The transformation of the steel industry towards hydrogen

October 6th, 2020 | Dr. Markus Schöffel
thyssenkrupp Steel Europe AG

tkH2Steel

engineering.tomorrow.together.

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We have defined clear interim goals

-30% Emissions from our own production operations and processes[1]

2030

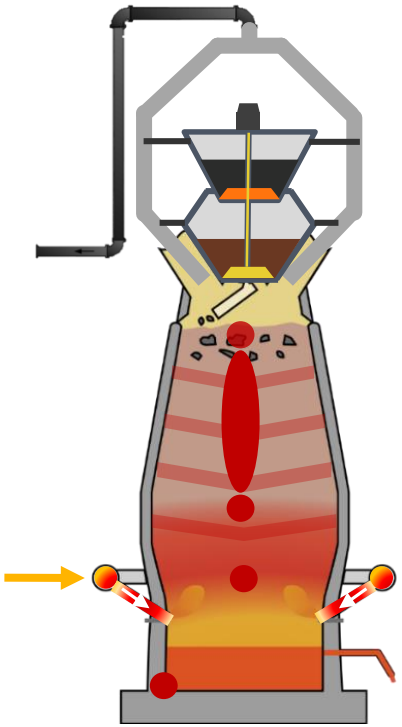
-30% Emissions from energy procurement[2]

[1] SCOPE 1-Emissions; [2] SCOPE 2-Emissions (Base year 2018)

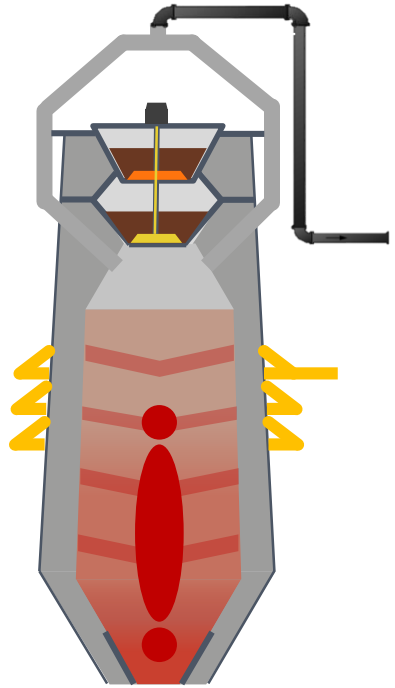
Gas will replace coal as reduction agent

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, H_2)



kg CO_2 emissions per t crude steel

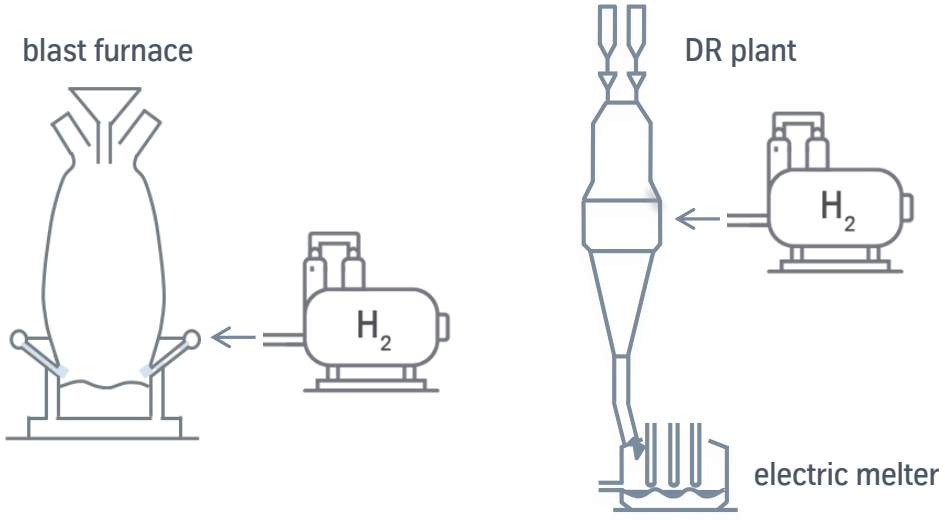
1800

About – 95 %

100

(electric melting with green electricity)

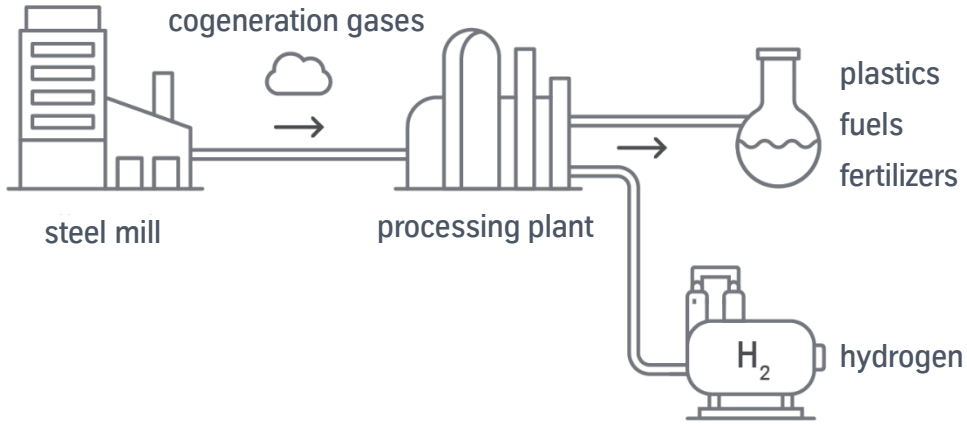
Two paths towards carbon neutrality



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

CO_2 avoidance (CDA)

2050
KLIMANEUTRAL
CLIMATE NEUTRAL



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

CO_2 utilization (CCU)

