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Hydrochar and postprocessing water as potential energy sources from the hydrothermal co-carbonization of waste

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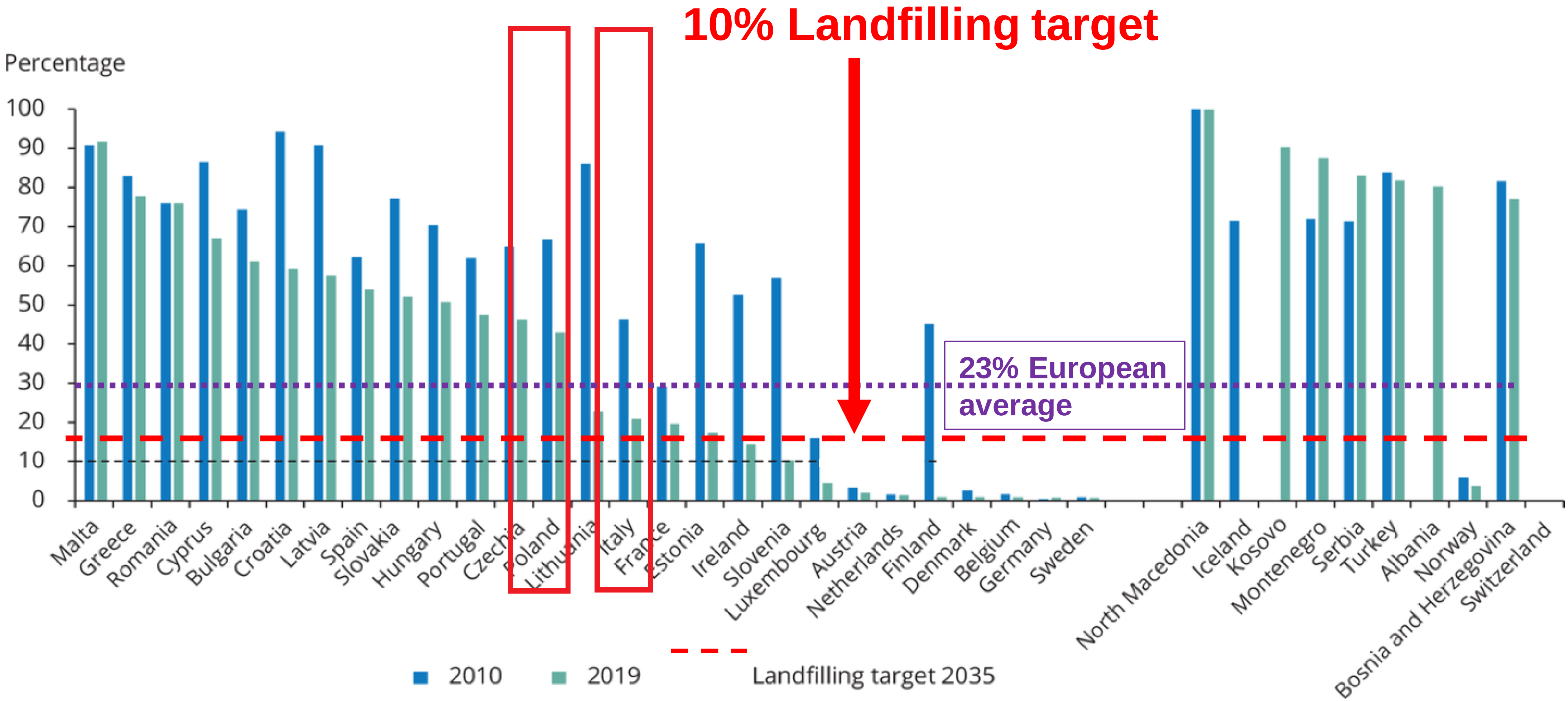
Naples, 5th June 2022

Outline

- Motivation
- Experience
- Materials
- Methods
- Results
- Conclusions

Motivation

Municipal waste landfill rates in Europe by country



https://www.eea.europa.eu/data-and-maps/indicators/diversion-from-landfill/assessment

WET ORGANIC WASTE

UNFAVOURABLE PROPERTIES

- High content of moisture
- Insufficient dewaterability
- Organic content - biodegradable elements
- Bacteria, viruses, pathogens
- Pharmaceuticals
- Microplastics
- Odorous
- High volume of waste
- Frequently disposed in landfill

