ESTEP SPRING DISSEMINATION EVENT

5-6 JUNE 2025 KRAKOW (POLAND)

Turning biowaste into **steel-grade biocoal** to decarbonize the steelmaking process

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Head of Unit, RE-CORD

ESTEP

Bio RECAST

TRANSinter

H2steel

HOTEL ★★★★ GALAXY JORDAN GROUP

Łukasiewicz GIT

1st Challenge: Decarbonizing the EU steel sector

136 Mt/y
Crude steel produced

56 Mt/y
fossil coal consumed

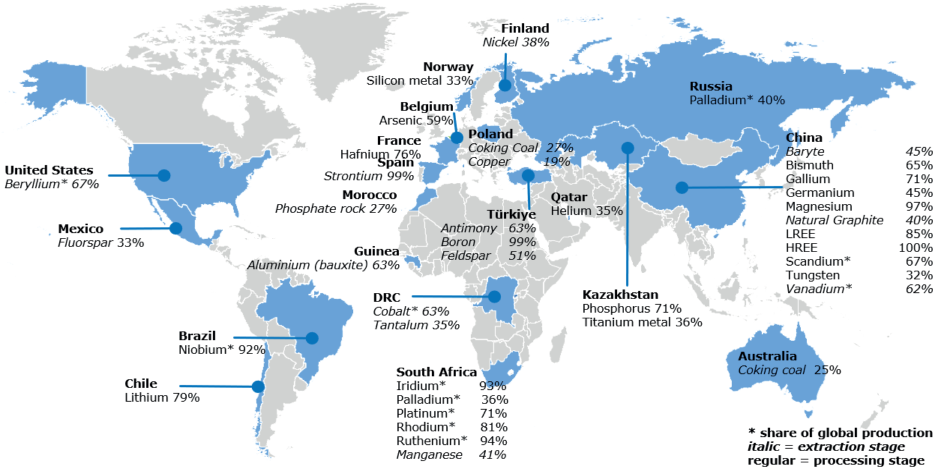
183 Mt/y of CO_2 emitted[1]

(5% of EU GHG Emissions)

EU ETS regulation – “Polluters pay” principle

[1]EU JRC Technical report – Greenhouse gas intensities of the EU steel industry and its trading partners, 2022

2nd Challenge: waste recycling



Source: "European Commission, Study on the Critical Raw Materials for the EU 2023– Final Report"

EU Critical Raw Materials Act

at least 15% of the EU's annual consumption for recycling

Sludge
11 Mil dt/y

OFMSW
40 Mil dry t/y

Objectives

Main goal

Use biogenic residues to produce biocoal for steel sector

Challenge

Waste streams contains not only in carbon, but also in inorganic contaminants not extracted by conventional processes

Proposed solution

Integrated process based on thermochemical treatment and chemical leaching

RFCS PROJECT- BIORECAST

BioRECAST

“BIObased REsidues Conversion to Advanced fuels for sustainable STeel production”.

RFCS funded project

11/2023 – 04/2027

Funded by
the European Union

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POLITECNICO MILANO 1863 DIPARTIMENTO DI MECCANICA

RE·CORD

RINA

ACCIAIERIE DI CALVISANO

HTT

WIP RENEWABLE ENERGIES

sidenor

TRANSINTER PROJECT

TRANSinter

“Valorisation of the sinter plants to support the transition towards Direct Reduction route”.

RFCS funded project

07/2023 – 12/2026

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H2STEEL PROJECT

H2STEEL

“Green H2 and circular bio-coal from biowaste for cost-competitive sustainable Steel”

EIC funded project
10/2022 – 09/2025

Politecnico di Torino
Department of Energy “G.Ferraris”

RE·CORD

Imperial College London

ArcelorMittal

Universiteit Leiden
Institute of Environmental Sciences

I3P Incubatore Politecnico di Torino

contactica innovation

Funded by the European Union

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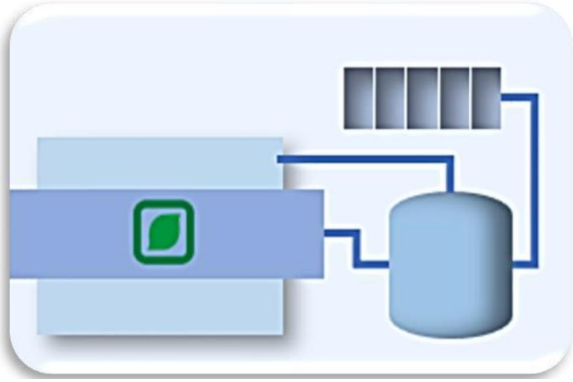
CHARLENE: Selective recovery process

