Simulation, Modelling, and Monitoring of Plasma and Arc-Based Processes for Green Metal Production

ESTEP 2024
Annual Event

Comparison of HPSR and Hy4Smelt with primary BF-BOF route

Hamideh Hassanpour, Christine Gruber

29.10.2024

ESTEP
European Steel Technology Platform
20 years together

H2 FOR GREEN STEEL
3rd INTERNATIONAL CONFERENCE
meets
A CIRCULAR ECONOMY DRIVEN BY THE EUROPEAN STEEL

voestalpine
ONE STEP AHEAD.

PRIMETALS TECHNOLOGIES

Outline

(1) Steel Industry

- Crude steel production
- Current CO_2 emission

(2) Hydrogen-based Steel Making Processes

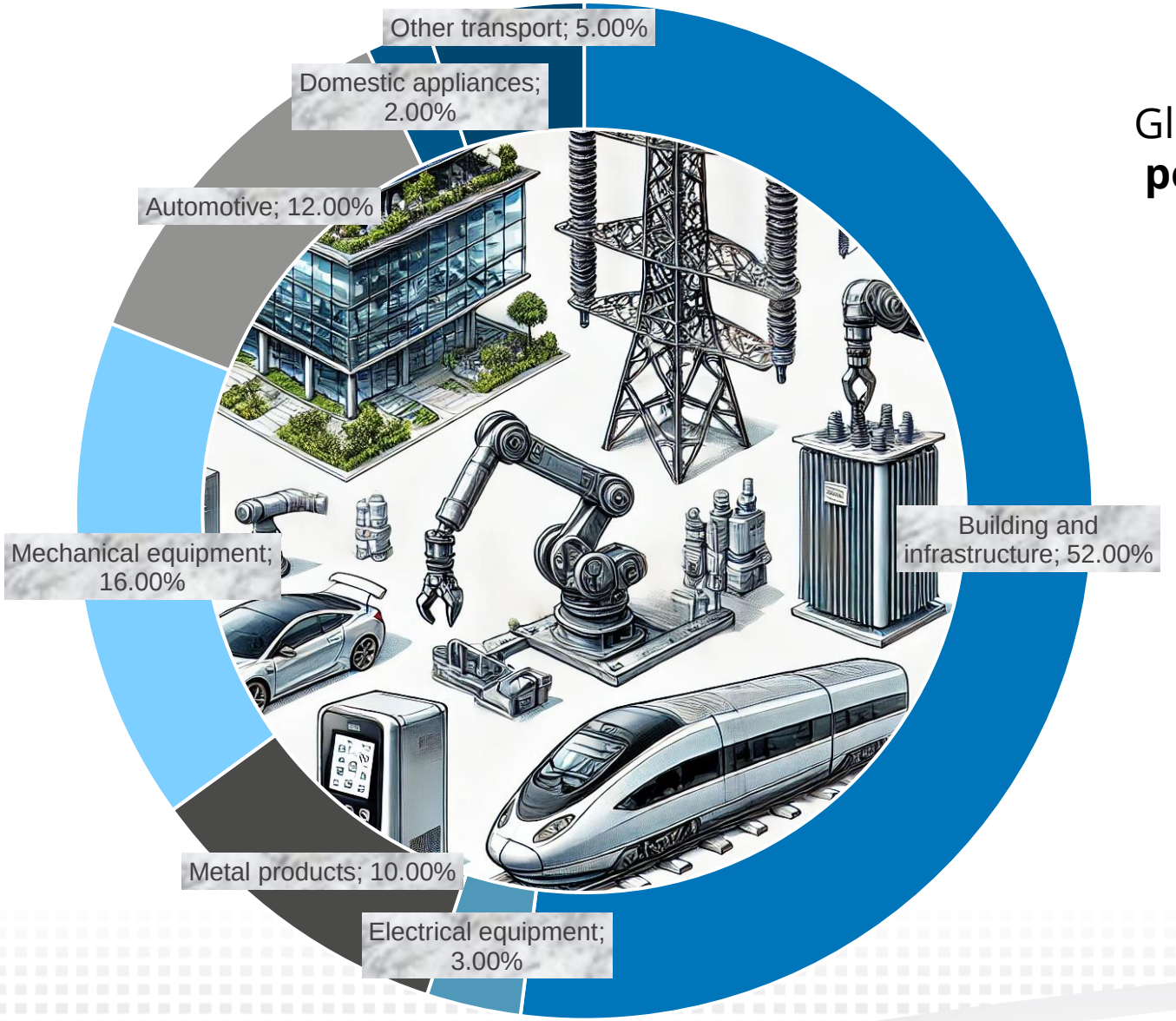
