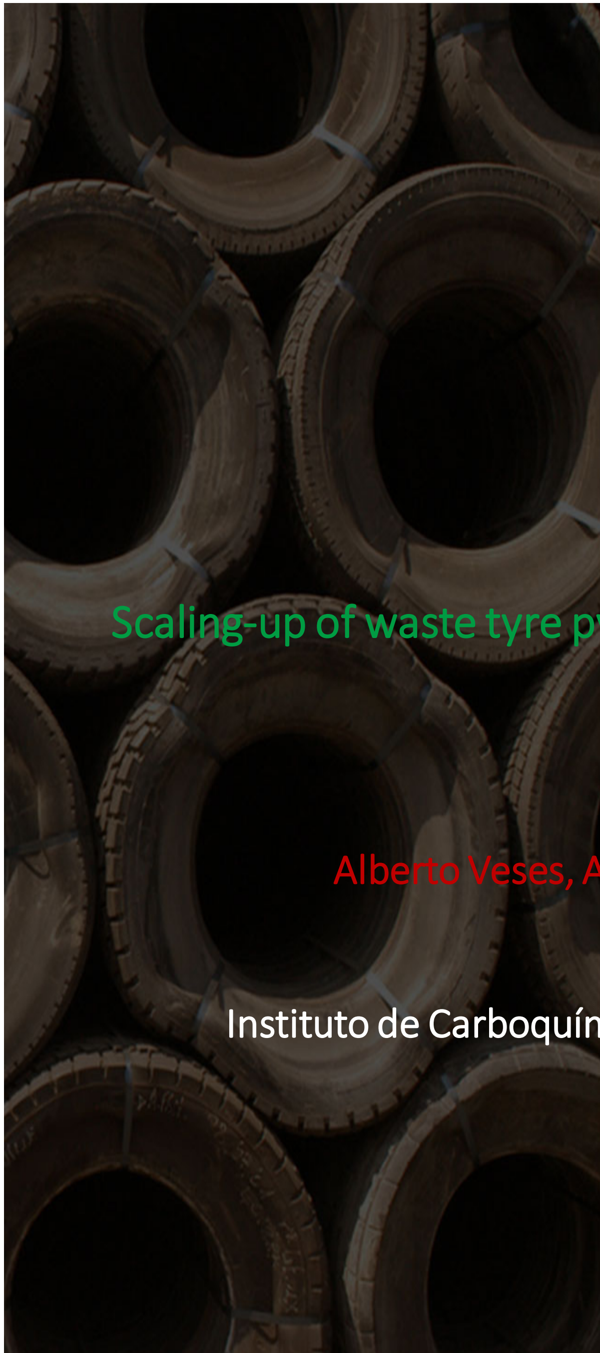

BLACK CYCLE

Move to the green revolution

Scaling-up of waste tyre pyrolysis process from TRL-5 up to TRL-7 using an auger reactor technology

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Goal of this work?

To demonstrate:

→ how are the yields and the properties of two different plants based on the auger technology

TRL5: pilot plant (4 kg/h) vs TRL7 semi-industrial plant (500 kg/h)

…using the same feedstock and experimental conditions

TRL5 pilot plant

Tire pyrolysis oil (TPO)

Tire pyrolysis gas (TPG)

Raw Recovered Carbon Black (RCB)

Similar yields, similar properties ?

TRL7 semi-industrial plant

BLACK CYCLE is a project funded by the European Commission - Project Number : 820687

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Content

A project funded by the European Commission lead by Michelin → Project number 869625

https://blackcycle-project.eu

The BlackCycle project aims at creating, developing, and optimizing a full value chain from ELT feedstock to Secondary Raw Materials (SRMs), with no waste of resources in any part of the chain and a specific attention for the environmental impact

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1. Background: why end-of-life tires (ELT)?

- Because it contains important raw materials susceptible to be recovered
- Because it shows serious environmental disposal problems
- Because it presents high generation

https://www.european-rubber-journal.com/news/potential-game-changer-end-life-tire-market

Some numbers:

- More than 1700 M of ELT are generated annually worldwide.
- Forecast to 2022: 2500 M
- EU27 + Norway + Swiss + Turkey ≈ 4 M t/year
- EEUU → ≈ 4 M t/year

