SESSION 1: 10:20–10:40

ESTEP European Steel Technology Platform

ESTEP workshop

SecCarb4Steel

Preparation and use of biogenic and non-biogenic secondary carbon carriers (SCC) in processes for iron and steelmaking

Application of hydrochar for a sustainable electric arc furnace process

Yu-Chiao Lu[1], Andrey Karasev[1], Björn Glaser[1], Chuan Wang[1,2]

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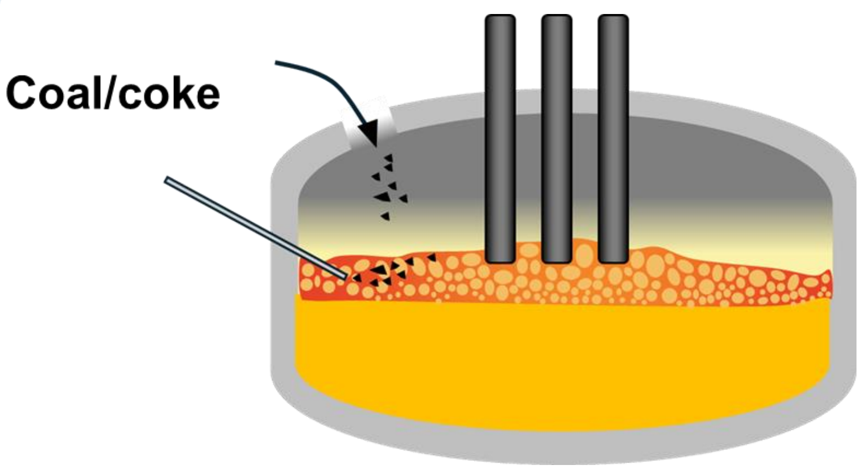
[2] Swerim AB, Process Metallurgy, 97125, Luleå, Sweden

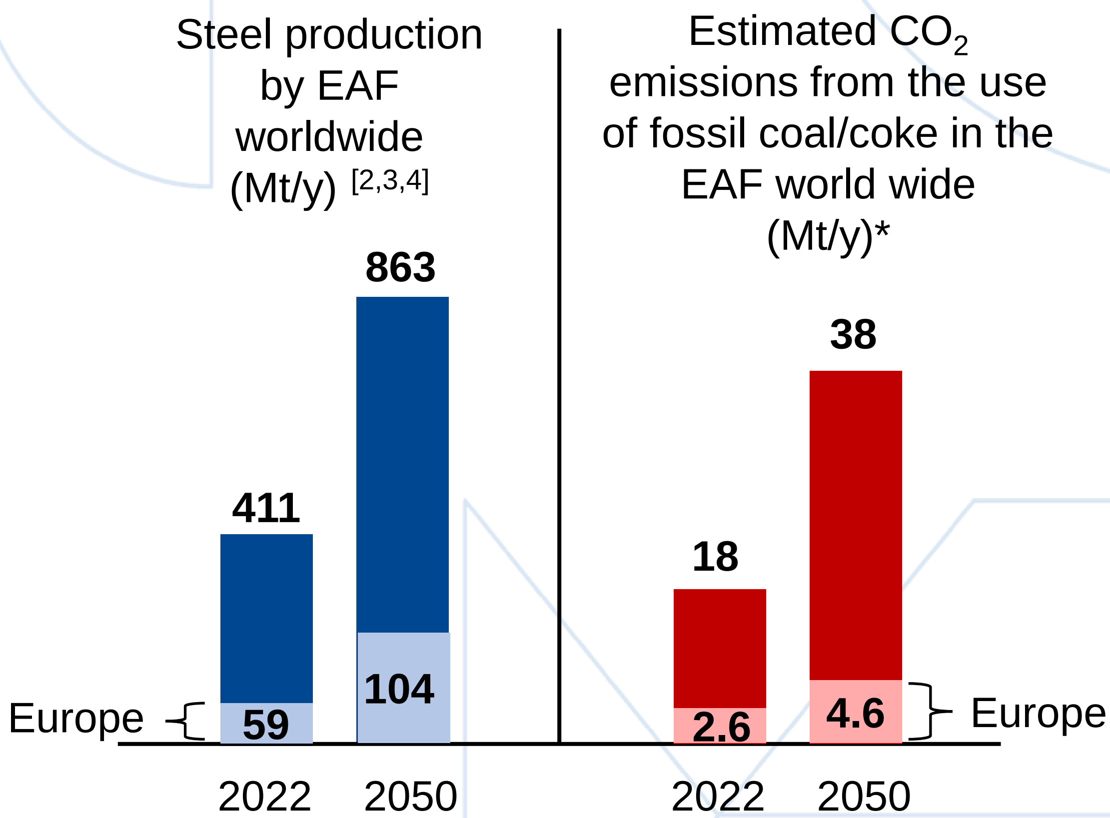
Agenda

- Background
- Challenges of biochar in Europe
- Roles of carbonaceous material in the EAF
- Lessons learned from OSMET 3.0 project
- Looking ahead – RFCS BioReSteel project

Background

Electric arc furnace (EAF)
12 kg carbon/t-steel [1]
= **44 kg** CO_2/t-steel

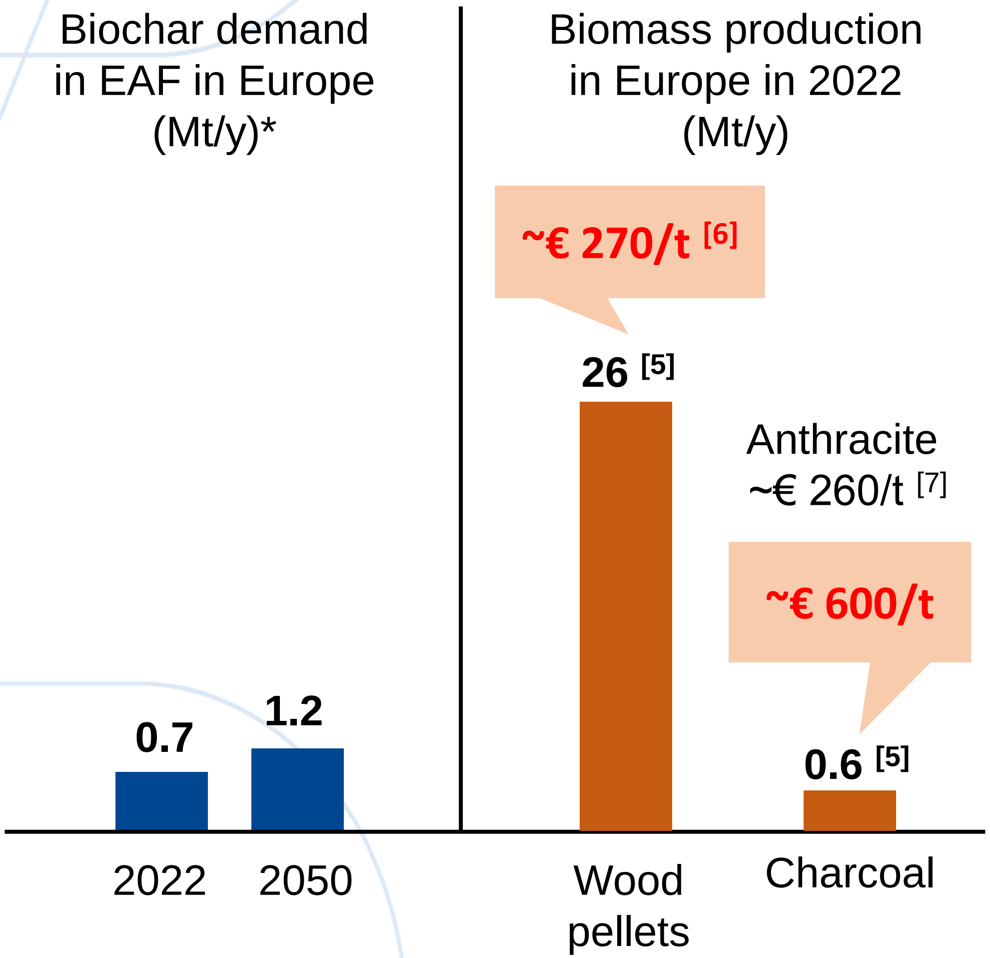




*Calculated based on the amount of steel produced in EAF and 0.044 kg-CO_2/t-steel.