- HY4Smelt
- HPSR

(3) Environmental Impact

- CO_2 emission
- Energy demand
- Research goals

(4) PlasmArc4Green

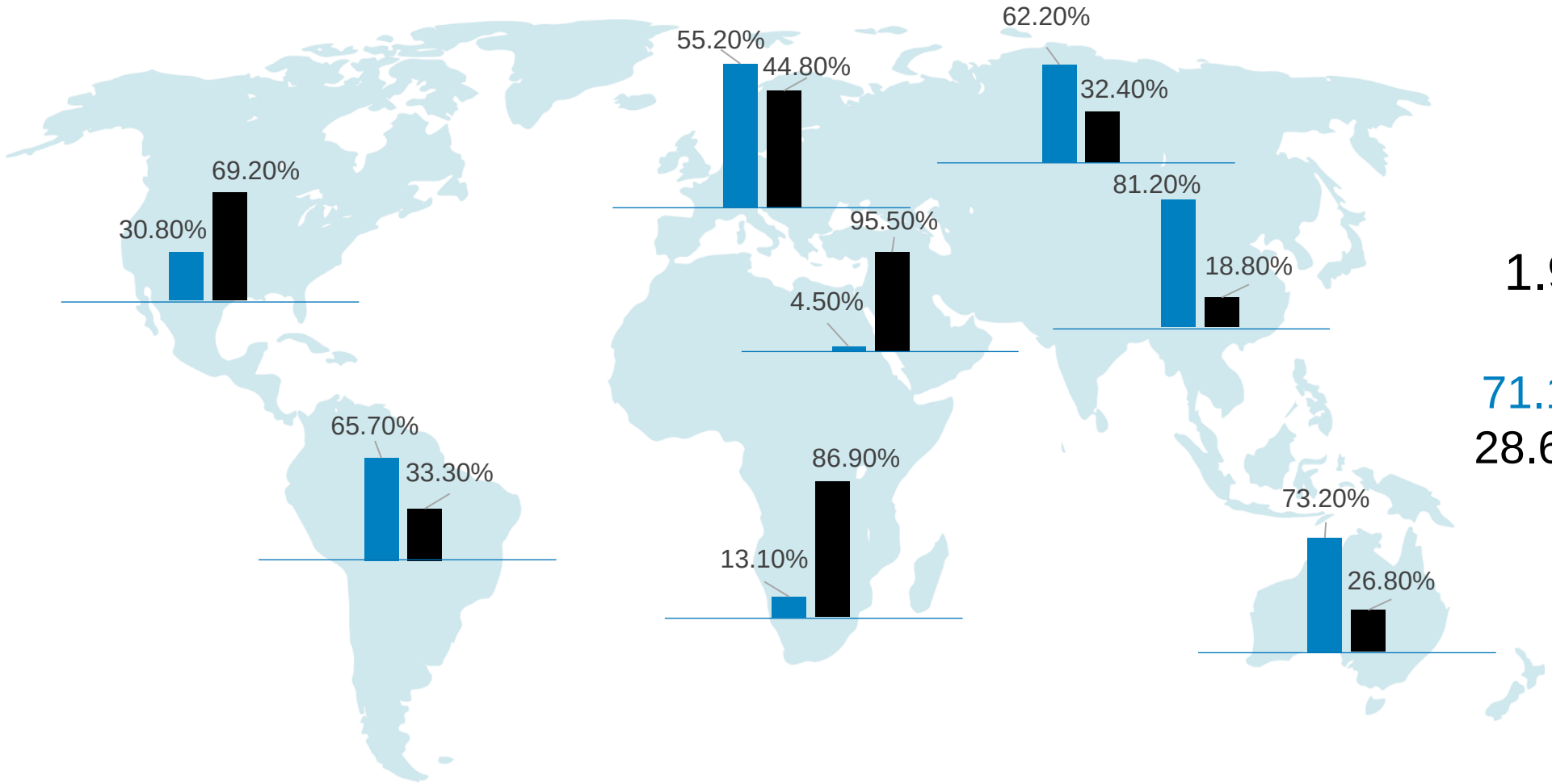
Steel use by sector



Globally, **219 kg of steel** was used in new products **per person in 2023**

Current status of steel industry worldwide

Crude steel production world wide



split-up 2023

1.9 bt crude steel

71.1 % BF-BOF route

28.6 % DRI-EAF route

0.3 % Other

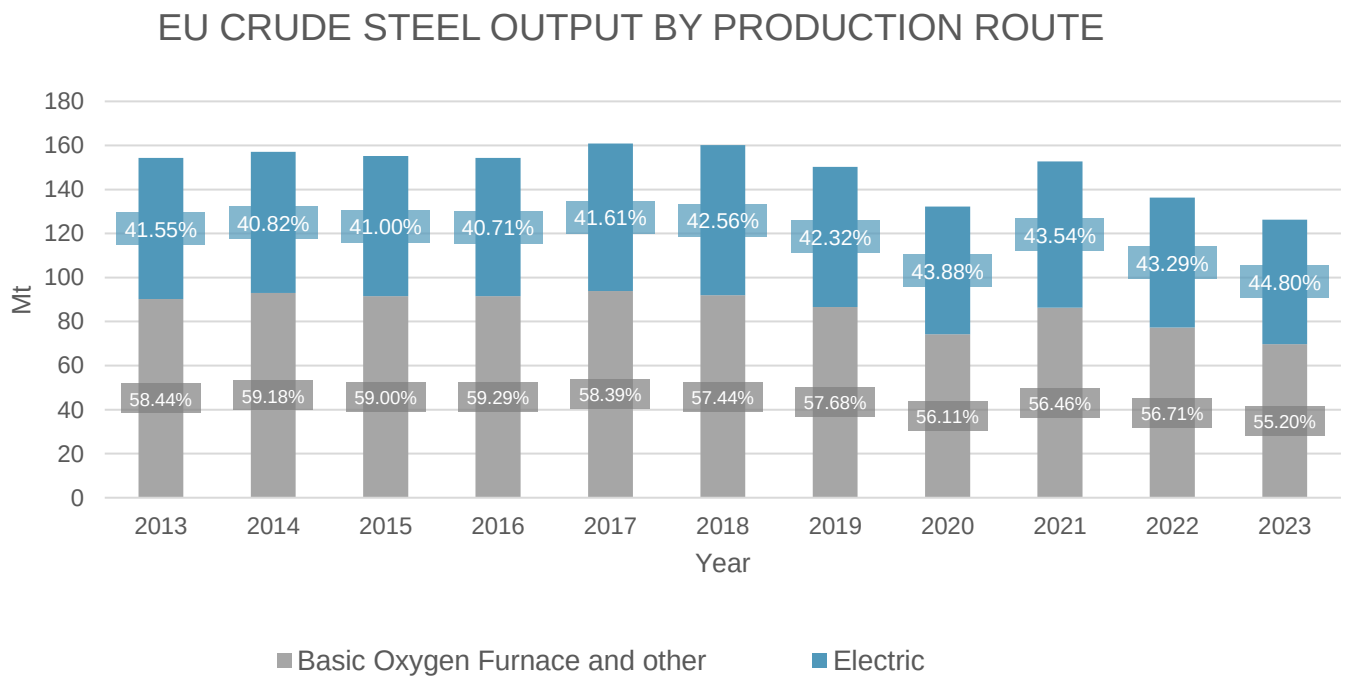
BF-BOF: **B**last **F**urnace-**B**asic **O**xygen **F**urnace
DRI-EAF: **D**irct **R**educed **I**ron- **E**lectric **A**rc **F**urnace

