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France-Wallonie-Vlaanderen

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PSYCHE

Avec le soutien du Fonds européen de développement régional
Met steun van het Europees Fonds voor Regionale Ontwikkeling

CONVERSION OF PLASTIC WASTE TO BASE CHEMICALS VIA GASIFICATION IN THE VORTEX REACTOR: THE PSYCHE PROJECT

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Plastic Production Trend

World

2018
359
million tonnes

2019
368
million tonnes

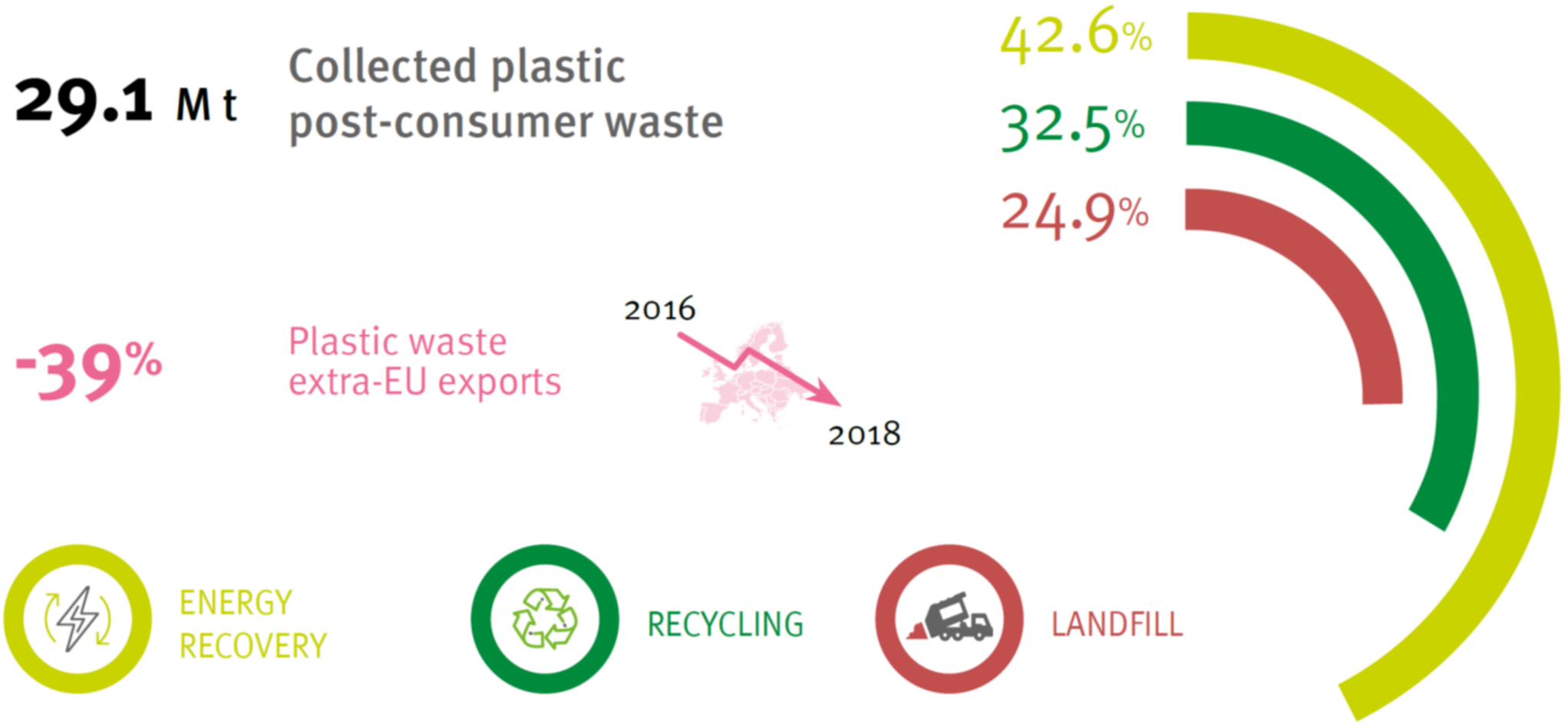
Europe
(EU28+NO/CH)

