WIRE

Waste biorefinery technologies for accelerating sustainable energy processes

Waste derived chars Sources and applications

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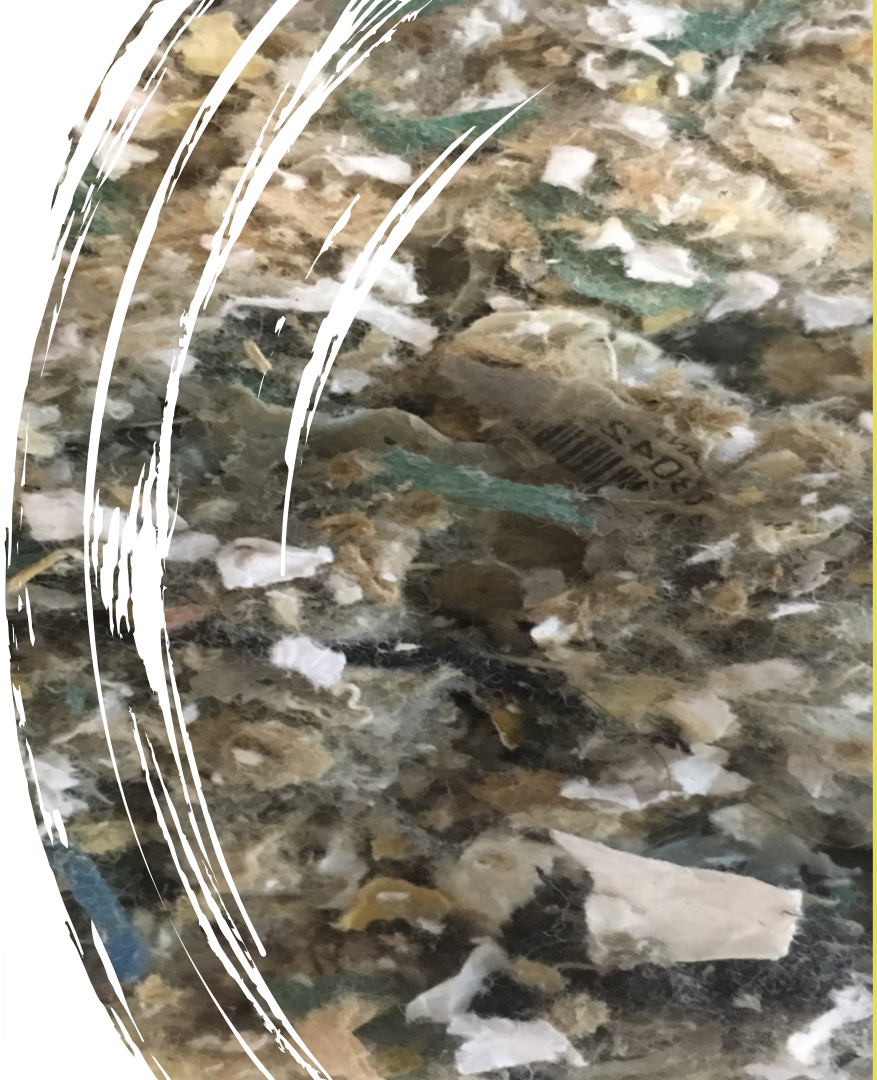
24 November 2023



cost
EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

Funded by the European Union

Contents

- Waste Production and management
- What are waste derived chars
- Main waste streams
- Questions to address by thermochemical conversion
- Case studies for specific waste streams
- Ideas to retain
- Next Challenges

MSW PRODUCTION IN EUROPE

M. Santos et al.

Table 1. MSW production in Europe and mainland Portugal between 2016 and 2020.

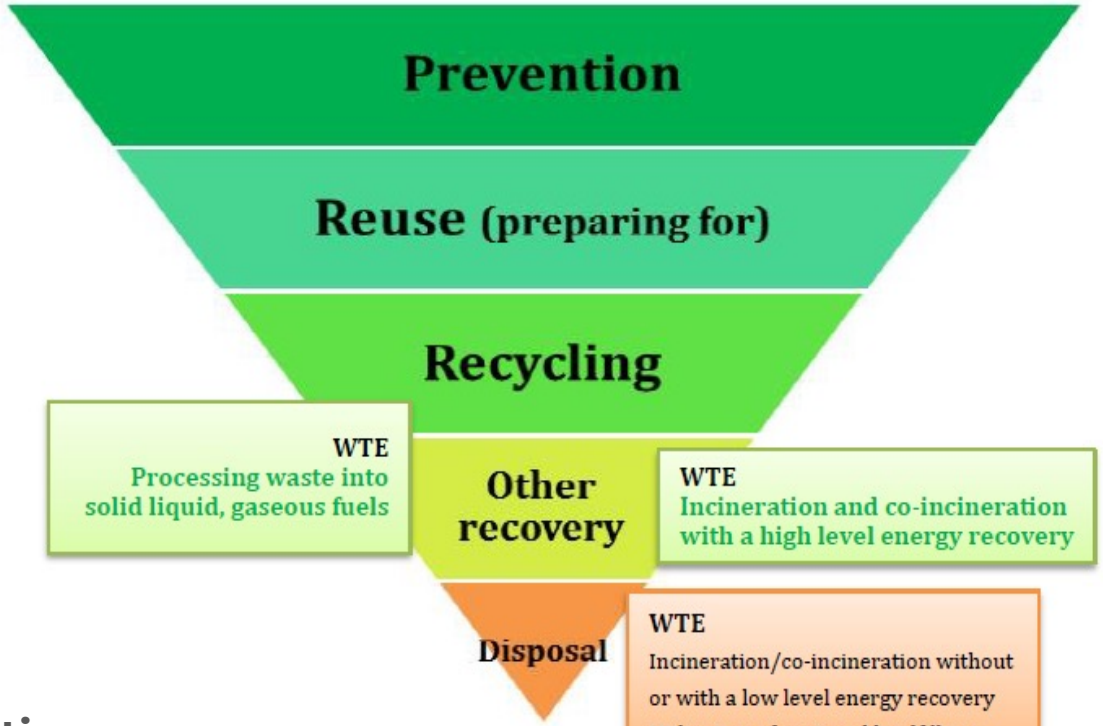
Region	Unit	2016	2017	2018	2019	2020
EU	10^3 t	218,028	220,957	221,610	223,956	225,732
Portugal		4640	4745	4945	5007	5014
EU	kg/hab.day^{-1}	1.34	1.36	1.6	1.37	1.38
Portugal		1.29	1.33	1.38	1.40	1.40

Table 2. Destination of MSW in Europe and Portugal in 2020. Source: authors' calculations using Eurostat data for Europe.