Challenge

EAF:12 kg carbon/t-steel [1]



Challenges:

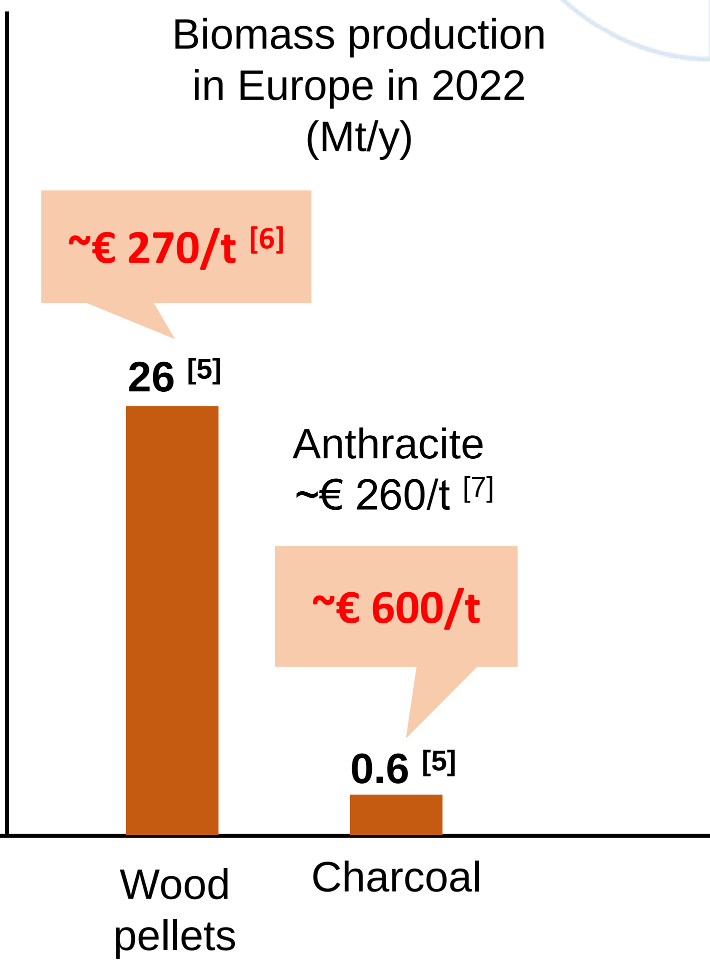
- High price of charcoal
- Stricter requirements for forest biomass

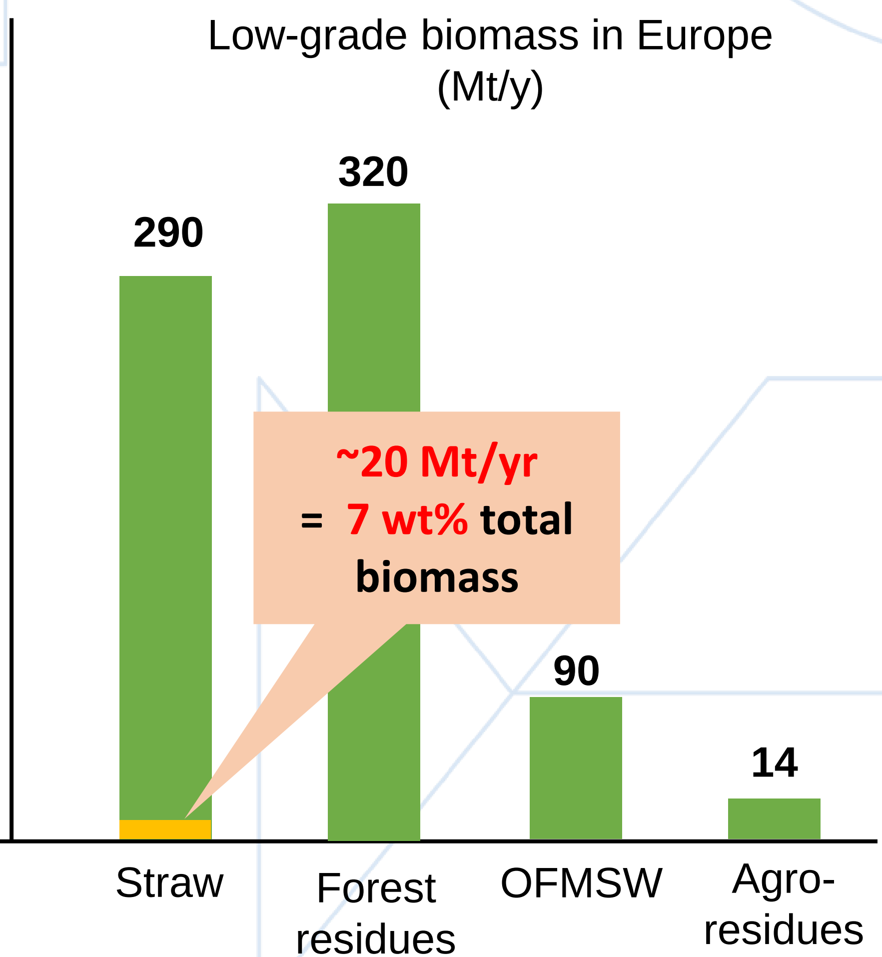
*Calculated based on the amount of steel produced in EAF and 12 kg-carbon demand per ton steel.

Opportunity

EAF:12 kg carbon/t-steel [1]

- High moisture
- High impurities: alkalis, S, P





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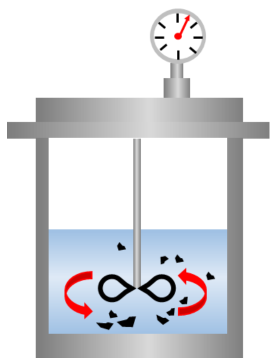
Opportunity

Low-grade biomass

Hydrothermal carbonization (HTC)



180-250 °C
~20 bar

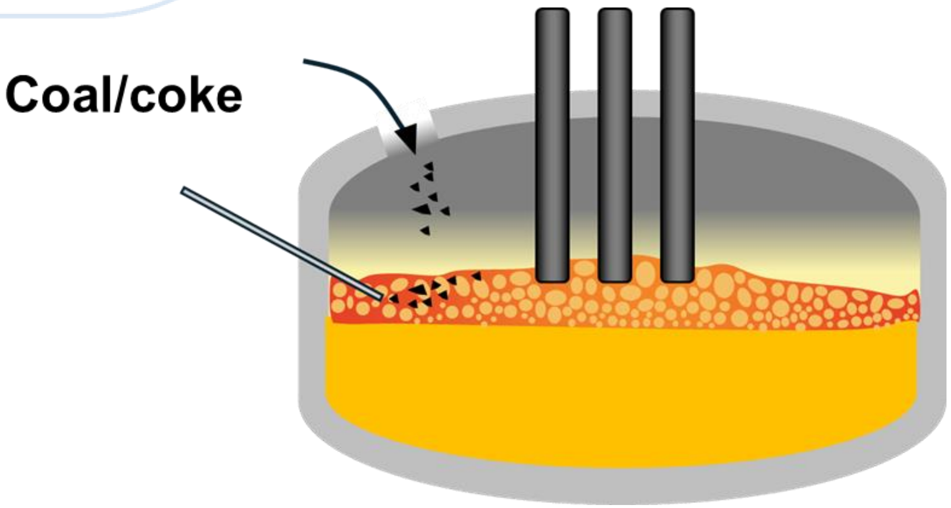
Hydrochar

Pyrolysis

Pyrolyzed hydrochar

- Mass yield **~50 wt%**
- Carbon content **50-60 wt%**
- Heating value **20-24 MJ/kg**
- Easy to pelletize
- Current production in Europe ~ **12 kt/yr**

Roles of carbon in the EAF



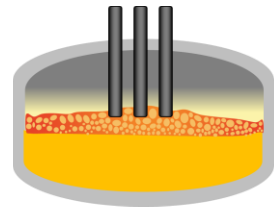
- Fuel
- Carburizing agent
- Reducing agent
    - Self-reduction
    - Slag foamig

Scope of work...

Hydrochar

in

EAF



Previous work
OSMET 3.0 (Sweden)

- **Carburization of liquid steel**
- **Reduction (Self-reduction)**

On-going work
BioReSteel (RFCS, Europe)

- **Reduction (self-reduction, slag foaming)**

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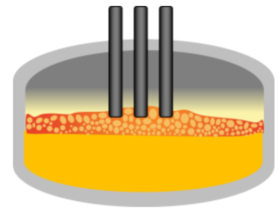
Hydrochar

in

EAF



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Properties of carbon materials

Properties	Hydrochar (fruit peel, rice husk)	Pyrolyzed hydrochar (fruit peel, rice husk)	Charcoal (Ch)	Anthracite (A)
Volatile matter (wt%)	**56-67**	0	11-16	2-8
Fixed carbon (wt%)	**23-27**	56-**84**	79-81	81-94
Heating value* (MJ/kg)	**20-24**	18-**30**	31	31-32
Ash (wt%)	4-21	**16-44**	5-7	5-11
Alkalis (wt%)	**0.4-0.7**	**1.2-1.5**	**0.6-2.0**	0.1-0.3
S (wt%)	0.07-0.15	0.20-0.23	0.03-0.07	**0.18-0.59**
P (wt%)	**0.16-0.25**	**0.26-0.37**	**0.07-0.20**	0.01-0.03

