Decarbonisation scenarios for the European steel industry

Workshop Decarbonisation of EU project CORALIS „Industrial symbiosis in energy intensive industries“

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Introduction

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- Short introduction BFI
- Overview Project "Green Steel for Europe"
- Decarbonisation scenarios of project "Green Steel for Europe"
- Latest developments and aspects of industrial symbiosis for decarbonisation of steel industry

BFI - short introduction

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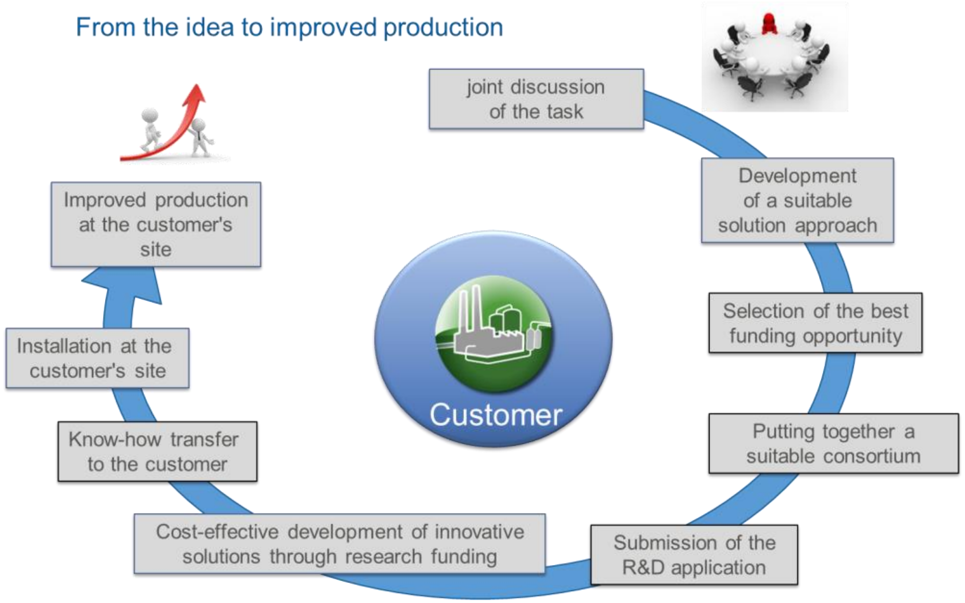
- Private, **non-profit institute** for applied R&D in steel industry and process industries
- Large national and international **network** (research & industry)
- Approx. **100 employees**, 70% academics and post-docs
- 4 strategic fields of activities:
  1. Decarbonisation and Energy Efficiency,
  2. Digitalisation, Industry 4.0 and Measurement Technologies,
  3. Circular Economy,
  4. Process Innovation and Process Optimisation.



Overview project Green Steel for Europe 1/2020 - 10/2021

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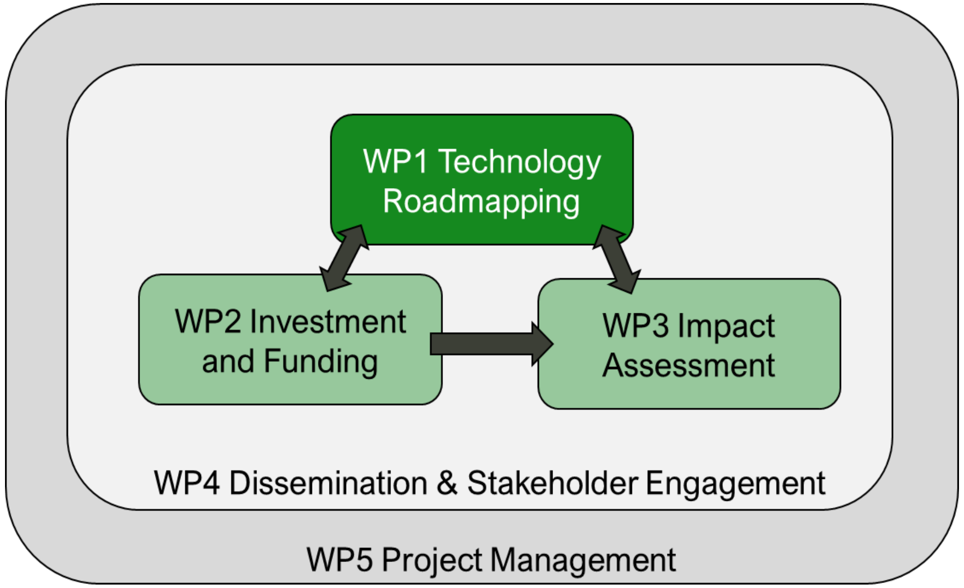
This project has received funding from the European Union under grant agreement NUMBER — 882151 — GREENSTEEL

