



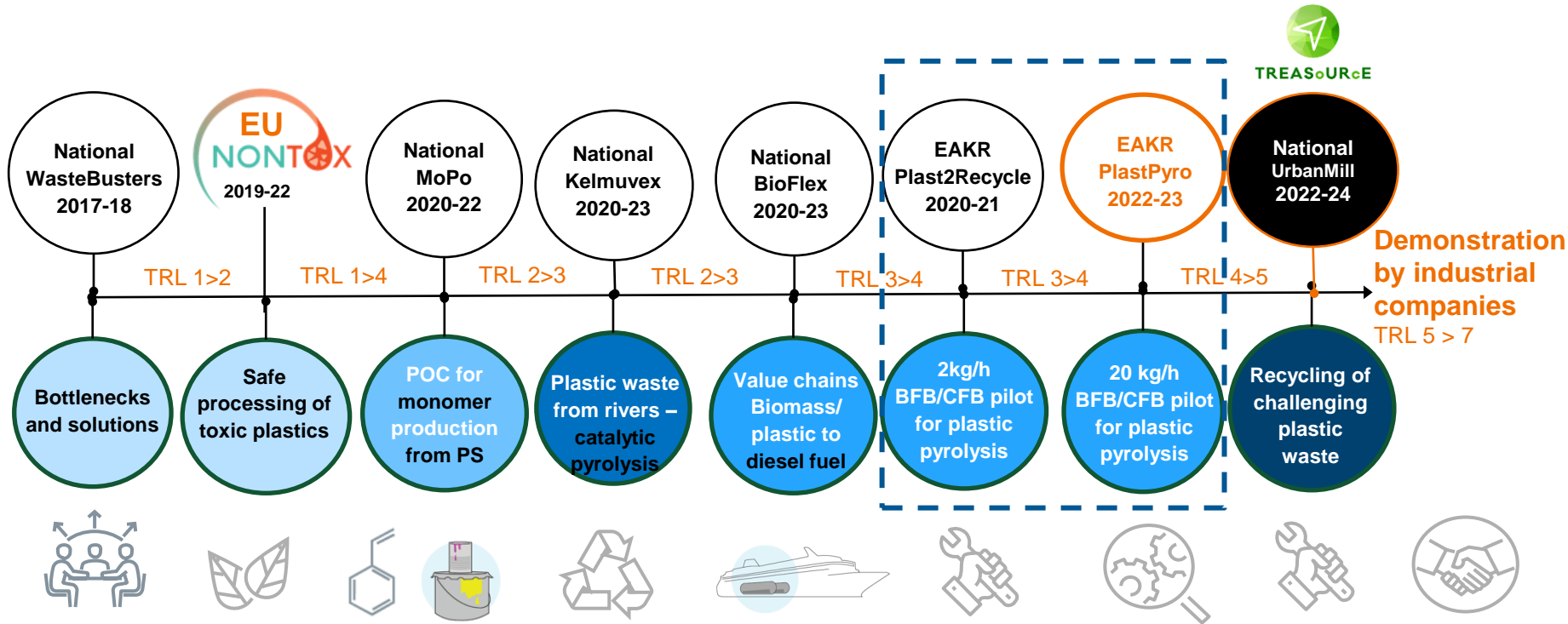
## UrbanMill

**New urban recycling concept to maximize the utilisation of plastic waste from industry, commerce, and consumers**

PlastPyro seminar 24.8.2023

Anja Oasmaa, Joonas Lahtinen, VTT

# Background on plastic recycling - Increasing TRL towards industrial operation



<https://www.vttresearch.com/en/news-and-ideas/polystyrene-can-be-circulated-back-raw-material-mopo-project-develops-collection-and>

<https://www.vttresearch.com/en/news-and-ideas/vtt-assess-bio-and-waste-based-oils-suitable-power-plants-and-ships>