***Lower heating value**

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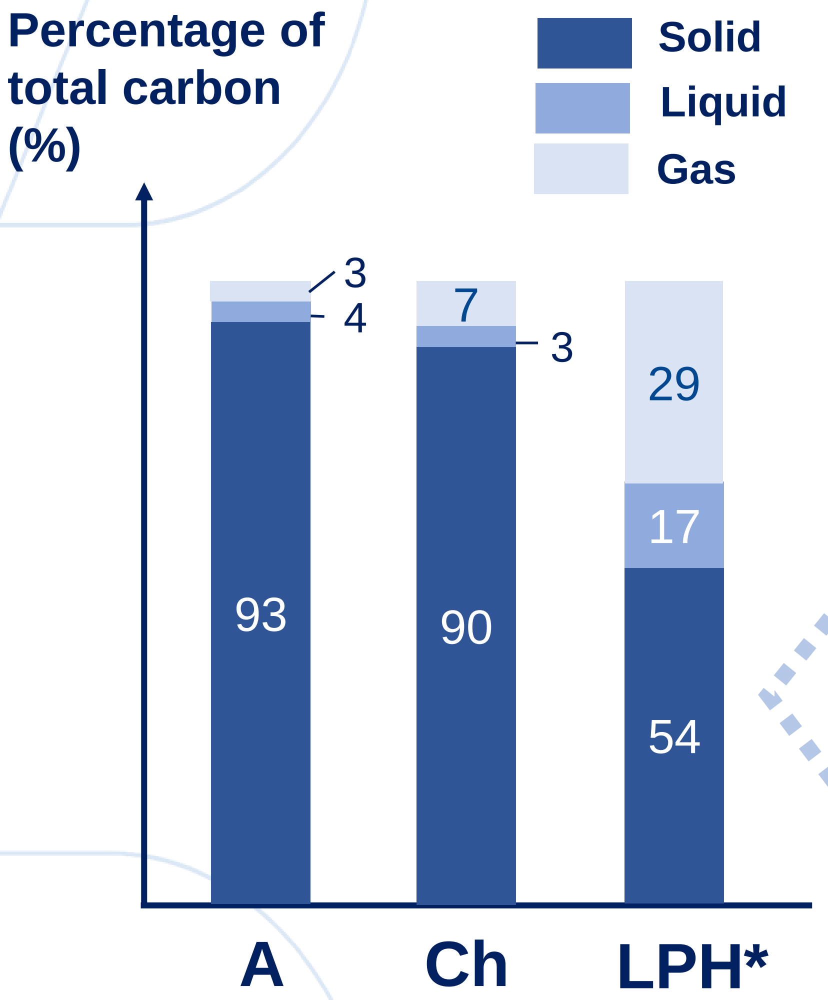
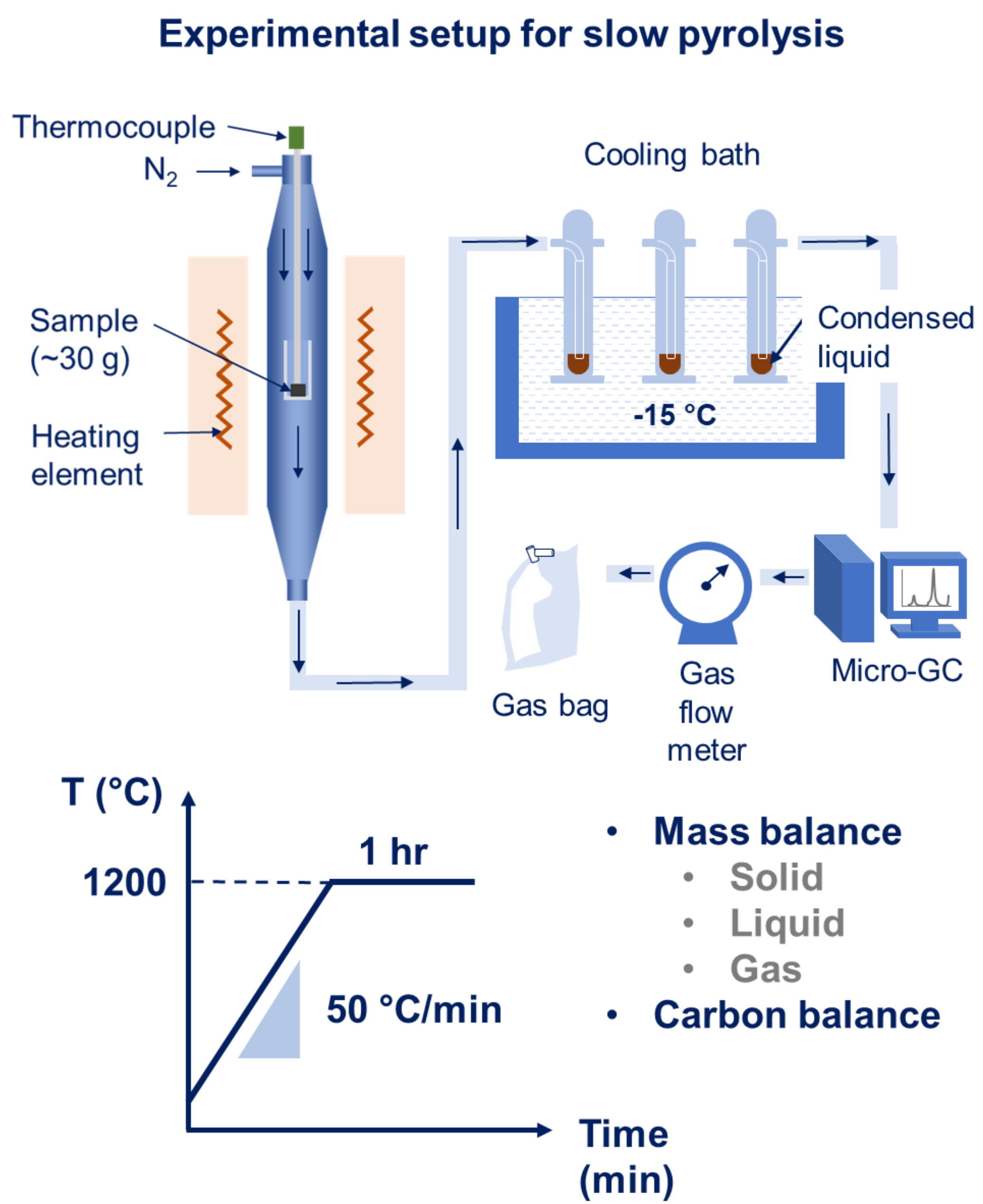
***Lower heating value**

