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Brancheforeningen for danske plastvirksomheder

Whats next for end-of-life for PUR?

A new Danish consortium will research
alternative solutions

Anders Lindhardt, Danish Technological Institute



PUR Section-Meeting May 15th, 2019



Outline

- Introduction to Danish Technological Institute (DTI)
- Polyurethane
- From oil to PUR
- Recycling of PUR today
- Short presentation of RePURpose
- Conclusion





DANISH
TECHNOLOGICAL
INSTITUTE



Established 1906

Supports Danish Industry

Independent and not-for-profit



Technological infrastructure

- More than 1.000 specialists
- State of the art-equipment and facilities
- 80+ laboratories

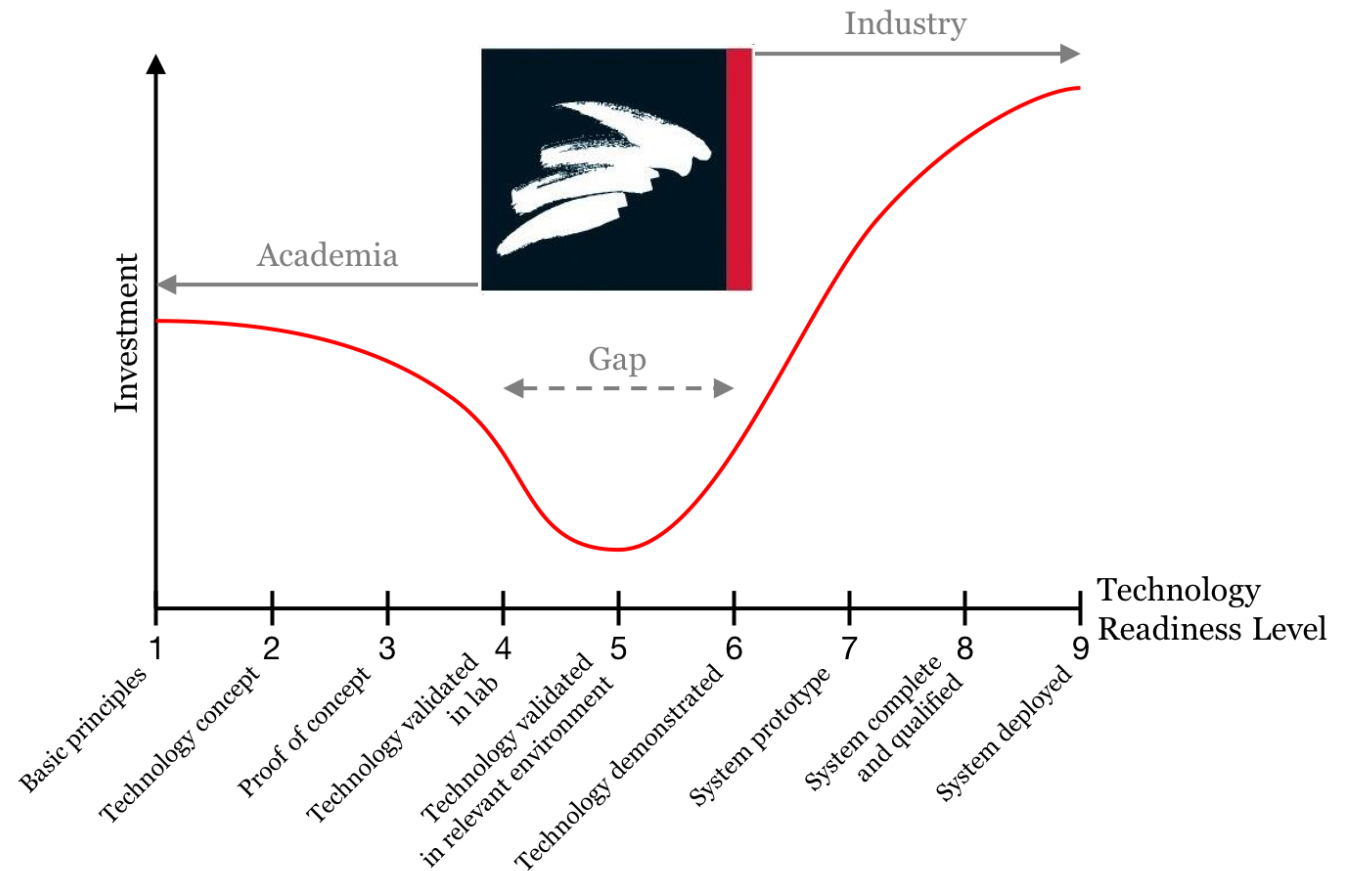




Danish Technological Institute

A key driver in R&D

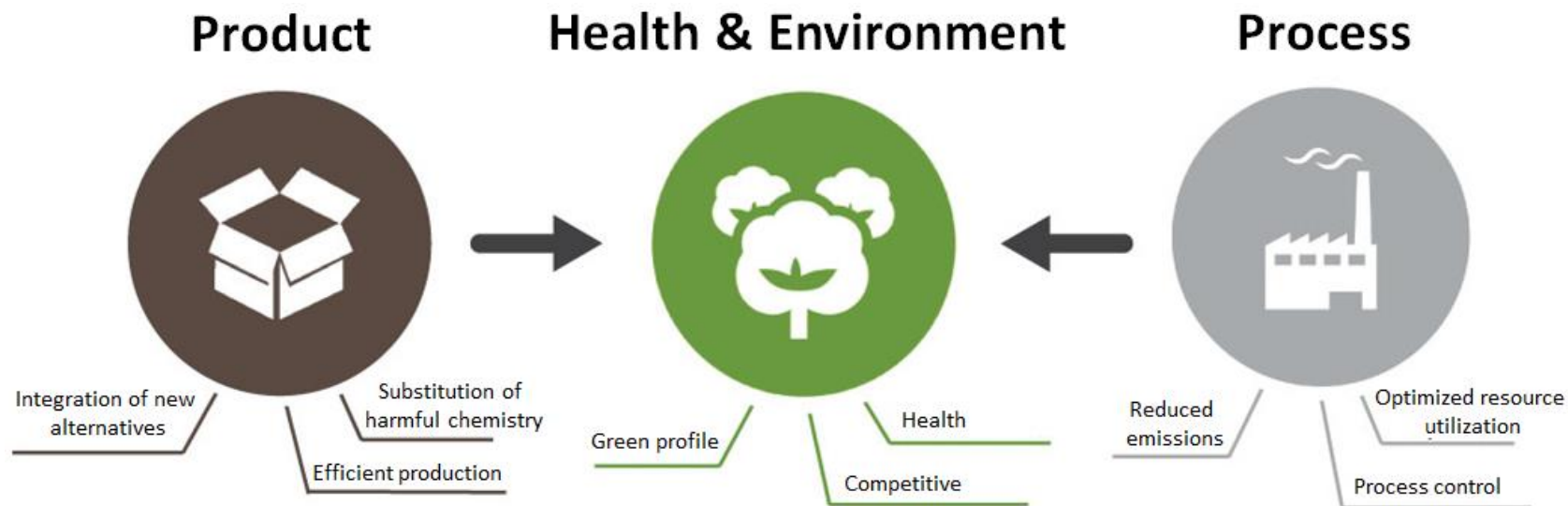
- Bridging the gap between research and practical application
- Since 2011, we have participated in 2,000 projects with 5,500 partners





Resources and materiel chemistry

- Working within waste-stream valorization, recycling, product development, chemistry, materials and polymers.
- Aiding industry with large challenges
 - Circular economy, new technologies, materials etc.
- Solve specific challenges
 - Trouble shooting, eliminating harmful chemistry, product development etc.





EDUCATION

- 2003-2007 Ph.D. Organic Chemistry, Department of Chemistry & iNANO, Aarhus University (AU)
- 2005 M.Sc. Department of Chemistry, AU
- 1999-2003 B.Sc. Department of Chemistry, AU



CAREER

- 2018- Consultant, Technological Institute, Process & Materials Chemistry, Life-Science Division
- 2016-2018 Associate Professor, Department of Engineering, Aarhus University. Working within the field of applied chemistry, continuous flow processing, materials, polymers and method development
- 2013-2016 Assistant Professor, Department of Engineering, Aarhus University
- 2012-2013 Synthetic Organic Chemistry, R&D Division, Cheminova A/S
- 2011- Co-founder of SyTracks. A company dealing with high-tech glassware solutions for research and development
- 2008-2012 Postdoctoral researcher, iNANO, Aarhus University. Transition Metal Catalysis in organic synthesis

SCIENTIFIC OUTPUT

67 scientific publications, 4 patents, 1 book chapter

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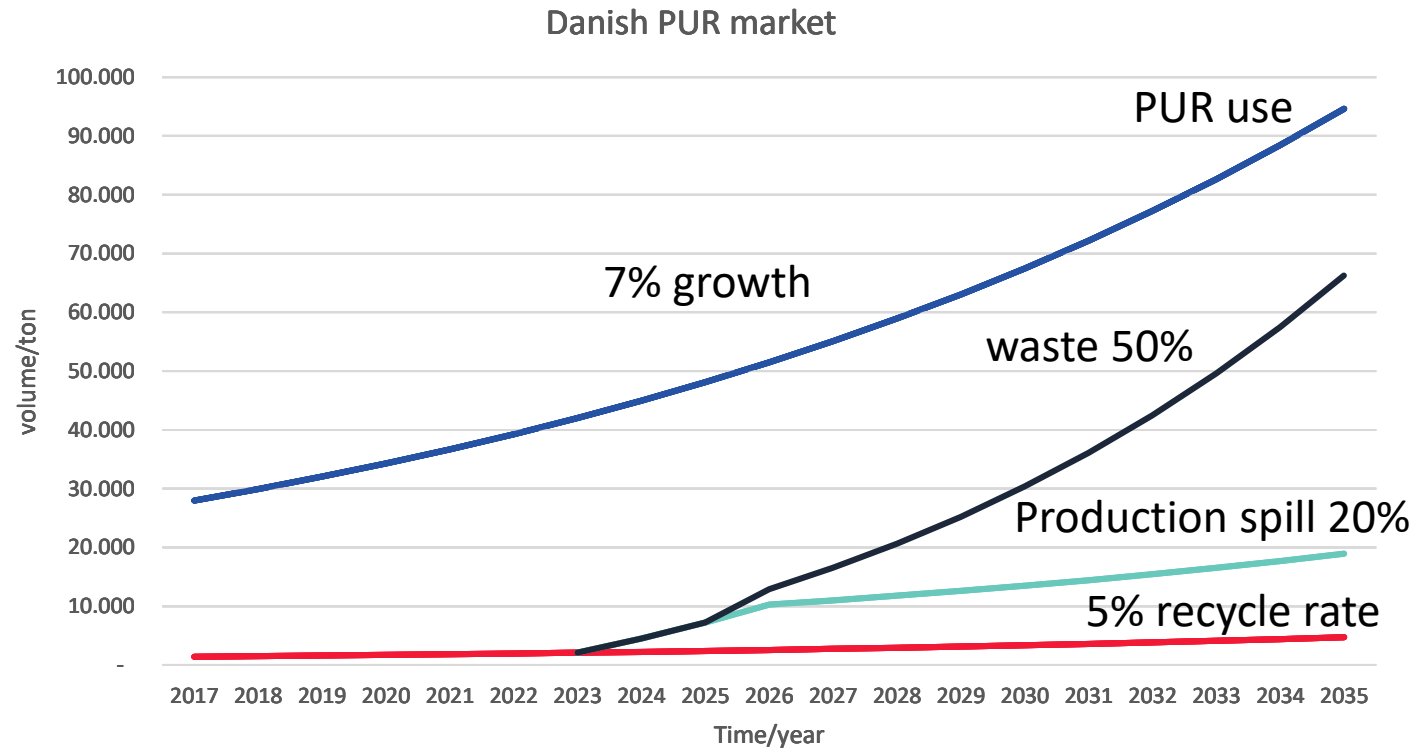


Why recycle PUR?

