Microwave-assisted pyrolysis valorisation of unsortable thermoplastic waste

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CIRCE Technology Centre

Funded by the European Union
GA nº 101058540

CIRCE in 2023

RESEARCH

10,3 M€ (+9,5% to 2022)

COMPETITIVE FUNDS EXECUTED

14

HORIZON EUROPE NEW PROJECTS

4

OF THEM ARE COORDINATED

TALENT

282

EMPLOYEES

35’4%

WOMEN

18

NACIONALITIES

36'4

AVERAGE AGE

29

DOCTORS

100%

SELF-FINANCING

TRANSFER AND SERVICES

7,2 M€

PRIVATE TURNOVER VOLUME

+25%

COMPARED WITH2020

8

NEW PATENTS IN 2022

EDUCATION

210

TRAINING COURSES

+500

STUDENTS

11377

TRAINING HOURS

BUSINESS LINES

RENEWABLE ENERGY

ELECTRICAL GRIDS OF THE FUTURE

SMART MOBILITY

INDUSTRY 4.0

ENERGY EFFICIENCY

CIRCULAR ECONOMY AND SUSTAINABILITY

Project Info

Title: New technologies to integrate PLASTIC waste in the Circular Economy - PLASTICE

Objective: To develop and upscale new plastic valorization and upcycling processes. Four different pilot demonstrators will be implemented for each technology.

Granting authority: European Health and Digital Executive Agency (HADEA)

Grant Agreement No 101058540

Duration: 1st June 2022 – 31st May 2026 (48 M)

Total budget: ca. 20 mill. € (ca. 75% EC funded)

