Freie Universität Bozen
Libera Università di Bolzano
Free University of Bolzano

Thermal energy, fillers and pigments from wood packaging waste

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Chania, 21-24 June 2023

Previously in Corfu…

Funded by the European Union in the framework of the Horizon 2020 Research and Innovation Programme under grant agreement No. 101037031

Circular systemic solutions

CSS1: Circular approach to wood packaging waste

CSS2: Circular approach to food and feed

CSS3: Circular approach to wastewater and nutrients

CSS4: Circular approach to industrial and urban plastic/rubber waste

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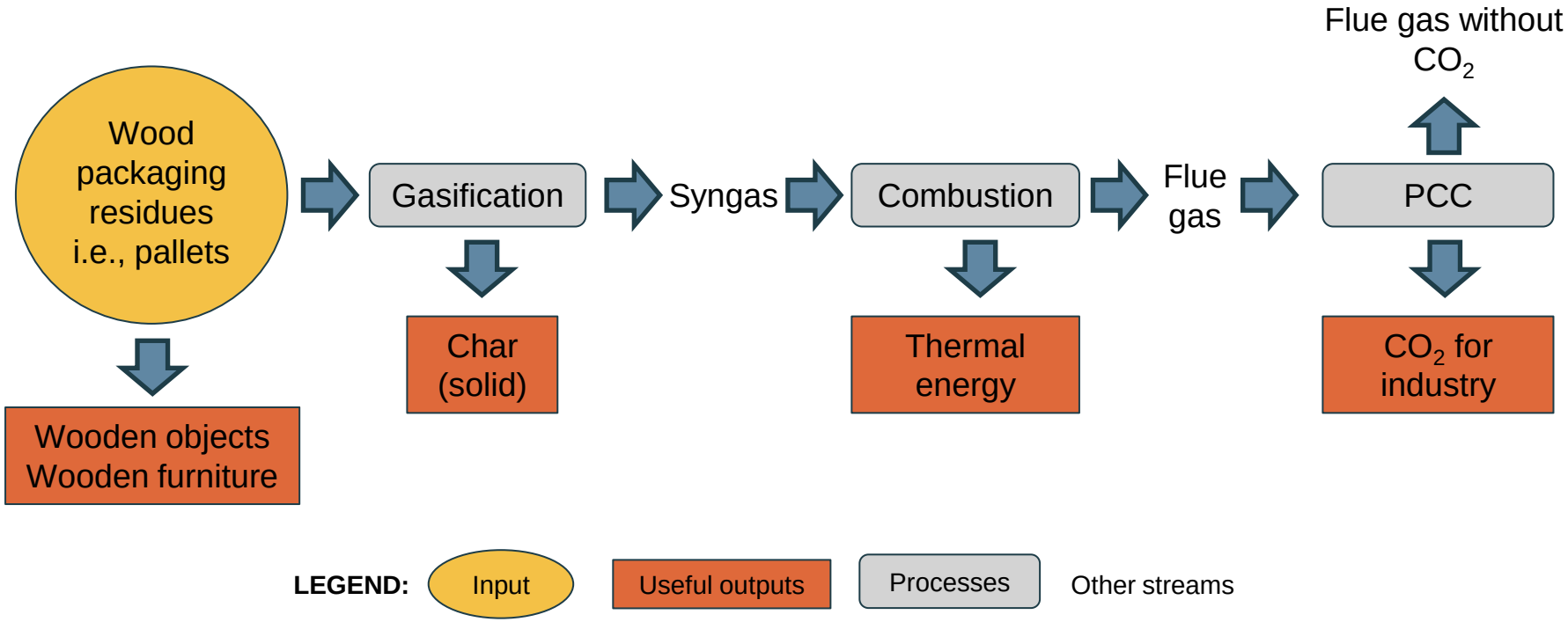
CSS1 – Overview

Objective: Development of a circular economy concept based on the valorization of wood packaging waste (e.g., pallets) through refurbishing, reusing, recycling, energy recovery, and material valorization.



