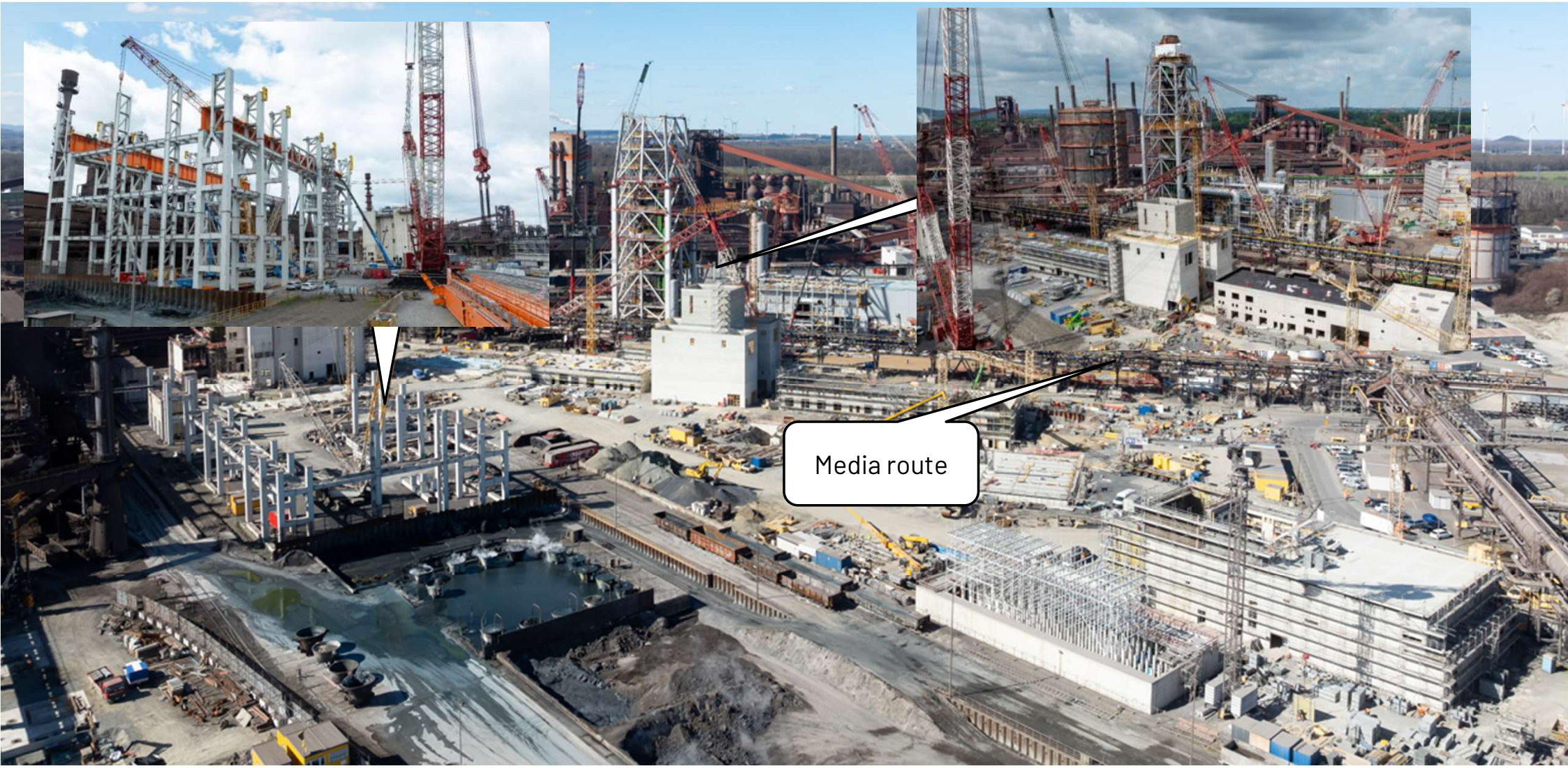
SALCOS

CHALLENGES AND POTENTIAL OF THE NEW EAF SLAG

SALZGITTER MANNESMANN FORSCHUNG

Ein Unternehmen der Salzgitter Gruppe

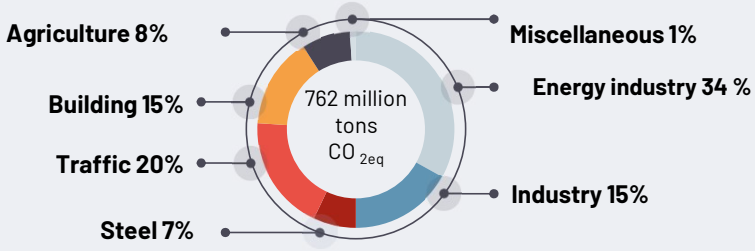


THE STEEL INDUSTRY

Key sector for the German economy and for achieving the climate targets

Steel is probably **the most** sustainable and **most universal material** in **industrial application.**

The **steel industry** is currently responsible for for **7 % of CO_2 emissions** in Germany.
The Salzgitter site's share is 1 % of the overall emissions.