2018
61.8
million tonnes

2019
57.9
million tonnes

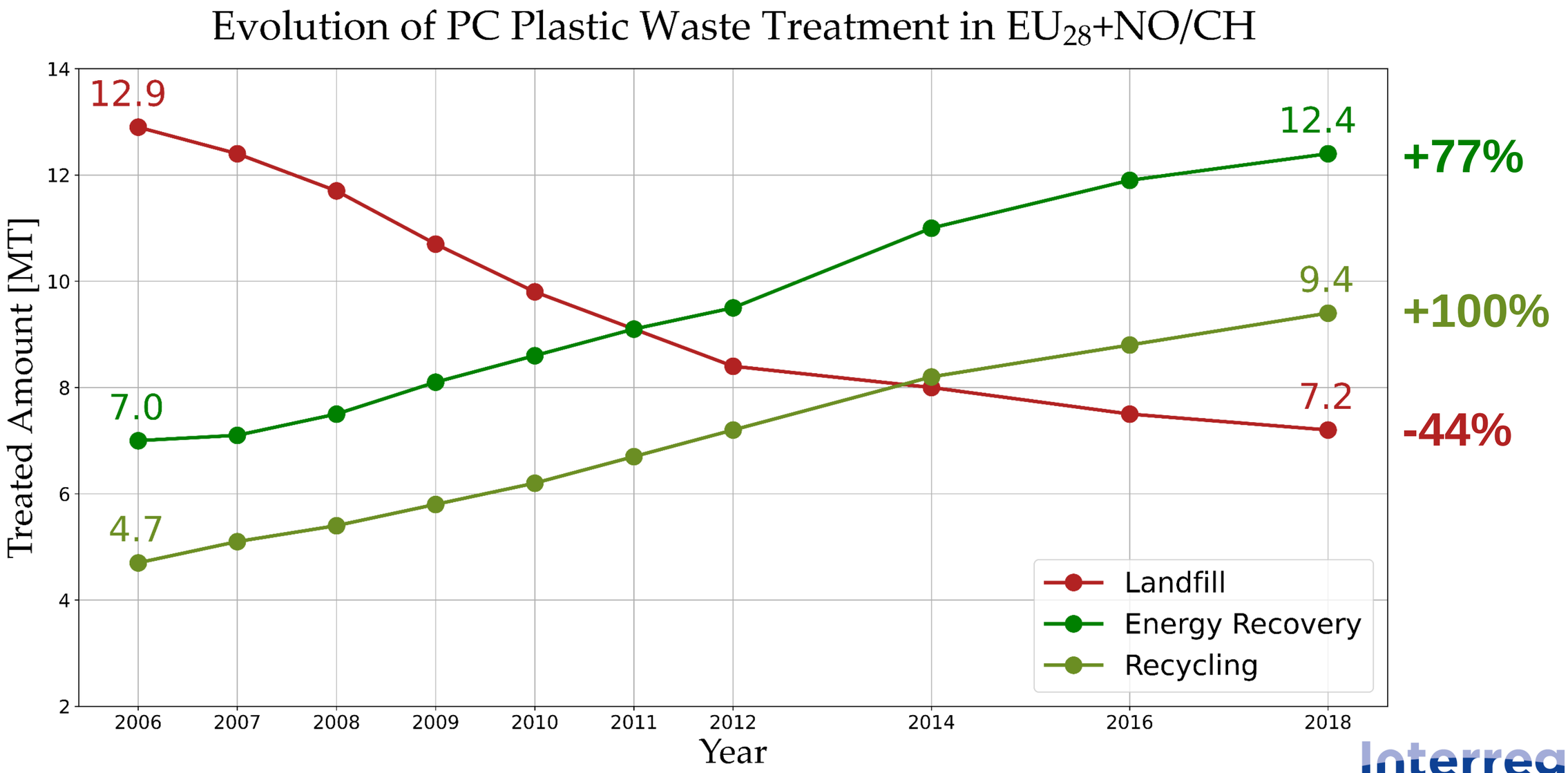
1. PlasticsEurope, *Plastics – the Facts 2020, An analysis of European plastics production, demand and waste data*, PlasticsEurope, Association of Plastics Manufacturers, Belgium, 2020.

Plastic PC Waste Treatment (EU28+NO/CH)



1. PlasticsEurope, *Plastics – the Facts 2020, An analysis of European plastics production, demand and waste data*, PlasticsEurope, Association of Plastics Manufacturers, Belgium, 2020.

Plastic PC Waste Treatment Evolution(EU28+NO/CH)



1. PlasticsEurope, *Plastics – the Facts 2020, An analysis of European plastics production, demand and waste data*, PlasticsEurope, Association of Plastics Manufacturers, Belgium, 2020.

PSYCHE Project

Conversion of plastic waste to base chemicals via gasification and subsequent Fischer-Tropsch synthesis

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€ 2.6 Million

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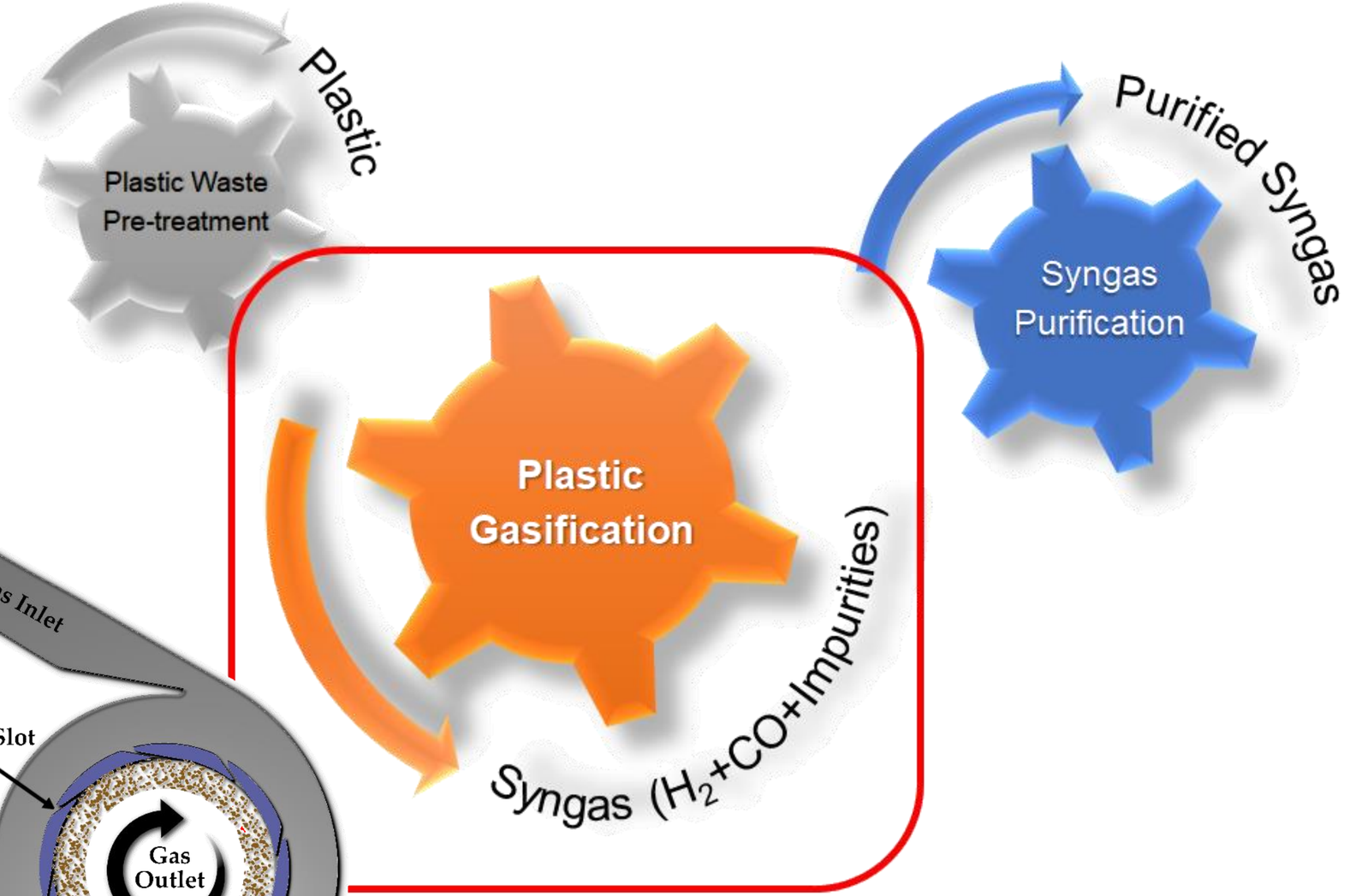
Chimie Lille
ÉCOLE NATIONALE SUPÉRIEURE DE CHIMIE

