Cost-Benefit Analysis of Bioplastic Sorting

Dr.Wang LI, Prof.Dr.Steven De Meester

GHENT UNIVERSITY

PROSPER

Circular Bio-based Europe Joint Undertaking

Bio-based Industries Consortium

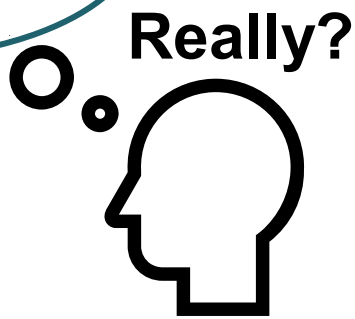
Co-funded by the European Union

LCPE Laboratory for Circular Process Engineering

The project is supported by the Circular Bio-based Europe Joint Undertaking and its members under grant agreement Nº 101157907. Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CBE JU. Neither the European Union nor the CBE JU can be held responsible for them.

Concerns about Biodegradable bio-based plastics

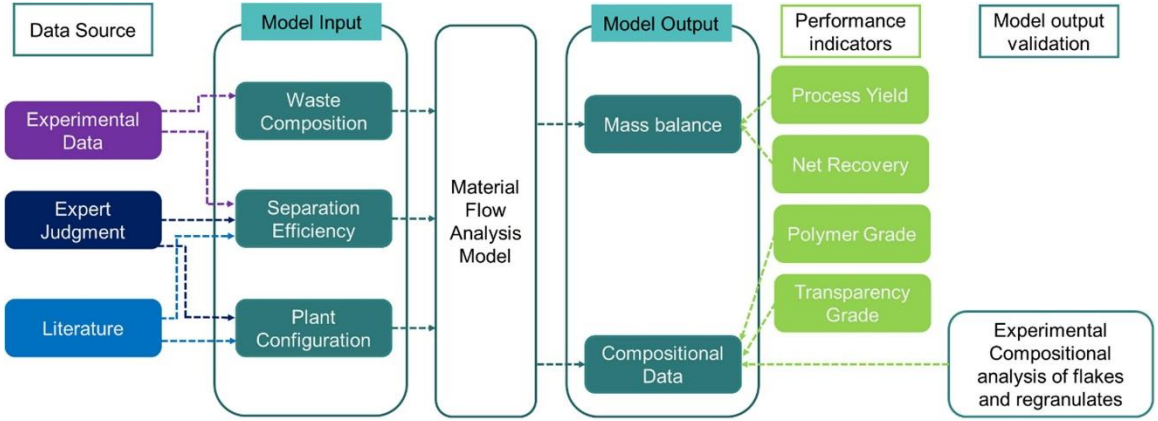
- Act as contaminants deteriorate conventional bale quality
- Too little to sort & recycle, not economically viable



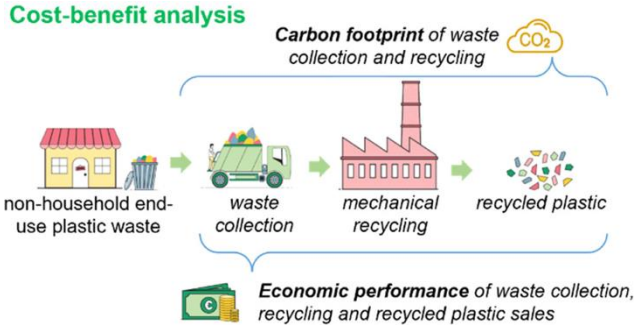
Consider the application and production capacity, we first focus on PLA

Sorting Model + Economic Assessment

A systematic, data-driven framework designed to simulate the material flows within Material Recovery Facilities (MRFs) based on material flow analysis (MFA) approach, coupled with economic viability assessment



(Saputra Lase et al. 2022)



How much can chemical recycling contribute to plastic waste recycling in Europe? An assessment using material flow analysis modeling

Method to Develop Potential Business Cases of Plastic Recycling from Urban Areas: A Case Study on Nonhousehold End-Use Plastic Film Waste in Belgium

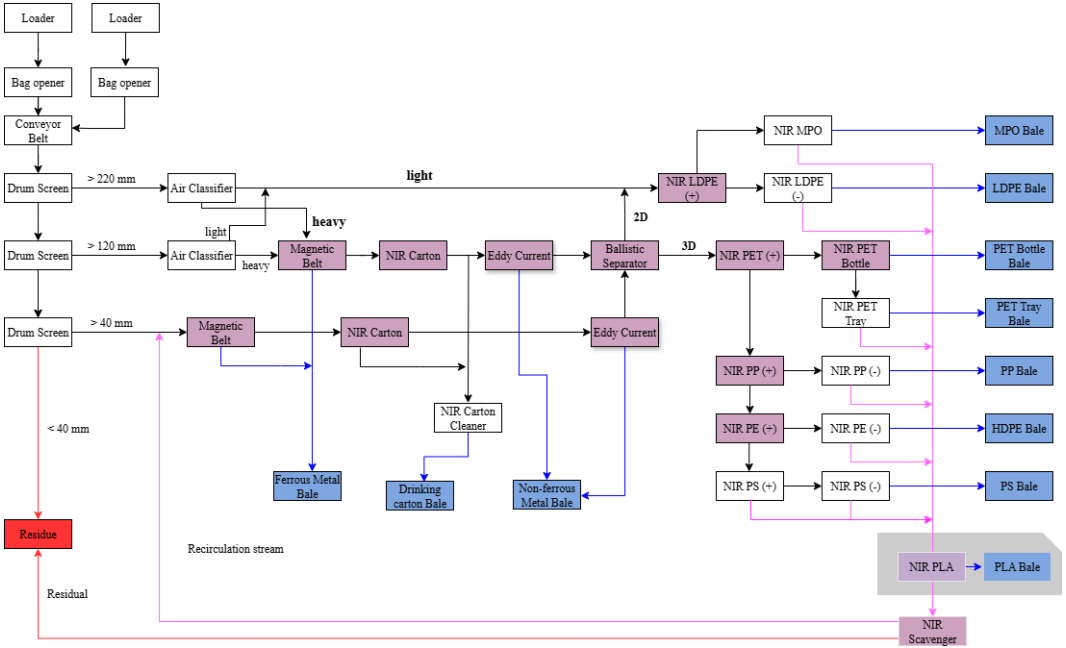
Operational Framework to Quantify "Quality of Recycling" across Different Material Types

Quality evaluation and economic assessment of an improved mechanical recycling process for post-consumer flexible plastics

nding the collection portfolio of plastic packaging: Impact on quantity quality of sorted plastic waste fractions

What have we done?

Material flow analysis of PLA packaging at MRFs with Cost-Benefit Analysis CBA



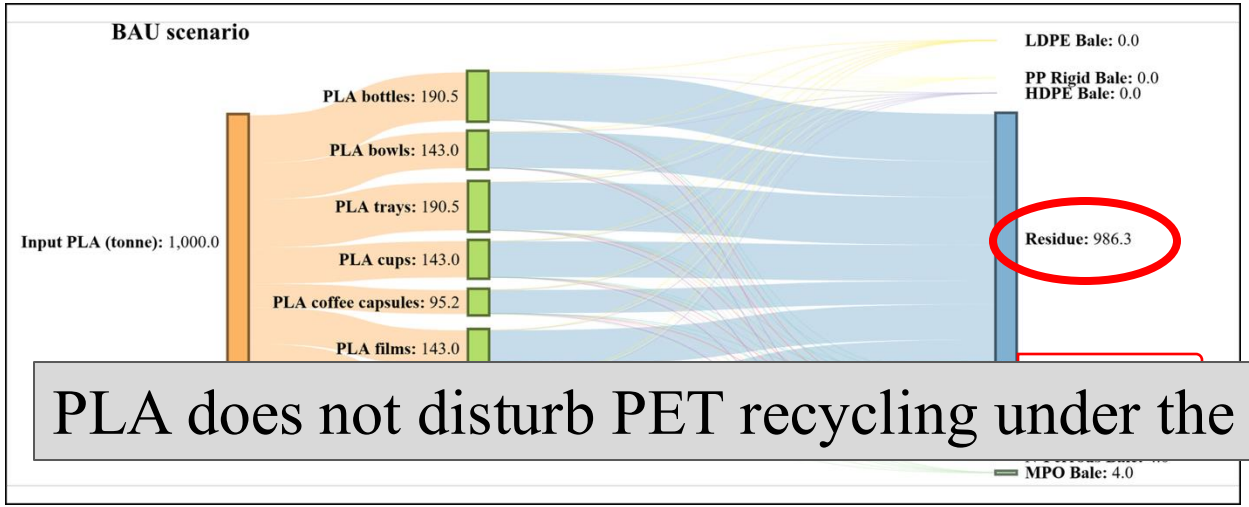
(Li et al., 2025, Resources, Conservation & Recycling, in revision)

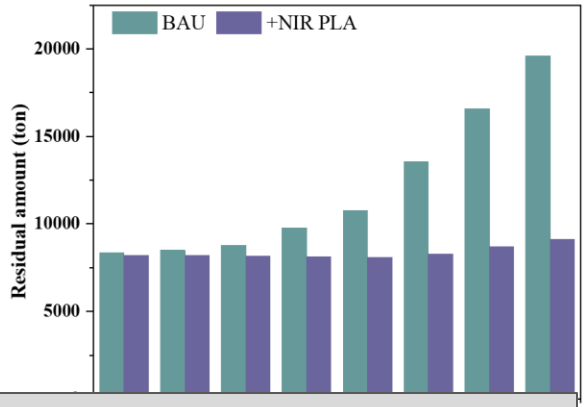
- Scenario: BAU and +NIR PLA
- Scenario: Increasing market penetration

