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RENEWABLE ENERGY INSTITUTE

Towards Carbon Neutral Steel in Japan

Learning from the Latest Trends in the European Union

December 2021

Table of Contents

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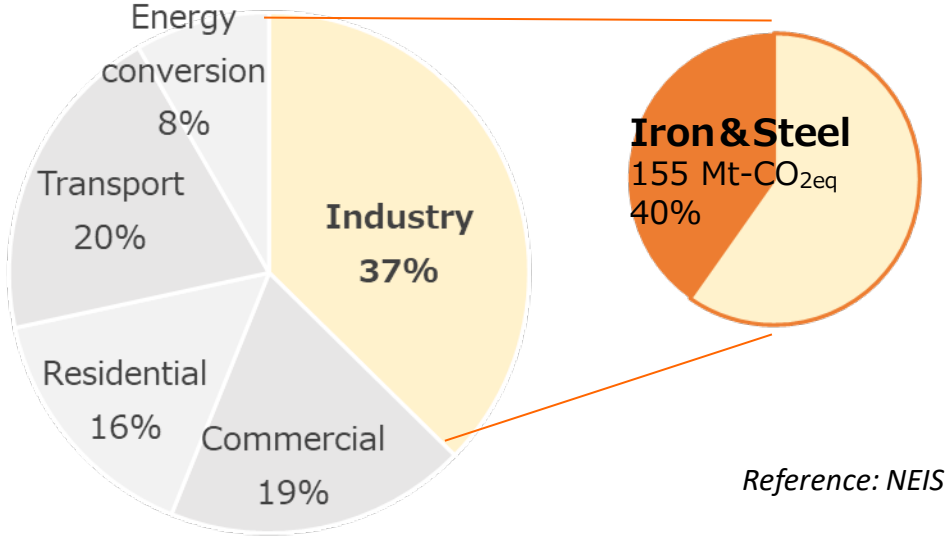
Part 1
Introduction

Decarbonizing Steel: Key for a 2050 Carbon Neutral Japan

- October 2020, Japan announced it is pursuing carbon neutrality by 2050.
- Of all the manufacturing industries in Japan, steel is the industry with largest greenhouse gas (GHG) emissions, making it a top priority for the country's decarbonization.
- The challenge to decarbonize steel is that this industry requires high-temperature heat and often still relies on coal – a major source of GHG emissions, as reducing agent in blast furnace (BF) notably.
- In recent years, however, progress towards steel decarbonization has accelerated around the world, and especially in Europe.
- Following Japan government's decarbonization agenda and witnessing some of its overseas peers' pioneering initiatives to become carbon neutral by 2050, the Japanese steel industry recently reacted by advancing its decarbonization target from 2100 to 2050, but many important decisions remain to be made, some of them quite soon.
- In this context, and with this Info Pack dedicated to carbon neutral steel – "Learning from the Latest Trends", Renewable Energy Institute aims at actively contributing to the ongoing debate around steel decarbonization in Japan.

Japan Energy-related CO_2 Emissions Breakdown 2019

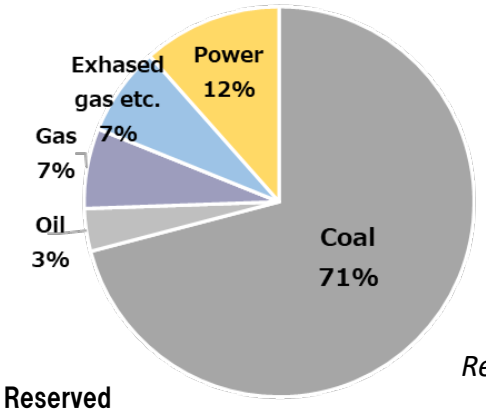
About 15% of Japan's total emissions came from the steel industry (allocated emissions)



Reference: NEIS

Japan Steel Industry Final Consumption Breakdown 2019

(Including private power and steam generation)



Reference: METI Energy Statistics

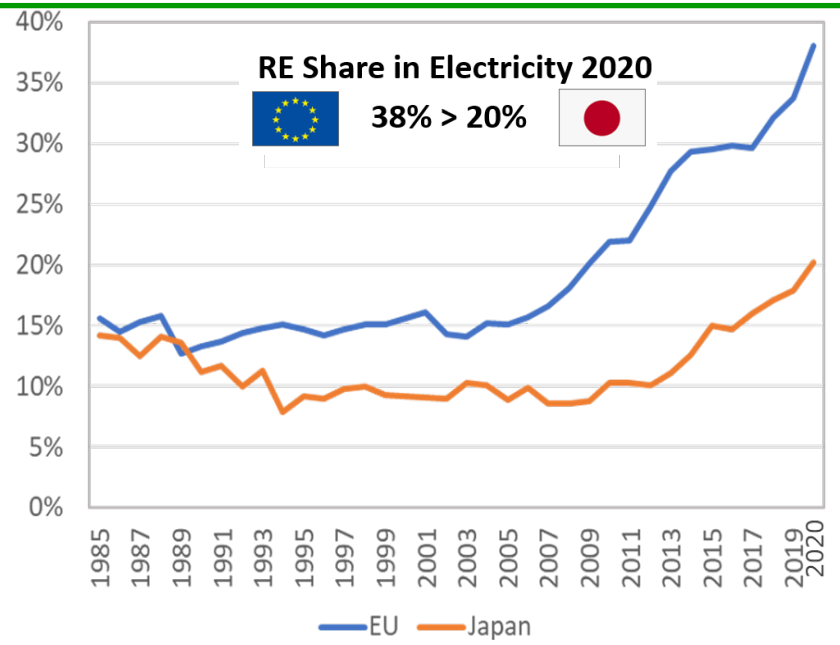
Japan Needs to Catch up with the EU

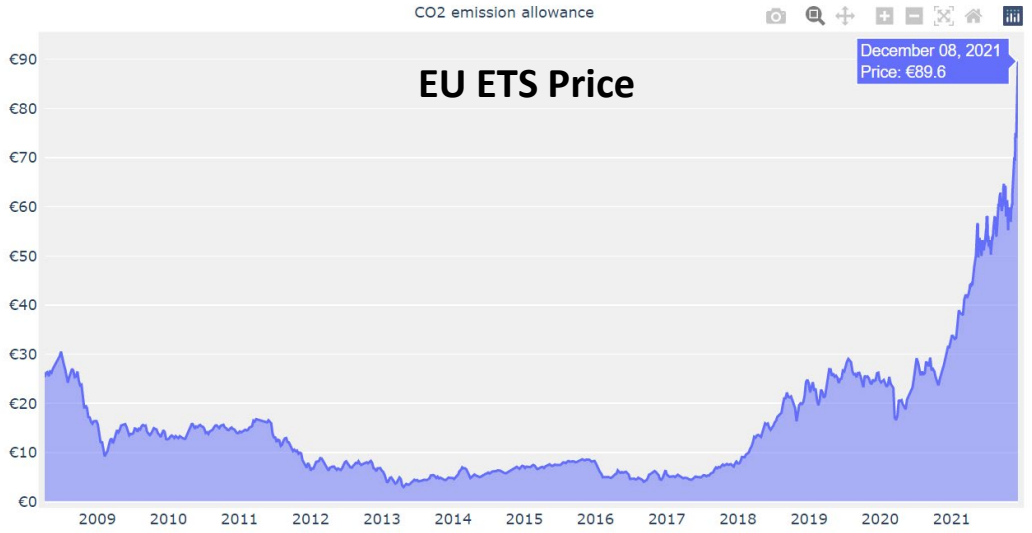
- Ranking #2 and #4, respectively, the European Union (EU) and Japan are among the world's largest producers of steel. **Decarbonization of these markets will have global impacts.**
- Until now, **the EU has often and in many ways moved faster and more ambitiously than Japan** when it comes to decisive climate & energy actions

  [See the charts on the right-hand side of this slide, and the table Selected Key Climate & Energy Policy in the EU and Japan (chronological order) on next slide.]

- As a result, **the EU has taken the global leadership for decarbonization, including that of steel. <u>As of Autumn 2021, 42% of the world's announced new low-carbon steelmaking projects* were located in the EU (based on project capacity)</u>**, which is all the more remarkable that the EU accounted for 8% of the world's steel total production in 2019. The European leadership should thus inspire Japanese stakeholders.

