GREENEAF: European Projects on Greener Steel via EAF and Biomass

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RWTH AACHEN UNIVERSITY

Introduction

Why start GREENEAF?

What to do in GREENEAF?

What are the results of GREENEAF?

Conclusions

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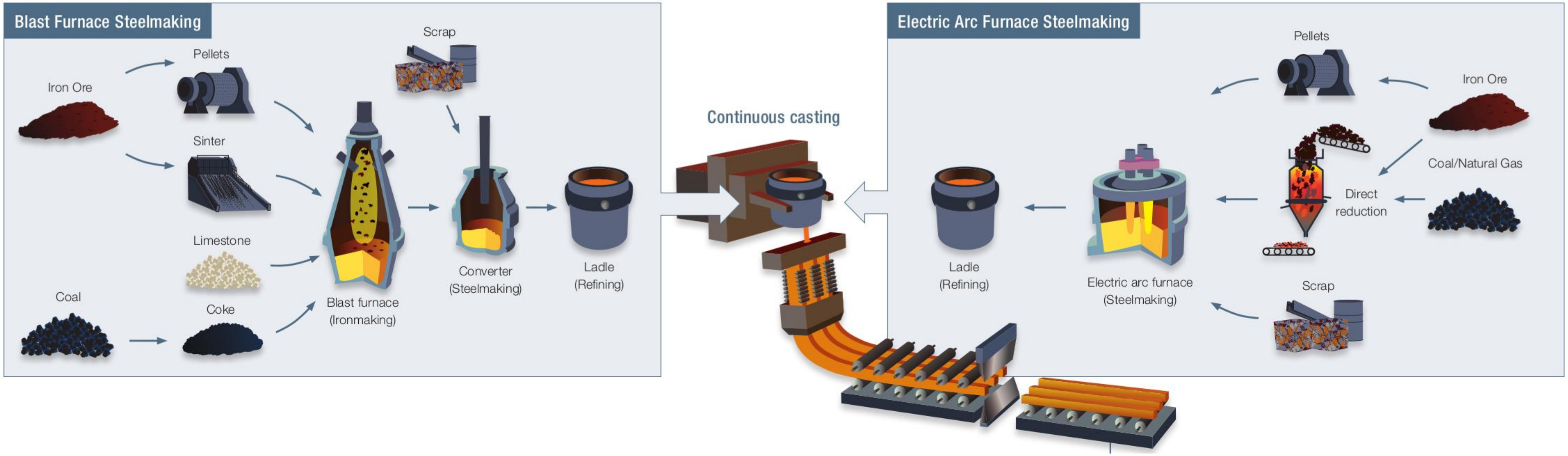
Why start GREENEAF?

Overview of the Steelmaking Process



Total Crude Steel Production 2013 and EAF share			
Germany	42.6 Mt	13.5 Mt	31.6 %
Europe	166.4 Mt	66.3 Mt	39.8 %
Canada	12.4 Mt	5.6 Mt	44.8 %