Carburization

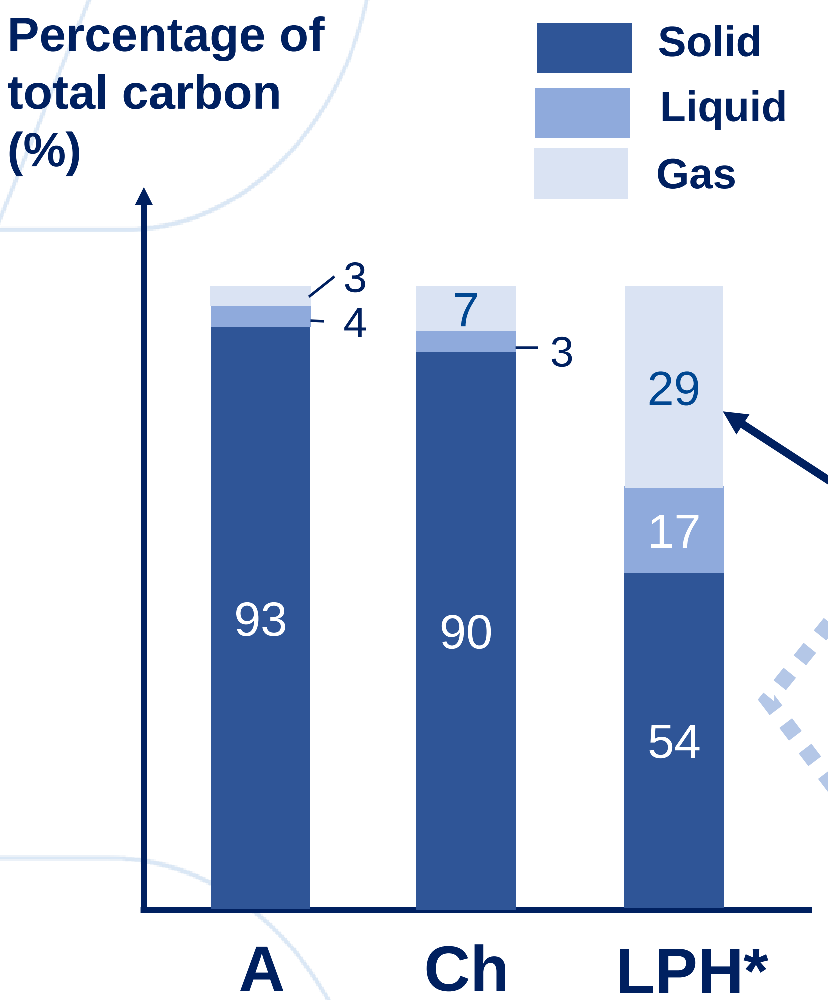


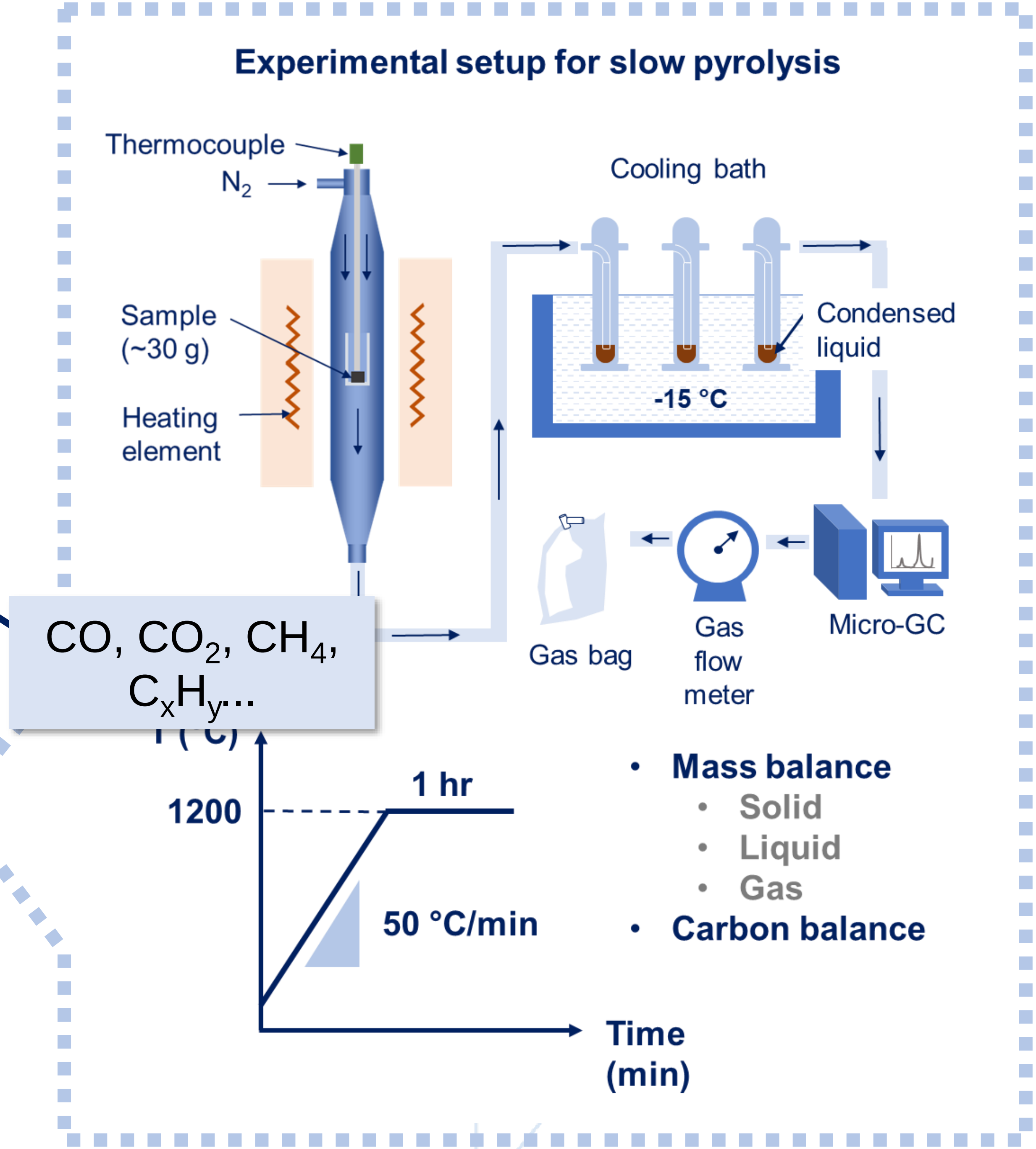
*Lemon peel hydrochar



- **Mass balance**
  - Solid
  - Liquid
  - Gas
- **Carbon balance**

Carburization



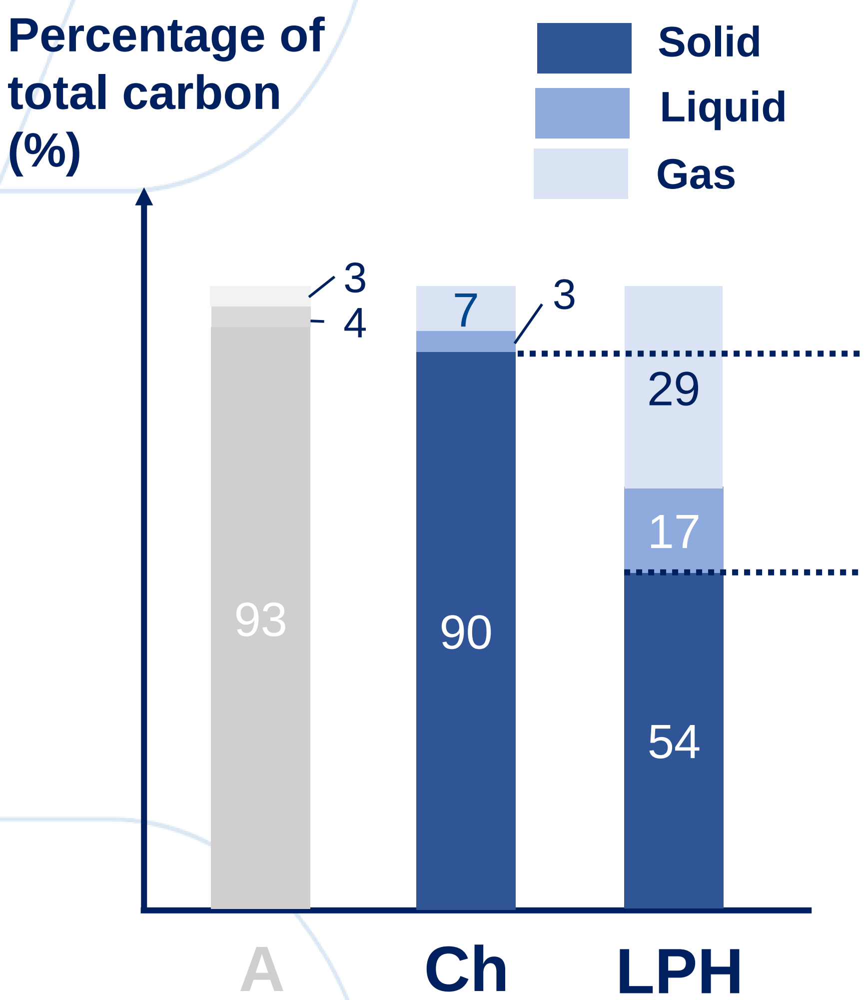


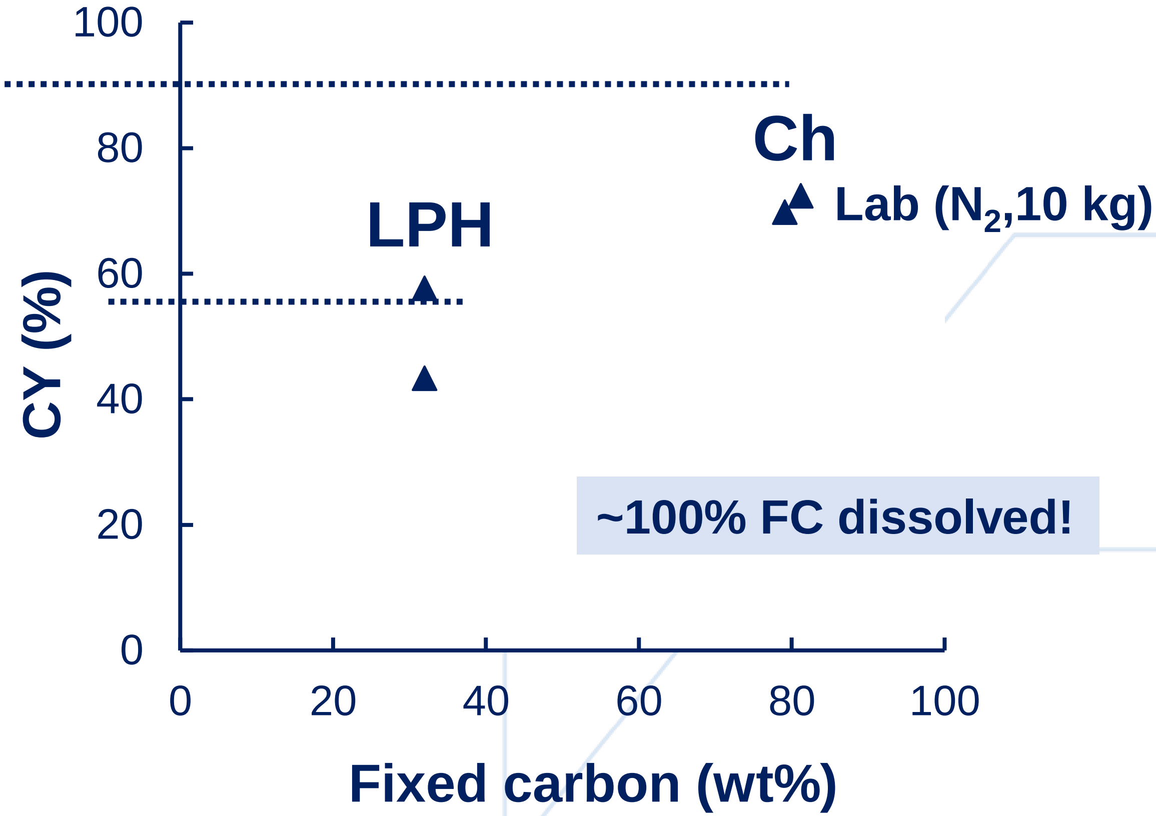
*Lemon peel hydrochar

Carburization

Carburization yield, CY (%)