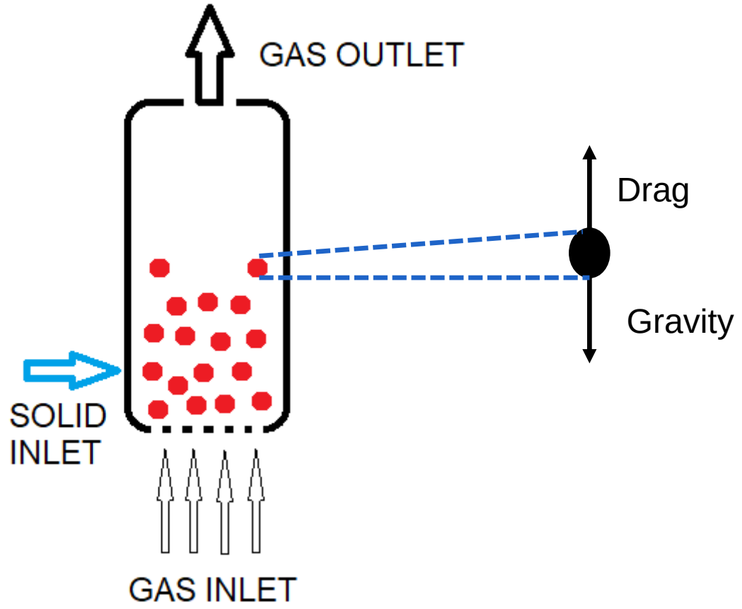
PSYCHE Process



Vortex Reactor

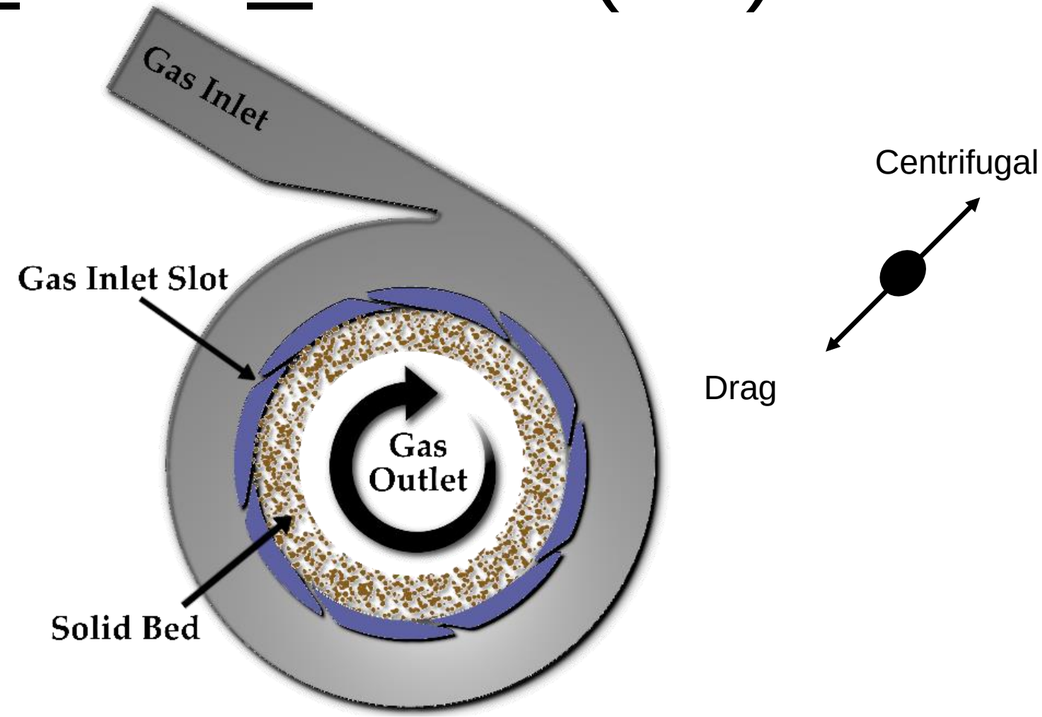
Conventional Fluidized Bed Vs. Vortex Reactor

