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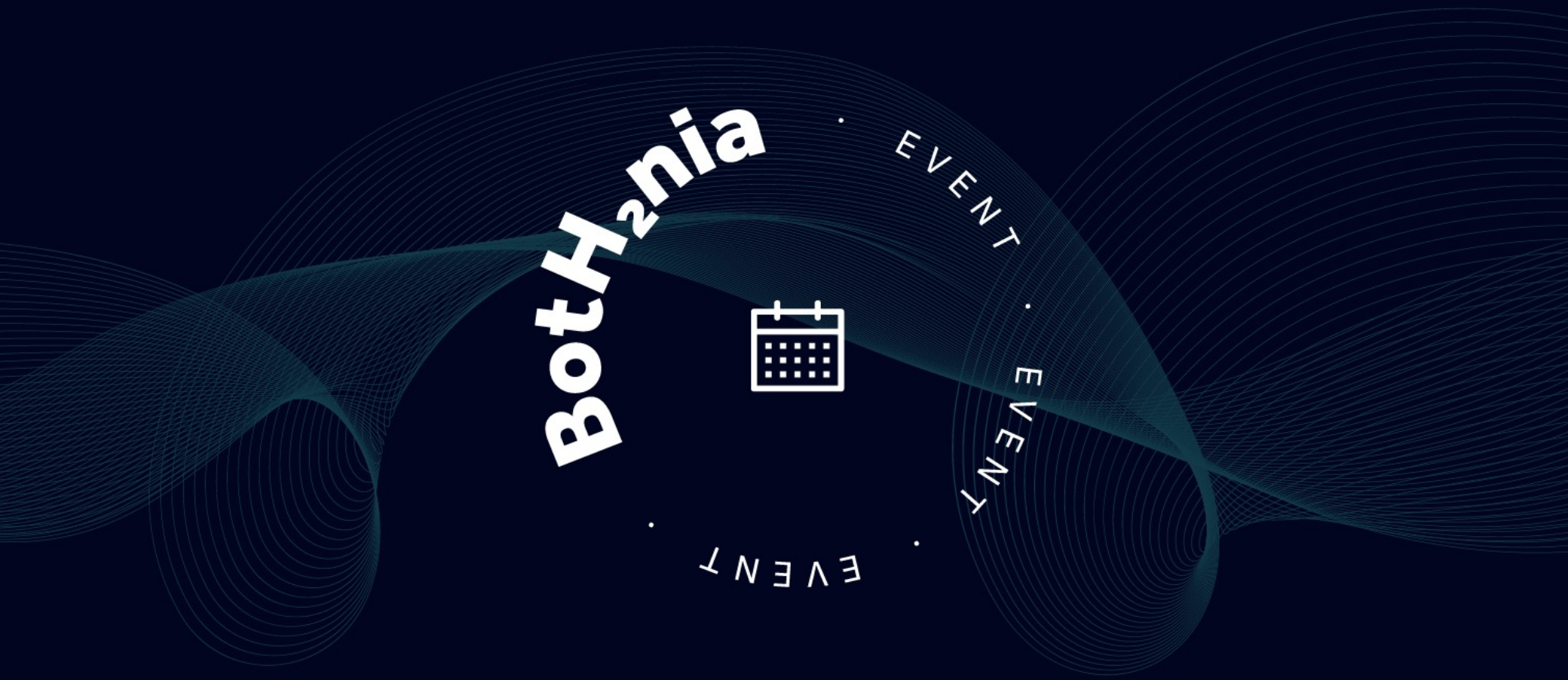

BotH$_2$nia goes Oulu & Raahe 5.–6.5.2022

This is a presentation given at the event BotH$_2$nia Goes Oulu & Raahe on 5.–6.5.2022.

BotH$_2$nia is a network of operators interested in hydrogen. The objective of the network is to create a Nordic hydrogen cluster around the Baltic Sea, beginning with the Bothnian Bay. BotH$_2$nia strengthens the position of the north in the European hydrogen industry!

BotH$_2$nia invites all businesses, research institutes, investors, municipalities and cities to roll up their sleeves for a greener future.

