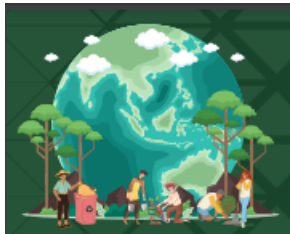
PÔLE DE COMPÉTITIVITÉ
CHIMIE, INDUSTRIES DE PROCÉDÉS
ET ENVIRONNEMENT



CLERMONT-FERRAND
5-6 DÉCEMBRE 2024

GREENDEAL,
CIRCULAR ECONOMY
AND INDUSTRIAL ECOLOGY SYMPOSIUM

Circular economy in tire and textile industries

Cluster for Chemical, Process industries & Environnement

4 pillars

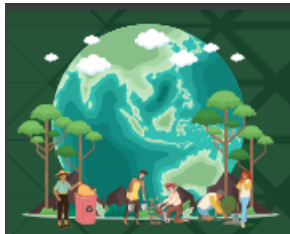
- Building Networks
- Promoting & Representing
- Accelerating Innovation
- Supporting Growth

Our 5 Strategic Axes

- Renewable raw materials
- Eco-efficient factorie
- Performance materials and products
- Recovery of wastes and by-products
- Preservation of resources water, air, soil

Digital
Eco-design
Circularity

PÔLE DE COMPÉTITIVITÉ
CHIMIE, INDUSTRIES DE PROCÉDÉS
ET ENVIRONNEMENT



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Circular economy in tire and textile industries

Context

Textile waste

- **Textile waste generation:** Over 15 kilograms of textile waste per person is generated annually in Europe, with discarded clothes and home textiles accounting for around 85% of total waste.
- **Environmental impact:** The primary destinations for textile waste are incineration and landfills, both inside and outside Europe, contributing to environmental harm.
- **Opportunities for transformation:** The textile waste issue presents an opportunity to create a sustainable new industry by turning waste into valuable resources.

Fiber-to-fiber recycling

- Turning textile waste into new fibers for use in clothes or other textile products.
- Existing technologies like mechanical recycling of cotton are well-established.
- Other technologies, like chemical recycling of polyester, have been subject to intense R&D and are on the brink of commercialization.
- **Potential for recycling 70% of textile waste** once fiber-to-fiber recycling is fully mature.

Source: Scaling textile recycling in Europe—turning waste into value – July 14, 2022 McKinsey & Company

Context

Barriers to scaling fiber-to-fiber recycling

- Collection, sorting, and preprocessing challenges limit recycling capacity.
- Collection rates currently range from 30-35%.
- High-quality sorting and preprocessing technologies are still under development.
- Fiber composition and purity requirements limit recyclability (e.g., elastane and metal parts like zippers in jeans).

Collaboration and innovation will be key

white cycle

Co-funded by the European Union
Project Number : 101036908

Source: Scaling textile recycling in Europe—turning waste into value – July 14, 2022 McKinsey & Company

axelera

Context

A well-organized field

EU Regulatory Framework :
Landfill Directive

95% Collected

40% Energy valorization

60% Material valorization

In Europe, more than half of these are exported to other countries.

Belgium	RECYTYRE
Czech Republic	eltma
Finland	SUOMEN RENGASKIERRÄTYS
France	ALIAPUR
Greece	eco elastika
Ireland	circol ELT
Italy	ecopneus
Netherlands	RecyBEM B.V. BAND & MILIEU
Norway	Norsk Dekkretur AS
Poland	CUO
Portugal	valorpneu
Romania	ECO ANVELOPE
Slovakia	eltma
Spain	SIGNUS
Sweden	Svensk Däckåtervinning
Turkey	LASDER

Source: https://www.etrma.org/key-topics/circular-economy/

Landfill Directive (EC Directive 1999/31)

Challenge of ELT valorisation in the next years ?

Regulation constraints for granulates use for artificial turf, sports & children playground - Microplastic ANNEX XVII

Exportation and Energy Valorisation constraints

Only a limited amount of secondary raw material that can be reused in the tyre industry.

Offering a **great potential for material recovery**, which is only partially exploited

BLACKCYCLE project aims to enable a massive circular economy of tyres

BLACKCYCLE
Move to the green revolution
This European project funded by Horizon 2020 (project number 869625)
axelera

A MAJOR EUROPEAN PROJECT FOR RECYCLING END-OF-LIFE TYRES INTO NEW TYRES

BLACK CYCLE

Move to the green revolution

POWERFUL Tool to move to the Tyre revolution!!!

Margarita Dorato

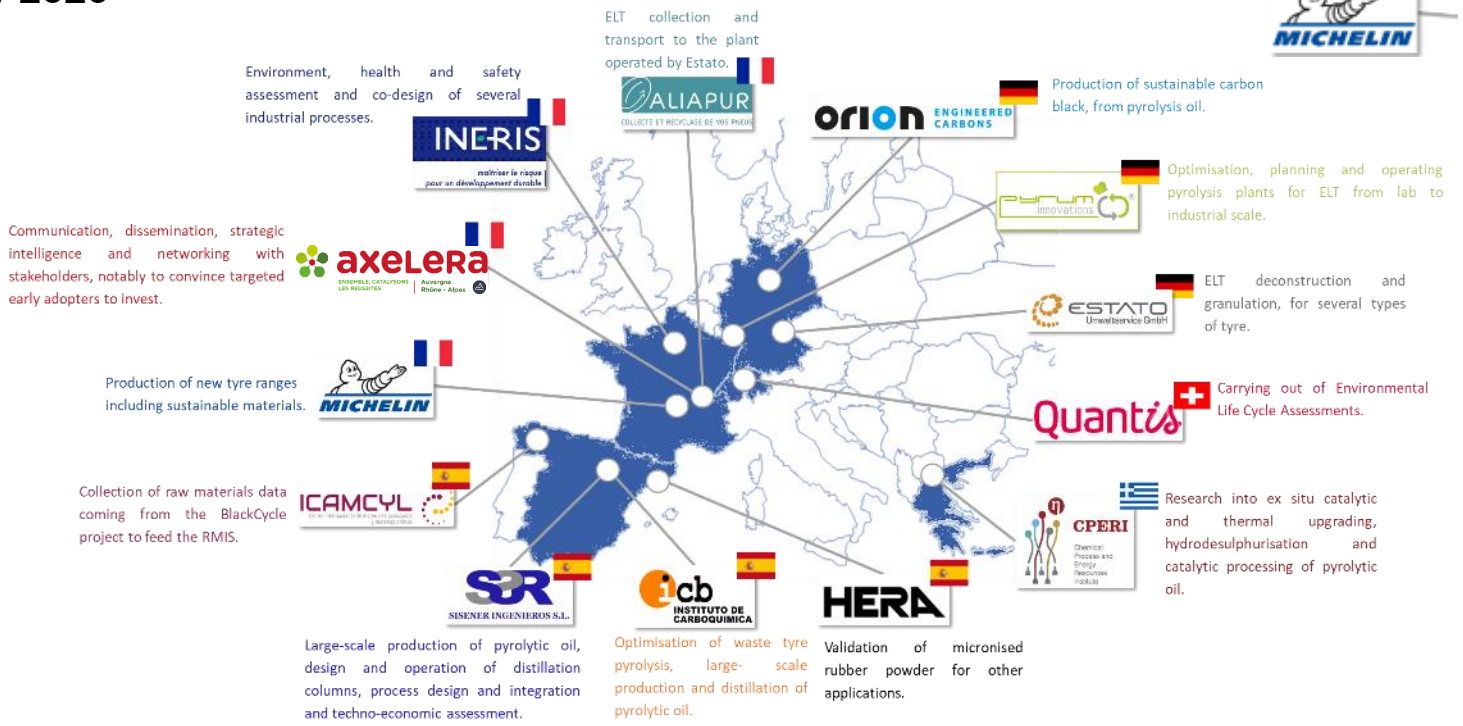
Technical Director Blackcycle

May 2020 June 2024

7 Industrial & Start up Partners, 5 Research Centers and an Innovation cluster gathered in a EU Consortium in 5 Countries

May 2020

June 2024



MICHELIN **BLACKCYCLE COORDINATOR**

- Waste Managers
- Technology Developers
- End Users and Validators
- Technology Providers and Manufacturers
- Environmental and HSE Experts
- Dissemination, Communication

TECHNOLOGICAL BARRIERS

NON-TECHNOLOGICAL BARRIERS

BLACK CYCLE is a project funded by the European Commission - Project Number : 869625

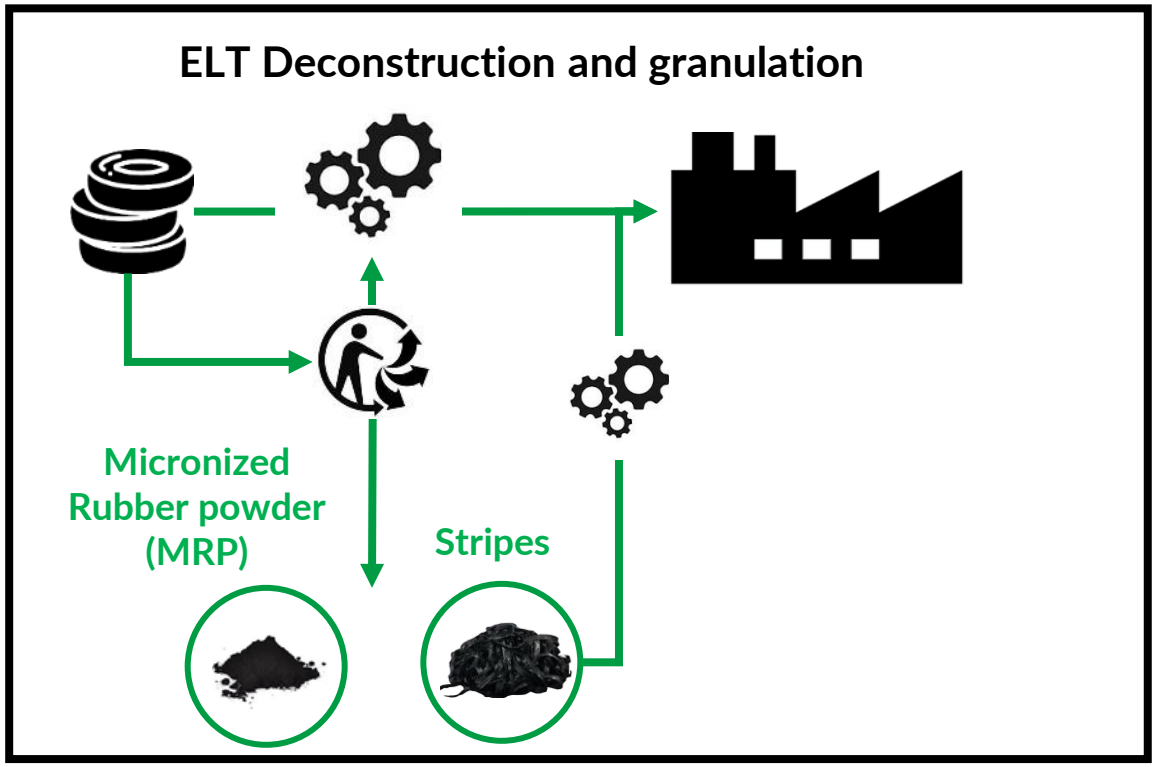
BLACKCYCLE aims at creating, developing and optimising a full Value Chain

TRL : 4 to 7

BLACK CYCLE is a project funded by the European Commission - Project Number : 869625

BLACKCYCLE aims at creating, developing and optimising a full Value Chain

ELT Deconstruction process to produce specified rubber granulates composition for MRP and pyrolysis application



BLACK CYCLE is a project funded by the European Commission - Project Number : 869625

2 new fully automatic tire deconstructions patented with a validated business model and environmental impact

9 PATENT PENDING PATENT PENDING

BLACK CYCLE
Move to the green revolution

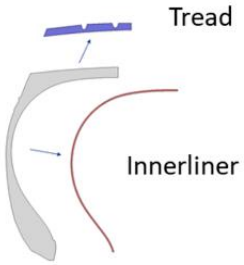
Validated at TRL6 by treatment of 80 tn of ELT

ORC

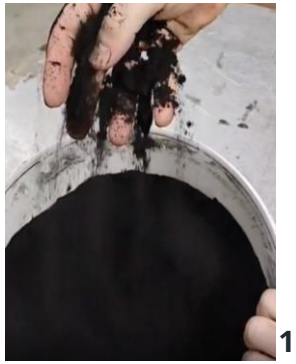
IRG

Delivering 2 pure feedstocks

PC and TT
Tread stripes



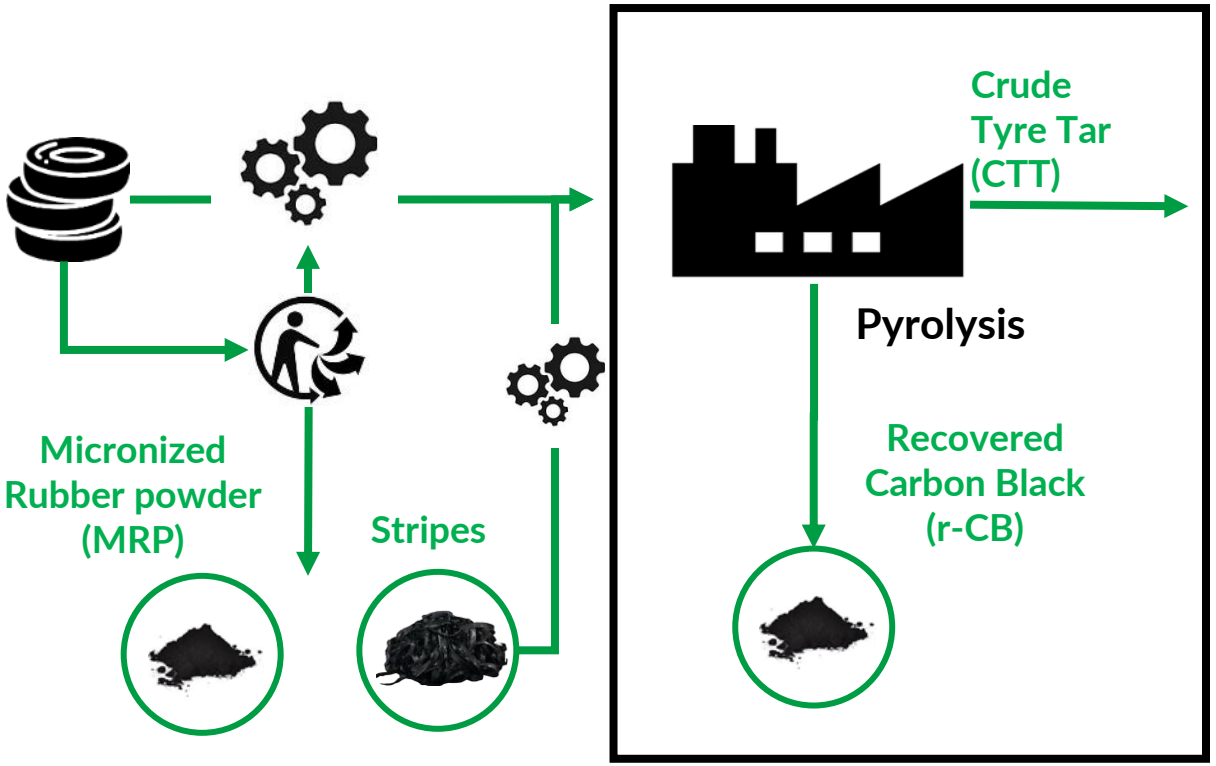
I-MRP
Micronized Rubber Powder



BLACK CYCLE is a project funded by the European Commission - Project Number : 869625

BLACKCYCLE aims at creating, developing and optimising a full Value Chain

Optimized pyrolysis process to produce high quality r-CB and optimized pyrolysis oil



BLACK CYCLE is a project funded by the European Commission - Project Number : 869625

To develop 2 pyrolysis technologies to produce pyrolytic oil and r-CB

Depending on the quality of the of ELTs granulates and the operating conditions of pyrolysis