Source:world-steel 2024

Production

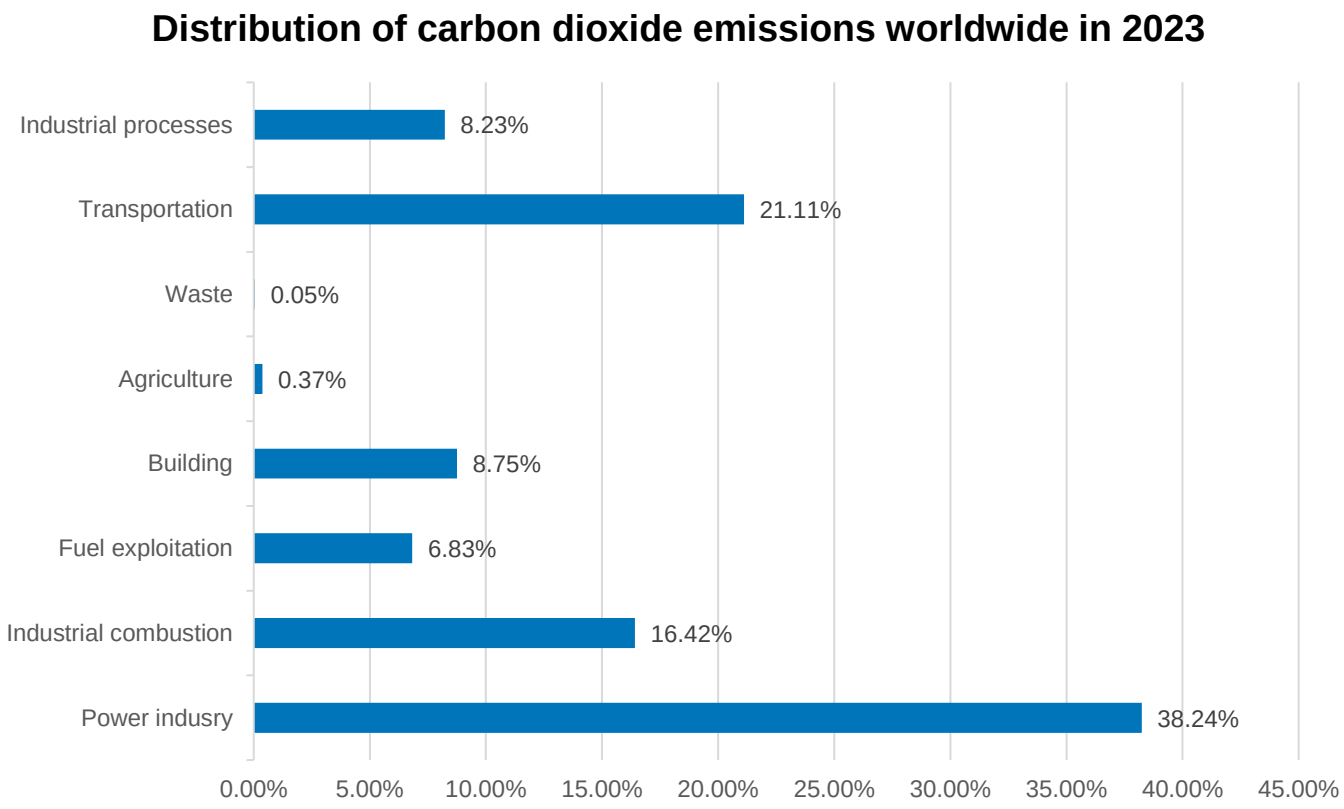
EU crude steel production over time

Column1	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023
Basic Oxygen Furnace and other (Mt)	90	93	92	91	94	92	87	74	86	77	70
Electric (Mt)	64	64	64	63	67	68	64	58	67	59	56
Total Crude Steel (Mt)	154	157	155	154	161	160	150	132	153	136	126



Source:www.eurofer.eu

Where are we on CO2 emission



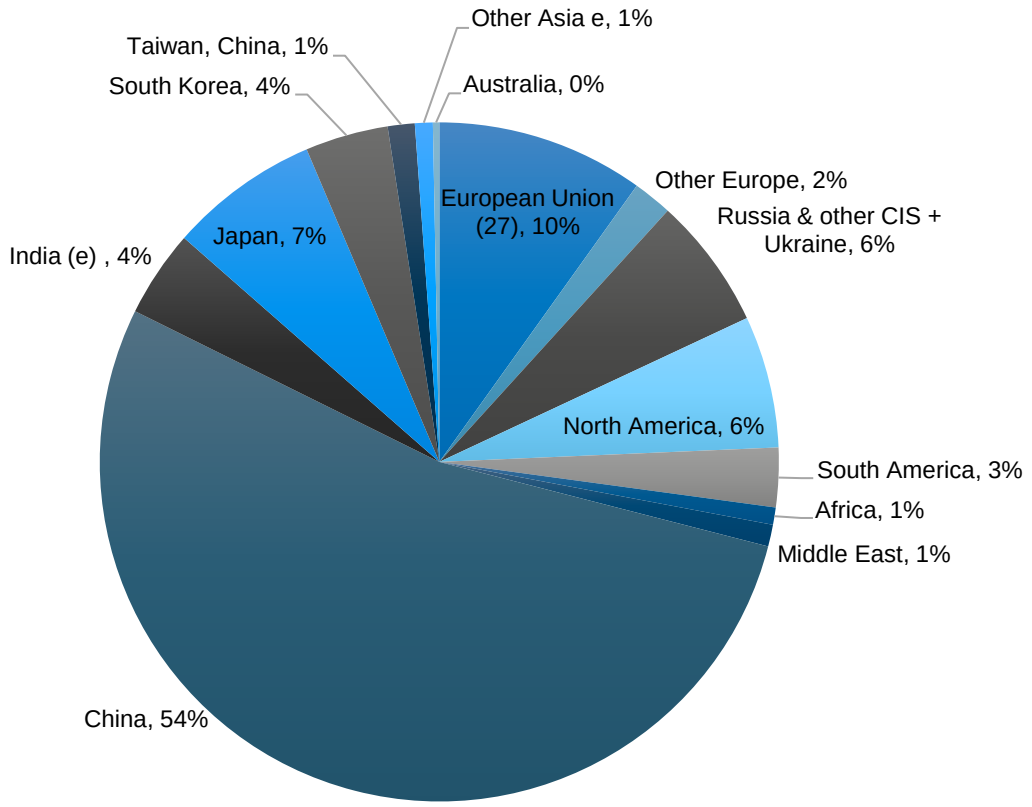
Steel industry is responsible for between **7%** and **9%** of global CO_2 emissions