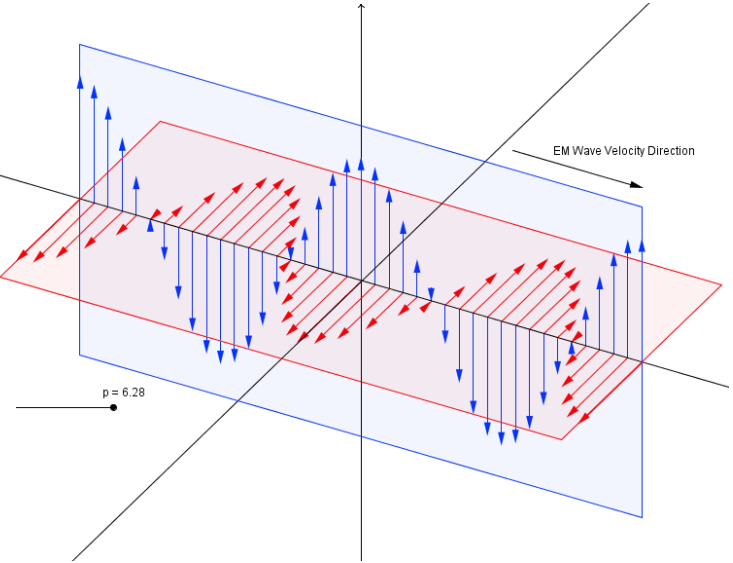
Project Coordinator: CIRCE

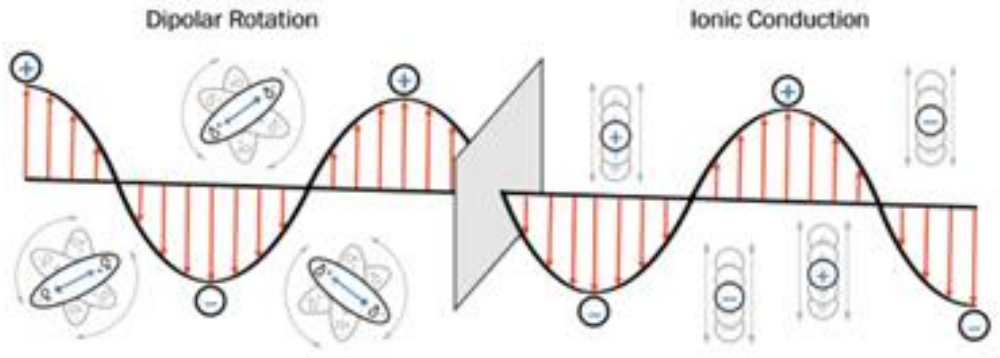
23 partners

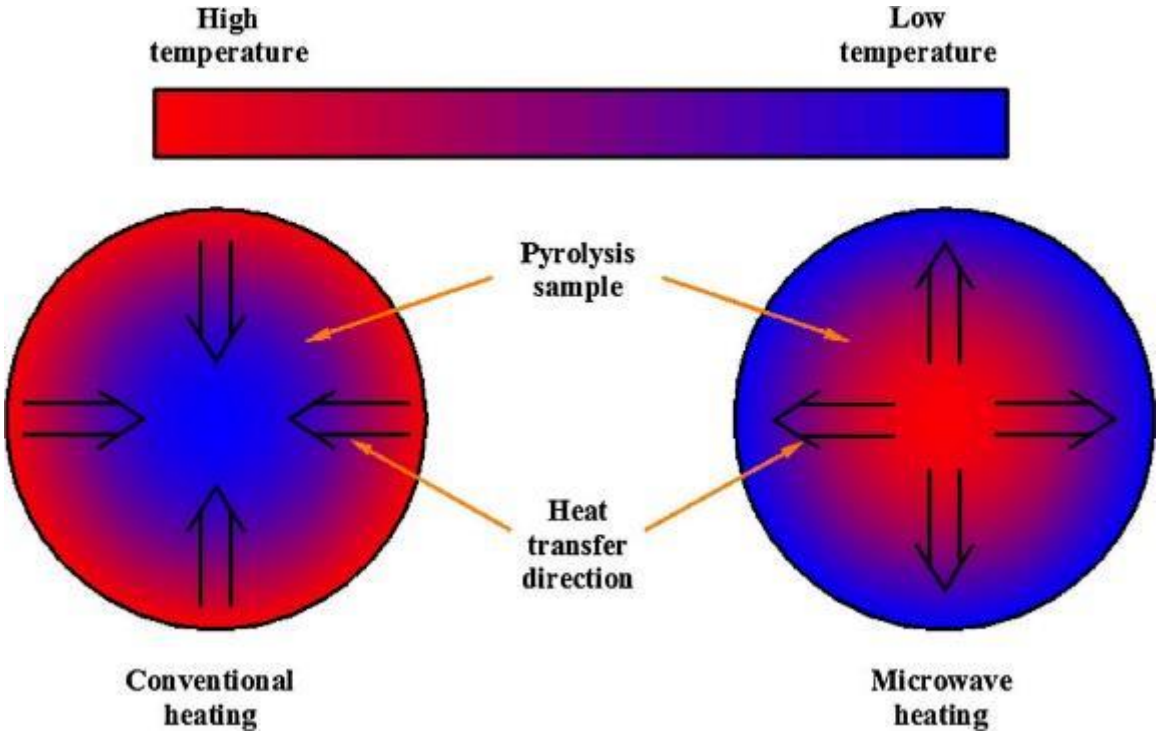
This project has received funding from the European Union's Horizon Europe research and innovation programme under grant agreement N° 101058540.

Microwave Heating: Identified Potential

Microwave Heating: identified potential







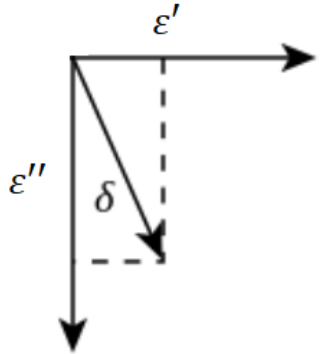
Technical advances, barriers, and solutions in microwave—assisted technology for industrial processing, Chemical Engineering Research and Design, Volume 181, 2022,