Martínez (2021). Renew. Sust. Energ. Rev. 144, 111032

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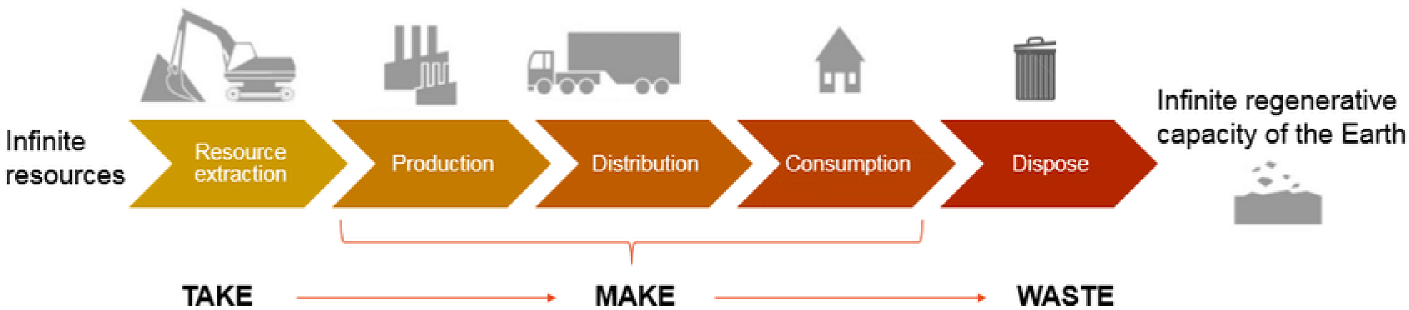
1. Background: why pyrolysis?

Linear economy model: after use → throw away



Wautelet T. MBA dissertation. EUFOM Bussines School, 2018.

Circular economy model: to maximize the use of the resources

EU-Parliament, 2015.

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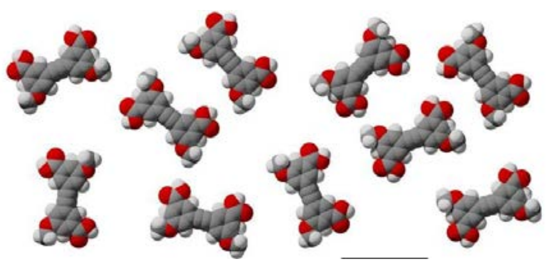
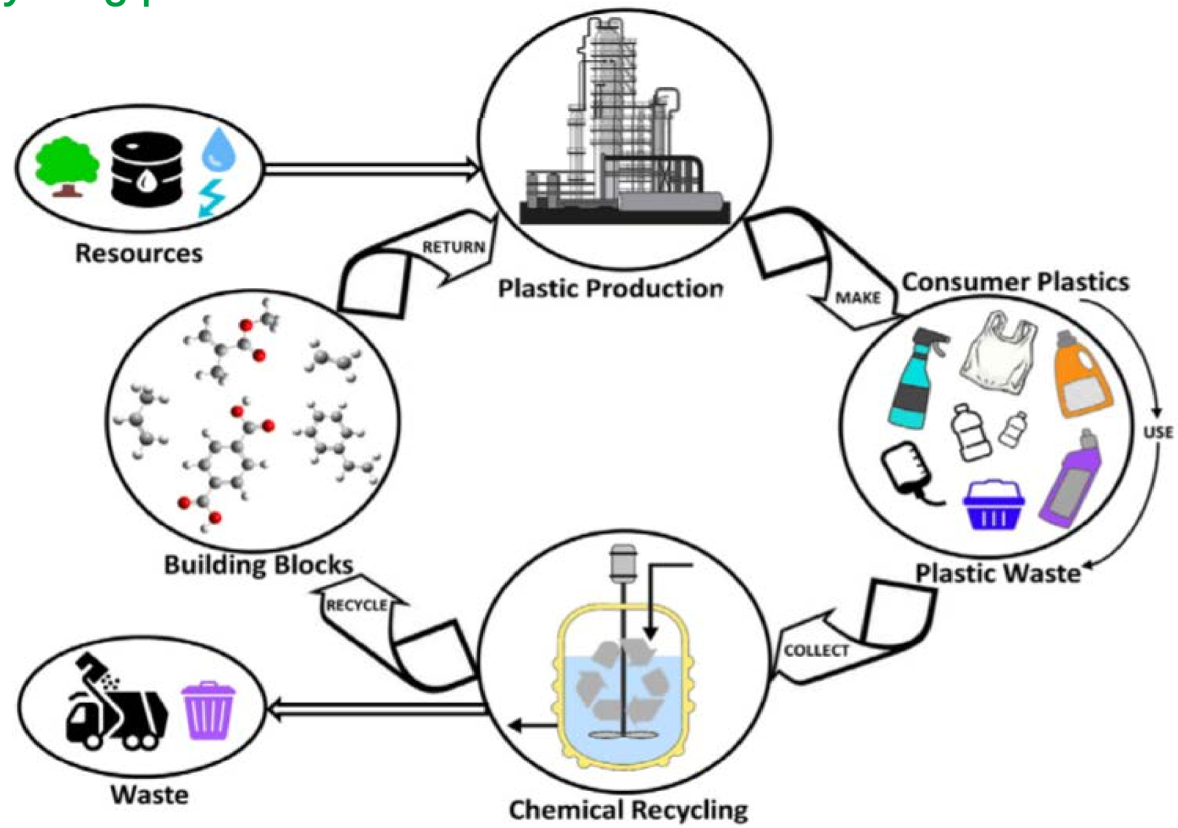
1. Background: Chemical recycling processess?