CO_{2e} emissions 2022(1)

The steel industry has a **special responsibility** in climate protection and is **part of the solution.**

LOWCO$_2$

(1) Sources: Statista & WV Stahl

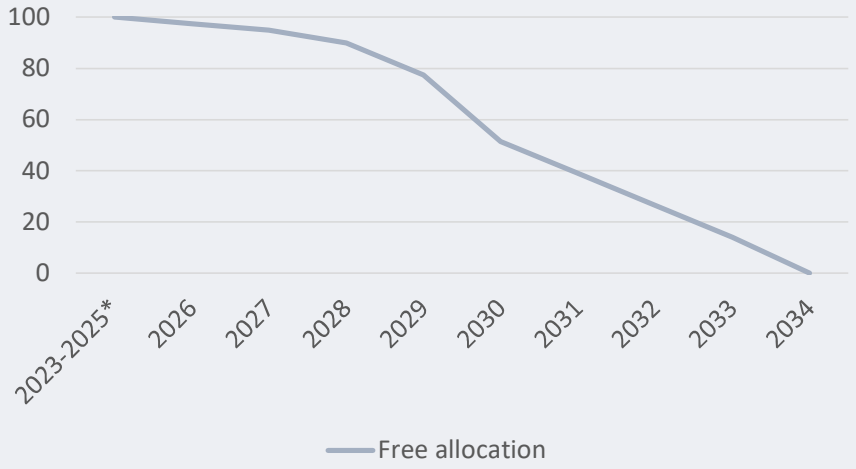
EUROPEAN CLIMATE TARGETS

Implementation pressure via emission trading

European Trading System (ETS) for CO_2

- **Free allocation** of allowances in the **EU ETS** will be phased out from 2026 **until 2034** (see progression on the right)
- **Road transport and buildings from 2027** in the new **EU ETS II**
- CBAM **border adjustment mechanism**
  But: Solution for **export compensation still pending**.
- In addition:
  Gradual reduction in the total quantity of CO allowances$_2$

Revision of the EU ETS - free allocation meltdown path



*The current shortfall in the sector is already around 25-30% on average!

Steel manufacturers must reckon with significantly rising costs for blast furnace production.

PILLARS OF THE "SALZGITTER AG 2030" STRATEGY

Vision and mission

PIONEERING FOR CIRCULAR SOLUTIONS

With our innovative products and processes, we are the market leader for circular economy solutions in global industrial value chains.

PARTNERING FOR TRANSFORMATION

Together, we are resolutely charting new courses, transforming the industry and creating sustainable value for the future.

KEY POINTS OF SALCOS®

Salzgitter **L**ow **CO_2** **S**teelmaking

/ Our approach: **Carbon Direct Avoidance process** (CDA)

/ **SALCOS®** is the way to **virtually CO_2** -free steel production

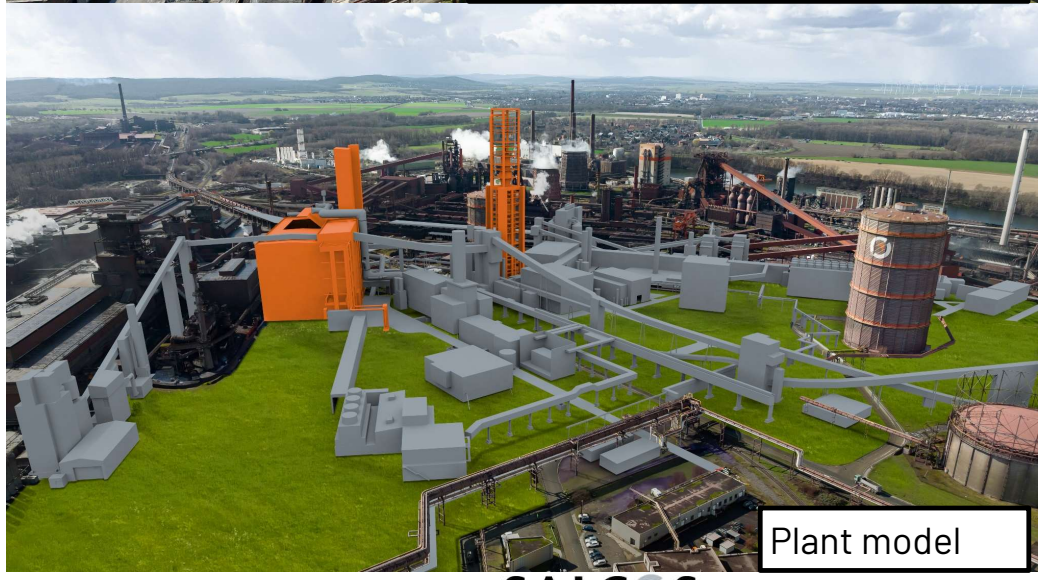
/ **Hydrogen** as a **reducing agent** will replace carbon