Objectives

- ✓ plan technological transformation
- ✓ identify decarbonisation barriers
- ✓ support communication between stakeholders
- ✓ rate investment demands and funding mechanisms
- ✓ evaluate & recommend policy options



Approach for Technology Roadmapping

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Deliverables D1.1 / D1.2
"Assessment and roadmapping of technologies"

Technology Assessment

Decarbonisation Barriers

Deliverables D1.4 / D1.5
"Collection of possible decarbonisation barriers"

Work Package 1
"Technology roadmapping"

Deliverables D1.3 / D1.6
"Stakeholder Consultations"

Stakeholder Consultations

Decarbonisation Pathways

Deliverable D1.7
"Decarbonisation Pathways 2030 and 2050"

Selected decarbonisation technologies

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Pathways: Smart Carbon Usage (+Carbon Capture and Storage)

	Iron bath reactor smelting reduction	Gas injection into the blast furnace	Alternative carbon sources	Increased scrap usage	Carbon oxide conversion
Reducing agent	Carbon	Carbon	Carbon	(Carbon)	Carbon
Current TRL	TRL 6	TRL 5-8 (preparation/gas reforming)	TRL 2-7	TRL 4-8	TRL 8 (conversion); TRL 4-5 (implementation)
Project examples	HIsarna	ULCOS	SHOCOM, GREENEAF2	FLEXCHARGE, ADAPTEAF	Carbon2Chem, STEELANOL

Pathways: Carbon Direct Avoidance

	Hydrogen based direct reduction	Hydrogen plasma smelting reduction	Alkaline iron electrolysis	Molten oxide electrolysis
Reducing agent	Hydrogen	Hydrogen	Electricity	Electricity
Current TRL	TRL 6-8	TRL 5	TRL 5-6	TRL 2
Project examples	Hybrit, Salcos, HYFOR	SuSteel	SIDERWIN, IERO, ASCoPE	ULCOS, IERO, VALORCO