Sludge,
biowaste



Charlene

- $P_2O_5 > 15$ %
- $CaO + K_2O > 20$ %
- Zn < 1500 ppm
- Pb < 120 ppm

Inorganic fertilizer

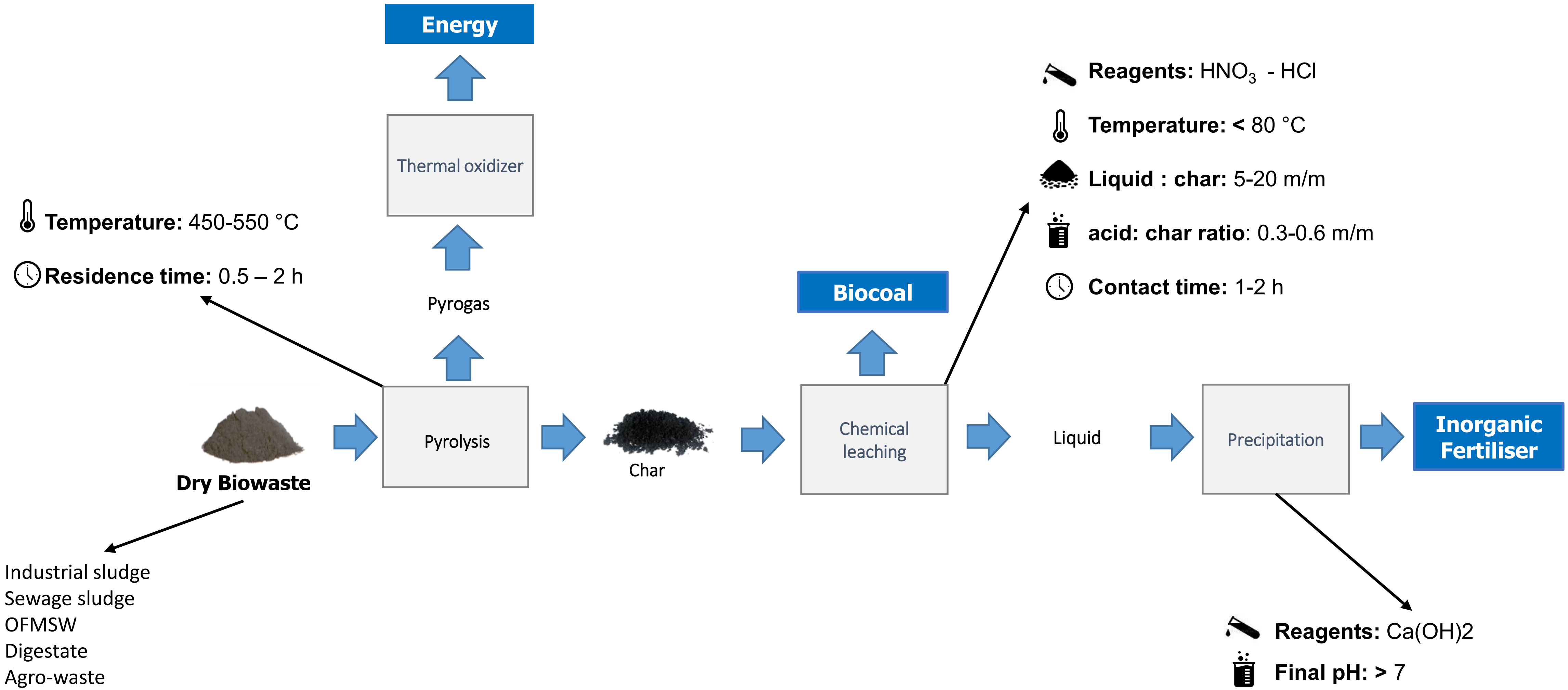
- ❖ **Direct soil use**
- ❖ **Liquid fertilisers production**

Biocoal

- C > 80% daf
- Volatile: < 20 % db
- Ash: 10-35 % db
- P: < 0.1 %
- HHV: > 25 MJ/kg