PRETREATMENT

HYDROTHERMAL CARBONIZATION PROCESS

180-350 °C, autogenous pressure

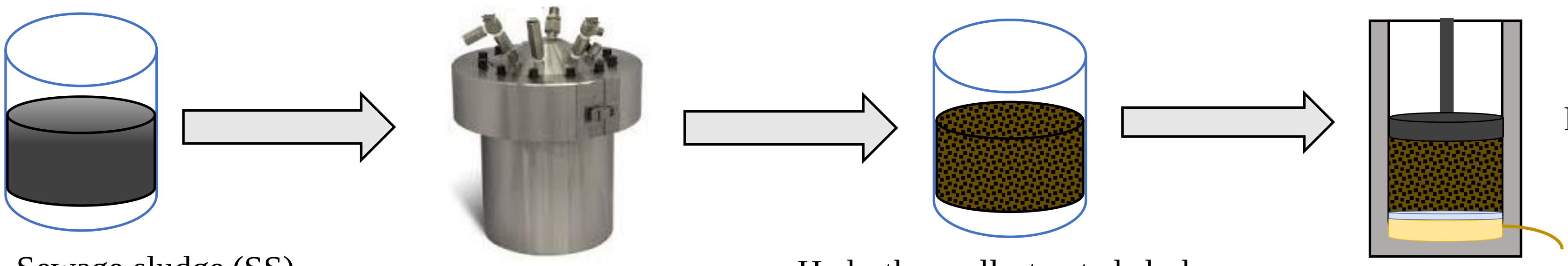
aqueous environment

IMPROVED PROPERTIES

- Dewaterability
- Disinfection
- Reduction of waste volume
- Biodegradability
- Microplastic and pharmaceutical removal

Experience

HYDROTHERMAL CO-CARBONIZATION



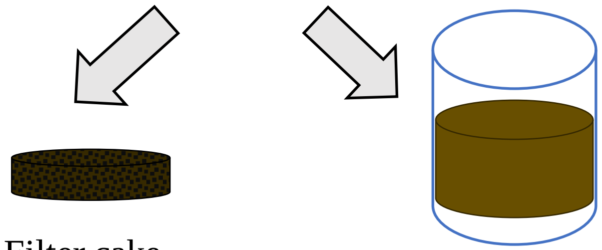
Pressure filtration, 4 bar

Sewage sludge (SS)

Sewage sludge + additives

200°C, 2h, 150 rpm

Hydrothermally treated sludge (HTC)



Filter cake (hydrochar)

Filtrate

Thermal utilisation

Waste disposal

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ELSEVIER

Hydrothermal co-carbonization of sewage sludge and fuel additives: Combustion performance of hydrochar

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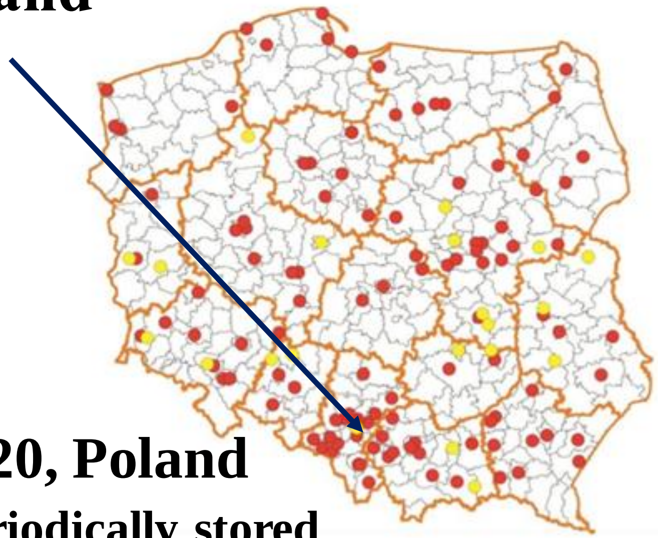
Results:

1. **Dewaterability improved by HT co-C**
2. **Hydrochar properties improved by additives**
3. **Drying cost decreased spectacularly!**

