Van plastic afval naar nieuwe chemische producten?

NPT webinar 30-03-22

Sprekers:

1. Jean-Paul Lange: Sr. Principal Research Scientist bij Shell & Professor in Chemical Bioraffinage aan de Universiteit Twente
2. Vincent Toepoel: Directeur en mede-eigenaar van Waste4Me
3. Jan Noordegraaf: Directeur Innograaf BV

KIVI Engineering Society

NPT Nederlandse Procestechnologen

KNCV mensen • meningen • moleculen

PLASTIC CIRCULARITY

Jean-Paul Lange

Shell Global Solutions International B.V.
Univ. Twente, NL

March 30, 2022

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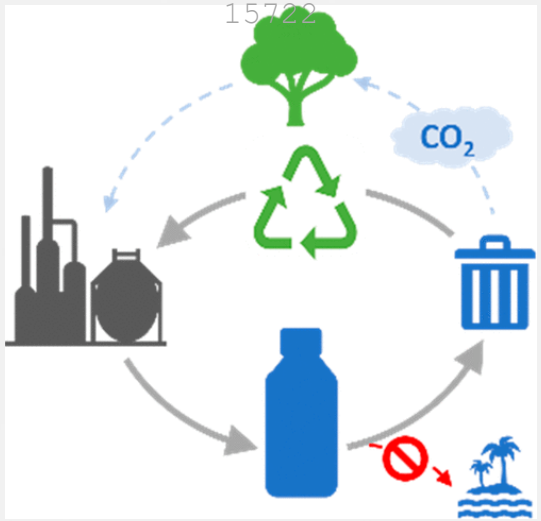

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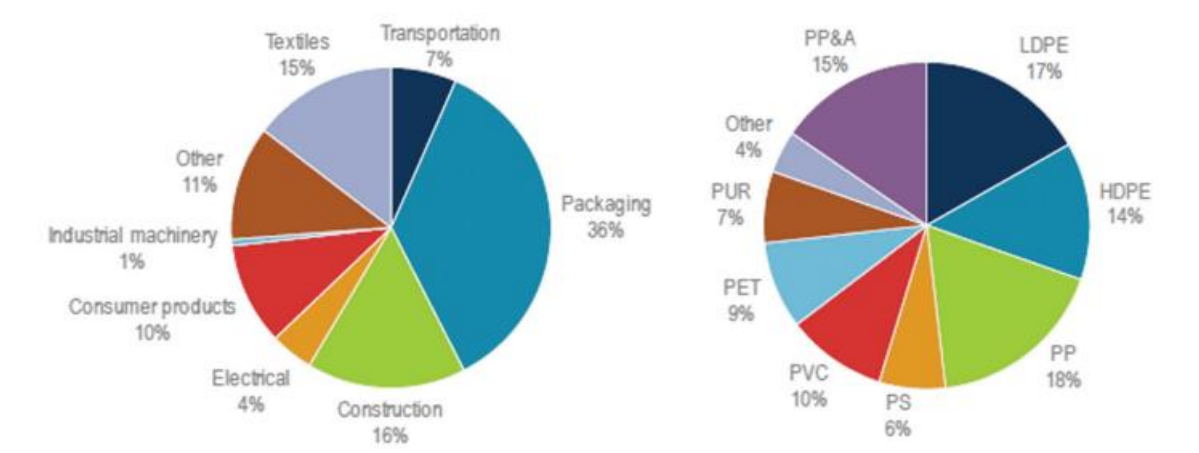
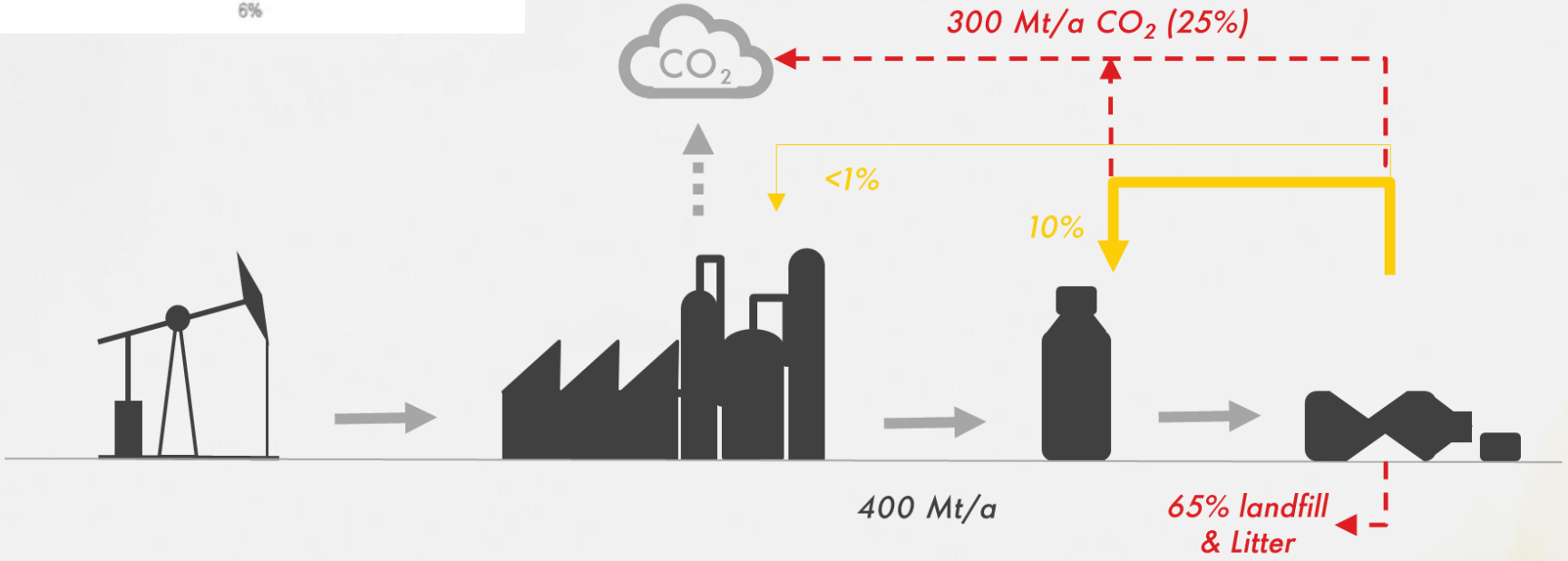
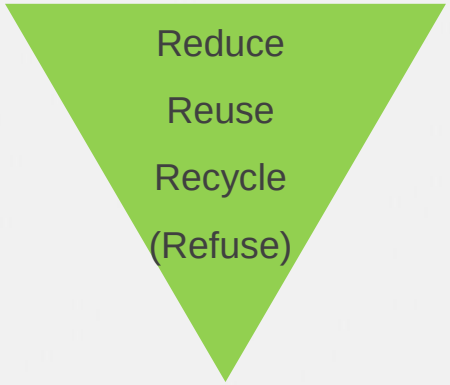
The world of plastics

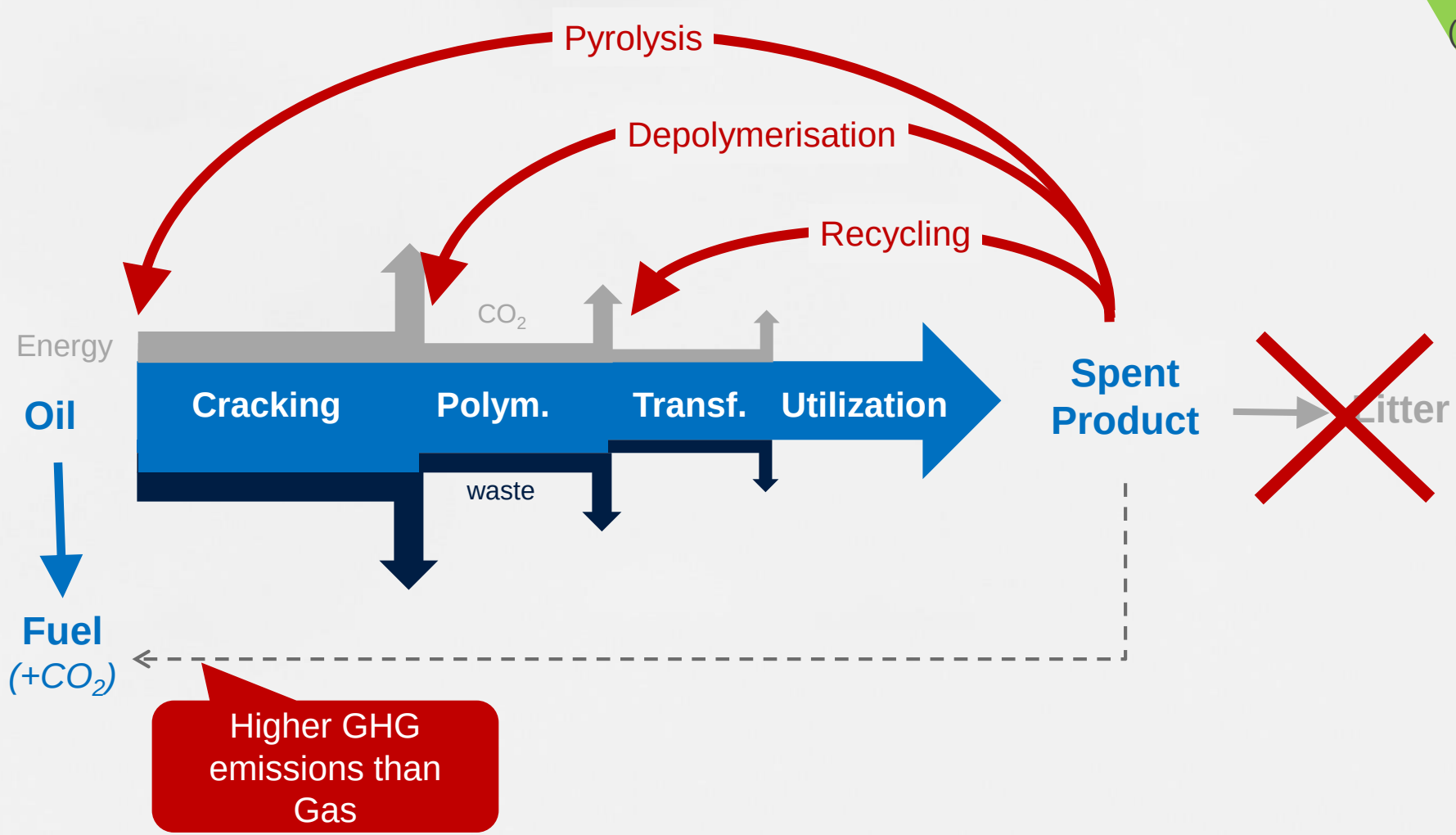


Source: IEA (2018)