Fluidized bed reactor



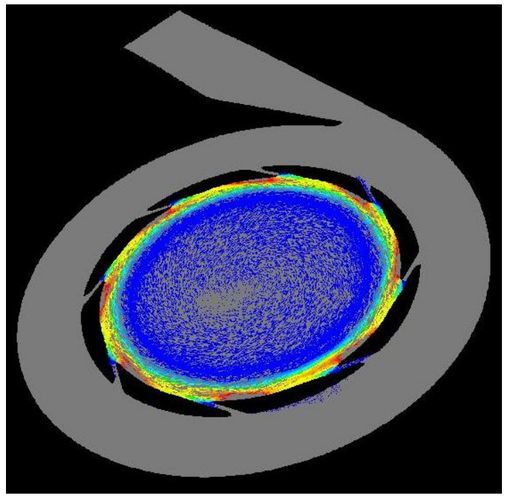
- Gas velocity limitation.
- Diluted bed.

Vortex Reactor (VR)

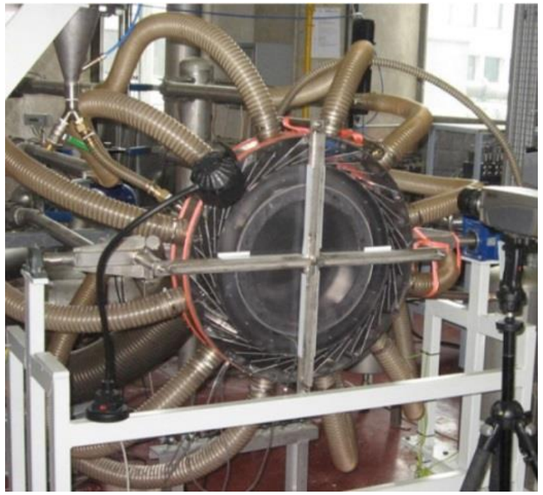


- Extended gas velocity limitations.
- High slip velocity.
- Packed bed.
- Short gas space time.

VR Research at LCT, UGent

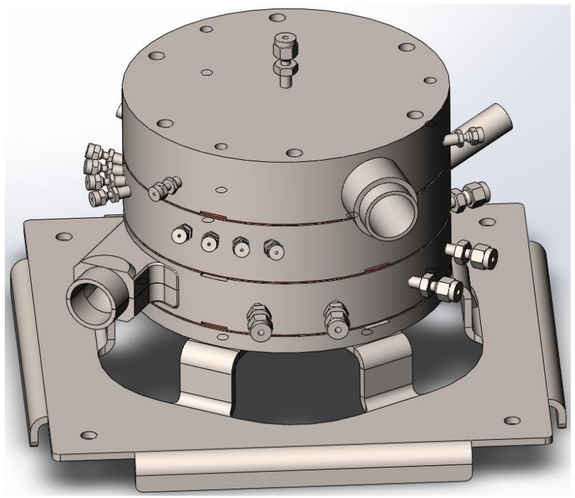


CFD

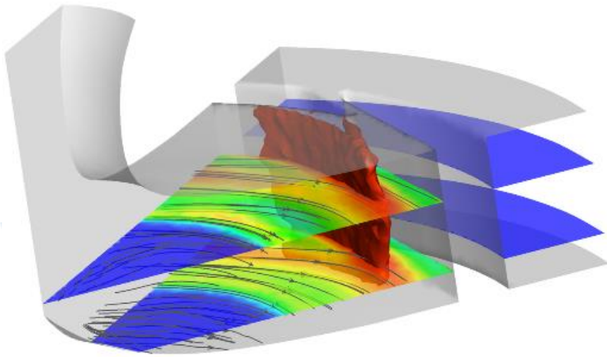


COLD FLOW VR

HOT FLOW VR



REACTIVE VR



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CFD Simulation of Plastic Gasification in VR

- Investigating numerically the plastic waste gasification in the vortex reactor by doing CFD simulations to create the design and optimization framework
  - Global kinetic model for plastic gasification
  - Hydrodynamic

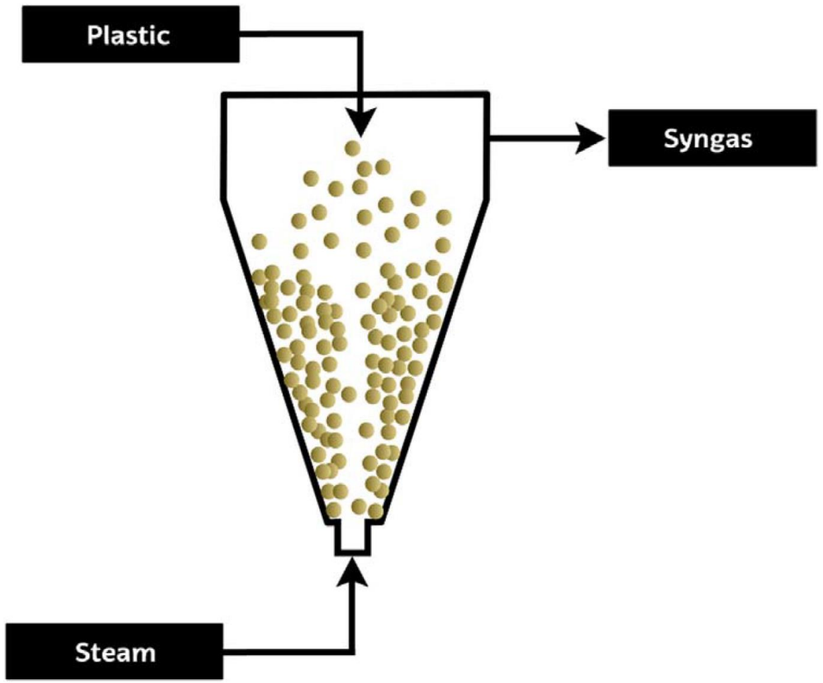
  } Reactive CFD Simulations

  - Validation: Post-processing the CFD results and validate them with experimental data

