# NIPPON STEEL Nippon Steel Carbon Neutral Vision 2050

March 30, 2021 NIPPON STEEL CORPORATION

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#### Abbreviations:

**BF:** Blast Furnace, **BOF**: Basic Oxygen Furnace, **BT/Y**: Billion Tons per Year, **CCS**: Carbon Capture Storage, **CCU**: Carbon Capture Utilization, **CCUS**: Carbon Capture Utilization Storage, **DRI**: Direct Reduced Iron, **EAF**: Electric Arc Furnace, **H**<sub>2</sub>: Hydrogen, **HBI**: Hot Briquetted Iron, **MT/Y**: Million Tons per Year





### **1. Scenario to realize Carbon Neutrality**





### Nippon Steel Carbon Neutral Vision 2050

Adopting "Nippon Steel Carbon Neutral Vision 2050," as our own new initiative against climate change, a critical issue affecting human beings, we will strive to achieve carbon neutrality by 2050 as our top priority management issue.

Key Phrase



We have decided to actively work to achieve carbon neutrality as a top priority management issue, and have established a new "Key Phrase" to summarize our environmental management. We will make a concerted effort to tackle these extremely difficult issues.



#### **Our CO<sub>2</sub> emissions reduction scenario**



2030 Target

#### 30% or more reduction in total CO<sub>2</sub> emissions vs. 2013

#### [Means]

- Actual implementation of the COURSE50 in the existing BF and BOF process
- Reduction of CO<sub>2</sub> emissions in existing processes
- Establishment of an efficient production framework.

Vision 2050

#### Aim to become carbon neutral

#### [Means]

- Mass-production of high-grade steel in large size EAFs
- Hydrogen reduction steelmaking (by Super-COURSE50 use of BFs; direct reduction of 100% hydrogen)
- Multi-aspect approach, including CCUS\* and other carbon offset measures,.

Total CO<sub>2</sub> emissions (MT/Y) (Vs. 2013) 30% reduction 102Carbon Neutral Carbon Offset 2013 2030 2050 Vision Target

[Scope of Scenario]

Domestic

SCOPE I + II

(Receipt of raw materials to product shipment) + ( $CO_2$  at the time of purchase power production)

\*Carbon dioxide Capture, Utilization, and Storage





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### **2.** CO<sub>2</sub> emissions in steelmaking process



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#### CO<sub>2</sub> emissions in steelmaking process

- Steel is an "Earth-friendly material" as steel • produces less CO<sub>2</sub> per unit of production and during its entire life cycle, compared to other materials, and is highly recyclable.
- The total amount of CO<sub>2</sub> emitted by the steel • industry is high since steel has an overwhelmingly wider range of applications and is used extensively in large quantities compared to other materials.

Japan's CO<sub>2</sub> emission by sector



Diverse application of steel products By emitting sector By using sector Non-energy source Households 7% Nippon Steel 16% Households 5% Steel 9% Industrv industry Commercial Other steel 25% Commercial -use 6% producers 6% Industrv -use19% 39% Transportation Other 18% industries Transportation Energy 23% 20% conversion Energy 39% conversio Source: Ministry of the Environment, National Greenhouse Gas Inventory Report of Japan 2020 NIPPON STEEL

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#### Iron ore needs to be reduced

In nature, iron exists as oxides, iron ore.

To produce steel products, oxygen must be removed (= reduced) from iron ore.

The use of carbon (coal) is the best, stable, cost-effective method for reducing iron ore in large quantities.

The reaction, however, emits  $CO_2$ .







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#### CO<sub>2</sub> emissions in steelmaking process

The majority of CO<sub>2</sub> emissions in the steelmaking process is derived from the iron ore reduction process in the blast furnace.



Source: Carbon Trust: International Carbon Flows (2011)



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#### Three eco-friendly efforts to address climate change

**Eco Process** (The way we manufacture is "eco-friendly") to Japan's steelmaking process is the most energy-saving in the world.



