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Session: Decarbonizing Value Chain Emissions (VCEs): Transitioning to a Net Zero Carbon Economy
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กลุ่มอุตสาหกรรมเหล็ก

Net Zero transition strategy and key challenges for Steel industry

Presented by
Mr. Somsak Pikkanesuan
Sahaviriya Steel Industries PLC., Thailand
[Vice chairman of Steel industry club, Federation of Industry Thailand]

Content :

FTI
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FTI*: The Federation of Thai Industries

(1)

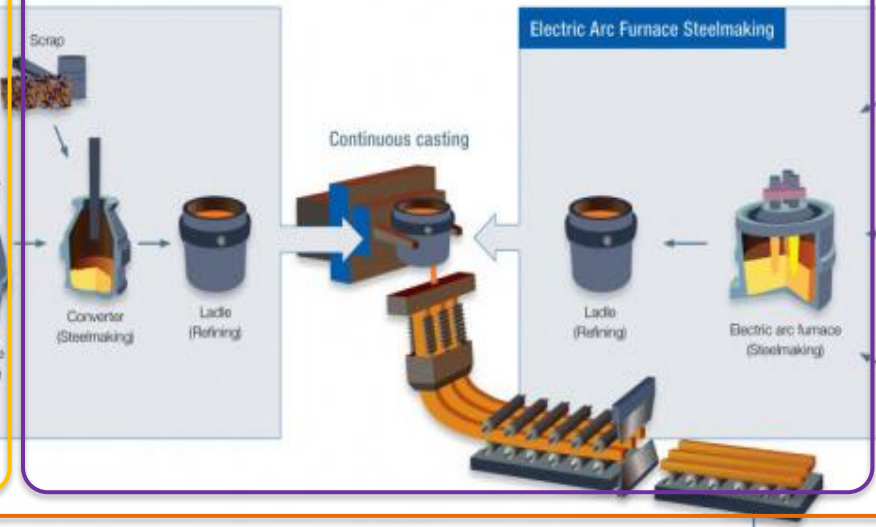
Overview of Iron & Steel industry

1.1) Overview of Iron & Steel production process

Upstream process – Ironmaking

It is the first part of the steel industry supply chain, which produces raw steel products. It starts with the crushing of iron ore before entering the smelting process to transform the iron ore into a purer form, called “raw iron”.

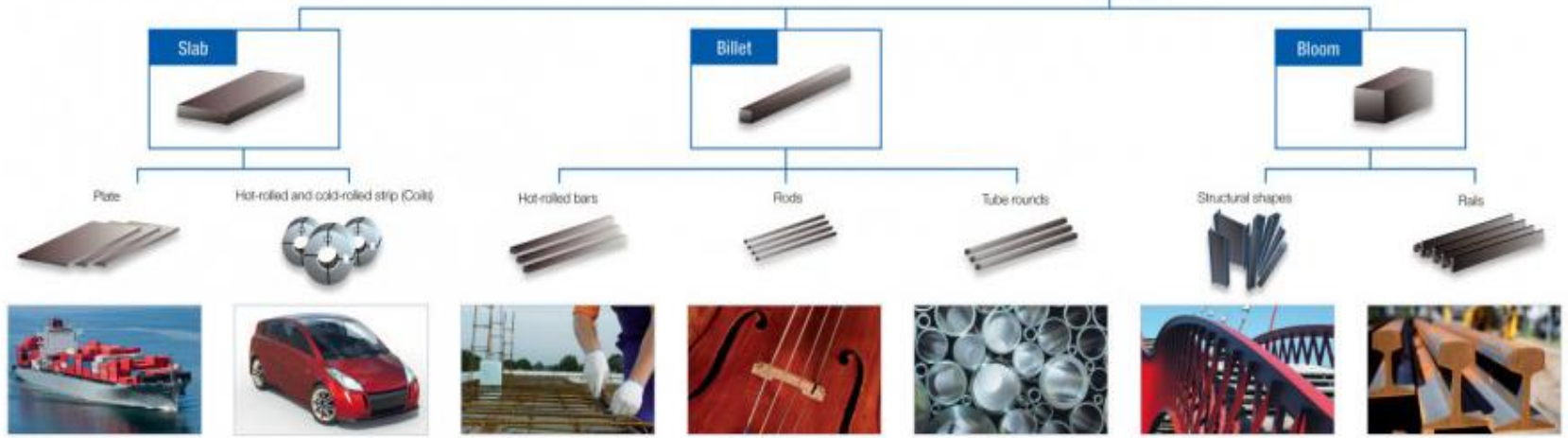
Midstream process – Steelmaking



Upstream process - Ironmaking

Downstream process

Steel rolling process



It is a process of transforming semi-finished steel into finished steel products through hot rolling, cold rolling, surface coating, forging and casting processes.

ที่มา : https://www.eurofer.eu/about-steel/learn-about-steel/what-is-steel-and-how-is-steel-made และ https://www.krungsri.com/th/research/industry/industry-outlook/construction-construction-materials/steel/io/io-steel-20

1.2) Perspective of steel industry to serve economic development

The steel industry is a basic industry that is important for the development of the country's downstream industries. This is because it is a material that is necessary for the development of infrastructure, such as bridges, energy structures (gas and oil tanks, gas and oil pipelines, solar farms, wind turbines, etc.), power transmission towers, and utility transmission towers. It is also used as a raw material in downstream industries, such as construction (office buildings, department stores, condominiums, warehouses, houses, etc.), electrical appliance industry, automotive industry, containers, cargo ships and ocean-going ships, and packaging, etc. Therefore, the steel industry is important for the economic development of every country to grow and develop sustainably.

Infrastructure

Downstream industries

Automotive industry

Electric equipment & packaging industry

Ship and container industry

Construction industry

Energy industry

1.3) Overview of the global steel industry

The steel industry is a major industry group that emits high levels of greenhouse gases, accounting for about 7% of the total CO2 emissions of the industrial sector worldwide (data from WorldSteel Association, 2021). China's steel industry accounts for the highest share of CO2 emissions, accounting for 54.1% of the total CO2 emissions in the world.

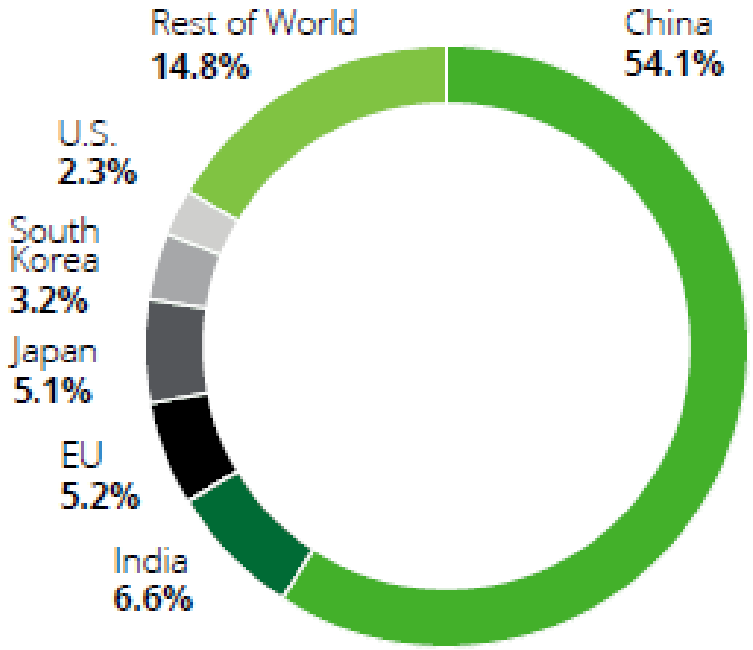
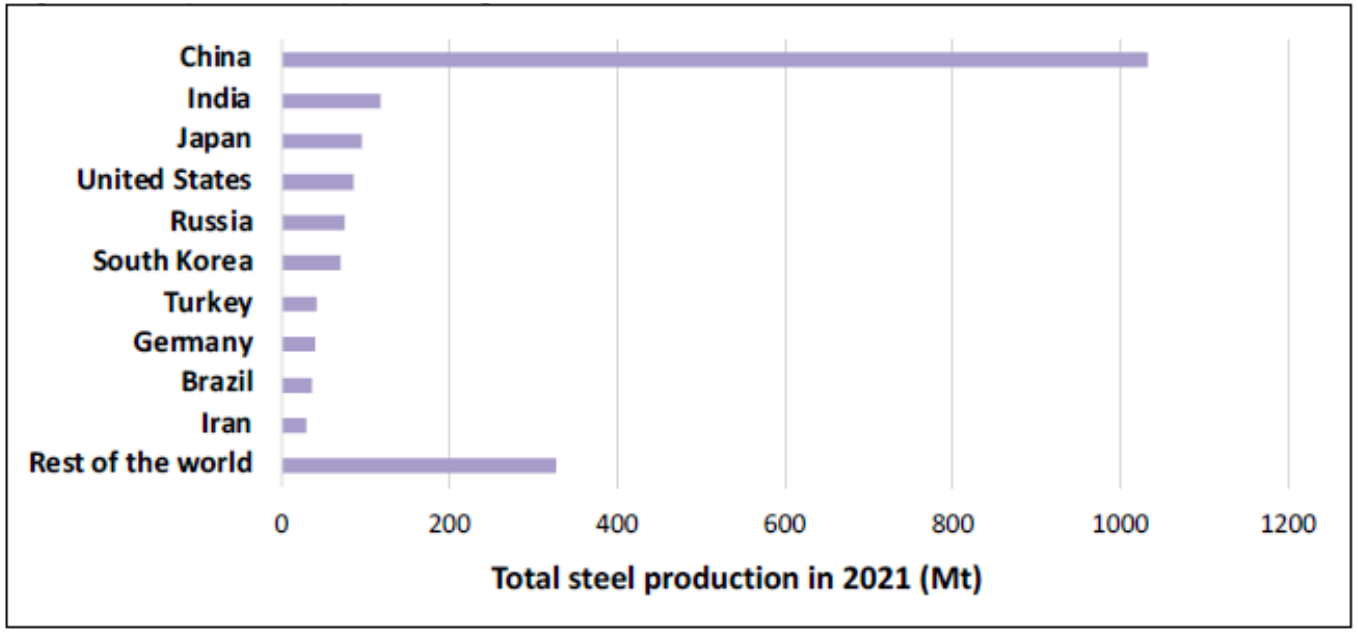


Figure 1.1: Estimated steelmaking CO2 emissions per region (2019)

Figure 1.2: Proportion of emissions per stage of steelmaking value chain

Figure 1.3) Top 10 steel producing countries in 2021



Source: Based on data by World Steel Association (2022).

From the Steelmaking value chain (Figure 1.2), the highest source of CO2 emissions comes from the use of coal in the steelmaking process in Blast furnace (BF) and Basic Oxygen furnace (BOF), with approximately 70% of the total global iron and steel production using the BF-BOF process (as of 2020).

Source: Global Efficiency Intelligence, Steel Climate Impact - An international benchmarking of Energy and CO2 intensities, 2022 and Deloitte analysis.

1.3) Overview of the global steel industry

Overview of current steelmaking technology

Currently upstream steel production technology are carried on by using 3 main routes as shown in Figure 4:

1) Blast furnace (BF) and Basic Oxygen furnace (BOF) process [70%]
2) Electric Arc Furnace (EAF) by using steel scrap [23%]
3) Direct Reduction Iron (DRI) process using Natural gas or coal [7%]

The average amount of Carbon intensity of each process is shown in Figure 1.4

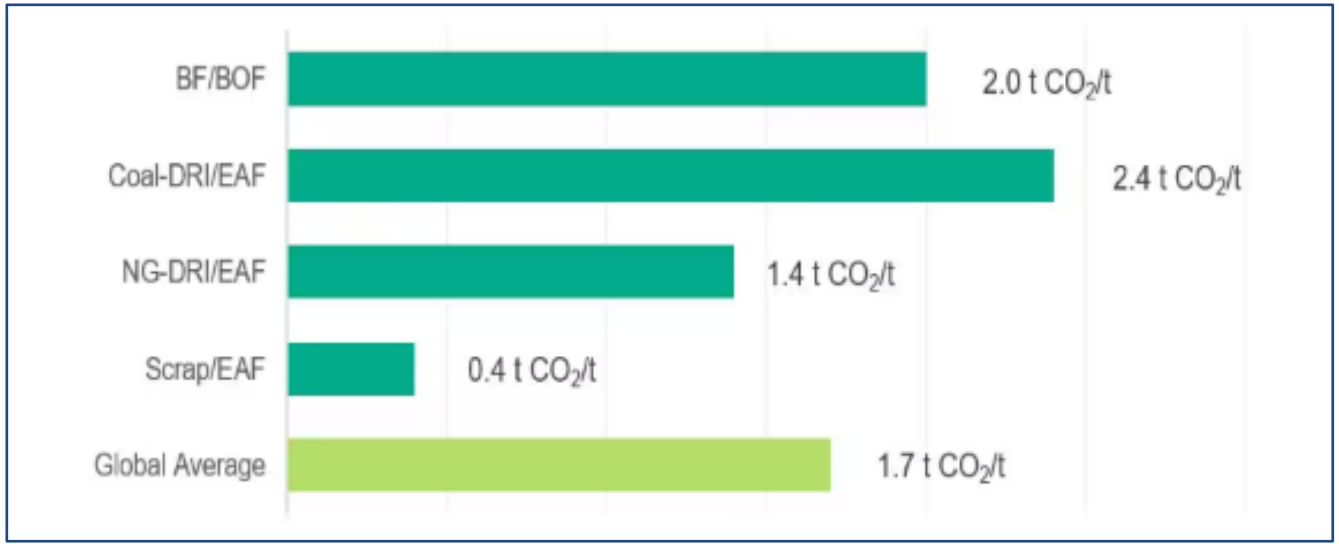


Figure 1.4: typical carbon emissions intensity by process.

Source :

- https://www.bhp.com/es/news/bhp-insights/2020/11/pathways-to-decarbonisation-episode-two-steelmaking-technology
- Global Efficiency Intelligence - Net-Zero Roadmap for China's Steel Industry, March 2023

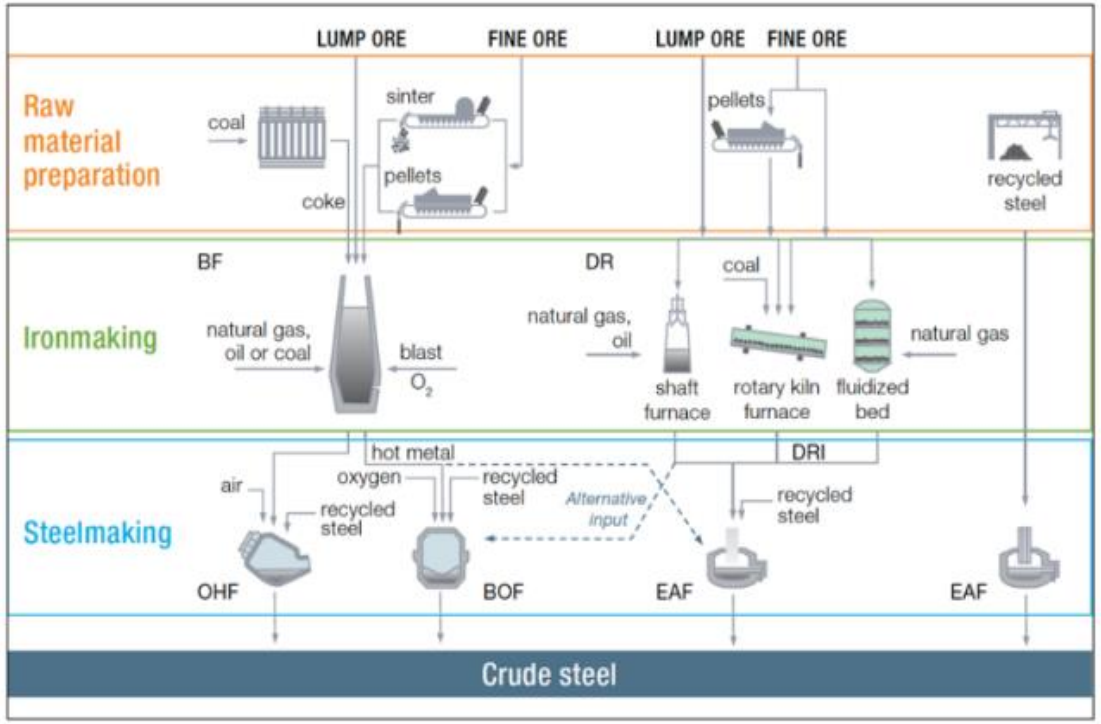


Figure 1.3 - Steelmaking production routes (Worldsteel 2020)

From figure 1.3 and Figure 1.4, most of major steelmakers in the world are trying and aiming to develop the ironmaking and steelmaking production process that will reduce greenhouse gas emissions in steel production worldwide and aim to produce steel that emits low CO2.

1.4) Steel production and consumption in Thailand

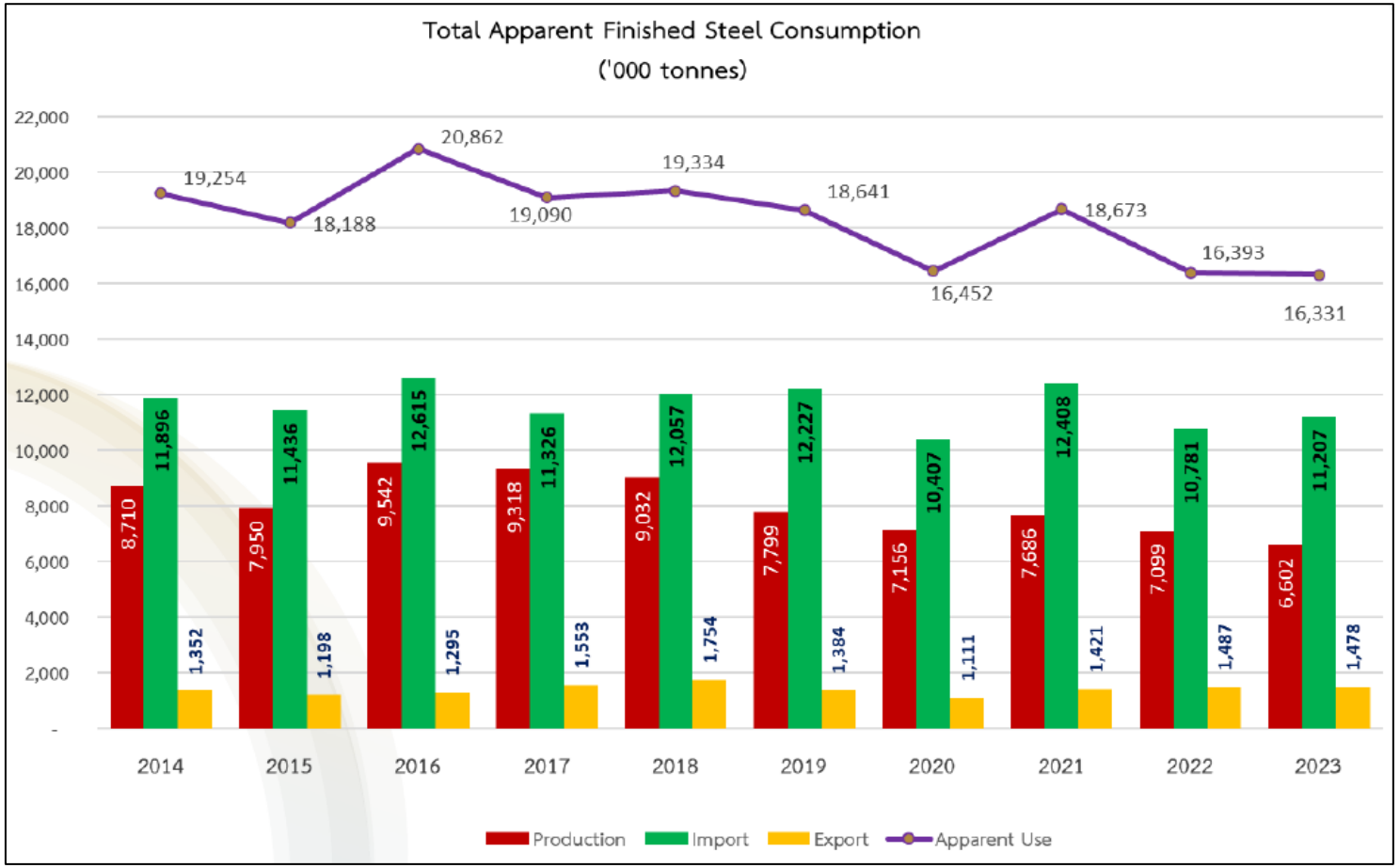


Figure 1.5: Steel production and consumption in Thailand over the past 10 years

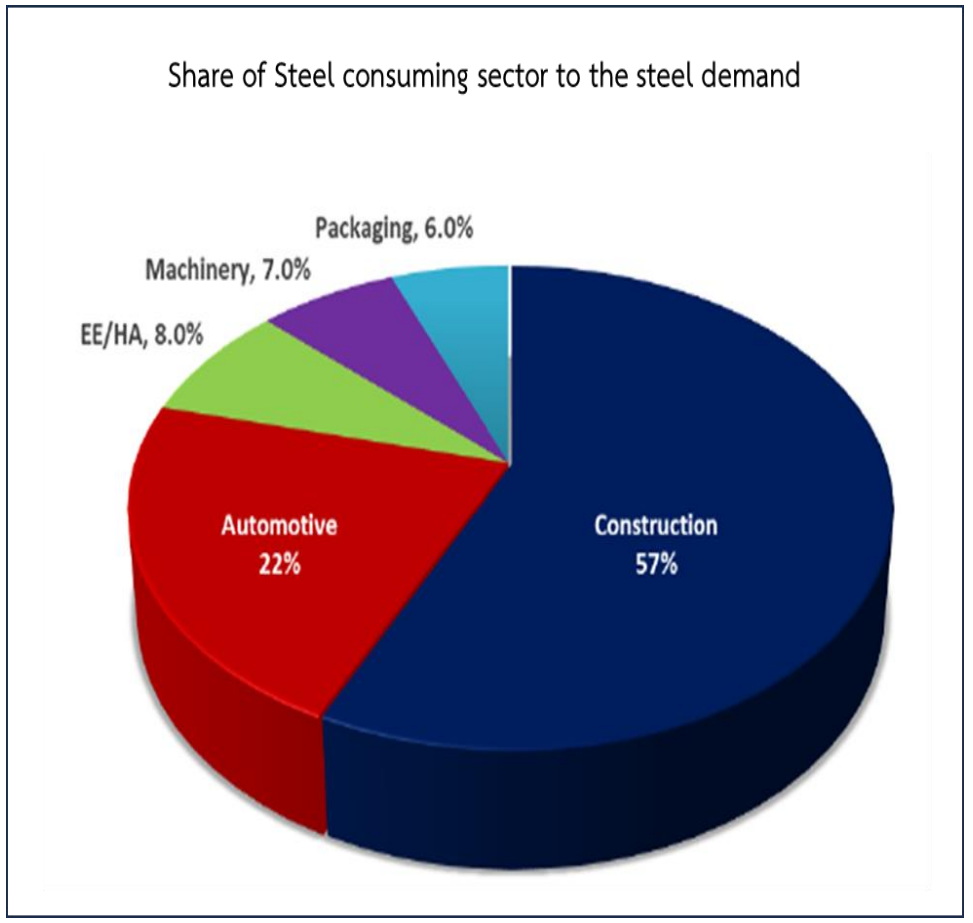


Figure 1.6 Proportion of finished steel product consumption in downstream industries in 2022

Source: Iron and Steel Institute of Thailand (ISIT)

1.5) Steel value chain in Thailand

Steel is a basic metal that is essential for production activities in various downstream industries, including construction and real estate, automotive, electrical appliances, and packaging, all of which are activities that are important to the economy. The structure of the steel industry can be classified according to the production line into 3 groups, as shown in Figure 1.7.