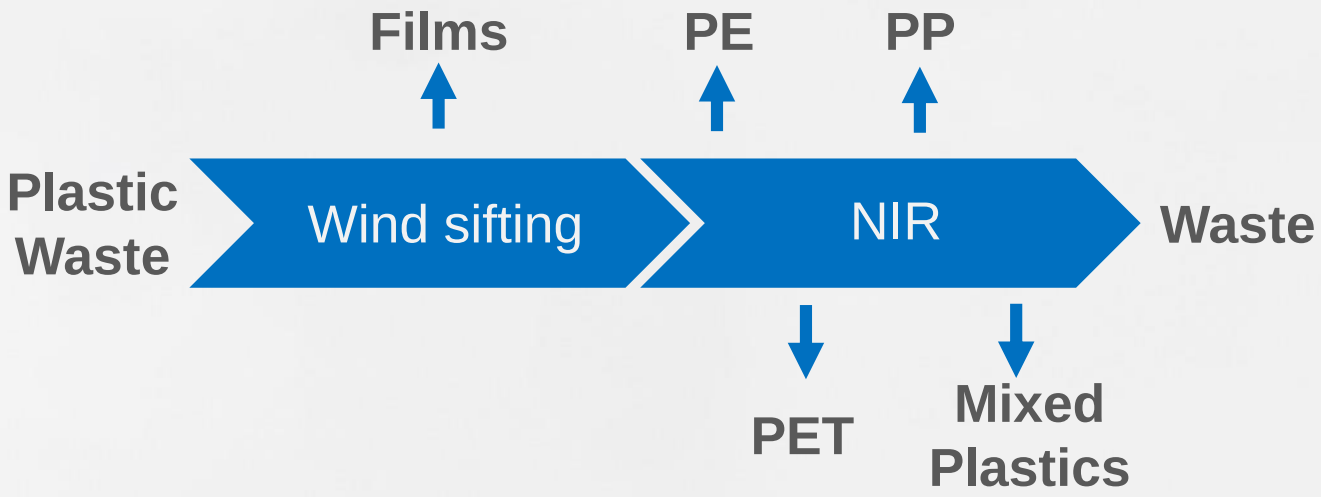
Circularity – Waste management

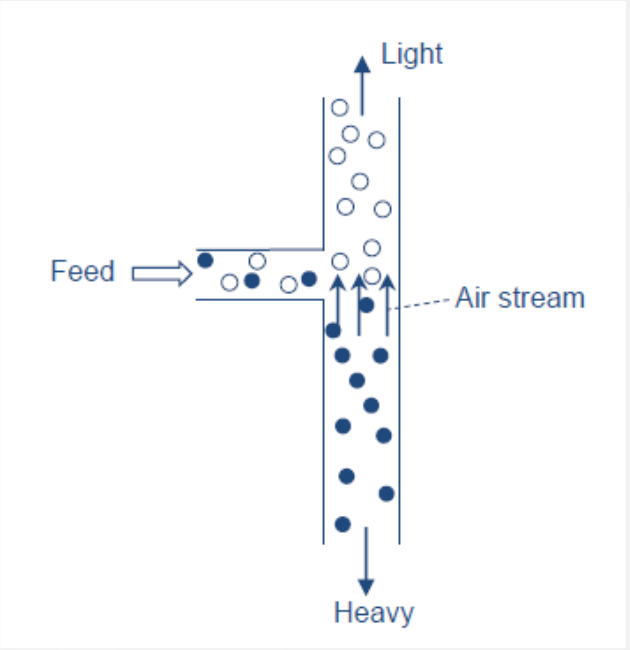


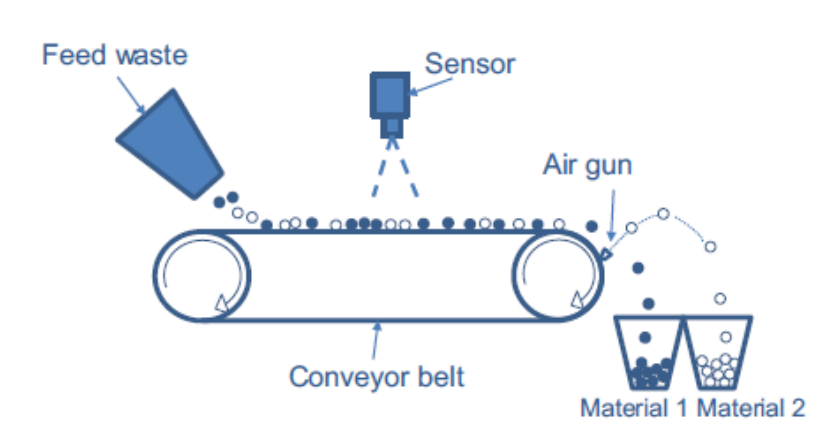


Lange, Green Chemistry 2002, 4, 546

Recycling - Plastic Sorting





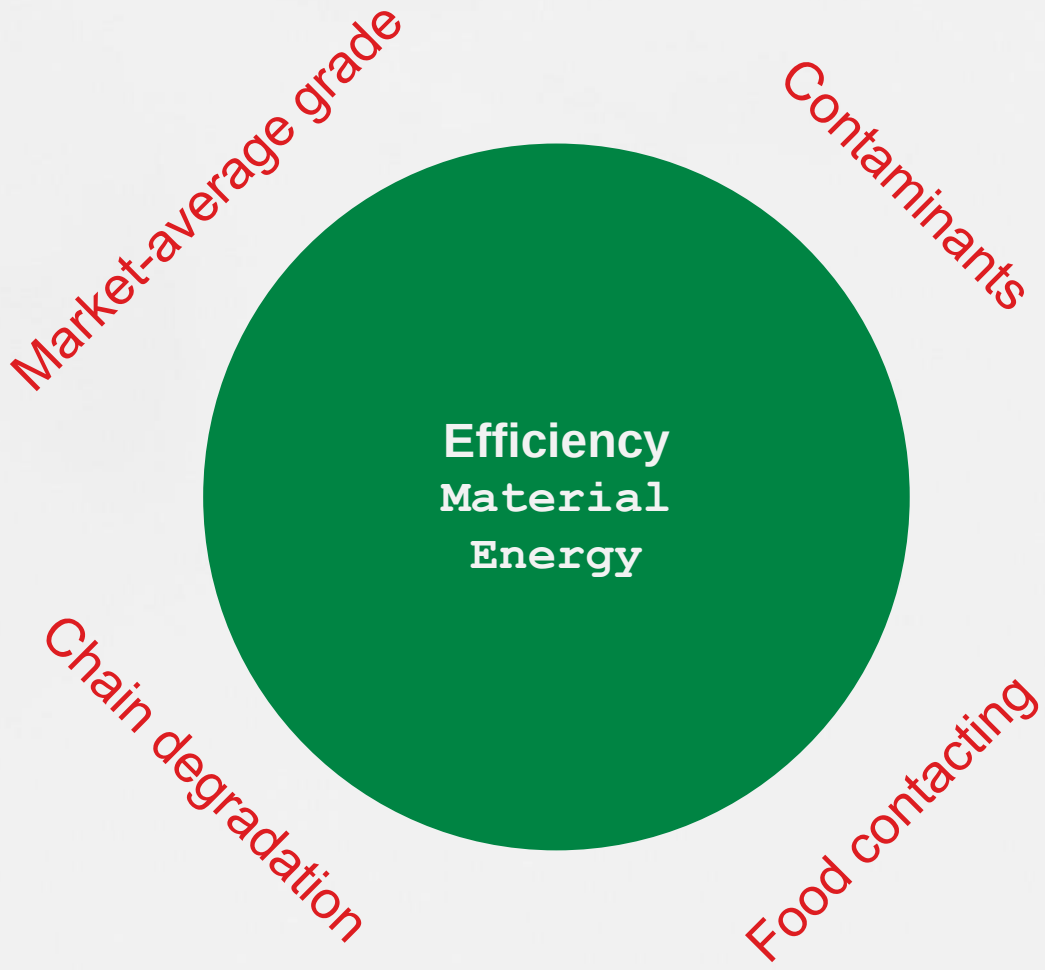


New Technologies

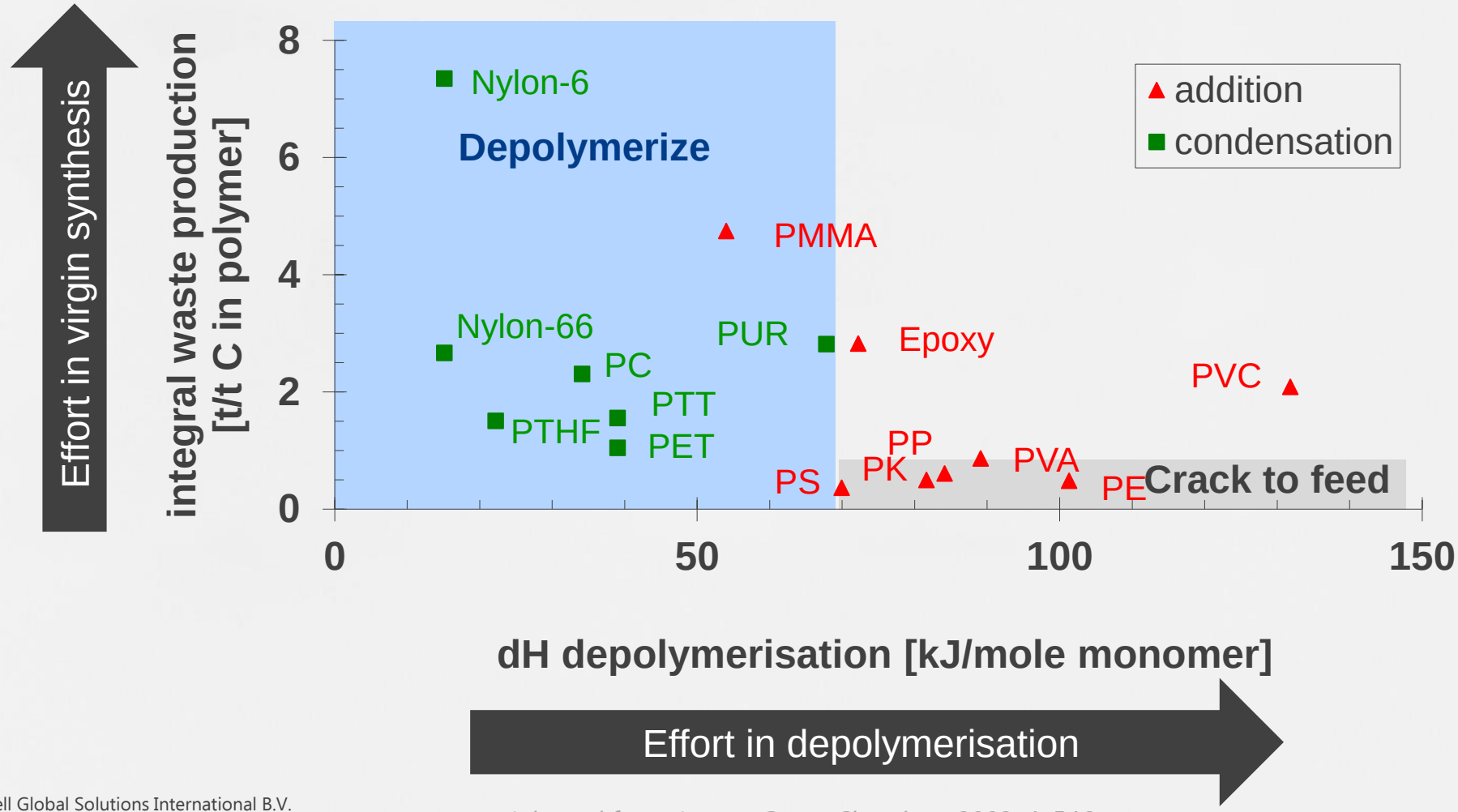
- Watermarks
- Fluorescent pigments
- Hyperspectral imaging
- AI

Serranti; Use of Recycled Plastics in Eco-efficient Concrete; Elsevier, 2019.

Mechanical Recycling – strengths & weaknesses

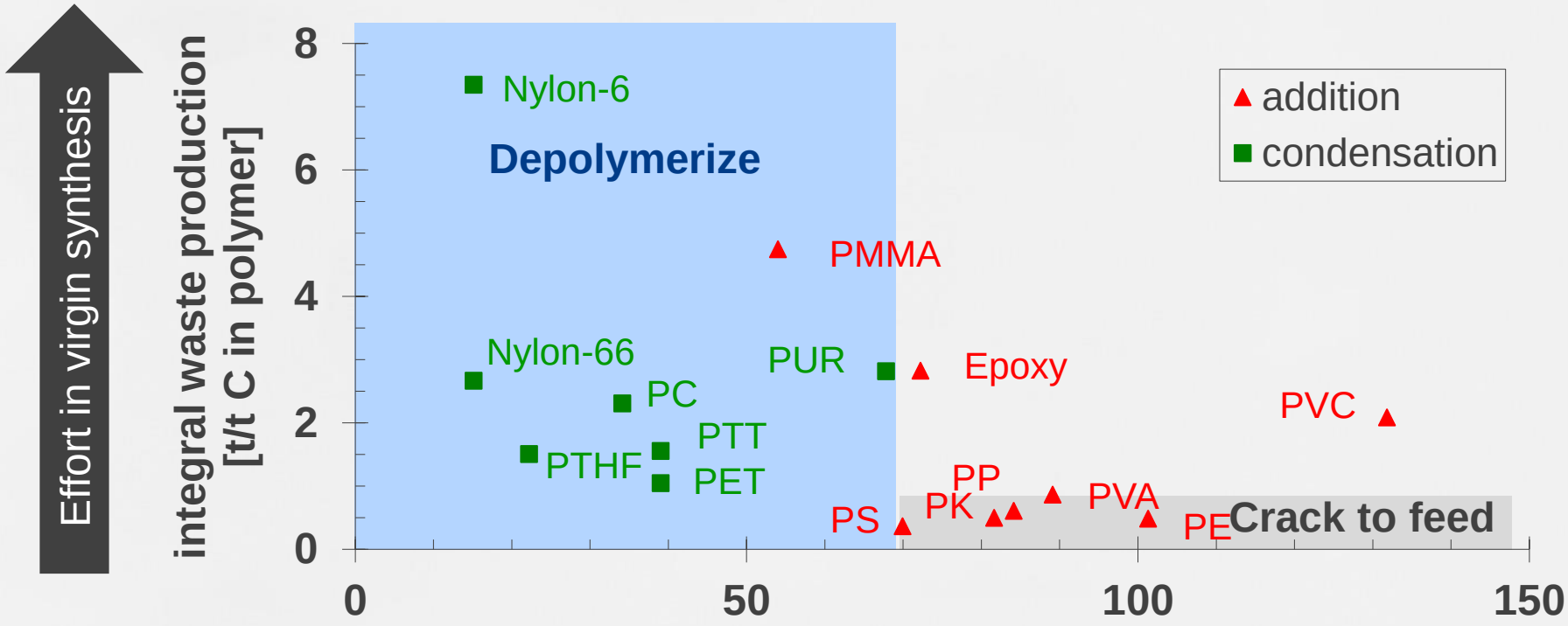


Advanced recycling – Back to monomer or to feedstock?



Adapted from: Lange, Green Chemistry 2002, 4, 546

Advanced recycling – Back to monomer or to feedstock?



But contaminants still matter !

Adapted from: Lange, Green Chemistry 2002, 4, 546

Conclusions

- **Plastic Recycling is ready to take off …**
  - Sorting
  - Mechanical Recycling
  - Advanced Recycling

- **… but will need fresh renewable Carbon input**
  - Biomass
  - Atmospheric CO_2

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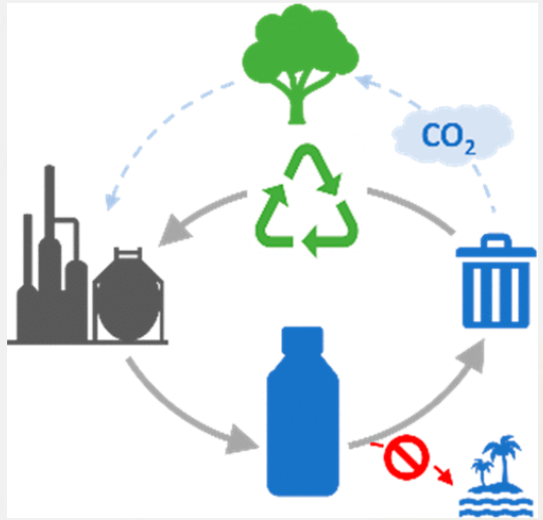

Webinar

CHEMICAL RECYCLING OF END-OF-LIFE PLASTICS

WASTE 4ME®

POWERING THE FUTURE WITH WASTE FROM THE PAST

waste4me.com

About Waste4ME

Ministerie van Economische Zaken

Provincie Noord-Brabant

OPZuid
Europees Innovatieprogramma Zuid-Nederland

EUROPESE UNIE
Europees Fonds voor Regionale Ontwikkeling
Mede gefinancierd in het kader van de respons van de Unie op de COVID-19-pandemie.

2010 Defense Innovation Competition

2013 Waste4ME BV incorporated

2015 Finish demo plant

2016 Joining Pyrolysis Cluster Moerdijk

2019 Demonstration plant operational in Moerdijk