Region	Landfill	Energy Recovery	Organic Recovery	Multi-Material Recovery and Other Recoveries
EU (%)	37.7	5.7	n.m. *	56.6
Portugal (%)	64.2	17.4	7.2	11.1

* n.m.: not mentioned.

Waste Hierarchy



- Energy recovery is the 4th priority
- Carbonization, Liquefaction or gasification are equivalent to incineration

WASTE-TO-CHAR
WHY?

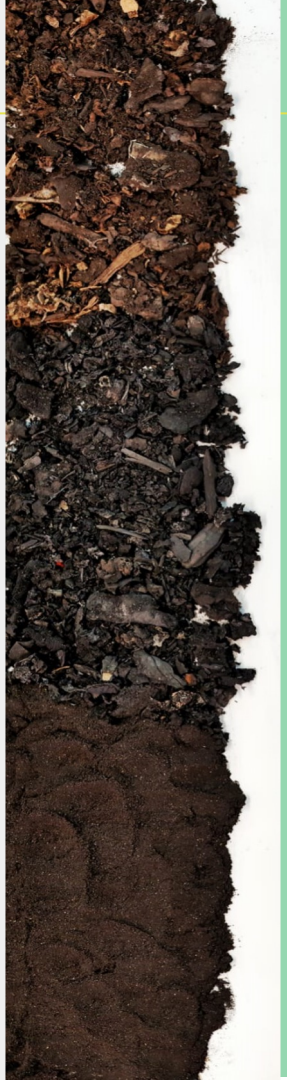
Increases Density

Improves homogeneity

Eliminates undesirable components

WASTE DERIVED CHARS

Obtained from **heterogeneous materials** containing **polymers, biomass** and **inorganic contaminants**.



Waste derived chars should be produced from materials that:

- ✓ Are not recyclable
- ✓ Are produced in large quantities
- ✓ May contain toxic components
- ✓ Are not biodegradable

Thermochemical Conversion

- **Traditional or Hydrothermal Carbonization**
- **Traditional or Hydrotermal Liquefaction**
- **Gasification**

- ✓ Energy and Carbon Recovery
- ✓ Incineration emissions
- ✓ Landfill deposition costs

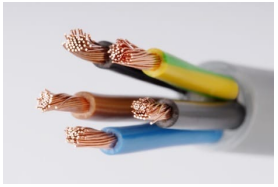
WASTE STREAMS

RDF

Industrial Waste

SRF

Construction and Demolition Wastes



RDF

Electric and Electronic Wastes

RDF

Municipal Solid Waste

Hydrocarbon Sludges

MARPOL Wastes

MSW rejected fractions

RDF By-product

WASTE-2-CHAR - QUESTIONS TO ADDRESS

POOR MASS YIELD

- High temperature required for conversion
- Gas phase energy recovery

HIGH ASH CONTENT

- Decrease of heating value
- Slagging / Fouling

HIGH CHLORINE CONTENT

- Corrosion in boilers or gasifiers
- Removal by char washing with hot water

AUTO-IGNITION

- Avoid waste aggregation
- Fast char cooling

REFUSE DERIVED FUEL

Industrial Waste

- **Torrefaction, Carbonization and Hydrothermal Carbonization**
- **Washing to remove chlorine**
- **Thermal gasification**
- **Adsorption properties**

C. Nobre et al.

RDF – Industrial Waste

C. Nobre et al.

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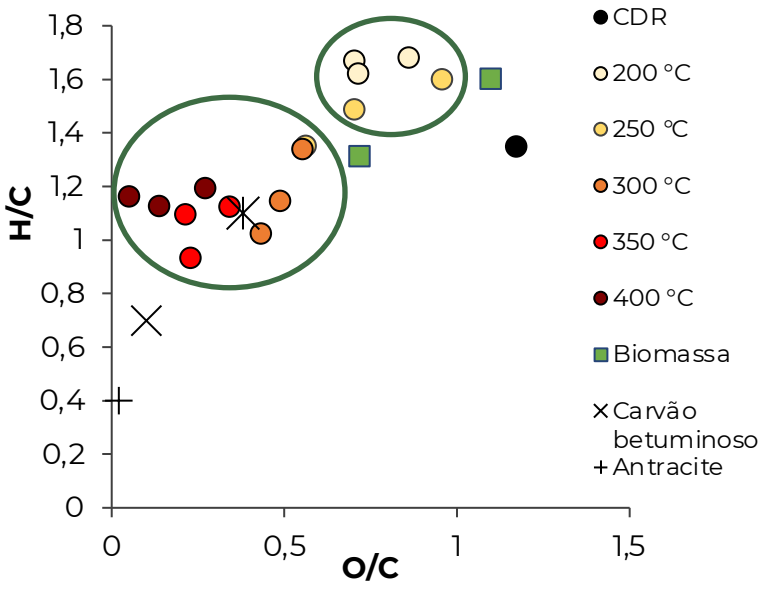
Torrefaction and Carbonization

