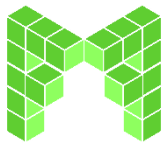


ADVANCES IN >> HYDROTHERMAL CONVERSION OF INDUSTRIAL BIOGENIC RESIDUES INTO INTERMEDIATE BIOENERGY CARRIERS

RESULTS FROM THE **F-CUBED PROJECT**



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 884226.



F-CUBED

Evaluation of utilizing hydrochar generated from TORWASH[®] process for the steelmaking industry

Chuan Wang

chuan.wang@swerim.se



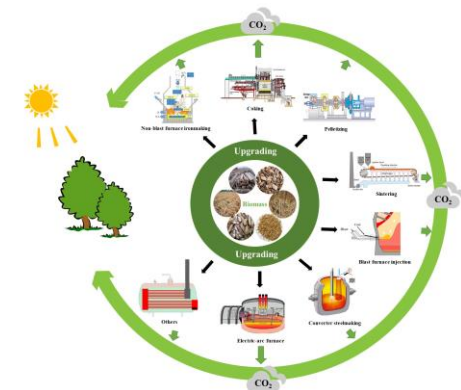
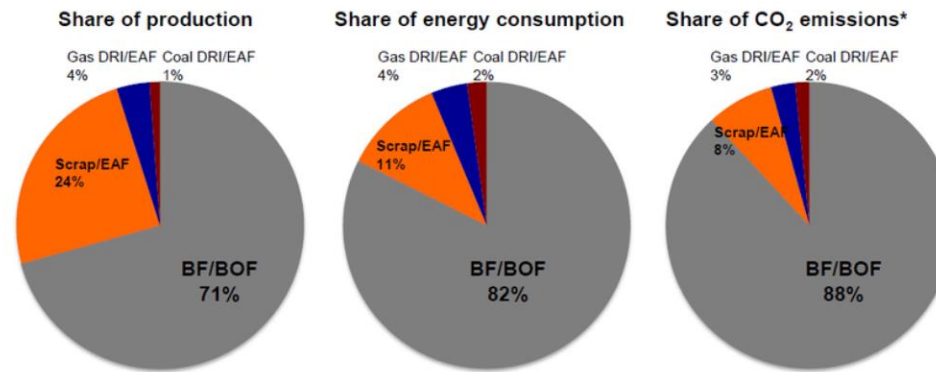
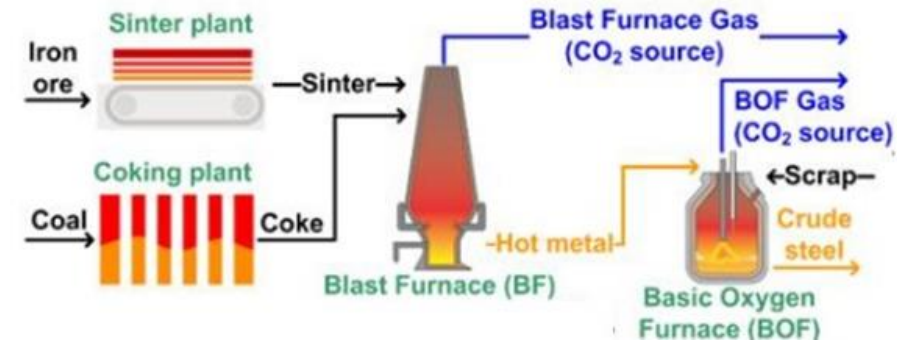
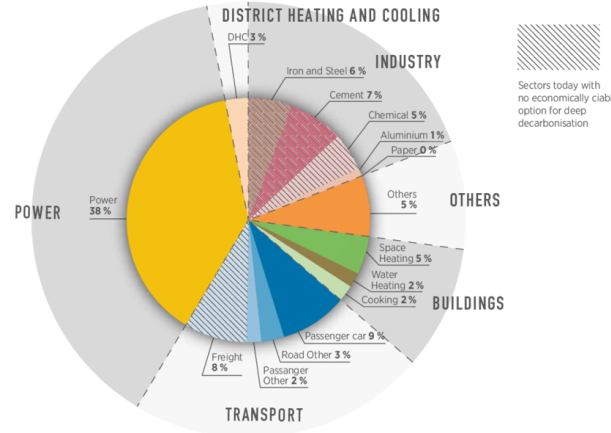
Steel production routes



Steel production and CO₂ emission

Steel industry in transition towards decarbonization process

Biocarbon is carbon neutral, which can play an important role.



