Synergies for phosphorus recovery and the decarbonization of the European steel industry by valorization of residual biomass

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Background

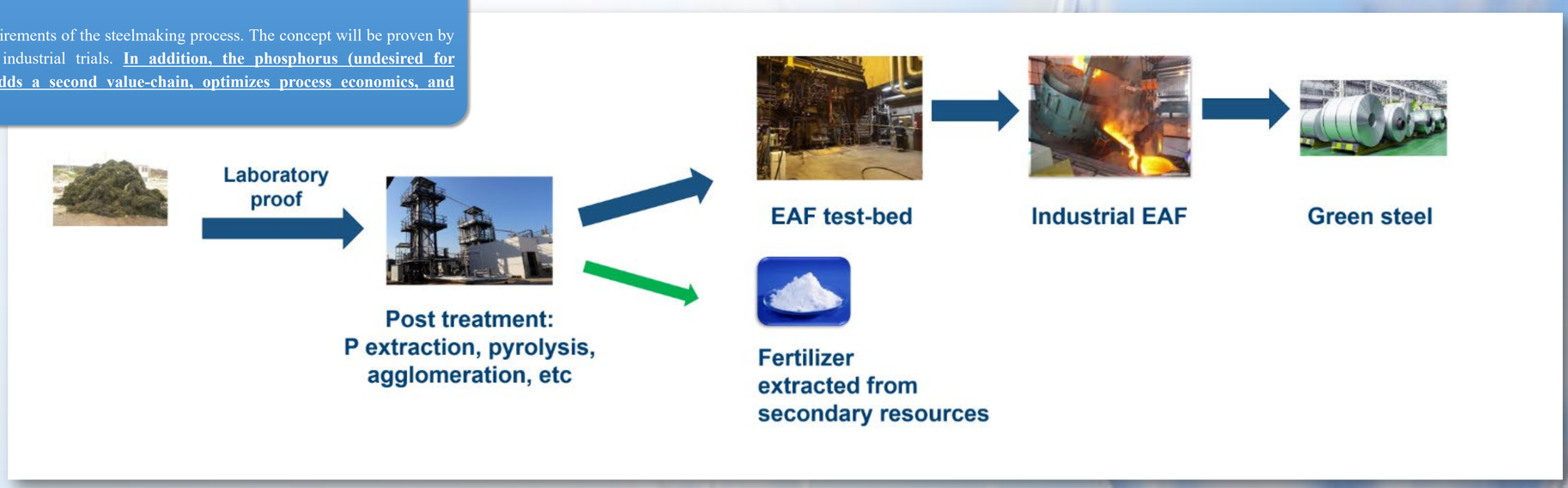
The transformation of residual biomass such as the organic fraction of municipal solid waste (OFSMW) has been identified as an alternative phosphorus resource when processed by hydrothermal carbonization (HTC) with subsequent phosphorus extraction.[1] During the HTC process, the carbon content of the biomass is concentrated mainly by chemical dehydration reactions. Under process conditions organic phosphorus is converted into inorganic phosphates that remain in the solid carbonaceous product, the hydrochar, as ash content.[2] Afterwards, mineral acids, such as nitric acid, sulfuric acid or hydrochloric acid, can be used to dissolve and extract the phosphate salts. Under suitable conditions, the ash content is reduced which improves the properties of the hydrochar as renewable solid fuel.

1. B. Oliver-Tomas, M. Hitzl, M. Owsianiak and M. Renz, Evaluation of hydrothermal carbonization in urban mining for the recovery of phosphorus from the organic fraction of municipal solid waste, *Resour Conserv Recycl*, 2019, **147**, 111–118.
2. R. Huang, C. Fang, X. Lu, R. Jiang and Y. Tang, Transformation of Phosphorus during (Hydro)thermal Treatments of Solid Biowastes: Reaction Mechanisms and