Supporting technologies: CO_2 capture, hydrogen production

Decarbonisation technology route roadmaps – direct reduction

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Direct reduction routes

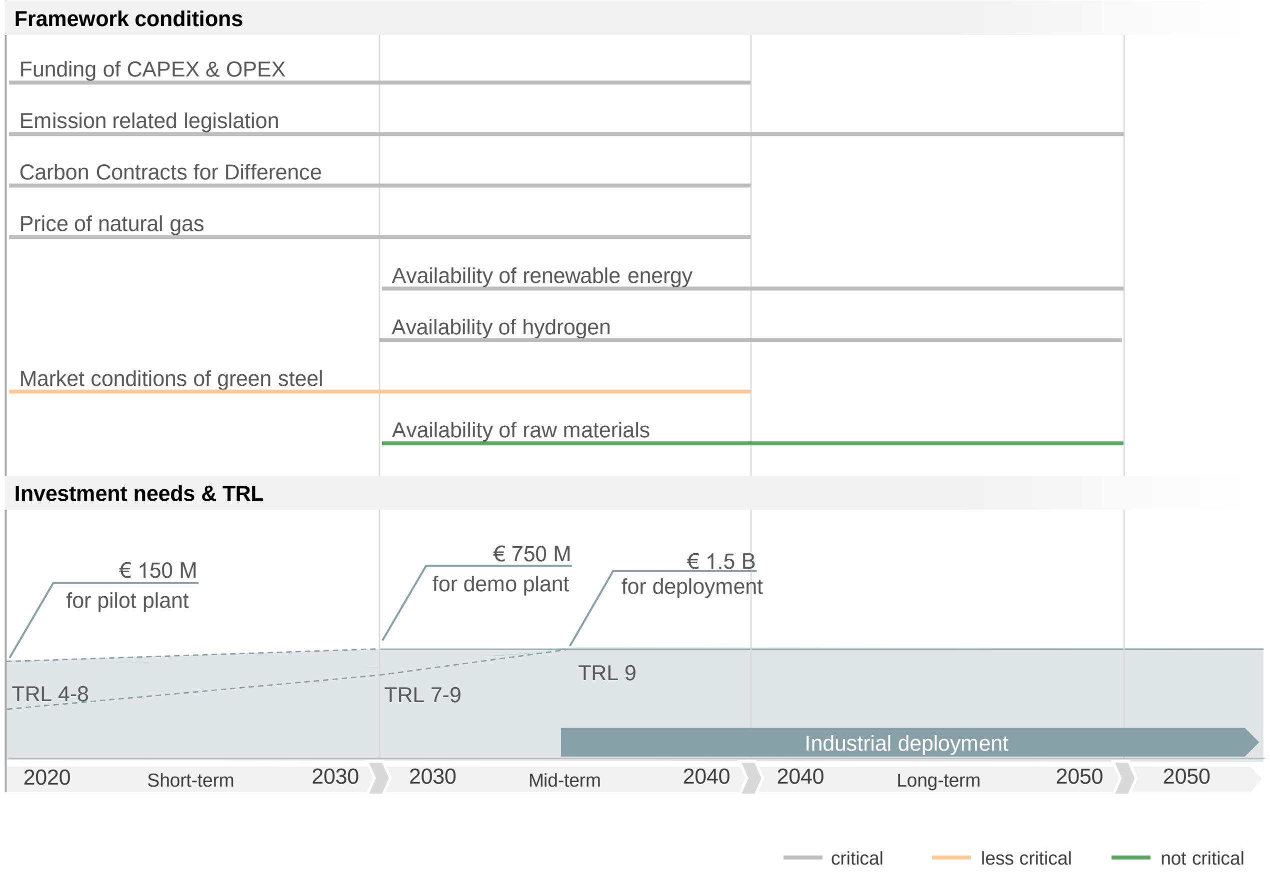
- ☐ Technology routes based on direct reduction processes
- ☐ Share of hydrogen as a partial substitute for natural gas can be increased stepwise (towards 100 % hydrogen-based reduction)

CO_2 mitigation potential of this routes almost 100 %

(compared to BF-BOF route)

