

› TNO CIRCULAR PLASTICS

TNO innovation
for life

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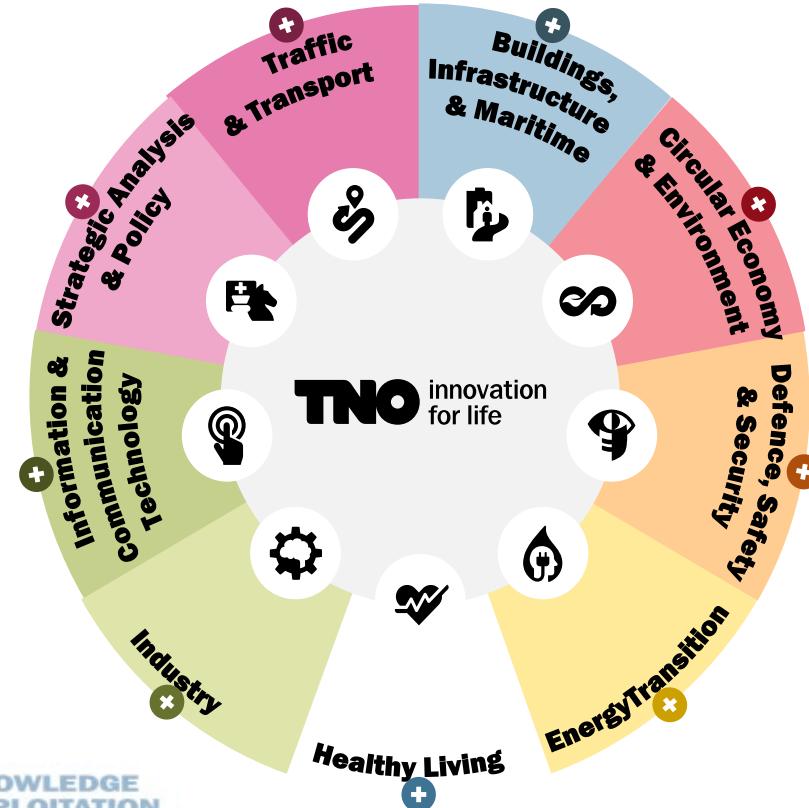
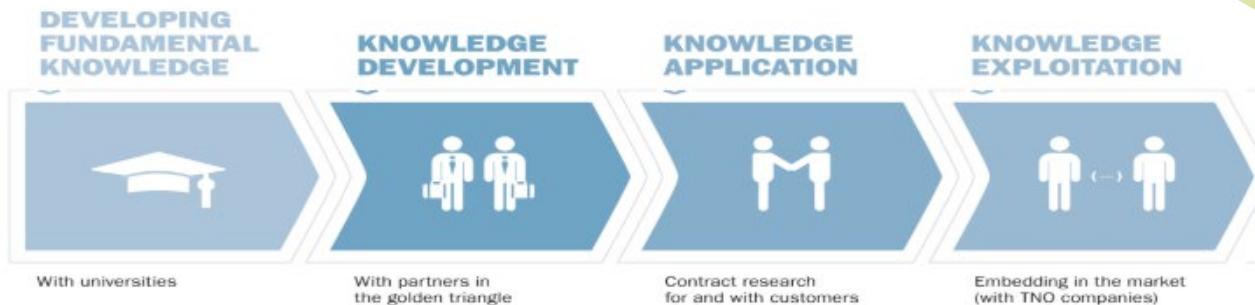
DR PIETER IMHOF



TNO: Dutch independent research organisation

TNO's MISSION

TNO connects people and knowledge to create innovations that boost the competitive strength of industry and the wellbeing of society in a sustainable way.



KEY DATA

NUMBER OF EMPLOYEES

3,500
TOTAL WORKFORCE

2,843 vs.
2016

47
professors
12
lecturers

856
patents
2188
publications

› TNO: EXPERTISE AREAS



INNOVATION

technology, social and business model



AFFORDABLE SUSTAINABLE SOLUTIONS

for issues in least developed countries



CLOSE COLLABORATION

with Dutch and local private sector –
knowledge transfer



INTEGRATED SYSTEM APPROACH

establishing new sustainable value chains
with viable business models for all stakeholders



“ORCHESTRATING INNOVATION”

and transition management



CREATING BUSINESS

with societal impact at most vulnerable groups

CIRCULARITY AND ENERGY TRANSITION IN THE INDUSTRY

CLIMATE GOALS

The greenhouse gas reduction targets are set in the Climate Act: 49% reduction in 2030 compared to 1990 and 95% in 2050.