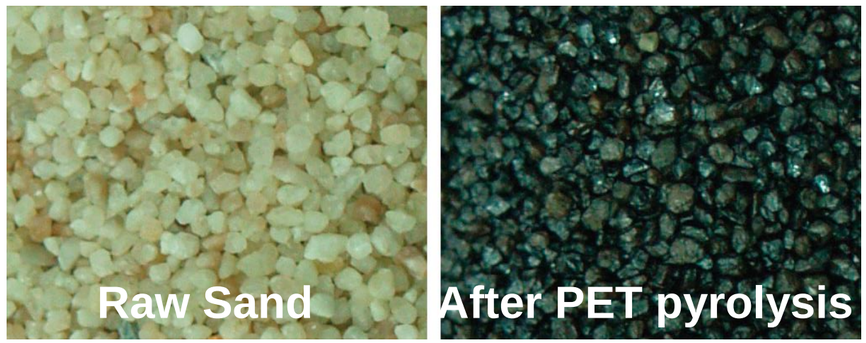
- No widely accepted and reliable global kinetic model for plastic gasification: Create the framework based on biomass → Shift to plastic

Simulating Biomass Thermochemical Recycling

- ✓ Available reliable kinetics
- ✓ The similarity to plastics (Solid/liquid phase reaction + phase transfer)
- ✓ Molten plastic injection (low flow rate)
- ✓ Covering the solid particles (sand/dolomite/olivine)
- ✓ Have been used in the spouted bed reactors



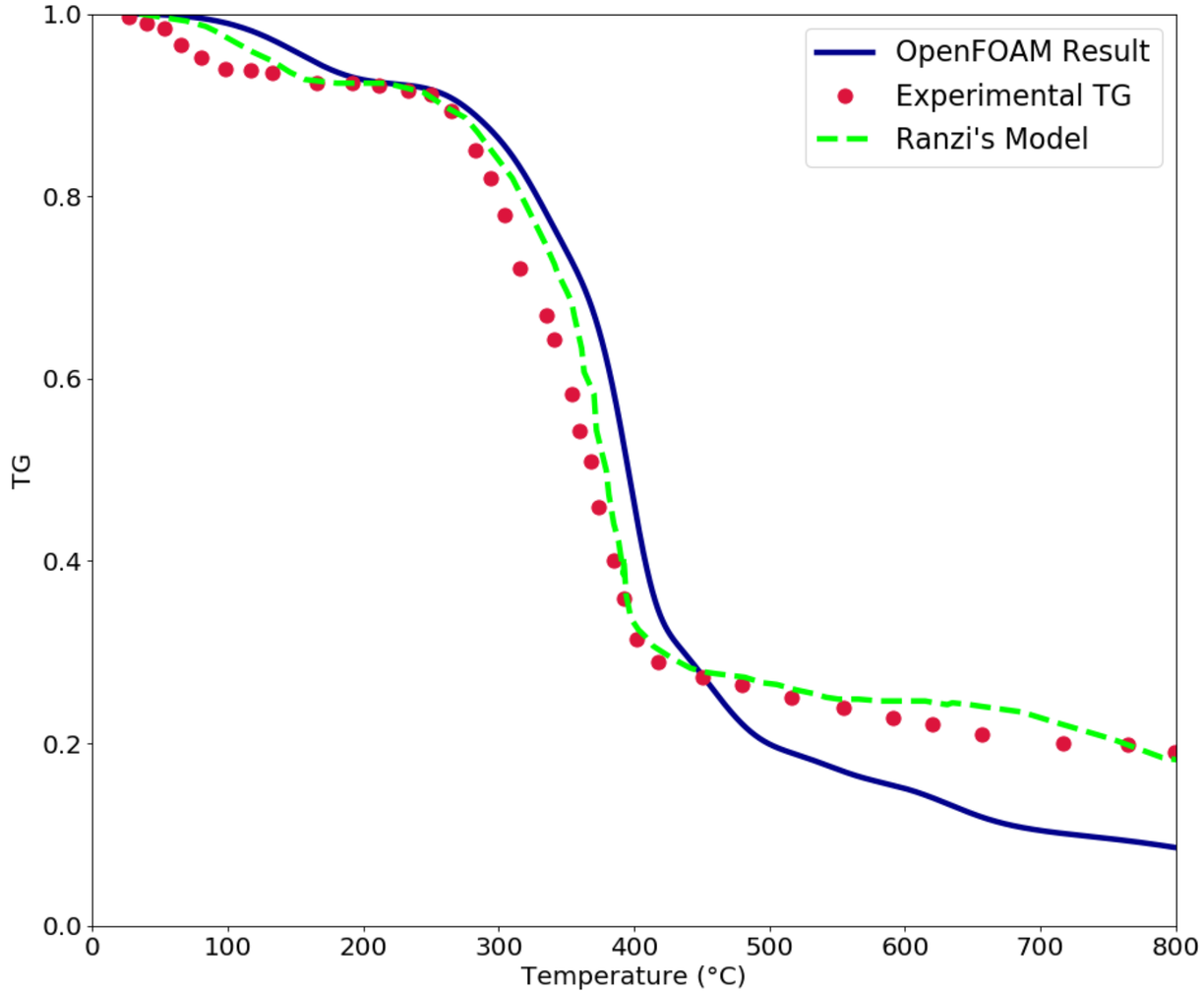
- ➢ High velocity → no agglomeration and defluidization
- ➢ Recirculation → uniform particle covering / thin layer
  → stable, non-sticky particle, fast degradation