"Building blocks": chemical compounds with potential to be used to elaborate new products



https://www.energy.gov/science/bes/articles/bringing-power-chemical-fuels-artificial-building-blocks



Dogu et al. (2021) Prog. Energ. Combust. 84, 100901

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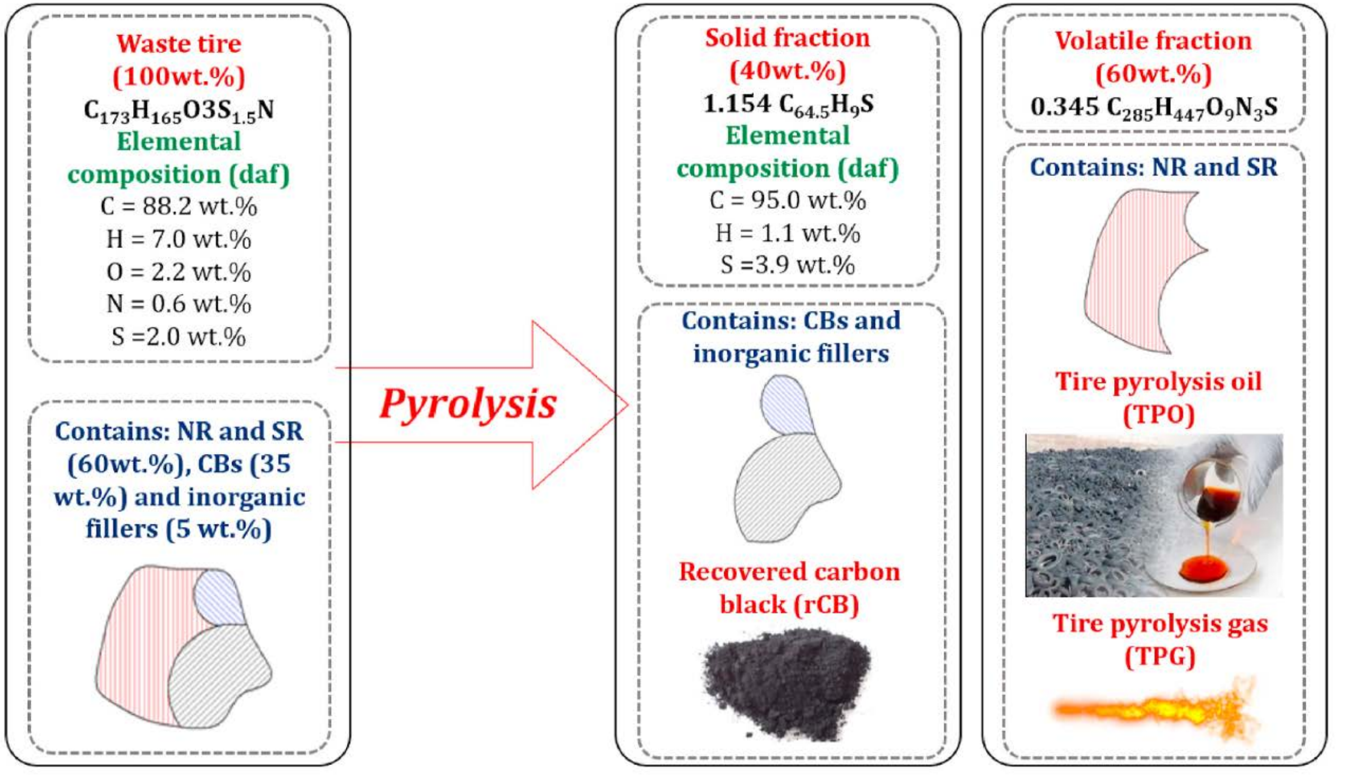
Recovering value-added hydrocarbons from pyrolysis of end-of-life tires: fractioning the derived oil in a pilot scale distillation plant