Auger Reactor

TRL5
Hundreds kg samples

TRL7 - dozens tons samples

Moving Bed Reactor

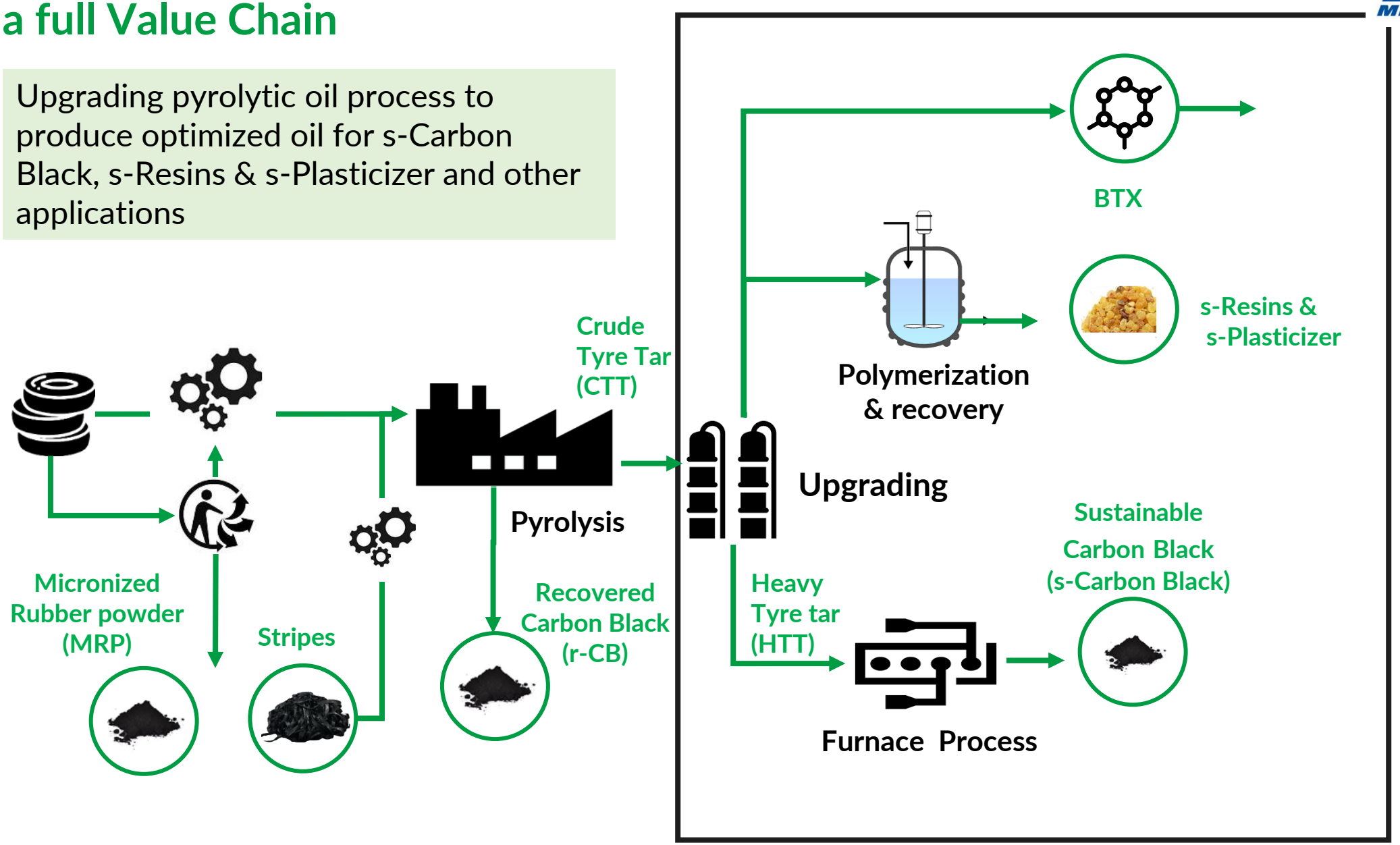
TRL4
kg samples

TRL7 - dozens tons samples

BLACK CYCLE is a project funded by the European Commission - Project Number : 869625

BLACKCYCLE aims at creating, developing and optimising a full Value Chain

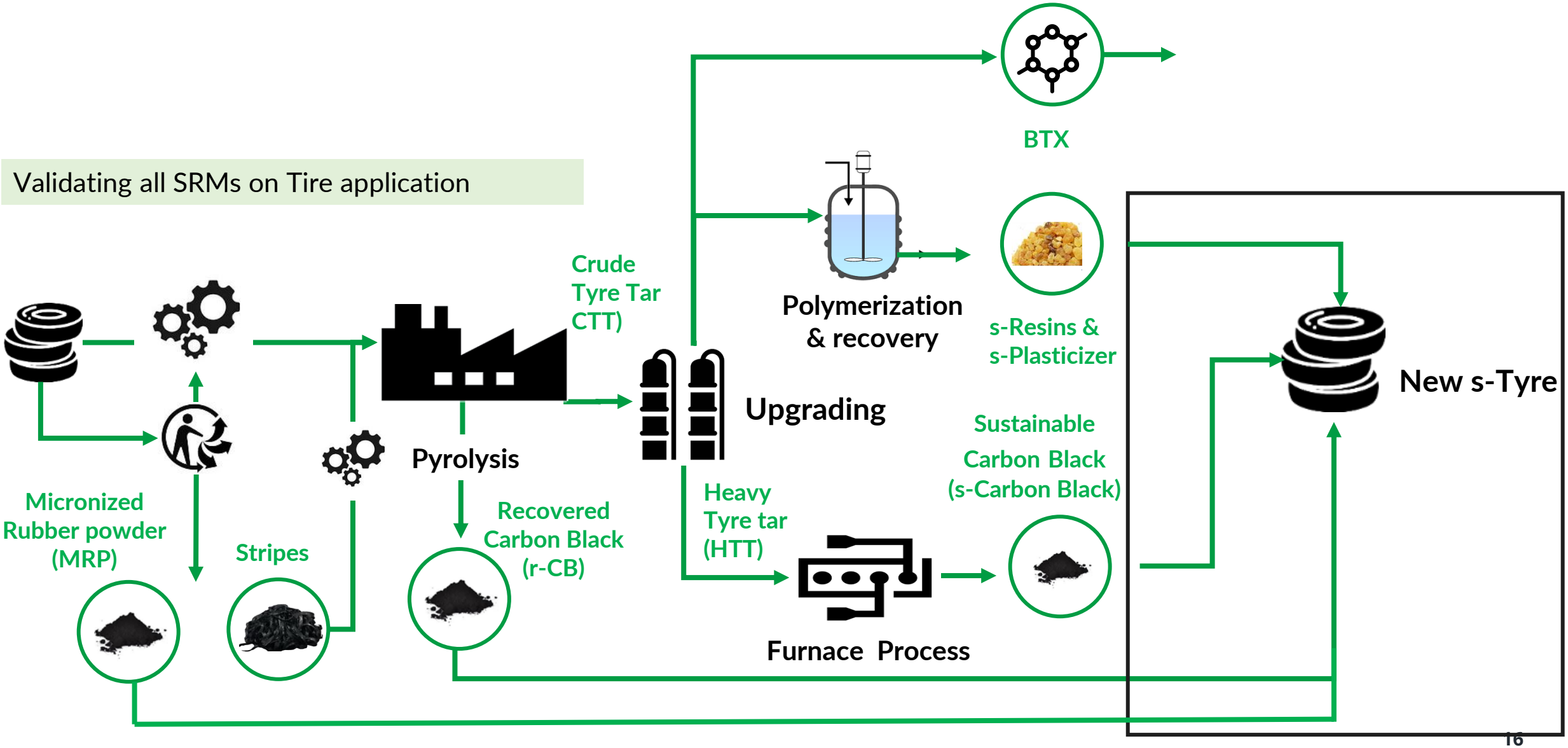
Upgrading pyrolytic oil process to produce optimized oil for s-Carbon Black, s-Resins & s-Plasticizer and other applications



BLACK CYCLE is a project funded by the European Commission - Project Number : 869625

BLACKCYCLE aims at creating, developing and optimising a full Value Chain

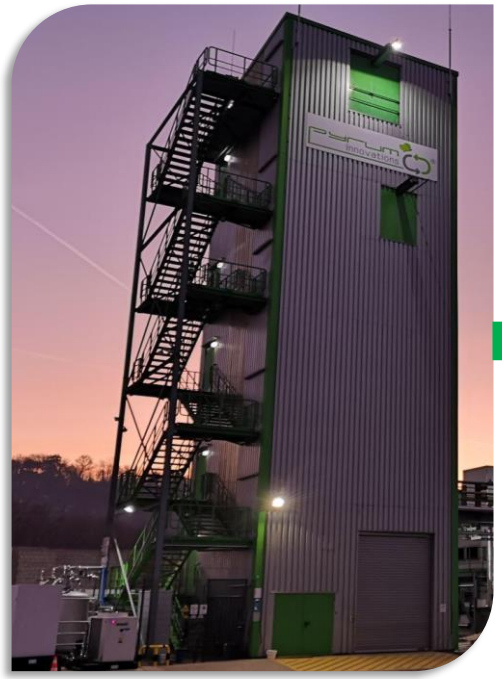
Validating all SRMs on Tire application



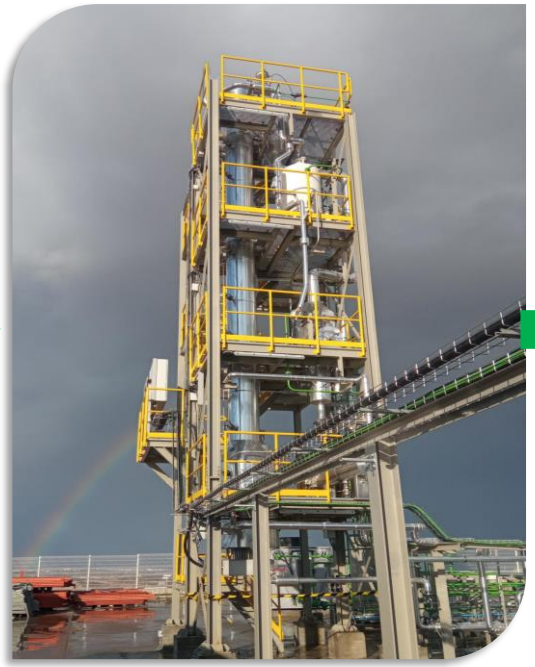
BLACK CYCLE is a project funded by the European Commission - Project Number : 869625

Blackcycle project validated 3 Grades of s-CB made on a TRL 7 equipment

Value chain scale-up validation at TRL7
Collaborative success

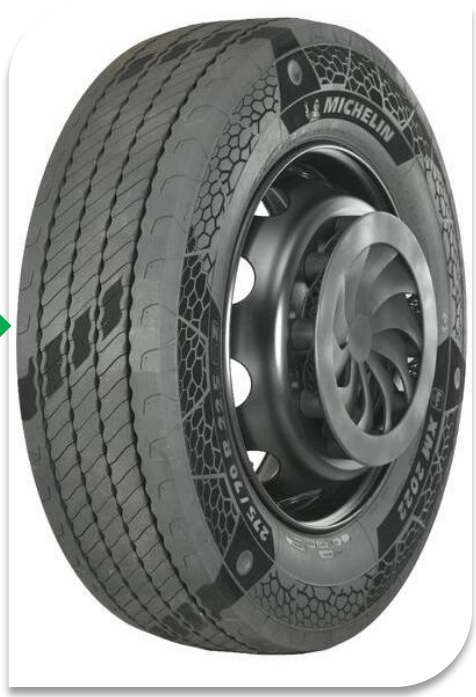


Pyrolyse



Distillation

Furnace



Tyre

BLACK CYCLE is a project funded by the European Commission - Project Number : 869625

The Blackcycle Secondary Materials could be used to reach more than 20% of recycled rate content in tyres while keeping the same performances

s-CB could be used at **100% in replacement of corresponding ASTM** grades even for the most technical CB.

r-CB could replace parcialy some ASTM grades in rubber mixes
Truck Tread feedstock has a positive impact

Innerliner MRP can be used in virgin innerliner rubber composition in **significant quantity**

s-Resin has be proven to act as a real resin in a rubber tread

BLACK CYCLE is a project funded by the European Commission - Project Number : 869625

BLACKCYCLE is internationally recognized and has won 3 awards

Recircle Award November 2023

Tire Tech Award March 2024

The French Association Competitiveness Clusters Award September 2024

"Best Recycling Research Project"

*This award recognizes the excellence of the work done within the **project Blackcycle** and its results that will greatly contribute to the circular economy.*

"Environmental Achievement of the Year"

Industry Contribution category' award, at this year's Tire Technology Awards for Innovation and Excellence.

"Impact"

"The project has delivered considerable impacts for the cluster members involved in their tyre recycling project"

BLACK CYCLE is a project funded by the European Commission - Project Number : 869625

BLACK CYCLE

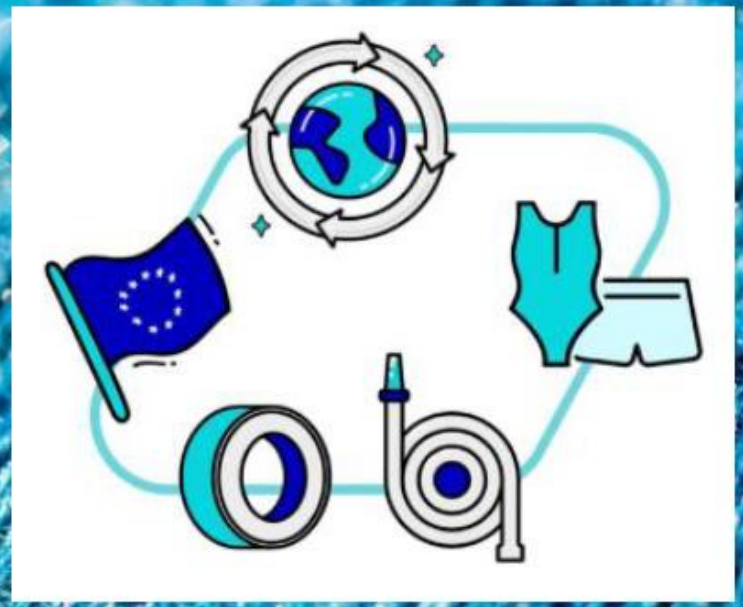
Move to the green revolution

THANK YOU

Q&A

Together To Make The Circular Economy A Reality

Co-funded by
the European Union



white cycle

Circular economy of PET from Complex Wastes (Tires, Clothes, Hoses) to TRL 6-8

Call: HORIZON-CL6-2021-CIRCBIO-01
Duration: 48 months
Estimated project cost: 9,541,261.25€
Requested EU contributions: 7,080,251.50€

Coordinator : MICHELIN / Olivier Cardon
olivier.cardon@michelin.com

Project website : https://www.whitecycle-project.eu
Project LinkedIn : https://www.linkedin.com/company/whitecycle/

Co-funded by the European Union

Key figures in Europe

1850 kt multilayer clothing

200 kt End of Life Tyres

10 kt End of Life Hoses

Feedstock for **2 Mt of r-PET / year**

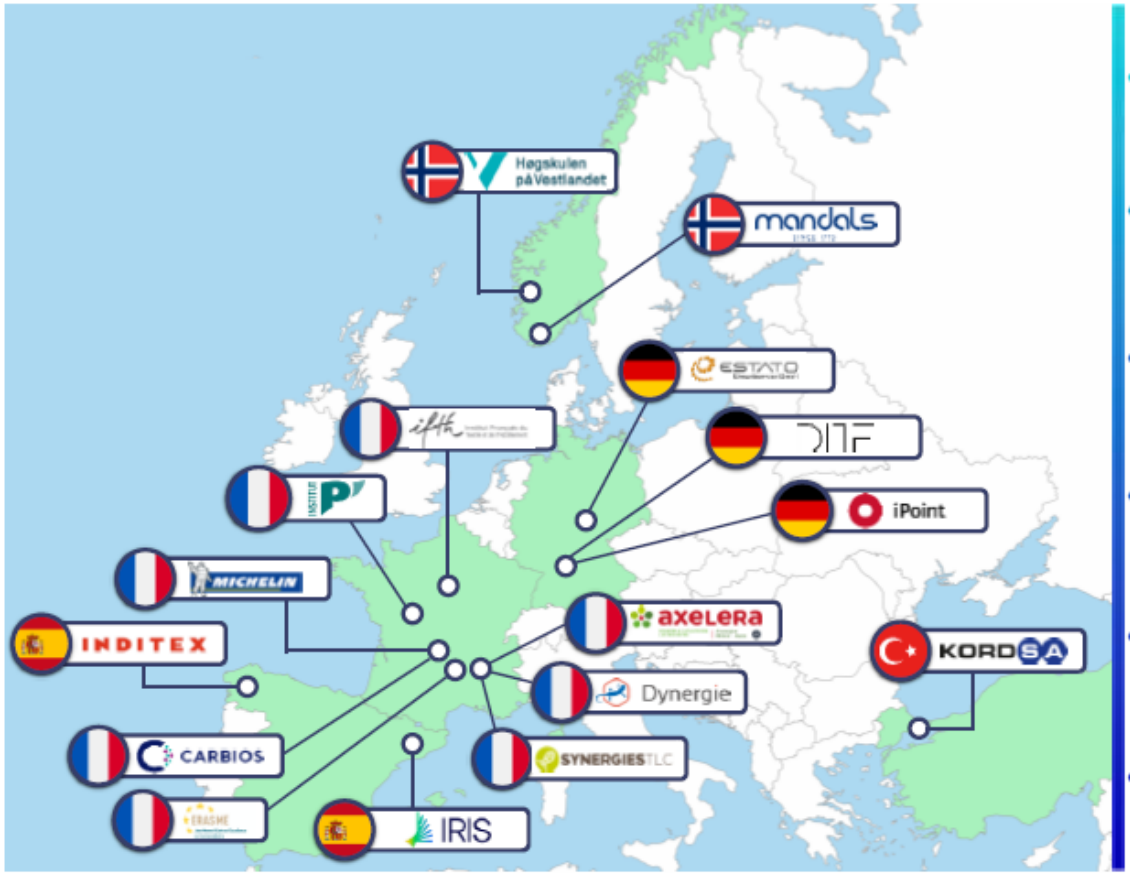
Co-funded by the European Union

A TEAM of Industrial Partners, Research Centers and an Innovation Cluster from 5 countries, united to develop PET recycling from complex waste