2020 Certification under ISO9001 & 14001 + registered waste handler

2020 Full cases proven

2021 team is made of 17 people

2021 Funded PyroCHEM park and joined Horizon2020 Frontsh1p

About Waste4ME: Technology

WASTE 4ME®

POWERING THE FUTURE WITH WASTE FROM THE PAST

Pyrolysis process applied

WASTE 4ME®
POWERING THE FUTURE WITH WASTE FROM THE PAST

- Slow pyrolysis at high temperature [650°C]
- Residence time of 30 to 90 minutes depending on the type of material
- Necessary heat for start up is provided by burning propane
- Use a small amount of the formed (syn)gas to provide the process with heat, switching from propane to syngas
- Excess gas is flared off but can be applied for other purposes
- The pilot can process 50 – 150 kg/hour depending on the composition of the waste
- Why Pyrolysis: suitable for non-recyclable mainly PE-PP plastic based flows

Pilot Plant (50 to 150Kg capacity)

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Technical Challenges

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- Output quality (Oil and gas) depends on Input quality of the material/feedstock, meaning deviations in consistency occurs
- Chemical and mechanical pollutants:
  - how to tackle the issue and take them both out prior to pyrolysis as well as for post-processing (oil upgrading, gas separation…)
- The Waste Framework Directive does not provide clear support for End-of-Waste status characteristics:
  - Thus, claiming the output as secondary raw material proves to be tough
- Sustainability analysis for hotspots determination, improvements through LCA and complying with National waste management plan:
  - helps for ISCC+ and Environmental management but
  - How to prove our point?