Steelmaking needs biocarbon

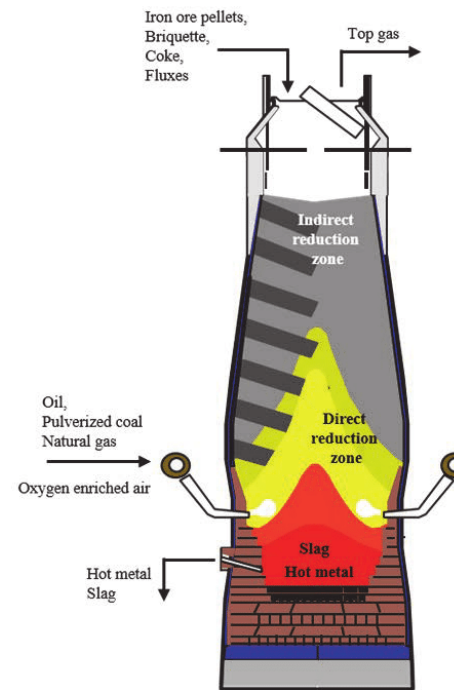


❑ Ironmaking blast furnace (BF)

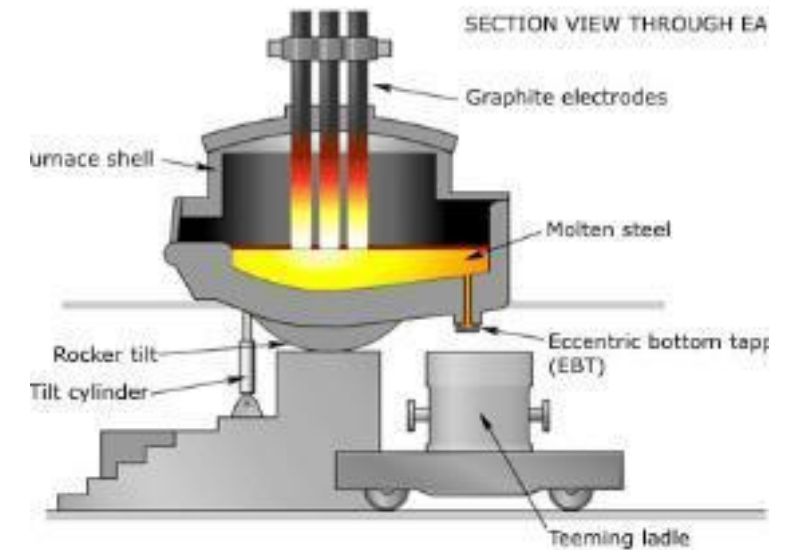
- Reducing agent
- Fuel
- Carburization
- Skeleton

❑ Electric arc furnace (EAF)

- Slag foaming agent
- Carburizing agent
- Fuel



BF



EAF

Project work

Investigate the possibility of using hydrochar generated from the TORWASH® process for the steelmaking by performing laboratory experiment work.