white cycle

2023 2024 2025 2026

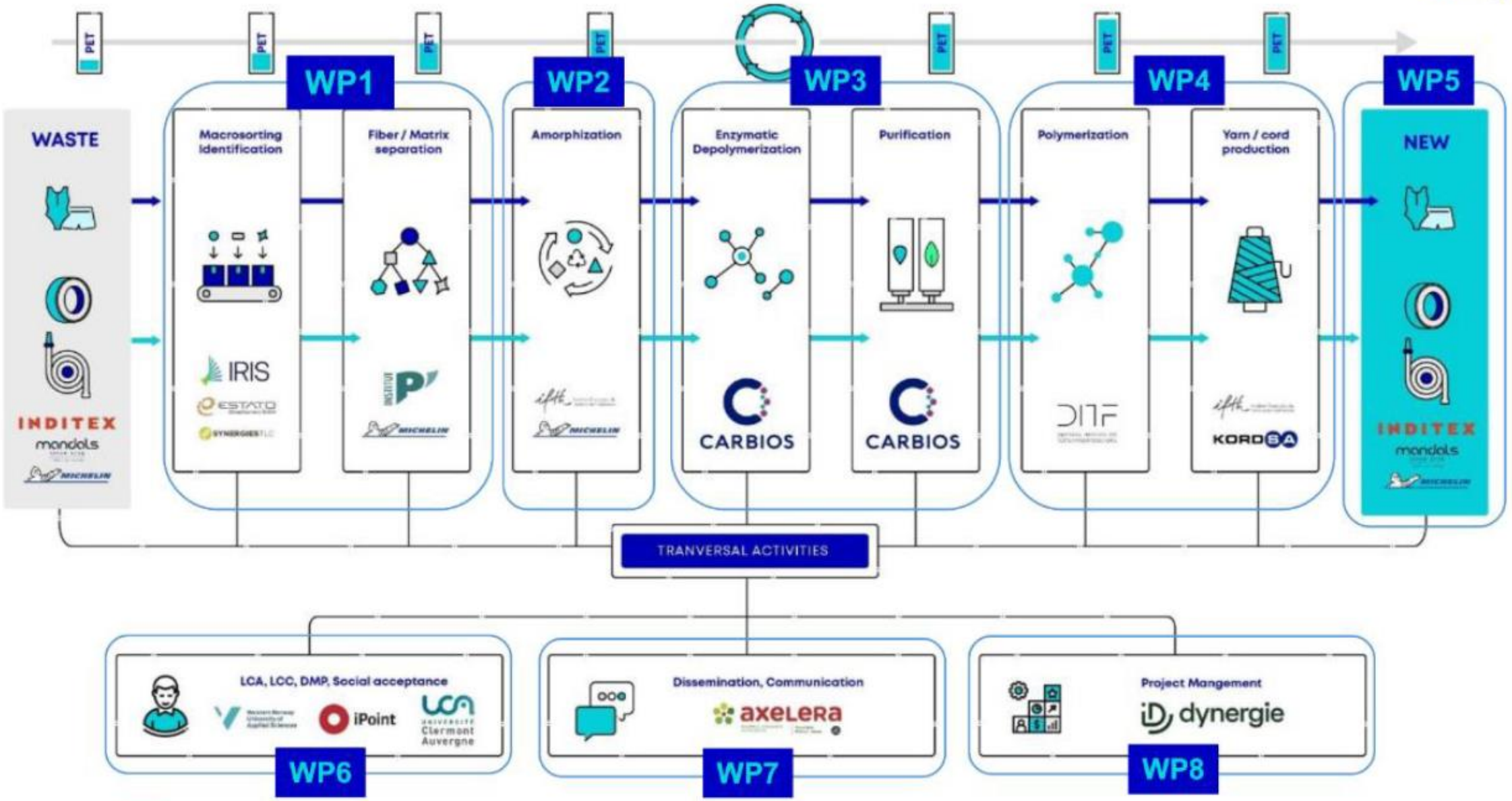
July 2022 — June 2026



- Waste Managers
- Technology Developers and providers
- Manufacturers
- End Users and Validators
- LCC, LCA, Social and HSE Experts
- Dissemination, Communication

Funded by the European Union

A united multiskilled consortium to cover the overall value chain



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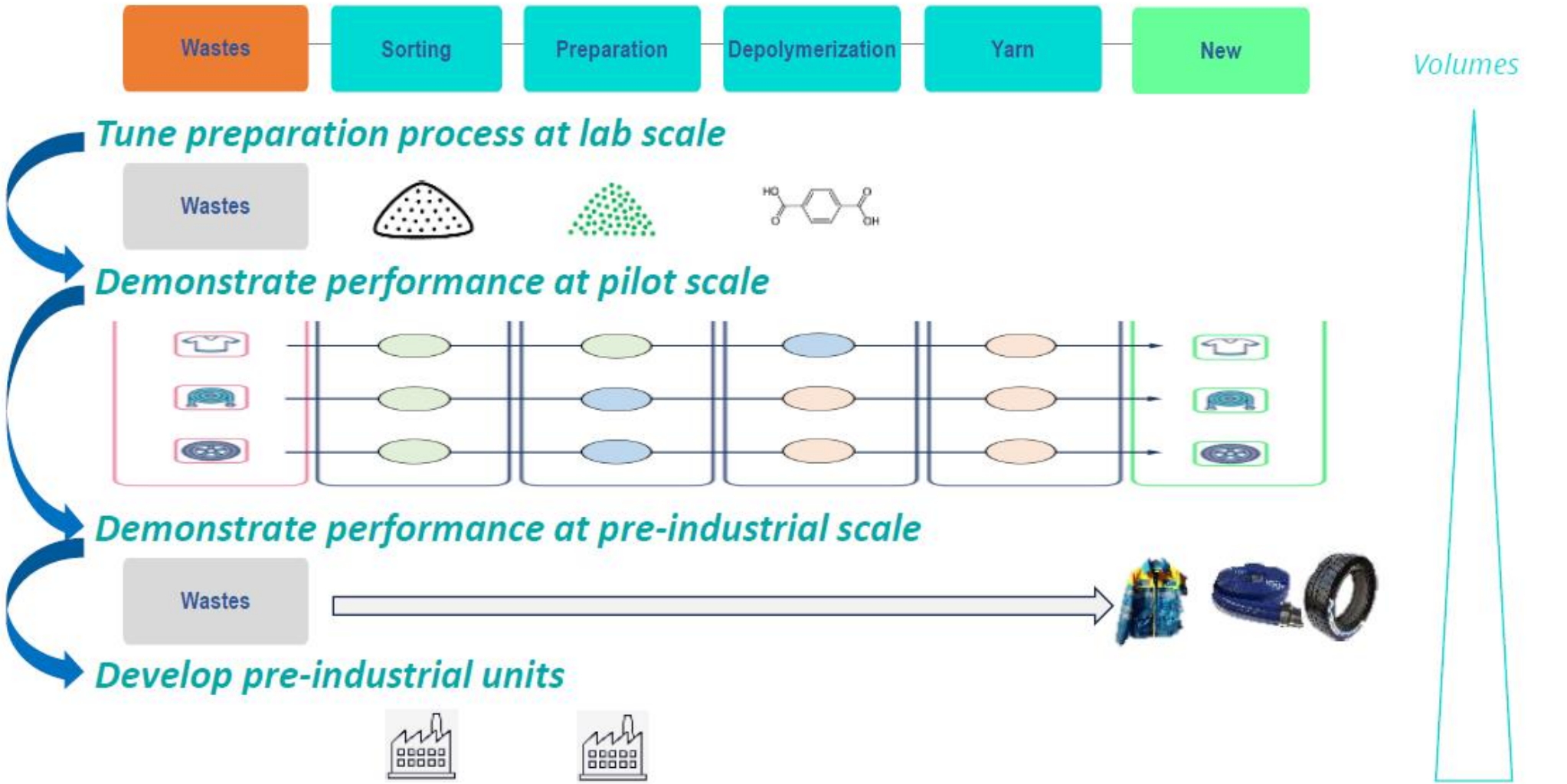
N° Grant Agreement : 101059639

A complete development program
from lab scale to pre-industrial units



Co-funded by the European Union

N° Grant Agreement : 101059639

Preparation of complex feedstocks : a technological challenge

Complex feedstocks contain not only PET, but various compounds that can perturbate fabrication processes

Technical / multilayer garments :

- Reflective tapes
- Coatings
- Puff
- Dye
- Hard points : knobs, zips
- Etc.

Technical articles (flexible hoses and tyres):

- Rubber
- Thermoplastics
- Other fibers
- Fillers
- Etc.

Preparation steps are needed to :

- ***Sort feedstocks with a content of 80% PET or more***
- ***Prepare the material to enable full depolymerization***

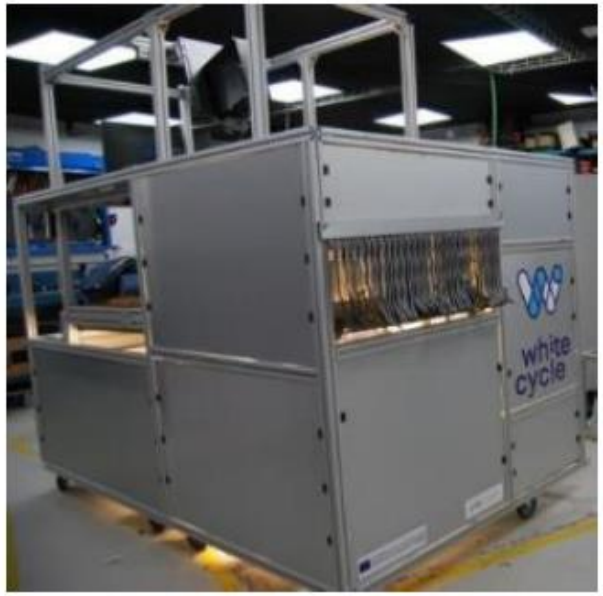
Co-funded by the European Union

N° Grant Agreement : 101059639

Sorting of material

select high PET content articles in complex garment feedstocks

=> Upgraded optical sorting technology by IRIS



Whitcycle developed an innovative sorting prototype (TRL5) based on IRIS identification technology

Operator gets information on all layers composition for each part of the garment (visualization at pixel size)

Operator isolates garments with 80% or more PET

Co-funded by the European Union

N° Grant Agreement : 101059639

Sorting of material

Isolate PET fiber from milled tyres and flexible hoses

Innovative electrostatic sorting developed by

Whitecycle prototype based on P' patented technology

PET fibers are collected on electrodes

Tyre material aspect before and after electrostatic sorting

Co-funded by the European Union

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Sorting of material

highly promising technologies to isolate high PET content materials

Multi-layer garments

IRIS Sorting

Tyre material

PPRIME purification

Hoses material

PPRIME Purification

Co-funded by the European Union

N° Grant Agreement : 101059639

Pretreatment of the material

1. Dismantling and milling process for complex / multi-layer garments

Dismantling — Milling — Amorphization

Dismantling

SYNERGIESTLC

Milling

ifth Institut Français du Textile de Habillement

→ Withdrawal of
. Hard points,
. Objects in pockets
. Etc.

Co-funded by the European Union

N° Grant Agreement : 101059639

Pretreatment of the material

2. Amorphization process

Dismantling — Milling — Amorphization

Amorphization

ifth Institut Français du Textile et de l'Habillement

Requirements for CARBIOS

Low cristallinity

High specific surface

IFTH prototype extruder enables optimization of

→ Compaction
→ Thermal treatment
→ Material shape

Co-funded by the European Union

N° Grant Agreement : 101059639

Material pre-treatment

=> Amorphization technology developed for the 3 feedstocks

Multi-layer garments	Tyre fiber	Flexible hoses fiber
		
		

Co-funded by the European Union

N° Grant Agreement : 101059639

Analysis and dissemination

Integration into the European scientific and business ecosystems

Data management

Lifecycle assessment

Lifecycle costs

Social impact

Social acceptance

Dynamic modeling

Strategic intelligence

Dissemination seminars

Discussion with early adopters

Dissemination toolkit

Training development

Co-funded by the European Union

N° Grant Agreement : 101059639

Thanks!

Follow #WhiteCycle

From Life Cycle Sustainability Assessment to Cross matrix impact,the project Whitecycle

Tipawan DURAND, Arnaud DIEMER
University of Clermont Auvergne, CERDI (CNRS-IRD)

Objective:

To define a step-wise method for selecting key indicators considering economic, environmental and social impact, using SWOT and cross-impact matrix analysis within innovative processes.

SWOT + CIM METHOD

SWOT

Strengths, Weaknesses, Opportunities, Threats

Widely used by organizations to analyze internal and external environments, particularly during periods of strategic decision-making (Rozmi et al., 2018; Wu, 2020)

Main Strengths	Main Weaknesses

Main Opportunities	Main Threats

SWOT + CIM METHOD

CIM

The Cross-Impact Matrix

A tool used to forecast the potential consequences of a decision or event. It is based on the idea that one event can cause a chain reaction of other events.

With the event i,
S = The expected impact
E = Event or indicator or variable
a = Impact of event
b = Conditional probability
P = An initial probability vector

$$\begin{array}{c} \\ E_1 \\ E_2 \\ E_3 \end{array} \begin{array}{c} \begin{array}{ccc} E_1 & E_2 & E_3 \end{array} \\ \begin{bmatrix} a_{11} & a_{12}b_{12} & a_{13}b_{13} \\ a_{21}b_{21} & a_{22} & a_{23}b_{23} \\ a_{31}b_{31} & a_{32}b_{32} & a_{33} \end{bmatrix} \end{array} \begin{bmatrix} P(E_1) \\ P(E_2) \\ P(E_3) \end{bmatrix}$$

$$= \begin{bmatrix} a_{11}P(E_1) + (a_{12}b_{12})P(E_2) + (a_{13}b_{13})P(E_3) \\ (a_{21}b_{21})P(E_1) + a_{22}P(E_2) + (a_{23}b_{23})P(E_3) \\ (a_{31}b_{31})P(E_1) + (a_{32}b_{32})P(E_2) + a_{33}P(E_3) \end{bmatrix} = S$$

Type 1. Qualitative Description of the trend-scenario.

(Ratcliffe, 2001).

Type 2. Trend Value Assessment.

(e.g. Gordon et al., 1968; Weerakkoday et al., 2003).

Type 3. The Conditional Probability.

(e.g.,Dalkey, 1972; Enzer, 1972; Gordon, 1994)

Type 4. The Conditional Probability method combines both the level of impacts and their probability of occurrence.

(KENNETH C. , 2008)

By considering conditional probability of occurrence, given the impact to preceding events and making a matrix procedure, the method provides a more comprehensive understanding of future development.

The ref. paper presents the procedure by the study of indicators impact to the family welfare.

Research design

This research will utilize a multi-step approach to explore the potential impact to a WHITECYCLE project.

