The transformation of the steel industry towards hydrogen

October 6th, 2020  |  Dr. Markus Schöffel
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engineering. tomorrow. together.
We have defined clear interim goals

-30% Emissions from our own production operations and processes\(^1\)

| 2030 | -30% | Emissions from energy procurement\(^2\) |

\(^1\) SCOPE 1-Emissions; \(^2\) SCOPE 2-Emissions (Base year 2018)
Gas will replace coal as reduction agent

Blast furnace needs coke as reduction and structural agent to produce liquid pig iron

Direct reduction plant uses gas (natural gas, coke oven gas or hydrogen) to produce solid sponge iron

Additional reduction agent (pulverized coal, natural gas, coke oven gas, H₂)

1800

kg CO₂ emissions per t crude steel

About – 95 %

100

(electric melting with green electricity)
Two paths towards carbon neutrality

CO₂ avoidance (CDA)

- Use of hydrogen in blast furnace operations
- Use of hydrogen in direct reduction plants
- Use of electric melters

CO₂ utilization (CCU)

- Conversion of steel mill cogeneration gases with hydrogen into valuable chemicals
- Carbon2Chem technology is already available today
Hydrogen for climate-neutral steel

2019 - 2022
H₂ in the blast furnace
We have been testing the use of hydrogen in a working blast furnace since 2019. The goal: The equipment of blast furnace 9.

2024 onwards
The milestone
Using a large-scale direct reduction plant (DR) which will be operated using green H₂ in the future, thyssenkrupp will produce sponge iron which will then be processed in the blast furnaces (BF), allowing a further reduction in emissions.

2026 onwards
The melting unit
We will optimize the hot metal system using a new, electrically powered melting unit. The sponge iron from the DR plant is thus liquefied for the BF meltshop. In this way, we will replace the first coal-based blast furnace.

2028 onwards
The scale-up
We will replace another coal-based blast furnace using a second, larger DR plant and another melting unit.

2030 onwards
The scale-up
We will replace another coal-based blast furnace using a second, larger DR plant and another melting unit.

2035 onwards
The scale-up
We will replace another coal-based blast furnace using a second, larger DR plant and another melting unit.

2050 onwards
Climate-neutrality
We will produce our steel climate-neutrally in four DR plants and four melting units.

Available quantity of climate-neutral steel (per year)
From 2022: 50,000 t
From 2025: 400,000 t
From 2027: 950,000 t
From 2030: 3 m t

-20 million t CO₂

2018
The world first
The concept: CO₂ becomes raw materials. In September 2018, thyssenkrupp produced methanol from steel mill gases for the first time at its Carbon2Chem® technical center in Duisburg.

2020 onwards
Industrialization
We will use the unavoidable CO₂ as a raw material on an industrial scale. The Carbon2Chem® technology can also be used in other sectors, like the cement industry.

2025 onwards
Large-scale production
We will use the unavoidable CO₂ as a raw material on an industrial scale. The Carbon2Chem® technology can also be used in other sectors, like the cement industry.
Step 1: Hydrogen injection in an existing blast furnace – trial operation

TODAY

FUTURE

Several injection campaigns over 8 h and one 24-h-trial completed

Pulverized coal → CO₂ emissions from pulverized coal

H₂ → Water vapor from hydrogen

Target: Study of kinetic and thermodynamic behavior of hydrogen
Step 2: Reallabor – Green steel production with hydrogen injection

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July 18, 2019
German Federal Minister of Economic Affairs Altmaier announces the 20 winners of the idea competition for Reallabore, a more than 0.5 bn € funding programme

thysenkrupp Steel Europe belongs to the 20 winners

Scheduled start-up
May 2022

Current project status: Preparational work with partners completed

**Step 3: Direct reduction plant with melter**

**PROCESS INNOVATION WITH SIGNIFICANT ECOLOGICAL AND ECONOMICAL ADVANTAGES**

- **Process innovation**
  First time use of a melter in the area of iron metallurgy