Key metallurgical properties and quality parameters

- **Proximate analysis**
- **Ultimate analysis**
- **Harmful elements (e.g. alkali, P)**
- **Heating value**

- **Ignition point**
- **Explosiveness**
- **Combustibility**
- **Reactivity**

**Evaluation of
hydrochar**

- **Ash fusion point**
- **Ash composition**

Agglomeration

- **Strength (e.g. tumble index, CCS, STS, etc.)**

Materials and samples



Bio-sludge hydrochar



Olive domance hydrochar



Orange peel hydrochar

Characteristic analysis of hydrochar



Samples	Proximate analysis (wt%)			Ultimate analysis (wt%)					Heating value (MJ/kg)
	Ad	Vd	FCd	C	H	O	N	S	
Bio-sludge	22.17	63.31	14.52	46.97	5.96	20.28	4.36	0.26	20.81
Olive domance	1.58	83.69	14.73	55.33	4.45	36.78	1.75	0.11	20.71
Bituminous coal	5.95	34.95	59.11	65.02	3.82	23.77	0.99	0.45	27.46
Anthracite	8.66	8.85	82.49	85.26	3.40	0.40	1.08	1.09	30.65

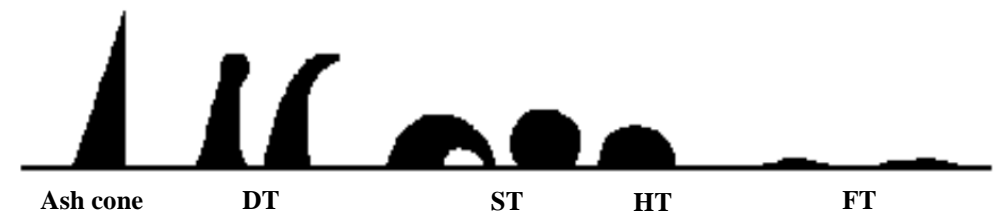
- The volatile content of hydro char is high, which is positive to the combustion efficiency of fuel in the tuyere;
- The ash content of hydro char is high and the fixed carbon content is low, which is not good to replace coke;
- The hydrogen content is high, which will improve the reduction reaction in the blast furnace;
- Anthracite has higher carbon content, but lower hydrogen and oxygen, so mixing anthracite and the fuel with high volatile content will help anthracite to ignite and burn;

Characteristic analysis of hydrochar



Samples	CaO	K ₂ O	MgO	SiO ₂	P ₂ O ₅	SO ₃	Al ₂ O ₃	Fe ₂ O ₃	Na ₂ O
Bio-sludge	47.76	4.60	2.36	9.17	13.03	3.58	2.85	15.23	0.51
Olive domance	37.96	10.73	4.85	8.65	7.21	7.43	2.79	16.58	1.82
Bituminous coal	19.28	0.55	-	38.15	3.10	13.90	14.16	7.36	-
Anthracite	3.22	0.64	0.30	47.69	-	-	36.89	4.79	0.56

	Deformation temperature	Softening temperature	Hemispherica l temperature	Flow temperature
Bio-sludge	1015	1110	1162	1180
Olive domance	1128	1177	1188	1191
Bituminous coal	1096	1107	1113	1127
Anthracite	1019	1121	1332	1347





Characteristic analysis of hydrochar

➤ Safety performance

	Ignition point
Bio-sludge	278.6 °C
Olive domance	269.8 °C
Bituminous coal	322.0 °C
Anthracite	430.0 °C



- The hydrochar has lower ignition point, which can ignite and burn quickly;
- Anthracite has a higher ignition point;
- In order to ensure the safety of milling and use, it is necessary to mix the hydrochar with anthracite coal.

	Explosiveness
Bio-sludge	> 800 mm
Olive domance	> 800 mm
Bituminous coal	> 800 mm
Anthracite	0 mm

