Decarbonisation Pathways 2030 and 2050

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Executive Summary

Based on the decarbonisation technologies (so called "decarbonisation pathways") assessed and presented in a separate report (D1.2, "Technology Assessment and Roadmapping"), this report analyses the industrial deployment of decarbonisation technologies in the European steel industry along the time scale. It considers the progress of technological maturities in combination with the different framework conditions of different sites and regions across Europe. As result the increasing industrial deployment of decarbonisation technologies in the European steel industry is prognosed and **6 probable decarbonisation pathway scenarios** are identified.

For 2030, an industrial pathway scenario for the use of **mixed technological implementation** in primary steel production is presented, and this reaches the decarbonisation targets set at European level. The consequences of **slower industrial deployment** of decarbonisation technologies or **additional hydrogen availability** are presented in additional 2030 pathway scenarios.

For 2050, the approach of **mixed technologies** is extrapolated. An additional pathway considers the availability of **additional decarbonisation technologies** by 2050. The third 2050 decarbonisation pathway is based on **increased availability of steel scrap** leading to a larger share of secondary steel production.

The **availability of energy and material flows** required for steel production are assessed as external framework conditions needed for industrial decarbonisation. In this context, eight availabilities and their probable future developments are assessed:

- Renewable Electricity
- Green Hydrogen
- Natural Gas
- Alternative Carbon Sources
- Iron Ore & Pellets
- Steel Scrap
- CO_2 Storage
- CCU Products

These elaborations are complemented by assessments of other framework conditions: Technological maturity, plant specific investment cycles as well as financial and legislative conditions including EU Emission Trading System (ETS) and Cross Border Adjustment Mechanism (CBAM) are the most important framework conditions that need to be considered.

As far as industrial deployment of decarbonisation technologies in primary steel production is concerned, the availabilities of green hydrogen, alternative carbon sources and steel scrap were found to differ across Europe and thus are exploited to estimate the **distribution** of technology routes in the different member states. The technological maturity and the investment cycles are interpreted as defining the **timing** of industrial deployment.

The conclusion of the Green Steel for Europe report D1.5 ("Decarbonisation barriers") and the projects' consultation activities was, that the most important barriers for decarbonisation are all

related to financial conditions. Financial conditions were consistently found to be the dominant background for the development of industrial deployment scenarios. In this sense, the availability of energy and materials flows must always be linked to the respective costs, respectively to the operational expenditures (OPEX). The OPEX must either themselves enable profitable steel production or the financial and legislative framework conditions must achieve appropriate compensation. The policy options to adapt the financial and legislative framework conditions to enable industrial decarbonisation are highlighted in the Green Steel for Europe D3.2 report – “Impact Assessment Report”.

In the report “Technology Assessment and Roadmapping” (Deliverable D1.2 of the Green Steel for Europe project), the most important decarbonisation technologies were completed to full process chains, so called “technology routes”. These technology routes are considered and further distinguished in this report. They are summarised as **technology route factsheets** in the Annexes A-G. These factsheets give a simplified but transparent overview of technological development and specific requirements of the different options with regard to framework conditions. The technology routes were categorised into four main groups:

- **Optimised Blast Furnace-Basic Oxygen Furnace (BF-BOF) route (Route 1)**
- **Direct Reduction (DR) based route (Route 2)**
- Smelting Reduction (Route 3)
- Iron Ore Electrolysis (Route 4)

The optimised BF-BOF route is further distinguished into utilisation of alternative carbon sources, CCUS and other actions (Route 1A/B/C). The direct reduction-based route is divided into natural gas based direct reduction (Route 2A) and hydrogen based direct reduction (Route 2B).

Based on this information, the optimised BF-BOF routes (Routes 1A/B/C) and the direct reduction-based routes (Routes 2A/B) were considered to reach TRL 9 by 2030-2035 and to start its industrial deployments, whereas Smelting Reduction (Route 3) and Iron Ore Electrolysis (Route 4) might just become options for later industrial deployment by 2050. This is reflected in the pathway scenarios elaborated.

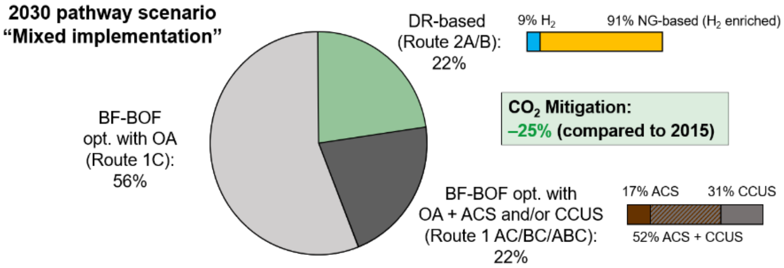
The pathway scenarios show the shares of the considered **primary steel production routes in the EU-27**. The pathway scenarios focus on primary steel production, as this is responsible for an estimated 87% of current CO_2 emissions of the European Steel Industry. This is consistent with the scope of this project: to consider at least 80% of CO_2 emissions from steelmaking. Due to its high share of CO_2 emissions, primary steel production provides huge mitigation potential, however, significant investments and changes of technology routes are needed, and this would obviously be a time-consuming transition. Thus, the demands to enable and start this technology leap in primary steel production are assessed as most urgent with respect to the policy options needed.