- **Technical innovation**
  Engineering of the melter

- **Ecological advantage**
  Hydrogen and green electricity substitute coal

- **Product development advantage**
  Electrical hot metal can be used like conventional hot metal

Entire current product portfolio can be covered with new route
The transformation requires large amounts of hydrogen

- 2050
- 8 bcm/a
- 720 kt/a

(only for the CDA path)
Our ramp-up will match availability of hydrogen and infrastructure

- **H₂ to BF9 (trial)**
- **H₂ to BF9 (28)**
- **Start-up 1st DR plant**
- **Start-up 2nd DR plant**
- **H₂ pipeline connection to Duisburg**
- **Initial operation of 1st DR plant on natural gas due to H₂ availability**
Initial volumes of hydrogen for tk SE Reallabor to be delivered by Air Liquide pipeline

German natural gas transmission grid

Regions with hydrogen pipeline grids

H₂ pipeline grid of Air Liquide in the Rhein Ruhr area (240 km total length, no external sources)

Connection pipeline will be constructed in the Reallabor project

approx. 7 km

Source:
Wasserstoff – Schlüssel zu weltweit nachhaltiger Energiewirtschaft, EnergieRegion.NRW, Dezember 2009
Cooperation with RWE for green hydrogen supply

• June 2020: MoU signed for delivery of green hydrogen
• Initial stage: 100 MW electrolysis with renewable electricity in Lingen
• Capacity can cover 70% of demand of H₂ injection in one blast furnace
• Possibility to produce 50,000 t of green steel

Source: https://www.manager-magazin.de/unternehmen/industrie/rwe-will-thyssenkrupp-mit-wasserstoff-versorgen-a-1307642.html#ref=rss
Feasibility Study on blue hydrogen with Equinor and OGE

Hydrogen production by autothermal reforming (ATR)
- CO₂ reduction by 95%
- 800,000 Nm³/h H₂ production capacity
- At least 200,000 Nm³/h H₂ available to third parties

CCOS (carbon capture and offshore storage) in Norwegian full scale project Northern Lights
Options for turquoise hydrogen supply

**Production of natural gas**

- Natural gas
- Pipeline

**Import of natural gas**

- Natural gas
- Pipeline

**Pyrolysis of natural gas**

- Germany near hydrogen user
- Currently only pilot plants available
- R&D for upscaling still necessary

**Use of hydrogen**

- Duisburg
- Hydrogen Pipeline
- Reduction with Hydrogen
- Melting with Electricity

**Important benefits to reach climate neutrality**

- Low leakage
- Low flaring rates
- Energy efficient transport
- No leakage
- Climate neutral solution for solid carbon
- Renewable energy supply for melting and downstream processes
Potential green hydrogen supply from third party projects

Moving towards 2030 and 2050 with hydrogen

The energy transition requires new forms of infrastructure and intelligent use of existing networks. Gasunie wants to invest in new infrastructure for renewable gases such as hydrogen.

H₂ backbone operational 2026

Northern part of pipeline grid start up 2024

Start up 2022

100 MW elektrolysis + storage + pipeline

Near Emden

Start up late 2022

Lingen

100 MW elektrolysis + 130 km pipeline

Sources:

H₂ supply to the state of North Rhine-Westphalia and potentially tk SE

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Transport of hydrogen within Germany by future dedicated pipeline infrastructure

- Potential sources of H₂
  - H₂ from the Netherlands pipeline grid
  - H₂ from PtG in Lower Saxony
  - H₂ from NL pipeline grid

Potential cavern storage
Refinery
Steel
Chemistry

- Potential new built H₂ pipelines
- H₂ pipelines after potential switch of existing natural gas pipelines
- Short to mid-term
- Long-term vision

Grid development plan gas 2020-30 (green gas variant):
37 km new built H₂ pipeline and conversion of existing NG pipelines to H₂ for supply of tk SE Duisburg by end of 2026

Source: Grid development plan gas 2020-30

Source: FNB Gas (modified with arrows for potential sources)
Thank you for your attention!

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