Source (image and data): worldsteel.org

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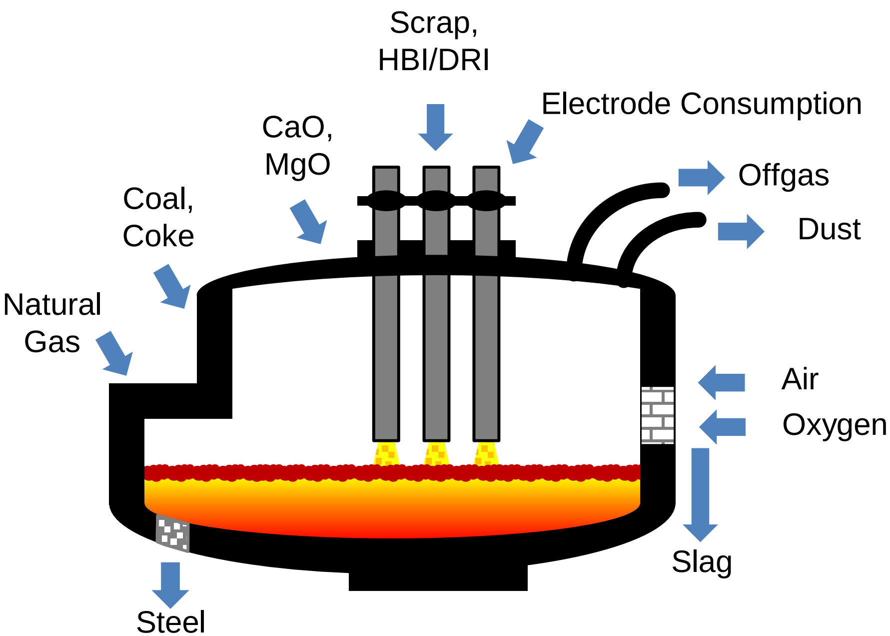
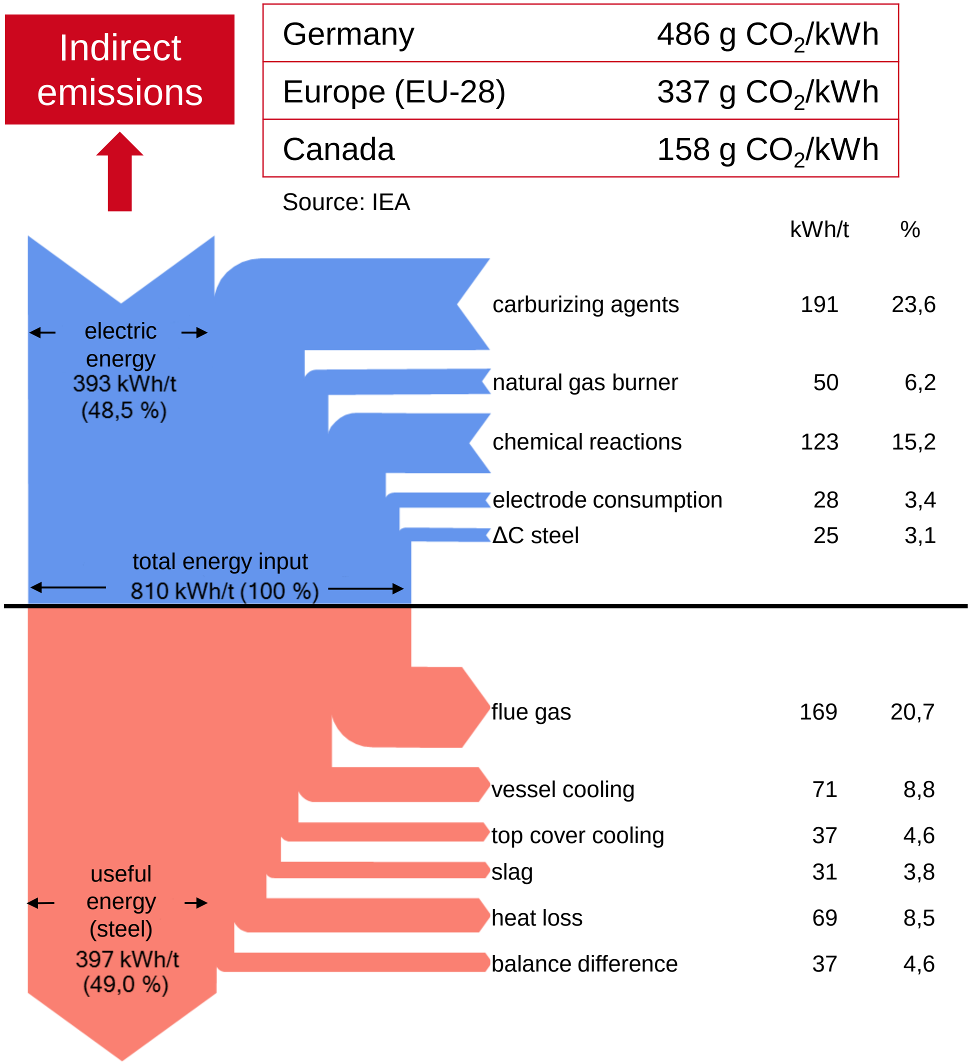
Why start GREENEAF?