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CSS1 – Biomass gasifier

BURKHARDT
ENERGIE- UND GEBÄUDETECHNIK

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CSS1 – Biomass gasifier

Performance data

50 kW
Electrical output

110 kW
Thermal output

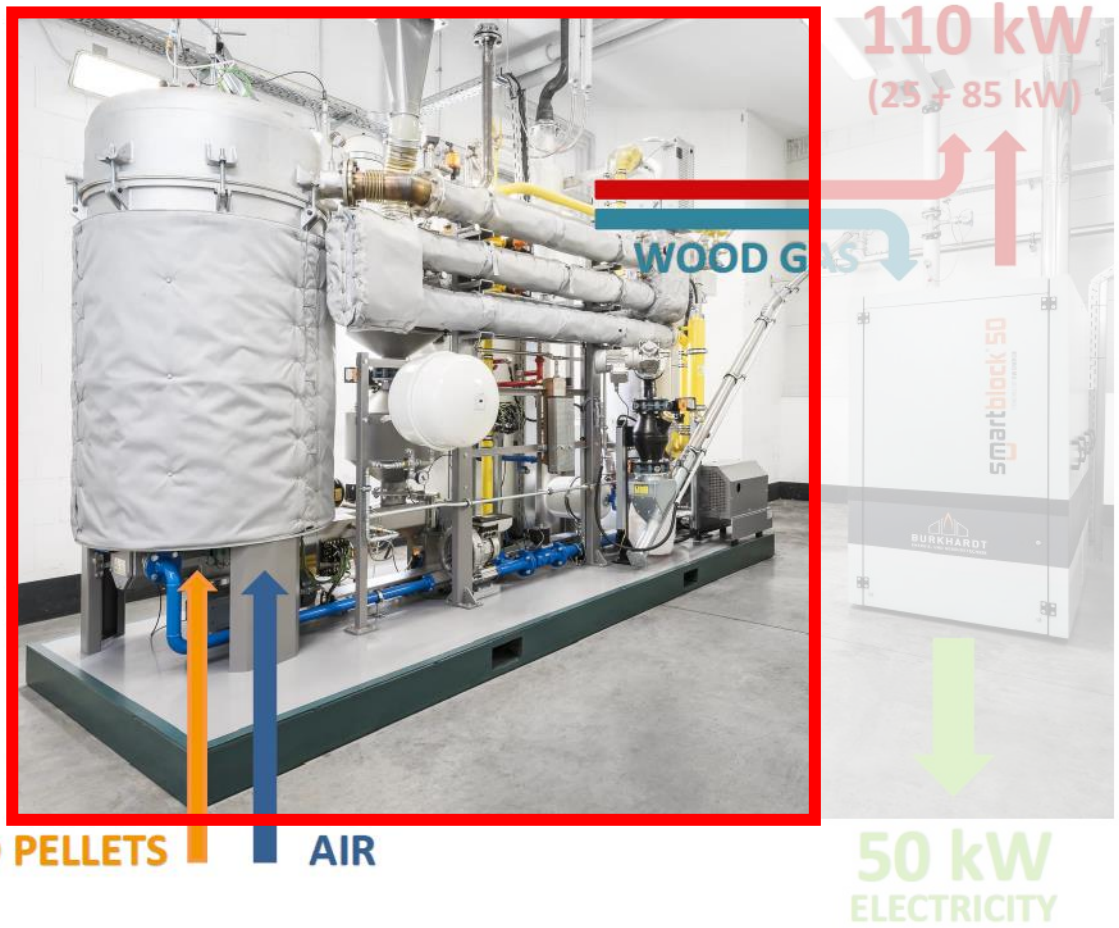
40 kg/h
Pellet-consumption

1,5 kW
Self-consumption electrical

25 %
Electrical efficiency

55 %
Thermal efficiency

80 %
Total efficiency



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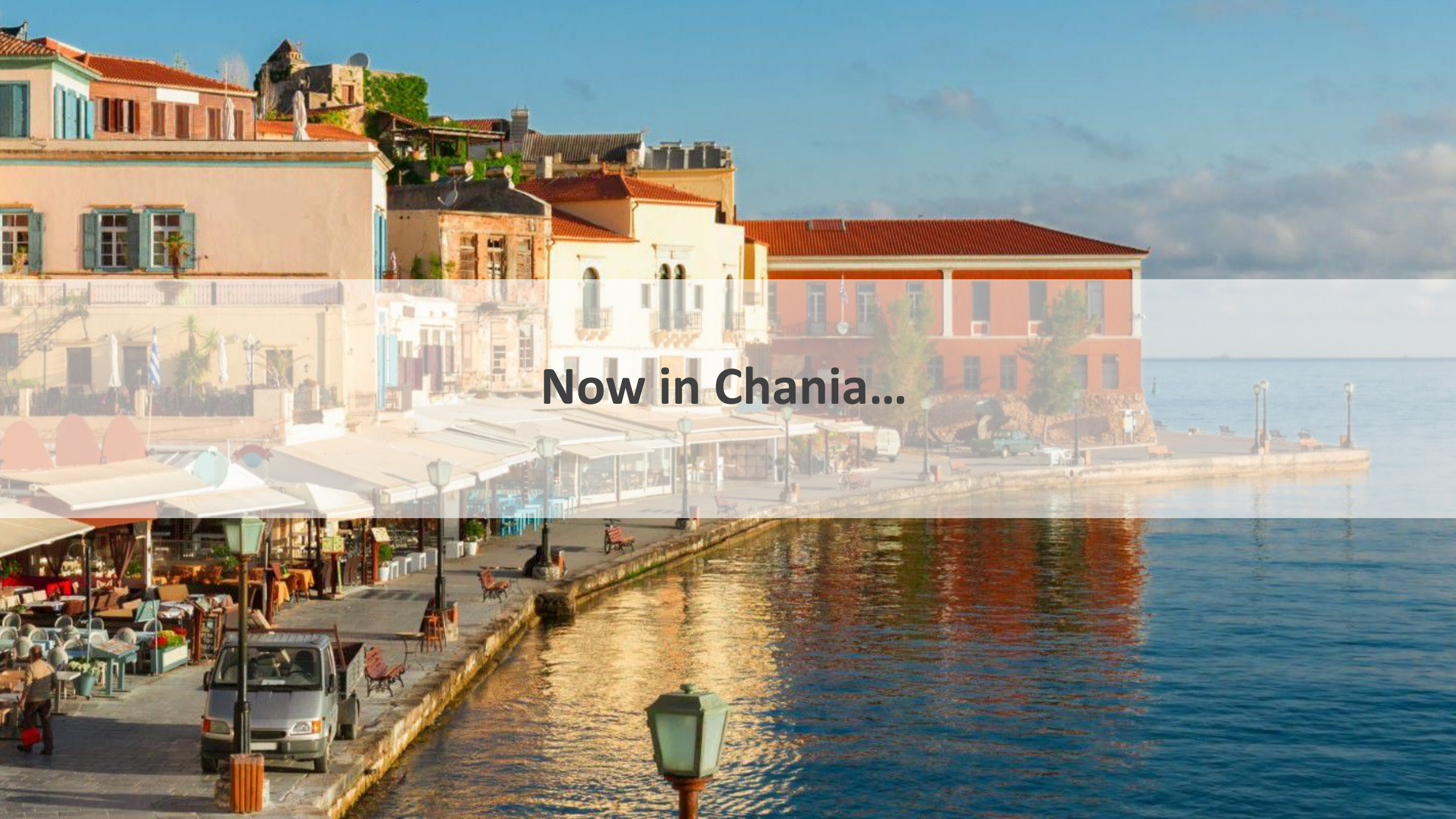
Now in Chania…