Energy intensity in BOF steel production (Japan = 100) Source: RITE







Eco Products (What we produce is "eco-friendly")

Provides a wide variety of high-performance steel products, contributing to reduction of CO<sub>2</sub> emissions in use

### High strength steel sheets for vehicles

Achieve higher fuel efficiency with lightweight, higher safety and high processability

#### **Electrical steel sheets**



Reduce energy loss of motors and transformers

#### High-strength stainless steel HYDREXEL<sup>™</sup> for high-pressure gaseous hydrogen



Improves the strength, safety, workability, and life of the hydrogen infrastructure

**Eco Solution** (Sharing our "eco-solutions")

Transfers best-available energy-saving technologies mainly in developing countries



#### **Global steel stock increases**



Steel stock in the form of final products, such as infrastructure (i.e., buildings and bridges), industry (i.e., machinery and ships), and durable consumer goods (i.e., automobiles and home appliances) is **30 billion tons** or **4 tons per capita** globally, although **8-12 tons per capita in developed countries**.

Expected to reach 10 tons per capita in China by 2050 and in India by 2100.



A challenge towards zero-carbon steel

#### Global steel stock: 70 billion tons in 2050

#### Assumption:

- Steel stock per capita of 7 tons in 2050,
- **Global population growth** from 7.4 billion in 2015 to 9.8 billion in 2050,
- Economic growth in emerging countries, and
- Efforts to SDGs.



#### Primary steel production is necessary to increase steel stock in the future <sup>16</sup>



Crude steel production needed to meet global steel stock growth will continue to increase.



Availability of scrap increases as the increase of steel stock.

Obsolete scrap: Available from end-of-life products Prompt scrap: Generated in production of steel-based products Home scrap: Generated in the steelmaking process \* Figures are rounded. Global pig iron production estimates



Even if all the scrap is recycled, it is insufficient to meet the annual need for crude steel production, and steel production from iron ore will need to be at the same scale in the future.

Source: JISF, Long-term vision for climate change mitigation: A challenge towards zero-carbon steel

In order to achieve carbon neutrality, it is necessary to reduce  $CO_2$  emissions not only from scrap recycling but also from iron ore reduction.





### 3. Breakthrough technology development (1) High-grade steel production in large-sized EAFs



### **Current EAFs for high-grade steel in Nippon Steel**



Pig iron, internal scrap and processed scrap are used to produce high-grade steel for the moment

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#### **Development of high-grade steel**

manufacturing technology in a large EAF

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### High-grade steel production in large-scale EAF

#### **Challenge 1: Impurities**

Steel products that can be manufactured with a scrap-based EAF are limited,

i.e. high-grade steel is difficult due to:

1) impurities such as copper contained or mixed in scrap, and

2) nitrogen contamination from the air



Challenge

# Manufacturing of high-grade steel in scrap-based EAF by eliminating unremovable impurities

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### High-grade steel production in large-scale EAF Challenge 2: Productivity

#### Problems

These are many problems in the production of high-grade steel in large-scale EAF:

- (1) The productivity of EAF is lower than BOF. Compared to the strong agitation with an oxygen gas jet in a BOF, refining with natural convection in an EAF takes a long time, in addition to the long melting time from DRI or steel scrap. These will be more pronounced in large-scale EAFs.
- (2) Gangue and void in DRI impede heat transfer, causing a long melting time. Gangue also raises the refining load and lowers the efficiency.

Average size of EAF < 100 t/charge (≒ 0.7 Mt/year)

Nippon Steel's average size of BF (after completion of structural measures)

 $\Rightarrow$  4,900 m<sup>3</sup>/unit ( $\Rightarrow$  4.0 Mt/year)

#### Challenge

Achieving high productivity in a large-scale EAF that can replace a BF in steelmaking by establishing the DRI melting and refining technology

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### 4. Breakthrough technology development (2) Hydrogen injection into BF (COURSE50 and Super COURSE50 projects)



### Hydrogen injection into BF (COURSE50 & Super COURSE50)

#### COURSE50 BF

#### Super COURSE50 BF



# COURSE50 and Super COURSE50 retrofit to existing BFs, partially replacing coking coal to hydrogen + iron ore to DRI



**Conventional BF** 

### Reduction of iron ore with hydrogen

#### Reduction with hydrogen

Hydrogen replaces coke as reducing agent, producing  $H_2O$  with no  $CO_2$  emissions.