G. Lopez, M. Artetxe, M. Amutio, J. Alvarez, J. Bilbao and M. Olazar, *Renewable Sustainable Energy Rev.*, 2018, **82**, 576-596.
M. Artetxe, G. Lopez, M. Amutio, G. Elordi, M. Olazar and J. Bilbao, *Industrial & Engineering Chemistry Research*, 2010, **49**, 2064-2069.

1D Simulations of Biomass Pyrolysis

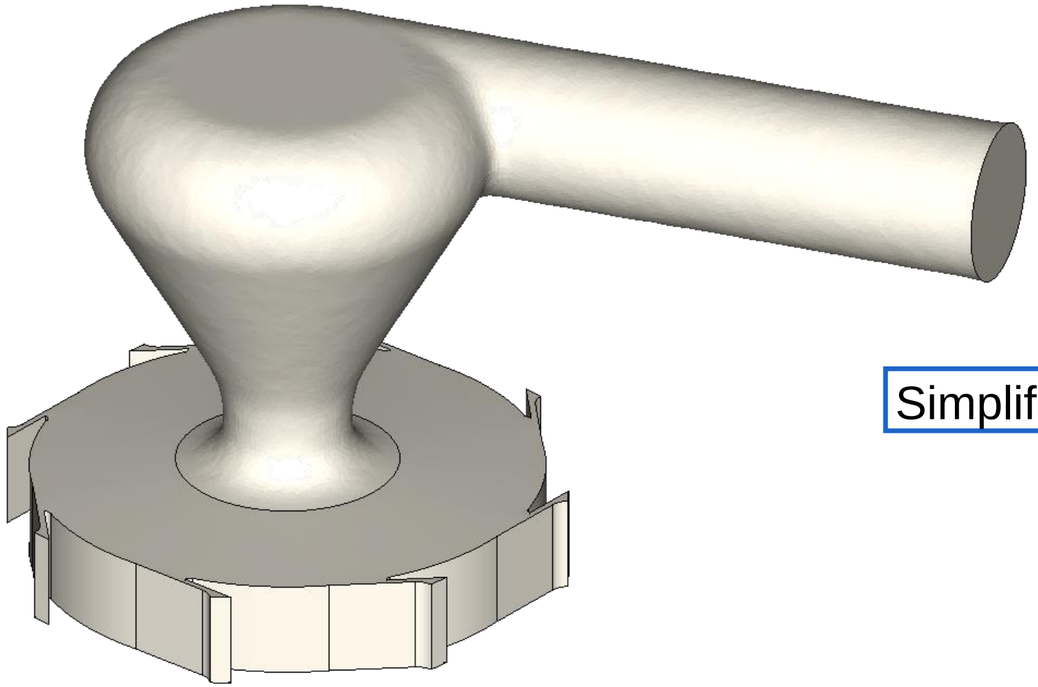
- Simulations done in OpenFOAM using an Eulerian-Eulerian solver
- Solid phase lumped mechanism: Ranzi et al.* (29 reactions, 54 species)
- Validation case: TGA graph of Pinus radiate



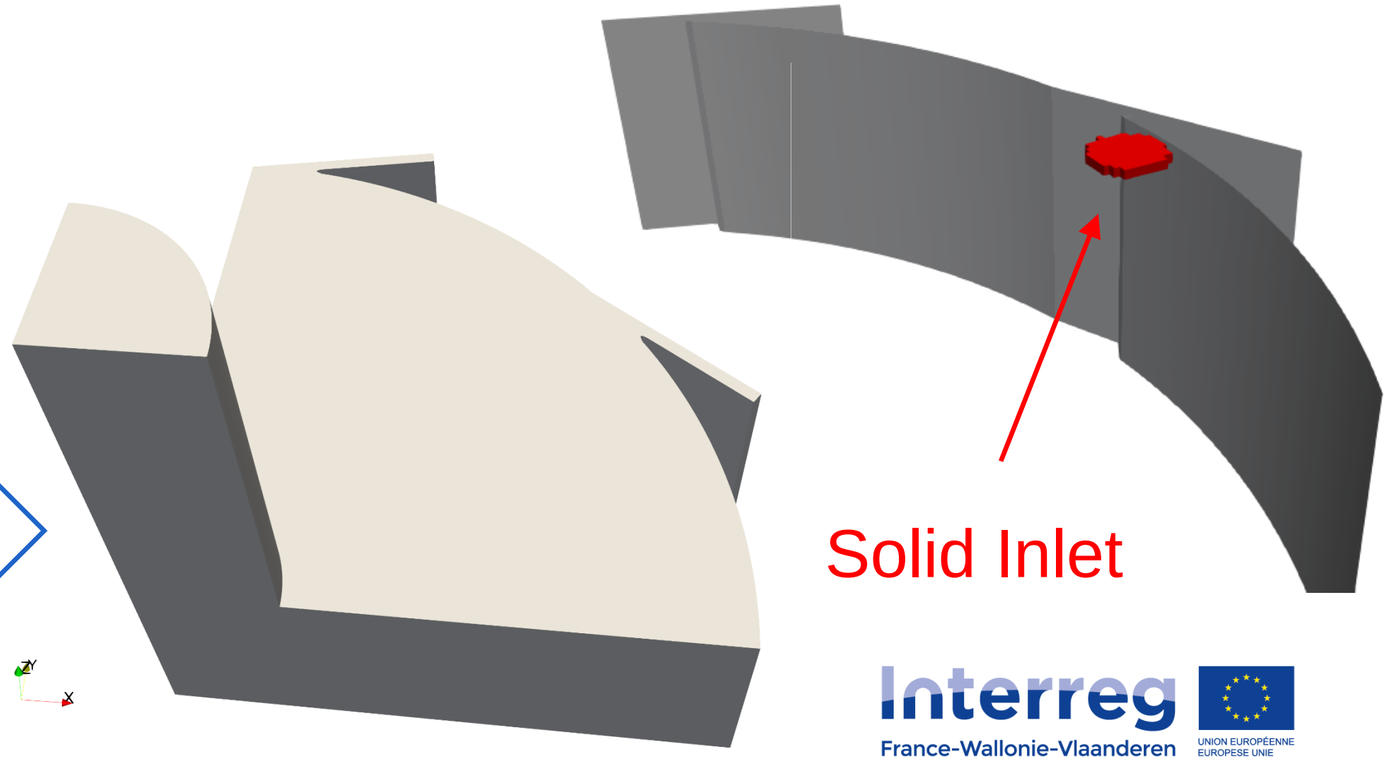
* Ranzi E, Debiagi PEA, Frassoldati A. Mathematical Modeling of Fast Biomass Pyrolysis and Bio-Oil Formation. Note I: Kinetic Mechanism of Biomass Pyrolysis. ACS Sustainable Chemistry & Engineering 2017;5(4):2867-81.