$$= \frac{Weight\ of\ carbon\ dissolved}{Weight\ of\ carbon\ added} \cdot 100$$





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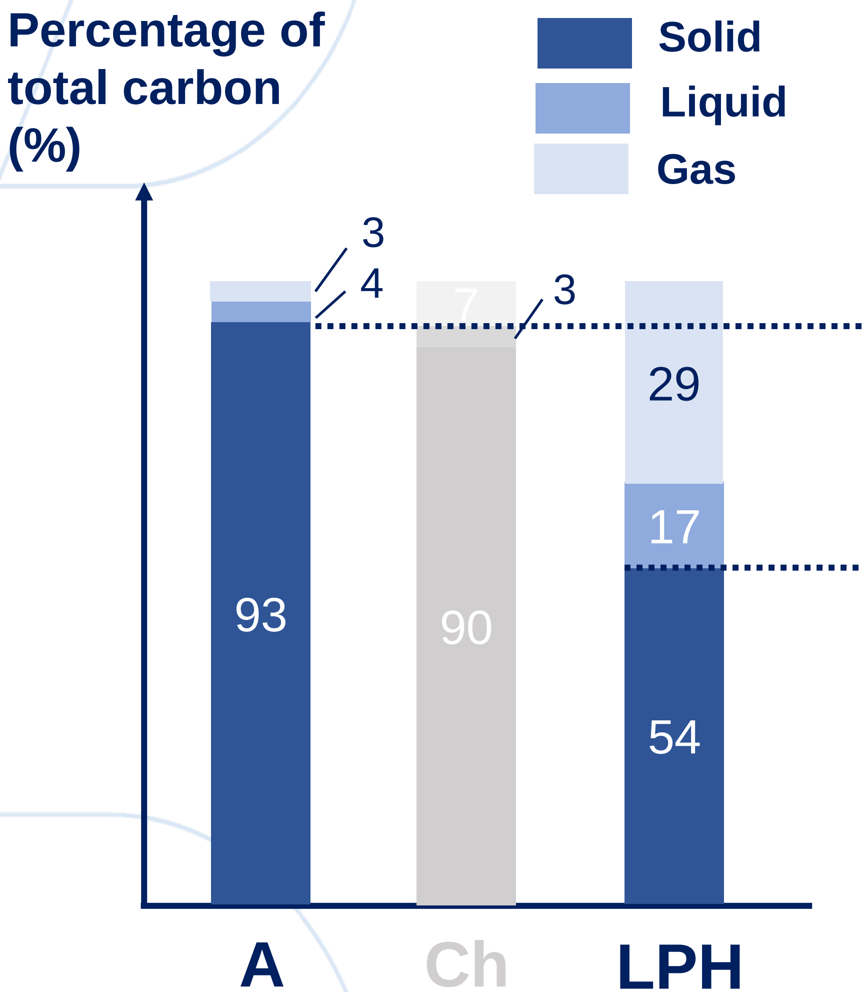

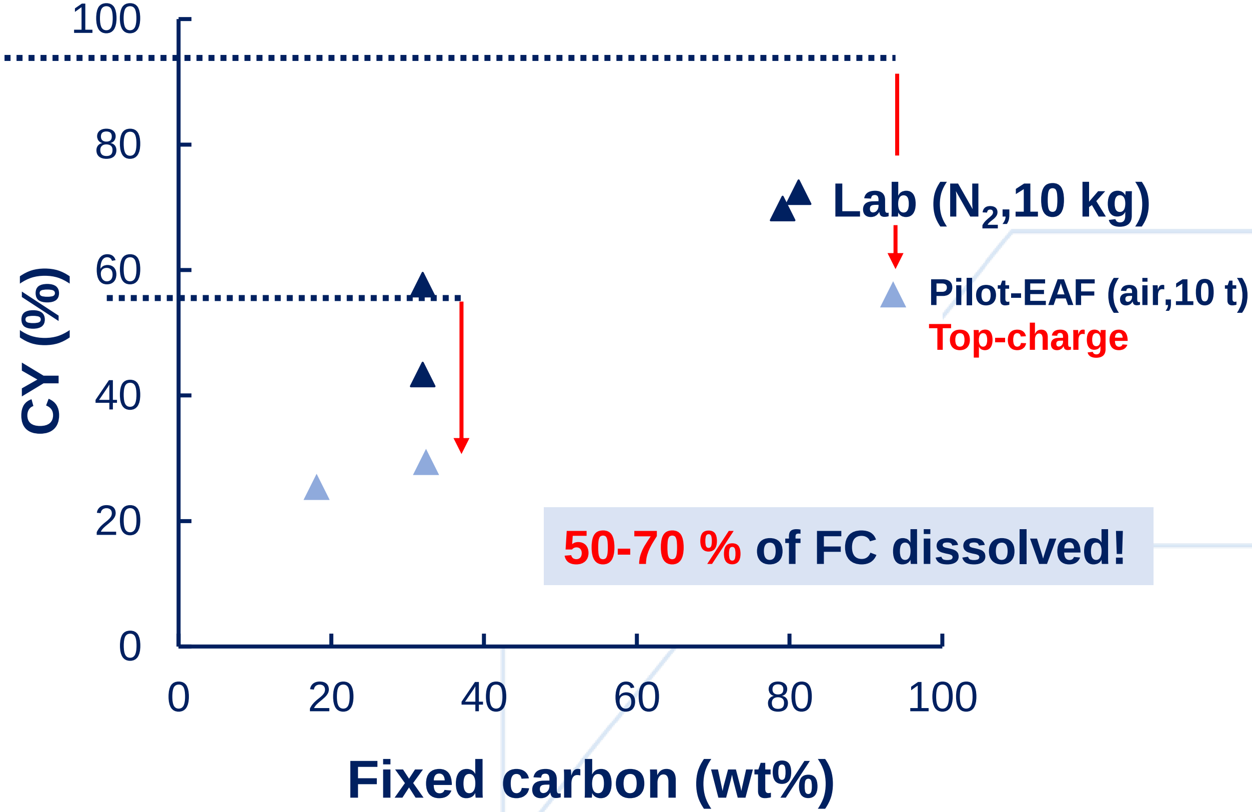

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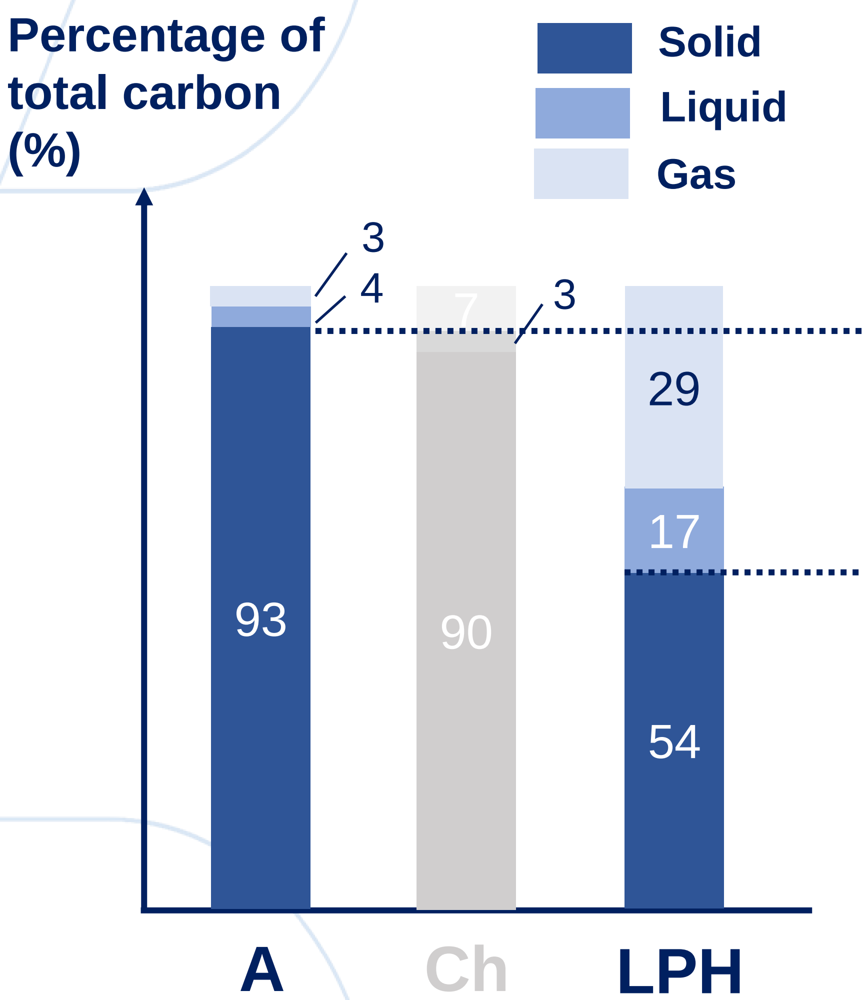