/ Transformation process is planned **in stages**

/ **Integration** of the new facilities **into the existing steelworks**

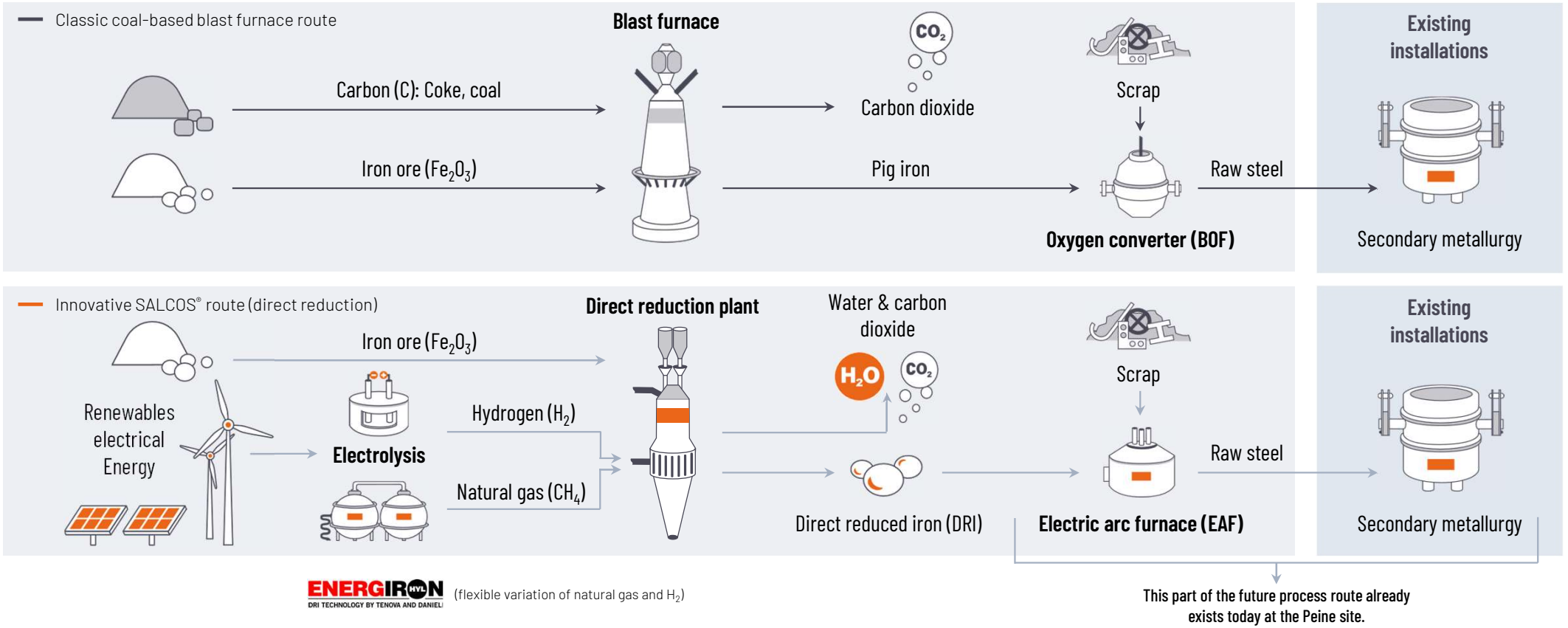
/ **Same production capacity**

/ By **2033: reduction of over 95 % of CO_2 emissions is targeted**



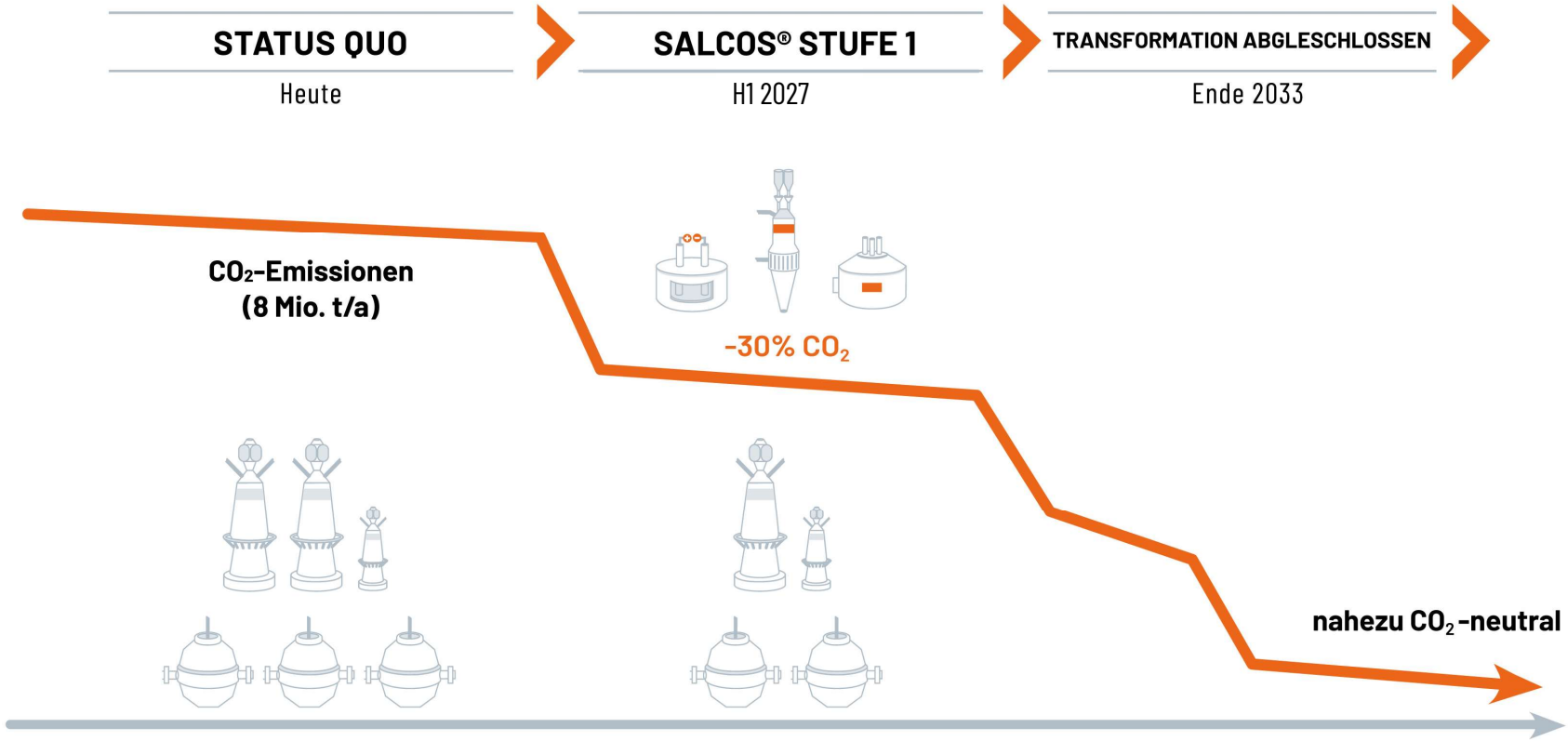
TECHNICAL IMPLEMENTATION

Comparison of conventional and future production technology



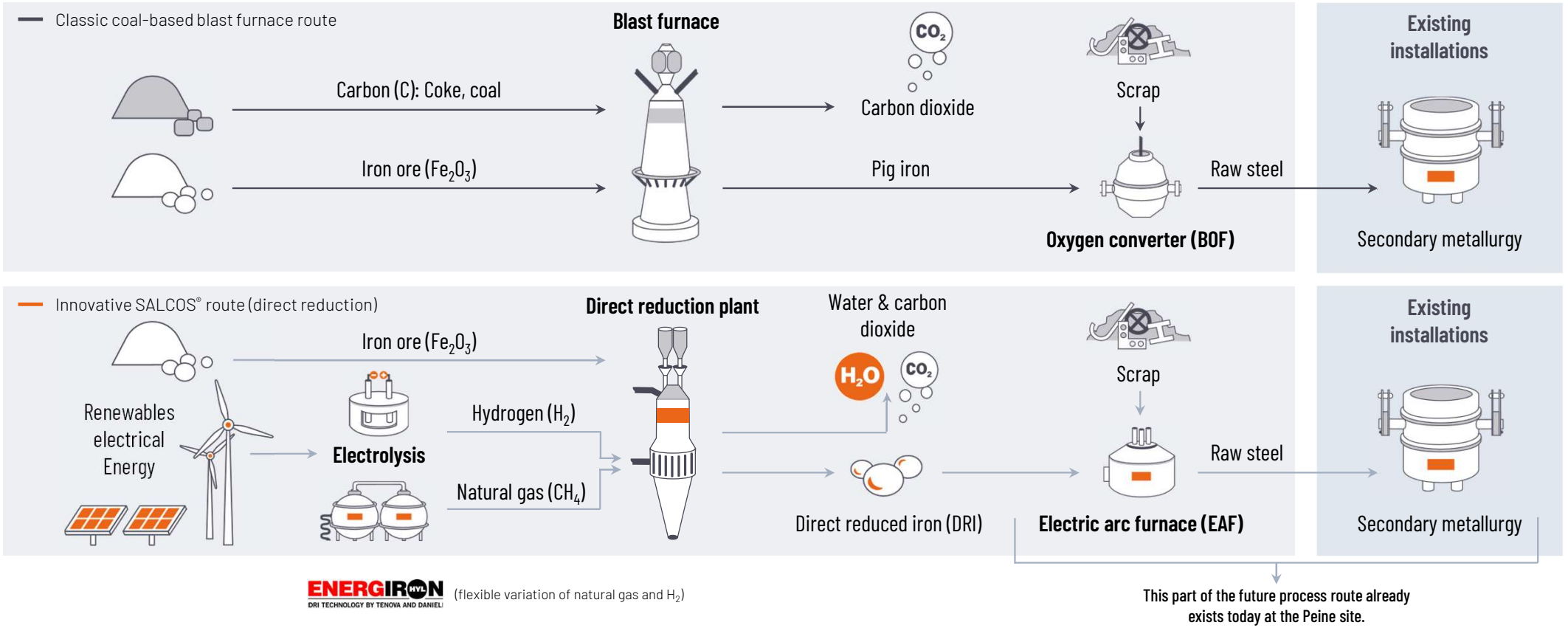
TRANSFORMATION OF THE SALZGITTER STEEL SITE

SALCOS® level 1 - #wemakeithappen; further transformation takes place step by step



SLAG PRODUCTION

Comparison of conventional and future production technology



SLAG PRODUCTION

Comparison of conventional and future production technology

BFS + GBFS
BOFS
LFS

Classic coal-based blast furnace route

Blast furnace

CO_2

Carbon dioxide

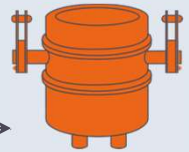
Pig iron

Scrap

Raw steel

Oxygen converter (BOF)

Existing installations



Secondary metallurgy

EAFS
LFS

Innovative SALCOS® route (direct reduction)

Direct reduction plant

Water & carbon dioxide

H_2O CO_2

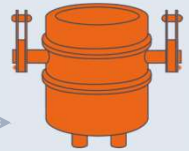
Direct reduced iron (DRI)

Scrap

Raw steel

Electric arc furnace (EAF)

Existing installations



Secondary metallurgy

ENERGIRON DRI TECHNOLOGY BY TENOVA AND DANIELI (flexible variation of natural gas and H_2)

This part of the future process route already exists today at the Peine site.