  **Projects which can achieve at least 66% CO_2 emissions reduction compared to conventional BFs.*





References: World Steel Association(1), BP, Leadership Group for Industry Transition, and Sandbag

Selected Key Climate & Energy Policy in the EU and Japan (chronological order)

European Union	Japan
2005: **Start of the EU Emissions Trading System** (ETS). As of December 8, 2021, €89.60 (¥11,555*) per ton of carbon dioxide (CO_2).	**2007**: **2020 GHG emissions reduction target set**. 25% compared to 1990.
2007: **EU 2020 climate & energy package proposal**. Integrates for the first time targets for renewable energy (RE) [i.e., 20% of total energy] and energy efficiency [i.e., saving 20% of energy consumption] to enable a GHG emissions reduction of 20% by 2020 compared to 1990 (24% achieved in 2019, latest year for which data is available).	**2012**: **Tax for global warming countermeasures introduced for all fossil fuel uses**. Currently ¥289 (€2.24*) per ton of CO_2.
	2013: After the Fukushima Daiichi nuclear accident, **2020 GHG emissions reduction target revised** to 3.8% compared to 2005 (i.e., 3.1% increase compared to 1990). Submitted to the United Nations Framework Convention on Climate Change (UNFCCC) for the Conference of the Parties (COP) 19.
2014: **First proposed framework for a 2030 competitive, secure and low-carbon EU economy**. Includes the targets of reducing GHG emissions by 40% compared to 1990, further increasing the share of RE [i.e., 27%] and improving energy efficiency [i.e., 27%].	**2014: 2030 GHG emissions reduction target set:** 26% compared to 2013. Submitted to the UNFCCC as Intended Nationally Determined Contribution (INDC) in 2015. 4th Strategic Energy Plan set the share of RE in electricity generation at 22-24% for 2030.
	2017 (1): **5th Strategic Energy Plan keeps the 2030 GHG emissions reduction & RE target unchanged**. Submitted to the UNFCCC as Nationally Determined Contribution (NDC) in 2020
2018 (1): **2030 RE and energy efficiency targets increased** [i.e., 32% and 32.5%, respectively].	**2017** (2): **Hydrogen Strategy**. Sets various H_2 introduction targets (production, cost…) for 2030 and beyond. Transition to carbon-free hydrogen in the future, but no preference is given to green H_2. The 2020 Green Growth Strategy brings additional details.
2018 (2): **Vision for a climate-neutral EU by 2050**. To limit global temperature increase to 1.5°C (Paris Agreement's goal – 2015), the EU recognizes that it needs to reach net zero GHG emissions by 2050 – this vision outlines how the EU could realize its ambition (adopted into law in 2021 "European Climate Law").	**2019**: **Long-term Strategy under the Paris Agreement**. Proclaims a "decarbonized society" as its ultimate goal to be accomplished as early as possible in the second half of this century. Sets a GHG emissions reduction target of 80% by 2050.
2020 (1): **Hydrogen strategy for a climate-neutral EU**. Identifies RE based ("green") hydrogen (H_2) as a key enabler for the EU to reach carbon neutrality. Sets the objectives of 40 gigawatts (GW) of electrolysers and 10 million tons (Mt) of green hydrogen production by 2030.	**2020**: **Carbon neutrality objective announced**. Adopted in the revision of the Global Warming Law in 2021.
2020 (2): **Proposal to raise the EU's 2030 GHG emissions reduction goal to 55%** (adopted in 2021).	**2021: GHG emission reduction target for 2030** raised to 46% of 2013 level. Submitted to the UNFCCC for COP26. 2050 carbon-neutral target adopted in the Act on Promotion of Global Warming Countermeasures. The 6th Basic Energy Plan sets a target of 36-38% for RE electricity in 2030.

References: REI created based on governmental documents

*Exchange rate: €1 = ¥128.96 (December 8, 2021)

Part 2
The European Union's Steel Decarbonization Leadership

Why and How Is the EU Leading Steel Decarbonization - Summary

Key Points:

- Building upon its advanced decarbonization policies; early adoption of ambitious GHG emissions reduction, RE and energy efficiency targets, as well as an effective carbon pricing mechanism and – more recently – of a carbon neutral compatible hydrogen strategy, **the EU has put together many of the enabling conditions required for steel decarbonization**.

Condition #1
Cost competitive RE – 38% in the EU in 2020, projected to increase to 81-85% by 2050

+

Condition #2
Meaningful carbon prices to be applicable to the steel industry from 2026 (decided in 2021, and understood since the inception of the EU ETS) – €89.60 per ton of CO_2 as of December 8, 2021

+

Condition #3
Expanding green H_2 – targets of 40 GW of electrolysers and 10 Mt of green H_2 production by 2030

- Thanks to this favorable framework, **forward thinking stakeholders both on the supply and demand sides have become quite dynamic to adopt decarbonized steel**:

- On the supply side; Decarbonized steel manufacturing projects are multiplying and being scaled up, and
- On the demand side; The automotive industry as well as other industries have begun to move towards green steel procurement.

References: European Commission (1) & (2) and Sandbag

EU Steel Decarbonization Vision

- Steel is capable of being **one of the first hard-to-abate sectors to produce green products**.
- As a part of its New Industrial Strategy, the European Commission published a major working document "***Towards Competitive and Clean European Steel***" in May 2021. This document describes the EU's steel decarbonization vision, which key points are:
- **Steel is a vital material for a modern, industrialized economy**,
- Production of low-carbon **steelmaking requires radical changes**.
- Low-carbon solutions **commercial roll-out is expected around 2030**, yet **ambitious plans are necessary today**.
- Engaged in a **race against time** because **2050 is just one investment cycle away and the large majority of BFs needs to be replaced in the coming decade** (according to Agora Energiewende, in the EU 70% of BF capacity will reach the end of its lifetime before 2030 and require reinvestment), the next five years are thus crucial.
- **Most low-carbon steel production pathways are not technologically mature**, and it is not yet clear which process will dominate in the future.

IMPORTANT UPDATE

Since the publication of the document referred to hereinabove, **empirical developments have demonstrated** that among low-carbon steel production pathways **steel recycling (EAF) is mature** and (green) **hydrogen-based direct reduction - electric arc furnace (H_2DR-EAF) is close to maturity with several commercial-scale projects to come online in the EU around 2025 already.**

References: European Commission (3) and Leadership Group for Industry Transition

EU Steel Decarbonization Policies

Fundamentally, the EU steel decarbonization policies combine financial incentives and regulations.
Climate change measures are a major pillar for steel decarbonization. In addition to financial support, the abolition of free emission allowances under the EU-ETS will result in a carbon price being applied to the steel industry and that will contribute funding the Innovation Fund.

Supporting policies	Selected main initiatives and brief description
Funding and budget programs **COMBINATION** **Regulatory environment**	**Recovery and Resilience Facility**; Makes €672.5 billion (2021-2023) available in loans and grants to support reforms and investments undertaken by Member States. An unprecedented opportunity to accelerate the decarbonization of heavy industries like steel.
	Innovation Fund; Provides €27-36 billion (assuming funding from the EU ETS as follows: auctioning of 450 million of emissions allowances and prices of €60-80 per ton of CO_2) in the period 2021-2030 for the demonstration of innovative low-carbon technologies in multiple sectors, including energy-intensive industries such as steel. In addition, the European Commission has proposed to introduce carbon contracts for differences that are funded by the Innovation Fund to also cover the operating expense of low-carbon projects.
	Clean Steel Partnership; Supports with up to €700 million research and innovation activities from the pilot to the demonstration phases of breakthrough technologies for carbon neutral steel production.
	EU taxonomy for sustainable investments; Includes steel production to incentivize manufacturing environmental improvements.
	EU ETS ("polluter pays principle"); Covers the steel industry and puts a price on carbon emissions. Free emission allowances for EU steel producers will be phased out from 2026 to 2035 (10% reduction per year) – decided in 2021 and understood since the inception of the EU ETS. As of December 8, 2021, the price of an allowance was €89.60 per ton of CO_2. The EU ETS partly funds the Innovation Fund as described above.
	CBAM proposal; Covers steel with the aim of reducing carbon leakage risks by ensuring that carbon emissions from imports are reflected in prices. It is an alternative to the EU ETS free emission allowances.
	Industrial Emissions Directive; Regulates GHG emissions from steel production by setting standards imposing emissions prevention or reduction techniques (mandatory transposition / applicable penalties determined by Member States).
	Circular Economy Action Plan; Identifies steel as one of the priority product/material groups with untapped potential for circularity thanks to its characteristics as a naturally long-lasting and durable product, well adapted for recycling, reuse and remanufacture.