CORFU 2022: 9th International Conference on Sustainable Solid Waste Management Corfu, Greece, 15 - 18 JUNE 2022

1. Background: Chemical recycling processess?

Pyrolysis of end-life-tires (ELT)

→ Solvolysis
→ Gasification
→ Pyrolysis



Martínez (2021) Renew. Sust. Energ. Rev. 144, 111032

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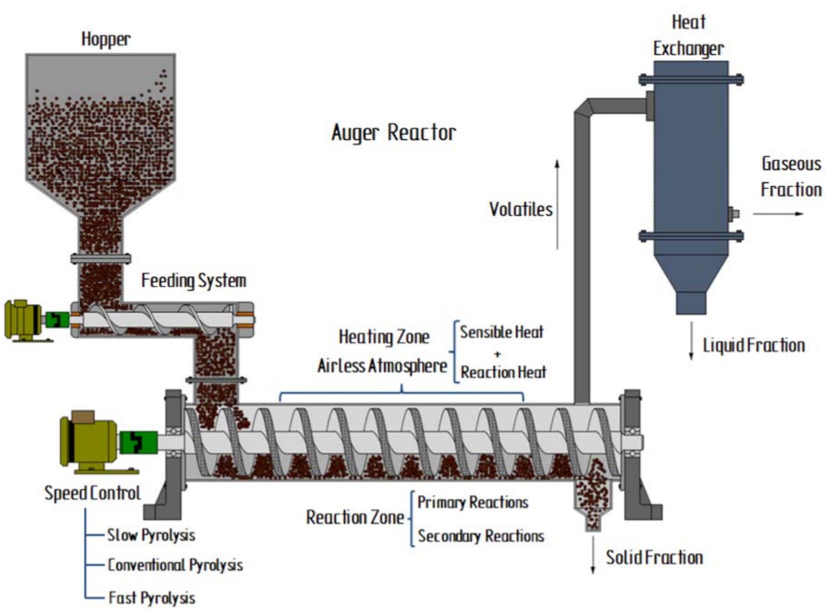
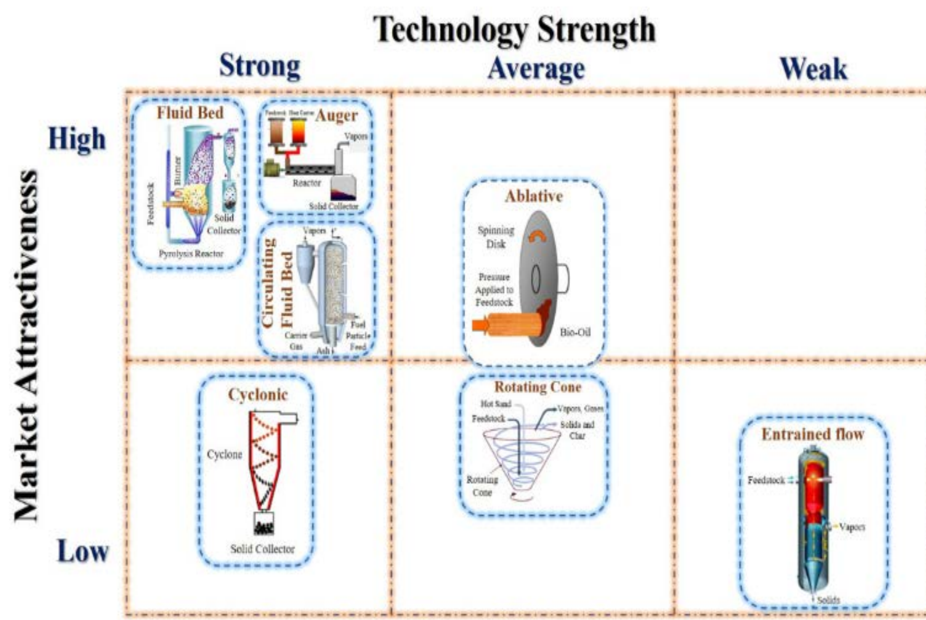
1. Background: Auger reactor

- Attractive for pyrolyzing a wide range of feedstocks
- Able to work for fast, intermediate and slow conditions
- Minimum requirement of carrier gas
- Low energy requirements
- Auger reactors together with BFB and CFB are the strongest contenders for commercial development (50-100t/day)