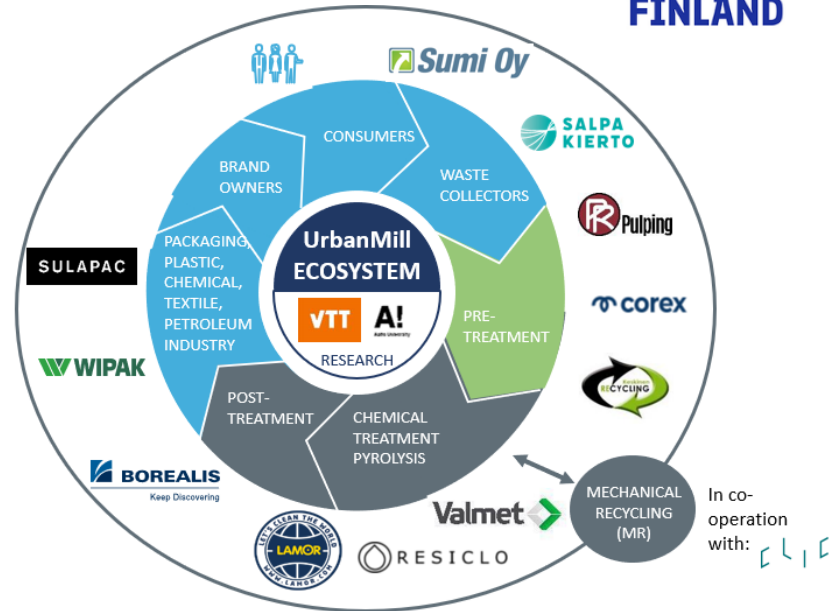
<https://www.vttresearch.com/en/news-and-ideas/plastic-waste-rivers-recycling-jakarta-indonesia-target-study>

Two-year project of 3 M€, Funded by Business Finland, VTT, and participating companies

UrbanMill co-innovation ecosystem aims to develop a pyrolysis-based industrial chemical recycling concept for plastic waste.

UrbanMill co-innovation project is developing enabling technologies to utilise highly mixed plastic waste as feedstock for chemical recycling producing high quality plastic materials complementing current recycled plastics.

The project aim to create novel concepts by combining tailored pre- and post-treatment technologies with pyrolysis.