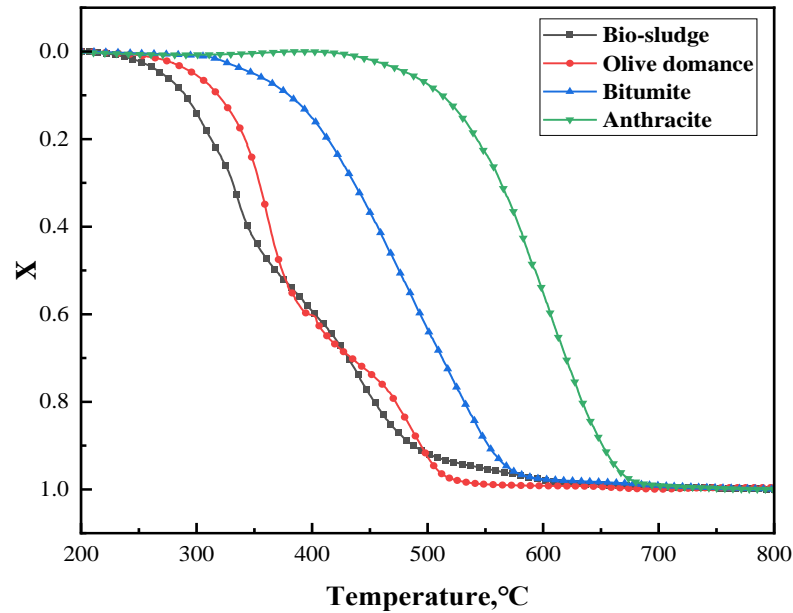


- The hydrochar has strong explosiveness;
- During the pulverizing process, the temperature and oxygen content of the mill is important;
- Mixing with non-explosive anthracite also significantly improves sample safety.

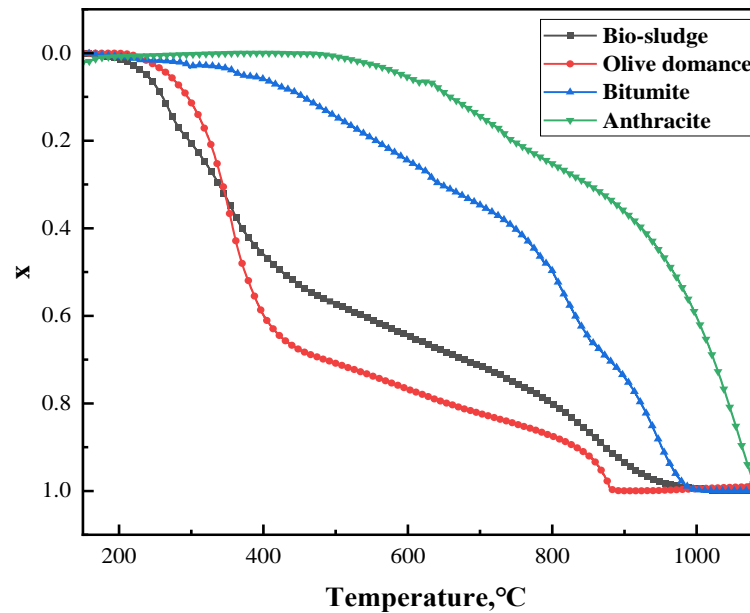
Combustibility and reactivity of hydrochar