Feedstock

Pallet chips

Dust

Pellets

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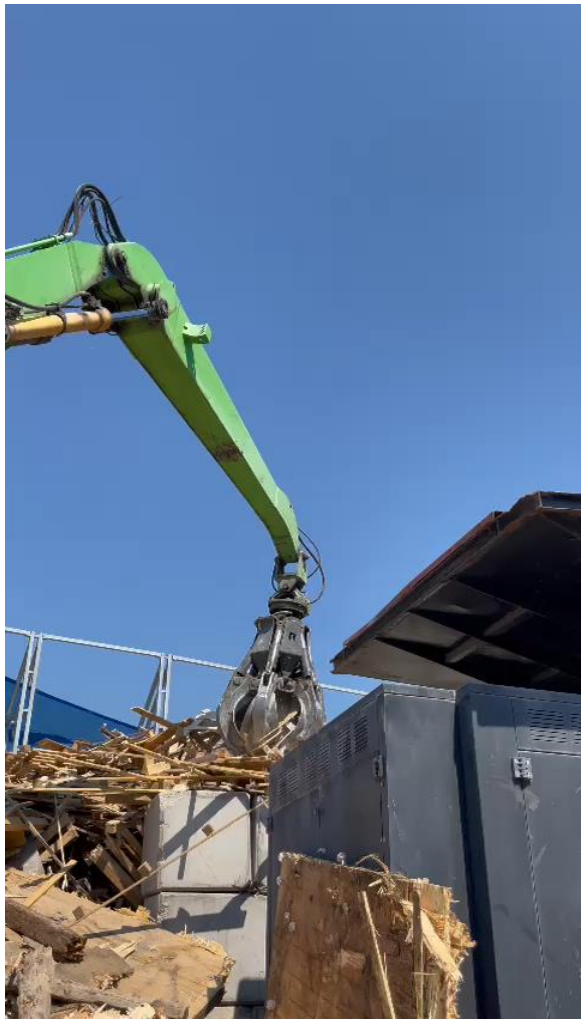
Feedstock

Lamafer
YOUR WASTE SOLUTION



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Feedstock

Metallic parts

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Feedstock

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Feedstock

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Feedstock characterization

	Standard pellets	Pellets from pallets	Unit
Proximate analysis			
Moisture	8.7	9.3	% as received
Volatiles	81.2	79.2	% dry basis
Ash	0.5	2.1	% dry basis
Fixed carbon	18.3	18.7	% dry basis
Ultimate analysis			
Carbon	49.95	49.30	% dry basis
Hydrogen	6.05	5.99	% dry basis
Nitrogen	0.12	0.35	% dry basis
Sulfur	0.01	0.02	% dry basis
Chlorine	0.01	0.03	% dry basis
Oxygen	43.38	42.24	% dry basis
Gross Heating Value	19.65	19.51	MJ/kg, dry basis
	17.93	17.69	MJ/kg, as received
Net Heating Value	18.33	18.21	MJ/kg, dry basis
	16.52	16.29	MJ/kg, as received

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Feedstock characterization

Concentration of major elements

Sample	Al (ppm)	Ca (ppm)	Fe (ppm)	K (ppm)	Mg (ppm)	Na (ppm)	Si (ppm)
Standard	42.7	1697	69.0	591	199	27.5	210
from pallets	943	1932	3614	770	545	284	1250

Concentration of trace elements

Sample	Cd (ppm)	Co (ppm)	Cr (ppm)	Cu (ppm)	Mn (ppm)	Ni (ppm)	Pb (ppm)	V (ppm)	Zn (ppm)
Standard	0.11	0.08	0.39	1.11	121	0.22	0.21	0.87	12.5
from pallets	0.16	0.21	7.45	14.9	107	5.34	5.45	0.85	52.0

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1st tests:

2nd tests:

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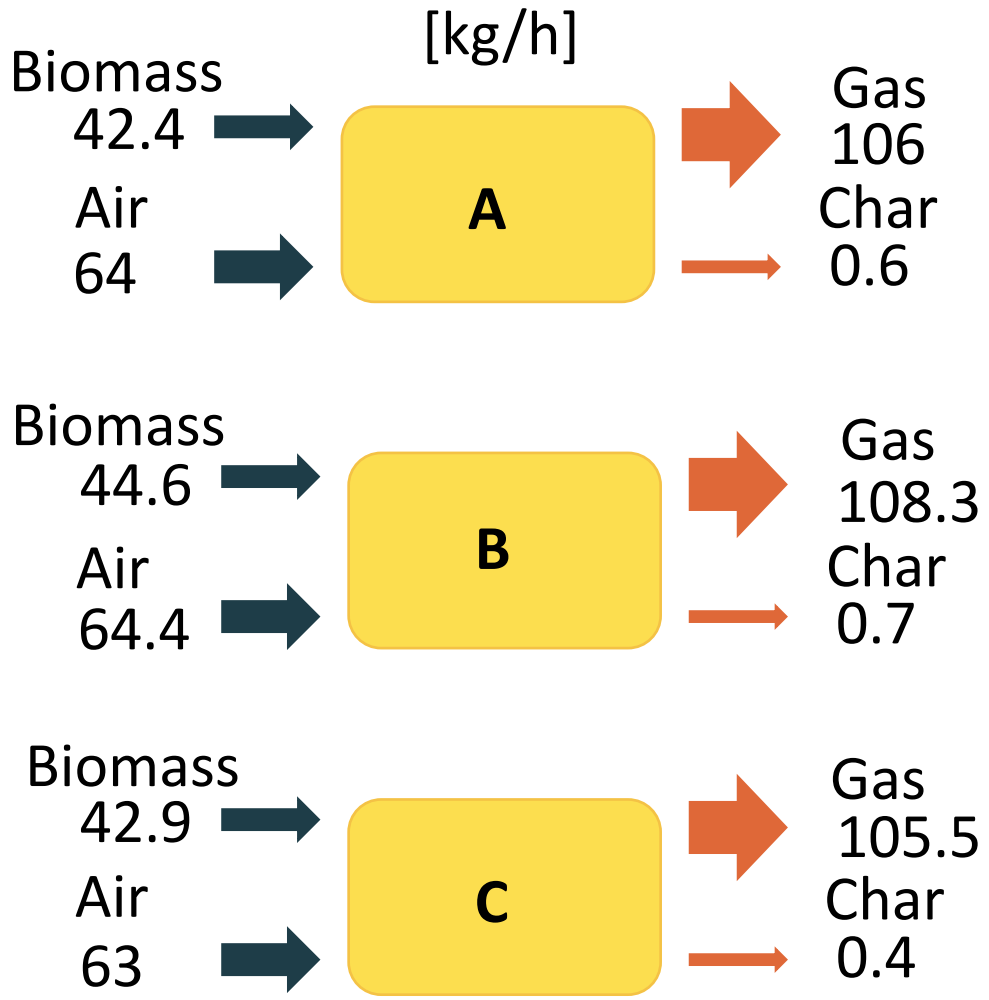
Gasification tests with standard pellets