Polyurethane is an indispensable high-tech thermoset polymer.

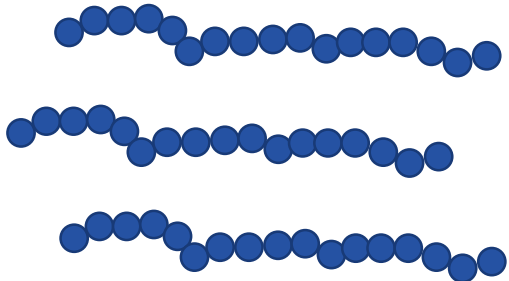
EU regulation requires recycling rates close to 100% of freezers, refrigerators, etc.

Currently, no forthcoming technologies are underway to meet upcoming demands





Polymer Properties

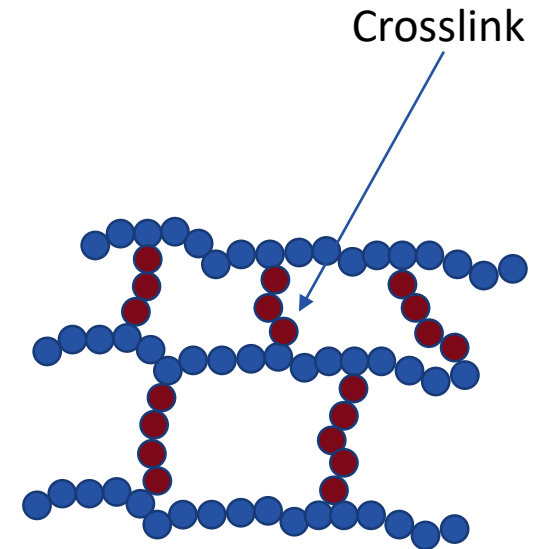


Thermoplastic

- Good impact resistance
- Chemical resistant
- Reshaping capabilities



Recyclable?



Thermoset

- Temperature resistant
- Thick and thin wall capabilities
- High dimensional stability
- Flexible design (Multi purpose)



PUR is not alone...

- **Other thermosets**
- Unsaturated polyester resins
- Vulcanized Rubber
- Epoxy
- Phenol formaldehyde (PF) resins
- Urea-Formadehyde
- Melamine (formaldehyde)
- Silicone
- Etc.

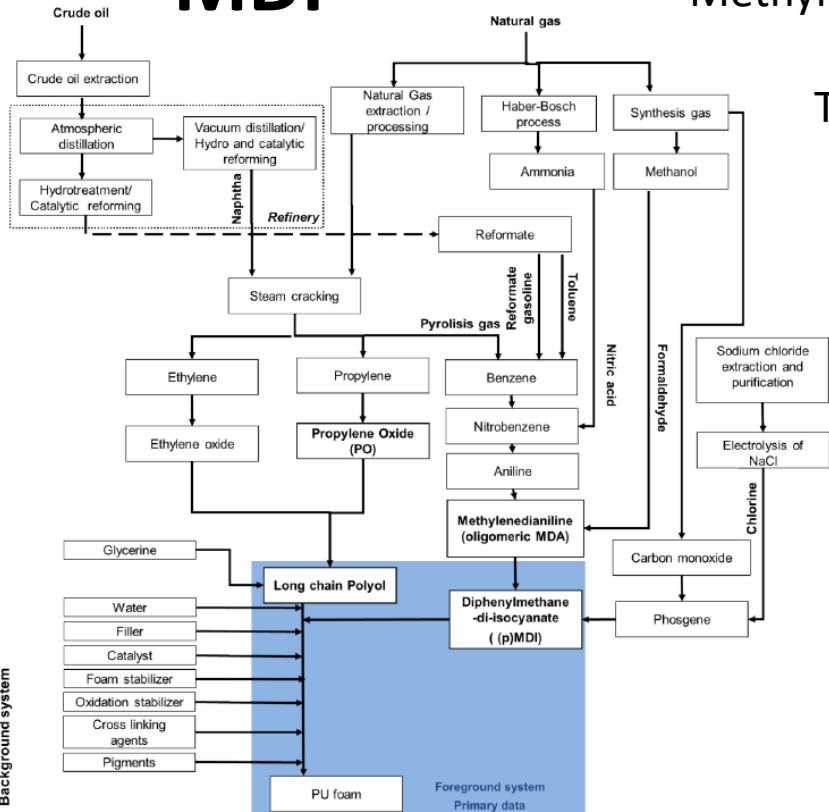




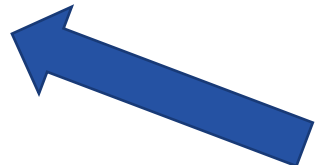
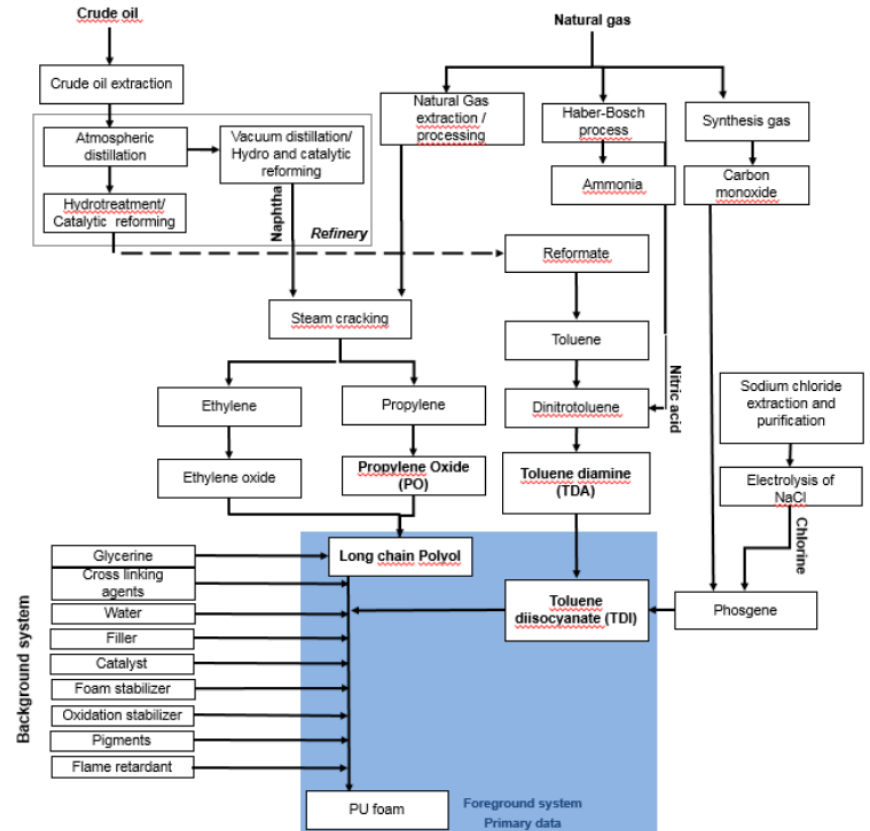
How are Polyurethanes made

The cases of
Methylene diphenyl diisocyanate (MDI)
&
Toluene Diisocyanate (TDI)

MDI

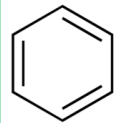


TDI

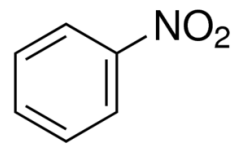




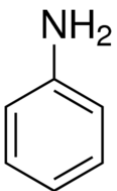
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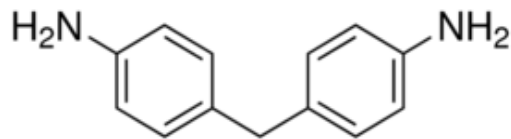
Benzene



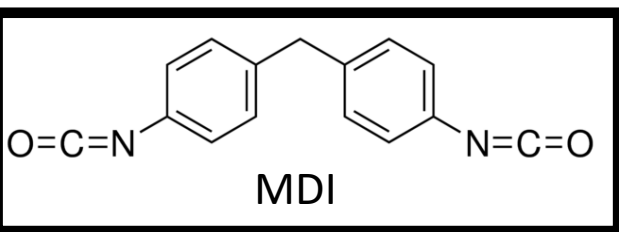
Nitrobenzene



Aniline

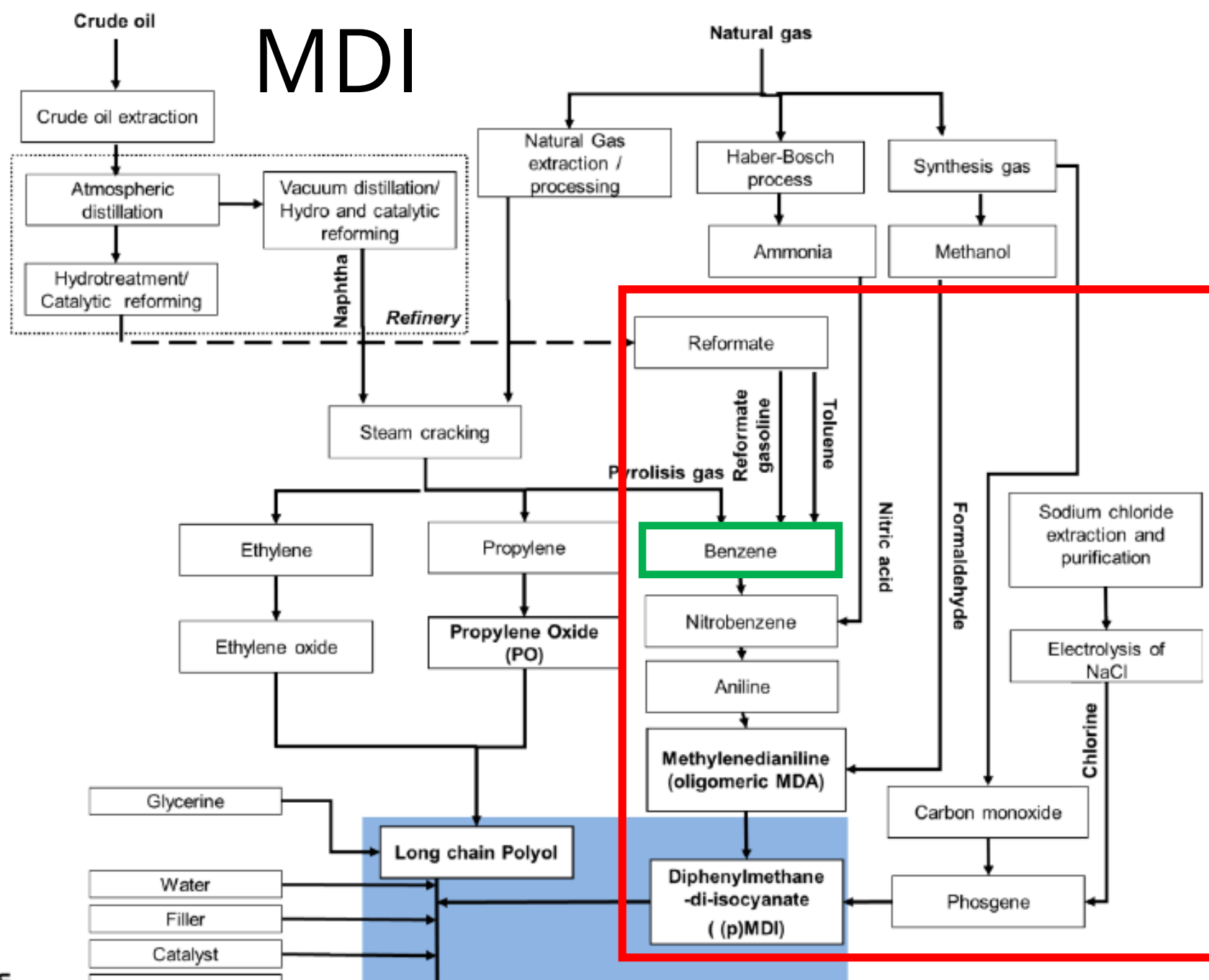


MDA



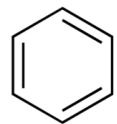
MDI

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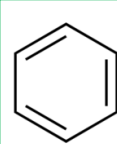