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Hydrogen: Reducing Agent and Energy Source in Steelmaking

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5.5.2022

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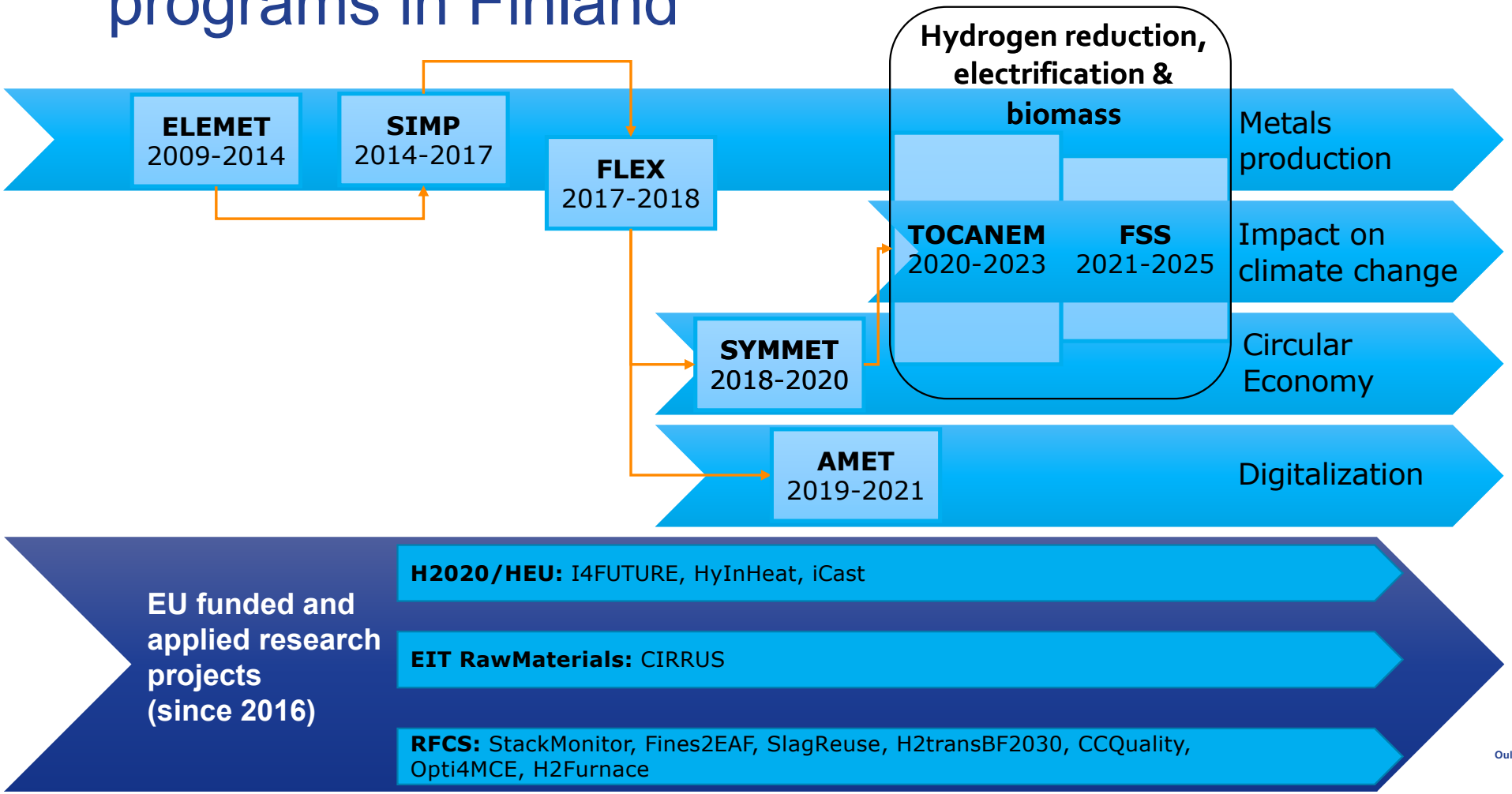
Low Carbon Road Map in Europe

- European steel industry has ambition to cut CO_2 emission 80-95% by 2050
- Forecasts are based on assumptions that there will be no one solutions to decrease remarkable CO_2 emissions
- Both BF-BOF and EAF based process chains are used but portion of EAF is increased
- Role of electricity, natural gas and H_2 will be remarkable
- Additional energy required is app. 400TWh CO_2-free energy

Source: Low Carbon Roadmap, Pathways to a CO_2-neutral European steel industry, EUROFER, European Steel Association, 2019.