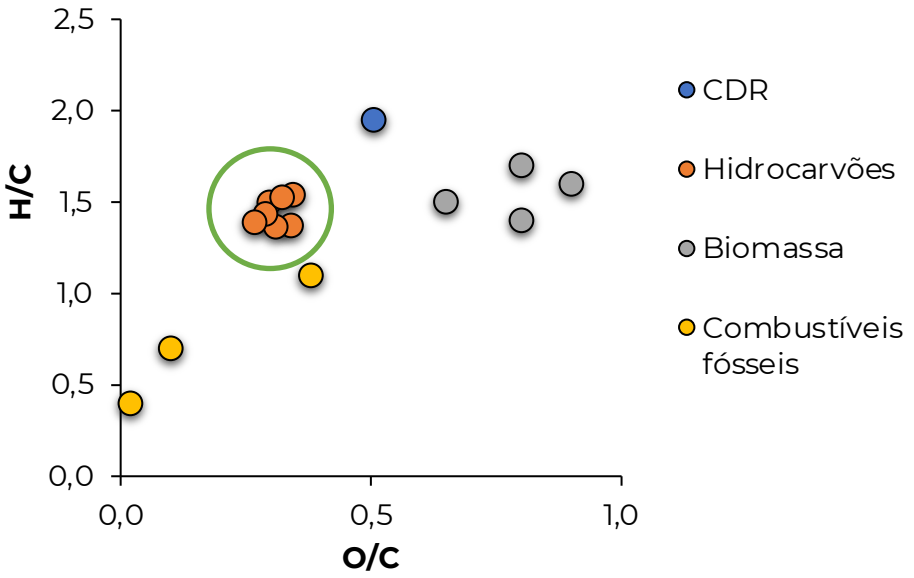


HHV

Torrefaction: **17.8 – 19.9 MJ/kg**

Carbonization: **20.0 – 26.1 MJ/kg**

Hydrothermal Carbonization



HHV

25.2 – 28.1 MJ/kg

RDF – Industrial Waste

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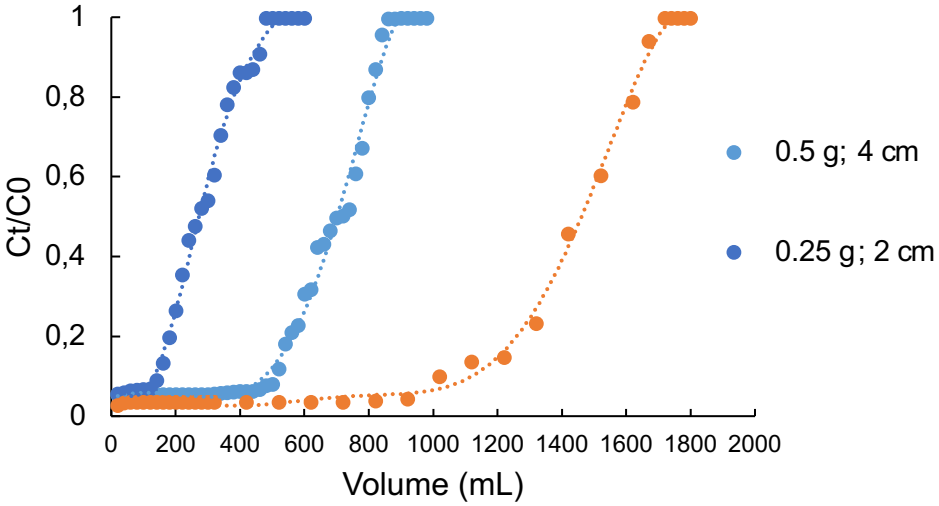
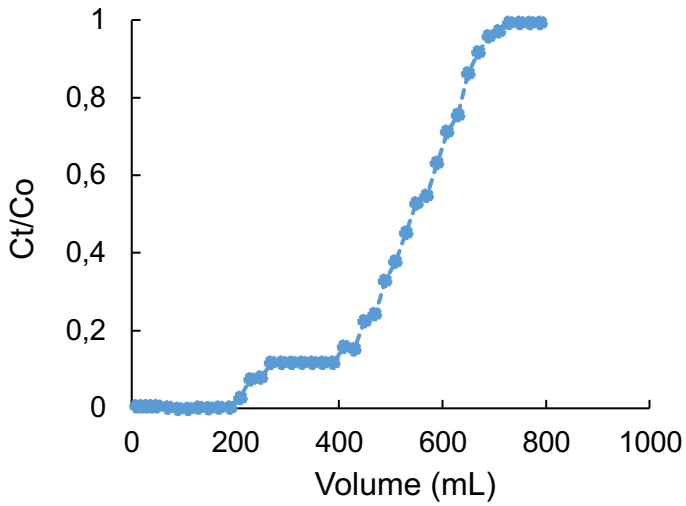
Char valorization after activation with KOH (aq)

Low-cost adsorbent for the leather industry



Column Adsorption of Methylene Blue



Column Adsorption of Chromium, Cr

Solid Recovered Fuels

Construction and Demolition Wastes

+

Municipal Solid Wastes

+

Sewage Sludge

- ✓ Traditional and Hydrothermal Carbonization
- ✓ Thermal Gasification
- ✓ Economic viability analysis