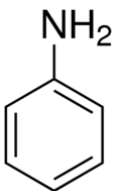
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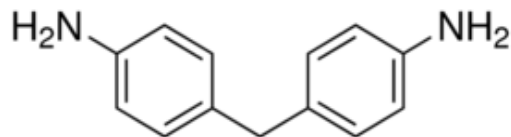
Benzene



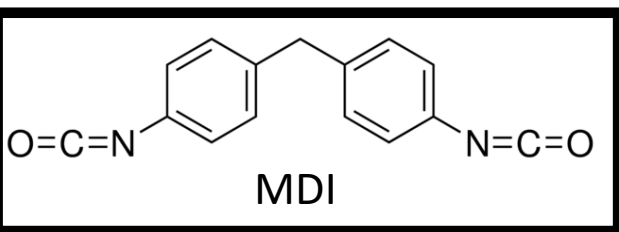
Nitrobenzene



Aniline

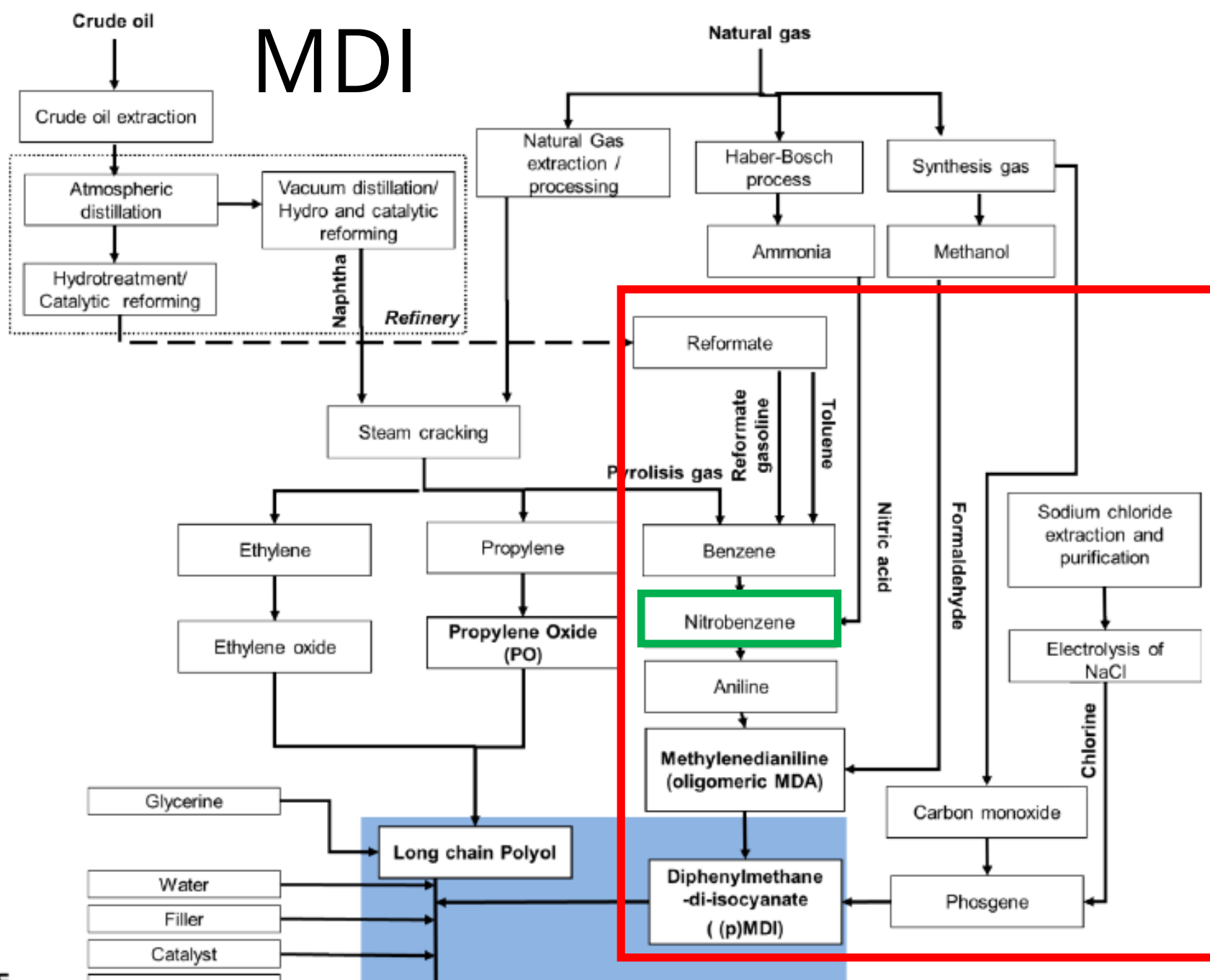


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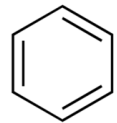
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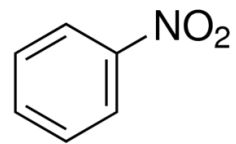




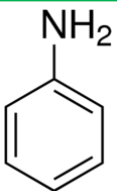
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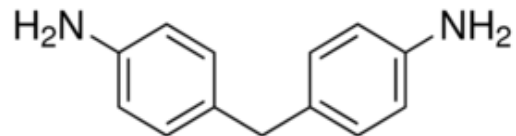
Benzene



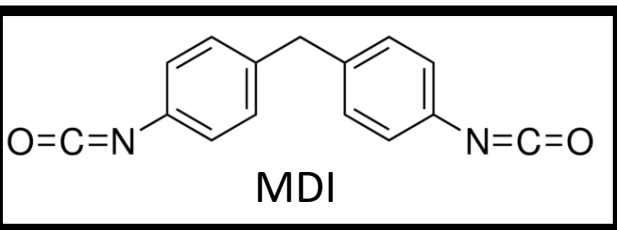
Nitrobenzene



Aniline

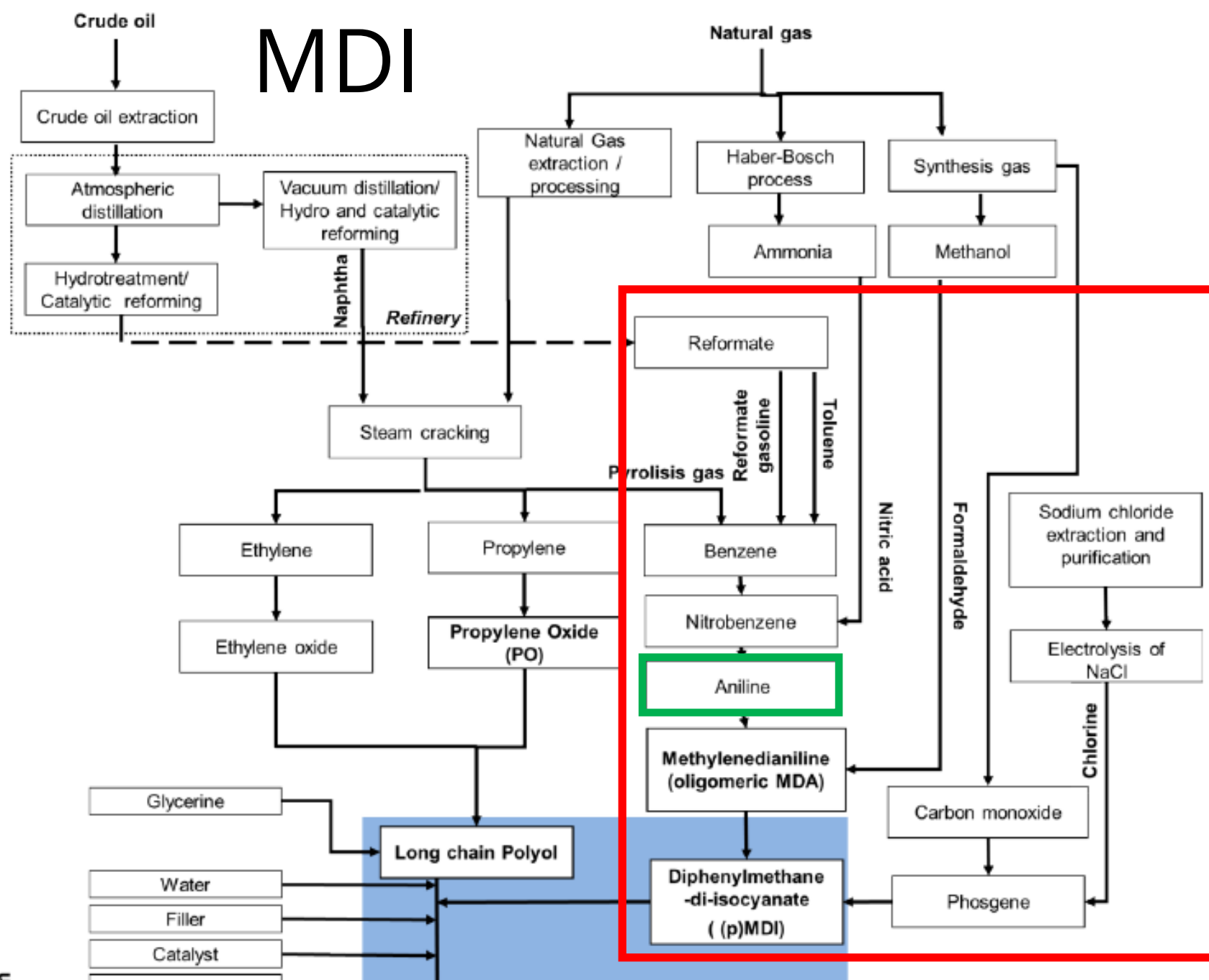


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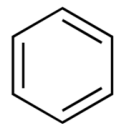
MDI

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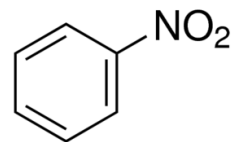




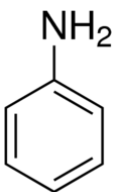
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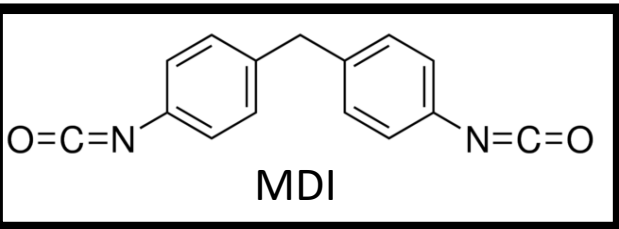
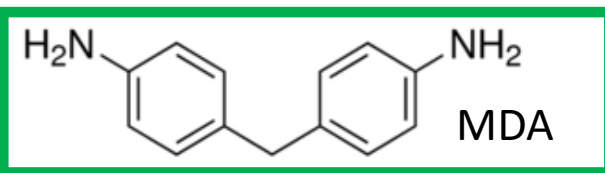
Benzene