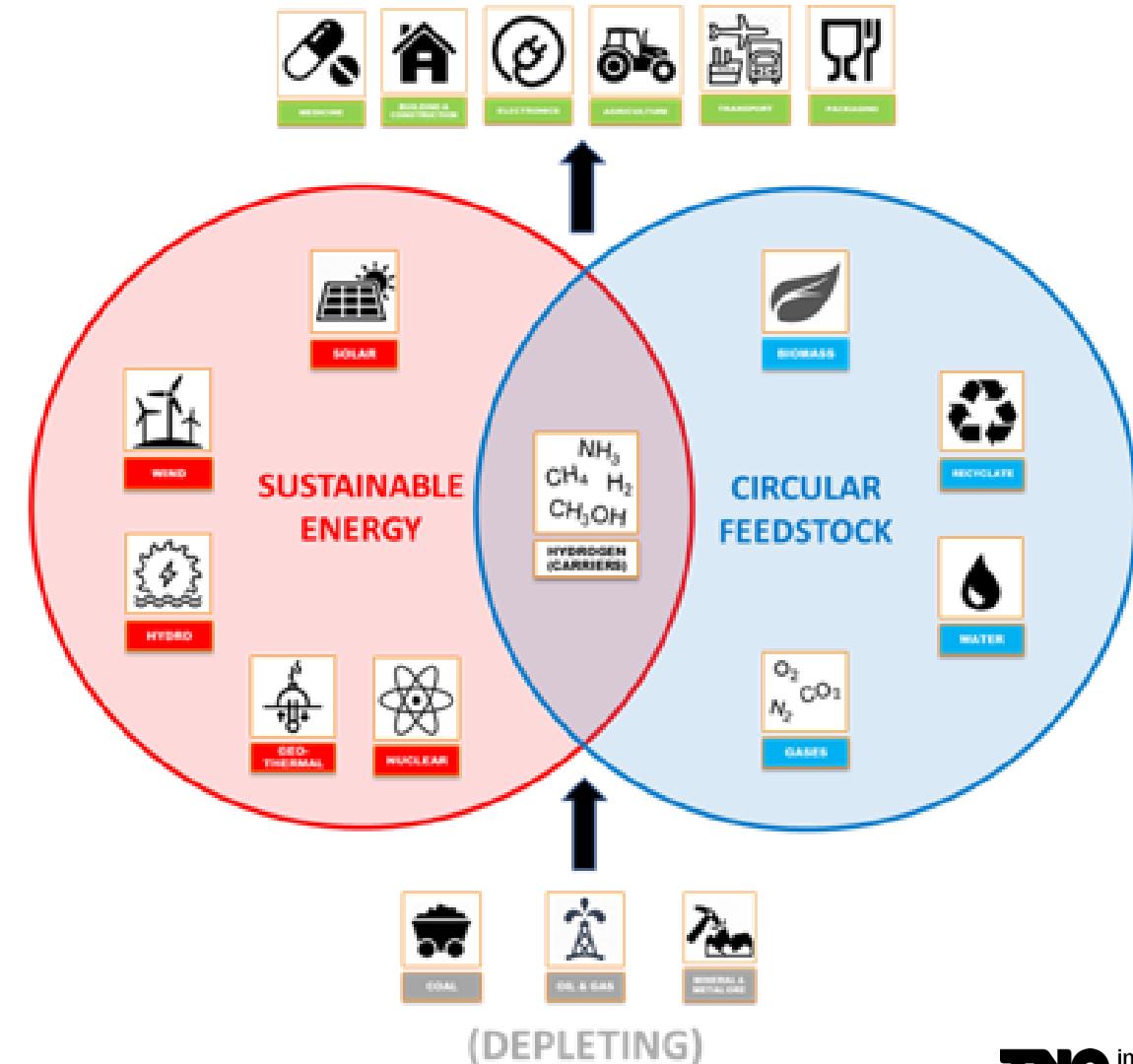
The reduction target from 2018 to 2030 is:

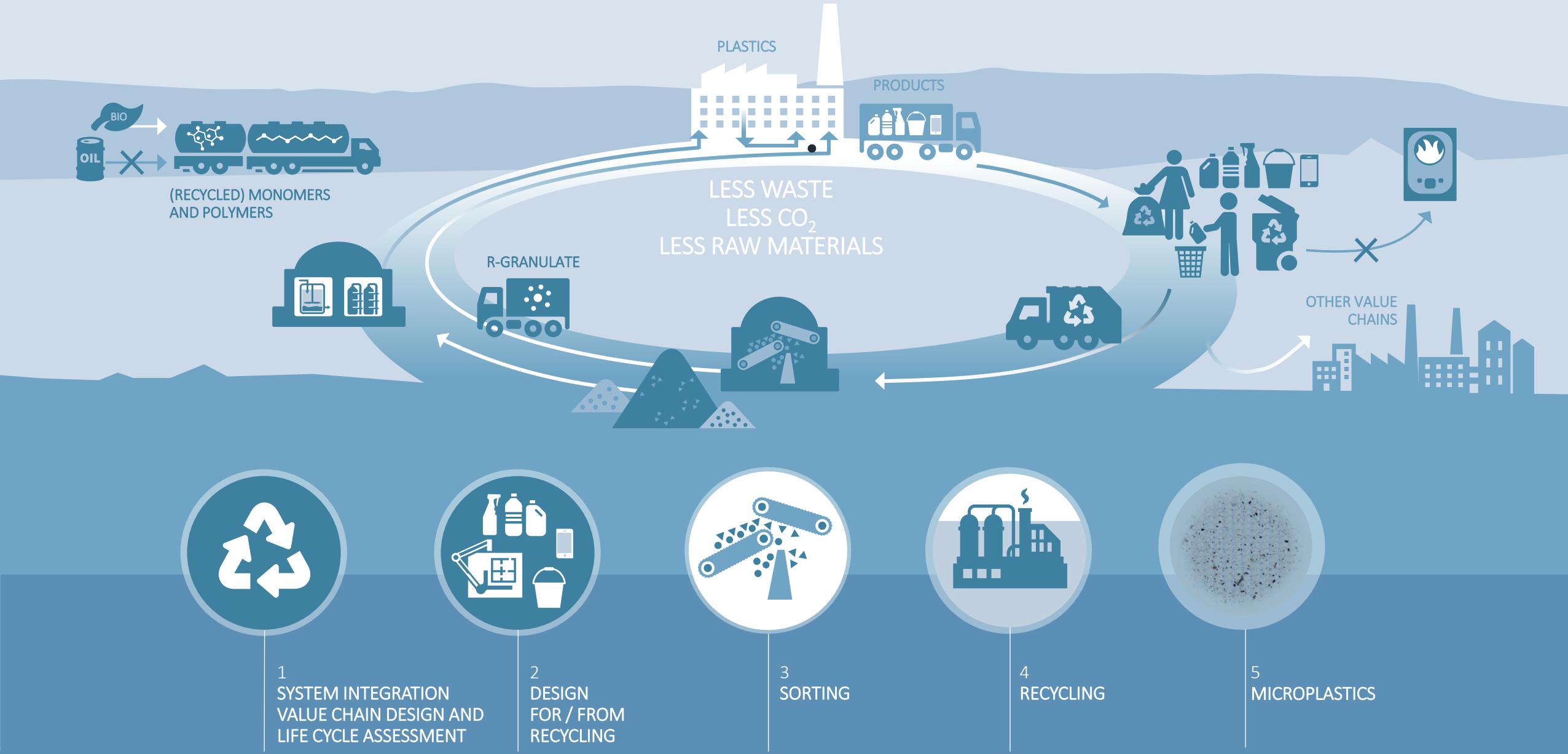
- Total target: 75 Mton CO₂-eq;
- Reduction target Industry: 17 Mton CO₂-eq

CIRCULARITY GOALS

The Netherlands Circular in 2050 aims to:

- In 2050: 100% circular.
- In 2030: use 50% less primary raw materials.





