

Riciclo chimico di plastiche tramite pirolisi e gassificazione: stato dell'arte, sviluppi e prospettive nella modellazione chimica e multiscala di reattori industriali

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POLITECNICO
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Giornata di studio “Rifiuti e Life Cycle Thinking” circolarità e sostenibilità - AWARE

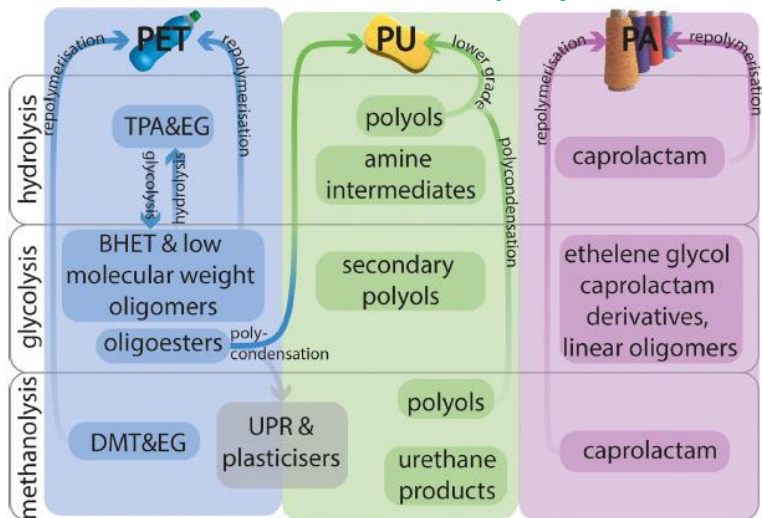


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Pathways to chemical recycling of SPW

For condensation polymers



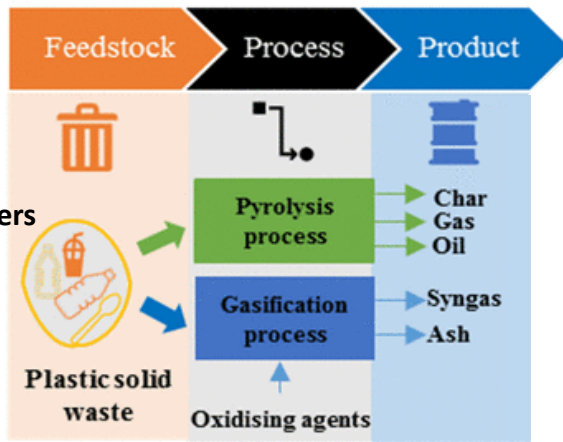
For ANY SPW mixture: pyrolysis and gasification