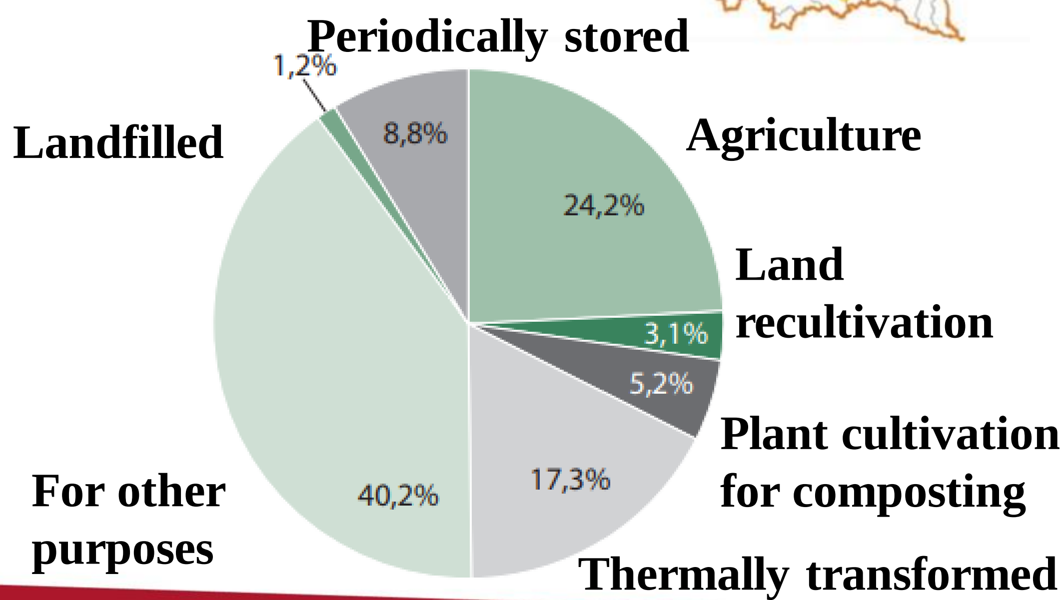
MATERIALS

Wastewater Treatment Plant in Żory, Poland



SEWAGE SLUDGE

DISPOSAL 2020, Poland



Mechanical-Biological Treatment Plant in Florence, Italy

MIXED SOLID WASTE

↓

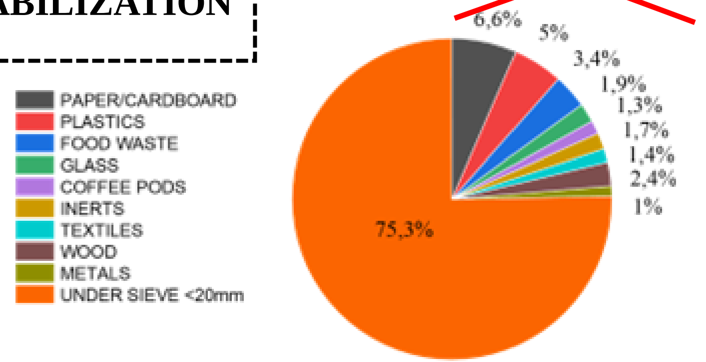
SHREDDING/ SIEVING (60 mm)