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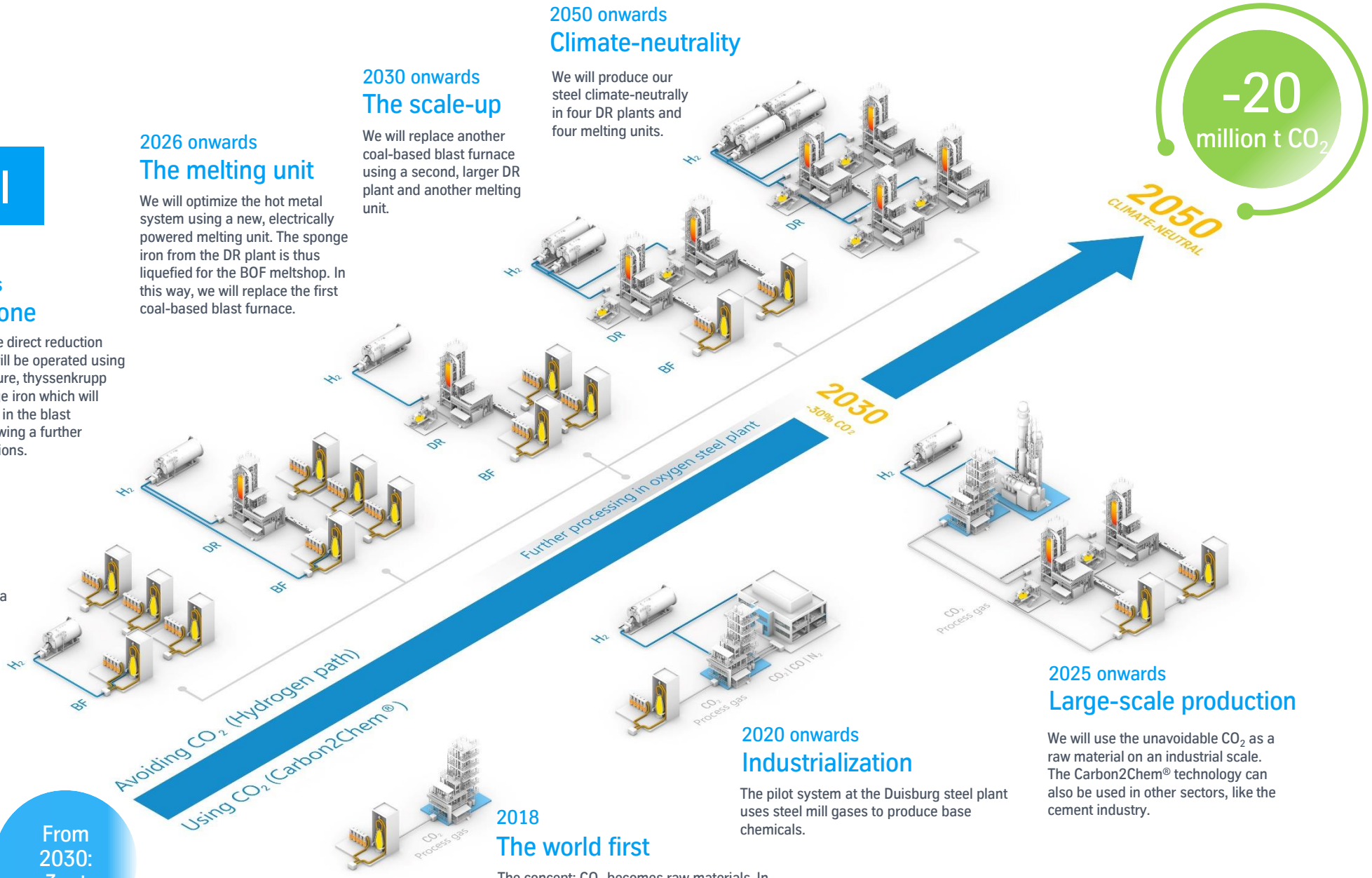
Hydrogen for climate-neutral steel



2019 - 2022
H_2 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 H_2 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 BOF meltshop. In this way, we will replace the first coal-based blast furnace.

2030 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.

2018
The world first

The concept: CO_2 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

The pilot system at the Duisburg steel plant uses steel mill gases to produce base chemicals.

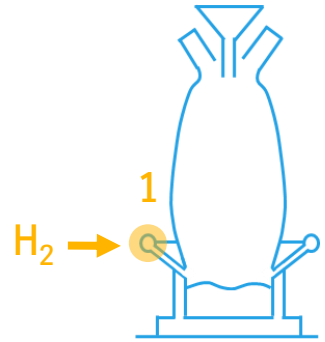
2025 onwards
Large-scale production

We will use the unavoidable CO_2 as a raw material on an industrial scale. The Carbon2Chem® technology can also be used in other sectors, like the cement industry.

Available quantity of climate-neutral steel (per year)

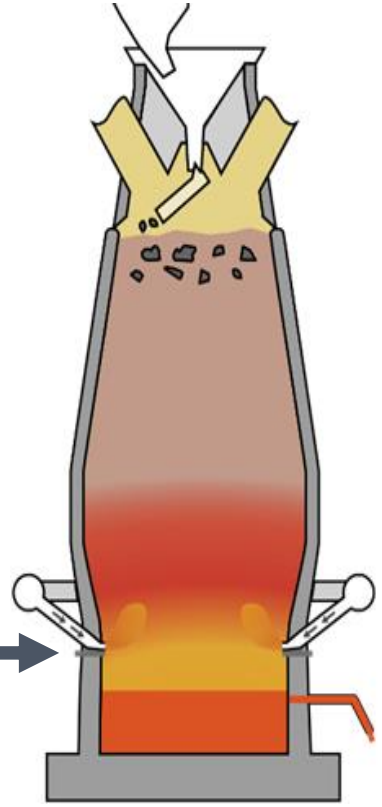
- From 2022: 50,000 t
- From 2025: 400,000 t
- From 2027: 950,000 t
- From 2030: 3m t