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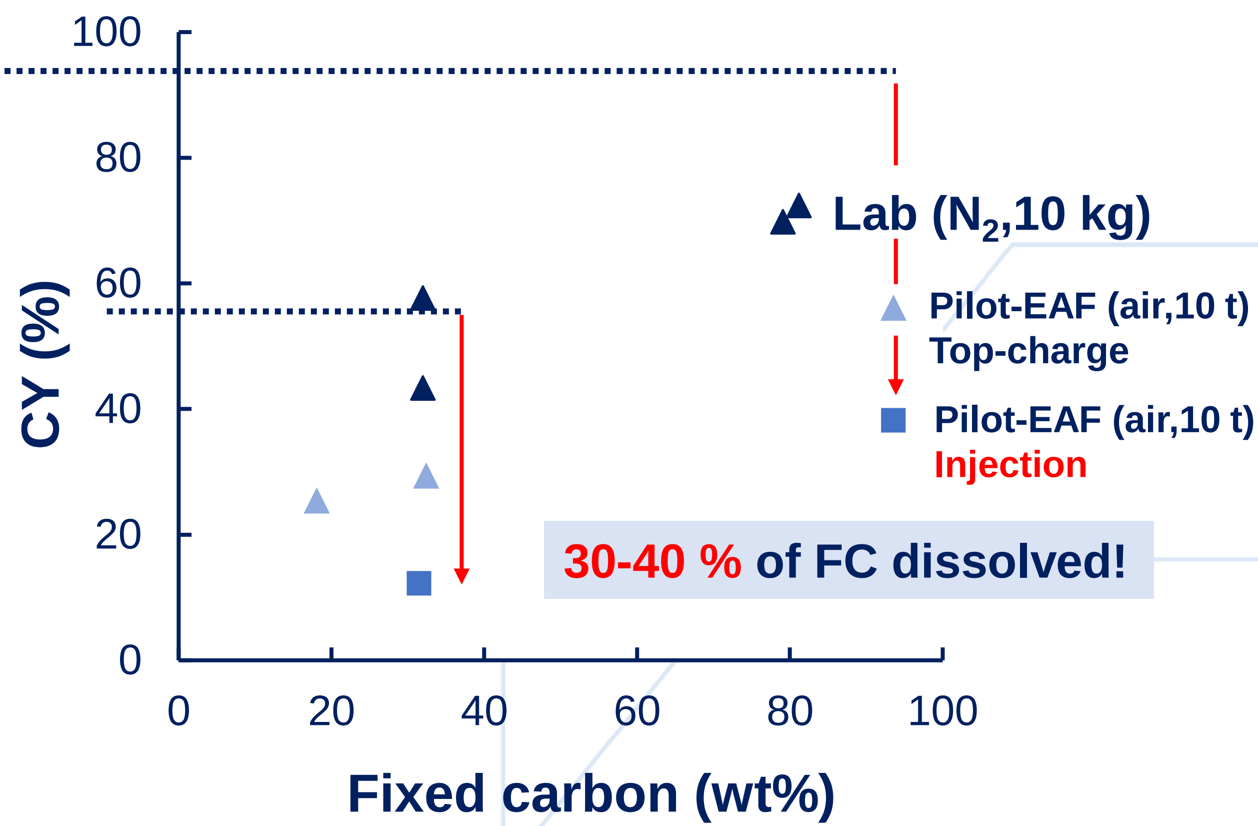
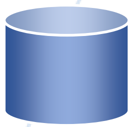


Lessons learned....

Carburization:

- Depends on **fixed carbon** content of material!
- **Fixed carbon yield** depends on addition method:
  Lab (~100%) > **Top-charge, EAF** (50-70%) > **Injection, EAF** (30-40%)

Self-reduction



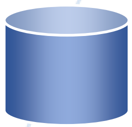
20-30 g

Briquette:

- **Hematite** (Fe_2O_3)
- **Hydrochar** (lemon peel, rice husk)
- Binder
- Molar ratio - $C_{fix}:O_{(FeOx)}$ = **0.4-1.0**

$$1 \cdot C_{fix} + 1 \cdot FeO_x \rightarrow CO + FeO_{(x-1)}$$

Self-reduction



20-30 g

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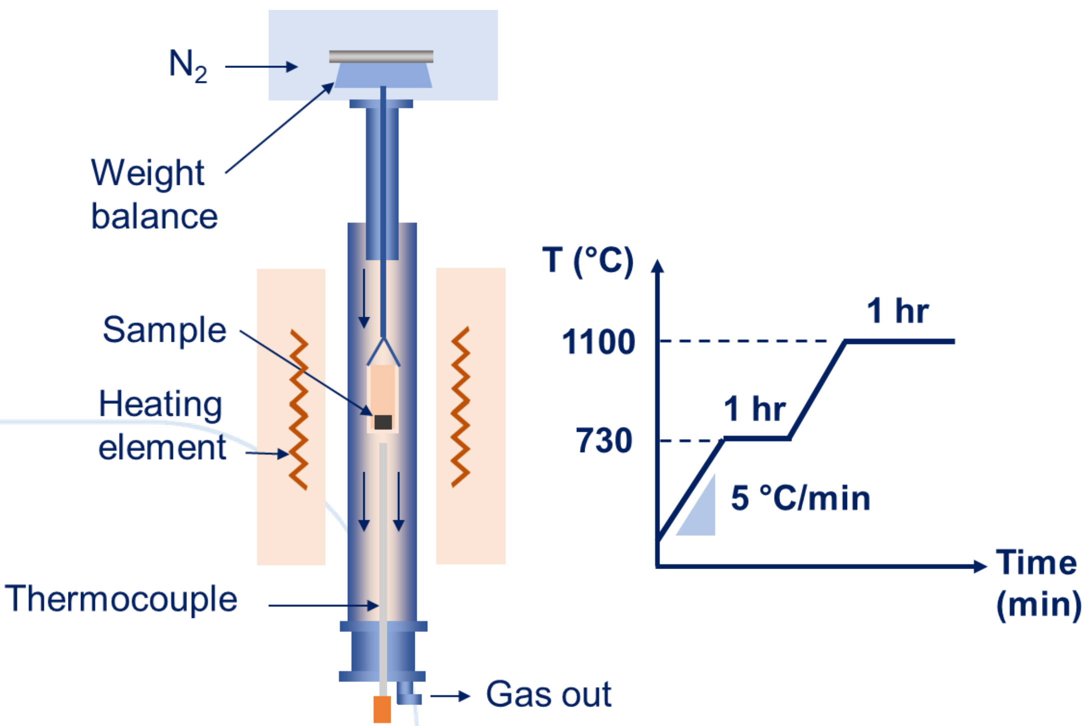
Thermogravimetric analyzer (TGA)



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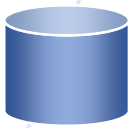