1. MULTILEVEL CIRCULAR (PLASTIC) ECONOMY MODELLING

Level

Level 4

Level 3

Level 2

Level 1

Level 0 Technology development

Model

Macro-economic modelling Global - EU - NL

EXtended Input-Output MODel

Acronym

EXIOMOD / EXIOBASE

Topics

- Macro-economy
- 163 sectors, 200 products
- CO₂
- Materials
- Energy
- Consumer behaviour
- Industry behaviour
- Policy measures

Industrial transformation NL-EU

Circular Industrial Transformation System

CITS

- Economy
- Materials
- Energy
- CO₂
- Costs
- Behaviour
- Policy measures

Plastic recycling NL-EU

Plastic Recycling Impact Scenario Model

PRISM

- Plastic recycling
- CO₂
- Costs
- Policy measures

Chemical cluster production

Chemelot (Chemical Cluster) Integrated Model System

CIMS

- Chemical production
- CO₂
- Costs
- Policy measures

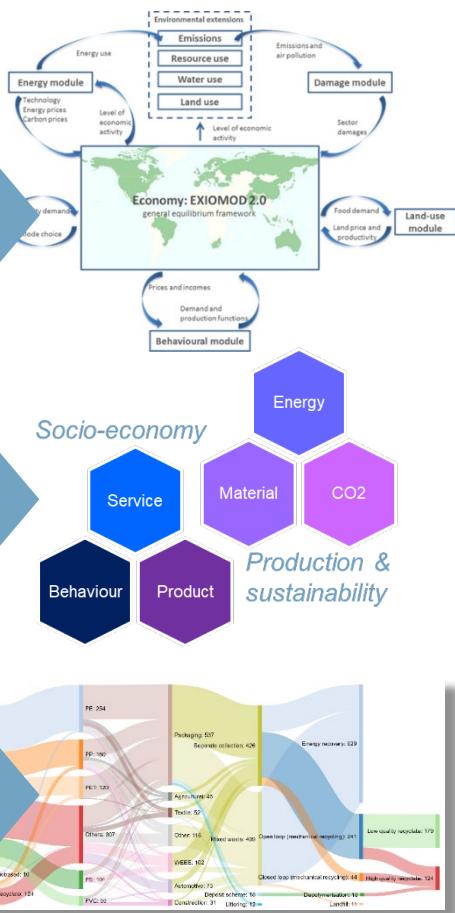
Clients

(Inter)national government

(Inter)national government

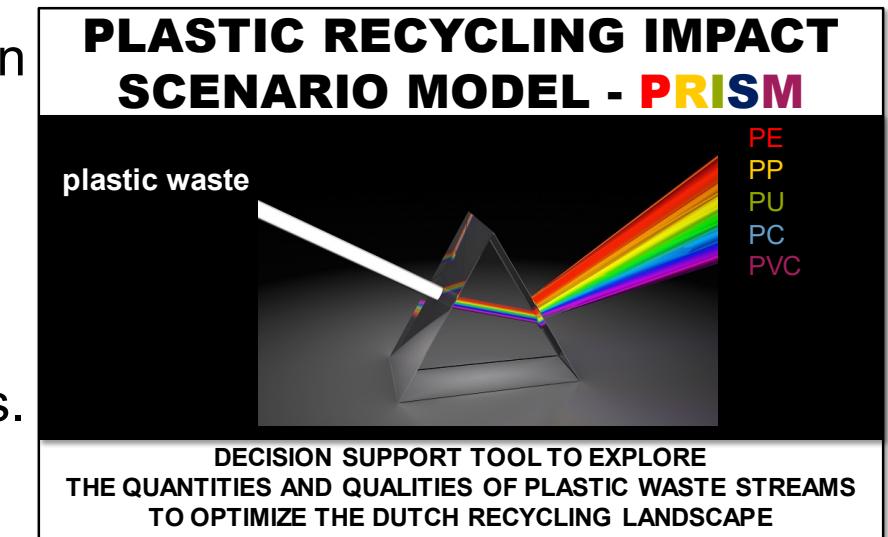
Chemical industry clusters / All governments