References: European Commission (3) and Sandbag

EU Main Steel Decarbonization Pathways: Approach and Reality

- EU Main Planned Pathways:

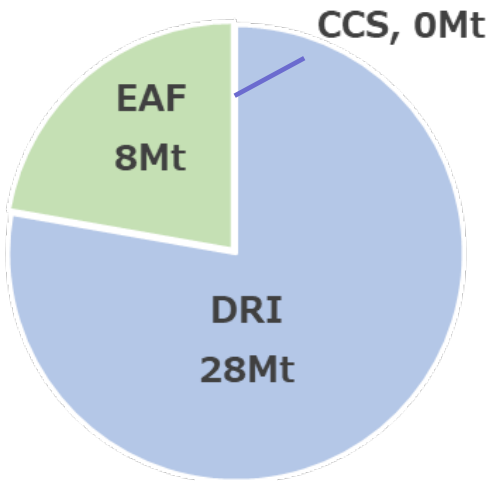
- **The EU considers all main technological options for steel decarbonization**: EAF, H_2DR-EAF, and blast furnace - basic oxygen furnace combined with carbon capture, utilization and/or storage (BF-BOF+CCUS).
- **Economic and technological progresses will determine the winner(s)**.
- In general, **the EU prioritizes "green" H_2 & electricity** because renewable energy has until now outperformed, and is expected to keep outperforming, nuclear power and carbon capture and storage (CCS) related technologies to deliver GHG emissions reductions.

- EU Main Empirical Developments:

- With the ongoing reinvestment cycle and thanks to the policy framework in place, **investments in new low-carbon steelmaking projects* are increasingly announced across the EU: 36 Mt**.
- So far, on the one hand **EAF and DR-EAF are the winners** of the steel clean transition with planned industrial-scale commissioning in the 2020s. [natural gas may first be used in DR-EAF, but the end-goal is to use green H_2.]
- On the other hand, **not a single project for new BF-BOF+CCUS has been announced**.

**Projects which can achieve at least 66% CO_2 emissions reduction compared to conventional BFs.*

Low-Carbon Steel Projects Announcements to be Built in the EU before 2030 (capacity in Mt)



References: Agora Energiewende (2)

References: European Commission (3) and Agora Energiewende (2)

Decarbonized Steel Supply (1)

- **In Europe in recent years, some major steel manufacturers have made important announcements in favor of carbon neutral steelmaking by 2050**: For examples, **Tata Steel Europe** (October 2018), **ThyssenKrupp Steel Europe** (July 2019), and **ArcelorMittal** (September 2020).

- To pave the way towards their mid-century objectives, these steel manufacturers have also announced **intermediate 2030 GHG emissions reduction targets**.

- **To replace existing BF-BOF, new pioneering projects, primarily focusing on H_2DR-EAF, varying by scale (including industrial-scale) are now advanced across the EU, with expectations of commissioning within the coming years**

  [See next slide.]

European Steel Manufacturers Intermediate Goals Towards Carbon Neutrality

Selected steel manufacturers	Intermediate 2030 GHG emissions reduction targets
ArcelorMittal (headquarter country: Luxembourg)	25% reduction of global carbon emissions intensity / 35% in Europe
SSAB (headquarter country: Sweden)	26% of direct and indirect emissions (and fossil free by 2045)
Tata Steel Europe (headquarter country: United Kingdom)	30% in the United Kingdom and 40% in the Netherlands
ThyssenKrupp Steel Europe (headquarter country: Germany)	30% from production and outsourced energy

- A **significant development** has been the announcement by Tata Steel Europe in September 2021 that the company **after considering BF-BOF+CCUS** (including the alternative ironmaking technology "Hisarna process"), **finally decided to only focus on H_2DR-EAF**.

**A smelting reduction process with two directly coupled process stages in which the production of liquid pig iron takes place. This process is more energy efficient and has a lower carbon footprint than conventional BF-BOF.*

References: ArcelorMittal (1), SSAB (1), Tata Steel Europe (1) & (2) and ThyssenKrupp Steel Europe (1)

Decarbonized Steel Supply (2)

Selected pioneering new low-carbon steelmaking projects* in Europe (alphabetical order):

Project	Country	Steel company	Innovative technology	Steel annual production (Mt)	Commissioning year	Financial information, if identified
Boden	Sweden 	H_2 Green Steel	H_2DR-EAF	5 Mt (by 2030)	by 2024	– not identified –
Dunkerque	France 	Liberty Steel	H_2DR-EAF**	2 Mt	– not identified –	– not identified –
Gent	Belgium 	ArcelorMittal	H_2DR-EAF**	2.5 Mt	by 2030	€1.1 billion of funding support [Belgian and Flanders governments]
Gijón	Spain 	ArcelorMittal	H_2DR-EAF**	2.3 Mt	by 2025	€1 billion of funding support [Spanish government]
H_2 Hamburg	Germany 	ArcelorMittal	H_2DR-EAF**	initially 0.1 Mt then over 1 Mt (by 2030)	by 2025	€55 million of funding support (half of the total capital expenditure required) [German government]
HYBRIT	Sweden 	SSAB	H_2DR-EAF	initially 0.01 Mt (started in 2020)	from pilot to commercial by 2026	€53 million of funding support [Swedish government]
tkH_2Steel	Germany 	ThyssenKrupp	H_2DR-EAF**	initially 0.4 Mt then 3 Mt (by 2030)	by 2025	– not identified –

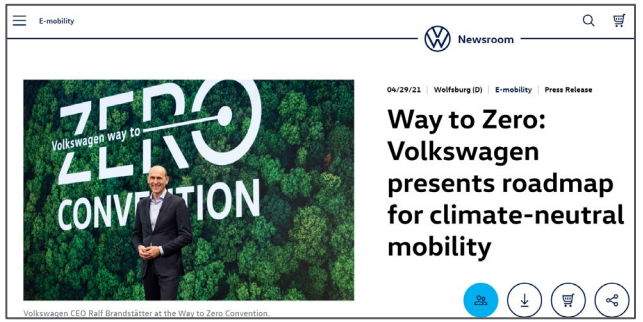
**Projects which can achieve at least 66% CO_2 emissions reduction compared to conventional BFs.*

***Natural gas may be used temporarily, but the end-goal is to use green H_2.*

References: Agora Energiewende (3), ArcelorMittal (2), (3) & (4), H_2 Green Steel, Liberty Steel, SSAB (2) and ThyssenKrupp Steel Europe (2)

Decarbonized Steel Demand

In recent months, major European industries have made important announcements directly or indirectly in favor of decarbonized steel (i.e., investments in decarbonized steelmaking and/or procurement of decarbonized steel):



- **Car manufacturers are at the forefront of this shift**:

- March 2021, **BMW** announced it is investing in an innovative method for decarbonized steel production developed by Boston Metal (to be industrialized by mid-decade).
- April 2021, **Volvo** announced it is collaborating with SSAB, a steel producer participating in the HYBRIT project, to commercialize the world's first vehicles to be made of decarbonized steel (manufacturing of the first concept vehicles with steel using H_2 will start in 2021 already).
- April 2021, **Volkswagen** announced it is working to decarbonize its supply chain, including steel production.
- May 2021, **Daimler (Mercedes-Benz)** announced it is taking an equity stake in H2 Green Steel, a producer of decarbonized steel (green steel in various vehicle models will be launched as early as 2025).

- In the framework of the Climate Group's SteelZero initiative, the **building industry** has also become more active (e.g., Landsec, Mace…) as well as the **power company** Ørsted with announced commitments to 100% net zero steel by 2050 at the latest. (intermediate target of 50% by 2030 at the latest).

- Beyond these sectors, some manufacturers of **domestic appliances** are also starting to procure decarbonized steel (e.g., Miele, Kaldewei…).