Step 1: Hydrogen injection in an existing blast furnace – trial operation



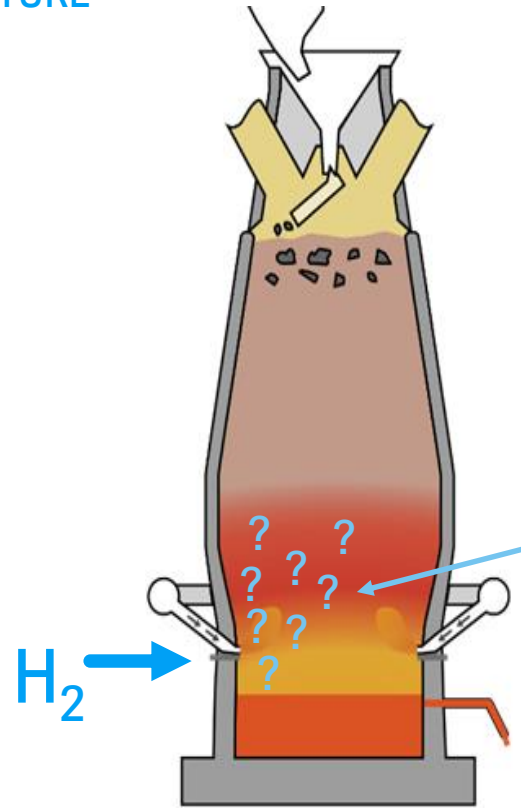
Several injection campaigns over 8 h and one 24-h-trial completed

TODAY



CO_2 emissions from pulverized coal

FUTURE



Target:
Study of kinetic and thermodynamic behavior of hydrogen

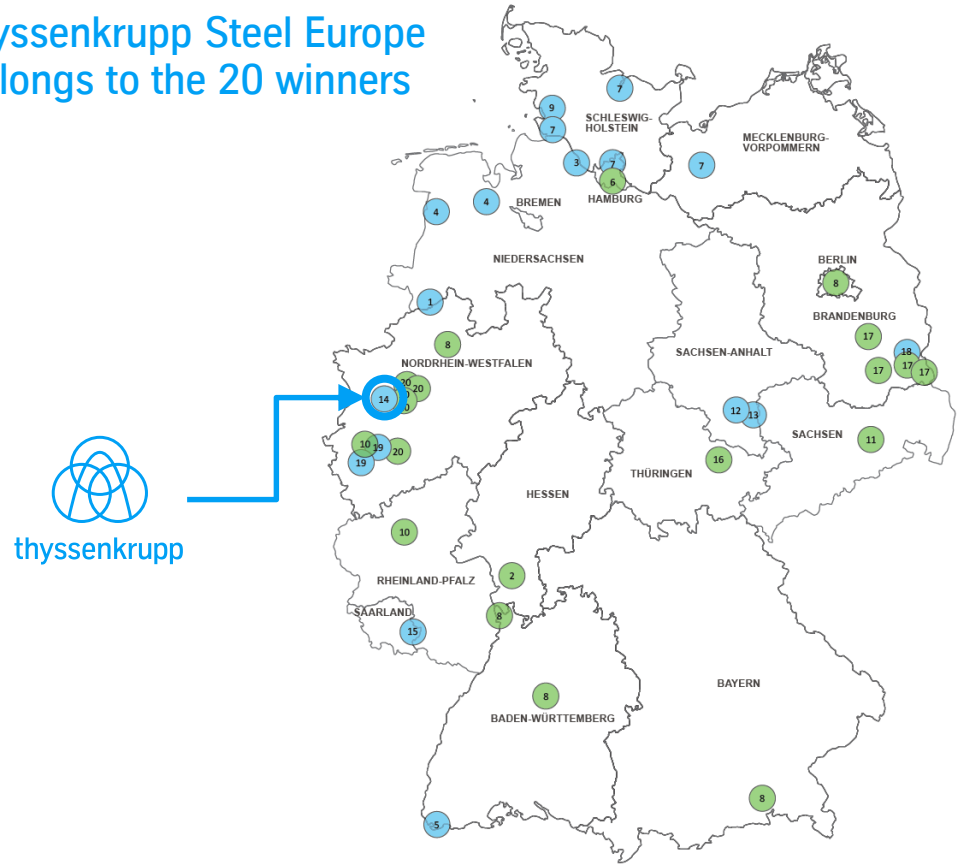
Water vapor from hydrogen

Step 2: *Reallabor* – Green steel production with hydrogen injection

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

thyssenkrupp Steel Europe belongs to the 20 winners



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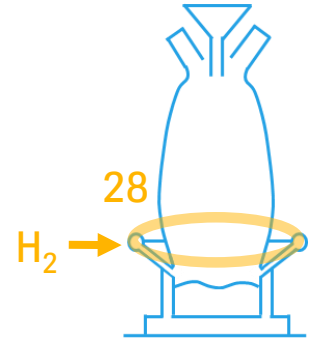


Scheduled start-up May 2022

Current project status: Preparational work with partners completed

Air Liquide · thyssenkrupp · BFI Angewandte Spitzenforschung

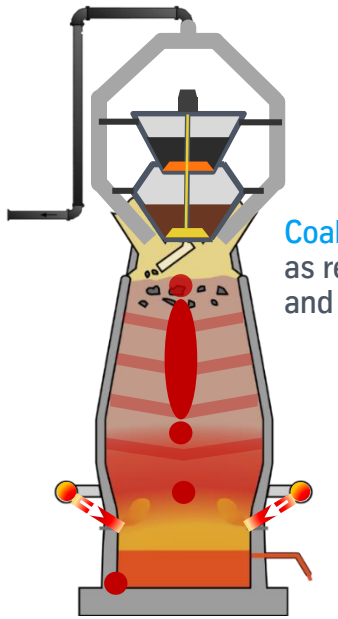
Source: https://www.bmwi.de/Redaktion/DE/Pressemitteilungen/2019/20190718-altmaier-verkuendet-gewinner-im-ideenwettbewerb-reallabore-der-energiewende.html