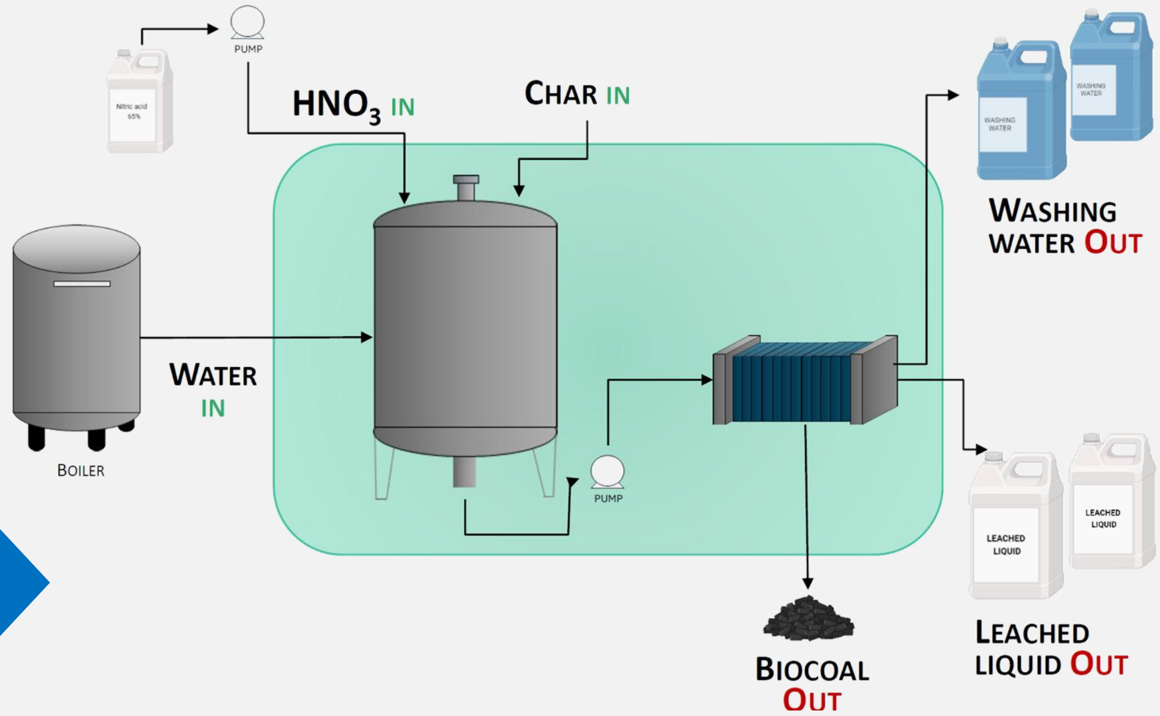
- ❖ **Steel Sector**
- ❖ **Metallurgy**

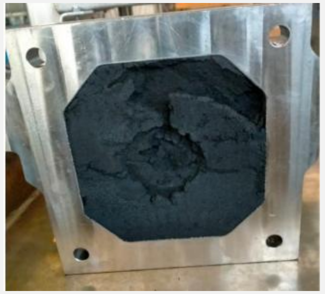
CHARLENE: Selective recovery solution



Biocoal production at pilot scale

METHODOLOGY AND PILOT PLANTS





CHARACTERIZATION OF WASTE STREAMS


SEWAGE SLUDGE

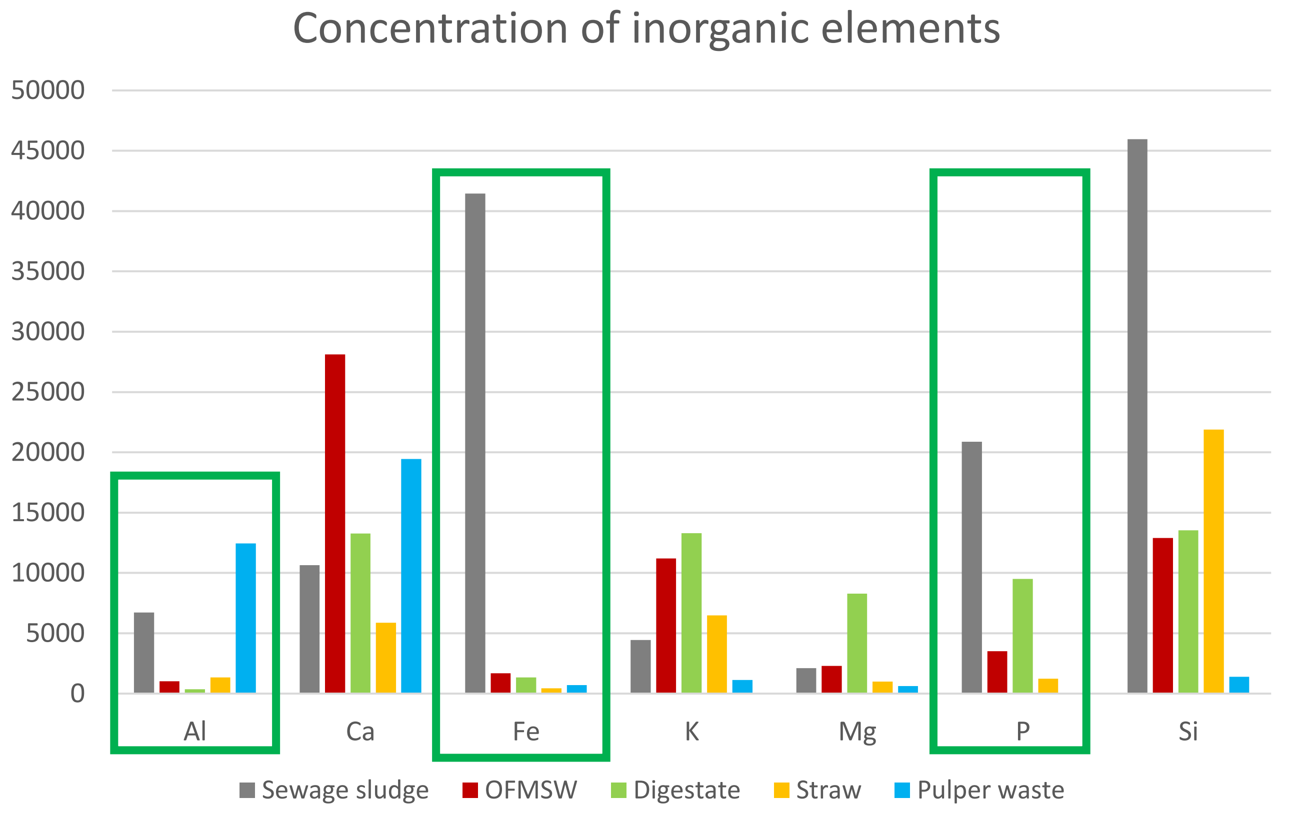

