Session : Decarbonation of Iron and Steel

DRAFT

Rev-2

WORLD MATERIALS FORUM

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Chairman of the Board

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Ⅰ. Current situation

1. Urgency of Green Steel Promotion

- The urgency and importance being recognized in the world.

2. Many Barriers and Challenges : Not easy to solve

(1) Geographical / Geological Differences in Availability and Cost

- Renewable energy resources and green / low-carbon hydrogen

(2) Society's Affordability and Acceptance

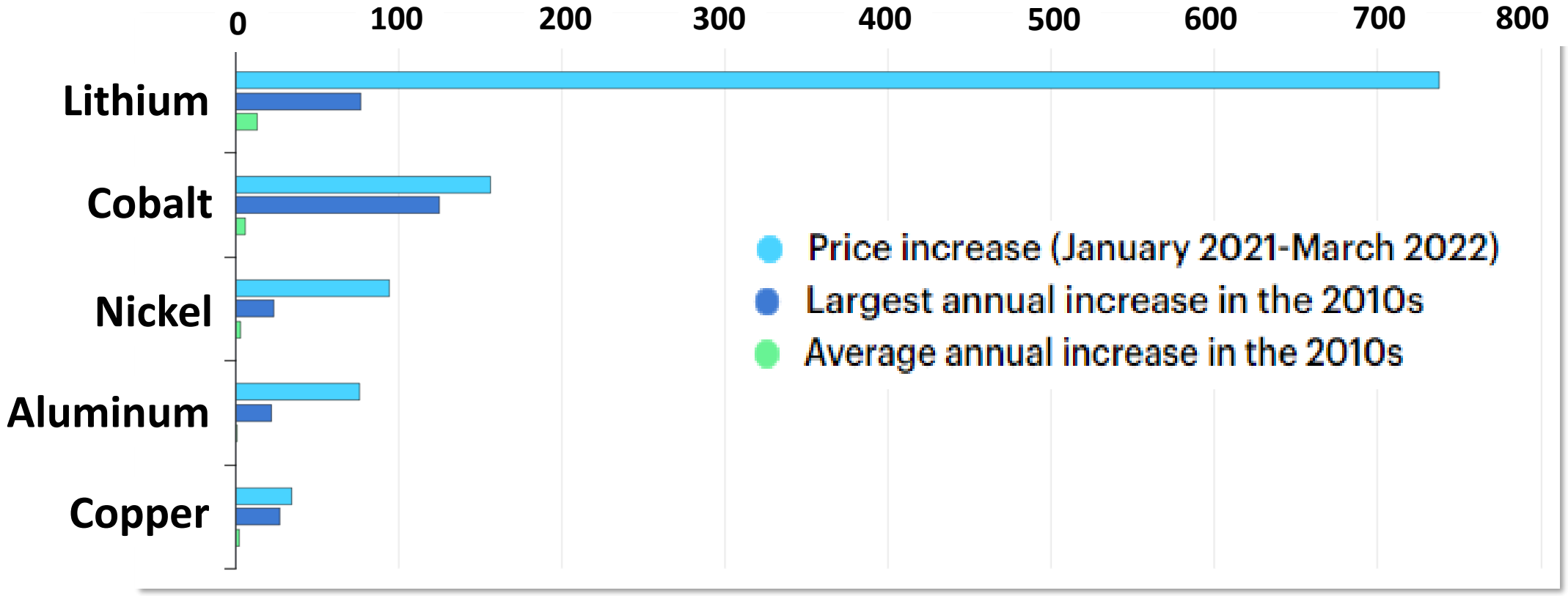
- Emission Trading System (ETS)
- Carbon Border Adjustment Mechanism (CBAM) ……

(3) Other Major Hindrance :

- Energy crisis and Critical minerals Availability (Refer to the next page)