Step 3: Direct reduction plant with melter

PROCESS INNOVATION WITH SIGNIFICANT ECOLOGICAL AND ECONOMICAL ADVANTAGES

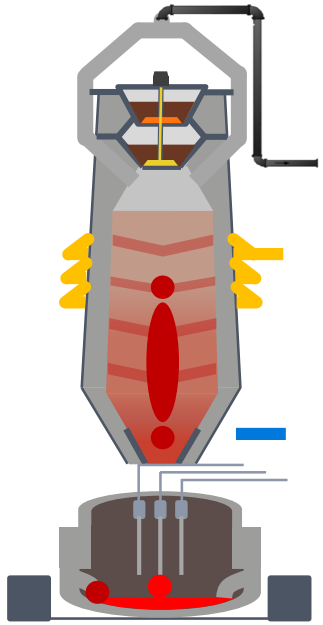
- **Process innovation**
  First time use of a melter in the area of iron metallurgy
- **Technical innovation**
  Engineering of the melter
- **Ecological advantage**
  Hydrogen and green electricity substitute coal
- **Product development advantage**
  Electrical hot metal can be used like conventional hot metal

CLASSICAL BLAST FURNACE



Coal
as reduction agent
and energy carrier

DIRECT REDUCTION PLANT WITH MELTER



Hydrogen
as reduction agent
in DR plant

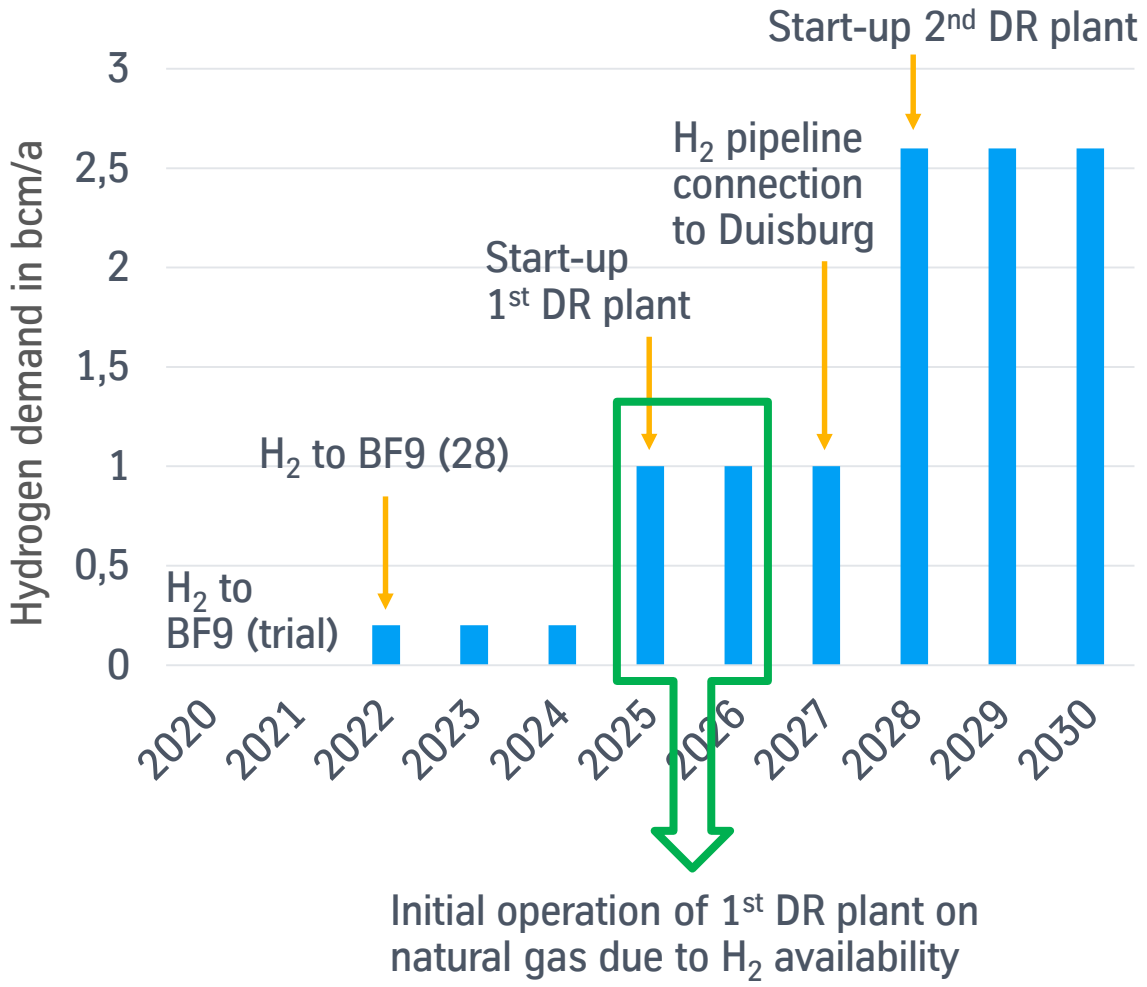
Green electricity
as energy carrier
in the melter