OFMSW


DIGESTATE

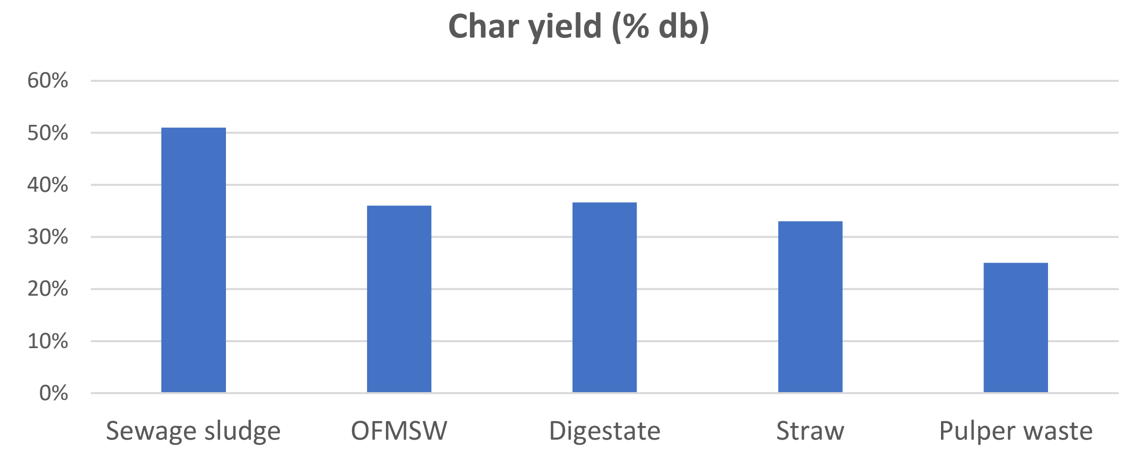

STRAW


PULPER WASTE

Parameter	Sewage sludge	OFMSW	Digestate	Straw	Pulper waste
Ash	27.7%	14.4%	13.8%	8.6%	7.8%
Volatiles	59.2%	71.4%	64.7%	72.7%	82.9%
C	38.0%	44.0%	45.3%	45.3%	63.4%
H	5.3%	5.8%	5.7%	5.8%	8.9%
N	6.6%	1.8%	1.5%	0.9%	0.2%
S	1.0%	0.1%	0.5%	0.1%	0.1%