References: BMW, Daimler(Mercedes-Benz), Volkswagen, Volvo and Climate Group

Part 3
Steel Decarbonization Technological Options

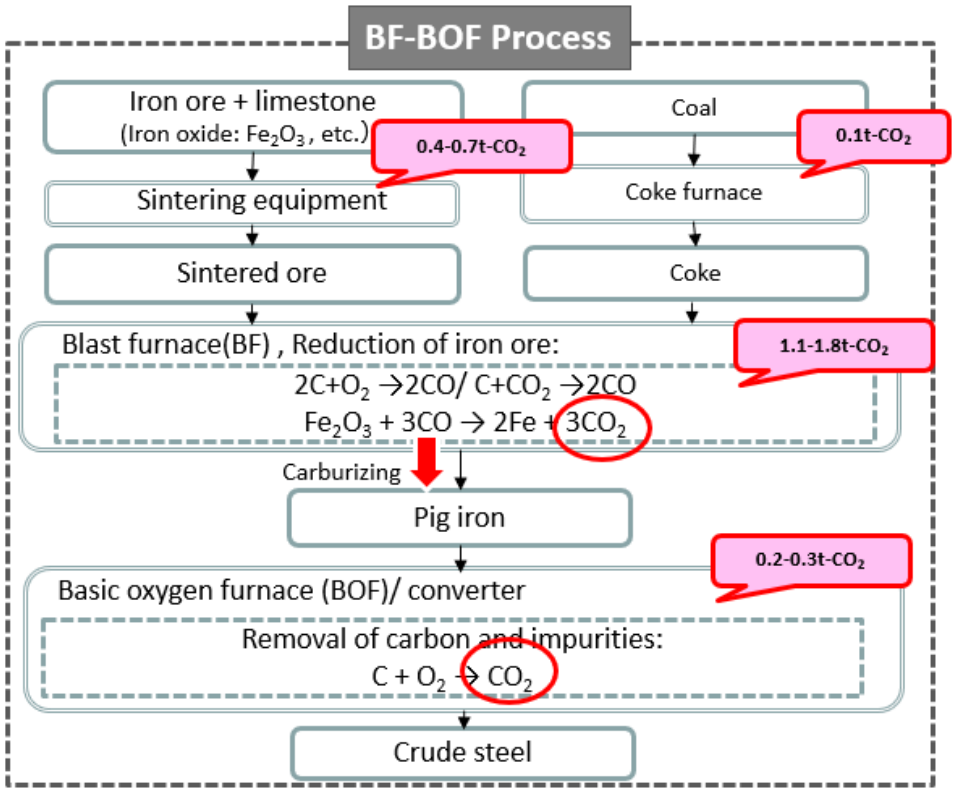
Main Technological Options for Steel Decarbonization – Simplified Summary

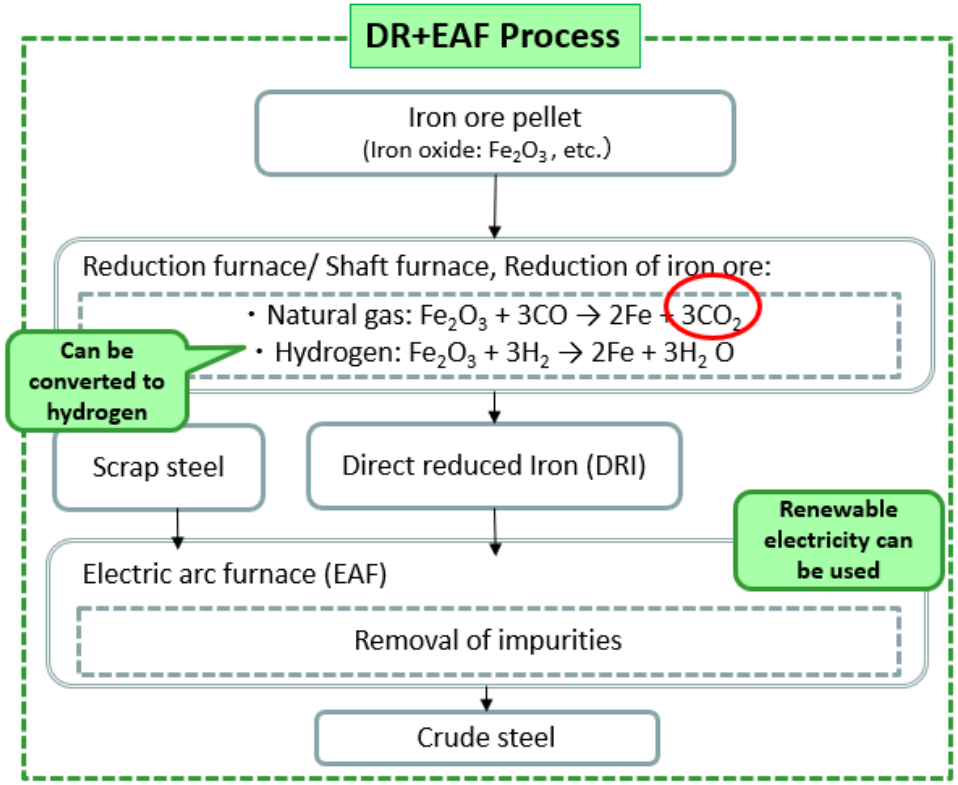
	Main TRADITIONAL approaches			Main DECARBONIZATION approaches		
Steel products	Recycled	Virgin		Recycled	Virgin	
Technologies	electric arc furnace (EAF)	natural gas-based direct reduction - electric arc furnace (NGDR-EAF)	blast furnace - basic oxygen furnace (BF-BOF)	electric arc furnace (EAF)	**hydrogen-based** direct reduction - electric arc furnace (**H_2**DR-EAF)	blast furnace - basic oxygen furnace **combined with carbon capture, utilization and/or storage** (BF-BOF+CCUS)
Key inputs	electricity	natural gas and electricity	fossil fuels, especially coal	**decarbonized electricity**	**decarbonized hydrogen and electricity**	fossil fuels **and CCUS**
GHG emissions	low	intermediate (can become low by switching to H_2)	high	near zero	near zero	low, if additional actions are implemented
Maturity	mature	mature	mature	mature	coming years	uncertain

Carbon neutral steel requires: Decarbonized electricity (EAF) / decarbonized hydrogen and electricity (H_2DR-EAF) / maximum capture and permanent storage of GHG emissions as well as carbon offsets and/or direct air capture (BF-BOF+CCUS).

Comparison of Conventional and Decarbonized Processes

- Conventional BF-BOF process results in massive CO_2 emissions: 1.8 to 2.9 t-CO_2 per 1 t of crude steel, as the reduction process of iron ore is based on coke made from coal, as well as sintering, coking and converting. Partial DR by hydrogen in the BF and use of exhaust gas can reduce some of the emissions, but CCS is a necessity.
- Emissions from DR process using natural gas are half those of BF-BOF, and can be zero if decarbonized hydrogen replaces natural gas.





Reference: Renewable Energy Institute, figures of CO_2 emission of BF-BOF are taken from Carbon Trust (2011)

Focus on EAF: Ready and Set to Increase

Brief Explanations:

- A **scrap EAF** powered by decarbonized electricity enables CO_2 emission-free steel recycling. It is the most straightforward way for steel decarbonization.

Opportunities:

- This technological option is **mature and cost competitive**, and it will further benefit from the expansion of cheap RE electricity.