The aspects of secondary steel production are also covered in the analyses. The most important framework condition needed to mitigate CO_2 in secondary steel production is the availability of huge amounts of renewable electricity at competitive prices. This demand is consistent with the main demand of primary steel production.

For the first 2030 scenario of "**Mixed implementation**" of decarbonisation technologies, the assessment of national and/or regional framework conditions was utilised to differentiate the EU member states with primary steel production into four groups.

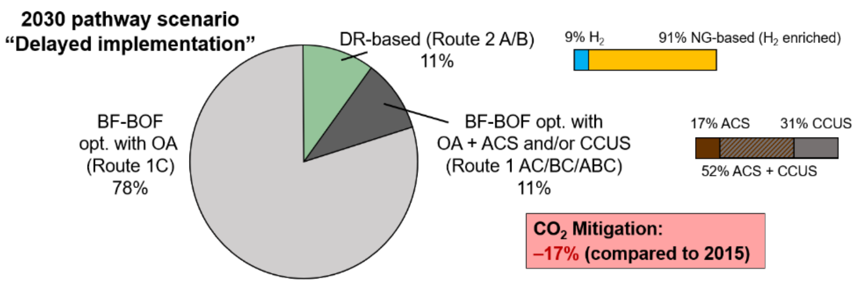
This assessment of national / regional framework conditions was fused with estimations of blast furnace relinings in the EU-27 by 2030. It was estimated that **at least 46%** of primary steel production capacity in the EU-27 will **not** be subject to major technology **switches by 2030** based on their **investment cycles**. The other 54% (i.e. with upcoming BF relinings) were assigned to the four groups of national and/or regional framework conditions. For all scenarios it was assumed that the total annual steel production capacity in the EU-27 remains constant at 160 million tonnes per year.

Based on these assumptions, the **2030 scenario "Mixed implementation"** leads to a production share of 56% being subject to gradual improvements to the BF-BOF route by other actions (Route 1C). Furthermore, 22% of production capacities are expected to utilise alternative carbon sources and/or CCUS measures. Another 22% of production capacities are shifted towards direct reduction-based production (Route 2), with an average share of 9% reduced by hydrogen. Such industrial deployment of decarbonisation technologies by 2030 would meet the targets set by the EU (a 25% reduction in CO_2 emissions compared to 2015). However, as the lead times (~5 years) between investment decisions and industrial implementation are significant, this 2030 scenario can be rated as quite ambitious: 44% of the capacities would need significant investment decisions before 2025 to ensure industrial implementation before 2030.



The **2030 scenario "Delayed implementation"** assumes that 50% of major technology switches to alternative carbon sources, CCUS or Direct Reduction are delayed and realised after 2030. This leads to 78% of primary production capacities being subject to only gradual improvements by "Other actions" (Route 1C); 11% are subject to major utilisation of alternative carbon sources and/or CCUS and a further 11% are estimated to be shifted towards direct reduction-based production. Overall, this pathway scenario results in a 17% reduction of CO_2 emissions compared to 2015, missing the target set by the EU by eight percentage points (+14 Mt CO_2 /a).

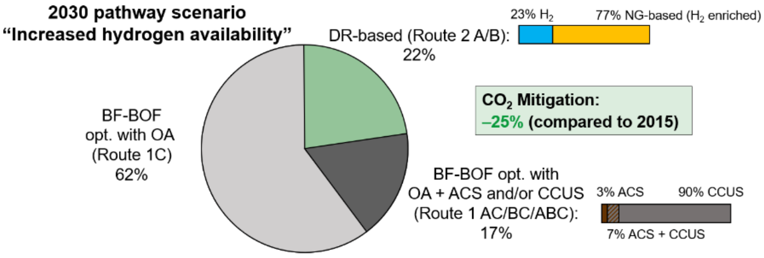
However, if the investments cycles and lead times (as discussed above) are considered, the assumptions for this scenario may be rated as more realistic. Several solutions can be discussed to close the gap to emission targets set for the EU-27.