NIR Sorting efficiency

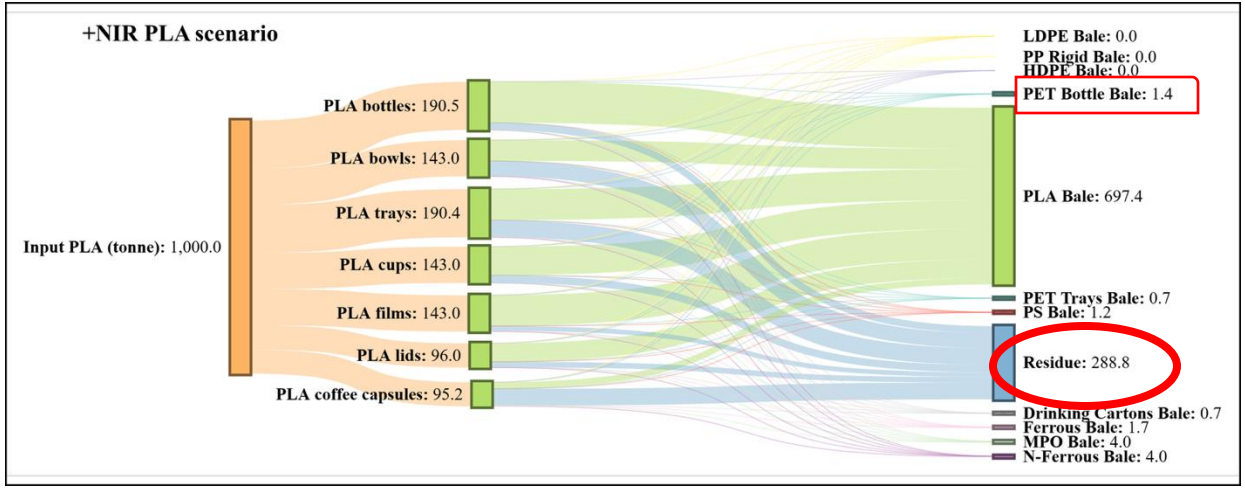
- **99%** for virgin, **97.4%** for degraded PLA products (Chen et al., 2021).
- **97.8%** (Titech) and **99.6%** (Gertman et al.,2013) from mixed PET waste stream.
- **88.04%** (CE Delft, 2019)

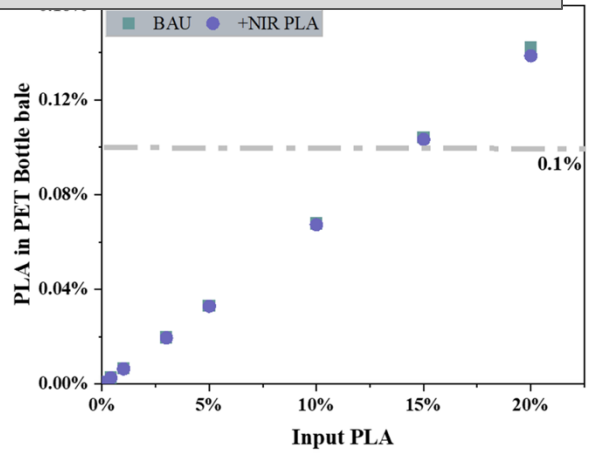
PLA flow at MRF





PLA does not disturb PET recycling under the current market share!





PROSPER

Economic assessment

CAPEX: 40.6 M€

Cost Breakdown				
Equipment	**Cost**	**Quantity**	**Sum**	**Reference**
Loader	€ 312,000	2	€ 624,000	Cimpan et al., 2016a with 30% inflation considered
Bag opener	€ 130,000	2	€ 260,000	Cimpan et al., 2016a with 30% inflation considered
Conveyor belt	€ 16,250	72	€ 1,170,000	Cimpan et al., 2016a with 30% inflation considered
Drum screen	€ 240,000	3	€ 720,000	IFE Aufbereitungstechnik GmbH
Wind shifter (include air compressor system and dust filtration)	€ 240,000	2	€ 480,000	Industrial reference (Kidney S&B)
Over belt magnet	€ 65,000	4	€ 260,000	Cimpan et al., 2016a; Van Camp et al., 2024
Eddy current separator	€ 105,000	2	€ 210,000	Cimpan et al., 2016a; Van Camp et al., 2024
NIR sorter 1.2m belt width (2.5-3 t/h)	€ 200,000	18	€ 3,600,000	Industrial reference (SUEZ)
NIR sorter 1.6m belt width (4-5 t/h)	€ 230,000	4	€ 920,000	Industrial reference (SUEZ)
NIR sorter 2.4m belt width (5-7 t/h)	€ 270,000	2	€ 540,000	Industrial reference (SUEZ)
Air compressor for NIR sorters	€ 39,000	24	€ 936,000	Cimpan et al., 2016a with 30% inflation considered
Ballistic separator	€ 175,000	2	€ 350,000	Model InSystem 001
Cage, bailer & container	€ 276,250	2	€ 552,500	Cimpan et al., 2016a with 30% inflation considered
	SUM (Equipment Costs EC)		**€ 10,622,500**	
Equipment installation		45.0% of EC	€ 4,780,125	Peters, 2003
Electrical engineering		20.0% of EC	€ 2,124,500	Peters, 2003
Instrumentation and control (automation/control system integration)		10.0% of EC	€ 1,062,250	Lang, 1948 Lang, 1948
Site preparation (grading, drainage)		5.0% of EC	€ 531,125	Peters, 2003
Process buildings (platform, substructures)		12.5% of EC	€ 1,327,813	Peters, 2003
Auxiliary building		12.5% of EC	€ 1,327,813	Peters, 2003
Service facilities (provide power, compressed air, utilities, including office)		40.0% of EC	€ 4,249,000	Peters, 2003
Land (property cost, survey, design)		6.0% of EC	€ 637,350	Peters, 2003
Engineering and supervision		33.0% of EC	€ 3,505,425	Peters, 2003
Construction expenses (temporary office, insurance, accounting, field tests)		39.0% of EC	€ 4,142,775	Peters, 2003
Contractor's fee		17.0% of EC	€ 1,805,825	Peters, 2003
Project management		7.0% of EC	€ 743,575	Industrial reference
		Sum (Total Investment Cost TIC)	€ 36,860,075	Cimpan et al., 2016a
Contingency (unforeseen costs)		10.0% of TIC	€ 3,686,008	Peters, 2003
		Annualized CAPEX	€ 4,224,087	Cimpan et al., 2016a

Labor cost	56,250€ per person per year	Industrial reference & Expert judgement
Electricity (0.162€/kW)	electricity price × electricity consumption (kWh)	Industrial reference & Expert judgement (details can be found in SI Table S14)
Repair and maintenance	6.5% of TIC	Industrial reference & Expert judgement
Insurance	2.0% of TIC	Industrial reference & Expert judgement
Fuel (1600 EUR/m³)	Fuel price × material load	Cimpan et al., 2016a
Disposal Cost (140 EUR/t)	140 EUR/t × Residue amount (t)	Cimpan et al., 2016a
Overall Sorting Cost (EUR/t)	**€ 186**	Overall plant OPEX/plant annual capacity (75 ktonne)

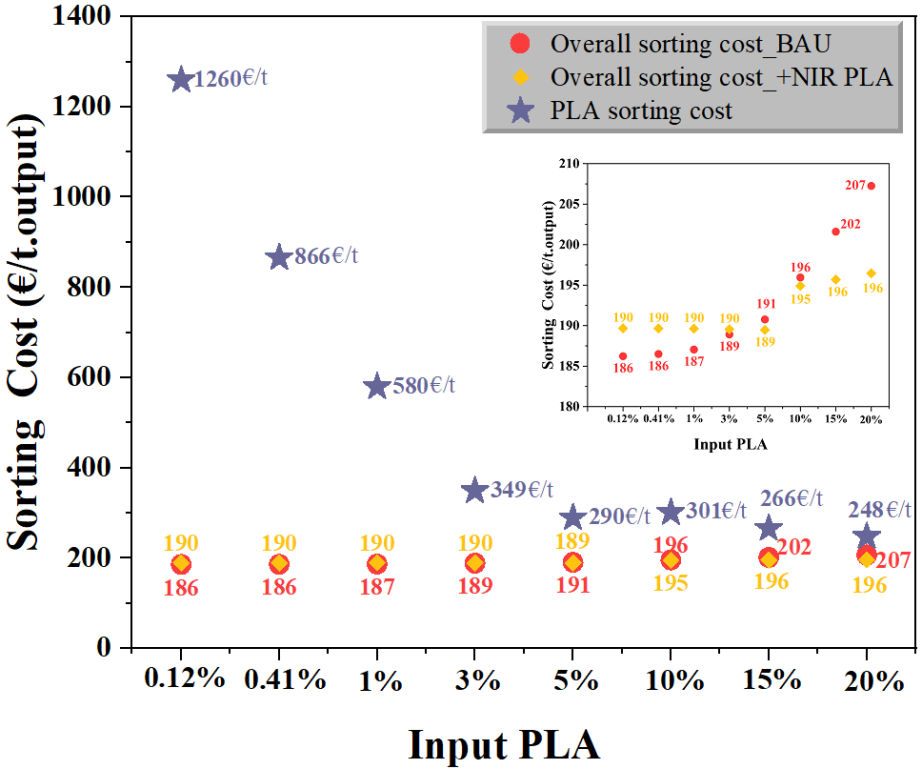
Sensitivity analysis:
±25% change of cost parameters in CBA