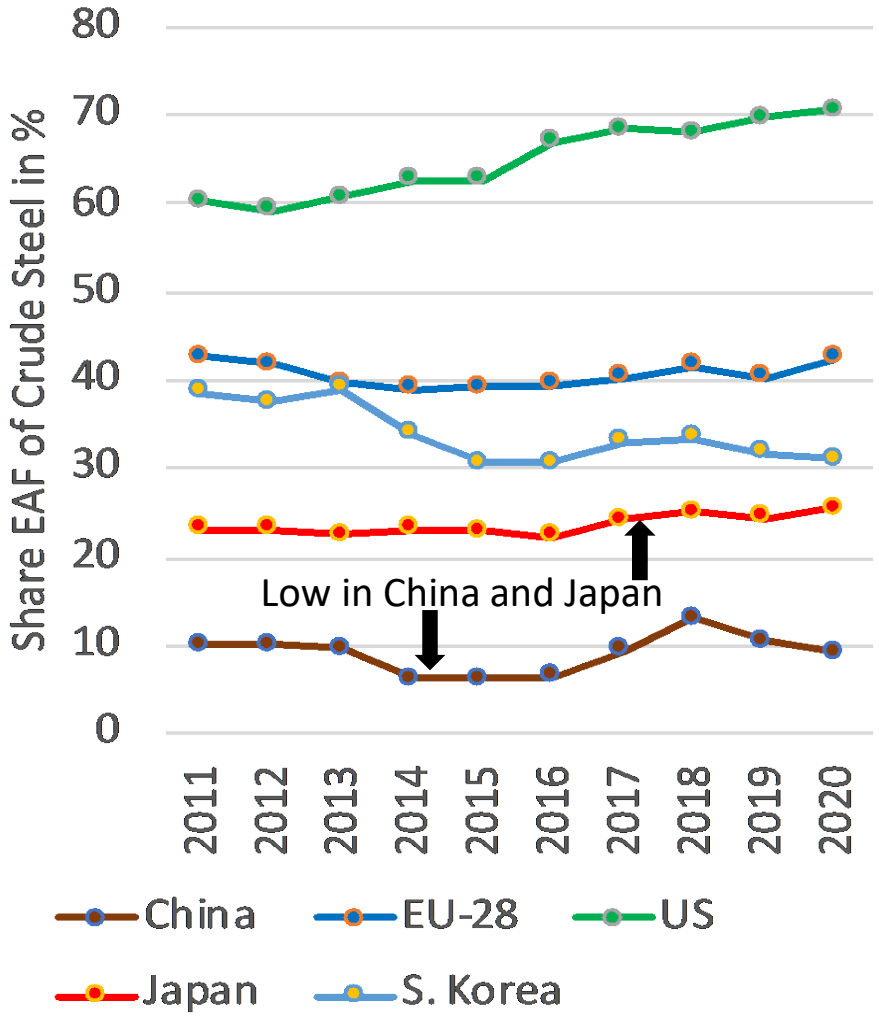
Challenges:

- This option is limited by a few key factors related to **scrap availability – finite supply**, **prices** and **quality**.

[In Japan, if the scrap steel that is currently exported was directed to domestic demand 2/3rds of the current demand could be covered. Also, regarding quality, it is being improved by domestic companies as demonstrated by the successful trial production of structural high-tensile steel plates for automobiles in 2013 already.]

- Depending on countries; **Abundant and cost competitive RE electricity**. As RE electricity quickly expands by outcompeting fossil and nuclear power in most parts of the world this issue should become less and less important.

EAF Shares in Major Countries



Reference: Bureau of International Recycling

References: BloombergNEF, International Renewable Energy Agency, Ministry of Environment and Tokyo Steel

Focus on H_2DR – EAF: The Most Promising Option

Brief Explanations:

- One option that many EU steelmakers pursue is to **build DR-EAF plants that are initially operated with natural gas**. These plants are **100% H_2-ready** and once clean H_2 becomes available, it can gradually replace the natural gas in the plant without any retrofit.

Opportunities:

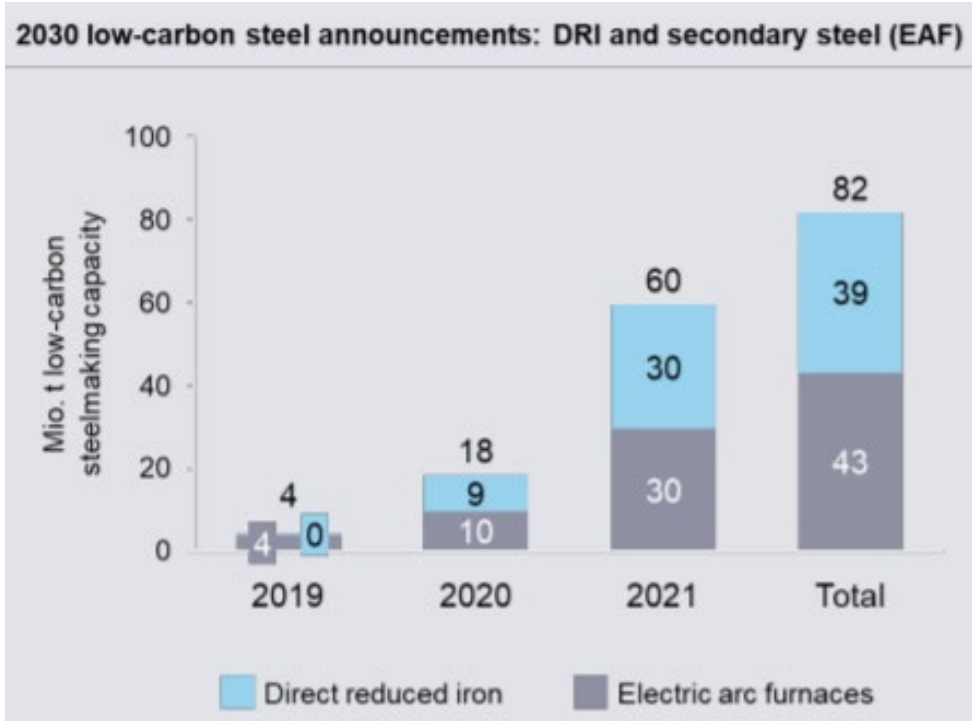
- This technological option is **mature and can be deployed now,** even if sufficient amounts of clean H_2 are not available yet.
- It **avoids a carbon lock-in and H_2 can be phased-in**, as it becomes available.

Challenges:

- There is currently an **economic gap** between BF-BOF and H_2DR-EAF (policy support instruments are needed in the 2020s, to bridge that gap).
- Deployment of **new infrastructure for H_2 production and distribution will be required but is not a precondition** for the first phase with natural gas.

Developments:

As of June 2021, **over 20 projects were advanced**, mainly in Europe (e.g., HYBRIT, H_2 Hamburg…).



Source: Agora Energiewende (1)

References: BloombergNEF, International Renewable Energy Agency and Leadership Group for Industry Transition

Example of H_2DR-EAF Project: HYBRIT

Brief outline:

Key stakeholders include **SSAB**, **LKAB** and **Vattenfall**. Test operations began in **September 2020**. Already **succeeded in producing fossil fuel free steel**. Aims to start **commercial operation by 2026**.

Goal:

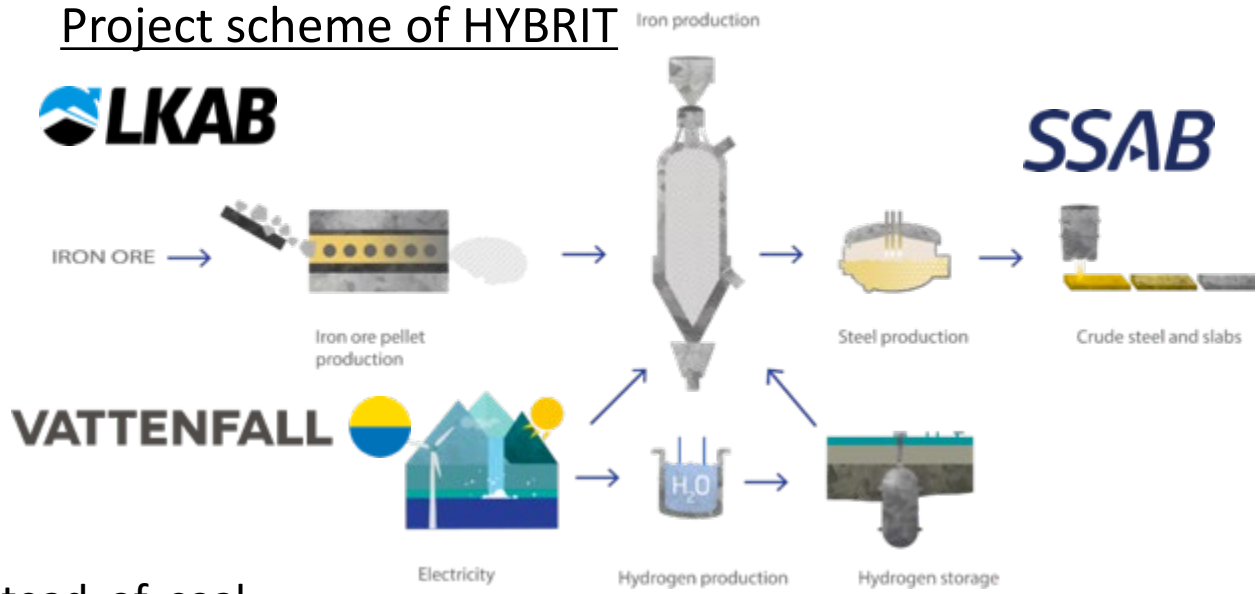
To create a **completely fossil-free value chain** from mine to finished steel, with fossil-free pellets, electricity and H_2.