Chemical industry clusters / regional governments

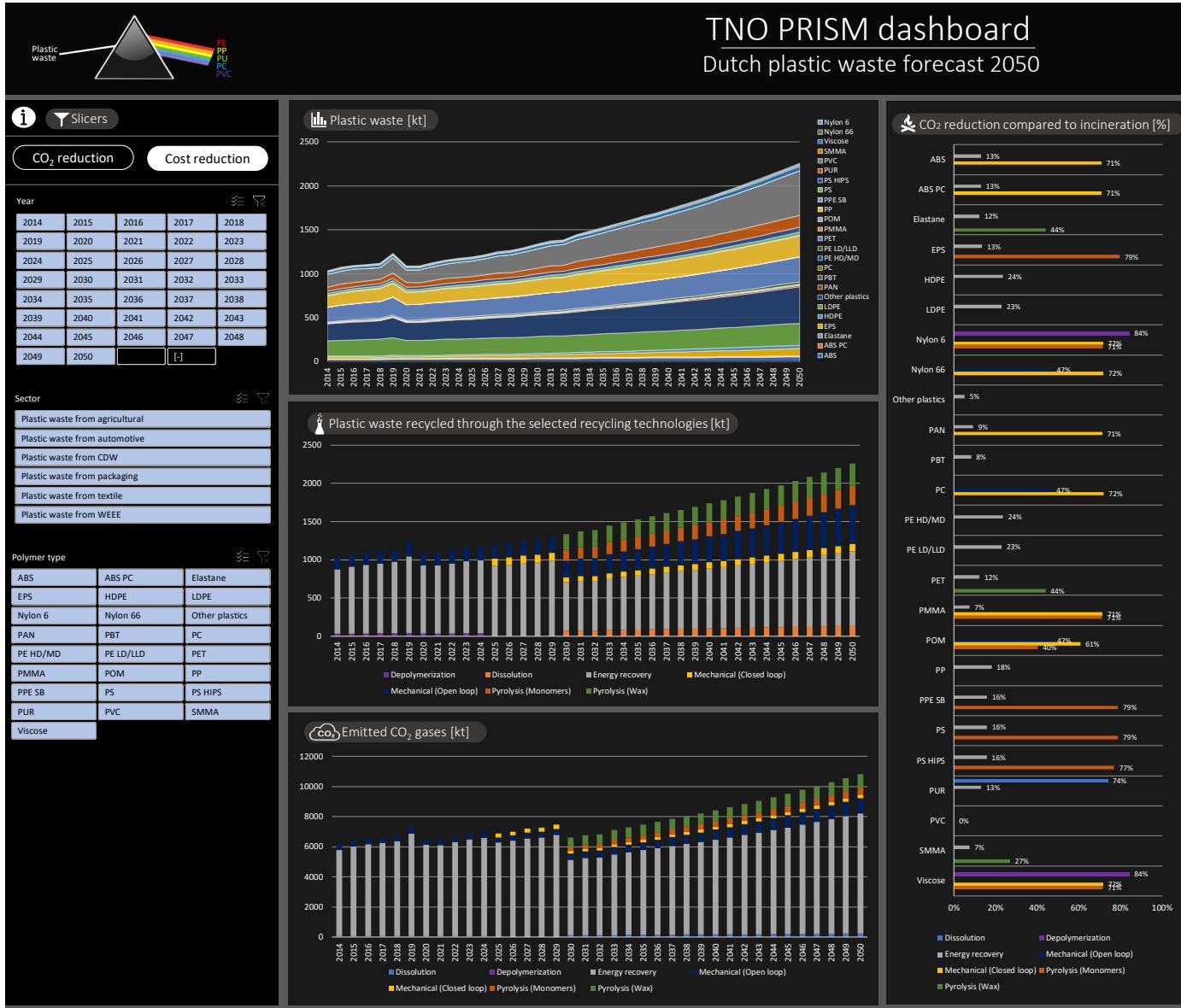


1. PLASTIC RECYCLING IMPACT SCENARIO MODEL

- A techno-economic optimization model that supports decision making by stakeholders in plastic value chains by
 - sketching the future plastic waste and recycling potentials (The Netherlands 2030/2050) and
 - estimating the societal (environmental, economic) life cycle effects of policy measures in such future scenarios.



1. PRISM, SCREEN SHOT



Missing: biobased angle in general and PLA, PEF in particular

1. PLASTIC WASTE TREATMENT TECHNOLOGIES: ENVIRONMENTAL PERFORMANCE LCA MATRIX

LIFE CYCLE EMISSIONS!

SCHWARZ ET AL., 2021

<https://authors.elsevier.com/sd/article/S0956053X20307091>

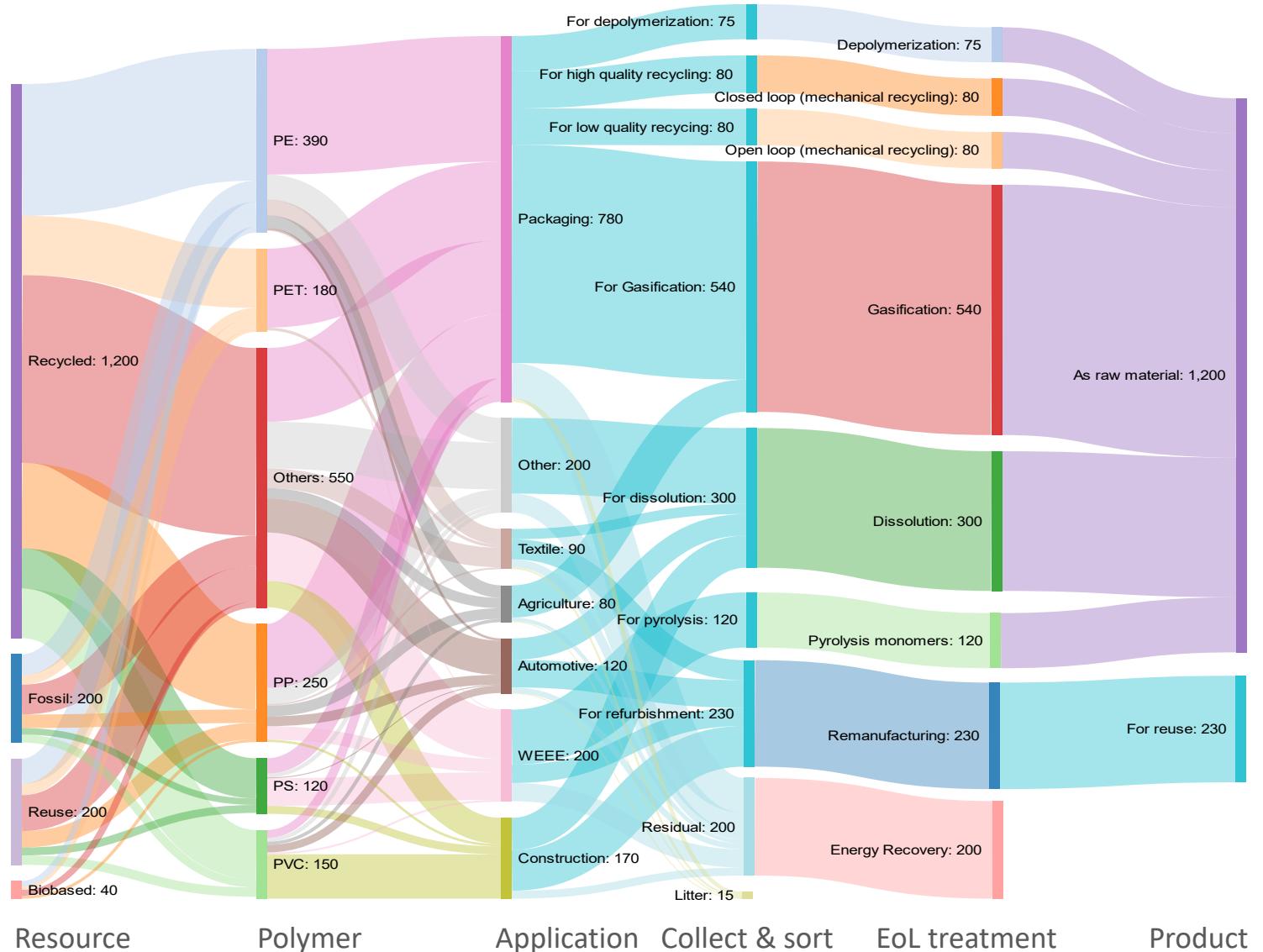
Climate change (kg CO ₂ eq. / kg polymer)		Polyolefins				Monomer forming polymers				Depolymerization/ hydrolysis polymers			Complex polymers										Thermoset polymers			
		PP	LDPE	LLDPE	HDPE	PS	EPS	HIPS	PMMA	PA (nylon 6)	PET	PLA	ABS	PVC	EVA	EVOH	PA (nylon 66)	PAN	PBT	PC	PEEK	POM	PSU	PTFE	PUR	Epoxy resins
High relative CO ₂ eq.	Incineration	4,8	5,0	4,9	4,9	5,6	5,7	5,8	9,3	9,3	4,4	3,1	6,4	4,0	4,4	7,7	9,1	8,9	4,5	6,6	13,6	3,4	10,5	138,9	6,5	7,0
	Energy recovery	3,8	3,8	3,7	3,7	4,5	4,8	4,7	8,6	8,6	3,8	2,6	5,4	3,4	3,6	6,9	8,4	8,1	4,1	5,8	12,8	3,0	9,7	138,7	5,6	6,0
	Pyrolysis (Energy)	1,5	1,6	1,5	1,5	2,0	2,2	2,2	7,0	6,6	2,4	3,1	3,0	2,0	2,3	5,5	6,6	5,6	2,4	4,3	10,7	2,5	7,6	137,4	4,4	4,6
	Gasification (Energy)	1,1	1,3	1,3	1,3	2,3	2,4	2,4	6,8	6,4	2,3	2,2	3,1	2,0	1,7	5,0	6,2	5,9	2,2	4,1	10,8	1,8	7,9	137,6	4,2	4,5
	Pyrolysis (Wax)	1,1	1,4	1,3	1,3	1,8	1,9	1,9	6,7	6,4	2,1	2,8	2,7	2,0	2,0	5,2	6,3	5,3	2,1	4,0	10,4	2,2	7,4	137,1	4,1	4,4
	Mechanical (Open loop)	1,7	1,8	1,7	1,7	2,1	2,2	2,2	4,8	4,7	1,9	2,0	2,6	1,7	1,8	3,8	4,6	4,2	1,9	3,1	7,1	1,6	5,3	82,9	-	-
	Pyrolysis (Monomers)	0,8	1,0	0,9	0,9	0,0	0,2	0,5	4,8	2,3	1,8	2,3	2,7	2,1	1,9	5,1	6,0	4,9	1,7	3,8	10,1	2,0	7,2	70,4	4,0	4,2
	Gasification (Monomers)	0,5	0,7	0,6	0,6	1,0	1,2	1,4	6,5	6,0	1,6	2,4	2,4	1,9	1,4	4,6	5,8	4,9	1,7	3,5	9,8	2,0	6,9	136,9	3,7	3,8
Low relative CO ₂ eq.	Mechanical (Closed loop)	1,2	1,2	1,2	1,2	1,4	1,4	1,4	2,3	2,3	1,2	0,9	1,6	1,1	1,1	1,9	2,3	2,2	1,3	1,6	3,3	1,0	2,7	33,6	-	-
	Dissolution	1,2	1,2	1,2	1,2	1,3	1,4	1,5	1,7	1,8	1,8	-	1,4	1,2	1,2	1,6	1,7	1,7	1,3	1,7	2,1	1,2	2,0	14,7	1,4	1,6
	Depolymerization	-	-	-	-	-	-	-	-	1,2	0,8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Hydrolysis	-	-	-	-	-	-	-	-	-	-	1,2	-	-	-	-	-	-	-	-	-	-	-	-	-	
										CO ₂ emission reduction		0%					100%									