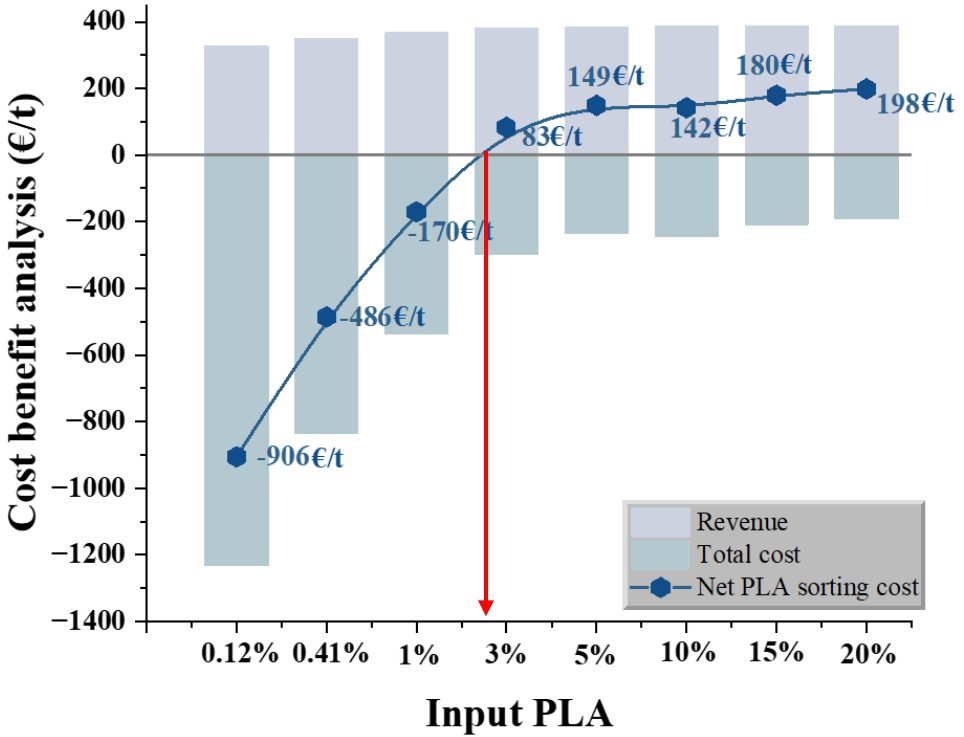
PROSPER

Costs-Add NIR PLA

Cost Parameters	0.165%	0.57%	1%	3%	5%	10%	15%	20%
NIR sorter (incl.conveyor&hopper)	230,000 €	230,000 €	230,000 €	230,000 €	230,000 €	460,000 €	460,000 €	460,000 €
Air compressor/blower	39,000 €	39,000 €	39,000 €	39,000 €	39,000 €	78,000 €	78,000 €	78,000 €
Installation cost (8% eq)	21,520 €	21,520 €	21,520 €	21,520 €	21,520 €	43,040 €	43,040 €	43,040 €
Project management cost (7%)	20,336 €	20,336 €	20,336 €	20,336 €	20,336 €	40,673 €	40,673 €	40,673 €
Contingency Cost (10%)	31,086 €	31,086 €	31,086 €	31,086 €	31,086 €	62,171 €	62,171 €	62,171 €
Annualized capital cost (7-year lifespan)	**48,849 €**	**48,849 €**	**48,849 €**	**48,849 €**	**48,849 €**	**97,698 €**	**97,698 €**	**97,698 €**
Labor (56,250 €/year, person)	168,750 €	168,750 €	168,750 €	168,750 €	168,750 €	168,750 €	168,750 €	168,750 €
Electricity (0.16 €/kWh)	50,976 €	50,976 €	50,976 €	50,976 €	50,976 €	50,976 €	50,976 €	50,976 €
Maintenace (6.5% Capex)	3,175 €	3,175 €	3,175 €	3,175 €	3,175 €	6,350 €	6,350 €	6,350 €
Insurance cost (2% Capex)	977 €	977 €	977 €	977 €	977 €	1,954 €	1,954 €	1,954 €
Depreciation cost (15%)	7,327 €	7,327 €	7,327 €	7,327 €	7,327 €	14,655 €	14,655 €	14,655 €
Total Operation cost	**231,205 €**	**231,205 €**	**231,205 €**	**231,205 €**	**231,205 €**	**242,685 €**	**242,685 €**	**242,685 €**
Allocated Costs (Input PLA share*plant OPEX)	**24,515 €**	**84,694 €**	**148,585 €**	**445,756 €**	**742,927 €**	**1,485,877 €**	**2,228,810 €**	**2,971,708 €**
Disposal saving (140€/t)	€ 14,899	€ 48,998	€ 85,199	€ 253,574	€ 388,727	€ 843,053	€ 1,235,127	€ 1,685,135
Revenue (Market value of sorted PLA,250€/t)	€ 29,351	€ 90,248	€ 154,903	€ 455,621	€ 756,399	€ 1,508,317	€ 2,260,230	€ 3,012,164