Energy and mass balance

Germany	486 g CO_2/kWh
Europe (EU-28)	337 g CO_2/kWh
Canada	158 g CO_2/kWh

Source: IEA





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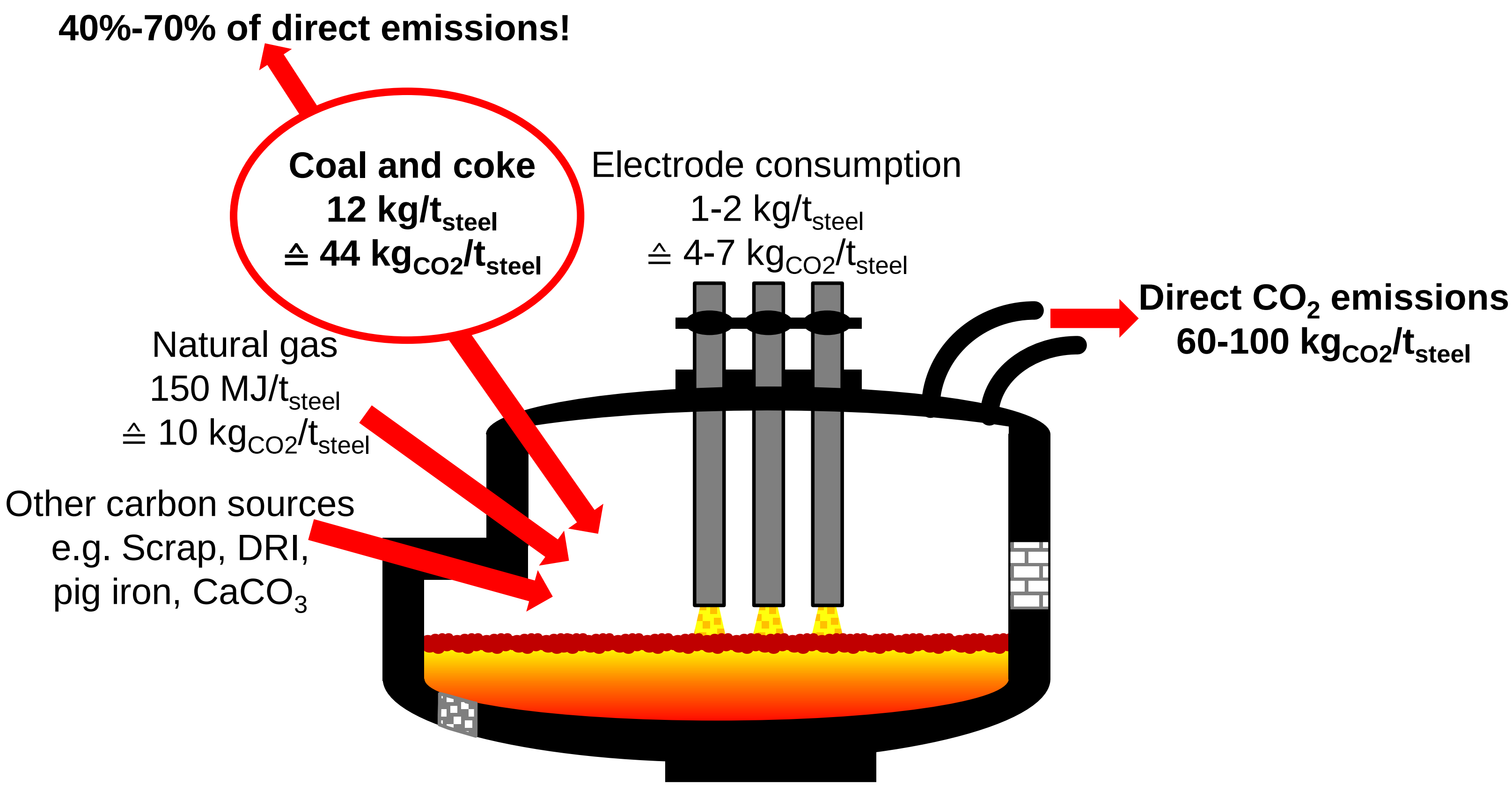
Energy and mass balance



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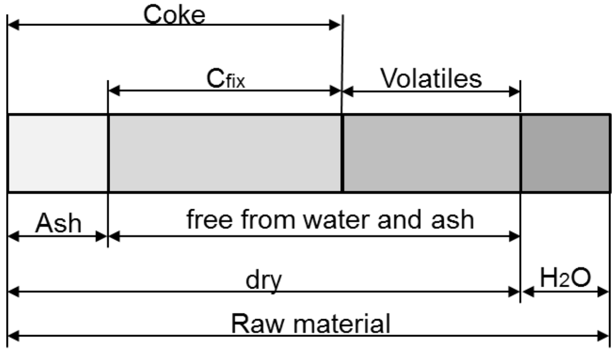
Why start GREENEAF?

Biomass and biochar compared to fossil coal

- Biomass is currently considered as CO_2 neutral by the European Commission[1]
- Different composition
  - 50 m.-% C
  - 40 m.-% O_2
  - 6 m.-% H_2
  - Rest: mineral substances and trace elements



- ➢ Lower heating value than fossil coal
- ➢ Higher proportion of volatiles (and water)
- ➢ Higher reactivity

[1] EU COMMISSION, Decision of 27 April 2011, Determining transitional Union-wide rules for harmonized free allocation of emission allowances pursuant to Article 10a of Directive 2003/87/EC of the European Parliament and of the Council, notified under document C ((2011) 2772), (2011/278/EU), Official Journal of the European Union, 05-17-2011

What to do in GREENEAF?