Main examples are:

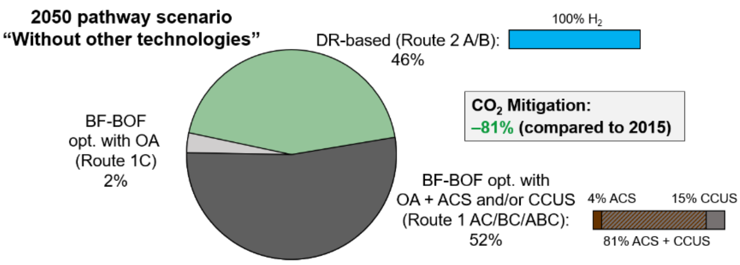
1. Significantly decreasing CO_2 emissions in secondary steel production by extensive use of renewable power. This can be rated as a preferable option since no adaption of steel production sites needing costly investments and involving technical risks is necessary.
2. Increasing hydrogen enrichment for new direct reduction plants.
3. Decreasing energy demand and emissions by increased use of scrap. This approach is however strongly limited for 2030 by the shortage of scrap of sufficient quality.
4. Another option is that primary steel production sites are shut down. However, due to the most probable consequences of carbon leakage and steel quality issues this option can be rated as the worst-case scenario for the European steel industry, for the European economy and for the global climate.

The third **2030 scenario "Increased hydrogen availability"** reflects the more extensive use of hydrogen in the steel industry by 2030 (+0.2 million tons resp. +25% was assumed to be utilised).

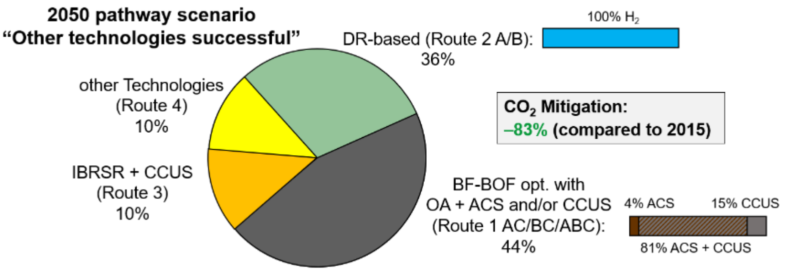


Since the availability of alternative carbon sources in 2030 is not yet clear, it was also assumed that fewer alternative carbon sources would be utilised. The specific CO_2 mitigation in the BF-BOF-route optimised by "other measures" (Route 1C) and direct reduction-based capacities was increased to reflect higher hydrogen usage. Overall, this pathway scenario needs 39% of primary production capacity to be substantially changed (compared to 44% for the "mixed implementation" scenario) and can be rated as ambitious but viable. This pathway scenario meets the EU target of 25% CO_2 mitigation compared to 2015 and thus reflects an alternative hydrogen-focused way to reach the target.

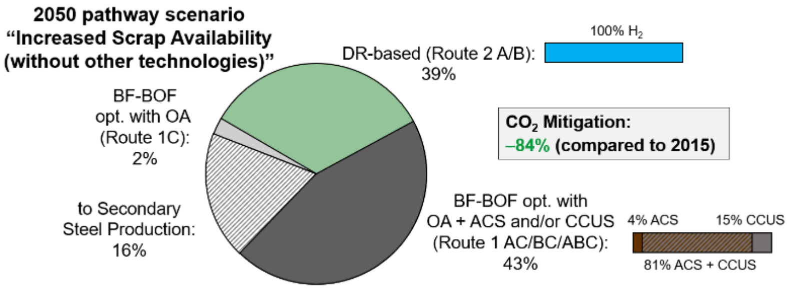
Analyses covering a forecast of almost 30 years obviously include huge uncertainties and a large variance of possible framework conditions and resulting industrial scenarios. To illustrate the range of options three 2050 scenarios were selected which all realise the targeted CO_2 mitigation of >80% but with different technologies. The **2050 scenario "Without other technologies"** extrapolates the 2030 "Mixed implementation" pathway scenario to 2050. It assumes that no other breakthrough decarbonisation technologies will be industrially successful by 2050, so that the decarbonisation process needs to be based on alternative carbon sources, CCUS and hydrogen based direct reduction. In this pathway scenario, 46% of primary steel production is covered by direct reduction-based processes utilising 100% hydrogen; 52% of primary production capacities operate the BF-BOF route improved with significant alternative carbon source and/or CCUS utilisation. However, only 2% of the BF-BOF capacities face gradual improvements. This technology distribution would lead to an 81% reduction in CO_2 emissions compared to 2015, thus building a strong basis for reaching the EU target of climate neutrality.