Outside Environment

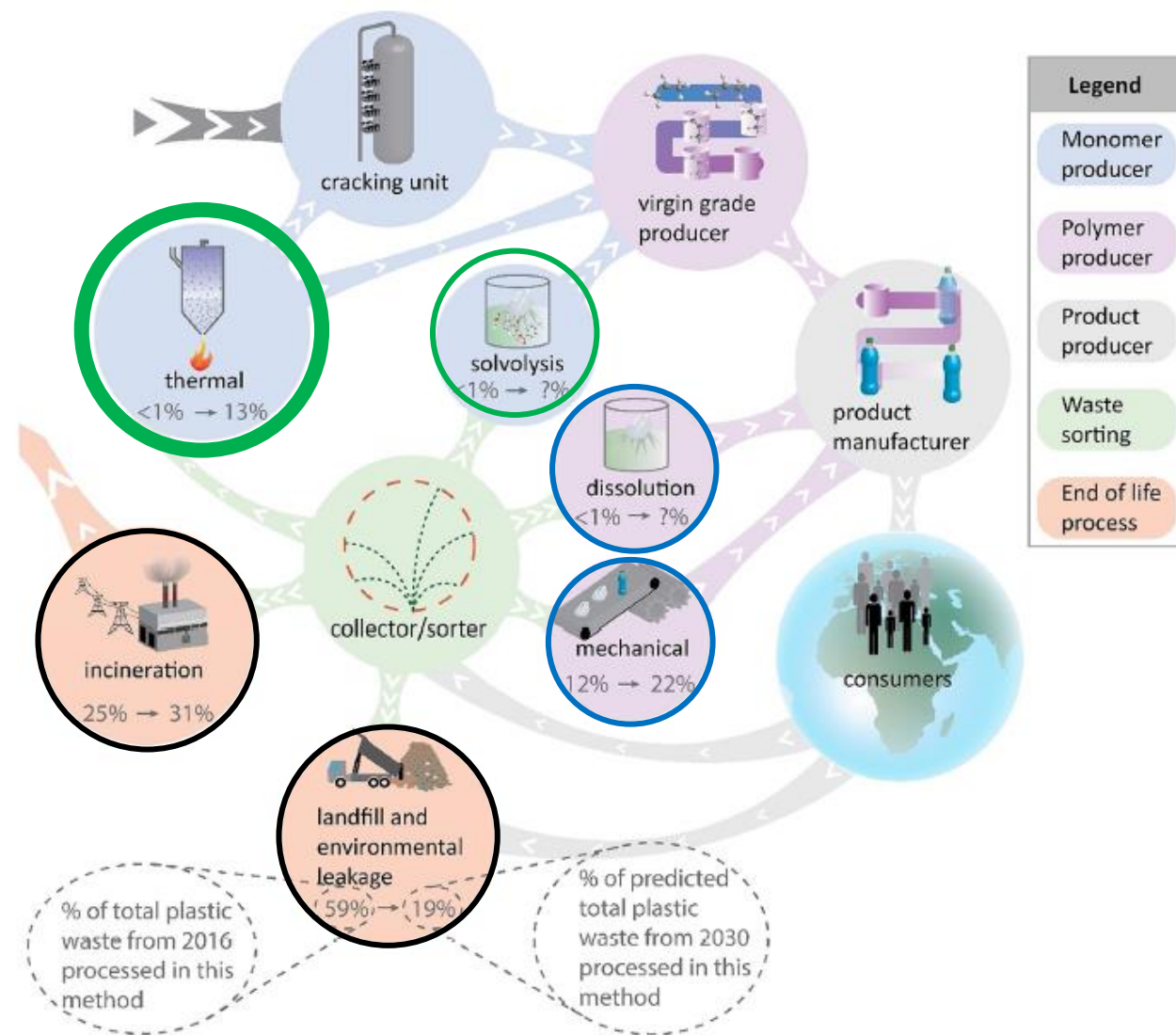


Food Side

PE
PET
Nylon (PA)
Specialty Polimers
Ethylene Vinyl
Others (e.g. AI)



0.06 Mtonn/year (0.2% of collected SPW)

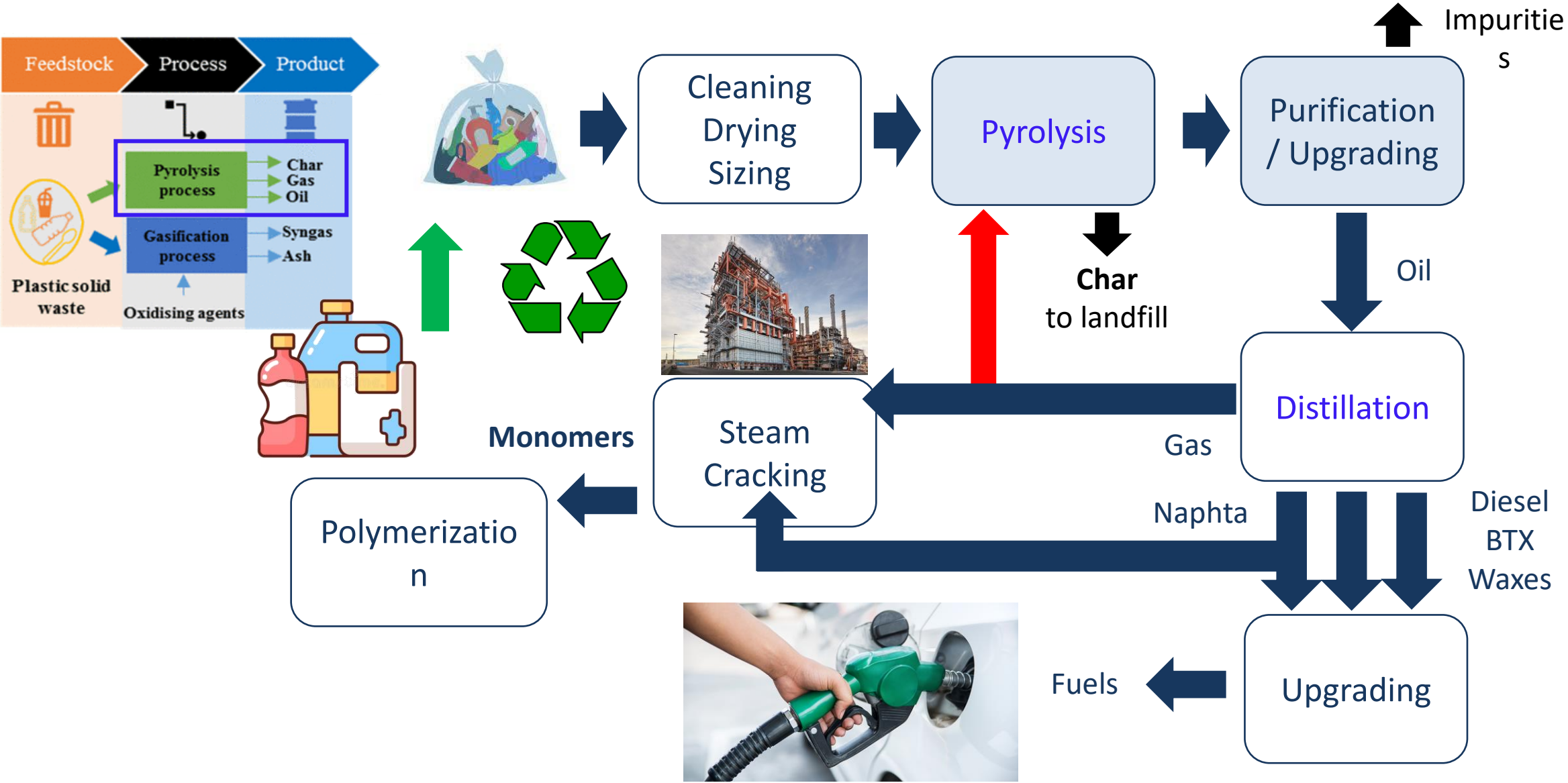


McKinsey, Report: "How plastics waste could transform the chemical industry" 2018.