← **UNDER SIEVE FRACTION**

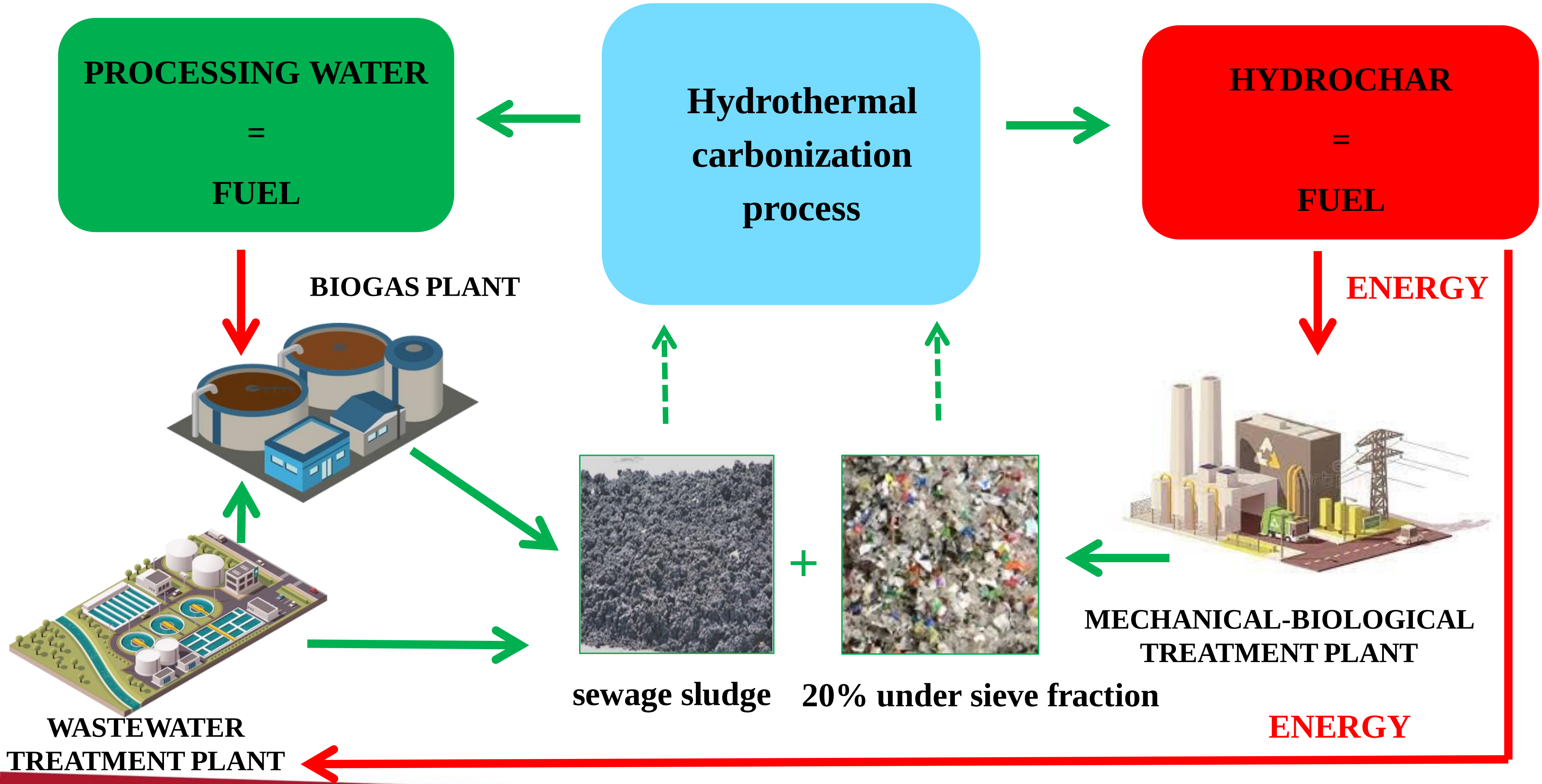
Over sieve Fraction → **ENERGY AND METAL RECOVERY**