Sustainable EAF steel production – GREENEAF (2009-2012)

Biochar for a sustainable EAF steel production – GREENEAF2 (2014-2016)

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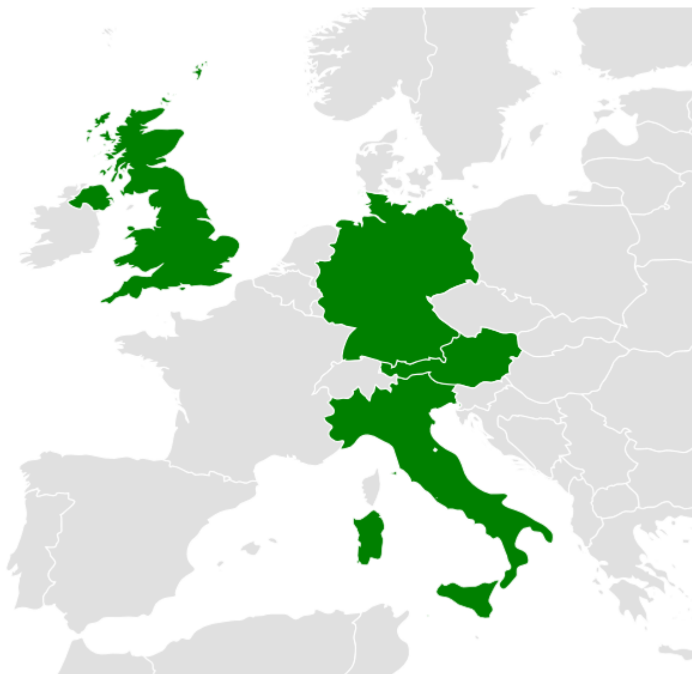
DEUTSCHE EDELSTAHLWERKE – Providing special steel solutions

MARIENHÜTTE STAHL-UND WALZWERK GMBH



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What to do in GREENEAF?

Sustainable EAF steel production - GREENEAF

Use of biochar in the EAF

Use of biogas in the EAF

Biomass selection

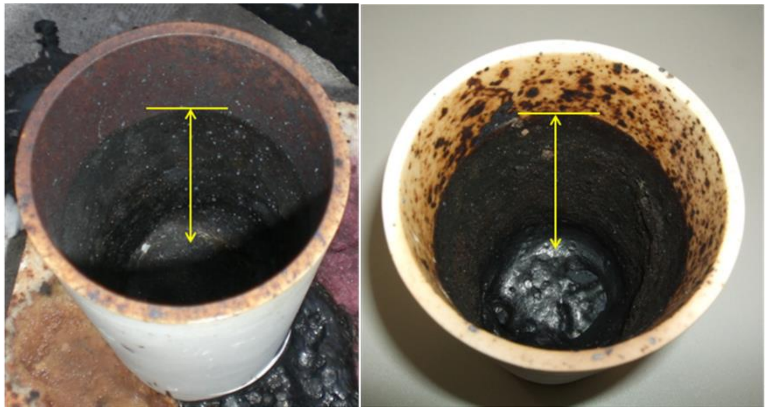
Pyrolysis process adjustment, char and biogas characterization

Laboratory and pilot plant tests

What are the results of GREENEAF?

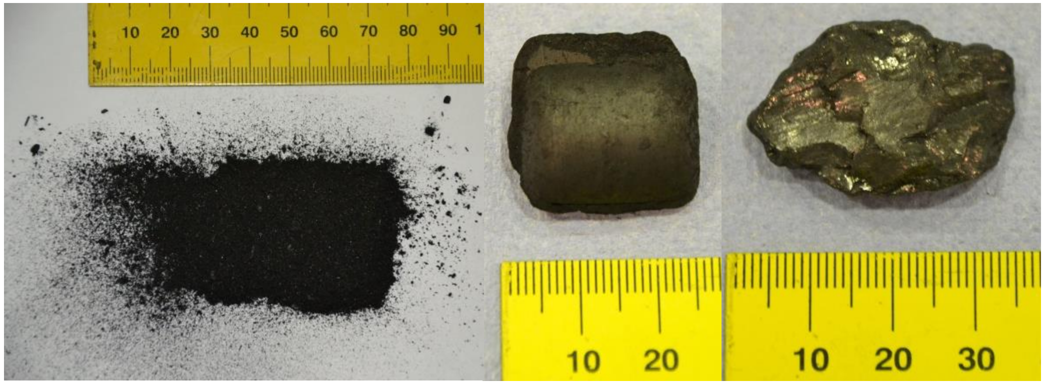
Laboratory and pilot plant tests

- Slag foaming tests in crucibles
- Melting trials in pilot EAF plant (600 kW, 200 kg melt)
- Agglomeration of biochar fines



Slag foaming tests with coal and with char

Tapping of a trial melt in the pilot EAF



Agglomeration of biochar fines

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What to do in GREENEAF?

Sustainable EAF steel production - GREENEAF

Use of biochar in the EAF	Use of biogas in the EAF

Biomass selection

Pyrolysis process adjustment, char and biogas characterization

Laboratory and pilot plant tests	Simulation of biogas use in the EAF
Industrial tests	

Techno-economic evaluation

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What to do in GREENEAF?