Combustibility



Reactivity

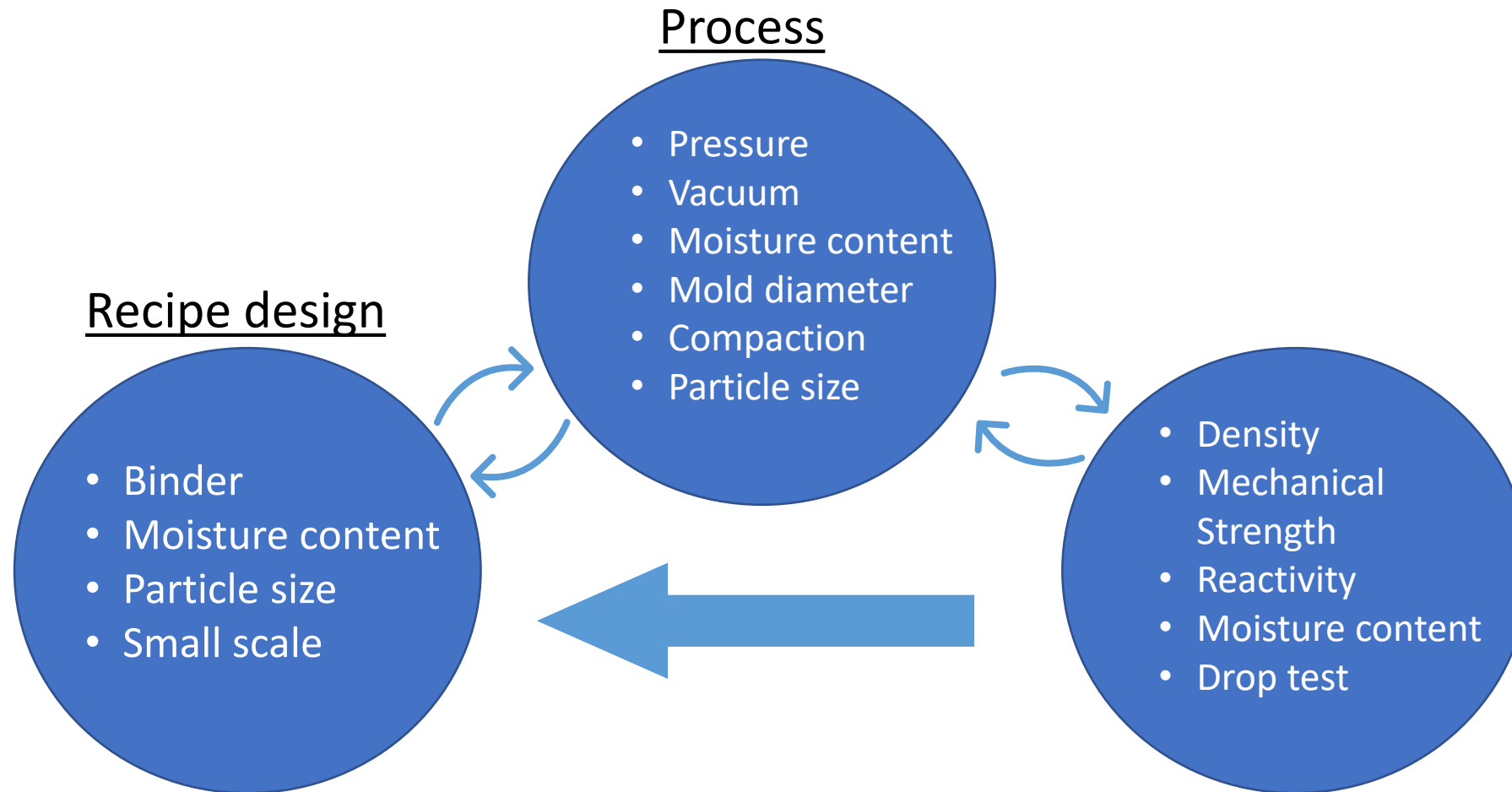


- The combustibility and reactivity curve of the hydro char are inclined to the low temperature region, the bituminous coal is in the middle, and the anthracite coal has the highest temperature.
- Blast furnace injection of highly reactive fuel can inhibit the melting loss reaction of coke, which is beneficial to improve the high temperature performance of coke.





Agglomeration





Agglomeration techniques



pellet press



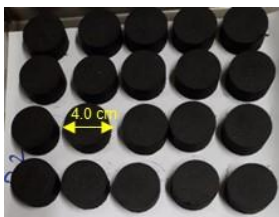
vibro press



roller press



Extruder



Vibro press



Recipes	REF	R4	R5	R9	R10
Hydro char (%)	0	4	8	4	8
Cement (%)	10	10	10	10	10
Iron oxide (%)	90	86	82	0	0
Blast furnace mix (%)	0	0	0	86	82
Moisture	11	14	17	12	14



Evaluation of vibro press briquettes after:

