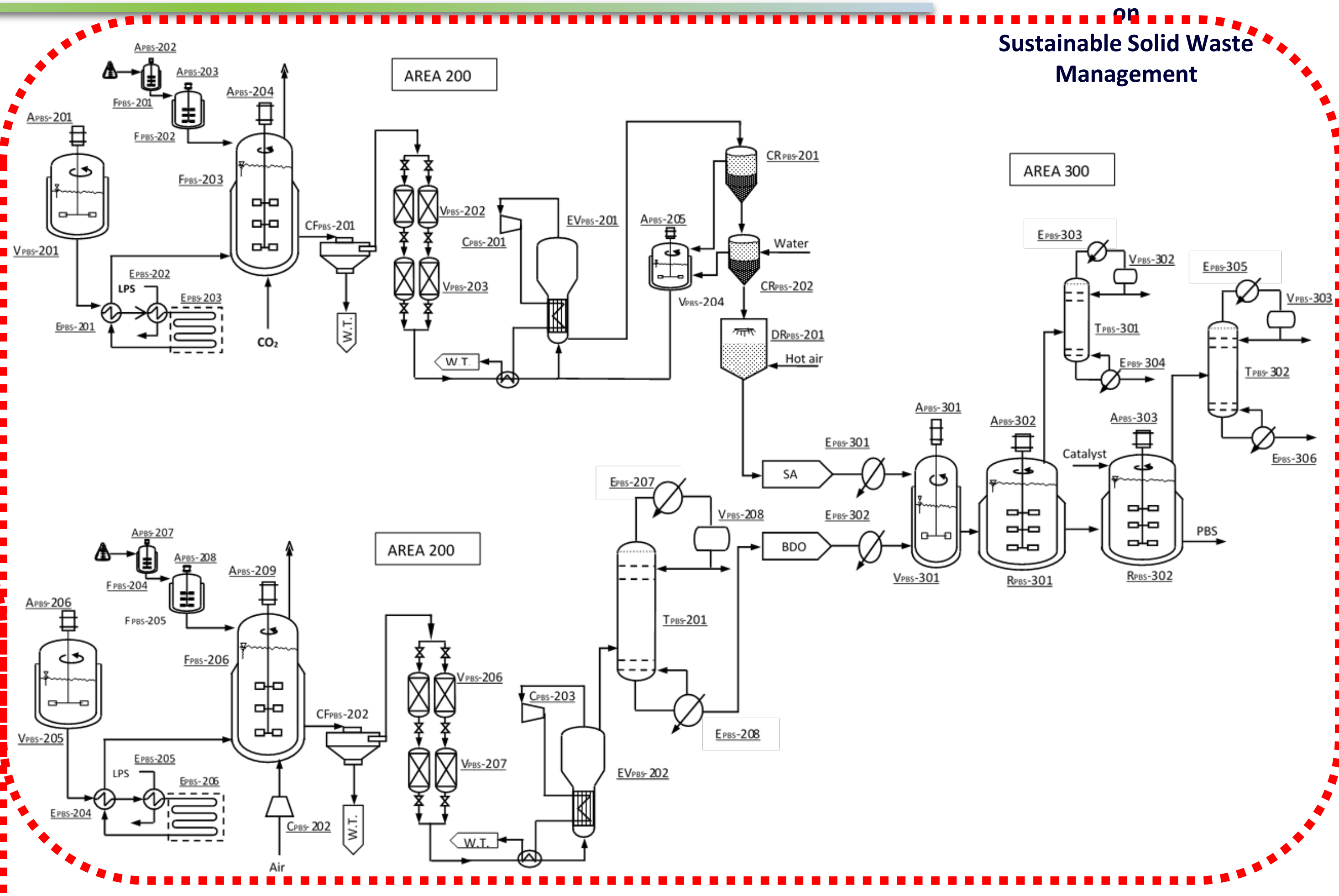
Process design

Specific code	Type of equipment	Specific code	Type of equipment
A-	Agitator	F-	Fermentor
C-	Compressor	M-	Presteamer
CF-	Centrifugal separator	P-	Pump
CR-	Crystallizer	R-	Reactor
DR-	Dryer	T-	Distillation column
E-	Heat exchanger	V-	Vessel
EV-	Evaporator		