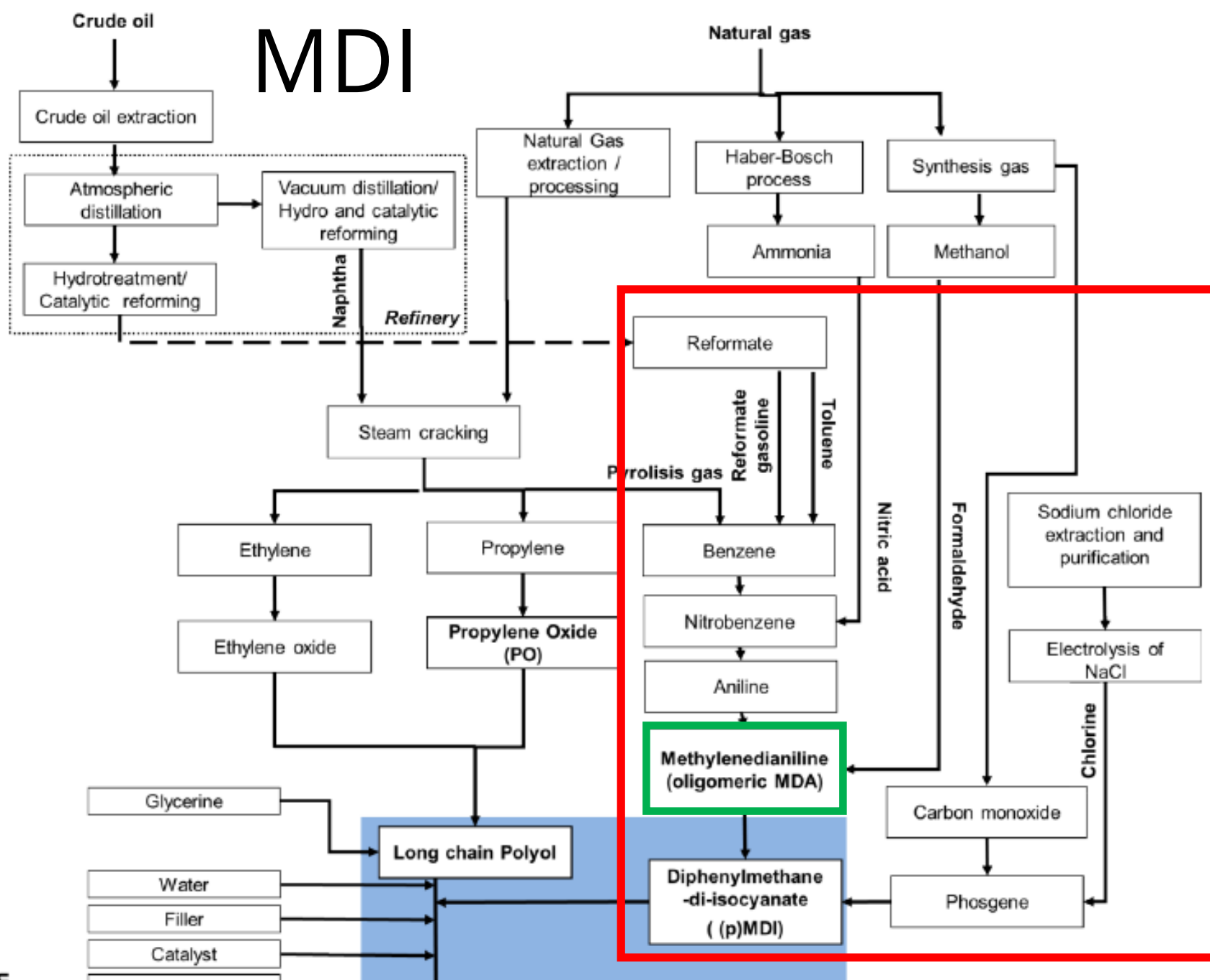
Nitrobenzene



Aniline

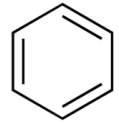


MDI

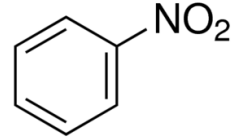




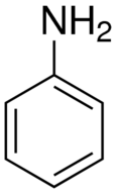
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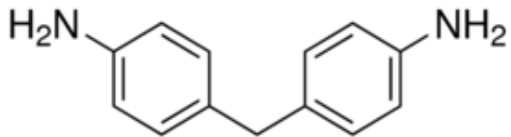
Benzene