Campuzano et al (2019). Renew. Sust. Energ. Rev. 102, 372-409



Van de Velden (2010). Renew. Energy 35, 232-242

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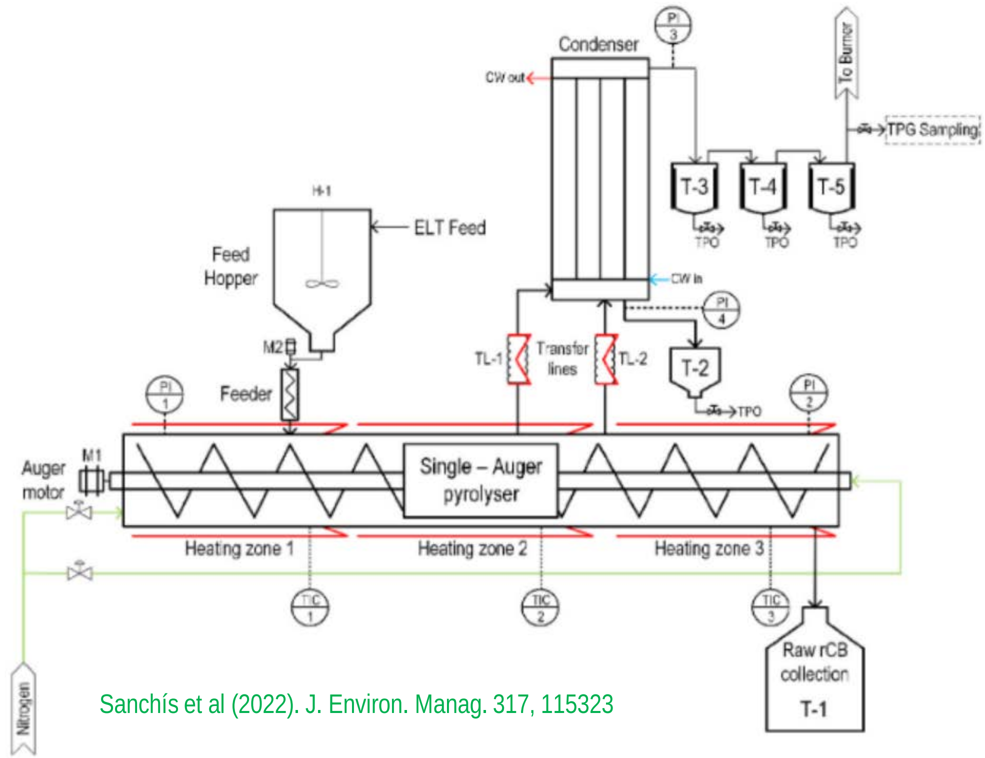
2. Material and methods

2.1 Pilot plant (TRL-5)

- 10 kg/h of nomical capacity
- 3 heating zones (independent electrical resistances)
- N_2 as carrier-gas
- Different reaction times



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2. Material and methods

2.2 Semi-industrial plant (TRL-7)

- 800 kg/h of nominal capacity
- Heating system: combustion of the pyrolytic gas through an external chamber supported by an auxiliary LPG burner
- N_2 as carrier-gas
- Different reaction times