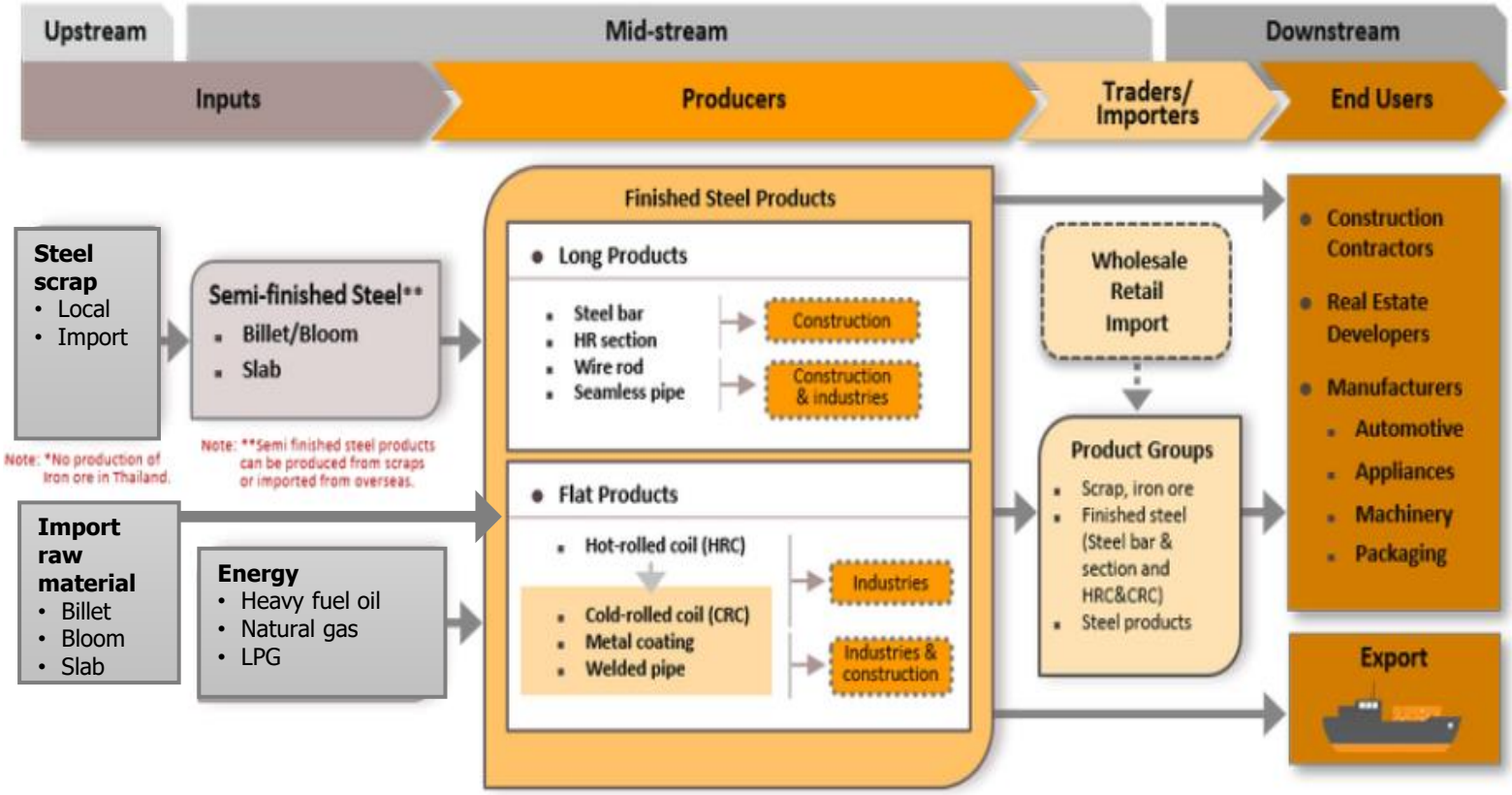


Figure 1.7 : Supply chain structure of steel industry in Thailand

Steel products are divided into 2 major groups as follows:

- ❑ Long products which are semi-finished steel which are two types of steel products (Steel bars and wire rods). There are two route of long steel producers. One is EAF which use steel scrap as raw material. Second one in Reheating furnace which use billet & bloom as raw material. Most long steel products are used in the construction sector.
- ❑ Flat steel products which are intermediate steels to be hot rolled and cold rolled steel sheets which are in the form of plates and coils. There are two route of long steel producers. One is EAF which use steel scrap as raw material. Second one in Reheating furnace which use slab as raw material. Most flat steel products are used as parts/components of automobiles, electrical appliances, and machinery.

Source: https://www.krungsri.com/th/research/industry/industry-outlook/construction-construction-materials/steel/io/io-steel-20

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Key factors driving the steel industry towards a low-carbon society

Key factor driving steel industry towards low carbon society

1) CBAM or Environmental trade barrier

CBAM is the EU's tool or other country's tools to put a fair price on the carbon emitted during the production of carbon intensive goods that are entering the EU or host country of CBAM, and to encourage cleaner industrial production in non-EU countries.

2) National Carbon emission target

National goal and commitment to reduce CO2 emissions towards carbon neutrality and net zero emission target. Including carbon pricing mechanism in the country (Carbon Tax and Emission Trading Scheme [ETS])

Thailand Taxonomy

BOT (Bank of Thailand), in collaboration with government agencies and private sectors, has developed a standard for categorizing economic activities that take into account the environment, to serve as a framework for classifying economic activities, enabling the financial sector to effectively operate in sustainable finance.

Customer's needs

Market demand and consumers of steel products are increasingly placing importance on the use of green products in products and the development of infrastructure.

Source: https://www.krungsri.com/th/research/research-intelligence/esg-survey-2024

2.1) Carbon Broader Adjustment Mechanism (CBAM)

CBAM's regulation which are developing

EU-CBAM

Timeline →

6	Oct 2023 – Dec 2025	Jan 2026-Dec 2034	Jan 2035
Sectors (Iron/Steel, Aluminum, Cement, Fertilizer, Electricity, Hydrogen)	**Transition Period** Report embedded emissions in goods at the end of each quarter, no need to buy CBAM Certificate	**Definitive Period** Start to pay a financial adjustment but CBAM will apply only to the proportion of emissions that does not benefit from free allowances under EU ETS	**Full Enforcement** End of free allowance in EU ETS, CBAM will fully apply

USA-CBAM
(CCA: Clean Competition Act)

- ❑ Scope: Covering to these sectors → Fertilizer, hydrogen, cement, iron and steel, fossil fuels, refinery products, petrochemicals, adipic acid, glass products, paper and pulp, and ethanol.
- ❑ Plan: will be affecting in 2026

UK-CBAM

- ❑ Scope: same as 6 sectors (including steel) but there are 2 additional sectors are Ceramic and glass
- ❑ Plan: will be affecting in 2027.

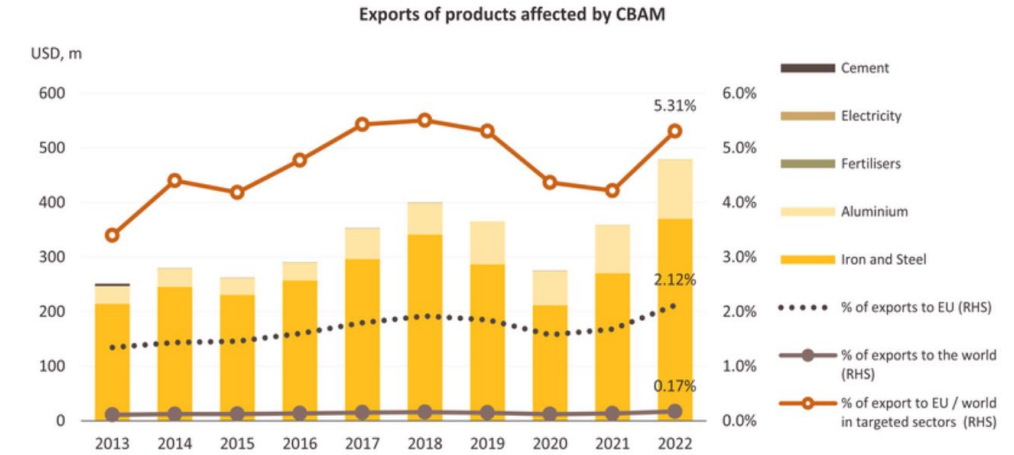
AUS-CBAM

- ❑ Regulation: under developing that they called BCA (Border Carbon Adjustment) that will be including steel sector.
- ❑ Plan: will be having clear picture in 2024.

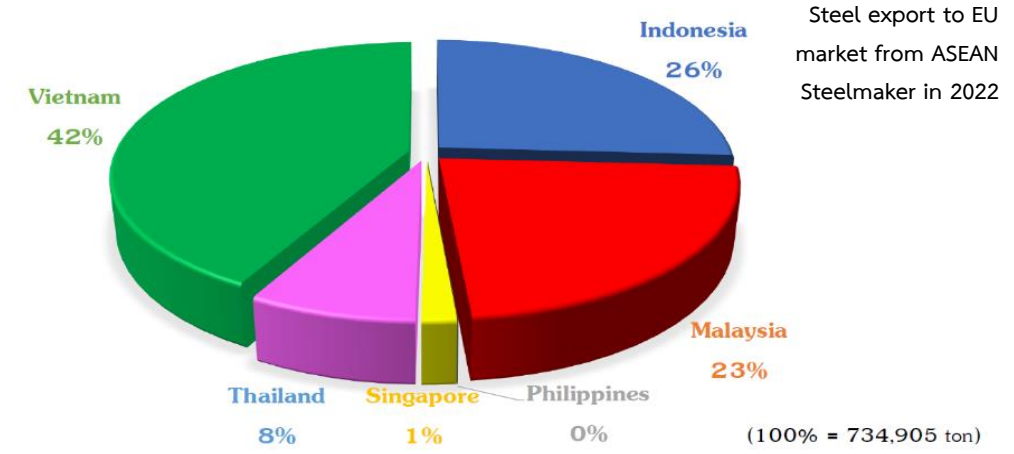
Other CBAM in other countries would be announced afterwards

Effect to steel industry in Thailand

Domestic



Asian region



Source: https://www.krungsri.com/en/research/research-intelligence/cbam-2023 and ISIT

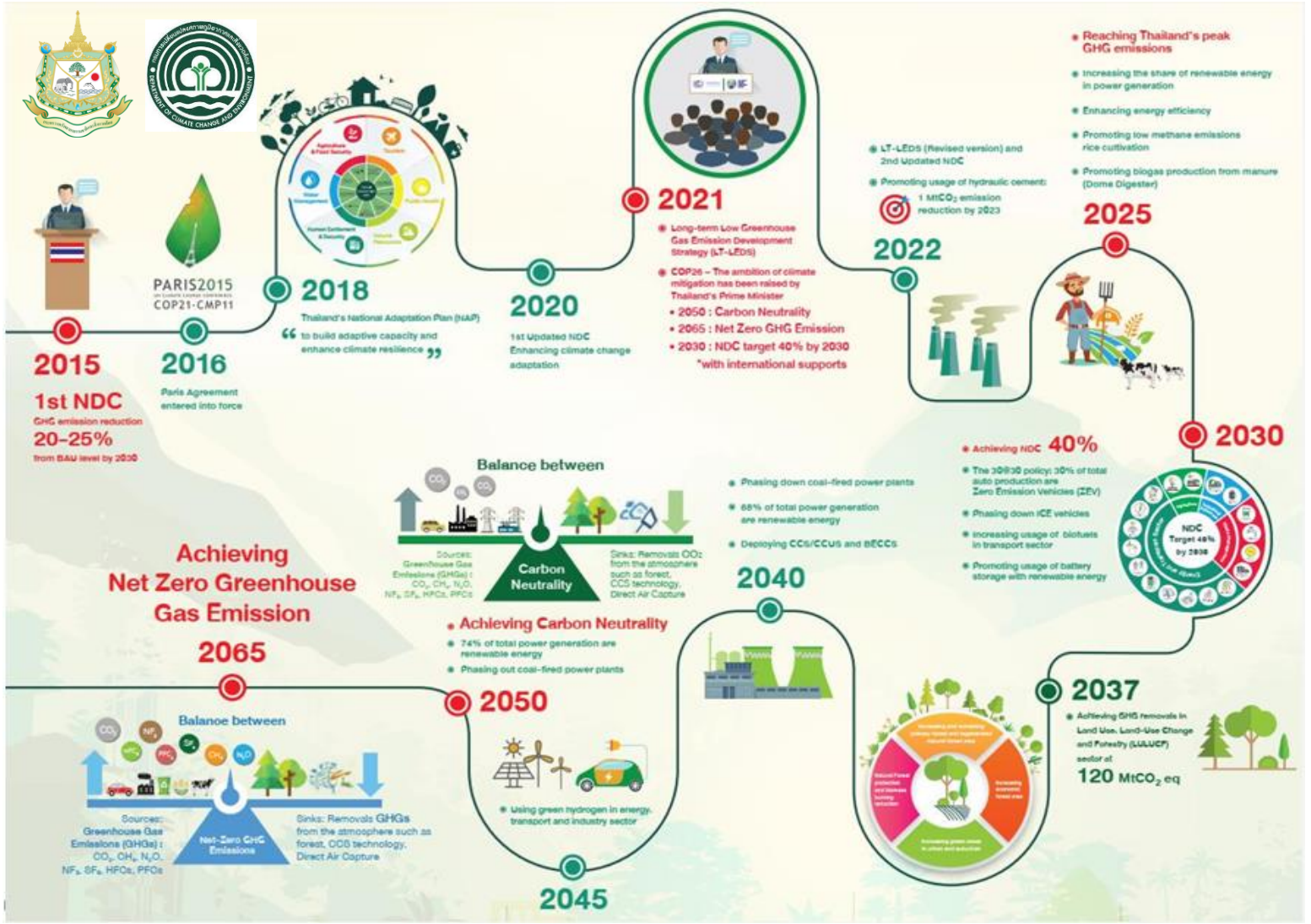
2.2) National Carbon emission reduction target

กลุ่มอุตสาหกรรมเหล็ก

Thailand's Carbon neutrality and Net Zero Roadmap 2065

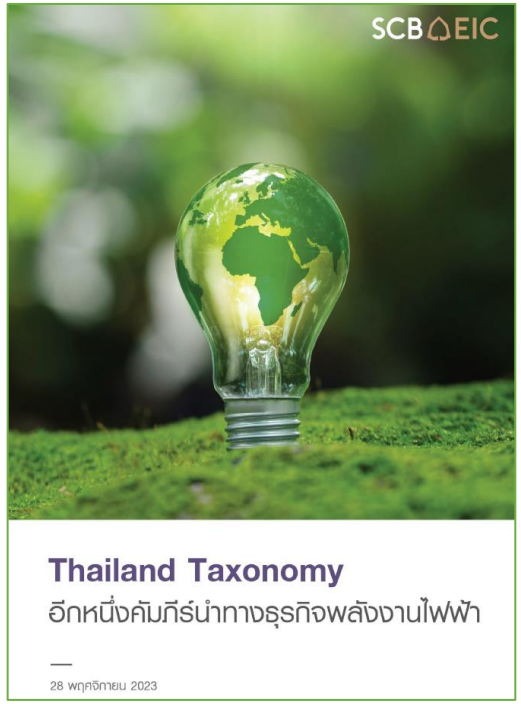
Key highlight activities

- Climate change Act will be affecting in 2025
- Carbon Tax will be started in 2024 and will be fully affecting in 2026.
- ETS will be started in studying phase in 2025 and would be started in focus group in 2030 (Steel sector will be included in focus group).



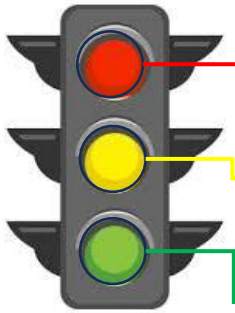
Ref. : Department of Climate Change and Environment

2.3) Thailand Taxonomy



- Definition: Thailand Taxonomy is reference standard for classifying and grouping economic activities that are environmentally friendly in Thailand. Thailand Taxonomy will specify clear definitions, descriptions, conditions, and indicators for each economic activity to serve as a guide for all sectors to understand and assess whether economic activities are carried out with environmental and social responsibility and to what extent. The development of Thailand Taxonomy takes into account the context of the country and the consistency with international standards (inter-operability) to support the adaptation of economic activities to be environmentally friendly comprehensively.
- Background and significance: Currently, each sector has a different understanding of environmentally friendly activities. This makes the promotion of environmental operations, especially the allocation of funds, not yet on point, which may lead to exaggerated claims that environmental operations have been carried out (greenwashing), or the allocation of funds to business sectors that need to adapt, especially during the transition period (transitional activities), insufficient. Therefore, there is a need for a standard for grouping economic activities that take into account the environment (Taxonomy) so that the government sector, business sector, and financial sector have the same understanding and have a point of reference for policy-making, strategic planning, and the development of products and services for the business sector in a standardized and consistent manner. This will help each sector assess the status of environmental operations and plan for adaptation during the transition period that is appropriate and timely in line with the Thai context.
- Latest progress: The assessment and classification of economic activities under the Thailand Taxonomy Phase 1 for the energy and transportation sectors was completed in June 2023, with the next phase being the industrial sector.

Thailand Taxonomy uses principles based on environmental science. It divides environmental considerations of activities into 3 levels (Traffic-Light System): Green, Yellow and Red.



Red means that the activity cannot be assessed as net GHG reduction friendly and does not meet the criteria and indicators for green or yellow level activities.

Yellow indicates activities that are currently near or equal to zero net GHG emissions and are in the process of adapting to reduce their GHG emissions, which will help mitigate climate change.

Green refers to activities that reduce climate change with near-zero net GHG emissions.

Source: SCB-EIC Thailand Taxonomy [28 Nov. 2023]

2.4) Market and consumer demand for steel products

Trends in market demand and consumers of steel products

At present, the mechanisms that contribute to the market demand and consumers of steel products turning to choose or purchase/procure steel products that are environmentally friendly or have low greenhouse gas emissions can be divided into 3 main groups of factors as follows:

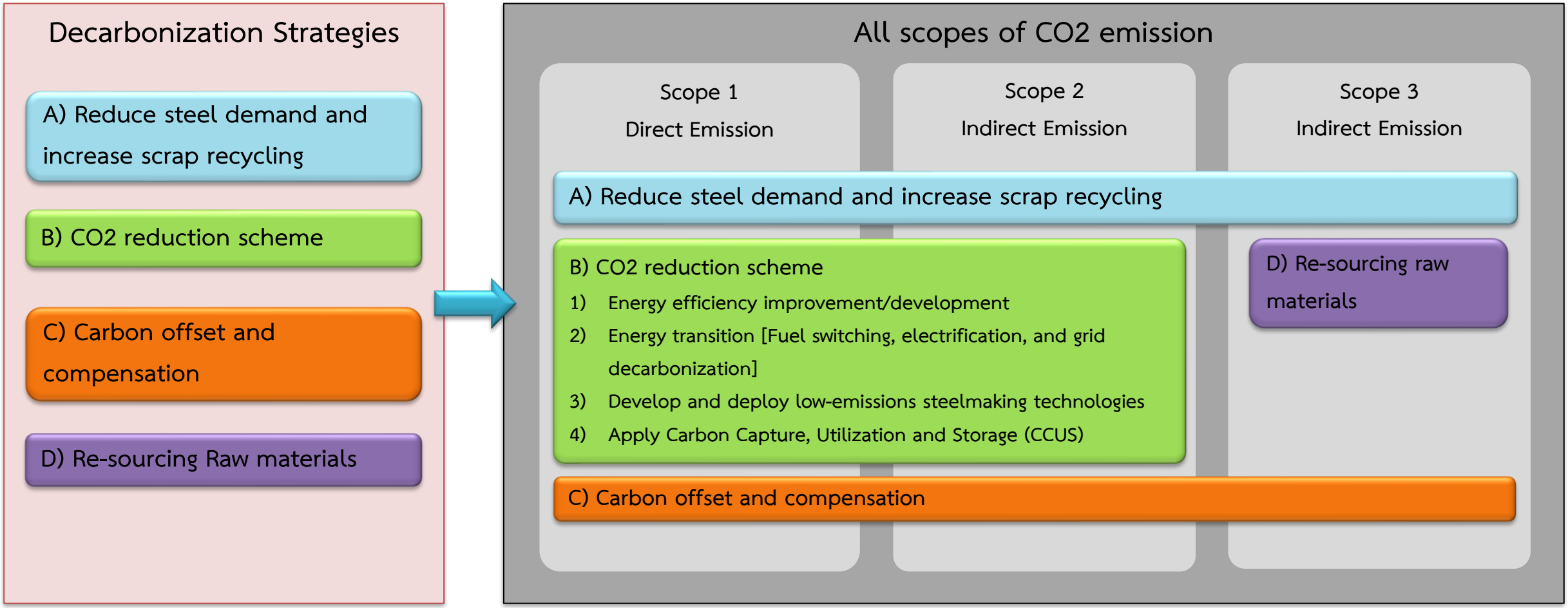
1) Factors from the global trade mechanism - International trade barriers to the environment to create equal competition with domestic entrepreneurs, in which the cross-border carbon tax measure or Carbon Broader Adjustment is one of the many measures that many countries are enforcing, causing entrepreneurs to select raw materials with low carbon emissions for use in production.
2) Factors from policies and measures to promote the use of environmentally friendly products
   - ❑ Measures to promote the use of environmentally friendly materials by the government in government procurement, such as Green Public procurement or green government procurement measures, are used to stimulate the use of environmentally friendly materials.
   - ❑ Standards that promote the use of environmentally friendly materials, such as the Green Building standard, which has specified criteria for the selection of environmentally friendly materials in the assessment criteria for green building certification.
3) Factors from consumers
   - ❑ Green policies of companies and organizations that focus on the selection of materials and products with low carbon emissions.
   - ❑ Awareness of global warming problems of consumers (End users) who want to choose products and services that release low carbon.

(3)

Decarbonized strategies to drive Iron & Steel industry to achieve Carbon neutral emission target

Overview of Decarbonized strategies for Iron & Steel industry

High-level overview of the available decarbonization levers to drive Steel industry towards Carbon neutral in 2050 by applying these strategies.



Source : MAKING NET-ZERO STEEL POSSIBLE - An industry-backed, 1.5°C-aligned transition strategy by the MPP (Mission Possible Partnership) modelling and analytics team. [published in September 2022]

3.1) Reduce steel demand and increase scrap recycling strategy

Aiming of this strategy to reduce steel demand and enhance scrap recycling. It looks like a National strategy in establishing a system and measures for management, promotion, and collection for reuse and recycling, which can be divided into 3 main approaches.

1) Material recirculation: Collection of end-of-life steel products/goods and introducing them into the recycling process to increase steel reuse and scrap steel recovery.
2) Productivity of use: Promoting to maximize the asset utilization of steel infrastructure, buildings, machinery and vehicles throughout the life of steel.
3) Material efficiency: Decreasing steel losses in fabrication and using less steel in each end use. By promoting the production process to reduce steel loss in production and use less steel in each step of use, producing steel that is strong but lightweight, including designing for cost-effective use of materials.

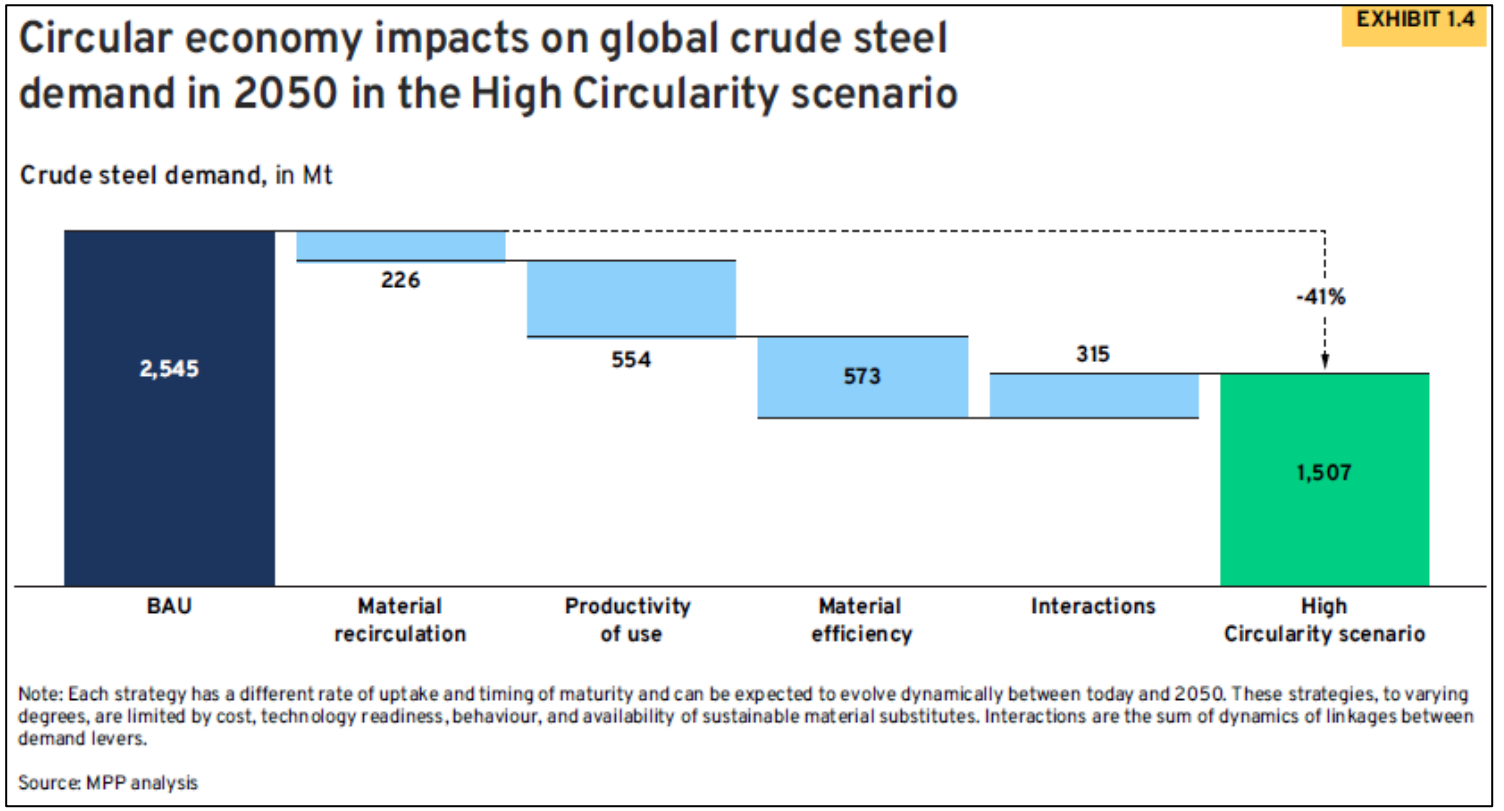


Figure 3.1: Reduction on steel demand by promoting material efficiency in downstream processes

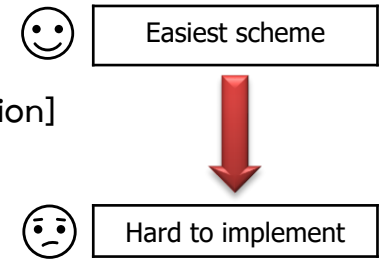
According to the research results, the High Circularity scenario where Material efficiency strategies are fully implemented will reduce the global Steel demand by up to 40% in 2050 compared to BAU or reduce the steel demand by up to 1,038 Mton in the next 30 years as shown in Figure 3.1.