O. Alves et al.

SRF – C&Dwaste + S. Sludge

O. Alves et al.

R1
Wood,
SRF

R2
Wood,
MSW

R3
Paper
MSW

R4
Plastic
packaging

R5
Composite
packaging

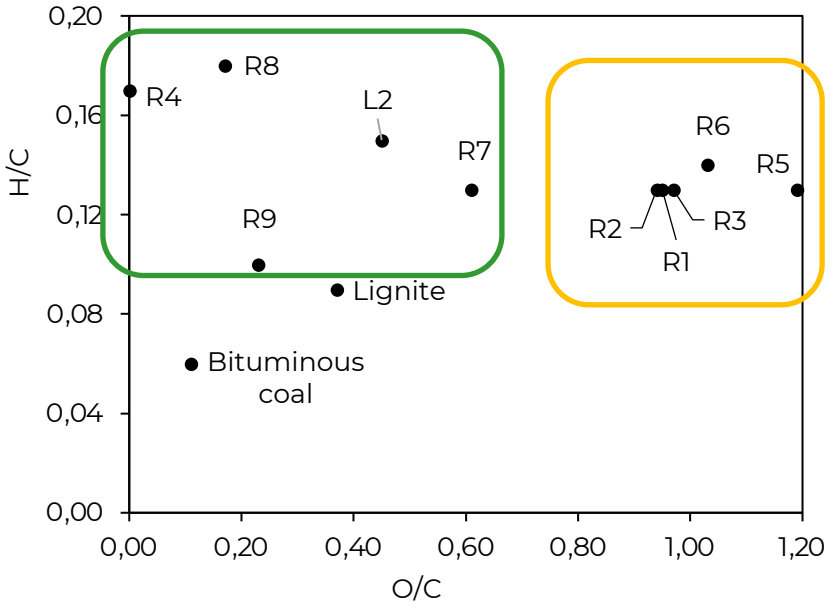
R6
Mixed
packaging

R7
Plastics, SRF

R8
Plastics,
SRF

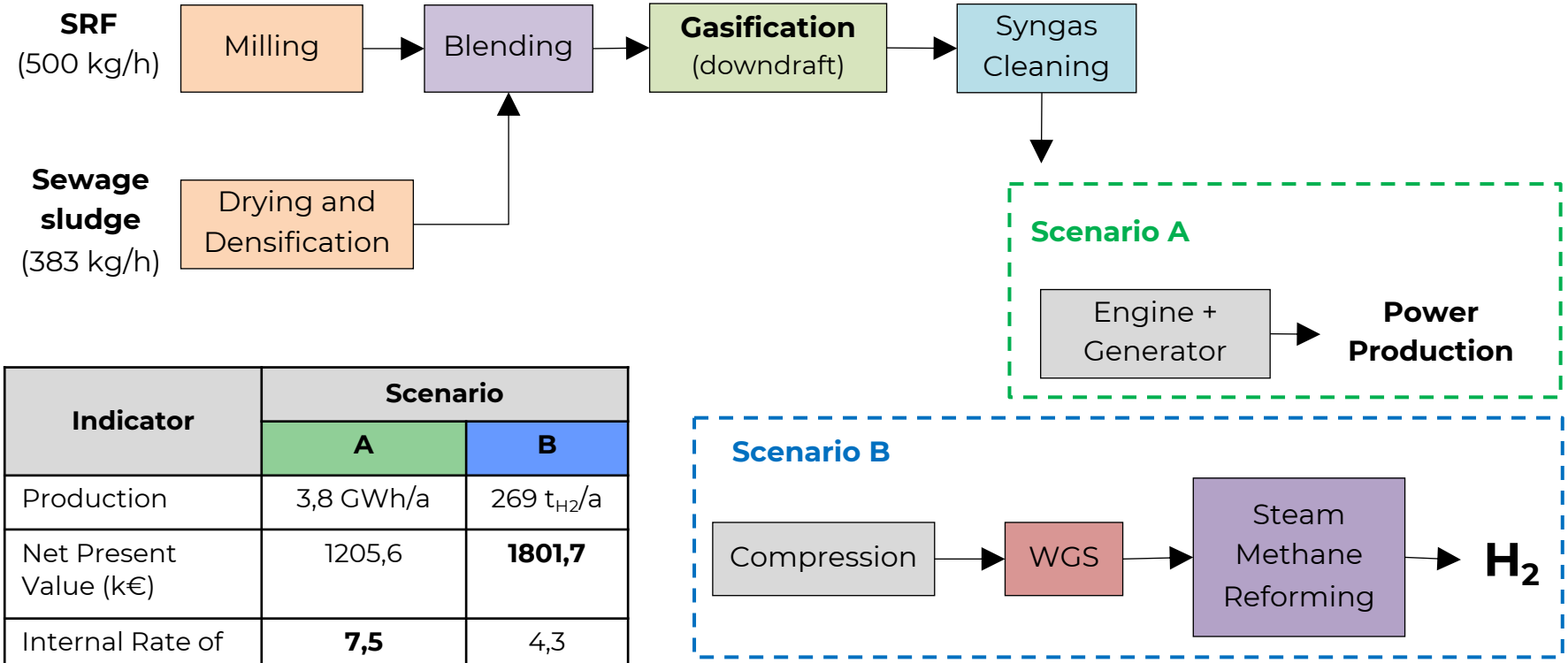
R9
Insulation
materials

L2
Sewage
sludge



SRF – C&Dwaste + S. Sludge

O. Alves et al.



Indicator	Scenario	
	A	B
Production	3,8 GWh/a	269 t_{H2}/a
Net Present Value (k€)	1205,6	**1801,7**
Internal Rate of Profitability (%)	**7,5**	4,3
Payback (years)	**9**	12

Refuse Derived Fuel

Municipal solid Waste

+

Sewage Sludge

- ✓ Traditional and Hydrothermal Carbonization
- ✓ Densification + Carbonization
- ✓ Chlorine washing step
- ✓ HHV additives
- ✓ Economic viability analysis