↓

AEROBIC BIO-STABILIZATION → ~~LANDFILL~~

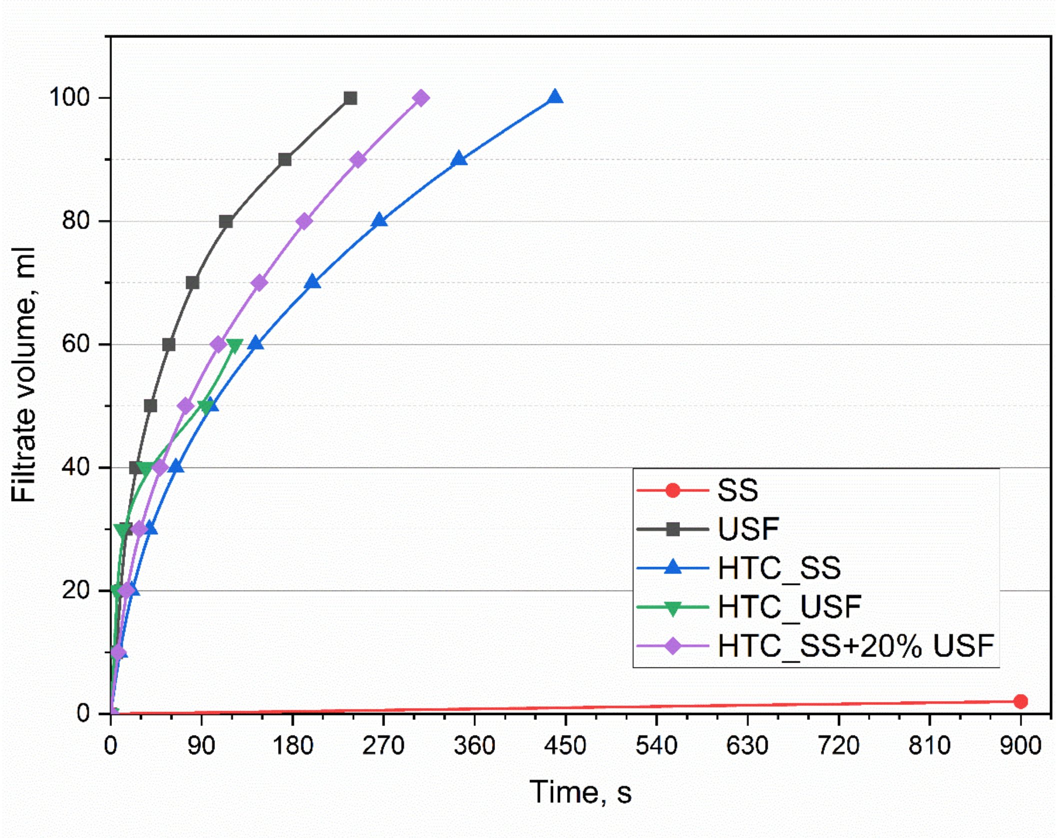


PRETREATMENT FOR WET ORGANIC WASTE

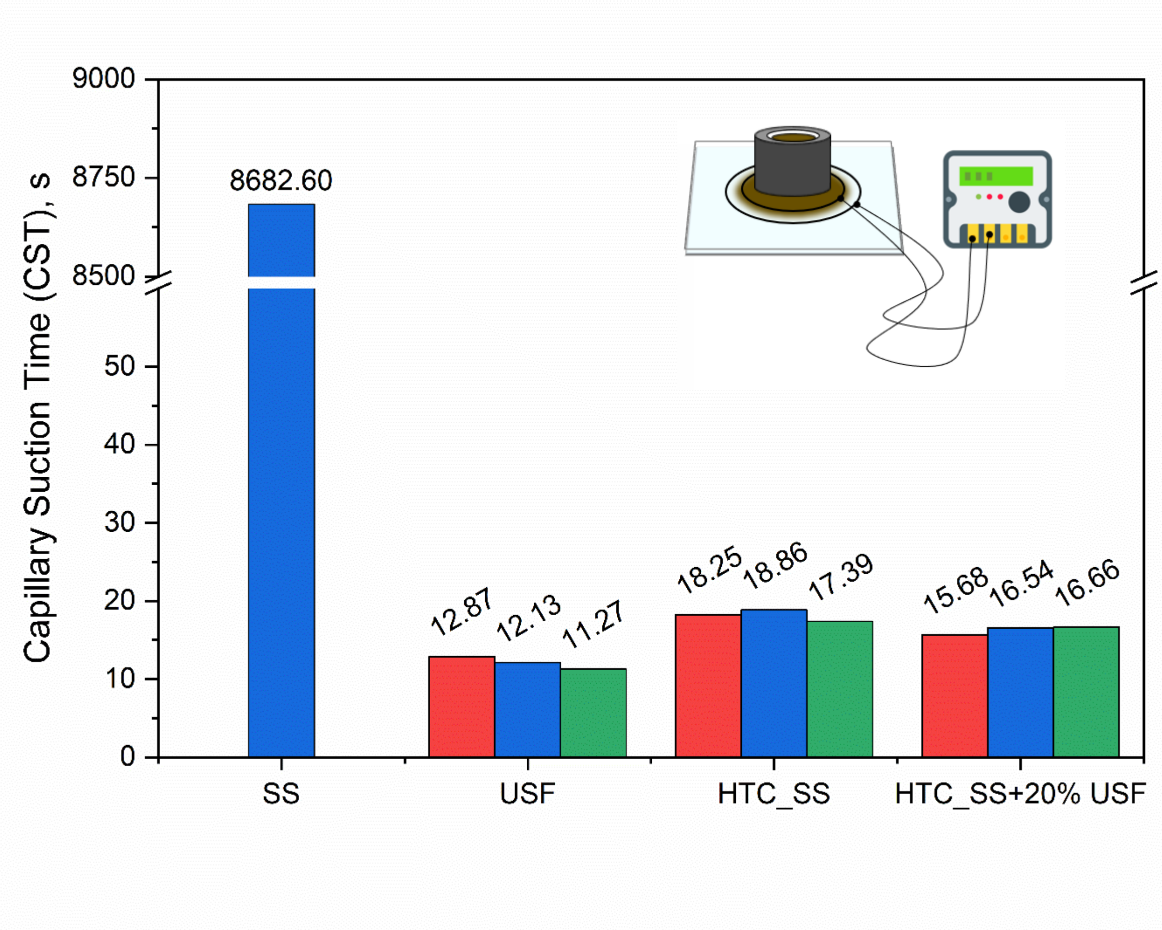


DEWATERABILITY PERFORMANCE

FILTRATION TEST



CAPILLARY SUCTION TIME



ANALYTICAL METHODS FOR SOLID SAMPLES

Type of analysis	Norm/method	Instrument
Ultimate analysis (Carbon, Hydrogen, Nitrogen, Sulphur content)	PKN-ISO/TS 12902:2007	Elemental Analyser Truespec CHNS 628 Leco, USA
Moisture content	EN ISO 18134-2:2017	Universal oven UN75plus, Memmert, Germany
Ash content	EN ISO 18122:2015	Muffle furnace FCF 22SHM CZYLOK Ltd., Poland
Volatile matter content	EN ISO 18123:2016	Muffle furnace FCF 22SHM CZYLOK Ltd., Poland
Higher heating value	PN-ISO 1928:2002	Leco AC500 isoperibolic calorimeter
Thermal analysis (TGA)	-	Mettler Toledo analyzer STAR W 16.10