Source : MAKING NET-ZERO STEEL POSSIBLE - An industry-backed, 1.5°C-aligned transition strategy by the MPP (Mission Possible Partnership) modelling and analytics team. [published in September 2022]

3.2) CO2 reduction scheme

This strategy focuses on projects and activities to reduce CO2 emission in the production process and utility systems in manufacturing plant through various CO2 reduction schemes, divided into 4 groups.

1) Energy efficiency improvement/development
2) Energy transition [Fuel switching, electrification, and grid decarbonization]
3) Develop and deploy low-emissions steelmaking technologies
4) Apply Carbon Capture, Utilization and Storage (CCUS)



3.2.1) Energy efficiency improvement/development

This scheme focus on improving and applying technologies and innovations to save energy consumption and increase energy efficiency of machines/equipment in the steel production process, utility system, office buildings, and transportation processes in order to save energy, reduce production costs, and reduce GHG emissions with an appropriate payback period (e.g. less than 3 years). However, for some major energy-saving technologies, a large investment may be required. These large investments may be not savings in an appropriate payback period. These projects may need some supporting/subsidy from government policies to enable entrepreneurs to invest and maintain their competitiveness.

Table 3.1 shows list of commercial energy-saving measures and BAT (Best Available Technologies) for the iron and steel industry.

Table 3.1. Examples of commercialized energy efficiency measures and technologies for the iron and steel industry (JISF 2022a, Worrell, et al. 2010)

No.	Energy-Efficiency Measures / Technologies	No.	Energy-Efficiency Measures / Technologies
	Sintering	32	Improving process control in EAF
1	Heat recovery from the sinter cooler	33	Refractories using engineered particles
2	Reduction of air leakage	34	Direct current (DC) arc furnace
3	Increasing bed depth	35	Scrap preheating
4	Use of waste fuel in sinter plant	36	Plastic waste and used tire injection in EAF (emerging technology)
5	Improve charging method	37	Airtight operation (emerging technology)
6	Improve ignition oven efficiency	38	Bottom stirring/gas injection
		39	Contiarc Furnace (emerging technology)
	Coke Making	40	Comelt Furnace (emerging technology)
7	Coal moisture control		
8	Programmed heating in coke oven		**Casting and Refining**
9	Variable speed drive on coke oven gas compressors	41	Integrated casting and rolling (Strip casting)
10	Coke dry quenching (CDQ)	42	Efficient Ladle preheating
11	Next generation coke making technology (SCOPE21) (emerging technology)		
			Shaping
	Iron Making – Blast Furnace	43	Use of energy-efficient motors
12	Injection of pulverized coal in BF to 130 kg/t hot metal	44	Installation of a lubrication system
13	Injection of natural gas in BF		
14	Injection of oil in BF		**Hot Rolling**
15	Injection of plastic waste in BF	45	Recuperative or regenerative burner
16	Injection of coke oven gas in BF	46	Flameless oxyfuel burners
17	Top-pressure recovery turbines (TRT)	47	Controlling oxygen levels and variable speed drives on combustion air fans
18	Recovery of blast furnace gas	48	Insulation of reheat furnaces
19	Improved blast furnace control	49	Hot charging
20	Slag heat recovery (emerging technology)	50	Process control in hot strip mill
21	Preheating of fuel for hot blast stove	51	Heat recovery to the product
22	Improvement of combustion in hot blast stove	52	Waste heat recovery from cooling water
23	Improved hot blast stove control	53	Walking beam furnace for reheating
	Steelmaking – basic oxygen furnace (BOF)		**Cold Rolling**
24	Recovery of BOF gas and sensible heat	54	Continuous annealing
25	Variable speed drive on ventilation fans	55	Heat recovery on the annealing line
26	Control system for oxygen supply to BOF process	56	Reduced steam use in the acid pickling line
27	Programmed and efficient ladle heating	57	Automated monitoring and targeting systems
	Steelmaking – EAF		**Cross-cutting measures**
28	Converting the furnace operation to ultra-high power (UHP)	58	Preventative maintenance in steel mills
29	Adjustable speed drives (ASDs) on flue gas fans	59	Energy monitoring and management systems in steel mills
30	Oxy-fuel burners/lancing	60	Motor systems and steam systems optimization
31	Post-combustion of flue gases	61	Smart sensors and real-time monitoring systems

Source: Net-Zero Roadmap for China's Steel Industry /studied by Global Efficiency Intelligence. [published in March 2023]

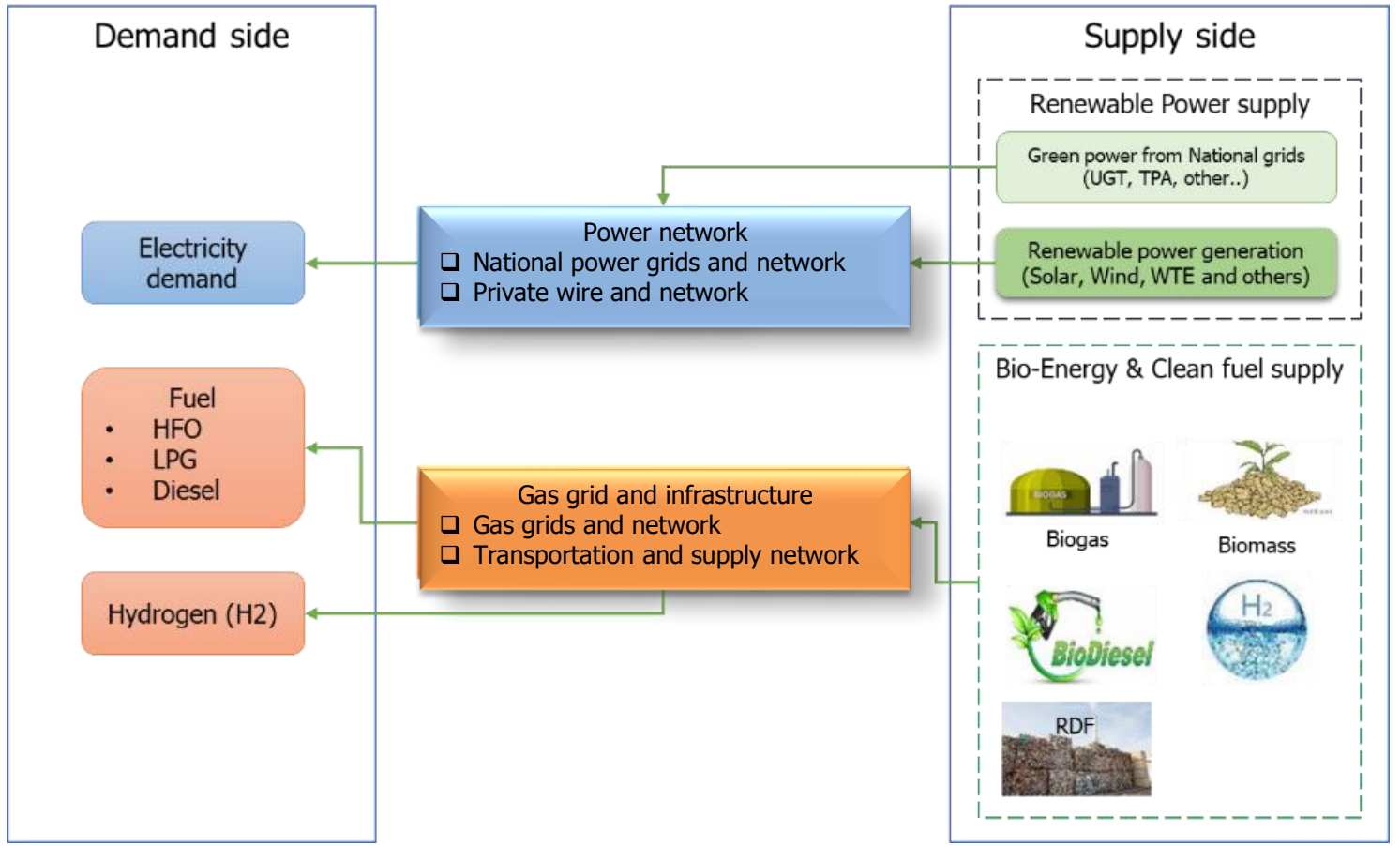
3.2) CO2 reduction scheme

3.2.2) Energy transition

Energy transition strategy includes changing the use of clean fuels to replace fossil fuels, transforming to use renewable energy sources instead of electricity from fossil fuel, changing the use of energy in machinery or vehicles from using fuels to using electricity.

- ❑ Fuel switching: Transforming to use clean fuels (Bio-fuel, Bio-oil, Biogas, Green hydrogen or e-fuel) instead of fossil fuel usages in manufacturing process and transportation.
- ❑ Increasing portion of Renewable energy using: Changing the use of electricity from renewable energy (Solar, Wind, etc.) to replace the use of electricity from fossil fuels.
- ❑ Electrification: Transforming the use of fuel-powered machinery/vehicles to use electric power, such as changing vehicles from ICE to EV Cars.

Energy transition from fossil fuel to Green/Clean energy



Source: Net-Zero Roadmap for China's Steel Industry /Studied by Global Efficiency Intelligence. [published in March 2023]

3.2) CO2 reduction scheme

3.2.2) Energy transition

3.2.2.1) Investment in Renewable energy to replace electricity consumption from fossil fuel source: By investing in solar power generation, Wind power, Biomass power generation, Waste to energy and so on. The details below summarize the cost of electricity production (LCOE: Levelized Cost of Electricity) from renewable energy.

Solar Power generation

Solar farm

- ❑ CAPEX : 23 MB./MW.
- ❑ LCOE : 1.70 Baht/kWh

Solar Rooftop

- ❑ CAPEX : 20 MB./MW.
- ❑ LCOE : 1.65 Baht/kWh

Solar Floating

- ❑ CAPEX : 25 MB./MW.
- ❑ LCOE : 1.75 Baht/kWh

Wind Power generation

Onshore Wind farm

- ❑ CAPEX : 60-80 MB./MW.
- ❑ LCOE : 1.85 Baht/kWh

Offshore Wind farm

- ❑ CAPEX : 120-150 MB./MW.
- ❑ LCOE : 2.95 Baht/kWh

Investment in BESS (Battery Energy Storage System) systems has been continuously decreasing. The latest data shows that the cost of electricity production (LCOE) from Solar farm + BESS systems is approximately 2.8-3.0 Baht/kWh.

Biomass / WTE power plant

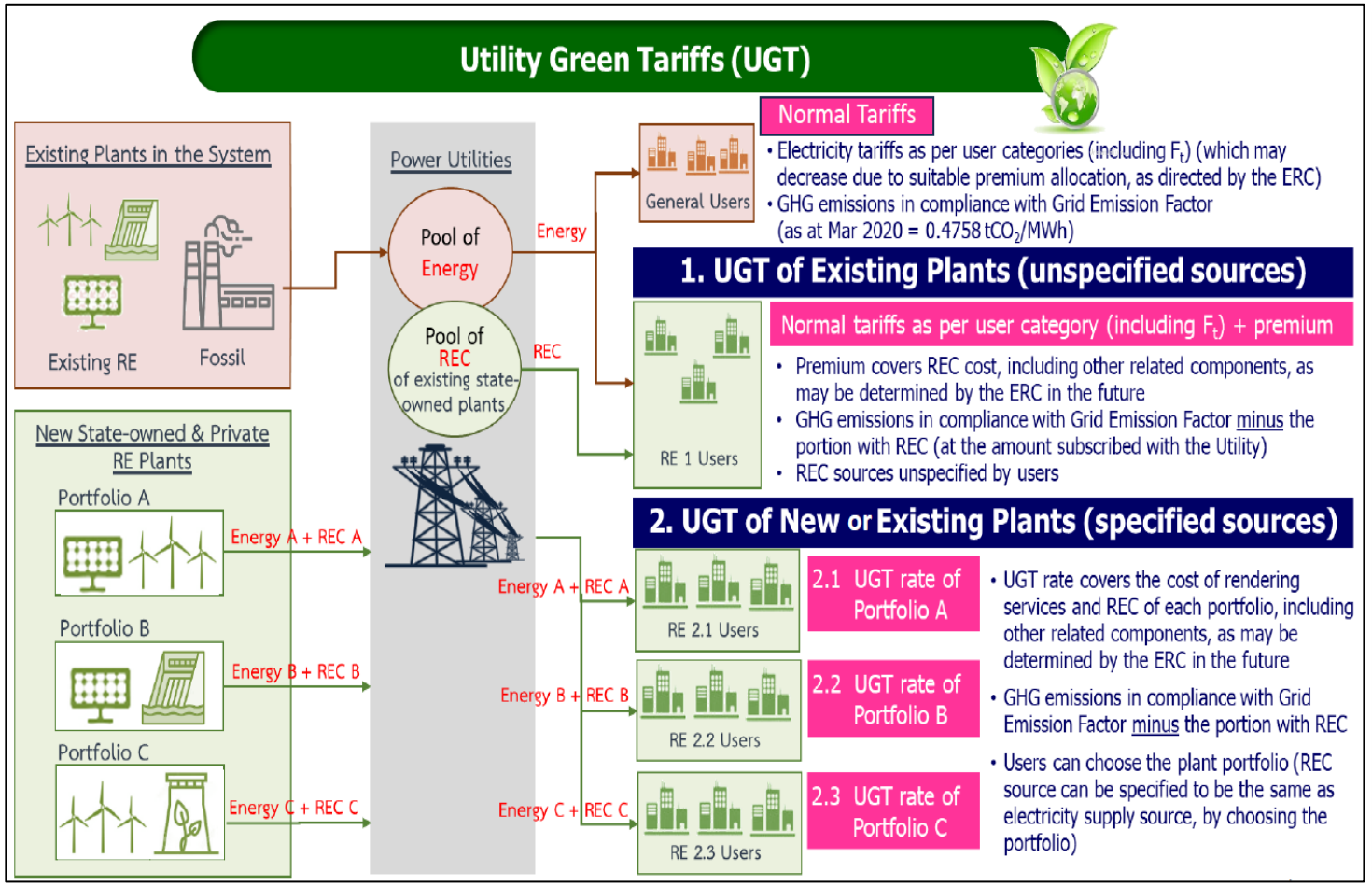
Both types of power plants require a large amount of feedstock to develop the project, which is quite difficult to estimate CAPEX & LCOE figures due to the diversity of feedstock.

Ref. : SCB EIC Industrial insight and Energy Absolute

3.2) CO2 reduction scheme

3.2.2) Energy transition

3.2.2.2) Purchasing electricity from renewable energy from power grids to replace fossil fuel electricity by purchasing from the UGT platform, TPA platform or private power producers.



Consumer Segmentation

The ERC (Energy Regulatory Commission), in collaboration with PEA, MEA and EGAT, offers the following UGT options:

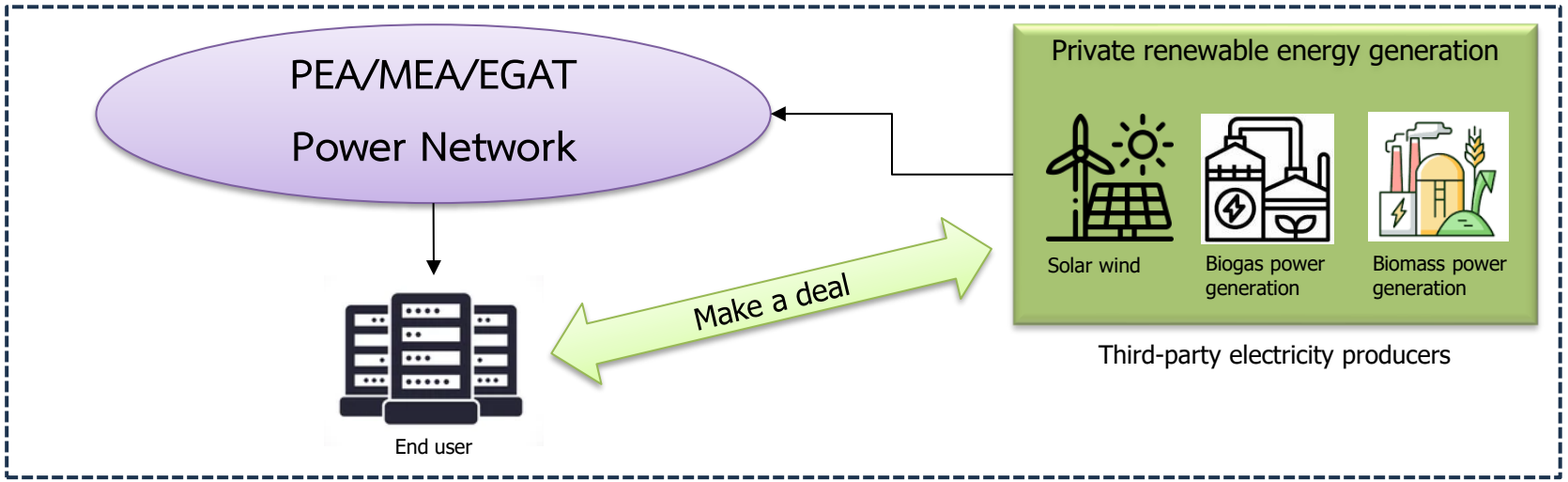
1) General User: A consumer who intends to use existing power plants. The tariff is the normal tariff.
2) UGT1: The user does not specify the source of electricity when ordering [for sale]. Electricity price = normal price + premium (0.0594 baht/kWh), contract period 1 year.
3) UGT2: Users specify the source of electricity when subscribing [Under construction, will be ready for sale in 2028 and beyond.
   - Portfolio A = 4.5622 Baht/kWh
   - Portfolio B = 4.5475 Baht/kWh

Ref. : Public hearing on the "(Draft) Green Electricity Tariff Proposal (Utility Green Tariff: UGT)" during 16-31 January 2024 by the Energy Regulatory Commission

3.2) CO2 reduction scheme

3.2.2) Energy transition

3.2.2.2) Purchasing electricity from renewable energy from power grids to replace fossil fuel electricity by purchasing from the UGT platform, TPA platform or private power producers.



- Third Party Access Code (TPA Code): refers to the grid service terms under which a third party is required to transmit electricity from private power producers to its customers through the PEA's grid system. Its customers must pay a service fee called a "transfer fee" and other service fees.
- Currently, PEA+MEA+EGAT have completed the drafting of the TPA regulations and have submitted it to the ERC (Energy Regulatory Commission) for review.

Concept of calculating TPA tariffs

Generator		Transmission		Customer
Proposed selling price	+	Wheeling Charge	=	Purchasing Price

End users who enter into a "power purchase price" deal with a private power producer must pay the private company for energy at the recommended selling price and a "toll" to the PEA.

Notes: Currently, the Energy Regulatory Commission (ERC) is reviewing the draft regulations for the TPA regulations in collaboration with PEA, MEA and EGAT. The implementation timeline has not yet been determined when it will be put into use.

Source: Hearing opinions on the study report on criteria and guidelines for preparing regulations for opening the electricity grid system to third parties (Third Party Access) [19 Feb. 24]

3.2) CO2 reduction scheme

3.2.2) Energy transition

3.2.2.3) To use alternative fuel (Biogas, Biomass, Syngas, RDF, Pyrolysis oil) and Green H2 to replace the fuel consumption from fossil fuels such as using H2 in Boiler, using H2 as fuel in Reheating furnace, etc.

Item	Fossil fuel				Bio-Fuel			Green H2	Waste plastic / RDF		
	HFO	LPG	Diesel	LNG	Biogas	Biomass			Pyrolysis oil	Syngas	RDF
						Woodchip	PKS				
Calorific value (mmbtu/Ton)	38	44	40	47	15.38	10	14	114	19	5.43	7.9
Fuel price (Baht/MMBTU)	448	540	855	487	243	170	265	1,161	430	396	85

Remark: All fuel prices are shown in this table are not including transportation cost

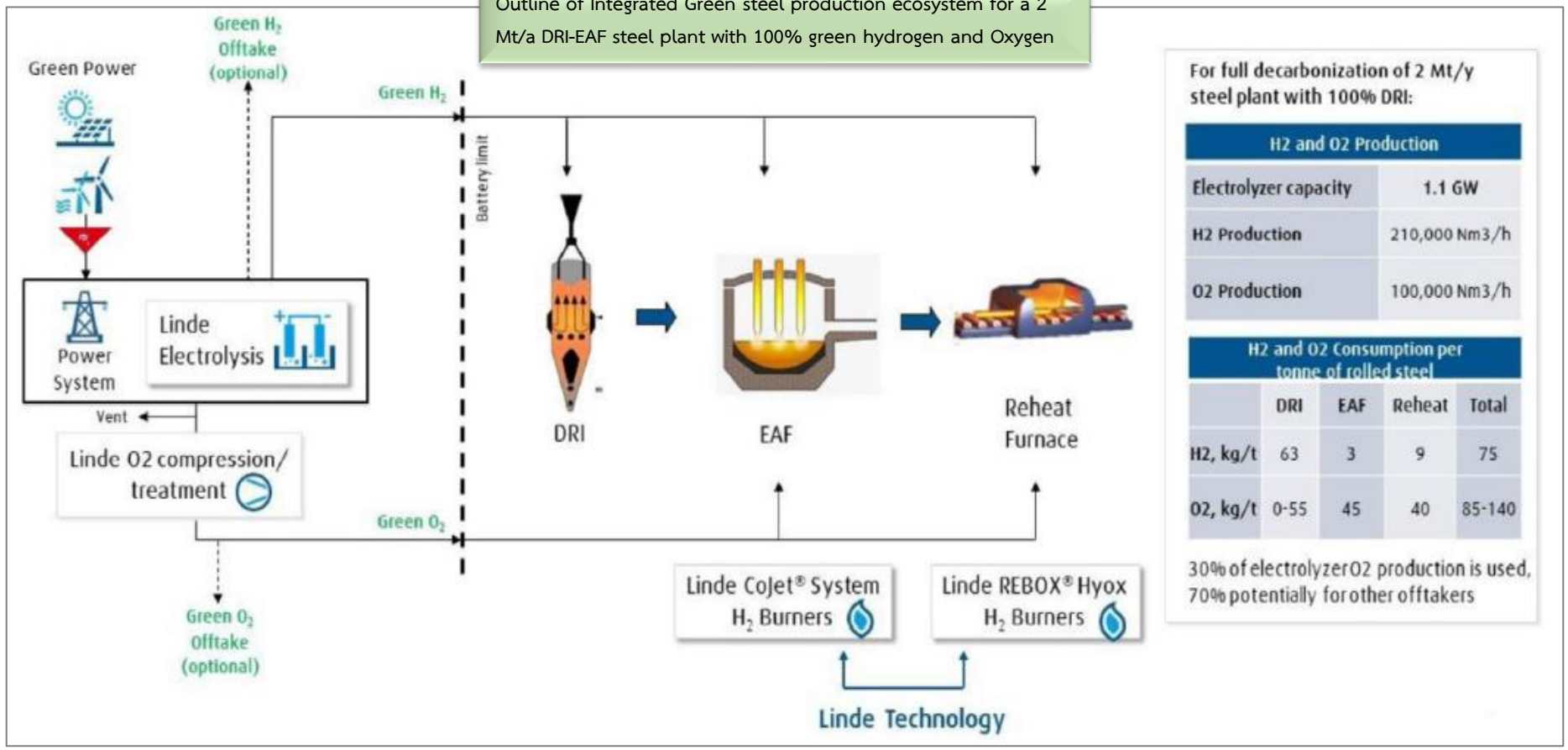
Reference:
- ❑ All fuel prices [(fossil fuel: HFO, LPG, Diesel and LNG), Biomass (Wood chip & PKS), Pyrolysis oil, RDF] are average in 2023
- ❑ Biogas price is reference from ERC (Energy Regulatory Commission)
- ❑ Green H2 price refers cost estimation from Bloomberg in 2023 at 4 USD/kg.H2
- ❑ Syngas price is reference from this article: Economic Analysis and Assessment of Syngas Production Using A Modeling Approach, 2023

3.2) CO2 reduction scheme

3.2.2) Energy transition

3.2.2.3) To use alternative fuel (Biogas, Biomass, Syngas, RDF, Pyrolysis oil) and Green H2 to replace the fuel consumption from fossil fuels such as using H2 in Boiler, using H2 as fuel in Reheating furnace, etc.