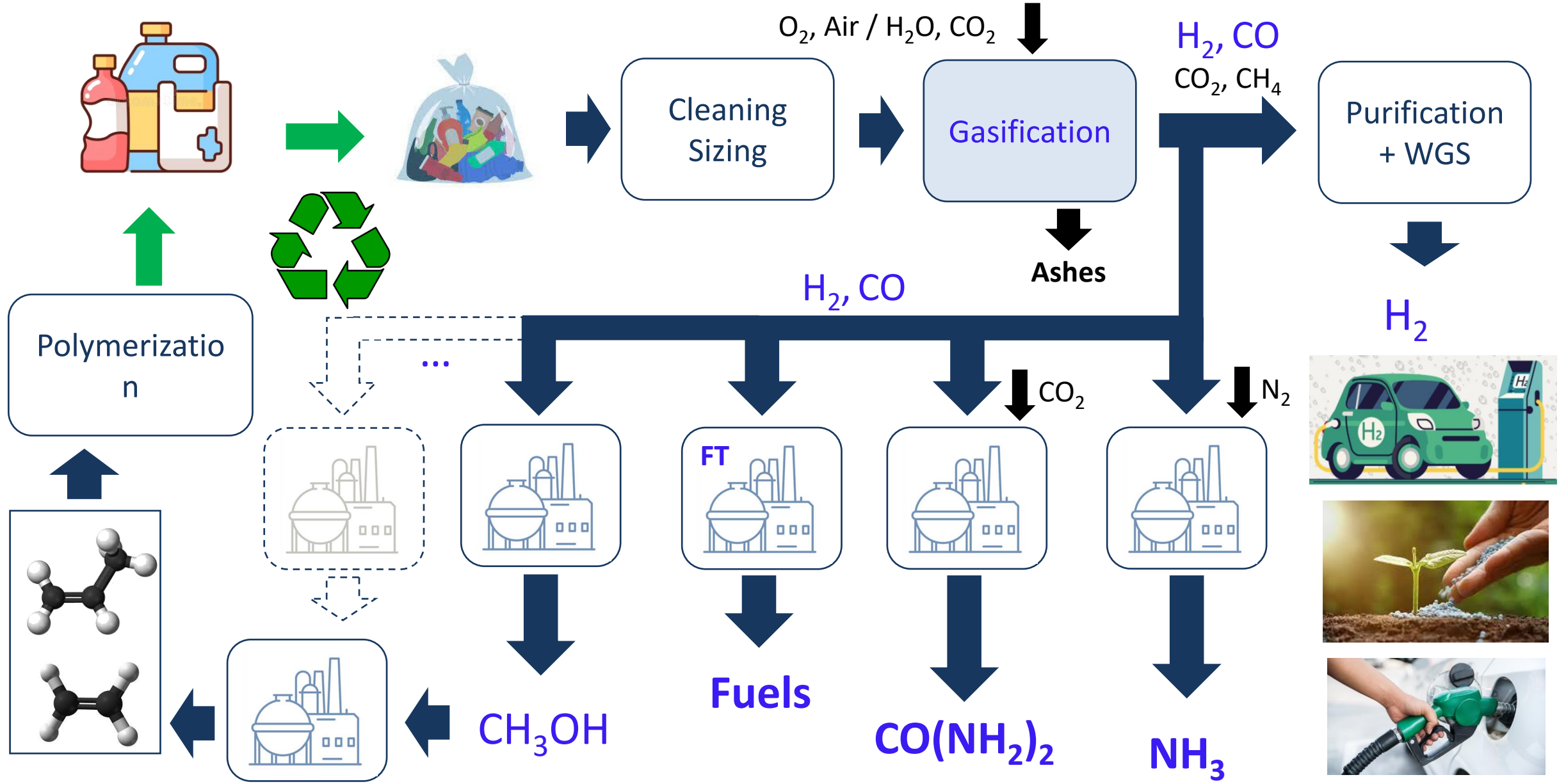
I. Vollmer, et al. "Beyond mechanical recycling: giving new life to plastic waste." *Angewandte Chemie International Edition* 59.36 (2020): 15402-15423. | A. Antelava, et al. *Energy & Fuels* 35.5 (2021): 3558-

3571
"Rifiuti e Life Cycle Thinking" circolarità e sostenibilità – AWARE, M. Pelucchi

The value chain downstream to chemical recycling: **pyrolysis**



The value chain downstream to chemical recycling: **gasification**





All in on plastics pyrolysis

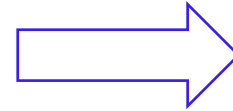
Chemical companies are fully backing this controversial plastic waste recycling process. To prove their detractors wrong, they will need to make it work

Chemical & Engineering News, October 2022

(Thermo) Chemical Recycling of Solid Plastic Waste: Pyrolysis and Gasification

Features:

- ✔ Converts polymers to new feedstock (e.g. **monomers, fuels, hydrogen, syngas, ...**)
- ✔ Only route for **heterogeneous, variable and contaminated feedstock** (e.g. multilayer packaging materials)
- ✔ **It is an upcycling process**
- ⚠ **Requires heating** (200-700°C) for melting and cracking
- ⚠ Products are strongly **feedstock and conditions dependent** (e.g. polymer/polymer interactions)
- ⚠ **Multiphase (gas, oil + solid char) and multicomponent** process
- ⚠ **Requires upgrading and removal of contaminants**
- ⚠ **Agglomeration** phenomena and **tar yields (G)**
- ⚠ **NO_x** release in air gasification / **dioxins (PVC)** in air/O₂