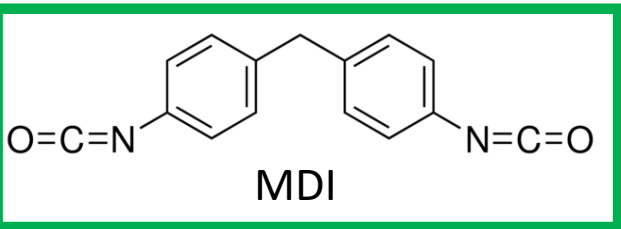
Nitrobenzene



Aniline

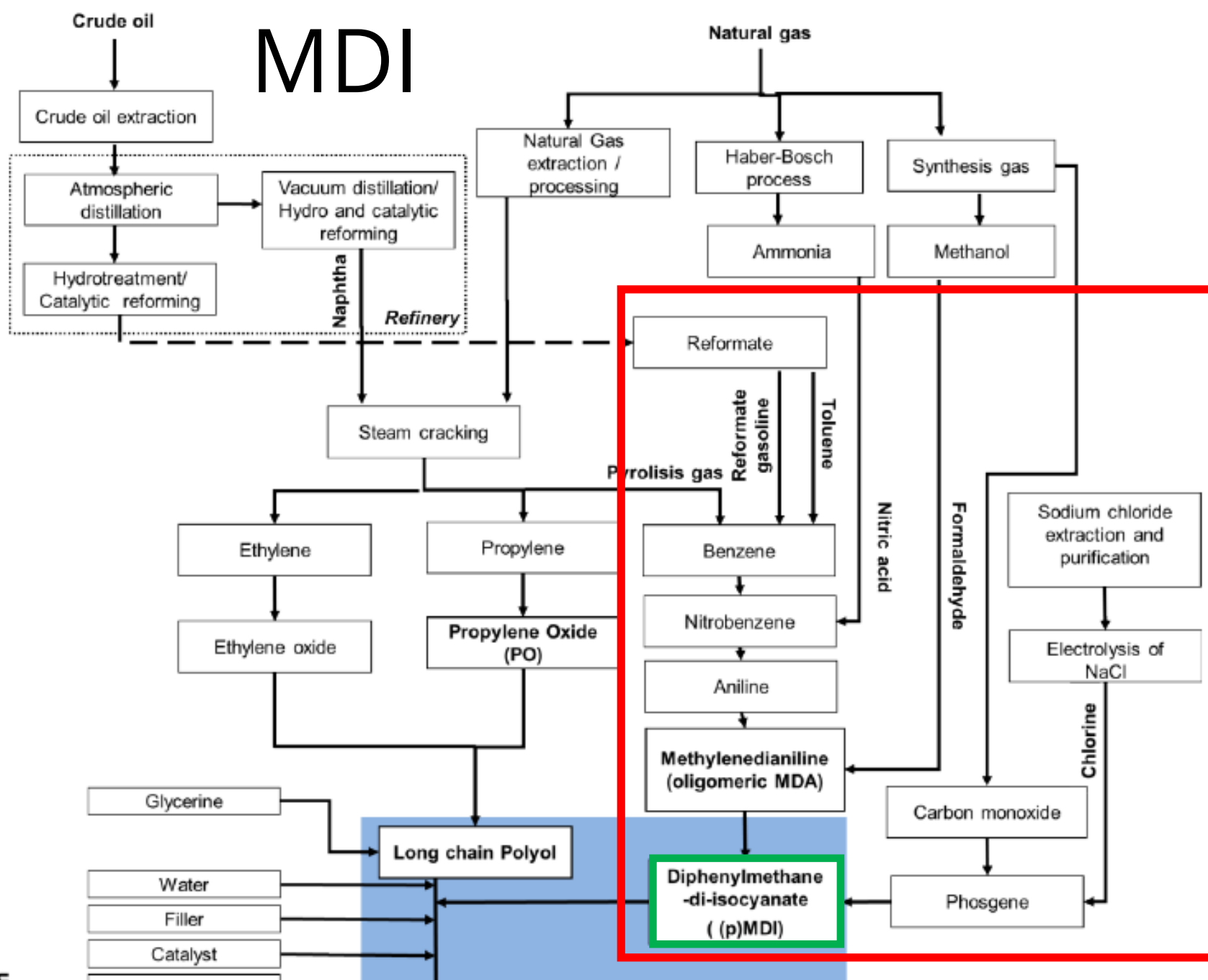


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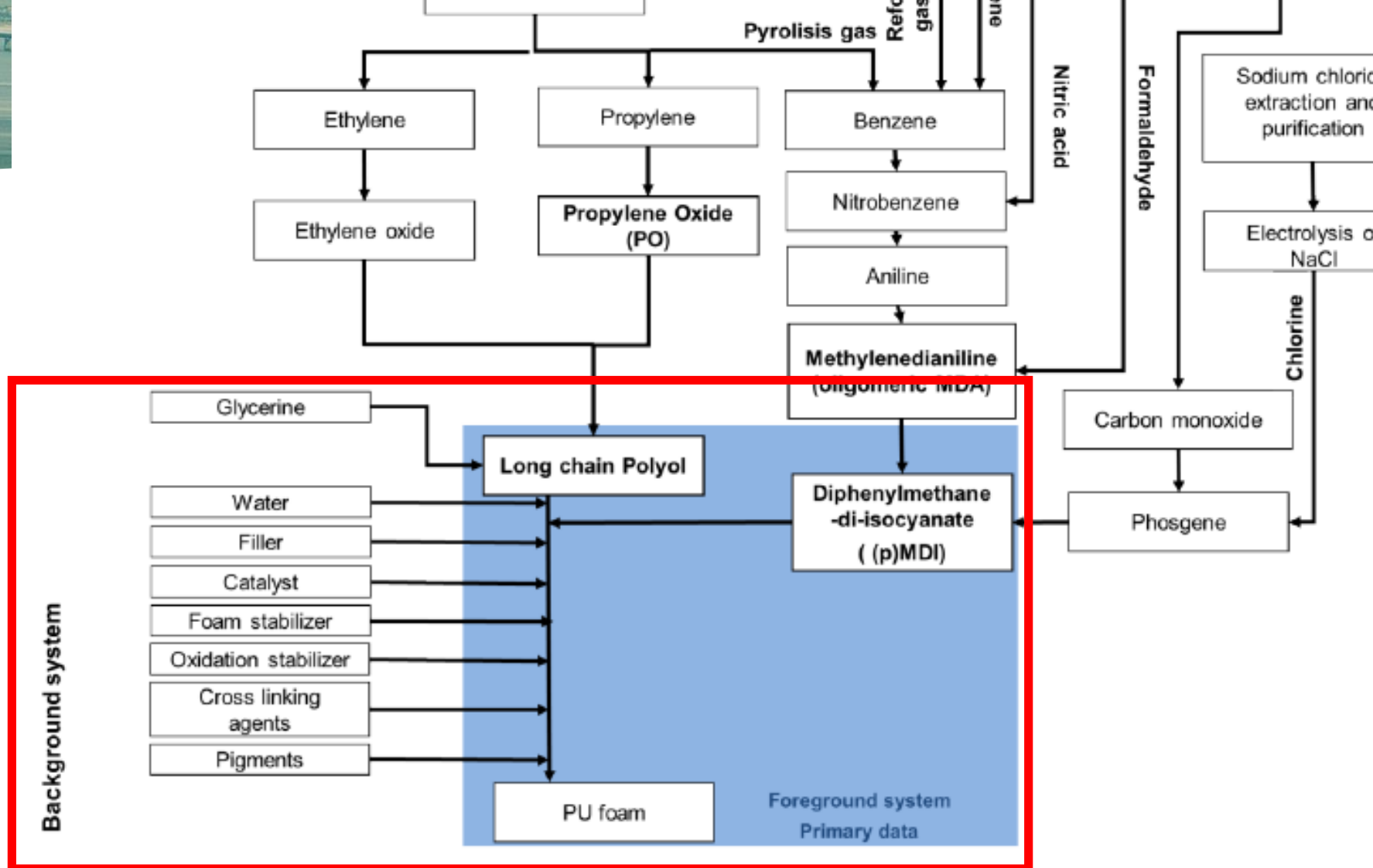
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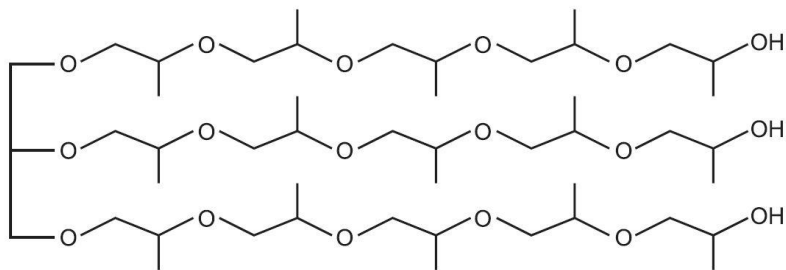
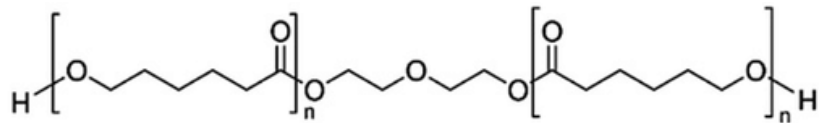
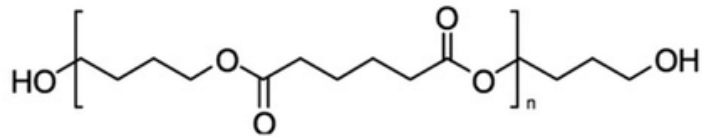
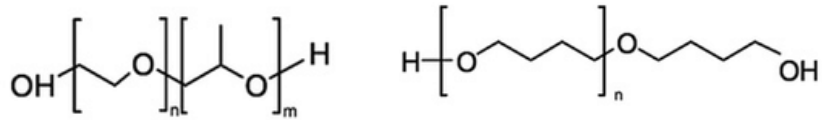
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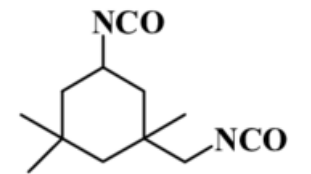
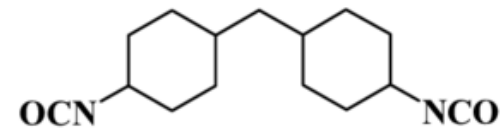
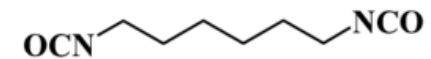
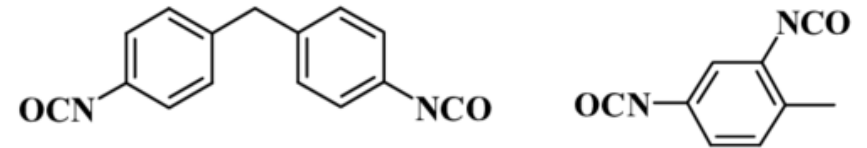


Complicated mix

Polyols

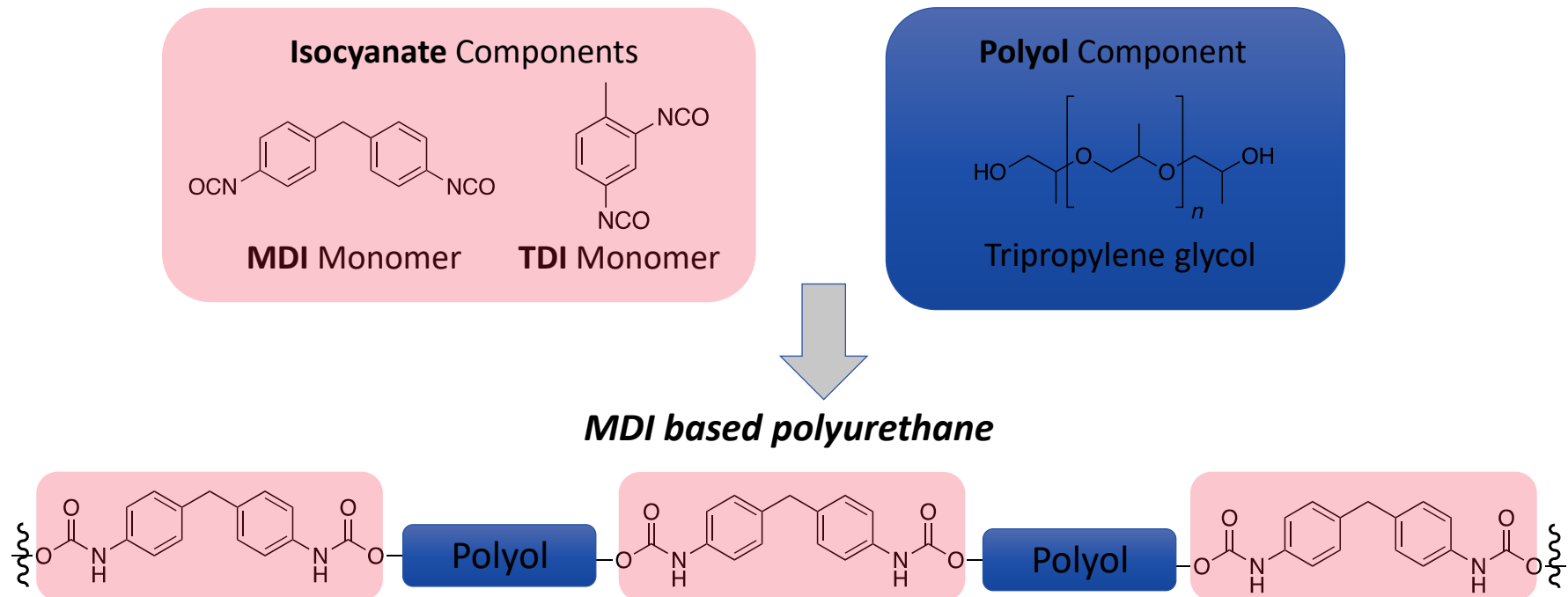


Diisocyanates





How is PUR recycled today?



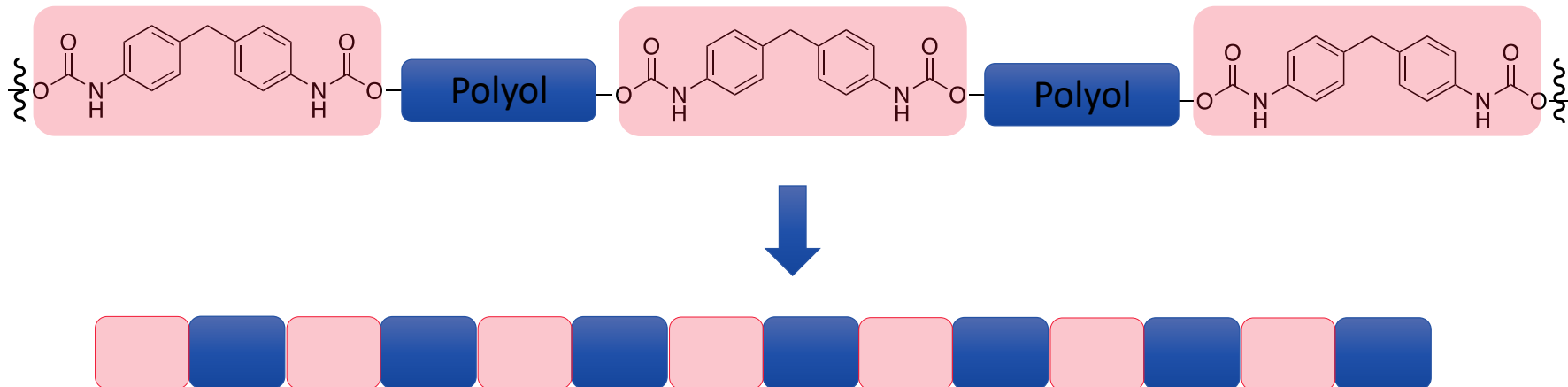


State of the Art

Polyurethane can not be remolded (Thermoset)

Few “recycling” methods currently available

- **Physical:** Reshaping
- **Chemical:** Hydrolysis, aminolysis and glycolysis





State of the Art

Physical Reshaping

Shredded Polyurethane



Glue, Adhesives,
Coloring, Additives



Rebound Polyurethane



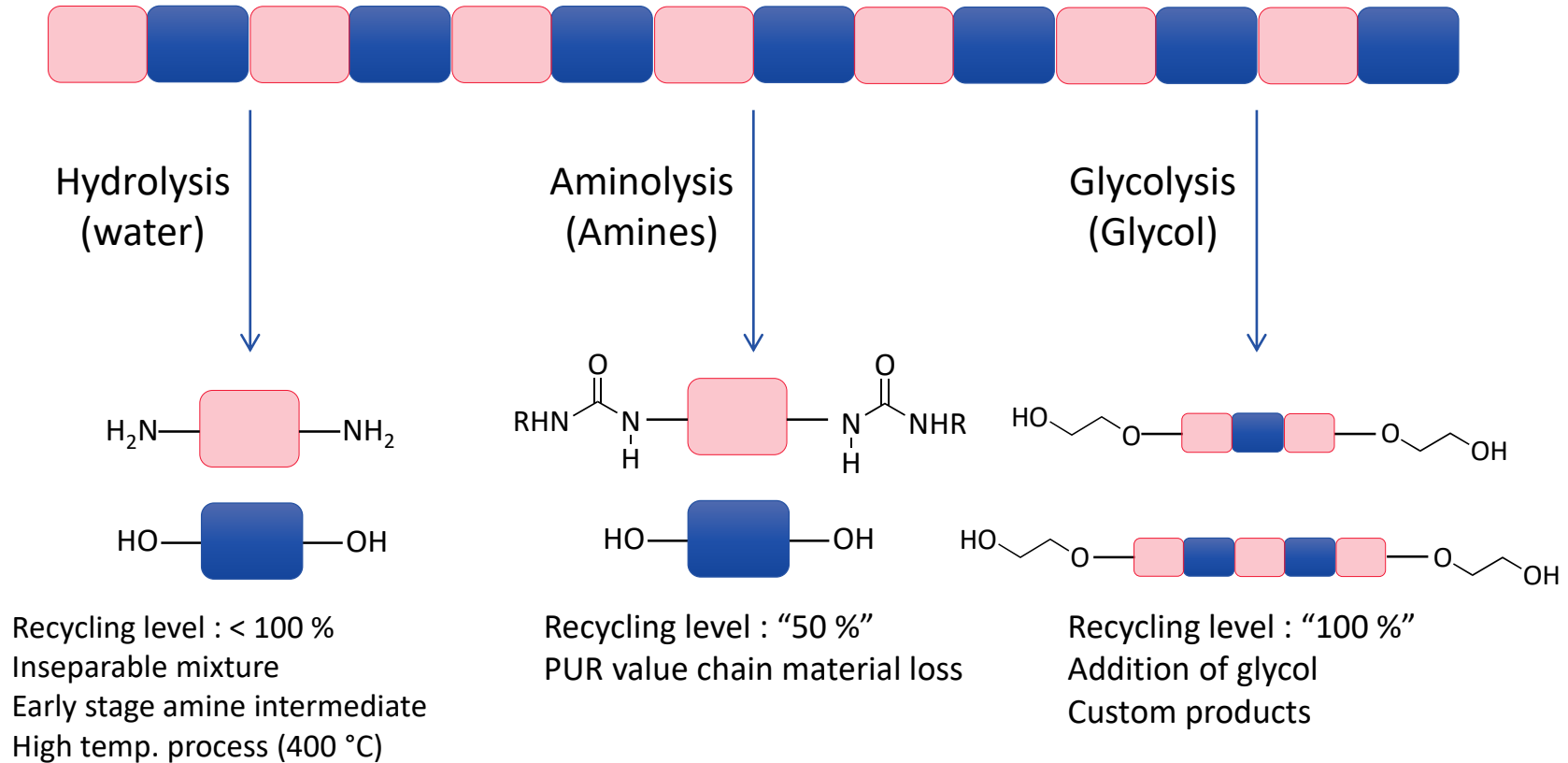
Recycling level : 100%
Loss of material properties

Powdered PUR applied as additives in cement, new cast PUR, etc.