COMPOSITION OF RAW CHAR AFTER SLOW PYROLYSIS



Parameter	Unit	S. Sludge char	OFMSW char	Digestate char	Straw char	Pulper char
Ash	% db	58.4	45.7	35.9	28.5	34.3
Volatiles	% db	17.4	18.1	12	12.2	17.1
C	% db	31.7	45.9	56.8	64.3	59.1
H	% db	1.38	1.3	1.6	2	1.5
N	% db	4.8	2.5	1.5	1.3	0.1
S	% db	0.26	0.2	0.3	0.1	0
Cl	% db	0.76	1.9	0.5	0.5	2.4
HHV	MJ/kg	12.7	16.4	20.9	24.4	23.7

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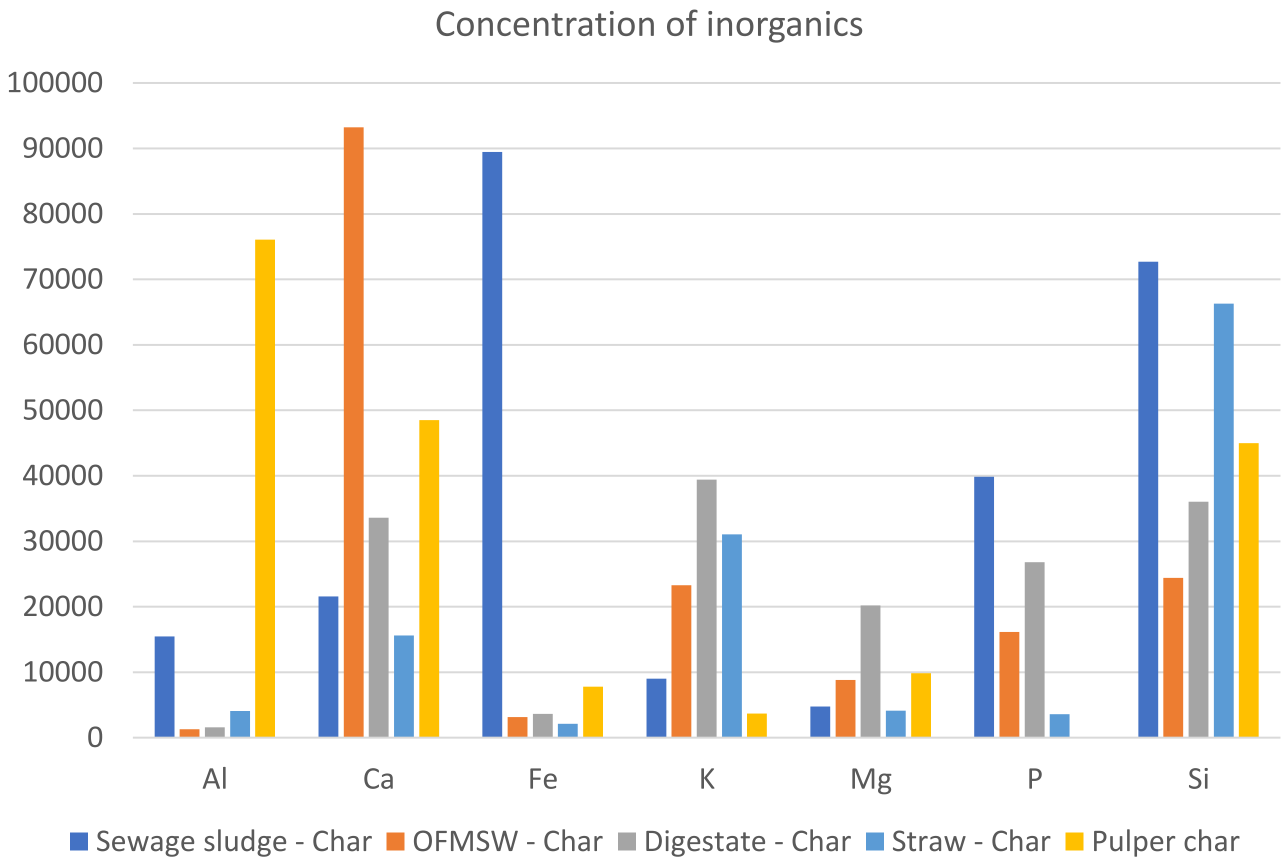
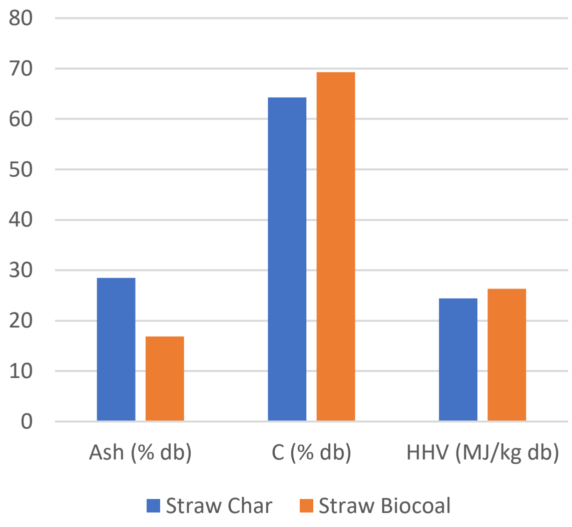
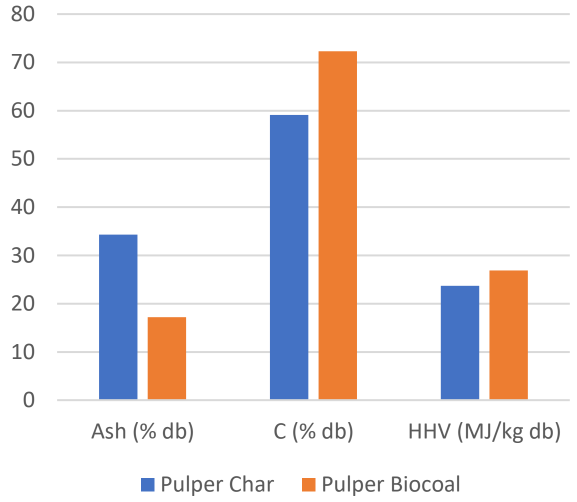