Source:statista 2024

Total CO_2 emission in steel industry

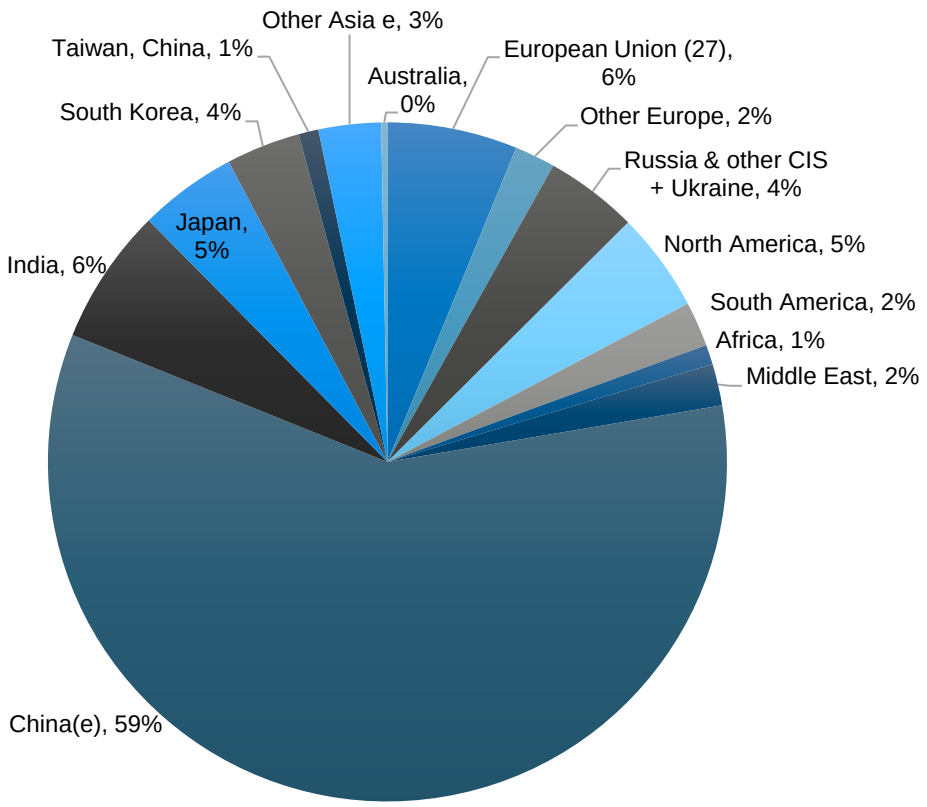
Comparison between 2013 and 2023

3271.34 Mt CO_2 (2013)



World CO_2-emmision per region 2013

3875.94 Mt CO2 (2023)



World CO_2-emmision per region 2023

European Union CO2 emission decreserd by **29%**

Source:world-steel 2024

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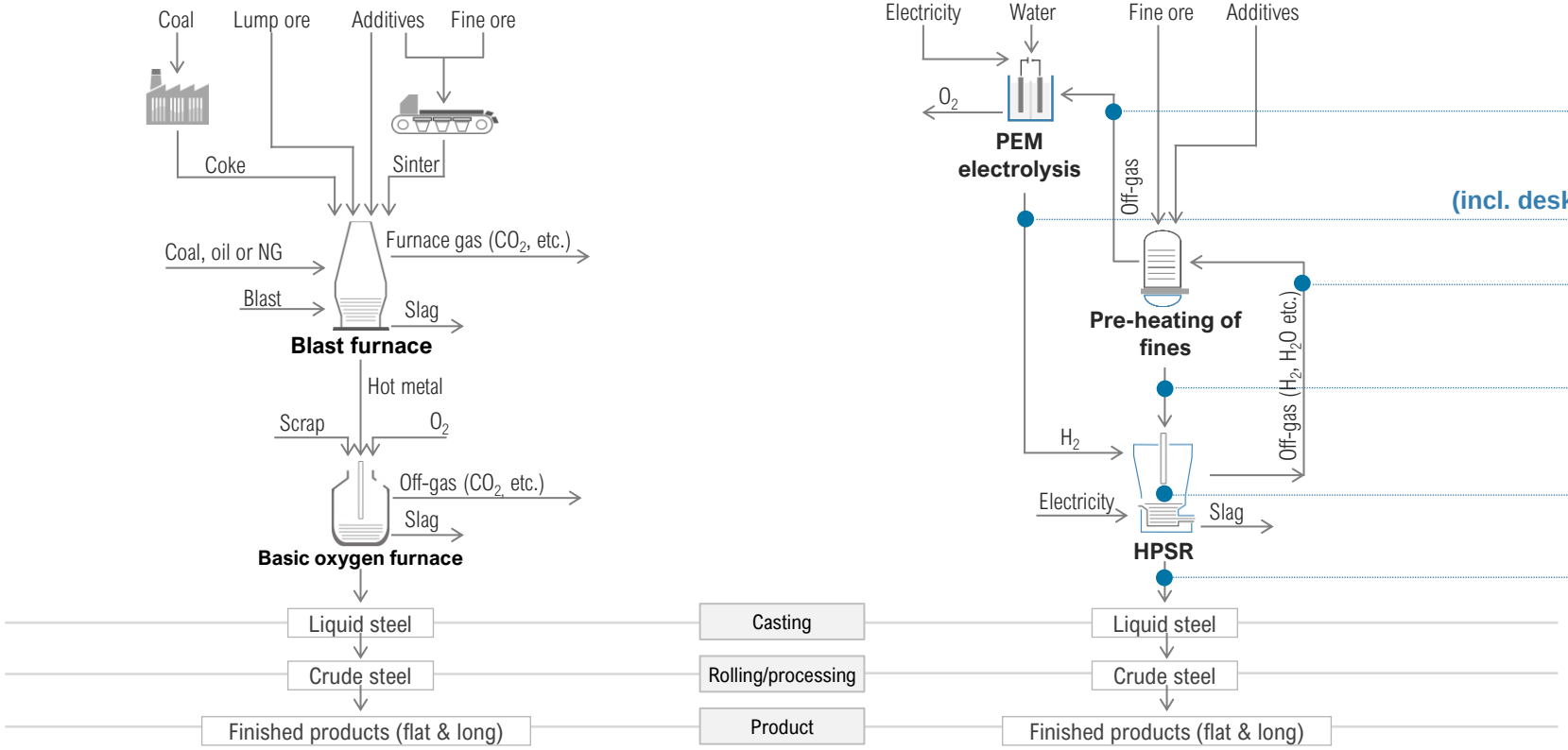
Overview of BF-BOF & HPSR

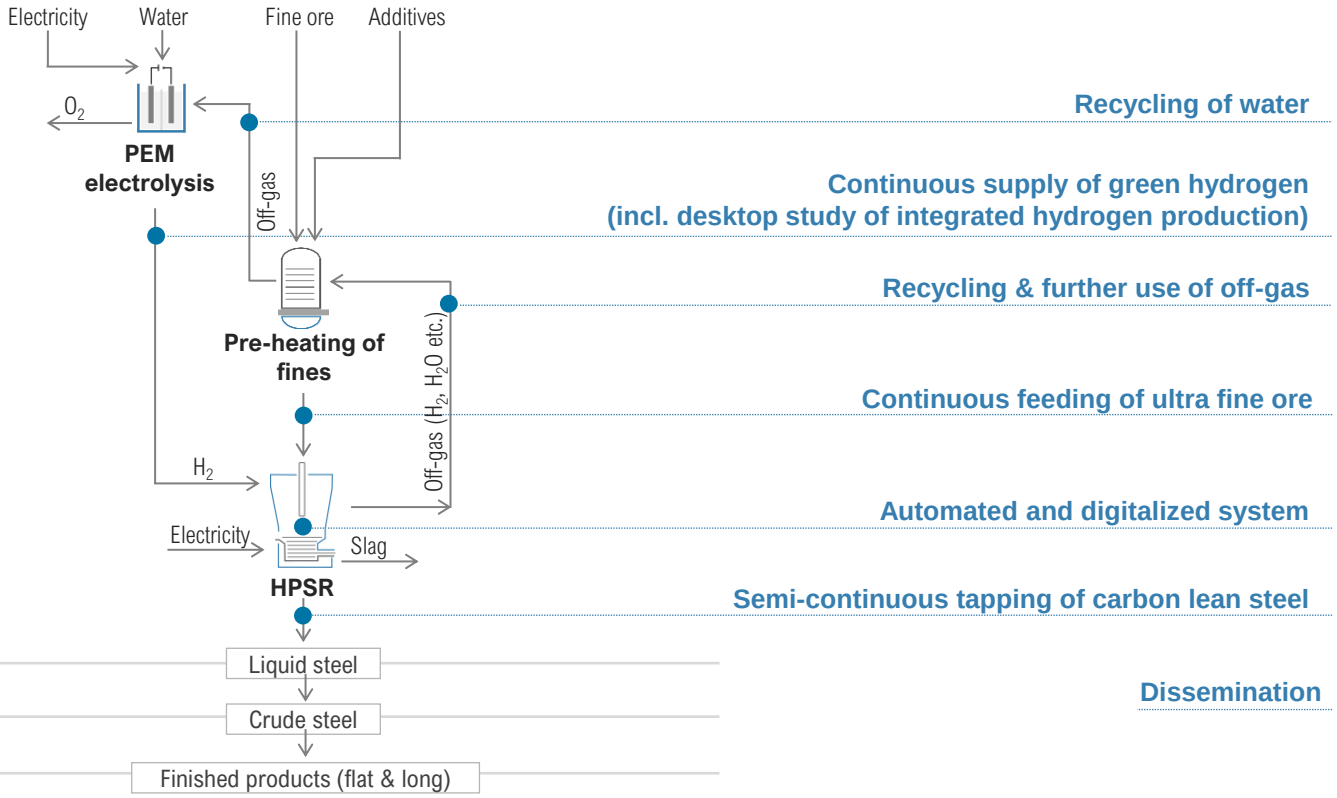
BF-BOF

Integrated route consisting of raw material preparation, blast furnace (iron making) and basic oxygen furnace (steel making)