-	A	B	C
Vibration	0	5 min, every 15 min	Always
Coke bed height	87 cm	87 cm	92 cm



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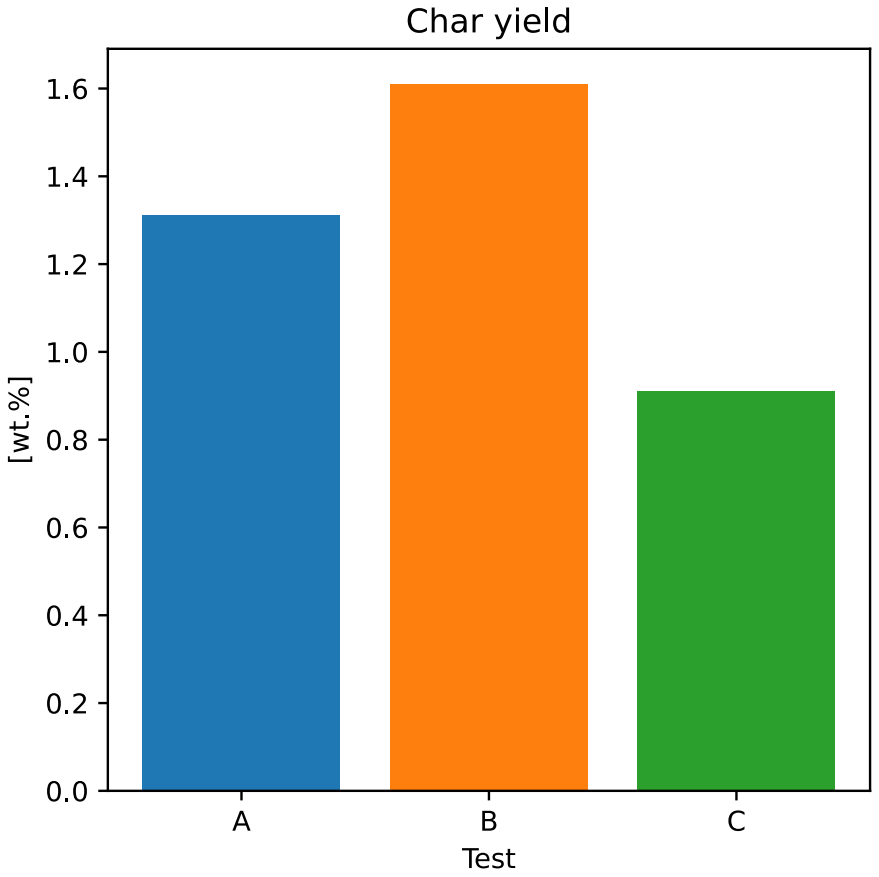

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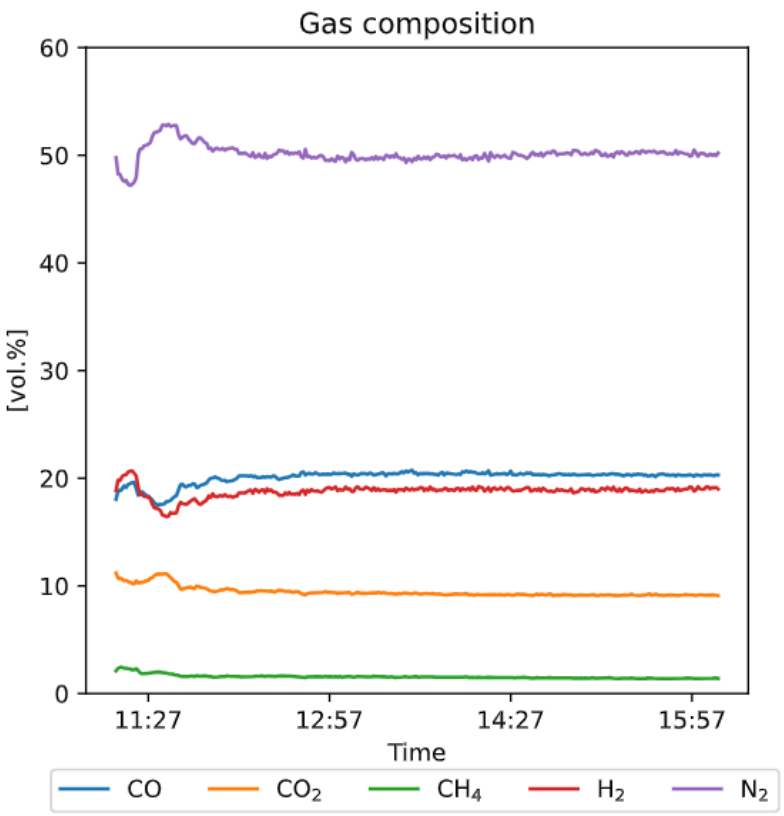
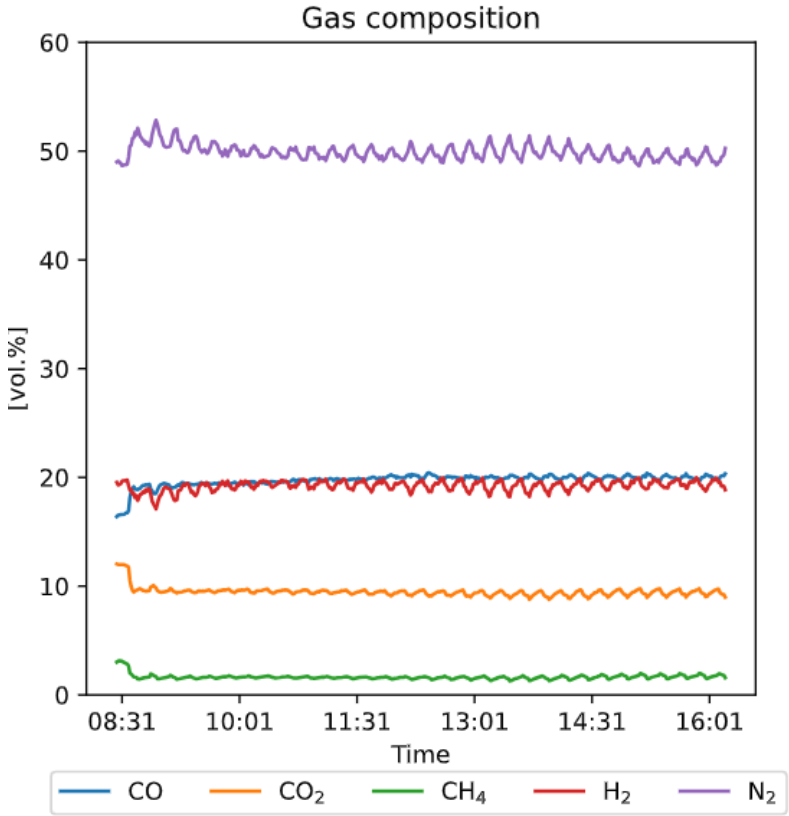