In the **2050 scenario “Other technologies successful”** two additional decarbonisation technology routes are assumed to be industrially established. This pathway scenario reflects an industrial deployment of iron bath reactor smelting reduction including CCUS measures (Route 3) and other technologies such as, for example, iron ore electrolysis (Route 4) in 10% of primary steel production capacities each; 36% of capacities would be covered by hydrogen-based direct reduction. The remaining share of 44% of primary production capacities is covered by the BF-BOF route adjusted to significant alternative carbon source and CCUS utilisation. This technology distribution would increase the CO_2 mitigation to 83% compared to 2015.



The **2050 pathway scenario “Increased Scrap Availability”** reflects a partial switch of primary steel production capacities towards secondary steel production due to higher availability of steel scrap. In this scenario 15 million tonnes of annual steel production are shifted towards secondary steel production. The distribution of the remaining primary steel production capacities reflects the other two 2050 pathway scenarios with either other technologies being successful or not. Both cases lead to a slight increase of CO_2 mitigation to 84% compared to 2015.



It can be concluded that:

- **framework conditions** such as production costs as well as the availability of resources and infrastructure **dominate** the industrial implementation of breakthrough decarbonisation technologies;
- the framework conditions are currently far from positive for decarbonisation investments;
- **policy actions are needed** to make the framework conditions better suited to promoting investments in breakthrough decarbonisation technologies;
- considering the long investment cycles and the significant lead times, the time pressure for these policy actions is extremely high, particularly for fulfilment of the **2030 targets**;
- actions to safeguard positive decarbonisation investment conditions both in the short term and the long term must be **taken now**.

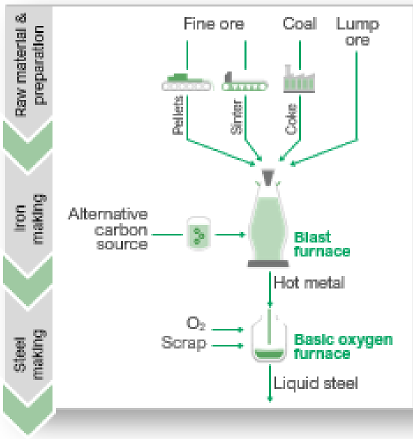
The next few years will be decisive in achieving the European CO_2 mitigation targets with many influential factors also changing in an unpredictable fashion. The Green Steel for Europe consortium is thus strongly in favour of continuing **the interdisciplinary roadmapping and assessment work** in a follow-up project with consideration to the actual framework conditions and targets and to provide a deeper investigation of aspects which have only been touched upon in this project: secondary steel production including downstream processes and decarbonisation during the decisive years 2030-2040.

Annex A: Optimised BF-BOF with alternative carbon sources (Route 1A) factsheet

Technology Routes Based on Optimised BF-BOF Utilisation of Alternative Carbon Sources

Development of effective Solutions towards a Low-CO_2 Steel Production

Fact Sheet



Technical description

The foundation of the technology route is for the blast furnace (BF) and the basic oxygen furnace (BOF). Fossil carbon (in the form of coal and coke) can be substituted by **alternative carbon** such as torrefied material or charcoal by upgrading various carbon containing feed stocks such secondary wood, forest biomass/agricultural residues. In addition, other types of **spent carbon streams** such as the fractions of plastic, paper and biogenic materials in waste societal streams can also be used as potential carbon sources, enabling the increase of the circularity of carbon use and sparing natural resources. This developed technology route can further be combined with carbon capture and usage or other additional mitigation technologies applied upstream and downstream the blast furnace.

Framework conditions

- Technologies to upgrade alternative carbon sources (e.g. torrefaction or carbonisation)
- Transportation, storage, price and availability of alternative carbon sources
- Possibility of integrating upgrading technologies at the steelmaking sites

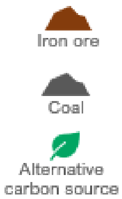
Economic assessment*

Cost for development up to **TRL 8**	From 5 to 150 M€
Cost for **first industrial deployment**	From 15 to 500 M€
Cost for **production plants**	From 15 up to 500 M€

* min with only alternative carbon source, max with all the others enhancement actions implemented

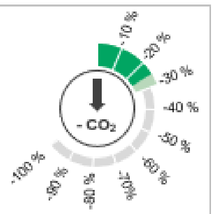
Feedstock

Beyond usual blast furnace feedstock, various types of alternative carbon sources such as secondary biomass, agricultural residues, sewage sludge or mixed waste streams containing plastics and biogenic materials can be utilised.



CO_2 mitigation potential

The mitigation potential of this option compared to conventional BF-BOF route is 25 % to 30 % (on full steel plant emissions) and can be combined with other mitigation routes (such as gas injections in the blast furnace etc.) to reach higher mitigation.