#### **Reduction with carbon** Coking coal $CO_2$ Iron ore Steel Fe<sub>2</sub>O<sub>3</sub> Fe **Reduction with hydrogen** Hydrogen ΗΩΟ Iron ore Steel Fe Fe<sub>2</sub>O<sub>3</sub>

#### Hydrogen steelmaking today

DRI with natural gas is operated in several locations in the world but not in Japan due to the high cost of natural gas.

There is no case of hydrogen injection into BF so far, due to the difficulty of supplying cost-effective hydrogen.

Cf. 1 "Hydrogen Basic Strategy" scenario by METI				
Hydrogen cost Hydrogen supply				
Present	<¥100/Nm <sup>3</sup>	200 tons*		
2030	¥30/Nm <sup>3</sup>	3 million tons		
2050	¥20/Nm <sup>3</sup>	20 million tons		
		*Present: as of 2017		

- Cf. 2 Hydrogen cost equivalent to coking coal  $\pm 8/Nm^3$
- Cf. 3 Hydrogen required to produce all the current domestic pig iron (75 Mt/year) 75 billion Nm<sup>3</sup> /year (7 Mt/year)



### BF and the role of coke

#### BF is an ultra-large reactor

that produces iron continuously and efficiently from iron ore. Oxygen in the hot blast blown through the tuyere and the coke produces a high temperature reduction gas which then reduces the iron ore, input from the top, to iron, and is continuously output as molten pig iron. 10,000 tons/day of iron (the amount used for 10,000 passenger cars) is continuously produced by the BF.

15 m



100 m

#### The role of the coke

- 1. Reducing agent (carbon C)
- 2. Source of heat (heat generated by combustion)
- 3. Support of raw materials at high temperature, maintaining ventilation in the furnace
- 4. Byproduct gas production in coke making, as an energy source in the steelworks (for power generation, heating furnace, etc.)



### Hydrogen injection into BF, Challenge 1: Heating of hydrogen



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#### **Problems**

Reduction with carbon is exothermic but that with hydrogen is endothermic, causing a temperature decrease. Pre-heating of hydrogen is necessary for the large amount hydrogen injection.



### Hydrogen injection into BF, Challenge 2: gas permeability



Ensuring maximum gas permeability for stable reaction and melting with less coke in the BF



### Hydrogen injection into BF, Challenge 3: Scale up



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COURSE50: CO2 Ultimate Reduction System for Cool Earth 50 Project

100% supported by NEDO (<u>N</u>ew <u>E</u>nergy and Industrial Technology <u>D</u>evelopment <u>O</u>rganization) Operated by Nippon Steel, JFE Steel, Kobe Steel and Nippon Steel Engineering

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### **Initiatives of the COURSE50 Project**

Nippon Steel, two other BF steelmakers, and Nippon Steel Engineering began development in 2008. The hydrogen reduction technology was experimented at a test BF in the East Nippon Works Kimitsu Area.







# 5. Breakthrough technology development (3) 100% hydrogen use in direct reduction





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### **Technical issues in direct reduction process**

The current direct reduction process uses <u>methane (natural gas)</u> instead of coal as a reducing agent.



### Challenges of 100% hydrogen use in direct reduction

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## We are challenging direct reduction using 100% hydrogen, not methane (natural gas), as a reducing agent.



#### **Problems**

In addition to the issues of the existing DRI process,

- 1) Hydrogen reduction is endothermic.  $\rightarrow$  Hydrogen preheating to be required.
- 2) Powdering of raw materials at low temperature and sticking of products.
   → Less powdering and less sticking ore (only 10% of commercially available ores) to be fed.

#### Challenge

Technologies for blowing a large amount of preheated flammable gases at hightemperature into the furnace, and expanding ores applicable to the hydrogen process



### (Ref.) Hydrogen steelmaking trials

Since renewable hydrogen is relatively easily obtained in Europe, demonstration trials of direct reduction with hydrogen have just started in such countries.

ArcelorMittal, Hamburg (Germany)	Development of a hydrogen use in an existing commercial natural gas DRI plant (100,000 tons/year). Construction cost: €120 million (¥13 billion)	
SSAB (Sweden) HYBRITT Project	Development of hydrogen steelmaking using a newly built or reduction plant (7,000 tons/year) Construction cost: €150 million (¥18 billion) Subsidized by the Swedish Energy Agency Production plan: 1.3 million tons/year from 2026	lirect
Baowu Steel Group (China)	Launch of the "China low carbon metallurgical technology innovation alliance" and establishment of a "low-carbon metallurgical innovation research center". Started research on the industrialization of hydrogen steelmaking using the existing 400m <sup>3</sup> test BF in Xinjiang.	