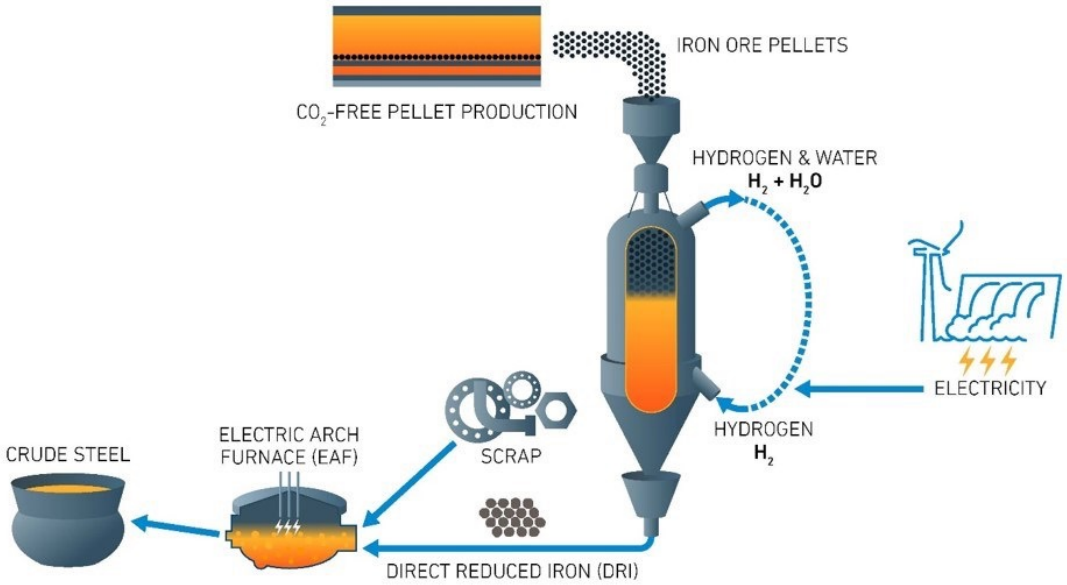
Main themes of metals production ecosystem programs in Finland



H_2-based process routes for steelmaking

- Traditional process route based on Blast Furnace (BF) and BOF conterver using coke as reducing agent
- Shaft Furnace could be used for hydrogen reduction producing direct reduced iron (DRI) pellets which are raw material for Electric Arc Furnace (EAF)
- Hydrogen plasma reduction technology (HPSR) iron ore fines are reduced and melted simultaneously

Hydrogen usage potential in the current and the future process units



In current the processes

- Injection to Blast Furnace for reducing agent
- Partial replacement of fossil fuels in slab reheating furnaces
- Injection to EAF for chemical energy and reductant