HPSR

HPSR route consisting of green hydrogen supply, pre-heating of fines and HPSR

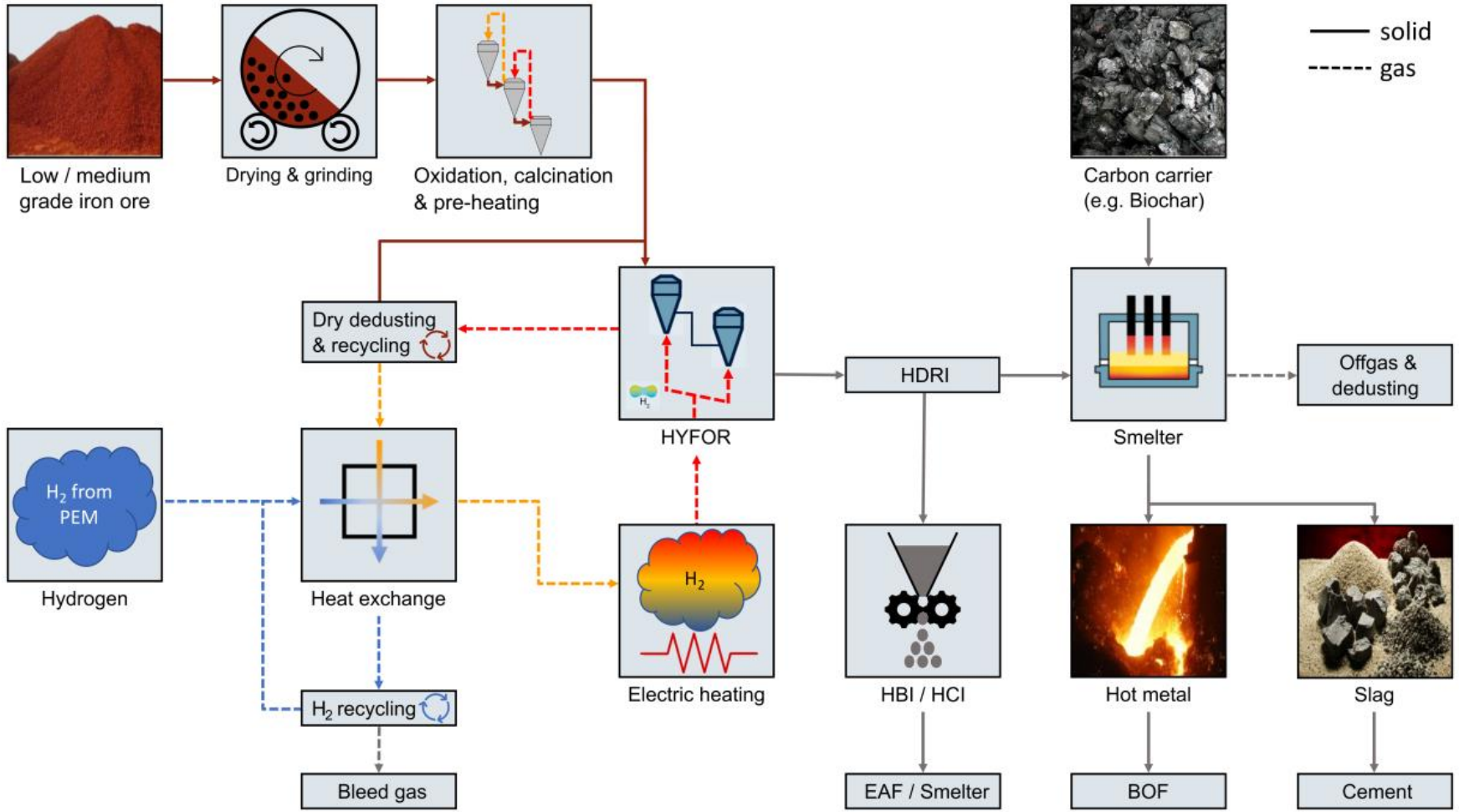


- Recycling of water
- Continuous supply of green hydrogen (incl. desktop study of integrated hydrogen production)
- Recycling & further use of off-gas
- Continuous feeding of ultra fine ore
- Automated and digitalized system
- Semi-continuous tapping of carbon lean steel
- Dissemination

HPSR: **H**ydrogen **P**lasma **S**melting **R**eduction

Source:SuS-F project

Overview of Hy4Smelt



- Iron ore pre-processing (heating and oxidation)
- Iron ore composition prior to the HYFOR reactor is homogenous

HYFOR:

- H2-based direct reduction
- Metallization of up to 97 %

Smelter:

- Methodology of DRI processing
- Continuous operation

Hy4Smelt:

- **avoids** any kind of **agglomeration** and enables the use of low/medium-grade ores to produce green hot metal
- can be fully integrated in an existing BF steel plant

Source: Hy4Smelt technical description (part B)