Technical Challenges

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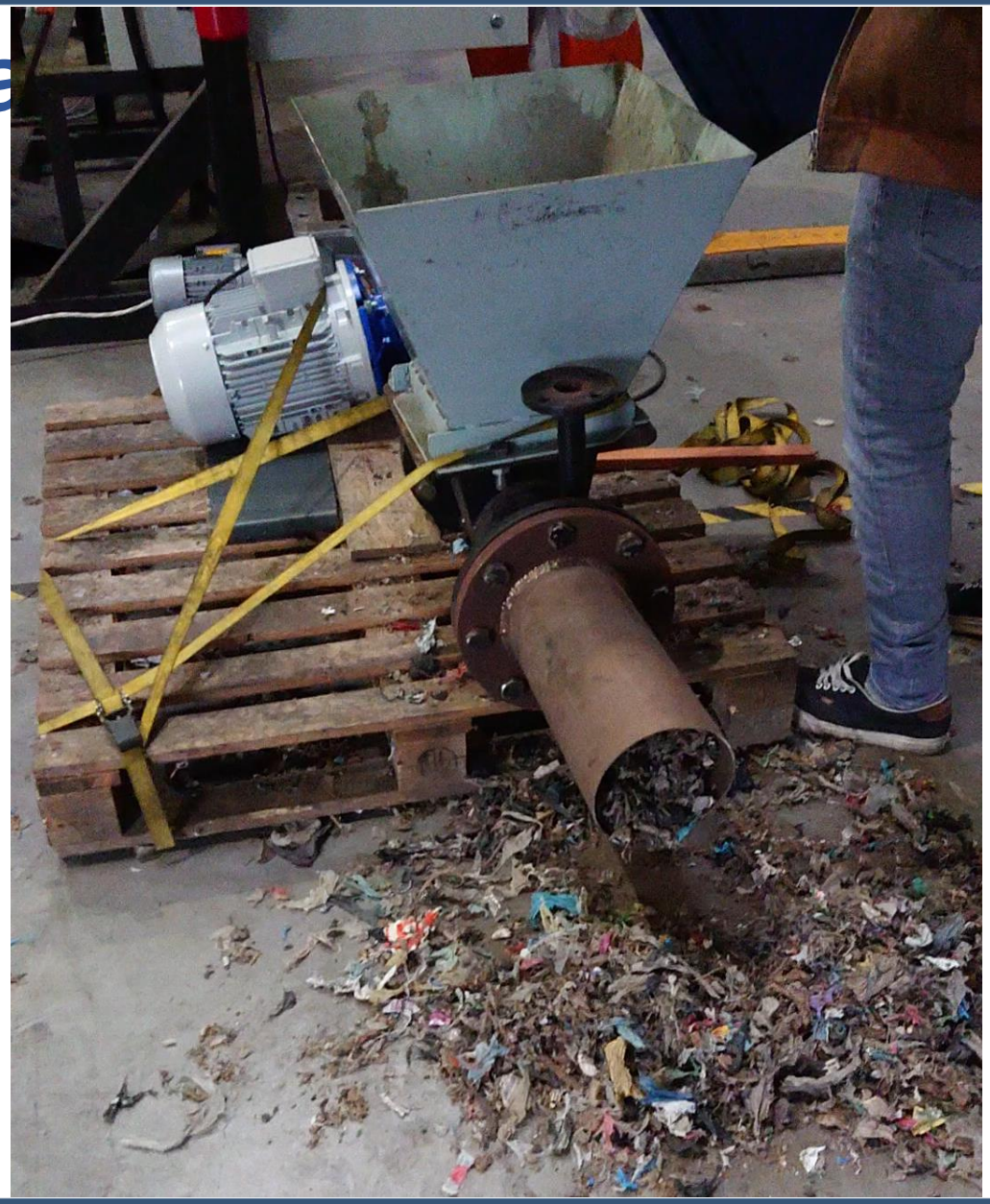
Technical Cha



WASTE 4ME®

POWERING THE FUTURE WITH WASTE FROM THE PAST

Solution Directions and Ideas

Pre-treatment and Mechanical Handling

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- Combination with a pre-treatment plant for recyclate production and mono-streams storage for operation at capacity
  - After which we build recipes for the WER Unit, so we can tweak specs and control our quality range in the output products

- Mechanical handling:
  - compressed feeding
  - Melting and de-chlorination project
    - Aims at preheating/melting the input material while capturing Chlorine gasses prior to pyrolysis
  - Ash and char particles have to be taken out to prevent spreading throughout our pyrolysis system

Solution Directions and Ideas

Process Optimization

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- Absorption of Chlorine and Sulfur through catalysts
- Water quality issues:
  - Engineering and implementation of our own water treatment plant for water recirculation and emission reduction
- Heavy Fraction Return:
  - To prevent clogging
  - ash spread through the system and fouling
  - further cracking of undesirable long-chain hydrocarbons
- Inline distillation in stages
  - Enables the basic purification step

Solution Directions and Ideas

Process Optimization

WASTE 4ME®
POWERING THE FUTURE WITH WASTE FROM THE PAST

Open Questions

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1. How to compress feed large flows without rotary valve?

2. How to take out organic pollutants from the oil, Chlorine, Nitrogen and Oxygen?

NPT webinar

Van plastic afval naar nieuwe chemische producten?

Jan Noordegraaf

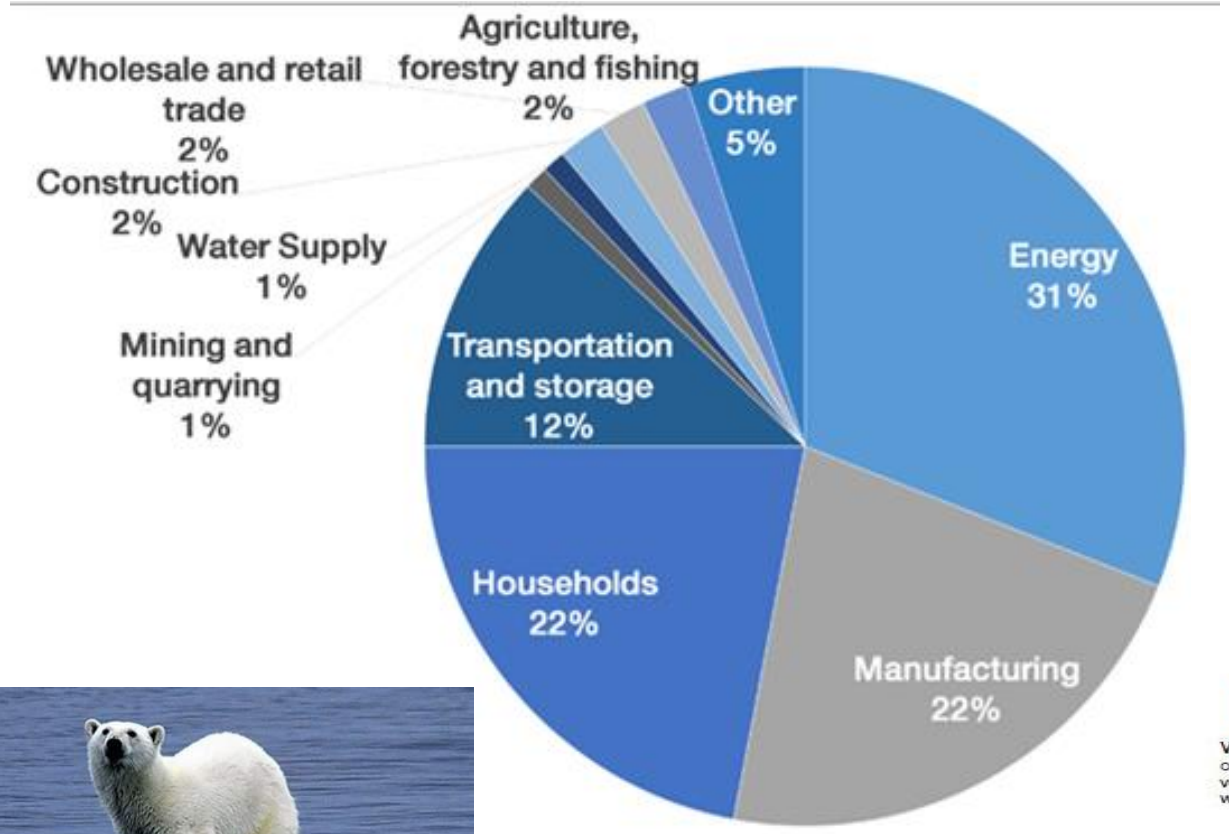
www.INNOGRAAF.com

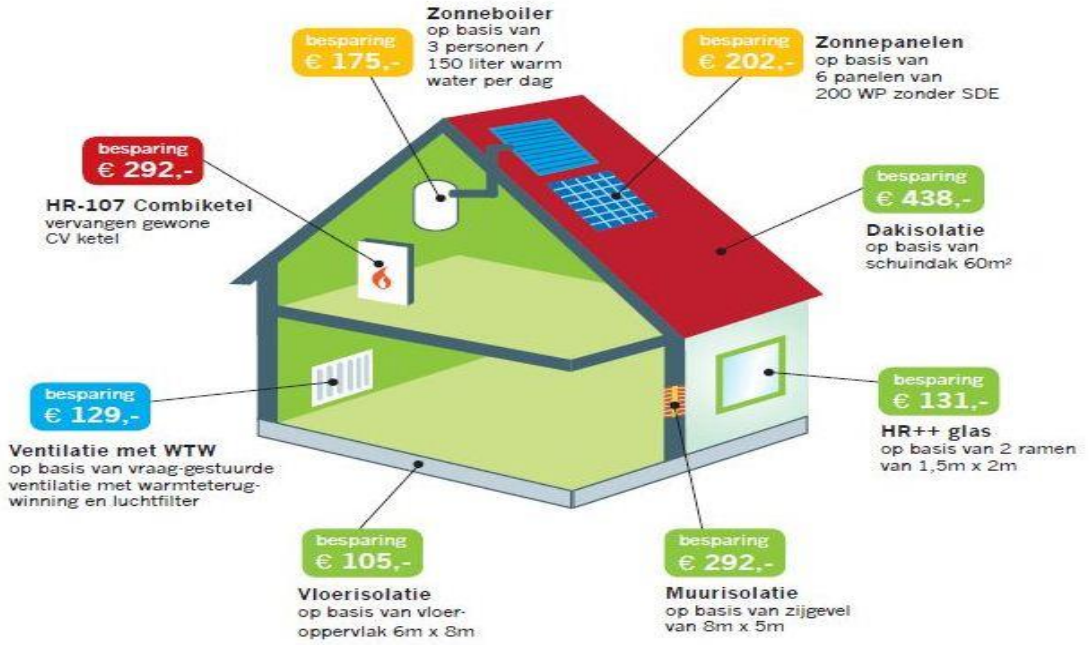
Innograaf bv

- Support for value chain cooperation and application of sustainable processes and materials.