Biochar for a sustainable EAF steel production - GREENEAF2

Substitution of charge coal

Substitution of injection carbon

Char and briquettes acquisition and characterization

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Char and briquettes acquisition and characterization

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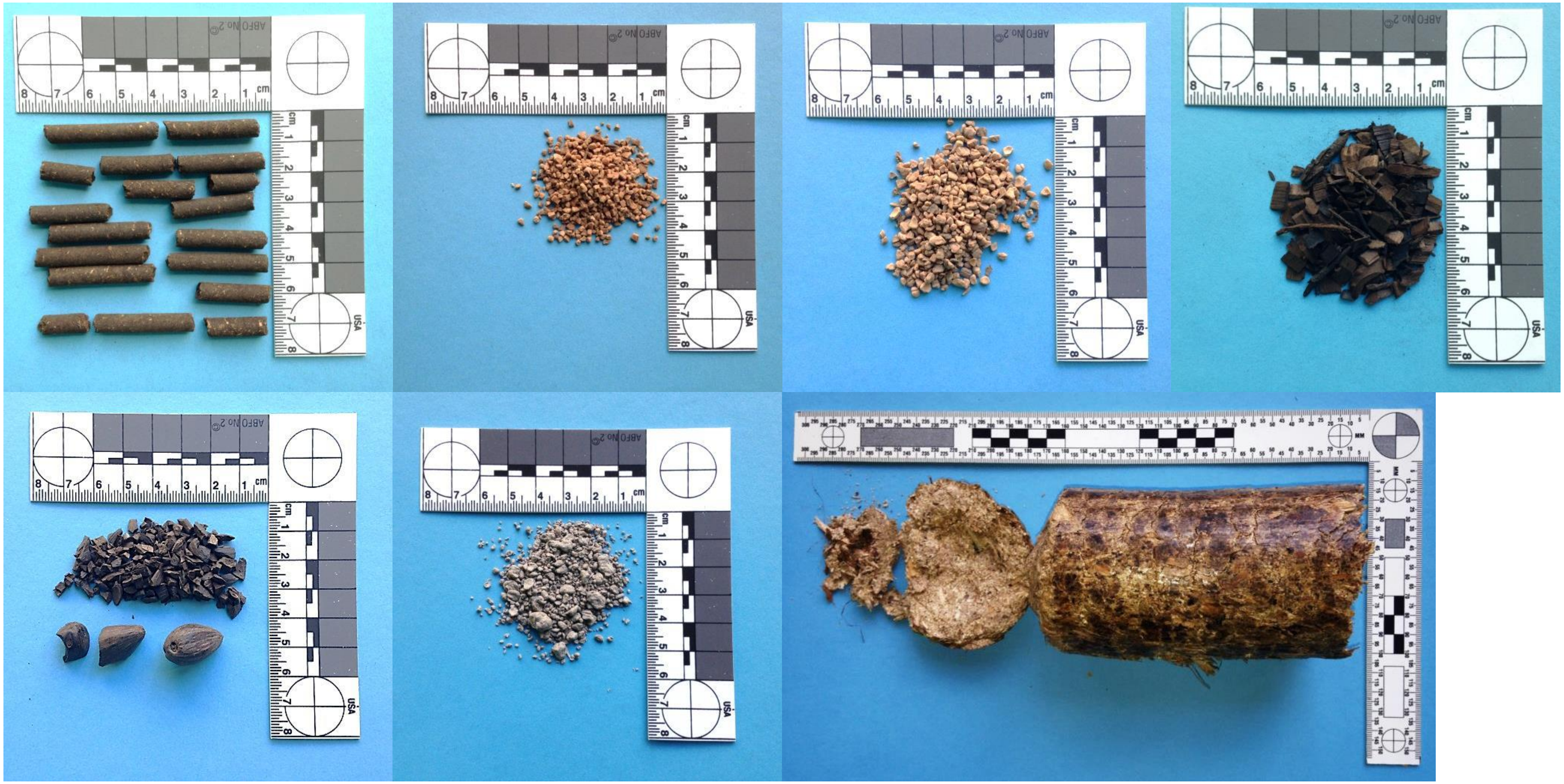
What are the results of GREENEAF?

Biomass acquisition and characterization



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What to do in GREENEAF?

Biochar for a sustainable EAF steel production - GREENEAF2

Substitution of charge coal

Substitution of injection carbon

Char and briquettes acquisition and characterization

Long time industrial tests of biomass charging

Development of char injection methodology

Industrial tests of char injection

What are the results of GREENEAF?

