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Sulzer GTC Technology

Chemical Recycling of Plastics: Coming Full Circle

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Technologies That Make a Difference – Now and in the Future

ARTC

The safe harbor statement under the US private securities litigation reform act 1995

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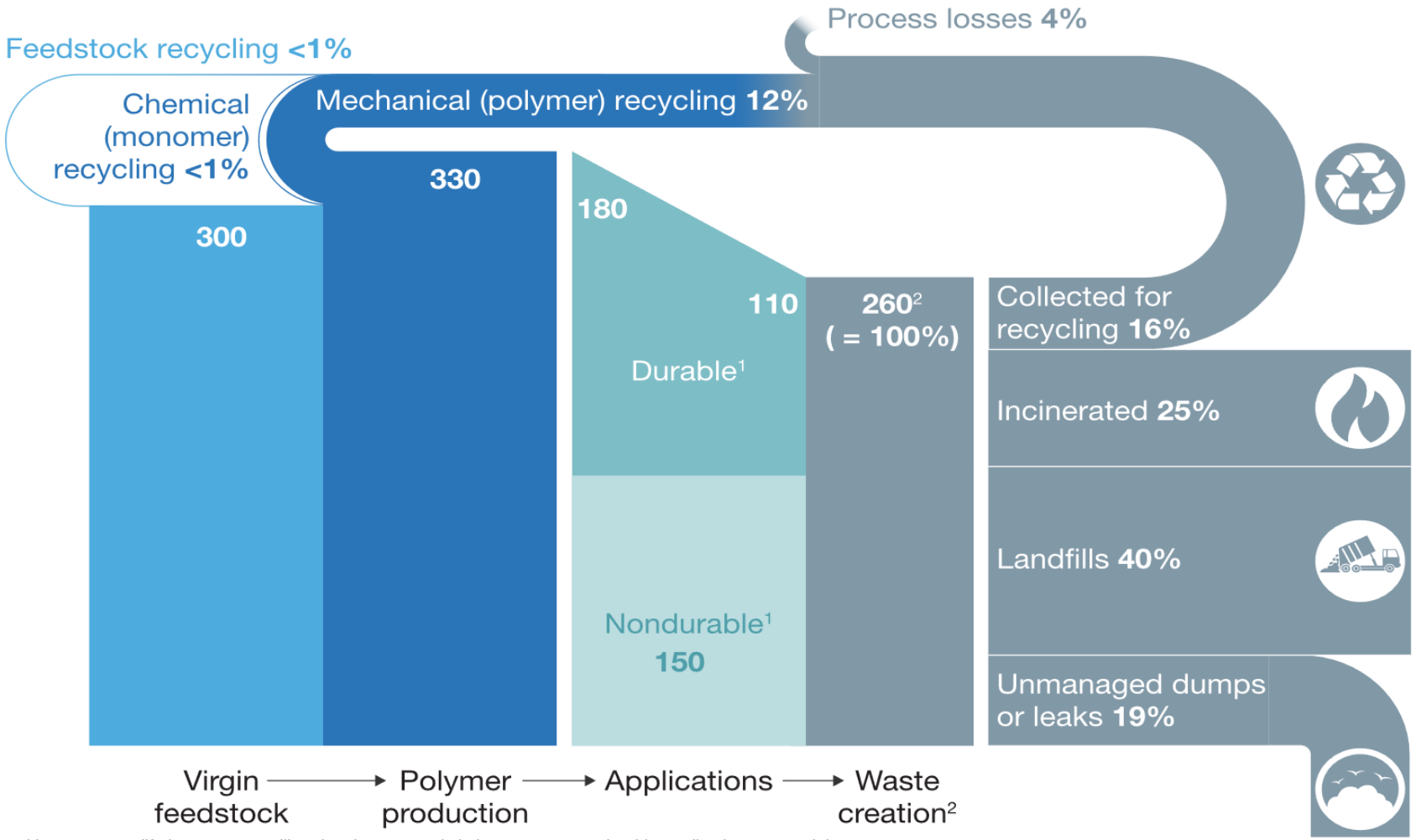
Global plastics flows

- Global polymer flows: Millions of metric tonnes per annum 2016



1. Durable applications with an average lifetime > 1 year will end up in waste only in later years; non-durable applications go straight to waste.

2. 150 million metric tons of mixed plastc waste from non-durable applications that end up as waste in same year plus 110 million metric tons of mixed plastic waste from previous years.