CHEMICAL AND PHYSICAL PROPERTIES, db

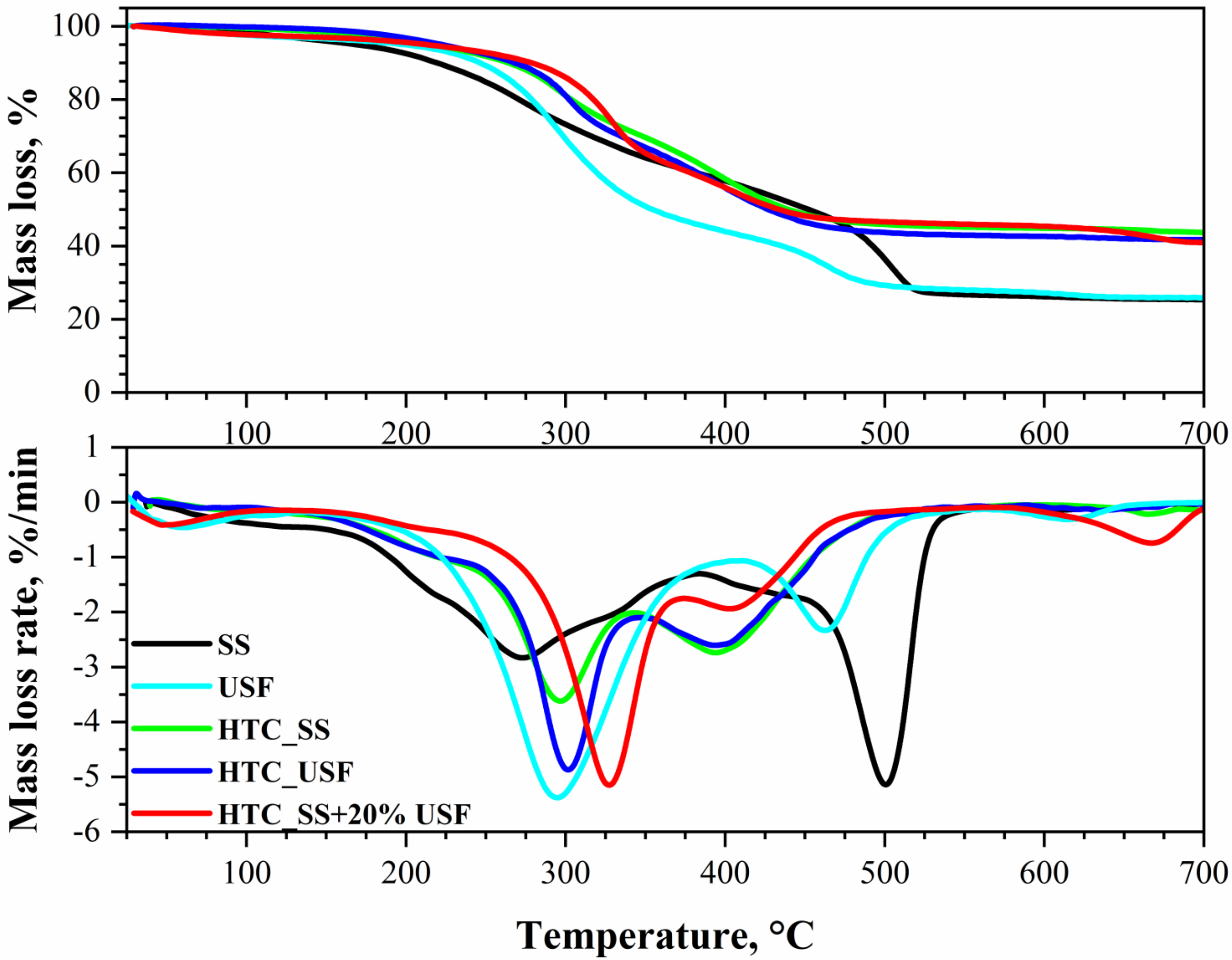
	SS	USF	HTC_SS	HTC_USF	HTC_SS+20%USF
Ultimate analysis					
C, %	36.90	43.30	35.30	44.50	37.10
H, %	5.50	6.22	4.69	5.83	4.81
N, %	5.99	1.23	3.36	0.90	3.15
S, %	1.57	-	1.23	-	1.07
O, %	22.00	18.65	10.81	17.52	12.85
Proximate analysis					
FC, %	10.54	6.63	9.21	10.35	10.27
VM, %	61.42	62.77	46.18	58.40	48.72
Ash, %	28.04	30.60	44.61	31.25	41.02
Mass loss, %			40	33	-
HHV, MJ	15.78	17.29	15.29	17.71	15.70