Geographical information

- Key projects for utilisation of alternative carbon sources in primary steel production in:
  - Ghent (Belgium)
  - Dunkerque, Fos-sur-Mer (France)
  - Bremen (Germany)
  - Dabrowa Gornicza (Poland)

TRL development

TRL 2 - 7 ◂ **2020** ▸

TRL 8 (TRL 9 is expected in 2035) ◂ **2030** ▸

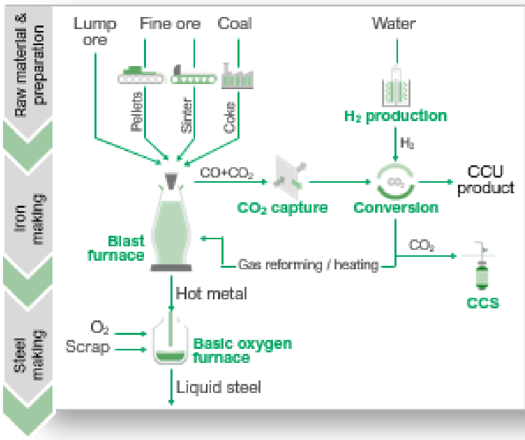
Industrially deployed ◂ **2050** ▸

Annex B: Optimised BF-BOF with CCUS (Route 1B) factsheet

Technology Routes based on Optimised BF-BOF
Utilisation of Carbon Capture, Usage & Storage

Development of effective Solutions towards a Low-CO_2 Steel Production

Fact Sheet



Technical description

Carbon capture and usage (CCU) in the iron and steel industry consists of the **capture of CO_2 or CO** from relevant process gases and their **conversion** into other valuable products. Therefore, a typical CCU process consists of multiple components: First, the carbon oxides are captured in a separation unit, and then converted into more valuable products in a biological or chemical reactor and finally the products are refined in a processing unit. If not all the captured CO_2 can be converted, CCU can be complemented by **carbon capture and storage** (CCS). This technology route can be combined with further mitigation technologies such as the utilisation of alternative carbon sources.

Framework conditions

- ☐ Energy efficient separation and purification technologies
- ☐ Availability and price of low-CO_2 hydrogen production
- ☐ Availability and volatility of renewable energy
- ☐ CO_2 and hydrogen transport system
- ☐ Marketability and price CCU products
- ☐ Social acceptance

Economic assessment*

Cost for development up to **TRL 8**	1000 M€
Cost for **first industrial deployment** (greenfield)	2000 M€
Cost for **production plants**	4000 M€

* including all costs for H_2 infrastructures, greenfield; brownfield, costs are 40%

Feedstock

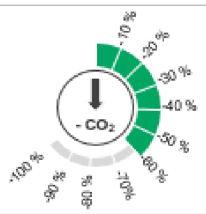
As CCU is an extension of the conventional blast furnace – basic oxygen furnace (BF-BOF) route usual blast furnace feedstock (ores, coke, lime…) is utilised within this technology route. The conversion process further requires hydrogen. In addition, the replacement of certain amounts of coal with alternative sources of carbon is feasible.

Iron ore

Coal

CO_2 mitigation potential

The overall CCU mitigation potential by carbon oxide conversion is estimated to up to 60 % compared to the BF-BOF route. CCU concepts can generally be combined with other CO_2 mitigation technologies



TRL development

TRL 4 - 8	**2020**	▮▮▮▮▯▯▯▯▯
TRL 9	**2030**	▮▮▮▮▮▮▮▮▮
Industrially deployed	**2050**	▮▮▮▮▮▮▮▮▮

Geographical information

- ☐ CCU projects in primary steel production as indicated in the map in France, Belgium, Netherlands, Germany and Poland
- ☐ CCS projects in primary steel production: Ghent (Belgium), Dabrowa Gornicza (Poland), Bremen (Germany), Eisenhüttenstadt (Germany), Dunkerque (France), Fos-sur-Mer (France)

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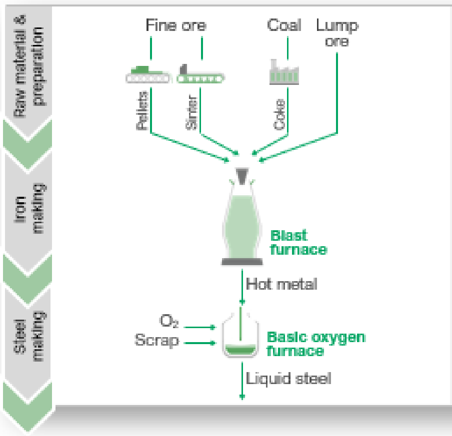
Annex C: Optimised BF-BOF with other actions (Route 1C) factsheet