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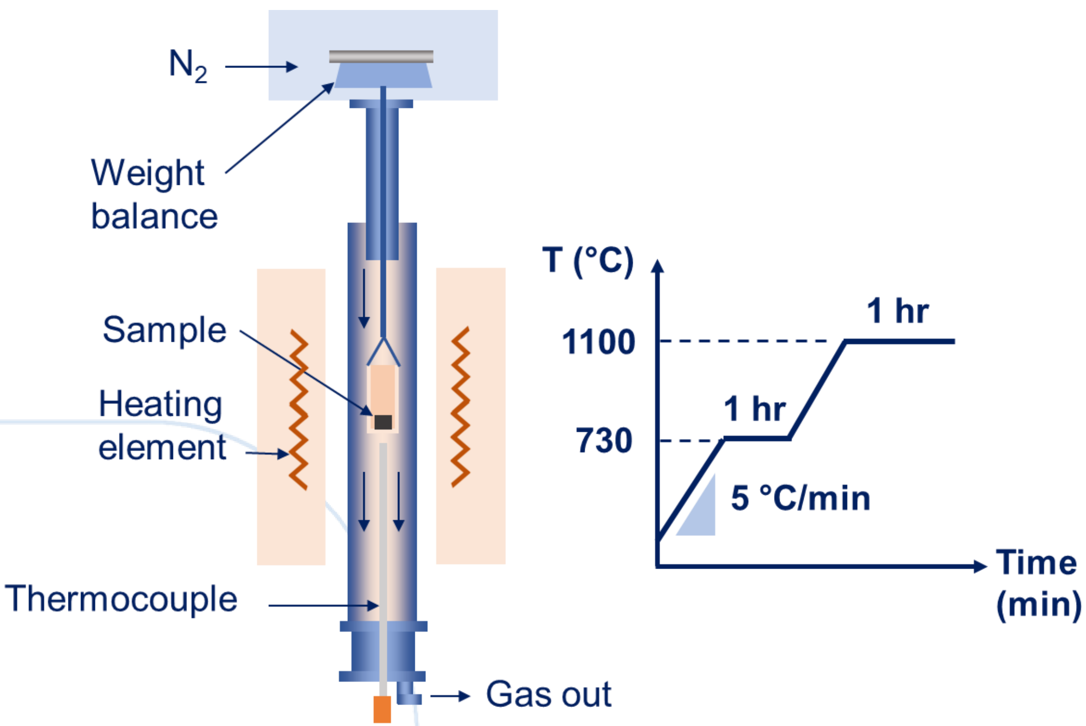
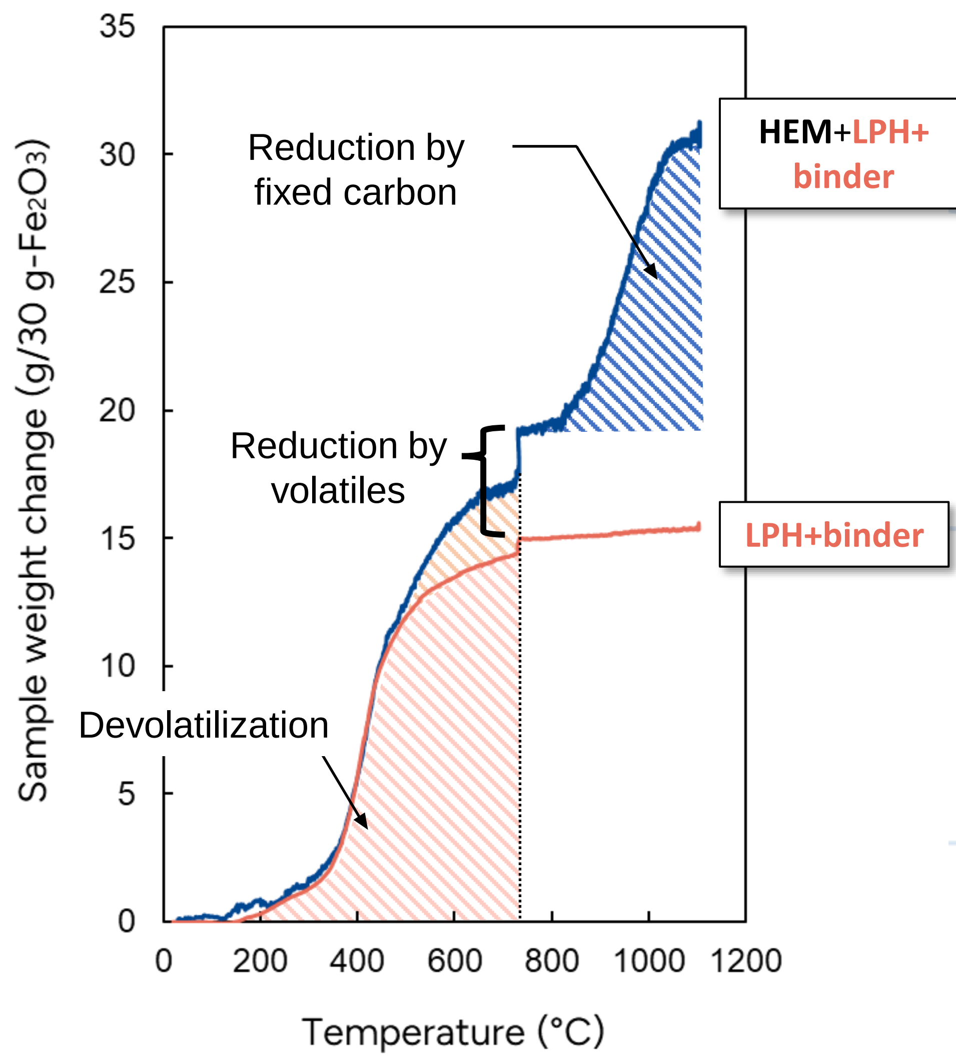
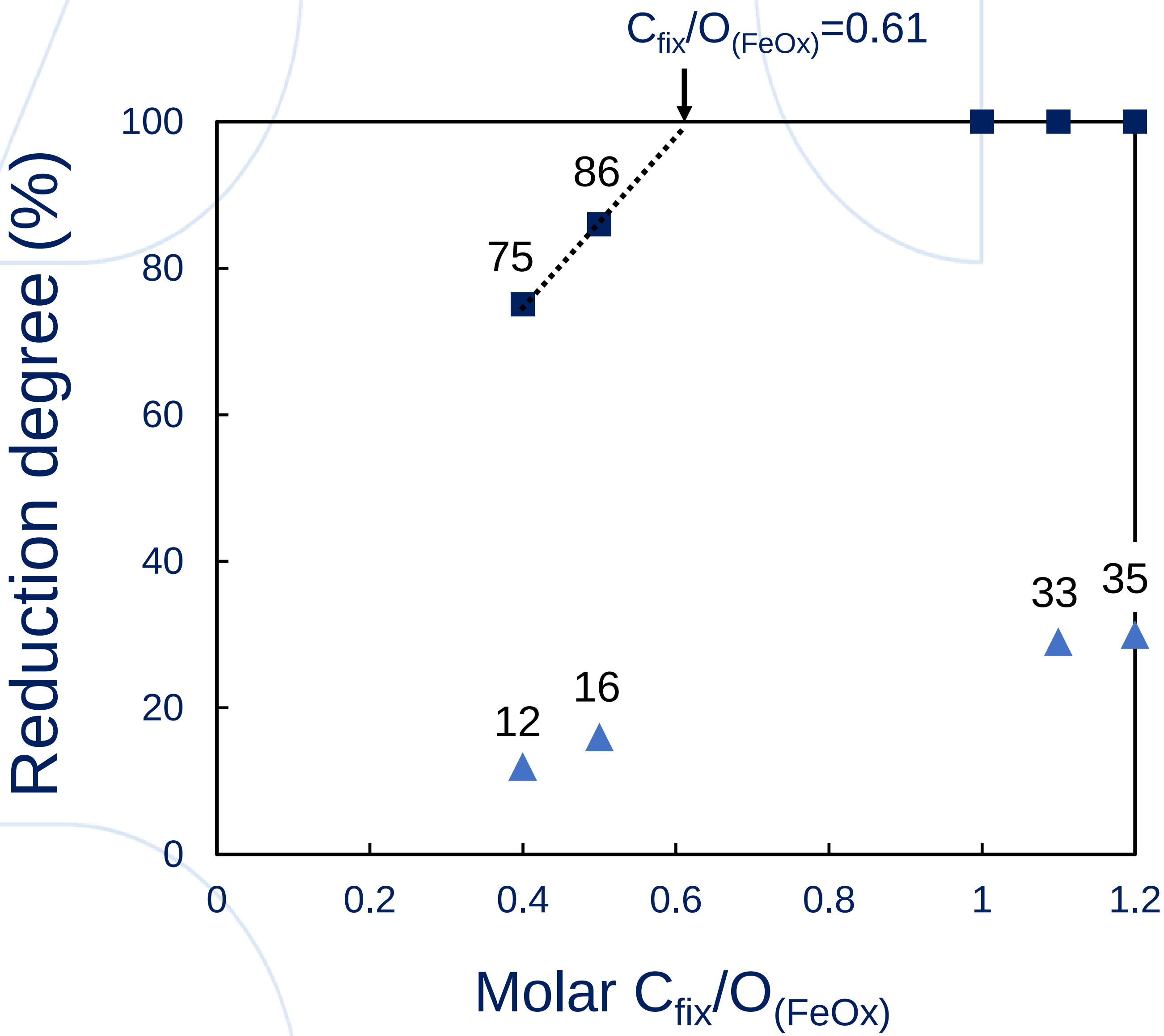


Weight loss of sample -TGA



Self-reduction



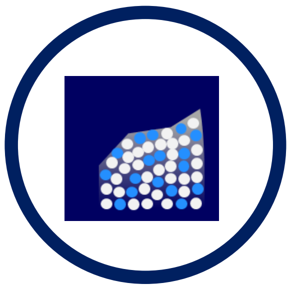
Reduction up to 1100 °C
= **Volatile** + **Fixed carbon**

Reduction up to 730 °C
= **Volatile** (**~50 wt%** utilized)

Lessons learned....

Carburization:

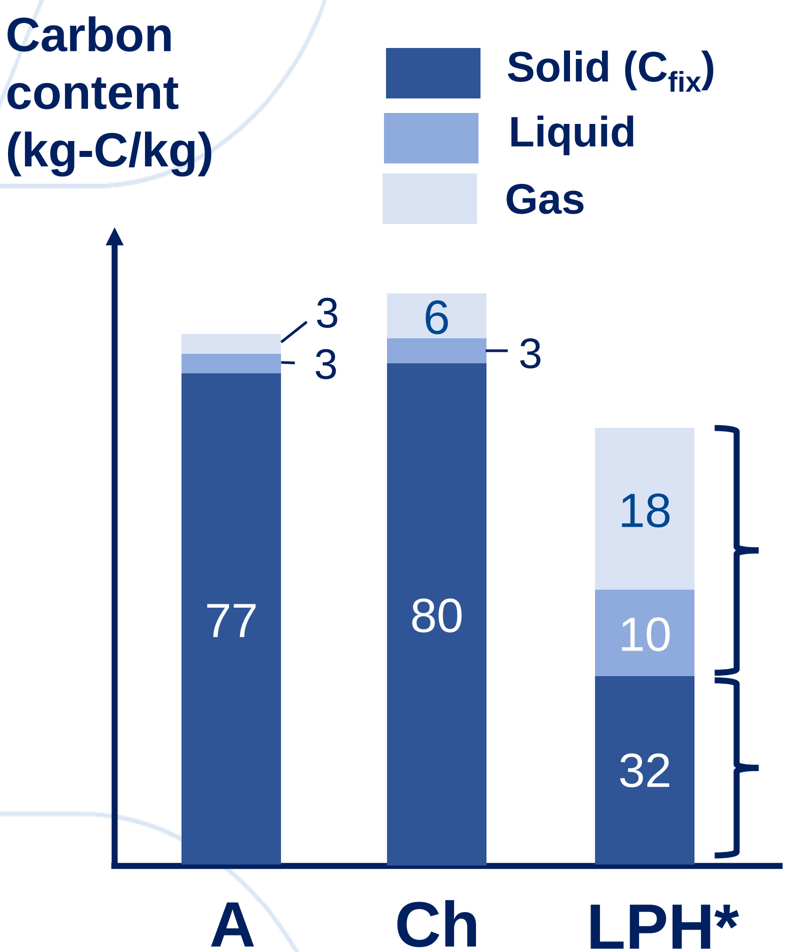
- Depends on **fixed carbon** content of material!
- **Fixed carbon yield** depends on addition method:
  Lab (~100%) > **Top-charge, EAF** (50-70%) > **Injection, EAF** (30-40%)