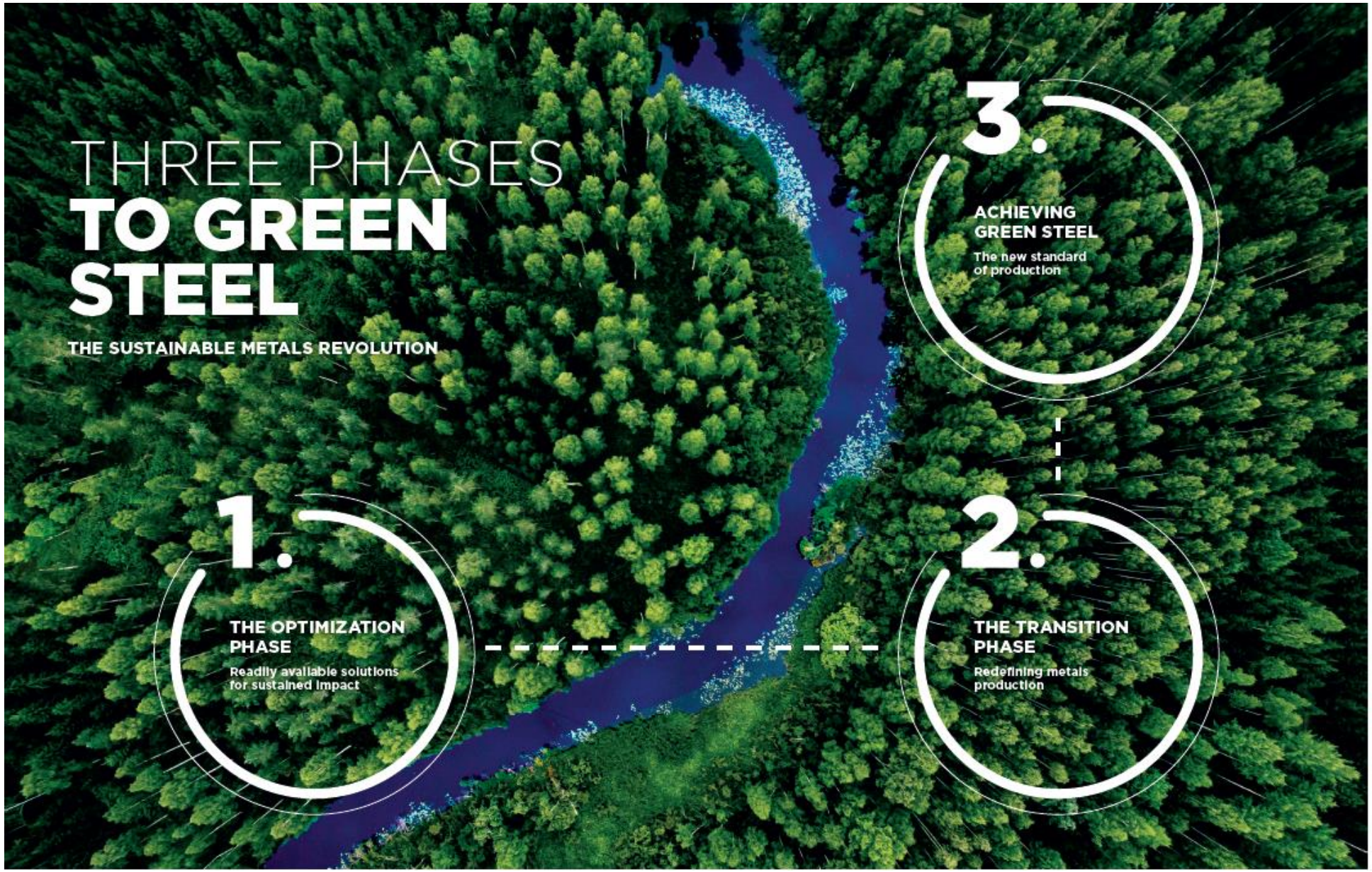
1. Current Situation (2)

Price increase in selected energy transition minerals and metals



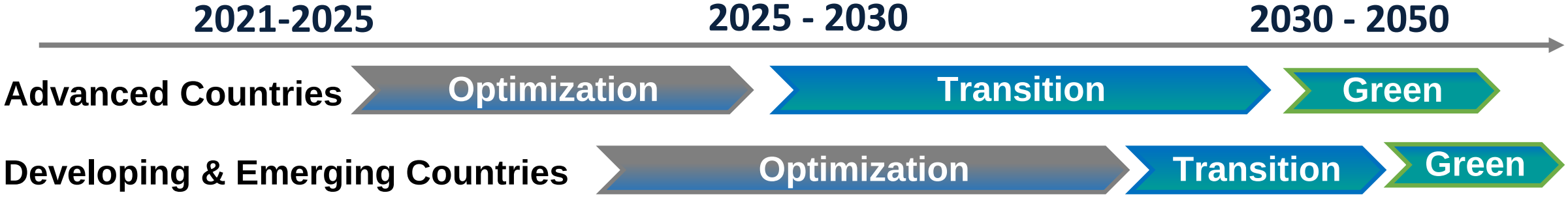
Source: https://www.iea.org/commentaries/critical-minerals-threaten-a-decades-long-trend-of-cost-declines-for-clean-energy-technologies