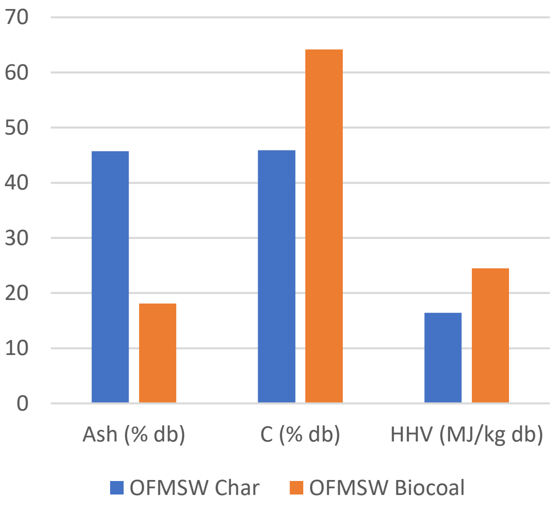
COMPOSITION OF OBTAINED BIOCOALS

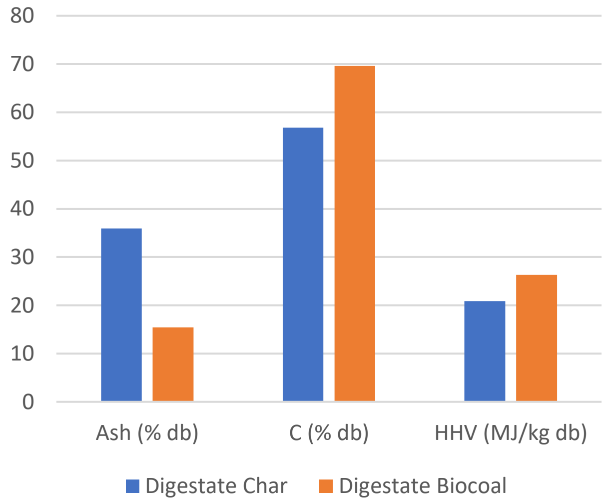
- C content increase of up to 60%
- P reduced to < 0.3%
- Cl reduced to < 0.4%

Parameter	BIOCOAL S. Sludge	BIOCOAL OFMSW	BIOCOAL Digestate	BIOCOAL Straw	Biocoal Pulper
Volatiles	19.5	20.1	18.7	16.9	17.2
Ashes	37.6	18.1	15.4	16.9	14.8
C	**42.0**	**64.2**	**69.6**	**69.3**	**72.3**
H	1.5	2.0	1.9	2	1.5
N	6.6	4.7	2.7	2	0.1
S	0.1	0.2	0.4	0.1	0
Cl	0.3	0.1	0.01	0.02	0.7
HHV	16.3	24.5	26.3	26.3	26.9