### 6. CCUS (Carbon Capture, Utilization and Storage)



### **CCUS (Carbon Capture, Utilization and Storage)**

Considerable amount of  $CO_2$  will still be emitted even from breakthrough BFs. Such  $CO_2$  can be captured, utilized to chemicals, or stored underground (CCUS).







Environment Policy Division, Industrial Technology and Environment Bureau, Ministry of Economy, Trade and Industry: CCS R&D/Verification-Related Businesses/Research on CO2 Storage Areas (June 20, 2019)



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### **CCU (Carbon Capture and Utilization): CO<sub>2</sub> recycling**

Converting captured  $CO_2$  into feedstock of chemicals, etc.

METI, Carbon Recycling Technology Roadmap (2019)



- Conversion cost is relatively high.
- A large amount of carbon-free hydrogen is required for chemical conversion (reduction) since CO<sub>2</sub> is chemically stable.
- Except for mineralization, the storage is temporal and the CO<sub>2</sub> is eventually re-released into the atmosphere through combustion and decomposition.
- The amount of chemicals and fixed amount of  $CO_2$  is limited.



### **CCUS by Nippon Steel (COURSE50 Project)**

#### Capture) Development of CO<sub>2</sub> capture technology

#### **Chemical absorption**





- High-performance heat exchanger for waste
- Capturing performance, demonstrated through

Achieving the stripping energy near the theoretical

Capturing cost less than ¥2,000/t-CO<sub>2</sub>, expected

Recovering waste heat at 200 - 400°C, currently unrecovered, and using it as a heat source for the  $CO_2$  capture enables a reduction in  $CO_2$  capture cost.

High-performance micro heat exchanger

Source: Prepared by Nippon Steel based on the data on NEDO's website



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### **CCUS by Nippon Steel (commercialized)**

#### Capture

#### ESCAP<sup>TM</sup> energy-saving CO<sub>2</sub> capture facility <sup>6</sup> NIPPON STEEL ENGINEERING

ESCAP<sup>®</sup> (Energy Saving CO<sub>2</sub> Absorption Process)

- Based on the energy-saving CO<sub>2</sub> absorption technology developed by COURSE50, Nippon Steel Engineering Co., Ltd. commercialized the technology for industrial use, by adding its own technology.
- By using the absorption solution jointly developed by Nippon Steel and RITE (Research Institute of Innovative Technology for the Earth), high-purity CO<sub>2</sub> can be captured from CO<sub>2</sub> containing gas with low energy.
- In the facility using the chemical absorption, high-purity CO<sub>2</sub> applicable for food and other use can be produced from the gas with high impurities, reducing heat consumption by more than 40% compared to conventional technologies.
- Also applicable to chemical feedstock, CO<sub>2</sub> removal in chemical processes, EOR (Enhanced Oil Recovery), and CCS (CO<sub>2</sub> stored in the ground).





Capacity: 120 t-CO<sub>2</sub> /day; Purity: 99.9 vol.%+

The first commercial facility based on the chemical  $CO_2$  absorber in the world, using hot-blast stove exhaust gas from steel works as the source of  $CO_2$ .



ESCAP<sup>™</sup> at Sumitomo Joint Electric Power Co., Ltd. Completion: July 2018 Capacity: 143 t-CO<sub>2</sub> /day; Purity: 99.9 vol.%+ The first commercial CO<sub>2</sub> capture facility for food application from the combustion exhaust of coal-fired power in Japan

Source: Nippon Steel Engineering's website



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### **CCUS by Nippon Steel (technology under development)**



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### 7. Technological challenges and required external conditions



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### **Technological challenges** and required external conditions

#### Production of high-grade steel in large scale EAF

- Scrap: Elimination of the effect of hazardous impurities using DRI **Technological** 
  - EAF: Improvement of productivity with larger scale and higher efficiency
  - Cost-effective fossil-free power