- **Innograaf B.V.** assisting companies to make a transition to sustainable materials.
  - Co-founder and lead in Recycling Cooperative PolyStyreneLoop UA (NL/EU)
  - Lead in circular economy scale up projects (NL)
  - Biobased infill project (FL)
  - Biobased foam development (USA)
  - Disposable production equipment toward new materials (NL)
  - Cap Closures Company (USA/B)
  - Cellulose foaming consortium (NL)
- Board member of the Dutch plastics and Rubber Federation NRK (Bio-Based)

The grand picture:sources of CO2 insulation reduces emission

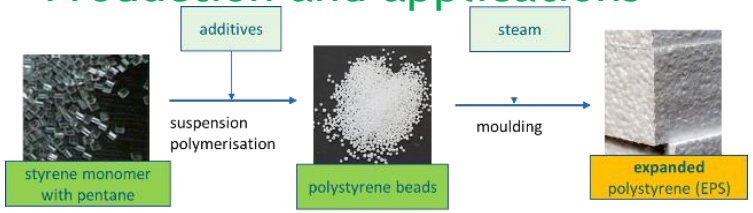




EPS and XPS is fire retarded

EPS
Production

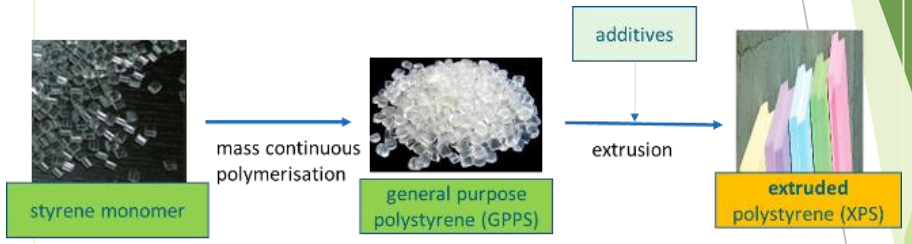
- Production and applications



- Building and Construction applications
- Density: 15-20 kg/m³

▸Used in foundation formwork, flooring, walls and facades, roofs as well as ground and waterworks