1. CIRCULAR PLASTICS

HOW MIGHT IT LOOK LIKE IN 2050?

An expert guestimation for ‘The Netherlands’ plastic supply & demand 2050 based upon TNO’s Plastic Recycling Impact Scenario Model PRISM

- › 1.5 x the current volume
- › 85% high quality recyclate; 15% losses ~ 6 full quality life cycles
- › A mix of remanufacturing, mechanical and chemical recycling technologies
- › Each best suited to reach circularity for specific plastic polymer families & applications
- › This determines the collection, sorting, cleaning & pretreatment challenge
- › TNO White paper “Don’t waste it!” (Nov. 2020)



2. DESIGN FOR CIRCULARITY

SCOPE BRIGHTLANDS MATERIAL CENTER “CIRCULAR PACKAGING”

4. ADVISING STAKEHOLDERS

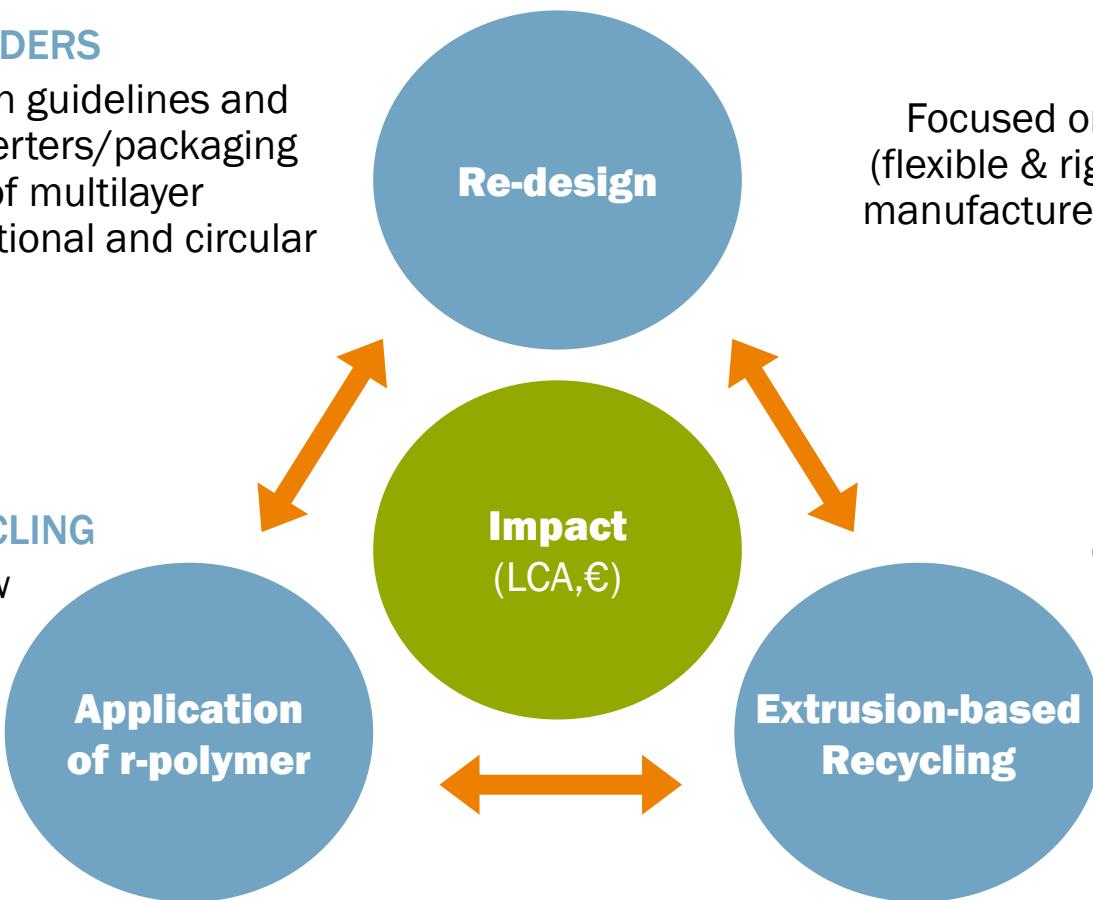
Advice on impact, design guidelines and standardization to converters/packaging producers on redesign of multilayer packaging fulfilling functional and circular requirements.