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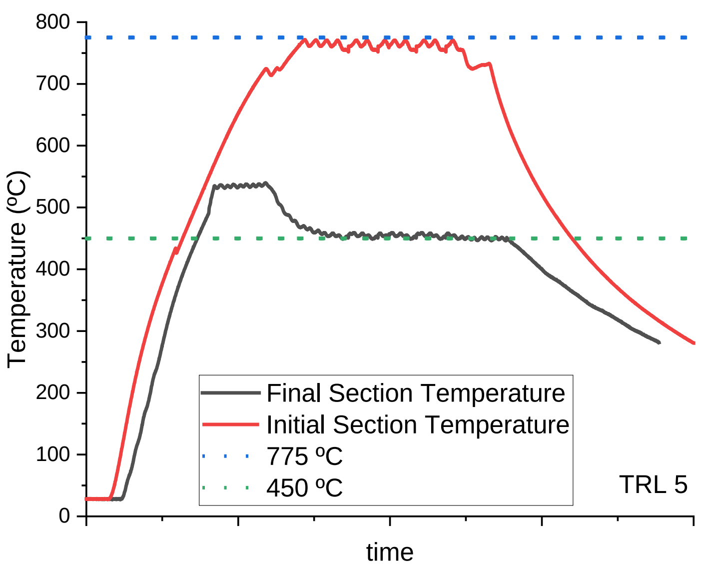
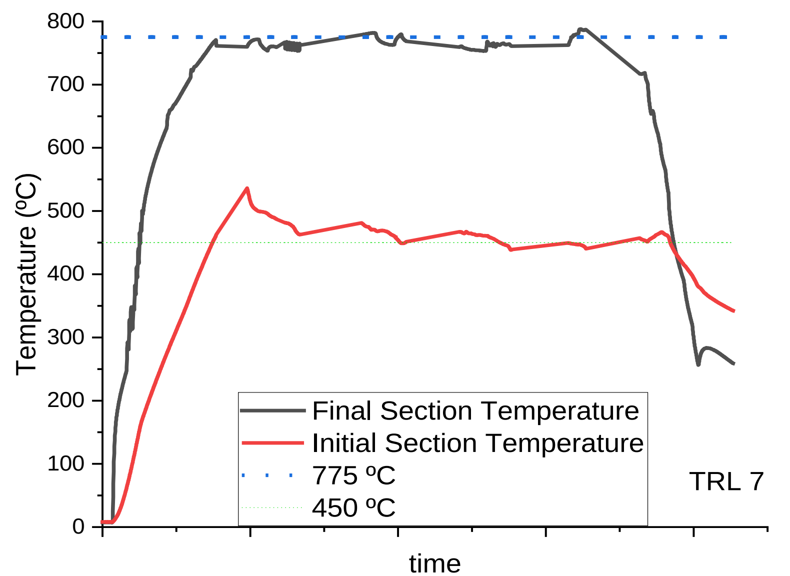
2. Material and methods

2.3 Experimental conditions

- Waste tire feedstock: Granulated **truck tires.**
- Temperature profile: 450 ºC - 550 ºC - 775 ºC
- Residence time for the rubber particles: 15 min
- Volatile residence time of 30 s → controlled by the mass flow rate: 4 kg/h (TRL5) and 500 kg/h (TRL7)





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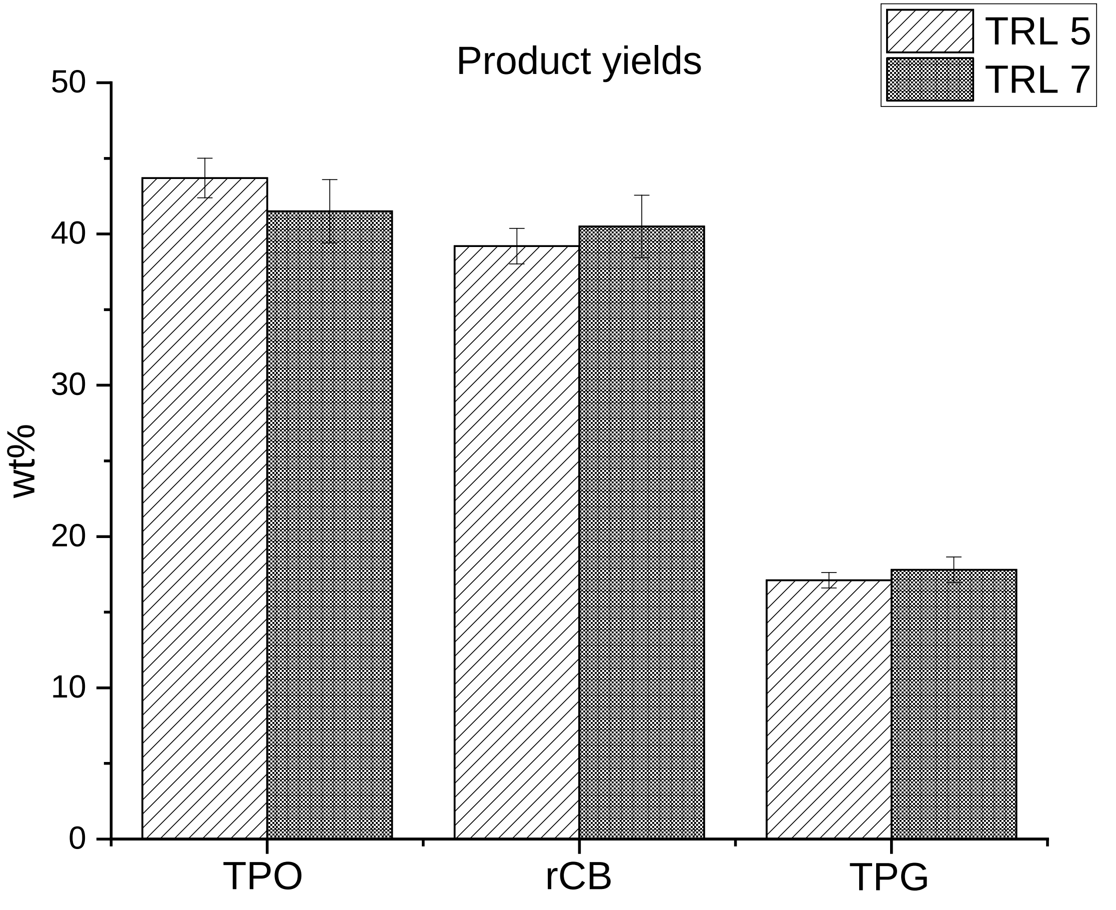
3. Results