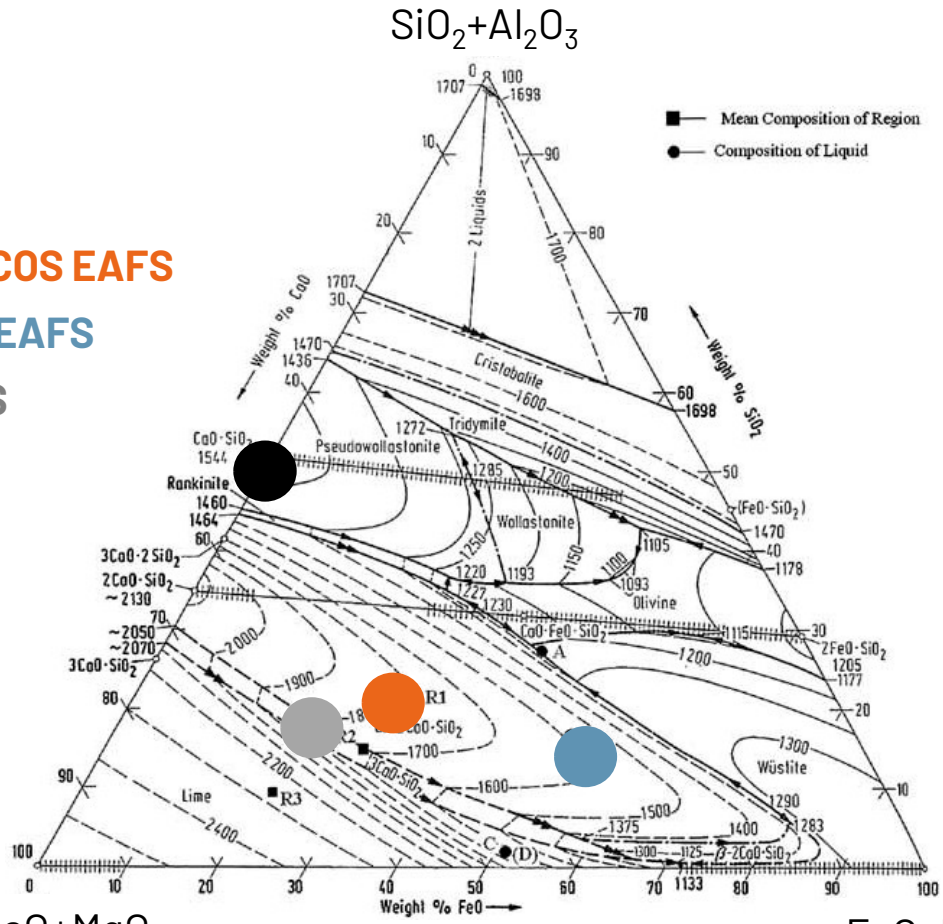
FUTURE EAF SLAG - COMPOSITION

SALCOS EAFS

PTG EAFS

BOFS

BFS



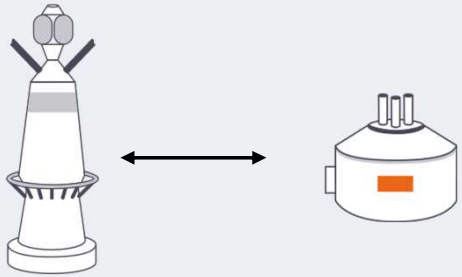
CHALLENGES WITH FUTURE EAF SLAG

Compared to high value slag product GGBFS

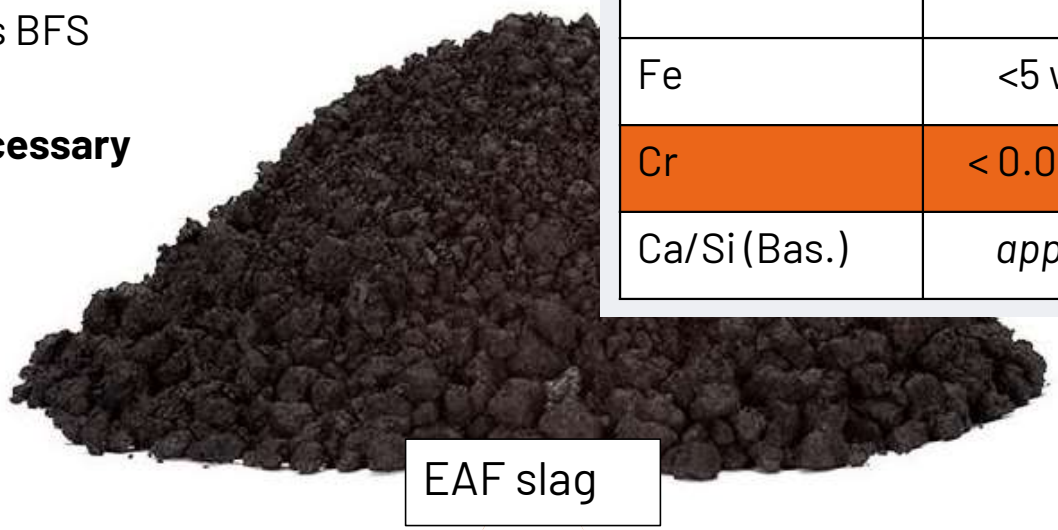
/ current slag use:
almost 2/3 used in cement industry
(GGBFS as clinker substitute)

/ future EAFS differs from todays BFS

→ **adjustment/modification necessary**
→ Fe
→ Cr
→ Bas.
→ structure



	GGBFS	EAFS
structure	amorphous	crystalline
Fe	<5 wt. %	> 25 wt. %
Cr	< 0.01 wt. %	up to 2 wt. %
Ca/Si (Bas.)	*approx.* 1	*approx.* 1.8



EAF slag

GOVERNMENTAL RESTRICTIONS FOR SLAG USE IN GERMANY

Relevant parameters for introducing DRI-EAF slag in cement or concrete industry

Technical rules for hazardous substances (in German: Technische Regeln für Gefahrstoffe (TRGS 613)[1])

application	relevant element	limit value
cement	Cr^{6+}	2 ppm
building construction	As	150 ppm
	Pb	700 ppm
	Cd	10 ppm
	Cr_{tot}	600 ppm
	Cu	400 ppm
	Ni	500 ppm
	Zn	1500 ppm