CFD: 3D Cold Flow Simulations of Biomass

- Walnut Shell PIV experiments ➔ Obtaining the velocity profile
- Gas: Air (40 nm^3/h)
- Ambient Temperature

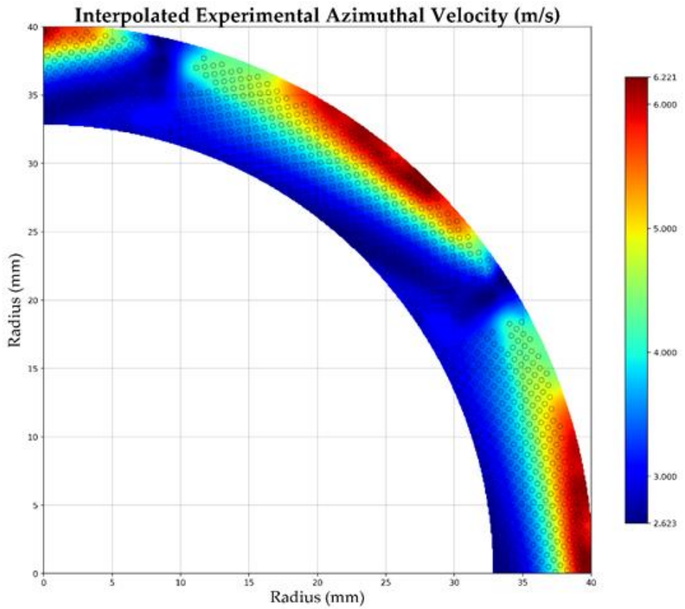


Simplified

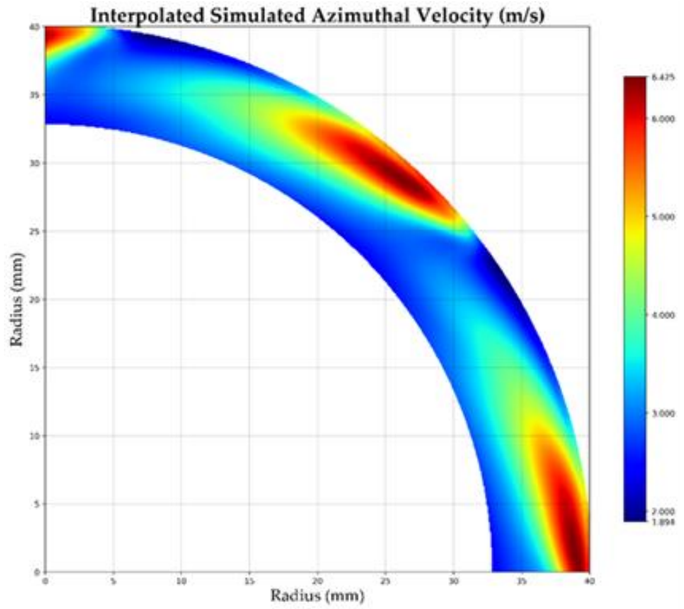


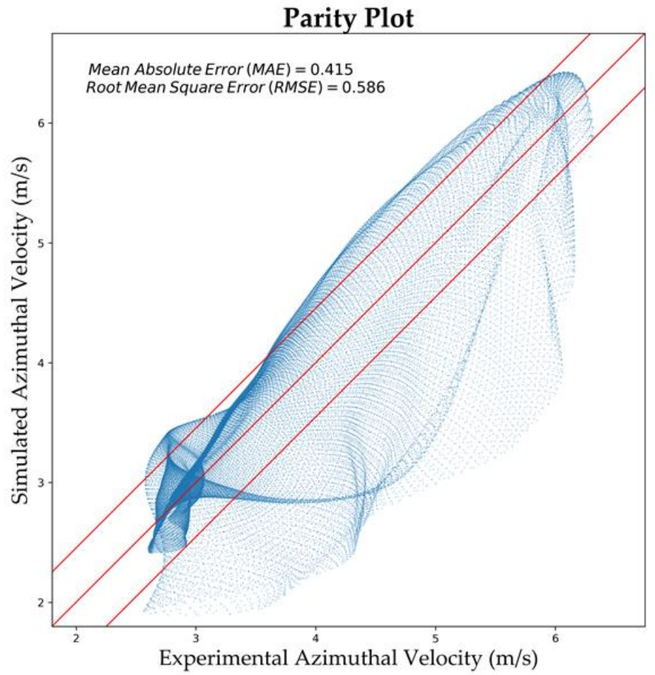
Validation of 3D Cold Flow Simulations of Biomass