- Economic impact
- Environmental impact
- Social impact

The research design proceeds in three steps:

(1) Indicator Identification

(2) SWOT Matrix Development

(3) Cross-Impact Matrix Analysis

Step 1: Indicator Identification

Analyze relevant frameworks concerned with Circular Economy principles to identify key indicators impacting the economy & financials, environment, and society for the whitecycle projects. These frameworks include:

- Company level reporting (i.e., EPD, 3P)
- Cost-Benefit Analysis (CBA)
- Sustainable Development Goals (SDGs)
- Life Cycle Sustainability Assessment (LCSA)

LCSA = ELCA + LCC + SLCA (Kloepffer., 2008)

ELCA = Environmental Life Cycle Assessment

LCC = Life Cycle Costing

SLCA = Social Life Cycle Assessment

Relevant frameworks

Example of List of ELCA., (OECD, 2020)

Subcatagory	Sector	Indicator	Unit	Year	Name of the study
Efficiency	Energy	Energy efficiency	NA	2017	Towards a Model of Circular Economy for Italy - Overview and Strategic Framework
Emissions	Air	CO2 avoided as a consequence of recovery and reuse of materials	NA	2017	1st Roadmap Paris Circular Economy Plan
Emissions	Air	CO2 emissions reduction	ktons	2016	Circular Amsterdam – A Vision and Action Agenda for the City and Metropolitan Area
Emissions	Air	GHG Emissions	t CO2/year	2019	The Green and Circular Economy of Barcelona City Council
Emissions	Air	Greenhouse gas reduction	%	2019	National Strategy for the Circular Economy
Emissions	Air	Total Greenhouse Gas Emissions	sand tonnes	2019	Agenda for the Development of the Circular Economy in Navarra 2019-2030
Output material process	Waste	Tons of waste avoided	Tonnes	2017	Paris Circular Economy Plan: 2017-2020
Output material process	Waste	Solid waste generated	Tonnes	2018	Circular Bilbao and Bizkaia
Output material process	Waste	Recycling rate	%	2019	National Strategy for the Circular Economy

Relevant frameworks

Example of LCC.,
(WHITECYCLE project, 2023)

The **LCC of WHITECYCLE products** will study three input cost categories and three output categories:

1. Input: Material costs (e.g., feedstock input)
2. Input: Labour cost (e.g., personal operating the sorting machines)
3. Input: Energy cost (e.g., contracts setting a price for a kWh)
4. Output: Waste handling (e.g., hazardous and non-hazardous waste)
5. Output: CO_2 expenses (e.g., carbon tax/price)
6. Output: PET value

Relevant frameworks

Example of List of SLCA.,
(JRC (2015, p. 44))

STAKEHOLDER	SUBCATEGORY	INDICATOR	Unit of measurement
WORKERS	CHILD LABOUR	Children in employment, male (% of male children ages 7-14)	%
		Children in employment, female (% of female children ages 7-14)	%
		Children in employment, total (% of all children agess 7-14)	%
	FORCED LABOUR	Evidence of forced labour	Text
		Frequency of forced labour	%
	FAIR SALARY	Living wage, per month	local currency
		Minimum wage, per month	local currency
		Sector average wage, per month	local currency
	WORKING TIME	Hours of work per employee, per day	h
		Hours of work per employee, per week	h
		Standard weekly hours	h
		Standard daily hours	h
	DISCRIMINATION	Occurrence of discrimination	Text
		Women in the labour force (% of economically active female population)	%
		Men in the labour force (% of economically active male population)	%
		Ratio of salary of women wages to men	%
	HEALTH AND SAFETY	Accident rate at workplace	#/100,000 workers
		Fatal accidents at workplace	#/100,000 workers
		Occupational risks	Text
		DALY due to indoor and outdoor air and water pollution	DALY/1,000 persons
		Presence of sufficient safety measures	# of security incidents
	SOCIAL BENEFITS, LEGAL ISSUES	Social security expenditures out of the total GDP	%
		Evidence of violations of laws and employment regulations	#/yr h
		% of workers with a contract	%
	FREEDOM OF ASSOCIATION, COLLECTIVE BARGAINING, RIGHT TO STRIKE	Trade union density (% of employees organised in trade unions)	%
		Right of association	index value
		Rigth of collective bargaining	index value
		Right to strike	index value
		Existence of standard rates	Y/N
LOCAL COMMUNITY	ACCESS TO MATERIAL RESOURCES	Level of industrial water use (% of total withdrawal)	%
		Level of industrial water use (% of total actual renewable)	%
		Extraction of material resources (fossil fuels, biomass, ores, minerals)	t/capita
		Presence of certified environmental management systems	#
		Description of (potential) material resource conflicts	Text
	RESPECT OF INDIGENOUS RIGHTS	Presence of indigenous population	Y/N
		Human rights issues faced by indigenous people	Text
		Respect of indigenous rights	Text
	SAFE AND HEALTHY LIVING CONDITIONS	Pollution level of the country	Index value
		Contribution of the sector to environmental load	Text
		Drinking water coverage (% of the population)	%
		Sanitation coverage (% of the population)	%
	LOCAL EMPLOYMENT	Unemployment rate in the country	%
		Work force hired locally	%
		Percentage of spending on locally based suppliers	%
	MIGRATION	Migrant workers in the sector	%
SOCIETY	CONTRIBUTION TO ECONOMIC DEVELOPMENT	Economic situation of the country	index value
		Contribution of the sector to economic development (in % of total GDP)	%
		Public expenditure on education (% of GDP)	%
	EDUCATION	Illiteracy rate, male (% of male population)	%
		Illiteracy rate, female (% of female population)	%
		Illiteracy rate, total (% of total population)	%
	HEALTH AND SAFETY	Health expenditure out of the total GDP of the country	%
		People affected by natural disasters (as % of population)	%
		Life expectancy at birth	Years
	PREVENTION AND MITIGATION OF CONFLICTS	Risk of conflicts with regard to the sector	Text
VALUE CHAIN ACTORS	FAIR COMPETITION	Presence of anti-competitive behaviour or violation of anti-trust and monopoly legislation	Text
		Presence of policies to prevent anti-competitive behaviour	Y/N
	CORRUPTION	Corruption index of country	index value
		Evidence of an active involvement of the enterprises in corruption and bribery	%
	PROMOTING SOCIAL RESPONSIBILITY	Presence of codes of conduct that protect human rights of workers among suppliers	index value
		Membership in an initiative that promotes social responsibility along the supply chain (number of enterprises)	#
	SUPPLIER RELATIONSHIPS	Interaction of the companies with suppliers (payment on time, sufficient lead time, reasonable volume fluctuations, appropriate communication…)	Text
CONSUMERS	HEALTH AND SAFETY	Presence of management measures to assess consumer health and safety	Y/N
	TRANSPARENCY	Presence of certifications or labels for the product/sites sector	Y/N
	END OF LIFE RESPONSIBILITY	Strength of national legislation covering product disposal and recycling	Text

Step 1: Indicator Identification

Appendices

TableA1 (Appendix A): Economy-related indicators

Framework	Specific Indicator	Unit	Year	Reference of the study
Circular Economy	-Raw material consumption indicator (RMC)	-Tonnes per capita	2024	Eurostat
	-Resource productivity	-Currency/physical unit, euro/Kilogram		
	-Generation of waste excluding major mineral wastes per GDP unit	-Kg per thousand euro		
	-Waste generation per capita	-Kilogram per capita.		
	-Trade in recyclable raw materials	-Trade value in thousand euro.		
	-Gross value added related to circular economy sectors	-Million euro		

Table A2 (Appendix B): Environment-related indicators

Framework	Specific Indicator	Unit	Year	Reference of the study
Circular Economy	-Percentage increase in materials recovery (t) and organic recovery (t)	-Tonnes	2017	Paris Circular Economy Plan: 2017-2020
	-Tons of waste avoided			
	-Tonnage of waste diverted via repair, reuse, recovery and upcycling activities (recycling centers, artisans, second-hand goods stores, fab labs, etc.)	-Tonnes		
	-Tons of waste avoided through the donation and reselling scheme to the city	-Tonnes		
		-Tonnes		

Table A3 (Appendix C): Social-related indicators

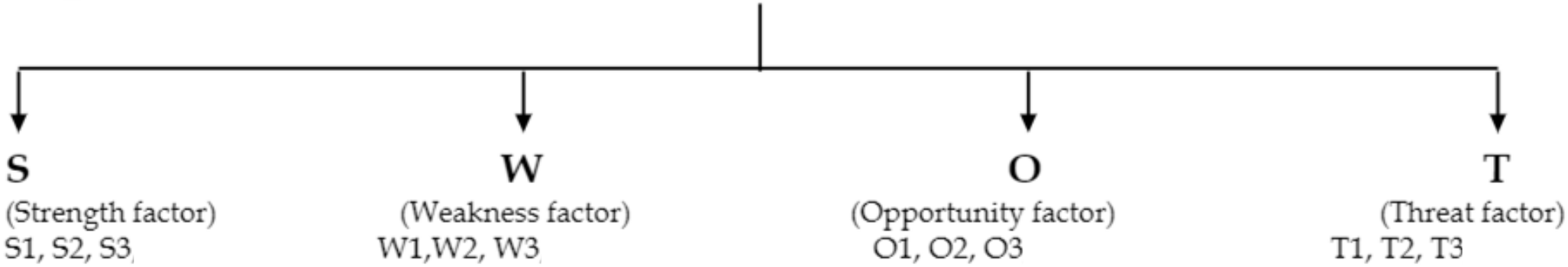
Framework	Specific Indicator	Unit	Year	Reference of the study
SDG	-Average hourly earnings of female and male employees, by occupation, age and persons with disabilities	-Euro		Target 8.5.1
	-Increase of labor share of GDP due to the project	-Number		Target 10.4.1
	-Level of safe working conditions	-Level		Target 8.8.2
	-R&D personnel by sector	-%		Target9

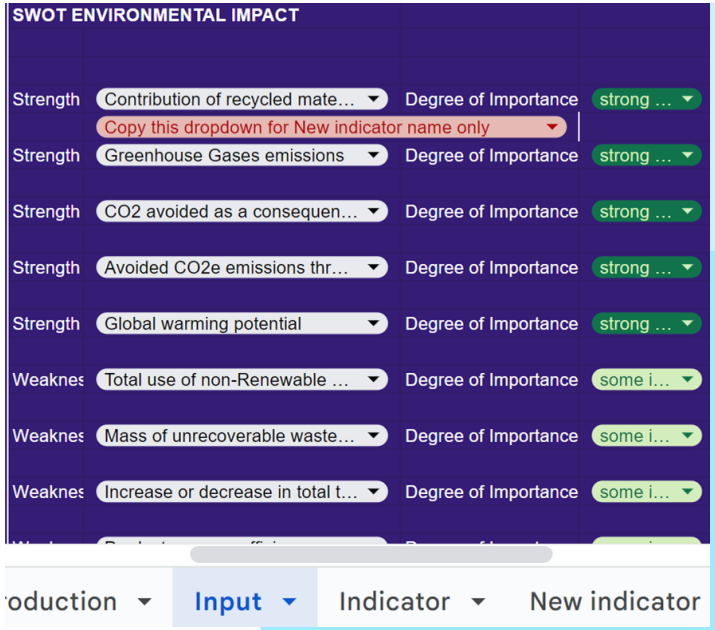
Total indicators: 182

- Environmental indicator: 87
- Economic indicator: 55
- Social indicator: 40

Vote SWOT indicator of 3 domains

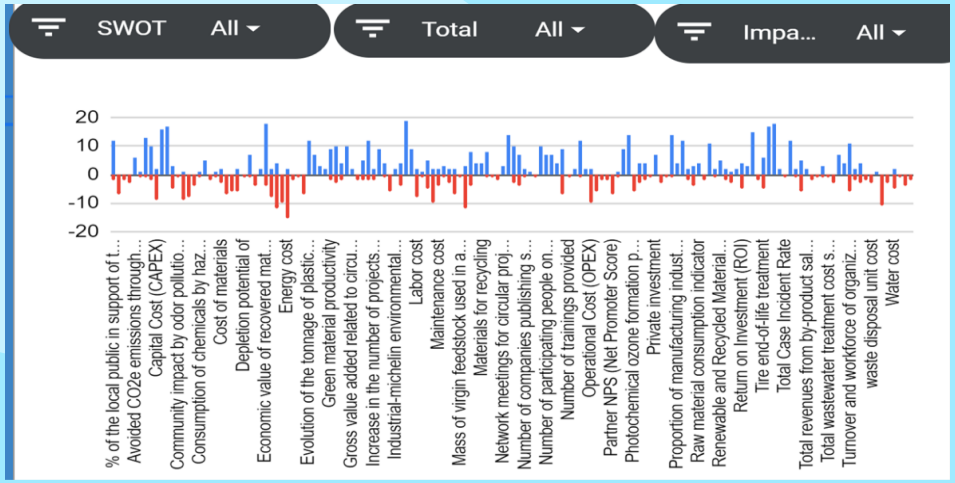
Step 2





Example of SWOT questionnaire and sheets

SWOT Dashboard



SWOT Social-related Summary

Main Strengths	Main Weaknesses
Number of new jobs	**Employee Engagement rate**
Increase number of partnerships with municipalities/distribution	Diversities and Inclusion Management Index
Number of connection between companies	Number of technologies transferred

Main Opportunities	Main Threats
Worker skill development	Local community acceptance, such as complaints from society
Numbers of articles published creating positive publicity	Cost of training and education programmes per employee
Improvement in well-being of worker	Turnover and workforce of organizations working in the circular economy

SWOT Economy-related Summary

Main Strengths	Main Weaknesses
New revenue models related to the circular economy	**Operational Cost (OPEX)**
Avoided cost for the waste disposal	Capital Cost (CAPEX)
Investment in research for increasing circular knowledg and expertise	Investment to maintain product quality

Main Opportunities	Main Threats
Material import dependency	Energy cost
Total cost savings due to avoided GHG emissions	Material cost
Gross value added in environmental goods and services sectory	Labor cost

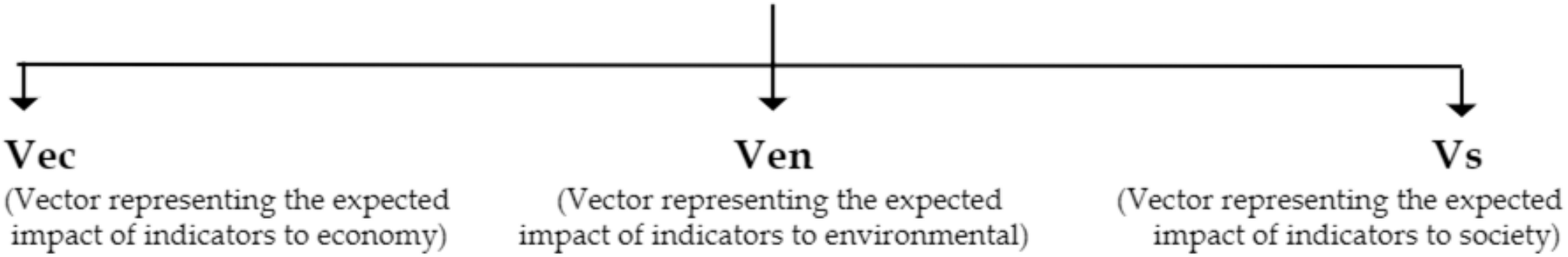
SWOT Environment-related Summary

Main Strengths	Main Weaknesses
Tons of waste avoided	**Energy (and Exergy) Consumption**
CO2 emission avoided as a consequence of recovery and reuse of materials	Mass of unrecoverable waste generated when producing recycled feedstock for a product
Circular material use rate	Increase in total thermal energy consumption

Main Opportunities	Main Threats
Tonnage of waste diverted via reuse and upcycling activities	Acidification potential
Evolution of the tonnage of plastics collected in the city	Product (with recycled material) end-of-life treatment
Recycling rate of municipal waste	Eutrophication potential(freshwater aquatic)

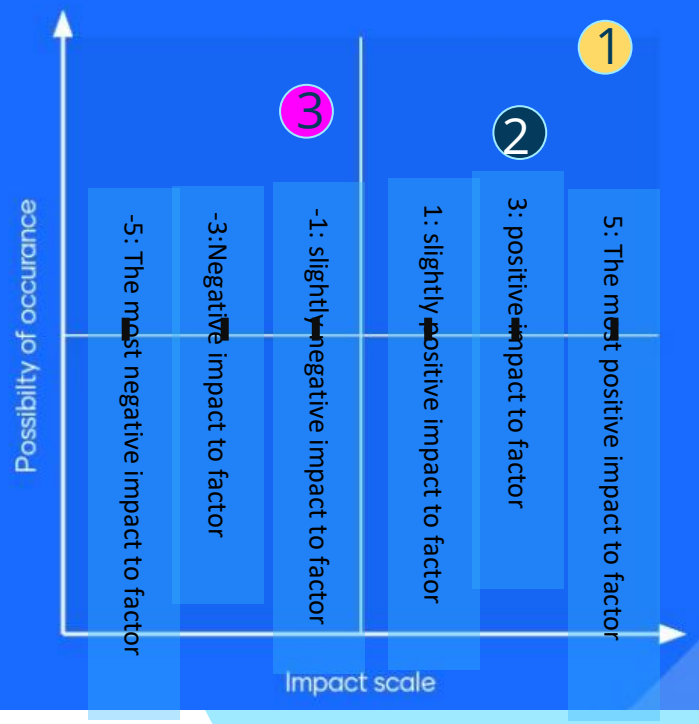
- Review important indicators by the most vote score (whatever SWOT)
- Identify impact and occurrence level to obtain cross-impact matrix

Step 3



What is impact weight and a probability of occurrence of these indicators can be happened in the project?