SBP pretreatment



PBS production



Pectins extraction
Zheng et al.
Appl. Energy. 105 (2013) 1-7

SBP pretreatment
Humbird et al. 2011 NREL report

1,4-BDO fermentation
Burgard et al.
Curr. Opin. Biotechnol. (2016) 118-125

SA fermentation
Ma et al.
Bioprocess Biosyst. Eng. 34 (2011) 411-418

PBS polymerization
Kamikawa et al. U.S. Patent (2013)

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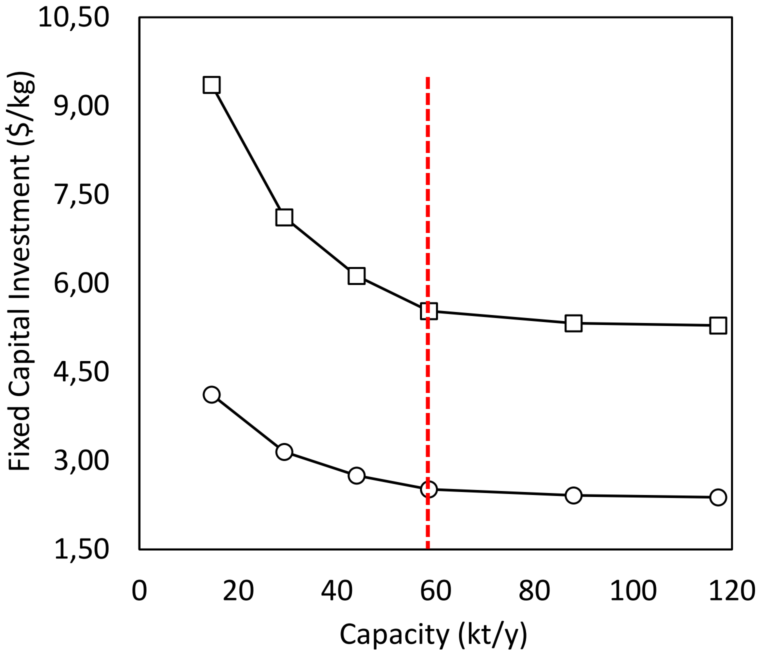
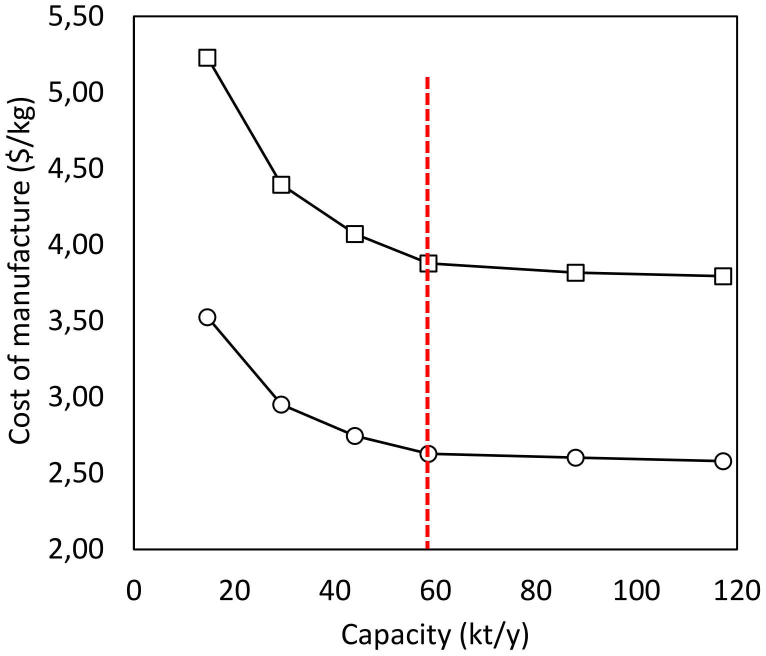
Techno-economic evaluation (methodology)