Dielectric Susceptibility of materials

Microwave Absorption Capacity

Material	Dielectric Loss Tangent
Activated carbon	0.62
SiC	0.02-1.05
Wood	0.11
Cellulose	0.035
Hemicellulose	0.062
Lignin	0.052
Glass	0.005-0.010
Polyestirene (PS)	0.002-0.003
Polyethylene (PE)	0.001-0.002

$$\tan\delta = \frac{\varepsilon''}{\varepsilon'}$$



Microwave assisted Pyrolysis

Innovation of MW-assisted Pyrolysis: Set-up configuration

Innovation of MW-assisted Pyrolysis: Set-up configuration

Pros

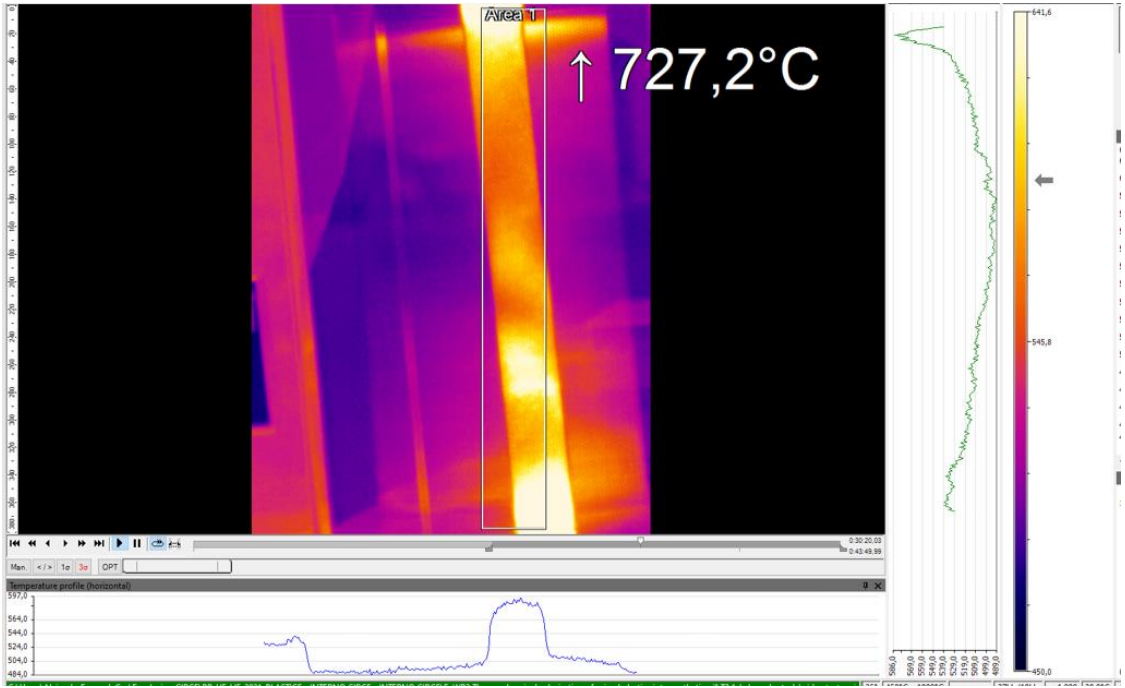
- Products quality improved
- Energy efficiency
- Reduce pre-treatment requirements
- Fast, uniform and volumetric heating
- Straightforward electrification

Innovation of MW-assisted Pyrolysis: Set-up configuration

Cons

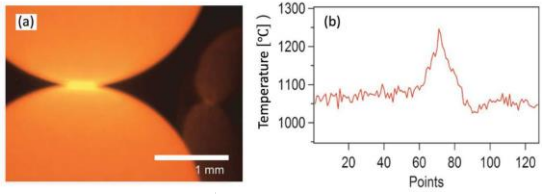
- Design Limitations
- Triggering temperature measurements
- Microwave susceptors are required
- Greatly complex upscaling