Simple description of the process:

- **Fossil-free iron ore pellets** are produced from **bio-oil** instead of coal and petroleum-based oil.
- **Fossil-free electricity** is generated from low-carbon technologies (e.g., RE; hydro and wind) and produces **fossil-free H_2** (the chemical reducing agent instead of coke in a BF) thanks to electrolyzers that is then used to obtain DR (i.e., "sponge iron" in the illustration) from fossil-free pellets.
- **Fossil-free steel** is produced from DR and scrap in the **EAF** that is powered by **fossil-free electricity**.

Reference: International Renewable Energy Agency

Project scheme of HYBRIT



The world's first vehicle made with fossil-free steel

Source: HYBRIT

Focus on BF-BOF+CCUS: The Most Questionable Option

Brief Explanations:

- It is possible to reduce the emissions intensity of BF-BOF by advancing alternative ironmaking processes combined with CCUS technologies. Alternative ironmaking technologies refer to the HISarna process (instead of BF) and top gas recycling (in combination with BF) for examples. H_2 may also be injected into BF, but some coal use remains.

Opportunities:

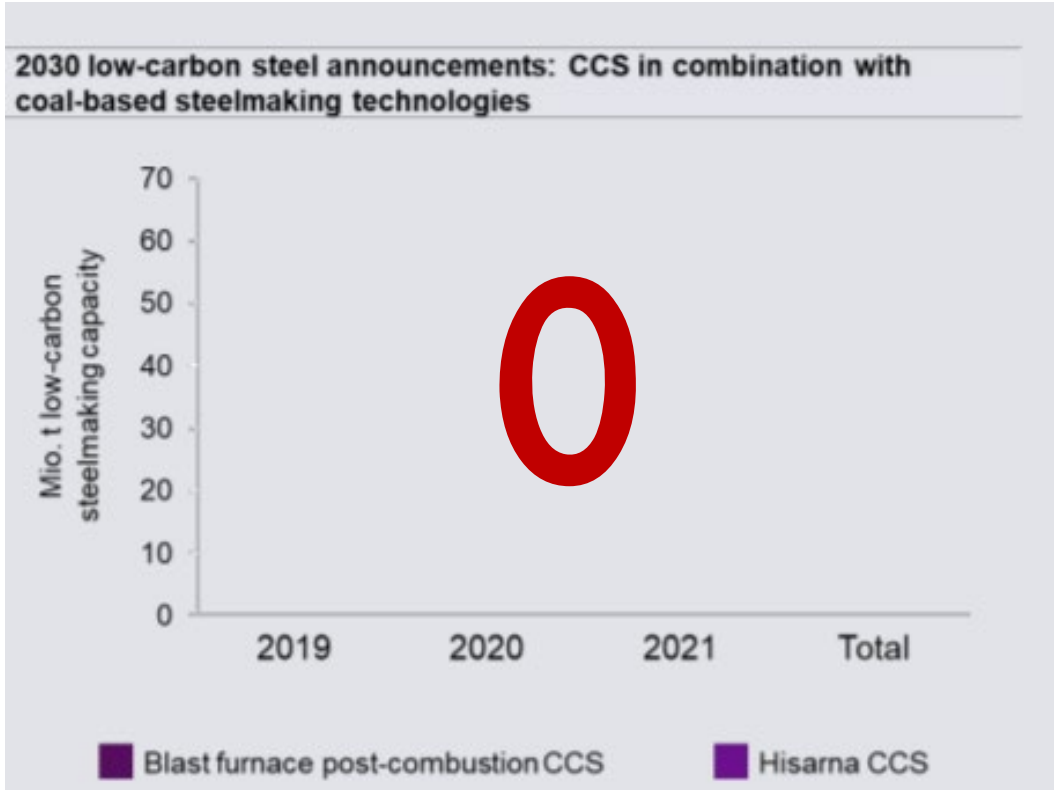
- This technological option could be carbon-free, **if carbon offsets and/or direct air capture are also implemented**.

Challenges:

- This option has **not reached maturity yet,** technological progress is taking place.
- Some preliminary cost projections show EAF and DR-EAF (either natural gas based + carbon offset, or H_2 based) having a competitive edge over BF-BOF+CCUS. *(For more information, please refer to the next slide dedicated to the costs of the different decarbonization technological options.)*
- **Sufficient GHG emissions storage capacity** must be identified and **emissions captured need to be permanently stored**.

Developments:

As of Autumn 2021, **no announcement in favor of low-carbon steel based on CCS in combination with coal-based steelmaking technologies** had been made.

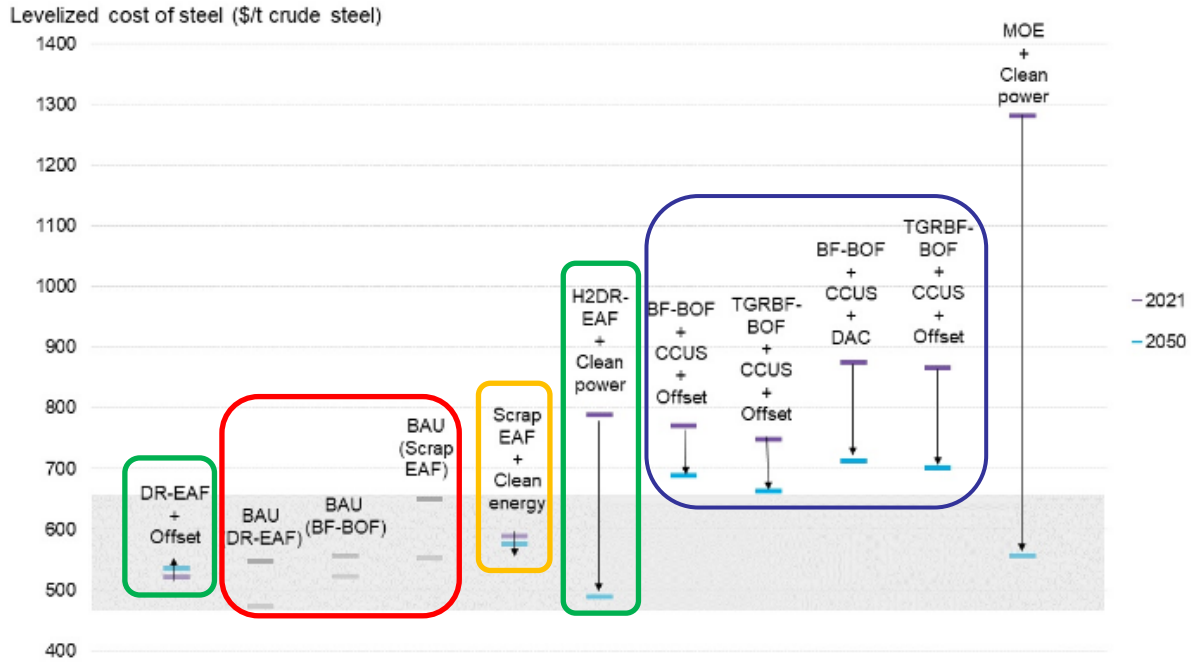


Source: Agora Energiewende (1)

References: BloombergNEF and International Renewable Energy Agency

Economics of Main Technological Options for Steel Decarbonization

Change in average levelized cost of net-zero steel compared to business-as-usual - 2021 to 2050



Source: BloombergNEF

Note: BF-BOF = blast furnace basic oxygen furnace, DR-EAF = direct reduction electric arc furnace (gas-based), TGR = top gas recycling, DAC = direct air capture, H2 = hydrogen, MOE = molten oxide electrolysis, CCUS = carbon capture storage & utilization

The molten oxide electrolysis (MOE) technological option, based on direct electrification of primary steelmaking through an electrolysis process, indicated in this chart (not elsewhere presented in this Info Pack) could be economically promising, but its market readiness lags behind that of other technologies.