A



B

C

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Char characterization

	Char A	Char B	Unit
Moisture	3.2	3.4	% as received
Volatiles	11.1	12.4	% dry basis
Ash	19.0	16.3	% dry basis
Fixed carbon	69.9	71.3	% dry basis
Carbon	81.20	83.70	% dry basis
Hydrogen	0.68	0.50	% dry basis
Nitrogen	0.41	0.66	% dry basis
Sulfur	0.10	0.07	% dry basis
Chlorine	0.15	0.15	% dry basis
Gross Heating Value	27.64	28.39	MJ/kg, dry basis
	26.75	27.42	MJ/kg, as received
Net Heating Value	27.50	28.29	MJ/kg, dry basis
	26.54	27.23	MJ/kg, as received
Specific surface area	587	1075	m^2/g
Pore volume	0.66	0.91	cm^3/g
Pore size	8.7	7.3	nm

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Char characterization

Concentration of oxides

Sample	Al_2O_3 (%)	CaO (%)	Fe_2O_3 (%)	K_2O (%)	MgO (%)	Na_2O (%)	SiO_2 (%)
Char A	0.66	38.32	1.52	14.45	4.84	0.64	4.97
Char B	0.32	39.49	0.85	16.71	4.50	0.53	1.92

Concentration of trace elements

Sample	Cd (ppm)	Co (ppm)	Cr (ppm)	Cu (ppm)	Mn (ppm)	Ni (ppm)	Pb (ppm)	V (ppm)	Zn (ppm)
Char A	41.9	2.03	33.8	222	4.99	42.6	50.1	1.25	1847
Char B	37.5	1.74	9.64	234	4.5	21.8	53.5	0.43	1832

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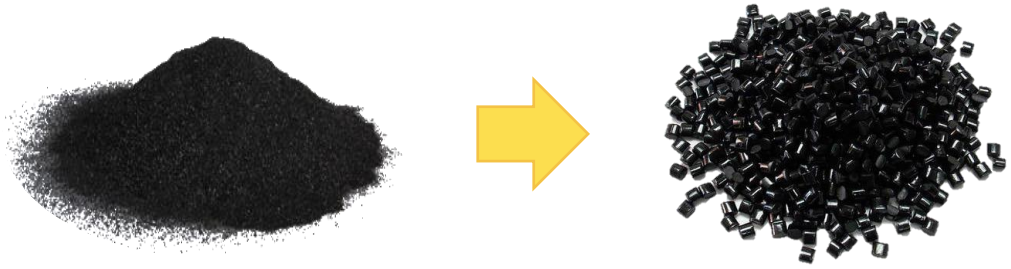
Char addition to polymers - materials

Samples:

1. **LDPE**: Pure low-density polyethylene
2. **Front S11.1**: Granulated compound
3. **PE+1%ST**: Polyethylene 99% + 1%wt char A - Standard (ST)
4. **PE+1%MCY**: Polyethylene 99% + 1%wt char B - Maximum Carbon Yield (MCY)

In collaboration with:

TYMOTHEUS srl



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Char addition to polymers - methods

Sample preparation:

- **Compounding** by DSM Micro-compounder 15 cc co-rotating twin-screw extrusion with mixing function.
- **Injection-moulding** by DSM Micro Injection Moulding Machine 10 cc .

For the production of the samples to be tested for Melt Flow Index (MFI), simple threads were produced by flowing the material from the extrusion head. This material was ground using a polymer recycling device, i.e., a TRIA blade mill.