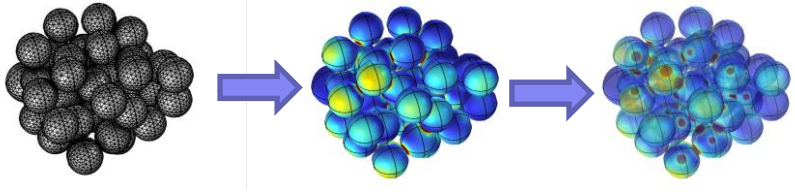
Thermal distribution: Infrared indirect temperature measures



Simulation methodology for microwave field and thermal distributions

H. Goyal, D.G. Vlachos, "Multiscale modeling of microwave-heated multiphase systems" Chemical Engineering Journal, vol 397, 2020

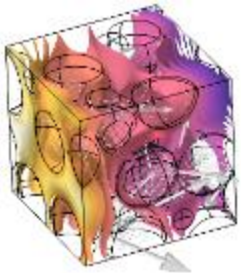




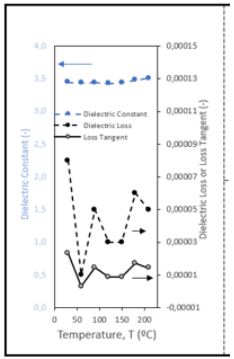
1. Tangencies concentrate the EM losses

2. Fully tangent geometry obtained

$$\boldsymbol{q} = -\boldsymbol{k}\cdot\nabla T$$



Thermal conductivity



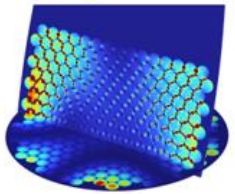
Permittivity

3. Thermal and Dielectric apparent (effective) properties of the granular media

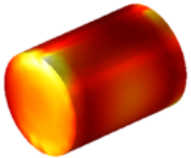
$$\langle\cdot\rangle = \frac{1}{\mathcal{V}}\int_{\mathcal{V}}(\cdot)dV$$

$$\varepsilon_{\text{eff}} = \frac{\langle \boldsymbol{D}\rangle}{\langle \boldsymbol{E}\rangle}$$