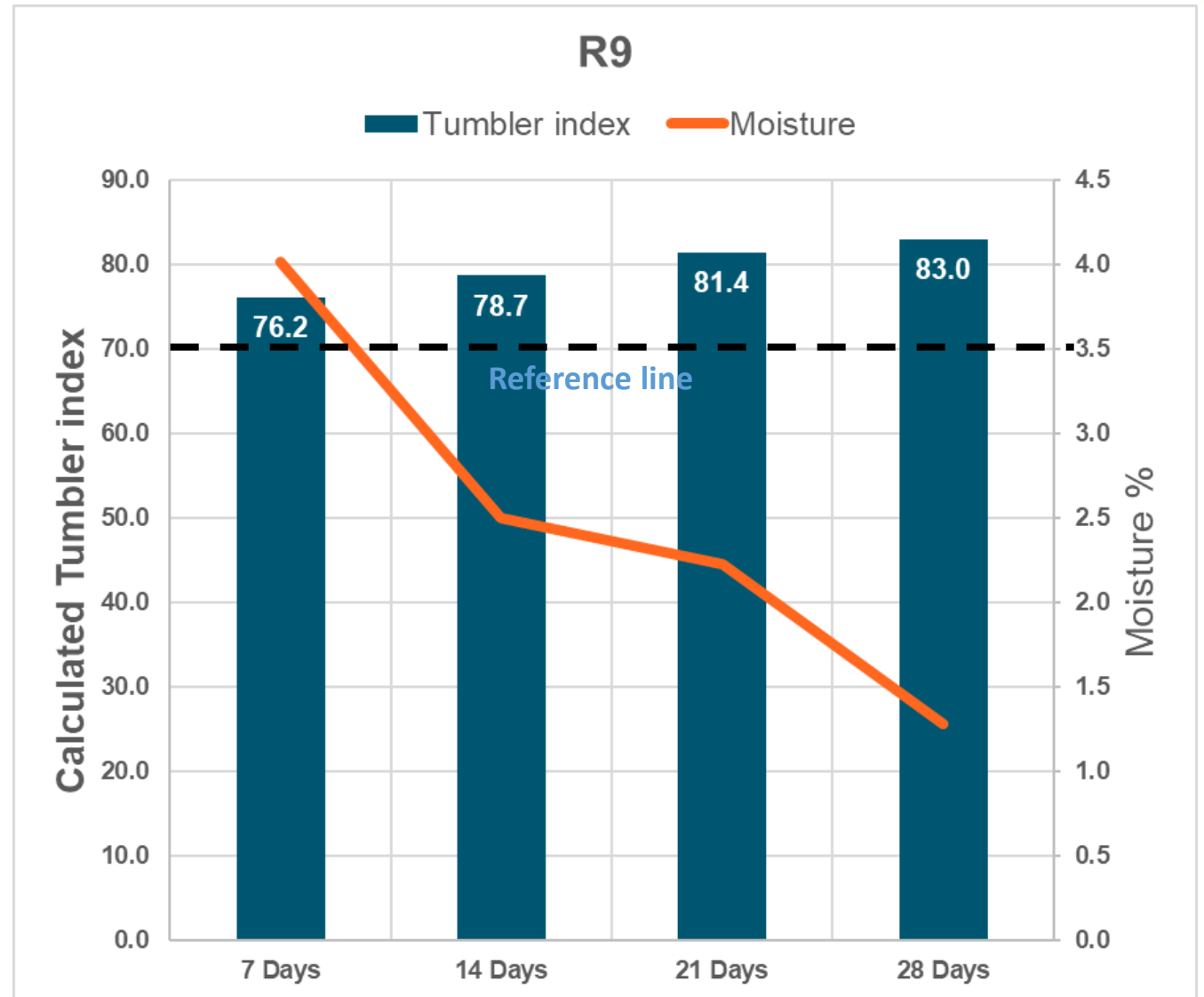
- Density of briquettes
- Tumbler Index
- Mechanical strength