TECHNOLOGY ROUTES BASED ON OPTIMISED BF-BOF OTHER ACTIONS (GAS INJECTION, SINTER PLANT,…)

DEVELOPMENT OF EFFECTIVE SOLUTIONS TOWARDS A LOW-CO_2 STEEL PRODUCTION

FACT SHEET



Technical description

The foundation of the technology route is for the blast furnace (BF) and the basic oxygen furnace (BOF). In addition to the use of alternative carbon sources, the application of CCUS and the recycling of spent carbon streams, further CO_2 mitigation technologies are available within the conventional blast furnace route. Examples of these are **gas injection into the blast furnace** (usually of hydrogen-rich gases to minimise or to avoid CO_2 formation), the **waste gas recirculation** and **use of low-CO_2 fuels** at the sinter plant as well as **the increased scrap usage** (mainly at the basic oxygen furnace plant) or the operation of **new heating applications** on hydrogen/internally generated gases (provided these gases replace natural gas imported in the steel plant).

Framework conditions

- ☐ Availability and price of low-CO_2 hydrogen production
- ☐ Availability of volatility of renewable energy for plasma torches
- ☐ Social acceptance
- ☐ Energy efficient separation and purification technologies
- ☐ CO_2 and process gases transport system

Economic assessment

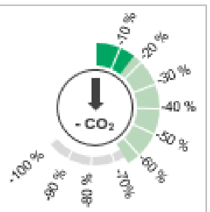
Cost for development up to **TRL 8**	200 M€
Cost for **first industrial deployment**	400 M€
Cost for **production plants**	650 M€

Feedstock

Beyond usual blast furnace feedstock (ores, coke, lime…), gases have to be injected. Either external (hydrogen or natural gas) either process gases, even BF ones after reforming and reheating.

CO_2 mitigation potential

The savings potential of TGR-blast furnace in combination with CCUS is up to 65 %, even when calculated on a full production perimeter, from raw materials to hot rolled coil. Without CCUS, it is limited to 35 % at blast furnace level and to 15 to 20 % on a full production perimeter.



TRL development

TRL 2 - 7	2020	■■□□□□□□□
TRL 8 (TRL 9 is expected in 2035)	2030	■■■■■■■■□
Industrially deployed	2050	■■■■■■■■■

Geographical information

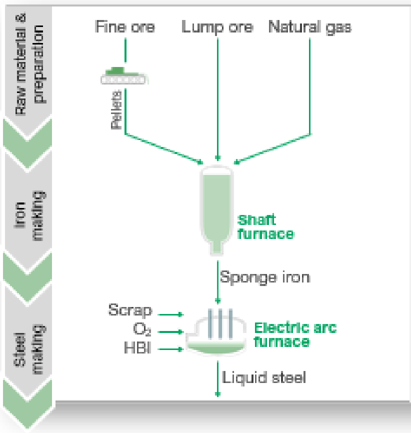
- ☐ Projects of further optimisation of BF-BOF routes are planned in
  - ☐ France (Dunkerque, For-sur-Mer)
  - ☐ Belgium (Ghent)
  - ☐ Netherlands (IJmuiden)
  - ☐ Germany (Duisburg, Bremen, Eisenhüttenstadt)
  - ☐ Poland (Dabrowa Gornicza)

Annex D: Natural Gas based Direct Reduction (Route 2A) factsheet

TECHNOLOGY ROUTES BASED ON DIRECT REDUCTION
DR-EAF BASED ON (H_2-ENRICHED) NATURAL GAS

DEVELOPMENT OF EFFECTIVE SOLUTIONS TOWARDS A LOW-CO_2 STEEL PRODUCTION

FACT SHEET



Technical description

This technology route consists of a **direct reduction** (DR) process utilising **natural gas** or coal to produce sponge iron in the form of direct reduced iron (DRI) or hot briquetted iron (HBI) from iron ore. The sponge iron is subsequently processed into crude steel in an electric arc furnace (EAF). The liquid steel will be processed in secondary metallurgy, then casted and rolled in similar steps as in the current integrated steelmaking route. Natural gas based direct reduction can be complemented by carbon capture and usage (CCU) and/or carbon capture and storage (CCS). Furthermore, the operating gas mixture could be gradually enriched with hydrogen and therefore, this technology route could be considered as an entry point to a technology route based on hydrogen-based direct reduction.

Framework conditions

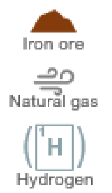
- ☐ Price and availability of natural gas
- ☐ Process gases transport system

Economic assessment

Cost for development up to **TRL 8**	50 M€
Cost for **first industrial deployment**	150 M€
Cost for **production plants**	500 M€

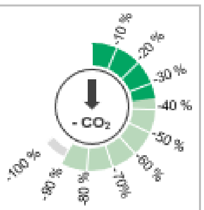
Feedstock

This technology route uses iron oxide pellets and lump ore. The reducing gas, which mainly consists of CO and hydrogen, can be generated by natural gas, coal or coke oven gas.