Confirms that it is possible to simulate the packed bed MW heating

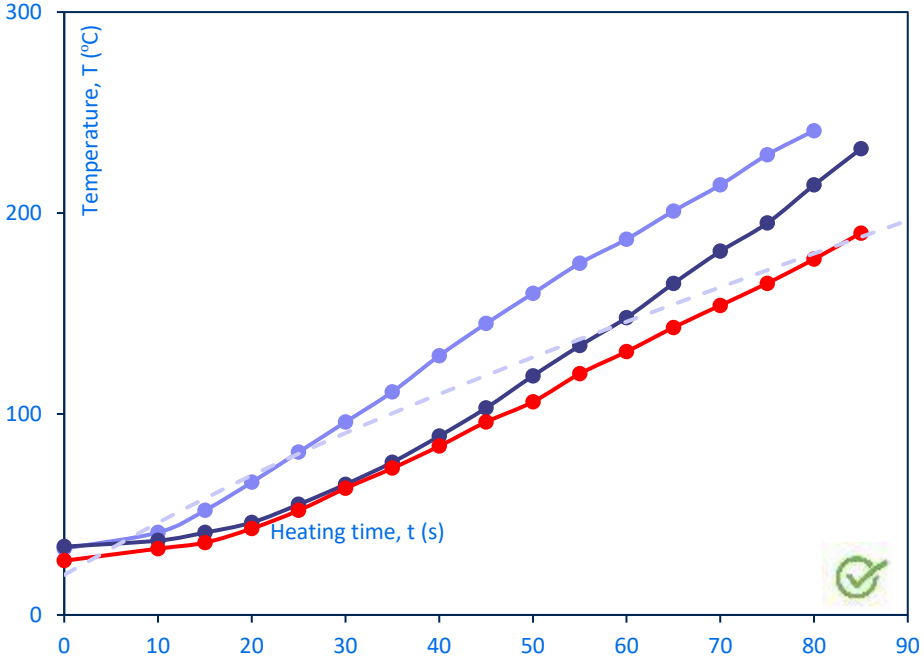


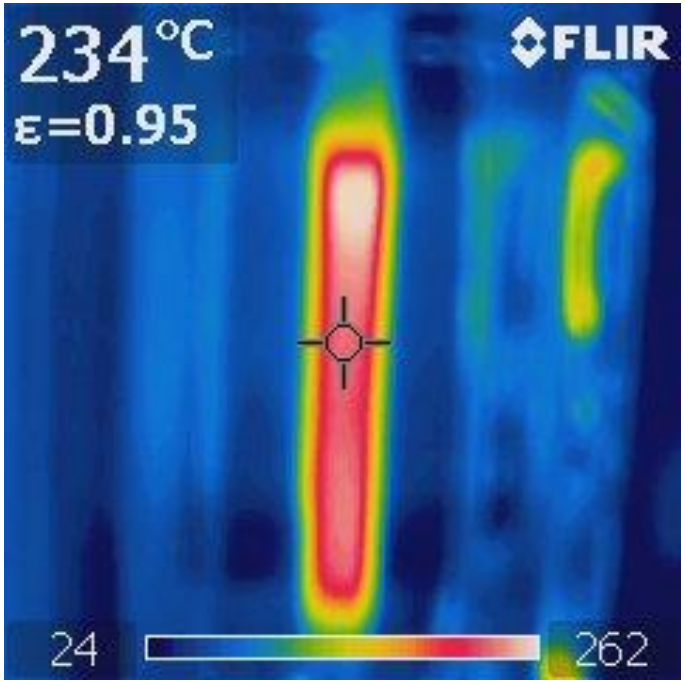
Resulting EM losses



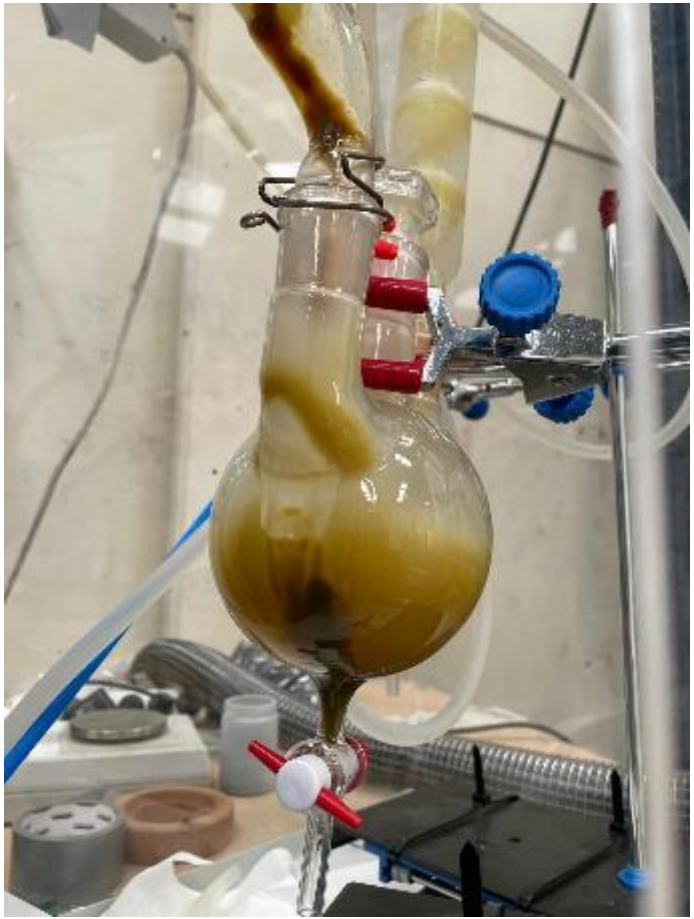
Thermal distribution

Experimental Validation of Microwave-heating and thermal distribution





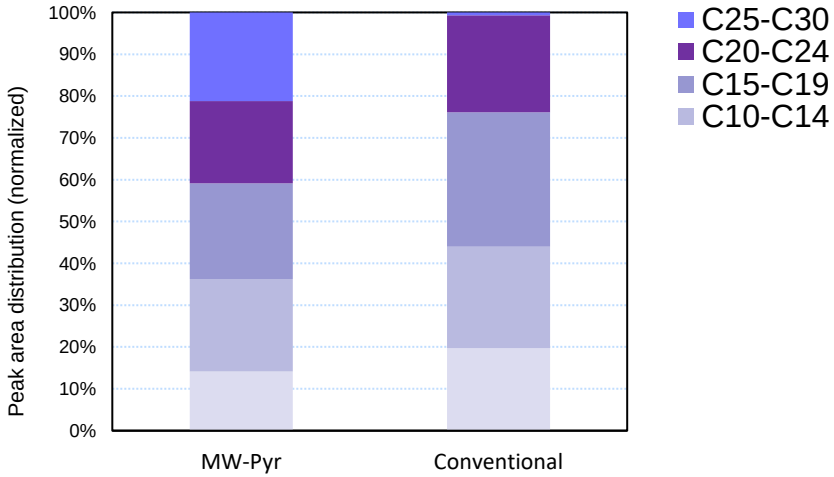
Synthetic oil results and perspectives

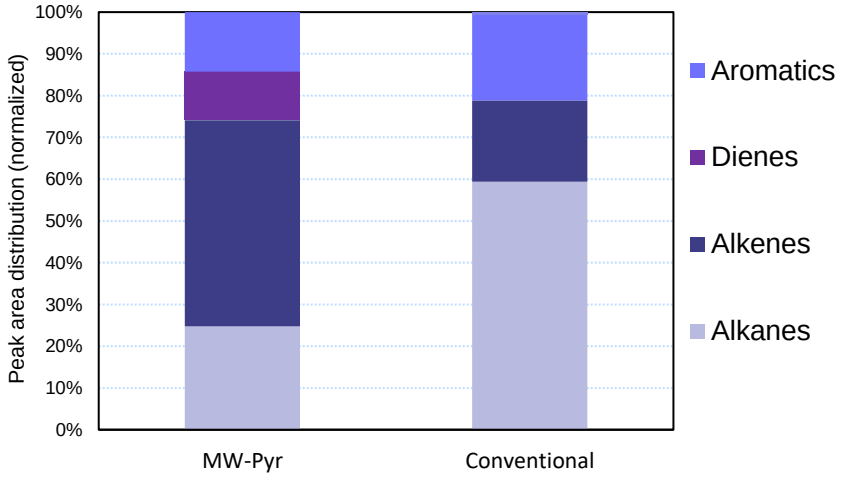


Pyrolysis-oil chemical composition and GC-MS Results

Experimental findings by MW-asssited Pyrolysis Vs Conventional Pyrolysis

- Larger HC chains
- Presence of diolefins / neglible presence of aromatics or oxygenated products
- Larger olefin/paraffin ratios
- 40-60%wt oil



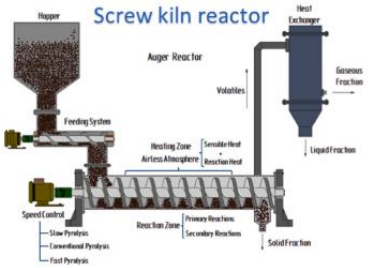


Perspectives: Pilot Upscaling

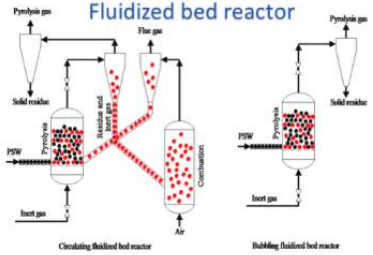
Main challenges for microwave-assisted systems scalability