3.1 Yields



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3. Results

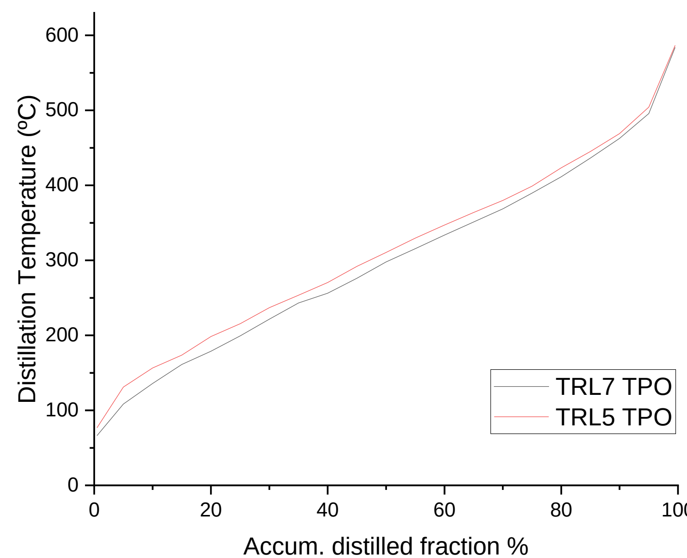
3.2 Characteristics of the TPO

Tire pyrolysis oil (TPO)

Yields
→ 40-45 wt%

Composition / property	TRL5	TRL7
C (wt%)	88.7	87.5
H (wt%)	10.2	11.3
N (wt%)	1.4	0.6
S (wt%)	0.76	0.96
C/H	0.7	0.6
HHV (MJ/kg)	42.3	41.5
pH	6.9	7.3
TAN (mg KOH/ g Sample)	6.2	5.4
Density (kg/m^3)	975.7	960.0
Viscosity (mPa.s)	7.0	5.6

Compounds	TRL5	TRL7
Benzene	2.53	1.54
Toluene	4.64	3.69
Ethylbenzene	0.47	0.56
(p+m)-Xylene	3.85	3.13
o-Xylene	0.65	0.45
Total BTEX	12.1	9.4
Styrene	1.27	0.55
Limonene	3.66	4.55



Simulated distillation curve (ASTM D2887)

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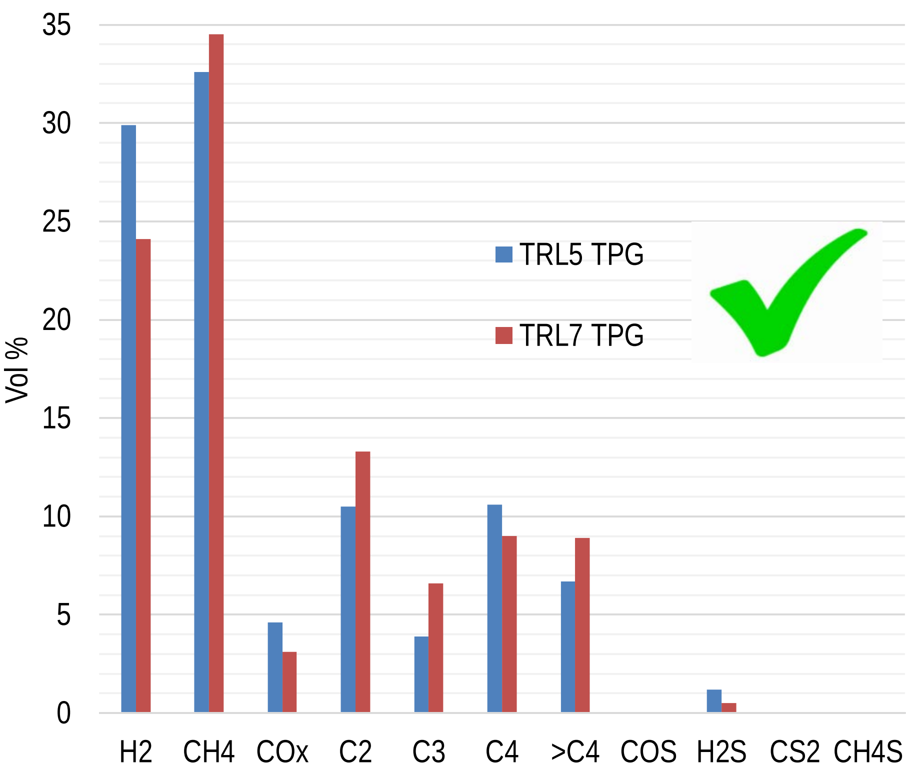
3. Results