Outline of Integrated Green steel production ecosystem for a 2 Mt/a DRI-EAF steel plant with 100% green hydrogen and Oxygen



For full decarbonization of 2 Mt/y steel plant with 100% DRI:

H2 and O2 Production	
Electrolyzer capacity	1.1 GW
H2 Production	210,000 Nm3/h
O2 Production	100,000 Nm3/h

H2 and O2 Consumption per tonne of rolled steel	DRI	EAF	Reheat	Total
H2, kg/t	63	3	9	75
O2, kg/t	0-55	45	40	85-140

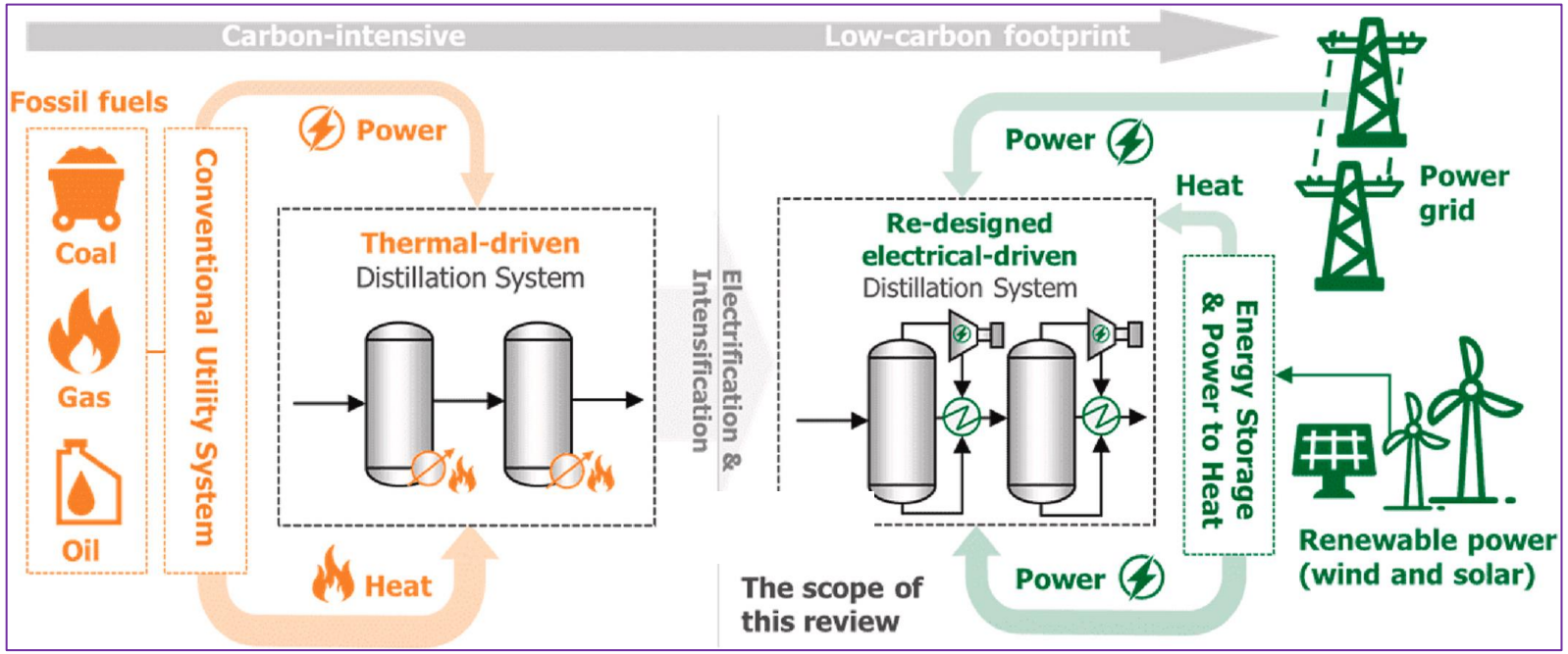
30% of electrolyzer O2 production is used, 70% potentially for other offtakers

Source : Pathways towards full use of hydrogen as reductant and fuel โดย Joachim von Schéele [LINDE GmbH]

3.2) CO2 reduction scheme

3.2.2) Energy transition

3.2.2.4) Electrification



Electrification is the change from other energy sources, such as fuels or heat, to electricity instead. The aiming to increase energy efficiency, reduce greenhouse gas emissions and support the use of clean and sustainable energy. This trend is expanding rapidly in many sectors of the global economy. With key details that will lead to full electrification in the future, such as:

- ICE conversion to EV or FCEV (Fuel cell Electric vehicle) by using Green H2 from Renewable energy source
- Convert Heater & Boiler to use electricity: By using electricity to produce heat or stream in Electric heater / Electric boiler instead of using coal and NG/LPG

Source: https://www.sciencedirect.com/science/article/pii/S1364032124002454

3.2) CO2 reduction scheme

3.2.3) Develop and deploy low-emissions steelmaking technologies

Figure 3.2 Show that Ironmaking and Steelmaking processes are most CO2 emission 45% and 30% respectively. Currently major Steel producers and technology providers are aiming to develop technologies for Ironmaking and Steelmaking. Figure 3.3 show the status of development for ironmaking & steelmaking in 4 key technology routes.

1) BF-BOF: Conventional ironmaking & steelmaking process including CCS.
2) DRI-EAF: Direct reduction iron (using NG or H2) and EAF.
3) DRI-MELT-BOF: Direct reduction iron (using H2), Melting unit and Basic oxygen furnace (BOF)
4) Iron ore Electrolysis: Innovative technology only using electricity to create iron/steel directly from (non-premium) iron ore.

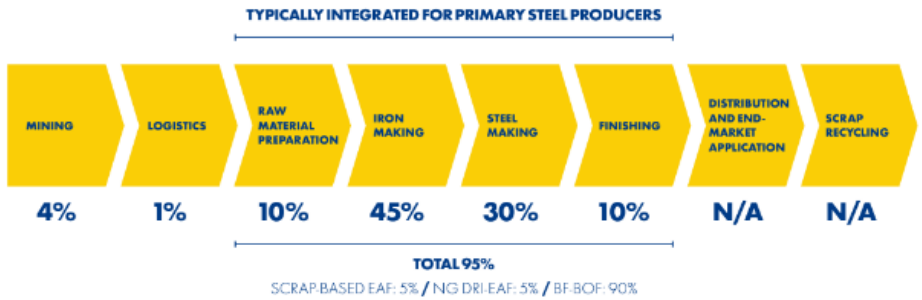


Figure 3.2: CO2 emissions split by value chain actor

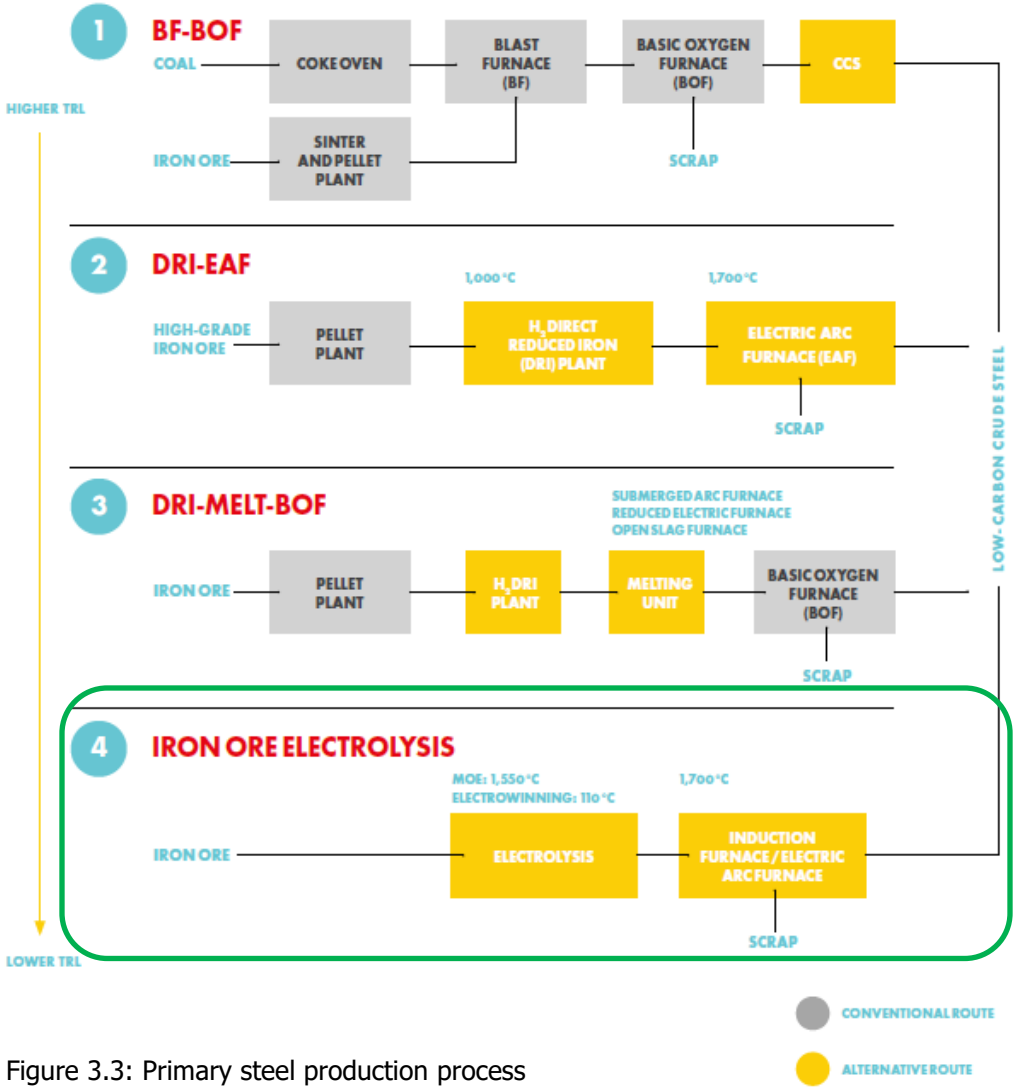


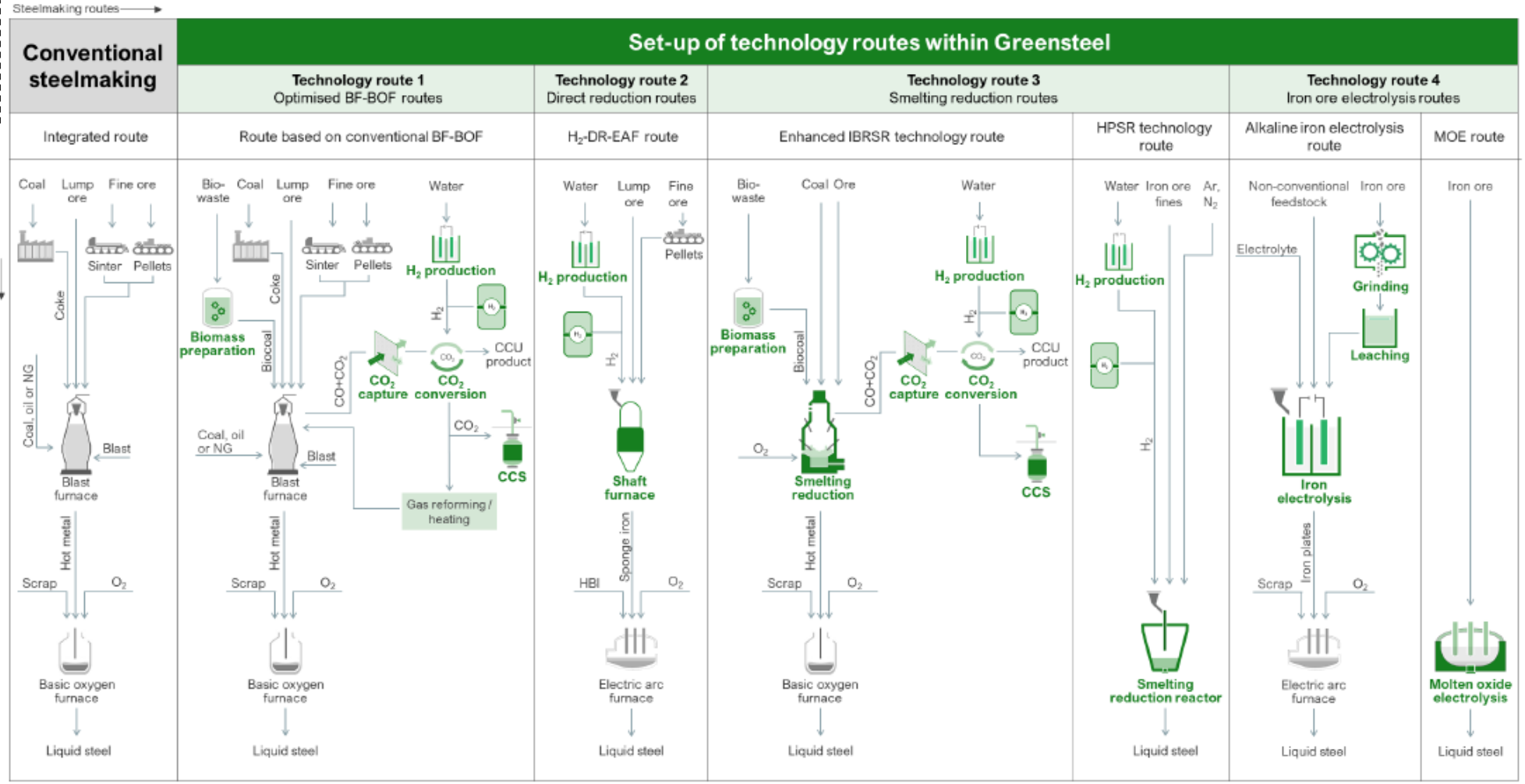
Figure 3.3: Primary steel production process

Source: Shell – Decarbonizing Steel: FORGING NEW PATHS TOGETHER by Deloitte, 2023

3.2) CO2 reduction scheme

3.2.3) Develop and deploy low-emissions steelmaking technologies

Figure 3.4: Overview of the set-up of technology routes in comparison to the integrated steelmaking route



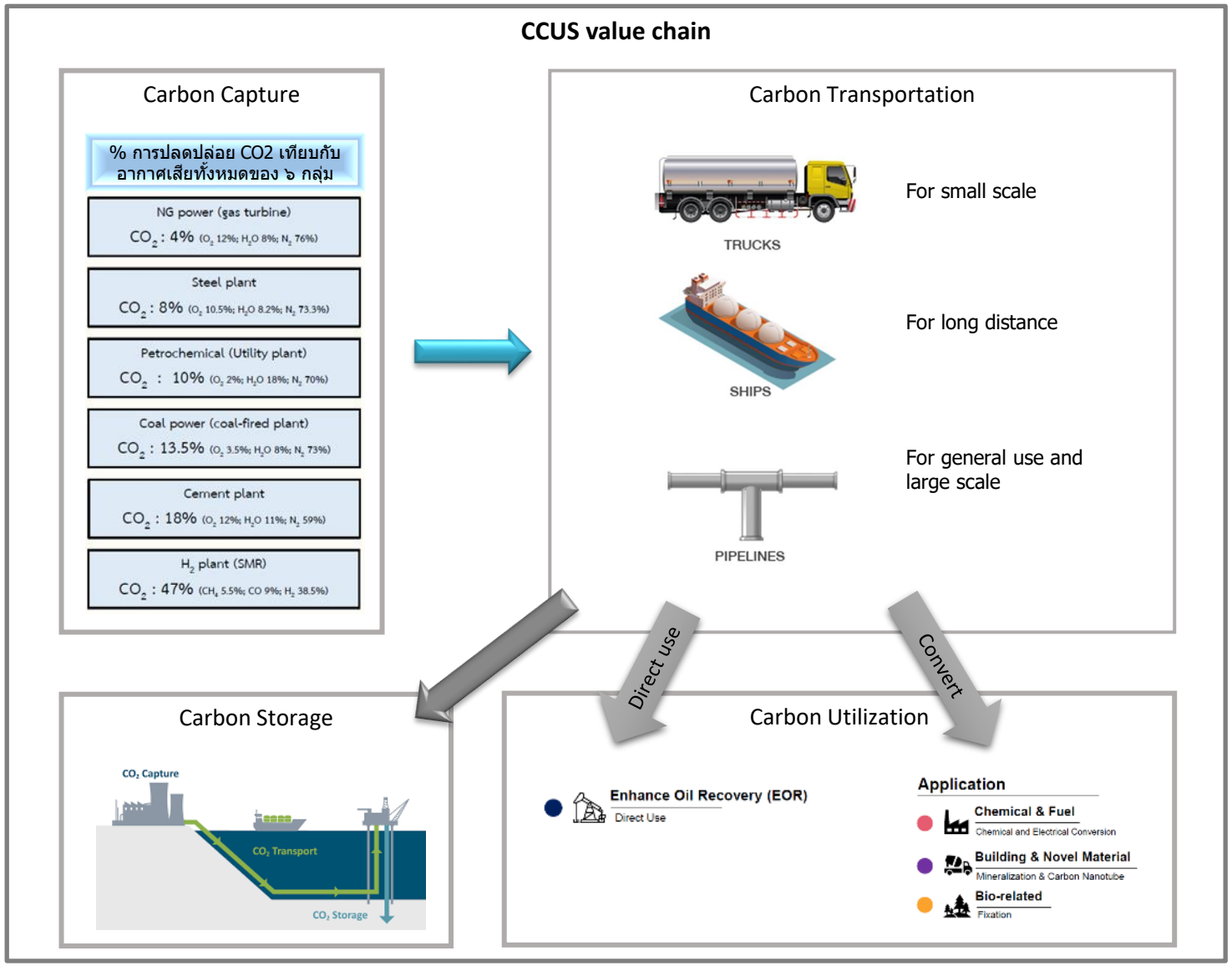
Source: Green Steel for Europe - Technology Assessment and Road mapping by Green Steel for Europe Consortium, June 2021

3.2) CO2 reduction scheme

3.2.4) Carbon Capture, Utilization and Storage (CCUS)

CCUS technology is divided into 3 parts as follows:

- CC: Technology for capturing CO2 from the steel production process, producing H2 from natural gas, or capturing CO2 from the atmosphere (Direct Air Capture: DAC) is a solution that plays an important role in supporting the steel industry to achieve Carbon neutrality or Negative carbon. Carbon capture technology is quite widely used.
- CCS: This technology is a ready-to-use technology. Most of them focus on injecting CO2 with high pressure into underground rocks or old oil wells that are no longer in use. However, due to the limitation that the area must be suitable for storage, it is developed in a relatively limited area.
- CCU: Technology for utilizing CO2 currently has many options, depending on the needs of steel producers who will use it, such as producing synthetic fuels, producing building materials, producing synthetic plastics, etc.



3.3) Carbon offset and compensation

Carbon offset and compensation

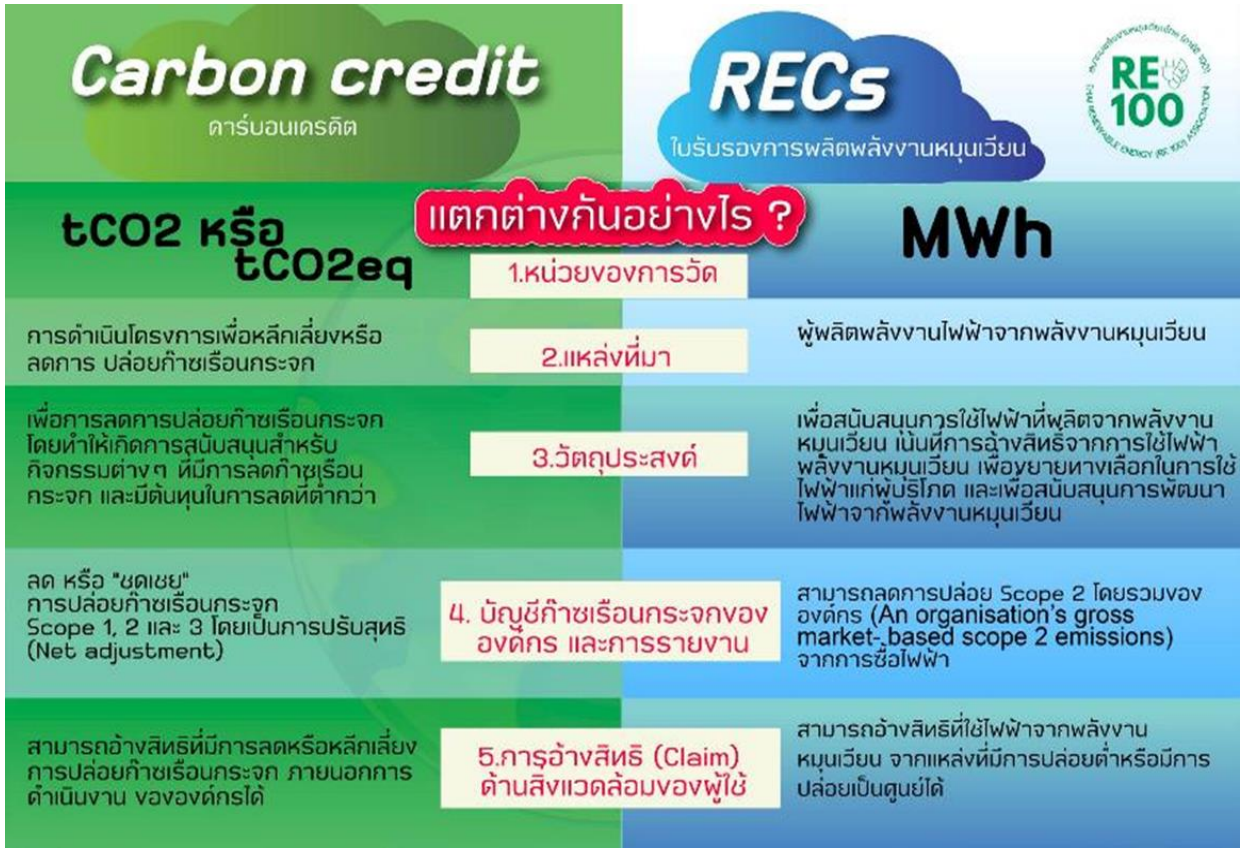
Carbon Offset and Compensation (CC/REC): A measure to use Carbon credits or RECs(Renewable Energy Certificate) to offset or compensate amount of CO2 emissions of an organization. There are two ways to obtain them: purchasing Carbon credits / RECs to offset or planting trees to offset the carbon credits obtained.

3.3.1) Carbon Credit (CC)

Carbon Credit is the amount of GHG that are reduced or sequestered from GHG reduction projects compared to business-as-usual (BAU) operations. The unit is tons of carbon dioxide equivalent (tCO2e). The amount must be certified according to various standards and carbon credits can be exchanged or bought-sold for use.

3.3.2) Renewable Energy Certificate (REC)

Renewable Energy Certificate: REC or Renewable Energy Power Generation Certificate or RE (Renewable energy) where RE power producers must be certified as renewable energy power producers. Currently, the Electricity Generating Authority of Thailand (EGAT) is the only one who has the right to be a certifier in Thailand. And can also bring the certified REC to buy and sell.



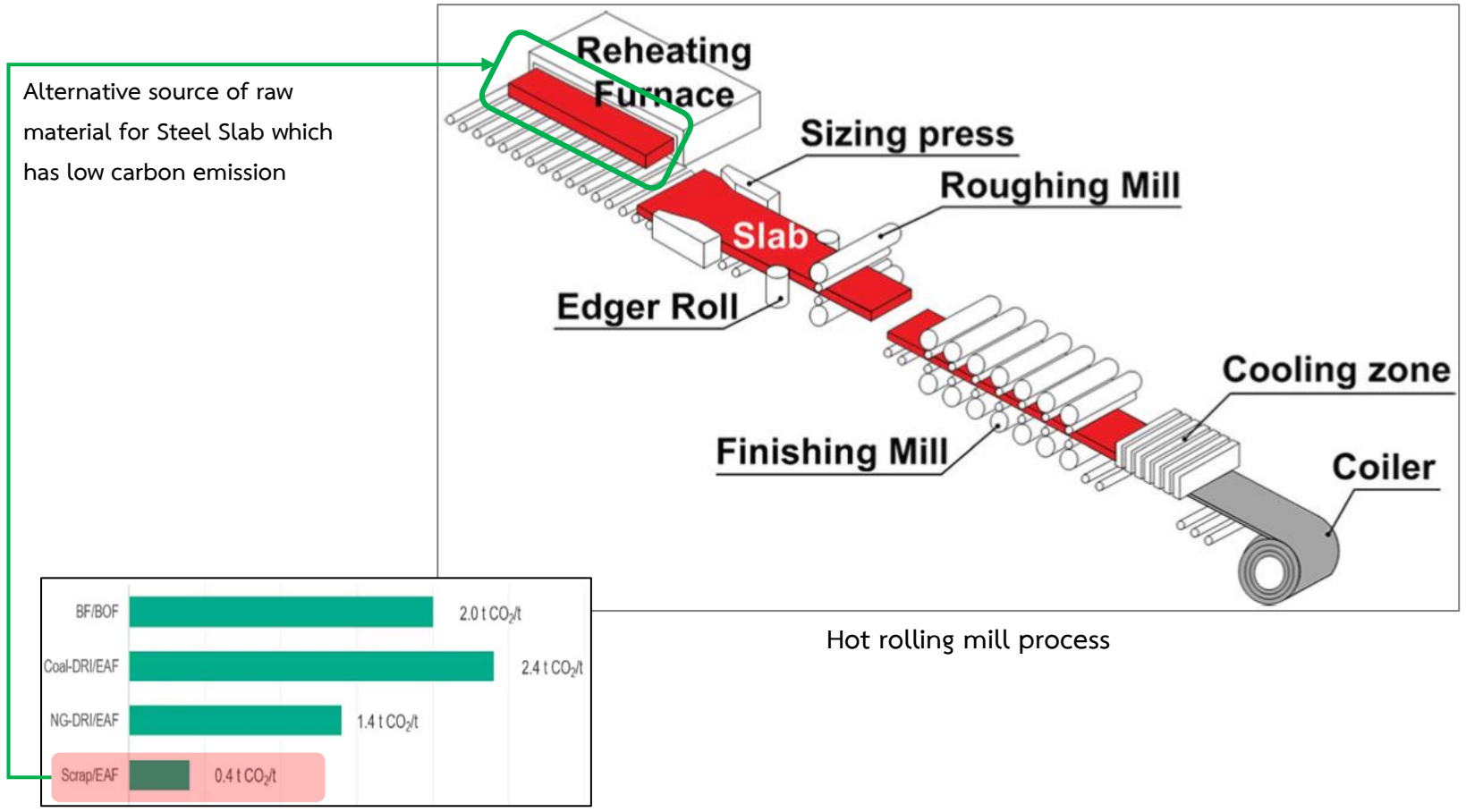
Source: https://www.krungsri.com/th/research/research-intelligence/carbon-credit-2023 /

3.4) Re-sourcing Raw materials

Low-carbon raw material sourcing strategies or Re-sourcing raw materials

It seems to be a relatively simple and easy-to-understand approach: selecting raw material sources for steel products that have low carbon emissions (low intensity of CO2 emissions per unit of production, or Carbon intensity) to be used in the production process in order to reduce the amount of carbon attached to raw materials.