A. Longo et al.

REFUSE DERIVED FUEL

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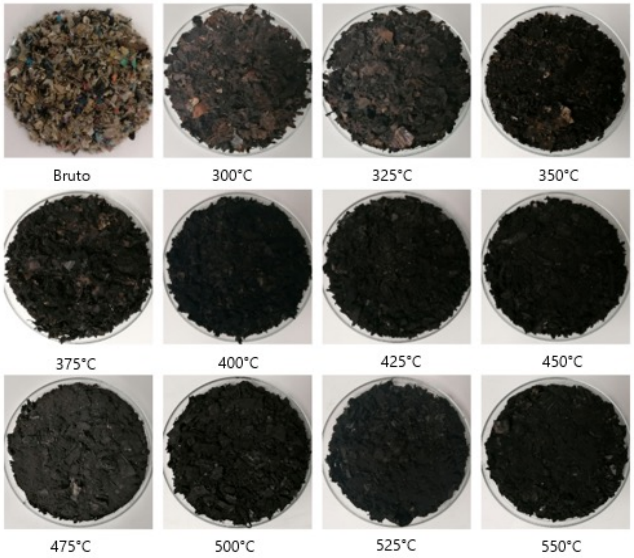
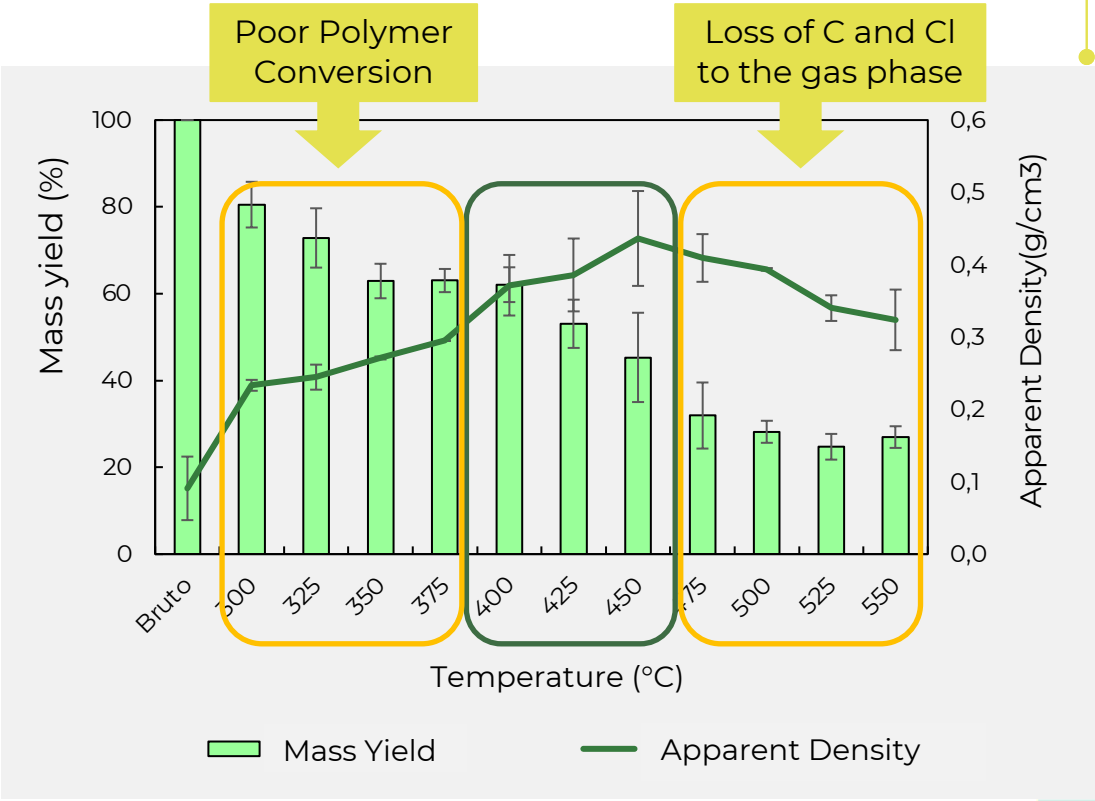
FROM MUNICIPAL SOLID WASTE



Traditional Carbonization

from 300 °C to 550 °C



REFUSE DERIVED FUEL

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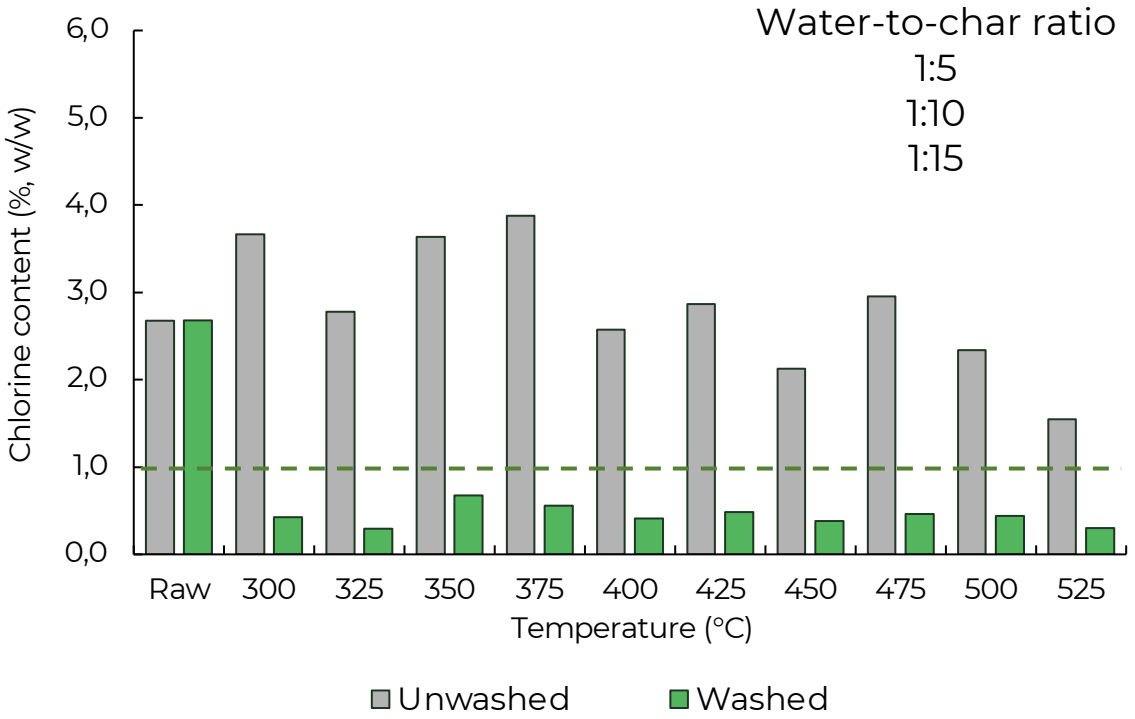
FROM MUNICIPAL SOLID WASTE