XPS
Production



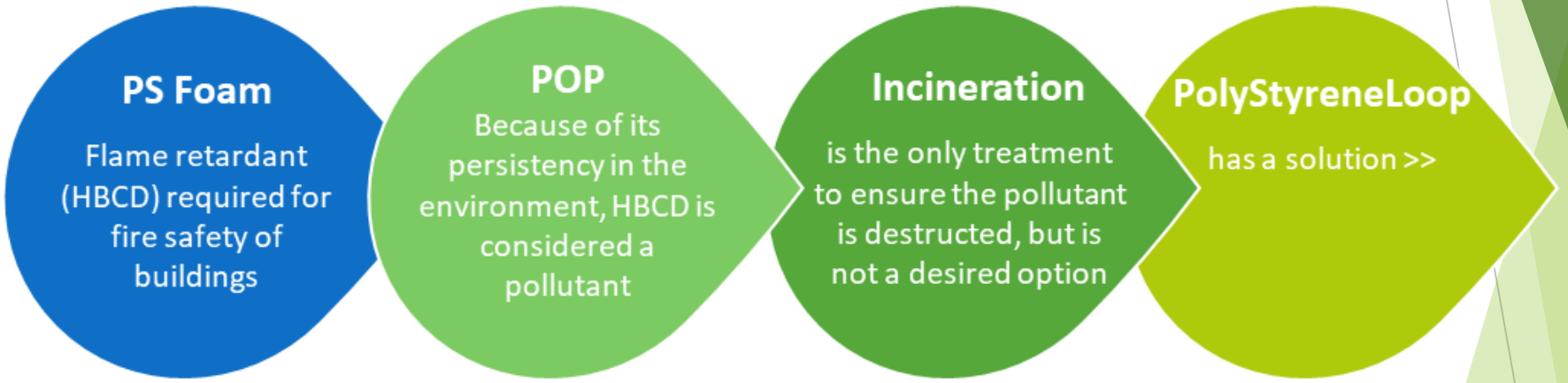
Building and Construction applications

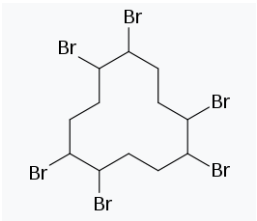
Density: 30-60 kg/m³

Mainly used in perimeter insulation, flooring and roofs

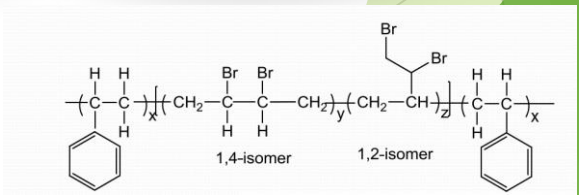
Context

- The historic development

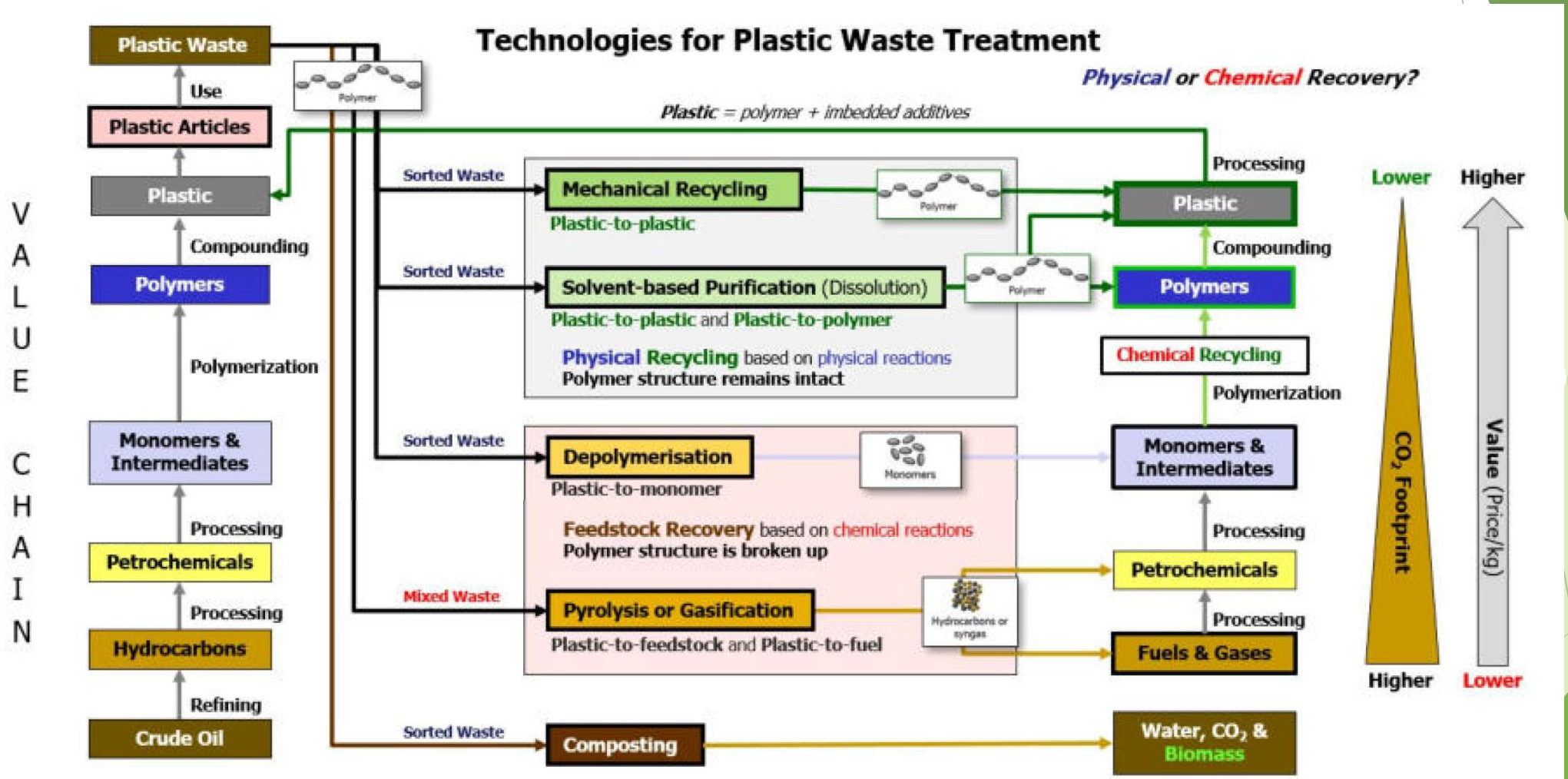




HBCD ---------- aug 2015 ---------- Polymeric FR

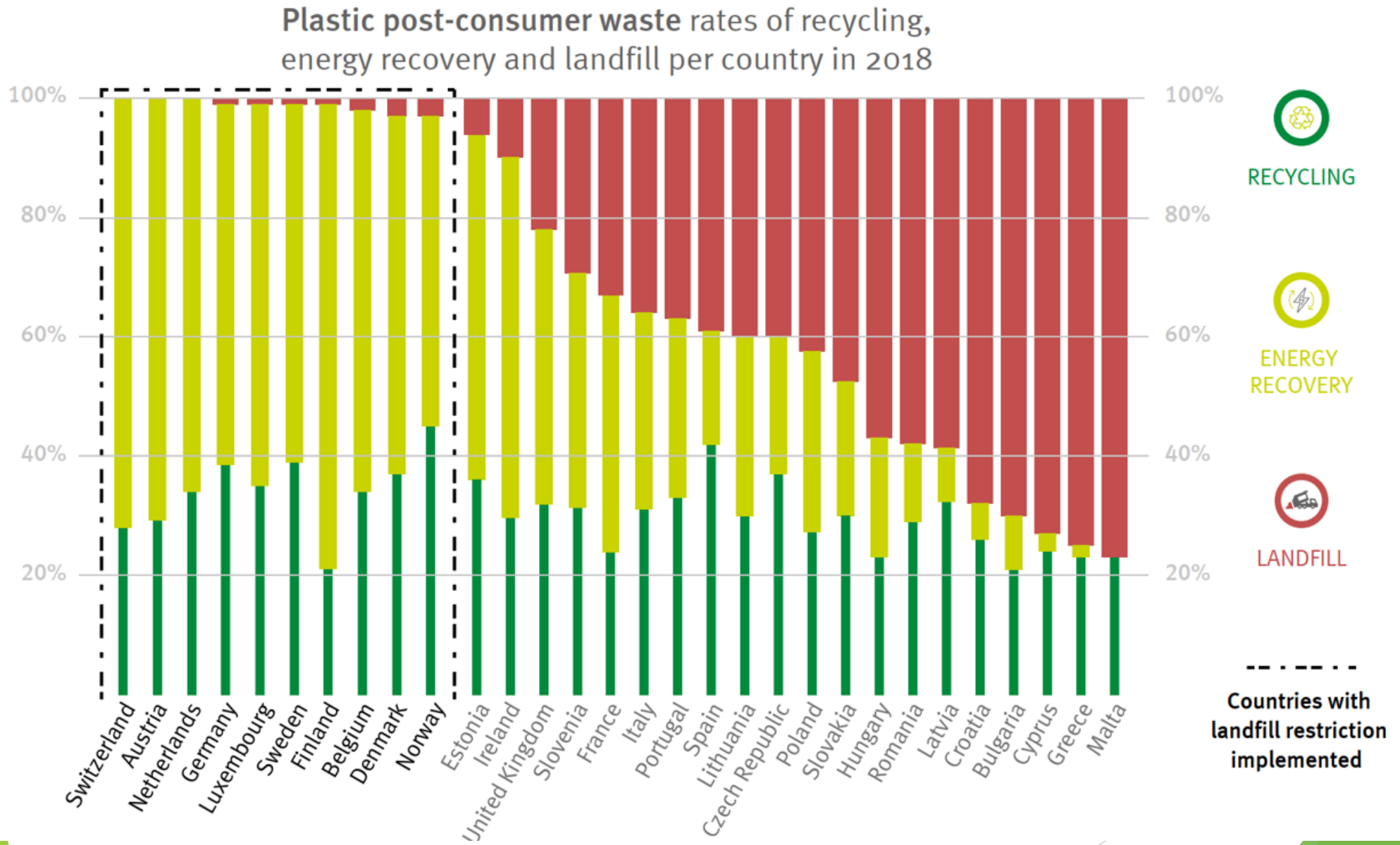


Chemical recycling | Mechanical recycling



SBP : Only solution for halogen containing feedstock

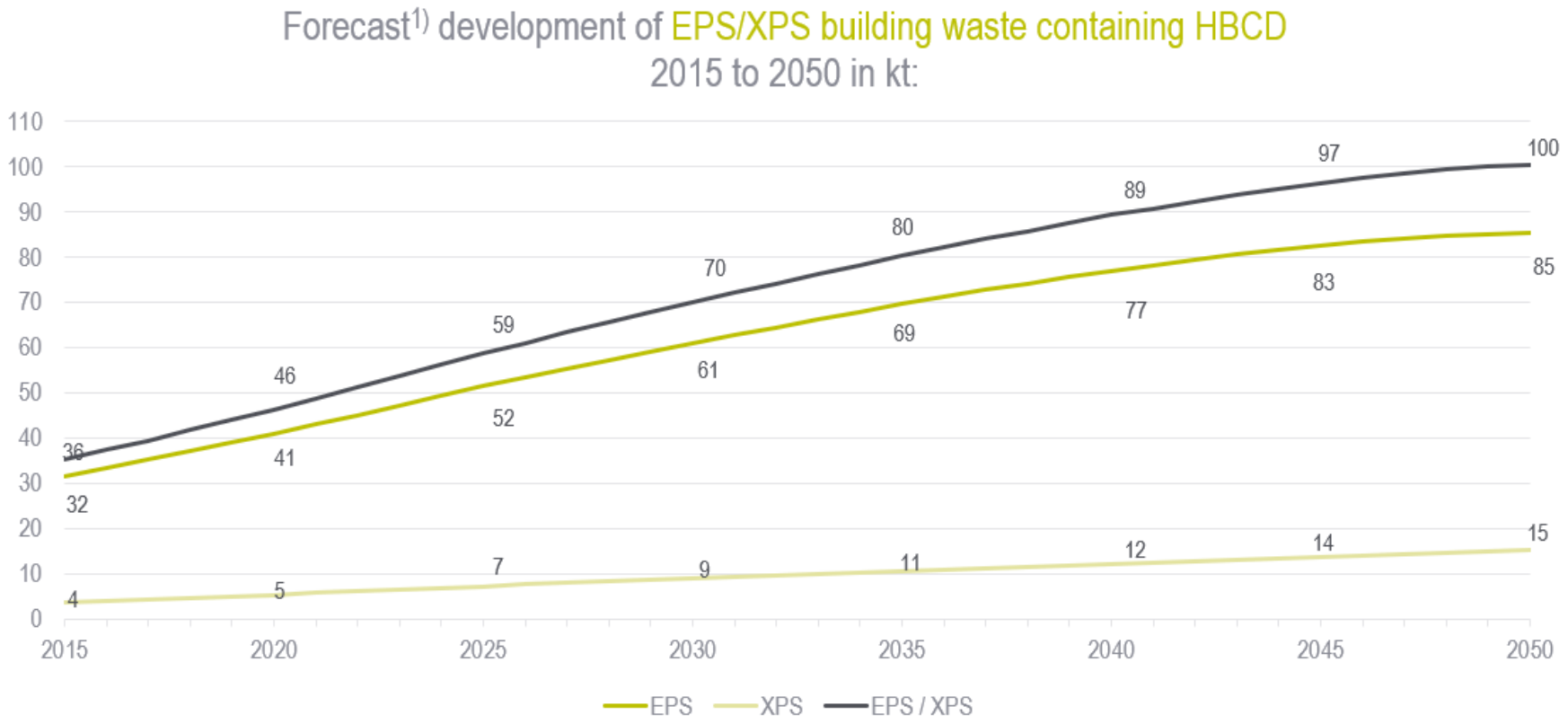
Recycling rates in the EU



EPS demolition waste

- EPS/XPS BUILDING WASTE WITH HBCD IN GERMANY

- How much material is there?



1) Forecast is based on a stable economic development, without political measures in the building sector

Conversio. (2017, August 2017). Generation and Management of EPS and XPS Waste in 2016 in Germany in the Packaging and Building Industries.

The PolyStyreneLoop cooperative

In a nutshell

Coop and B.V. Organisation

founded by Synbra Technology and ICL

Focus

joint commitment to
Circular Economy by
European Styrenics industry

Goal

building and operation of a demoplant,
further implementation of process all over Europe
Upop Basel : UTC< 100 ppm HBCD

Members

industry representatives of the
whole PS foam value chain

PS-foam and Bromine recycling

- FROM DEMOLITION SITE TO RECOVERING BROMINE AND POLYSTYRENE

- Closing the loops

2. Compaction

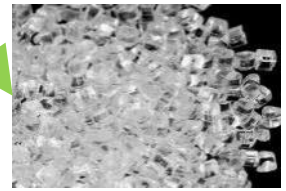
1. Demolition

3. PS-foam is being treated in the PolyStyreneLoop demonstration plant in Terneuzen, Netherlands

4. HBCD-sludge is being treated in the Bromine Recovery Unit, safely destructing HBCD

35
Br
Bromine
79.904

4.1 Bromine is reovered and can be used in new flame retardants (Poly-FR)



5. From PS-foam new GPPS is made

5.1 GPPS can be used for new XPS or X-EPS

PolyStyreneLoop in the political context

VOLUNTARY PLEDGE BY THE EUROPEAN MANUFACTURERS OF EPS (EUMEPS)

- EU Circular Plastics Alliance

Object	Polymer	Baseline	Pledge	Quantities 2025 (estimates)		Quality	New Technologies involved
				Market	Recycle		
Insulated Packaging (e.g. fish boxes)	EPS	Conversio Study 2017	50 %	140,000	70,000	High quality EPS	Food grade quality potential (EPS SURE)
Protective Packaging (e.g. appliances)	EPS	Conversio Study 2017	50 %	230,000	115,000	Standard EPS	
Building Deconstruction	FR-EPS EPS	Estimated 2025 market	27 %	150,000	40,000	High quality EPS	PolyStreneLoop – HBCD removal and recycling of bromine and chemical recycling.
New build and renovation	FR-EPS EPS	Conversio Study 2017	80 %	40,000	32,000	Standard EPS	
Civil Engineering New build and Deconstruction	EPS		90 %				
TOTAL			**46 %**	**560,000**	**257,000**		

