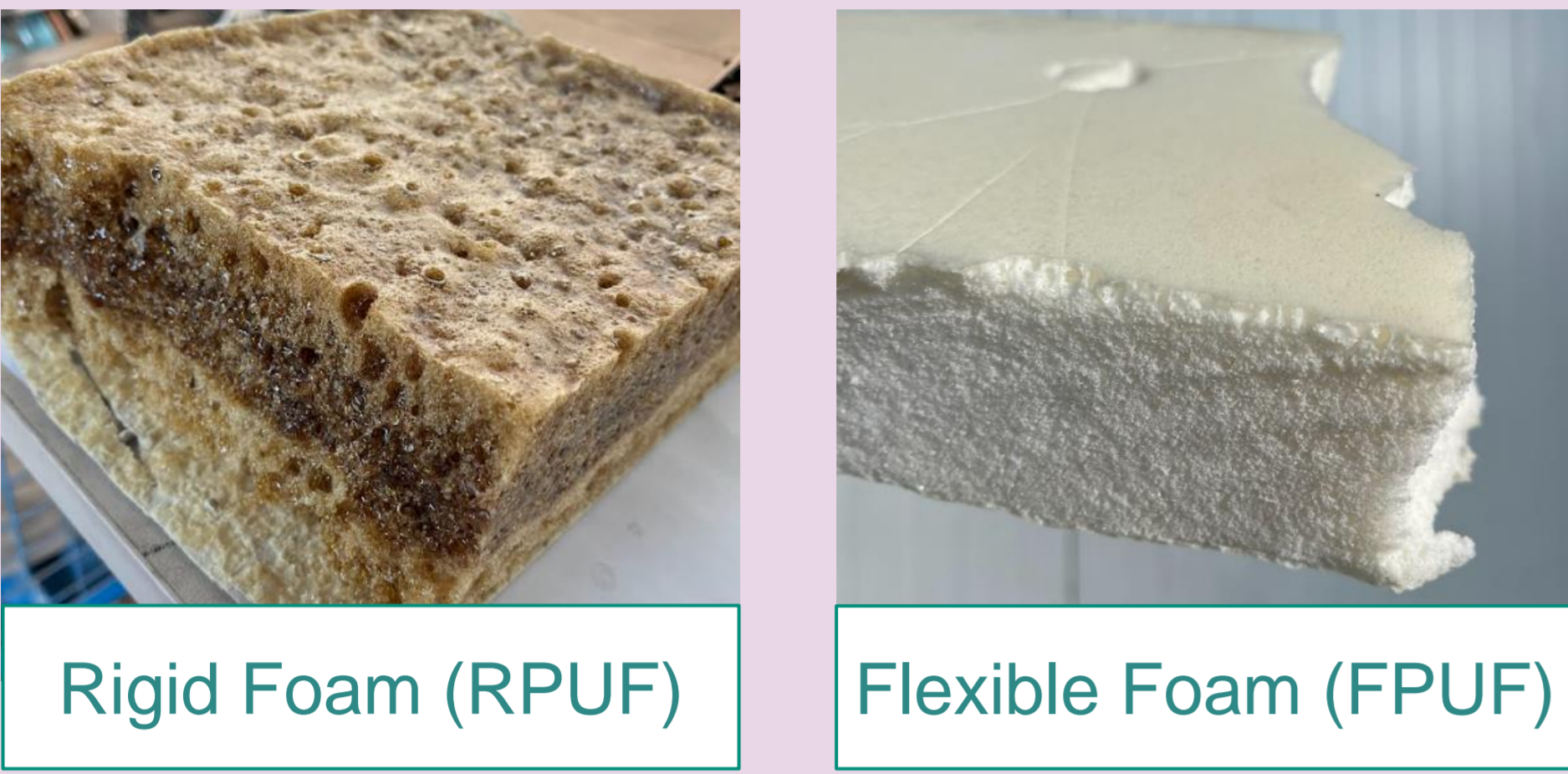


Towards Polyurethane Circularity by Pyrolysis


Lab-scale Investigations & Detailed Product Analyses

Michael Zeller, Luca Weigel, Aylin Hannemann, Pratistha Shrestha, Ankh-Erdene Erdenepurev, Lea Wattenberg, Daniela Merz, Salar Tavakkol, Dieter Stapf



Rigid Foam (RPUF)

Flexible Foam (FPUF)



Cast Elastomer (CE)

- Coatings
- Adhesives
- Thermoplastic PUR (TPU)
- ...

many more...