Evaluation of Vibro press briquettes



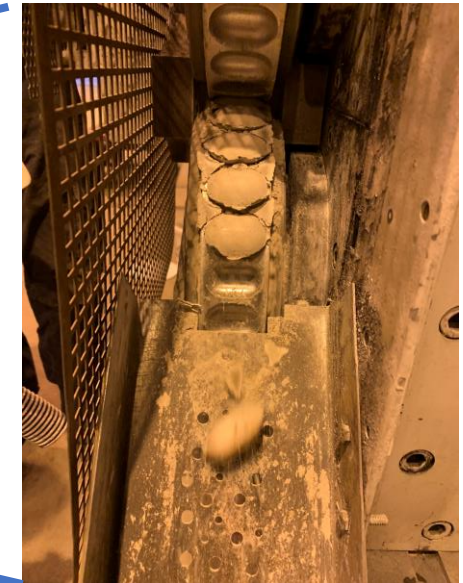
- Blast furnace mix with 4% hydro char showed promising results.
- A higher amount of hydro char in the briquettes reduces the mechanical strength of the briquettes





Roller press

Recipes	R4	R6
Hydro char	10	10
Lime	40	0
Fly ash (lime)	50	0
Iron powder	0	90



Evaluation of roller press briquettes:

- Density of briquettes
- Production rate
- Generation of fines – drop test
- Generation of fines compared to reference case

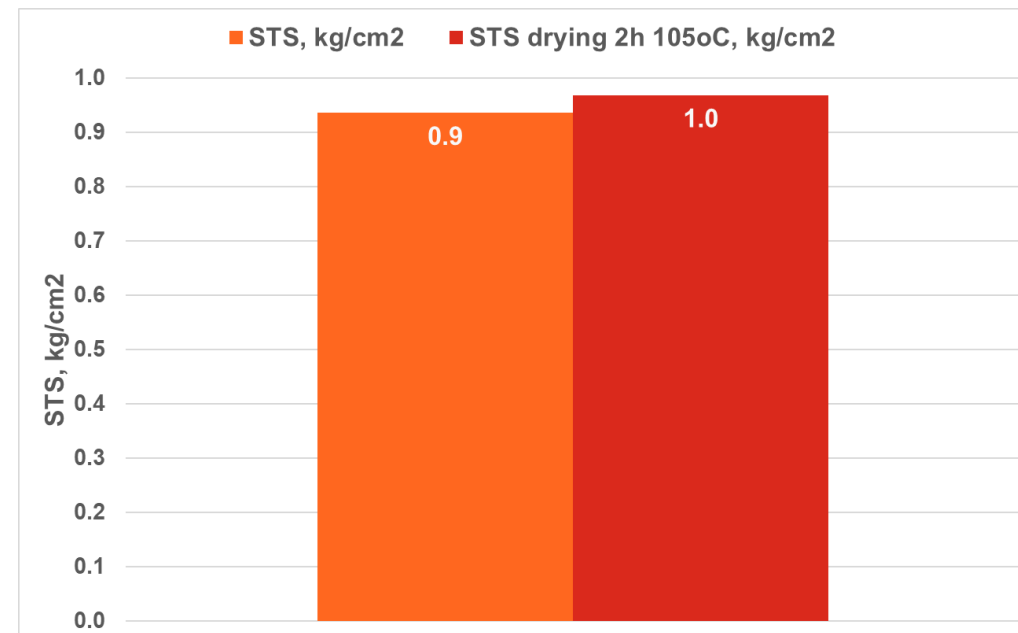
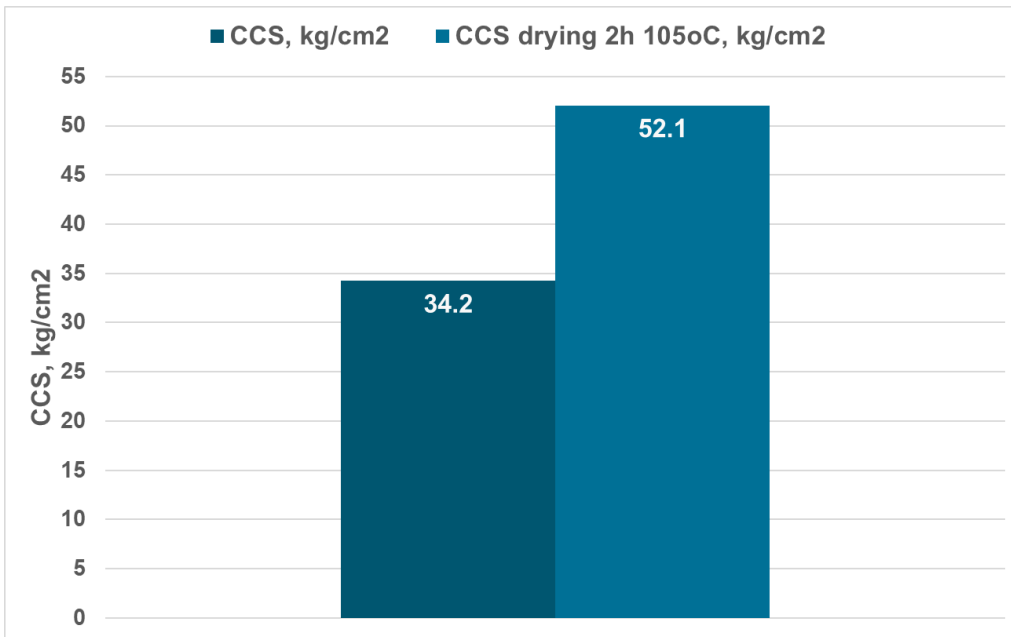