Entire current product portfolio can be covered with new route

The transformation requires large amounts of hydrogen

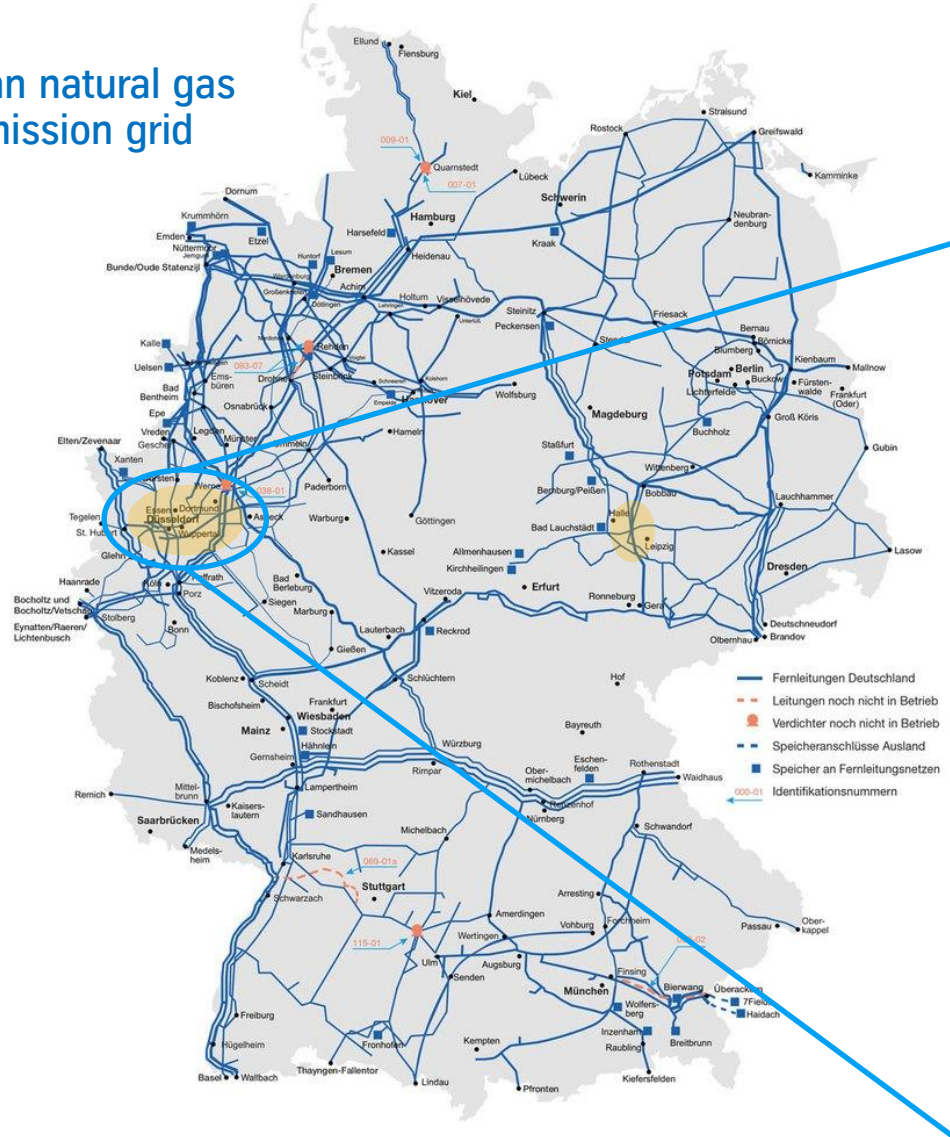
2050
8 bcm/a
720 kt/a
(only for the CDA path)

Our ramp-up will match availability of hydrogen and infrastructure



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

H_2 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

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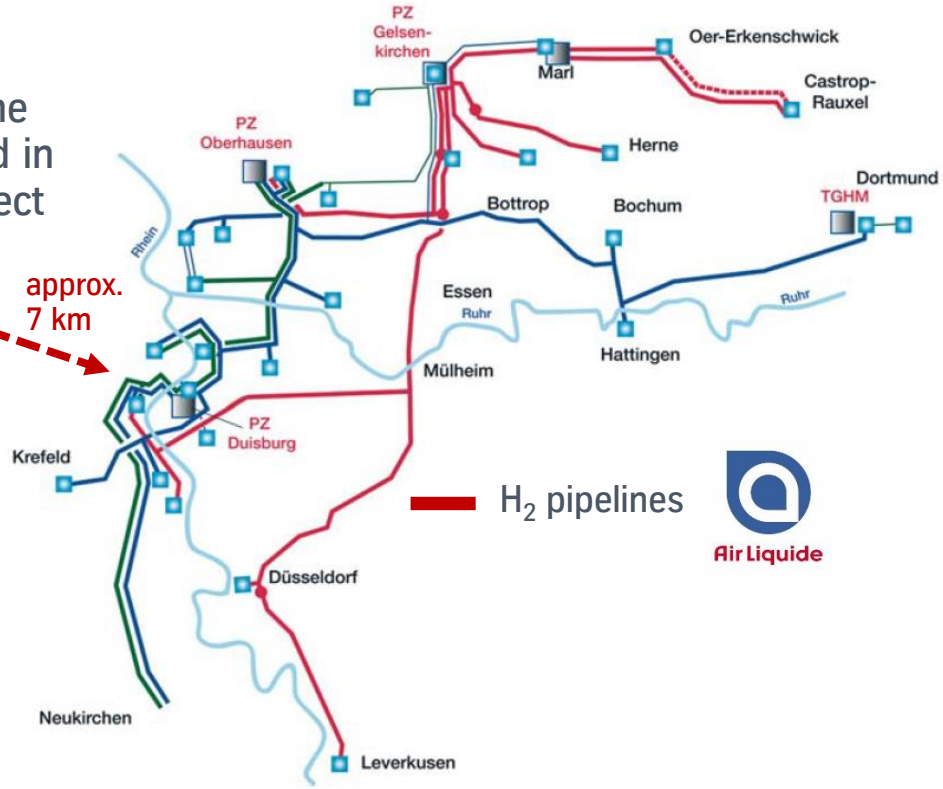
approx. 7 km



Source:
https://www.bmwi.de/Redaktion/DE/Artikel/Energie/gas-erdgasversorgung-in-deutschland.html
Wasserstoff – Schlüssel zu weltweit nachhaltiger Energiewirtschaft, EnergieRegion.NRW, Dezember 2009