State of the Art

Chemical Recycling of Polyurethane



All methods are high temperature transformations



State of the Art

Chemical Recycling of Polyurethane

Conclusion

- Loss of material
- Loss of compatibility
- Further chemical modification or addition of new virgin polyurethane monomers needed in all cases
- Addition of new technologies is needed

Recycling level : < 100 %
Inseparable mixture
Early stage amine intermediate
High temp. process (400 °C)

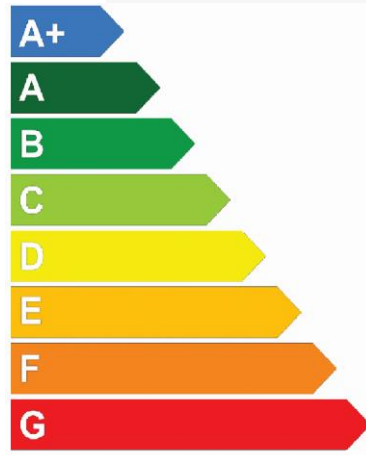
Recycling level : 50 %
High temp. process
50% PUR value chain material loss

Recycling level : "100 %"



CE learnings from thermoplastics

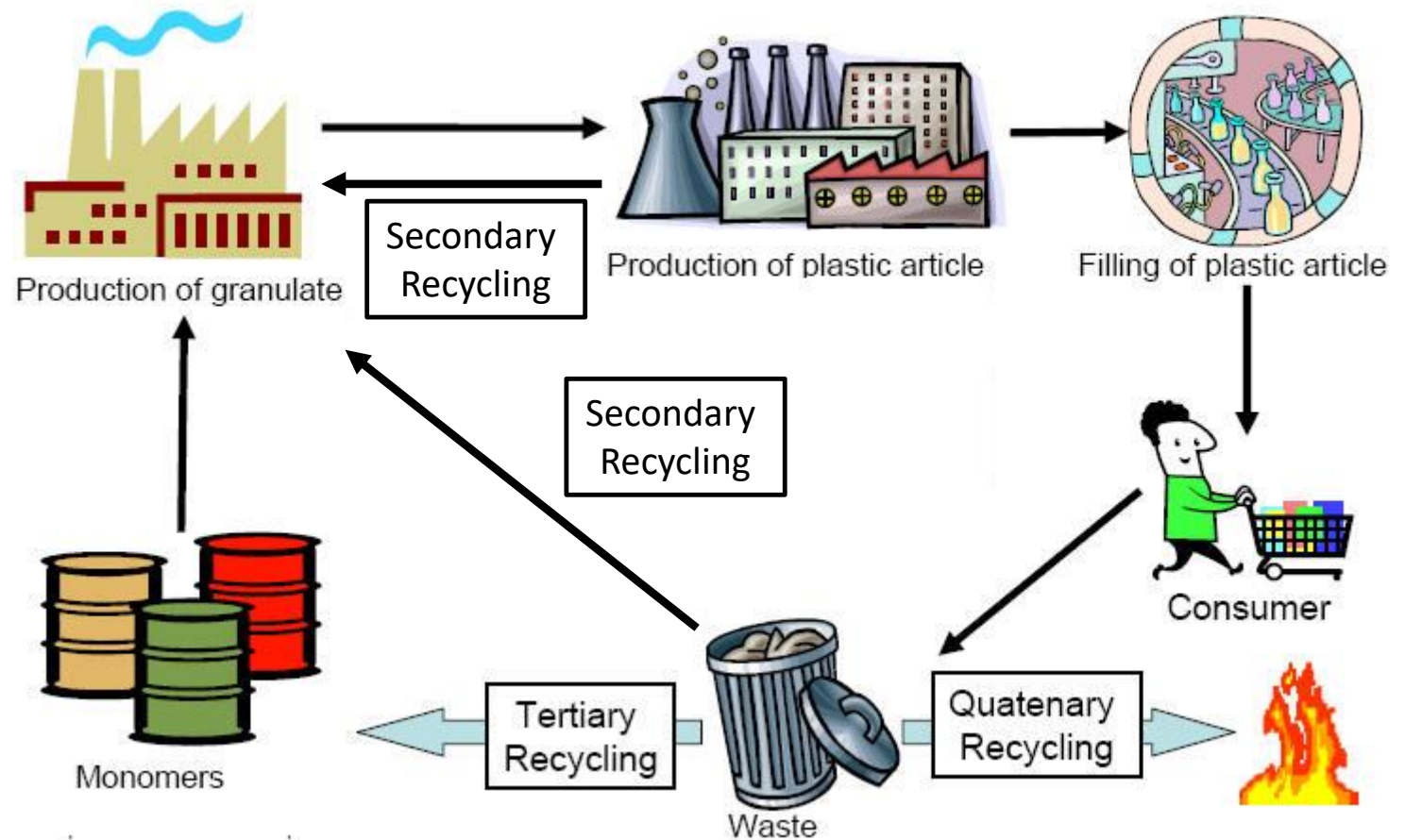
- Primary recycling
- Secondary recycling
- Tertiary recycling
- Quaternary recycling – Loss of material





CE learnings from thermoplastics

- Primary recycling
- Secondary recycling
- Tertiary recycling
- Quaternary recycling

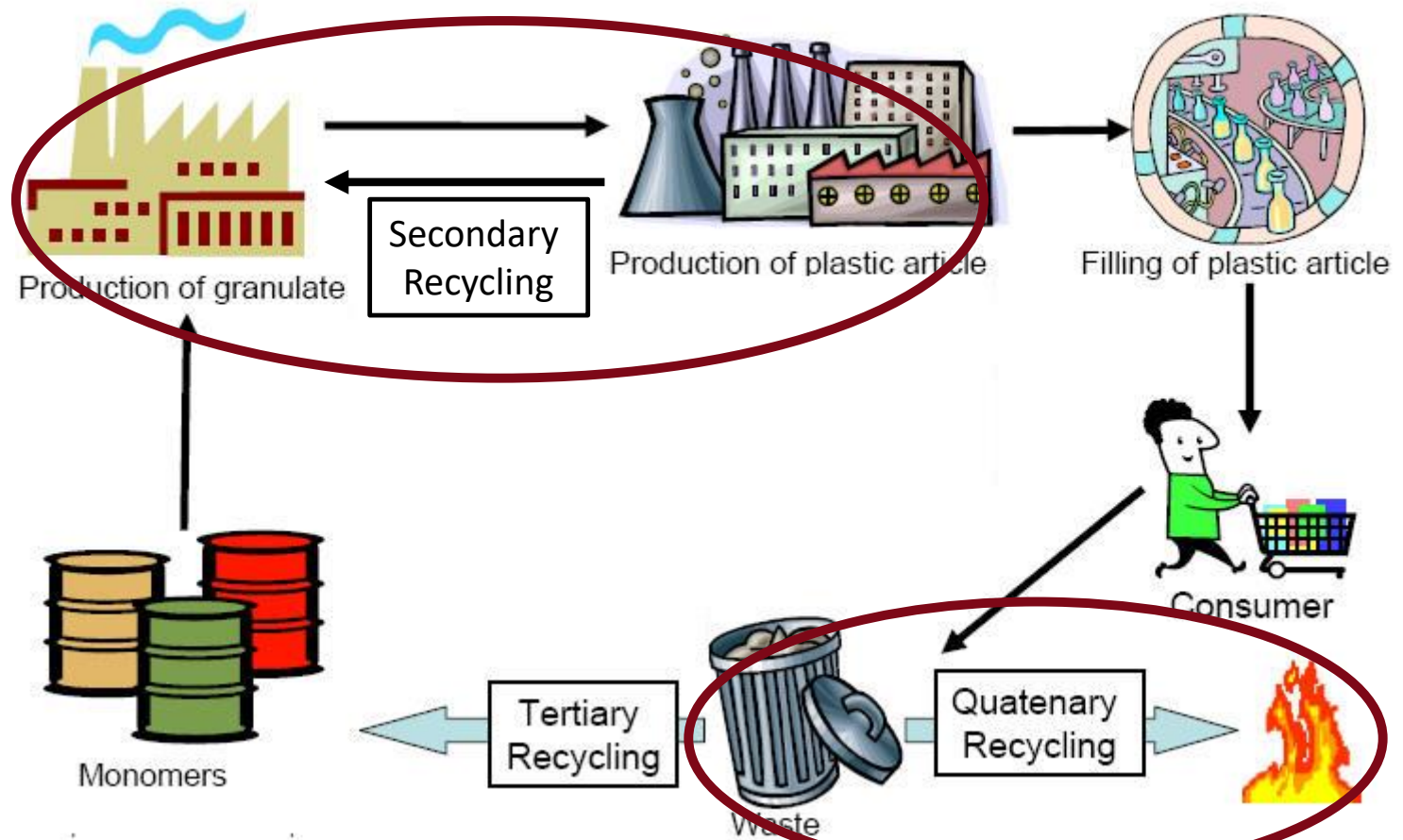




CE learnings from thermoplastics

Reality check:

Thermoplastics

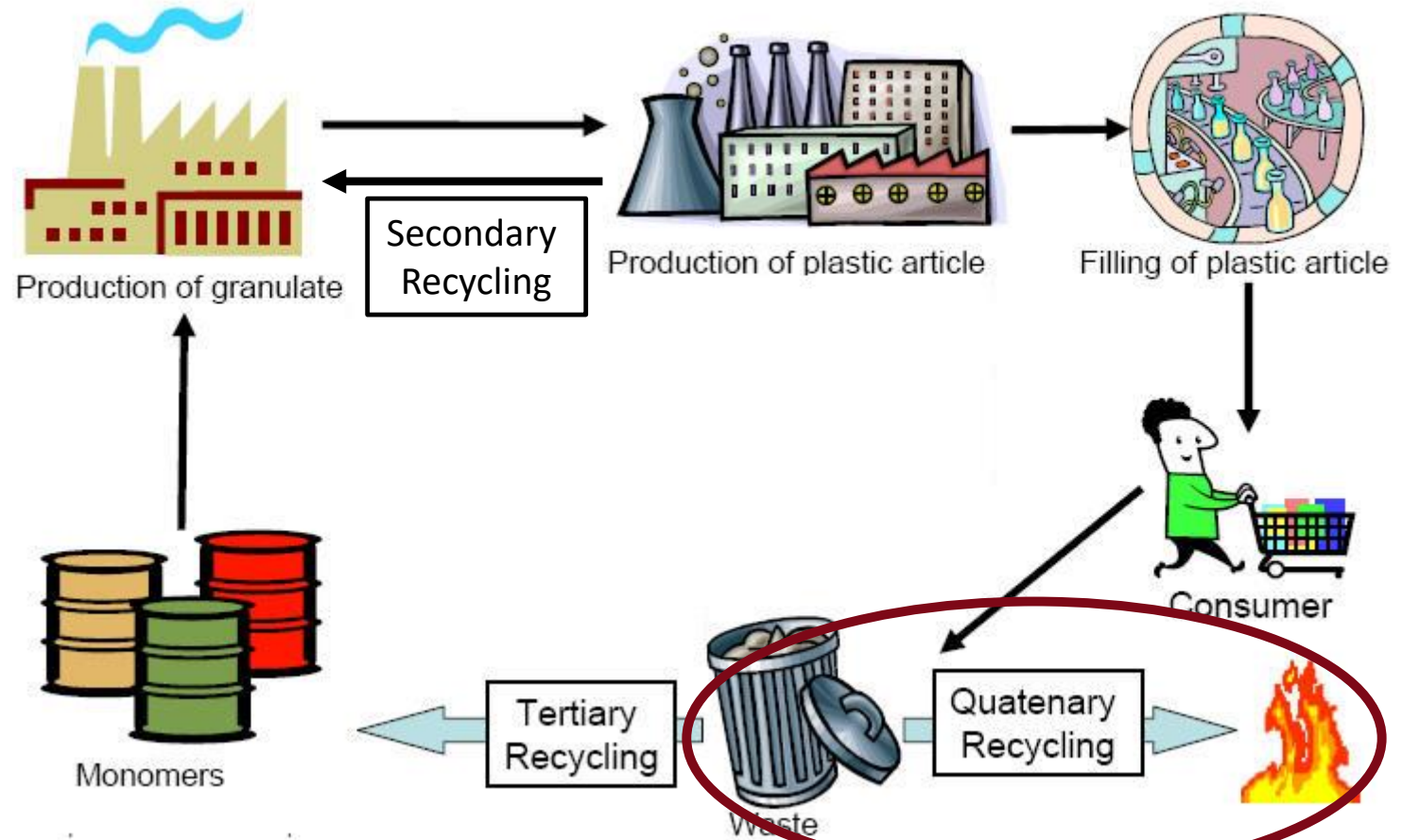




CE learnings from thermoplastics

Reality check:

Polyurethane

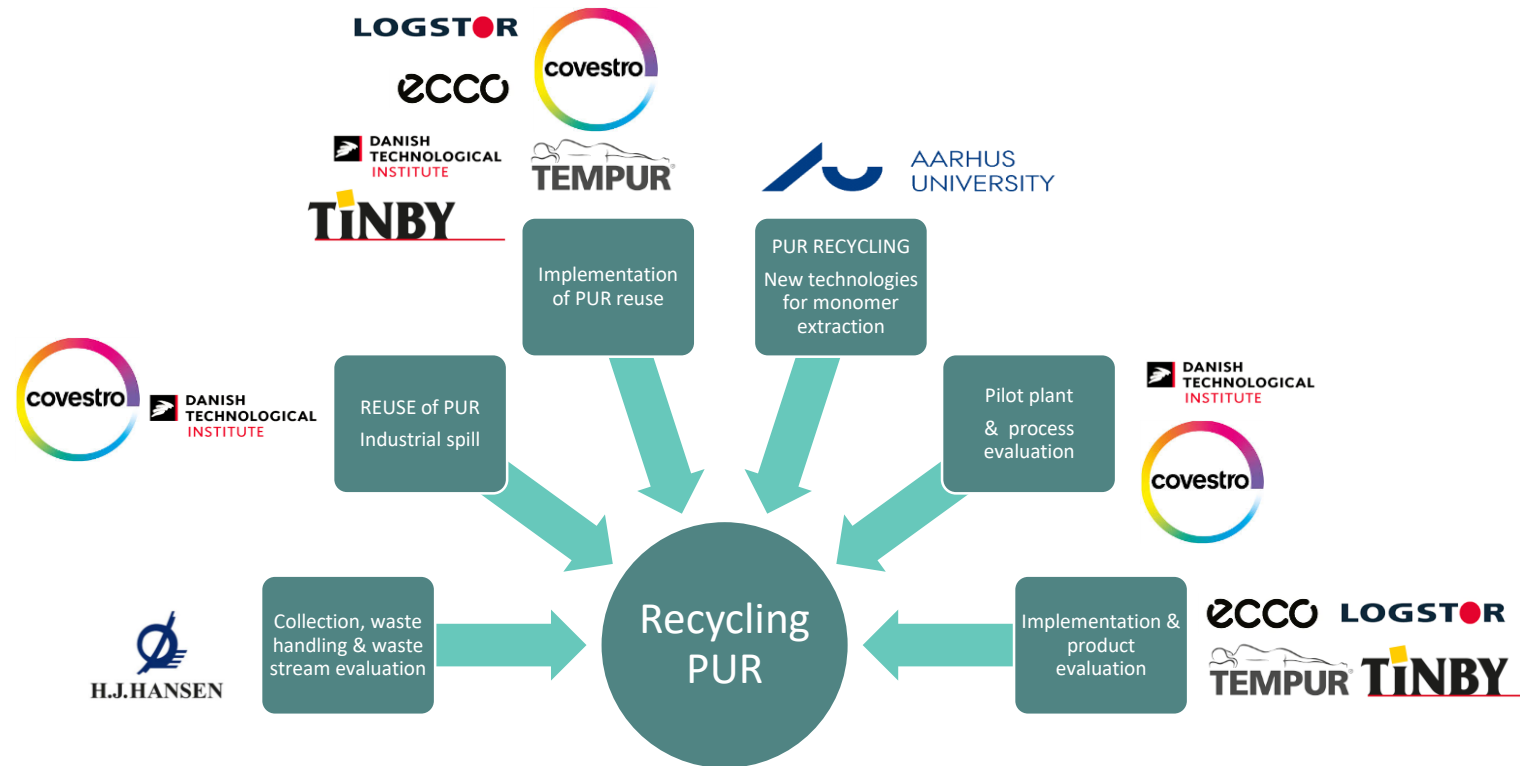




What to do with PUR?

The **RePURpose** consortium will develop new technologies for PUR recycling

- Six leading Danish industrial partners
- One of the worlds best organic chemists
- Entire PUR value chain present
- Strongest technical capabilities

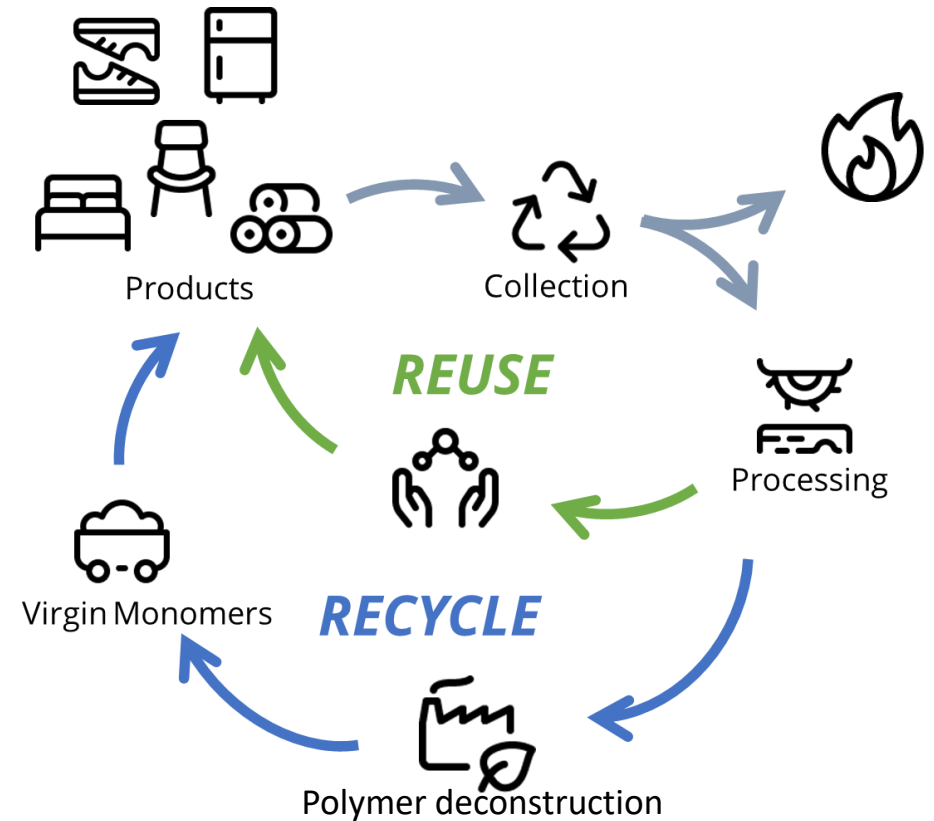




Dual Approach

RePURpose will develop two technologies

1. ReUSE will develop new methods elimination of production spill
2. ReCYCLE targets regeneration of original polyurethane monomers.

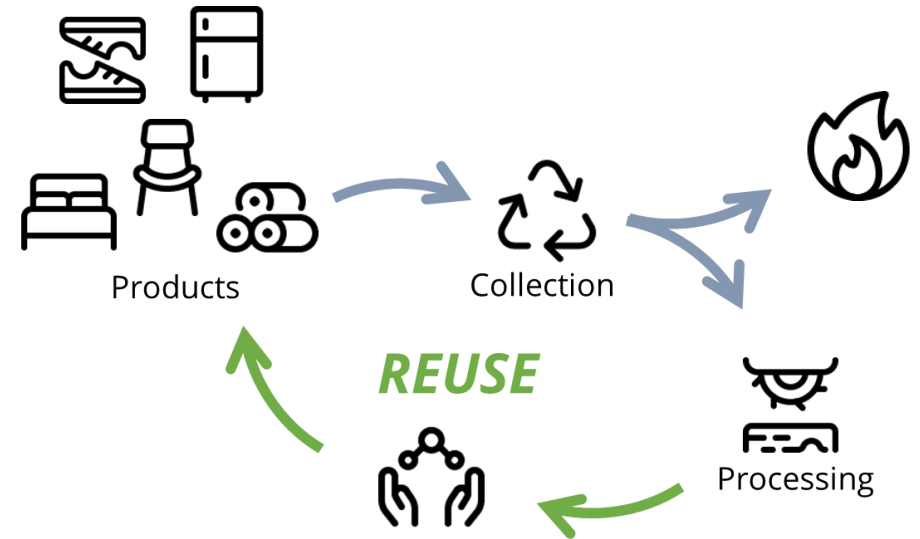


ReUSE before **ReCYCLE**



ReUSE

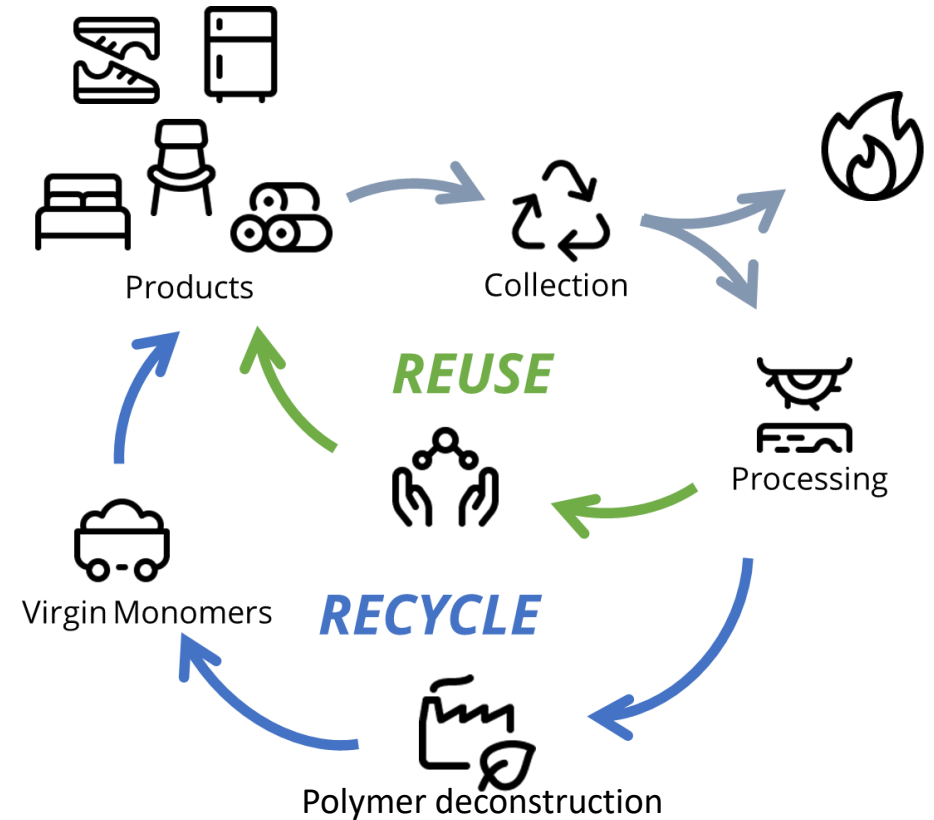
- Production spill is not waste before it leaves the factory
- Production-site solution
 - No transportation of light weight materials (foams)
- Short time to implementation (2-4 years)
- Operation cost target \leq cost of virgin material