Chlorine removal by washing with hot water



REFUSE DERIVED FUEL

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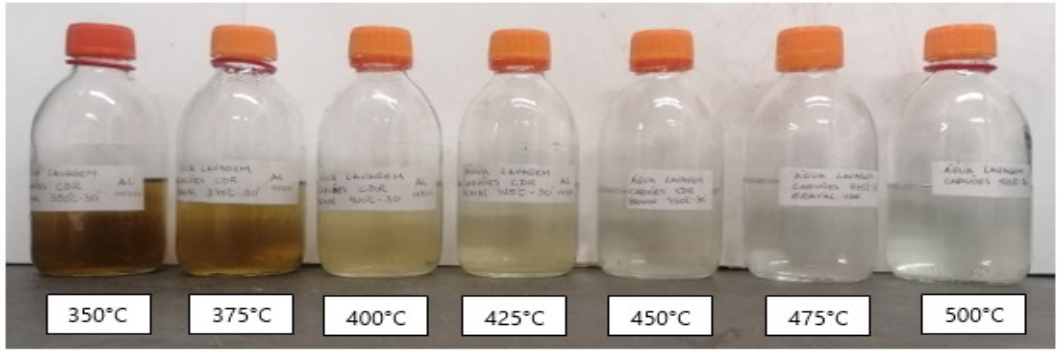
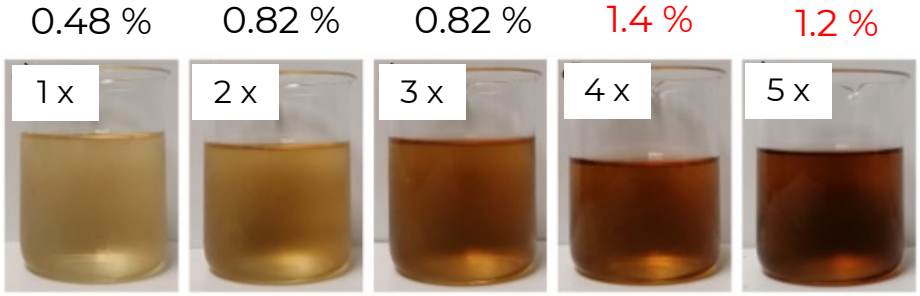
FROM MUNICIPAL SOLID WASTE

Chlorine removal by washing with hot water





Recycling the washing solution

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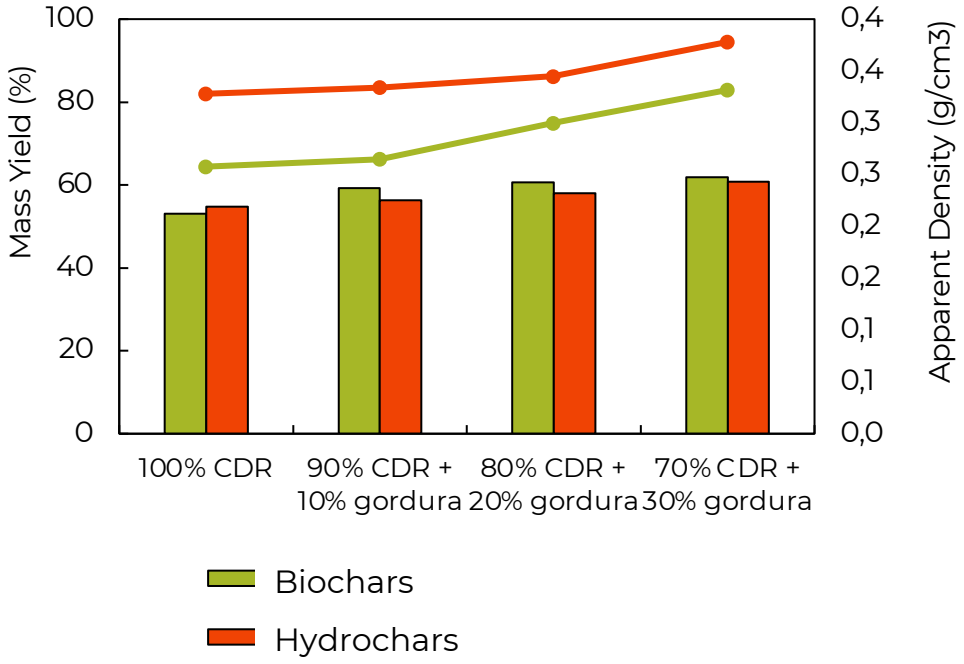
FROM MUNICIPAL SOLID WASTE



HHV variation

for waste animal fat

incorporation of 0% to 30%

Biochars: 23.5 to 26.4 MJ/kg

Hydrochars: 24.1 to 32.9 MJ/kg

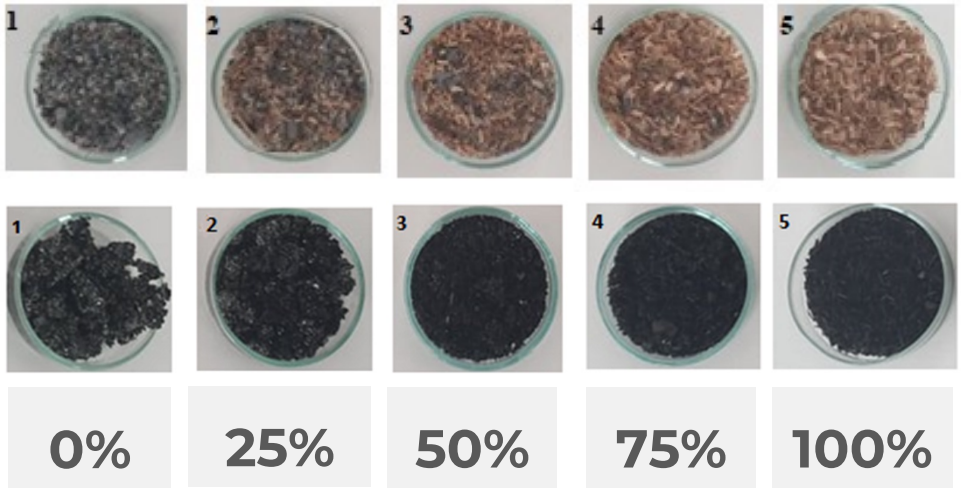
E-waste (electric cables)

- Carbonization from 300°C to 400°C
- Washing to remove chlorine
- Thermal gasification
- Mortar incorporation