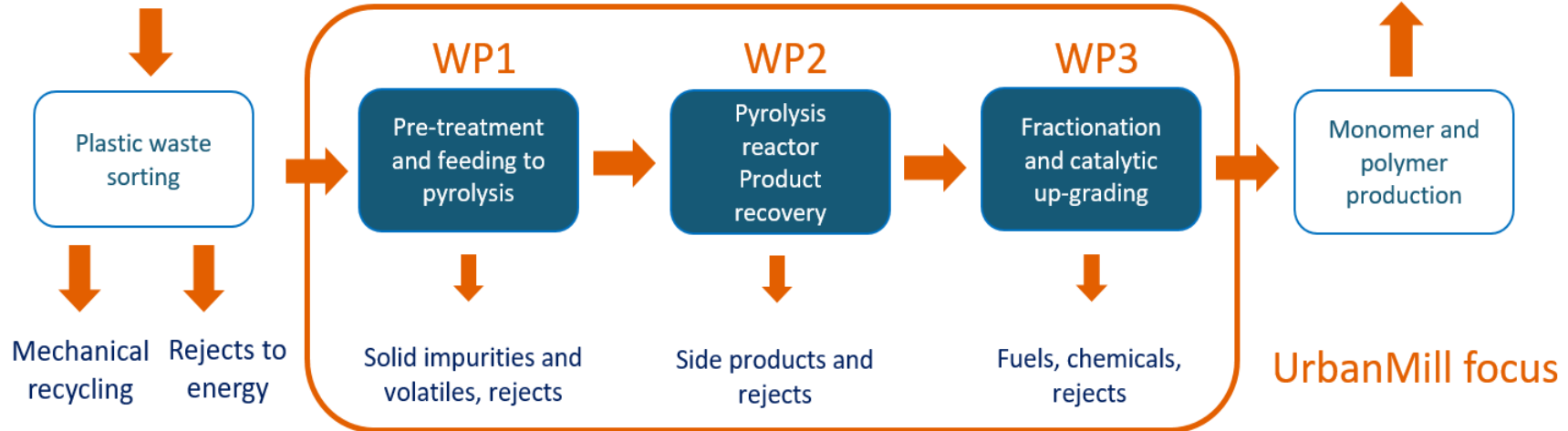


# Pyrolysis based chemical recycling of plastics – process steps to enable use of mixed plastic waste as feedstock

## Mixed plastic waste

- PE, PP, PS (preferred components)
- PA, PET, PVC, ABS, fillers, additives...

Recycled high quality plastics



# Workpackages

## WP 1: Feedstocks and pre-treatment

- Procurement of feedstocks
- Characterization of thermal degradation behaviour of feedstocks for pyrolysis
- Separation and pre-treatment

## WP 2: Pyrolysis of plastic waste

- Pyrolysis pathway study by model mixtures
- Pyrolysis experiments
- Modelling for industrial scale-up

## WP 3: Post-treatment of pyrolysis intermediates

- Physical treatments -  
Fractionation/Isolation/Separation
- Chemical purification - adsorption
- Catalytic hydrotreatment of pyrolysis intermediate
- Concept development

## WP 4: Markets, concepts, integration, sustainability, TEA

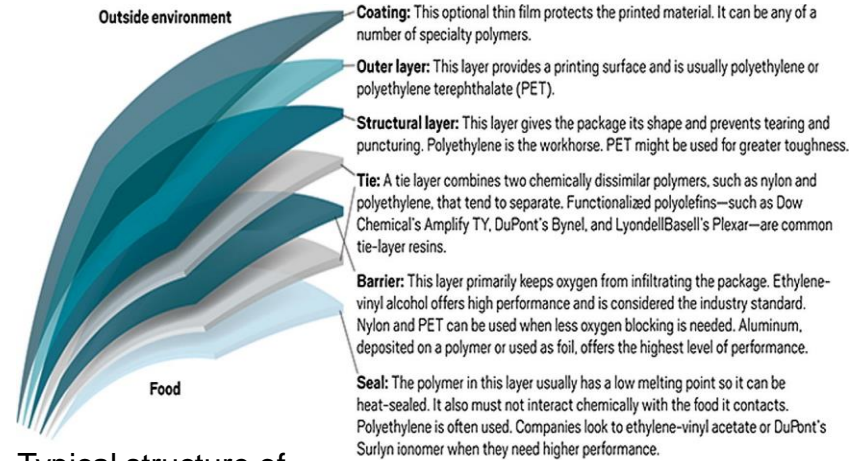
- Evaluation of market needs and volumes
- Definition of 1-2 recycling concepts
- Considering integration to existing recycling infrastructure and value chains
- Estimation of potential environmental and economic impacts of the developed concepts
- Review of relevant legislation and identification of bottlenecks

## WP 5: Management, Coordination, Collaboration and Dissemination

- Coordination and management
- Dissemination and exploitation
- National and international collaboration

# Experimental work in UrbanMill

- Pyrolysis of challenging raw materials are studied
- Materials include:
  - Multilayer plastics e.g. PA, PET, EVOH
  - Mechanical recycling reject from plastic waste stream
  - Liquid packaging board
- Experimental work will be carried out in different scales
  - From lab-scale to pilot scale



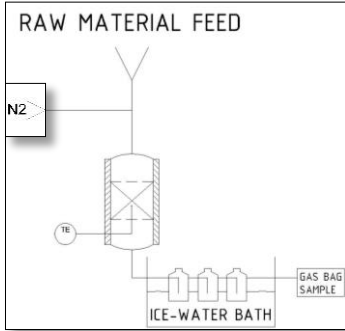
Typical structure of multi-layer packaging