1. DESIGN *FOR* RECYCLING

Focused on multilayer/material packaging (flexible & rigids). Technological capability to manufacture ‘prototypes’ and test functional requirements available.

3. DESIGN *FROM* RECYCLING

Design and produce new applications based on recycled materials

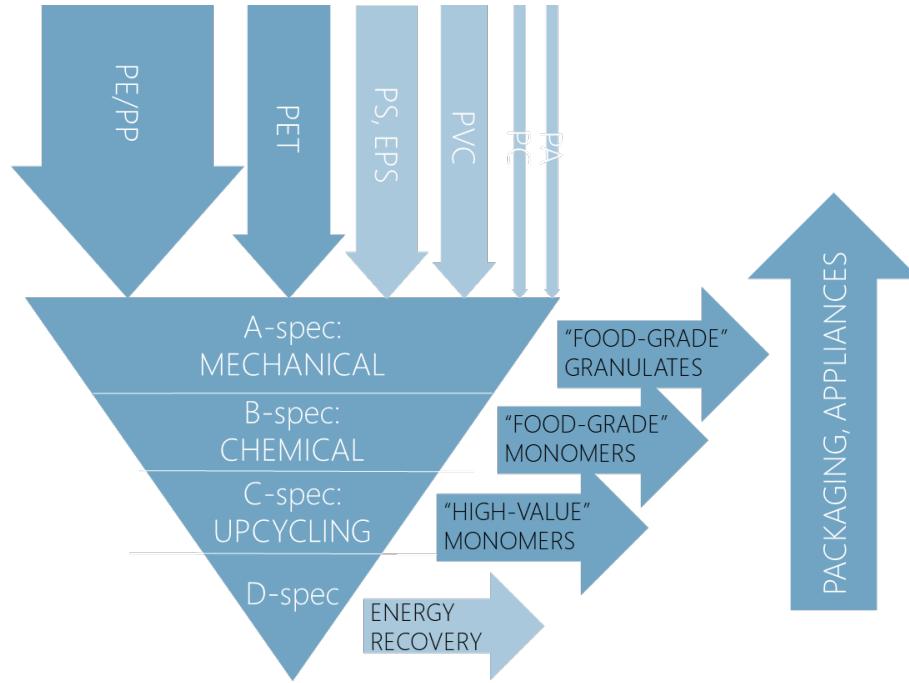


2. UPGRADING QUALITY

Characterization of recycled materials. Restore, or upgrade functionality. Access to recycling facilities to test specifications and requirements.

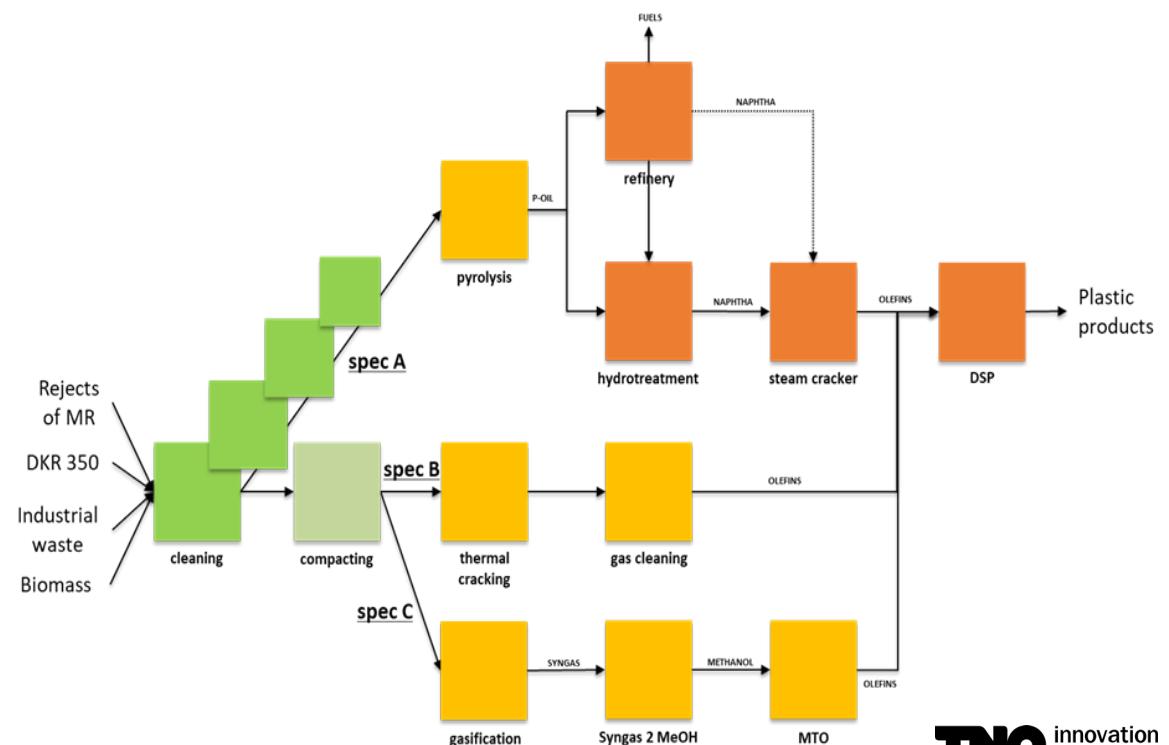
3. SORTING AND WASHING

DEVELOPMENT OF SPECS & COMMODITIZATION



Integral sorting, washing & recycling strategies
for bringing sorted plastics on spec for
mechanical and chemical recycling

Commodification of plastic waste important for chemical industry (logistics, stringent cracker specifications)