Framework conditions

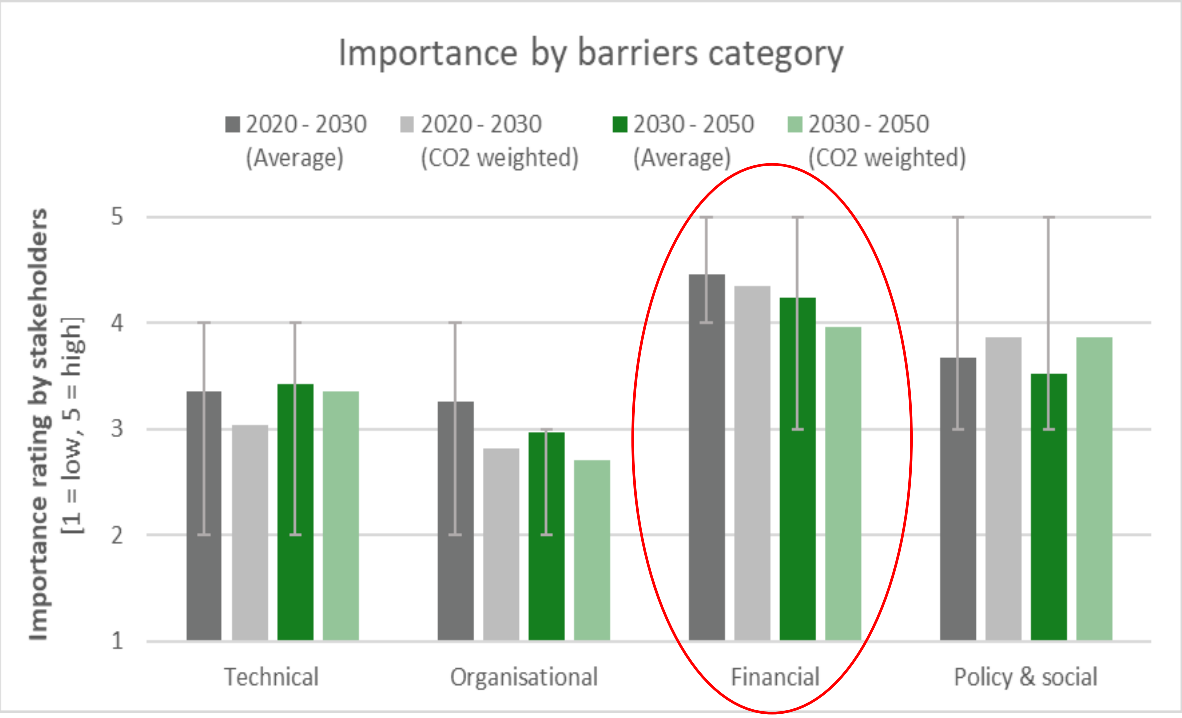
- ☐ Reduction behaviour at 100 % H_2
- ☐ Energy system without or with minimal carbon input
- ☐ Strengthening of high-voltage grids
- ☐ Availability and price of green electricity and hydrogen
- ☐ Hydrogen transport and storage infrastructure



Decarbonisation Barriers – rating of relevance by stakeholders

Relevance of barriers categories as rated in the stakeholder consultations

- Scale: 1 (not important) to 5 (high importance)



- **Utilisation of different metrics:**
  - Average value („Avg.“)
  - CO_2-weighted value („CO_2“) (weighted by CO_2 allocations of stakeholders within ETS)
  - Error Bars contain at least 50% of answers

#	Decarbonisation Barrier Category	2030		2050	
		Avg.	CO_2	Avg.	CO_2
1	**Financial barriers**	**4.5**	**4.2**	**4.3**	**4.0**
2	Policy / Social barriers	3.7	3.5	3.9	3.9
3	Technical barriers	3.4	3.4	3.0	3.4
4	Organisational barriers	3.3	3.0	2.8	2.7

Green Steel – Future Scenarios of decarbonised steelmaking

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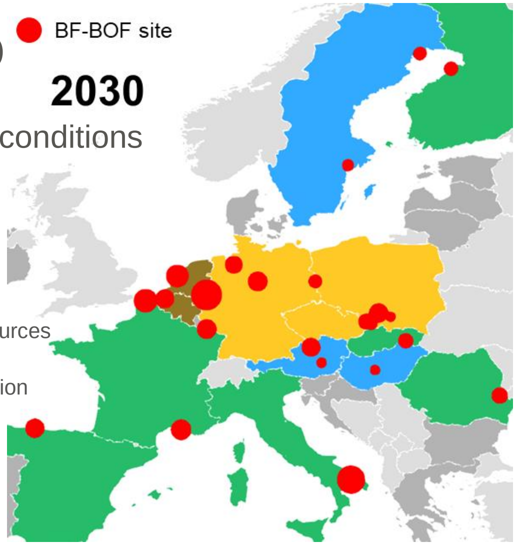
- ✓ Main barriers (technical/financial/societal) identified:
  - (1) 6 out of 7 highest rankings are <u>financial</u> barriers
  - (2) availability of renewable energy also important
- ✓ Assessment of national <u>boundary conditions</u>:
  - (1) availability of CCS / secondary C / H_2
  - (2) natural gas price
  - (3) CO_2 load of electricity
  - (4) plant conditions incl. investment cycles
  - (5) political trends
- ✓ Definition of 3 <u>scenarios</u> for 2030/2050:
  - (1) <u>plausible technology mixes</u>
  - (2) decelerated transformation
  - (3) higher H_2 availability