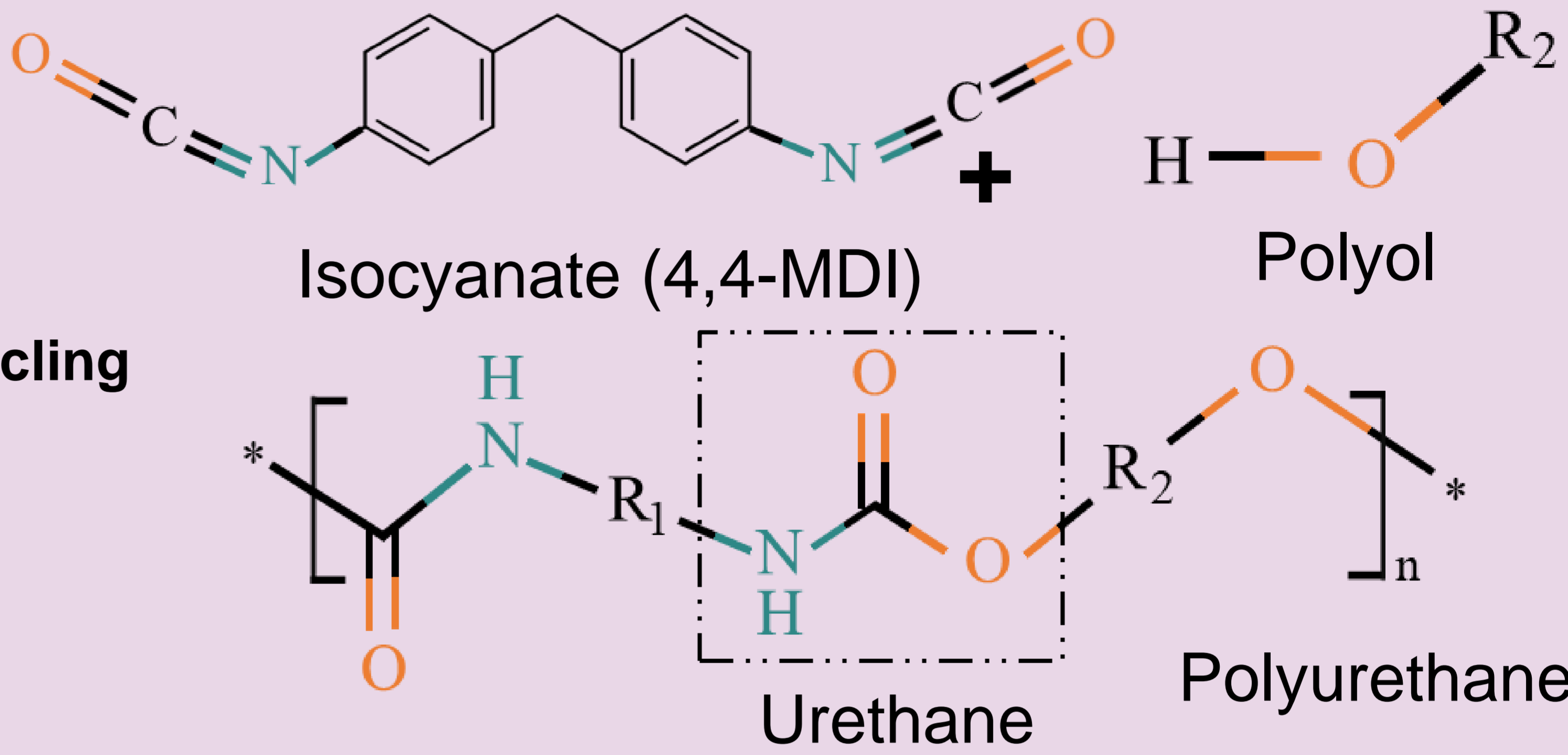
Mechanical Recycling

- Thermoset properties
- Variety of PUR
- Additives
- Downcycling

Chemical Recycling Solvolysis

- PUR type-dependent processes
- Additives
- Product Yield

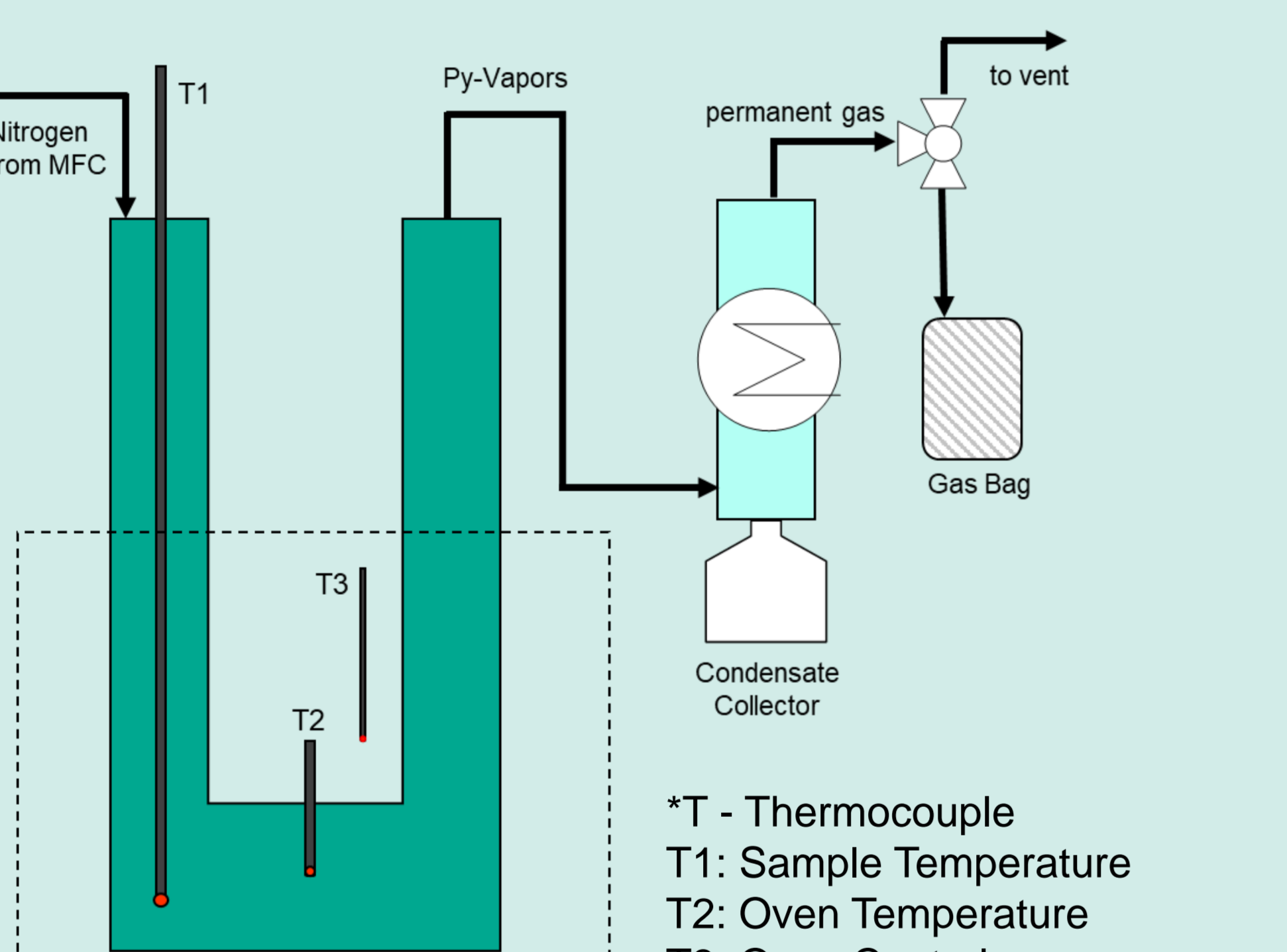