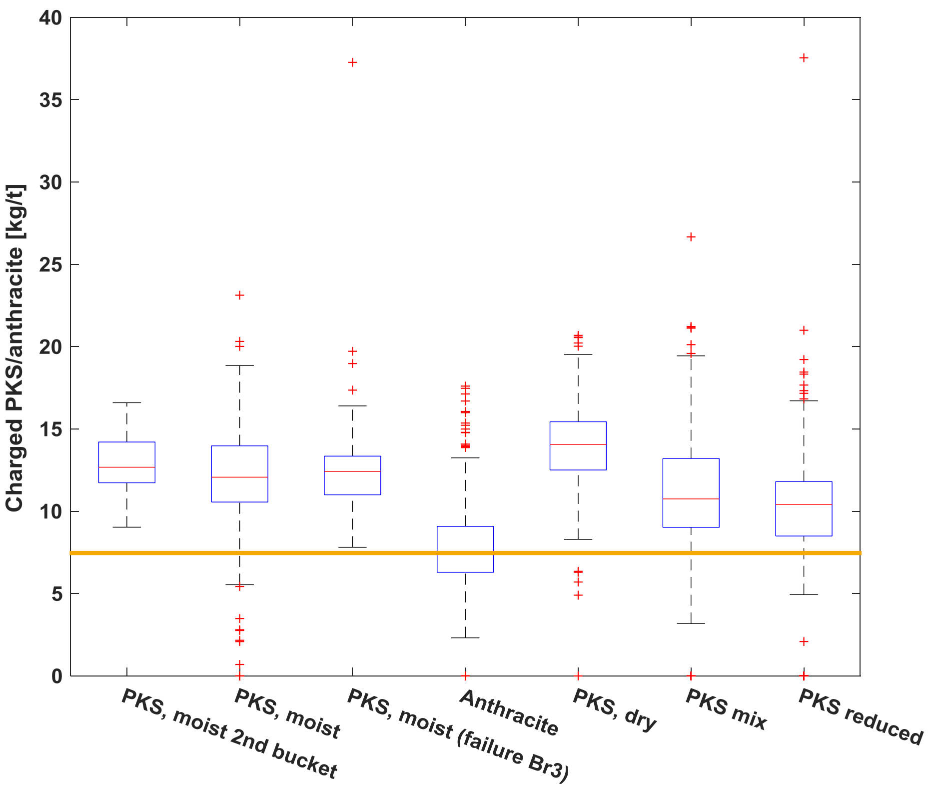
Charging trials – Palm kernel shells

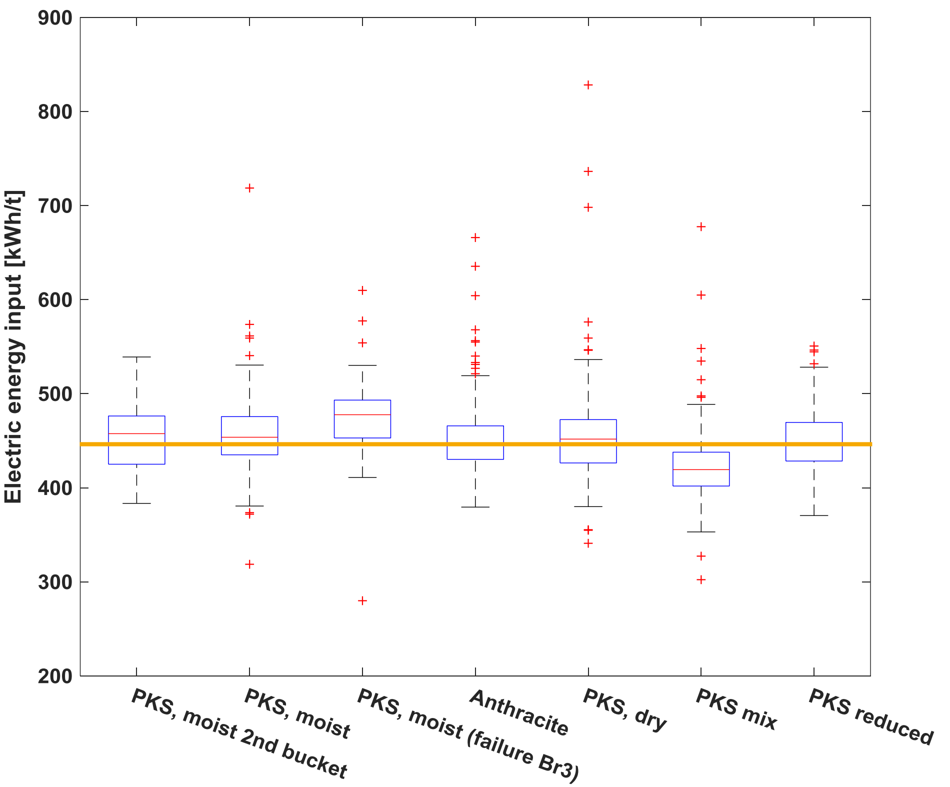
	C_{total} / C_{fix} (%)	Volatiles (%)	Ash (%)	Heating Value (MJ/kg)	Sulphur (%)	Phosphor (%)
Anthracite	85-90 / -	8	10	29	1	0.01
PKS	43-55 / 28	63-72	2-4	16-19	< 0.005	0.04

Six campaigns consuming a total of 2,600 t of PKS and PKS mix respectively in 1542 heats accompanied by 374 reference heats.