Ⅱ. A Pragmatic Approach toward Green Steel



Ⅱ-1. Three-Phased Approach

1st Phase	2nd Phase	3rd Phase
1.Optimization of Available Technology	2.Transition	3.Green Steel
10-30% CO_2 reduction	30- 40% CO_2 reduction	80- 90% CO_2 reduction
Process optimization Energy optimization Technology improvements Raw material optimization	Use of low carbon fuels Partial H_2 use in DRI processes H_2 use in BF/Pellet/EAF Endless processes (direct rolling) Hybrid flexible melt shops Starting phase for CCUS	Carbon direct avoidance H_2 based DRI plants Renewable powered EAF's Deployment of Carbon Capture Utilization and Storage



Ⅱ-2. Optimization of Current Technology

(1) Main focus on Blast Furnace (BF) Technology

- The most efficient technology for iron making (reduction of iron oxides)
- New BFs still under construction and planning in developing/emerging countries.
- 33% of steel production via BF-BOF forecast in 2050.

(2) Recent improvements to reduce up to 40% of CO2 emissions

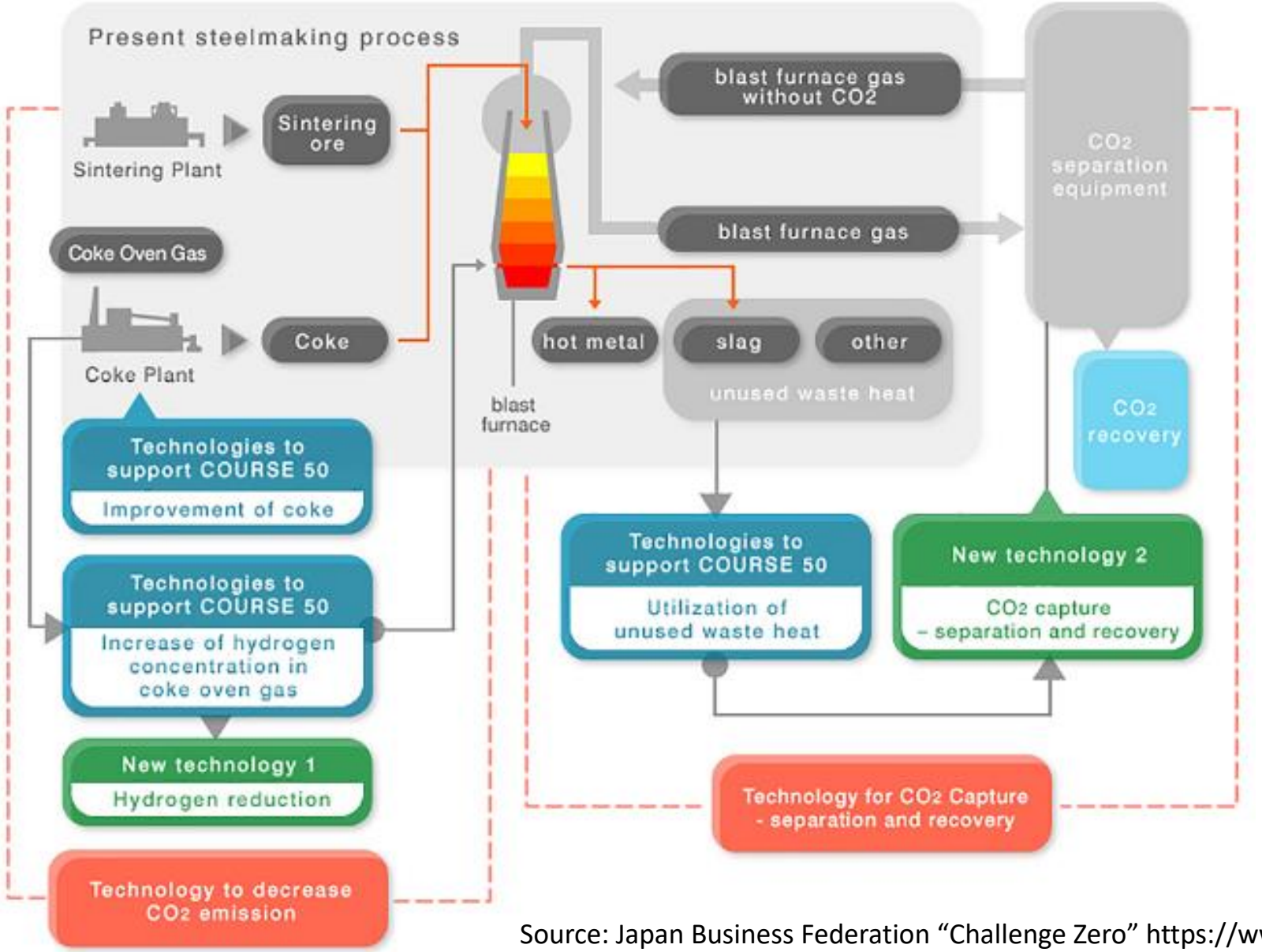
- By Gas injection, H2 injection, SIP (Sequence Impulse Process) oxygen injection.
- The solution for the residual CO2 to be CCUS.