CO_2 mitigation potential

Depending on the share of hydrogen in the reduction gas, a CO_2 mitigation potential between 35 % to 90 % compared to the blast furnace – basic oxygen furnace route is estimated. To further enhance the CO_2 mitigation potential, it is possible to supplement this route with CCU or CCS.



TRL development

TRL 6 - 8	**2020**	
TRL 7 - 9	**2030**	
Industrially deployed	**2050**	

Geographical information

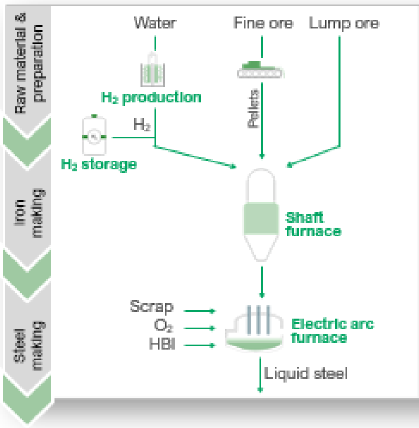
- ☐ As most planned Direct Reduction projects include the utilisation of (H2-enriched) Natural Gas as a bridge technology, all current key Direct Reduction projects are included in the map
- ☐ Direct Reduction Plants in primary steel production are planned in Austria, Belgium, France, Germany, Poland and Sweden

Annex E: Hydrogen-based Direct Reduction (Route 2B) factsheet

Technology Routes based on Direct Reduction DR-EAF based on Hydrogen

Development of effective Solutions towards a Low-CO_2 Steel Production

Fact Sheet



Technical description

The technology route based on **hydrogen-based direct reduction** (H_2-DR) is derived from the already industrially established direct reduction route, which is usually operated with natural gas or coal. Natural gas based direct reduction could therefore be utilised as an entry point to H_2-DR. There are different technological approaches to the hydrogen-based direct reduction process: The most common approach is the direct reduction of iron ore pellets in a shaft furnace by hydrogen gas. The product of this process is called sponge iron in form of direct reduced iron or hot briquetted iron (HBI). In a next step, the produced sponge iron is further processed in an electric arc furnace (EAF) to liquid steel. The rest of the downstream production will remain, and the liquid steel will be processed in secondary metallurgy, then casted and rolled in similar steps as in the current integrated steelmaking.

Framework conditions

- Availability and price of low-CO_2 hydrogen production
- Energy system without (or with minimum) carbon input
- Strengthening of high-voltage grids
- Hydrogen transport and storage infrastructure must be provided

Economic assessment

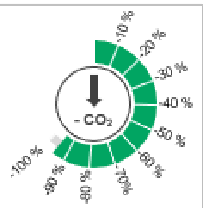
Cost for development up to **TRL 8**	100 M€
Cost for **first industrial deployment**	300 M€
Cost for **production plants**	700 M€

Feedstock

Depending on the technological approach, either iron ore pellets (shaft furnace), or iron fines (fluidised bed reactor) are used within the direct reduction process step. The reducing agent is hydrogen, generated by low-CO_2 processes (e.g. water electrolysis).

CO_2 mitigation potential

This technology route utilising 100 % hydrogen in combination with renewable energy has a high CO_2 mitigation potential and a CO_2 mitigation of up to 95 % can be reached compared to the integrated steelmaking route.



TRL development

TRL 6 - 8	2020	
TRL 7 - 9	2030	
Industrially deployed	2050	

Geographical information

- As most planned Direct Reduction projects target the utilisation of hydrogen in the future, all current key Direct Reduction projects are included in the map
- Direct Reduction Plants in primary steel production are planned in Austria, Belgium, France, Germany, Poland and Sweden

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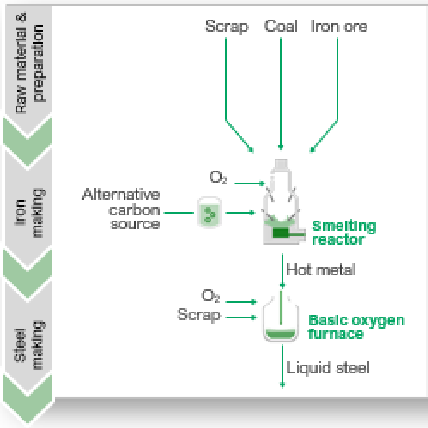
Annex F: Smelting Reduction (Route 3) factsheet

TECHNOLOGY ROUTES BASED ON SMELTING REDUCTION
IRON BATH REACTOR SMELTING REDUCTION

DEVELOPMENT OF EFFECTIVE SOLUTIONS TOWARDS A LOW-CO_2 STEEL PRODUCTION **FACT SHEET**



Technical description

The **iron bath reactor smelting reduction** (IBRSR) is an ironmaking process that eliminates the coke making and ore agglomeration steps. The ore is liquified in a high-temperature cyclone and drips to the bottom of the reactor where powder coal is injected. The powder coal reacts with the molten ore to produce liquid iron, which will be processed in secondary metallurgy, then casted and rolled in similar steps as in the current integrated steelmaking route.