Requirements for construction measures with regard to effects on soil and water (in German: Anforderungen an bauliche Maßnahmen bezügl. Auswirkungen auf Boden und Gewässer (ABuG))

Reduction of chromium in the solid **is essential** to ensure any use of the GBFS 2.0 in **cement or building applications**

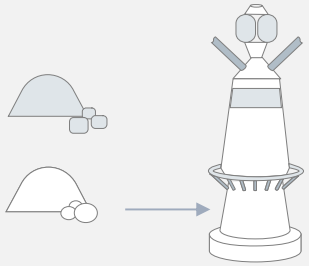
[1] „Ersatzstoffe, Ersatzverfahren und Verwendungsbeschränkungen für chromathaltige Zement und chromathaltige Zubereitungen“ (1999/2000)

Bundesministerium für Bildung und Forschung

PROJECT DRI-EOS

BAM Bundesanstalt für Materialforschung und -prüfung · HOLCIM · FRIEDRICH · INSTITUT FÜR BAUSTOFF FORSCHUNG · FEHS · tenova LOI THERMPROCESS

TODAY

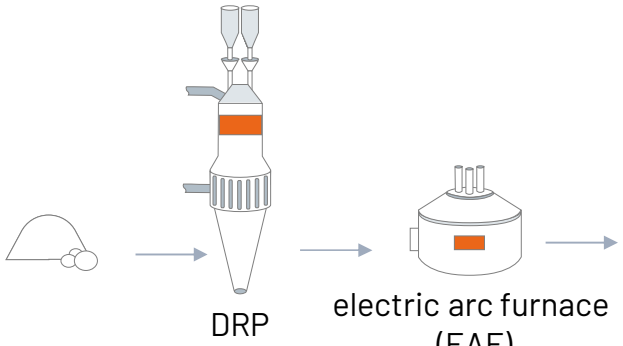


blast furnace

granulated blast furnace slag (GBFS)
amorphous
latent hydraulic
Fe_{tot} < 1 wt.-%
Cr_{tot} < 0,01 wt.-%

application in cement

FUTURE



DRP

electric arc furnace (EAF)

electric arc furnace slag
crystalline
not hydraulic
Fe_{tot} = 25 wt.-%
Cr_{tot} = 0,5-2 wt.-%

DRIEOS

GBFS 2.0

building material

- **Modification**: Reduce basicity by adding SiO_2
  → requirement for amorphous structure
- **Reduction**: Lowering Cr (and Fe) content
  → requirement for later use (restrictions)
- **Rapid cooling**: Create amorphous structure
  → requirement for hydraulic activity

POTENTIAL OF FUTURE EAF SLAG

Element composition

EAF slag

Element	Content in slag [wt. %]	Content in natural ores [wt. %]
Mn	up tp 2	35-54 (poor *approx.* 15) [1, 2]
V	up to 1.5	0,1-0,6 (rich *approx.* 1,2) [3]
Fe	> 25	50-65 [4]
Cr	up tp 2	12-39 [5, 6]

[1] USGS Mineral Commodity Summaries 2025, p. 17
[2] Liu et al. DOI: 10.1016/j.mineng.2018.11.016
[3] Boni et al. DOI: 10.1016/j.oregeorev.2023.105423
[4] USGS Minerals Yearbook 2006 ISBN: 978-1-4113-2300-1
[5] Cheng et al. DOI: 10.1111/j.1751-908X.2012.00162.x
[6] Esenzhulov et al. DOI: 10.3103/S096709120804013X

POTENTIAL OF FUTURE EAF SLAG

Critical raw materials & iron

EAF slag

Element	Content in slag [wt. %]	Content in natural ores [wt. %]
Mn *	up tp 2	35-54 (poor *approx.* 15) [1, 2]
V *	up to 1.5	0.1-0.6 (rich *approx.* 1,2) [3]
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* critical raw material according to EU critical raw materials act, 2024

[1] USGS Mineral Commodity Summaries 2025, p. 17
[2] Liu et al. DOI: 10.1016/j.mineng.2018.11.016
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[6] Esenzhulov et al. DOI: 10.3103/S096709120804013X