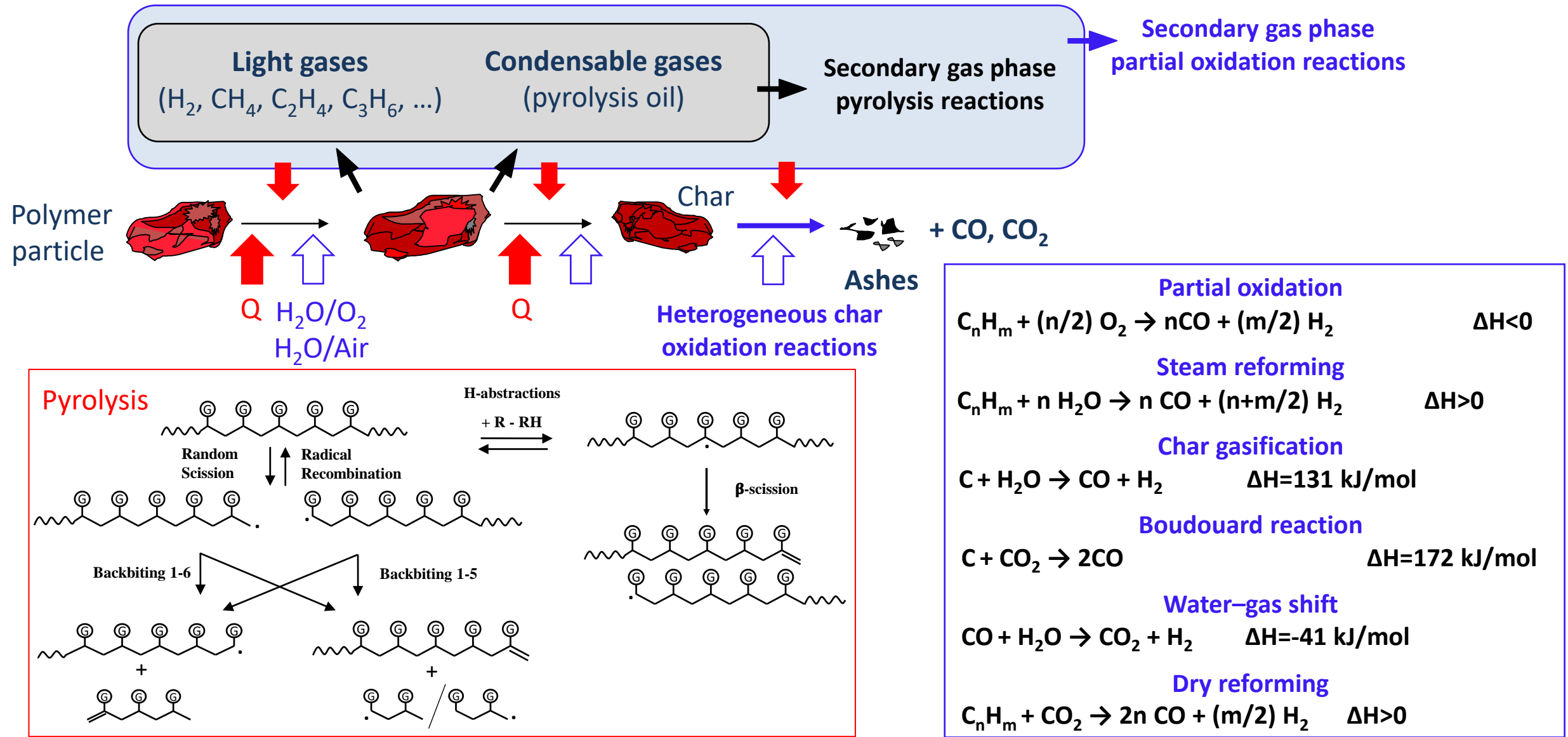


“We kind of joke sometimes that every day we need to make a birthday cake, but the ingredients keep changing all the time, and the birthday cake better be good and taste the same.”

—Eric Hartz, cofounder, Nexus Circular

Pyrolysis and Gasification at the particle scale

Thermal **pyrolysis** is the first step even in catalytic pyrolysis, gasification and catalytic gasification of solid fuels



Recent/ongoing publications on chemistry models for SPW recycling

Progress in Energy and Combustion Science 84 (2021) 100901



Contents lists available at ScienceDirect

Progress in Energy and Combustion Science

journal homepage: www.elsevier.com/locate/pecs

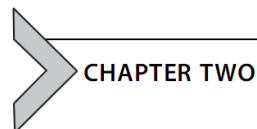


The chemistry of chemical recycling of solid plastic waste via pyrolysis and gasification: State-of-the-art, challenges, and future directions



Onur Dogu^a, Matteo Pelucchi^b, Ruben Van de Vijver^a, Paul H.M. Van Steenberghe^a, Dagmar R. D'hooge^{a,c}, Alberto Cuoci^b, Marco Mehl^b, Alessio Frassoldati^b, Tiziano Faravelli^{b,*}, Kevin M. Van Geem^{a,*}

Review paper



CHAPTER TWO

Book chapter

Chemical kinetics of catalytic/non-catalytic pyrolysis and gasification of solid plastic wastes

Andrea Locaspi^{a,†}, Matteo Ferri^{b,†}, Francesco Serse^a, Matteo Maestri^b, and Matteo Pelucchi^{a,*}

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Waste Management 156 (2023) 107–117



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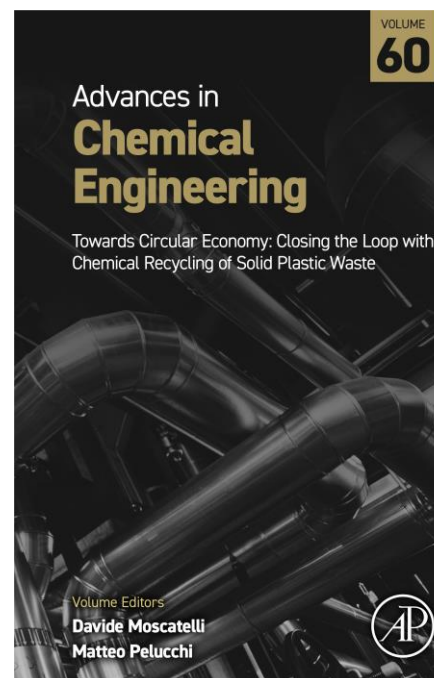
Towards a lumped approach for solid plastic waste gasification: Polyethylene and polypropylene pyrolysis