The example of re-sourcing raw material in Hot Strip mill process



Hot rolling mill process

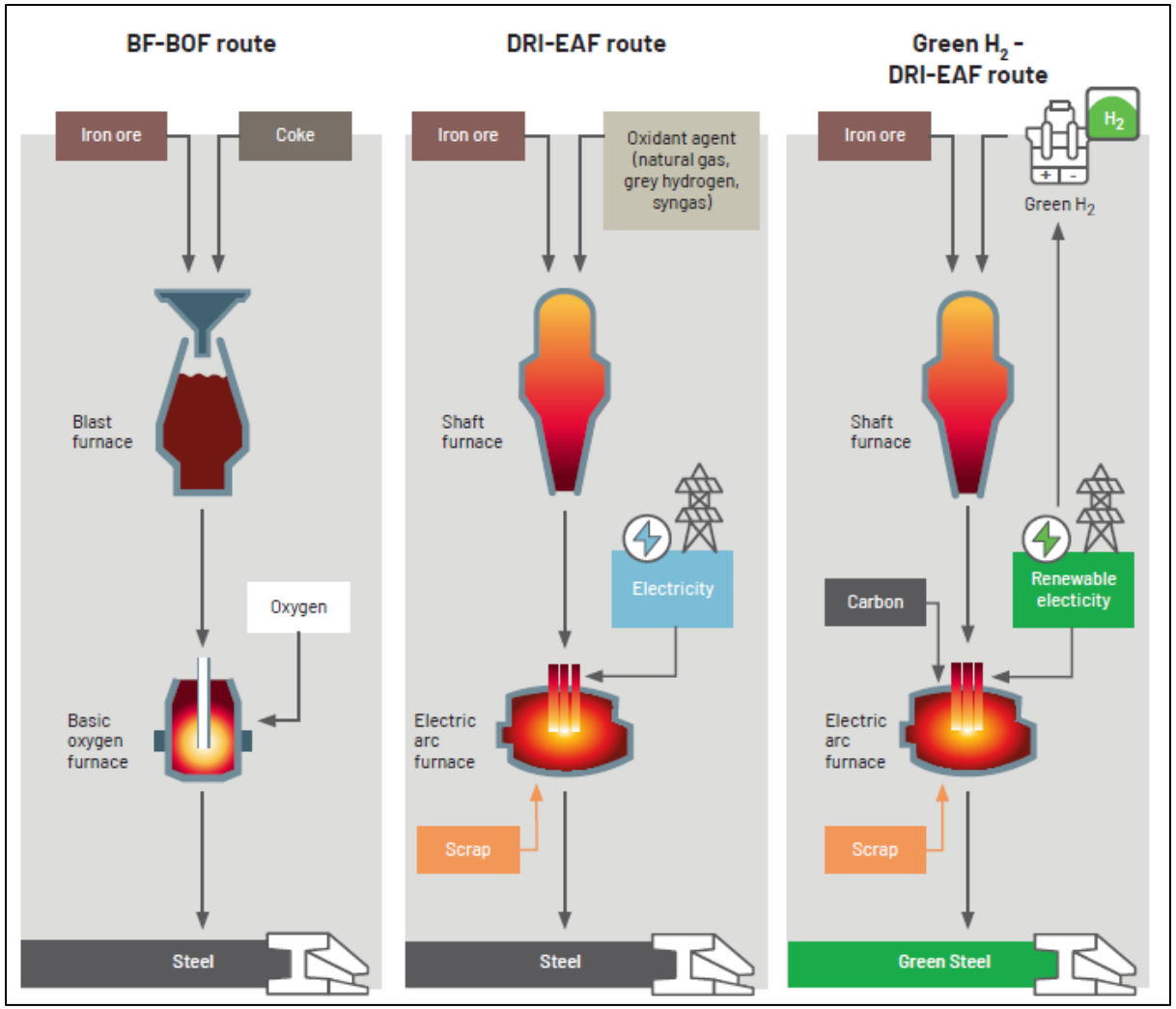
Source :

- https://www.bhp.com/es/news/bhp-insights/2020/11/pathways-to-decarbonisation-episode-two-steelmaking-technology
- Global Efficiency Intelligence - Net-Zero Roadmap for China's Steel Industry, March 2023

(4)

The latest development of the Major steelmakers are aiming towards Green Steel

4.1) Evolution of Steel production technology to Green steel



Evolution of Reducing agent in Ironmaking process

BF-BOF route

- $Fe_2O_3+3CO \rightarrow 2Fe(s)+3CO_2$
- Key energy source: Coal

DRI-EAF route

- $2Fe_2O_3+3CO+3H_2 \rightarrow 4Fe+3CO_2+3H_2O$
- Key energy source: Coal or NG/Elec.

Green H2-DRI-EAF route

- $2Fe_2O_3 + 6H_2 \rightarrow 4Fe + 6H_2O$
- Key energy source: RE/H2/Bio-carbon

Figure 4.1: Ironmaking & Steelmaking process BF-BOF, Natural gas DRI-EAF and H2-DRI-EAF (IRENA, 2022)

Source: Green Steel Economics - Comparing Economics of Green H2-DRI and Traditional Steelmaking Around the World โดย Global Efficiency Intelligent [Published: July 2024]

4.2) Overview of Green steelmaking in global

Table 4.1: Green steelmaking initiatives

Company	Project/Technology	Location	Target
ArcelorMittal	Hydrogen reduction with grey hydrogen Blast furnace + electrolysis for hydrogen production Hybrid blast furnace with direct reduced iron (DRI) gas injection Coke oven gas with grey hydrogen; hydrogen in DRI-EAF	Hamburg, Bremen, Germany Dunkirk, Germany Asturias, Spain	Fossil free by 2050
HYBRIT (SSAB, LKAB and Vatenfall)	Replacing coking coal with hydrogen and fossil-free electricity	Sweden	Fossil free by 2045
Boston Metal, BHP & Vale	Molten oxide electrolysis (MOE) technology	Massachusetts, USA	n/a
China Baowu & BHP	Memorandum of Understanding to share technical expertise in reducing emissions from steel, including using CCUS	Multiple steelmaking bases in China	n/a
Ovako	Hydrogen use to heat steel before rolling	Hofors, Sweden	n/a
Liberty Ostrava	Building hybrid furnaces	Czech Republic	Hybrid furnaces built by 2022
Rogesa	Hydrogen in coke gas as reducing agent	Dillingen, Germany	Started operations in
Tata Steel	CCS under North Sea; water electrolysis to produce hydrogen and oxygen	Ijmuiden, Netherlands	Carbon-neutral in Europe by 2050
Thyssenkrupp	Hydrogen as reducing agent; use of renewable hydrogen from RWE & feasibility study for water electrolysis plant	Duisburg,	First phase testing in 2021, second phase in 2022.
Voelstalpine Primetals Tech.	Hydrogen as reducing agent to process iron ore concentrates	Linz, Austria	80% carbon emissions reduction by 2050
Tenaris, Edison and Snam	Electrolysis/hydrogen-based steelmaking	Bergamo, Italy	
Salzgitter AG (Salcos project)	Electrolysis/hydrogen-based steelmaking	Wilhelmshaven, Germany	2 million tonnes per year of DRI (by the end of first implementation stage, expected for 2025)
Duferco	Using hydrogen in beam furnace with green PPA.	Brescia, Italy	
Celsa, Statkraft & Mo industrial park AS	Electrolysis/hydrogen-based steelmaking	Norway	50% emissions reduction by 2030, decarbonization by 2050.
H2 Green Steel Initiative	Hydrogen-based steelmaking	Northern Sweden	Planned production to start in 2024. Annual production target of 5 million tons of green steel by 2030.

Source: Considerations for making green steel using carbon capture and storage (CCS) and hydrogen (H2) solutions , OIES [Published on May 2023]

4.3) Highlight of Green steelmaking projects ArcelorMittal

Preliminary data on steelmaker ArcelorMittal's Green Steel Project

Green steel project
(ArcelorMittal)
With subsidized by EU

ArcelorMittal, Gijon [Spain]	
Facility	H2-DRI with EAF 2.3 Mton
Public subsidies [million Euro]	**460**
Total investment [million Euro]	1,000
CO2 reduction [millionTon.CO2]	4.8
Operation date	2025

ArcelorMittal, Dunkerque [France]	
Facility	H2-DRI with EAF 2.5 Mton
Public subsidies [million Euro]	**850**
Total investment [million Euro]	1,800
CO2 reduction [millionTon.CO2]	70
Operation date	2027

ArcelorMittal, Ghent [Belgium]	
Facility	H2-DRI with EAF 2.3 Mton
Public subsidies [million Euro]	**280**
Total investment [million Euro]	1,100
CO2 reduction [millionTon.CO2]	50
Operation date	2026

ArcelorMittal, Bremen [Germany]	
Facility	H2-DRI with EAF 3.8 Mton
Public subsidies [million Euro]	**1,300**
Total investment [million Euro]	2,500
CO2 reduction [millionTon.CO2]	6.3
Operation date	2030

ArcelorMittal, Hamburg [Germany]	
Facility	H2-DRI with EAF 0.1 Mton
Public subsidies [million Euro]	**55**
Total investment [million Euro]	110
CO2 reduction [millionTon.CO2]	0.7
Operation date	2026

Source : STEELWATCH: ArcelorMittal Corporate Climate Assessment 2024 [published in My 2024]

4.3) Highlight of Green steelmaking projects ArcelorMittal

Overview of EU supporting for ArcelorMittal

Table 4.2: DRI projects announced by ArcelorMittal

Plant / location	Planned capacity (Mtpa)	Announced costs (EUR)	Public subsidies (EUR)	Announced operational date
Gijón and Sestao (Spain)	2.3	EUR1,000 mn	EUR460 mn[92]	2025
Dunkerque (France)	2.5	EUR1,800 mn	EUR850 mn[93]	2027
Ghent (Belgium)	2.3	EUR1,100 mn	EUR280 mn[94]	2026
Bremen and Eisenhüttenstadt (Germany)		EUR2,500 mn	EUR1.300 mn[95]	2030
Hamburg (Germany)	0.1		EUR55 mn[96]	2026
Dofasco (Canada)*	2.5	EUR1,286 mn *(CAD 1.8 billion)*	EUR643 mn[97] *(CAD 0.9 billion)*	2028
			Total: EUR3,588 mn	

*Based on an exchange rate of 1 EUR = 1.4 CAD

Innovative DRI: Backtracking on green hydrogen

ArcelorMittal have proposed project: Green H2 DRI-EAF to EU Commission according to table 4.2 that received public subsidies approx. 3,588 Million EURO

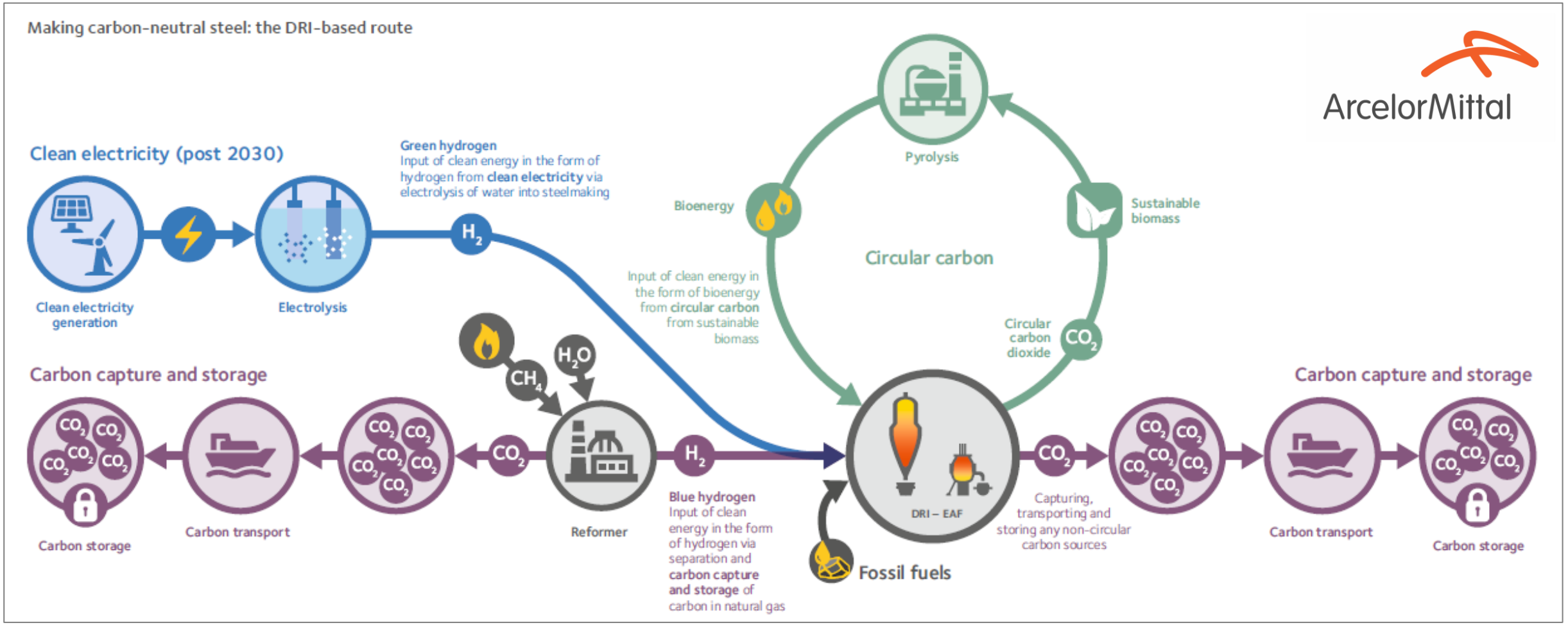
The main reasons that EU Commission supports these projects of ArcelorMittal Group:

- ❑ These measures are in line with the development of economic activities and are in line with key EU policies, namely the European Green Deal, the EU Hydrogen Strategy, the Green Deal Industrial Plan and the RE Power EU Plan.
- ❑ The project owners will not invest in Green Steel production without government support.
- ❑ The measures include sufficient "safeguards" to ensure that there is no unfair competition. If the project is very successful and generates additional net income, the beneficiary will return some of the subsidy received to EU Commission (claw-back mechanism).
- ❑ The project developer is committed to disseminate the experience and technical know-how gained from the project to the steel industry and interested parties.
- ❑ The project is subject to monitoring to monitor and assess the achievement of the targets of reducing CO2 emissions, phasing out natural gas and switching to Green Hydrogen.

Source: STEELWATCH: ArcelorMittal Corporate Climate Assessment 2024 [published on My 2024]

4.3) Highlight of Green steelmaking projects ArcelorMittal

Overview of ArcelorMittal's steelmaking, hydrogen production and CCUS processes.

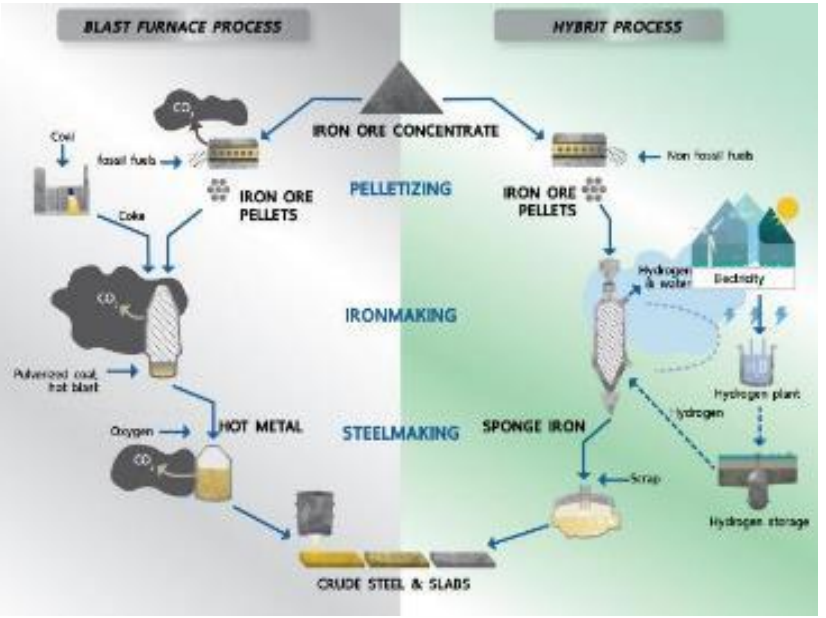


Source : ArcelorMittal-Climate action report 2_Published in July 2021

4.3) Highlight of Green steelmaking projects SSAB, Sweden

Project; Hydrogen Breakthrough Ironmaking Technology (HYBRIT) Launched in 2016 as a joint venture between three private companies [SSAB, LKAB and Vattenfall]. This project is financed by the Swedish Energy Agency through its Innovation fund (100% from EU-ETS) with a contribution of approximately USD 282 million.

In 2021, HYBRIT produced Fossil free steel to the market with Pilot plant and plan to scale–up Fossil free steel in industrial scale within 2030.



Source: chrome-extension://efaidnbmnnnibpcajpcglclefindmkaj/https://climate.ec.europa.eu/system/files/2022-07/if_pf_2022_hybrit_en.pdf

Source: https://www.hybritdevelopment.se/en/

4.3) Highlight of Green steelmaking projects

Boston Metal, USA

Boston Metal

Boston Metal is a ten-year-old MIT spin-out* startup formed in 2013. Aiming to fight climate change and reduce carbon emissions from its steel production, this 120-person company has raised a total of $250 million to make “green” steel possible.

- Boston Metal is commercializing a new method for making steel and other metals, to help clean up the emissions-intensive industry.
- Boston Metal plans to use an electrochemical decarbonizing process called Molten Oxide Electrolysis (MOE) by supplying electricity through iron oxide mixed with Electrolyte

Figure 4.2: Configuration of Molten Oxide Electrolysis process

Source: https://medium.com/@DiggerInsights/startup-boston-metal-works-on-green-steel-3424a0b7485f

4.3) Highlight of Green steelmaking projects Thyssenkrupp Steel, Germany

EU Commission approves German federal and state government funding for thyssenkrupp Steel's "tkH2Steel" decarbonization project

[reported on Jul 20, 2023 5:15 PM]

Thyssenkrupp has received approval from the EU Commission for a €2 billion ($2.3 billion) state subsidy for the development of its Green Steel plant in Duisburg, using DRI technology. The project is scheduled to start production in 2029 and represents an important step in Thyssenkrupp's efforts towards its net zero target for steel production. The EU Commission has approved the assistance. The assistance will be provided through two linked financial instruments: an "initial grant" and a "conditional payment" to support and promote innovation and an early phase-out of natural gas. The project idea is to pioneer innovation and accelerate the production/use of hydrogen and achieve rapid CO2 reductions. In a sense, the "tkH2Steel" project is a major driver of Europe's hydrogen economy.

- ❑ Plant capacity: 2 units of H2-DRI process total capacity 2.5 Mton/year (Thyssenkrupp invests approx. EURO 1,000 Million) This project can reduce CO2 emission around 3.5 Million tonCO2e
- ❑ Plan: Start for construction at the end of 2026 and will start the production within 2029 by consuming Hydrogen 143,000 ton/year.
- ❑ Technology provider: SMS Group will be EPC for this project.

Funding arrangement: The EU commission has allocated funding in two parts:

1) Initial grant of EUR 550 million will support ThyssenKrupp in investing in green steelmaking processes by supporting the construction and installation of DRI and two EAF units in Duisburg, with an estimated CO2 reduction > 58 million tons over the life of the project.
2) Conditional payments of EUR 1.45 billion to support the use of green hydrogen in the steelmaking process, covering the additional costs of sourcing and using green hydrogen during the first 10 years of operation of the new DRI plant. Conditional payments are subject to annual reviews by a third-party expert to assess the actual volumes and prices paid for the use of green hydrogen. Thyssenkrupp will conduct a bidding process to select Green Hydrogen's supplier.

ที่มา - https://www.thyssenkrupp.com/en/newsroom/press-releases/pressdetailpage/eu-commission-approves-german-federal-and-state-government-fund-ing-for-thyssenkrupp-steels-tkh2steel-decarbonization-project-228875

4.3) Highlight of Green steelmaking projects

Salzgitter AG, Germany

Salzgitter AG receives official notice of government funding for the SALCOS® low-CO2 steel production program

[reported on 18 April 2023]

Salzgitter, Germany's second largest steel producer with a crude steel production capacity of around 9 million tons per year.

EU Commission approved to support Salzgitter Flachstahl GmbH ('Salzgitter') around EURO 1,000 Million for investing Green steel production with Green hydrogen

- Detail of project: SALCOS® - Salzgitter Low CO2 Steelmaking (Plan for production in 2026) that is consist of
  1) Green Hydrogen-DRI-EAF with cap. 1.9 TPA. For replacing the existing process (Blast furnace)
  2) Green hydrogen production cap. 9,000 ton.H2/year by using Electrolyzer cap. 100 MW with Renewable energy that Green hydrogen will be feedstock for DRI
- CO2 emission reduction: can be avoided to emiss CO2 approx. 3.6 Mton.CO2e
- Funding allocation:
  1) € 700 million in federal funding
  2) € 300 million from the state government.

  The excess of €1 billion will be covered by Salzgitter AG, which plans to develop the SALCOS® project by the end of 2025.

Source: https://ec.europa.eu/commission/presscorner/detail/en/ip_22_5968 และ https://www.steeltimesint.com/news/salzgitter-awarded-eur1b-for-hydrogen-based-production

4.3) Highlight of Green steelmaking projects

TataSteel, UK

A blast furnace at the Tata Steel works in Port Talbot. Photograph: Geoff Caddick/AFP/Getty

Tata Steel reportedly close to securing £500m funding from UK government

[reported on September 2nd, 2023]

The UK government confirmed on 15 September 2023 that it would provide £500 million ($621 million) to Tata Steel UK to replace its Port Talbot coal-fired blast furnace (the highest CO2 emitting process in the UK) with an EAF technology, which would reduce the UK's overall CO2 emissions by around 1.5%. The total investment is expected to total £1.25 billion, with Tata Steel providing an additional £725 million in funding from its Indian parent, the Tata Group, which is expected to directly reduce greenhouse gas emissions by 50 million tonnes over 10 years. The project will also support the country's scrap utilization policy.

Source:
https://news.sky.com/story/government-in-advanced-talks-over-500m-tata-steel-aid-package-12952845
https://www.theguardian.com/business/2023/sep/02/tata-steel-reportedly-close-to-securing-500m-aid-deal-from-uk-government
https://www.tatasteel.com/media/newsroom/press-releases/india/2023/tata-steel-and-the-uk-government-jointly-agree-on-a-proposal-for-the-largest-investment-in-the-uk-steel-industry-for-decades/

4.3) Highlight of Green steelmaking projects BlueScope, New Zealand

BlueScope and NZ Government agree to co-fund NZ$300M for decarbonization at NZ Steel

[reported on May 22nd , 2023]

Australian flat steel producer BlueScope has announced an accelerated feasibility study to build a new electric arc furnace (EAF) at its New Zealand Steel (NZ Steel) works at Glenbrook, south of Auckland for around NZ$300 million.

- BlueScope NZ Steel is working with the New Zealand Government to develop a NZ$ 300 million project to build an electric arc furnace (EAF) at New Zealand Steel's (NZ Steel) Glenbrook plant, south of Auckland.
- The EAF is targeted to be operational by 2026.
- CO2 emission reduction: This will reduce NZ Steel's Scope-1 and Scope-2 CO2 emissions by at least 45 per cent, equivalent to removing approximately 300,000 ICE vehicles.
- Funding Support for the Project: The New Zealand Government has confirmed an unconditional co-funding agreement to support the project, under which:
  1) The New Zealand Government will contribute up to NZ$140 million through the Government Investment in Decarbonizing Industry (GIDI) Fund.
  2) NZ Steel will invest approximately NZ$160 million in capital and transition spending.
- Investing in EAF only makes sense when there is sufficient, reliable, affordable domestic sources of renewable energy and scrap metal, and the right public policies and support. That is what New Zealand is ready for, and that is why the Government is so pleased to support the implementation of this important decarbonization project.

Source:
- https://www.steeltimesint.com/news/bluescope-to-decarbonize-australian-steelworks
- https://www.listcorp.com/asx/bsl/bluescope-steel-limited/news/bluescope-and-nz-government-agree-to-co-fund-eaf-at-nz-steel-2876545.html

4.3) Highlight of Green steelmaking projects

Posco, South Korea

South Korea ranks 6th in the world in steel production capacity with a total steel production capacity of 67 million tons/year, of which around 70% is BF-BOF. It has a strategic plan to reduce CO2 emission to achieve carbon neutrality for the Korean steel industry.

- ❑ Aim to produce > 10 million tons of steel using H2-DRI production by 2040 (full-scale H2-DRI steel production capacity may start before 2040, with an expected production of 3.5 million tons in 2035, 12.5 million tons in 2040, and 36.5 million tons in 2050).
- ❑ Reduce GHG emissions compared to 2018 by 19% in 2030, 53% in 2040, and 95% in 2050. The government also aims to produce H2 at a cost of 1.8 USD/kg.H2 by 2050.

The Ministry of Trade, Industry and Energy aims to promote the development of steelmaking technology with HyREX-Fluidized Bed Reactor [Pilot scale – 300,000 ton] at Pohang Steel (POSCO group) by 2026 as a world first installation with an investment of 27 billion won (20.7 million dollars) and to develop it from a pilot reactor to an industrial scale of 1 million tons of steel by 2030. The government plans to retrofit shaft furnaces nationwide with 14 Fluidized bed reduction reactors [HyREX] by 2050.