Biocoal compactation for sintering process

BIOCOAL PREPARATION AND TESTING

1. > 50 kg biocoal powder dry mixing with starch (3-4% db)

2. Hot water added (> 70°C)

3. Pelletization performed in a 30 kg/h unit

4. Wet pellet dried in oven at 105°C overnight

RESULTS

- ❖ Water resistant
- ❖ High durability
- ❖ No dust formation during storage

Biocoal use as carburizer

BIOCOAL CARBURIZATION TEST

Biocoal from
- Sewage sludge
- Manure digestate
- Straw
- OFMSW

Pure Iron

Biocoal origin	Mass Fe (g)	Carburazing C (%)	C fix in biocoal (%)	C stoichiometric (g) to add	Biocoal to add (g)	Added biocoal (30% more)
OFMSW	150	3	63.4	4.5	7.10	10.14
Digestate	150	3	64.2	4.5	7.01	10.01
Straw	150	3	65	4.5	6.92	9.89
Sludge	150	3	42	4.5	10.71	15.31

RESULTS OF CARBURIZATION TEST

Melting test N.	C (%)	S (%)	N (%)	O (%)	Added biocoal (g)	Pure Fe (g)	C in the hot metal (%)
1 (Biocoal OFMSW)	5.17	0.013	0.0046	0.011	17	150.25	69.2
2 (Digestate)	3.81	0.022	0.0059	0.0055	20.02	150.05	41.4
3 (Straw)	5.12	0.0085	0.0023	0.0068	20.15	150.45	55.4
4 (Sludge)	2.05	0.018	0.0021	0.0076	20	150.5	35.1

Biocoal use as catalyst in catalytic methane pyrolysis

H2STEEL in a Nutshell

Catalyst:

Biocoal obtained from sludge, digestate, and other biowaste

Products:

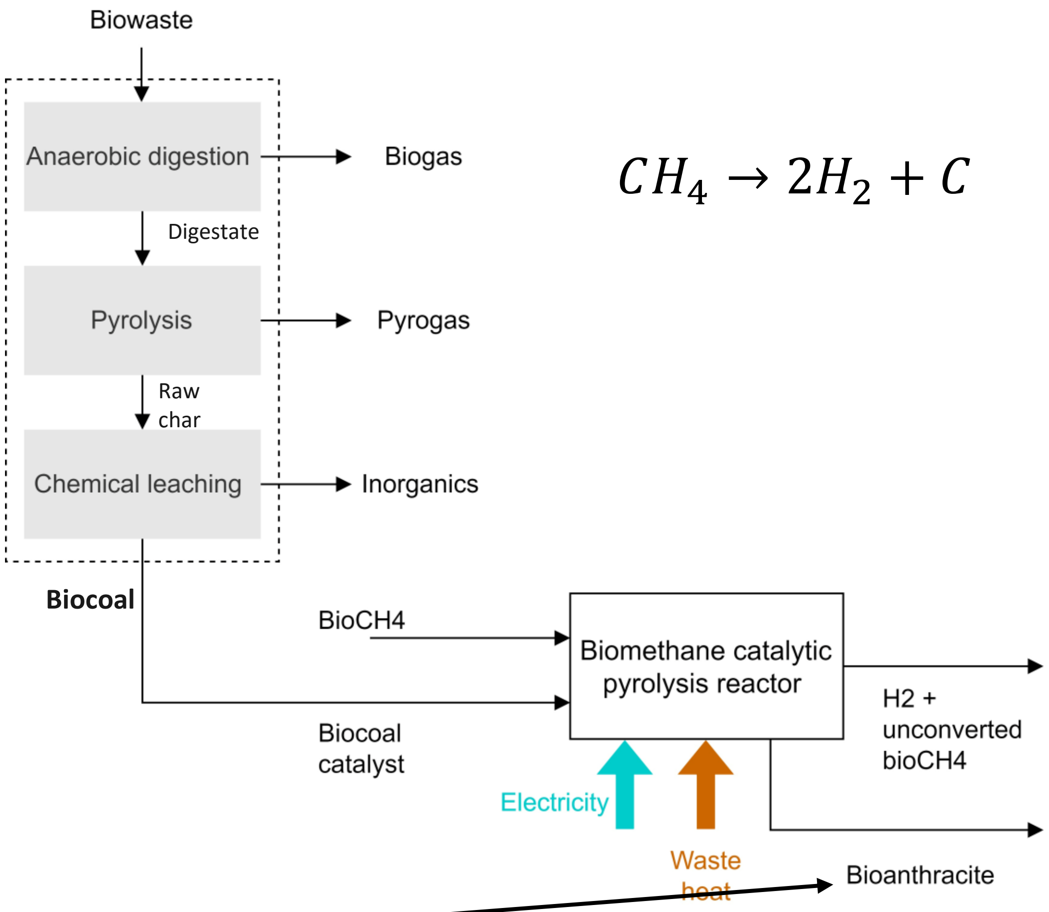
- Hydrogen
- Upgraded Bio-coal (C-enriched)