Cooperation with RWE for green hydrogen supply

Zusammenarbeit geplant

RWE will Thyssenkrupp mit Wasserstoff versorgen

10.06.2020, 20.52 Uhr

Stahlwerk von Thyssenkrupp in Duisburg, Nordrhein-Westfalen: Das Werk soll von RWE mit grünem Wasserstoff versorgt werden Foto: Marcel Kusch / DPA

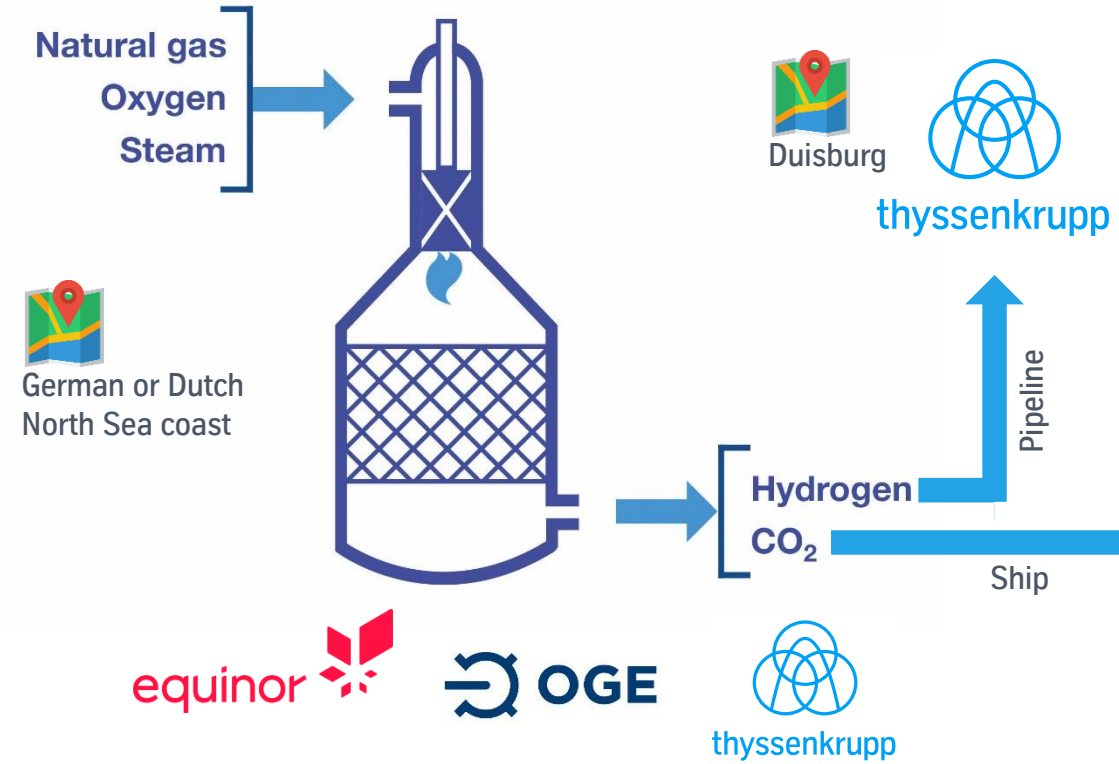
Die Ruhrgebietskonzerne Thyssenkrupp und RWE planen eine Zusammenarbeit beim Einsatz von Wasserstoff in der Stahlproduktion. RWE könnte an seinem Kraftwerksstandort in Lingen im Emsland mit Ökostrom grünen Wasserstoff erzeugen, der dann über Leitungen zum Hüttenwerk von Thyssenkrupp in Duisburg transportiert wird. Der Stahlhersteller will mit dem Einsatz von Wasserstoff in den Hochöfen seinen Kohlendioxidausstoß verringern.

- 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 H_2 injection in one blast furnace
- Possibility to produce 50.000 t of green steel

RWE

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)

- CO_2 reduction by 95 %
- 800.000 Nm^3/h H_2 production capacity
- At least 200.000 Nm^3/h H_2 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