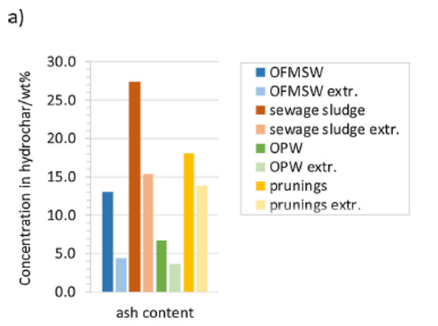
BioReSteel Concept

BioReSteel will develop a novel concept for biocarbon production suitable and optimized for the EAF steelmaking process. Instead of producing biochar from high grade and high value biomass resources (e.g., forest wood), BioReSteel focuses on exploring, developing, and utilizing hydrochar (one type of biocoal), derived from various locally available biomass residues via the hydrothermal carbonization. This technology is suitable for low value, wet materials which are not valorized (mainly land-filled) currently, due to its properties.

The challenge is the adaption of the pristine materials to the requirements of the steelmaking process. The concept will be proven by the laboratory test, validated by pilot trials and short-term industrial trials. **In addition, the phosphorus (undesired for steelmaking) extracted will be used as fertilizer, which adds a second value-chain, optimizes process economics, and contributes to the sustainability of the overall process.**



Phosphorus extraction results (from literature)



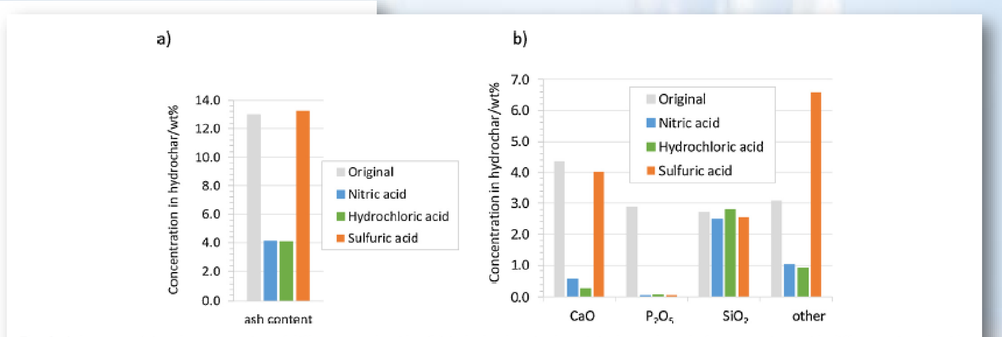


Fig. 1. Ash content (a) and concentration of different metal oxides (b) in hydrochar, in the original sample and after extractions with different mineral acids.

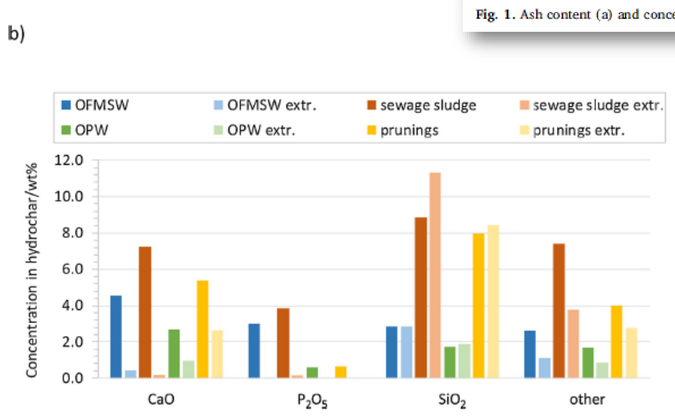
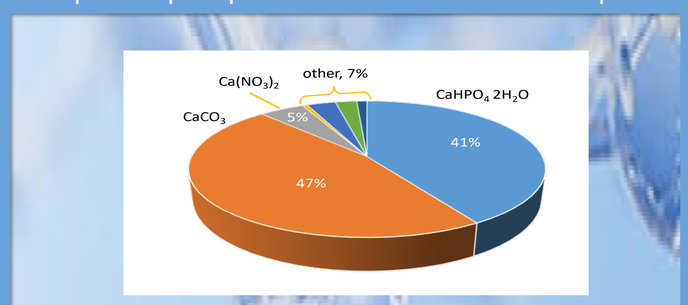


Fig. 2. Ash content (a) and concentration of different metal oxides (b) in hydrochar, measured for the original sample and after extractions with hydrochloric acid (4%, 60 °C, 4 h). Hydrochars were prepared from the organic fraction of municipal solid waste (OFMSW), sewage sludge, orange peel waste (OPW), and garden prunings.