3.3 Characteristics of the TPG

Tire pyrolysis gas (TPG)

Yields
→ 16-18 wt%

- A very high presence of H_2 (24-29 vol%)
- A very high presence of CH_4 (32-34 vol%).
- LHV → 52-54 MJ/Nm^3 , which is higher than that from natural gas (~42 MJ/Nm^3)
- Sufficient energy to provide the energy need by the process



Volumetric composition of the gas stream (in a N_2-free basis)

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3. Results

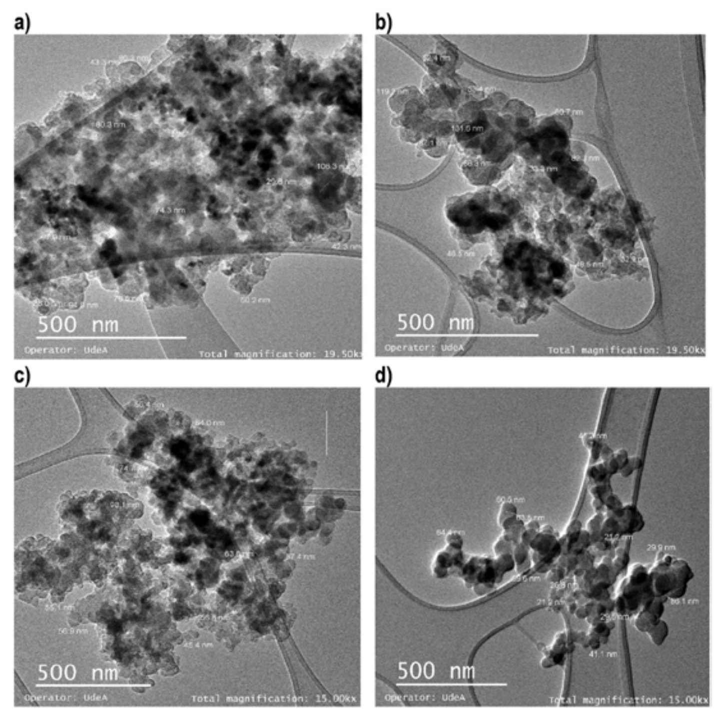
3.4 Characteristics of the RRCB

Raw Recovered Carbon Black (RCB)

Yields
→ 39-41 wt%

Composition / property	TRL5	TRL7
Moisture (wt%)	1.3	0.6
Ash (wt%)	14.5	16.5
Volatile matter (wt%)	1.6	4.6
Fixed Carbon (wt%)	82.7	75.9
Carbon (wt%)	83.4	79.1
Hydrogen (wt%)	0.4	1.7
Nitrogen (wt%)	0.3	0.4
Sulfur (wt%)	2.8	3.3
HHV (MJ/kg)	29.6	27.8

- Carbon content (79 – 83 wt%)
- Sulfur content (2.8 – 3.3 wt%)
- HHV (27.8 – 29.6 MJ/kg)
- Volatile matter content (1.6 vs. 3.6 wt%)
- The residence time in the TRL7 plant should be a little bit higher in order to decrease the volatile matter content in the RRCB



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4. Conclusions

- ✓ The yields of TPO, TPG and RRCB in both plants were vey similar
- ✓ The compositions of TPO, TPG and RRCB in both plants were very similar.
- ✓ An important content of limonene has been produced in the TRL7 plant (4.5 wt%)
- ✓ The volatile matter content in the RRCB produced in the TRL7 must be reduced → by adjusting particle size and solid residence time.
- ✓ The auger technology has been confirmed to be a robust technology with a very high potential for valorizing waste tire by pyrolysis at semi-industrial scale.

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Thank you very much for your attention!

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