RESEARCH ON FUTURE EAF SLAG

EnAM4Steel project idea

/ Basic research on selective recovery of different elements from EAFS

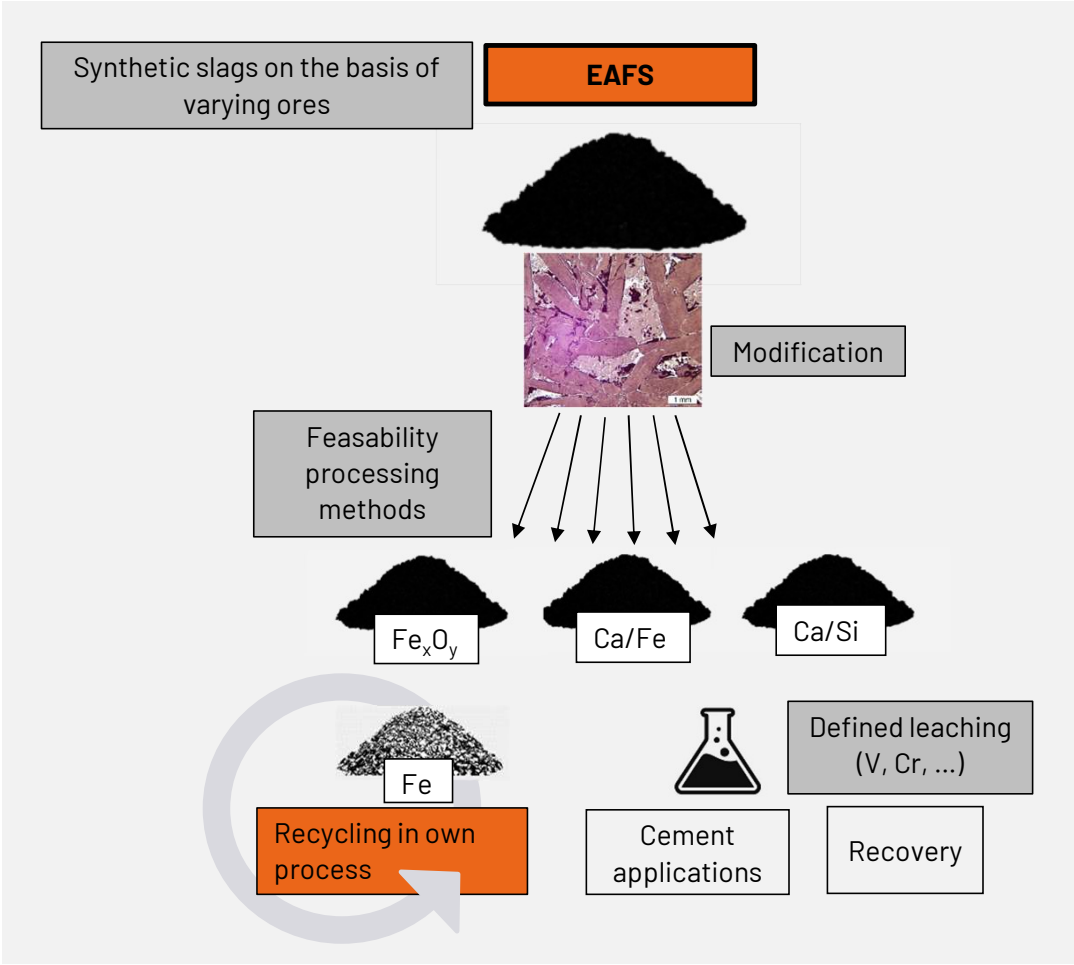
/ Melt modification and research on processing methods suitable for respective texture

/ Focus on Fe and Ca/Si fraction

GOAL:

/ selective recovery of Fe_xO_y and reuse in own process of DRP

/ production of a Ca/Si fraction depleted in Cr to ensure application in cement industry



PILLARS OF THE "SALZGITTER AG 2030" STRATEGY

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SUBSIDIES FOR SALCOS® STAGE 1

Significant support for investment costs

Gefördert durch:

Bundesministerium
für Wirtschaft
und Energie

aufgrund eines Beschlusses
des Deutschen Bundestages

Finanziert von der
Europäischen Union
NextGenerationEU

Niedersächsisches Ministerium
für Umwelt, Energie, Bauen und Klimaschutz

Niedersächsisches Ministerium für Wirtschaft,
Verkehr, Bauen und Digitalisierung

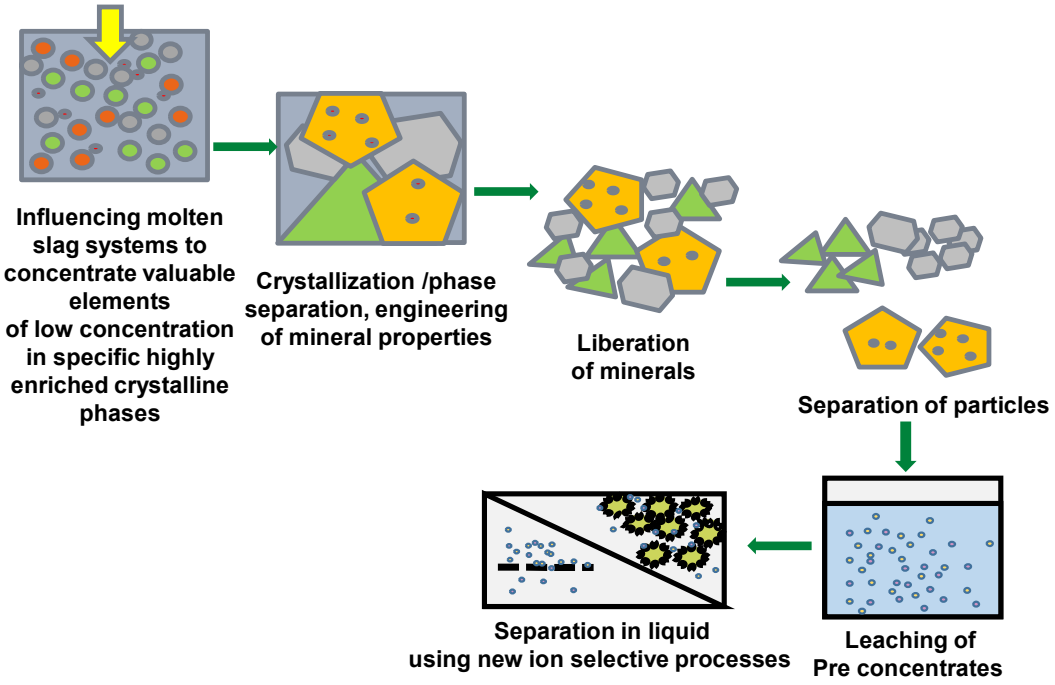
SALZGITTER AG

Mensch, Stahl und Technologie

TU Clausthal
Clausthal University of Technology

Slag as anthropogenic ore and source of byproducts

Slag treatment and processing, recovery of steel alloying elements and generation of raw materials for cement production „EnAM4Steel“