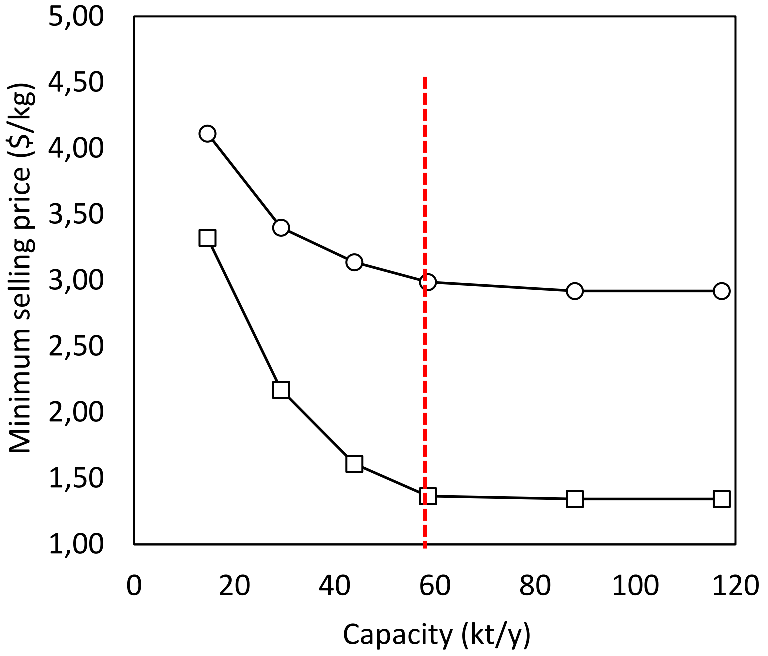
1. Development of the Process Flow Diagram (process design-Unisim, material and energy balance)
2. Sizing of all process equipment using standard chemical engineering techniques and widely acceptable rules of thumb
3. Estimation of purchased equipment cost (C_p) using relevant textbooks and reports
4. Conversion to todays prices by using the CEPCI (CHEMICAL ENGINEERING PLANT COST INDEX)
5. Economic evaluation by estimation of the price and other techno-economic indicators

OPC	:	Optimum Plant Capacity
FCI	:	Fixed Capital Investment
COM	:	Cost of Manufacture
MSP	:	Minimum Selling Price
DPP	:	Discounted Payback Period
MFR	:	Minimum Feedstock Capacity Requirement

Techno-economic evaluation (results)







o glucose □ sugar beet pulp

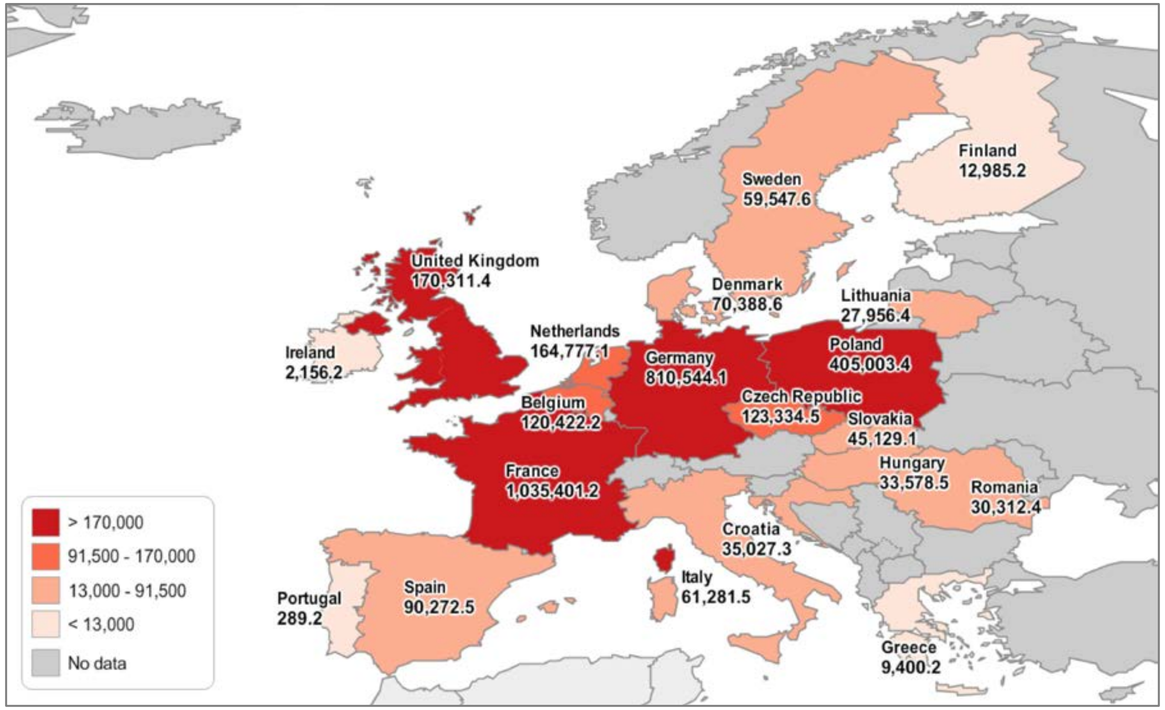
Metrics in the optimum plant capacity

	OPC (kt/year)	COM ($/kg)	MSP ($/kg)	DPP (year)	MFR (kt/year)
Glucose	58.63	2.63	2.99	7	151.28
Sugar beet pulp	58.63	3.88	1.37 *	6	865.18 **