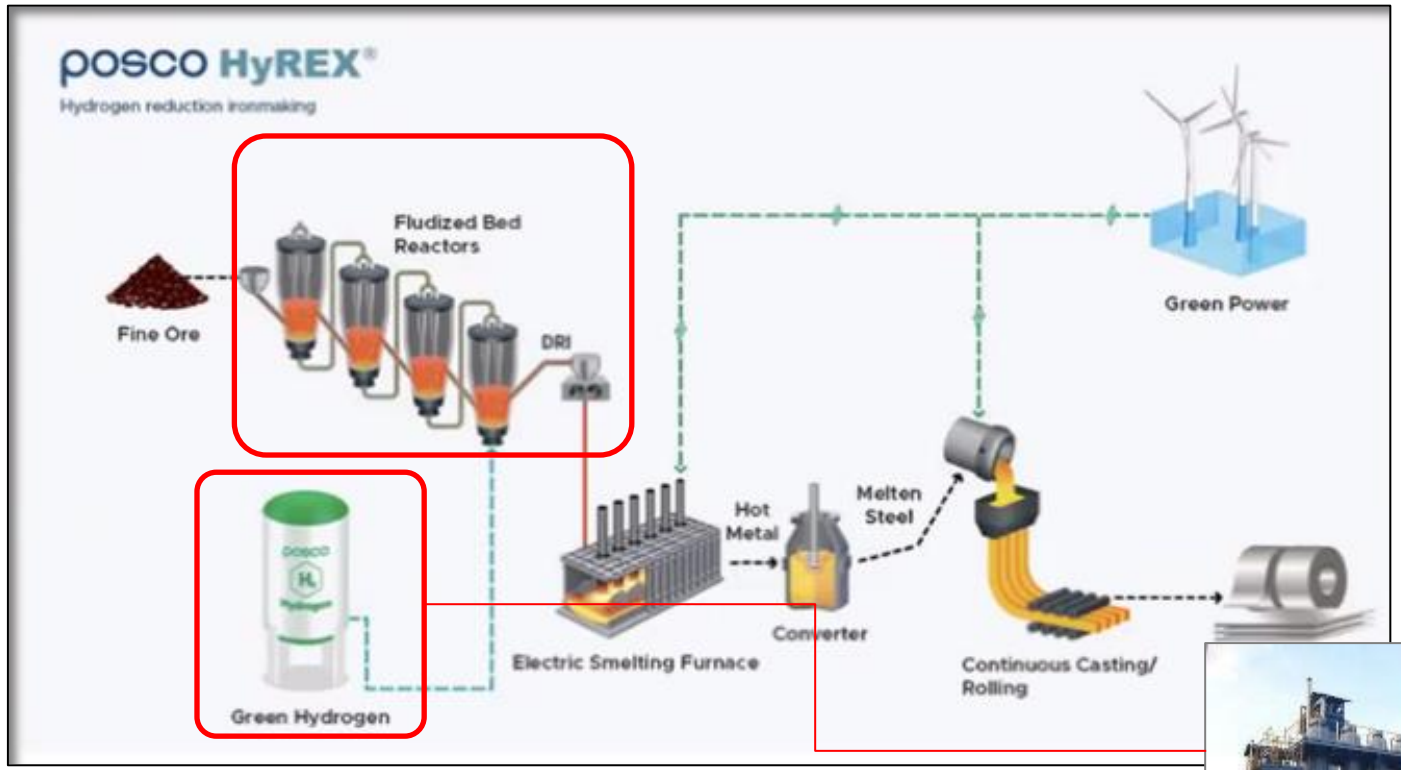


Figure 4.3: POSCO HyREX – Hydrogen reduction ironmaking

Source: https://www.kedglobal.com/steel/newsView/ked202305300017

Source: https://www.kedglobal.com/steel/newsView/ked202305300017

4.3) Highlight of Green steelmaking projects

Nippon Steel, Japan

Nippon Steel, the world's 4th largest steelmaker, is moving towards green steel in 2 ways:

- H2-DRI: Plans to start testing 100% H2-DRI in a 10-tonne blast furnace by 2025 at the Hasaki R&D center. The project is part of the Green Innovation fund, and Nippon expects to use 7 million tons of hydrogen per year to produce zero carbon steel.
- H2 injection in Blast furnace: Hydrogen injection in BF is being carried out under the Super COURSE50 project by Nippon Steel. Previously, hydrogen-rich syngas from within the steel plant was injected into the BF, but with the Super COURSE50 project, externally produced hydrogen is injected into the BF. The Super COURSE50 project has been tested in 2022 and is expected to be put into practice by 2050, resulting in a 50% reduction in CO2 emissions.

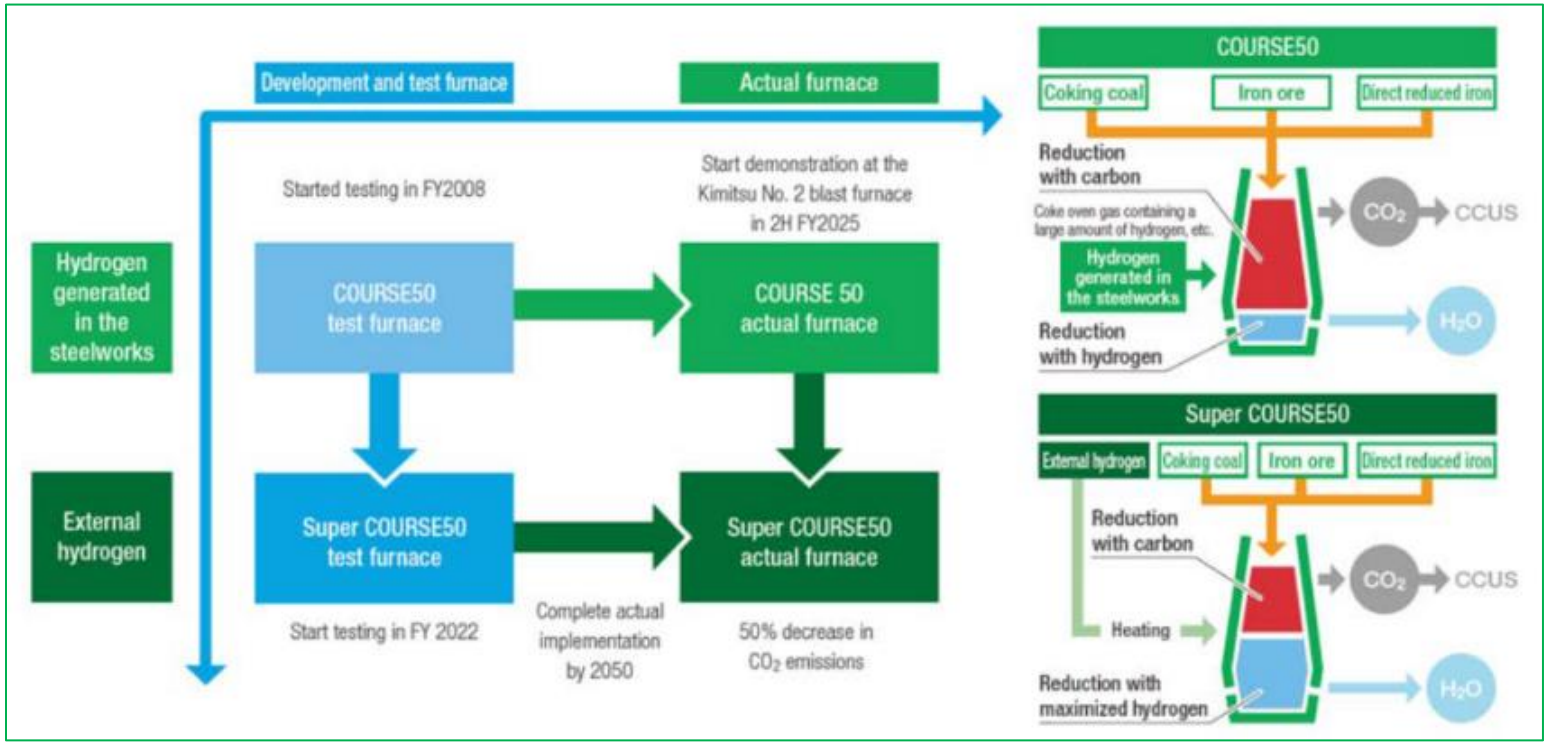


Figure 4.4: Nippon Steel's COURSE50 and Super COURSE50 projects

Source: **Hydrogen and the Decarbonization of Steel Production in Canada** REACHING ECONOMIES OF SCALE โดย The Canadian Steel Producers Association published in September 2023

4.3) Highlight of Green steelmaking projects

China

- Baowu Group, the world's largest steelmaker, has hired Energiron to develop the world's largest hydrogen-based DRI process, which will run on 100% hydrogen. Initially, it will use natural gas and coke oven syngas. It plans to start operations by 2024 with a DRI capacity of 1 million tons per year, including a carbon capture and storage (CCS) system.
- Another Chinese steelmaker, Ansteel Group (also known as Angang Group), the world's third largest steelmaker, is developing a DRI-Own Fluidized Base process. The plant is set to start operations in 2023, producing 10,000 tons per year of DRI. They have also signed MOUs to purchase or produce hydrogen from electrolysis processes using wind and solar power.
- The world's top five steelmakers are Jiangsu Shagang Group, or China's Shagang Group. The company currently has no clear plans to use hydrogen or DRI, but is focusing on sourcing cleaner raw materials in partnership with Vale.

BHP announces decarbonization project with China Baowu

Global iron ore mining giant BHP has announced that it has commenced a commercial-scale direct reduced iron production project with China Baowu Steel Group Corporation to support the development of decarbonization of steelmaking in China. The project, which will use BHP's iron ore to produce direct reduced iron (DRI) at Baowu's new Zhanjiang DRI plant, aims to support the wider adoption of DRI technology to accelerate the reduction of greenhouse gas emissions from steelmaking, using H2 as a reducing agent in reduction furnaces.

BHP has signed a memorandum of understanding (MOU) with China Baowu, with the intent to invest up to US$35 million over five years to support China Baowu's research/development and trials focused on the development of low-carbon technologies and the application of CCUS technology at one of China Baowu's steelmaking plants.

Source: https://www.chinadaily.com.cn/a/202402/02/WS65bcdff5a3104efcbdae96cb.html

Source: **Hydrogen and the Decarbonization of Steel Production in Canada REACHING ECONOMIES OF SCALE** โดย The Canadian Steel Producers Association published in September 2023

4.3) Highlight of Green steelmaking projects

Stegra, Sweden

H2 Green Steel changes name to Stegra

Photos and information from news on September 19, 2024

The company's purpose is to decarbonize hard to-abate industries. Stegra will do so by leveraging all three platforms it works with: green hydrogen, green iron and green steel

Launched in 2021 to reduce emissions in the steel industry on an ambitious timeline, H2 Green Steel has shown that it can be done. The company aims to inspire the current steel industry to accelerate its transformation. It has received €6.5 billion in funding and is currently building the world's first large-scale green steel plant, which is set to start production in 2026. Now, the company has started a new chapter with a new name: Stegra. "Stegra is a Swedish word meaning 'to lift', reflecting the team spirit of moving forward in the face of challenges and constantly moving forward. It is a constant reminder of the company's purpose and a tribute to its Swedish roots and its origins in Boden." It consists of three different platforms currently being built in Boden.

- ❑ Green hydrogen: one of the world's largest electrolyzers
- ❑ Green iron: where the bulk of the emissions are reduced by replacing coal and coke in traditional steelmaking with green hydrogen – emitting water instead of carbon emissions
- ❑ Green steel: a fully electrified large-scale production facility for near-zero emissions steel

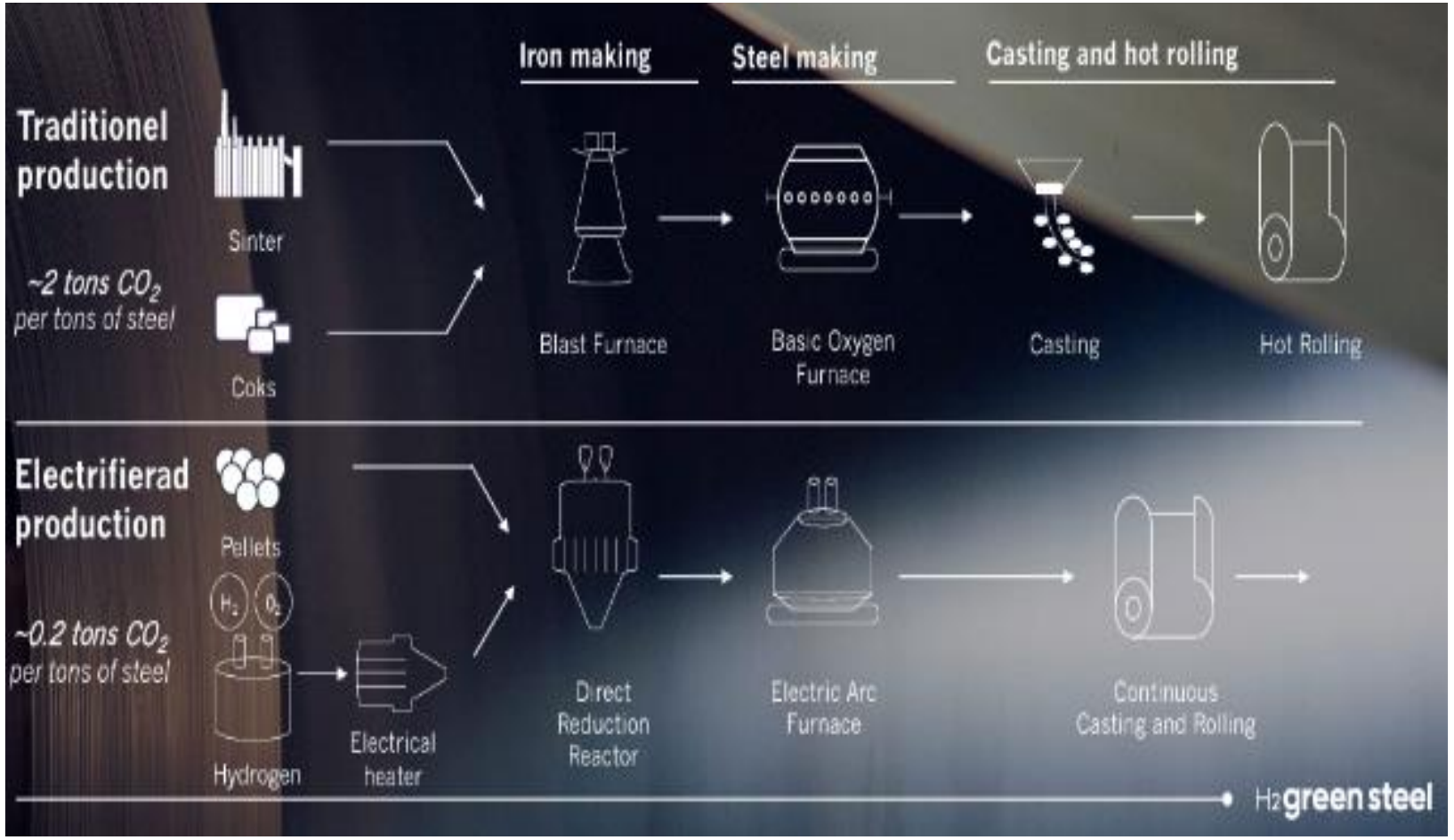
Source: H2 Green Steel changes name to Stegra - GreenSteelWorld.com

4.3) Highlight of Green steelmaking projects

Stegra, Sweden

Project Overview

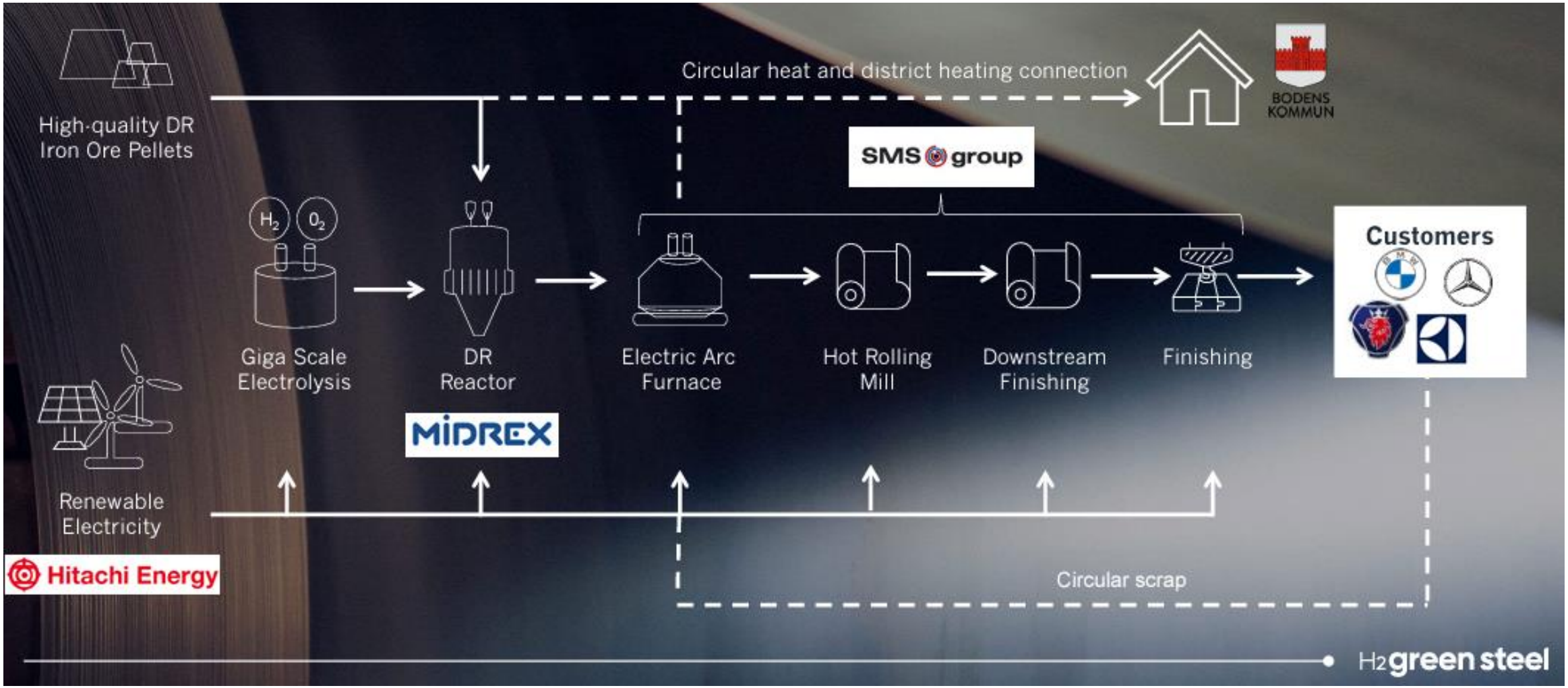
- Uses 100% hydrogen to produce DRI (Direct Reduced Iron)
- Uses clean electricity to produce hydrogen
- Located in Boden, northern Sweden
- Production capacity is 2.5 million tons per year, expected to start production in 2025
- Area size 300 hectares



Source : https://greensteelworld.com/wp-content/uploads/sites/24/2023/04/3-Maria-Persson-Gulda-H2-Green-Steel.pdf

4.3) Highlight of Green steelmaking projects

Stegra, Sweden



Source : https://greensteelworld.com/wp-content/uploads/sites/24/2023/04/3-Maria-Persson-Gulda-H2-Green-Steel.pdf

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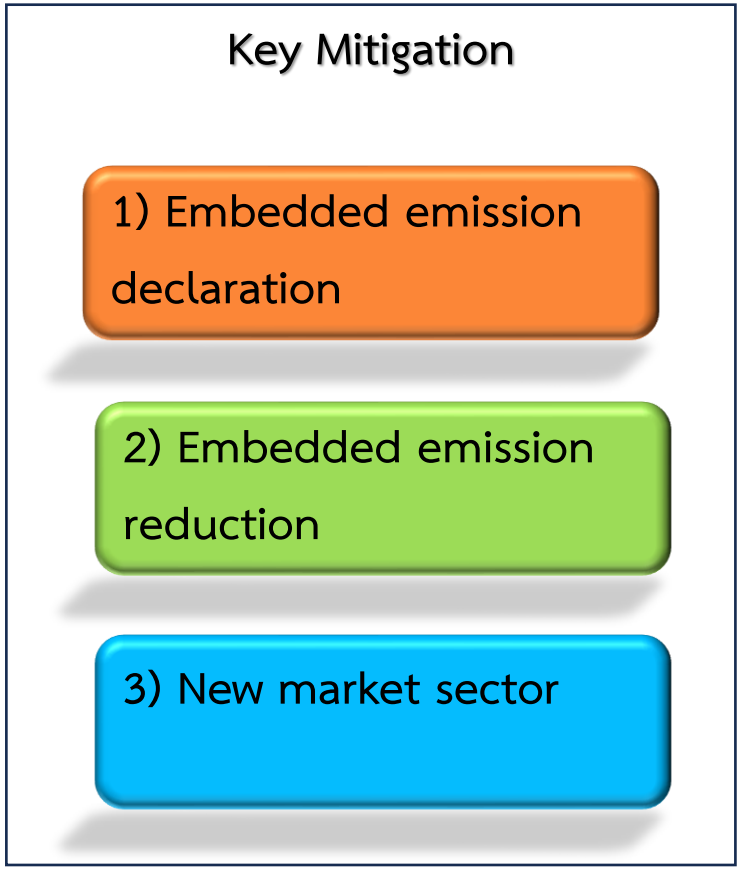
Mitigation and adaptation of Steel industry in Thailand

5.1) Adaptation and Preparation for CBAM Measures

EU-CBAM will be in force on January 2026 (Exporter have pay CBAM Certification) and then USA, UK, Australia, Canada and other countries will set up CBAM's regulation in the coming year after 2026. Steel is majority products that will be included in these scope.

These guidelines of adaptation to CBAM measures for Steel producer are as follows:

1) CBAM Declaration: Preparing Embedded Emission data according to the EU Commission's requirements to report Embedded Emission data of products exported to the EU. Including to select 3rd party certify body who can do verification and certification Embedded emission.
2) Embedded Emission Reduction scheme: Accelerating the improvement or development of the production process to reduce Embedded Emission of products to be exported to the EU and other countries, such as energy conservation, energy efficiency improvement, changing energy from fossil fuels to clean energy, etc.
3) New market sector: Find new markets to replace the EU market, especially the CLMV market, etc.



Source : https://krungthai.com/th/financial-partner/learn-financial/1812

5.2) Mitigation and adaption of Steel industry for CBAM

5.2.1) To make understanding of CBAM measures and its effect to steel industry.

In-depth study report "CBAM measures and the Thai steel industry"

The Iron and Steel Institute of Thailand (ISIT) has studied the requirements of the EU's Carbon Border Adjustment Mechanism (EU-CBAM measures), the assessment of embedded emission according to the EU's Guideline, the impact of CBAM measures on the Thai steel industry, and has studied in-depth information on the steel industry's readiness, presented to the Industrial Policy Division, Office of Industrial Economics, Ministry of Industry, to be informed of the impact on the steel industry and for relevant government agencies to support the steel industry in adapting and preparing.