HYDROGEN ON-SITE GENERATION VS. DEMAND

In addition to self-generation, a connection to the hydrogen grid is required

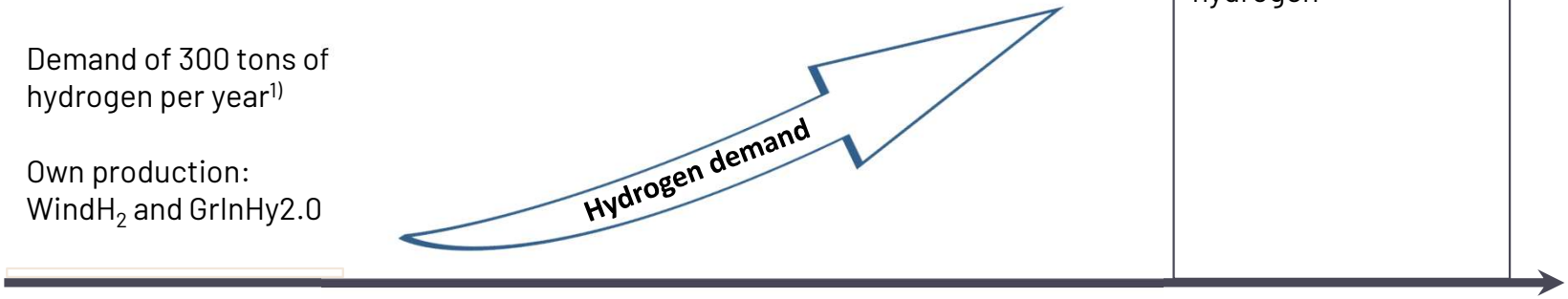
SALCOS
Younited. Steelmaking. Reinvented.

- 100 MW electrolyzer produces approx. 9,000 tons of hydrogen per year
- Hydrogen demand is greater than the possible own production
- **Additional connection to hydrogen network required!**

150,000 tons per year are needed to operate the direct reduction plant with pure hydrogen

Demand of 300 tons of hydrogen per year[1)]

Own production: WindH_2 and GrInHy2.0



[1)] For bell annealing and hot-dip galvanizing lines

H_2-CONNECTION SZAG

Hydrogen core network*

10/29
North-west connection

12/28
Connection Central Germany

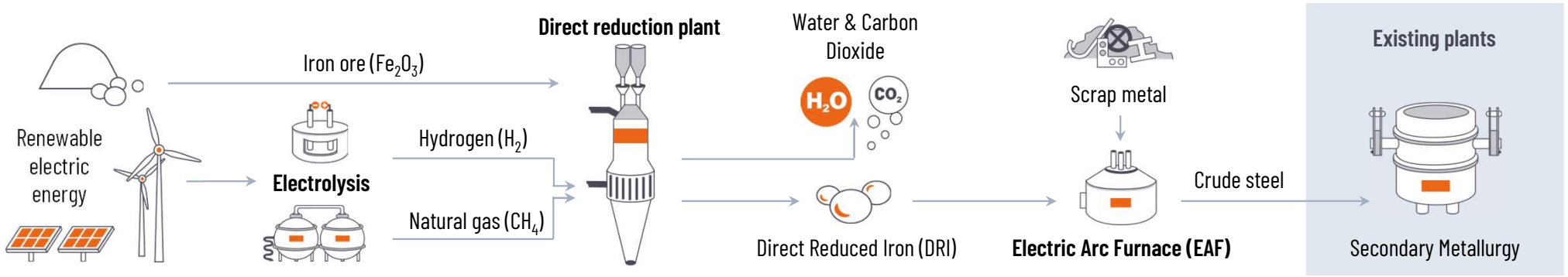
12/29
Baltic Sea connection via Uhrsleben

- On 22.10.2024, the Federal Network Agency approved the construction of the Germany-wide hydrogen core network, which will create the largest hydrogen network in Europe by 2032
- The Salzgitter/Peine steel location forms an efficient hub for a west-east network connection
- Salzgitter AG will be supplied with hydrogen via three supply routes:
  - Hydrogen production on site
  - Domestic production
  - Imports

*according to approval from 22.10.2024

WHAT DOES FUTURE STEEL PRODUCTION LOOK LIKE?

The innovative and flexible SALCOS® route - some key data



Electrolysis

- Pressure Alkali Electrolysis by Andritz Group
- 100 MW power
- A DR plant for 5 % of the required amount of H_2
- Generation of around 9,000 tons of green hydrogen per year

Media infrastructure incl. 380 kV

- Various media necessary, including natural gas, steam, compressed air, oxygen, water, electricity, nitrogen
- New 380 kV power connection (overhead line, substation, distribution network)
- Significant increase in the electrical connected load

Direct reduction plant

- Tenova "Energiron ZR® Direct Reduction" technology, i.e. flexible use of natural gas and hydrogen
- 2.1 million t DRI production capacity
- Reactor tower with a height of approx. 140 m
- Transport from DRI to EAF via Hy-Temp tower

Electric arc furnace

- Alternating electric arc furnace from Primetals Technologies
- Tapping weight 220 t
- Average tap-to-tap time of less than one hour
- Preservation of existing secondary metallurgy to ensure product quality

DIRECT REDUCTION PLANT

Enables reduction with flexible mixtures of natural gas and hydrogen

Construction site

Plant engineers: tenova/danieli

Process: Energiron ZR®

Plant height: approx. 140m

Reducing agent: Hydrogen, natural gas

Reduction time: 3 hours

Temperature: approx. 1050°C

Pressure: 6-8 bar

Product: DRI (Direct Reduced Iron)
or sponge iron