Clustering of main (not only!) decarbonisation pathways based on national boundary conditions

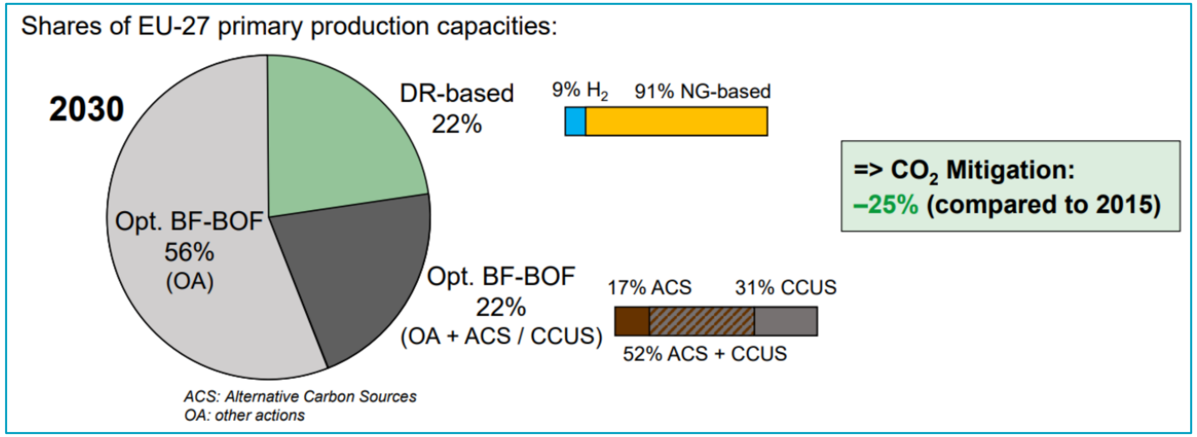


BF replaced by H2-DR

BF replaced by NG-based DR

BF adjusted to alternative carbon sources and/or CCUS utilisation with additional incremental optimisation

BF replaced by / adjusted to mix of all technologies above



Decarbonisation Scenarios

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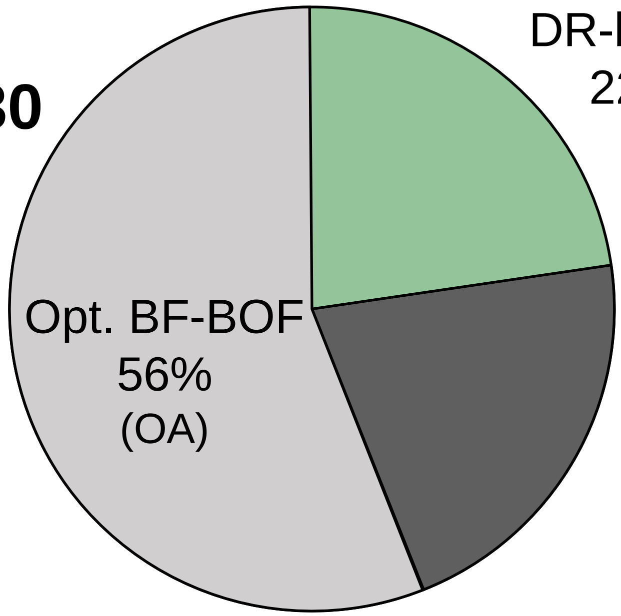
2030 basic Scenario **“Mixed implementation”**
(based on national framework condition mapping & BF-specific assumptions)

Scenario 2
“Increased H_2 availability”

Scenario 3
“Delayed implementation”

Shares of EU-27 primary production capacities:

2030



DR-based
22%

9% H_2 91% NG-based

Opt. BF-BOF
22%
(OA + ACS / CCUS)

17% ACS 31% CCUS

52% ACS + CCUS

=> CO_2 Mitigation:
–25% (compared to 2015)

ACS: Alternative Carbon Sources
OA: other actions

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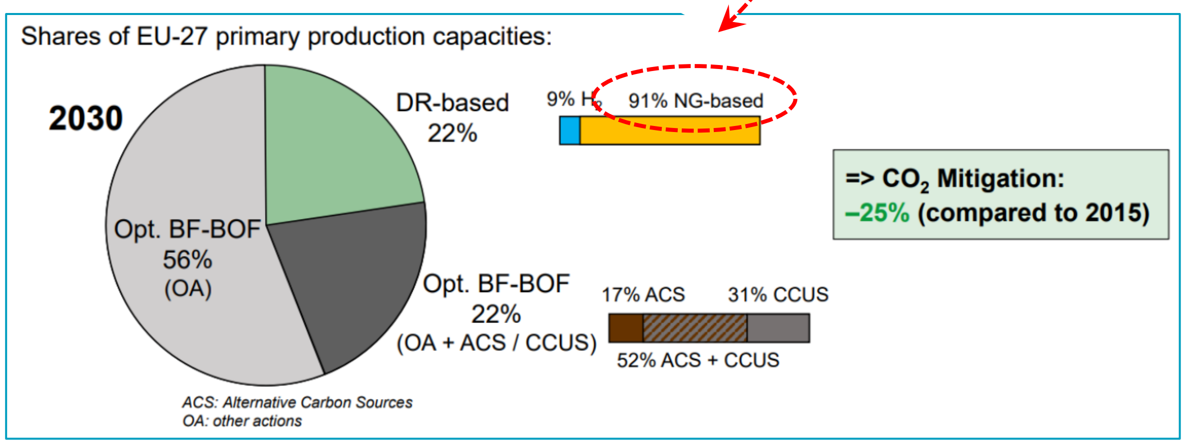
Influence of energy crisis on steel industry industry decarbonisation

- natural gas availability and costs have key roles for bridge technologies
- Russian attack on Ukraine hit European energy supply to the bones
- investments may be delayed before 2030
- profitability of decarbonisation may benefit after 2030



➢ **Roadmaps have to be adapted to new boundary conditions and new views**

Aspects of industrial symbiosis for decarbonisation of steel industry

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- infrastructures and supply with renewable energy (RE):
  - electricity: CO_2 footprint and fluctuation of availability and costs
  - hydrogen: source / CO_2 footprint, costs, availability of H_2 derivates
  - local RE production or import: resilience vs. costs ?
  - fast decarbonisation or full optimisation (e.g. source of H_2) ?
- integration of decarbonised energy systems defines costs and availabilities
- material and energy flows along supply chains and across different industries needs numerous adaptions for decarbonisation
- cross-industrial aspects of industrial decarbonisation
  - fixed sector decarbonisation targets or free techno-economical development ?
  - high energy costs change ROIs for many energy/heat usage optimisations

Conclusions

- Steel industry transformation will result in a heterogeneous situation in the next 15 years but H_2 based direct reduction and electrification will play major roles.
- Boundary conditions are changing and so are decarbonisation roadmaps ...
- Hard global market setting defines existance and transformation of steel industry.
- Integrated decarbonised energy systems have fundamental importance, but do not yet exist and cannot yet be prognosed in a reliable way.

➢ **Industrial symbiosis has existantial importance for decarbonisation and it needs continuous and holistic coordination and optimisation.**

Thank you for your interest !

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How industrial decarbonisation scenarios were derived

1) Prognosis of future local / national framework conditions

2) Assessment of framework conditions and coupling with local / national steel production

3) Fusion with investment cycles (BF relining) and site-specific information

4) Synthesis into basic overall European scenario "Mixed implementation"

5) Assessment of CO_2 mitigation

6) Variation of assumed future framework conditions to derive further scenarios