Operational expenditures (e.g., energy and reductants, raw materials…) are key components impacting the cost of steel. In addition, a carbon price helps bridging the gap between polluting and clean technologies.

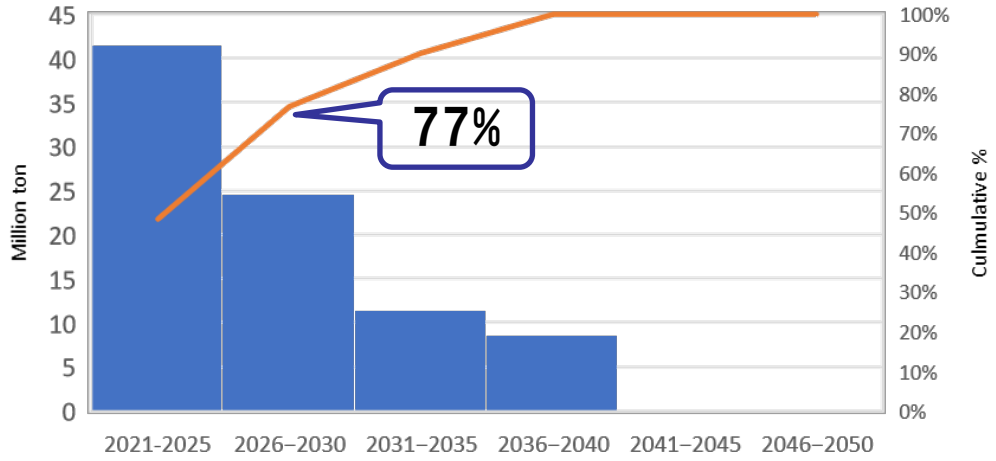
- Recent **cost projections for decarbonized steel show that in 2050 EAF and DR-EAF** (either natural gas based + carbon offset, or H_2 based) **technologies could**:
  - **Be competitive with today's technologies, and**
  - **Outcompete BF-BOF+CCUS technologies**.

Reference: BloombergNEF

Part 4
Conclusion

Summary

- In the past few years, **steel decarbonization has accelerated across the world, and it is especially dynamic in the EU** thanks to a **combination of political support** (including funding and regulation) **and enabling conditions**.
- Forward-thinking **stakeholders both on the supply & demand sides deliver economic and environmental progress together**, by advancing **technological innovation** for the former, and **new business models** for the latter.
- Among steel decarbonization technological options, **EAF (steel recycling) and DR-EAF (new steel) increasingly appear as the most likely important solutions**. In the case of DR-EAF, natural gas could be used temporarily to start with now, but the end-goal should be to use H_2. In both cases**, availability of cost competitive decarbonized electricity and H_2 will be critical**.
- Progress is taking place fast, and one of the challenges will be to go from demonstration to commercial projects. **The coming years should start delivering significant full-scale commissioning**.
- Also **in Japan, there are many BFs in need of refurbishment, but the transition to low carbon projects* has not yet been announced, with the exceptions of a few EAF projects****. Once refurbished or replaced, there are few opportunities for asset reinvestments until 2050. Investment decisions need to be made as early as the 2020s to change gears towards decarbonization.



Reinvestment Cycle of BFs in Japan***

** Projects which can achieve at least 66% CO_2 emissions reduction compared to conventional BFs.*
*** As of December 2021, three EAF projects have been announced.*
**** Existing BFs that have passed 20 years since their last refurbishment.*

Reference: Agora Energiewende (2)

Annexes

COP26 Glasgow Breakthrough Agenda: Accelerate Decarbonization of Steel Sector

The Breakthrough Agenda, a high-level international cooperation initiative, was launched at COP26 held in November 2021. The first of these agendas, the "Glasgow Breakthrough Agenda," focuses on sectors that are considered difficult to decarbonize, such as steel.

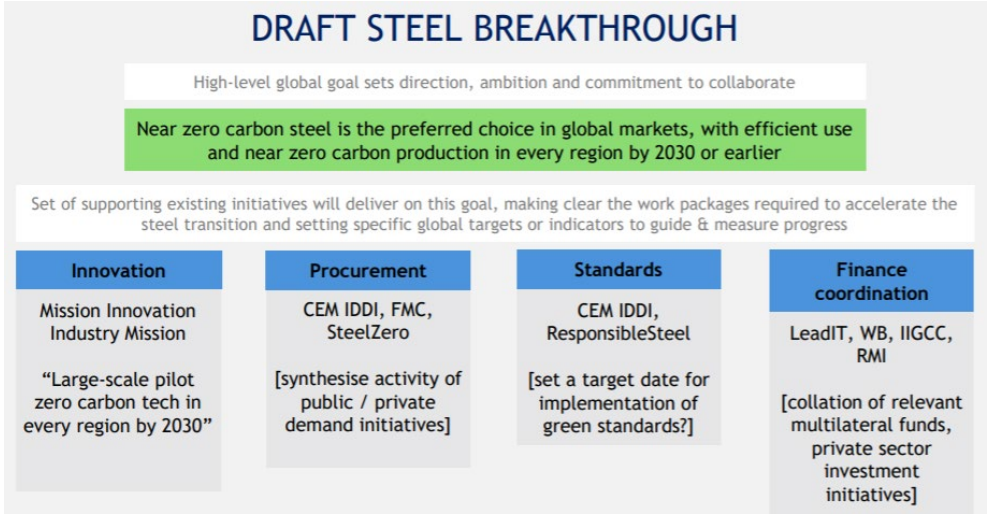
The agenda for steel includes 26 countries, including Japan, and aims to achieve "efficient and near-zero emission production in all regions by 2030, so that near-zero emission steel becomes the preferred choice for the global market.

The definition of near-zero emission steel is a reduction of 90% or more compared to conventional blast furnace and converter production, including the use of scrap iron.

A number of international initiatives have recently been launched to decarbonize steel, and the Agenda seeks to strengthen the coordination of these initiatives to achieve a solution.

Steel Breakthroughs Overview

Focusing on innovation, procurement, standardized investment, and cross-cutting initiatives, the report seeks to coordinate various international initiatives to further promote international cooperation.



Source: UK government

References: UNFCCC, World Steel Association

International Initiatives for Steel Industry Decarbonization: Launching Rush

Targeting the steel industry and other high-emission sectors that are said to be "difficult to deal with" as the "next frontier".
Although the goal is to decarbonize by 2050, the focus of activities will be on the next 10 years, with the period up to 2030 being the most important.
Diverse initiatives are promoted: not only focusing on production, but also on demand, investment, and supply.
These are formed by a collaborative body of diverse actors, including governments, companies, investors, NGOs, and academics.