- Mapping experimental and simulation data on the same grid → Compare the interpolated values

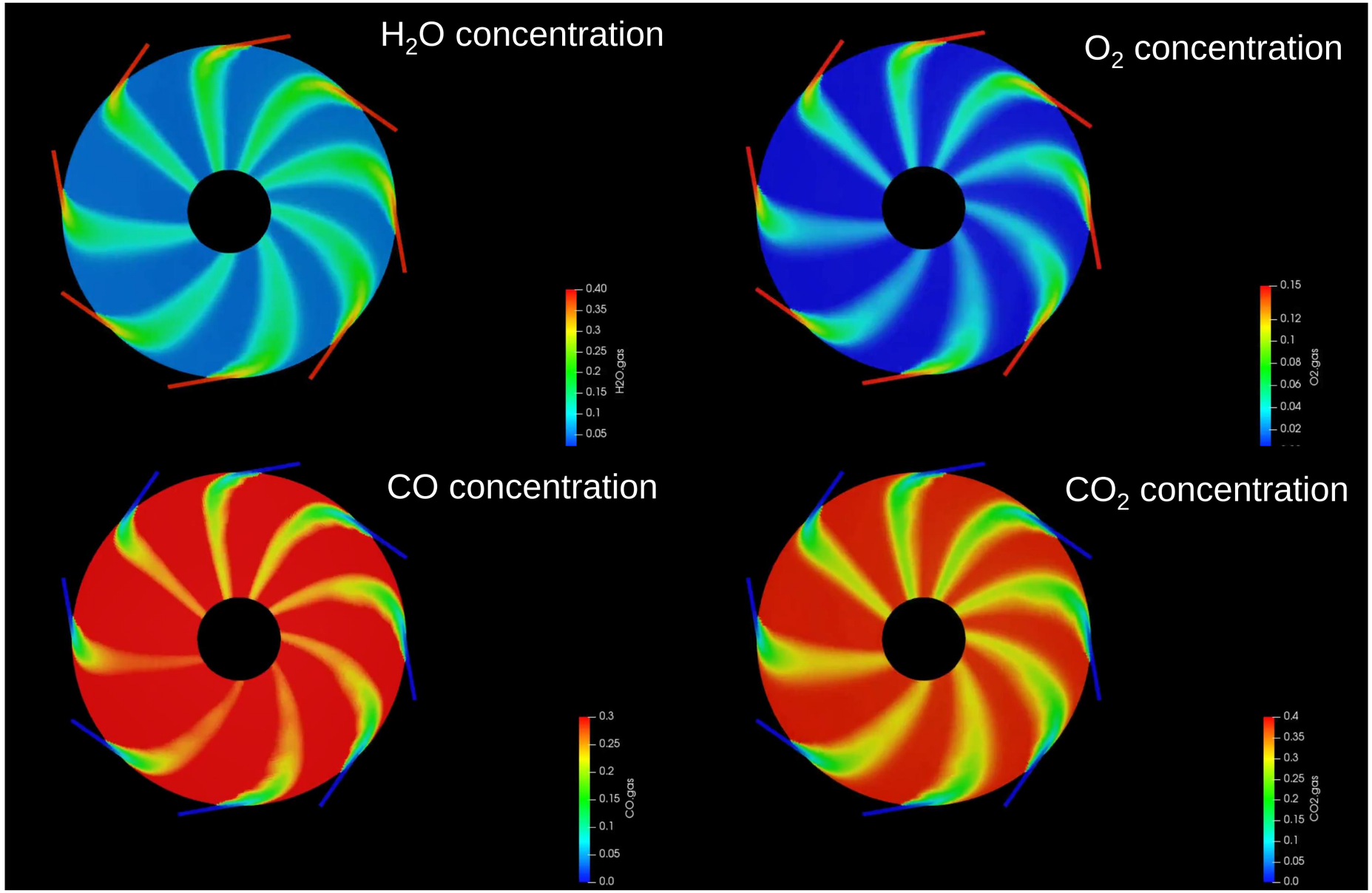


vs





2D Reactive Framework Sample: Biomass Gasification



- Instantaneous concentration
- No continuous biomass injection

Conclusions and Future Work

- The PSYCHE project aims to demonstrate that a compact and scalable process for the conversion of different streams of plastic waste into syngas and chemicals is possible. This is done by plastic waste conversion to light olefins via the gasification and Fischer-Tropsch route in a circular process.

- Fundamental studies during this project, including the plastic pre-treatment, gasification in the vortex reactor, syngas purification, and optimized Fischer-Tropsch synthesis have shown that this circular process, though it is still immature, has the potential to become a commercialized plant that can contribute to decreasing the environmental impact of the solid plastic waste.

- The reactive CFD simulations will be completed and validated for the biomass gasification
- A global kinetic model for the plastic gasification will be implemented from the literature to create the plastic gasification framework. This is going to be done by covering a thin layer of molten plastic on the fluidization agent.

Acknowledgements

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