*considering that the sales price of pectin-rich extract is 4 $/kg

** considering that the SBP contains 70% water, which means that drying and pelletisation have not been carried out

	Availability (million t for 2018)	Ratio
France	2.34	0.12
Germany	1.55	0.18
Poland	0.85	0.33



Cost of externalities (methodology)

External costs:
- physical parameter representing the unit of the impact
- economic parameter representing the accounting price per unit of impact

Principal stages for the implementation of externalities methodology

- Definition of the activity to be assessed
- Estimation of the impacts or effects of the activity (in physical units)

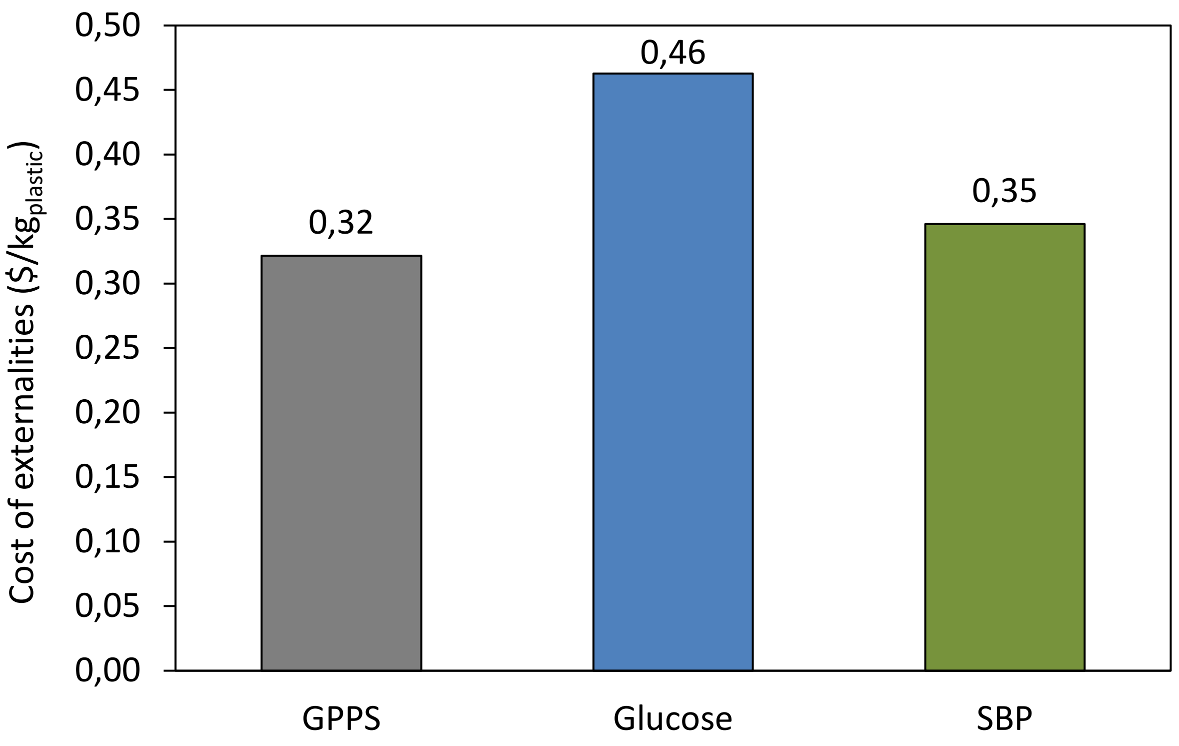
  → Gabi software, ReCiPe Mid/Endpoint methodology, version 1.08
- Monetisation of the impacts leading to external costs estimation.
- Assessment of uncertainties and sensitivity analysis.
- Analysis of the results and conclusions