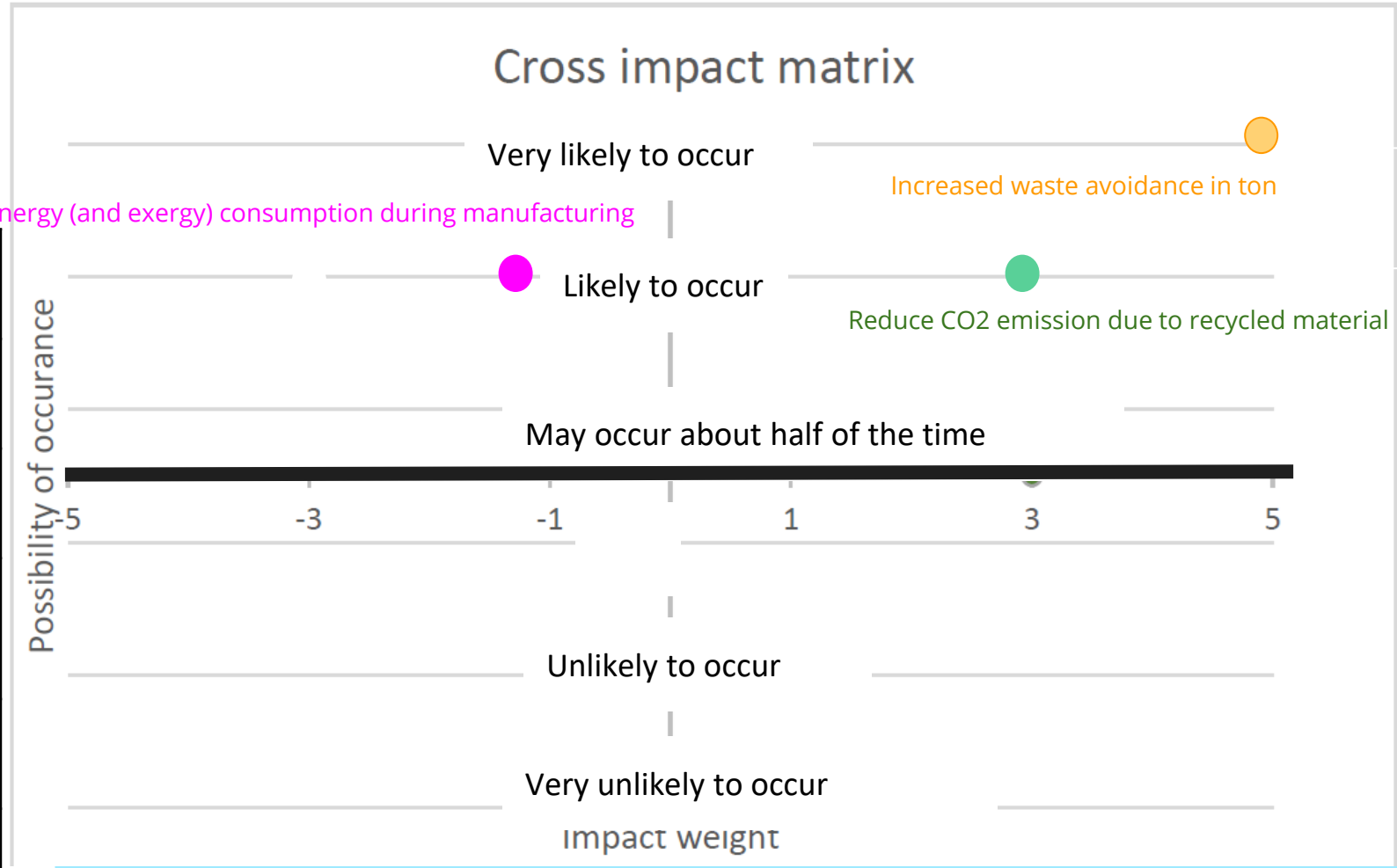
Affect this/ How does this	Increased waste avoided in Ton	Reduce CO2 emission	High energy consumption during manufactured
Increased waste avoided in Ton	5		
Reduce CO2 emission		3	
High energy consumption during manufactured			-1



1. Increased waste avoidance in ton
2. Reduce CO2 emission due to recycled material
3. High energy (and exergy) consumption during manufacturing
4. Created number of new jobs
5. Weak employee engagement rate
6. Improve worker skill development
7. New revenue models related to the circular economy
8. Material import dependency
9. Increase operational Cost

Impact and possibility of indicators to the project

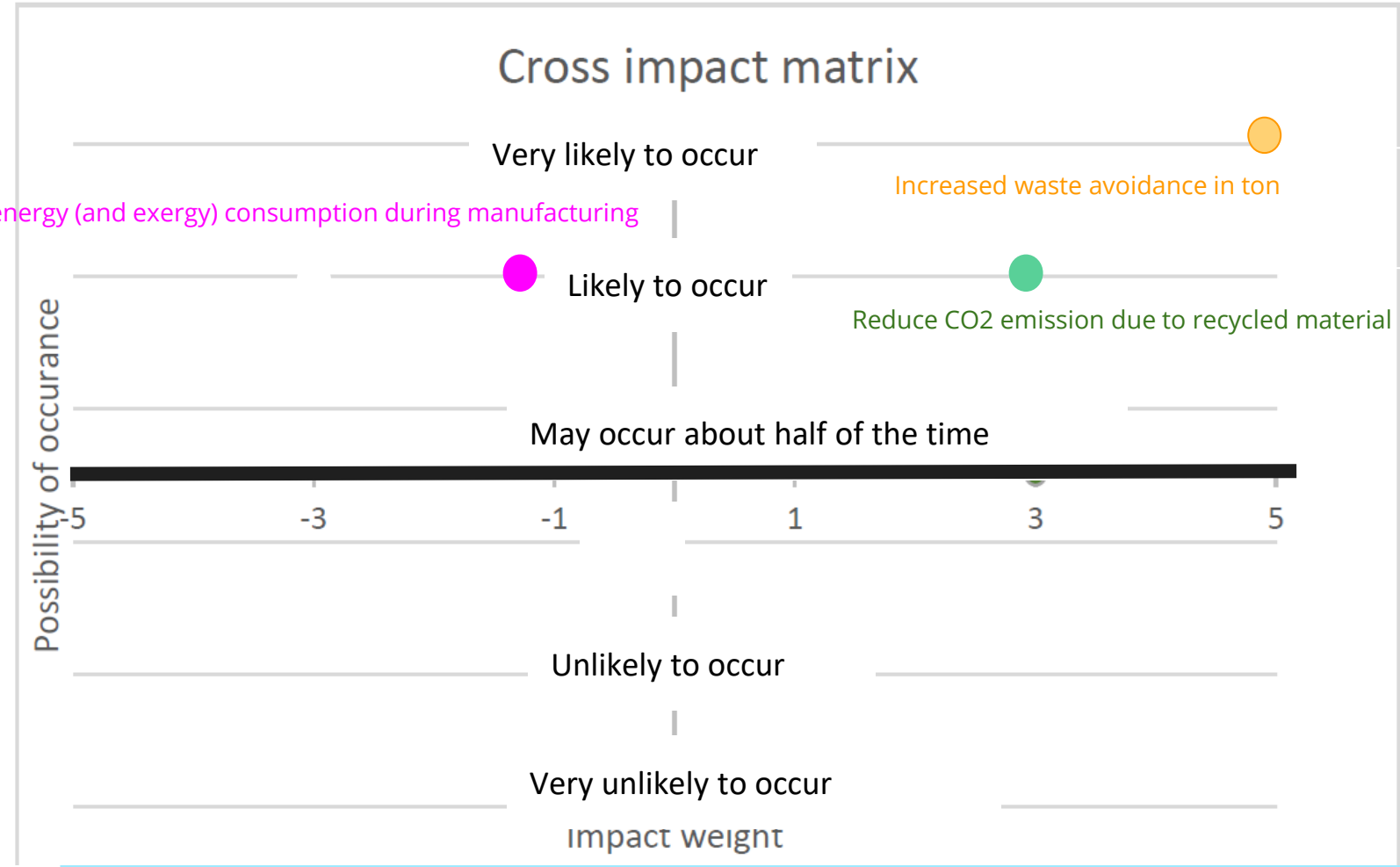
Scale	Probability	Probability score	Scope
VLO	<10%	0.1	Very unlikely to occur
LO	10 - <30%	0.3	Unlikely to occur
MED	30 - <50%	0.5	May occur about half of the time
HI	50 - <70%	0.7	Likely to occur
VHI	≥70%	0.9	Very likely to occur



Source: Project risk analysis and management guide 2nd edition (2007)

Impact and possibility of indicators to the project

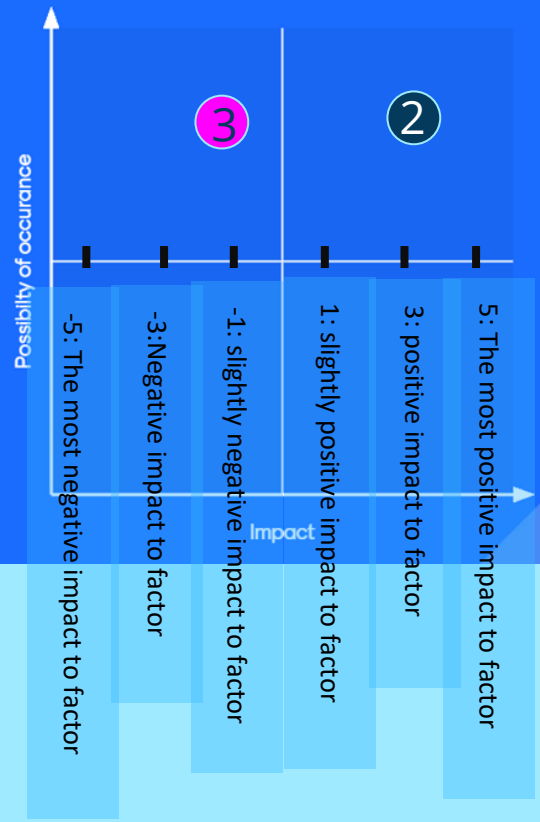
The probability of impacting from indicator to other indicators	Increased waste avoided in ton **(0.9)**	Reduce CO2 emission **(0.7)**	High energy consumption during manufactured **(0.7)**
Increased waste avoided in Ton			
Reduce CO2 emission			
High energy consumption during manufactured			



Impact and possibility between indicators to understand their interaction

What is impact of increased waste avoided in ton can be affected indicators below?

Affect this/ How does this	Increased waste avoided in Ton	Reduce CO2 emission	High energy consumption during manufactured
Increased waste avoided in Ton	5		
Reduce CO2 emission	3	3	
High energy consumption during manufactured	-1		-1



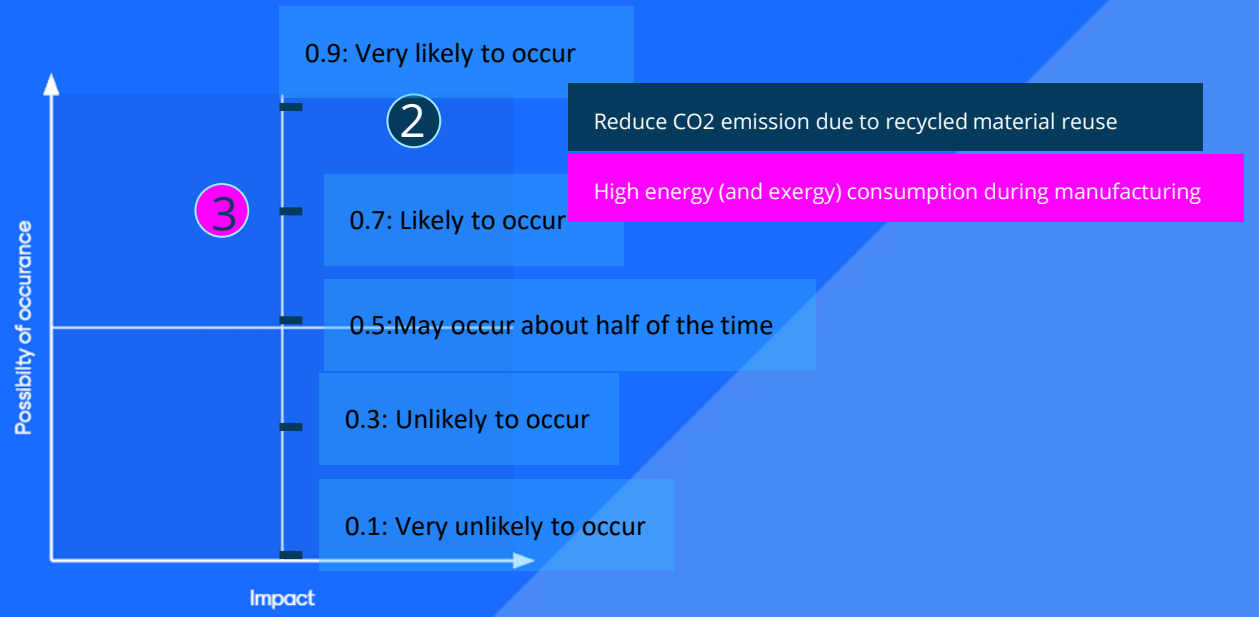
2 Reduce CO2 emission due to recycled material

3 High energy (and exergy) consumption during manufacturing

Impact and possibility between indicators to understand their interaction

The probability of impacting from indicator to other indicators	Increased waste avoided in ton (0.9)	Reduce CO2 emission (0.7)	High energy consumption during manufactured (0.7)
Increased waste avoided in Ton	1		
Reduce CO2 emission	0.9	1	
High energy consumption during manufactured	0.7		1

What is a probality of occurance and impact of Ton of waste avoided can be effected indicators below?



Example of Economy cross-impact matrix

+5	+3	-1
+3	+3	-1
-1	+1	-1

Impact vector

.

1.0	0.7	0.1
0.9	1.0	0.3
0.7	0.1	1.0

Conditional probability vector

=

5.0	2.1	-0.1
2.7	3.0	-0.3
-0.7	0.1	-1.0

Likely cross-impact vector

5.0	2.1	-0.1
2.7	3.0	-0.3
-0.7	0.1	-1.0

Likely cross-impact vector

x

0.9
0.7
0.7

An initial probability vector

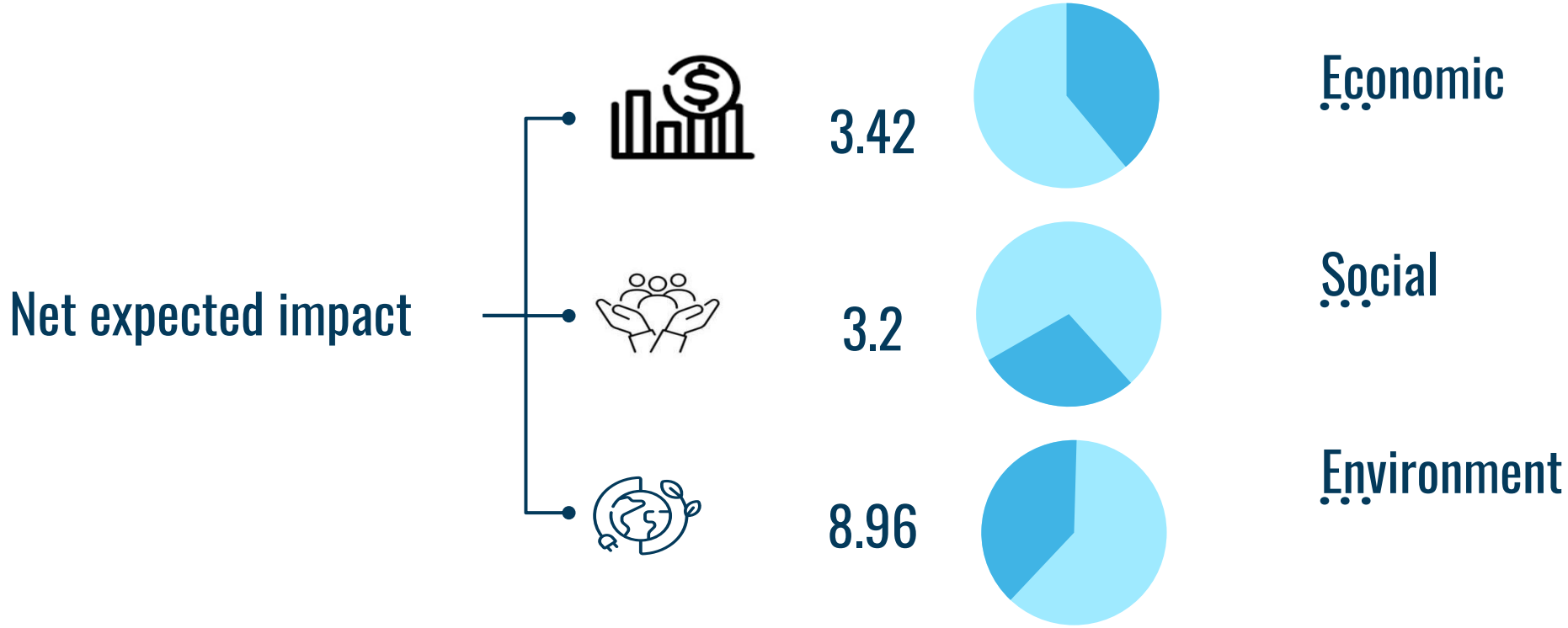
=

5.90
4.32
-1.26

Expected impact vector

Reference Paper: “A new look at the cross-impact matrix and its application in futures studies”, K.Chao , May 2008

Dashboard of net expected impact from the cross impact matrices



Conclusions, study limitation and future research

- No standardized threshold defining impact value which require action plan
- Challenges remain in comprehensively capturing cause-and-effect relationships for some indicators, necessitating careful interpretation.
- All impactful indicators will be retained as critical variables for incorporation into future dynamic model studies.