- Currently only pilot plants available
- R&D for upscaling still necessary

Germany near hydrogen user

Hydrogen

Pipeline

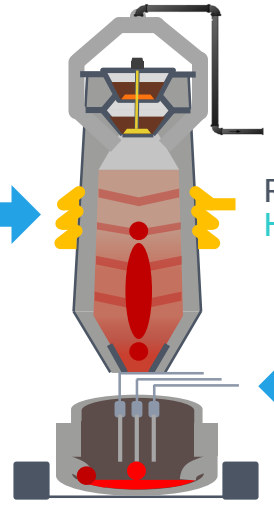
Solid carbon

- Agriculture
- Construction
- Special chemistry

Use of hydrogen

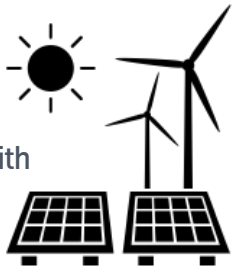
Duisburg

thyssenkrupp



Reduction with Hydrogen

Melting with Electricity



Important benefits to reach climate neutrality

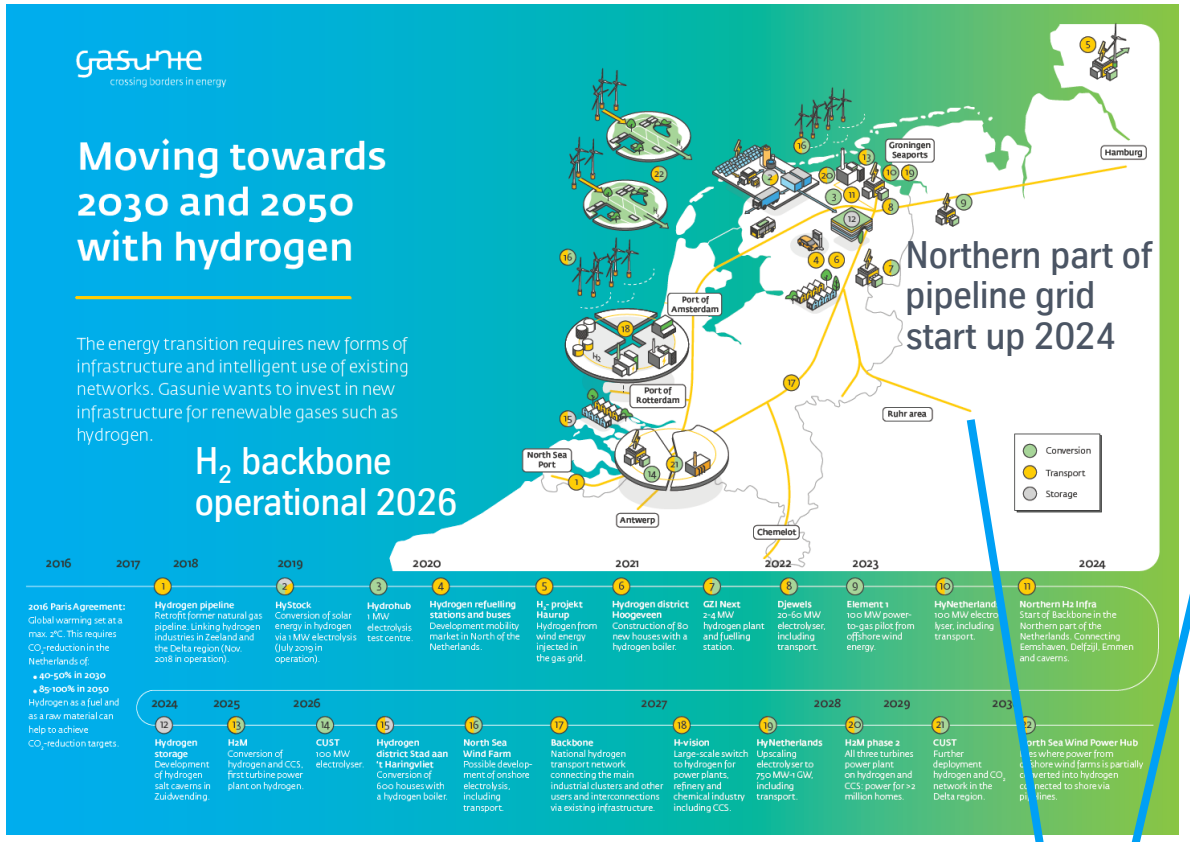
- Low leakage
- Low flaring rates

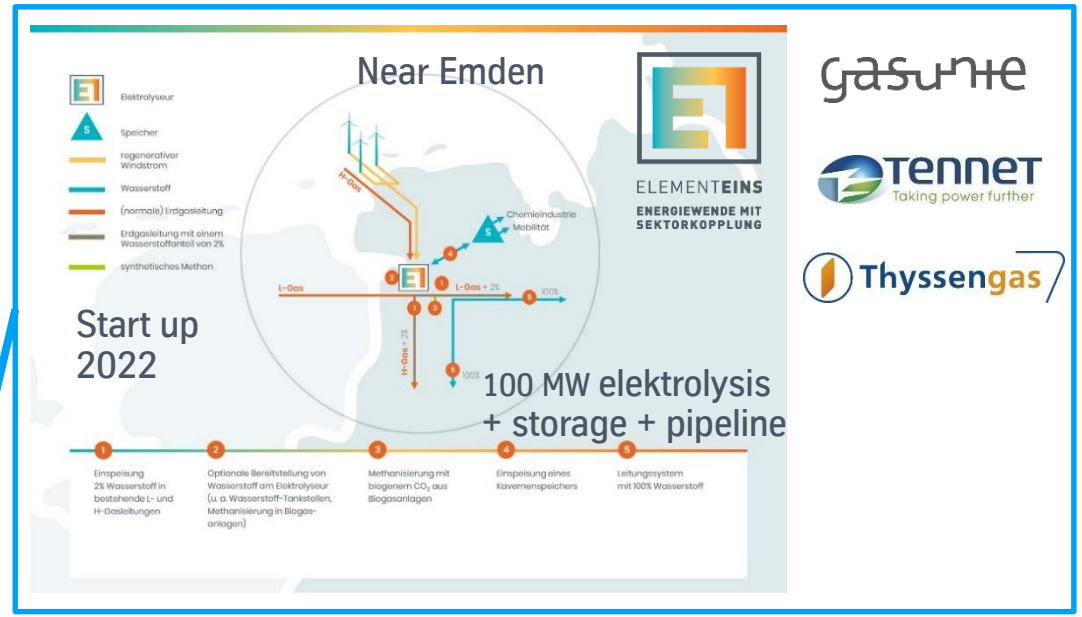
- Energy efficient transport
- No leakage