In the tuture processes

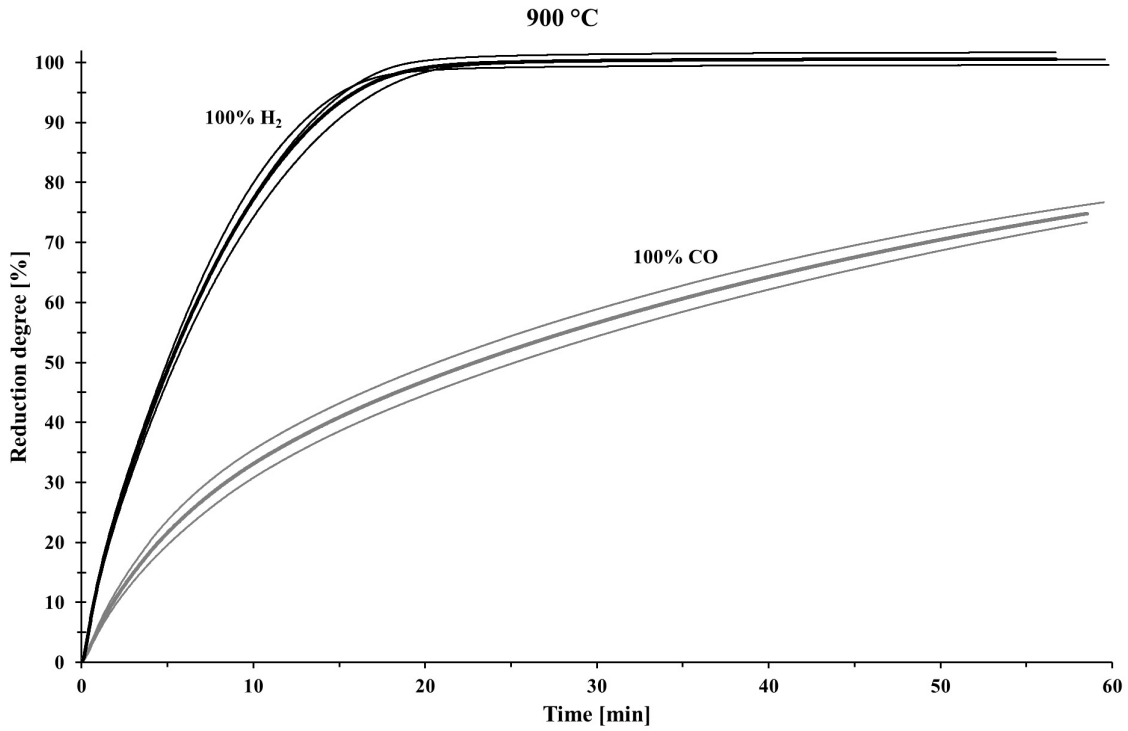
- Reducing agent in process under development (shaft furnace, fluidized bed, hydrogen plasma smelter)
- As fuel in heating processes

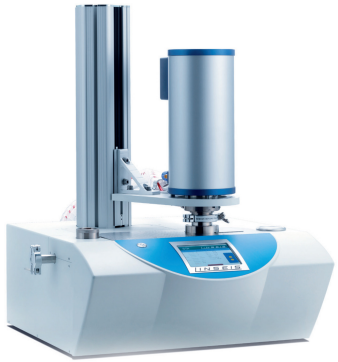
Replacement of CO by H_2 in current Blast Furnace

- Replacement of CO by H_2 in blast furnace process is studied by Blast Furnace Simulator
- Reducing gases containing H_2 and H_2O resulted in higher porosity and surface areas in reduced pellets, leading to a better reduction performance in current Blast Furnace (BF) process
- For maximized short-term CO_2 cutting purposes current ironmaking processes maximal hydrogen usage should be studied (appox. 20-30% could be possible)

Reference:
A. Abdelrahim, M. Iljana, M. Omran, T. Vuolio, H. Bartusch and T. Fabritius (2020) Influence of H_2–H_2O Content on the Reduction of Acid Iron Ore Pellets in a CO–CO_2–N_2 Reducing Atmosphere. *ISIJ Int.* 60(10): 2206–2217.