Source: ISIT (Iron and Steel Institute of Thailand)

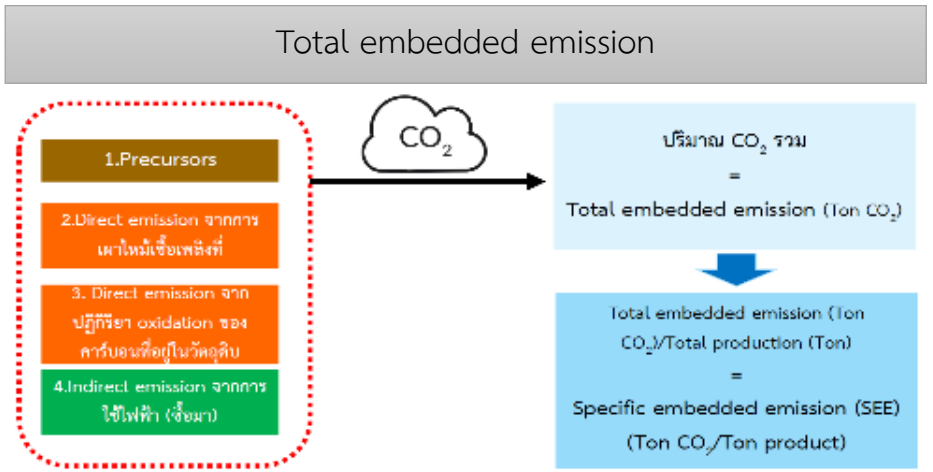
5.2) Mitigation and adaption of Steel industry for CBAM

5.2.2) Project: Environmental database development for steel products to serve CBAM measures

- The objective of the project
  1) To study an environmental database of steel products by applying LCI (Cradle to Gate) to assess environmental impacts from steel product production
  2) To establish the National environmental database of steel products in Thailand
- Scope of study: This project will be studied covering 7 types of steel products that consist of:
  - ✓ Long steel products 2 databases
  - ✓ Flat steel products 5 databases
- Duration time: 12 months (February 2024 – January 2025)

5.2) Mitigation and adaption of Steel industry for CBAM

5.2.3) Deep study project on Embedded emission of Steel products according EU-CBAM



Detail of project

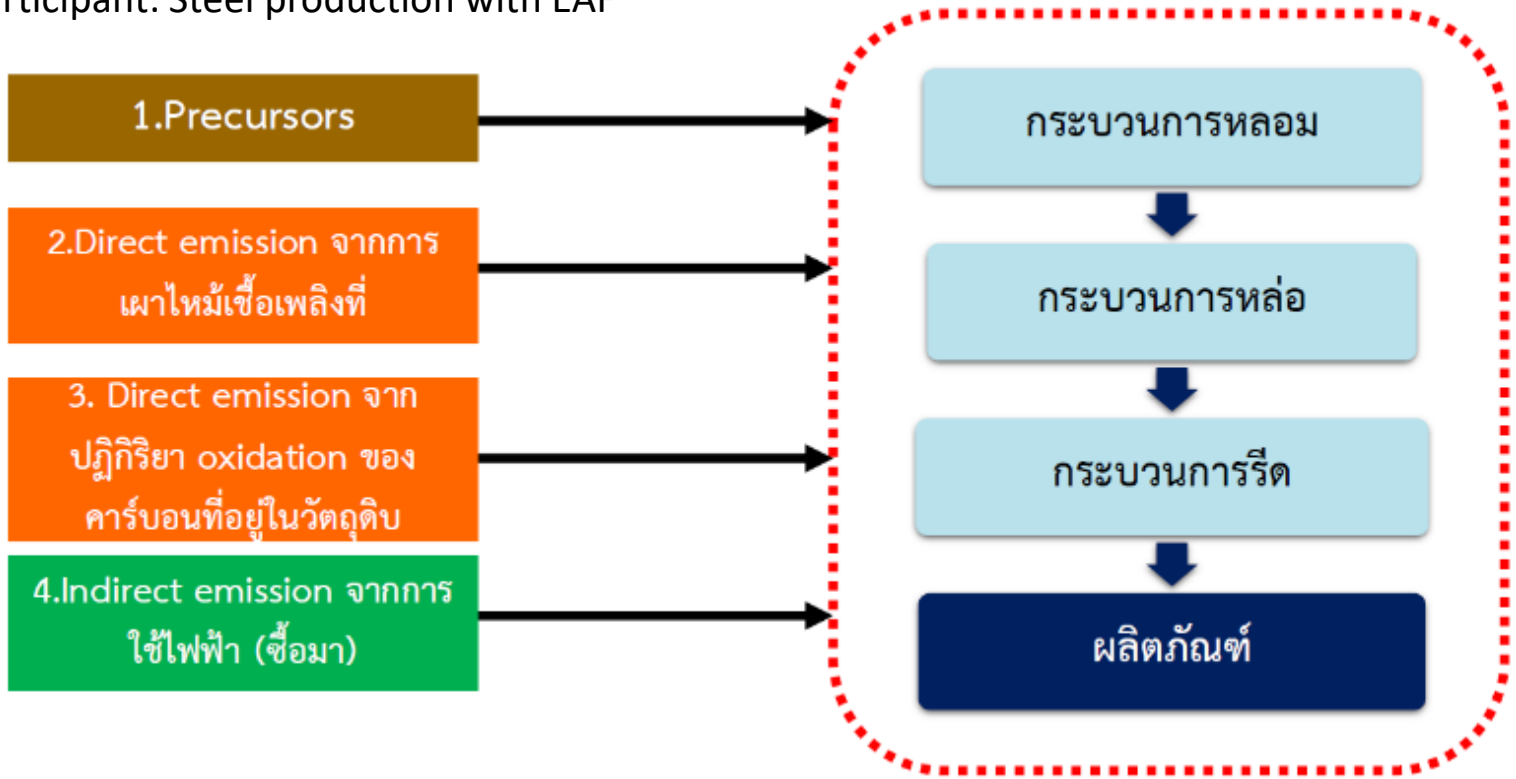
- ❑ Participating companies in the field data collection project
  1) ZUBB STEEL Co., Ltd.
  2) Lingnan Steel Co., Ltd.
  3) G-Steel Public Company Limited
  4) GJ Steel Public Company Limited
- ❑ Consulting firm: Tree moments Co.,Ltd
- ❑ Step to assess embedded emission by following to EU-CBAM
  1) Set goals and scope: Select products to be evaluated (according to CN Code)
  2) Collect data
     - ✓ List all relevant processes in the main production process
     - ✓ Collect data
     - ✓ Check data quality
  3) Calculate Embedded emission
  4) Calculate Embedded emission value
  5) Check accuracy
     - ✓ Report Embedded emission value:
     - ✓ Report Embedded emission value
  6) Analyze and determine management guidelines to reduce greenhouse gas emissions

Source: ISIT (Iron and Steel Institute of Thailand)

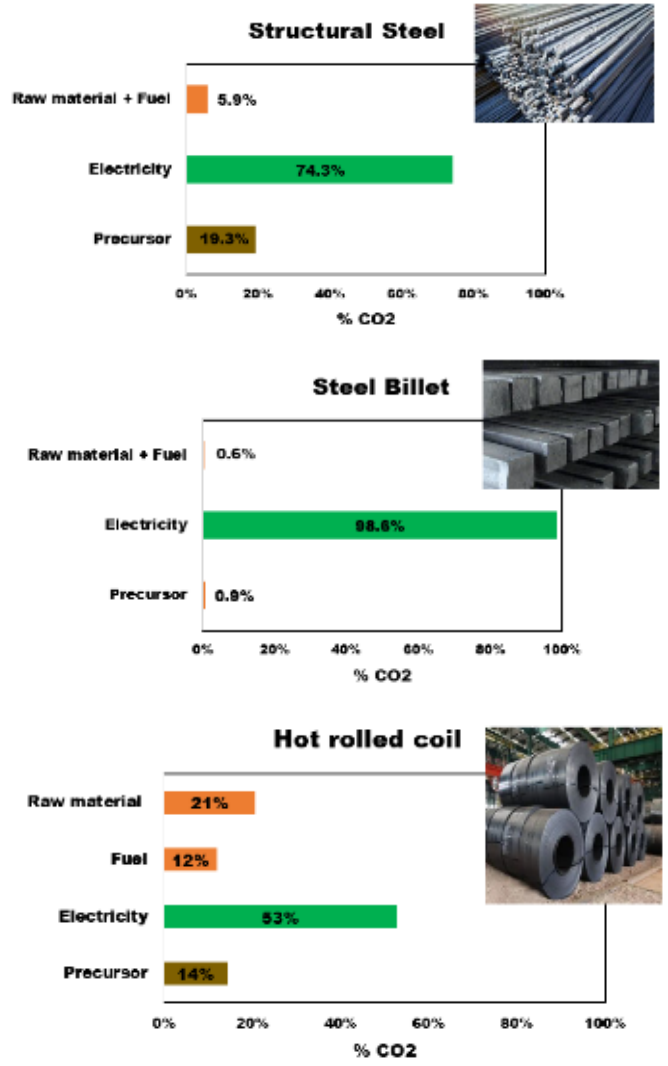
5.2) Mitigation and adaption of Steel industry for CBAM

5.2.3) Deep study project on Embedded emission of Steel products according EU-CBAM

Participant: Steel production with EAF



% Ratio of Embedded emission



Source: ISIT (Iron and Steel Institute of Thailand)

5.2) Mitigation and adaption of Steel industry for CBAM

5.2.3) Deep study project on Embedded emission of Steel products according EU-CBAM

Embedded emission of steel companies who participated in this project

Products	Steel Billet	Hot rolled coil	Structural steel	
Specific direct embedded emissions	0.003 – 0.005	0.220 – 0.250	0.025 – 0.045	t CO_2 / t product
Specific indirect embedded emissions	0.380 – 0.450	0.330 – 0.370	0.290 – 0.470	t CO_2 / t product
Specific indirect embedded emissions (precursor)	0.004 – 0.005	0.090 – 0.160	0.075 – 0.090	t CO_2 / t product
Specific total embedded emissions	**0.387 - 0.460**	**0.640 - 0.730**	**0.390 - 0.605**	t CO_2 / t product

Source: ISIT (Iron and Steel Institute of Thailand)

5.2) Mitigation and adaption of Steel industry for CBAM

5.2.4) CBAM's consequential impact and Thailand-CBAM

Finding/seeking new markets to replace the EU market

This approach is the most of adaptation that exporters who originally exported goods to the EU market have turned to focus on and choose this approach to solve immediate problems after the EU announced the enforcement of CBAM measures in early 2026.

Note : Iron and Steel and Aluminum Export Value to EU Comparison between Thailand and China (Million USD)
Source – MOC, International Trade Centre (ITC) in 2022

Threats and risk from CBAM

There is a high possibility that Chinese steel and aluminum products will enter other countries more if they can't adapt to CBAM measures. From above data on exports to the EU in 2022, when comparing the exporting value between Thai vs China, the exporting value of China is several times higher than Thailand. This shows the risk that there is possibility that Chinese steel products will entry to Thai market that will be effect to Thai steel producers. Therefore, the impact of CBAM on Thai entrepreneurs may not be limited to exporting to the EU, which will become more difficult, but also covers the risk of being marketed by products from other countries that cannot export to the EU as usual. Thailand-CBAM is one mitigation which steel industry are looking for, isn't it?

Source : https://thaipublica.org/2023/10/krungthai-compass57/

5.2) Mitigation and adaption of Steel industry for CBAM

5.2.4) How to reduce Embedded emission

Decarbonization pathway

1) Energy Conservation and Energy Efficiency Development

2) Energy Transition (Switching from fossil fuel to Green energy)

3) Re-sourcing Raw materials

4) Carbon Capture Utilization and Storage (CCUS)

Embedded Emission

Scope 1 Direct Emission	Scope 2 Indirect Emission	Scope 3 Indirect Emission
Energy conservation and energy efficiency improvement such as improving the efficiency of Boiler, installing VSD for Fan & Pump equipment.		Procurement and selection of raw materials with low GHG emission for steel production, such as changing steel raw materials from Blast Furnace (BF) production process to Electric Arc Furnace (EAF), etc.
Changing energy from fossil fuels to clean energy, such as choosing RE to replace electricity from fossil fuels, using Biogas or Biomass to replace Fossil fuel, using Green H2 to replace Fossil fuel.		
Carbon Dioxide capture for utilization or permanent storage		

5.2) Mitigation and adaption of Steel industry for CBAM

5.2.4) How to reduce Embedded emission

5.2.4.1) Applying Best Available Technologies (BAT)

The steel industry club has studied and understood the technology in the Decarbonization pathway aimed at reducing CO2 emissions. It has coordinated and created cooperation with the Asean-Japan Steel Initiative (AJSI) to apply the Best Available Technologies and New Innovations from Japan in the Thai steel industry.

TCL. or Technologies Customized List is a “low-carbon steelmaking technology list” that collects the latest energy-saving and energy-efficiency-enhancing technologies in the steelmaking process, which is studied, compiled and compiled by the ASEAN-Japan Steel Initiative (AJSI). The latest version has been developed and updated to Version 4.0.

Source : ASEAN Technologies Customized List 2023 version Part-1 : EAF (v. 4.0)

5.2) Mitigation and adaption of Steel industry for CBAM

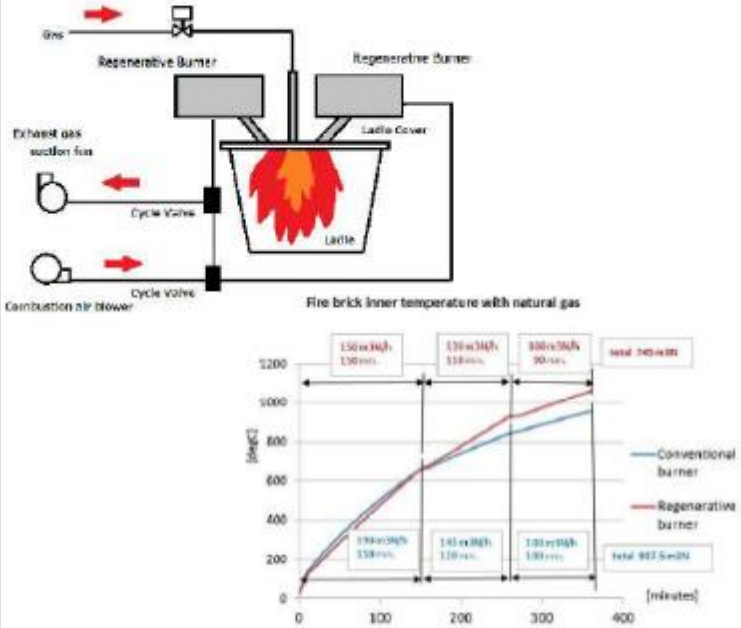
5.2.4) How to reduce Embedded emission

5.2.4.1) Applying Best Available Technologies (BAT)

Technologies Customized List for Energy Saving, Environmental Protection, and Recycling for ASEAN Steel Industry 2023 version (v.4.0) part 1: EAF

No.	ID	Title of technology	Technical description	Expected effects of introduction: Electricity saving (kWh/t of product)	Expected effects of introduction: Thermal energy saving (GJ/t of product)	Expected effects of introduction: Profit of operation cost (Effect of product, Japan)	Expected effects of introduction: Environmental benefits	Expected effects of introduction: Co-benefits	Assumed investment cost: Assumed investment cost (million US$ in Japan)	Assumed investment cost: Payback time (year in Japan)
A. Energy Saving for Electric Arc Furnace (EAF)										
1	A-1	High temperature continuous scrap preheating EAF	Combination of the technologies of - Air tight structure - High temperature scrap preheating (over 700 degC) - Continuous preheated scrap charging - Automatic process control by using data logging - Post-combustion of generated CO gas - Dioxin decomposition by secondary combustion	150.0	-	21.45	- Decomposition and reduction of dioxin, dispersing dust, & noise	- Low electrode consumption (0.8 - 1.0 kg/ton-product at AC)	28.00	3.5
2	A-2	Medium temperature batch scrap preheating EAF	- High melting efficiency batch charging type EAF with SPH. - Preheated scrap temperature is about 250 - 300 degC - Fully enclosed automatic charging system to keep working floor clean. - Minimize scrap oxidation by temperature controlling - Material limitation free	68.8	-	5.72	- Reduction of dioxin emission, dispersing dust, & noise	-No limit of material for high quality products as like stainless steel.	16.00	3.5
3	A-3	High efficiency oxy-fuel burner/lancing for EAF	- Supersonic or coherent burner - Accelerate scrap melting during melting stage - Facilitate slag foaming during refining stage over the bath	14.3	-	2.64	-	- Reduction of nitrogen in steel for quality improvement	2.05	2.0
4	A-4	Eccentric bottom tapping (EBT) on existing furnace	- Slag free tapping - Reliable stopping and scraping mechanism	15.8	-	2.15	-	- Increase in Fe & alloy yield, productivity - Improve steel quality	4.00	3.7
5	A-5	Ultra high power transformer for EAF	- Long arc by high voltage and low ampere operation - Water cooled wall-panel to protect refractories	15.8	-	2.15	-	- Productivity increase	5.44	5.3
6	A-6	Optimizing slag foaming in EAF	- Proper chemical ingredients of slag - High efficient burner and/or lance - Controlled OE & C injection into EAF proper position - Keeping slag thickness with air-tight operation	6.0	-	8.86	- Noise reduction & working floor cleaning	-	1.50	3.5
7	A-7	Optimized power control for EAF	- Data logging and visualization of melting process - Automatic judgement on meltdown and additional scrap charge - Automatic phase power independent control for well-balanced melting	15.8	-	2.15	-	- Productivity increase - Manpower saving	2.50	2.3
8	A-8	Operation support system with EAF meltdown judgment	Automatic Rapid Melting system - Data logging - Optimum electric power control - Alloy calculation	6.0	-	8.74	-	- Productivity increase - Manpower saving - Operation standardization	8.65	1.5
9	A-9	Low NOx regenerative burner system for ladle preheating	- Regenerating burner use - High Energy Saving (about 40 %) - Automatic control - FOI Combustion	-	0.20		- NOx reduction	Contribute to better atmosphere around at workfloor	0.40	0.2
10	A-10	Oxygen burner system for ladle preheating	- Rapid and high temperature ladle heating by oxygen burner - Automatic control - High Energy Saving (about 40 %)	-	0.20		- NOx reduction	Contribute to better atmosphere around at workfloor	0.30	0.2

Source : ASEAN Technologies Customized List 2023 version Part-1 : EAF (v. 4.0)

A-9	A. Energy Saving for Electric Arc Furnace (EAF) **Low NOx regenerative burner system for ladle preheating**
Item	**Content**
1. Process Flow or Diagram	
2. Technology Definition/Specification	While one of the burners is burning, the other burner will work as an exhaust outlet. The exhaust gas is discharged from the system after the waste heat of the gas is recovered so that the temperature of the gas will be lowered to the extent that there will be no condensation in the regenerator. The combustion air receives heat from the regenerator. Therefore, the combustion air will be preheated to a super-high temperature (i.e., 90% of the temperature of the exhaust gas or over) before the combustion air is supplied to the burner. When the preset cycle time elapses, the burners exchange their roles of combustion and exhaustion.
3. Expected Effect of Technology Introduction • Electricity Saving	-
• Thermal Energy Savings	40 % fuel saving is expected comparing to existing preheater with conventional burner. 900 m3N natural gas in 6 hour burning for 80 ton ladle consumes about 40 GJ ---> 0.5 GJ/ton-steel x 40 % = 0.2 GJ/ton-steel save
• Environmental benefits	Low NOx
• Co-benefits	Higher brick temperature can allow lower tapping temperature for energy saving at EAF. Improving meltshop atmosphere by reducing hot gas which disturbs dirty gas suction at the canopy
4. Japanese Main Supplier	Chugai-Ro, Nippon Furnace
5. Technologies Reference	
6. Comments	-

5.3) Participation with Decarbonization network

5.3.1) Thailand carbon neutral network (TCNN)

1) The Thailand Greenhouse Gas Management Organization (Public Organization) or TGO has established the Thailand Carbon Neutral Network (TCNN) in collaboration with Climate Neutral Now under the UNFCCC to promote cooperation in all sectors to enhance GHG reduction and aim for net-zero GHG emissions, in line with the global community's intentions as stated in the Paris Agreement on climate change.
2) Currently, there are 543 members of the Thailand Carbon Neutral Network (December 2023). Many organizations that have expressed their intention to become Carbon Neutral organizations, including companies in the industrial sector, have joined as members.

Member of TCNN

Source: Thailand carbon neutral network (TCNN)

5.3) Participation with Decarbonization network

5.3.2) Hydrogen Thailand club

Vision of Hydrogen Thailand

"To drive **HYDROGEN** AS A **FUTURE ENERGY PLATFORM** in decarbonized circular economy in Thailand"

Hydrogen Thailand

Expected Outcome

1. Hydrogen Roadmap for Thailand which can be a guidance for a believer, researcher, investor to initiate hydrogen-related projects in Thailand
2. Opportunities for Technology Implementation leading to a widespread information sharing and public awareness of hydrogen in Thailand
3. Hydrogen Ecosystem consisting of businesses along the value chain of hydrogen, eventually resulting in decarbonized circular economy in Thailand
4. Future Hydrogen Outlook which comprises of analytical data how hydrogen can be contributed in Thailand, resulting in a goal of hydrogen

Hydrogen Thailand Club (H2TH Club) is a group of experts in the private sector, both domestic and international, and the government sector involved in production, storage, and utilization. and hydrogen policy.

Member of H2TH club

The first collaboration was organized and announced in October 2020 as a group established jointly between the private and public sectors. To drive preparation for whole value chain in Hydrogen Ecosystem in Thailand.

Source: Hydrogen Thailand club (H2TH club)

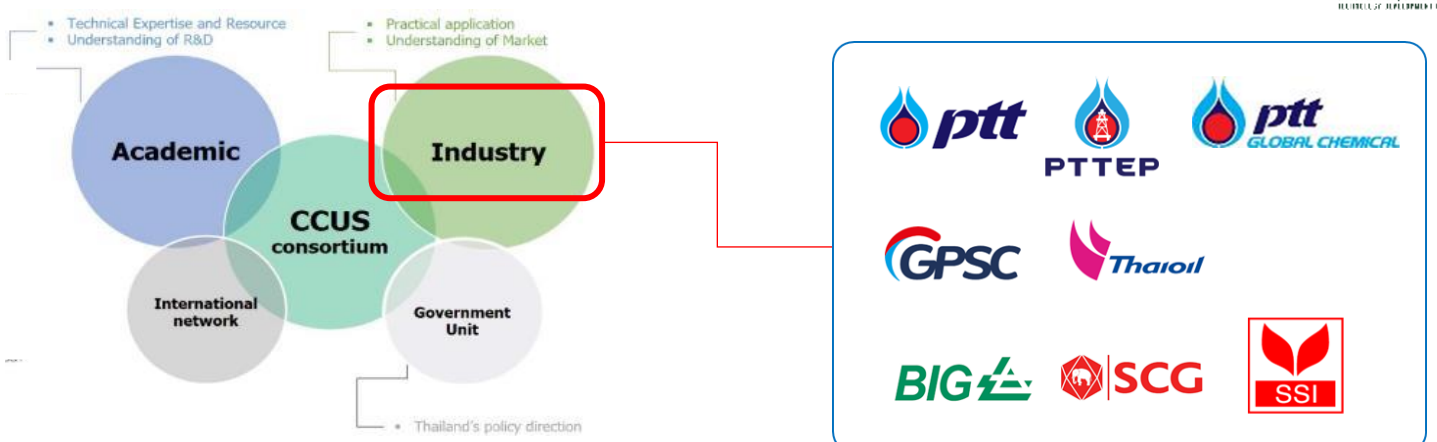
5.3) Participation with Decarbonization network

5.3.3) CCUS Consortium

- Established to support the development and research of CCUS (Carbon Capture Utilization and Storage) Technology to occur in Thailand effectively from the research level to the commercial level.
- Currently, there are 8 industrial members participating, with BCGeTEC, Faculty of Engineering, Chulalongkorn University, acting as a link between the private sector and related government agencies, such as the Office of Policy and Planning, Ministry of Natural Resources and Environment (ONEP) and the Energy Policy and Planning Office, Ministry of Energy (EPPO).

Practices of Collaboration
Technology developments ❑ Cross-benefit ❑ Matching ❑ Research pairing
Knowledge Sharing ❑ Workshops ❑ Technology updates from experts
Direct Feedback from industries to regulatory bodies
Create public awareness

Structure of CCUS Consortium



Source: CCUS Consortium

5.3) Participation with Decarbonization network

5.3.4) Network of Thai Renewable energy association (RE-100)

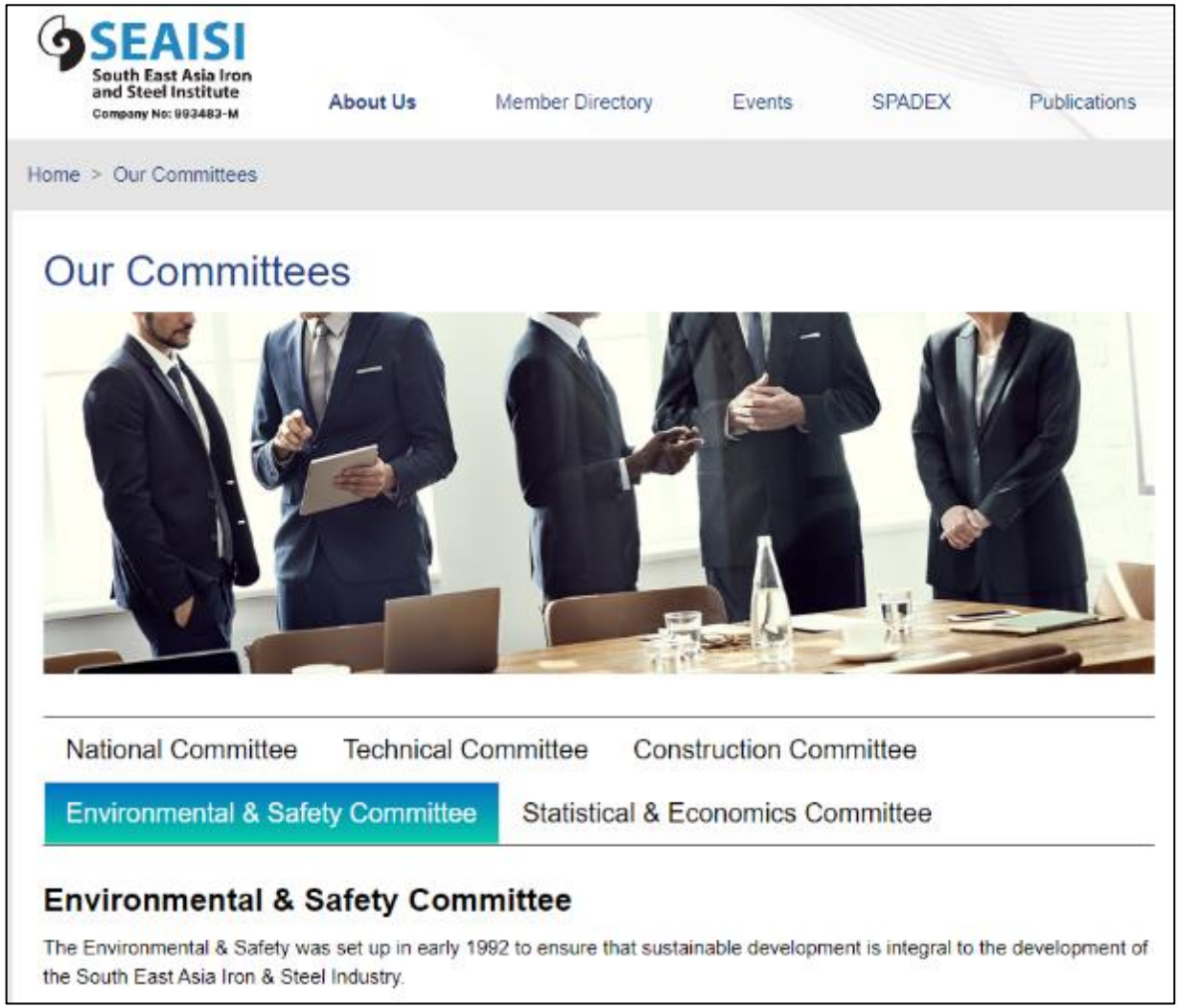
Member of Founder (RE-100)

Member of RE-100

Source : https://re100th.org/

5.3) Participation with Decarbonization network

5.3.5) Collaboration with ESCO : Environmental & Safety Committee (SEAISI)



Vision of ESCO : To be Center of contribution on Energy, Environment and Safety development for ASEAN Iron & Steel Industry

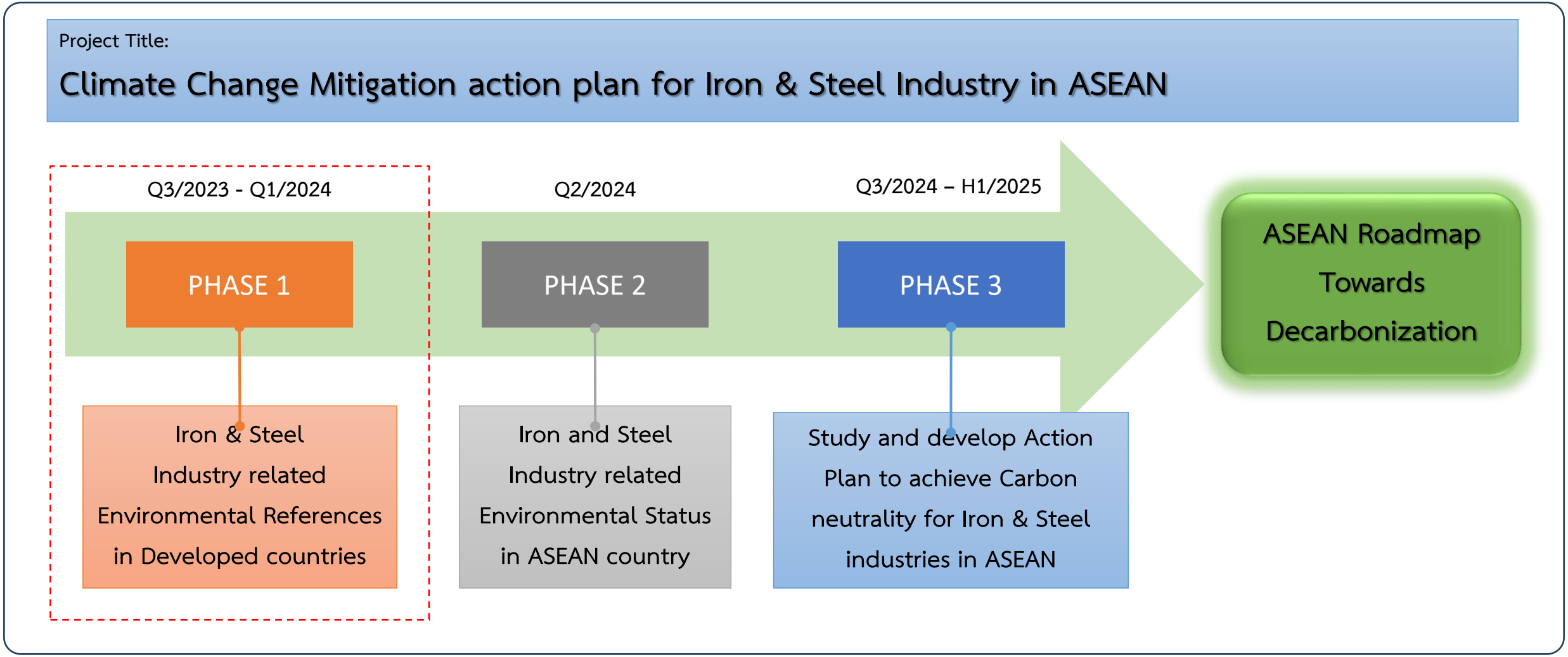
Mission :

1) Build up and promote sharing of information and good practice intra-ASEAN and globally on Energy, Environment and Safety.
2) Develop study & research projects on Energy, Environment and Safety Improvements
3) Set up activities / tasks to contribute and perform our role continuously.
4) Create network with Technical Associations or Institutes
5) Support ASEAN Iron & Steel Sustainability Forum and facilitate all preparations effectively.