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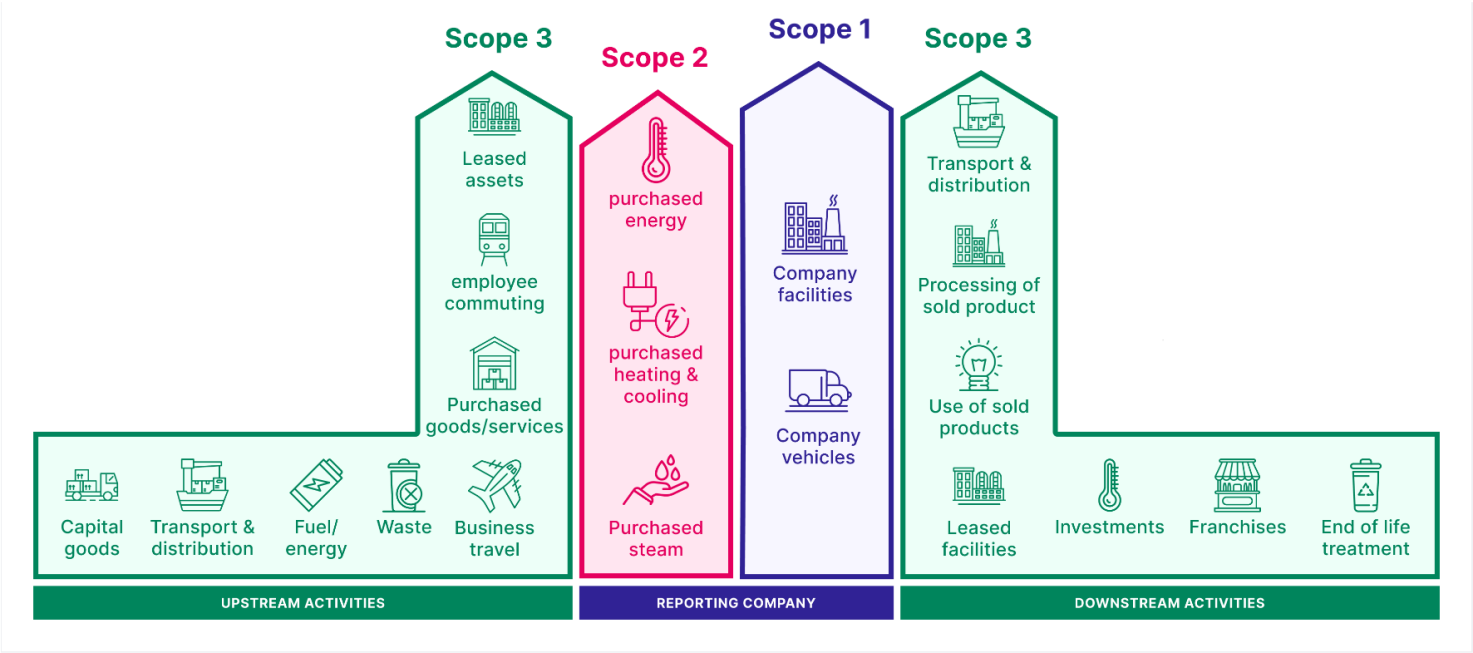
Environmental impact

CO_2 emission

Plant	Scope 1 Emissions (kg CO_2 /t HM)	Scope 2&3 (kg CO_2 /t HM)[1]
BF	1678	358
Hy4Smelt Industrial	0 (theory)	272

[1] **100 % CO_2 savings possible,** once **Scope 2 and 3 emissions of input resources** are eliminated



Source:HY4Smelt technical report

Energy evaluation

Per metric tonne of hot metal

	BF	HY4Smelt	HPSR
Hydrogen	0	60 kg	65 kg
Electric energy	200 kWh	2000-2150 kWh	1500-2000 (e) kWh
Carbon	470 kg	100 kg	<10 kg
Total power (round numbers)	4025 kWh	4800-4950 kWh	3700-4300 kWh
Technology readiness level	Industrial	7-8	5
CO2 reduction	0 %	80 %	90 %

Estimated

- HY4Smelt is developed to replace **BF** route
- HPSR is developed to replace **BF-BOF** routes
- Preparation of materials sintering and pelletizing

Source:HY4Smelt technical report, HPSR-the vision of Green steel 2024

Research Goals and Strategic Directions

Ensure Environmental Sustainability

- Decarbonize steel production to support CO_2-neutrality by 2050
- Ensure industry success by adapting to changing market and regulatory demands

Overcome knowledge gap

- Predict arc behavior and interactions with molten metal baths
- Understand the role of various gas mixtures
- Study plasma composition and temperature

Develop high-fidelity simulation models

- Complex physics of arcs
- Movement of cathode spot
- Plasma behavior
- Magnetohydrodynamics: evaluate the effect of magnetic field on arc stability

Realize real-time control and optimization

- Adjust operating parameters
- Minimize energy usage and CO2 consumption

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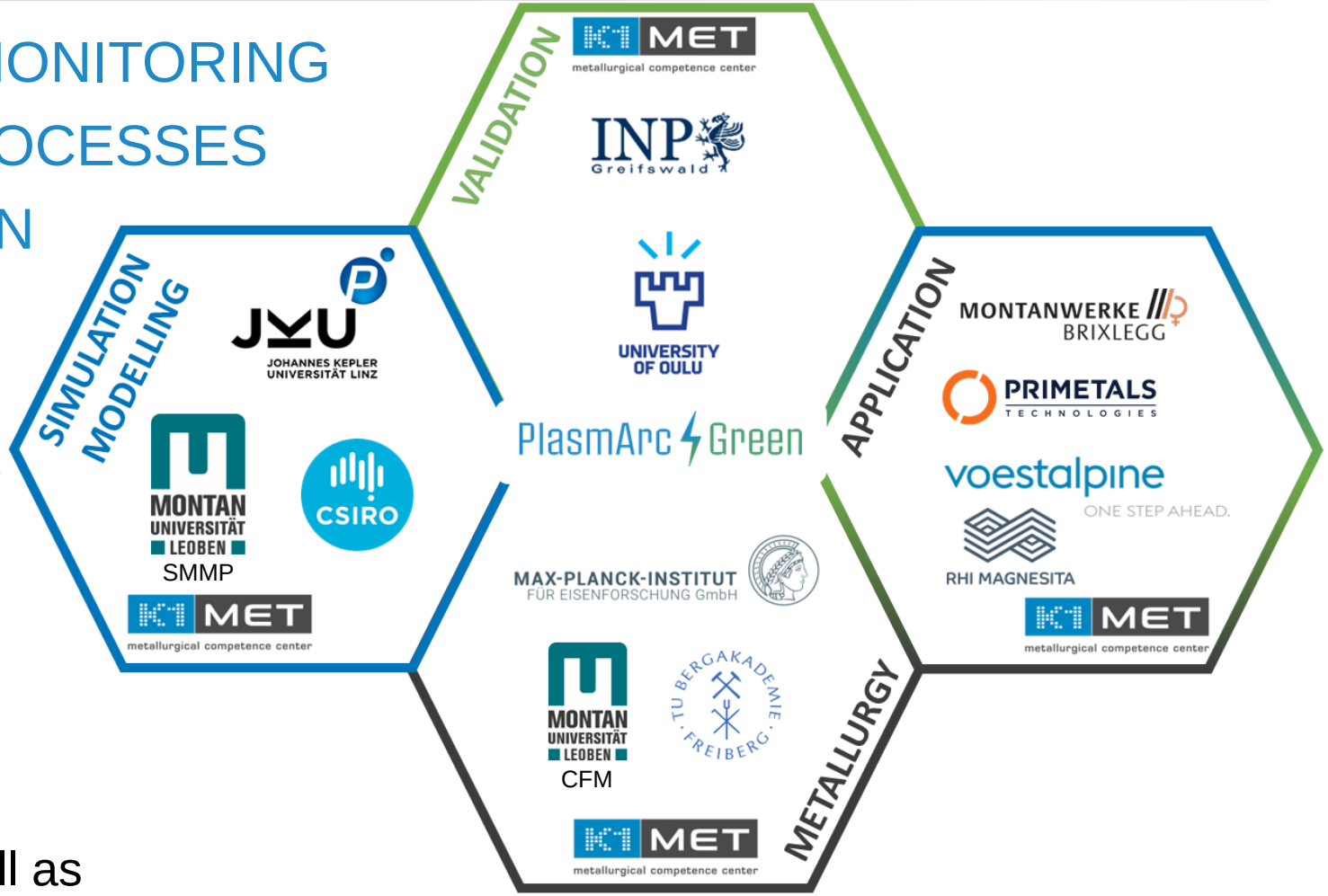
PlasmArc Green

FFG COMET Module (July 2024 – June 2028)

K1 MET metallurgical competence center

SIMULATION, MODELLING AND MONITORING OF PLASMA AND ARC BASED PROCESSES FOR GREEN METAL PRODUCTION



Coordinator:
K1-MET, Magdalena Schatzl

FFG Promoting Innovation.