(3) COURSE50[*1]/ Super COURSE50 : project by the government and steel companies in Japan

- Aiming more use of hydrogen for reduction in BF.
- Endothermic reaction caused by hydrogen need to be solved economically.

[*1] CO_2 Ultimate Reduction System for Cool Earth 50 (COURSE50) Project

(For reference)
COURSE 50 Project 【The Japan Iron and Steel Federation】



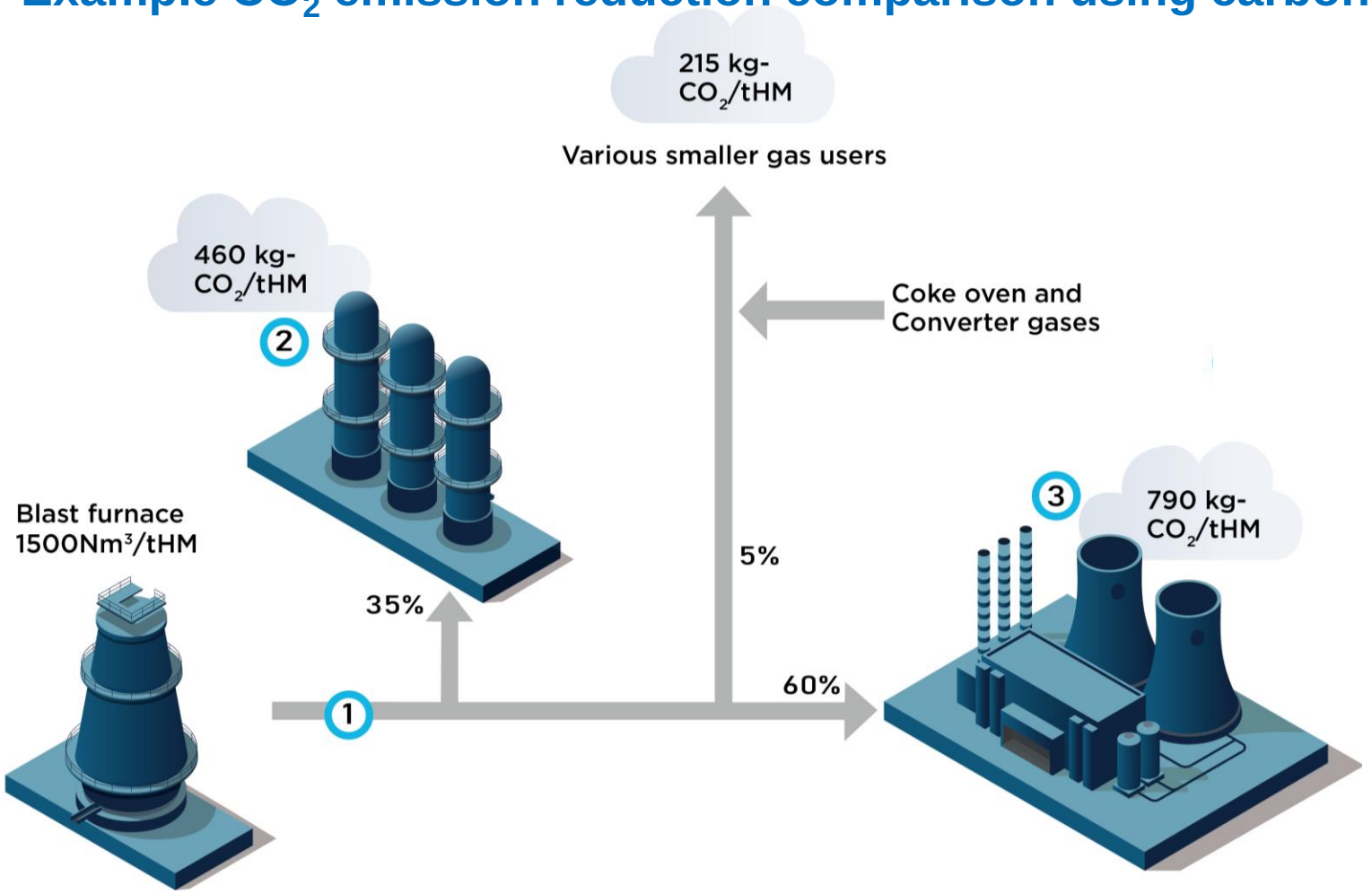
- Technology development is the key to responding to requests for further reduction of CO2 emissions on a global scale, and drastic steps powered by innovative technologies are deemed indispensable in the long term.
- To accomplish this aim, the “CO2 Ultimate Reduction System for Cool Earth 50” (COURSE 50) initiative was established and positioned as an Innovative Technology Development scheme.