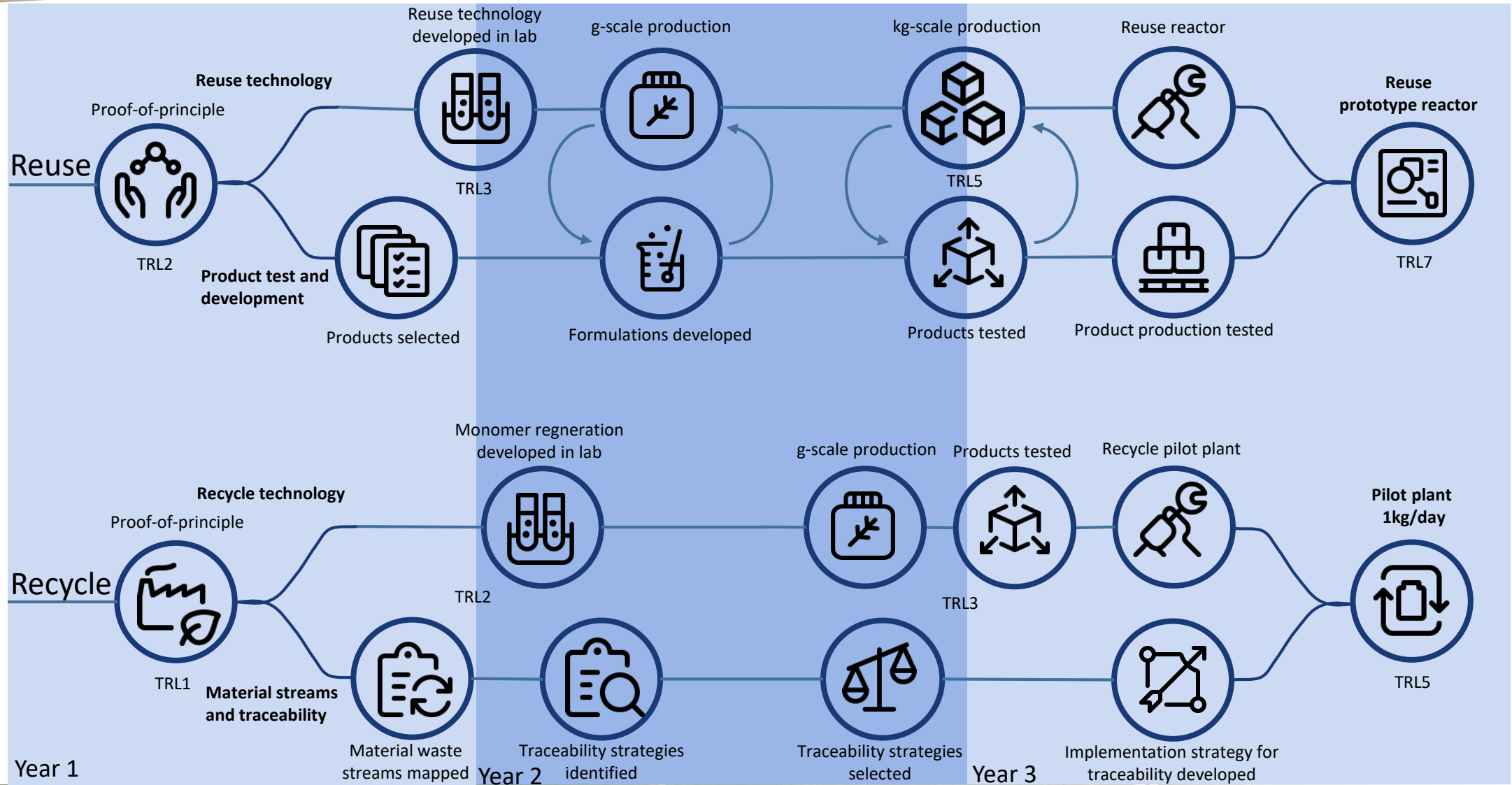




ReCYCLE

- End-of-life polyurethane products
- Targets monomer regeneration through chemical recycling
- High-risk approach
- Time to implementation (6-9 years)
- Operation cost target \leq cost of biobased polyurethane



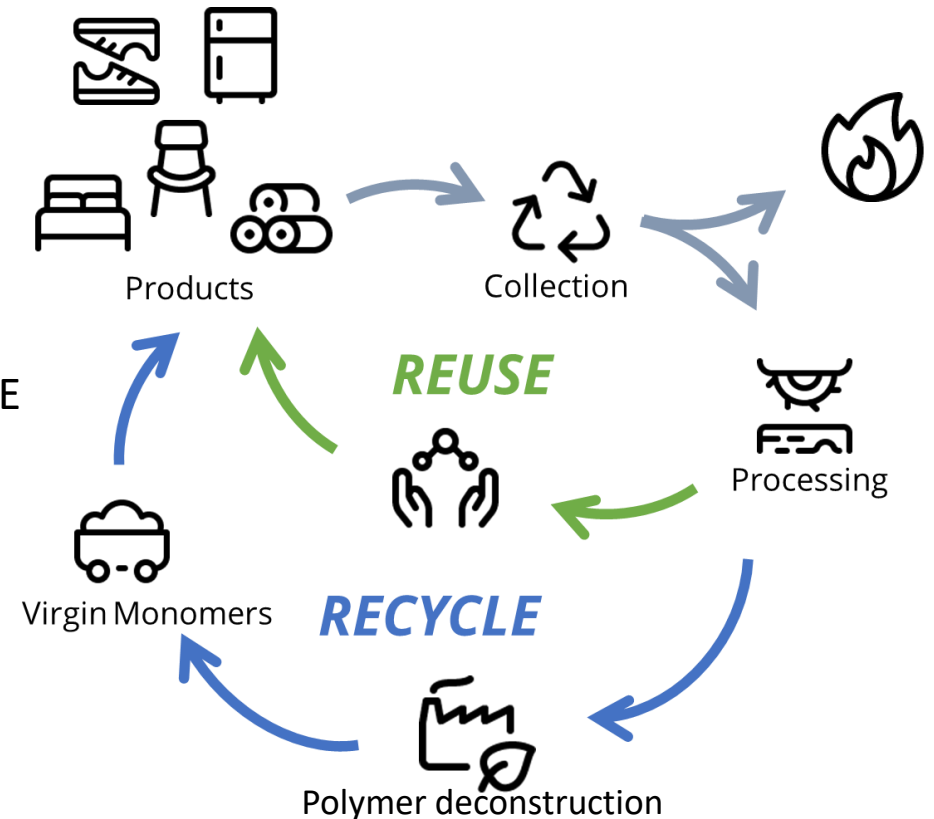




ReUSE & ReCYCLE

Important to develop both technologies

1. ReUSE before ReCYCLE
2. ReUSE material needs to be adaptable with ReUSE and ReCYCLE
3. New technologies will define future legislation and regulation
4. Traceability strategies for both strategies developed at once
5. Complete value chain will realize full potential for all PUR product producers

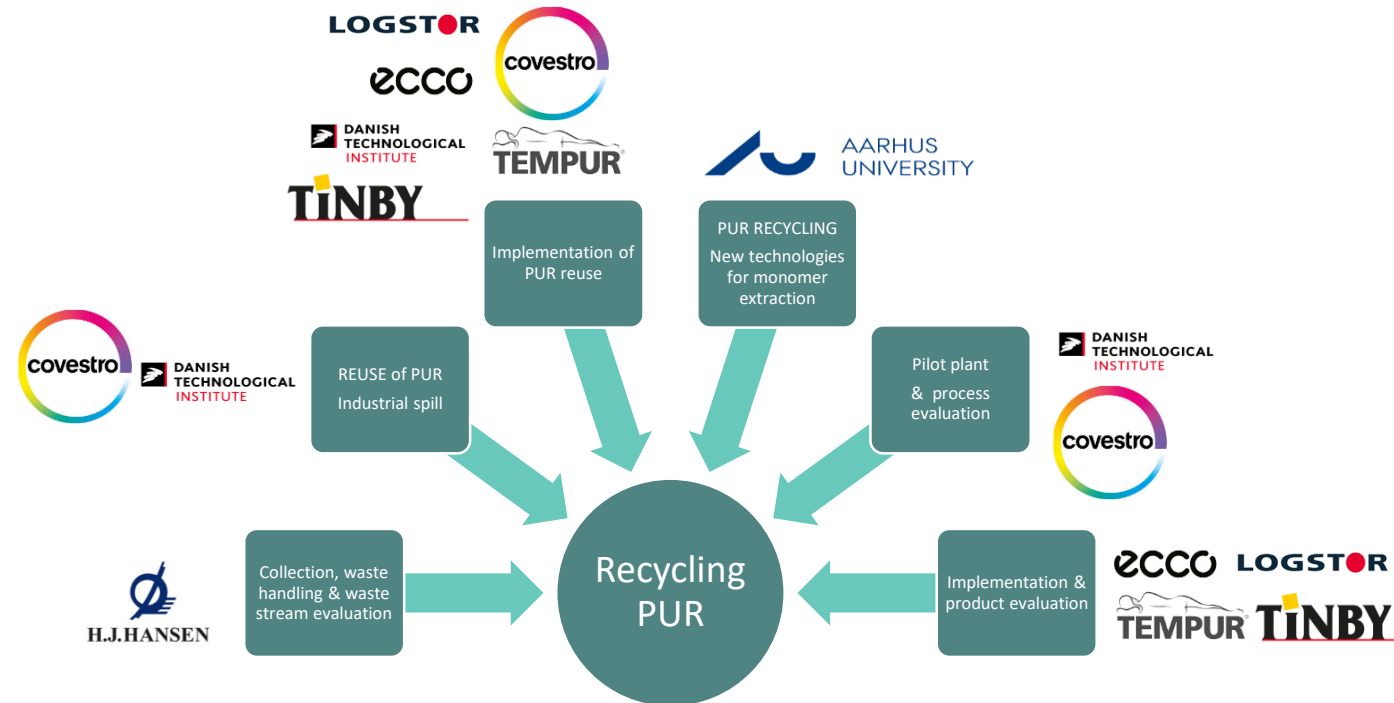




So what is next step for end-of-life PUR

- Polyurethane is here to stay and volumes goes up
- Requirement/regulation for recycling
- New recycling technologies are needed
- Our suggestion is RePURpose

REUSE
RECYCLE
RePURpose





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It's all about innovation