R. Panizio et al.

E-waste (electric cables)

R. Panizio et al.



0% 25% 50% 75% 100%

Mixing with forestry biomass wastes

Char Average LHV

18.3 MJ/kg

Gasification of
E-waste Char produced with
incorporation of
0%, 10% and 20% biomass

E-waste (electric cables)

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Gasification + Power production

Gasification + Power production + H_2

Production Expectations	Value	Unit
Syngas volume	2.8	m^3/h
Syngas LHV	6.5	MJ/kg
H_2 (syngas)	0.41	kg of H_2/kg of feed
H_2 (WGS)	0.03	kg of H2/kg of feed
Biochar	66.6	ton / year
Ashes	93	ton / year

Carbonization Temperature

Gasification Temperature

Gas Yield

CO & H_2 concentration

RDF Char from E-waste

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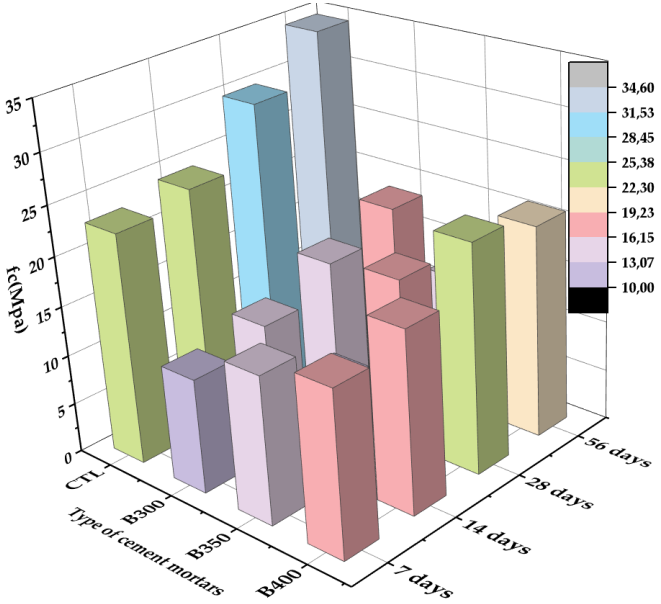
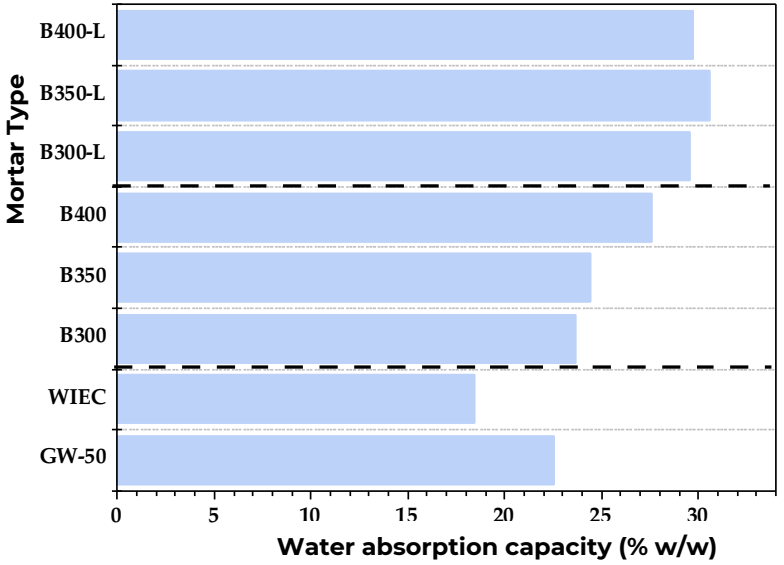
Incorporation in Cement Mortars (5% v/v)



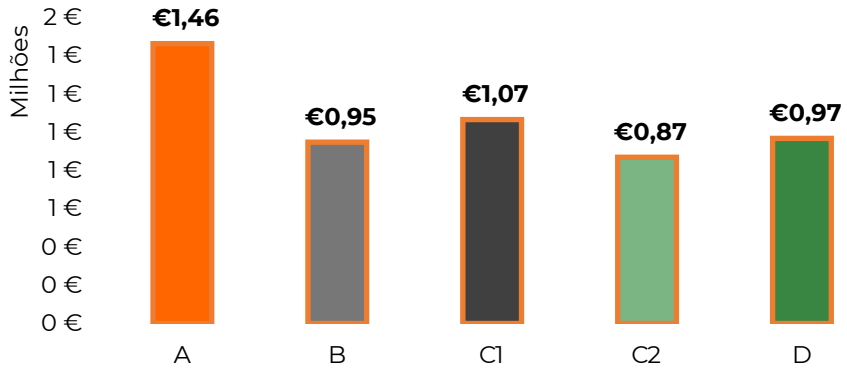


- Mortar compressive strength decreases
- Chars produced at higher temperatures yielded mortars with higher compressive strength
- Water absorption capacity was improved by char incorporation
- Moisture regulation in indoor environments

RDF + OLIVE BAGASSSE

	WASTE MANAGEMENT SCENARIOS
A	CDR Landfill Deposition
B	CDR Valorization as Fuel to Cement Production
C.1	CDR Carbonization + Landfill Deposition
C.2	CDR + Olive Bagasse Co-gasification
D	CDR + Carbonization + Gasification

Annual Costs Estimated for Different Scenarios (€/ano)



REFUSE DERIVED CHAR

+ Hydrocarbon Sludge

- Simultaneous distillation and Carbonization
- Mixing Solid Wastes, Sludges and Oils
- Water separation from persistent emulsions
- Production of biochar, bio-oils and aqueous effluents