Source: Japan Business Federation “Challenge Zero” https://www.challenge-zero.jp/en/casestudy/549

Ⅱ-3. Transition with Innovations (1)

BF with CCS

Applying KM CDR Process™ to the steel industry
Example CO_2 emission reduction comparison using carbon capture



1. CC at the BF only
   40% CO_2 emission reduction
2. CC at the stoves only
   30% CO_2 emission reduction
3. CC at the power plant only
   50% CO_2 emission reduction
2 + 3 CC at the stoves and power plant
   80% CO_2 emission reduction
   ... could be increased by future fuel-shifting, i.e. carbon fuels to hydrogen fuels

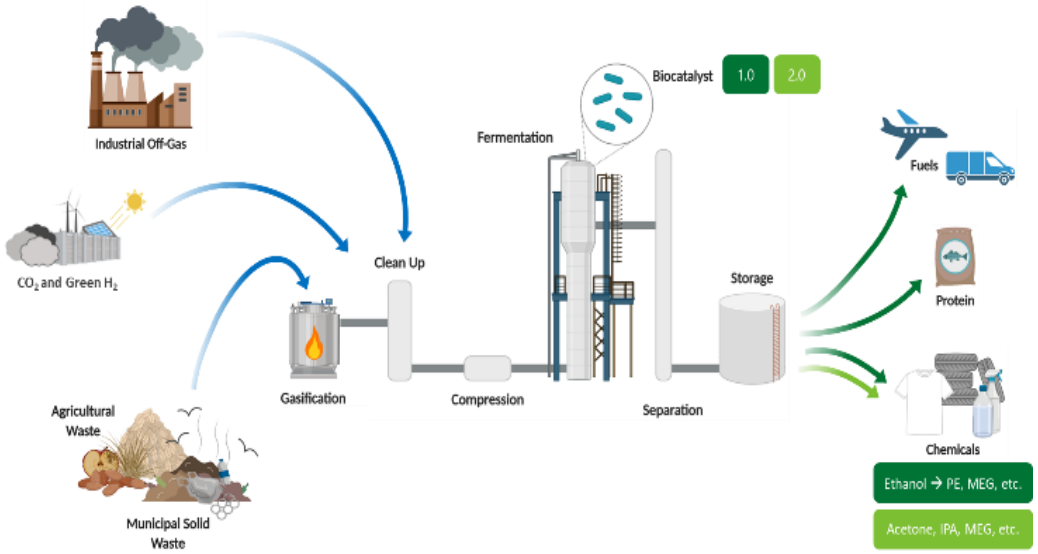
X Location of possible carbon capture

Ⅱ-3. Transition with Innovations (2)

BF with CCU - LanzaTech Bio-Fermentation

Shougang (SGLT), China

Arcelor Mittal / Gent, Belgium - Partners Primetals – AM – LanzaTech Start-up: June 2023 (62.000 ton Ethanol per year)