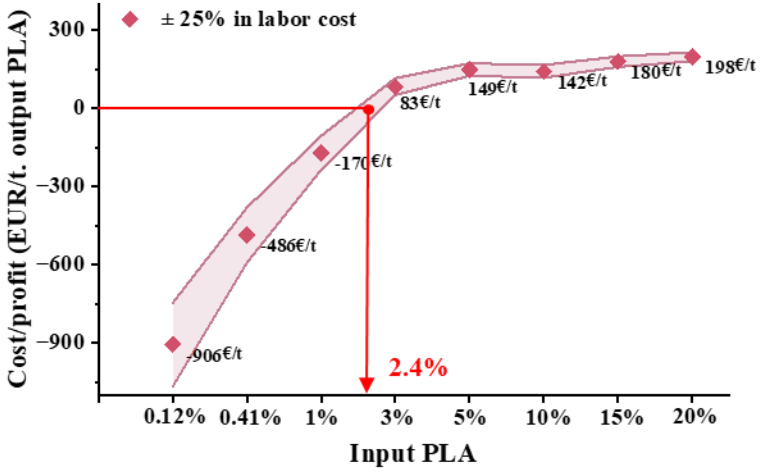
PLA sorting cost

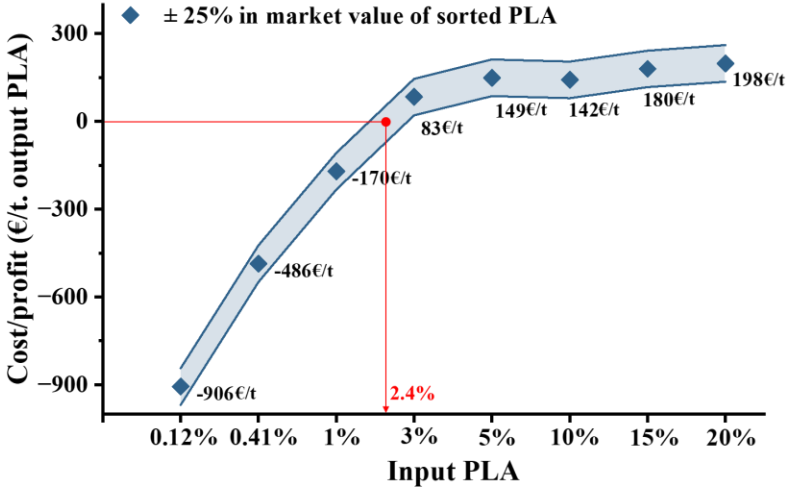


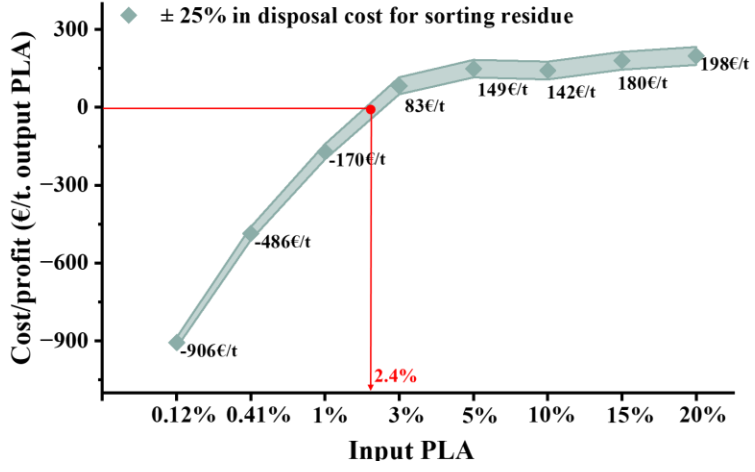


Break-even point: **2.4%** of PLA at MRF input waste stream

Sensitivity analysis

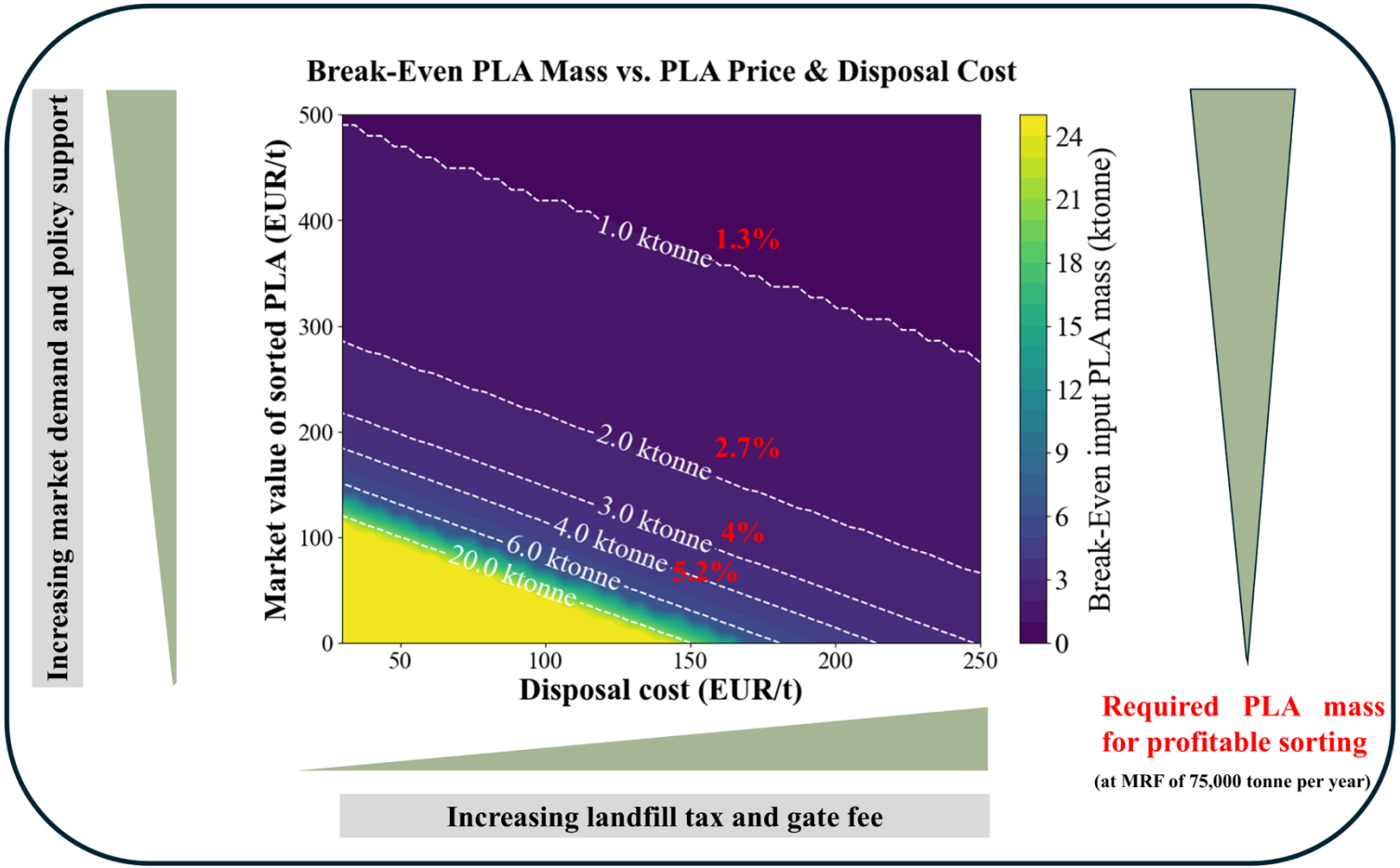




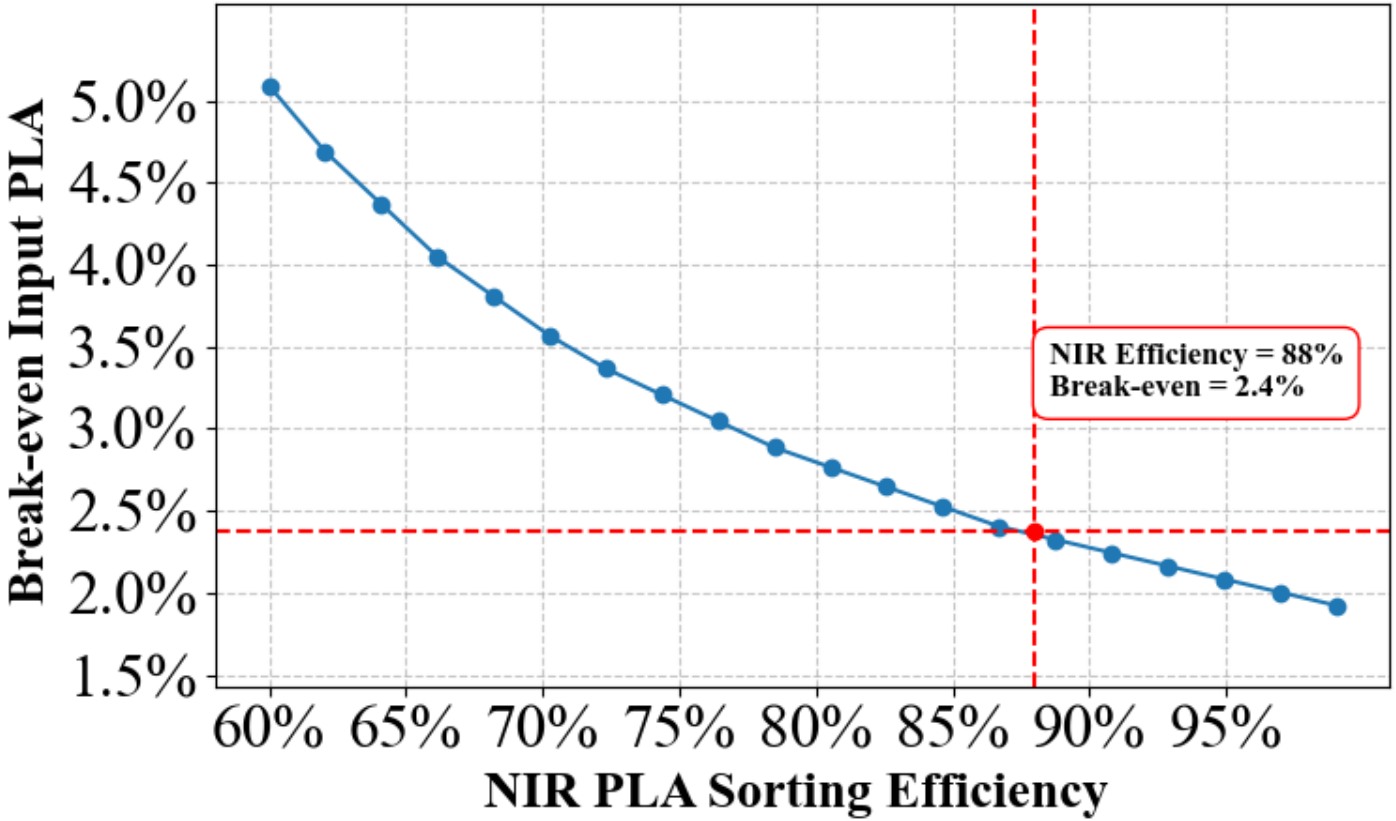


Low (<1%) : Labour cost
High : Sorted PLA price & Disposal cost

Break-even point (PLA price & disposal cost)



Break-even point (NIR sorting efficiency)



Take-Home Message

- PLA is unlikely to disturb PET recycling under the current market share
- PLA sorting can be economically viable when it reaches 2.4% at MRF input
- Improvement in NIR sorting can facilitate PLA sorting investment