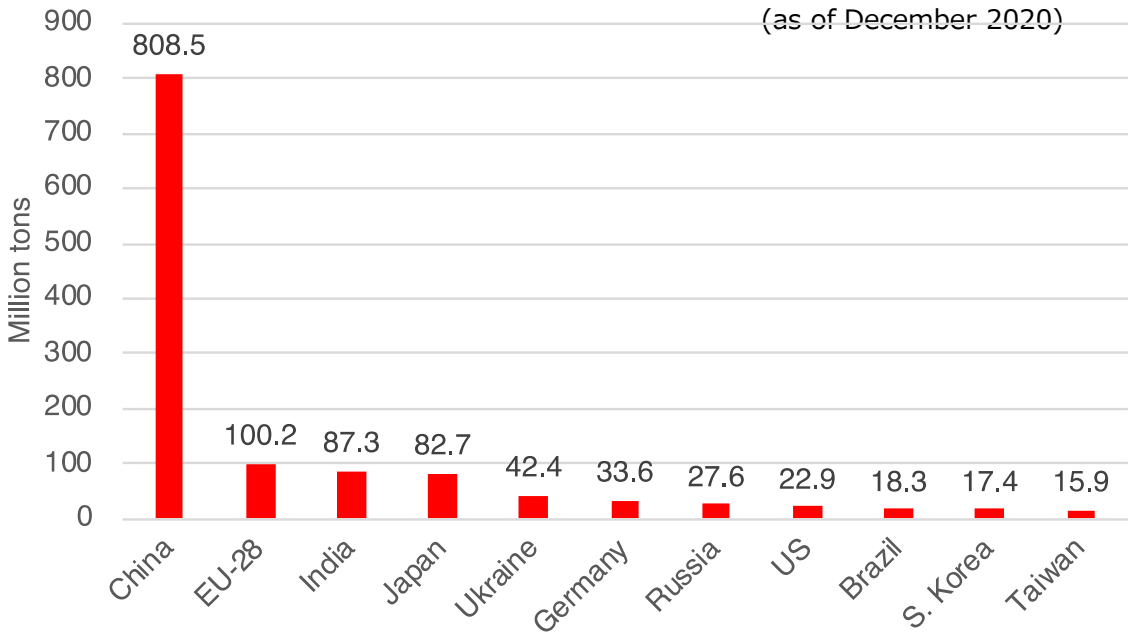
Initiative	Organizer, partner	Mission, activities
Mission Possible Partnership Net-Zero Steel Initiative	Funding partners; Energy Transitions Commission, RMI, We Mean Business Coalition, World Economic Forum	Form and promote a community of industry CEOs, customers, and suppliers to decarbonize 7 high-emission industries, including steel. Market zero-carbon primary steelmaking technology in the next 10 years, promote scrap-based manufacturing, and avoid building high-carbon emission facilities after 2030.
Leadership Group for Industry Transition (LeadIT)	Launched by the governments of Sweden and India at the 2019 UN Climate Action Summit, supported by the World Economic Forum, with 19 members from 16 countries.	LeadIT members must make progress in low-carbon energy-intensive industries with the goal of zero emissions by 2050.
Clean Energy Ministerial（CEM)/ Industrial Deep decarbonization initiative	A public-private collaborative initiative of CEM, an international forum formed by 29 countries including Japan. Led by UK and India, with participation by Germany, Canada, and UAE, in collaboration with MI, LeadIT, IRENA, and the World Bank.	Promote public-private procurement with the aim of creating a market for low-carbon steel and cement in collaboration with UNIDO.
First Movers Coalition (FMC)	A Public-Private Partnership between the U.S. Department of State and the World Economic Forum. Lead by U.S. Special Envoy for Climate Change, John Kerry.	By 2030, increase initial demand for low-carbon products and services and expand solutions in four high-carbon emission sectors, including steel .... Members will ensure that at least 10% of steel procurement is near zero emission steel by 2030.
Climate Group's Steel Zero	International initiative by Climate Group, organizer of RE100, 15 companies/organizations including Ørsted.	Bring together companies and organizations committed to making steel sourcing, selection, and storage 50% net zero steel by 2030 and 100% net zero steel by 2050. Send a strong signal from the demand side for a market and policy shift.
Mission Innovation/ Industry Mission	An international initiative involving 22 countries and the European Commission at the same time as the Paris Agreement, with the launch of the more action-oriented 2.0 in 2021 and the launch of the Net Zero Industries Mission.	Promote research, development, demonstration, and investment to make clean energy affordable, attractive, and accessible to all over the next decade..
Responsible Steel	A Multi-Stakeholder Standard and Certification Initiative for the Steel Industry. BlueScope Steel, Founded by ArcelorMittal	Announced the Responsible Steel Standard V.1.1, which will apply to production and processing in 2021, with the mission of achieving net zero in the steel industry in 2050.

Reference: Prepared by the REI based on the websites of each initiative

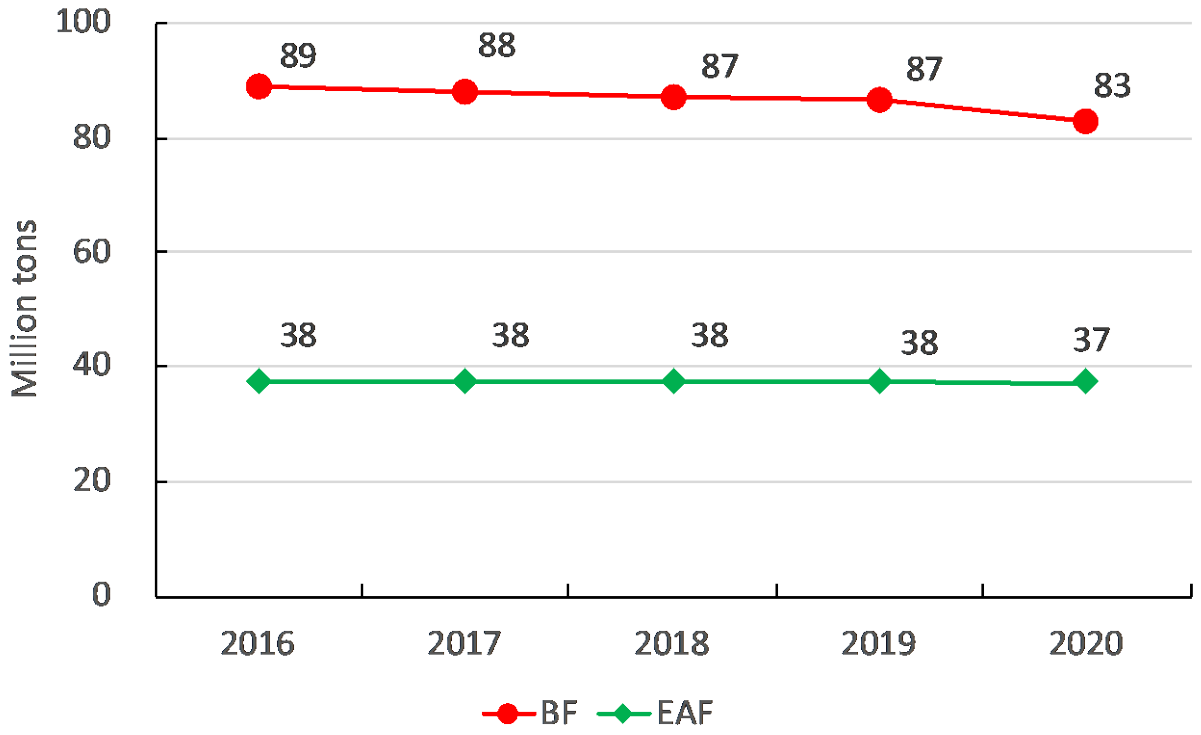
Current Japanese Steel Production Assets – Overview

- As of December 2020, 24 BFs were in operation at 12 sites across the country.
- Due to consolidation, only three companies (Nippon Steel, JFE and KOBELCO) have BFs.
- Total capacity of BFs in Japan accounts about for 83 Mt, the fourth largest in the world.
- EAF capacity is considerably large with 37 Mt, and stable.
- Currently, there is no DRI plant in Japan.

World top-10 countries in BF capacity:



BF and EAF capacities in Japan:



References: Global Steel Tracker, except for Japan (Ministry of Economy, Trade and Industry) and EU-28 and Germany (Agora Energiewende (2))

Reference: METI 2021

Lists of Acronyms and References

List of Acronyms

BF: Blast furnace
BF-BOF: Blast furnace - basic oxygen furnace
BF-BOF+CCUS: Blast furnace - basic oxygen furnace combined with carbon capture, utilization and/or storage
BOF: Basic oxygen furnace
CBAM: Carbon Border Adjustment Mechanism
CCS: Carbon capture and storage
CCUS: Carbon capture, utilization and/or storage
CO_2: Carbon dioxide
COP: Conference of the Parties
DR: Direct reduction
DR-EAF: Direct reduction - electric arc furnace
EAF: Electric arc furnace
ETS: Emissions Trading System
EUROFER: European Steel Association
GHG: Greenhouse gas
GW: Gigawatt
H_2: Hydrogen
H_2DR-EAF: Hydrogen-based direct reduction - electric arc furnace
INDC: Intended Nationally Determined Contribution
Mt: Million tons
MWh: Megawatt-hour
NDC: Nationally Determined Contribution
NGDR-EAF: Natural gas-based direct reduction - electric arc furnace
RE: Renewable energy
UNFCCC: United Nations Framework Convention on Climate Change

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