	H_2:CO ratio	$\Delta G°_{rxn}$ (kJ/rxn mol)	Carbon efficiency	Energy efficiency
CO 6 CO + 3 H_2O ➔ C_2H_5OH + 4 CO_2	0:1	-216	33.3%	72.8%
CO + H_2 3 H_2 + 3 CO ➔ C_2H_5OH + CO_2	1:1	-156	66.7%	78.5%
CO + H_2 4 H_2 + 2 CO ➔ C_2H_5OH + H_2O	2:1	-135	100%	80.6%
CO + H_2 + CO_2 5 H_2 + 1 CO + 1 CO_2 ➔ C_2H_5OH + 2H_2O	5:1	-115	100%	82.9%

Ⅱ-3. Transition with Innovations (3)

Multiple transition projects in execution

H2green steel, Sweden

- Strategic investors
- 1st large-scale greenfield fossil-free steel plant in Sweden, using green hydrogen
- 2,5 bn€ investment to produce 2,5 mtpy green steel
- Start-up 2025
- 95% CO_2 reduction

SALCOS, Germany

- Steelmaker investment
- Transformation of an integrated 6 mtpy steel plant to an H2-DRI-EAF plant
- 1,7 bn€ investment for to produce 1,9 mtpy green steel (1st phase)
- Start-up 2025
- 95% CO_2 reduction

GravitHy, France

- Strategic investors
- Planning to build, own and operate its first green iron and steel plant in France
- 2,2 bn€ investment to produce 2 mtpy green DRI
- Start-up 2027
- 95% CO_2 reduction

Arvedi, Italy

- Steelmaker investment
- 1st net-zero steel plant (Scop1 and 2)
- Optimizing the existing 3,3 mtpy EAF steel plant continuously
- 1,7 bn€ investment over the last 10 years
- Net-zero CO_2 emission from September 2022

Algoma, Canada

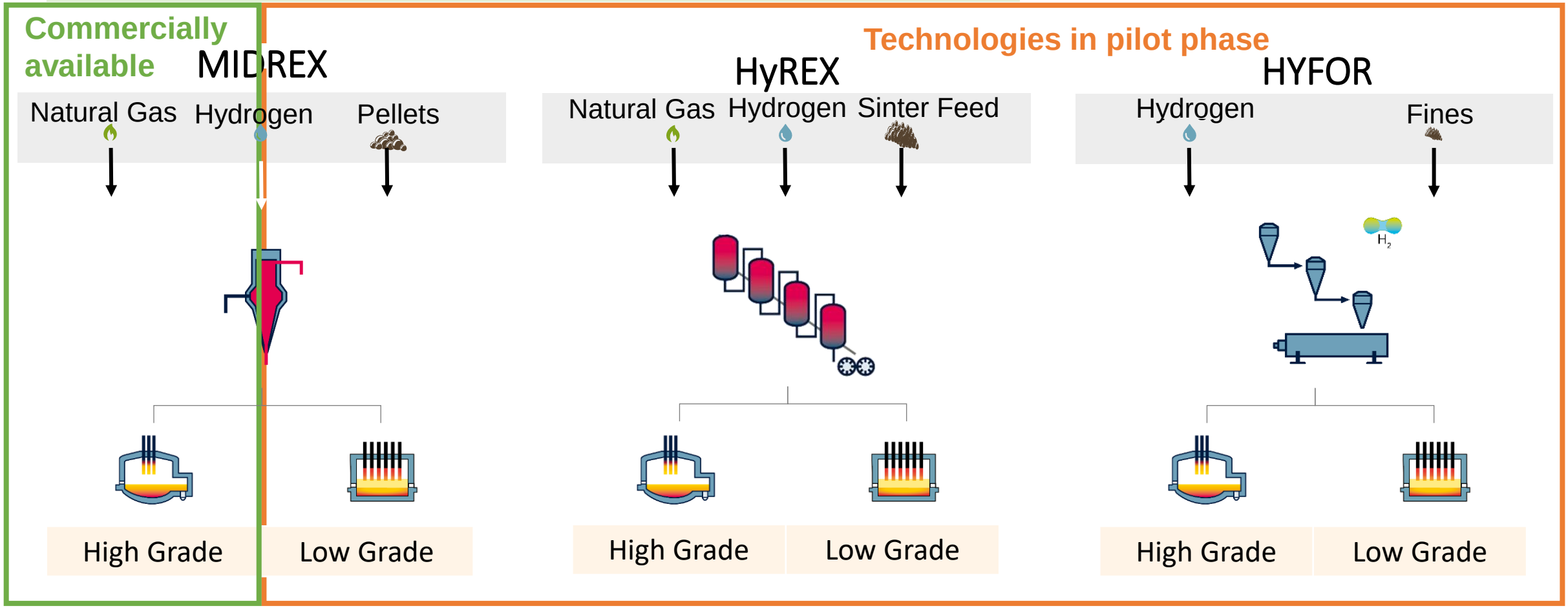
- Steelmaker investment
- Transformation of an integrated 4 mtpy steel plant to an EAF plant
- 700 m$ investment change from BF-BOF to 2x EAF
- Start-up 2024
- 70% CO_2 reduction