#### Hydrogen injection into BF (COURSE50, Super-COURSE50)

- Preheating and injection of high-temp hydrogen for endothermic reactions
- Stable gas flow in BF with less coke  $\succ$
- Technological  $\succ$ Scaling-up from experimental to actual super-large-scale BF
  - Establishment of the technology to offset remaining CO<sub>2</sub> emissions (CCUS)
  - Implementation of CCU and CCS
  - Large supply of carbon-free hydrogen

#### 100% hydrogen use in direct reduction (Shaft furnace etc.)

Establishment of the technology of hydrogen direct reduction

Technological challenge External conditions

challenge

External

conditions

challenge

**External** 

conditions

- Large-amount supply of carbon-free hydrogen

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# Challenges to realize carbon neutrality and collaboration with society

Take on the challenge to <u>develop and practically implement breakthrough technologies ahead of</u> <u>the other countries</u> to realize carbon neutrality, as Nippon Steel's top priority issue, which is essential for Japan's steel industry to continue to lead the world and to maintain and strengthen the competitiveness of Japanese industry in general.

#### 3 factors to increase costs for the realizing carbon neutrality

1) Huge R&D costs

2) Huge CAPEX for practical implementation

3) Increase in operational cost, even if inexpensive carbon free hydrogen and zero-emission power are to be secured

The production cost of crude steel may more than double the current cost.

3 collaborations required for realizing carbon neutrality

Images of R&D cost and CAPEX for realizing carbon neutrality

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### CAPEX for practical implementation **¥4 to ¥5 trillion** R&D cost Approx. **500.0 billion**

\* Minimum level estimated to be required for the time being

#### 1) A national strategy to realize a "virtuous cycle of environment and growth"

- Long-term and continuous government support for R&D in the field of breakthrough innovation etc.
- Establishment of inexpensive and stable large-scale hydrogen supply infrastructure
- Realization of carbon free power at an international competitive cost
- Promotion of national projects for the development and commercialization of CCUS
- 2) Realization of government's comprehensive policies to secure equal-footing in international competition, strengthen industrial competitiveness, and lead to business chances

#### 3) Formation of consensus on the issue of cost bearing by society

• Establishing a system for society as a whole to bear the enormous costs of realizing carbon neutrality, such as R&D costs, CAPEX for replacing existing facilities, and significant increase in production costs.

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### (Reference) Carbon pricing



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### Energy and environment-related taxes by country

- ✓ Several countries have coal taxes, but mostly only for commercial heating. (Some have industrial coal taxes but coal is virtually tax-free due to refunds and tax incentives at an equivalent rate).
- ✓ Virtually no country has taxes on coal, coke or byproducts for steelmaking.

Country	Nature of the tax	Coal taxation	Exemptions and preferential treatment for coal
Sweden	Carbon Tax	Up to ¥38,300/t	Tax exempt for steelmaking and power generation
Norway	Carbon Tax	No tax	-
Germany	Energy Tax	Up to ¥1,240/t	Taxable only for business heating. Tax exempt for ETS companies
Italy	Energy Tax	Up to ¥600/t (business) Up to ¥1,200/t (home)	Taxable for heating applications only
U.K.	Climate change tax	From ¥4,800/t	Tax exempt for raw materials and reductant
France	Coal Tax	Up to ¥15,220/t	Tax-exempt for raw materials and reductant, and ETS companies
Spain	Hydrocarbon tax + electricity tax	Up to ¥560/t (business) Up to ¥2,430/t (home)	Tax exempt for steelmaking, power generation, and some other industries
Belgium	Energy Tax	Up to ¥48/t	No tax for raw materials and reductant. Some tax-exempt for ETS companies
U.S.A.	Energy Tax	No tax	-
China	Energy Tax	No tax	-
S. Korea	Energy Tax	From ¥4,410/t	Taxable for power generation only
India	None	No tax	-
Australia	None	No tax	-



### Comparison of electricity rates b/w Germany and Japan <sup>48</sup>

- ✓ Germany's electricity rates for the power-consuming industrial use are about one third of the prices of industrial electricity in Japan.
- ✓ Germany has various exemption schemes, and most taxes and transfer fees are reduced for power-consuming industries.