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Char addition to polymers - methods

	LDPE	FrontS11.1	PE+1%ST	PE+1%MCY
Mixing time [s]	60		75	
T profile [°C]	150 - 165 - 180			
T melt [°C]	176			
Screw rotation speed [rpm]	50		39	
T mould [°C]	25			
T injection [°C]	185			
P injection [bar]	11			
Injection time [s]	19			

Different viscosity

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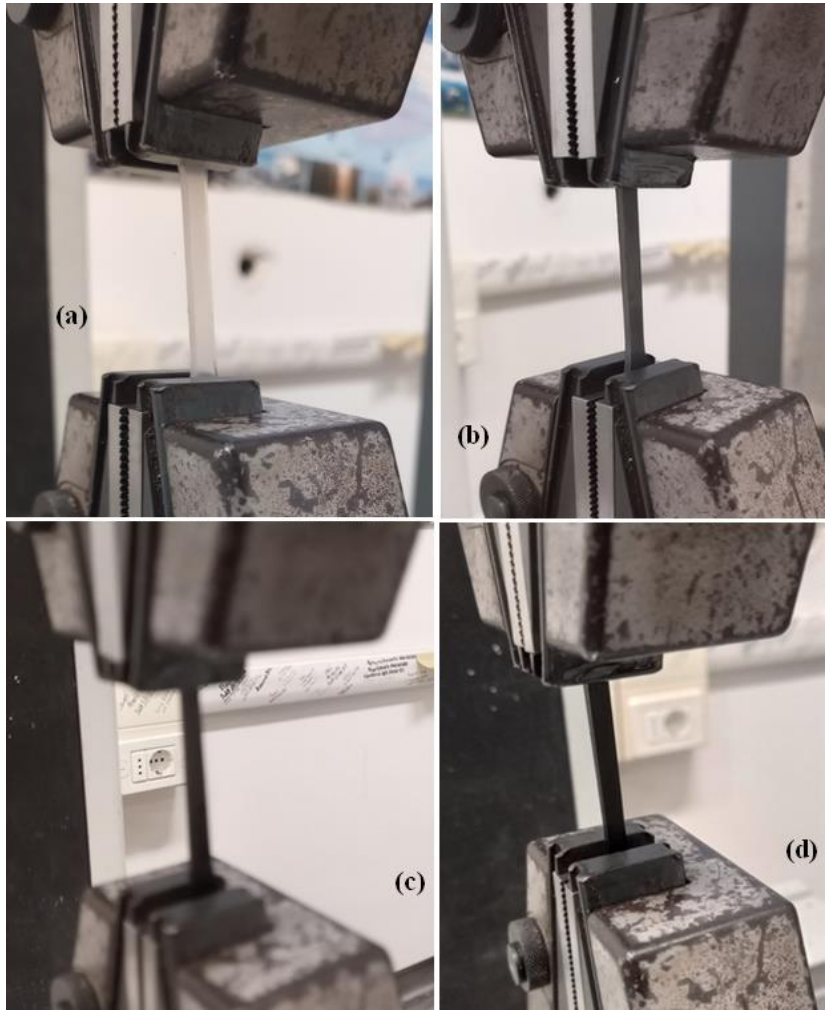
Char addition to polymers - methods

Tensile tests:

- Following ISO 527
- Universal electronic dynamometer from LLOYD INSTRUMENT, model 30K (no external strain gauges)
- Type 1BA geometry
- Traverse speed of 50 mm/min
- Useful stretch ~ 50 mm
- Tests were conducted until the specimens ruptured, which occurred for limited plastic deformations

MFI tests:

- MFI 452 device from MP strumenti
- T = 190 °C
- w = 2.16 kg
- t = 60 s



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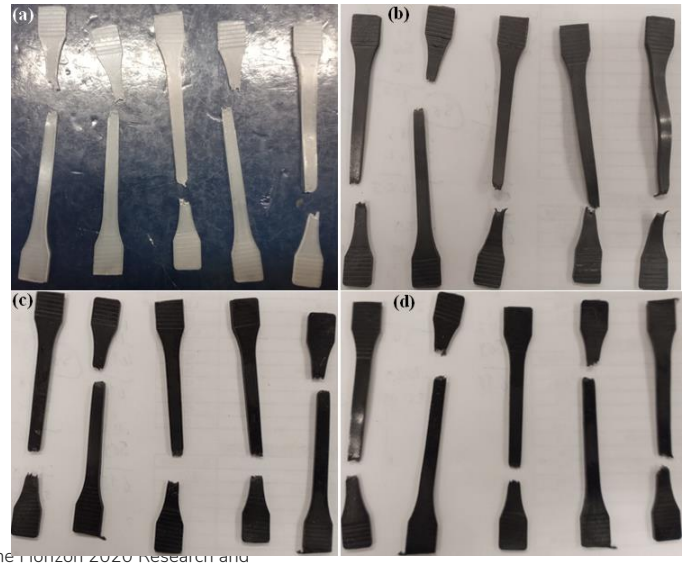
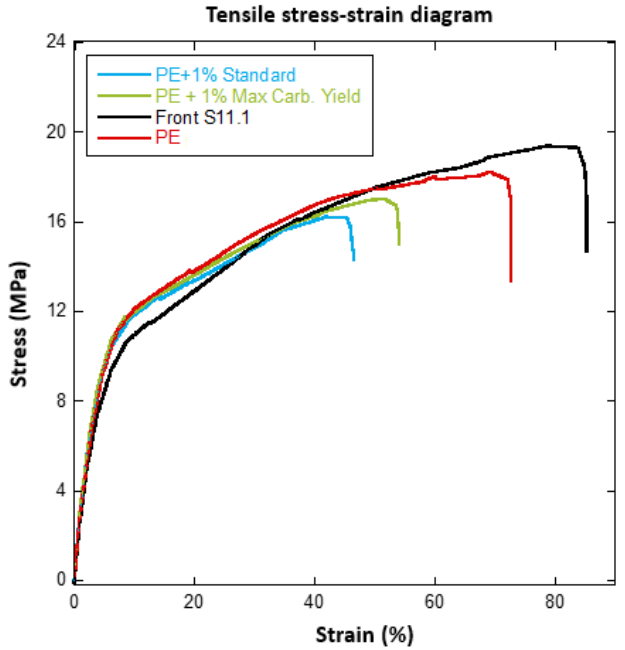
Char addition to polymers - results