Federal Ministry Republic of Austria Labour and Economy

Federal Ministry Republic of Austria Climate Action, Environment, Energy, Mobility, Innovation and Technology

Participants:

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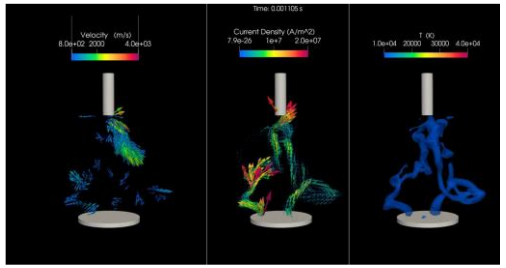
Funded by: BMK, BMAW as well as federal provinces of Upper Austria, Styria and Tyrol

COMET Module PlasmArc Green

Plasma modelling and experimental validation

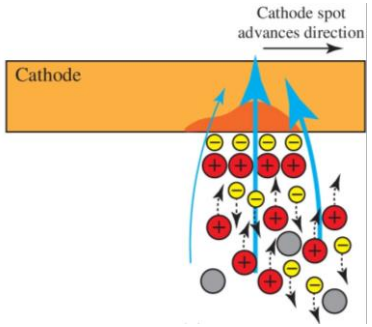
metallurgical competence center

- **Project 1 – Bulk Plasma Properties and Dynamics**



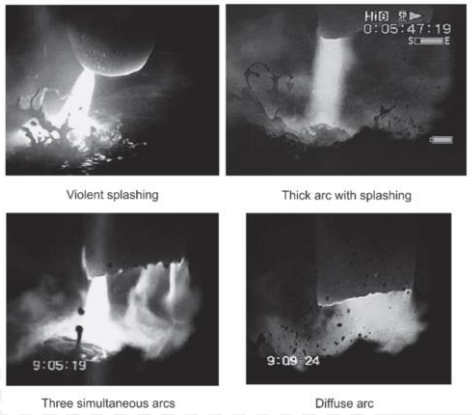
[Reference: A. Kharicha]

- **Project 2 – Plasma-solid interaction**

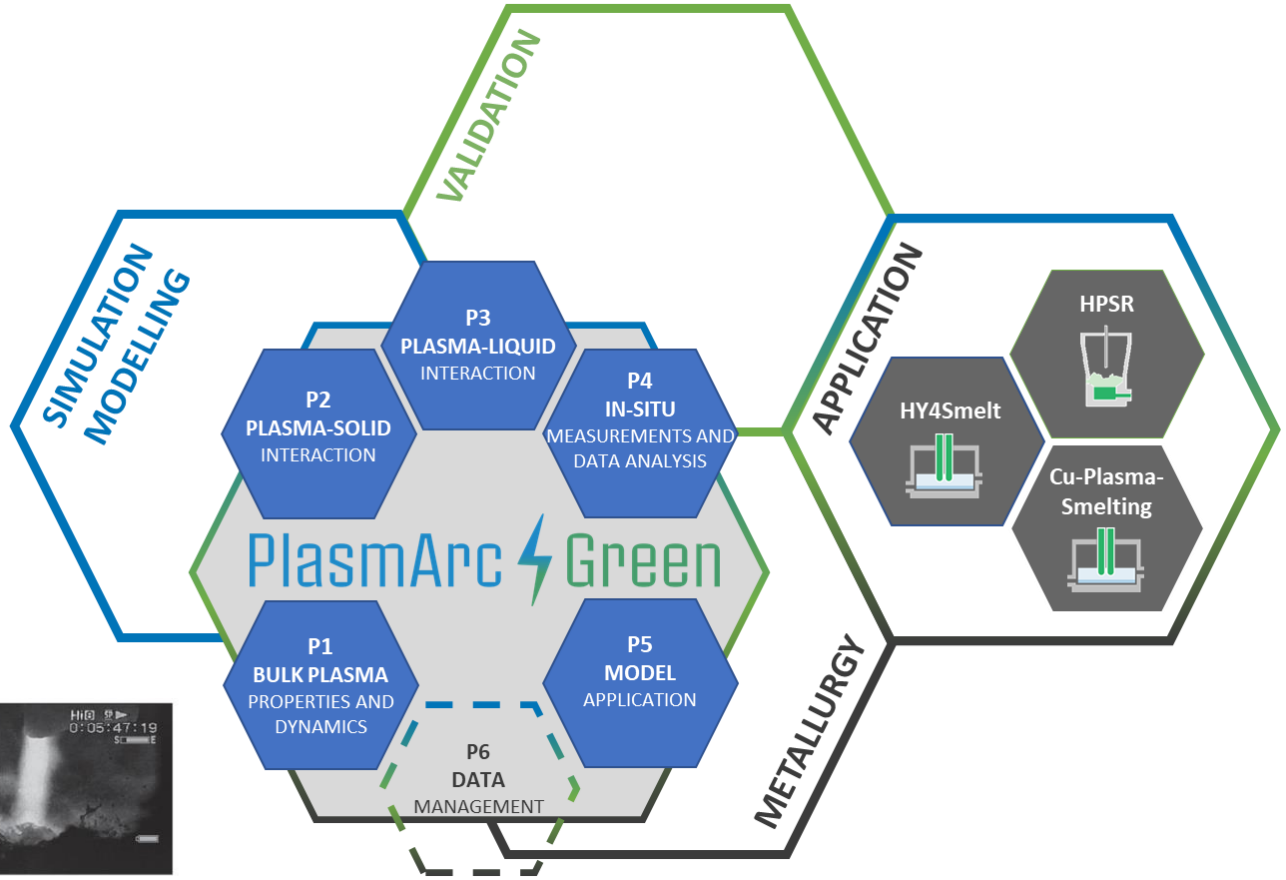


[Z. Ren et al, 2022]

- **Project 3 – Plasma-liquid interaction**



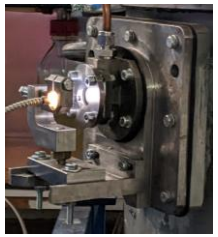
[Jones et al.,
Minerals Engineering, 2002]

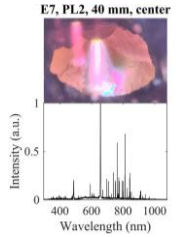


COMET Module PlasmArc Green

Plasma modelling and experimental validation

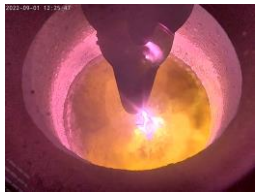
- **Project 4 – In-Situ Measurements and Data Analysis**





[Pauna et al., 2022]