Targeted sector: Steel sector

Hydrogen
in DRI process

Bioanthracite
In EAF, Sintering, BFs

Conversion technology: catalytic methane pyrolysis process



$$CH_4 \rightarrow 2H_2 + C$$

After catalytic methane pyrolysis spent catalyst is a low volatile, C-enriched biocoal

H2STEEL: from lab tests to POC

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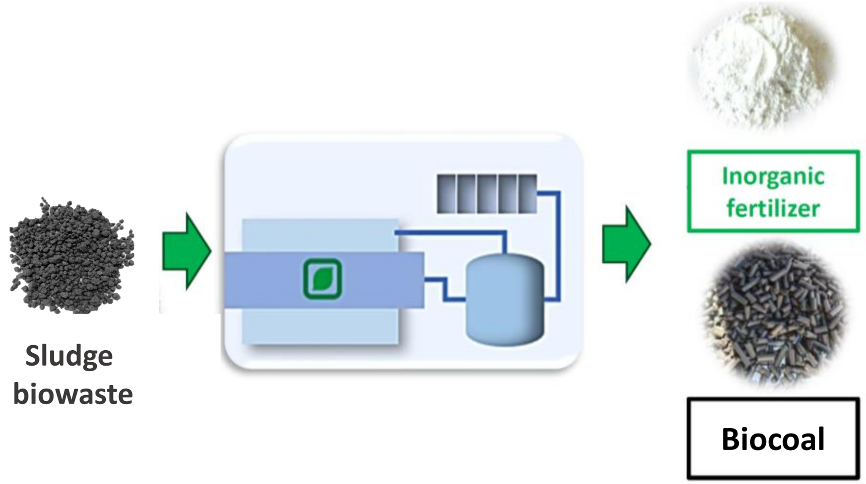
Continuous biocoal based catalytic methane pyrolysis unit

CONCLUSIONS

- A 95-99% P extraction efficiency is obtained
- Sludge ash is extraction can be by up to 90%
- Biocoal has reduced reactivity at high Temperatures
- Silica is not removed by the process
- Calorific value is increased from 15-20 to 24-27 MJ/kg
- Leaching process remove PAH, Cl, and > 50% ash from char
- Nutrients recovery improve the economic feasibility and sustainability



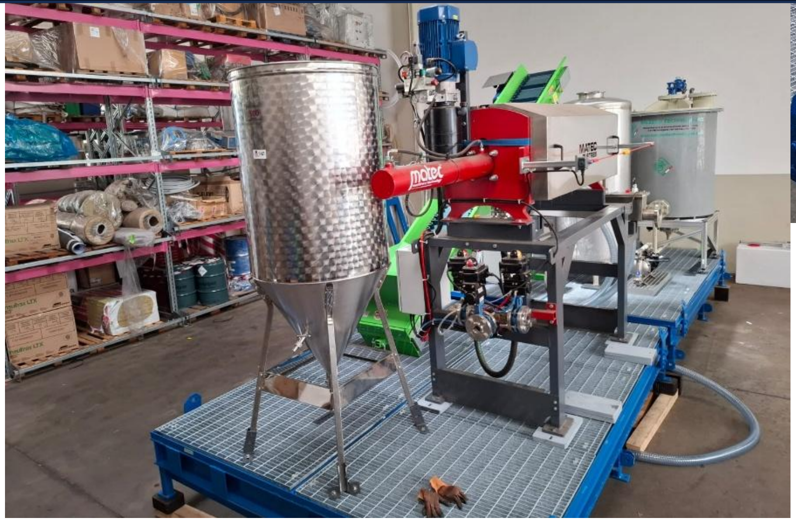
FOLLOW UP

3 tons char production in 100 kg/h rotary kiln

PYROK rotary kiln

> 1.3 tons biocoal production in a 500 lt/h leaching unit

ADELE leaching unit



Thanks for the attention!

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