Feedstock | Polyurethane



Isocyanate (4,4-MDI) + Polyol → Polyurethane

Urethane

Experimental Setup



Nitrogen from MFC → T1 → Py-Vapors → permanent gas → to vent / Gas Bag

Condensate Collector

Oven: T2, T3

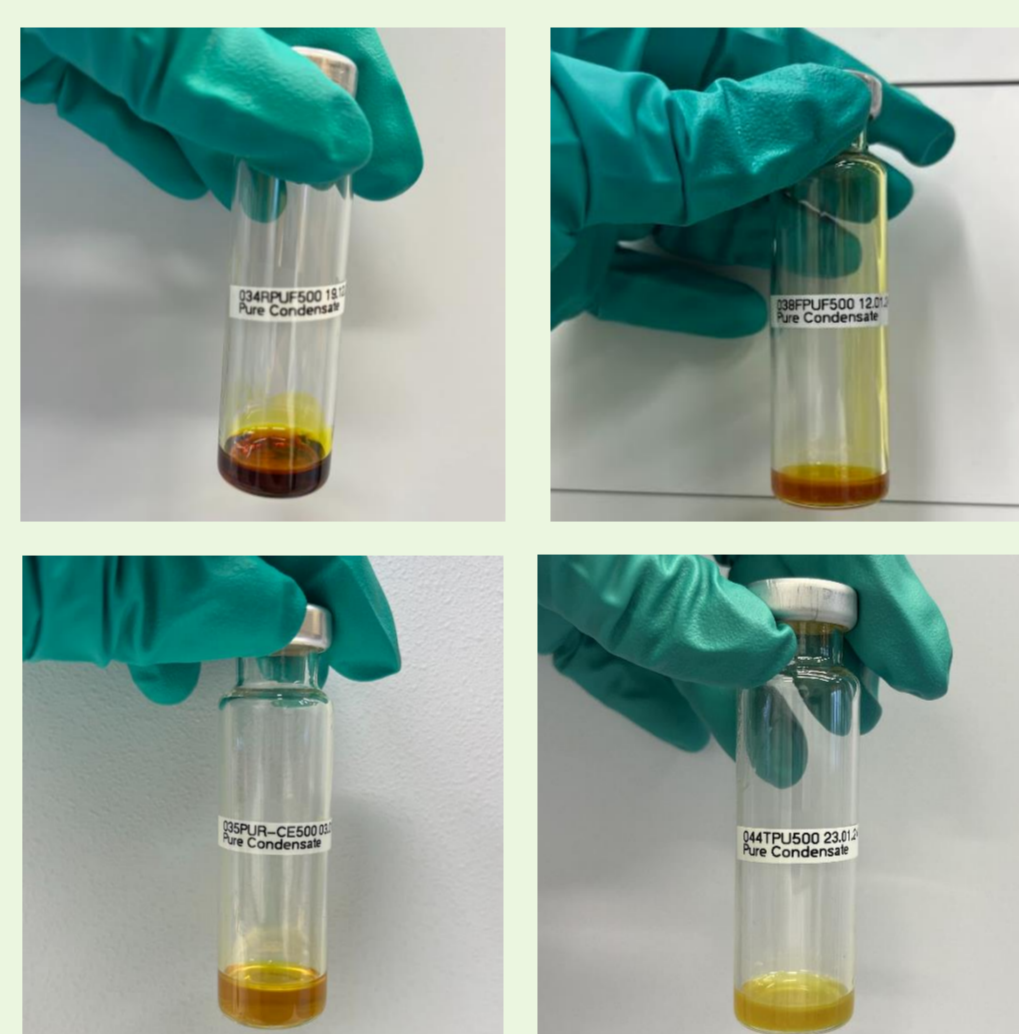
*T - Thermocouple
T1: Sample Temperature
T2: Oven Temperature
T3: Oven Control

- Oven Set Temperature: 500 °C
- Inert Flushing Gas Flowrate: 50 ml/min
- Isothermal Dwell Time: 60 min
- Feedstock Sample Mass:
 - TPU, CE, RPUF: 3.5 ± 0.1 g
 - FPUF: 2.5 ± 0.1 g