What are the results of GREENEAF?

Charged PKS/anthracite and electric energy input per ton of steel

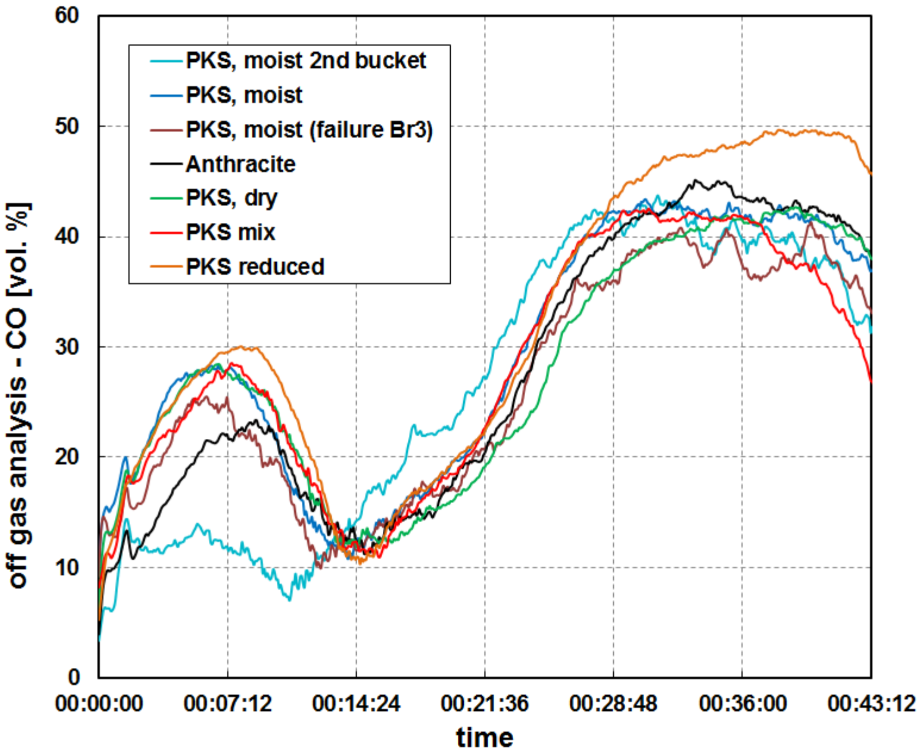


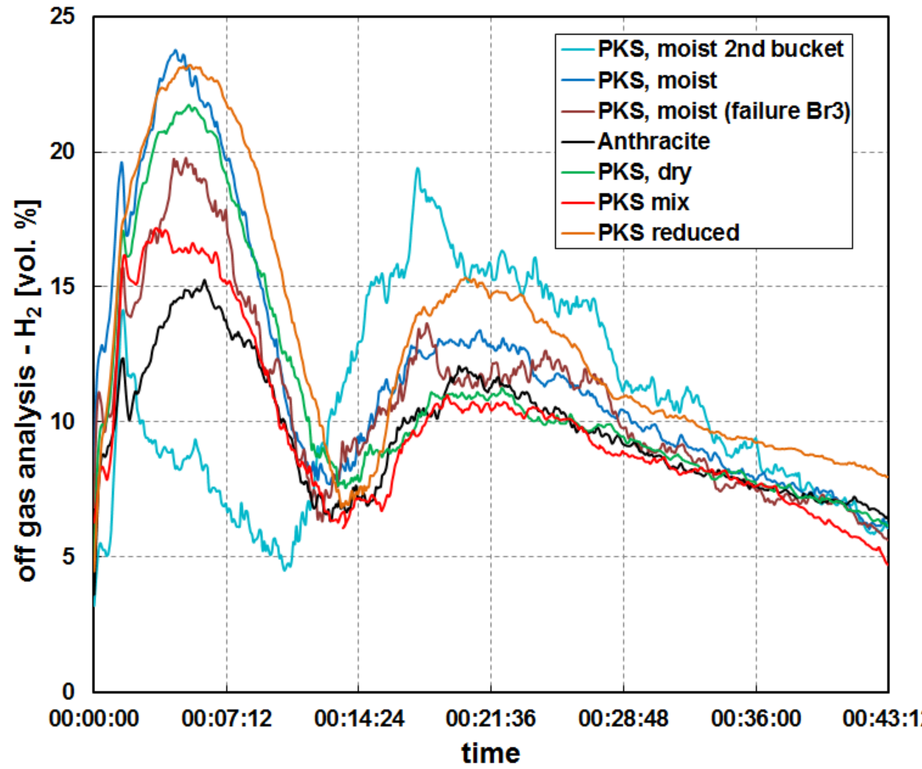


Source: Echterhof, T.; Demus, T.; Pfeifer, H.; Schlinge, L.; Schliephake, H., Investigation of palm kernel shells as a substitute for fossil carbons in a 140 t DC Electric Arc Furnace, 11th European Electric Steelmaking Conference & Expo, 25.-27. Mai 2016, Venice, Italy

What are the results of GREENEAF?

Averaged CO and H_2 concentrations in the off gas





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Biochar for a sustainable EAF steel production - GREENEAF2

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Industrial tests of char injection

LCA assessment

Evaluation of project results and definition of EAF operating practices designed for biochar/biomass utilization

Conclusions

Technical

- EAF steelmaking is a complex batch process with a very high variability from batch to batch but also a high flexibility. Each plant is unique in the steel grades it produces in combination with the equipment it has available
- Operating practices have to be adjusted to biomass/biochar behaviour in the furnace (e.g. use of post-combustion oxygen has to be adjusted)
- Biochar fines are not suitable as a substitute for fossil charge carbon, because of their very large surface area and high reactivity
- Agglomeration tests showed that it is possible to produce briquettes of biochar, which have similar characteristics as anthracite coal with regard to abrasion tests and combustion behavior
- Slag foaming is in general possible, but needs further R&D
- None of the trial campaigns with CO_2-neutral biochar and biomass used as charge carbon showed any negative impact on steel or slag quality or furnace operation