...

Thank you

Industrial Dynamics: applications to the PET process in the tire industry

Henri Sourgou, Arnaud Diemer
University of Clermont Auvergne, CERDI (CNRS-IRD)

GREENDEAL, CIRCULAR ECONOMY AND INDUSTRIAL ECOLOGY SYMPOSIUM

December 5th & 6th , 2024
Clermont-Ferrand

Introduction

- Polyethylene terephthalate (PET) is widely used in plastics and textiles. Every year in the world, over 20 Million tons of complex waste (textile, tire, hose, …) is produced;
- Most complex waste is incinerated or landfilled due to the lack of viable recycling solutions;
- Contributing to over 2.06 million tons of CO_2eq emissions, soil, and water contamination leading to health problems.

Introduction

- The Whitecycle which is a lab-scale project was created to tackle the landfill and incineration of PET in complex waste;

- Then, 2 tons of waste will be used to produce 3 highly technical products containing recycled PET (r-PET) notably, 100 tires, 1,500 m of hoses, and 400m² of textile;

- By 2030, the project aims to recycle 2 Million tons of PET per year, reduce 2.06 Million tons CO2eq, and avoid 1.8 Million tons of PET landfilling.

Research question and objectives

- How can System Dynamics (SD) modeling help to minimize environmental, social, and economic adverse impacts of PET recycling and to foster circular economy of PET recycling (rPET) supply chain?

- Objectives:
  - Develop an experimental model to describe the complexity of interactions in the rPET supply chain (experimental model approach and computer use);
  - Identify the different inputs used and outputs in the recycling process;
  - Create more successful management policies and structure of rPET supply chain to minimize the environmental, social, and economic costs of PET recycling.

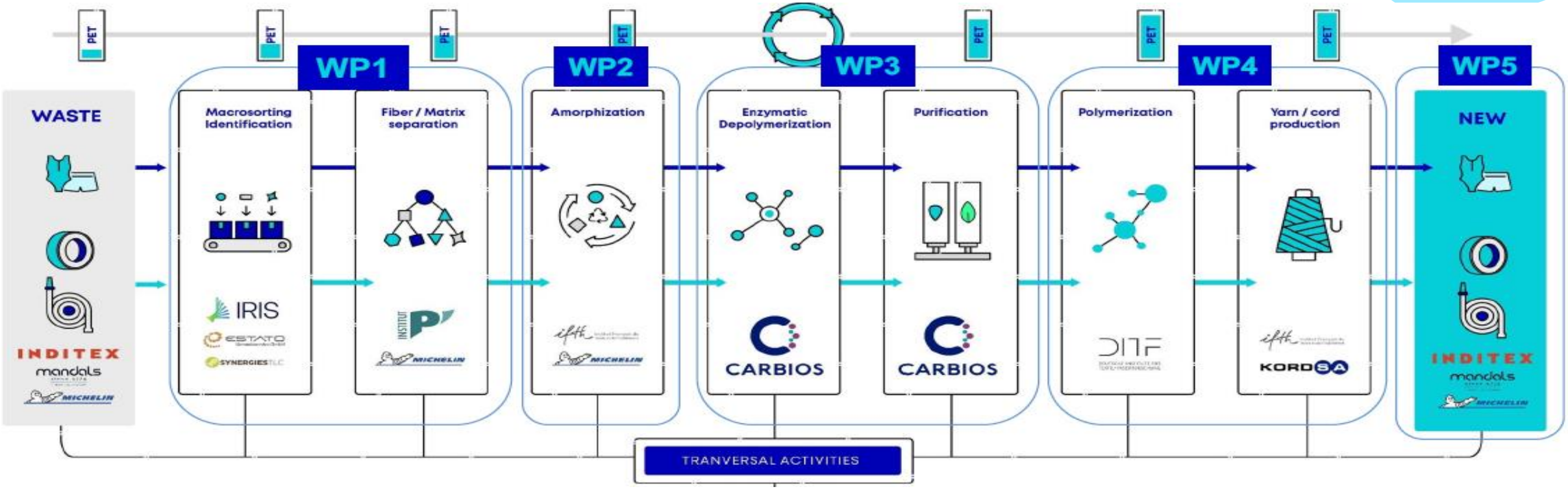
Theoretical Foundations

- According to Forrester, 1961 in Industrial Dynamics, the different management components interact and lead to the dynamic behavior of the overall system
- These components are interrelated by a flow of information, money, orders, and material, … (Forrester, 1961). So, the change in one component influences others (information feedback control theory) (Meadows, 2008);
- Therefore, the manager’s actions, decisions, shocks, and delays in the manufacturing system components are determinants for its growth, stability, and failure (the place of decision-making in industry analysis);
- The continual and non-linear process is a characteristic of most of business activities such as the PET recycling value chain which is based on circularity.

Methodology and data

- We apply SD methodology in this study to model the r-PET value chain through the organization of stakeholders by Work Packages (WP) in the below picture:

Figure 1: PET recycling activities per WP



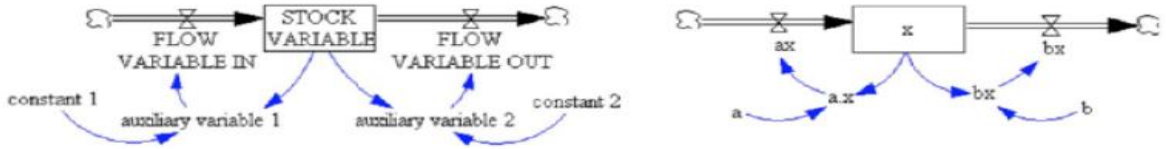
Methodology and Data

Figure 2: System Dynamics (SD) approach

Causal Loop Diagrams (CLD)

Stock and Flow Diagrams (SFD)

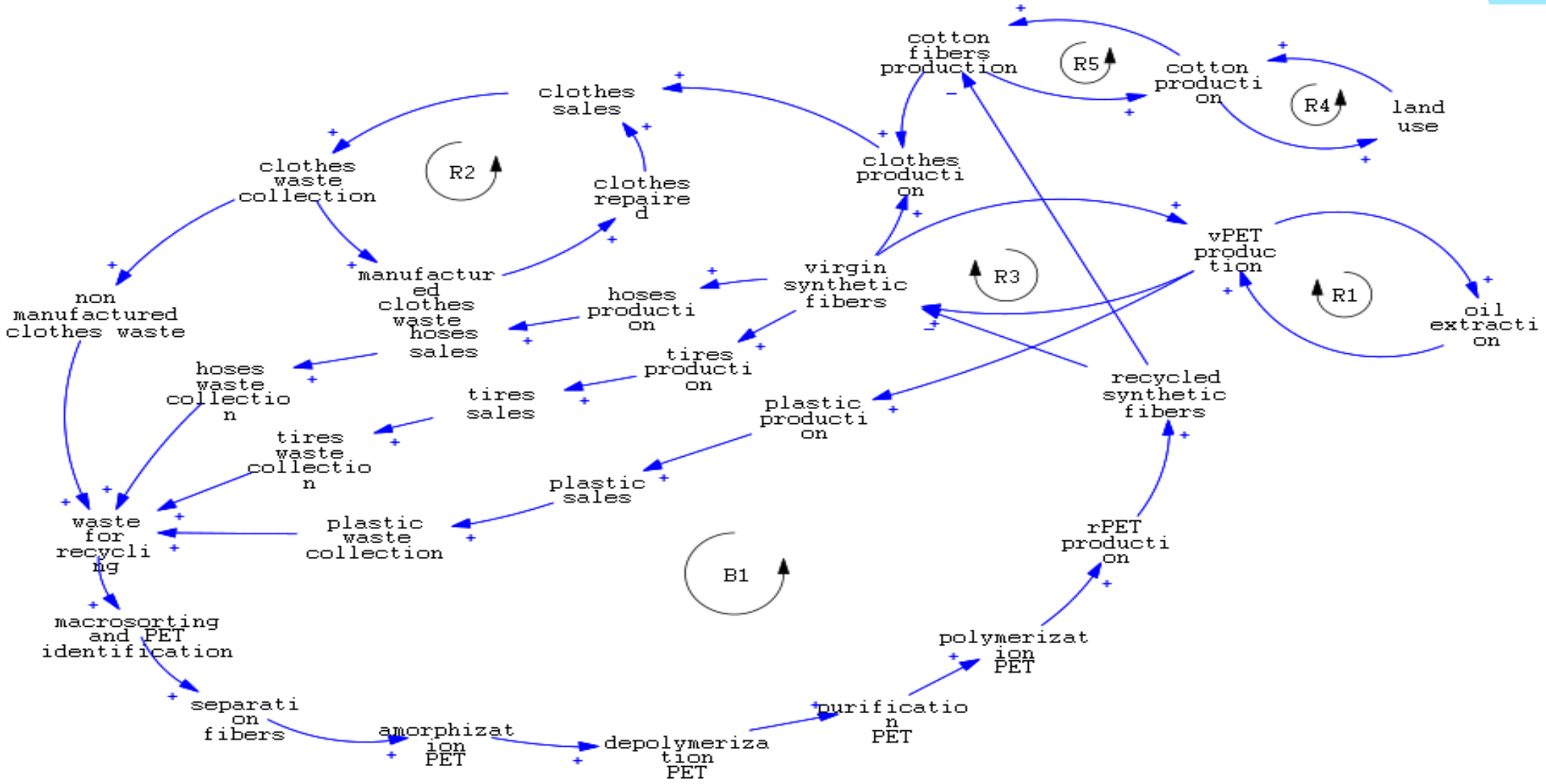
$$x = x_0 + \int_{t_0}^{t} (+ax - bx)\, dt$$



- Data must be provided from lab-scale experiences of waste treatments by stakeholders