### **EU Emissions Trading System (ETS) (Europe)**

- ✓ Emissions of EU ETS companies are about 2 billion tons of  $CO_2$  p.a.
- ✓ In Phase 2 (2008-2012), the allocated allowances and verified emissions were roughly balanced.
- ✓ In Phase 3 (from 2013), due to no free allocation to power generators and the decrease in allowances in other sectors each year, there were significant gaps between them resulting in a lack of allowances.



Source: (EU) Emissions Trading System (ETS) data viewer (European Environment Agency) form EU Transaction Log (EUTL)



### EU Emissions Trading System (ETS) (Steel industry)

- $\checkmark$  CO<sub>2</sub> emissions by the EU steel industry total about 150 million tons per year.
- ✓ The EU steel industry continued to have surplus allowances and its CO<sub>2</sub> emissions did not decrease.



Source: (EU) Emissions Trading System (ETS) data viewer (European Environment Agency) form EU Transaction Log (EUTL)

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#### **Outline of the China Emissions Trading System**



- ✓ China, the world's largest CO<sub>2</sub> emitting country, started emissions trading nationwide on February 1, 2021 with the aim of achieving a decarbonized economy by 2060.
- Starting with power generators with high annual greenhouse gas emissions, steel, building materials, petrochemicals, chemicals, non-ferrous metals, paper, and aviation sectors are also to be included in coming five years.
- ✓ For the moment, the government allocates free allowances and will start to allocate cap for auction "at the appropriate time, depending on the situation."

<Reference> Remarks by CISA Executive Chairman

"When designing systems that include  $CO_2$  emissions trading, we need to ensure that good companies take the lead by making sure that profits flow to good companies in the industry, not to outside. We hope that the reduction of carbon emissions will not reduce the competitiveness of the industry, but rather promote greater competitiveness among companies."



### **Carbon pricing**

(1) Since the energy costs borne by the Japanese steel industry are higher compared to the costs in other countries even now, carbon pricing, such as carbon taxes and emissions trading systems, will become an additional burden, and will have a significant impact on international competitiveness. The loss of competitiveness of the Japanese steel industry will shaken the foundations of all the manufacturing industries that are competing in the world using Japan's highperformance steel.





High electricity rates are a big handicap in international competition

\* In Germany, industries exposed to international (USD/MWH)

(2) While the "carbon neutrality" of the steel industry is important in realizing Japan's green growth strategy, the carbon neutral technology has not been established anywhere in the world, and we need to take up an extremely difficult challenge of technology development from scratch. In addition to long-term R&D investment, the huge cost is required for new capital investment for the conversion of existing equipment when implementing the technology. Further burdens such as carbon pricing will mean for the industry to be deprived of the source of innovation toward decarbonization. Since each steel company has already positioned the carbon neutral technology development as its priority issue, carbon pricing for the promotion of the development is not needed.



#### Border adjustment mechanism

• In the EU and the USA, introducing of border adjustment mechanism is started to be considered for imports from countries that are insufficient in climate change actions.

Border adjustment mechanism

- ✓ A border adjustment mechanism is to take adjustment measures at the border according to carbon emissions.
- ✓ For example, imports from countries with high emissions may be subject to customs duties at the border.

(Europe)

The Green Deal will impose carbon prices on certain items from outside the EU. Announcement was made to propose the details of the system by June 2021 and plan to introduce the mechanism by 2023.

(USA)

✓ President Biden is committed to the measures (listed in the Democratic Party Summary).

Problems of the boarder adjustment mechanism

- 1. Inconsistency with WTO rules (The measures must be consistent with the EU ETS but if the free allowance of the EU ETS sustains, it would become excessive compensation of the EU and may be inconsistent with WTO rules.)
- 2. Lack of international rules to ensure the transparency of carbon intensity measurement methods and data in products.

[Reference] European Parliament: A non-binding preliminary vote on border adjustment mechanism The focus was on the continuation or abolition of the EU ETS free allocation of allowance, associated with border adjustment mechanism.

On February 5, 2021, the abolition of the free allocation was decided but the EUROFER strongly opposed it, describing it as "a death sentence."

On March 10, 2021, the continuation of the free allocation was passed by a close margin and the EUROFER welcomed the border adjustment mechanism.



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