Phosphorus precipitation from the extraction liquid

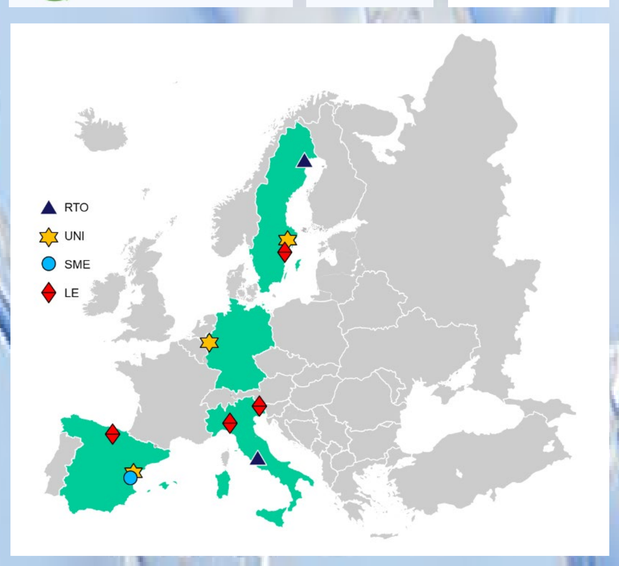


Solid fuel properties of different hydrochars before and after applying an extraction procedure with HCl (4%, 60 °C, 4 h).

entry	starting material	initial HHV[a] [MJ/kg]	final HHV[b] [MJ/kg]	HHV increase[c] [%DRY]	HHV change[d] [%DAF]	final ash content[e] [%]	mass yield[f] [%]	energy balance[g] [%]
1	OFMSW	27.9	30.6	9.6	−0.3	34	86	94.2
2	OPW	24.1	25.4	5.5	2.2	55	92	97.1
3	prunings	20.4	22.3	9.5	4.2	77	90	98.6

[a] HHV of hydrochar before extraction on dry base.
[b] HHV of hydrochar after extraction on dry base.
[c] Change in HHV caused by the extraction procedure on dry base.
[d] Change in HHV caused by the extraction procedure on dry and ash-free (DAF) base.
[e] Final ash content compared to the initial one.
[f] Mass yield for hydrochar after the extraction procedure.
[g] Energy balance considering hydrochar as an energy carrier and comparing the final energy amount (mass x HHV) with the initial one (Formula: energy balance = (final HHV x mass yield)/initial HHV).

BioReSteel Partners



For updated information: https://bioresteel.eu/

Environmental and Social Impact

The BioReSteel project represents a great opportunity for the EU to reduce the environmental and social impact of both the organic waste value chain, and of fossil fuel (coal and natural gas) extraction and use. By producing solid fuels from biowastes, the BioReSteel project will contribute to the reduction in greenhouse gas emissions: the consortium estimates that the project will contribute to reduce GHG emissions due to the residues processing, transportation and disposal by more than 50% from two categories:

- direct emissions that originate from waste management activities such as methane from landfills and CO_2 emissions from transport, incineration and recycling plants;
- avoided emissions, which represent the life cycle benefits from resource recovery (using waste as a secondary material or energy source) and replacing the use of virgin materials or fuels.

At the end users' side, around 70 Mton steel is produced from EAF production route in Europe. By only switching coal to the developed biocarbon, the fossil CO_2 reduction is estimated to be 2.5 Mton/year. **In addition, around 900 kton bio-based struvite fertilizer can be produced annually.** Currently, the steel production from the EAF process is around 40% of the total steel production in Europe, therefore, in a long-term when the EAF steelmaking is dominate, the fossil CO_2 reduction can be doubled, contributing to the fossil-free steelmaking industry and bio-based fertilizer for the agriculture.

Acknowledgement

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