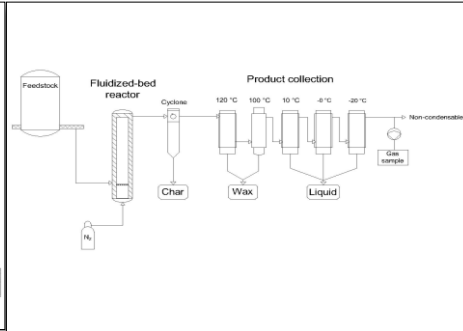
Reject from the recycling line

# Experimental work in UrbanMill

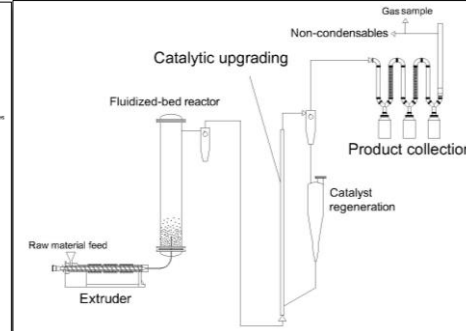
Lab scale  
pyrolysis unit



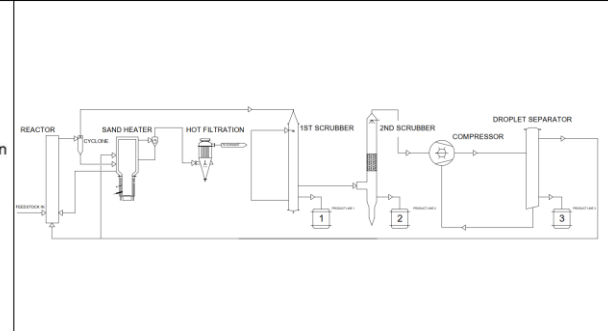
Bench scale continuous  
pyrolysis unit



Process development  
unit BFB+CFB



Process development  
unit, pilot CFB

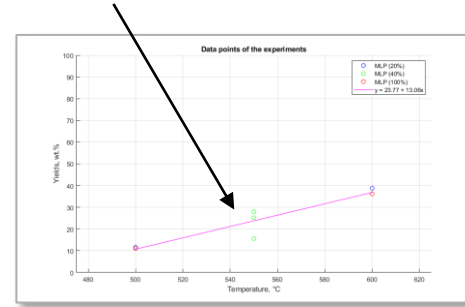


- Designed for parametric screening
  - Temperature
  - Feedstock
  - Catalyst
- Capacity ~5 g
- Temperature controlled by electrical heating oven
- Product collected in cold trap
- Operational variables
  - Temperature
  - Residence time
  - Feedstock
  - Catalyst
- Capacity ~300-500 g/h
- Temperature controlled by electrical heaters
- For both biomass and plastic pyrolysis
- Thermal/catalytic pyrolysis
  - Ex-situ catalytic process
- Capacity ~2 kg/h
- Catalyst regenerator
- In design to implement extruder as a feeding unit for homogeneous feeding
- Mainly used for biomass but plastic feedstock to be introduced
- Heat provided by hot sand which is circulated from sand heater
  - Some burning medium used in the heater
- Capacity ~20 kg/h
- Scrubbers for product condensation

# Results

- Pyrolysis of multilayer films has produced important data for piloting scale runs
  - The formation of toxic HCN was not identified during the small-scale experiments below 600 °C
  - Pyrolysis of PA can yield valuable caprolactam
    - The yields ranged between 40-50 wt.%, more tests required

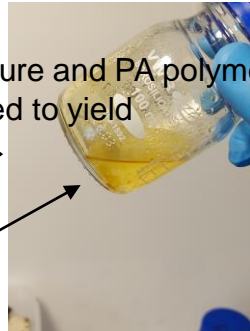
## Gas yield behaviour in bench-scale runs