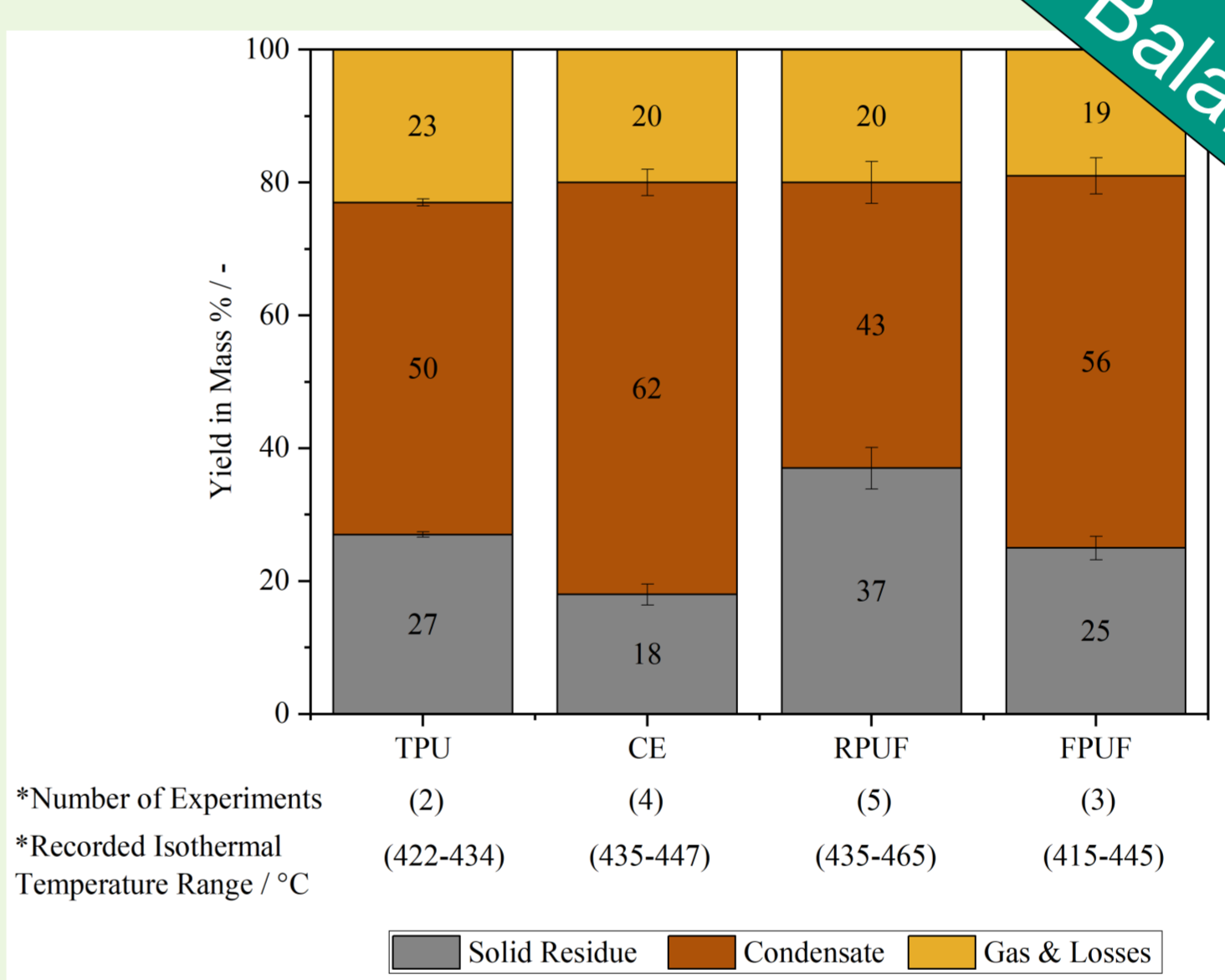
To-Do's

- Process Parameter Variation
 - Temperature
 - Residence time
- Detailed Product Analyses (GC-MS, GCxGC, NMR, ATR-FTIR)
- Quantitative Product Analyses (GC-MS, GCxGC)
- Scale-Up Evaluation