1. Complex design of the different involved parts, e.g. magnetron or solid-state generator, waveguides, resonator cavity, chokes, antennas
2. High price of some parts of the assembly
3. Eventual malfunctions such hot spots formation, thermal runaway or arcing issues
4. Incompatibility of microwave irradiation with some materials, specific material geometries and moving parts

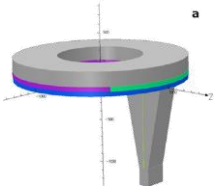
Screw kiln reactor



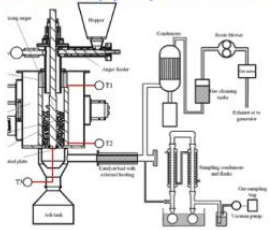
Fluidized bed reactor



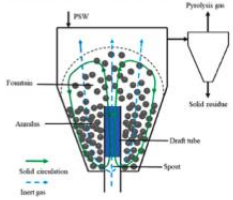
Rotating ceramic disc



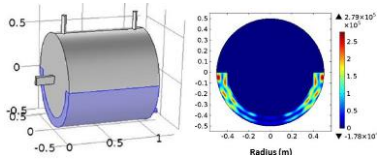
Microwave pyrolysis reactor



Conical spouted bed reactor



Rotary kiln

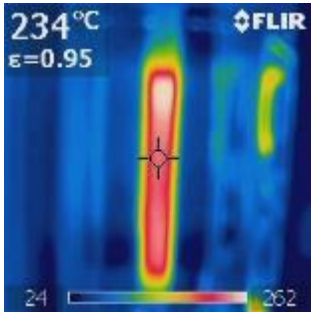


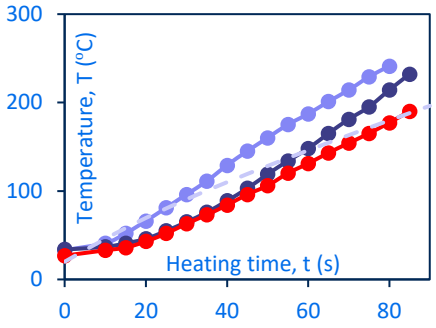
A. Fresneda-Cruz, I.Julian. Advances in Microwave-assisted Heterogeneous Catalysis, Royal Society of Chemistry, 2023. In press

Progress in Energy and Combustion Science 93 (2022) 101021

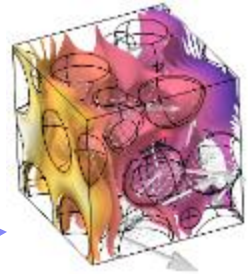
Conclusions

Microwave selective heating results in unbeatable energy density, greatly improving energy efficiency of waste valorization processes



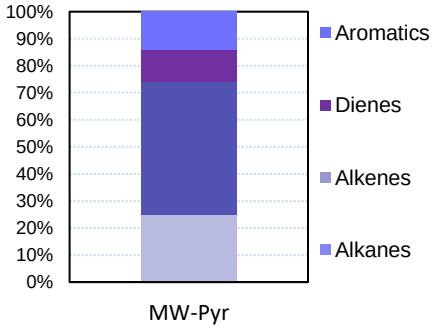


The microwave technology enables a fast and volumetric heating, leading to reduced operational times

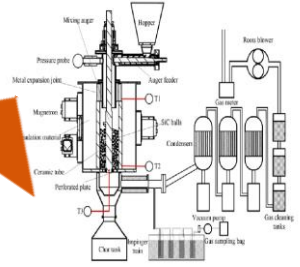


Complex particle mediums were sucessfully simulated and modeled

Pyrolysis oils yields and hydrocarbons distribution can be controlled by the temperature and residence time of the MW-assisted pyrolysis



Engineering challenges are being overcomed in the ongoing upscaling technology



Catalytic pyrolysis of plastic wastes in a continuous microwave assisted pyrolysis system for fuel production. Chemical Engineering Journal 2021;418

PLASTICE

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Organization: **CIRCE**

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