C – carbon, H – hydrogen, N – nitrogen, S – sulphur, O – oxygen
FC - fixed carbon, VM - volatile matter, HHV – high heating value

Distribution of products for HTC_SS

solid fraction, % wt.	liquid fraction, % wt.	gas and losses, % wt.
6.00	90.14	3.86

THERMAL ANALYSIS



KEY COMBUSTION PARAMETERS

Material	SS	USF	HTC_SS	HTC_USF	HTC_SS+20%USF
T_i,°C	202	247	243	288	265
T_b,°C	522	489	456	443	456
T_1, °C	273	289	296	327	302
DTG_1, %/min	2.953	5.973	3.918	5.934	5.990
DTG_{mean}, %/min	1.068	1.097	0.809	0.765	0.838
D_i, $\%/min^3 \cdot 10^{-2}$	0.0044	0.0106	0.0049	0.0075	0.0069
D_b, $\%/min^4 \cdot 10^{-5}$	8.2	22.0	9.9	17.0	14.3
S, $\%^2/(min^2 \cdot °C^3) \cdot 10^{-8}$	14.8	22.0	11.8	12.4	15.7
H_f, $\%/(min \cdot °C^2)$	845.6	880.3	1052.6	1174.9	1076.5

DTG_{mean} – mean combustion rate
DTG_1 – maximum combustion rate
$D_i = DTG_1 / (t_1 \cdot t_i)$, t_1 – corresponding time for DTG_1
t_i – ignition time; t_b – burnout time

$D_b = DTG_1 / (t_1 \cdot t_b \cdot t_{0.5})$; $t_{0.5}$ - time range of $DTG/DTG_1 = 0.5$
$S = (DTG_1 \cdot DTG_{mean}) / (T_i^2 \cdot T_b)$
$H_f = T_1 \cdot \ln(t_{0.5} / DTG_{mean})$