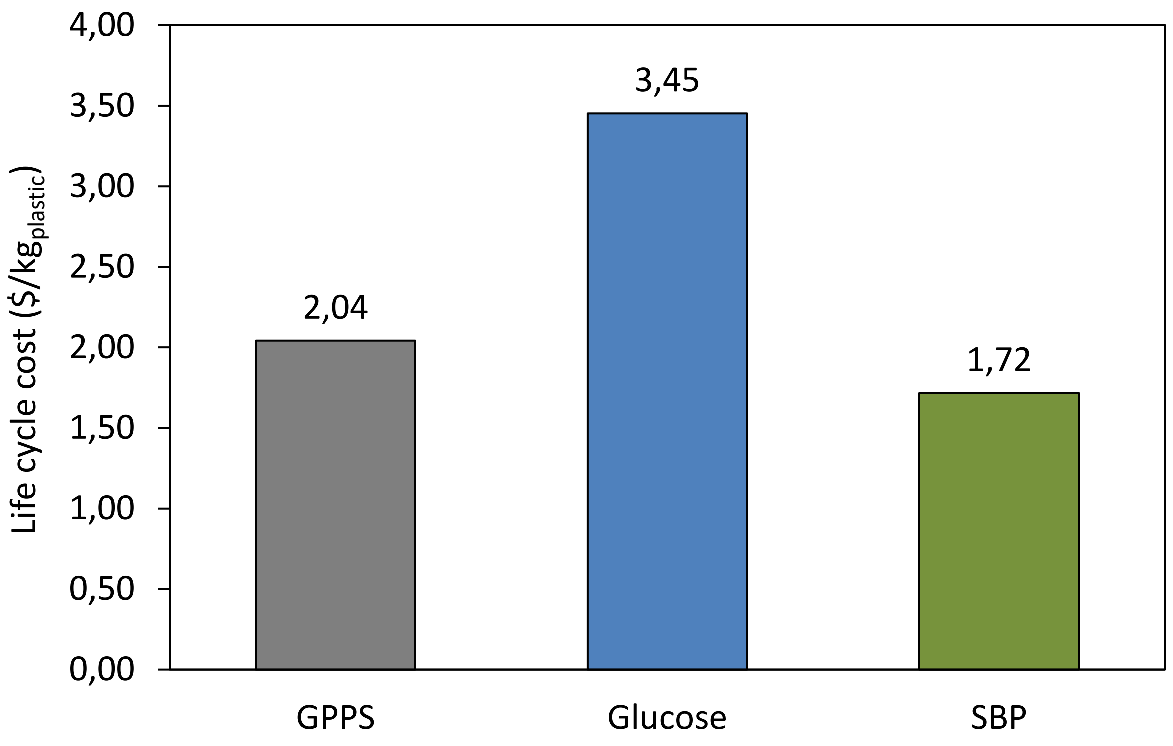
Impact Category	Unit	Monetary Value[1]
Climate Change	€/kg $CO_{2\text{-eq}}$	0.0566
Stratospheric Ozone Depletion	€/kg CFC-$_{11\text{-eq}}$	30.4000
Human Toxicity	€/kg 1,4 $DCB_{\text{-eq}}$	0.0991
Photochemical oxidant formation	€/kg $NMVOC_{\text{-eq}}$	1.1500
Fine Particulate Matter Formation	€/kg $PM_{10\text{-eq}}$	39.2000
Ionizing Radiation	€/kg kBq $U_{235\text{-eq}}$	0.0461
Acidification	€/kg $SO_{2\text{-eq}}$	4.9700
Freshwater eutrophication	€/kg $P_{\text{-eq}}$	1.8600
Marine eutrophication	€/kg $N_{\text{-eq}}$	3.1100
Terrestrial ecotoxicity	€/kg 1,4-$DB_{\text{-eq}}$	8.6900
Freshwater ecotoxicity	€/kg 1,4-$DB_{\text{-eq}}$	0.0361
Marine ecotoxicity	€/kg 1,4-$DB_{\text{-eq}}$	0.0074

[1]De Bruyn et al. Environmental Prices Handbook EU28 version - Methods and numbers for valuation of environmental impacts. CE Delft.

Externalities & Life Cycle Cost (LCC) – Comparison to fossil counterparts

Life cycle cost = Minimum Selling Price or Current Price + Cost of externalities





Thank you for your attention

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