Results



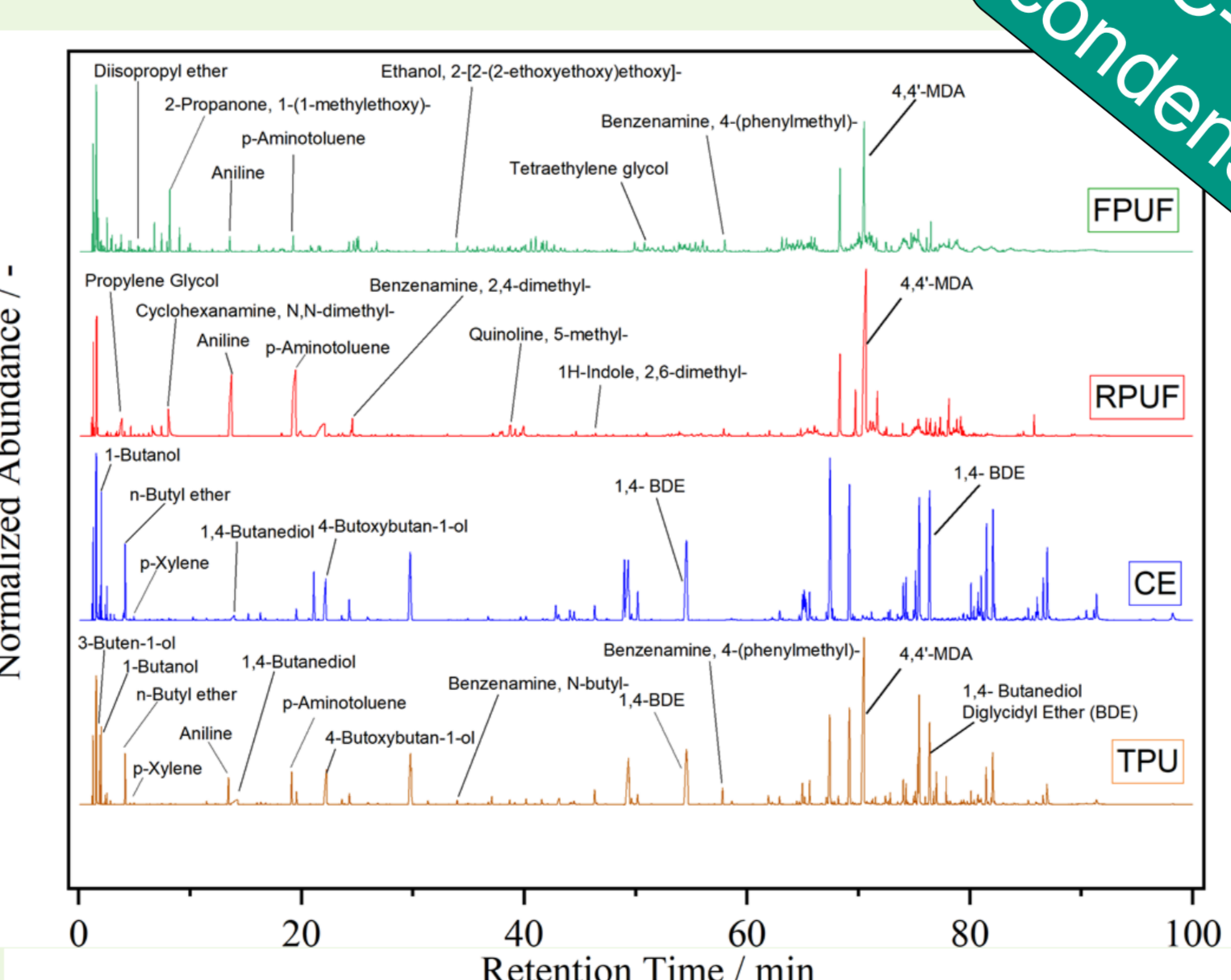
Liquid condensate obtained from all feedstocks



Feedstock	Experiments	Temp Range (°C)	Solid Residue (%)	Condensate (%)	Gas & Losses (%)
TPU	(2)	(422-434)	27	50	23
CE	(4)	(435-447)	18	62	20
RPUF	(5)	(435-465)	37	43	20
FPUF	(3)	(415-445)	25	56	19