Polyamide



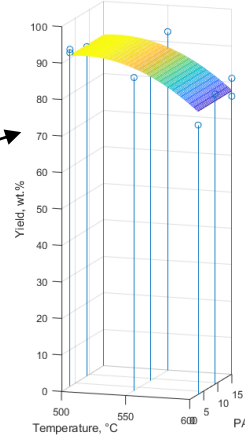
Caprolactam



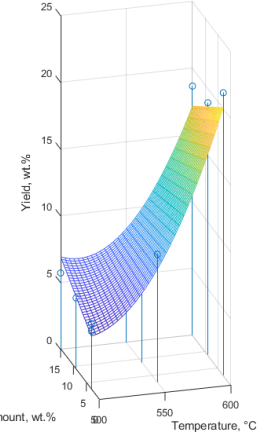
Effect of temperature and PA polymer in PA:PE mixture feed to yield

Caprolactam found from the product sample

Response surface model of Wax



Response surface model of Gas





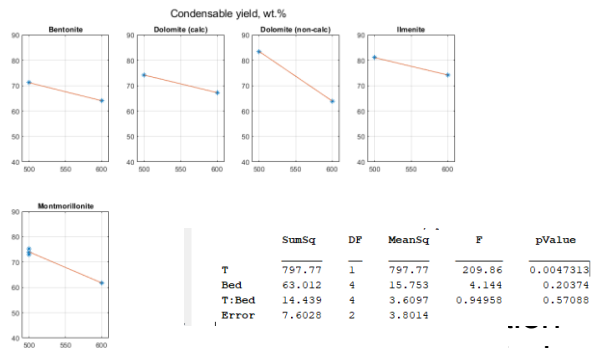
# Results from the project

- The project aims to answer key questions regarding the pyrolysis of various waste streams such as:
  - What feedstocks can be tolerated in pyrolysis
  - What are the optimal conditions to produce intermediate for downstream processes
  - Can the catalyst be employed to either remove unwanted components or to refine the product

- Too high amount of PET → blockages and agglomeration
- Too high concentration of halogens → poisoning of the catalyst
- Too many heteroatoms → High costs in downstream processes

- What parameters have significant effect on the product?
- Do they have interactive effects
- How they change in scale-up?

## Catalyst screening results



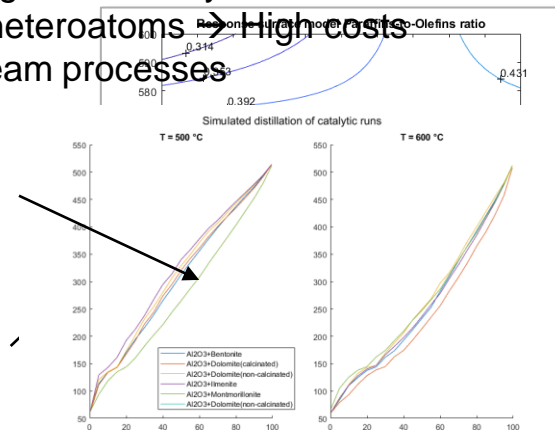
halogens

→ poisoning of the catalyst

- Too many heteroatoms → High costs in downstream processes

Montmorillonite acts differently at T = 500 °C from the rest, to be further analyzed

Model for paraffin-to-Olefin ratio in Fiber containing feedstock



# Link between UrbanMill and PlastPyro

- At final stage of UrbanMill, the objective is to validate the concept where large amount of selected feedstock will be processed
- **EAKR PlastPyro provides the equipment to validate UrbanMill results**
  - The EAKR PlastPyro project plays a crucial role in this project, as the previous concept for Pilot was unsuitable for handling this type of feedstock. The modifications done in PlastPyro serves the upcoming experiments and projects