Source: McKinsey

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Legislative & brand-owner push

- Legislation, taxes and brand-owner commitments drive the change to higher recycling rates
- In Europe first plastic tax in place (€800 per ton for non-recycled plastics)

GROUPE RENAULT

Groupe Renault has signed the French government's Circular Economy Roadmap, which focuses on moving towards a 100% plastic recycling rate in France by 2025.

As a carmaker, we must limit the environmental footprint of our products and activities as much as possible in order to address the issues of global warming, air quality and the increasing scarcity of natural resources. It is with this in mind that via our automobile business, we have just given the French government reaffirmation of our goal to increase our overall use of recycled plastics by 50% from 2013, or 64,000 tons for all of Groupe Renault

JEAN-DENIS CURT
Head of the Circular Economy Division at Groupe Renault

12 RESPONSIBLE CONSUMPTION AND PRODUCTION
13 CLIMATE ACTION
14 LIFE BELOW WATER

VOLVO

25% recyclable plastics in every car by **2025**

P&G

100% of packaging reusable/recyclable by 2030

DANONE

25% of plastic packaging recycled material by **2025**

TOYOTA ENVIRONMENTAL CHALLENGE 2050

CO_2 0 CO_2 0

Reducing global average new-vehicle CO_2 emissions by **90 percent** by 2050 (compared to Toyota's 2010 global average)

Completely **eliminating all CO_2** emissions, including materials, parts and manufacturing, from the vehicle lifecycle

Coca-Cola

50% recycled material by **2030**

Dutch Students Create Almost 100% Recycled Car

Recycling categories

Category	Mechanical Recycling	Chemical Recycling
Plastics Feed	Limited to clean and select categories	Can accommodate wide variety and complex compounds
Polymer Degradation	Degradation with every cycle	No degradation, virgin quality products
GHG* Emissions	Optimal when applicable	GHG savings as compared to fossil feed after accounting for incineration.

*GHG: Greenhouse Gas

- Mechanical Recycling will continue to dominate due to low process costs
- Chemical Recycling will augment as it enables recycling of previously hard-to-recycle plastics

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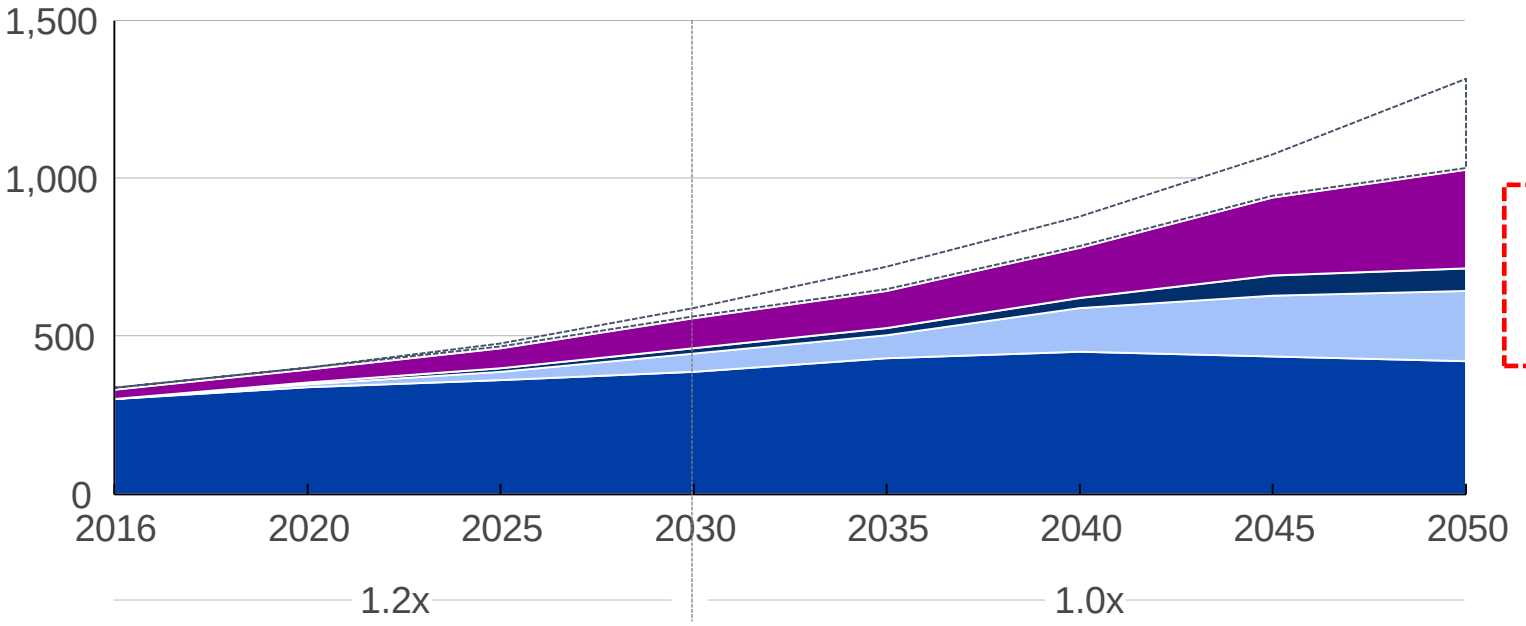
Feedstock recycling presents the highest growth potential