Circular Bio-based Europe Joint Undertaking

Bio-based Industries Consortium

Co-funded by the European Union

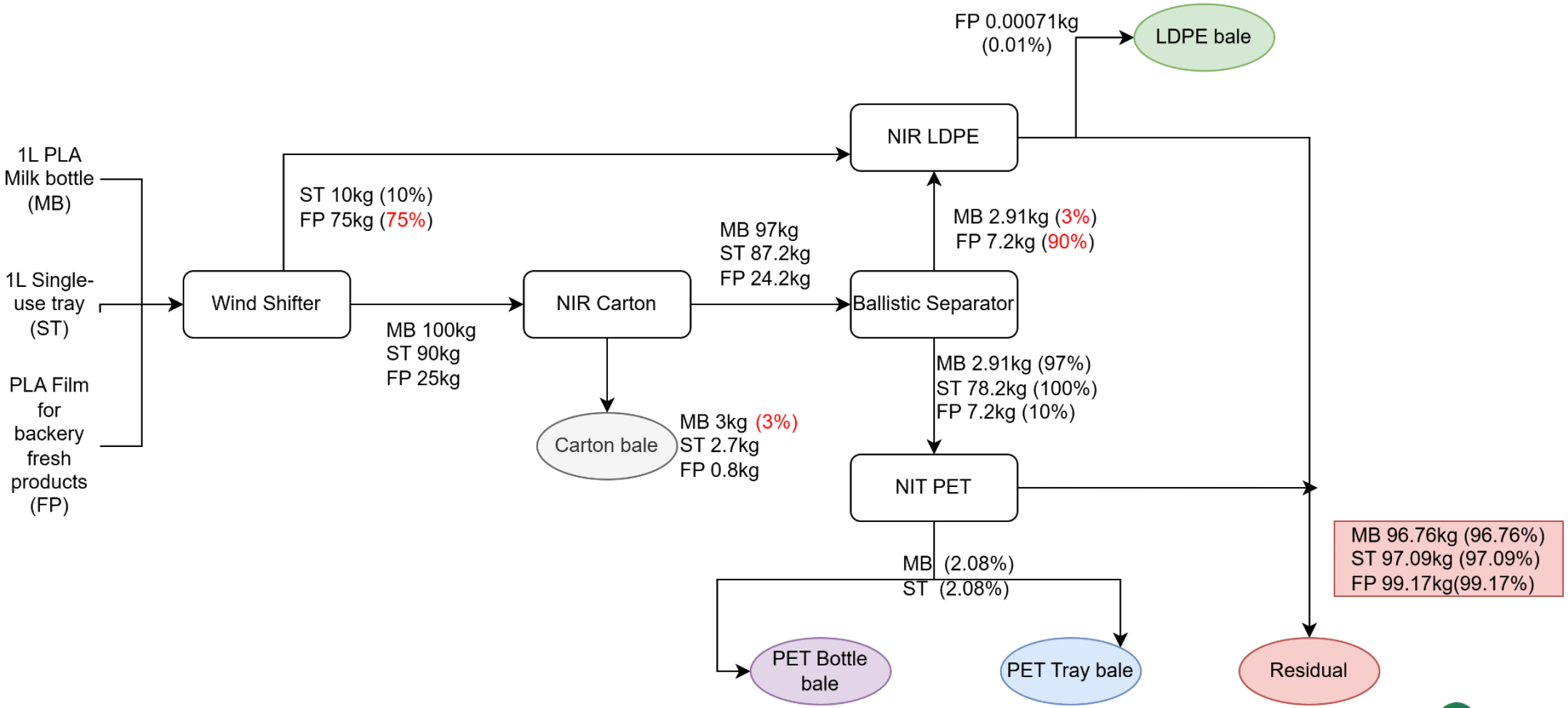
The project is supported by the Circular Bio-based Europe Joint Undertaking and its members under grant agreement № 101157907. Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CBE JU. Neither the European Union nor the CBE JU can be held responsible for them.

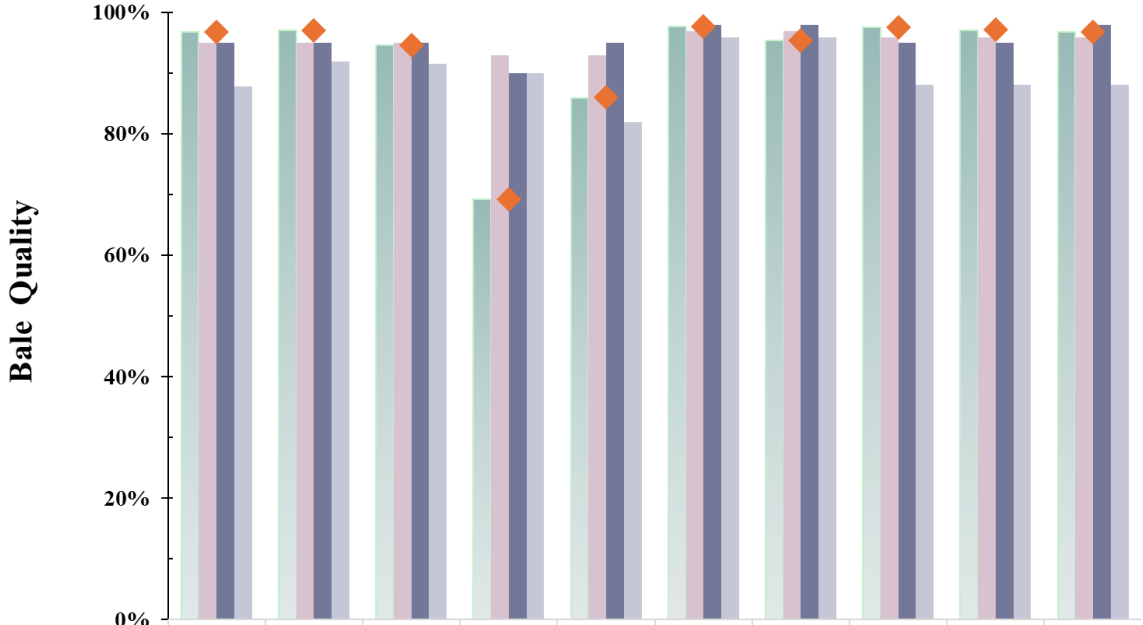
Thank you.