AM/NS, USA

- Steelmaker investment
- New 1,5 mtpy EAF steelmaking facility for high quality steel
- 780 m$ investment
- Start-up 2023
- 70% CO_2 reduction

Ⅱ-4. Green Steel (1)

Direct Reduction with Electrification



High-grade ores: Electric arc furnaces (EAF)
Low-grade ores: "Smelter" for DRI melting and final reduction

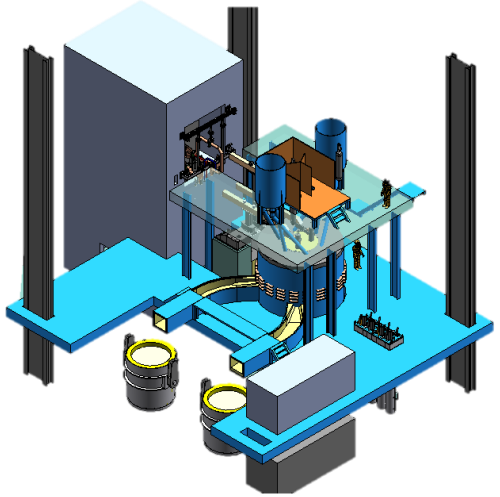
Ⅱ-4. Green Steel (2)

Development of New Smelter

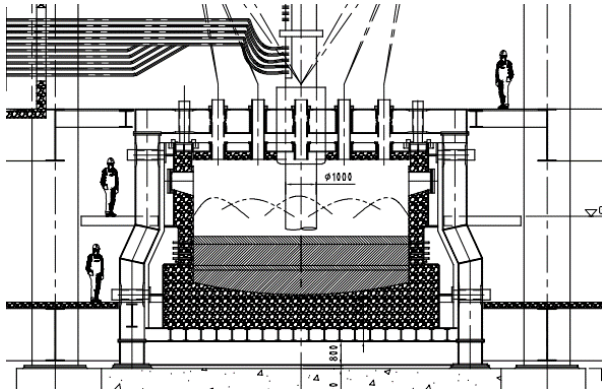
Pilot Testing

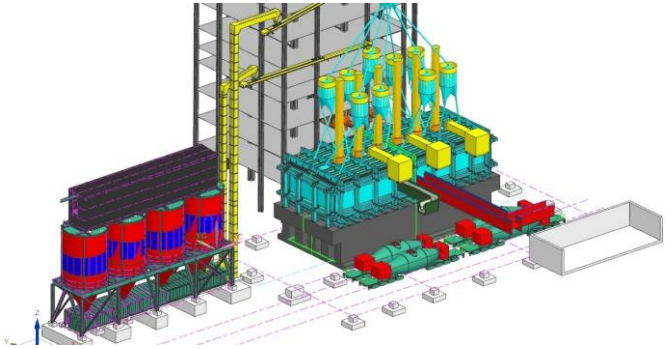
HYFOR-Smelter - Prototype, 3t/h

HyREX-Smelter - Industrial Demo, 40t/h



Full industrial plant, 1,25mta





2022 2023 2024 2025 2026 2027 2028

Ⅲ. Summary

We know
Earth cannot wait.

We also know Green Steel is a huge difficult challenge.

We must be pragmatic ;

- **Deploying** best available technologies for decarbonization of steel industries as broadly and quickly as possible.
- **Developing** ideal technologies toward Green Steel parallelly.

We need to consider the followings;

- **Phased approach** as mentioned.

Optimization of Current Technologies ➡ Transition with Innovations ➡ Green Steel

- **Multiple pathways** suitable to each country/ region's geographical/ geological characteristics and economical/ industrial structure and so forth.

Thank you.