*Number of Experiments
*Recorded Isothermal Temperature Range / °C

GC-MS of condensates



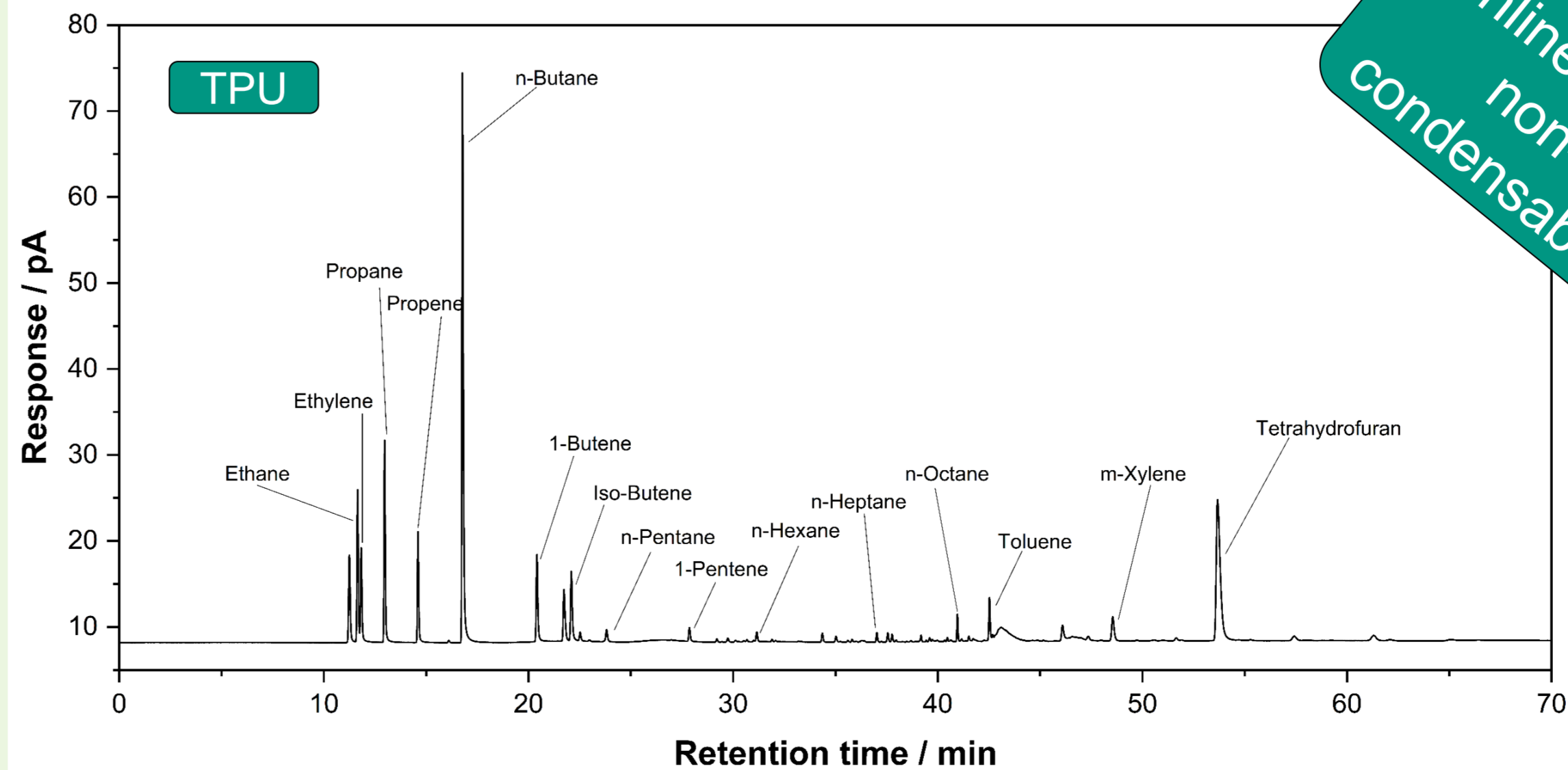
Peak Area fraction in %:

- Not identified: 23%
- diverse: 6%
- Polyols: 10%
- Dimethyl-MDA: 9%
- 2,4-MDA: 10%
- Aniline: 16%
- o-Toluidine: 17%
- 4,4-MDA: 17%

PUR- Monomer Precursors

4,4'-Methylenedianiline (MDA)

Online-GC of non-condensables



Response / pA vs Retention time / min

Non-condensables contain:

- Carbon Dioxide, CO
- Methane
- Alkanes & Olefins
- THF (TPU-specific)