www.prosperbioplastics.eu
info@prosperbioplastics.eu

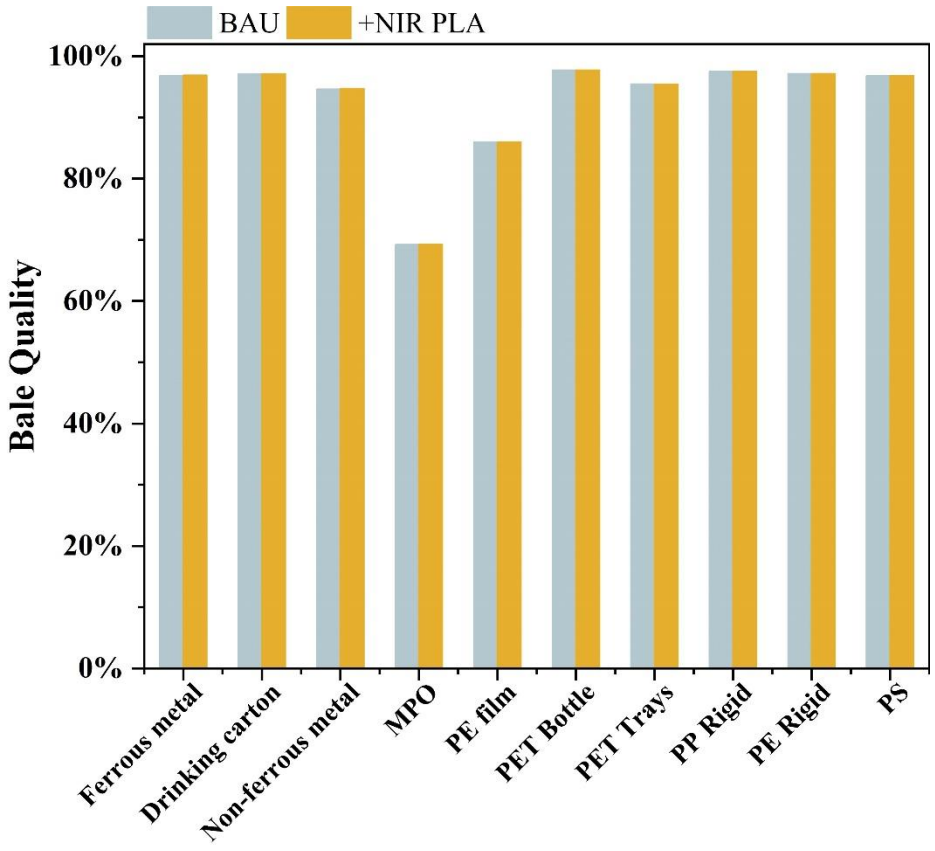
PROSPER

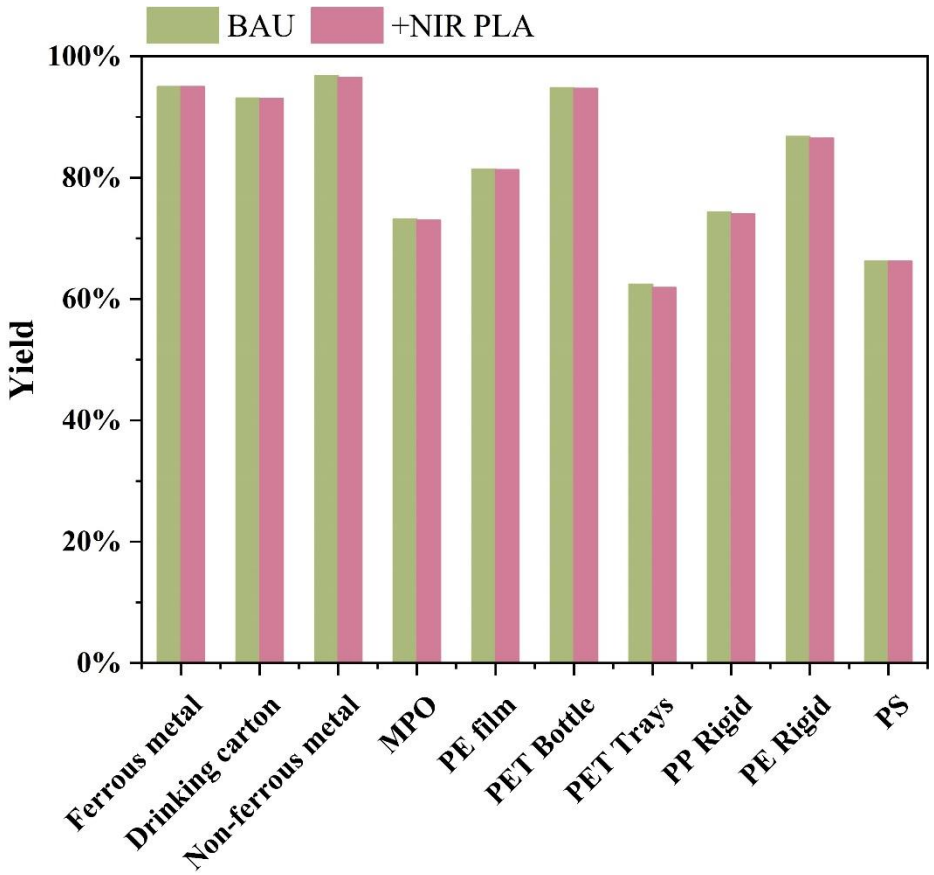
Model Output_Process yield





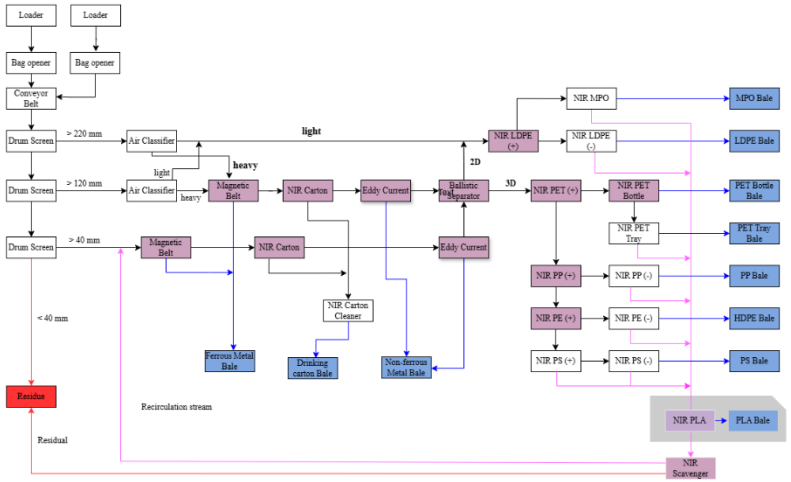
	Ferrous	Cartons	NFe	MPO	LDPE	PET Bottle	PET Trays	PP Rigid	HDPE	PS
Model_BAU	96.9%	97.1%	94.6%	69.2%	86.0%	97.7%	95.5%	97.5%	97.2%	96.8%
Belgium_Fost Plus	95.0%	95.0%	95.0%	93.0%	93.0%	97.0%	97.0%	96.0%	96.0%	96.0%
France_CITEO	95.0%	95.0%	95.0%	90.0%	95.0%	98.0%	98.0%	95.0%	95.0%	98.0%
Quality observatory report (CITEO 2023)	87.9%	92.0%	91.6%	90.1%	82.0%	96.0%	96.0%	88.1%	88.1%	88.1%
Model_+NIR PLA Scenario	96.9%	97.1%	94.6%	69.3%	86.0%	97.7%	95.4%	97.5%	97.2%	96.8%


BAU
+NIR PLA
Bale Quality
100%
80%
60%
40%
20%
0%
Ferrous metal
Drinking carton
Non-ferrous metal
MPO
PE film
PET Bottle
PET Trays
PP Rigid
PE Rigid
PS

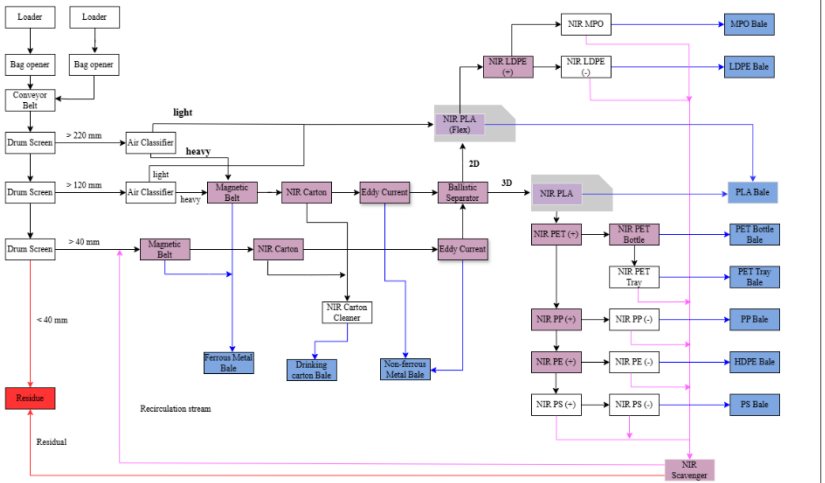

BAU
+NIR PLA
Yield
100%
80%
60%
40%
20%
0%
Ferrous metal
Drinking carton
Non-ferrous metal
MPO
PE film
PET Bottle
PET Trays
PP Rigid
PE Rigid
PS