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S. Leal

REFUSE DERIVED CHAR

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S. Leal

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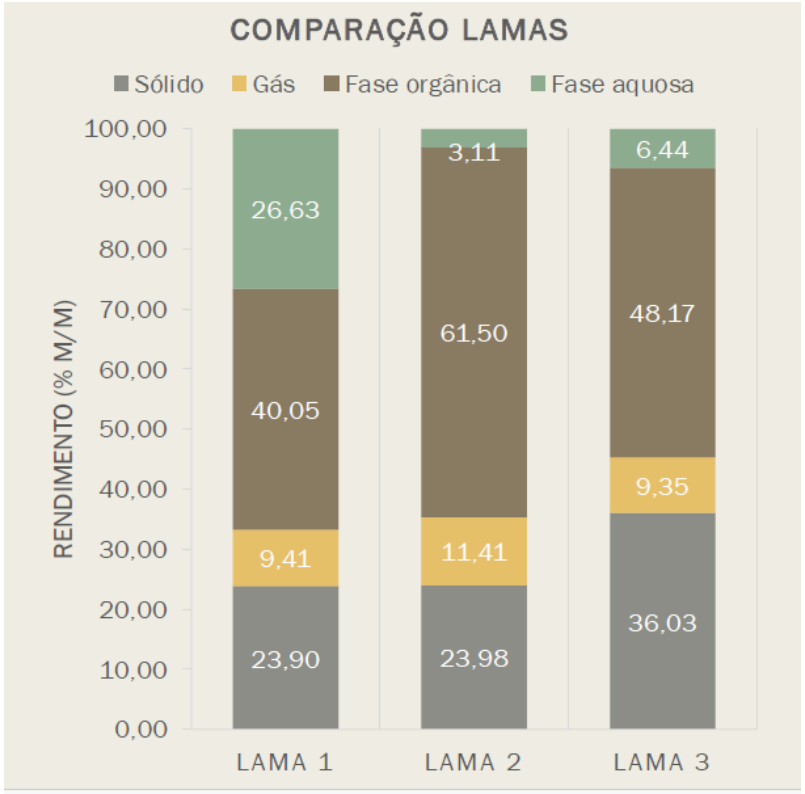
+ Hydrocarbon Sludges



9 – 35 MJ/kg

42-45 MJ/kg

< 1,2% m/m Sulfur

REFUSE DERIVED CHAR

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S. Leal

WIRE

+ Hydrocarbon Sludges

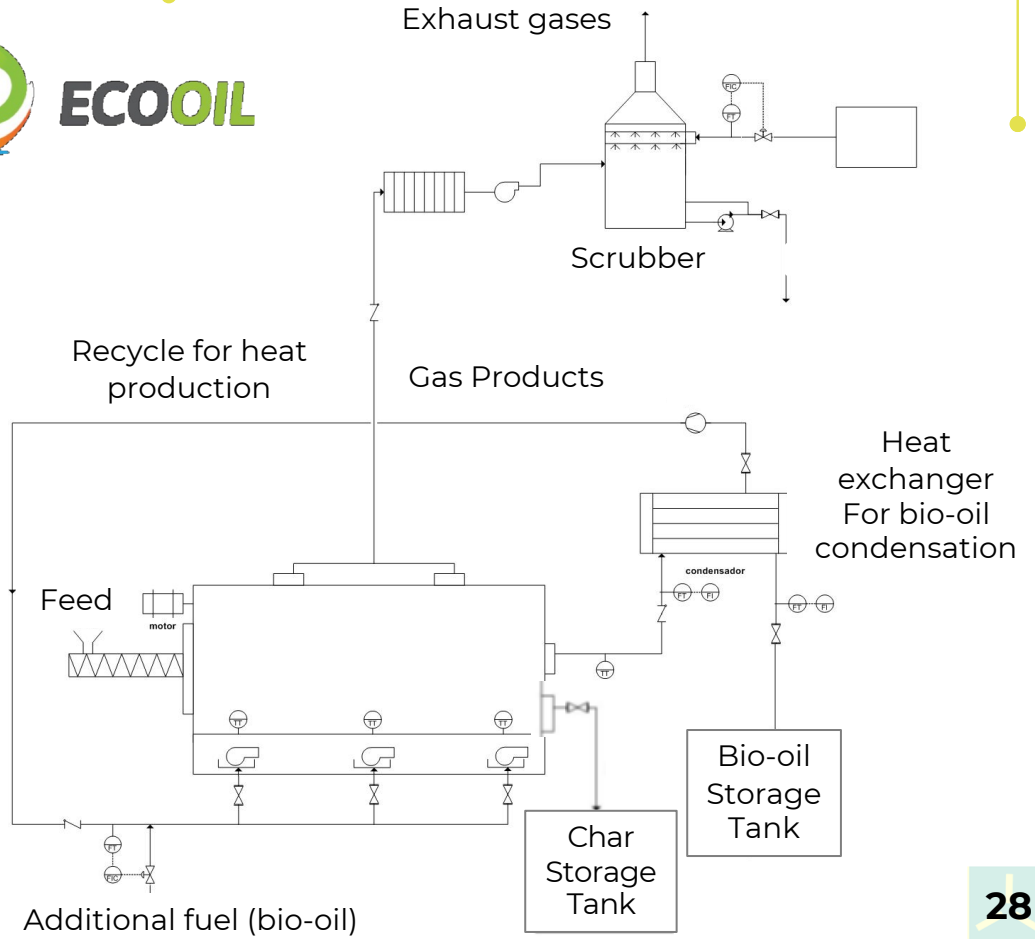
ECOOIL

Feed:

RDF char or Waste biomass
+
Hydrocarbon Sludge
+
Fuel Oil

Products:

Char
+
Bio-oil (Fuel oil)
+
Aqueous effluent



IDEAS TO RETAIN

Potential

Abundant Sources of Different Wastes

Landfill Costs

Technology

Carbonization

&

Gasification

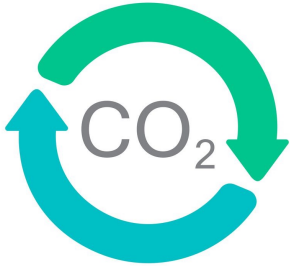
Circular Economy

Carbon & Energy

Recycling

Challenges

Waste Chars as soil amendment agents for forestry and marginal lands



Waste Chars as CO_2 adsorbents for capture and use of CO_2

Waste Chars for complex effluent treatment

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Thank you for your attention