Andrea Locaspi, Matteo Pelucchi, Marco Mehl, Tiziano Faravelli^{*}

CRECK Modeling Lab, Department of Chemistry Materials and Chemical Engineering "G. Natta", Politecnico di Milano, P.zza Leonardo da Vinci 32, 20133 Milan, Italy



Polyethylene
Polypropylene



+ Locaspi et al., *J. Anal. Appl. Pyr.*, accepted

Towards a lumped approach for solid plastic waste gasification: polystyrene pyrolysis



PMMA

PET

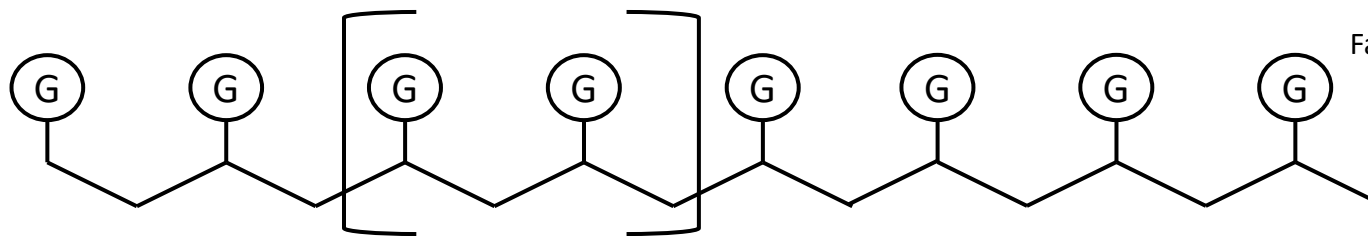
PA

PU

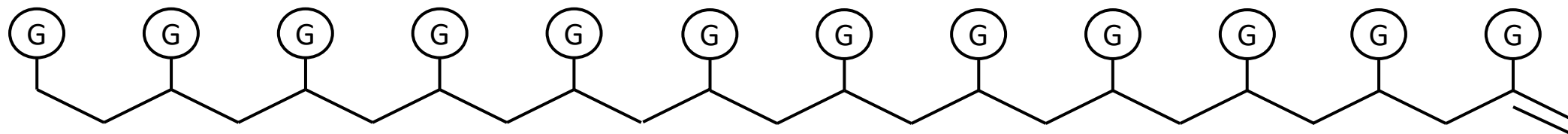
Functional group approach: description of the chain distribution

Ⓞ

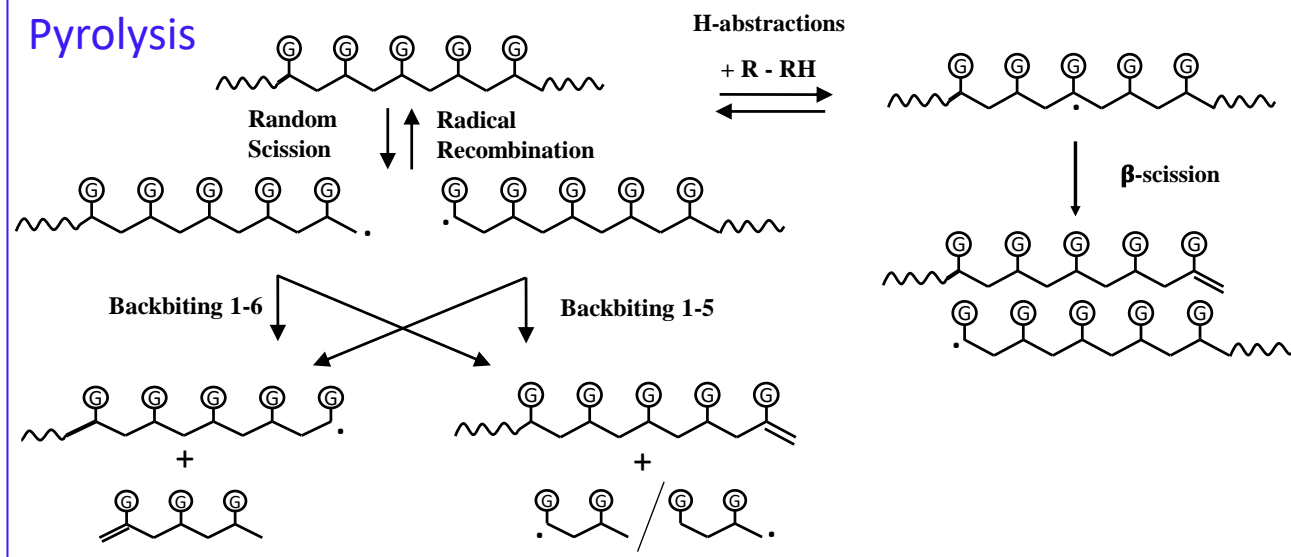
- H for PE
- CH₃ for PP
- C₆H₅ for PS



*J. Anal. Appl. Pyrol. : Ranzi et al., 40 (1997), 305–319 |
Faravelli et al., 52 (1999) 87-103 & 70 (2003), 761–777. |*