PROSPER

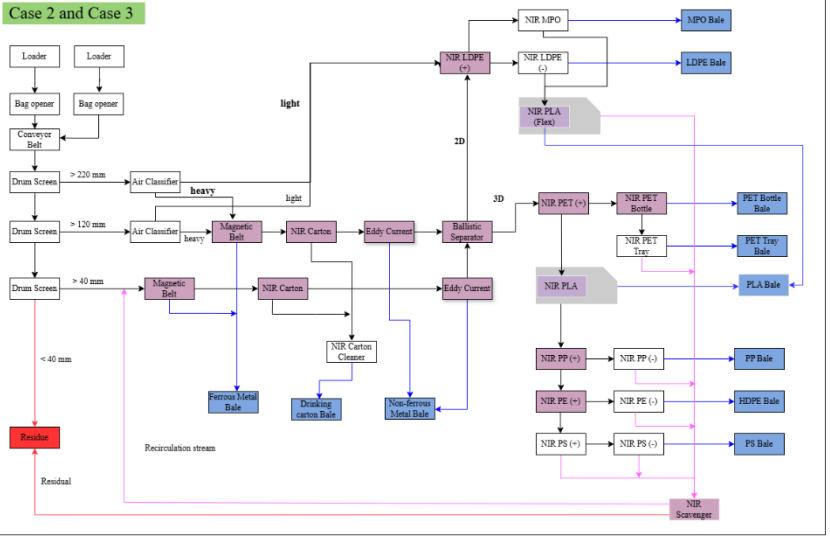
Business-as Usual and +NIR PLA Scenario

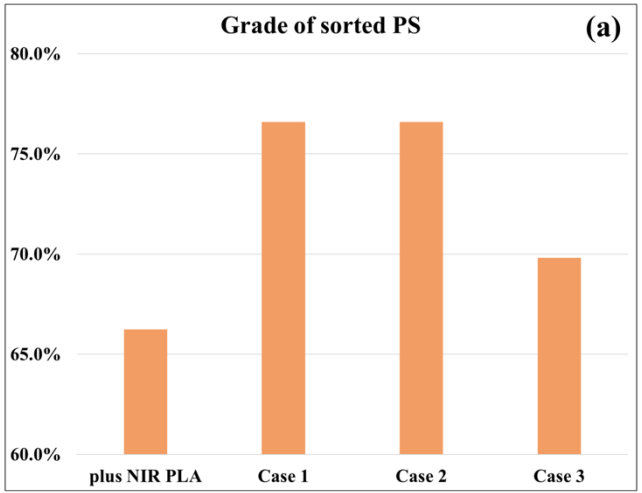


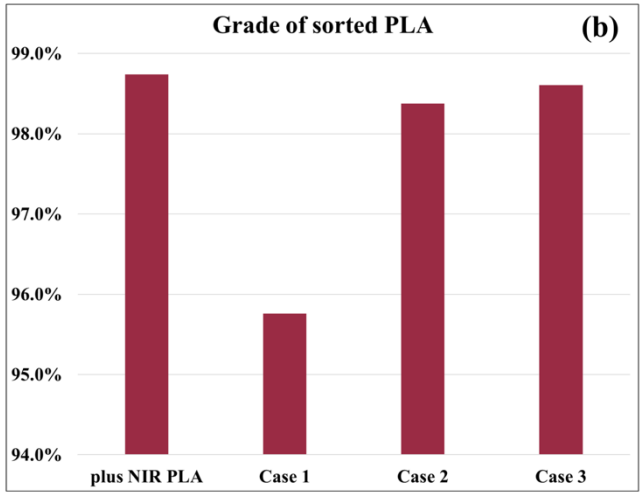
Case 1

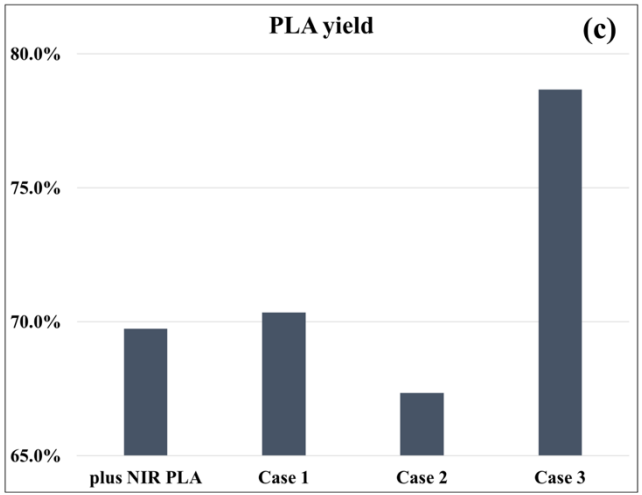


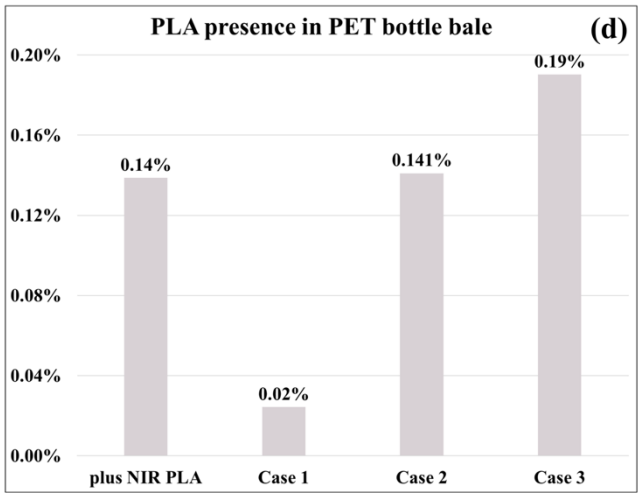
Case 2 and Case 3



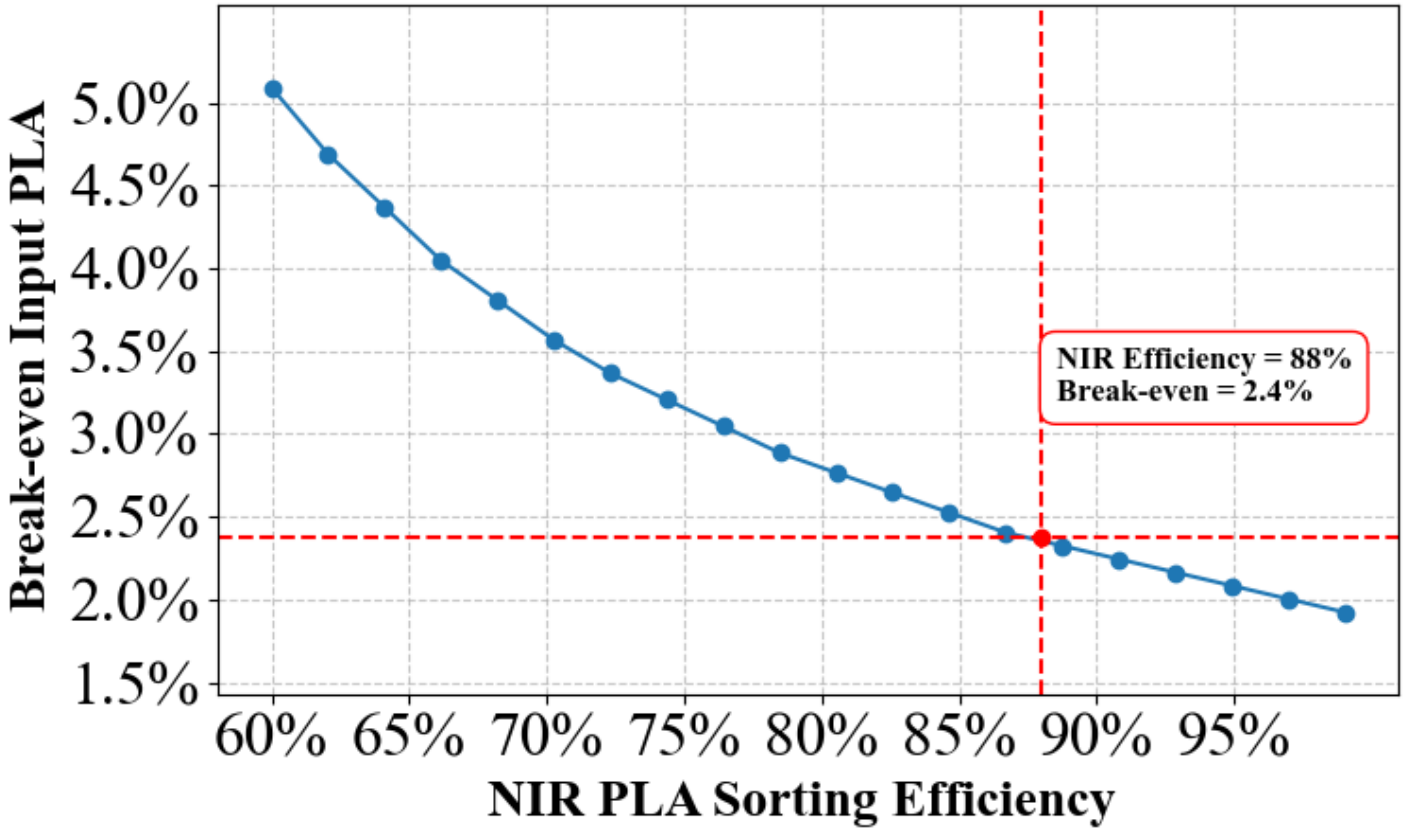

Grade of sorted PS
(a)
80.0%
75.0%
70.0%
65.0%
60.0%
plus NIR PLA
Case 1
Case 2
Case 3

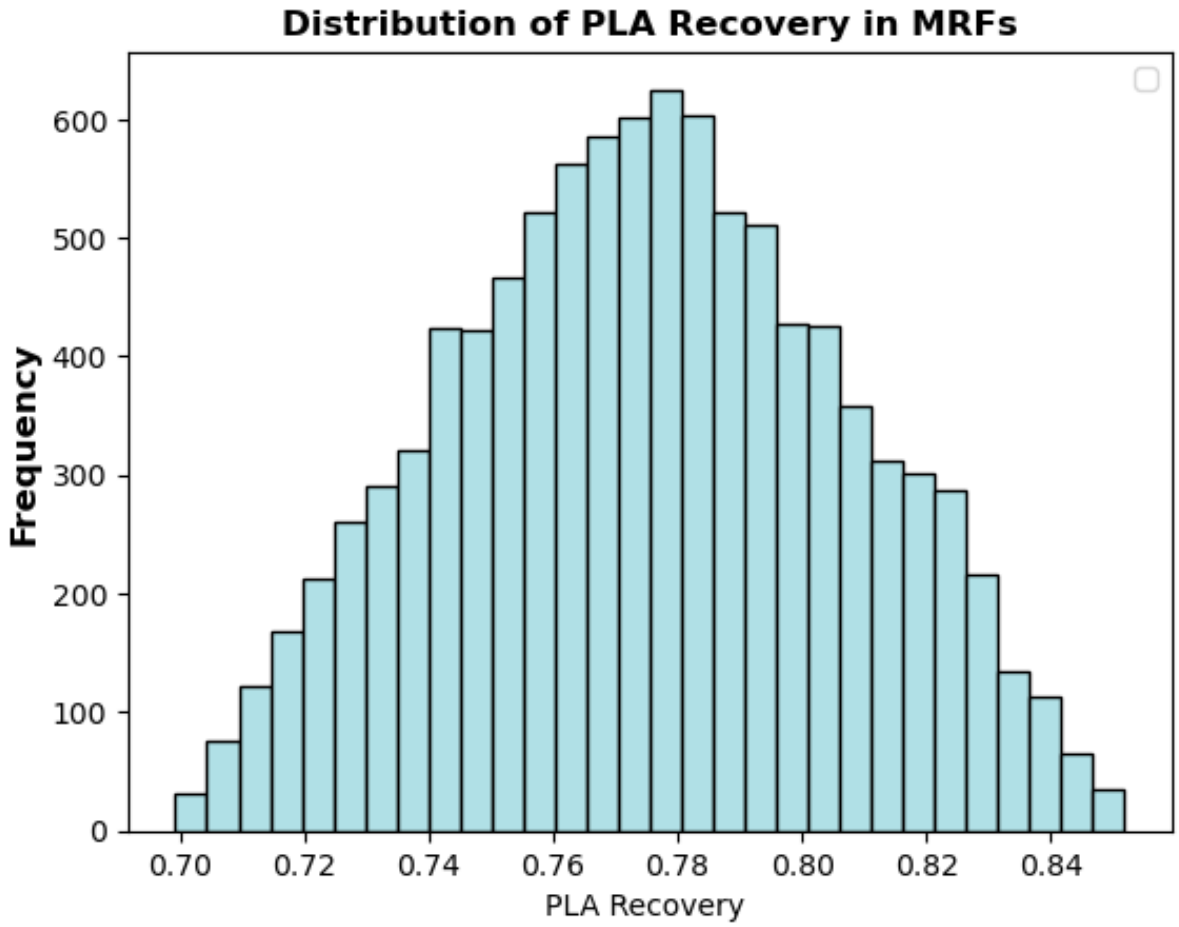

Grade of sorted PLA
(b)
99.0%
98.0%
97.0%
96.0%
95.0%
94.0%
plus NIR PLA
Case 1
Case 2
Case 3