Global polymer demand 2016-50 from waste recovery
MTA



Polymer to GDP growth[1]

	Share of total 2018	Share of total 2050[3]
Demand reduction		
Mechanical recycling	12	30
Recycled monomers	~ 0	7
Feedstock recycling Pyrolysis	<1	22
Virgin liquid feedstock	87	41
Total	100	100

1 Actual growth after demand reduction, assuming global GDP growth of 3.1% (IHS);
2 IHS forecast, demand if current IHS projections until 2027 for plastic growth continue through to 2050;
3 Mechanical recycling limited by downcycling and applicable materials, monomerization limited by applicability to condensates only, pyrolysis limited by likely rise in input costs;

Source: McKinsey plastic waste stream model

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Chemical PET Recycling

High-Purity Monomers from Post-Consumer PET

Different Technologies to Purify PET Monomers

- **Distillation**
  - Monomer recovery
  - Process solvent recovery
- **Crystallization**
  - Crystallization of monomers like DMT or BHET to achieve high purity products
- **Hydrolysis of DMT to TPA**
  - TPA is main monomer used for PET polymerization

Monomer purification for depolymerization processes

Hybrid Processes

For purification of PET monomers

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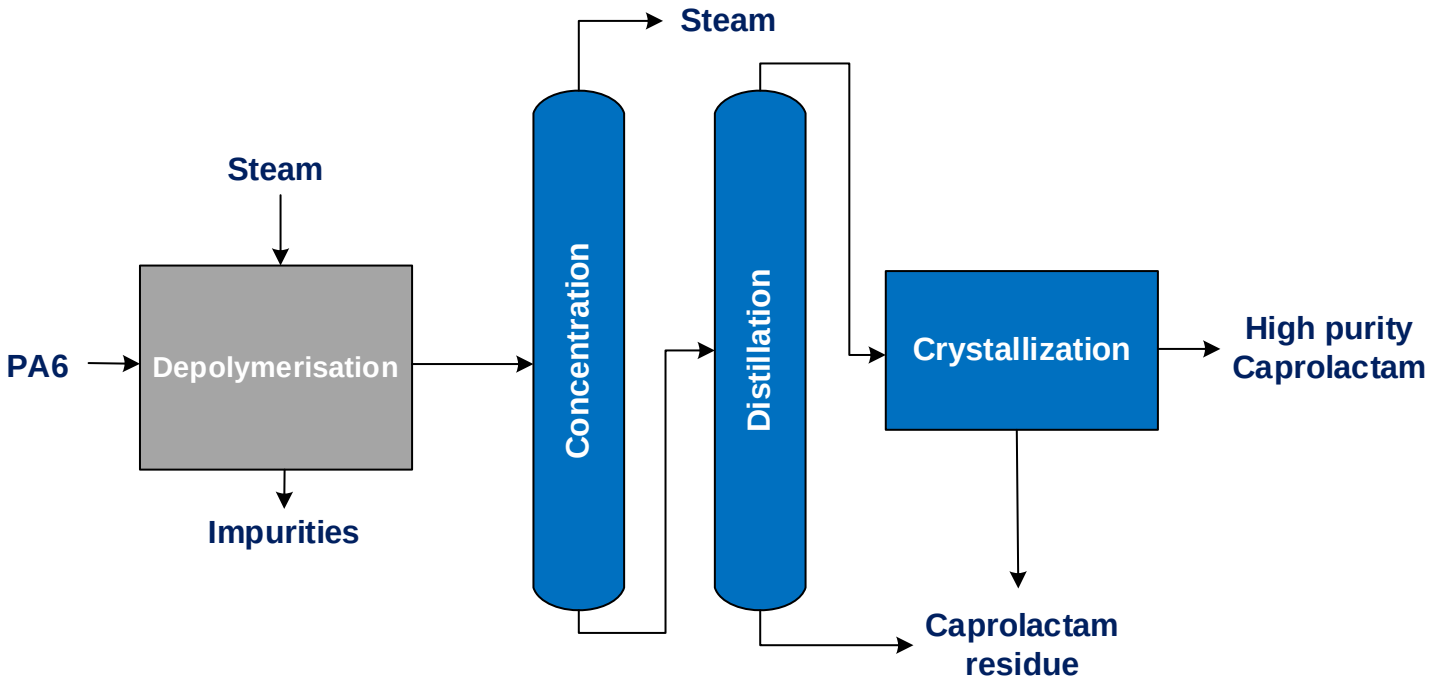
Chemical Recycling of Polyamide 6