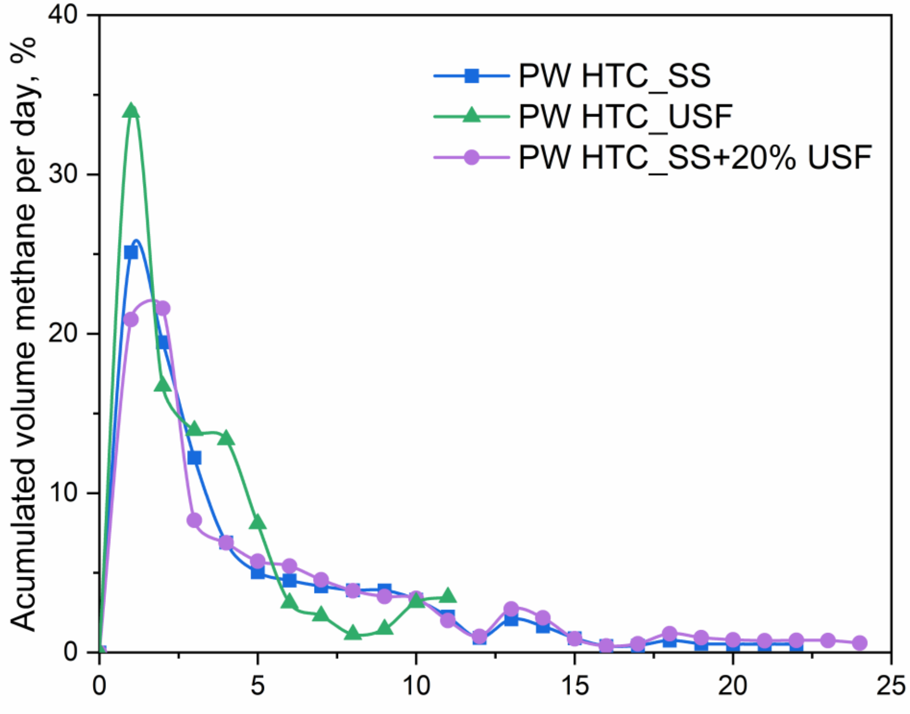
METHODS FOR LIQUID SAMPLES

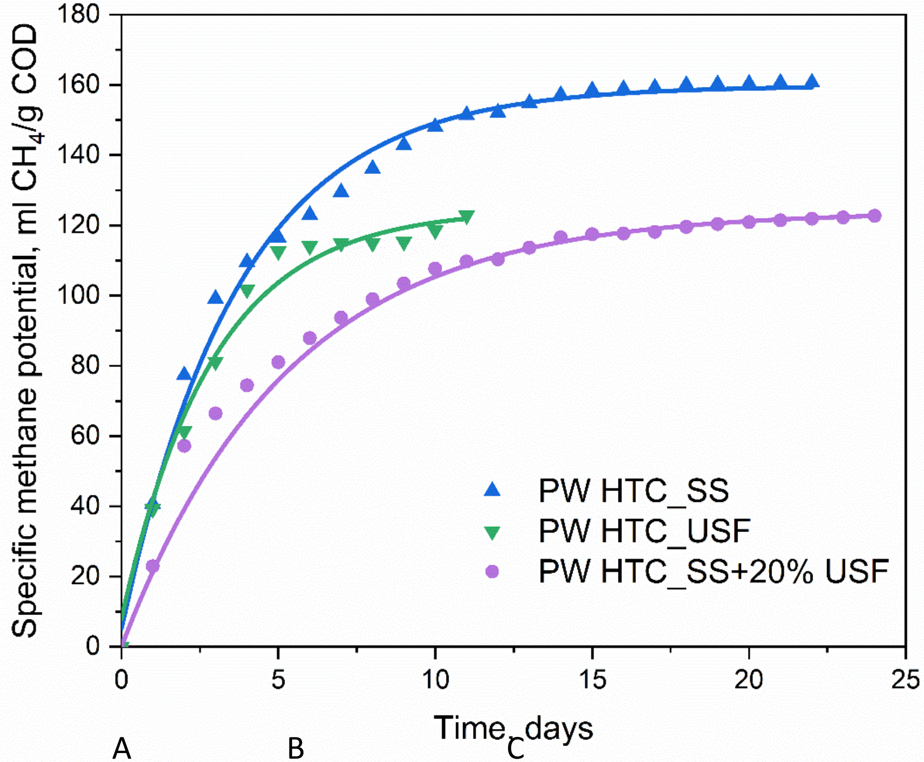
Type of analysis	Norm/method	Instrument
pH and conductivity	-	Multifunction Laboratory Meter CX-505 ELMETRON
Chemical oxygen demand	PN-ISO 6060:2006	
Elemental analysis	PKN-ISO/TS 12902:2007	Elemental Analyser CHNS 628 Leco, USA
Biomethane potential test	-	AMPTS II Bioprocess Control, Sweden

RESULTS

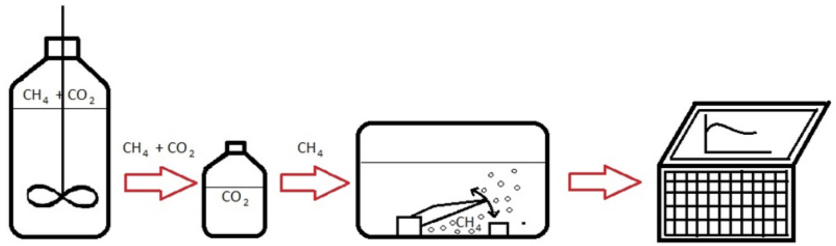
Material	HTC_SS	HTC_USF	HTC_SS+20%USF
pH	7.33	4.64	7.52
Conductivity, mS/cm	13.95	7.06	11.88
COD, mgO_2/l	46 600	32 325	46 500
Methane potential, $mlCH_4/gCOD$	160.7	122.8	122.7

METHANE POTENTIAL TEST





A B C



Automatic Methane Potential Test System Bioprocess Control

CONCLUSIONS

Hydrothermal carbonization of waste provides to:

- Significant decrease of waste amount
- Spectacular decrease of energy demand for drying process of waste
- Postprocessing water has a methane potential with short retention time (10 days)
- The addition of 20%USF to SS does not improve much hydrochar fuel properties and methane potencial of HTC

Thank you for your attention

Acknowledgements

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