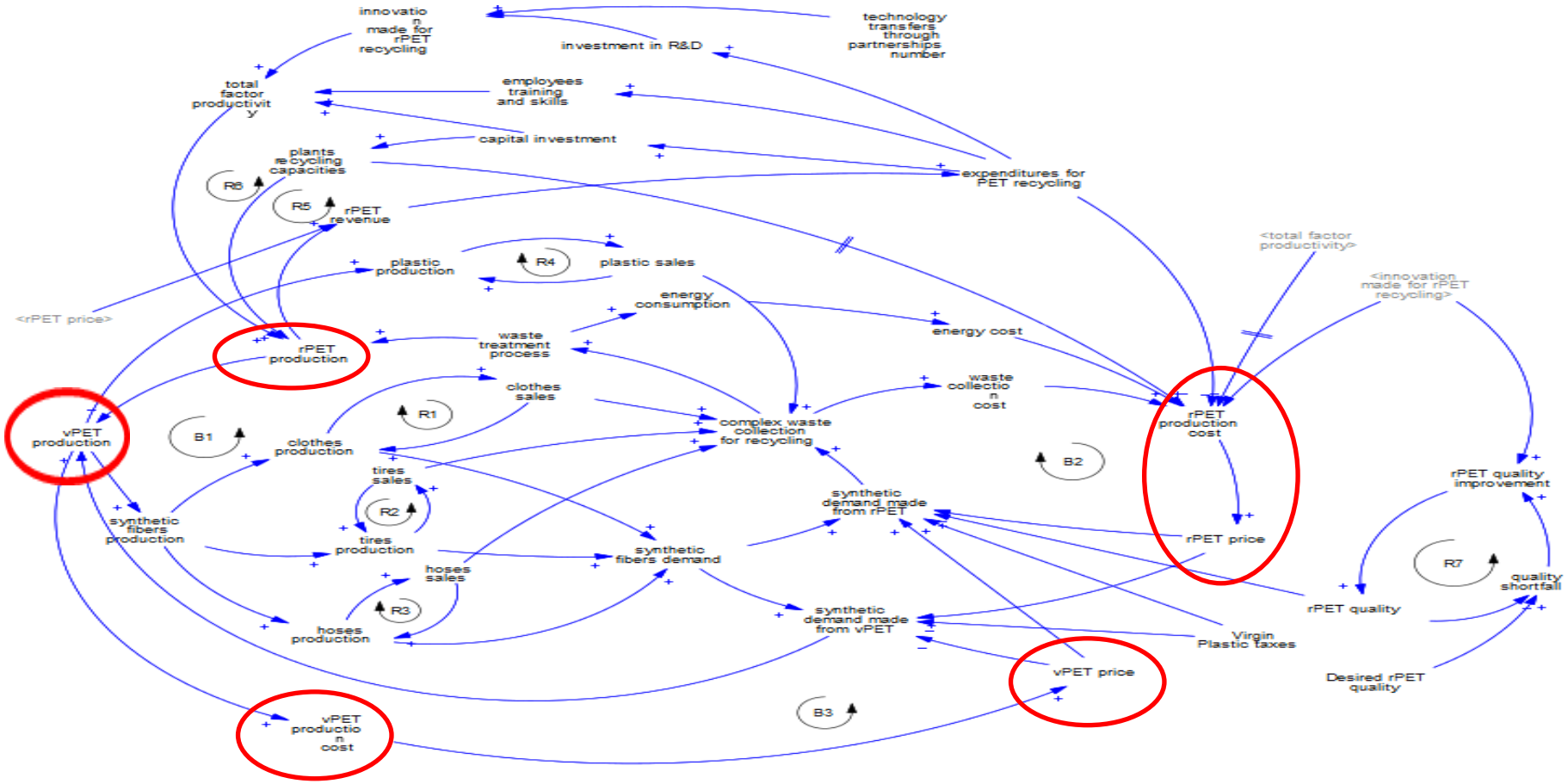
Results

Figure 3: PET supply chain organization



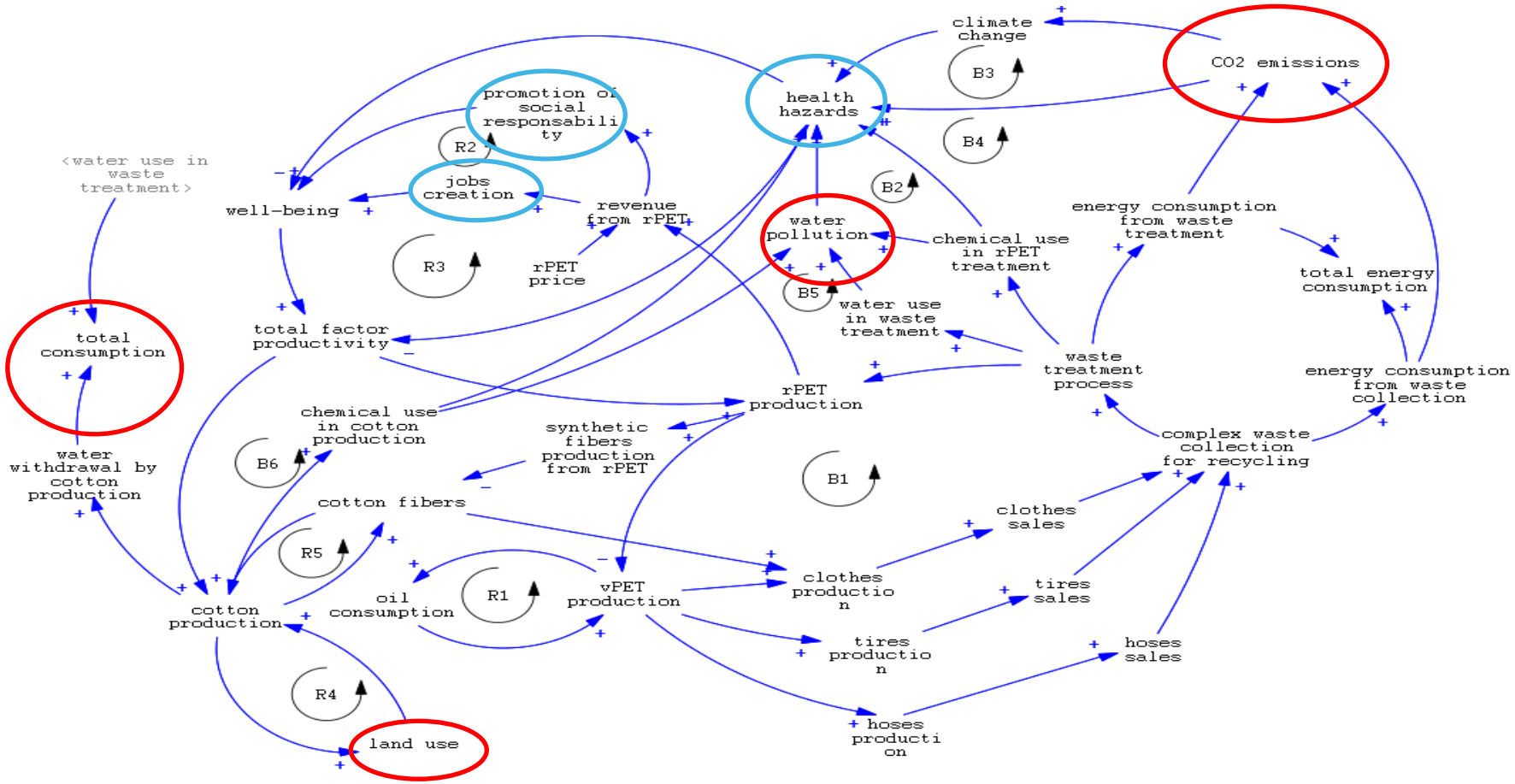
Results

Figure 4: the economic value of the rPET supply chain



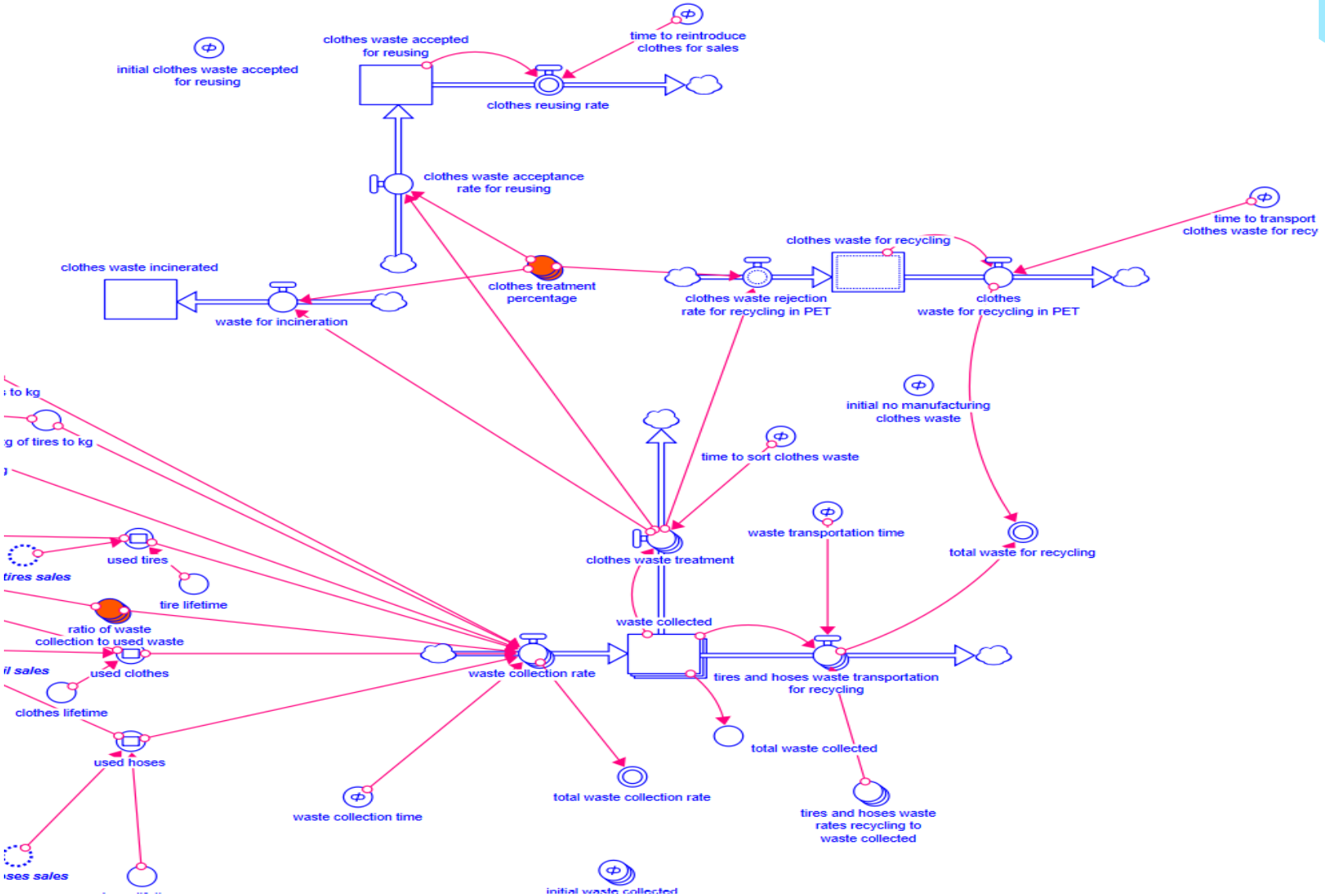
Results

Figure 5: environment and social impacts of the rPET supply chain



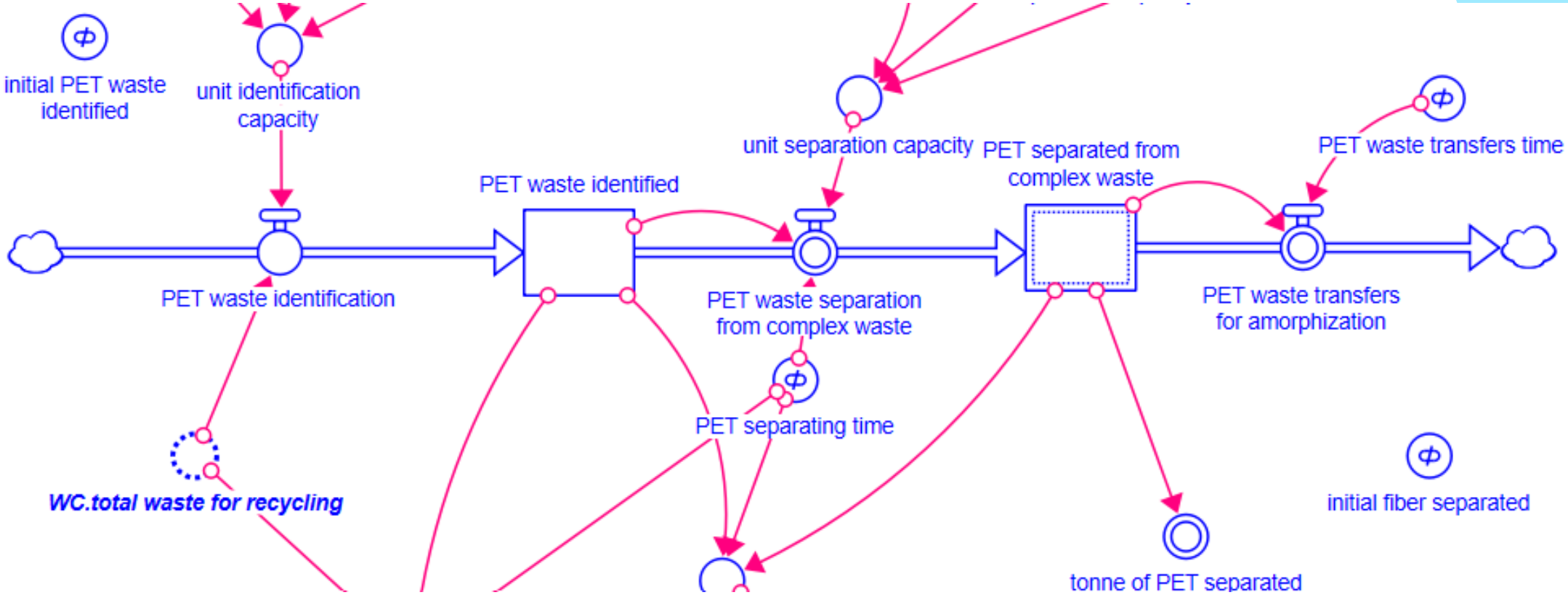
Results

Figure 6: Waste collection SFD



Results

Figure 7: PET identification and sorting SFD



Conclusion

- The model development is still progressing and data acquisition from the lab-scale experience will come to improve the model's robustness
- Based on ID of Forrester, the model in progressing aims to describe the structure of the rPET supply chain and to measure the impacts associated to waste recycling
- The qualitative description shows PET recycling from complex waste is associated with environmental, social, and economic impacts such as emissions, employment, revenue, investment
- Then, the challenge of the White cycle project is to propose innovative and transformative innovations that minimize the negative impacts, reinforce the positive impacts of the supply chain and make the rPET more competitive than vPET.

PÔLE DE COMPÉTITIVITÉ
CHIMIE, INDUSTRIES DE PROCÉDÉS
ET ENVIRONNEMENT

Rond table

Margarita DORATO – Michelin

Jean-Philippe FAURE – Aliapur

Thibaud Herbst – Michelin

Tipawan Durand - UCA

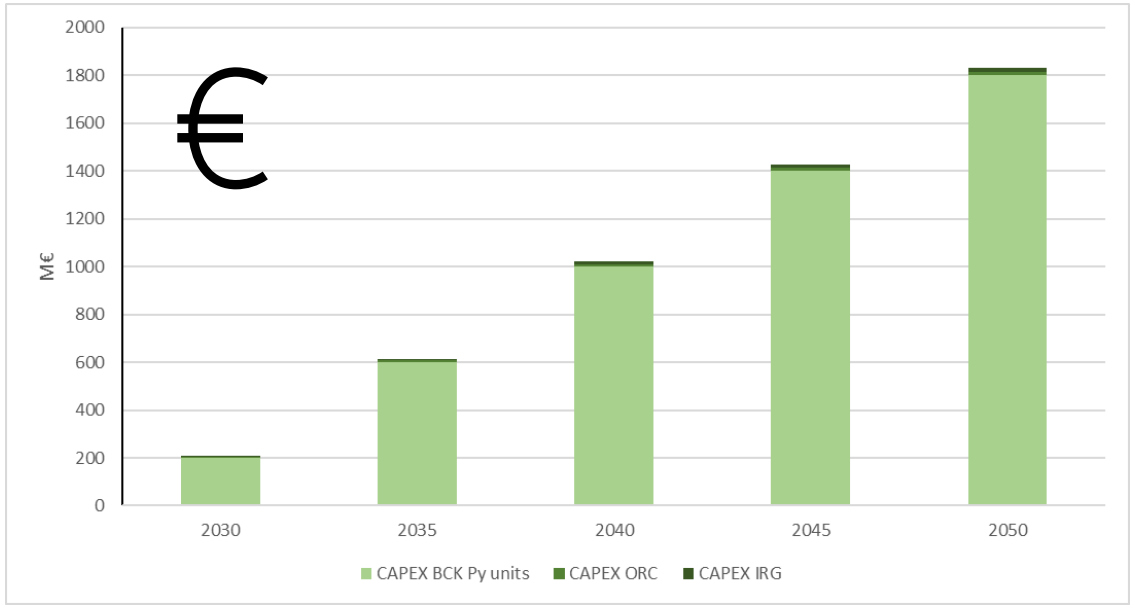
The full business model is robust and fullfils the technical, economical and environmental requirements identified as destructive criterias.

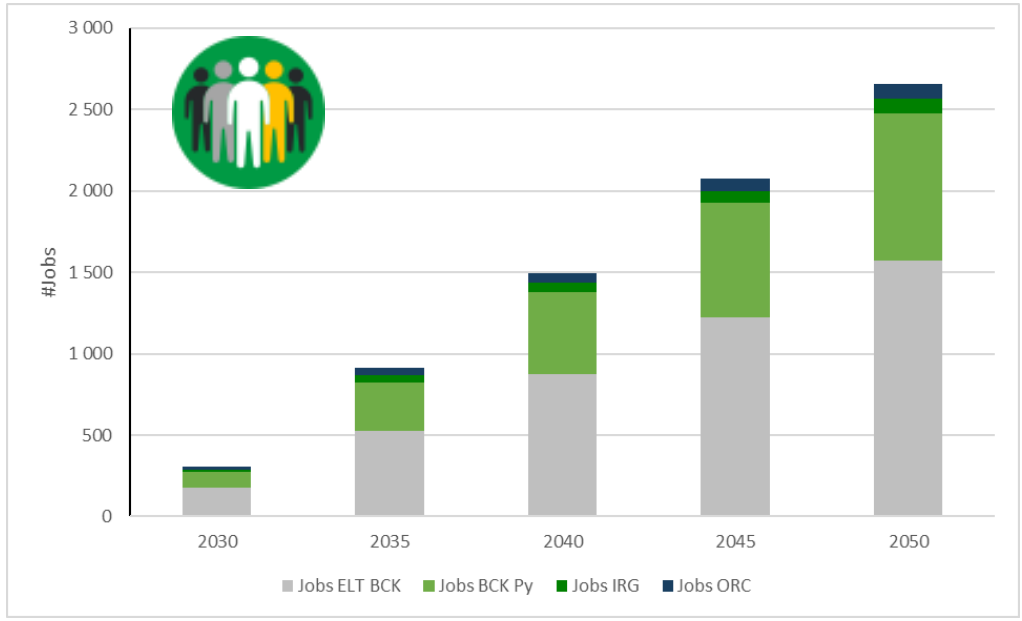
BlackCycle deployment of the technologies (5 new process + 4 SMRS) will start in 2030

INTEGRATED PYROLYSES	ORC	IRG
		
Granulation/Pyrolysis/Distillation rCB treatment	ORC Granulation	IRG I-MRP post treatment
30 - 40M€	0,5 M€	0,5 M€
20 direct jobs	3 direct jobs	3 direct jobs

BLACK CYCLE is a project funded by the European Commission - Project Number : 869625

This new value chain will create a new business of tyre recycling in EU, which will create jobs and private investment across Europe





Investment up to 1,8B€ and created up to 900 direct jobs and ~1500 indirect jobs

BLACK CYCLE is a project funded by the European Commission - Project Number : 869625

BLACKCYCLE is a POWERFUL tool to create a MASSIVE tyre Circular Economy but…

Other than Social acceptance, 5 Non technical barriers for the industrial scale-up

Availability of ELT : in competition with other recovery types

Recognition of Pyrolysis as material recovery process

Industrial Investment and ramp-up:
- Investment is needed to create the capacity of ELT transformation
- The productivity during the ramp up (2 years?) won't be optimized

Waste Status : This status of "waste" creates numerous administrative and financial complications, both for transport, transformation (recycling), trade and use of materials

Identified domains where there could be a **lack of economic attractiveness** of products with more expensive SRM.

BLACK CYCLE is a project funded by the European Commission - Project Number : 869625

About Aliapur

ALIAPUR
COLLECTE ET RECYCLAGE DE VOS PNEUS

Eco-organization specialized in the collection and recycling of tires in France.Created in 2003 by BRIDGESTONE Continental GOODYEAR MICHELIN PIRELLI

Keys data

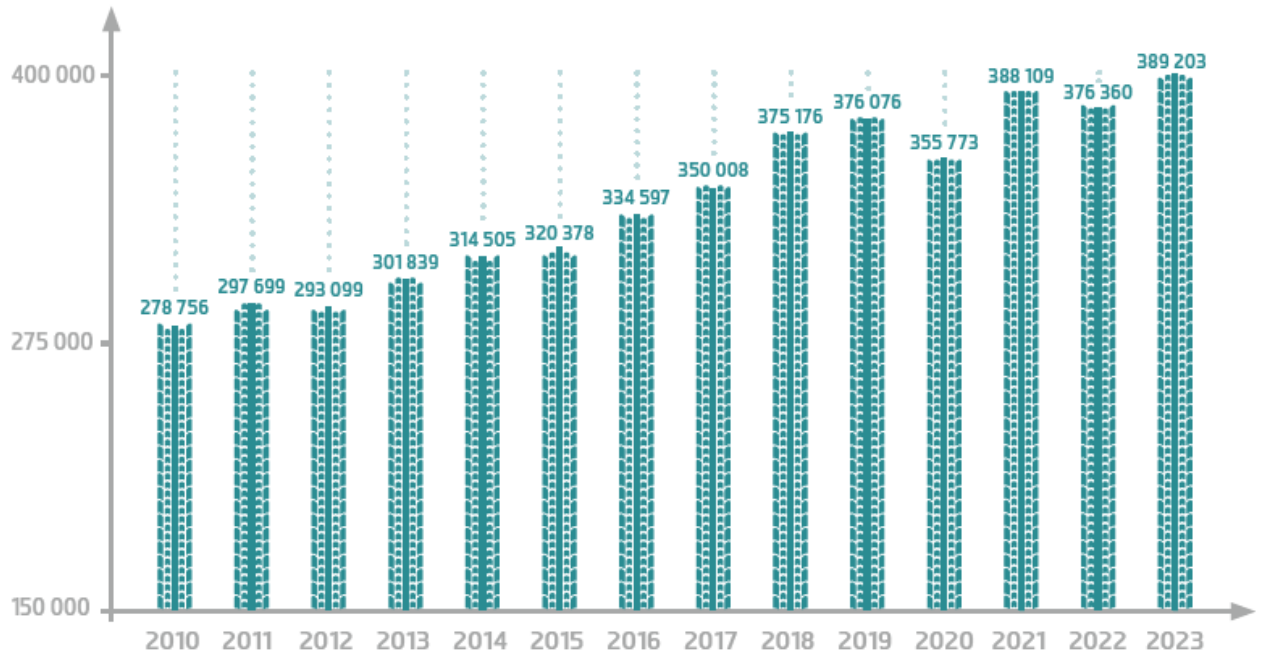
389 203
TONNES DE PNEUS ONT ÉTÉ COLLECTÉES EN 2023

32 534
PROFESSIONNELS DE L'AUTOMOBILE

1551 TONNES COLLECTÉES / JOUR

UNE COLLECTE TOUTES LES **37 SEC.**

Evolution of collection in tons



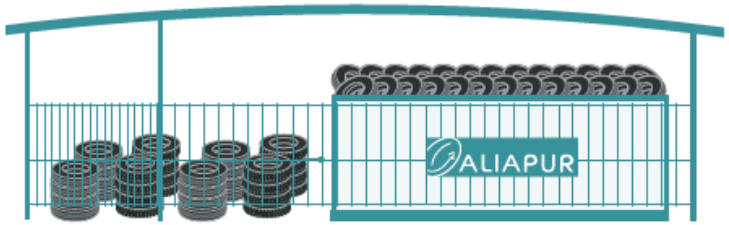
Recycling tyres : how does it work ?