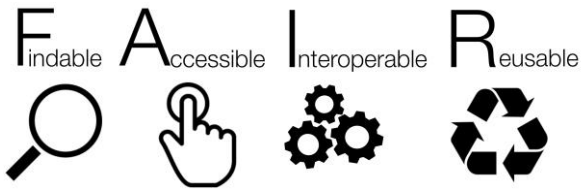
- **Project 5 – Model Application**



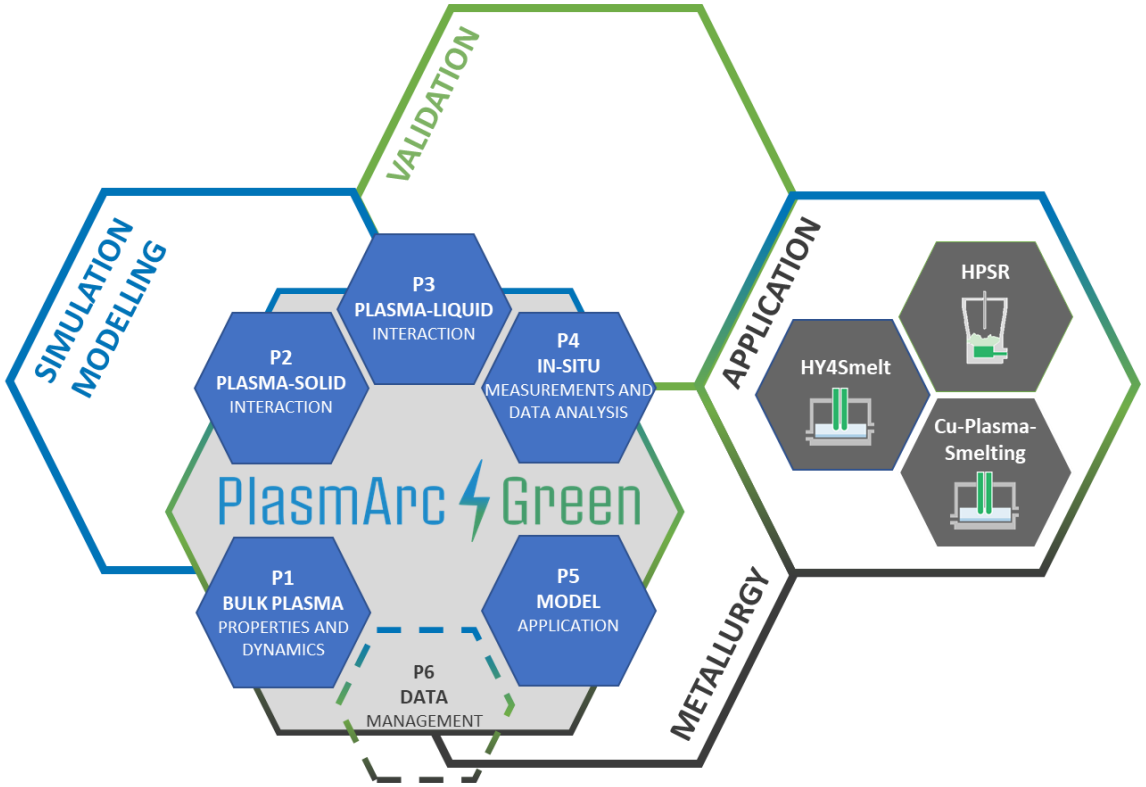
© Michael Zarl, K1-MET

Reference: voestalpine

- **Project 6 – Data Management**



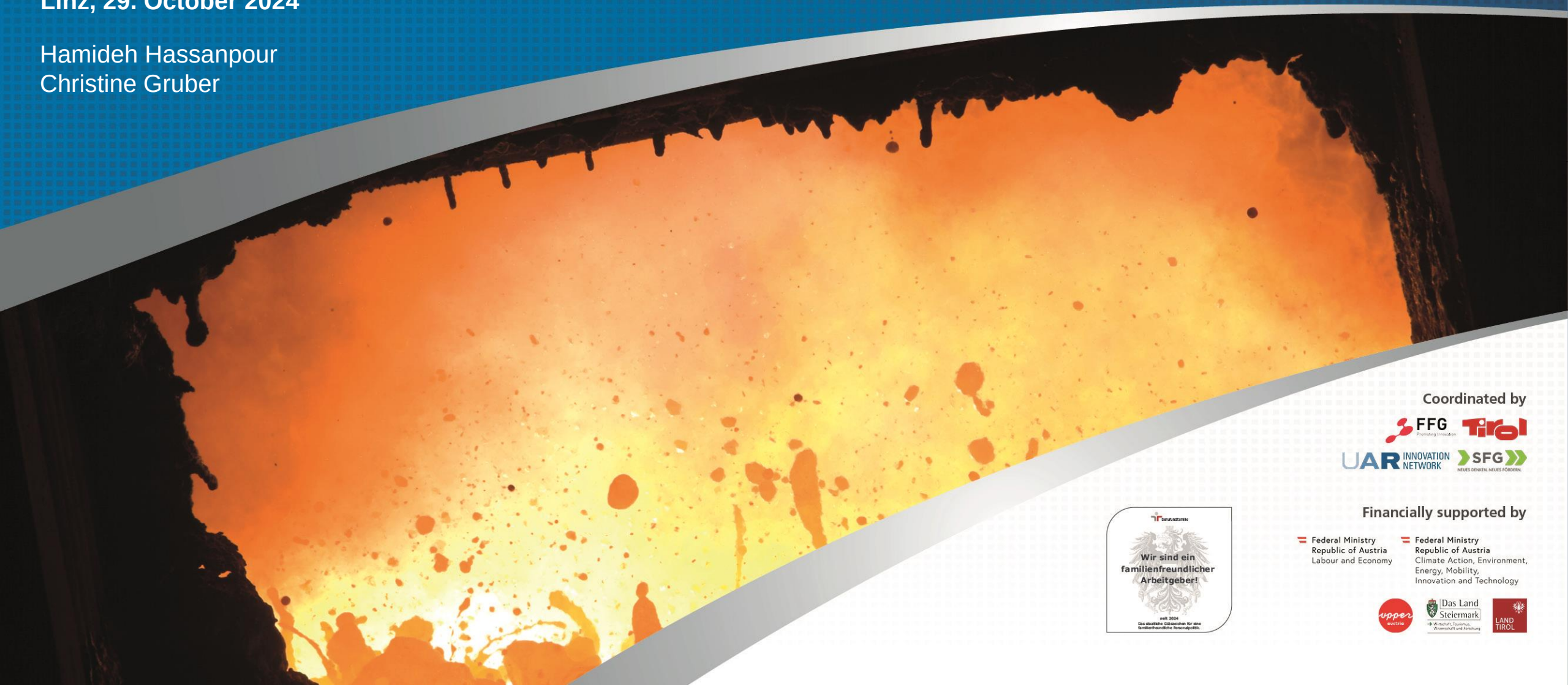
[Sangya Pundir / CC BY-SA (https://creativecommons.org/licenses/by-sa/4.0)]



Thank you!

Linz, 29. October 2024

Hamideh Hassanpour
Christine Gruber



metallurgical competence center

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