4. RECYCLING TECHNOLOGY DEVELOPMENT

ANALYSIS & TECHNOLOGY DEVELOPMENT

TECHNO-ECONOMIC & STRATEGIC BUSINESS ANALYSIS

- › Techno-economic Feasibility studies
- › Market analysis and benchmarking
- › Business analysis

TECHNOLOGY DEVELOPMENT

- › Waste pre-treatment (upwash)
- › Pyrolysis, gasification, dissolution and chemolysis
- › Various polymers, plastic mix streams, biomass streams
- › Experience with fixed bed, fluid bed and screw reactor technology for conversion of feedstock



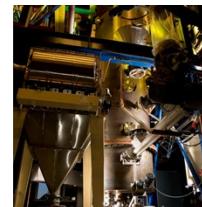
Dissolution



Screw reactor



Bubbling fluidized bed



Indirect fluidized bed



Polystyrene



Refuse derived fuel (RDF)



Packaging foils

4. DISSOLUTION AT TNO

EXAMPLES

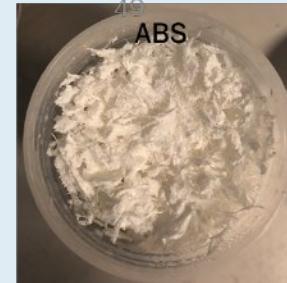
Purification of polymers Multi-layered materials

2/3-layer film packaging



Removal of additives from multi-material engineering plastics

WEEE plastics



Carpet, Sports turf



PP-GF

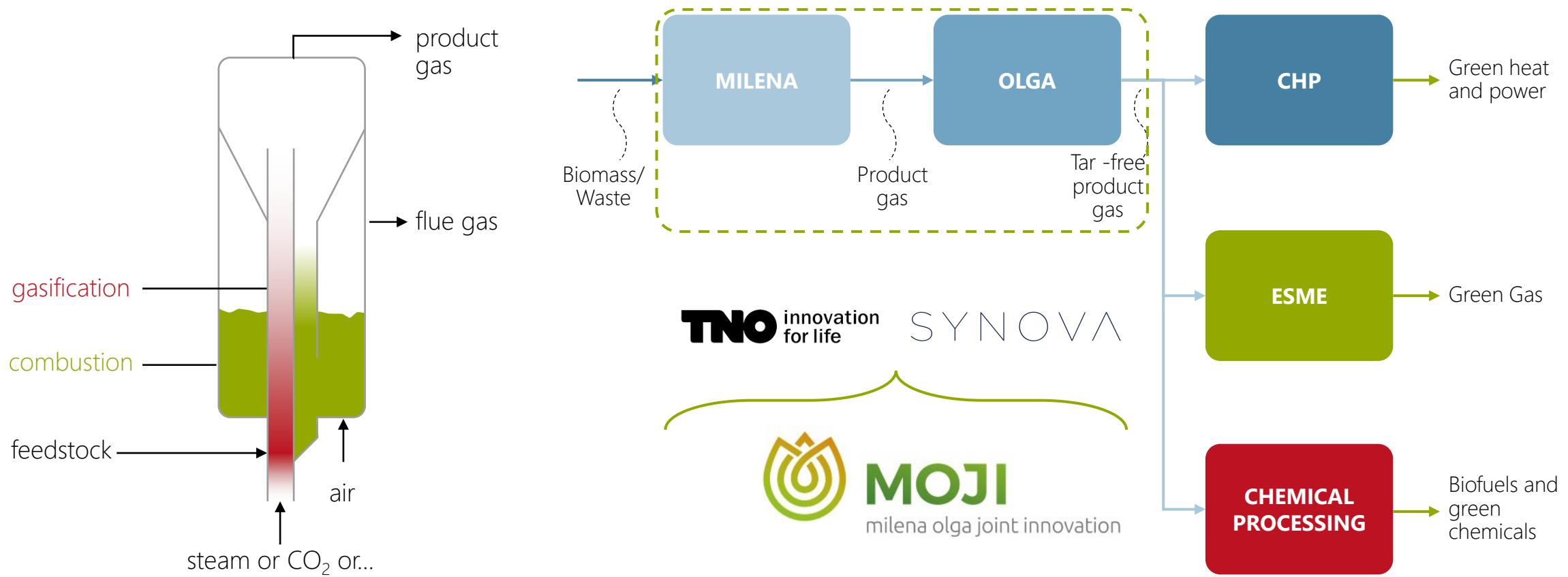


HIPS/ABS

PC

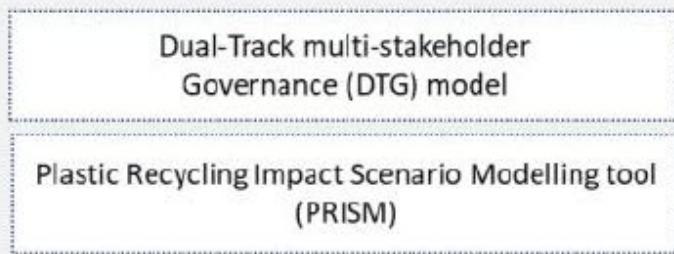
4. THERMAL CRACKING

A PLATFORM TECHNOLOGY FOR ENERGY AND CHEMICALS



SYSCHEMIQ

1. Fact-based scenario driven Governance for systemic transition



2. MPW Recycling Quality (RQ) standards

Assess composition of MPW streams in trilateral region and define potential for high quality MPW streams

Define RQ sorting standards for MR and CR

3. New sorting solutions and processes

Cities and citizens engagement ('nudging experiments')

Design new sorting line configuration with RQ software

4. Design for and from recycling

Mechanical Recycling Q-requirements

Chemical Recycling Q-requirements



This Project has received funding from the European Union's Horizon 2020 Research and Innovation Programme under Grant Agreement N. 821087