Climate neutral solution for solid carbon

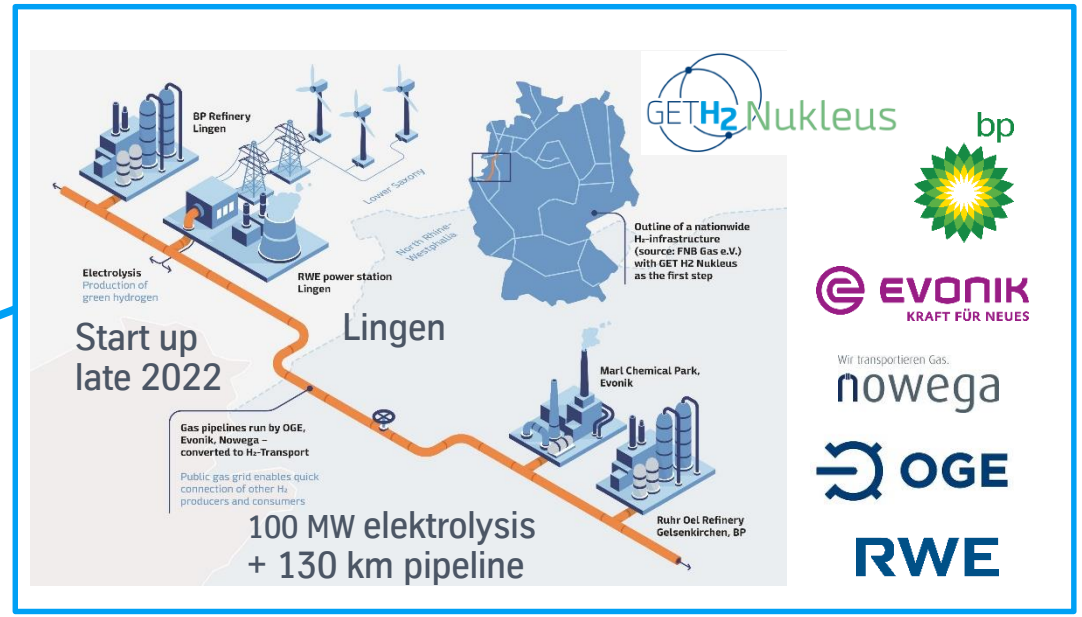
Renewable energy supply for melting and downstream processes

Potential green hydrogen supply from third party projects





gasunie
TenneT Taking power further
Thyssengas



bp
EVONIK KRAFT FÜR NEUES
Wir transportieren Gas. nowega
OGE
RWE

Sources:
Gasunie; Press Release Get H2 Nukleus, March 17, 2020;
https://www.bmwi.de/Redaktion/DE/Downloads/P-R/reallabore-der-energiewende-karte.pdf?__blob=publicationFile&v=8

H_2 supply to the state of North Rhine-Westphalia and potentially tk SE

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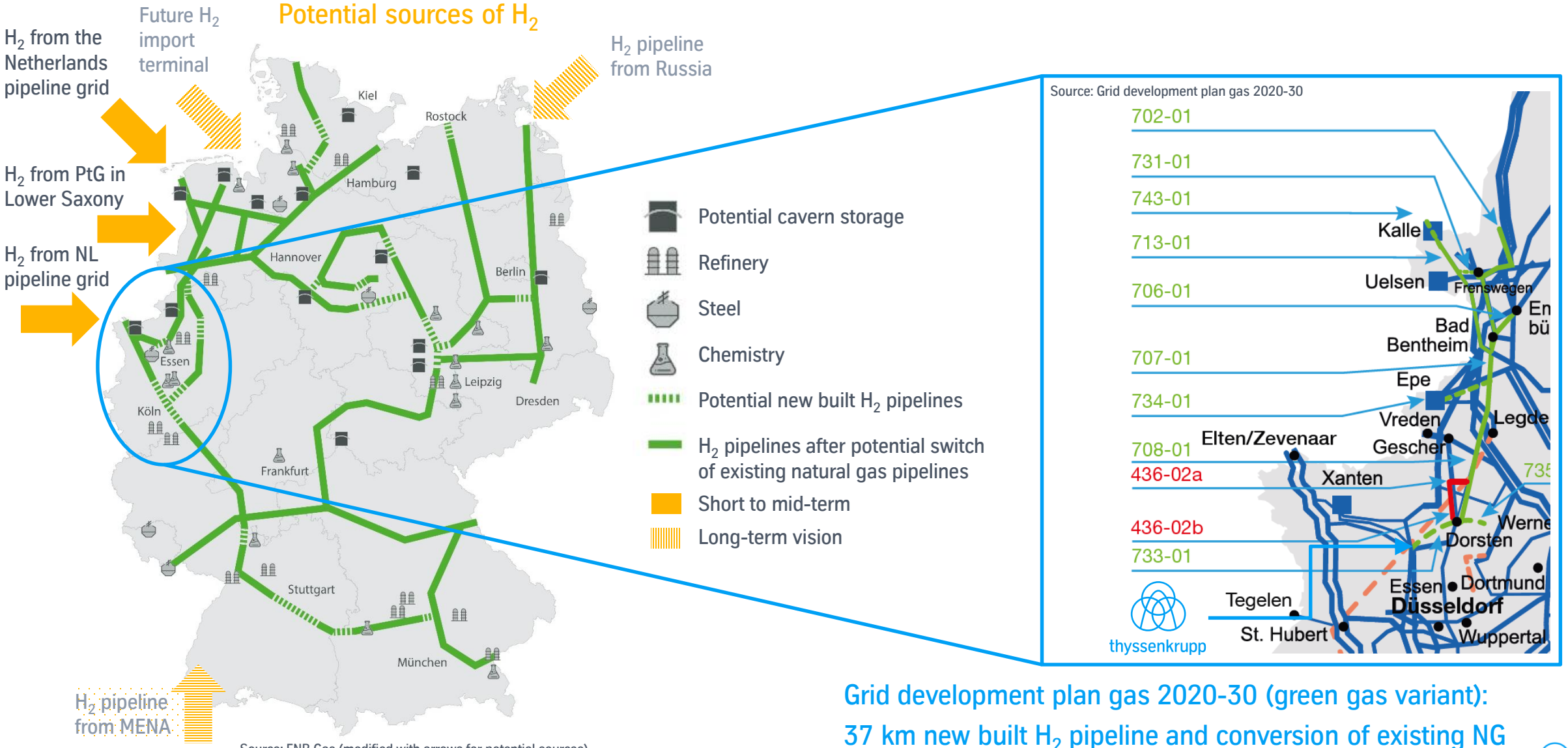
Transport of hydrogen within Germany by future dedicated pipeline infrastructure



Source: FNB Gas (modified with arrows for potential sources)

Grid development plan gas 2020-30 (green gas variant):

37 km new built H_2 pipeline and conversion of existing NG pipelines to H_2 for supply of tk SE Duisburg by end of 2026


Thank you
for your attention!
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