Extruder

The optimal moisture content is important for the extruder process. The dried briquettes have higher strength.

Recipes	R6
Hydro char	10
Iron powder	90
Moisture content	9





Conclusions

- ❑ The hydrochar has strong combustion performance and gasification reaction performance, which is beneficial to the utilization.
- ❑ The hydrochar has higher ash content and higher CaO content, resulting in a low ash melting temperature.
- ❑ For injection applications, attention should be paid to the lower ignition point and higher explosiveness. Mixing with anthracite would be a good solution!
- ❑ P content in the hydrochar has to be further reduced in order to use it for ironmaking and steelmaking.
- ❑ The amount of hydrochar influences the mechanical strength of the briquettes. In order to increase the amount of hydrochar in the briquettes, future look into moisture content and addition of binder.
- ❑ From an environmental aspect, it's important to find more sustainable binders that can replace cement in blast furnace briquettes.

Disserminations

Journal paper

Wang Liang, Pavlina Nanou, HeatherWray, Jianliang Zhang, Ingemar Lundstrom Lundqvist and Chuan Wang. Feasibility Study of Bio-Sludge Hydrochar as Blast Furnace Injectant. **Sustainability** 2022, 14, 5510. <https://doi.org/10.3390/s14055510>



Conference papers

Wang Liang, Guangwei Wang, Jianliang Zhang, Chuan Wang. Biomass Residue Hydrochar as Blast Furnace Injectant. Proceedings of the 12th International Conference on Green Steel, 2022.

Ludvig Ånnhagen. Fossil-free value chain for iron-ore of paper mill sludge hydro char as steel production. Proceedings of the 12th International Conference on Green Steel, 14-15 September 2022, Skellefteå, Sweden.

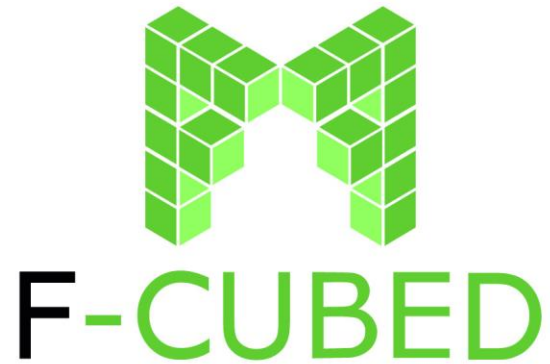


Others

Chuan Wang. Interview by Green Steel World. "Bio-based industry's sustainable future"

Metallurgical properties comparison of hydrochar samples prepared from different biomass. Under preparation for a journal publication.

THANK YOU



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 884226.