Hybrid technology with distillation and layer melt crystallization



- Hybrid removes close boiling impurities which cannot be removed via distillation.
- Capability to produce the highest grade Polyamide 6 with high purity caprolactam (Permanganate number > 16000 and Color APHA < 6)

Solvent-Based Recycling

Low VOC Polymers & Pure Solvents

Polymer / solvent separation

- Sulzer's devolatilization (DEVO) technology can separate polymer / solvent mixtures in a broad viscosity range
- Very low VOC levels can be achieved for all thermoplastic polymers

Solvent purification

- Recovered solvents may need purification for the reuse in the dissolution stage
- Separation of impurities through evaporation, distillation or LL-extraction technologies.

worn again technologies

- UK based start-up has developed a genuine patented process to recover polyester and cotton from end-of-use textiles
- Sulzer is major shareholder and involved in process scale-up

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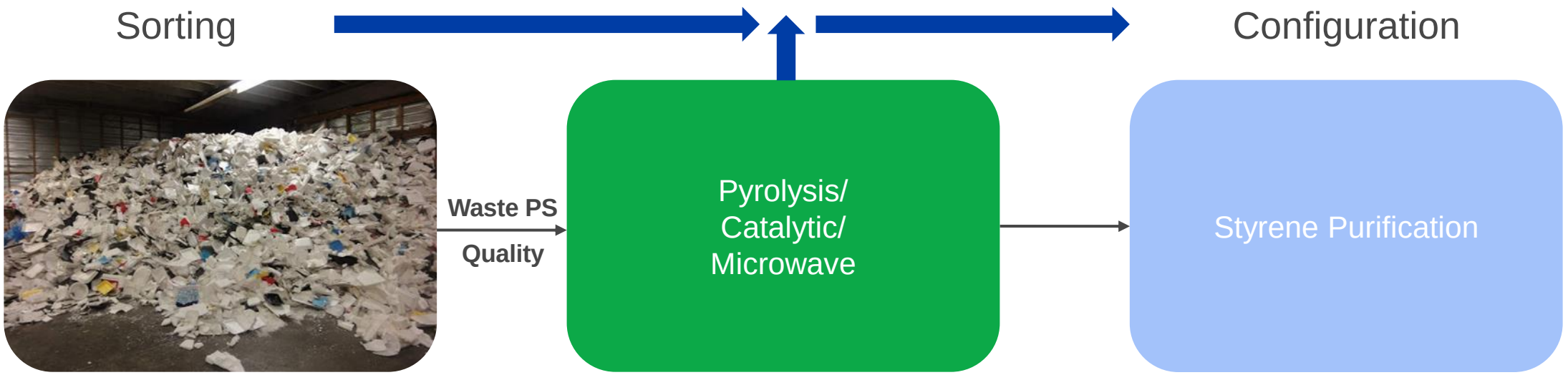
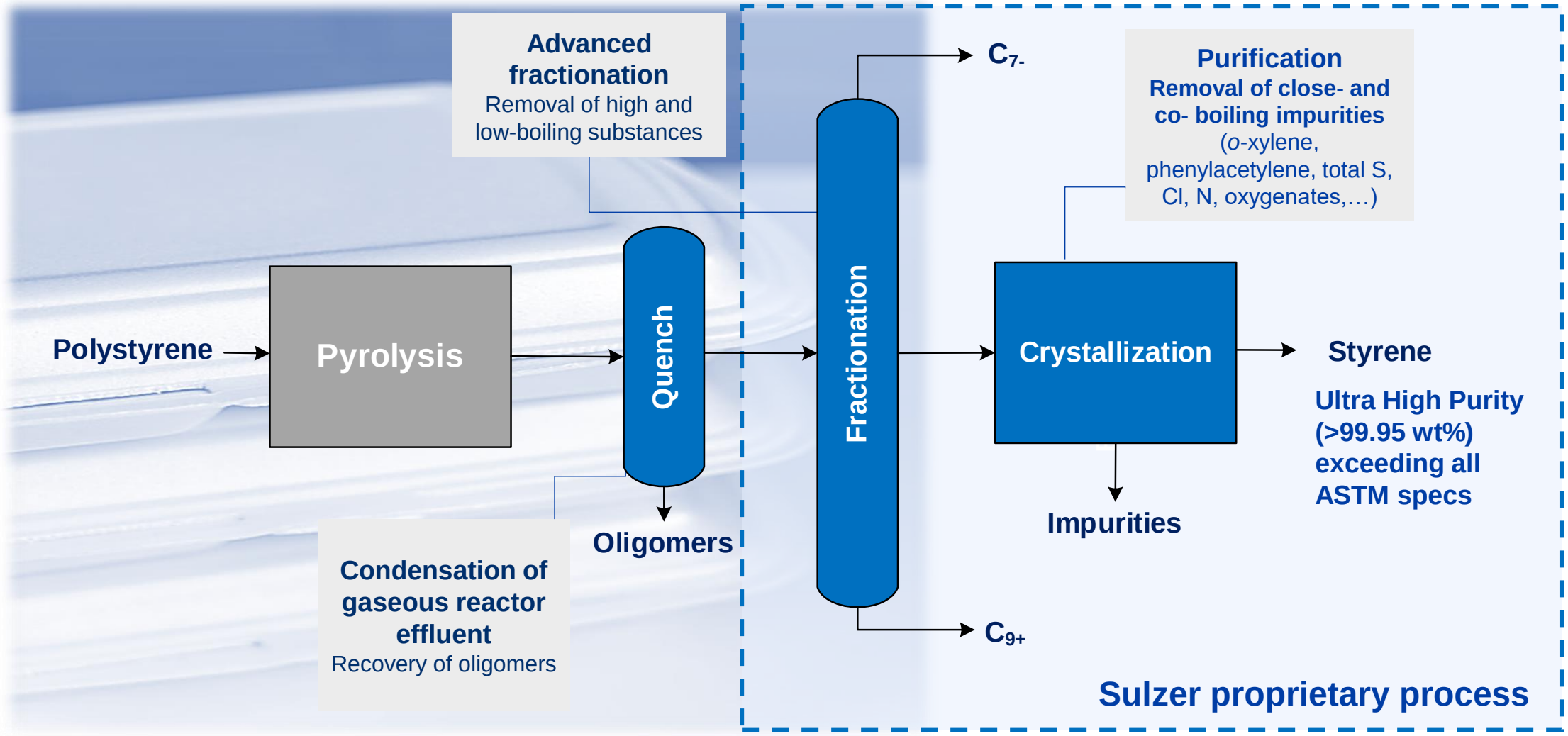
PS recycling