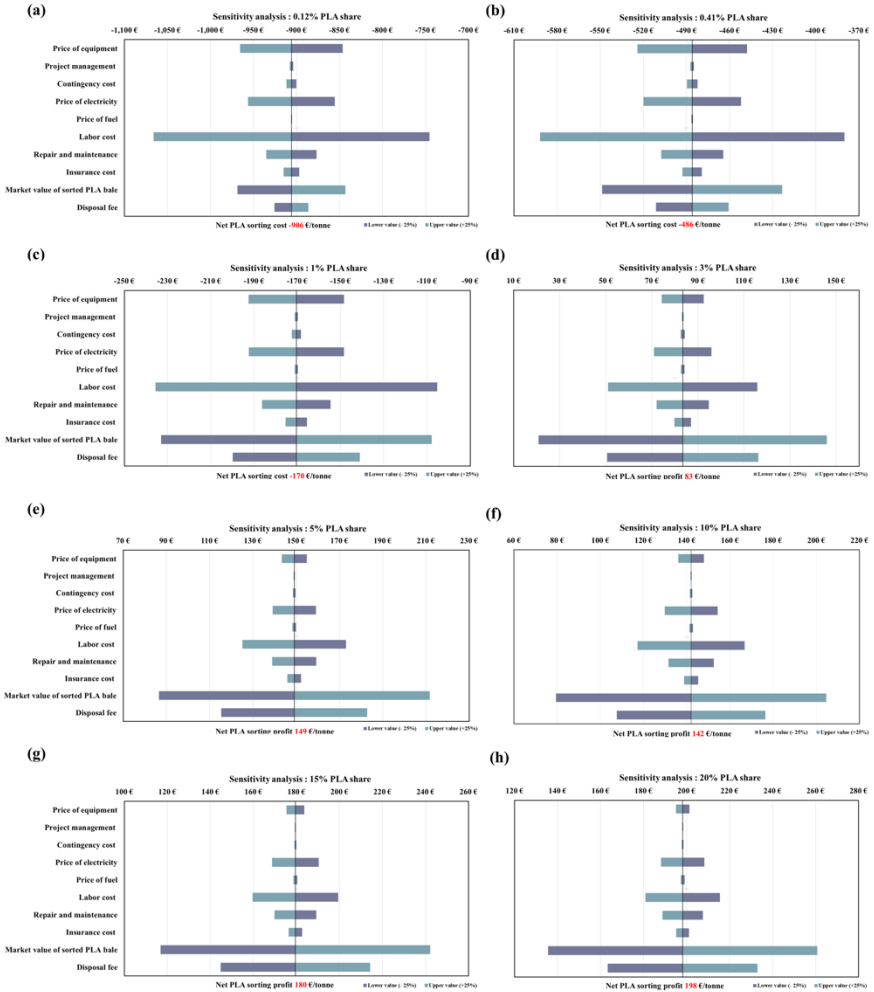

PLA yield
(c)
80.0%
75.0%
70.0%
65.0%
plus NIR PLA
Case 1
Case 2
Case 3

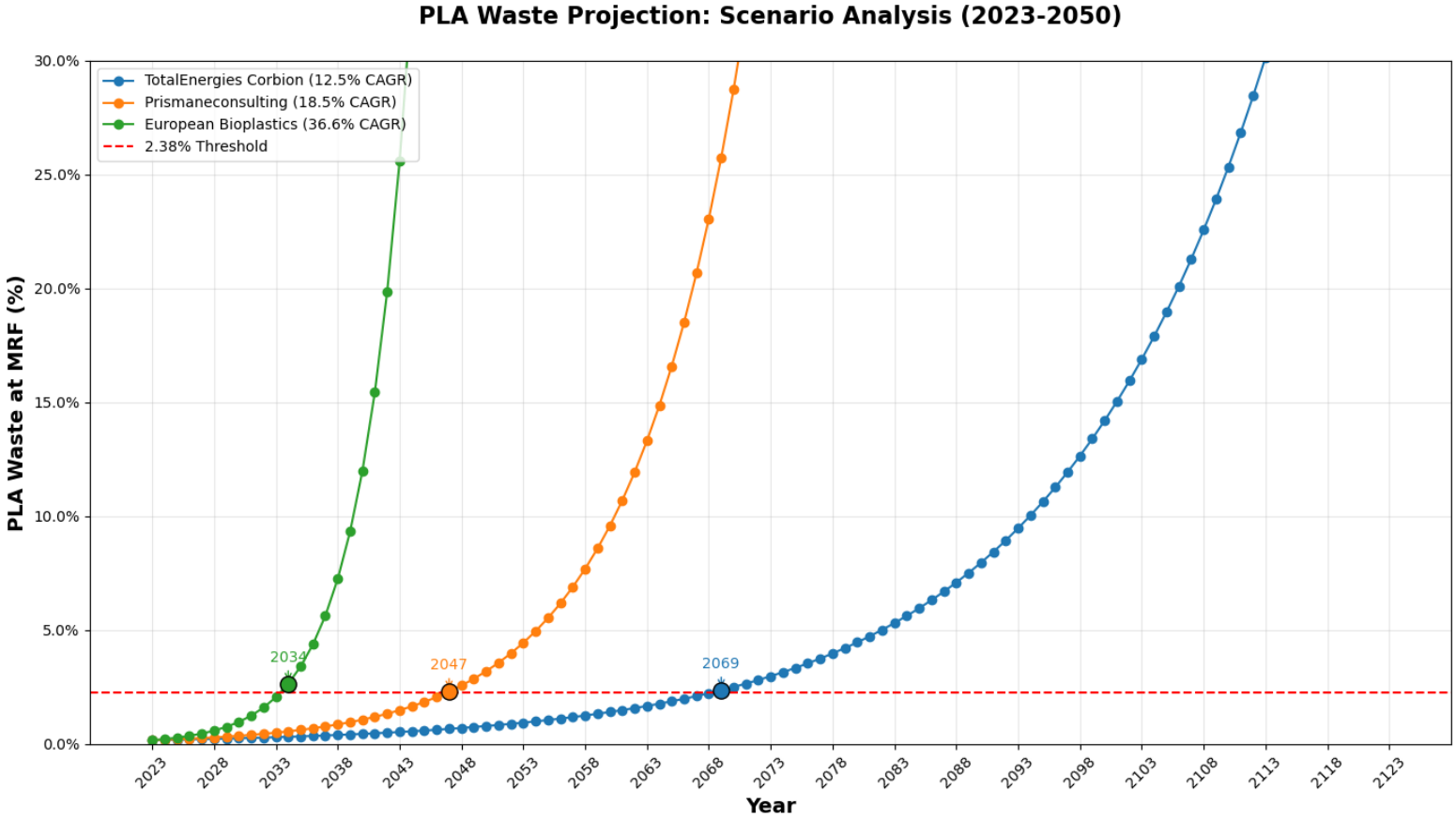

PLA presence in PET bottle bale
(d)
0.20%
0.16%
0.12%
0.08%
0.04%
0.00%
0.14%
0.02%
0.141%
0.19%
plus NIR PLA
Case 1
Case 2
Case 3

PROSPER


Break-even Input PLA
5.0%
4.5%
4.0%
3.5%
3.0%
2.5%
2.0%
1.5%
60%
65%
70%
75%
80%
85%
90%
95%
NIR PLA Sorting Efficiency
NIR Efficiency = 88%
Break-even = 2.4%


Distribution of PLA Recovery in MRFs
Frequency
0
100
200
300
400
500
600
0.70
0.72
0.74
0.76
0.78
0.80
0.82
0.84
PLA Recovery


(a)
Sensitivity analysis : 0.12% PLA share
-1,100 € -1,050 € -1,000 € -950 € -900 € -850 € -800 € -750 € -700 €
Price of equipment
Project management
Contingency cost
Price of electricity
Price of fuel
Labor cost
Repair and maintenance
Insurance cost
Market value of sorted PLA bale
Disposal fee
Net PLA sorting cost -906 €/tonne
Lower value (- 25%)
Upper value (+25%)
(b)
Sensitivity analysis : 0.41% PLA share
-610 € -580 € -550 € -520 € -490 € -460 € -430 € -400 € -370 €
Net PLA sorting cost -486 €/tonne
(c)
Sensitivity analysis : 1% PLA share
-250 € -230 € -210 € -190 € -170 € -150 € -130 € -110 € -90 €
Net PLA sorting cost -170 €/tonne
(d)
Sensitivity analysis : 3% PLA share
10 € 30 € 50 € 70 € 90 € 110 € 130 € 150 €
Net PLA sorting profit 83 €/tonne
(e)
Sensitivity analysis : 5% PLA share
70 € 90 € 110 € 130 € 150 € 170 € 190 € 210 € 230 €
Net PLA sorting profit 149 €/tonne
(f)
Sensitivity analysis : 10% PLA share
60 € 80 € 100 € 120 € 140 € 160 € 180 € 200 € 220 €
Net PLA sorting profit 142 €/tonne
(g)
Sensitivity analysis : 15% PLA share
100 € 120 € 140 € 160 € 180 € 200 € 220 € 240 € 260 €
Net PLA sorting profit 180 €/tonne
(h)
Sensitivity analysis : 20% PLA share
120 € 140 € 160 € 180 € 200 € 220 € 240 € 260 € 280 €
Net PLA sorting profit 198 €/tonne


PLA Waste Projection: Scenario Analysis (2023-2050)
TotalEnergies Corbion (12.5% CAGR)
Prismaneconsulting (18.5% CAGR)
European Bioplastics (36.6% CAGR)
2.38% Threshold
2034
2047
2069
PLA Waste at MRF (%)
Year
30.0%
25.0%
20.0%
15.0%
10.0%
5.0%
0.0%
2023
2028
2033
2038
2043
2048
2053
2058
2063
2068
2073
2078
2083
2088
2093
2098
2103
2108
2113
2118
2123

PROSPER