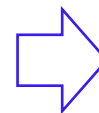


Pyrolysis



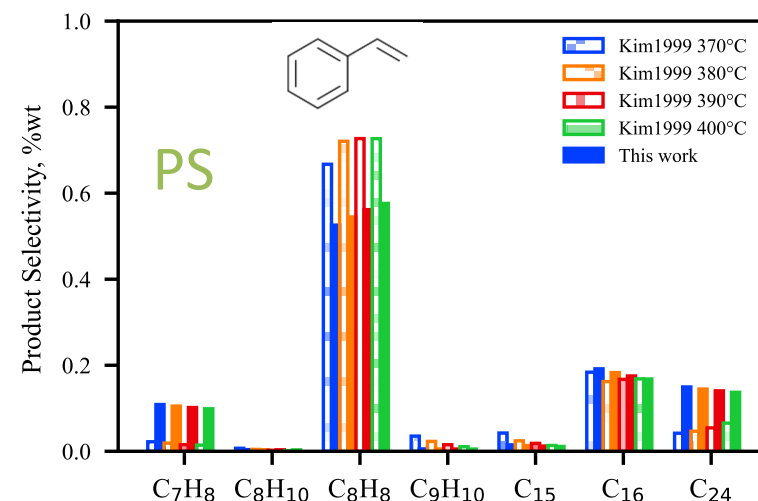
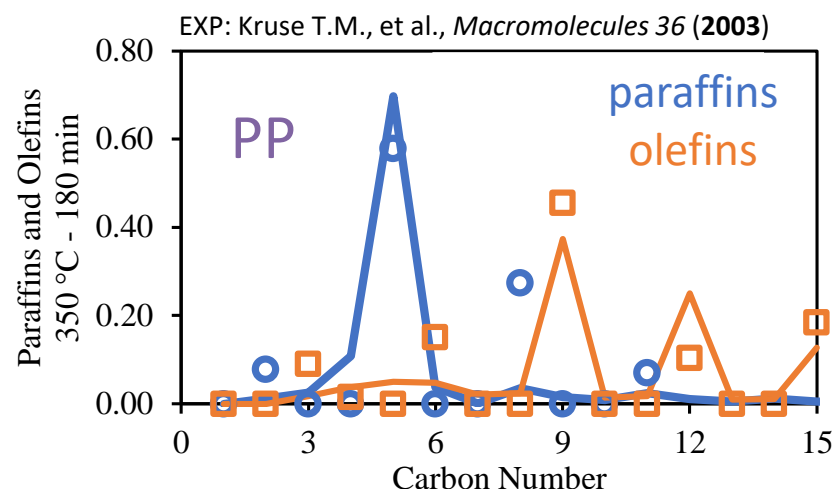
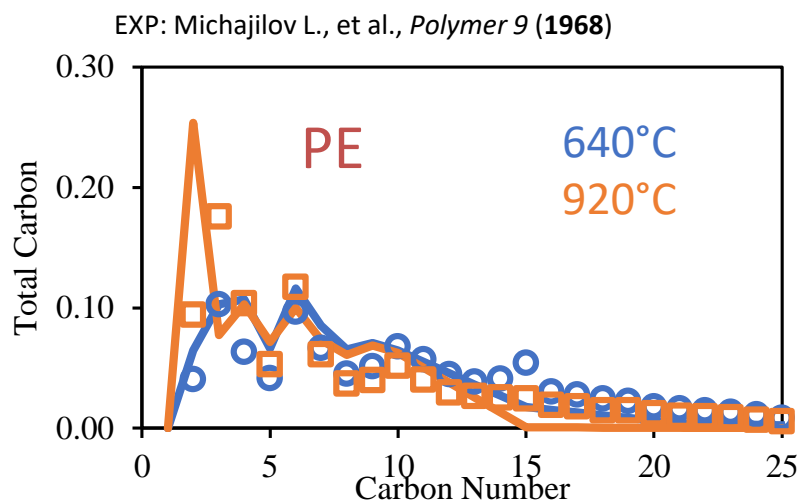
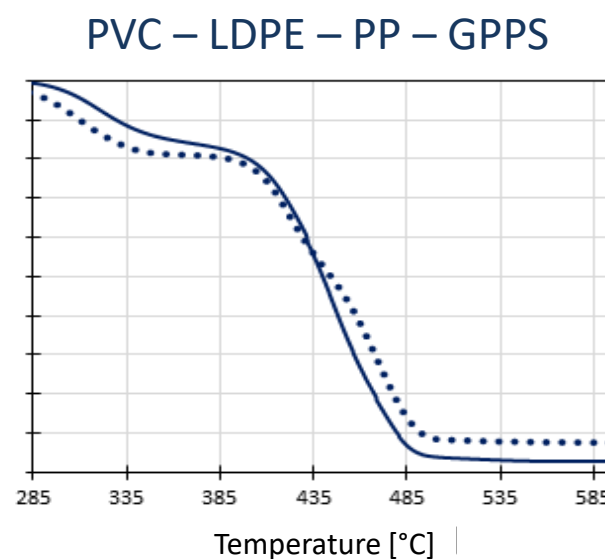
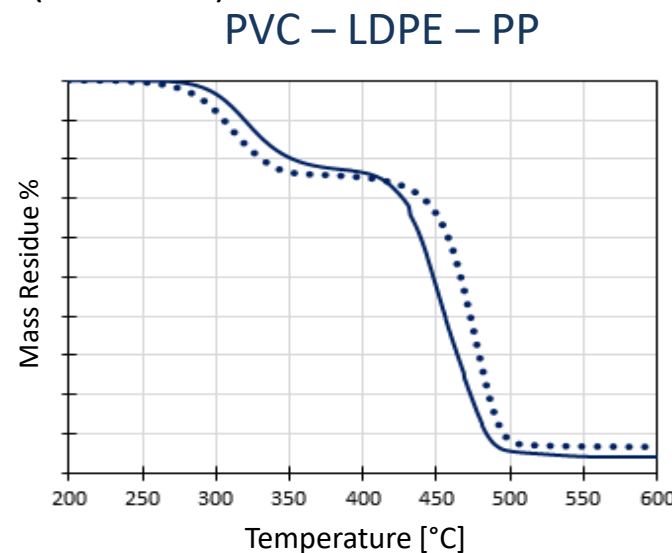
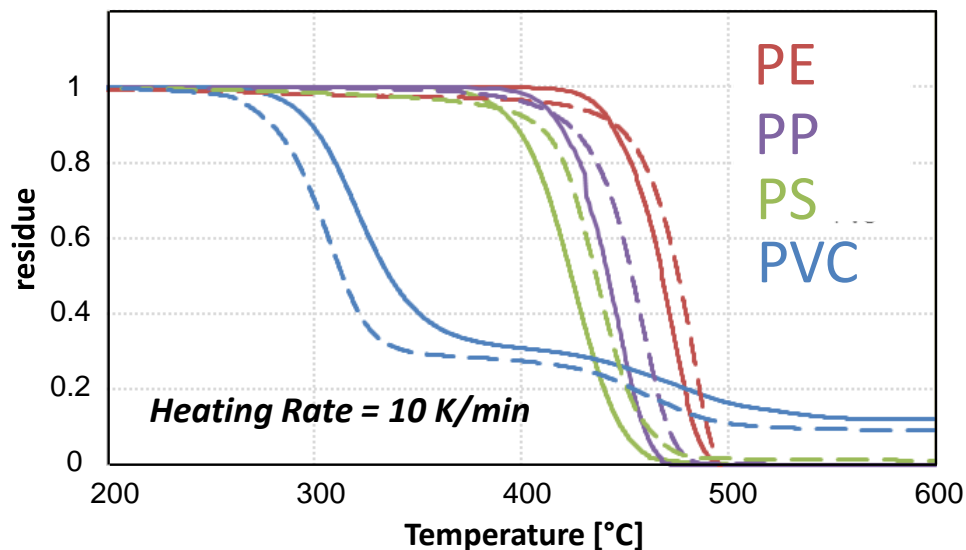
Outputs:

- Detailed **product distribution**
- Dependence of **product quality** on reactor operating conditions (T, time, P, feedstock composition)
- Investigation of **mixture interactions**
- Support to **industrial reactor design and scale-up**



Model validation: mass loss profiles and product distribution

Experimental Data LCCP (dashed lines), Model Results CRECK (solid lines)



Fluidized bed gasifier model with detailed kinetics

PVC: 41 species, 235 reactions
Euler-Euler model



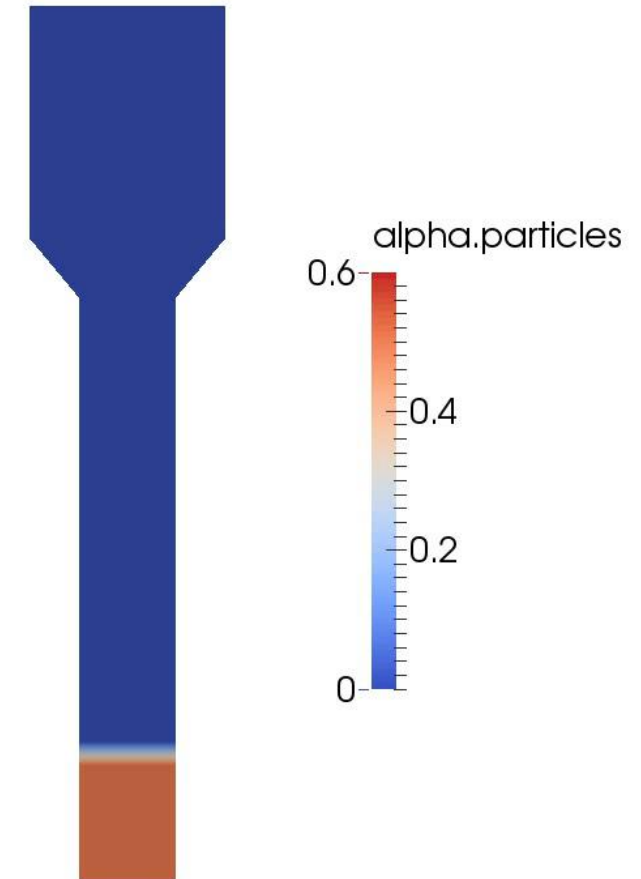
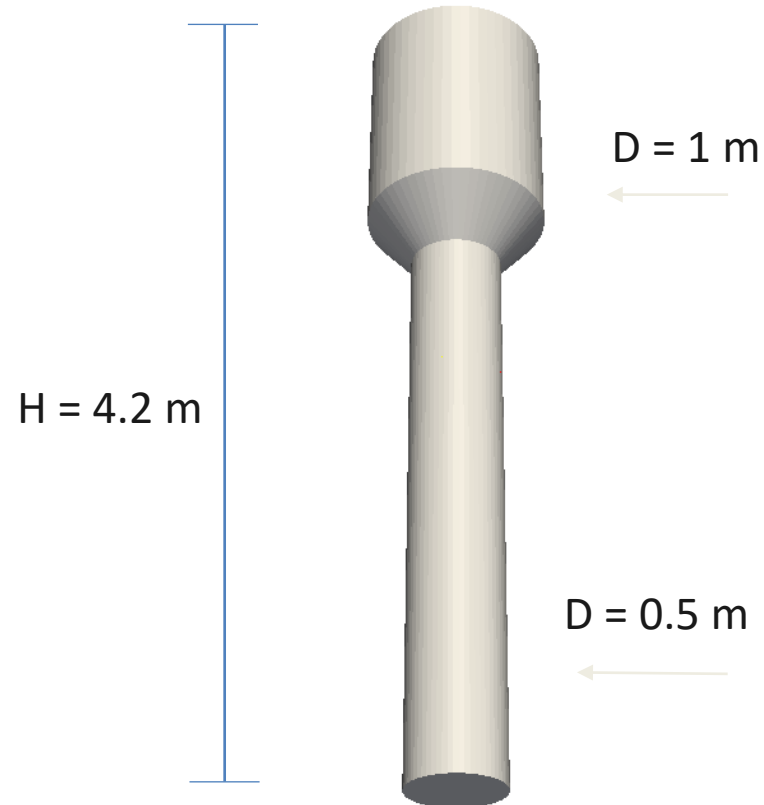
Alberto Cuoci