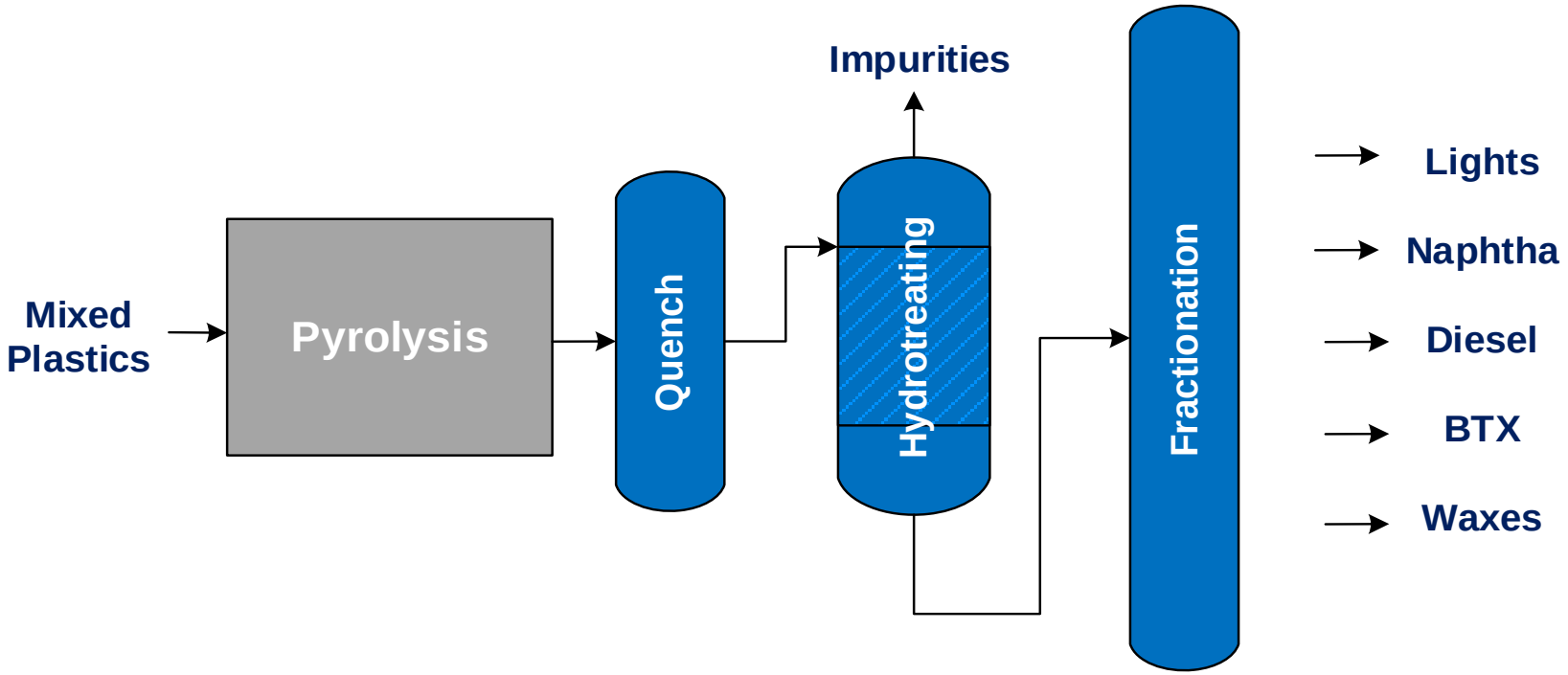
Need for styrene purification scheme which:

- Can accommodate relaxed waste PS quality:
  S, Cl, N, oxygenates, co-boiling impurities.
- Can remove co-boilers coming from depolymerization process.

SuRe Styrene - robust technology for Ultra High Purity recycled styrene from Polystyrene



Mixed plastics/tires recycling



Quench	Hydrotreating	Fractionation	Valuable Products Recovery
Skid mounted solution, tailor-made for your application. In-house simulation and testing capabilities.	MAXFLUX: 30-40% lower CAPEX and OPEX Removal of Total N, S, Cl, Oxygenates and saturation of olefins	Industry leading distillation technology, skid-mounted solution. Operating Reference: Quantafuel skid (20 kt/a)	Leading licensor for aromatics extraction. Technology to recover pure waxes.

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Mixed plastics: valorization

Refinery

- Co-processing in existing units:
  FCC, Delayed Coker, Slurry Hydrocracker, Visbreaking etc.
- Plastic waste must be dissolved and mixed in low proportions.
  Contaminants pose a concern.
- Blend wall limitation: Generally 5-10%.
- Overall unit production profile:
  Should stay unaffected.
- Fuels route as opposed to Petrochemicals.

Steam cracker

- Plastics oil, obtained after pyrolysis, as cracker feedstock.
- Plastics oil contains contaminants which will require prior removal via hydrotreating/purification steps.
- Hydrotreating a robust solution.
  To be CAPEX cognizant.
  MaxFlux offers 30-40% CAPEX reduction.
- End point limitation: ~ 200/400 deg C depending on cracker furnaces.
- Establishes circularity due to olefins production.

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Key take-aways

- ✓ **We live in a world with high societal pressure for creating a cleaner planet**
- ✓ **Brand Owner and Legislative Push for sustainability generates pull on plastics recycling technologies**

- ✓ **Chemical recycling, as opposed to mechanical recycling, offers the capability to produce recycled polymers with properties parallel to virgin polymers**
- ✓ **Mechanical Recycling will continue to dominate but chemical recycling will increase exponentially in market share**

- ✓ **Sulzer has a broad range of offerings (process technologies and equipment) for following applications:**
- ✓ **1. Mixed Plastics/Tires**
- ✓ **2. Polystyrene**
- ✓ **3. PMMA**
- ✓ **4. PET**
- ✓ **5 Polyamide**

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Questions?