Testing in 4kT/a pilot scale MR plant

Testing in 18kT/a Commercial CR demo plant

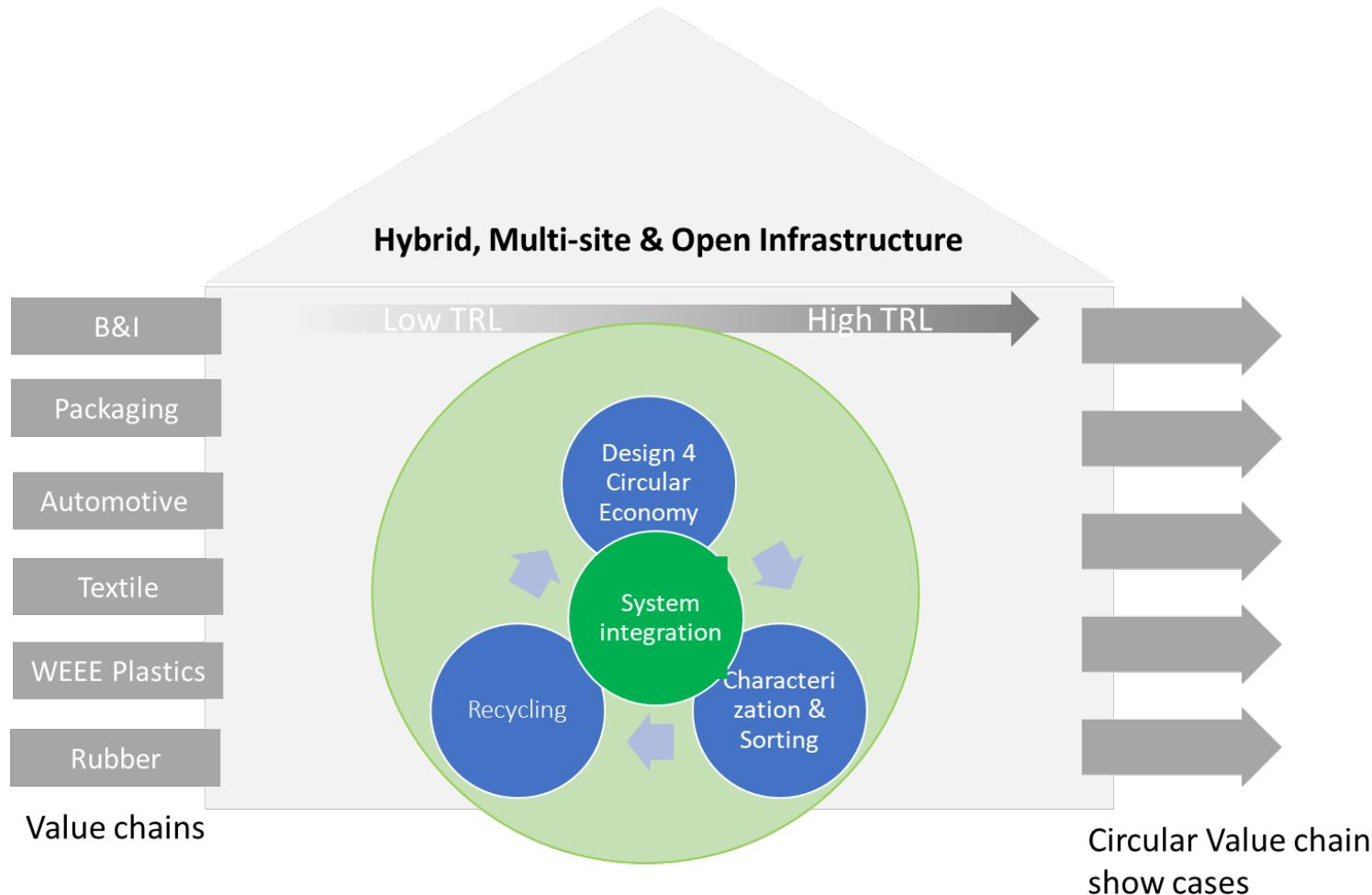


Optimal MR vrs CR trade-off



This project is under grant agreement preparation to receive funding from the Horizon Europe Research and Innovation Programme

› 220 MILLION EURO FOR CIRCULAR PLASTICS IN NL COFUNDED BY INDUSTRY TO 530 MILLION



Circular Value Show Cases

1. Circularity of HDPE rigids
2. Circularity of PP rigids
3. Circularity of LDPE/LLDPE
4. Plastics circularity i.r.t. thermochemical recycling
5. Circularity of PET trays
6. Circularity of Polycondensates/cotton from textile
7. Circularity of carpets
8. Styrenics from WEEE (PS, HiPS, ABS)
9. PC from WEEE/automotive
10. PUR
11. Rubber

SUMMARY

TNO'S APPROACH & EXPERTISE CIRCULAR PLASTICS



1. System integration, value chain design and Life Cycle Assessment

- Multilevel circular (plastic) economy modelling & Scenario analysis (PRISM)
- Impact Assessments (LCA, LCC, TEA, true costing...)



2. Design for circularity

- “Circular packaging” at Brightlands Material Center
- Polymer durability



3. Sorting & Washing

- “Systems engineering” approach to connect waste, technologies & product requirements
- Sorting & pre-treatment for mechanical and chemical recycling
- Technology development: upwash – upgrading of sorted plastics through washing



4. Recycling

- Technology development: plasma, dissolution, depolymerization
- Thermal cracking, pyrolysis, gasification



5. Microplastics

- Source, fate & effect analysis (formation, release, exposure, impact)
- Focal areas: packaging, tyres, textile



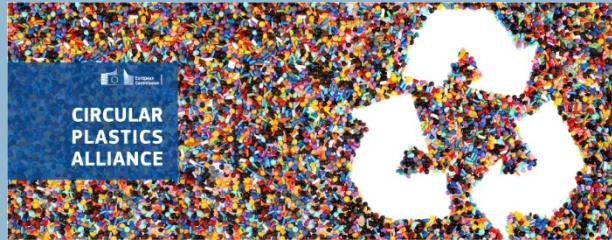
6. Analysis, Characterization & interpretation

- State-of-the-art laboratory, methodology & technology development
- Material degradation
- Expertise on polymer, composites and additives

› TNO IS EMBEDDED IN RELEVANT (INTER)NATIONAL CIRCULAR ECONOMY NETWORKS

EXTERNAL MEMBERSHIPS

European



National (NL)

Transition Team Plastics Netherlands

Missie C



Regional



ACKNOWLEDGED EXPERIENCE WITH LARGE & COMPLEX COLLABORATIONS (INTER)NATIONAL, WITH INDUSTRY AND RESEARCH ORGANIZATIONS

Brightsite
Transforming industry



PLAST2bCLEANED



MUCIPACK



NTCP nationaal testcentrum circulaire plastics

SYNOVA
RENEWABLE TECHNOLOGY

MOJI
milena olga joint innovation

INREP

Alma
ADVANCED LIGHT MATERIALS

cimpa

PRIMA



› MORE INFORMATION CIRCULAR PLASTICS TNO:



WEBSITE:

<https://www.tno.nl/plastics>

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