Sample	σ_y (MPa)	ε_y (%)	σ_{br} (MPa)	ε_{br} (%)	E (MPa)	MFI (g/10min)
LDPE	10.77 ± 0.31	3.33 ± 0.10	17.95 ± 0.30	70.72 ± 2.35	325.13 ± 10.68	1.92 ± 0.03
Front S 11.1	9.94 ± 0.51	3.45 ± 0.11	19.25 ± 0.97	81.53 ± 7.01	294.90 ± 25.65	2.40 ± 0.03
PE+1% ST	11.02 ± 0.42	3.37 ± 0.20	16.75 ± 1.22	46.90 ± 3.58	326.18 ± 28.00	1.66 ± 0.03
PE+1% MCY	11.03 ± 0.55	3.50 ± 0.29	17.14 ± 0.45	47.52 ± 3.38	314.62 ± 20.96	1.60 ± 0.01





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Char addition to polymers - results

Sample	σ_y (MPa)	ε_y (%)	σ_{br} (MPa)	ε_{br} (%)	E (MPa)	MFI (g/10min)
LDPE	10.77 ± 0.31	3.33 ± 0.10	17.95 ± 0.30	70.72 ± 2.35	325.13 ± 10.68	1.92 ± 0.03
Front S 11.1	9.94 ± 0.51	3.45 ± 0.11	19.25 ± 0.97	81.53 ± 7.01	294.90 ± 25.65	2.40 ± 0.03
PE+1% ST	11.02 ± 0.42	3.37 ± 0.20	16.75 ± 1.22	46.90 ± 3.58	326.18 ± 28.00	1.66 ± 0.03
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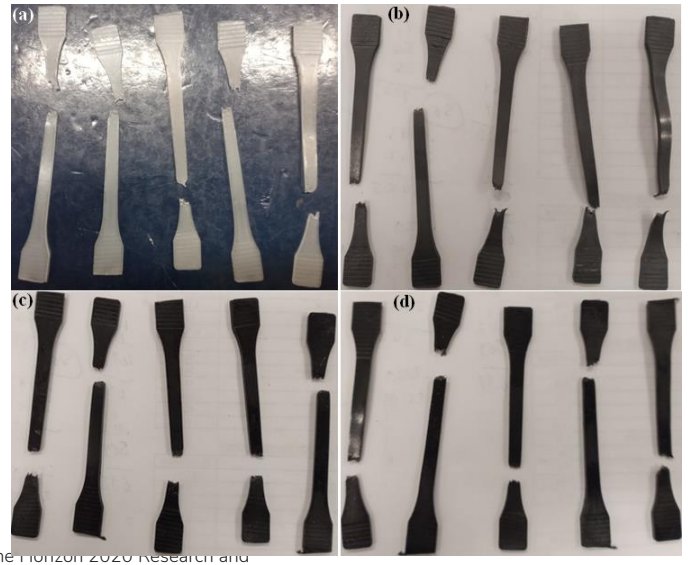

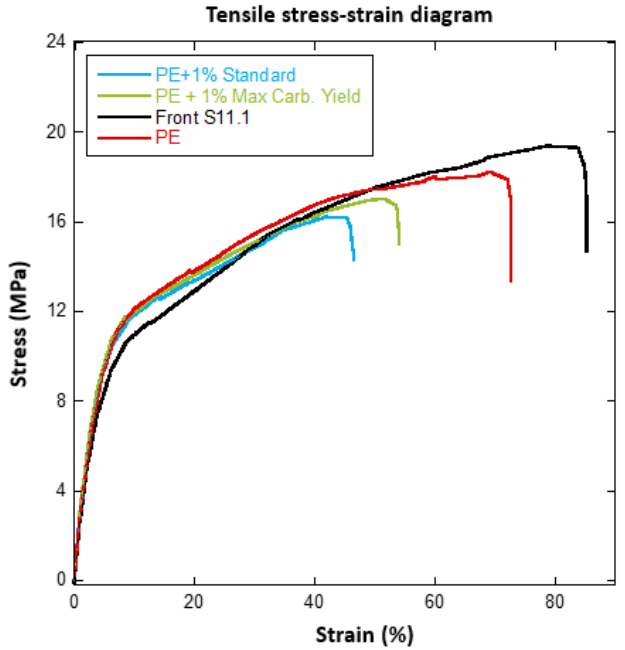

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1st tests:

2nd tests:

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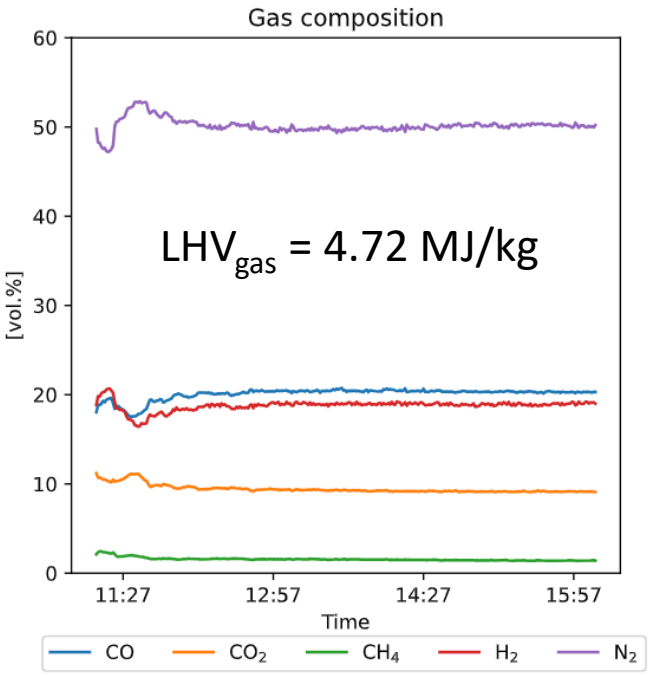
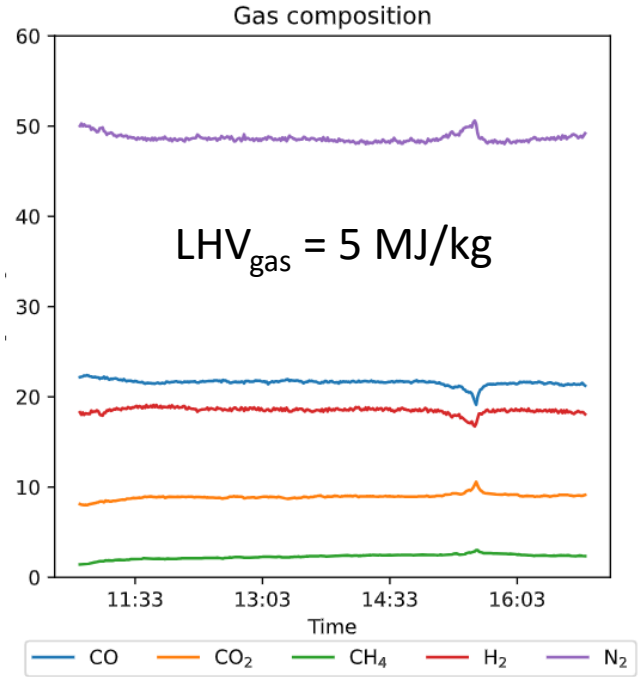
Gasification tests with pellets from pallets

Condition A





[kg/h]

Biomass 42.4
Air 64

Gas 106
Char 0.6

Char yield: 1.31%

Biomass 42.1
Air 65

Gas 106.6
Char 0.5

Char yield: 1.15%

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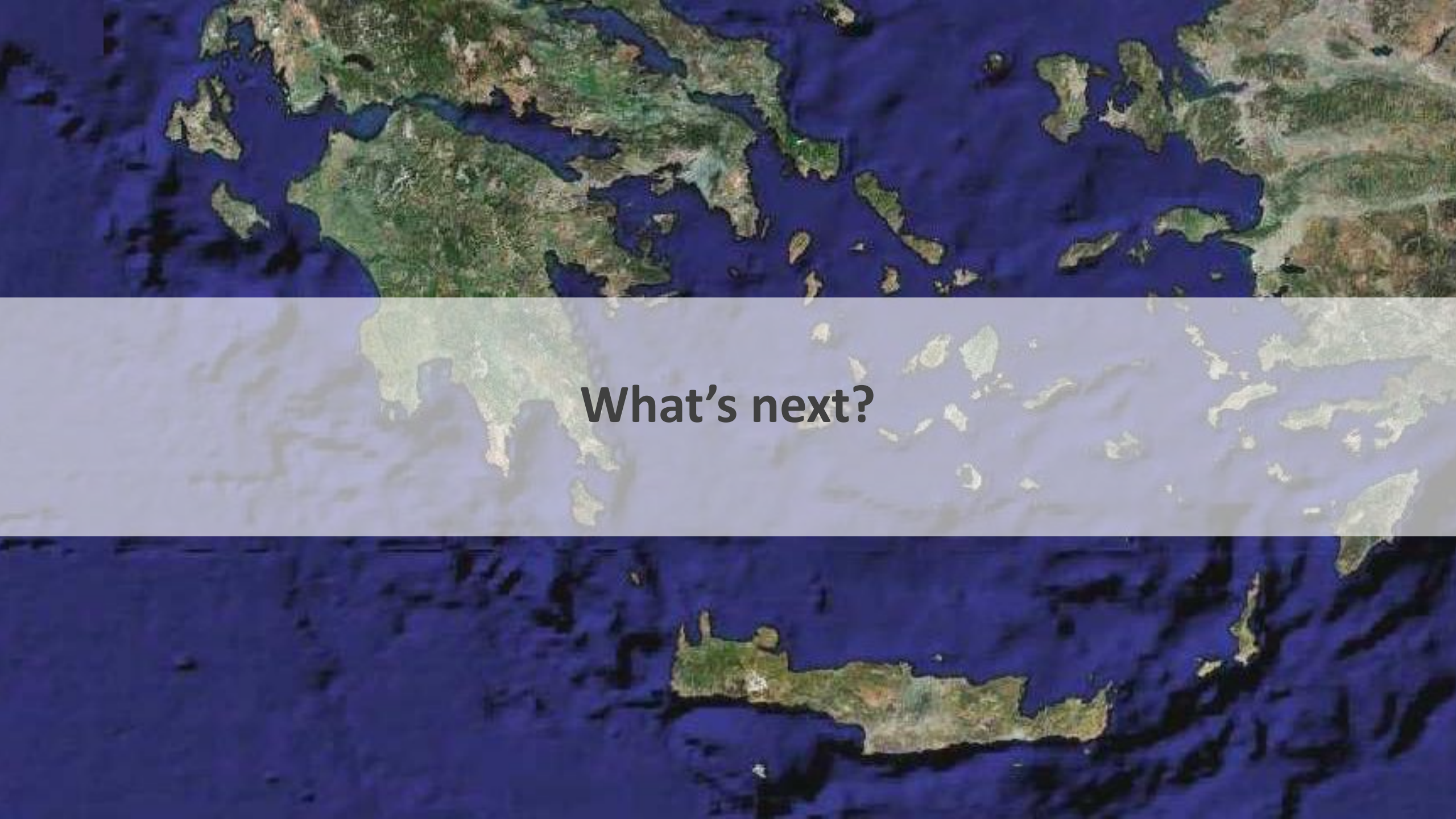

What’s next?

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Thank you for your attention

Thermal energy, fillers and pigments from wood packaging waste

#FRONTSH1P

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Lab website: https://bnb.groups.unibz.it/
Project website: https://frontsh1p.eu/

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