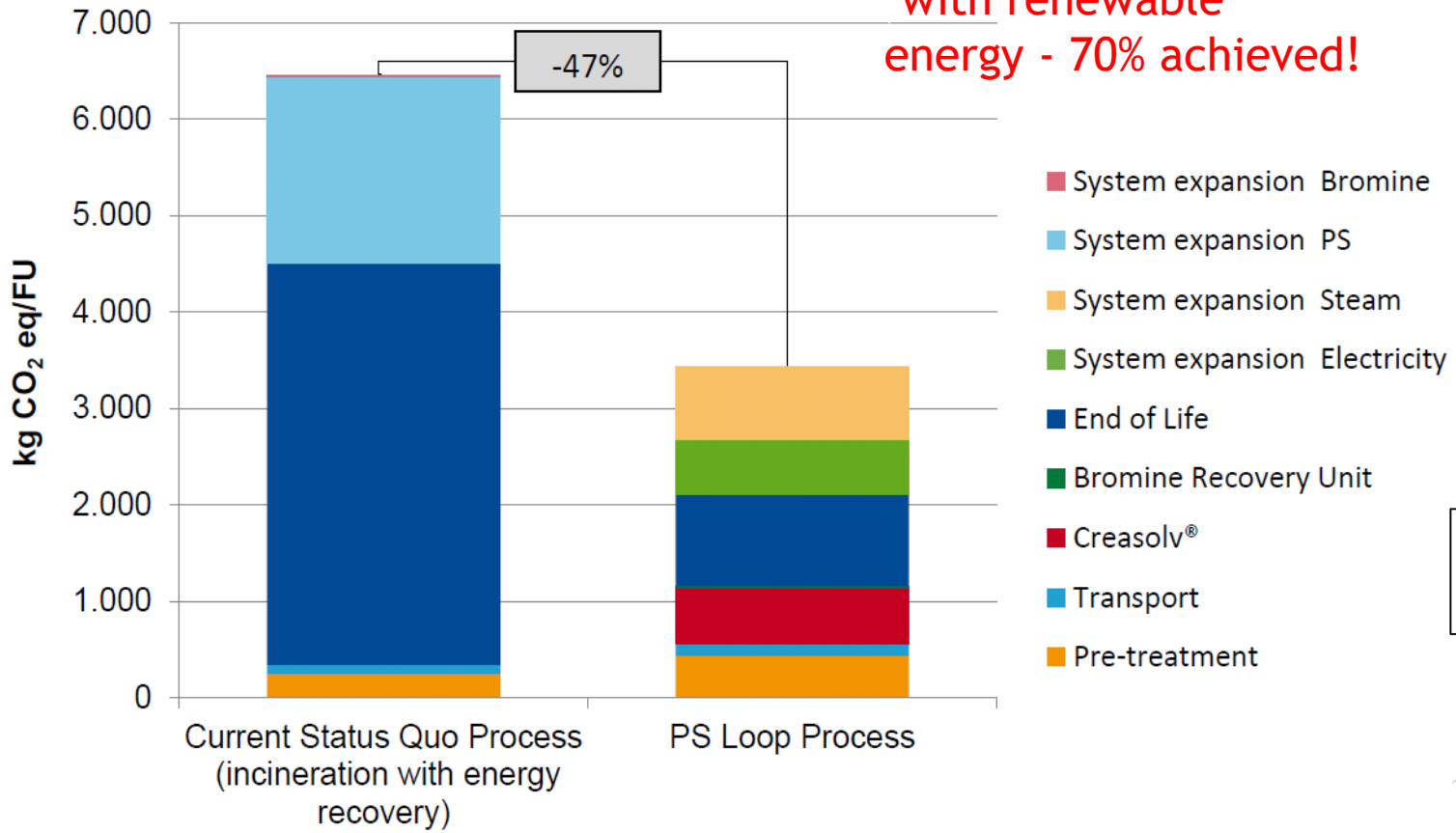
FR = Flame Retarded

Favourable Environmental benefits

- END OF LIFE TREATMENT OF EXPANDED POLYSTYRENE (EPS) FROM
- EXTERNAL THERMAL INSULATION COMPOSITE SYSTEMS (ETICS)

- Life Cycle Assessment

with renewable energy - 70% achieved!



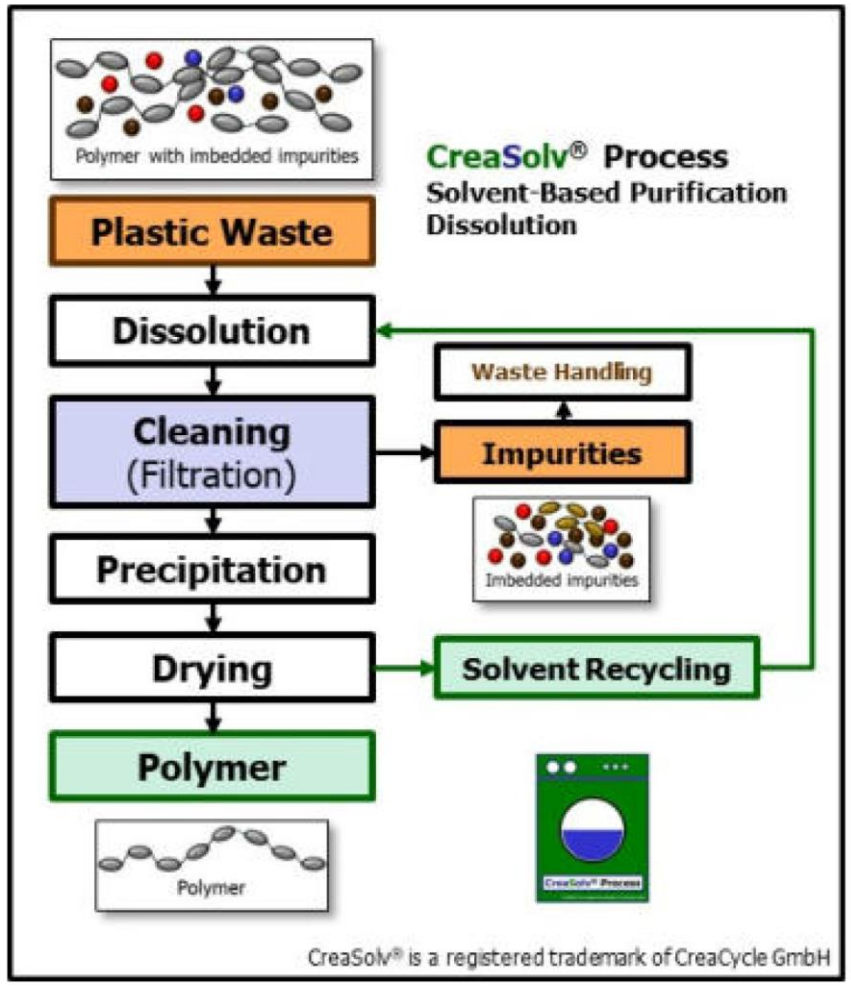
TÜVRheinland®
Precisely Right.

TüV Rheinland (2018, January 22). Life Cycle Assessment for End of Life Treatment of Expanded PolySryrene (EPS) from External Thermal Insulation Composite Systems (ETICS)

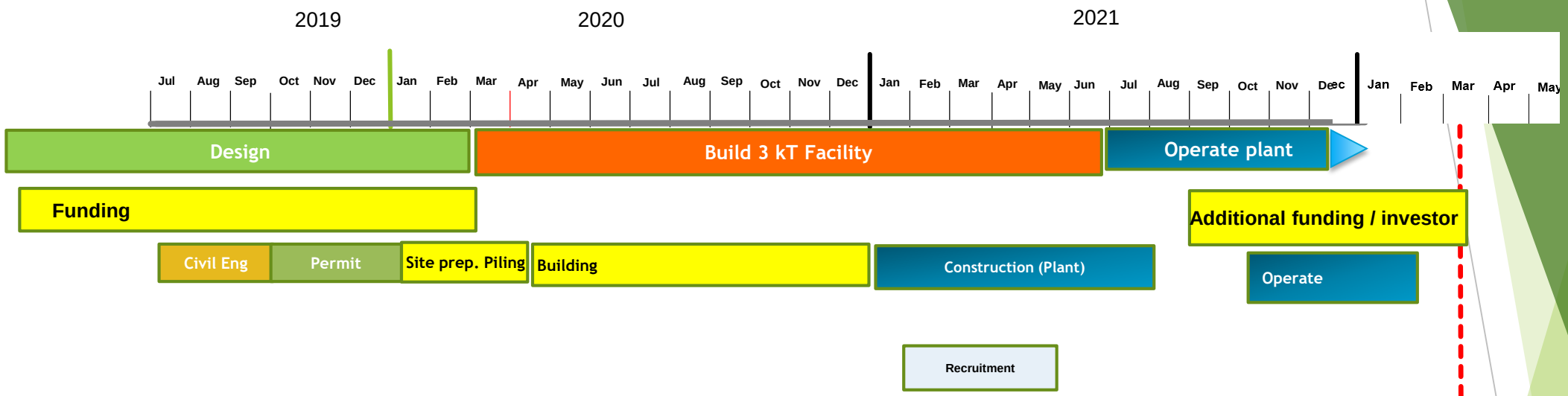
Demoplant : The Technology works

First Loop-PS in the demoplant oct-2021

- DISSOLUTION -PURIFICATION RECYCLING …



Execution of Project | Not budgeted issues



Steel price

PAS (N2) permit issue

COVID

supply of equipment delays

PFOS (soil)

Energy price explosion

Debottlenecking oil heating

- Model created to set up a true value chain cooperation

Time line 1 entities and deliverables

- 2014-2015 Started with a Foundation under Dutch law
  - Raised funds for basic engineering
  - Applied for an EU LIFE grant subsidising the circular economy
- 2017 Created PolystyreneLoop Coöperatief UA
  - Statutes
  - Membership agreements Verified compliance with anti trust EU legislation
  - Weigthed Voting (using Dutch cooperative experience)
  - FTO study /Infringement
  - Negociating bank loans 5mil€
- 2017 Created PolystyreneLoop BV