Conclusions

Emissions

- Use of CO_2-neutral biomass or biochar can avoid CO_2 emissions relevant for the EU ETS in the range of 12 % to 60 % of the total emissions per ton steel
- The replacement of fossil coal with biochar can avoid a large proportion (up to 70 %) of direct CO_2 emissions of the EAF steelmaking process
- From a European perspective, 4 million t_{CO2} could have been saved by the ten biggest European electric steel producers in 2010

Potential CO_2 savings (2010)[2]

	EAF steel production	Potential CO_2 savings	
Germany	13.2 Mt	22.7 %	0.8 Mt
Canada	5.5 Mt	39.5 %	0.3 Mt

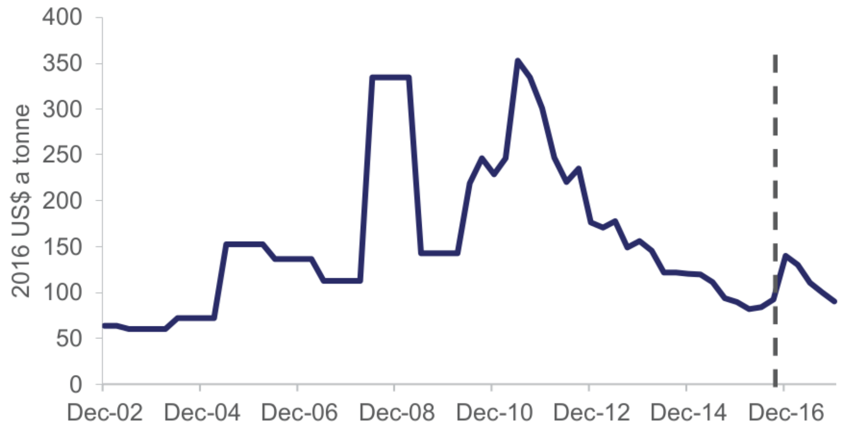
[2] Demus, T.; Reichel, T.; Echterhof, T.; Pfeifer, H.: Biochar Usage in EAF-Steelmaking Potential and Feasibility, 1st European Steel Technology & Application Days (ESTAD) & 31st Journées Sidérurgiques Internationales (JSI), 7.-8. April 2014, Paris, France

Conclusions

Economy

- Economic feasibility of fossil coal substitution depends on steel grades produced, operating practices and furnace equipment due to possible impacts on productivity
- Due to low prices for fossil coal and EU emission allowances (EUA) and an insufficient biochar market the substitution of fossil coal with biomass or biochar is currently not economic in Europe
- In the future, especially the use of biogenic residues could have a positive effect on the economics of the coal → biochar substitution
- Rising prices for fossil coal or the expected rise of prices for EUA's will change the economy of biomass/ biochar use in electric steelmaking in Europe

Benchmark contract prices for Australian metallurgical coal



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Thank you
for your attention

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