Matteo Maestri (LCCP)

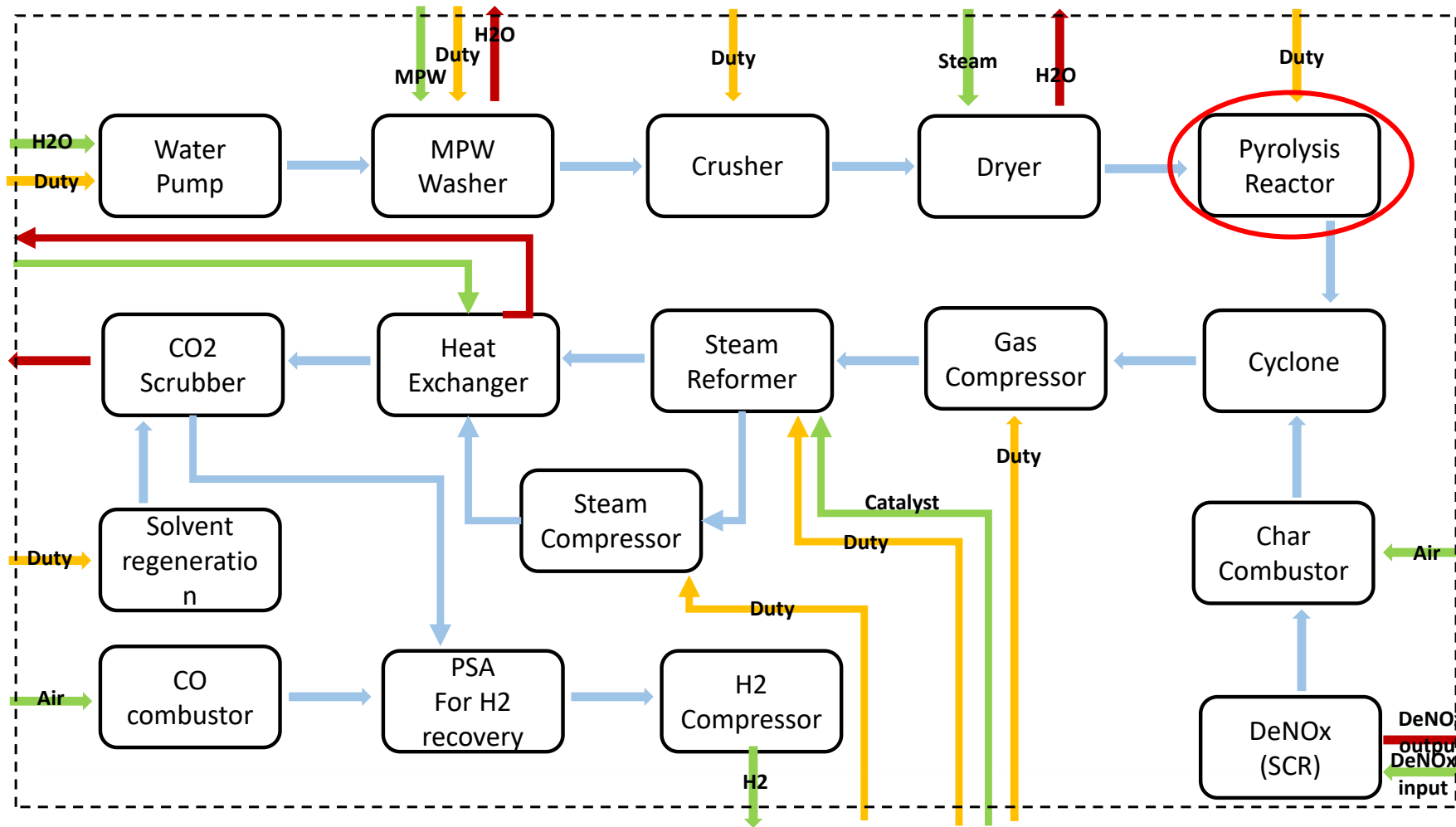


Mauro Bracconi (LCCP)



Effect of T and particle size on liquid mass fraction, gas fraction and products

Application of detailed chemistry models to process simulations. LCA / E-LCA of SPW pyrolysis and online reforming processes.



Alessandro Salvi



Giovanni Dotelli

Thanks for your attention!

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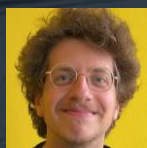
Funding:



Horizon Europe GA 101058412
Electrified conversion of plastic waste
into olefins & downstream integration



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