Framework conditions

- Carbon capture, usage and storage technologies have to be used in combination with IBSR to attain sufficient mitigation
- Pre-treatment processes for alternative carbon sources
- Price and availability of alternative carbon sources
- O_2 production and CO_2 capture and compression
- Social acceptance

Economic assessment

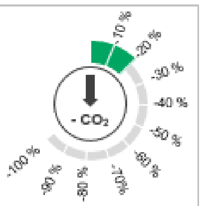
Cost for development up to **TRL 8**	400 M€
Cost for **first industrial deployment**	500 M€
Cost for **production plants**	850 M€

Feedstock

This technology route produces liquid hot metal directly from the raw materials, iron ore fines and coal. Several pre-processing steps are removed requirements about ores quality are less stringent. In addition, the replacement of certain amounts of coal with alternative sources of carbon is feasible.

CO_2 mitigation potential

This technology reduces CO_2 emissions by 20% and reduces the emissions of fine particles, sulphur dioxide and nitrogen oxide between 60 to 80%. Due to the full O_2 operation, the off-gases are concentrated on CO_2 and well-fitted for CCUS.



TRL development

TRL 6	2020	██████░░░
TRL 8	2030	████████░
Industrially deployed	2050	█████████

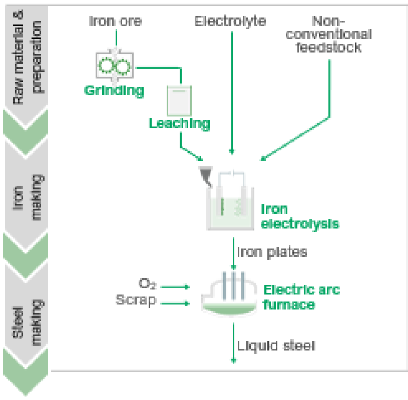
Geographical information

- This technology route (HISARNA) is developed at Tata Steel Europe Ijmuiden plant. All the related investment, energy, feedstock and infrastructures are therefore to be addressed first in the Netherlands.

Annex G: Iron Ore Electrolysis (Route 4) factsheet

TECHNOLOGY ROUTES BASED ON ORE ELECTROLYSIS
ALKALINE IRON ELECTROLYSIS

DEVELOPMENT OF EFFECTIVE SOLUTIONS TOWARDS A LOW-CO_2 STEEL PRODUCTION **FACT SHEET**



Technical description

In the technology route based on iron ore electrolysis, iron oxides are converted into iron plates, which in a subsequent step are further melted in an electric arc furnace. **Low temperature alkaline iron ore electrolysis**, or electrowinning, is the direct deposition of iron from its ores on an electrode. During the electrolysis step, the released gas is almost pure oxygen, which can be recovered, compressed and used at electric arc furnace and downstream processes. The remaining downstream processes are similar to those of the current integrated steelmaking route and the liquid steel will be processed in secondary metallurgy, then casted and rolled.

Framework conditions

- ☐ Energy system without (or with minimum) carbon input
- ☐ Strengthening of high-voltage grids

Economic assessment

Cost for development up to **TRL 8** ▶ M€ 250

Cost for **first industrial deployment** ▶ M€ 500

Feedstock

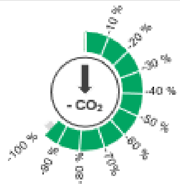
This technology route requires preliminary grinding steps of iron ores and leaching out part of its gangue before electrical reduction. Non-conventional feedstock (i.e. by-products from non-ferrous metallurgy residues) can also be used in this process.

Iron ore

Non-conventional feedstock

CO_2 mitigation potential

The mitigation potential of this option compared to conventional integrated steelmaking route is almost 100 %, without any need of carbon capture and usage or storage.



TRL development

TRL 5 - 6	2020	
TRL 6 - 8	2030	
Industrially deployed	2050	

Geographical information

- ☐ In scope of the SIDERWIN project, a pilot plant is being erected in Maizieres (France).
- ☐ This is not a BF-BOF site.