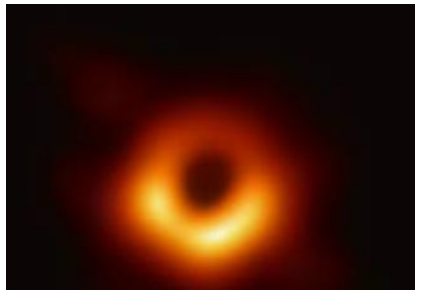
Time line 2 Funding

- 2017-2019 base Funding 5,0 mil€ plus 2,5 mil€ top funding
- All banks use same spreadsheet model

- Top financing only via a very limited amount of special funds
- Need Deloitte Corporate financing memorandum @ 30k€ (2x)
- 2019 Negociating additional top investment loans 2,5mil€
- Covid Briginbg Loan 2021 via Impuls Zeeland
- End 2021 investor sought to take over plant

Time line 3 Top Funding

Many funds use Black Hole Management



- Participated in Versnellingstafel XXL
- Many funds provincial / special sector but not circular economy
- Triodos , ASR etc. no funds
- Approached brokers that would charge 300€/hr &, no guarantees

POLAR STAR Capital Partners

- Polarstar 18% interest

INVESTNL

- Invest NL via Versnellingstafel XXL contact too early,
- Later no funds availbale,
- Then later only as indirect investor

Nationaal Groenfonds

- 2019: Succeeded with 8% intrest

INFINITY RECYCLING

- 2021/22 Infinity recycling ,started in 2019 Fund not open until March 22)

Time line 4 not budgetetd items

- Construction

National policy; in 2018 decided to be natural gas free, full electic CO2 neutral plant (wind powered)

More expensive unit operations

Plant modification during installation

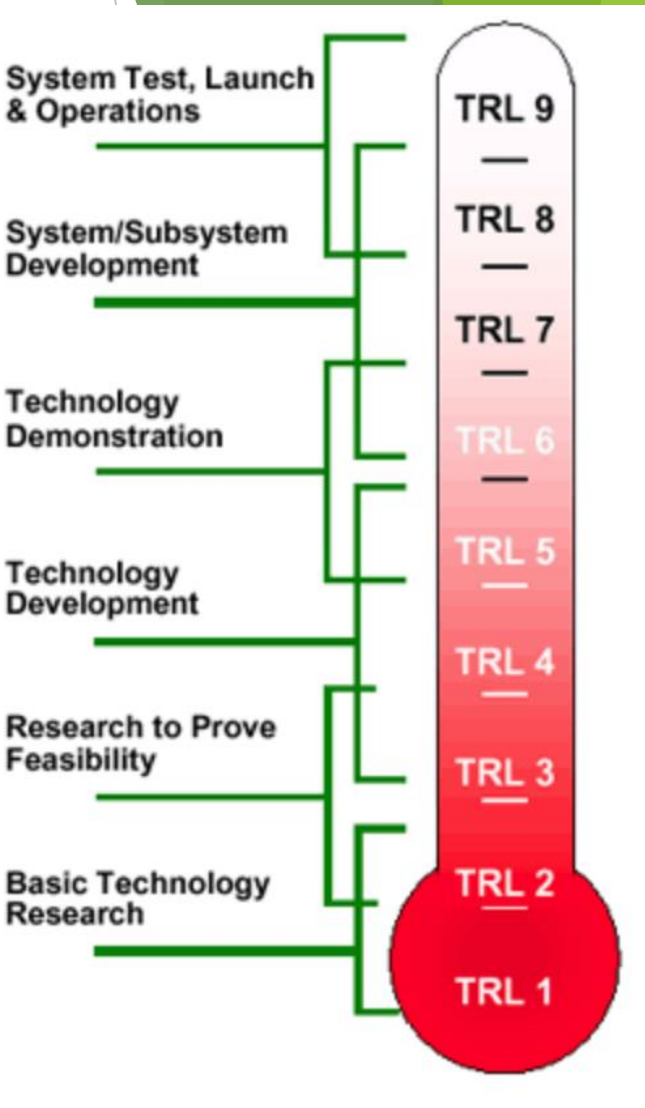
End of 2019 **Steel prices** -steel and stainless steel, copper cables

PAS (N2)	Consequences for final permit application
Covid-19	Delays and non supply- new suppliers <-> Covid bridging Loan (COL) 1,3 mil€
PFOS	Cost increase to remove excavated soil 5k€-> 75k€
Staffing ,	For recycling and non fossil industry , many young talents can be attracted
Insurance(s)	Mandatory for banks , but Impossible for companies that are in recycling branche
	Solution, become process industry; producing prime polymers (SBI code)
	Extensive support needed from specialist broker
	cost 20 0/00 on CAPEX ; 200k€/a , well over budget
Energy cost ,	end 2020 For a new plant 100% exposure to free market , cost increase 700%
	Opex from 300k€-> 2,5 mil€ , end- users not prepared to accept price index on energy

Time line 5 TRL-itus

TRL-itus is an industry wide phenomenon. Higher TRL numbers claimed than can be realised

- **Despite HAZOPS and FMEA's :**
  - Process engineers chronically under-estimated proces complexity
  - e.g. effects of (very) long residence times in case of start up issues
  - Contingency for start up delays too low,
    - Banks do not want to understand that techology/equipment can fail
- **Feedstock / Waste Incoming specs vs design**
  - Incoming specs Tolerance for incoming impurities 10% (m/m)
  - Experienced 20-80% impurities including water
- **Feedstock / Waste**
  - Poor packing/ spillage
    - Solution leveraged fee, higher more for better quality pacakaging
  - Suppliers claim inability to measure and control feedstock
    - Solution appoint circular economy manger that visits the source



Time line 6, lessons learned Process design

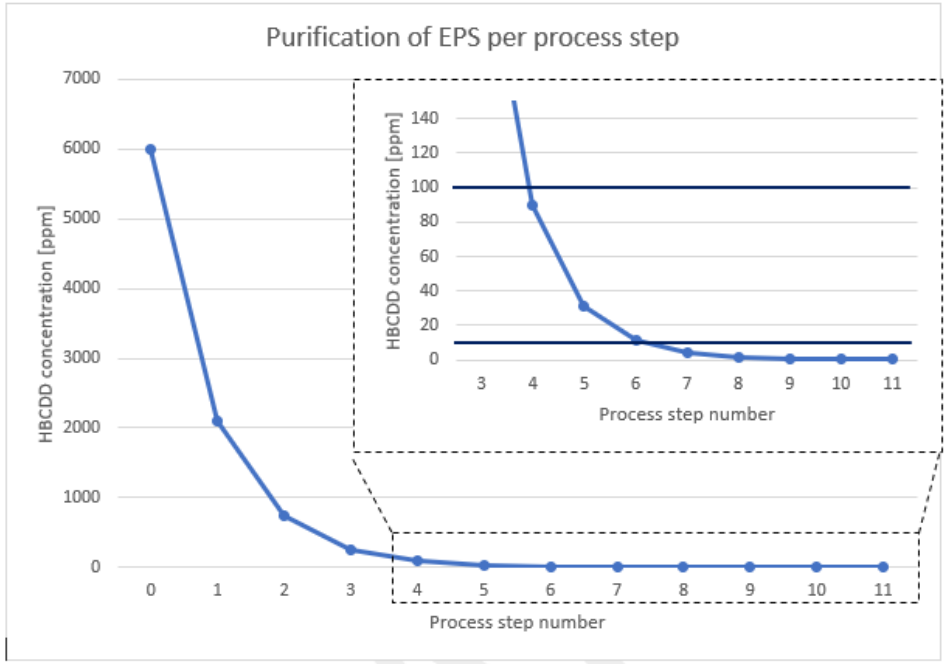
- **EU Legislation** intended to change
  - UTC form 100 ppm to 10 ppm
  - Instead of 4 steps purification 7/8 needed , and
  - Analytical detection 3*sigma 45-50 ppm

- Too wet PS did not dissolve fast enough in solvent :-> polarity
- Processing Hansen **solubility parameters** not fully anticipated

- **Waste composition** surpise: next to HBCD also the new pFR present
  - PFR stays with PS, only HBCD is extracted
  - Needs use of Acid scavenger <-> well understood technology , but implementation :time and €

- **Dryer** needed for wet feedstock
- In process **Solvent recyling** – more equipment needed.

- Additional 3-500k€ Capex needed (not foreseen)



The production of a purified EPS foam at 99.99% requires four purification steps (from 6000 ppm to below 100 ppm HBCDD). To reach a purity of 99.999% (from 100 ppm to below 10 ppm HBCDD), three additional process steps would be necessary. In this example, 7 instead of 4 steps would be necessary, which would roughly translate into an effort/cost increase of roughly 75%. In reality, i.e. outside of the bounds of this simplified model, the purification efficiency per process step will decrease as the delta between the concentration of HBCDD in the material and the solvent decreases.

Lessons learned 7 (last slide)

- From design phase to execution 100% more expensive process

A bucketfull of Bad luck

  - Covid, PAS, PFOS, Energy price
- Process contingency
  - Effects of residence time and mishaps underestimated
  - Proces engineers not inventive enough to pre-empt process challenges
  - Capex need identified during start up <-> no funding possible
- IP: High emphasis on licencing and fees
- Private investors are greedy , look too much for high returns and IP
- Equity no loans
  - Organisation: A cooperative is complex
  - Interest rates and mandatory early repayment of loans is killing

- Cause of bankruptcy: Investor had no funds yet: banks would not provide bridging credit, offer to buy company withdrawn by investor.
- Curator now looks for restart

DISCUSSIE

Voor meer content:
https://www.kivi.nl/afdelingen/nederlandse-procestechnologen

KIVI Engineering Society

NPT Nederlandse Procestechnologen

KNCV mensen • meningen • moleculen