Self-reduction:

- Utilizes both **volatile matter** and **fixed carbon**!
- Volatiles reduced hematite by max. **35% up to wüstite** (**~50 wt%** volatile utilized!)
- Volatiles reduce the amount of fixed carbon required for reduction-
  $C_{fix}:O_{(FeOx)}$ = **1.0 → 0.6**

Coming back....



*Lemon peel hydrochar

To replace 1 kg of Anthracite....

Contributes to heating, slag foaming!

...requires ~ 1.7 kg hydrochar

30-70 wt% contributes to carburization

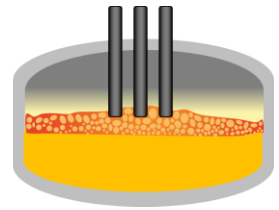
...requires ~ 2.4 kg hydrochar

Scope of work...

Hydrochar

in

EAF



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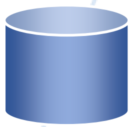
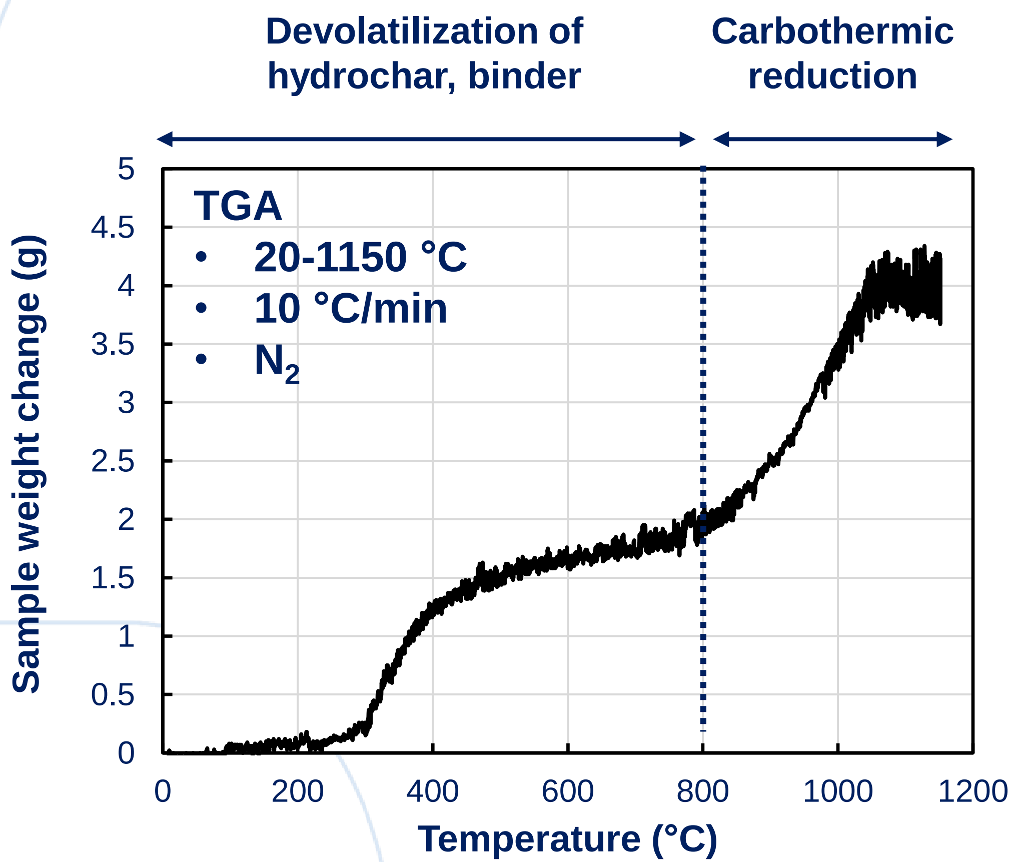
Self-reduction + slag foaming

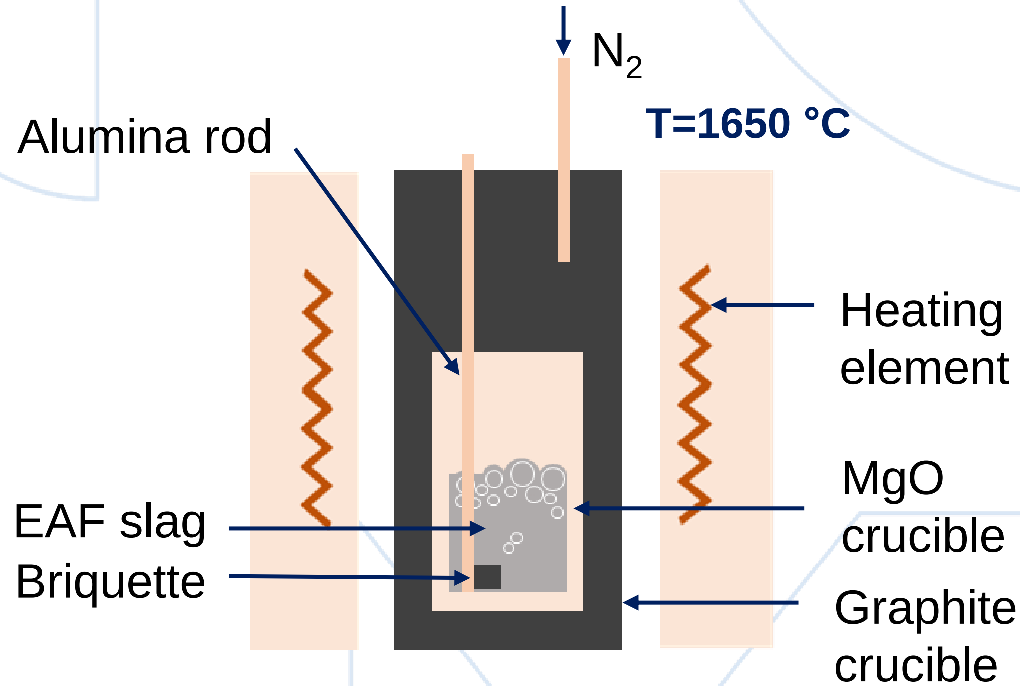


~20 g

Briquette:
- **Mill scale** (Fe_3O_4, FeO)
- **Hydrochar** (green waste)
- Binder
- Molar ratio - C_{fix}:$O_{(FeOx)}$ = **0.1-0.3**



Slag foaming setup



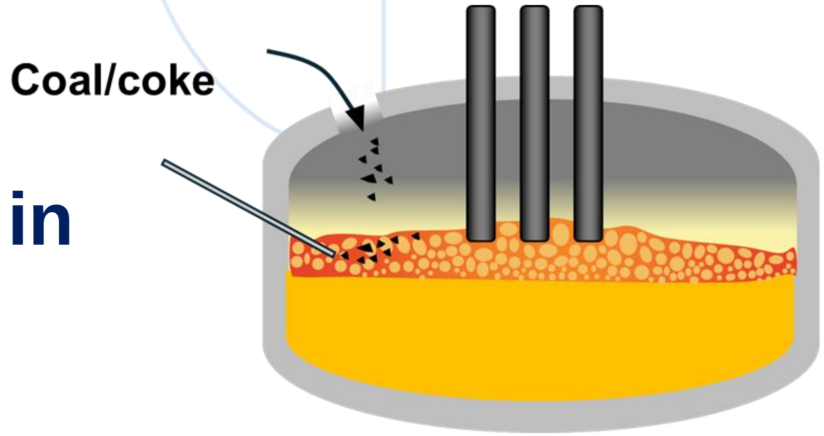
Slag height:

Summary

Hydrochar....

in

EAF



- Fuel
- Carburizing agent
- Reducing agent

- Can be produced from wide range of **low-grade biomass**
- High volatile, low fixed carbon
- Inefficient **carburizer**...(30-70% FC utilized)
- Great **reducing agent**! (Volatile + FC)
- Low S, relatively low ash, **high P -> extracted (BioReSteel)**

Contacts

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