Shaft Furnace tecnology: 100% CO v 100% H_2 as a reducing gas

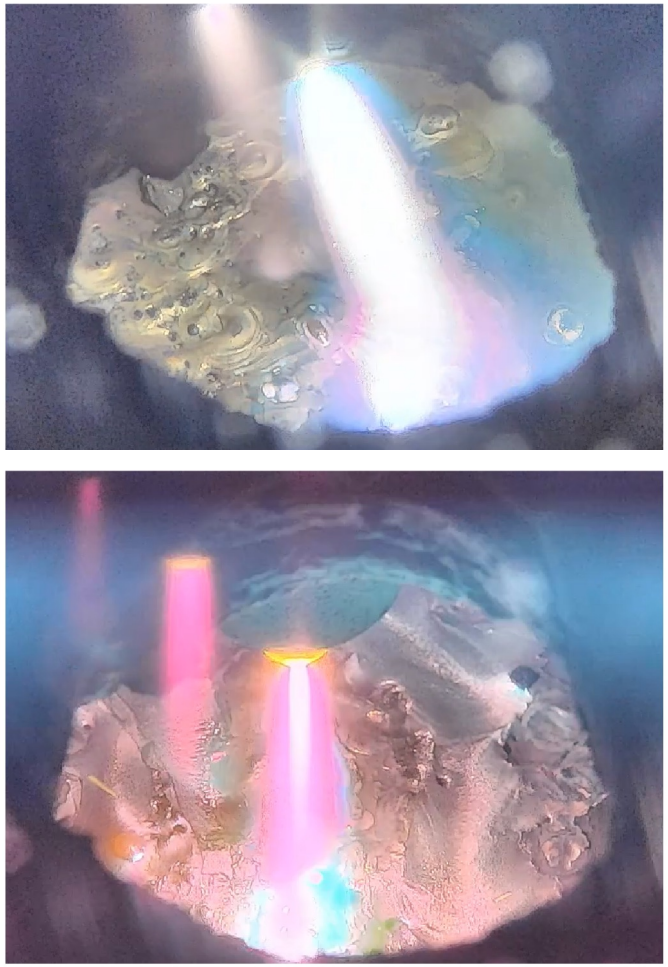




- Simultaneous mass and heat difference measurement with optional mass spectrometer gas analysis in reducing atmosphere up to 1600°C.
- Available gases include CO, CO_2, H_2, H_2O and N_2.
- At 900°C, reduction rate at 100% H_2 is significantly higher compared to 100% CO.
- 900 - 950°C is typical temperature used in shaft furnaces to produce direct reduced iron (DRI)

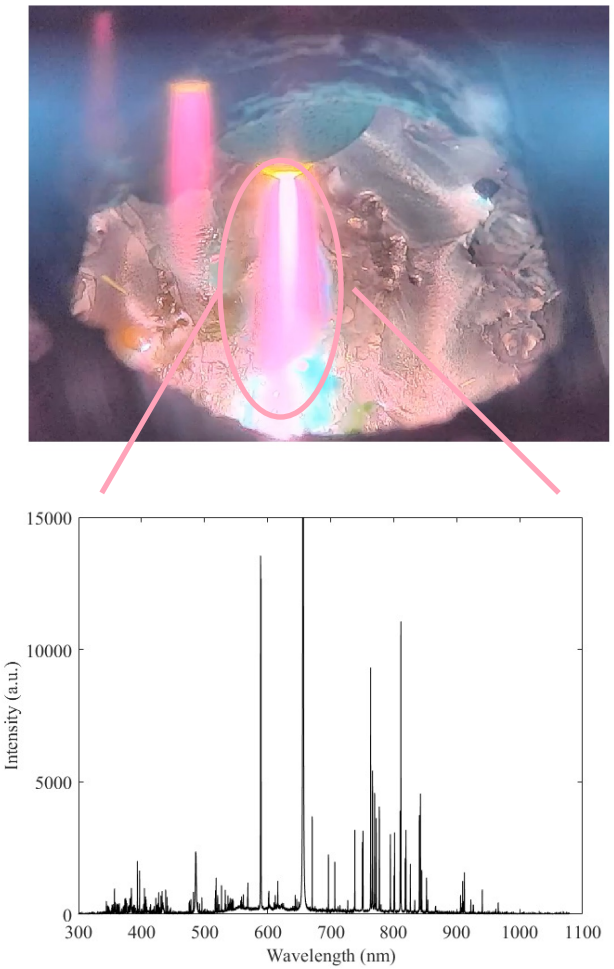
Hydrogen plasma smelting reduction studies with OES

- **Joint research with Montanuniversitaet Leoben**
  - Leoben: plasma reactor studies
  - UOulu: data analysis
- **Optical emission spectroscopy (OES) is used to characterize the plasma in hydrogen plasma smelting reduction (HPSR)**
  - In HPSR, iron ore is fed e.g. through a hollow electrode in the furnace to a reduction process with the hydrogen plasma
- **The aim is to optimize the HPSR process by**
  - Studying the temperature and electron density of the plasma with OES
  - Determining the position of the plasma arc in the furnace from the OES spectra



Hydrogen plasma smelting reduction studies with OES

- **OES provides information about**
  - Composition of the plasma
  - Temperature of the plasma
  - Electron density
- **Long term goal is to make an on-line process control tool for HPSR with OES**
  - To optimize the HPSR process
  - To detect malfunctions early
  - To reduce H_2 consumption



Thank you for your attention