ALIAPUR
COLLECTE ET RECYCLAGE DE VOS PNEUS

1 PURCHASE OF NEW TYRES

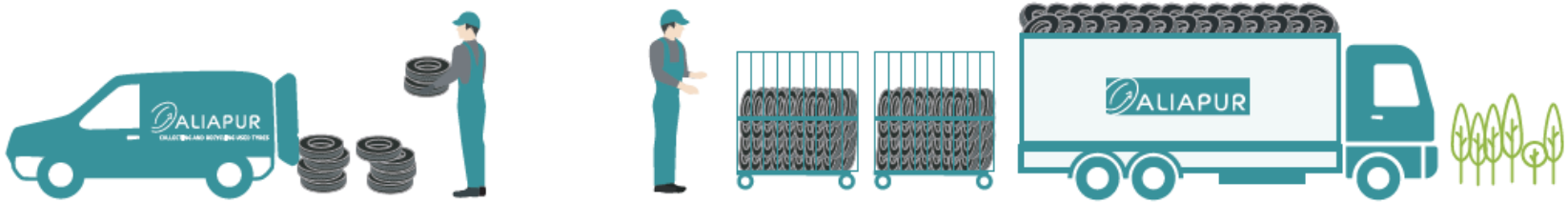
Removing end-of-life tyres to replace them

Storing tyres with protection from bad weather and theft



2 FREE COLLECTION BY AN ALIAPUR SERVICE PROVIDER

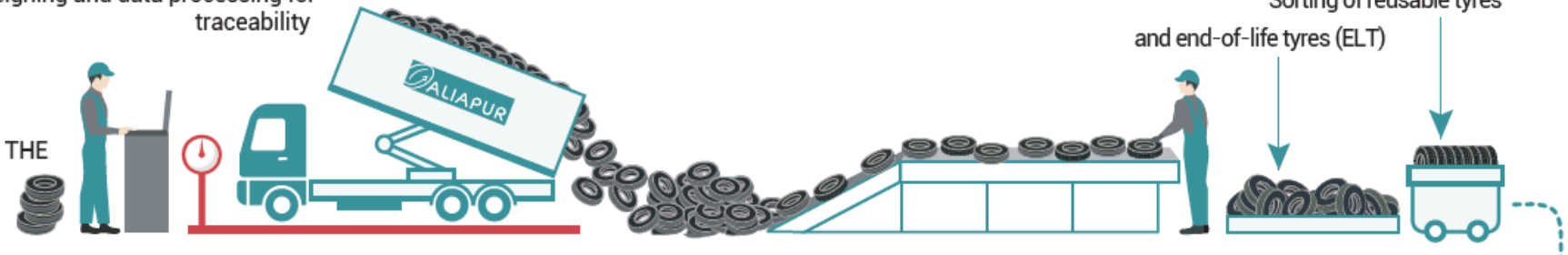
Depending on the volumes to be collected, either manual or mechanical collection (skips and small containers)



3 DELIVERY AND SORTING OF THE TYRES ON THE PREMISES OF THE COLLECTOR

Weighing and data processing for traceability

Sorting of reusable tyres and end-of-life tyres (ELT)



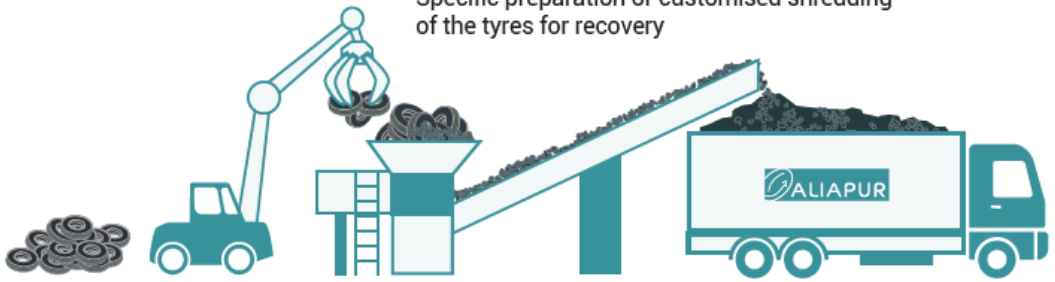
Recycling tyres : how does it work ?

ALIAPUR
COLLECTE ET RECYCLAGE DE VOS PNEUS

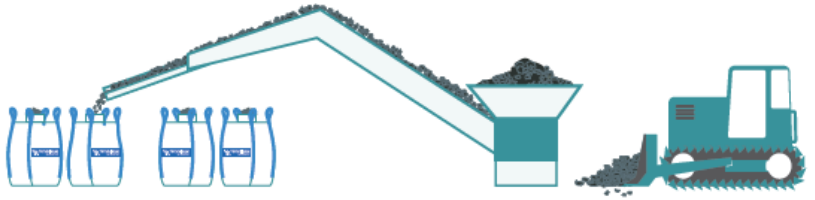
4 DELIVERY OF THE END-OF-LIFE TYRES TO AN ALIAPUR TRANSFORMATION SITE

As soon as the tyres arrive, they are weighed again and data processed for traceability

Specific preparation or customised shredding of the tyres for recovery



Granulation by fine shredding and cleaning of the rubber for recycling



CHIPS AND TYRES (PUBLIC WORKS)

GÉOGOM by ALIAPUR

SHREDS AND TYRES AS SOURCES OF FUEL (INDUSTRY, ENERGY)

POWERGOM by ALIAPUR

RUBBER GRANULATE (PUBLIC WORKS, INDUSTRY, SPORTS & LEISURE)

TECHNIGOM by ALIAPUR

RE-USE

Second-hand

Retreading

PÔLE DE COMPÉTITIVITÉ
CHIMIE, INDUSTRIES DE PROCÉDÉS
ET ENVIRONNEMENT

Rond table

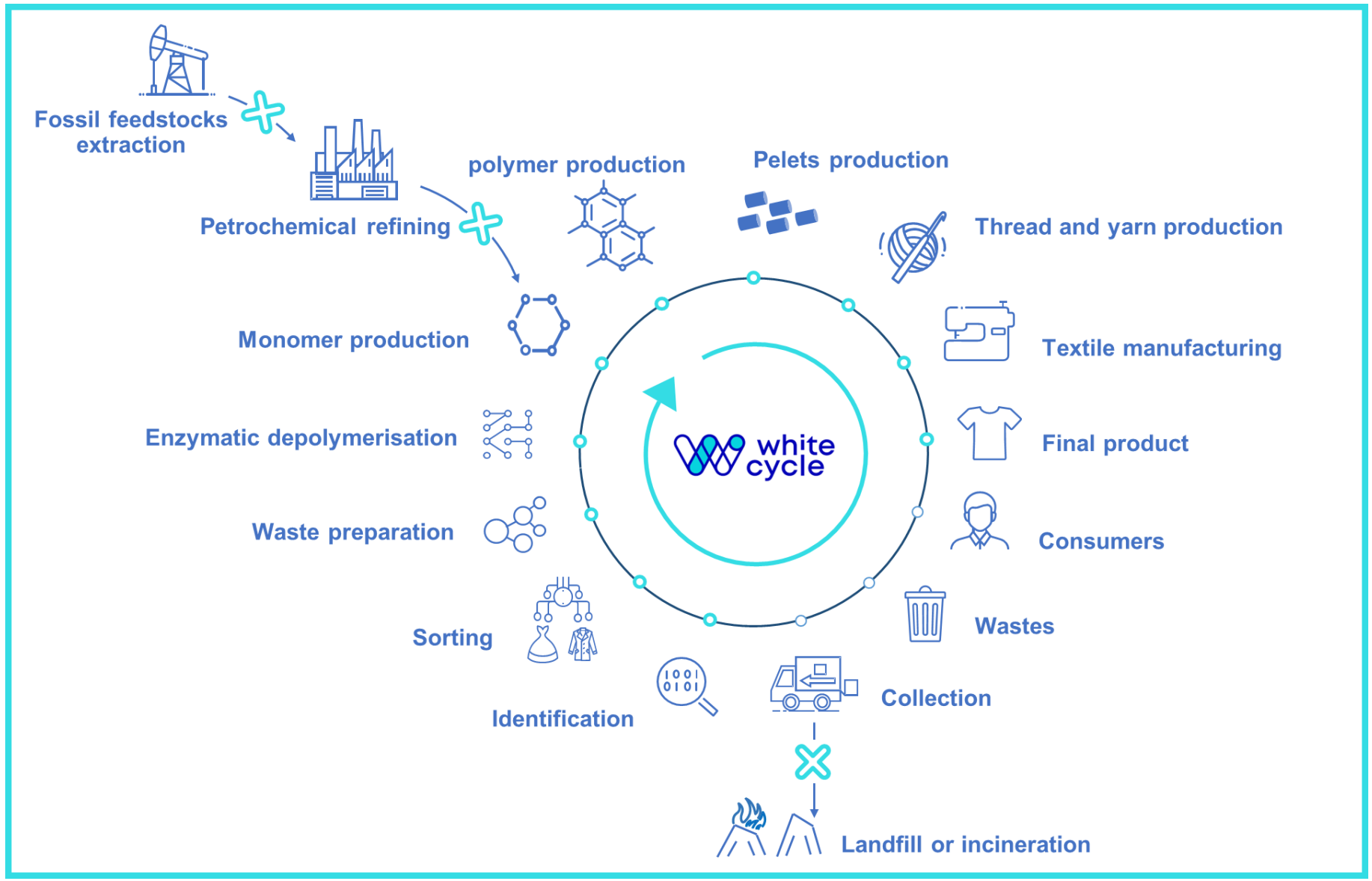
Margarita DORATO – Michelin

Jean-Philippe FAURE – Aliapur

Thibaud Herbst – Michelin

Tipawan Durand - UCA

WhiteCycle : a circular economy initiative



White Cycle is a project funded by the European Commission - Project Number : 101036908

PÔLE DE COMPÉTITIVITÉ
CHIMIE, INDUSTRIES DE PROCÉDÉS
ET ENVIRONNEMENT

Rond table

Margarita DORATO – Michelin

Jean-Philippe FAURE – Aliapur

Thibaud Herbst – Michelin

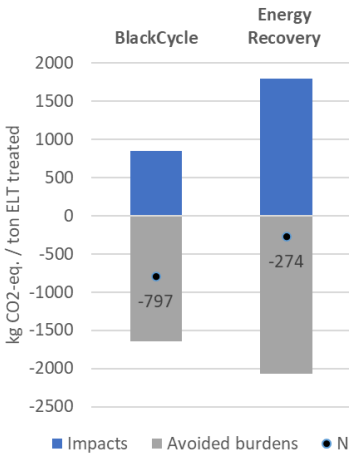
Tipawan Durand - UCA

Blackcycle value chain is economic and environmentally viable

- Analytic and testing approaches led to **a positive HSE conclusions.** No specific issue identified in the Blackcycle value chain.

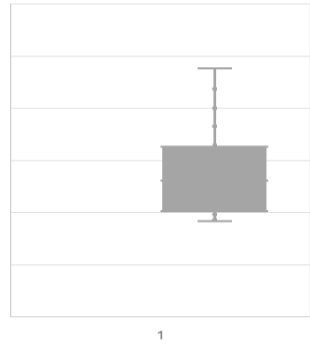
-66%

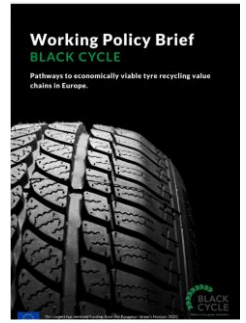
- BlackCycle value chain **significantly reduces climate change (GHG)** impacts compared to energy recovery



- **Social licence to operate**

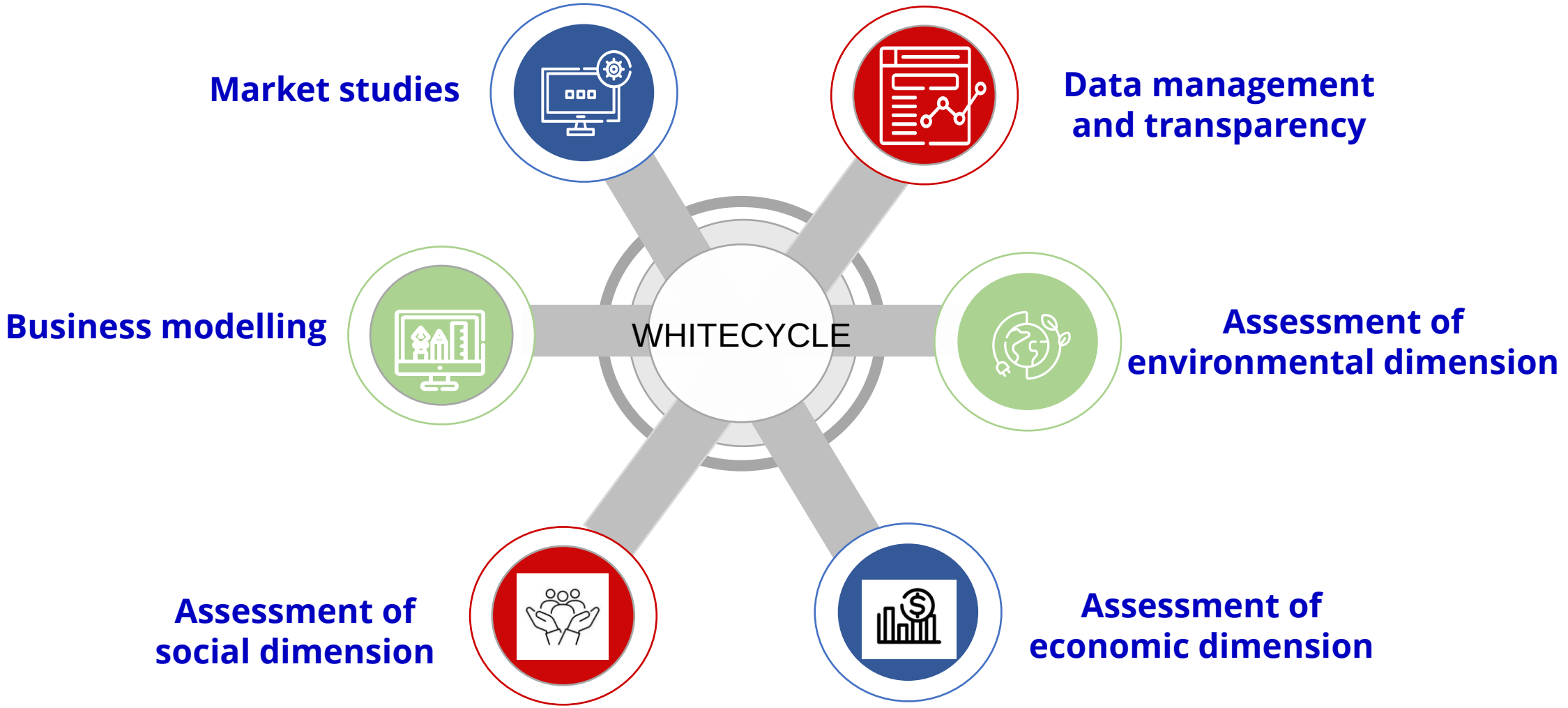
- **Policy brief**





BLACK CYCLE is a project funded by the European Commission - Project Number : 869625

LCA, social-LCA, LCC, Market studies and business modelling



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Rond table

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