Source : https://www.seaisi.org/our-committees

5.3) Participation with Decarbonization network

5.3.5) Collaboration with ESCO : Environmental & Safety Committee (SEAISI)



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Barriers and key challenges in developing steel industry towards Carbon neutrality

Barriers and key challenges in developing Green steel

1) Renewable energy supply
2) Regulatory framework, incentives and standardization
3) High quality raw materials
   - ❑ High grade iron ore
   - ❑ Good quality if steel scrap
4) Funding & Financing supports
5) End market demand

1) Renewable energy supply

Renewable energy sources and/or clean energy in sufficient quantities and at affordable prices are required to supply the EAF process, including as a primary energy source for producing Green Hydrogen for supplying the DRI process. The expansion of the Capacity of Renewable energy and the infrastructure of the clean energy power grid system still have limited production capacity and instability in the continuous supply of electricity produced from renewable energy. It may be necessary to invest in an energy storage system to be able to supply electricity continuously, but in exchange for higher electricity costs.

2) Regulatory framework, incentive and Standardization

Policies and regulations, as well as incentives, are effective tools through which government agencies can support the industry to accelerate decarbonization and achieve net zero targets. In addition, clearer and more stringent global requirements and standards for green steel and green hydrogen are being developed, which will help to clarify the definition of green steel products and create a common understanding between steel producers and consumers.

3) High quality raw materials

- ❑ High grade iron ore - DRI steel production requires high grade iron ore as raw material. According to the study report, only one-third of the world's iron ore has the suitable properties for the current DRI process.
- ❑ Good quality of steel scrap - EAF steel production requires good quality of scrap to support the increasing demand for product quality.

4) Financing

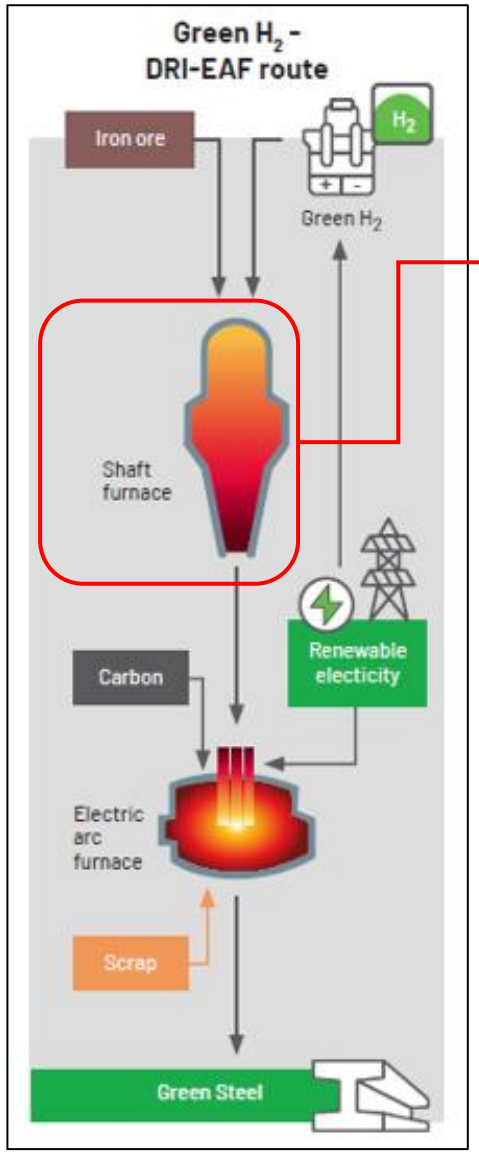
A significant amount of capital is required to decarbonize the iron ore and steel value chain, particularly in the area of investing in the replacement of existing steelmaking facilities with newer, cleaner technologies. As is commonly understood, the steel industry is not a high-margin industry, and thus financing is a barrier. However, the general view within the industry is that financing can be secured if the investments are less risky, if they use high-quality iron ore, use clean or green energy, or if end-user investors have agreements to purchase green steel as raw materials, etc.

5) End market demand

The demand for green steel continues to be a hot topic with a lot of discussions on how to create a mechanism for sustainability. Some examples of markets with demand for green steel include those with a commitment to decarbonize their supply chains, particularly in Europe.

ที่มา: Shell – Decarbonizing Steel: FORGING NEW PATHS TOGETHER by Deloitte, 2023

6.1) Renewable energy supply for Steel decarbonization



Green H2 and Renewable Energy Demand for H2-DRI-EAF Process

Renewable energy is important for replacing fossil fuel electricity in steel production. It is also the main energy source for Green H2 production. Shaft furnace steel production of 1 ton uses approximately 60 kg of H2. For a steel mill designed to produce 1 million tons of steel per year, it must have a H2 production process of 60,000 tons per year. Considering H2 production by Electrolysis process with an electricity consumption rate of 56 kWh/kg.H2 (at an efficiency of Electrolyzer 70%), a steel mill that wants to produce 1 Mton of steel per year will use approximately 3,377 GWh/year of electricity from Renewable energy to produce H2.

Key Factors to Consider in Green Steel Project Development

- ❑ The efficiency of the Hydrogen production system is the heart of H2 production, namely Electrolysis technology. The most popular systems are Proton Exchange Membrane (PEM) electrolyzer and Alkaline electrolyzer, which operate at 60% to 80% efficiency.
- ❑ Stability of Renewable power: The performance of the Electrolysis system is greatly influenced by the variability of renewable energy sources. Considering the electrolyzer capacity required for H2 production for a Green H2-DRI steel plant with a cap. of 1 million tons per year, it can vary significantly depending on the consistency of renewable energy. For example, if the capacity factor is 30%, the steel plant will require approximately 1,285 MW of electrolyzer capacity. However, if the capacity factor is 80%, the electrolyzer cap. may be reduced to only 482 MW.

Source: Green Steel Economics - Comparing Economics of Green H2-DRI and Traditional Steelmaking Around the World โดย Global Efficiency Intelligent [Published: July 2024]

6.2) Regulation/policy to serve Steel decarbonization

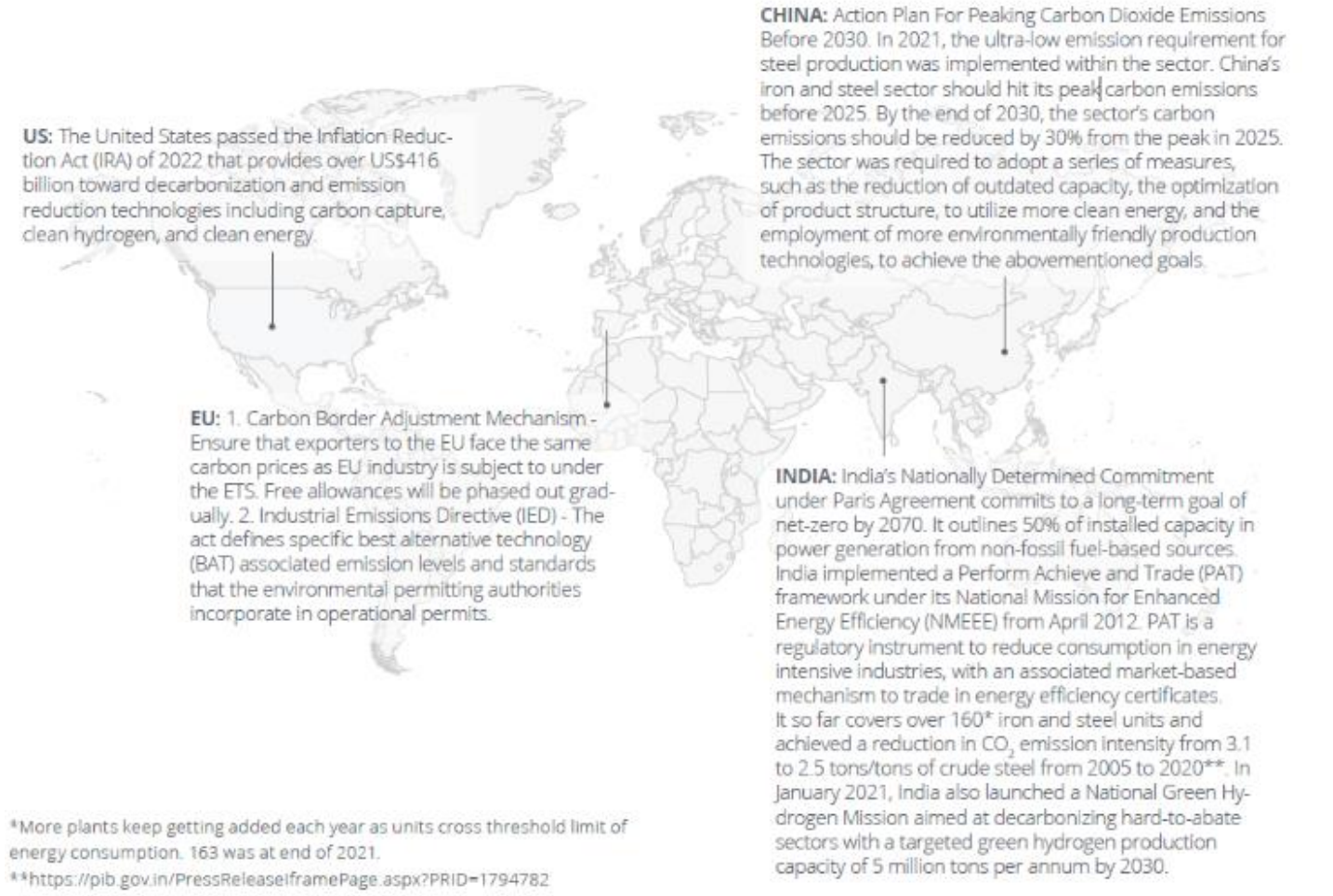


Figure 6.1: Selection of regional regulations influencing the decarbonization of the steel industry

Policies and regulations to promote and support the development of Green steel in countries with the Top 4 steel industries

- ❑ China: Action Plan to reduce CO2 Emissions Before 2030
  - ✓ 2021 Ultra-low emission requirements for steel production
  - ✓ Aim to reduce CO2 emissions 30% from 2025 by the end of 2030
  - ✓ Measures such as reducing outdated steel production capacity, promoting greater use of clean energy, and introducing environmentally friendly production technologies

USA: Under the Inflation Reduction Act (IRA) 2022, more than 416 billion USD has been allocated for the application of low-carbon steelmaking technologies, including CCUS, Green H2 and clean energy.

- ❑ EU:
  - ✓ CBAM
  - ✓ Industrial Emissions Directive (IED) – Specific Best Alternative Technology (sBAT) requirements related to Emission level and standard
- ❑ India: Net zero target in 2070
  - ✓ Increase ratio of renewable energy to be 50%
  - ✓ 2012: Promote the implementation of Perform Achieve and Trade (PAT) under the National Mission for Enhanced Energy Efficiency (NMEEE), whereby PAT is a market mechanism involved in the trading of Energy Efficiency Certificates.
  - ✓ 2021: India has announced National Green H2 and is targeting a Green H2 production capacity of 5 million tons per annum by 2030.

Source: Steel - Pathways to decarbonization by Deloitte, 2023

6.2) Regulation/policy to serve Steel decarbonization

Table 6.1: Green Hydrogen policy snapshot in some countries

Country	Policy Framework	Financial & Strategic Initiatives
China	Green H_2 Energy Plan	• Target of 80 GW electrolyzer capacity by 2030. • Expanding from alkaline to PEM electrolyzer technologies. • Reduction in renewable energy costs to make green H_2 competitive. • Comprehensive investment in green H_2 infrastructure. • Integration of H_2 in various sectors by 2035.
Japan	Basic H_2 Strategy	• Aims for 10% of the global electrolyzer market by 2030. • Plans to establish 15 GW of H_2 electrolyzer capacity. • Investment in various electrolyzer technologies. • Significant funding from the Green Innovation Fund. • International collaborations to secure green H_2.
South Korea	H_2 Economy Roadmap	• Developing 10MW scale H_2 electrolyzer technology by 2030. • Aims to enhance electrolyzer efficiency. • Strong emphasis on domestic supply chain for electrolyzer technologies. • Major financial investments in R&D. • Launch of pilot projects to scale green H_2 technologies at 0.25M tons capacity by 2030. • International cooperation and policy development support.
U.S.	National Clean H_2 Strategy	• Tax incentive under Section 45V of the Inflation Reduction Act. • Significant federal funding and R&D investments. • Expanding infrastructure for H_2 production, storage, and distribution. • Focus on efficiency and reducing production costs.
E.U.	EU H_2 Strategy	• Establishment of the European Clean H_2 Alliance. • Innovation Fund and European H_2 Bank funding. • Clear criteria for "renewable H_2" under Renewable Energy Directive. • First auction awarded €720 million to seven green H_2 projects in April 2024.
Brazil	National H_2 Program	• Green H_2 Bill creating a legal framework for production. • Development of the Low-Carbon H_2 Development Program. • Promotes use of green H_2 in various sectors. • "Regulatory sandboxes" for innovation in H_2 production.
Australia	National H_2 Strategy	• $2 billion H_2 Headstart program for large-scale projects. • Emphasis on technological innovation and domestic capabilities. • Investment in regional H_2 hubs through a $500 million program.

Hydrogen Ecosystem Development and Promotion Policy

China, Japan, South Korea, the United States, the European Union, Brazil, and Australia are driving Green hydrogen strategies through various policies and support measures that aim to grow this new industry to integrate the production and application of Green H2 in all sectors, including the Green steel industry through the Green H2-DRI process. Table 6.1 summarizes each country's hydrogen policies with various strategies related to financial incentives, promotion of technological development, and infrastructure development.

Source: Global efficiency intelligence-Green Steel Economics Comparing Economics of Green H2-DRI and Traditional Steelmaking Around the World, July 2024

6.2) Regulation/policy to serve Steel decarbonization

Policy and regulation to support Green steel

Green procurement policies

Governments can accelerate the transition to a low-carbon energy system by adopting green procurement policies to support demand, particularly for construction and infrastructure projects. Sustainable practices in this sector are often not low-cost in the short term. Using green procurement criteria can help offset the impact of the lowest-cost tender process. For example, in the Netherlands, construction and infrastructure businesses report that green procurement processes enable them to deliver low-carbon projects using materials with a low carbon footprint while remaining competitive. One construction company involved in a large European project said:

Green steel standards

There is currently no clear standard for low-carbon steel or Green steel. Existing green steel standards are based on emissions or manufacturing processes, and emission intensity criteria can vary from 2.5 ton.CO2/ton.steel to nearly zero (see Figure 6.2). Certification companies have confirmed the widespread interest in steel standards.

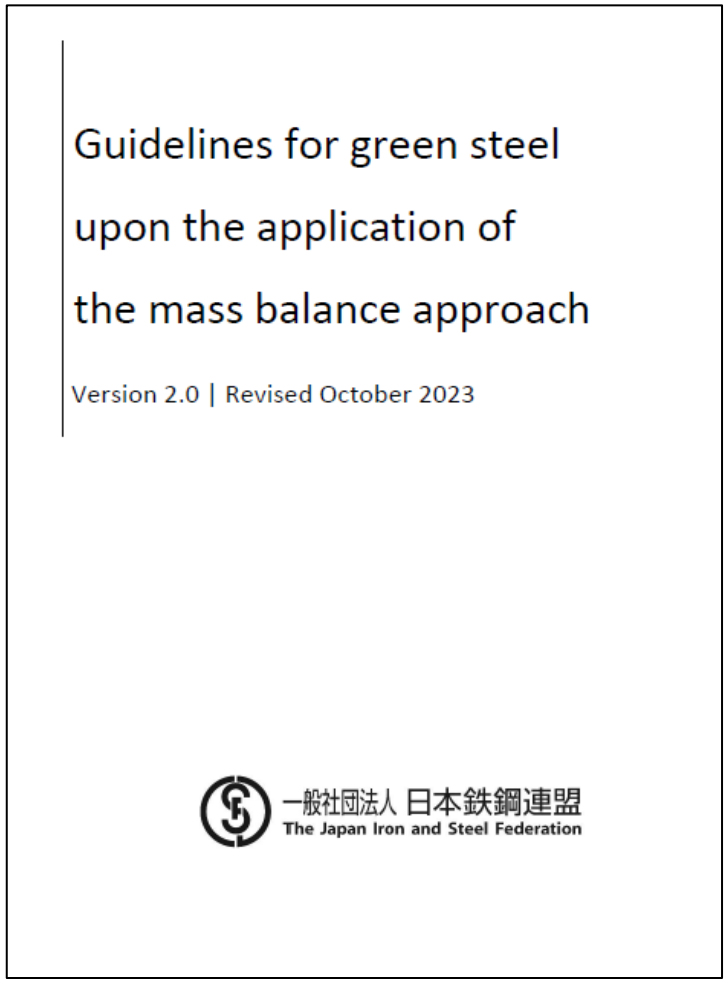
CERTIFICATE	TERMINOLOGY	DEFINITION	INVOLVED COMPANIES
ResponsibleSteel™	Responsible steel production and sourcing standard	A standard based on emission intensity (0.5t CO_2/t crude steel) for primary and secondary steel production and sourcing, validated through third-party audits	ArcelorMittal, U. S. Steel, Tata Steel, BHP, Mercedes-Benz Group AG, Volvo, etc.
XCarb™	Green steel certificates	Aggregated and verified carbon emission savings from a BF, converted into certificates based on mass-balance approach	ArcelorMittal, DNV
bluemint®	Climate-friendly steel certificates	Two products with lower CO_2 emission intensity through use of HBI1 in BF (0.6 t CO_2/t, lower when using H_2 in long-run) and scrap (0.75 t CO_2/t)	thyssenkrupp, DNV, TÜV
ENVIRONMENTAL PRODUCT DECLARATION	Fossil free steel	Internationally comparable standard with emission intensity per tonne of steel	SSAB coalition, EPD

Figure 6.2: Low carbon primary steel certification

Source: Shell – Decarbonizing Steel: FORGING NEW PATHS TOGETHER by Deloitte, 2023

6.2) Regulation/policy to serve Steel decarbonization

Example: Guideline of Green steel [Japan]



Guidelines for green steel upon the application of the mass balance approach

JISF proposes a method for assessing Green steel using the mass balance approach, which is a method of integrating GHG or CO2 emission reduction from emission reduction projects, and further implementing it by companies, allocating the emission reduction to any product, and providing steel products with a certificate that can reduce the customer's Scope 3 emissions.

The method consists of three steps:

1) First, calculate the GHG emission intensity of the steel product or CFP.
2) Second, identify the GHG reduction project and assess the amount of GHG emission reduction from that project.
3) Third, issue a certificate of emission reduction that does not exceed the total GHG emission reduction and deliver the steel products with a certificate of emission reduction.

All steps must be verified by a third-party certification body. This document explains the concepts, requirements, and general rules of this method.

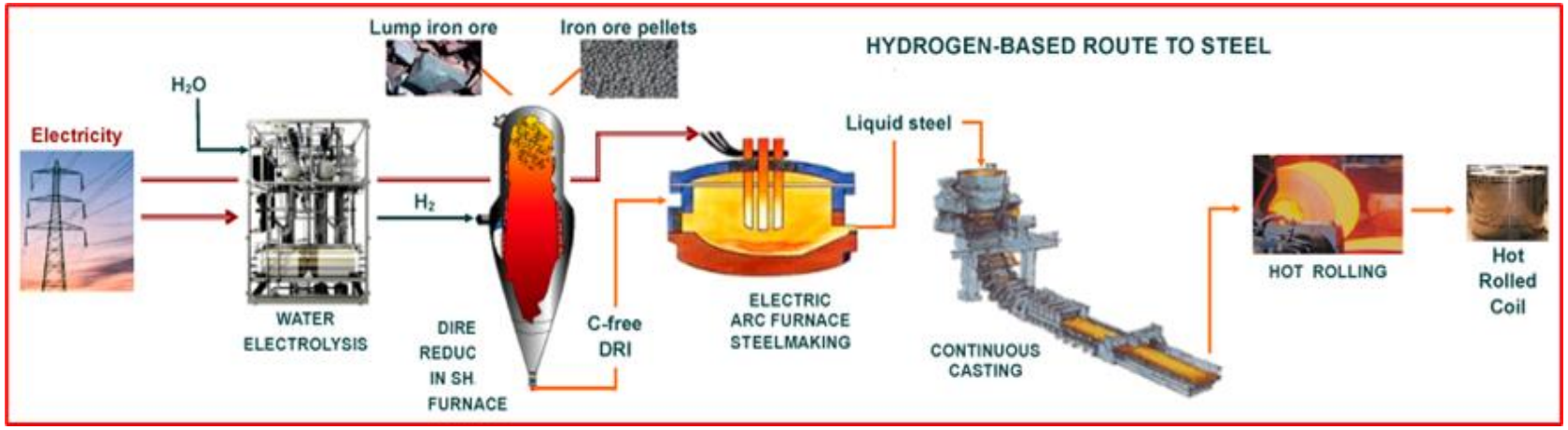
Source: https://www.jisf.or.jp/en/activity/climate/documents/Guidelines_231117.pdf

6.3) Funding & Financing supports for H2-DRI Projects

Table 6.2: A summary of financing details for various international H2-DRI projects

Project	Location	Equity Funding	Debt Financing	Subsidies	Total Funding
H_2 Green Steel (H_2GS)	Europe	€1.5 billion raised in equity for setting up operations.	Secured over €4 billion in debt in January 2024 to support construction and operations.	Awarded a €250 million grant from the EU Innovation Fund to aid in the development of green steelmaking facilities.	>€5.75 billion
Salzgitter AG - SALCOS®	Germany	Financing primarily through more than €1 billion of company's own funds.	None specified.	Received around €1 billion in subsidies from the Federal Republic of Germany and the State of Lower Saxony, specifically allocated for this pioneering green steelmaking technology.	>€2 billion
SSAB H_2 DRI - HYBRIT	Sweden	Predominantly funded by the owner companies—SSAB, LKAB, and Vattenfall.	None specified.	Granted SEK 3.1 billion (approximately US$ 282 million) by the Swedish Energy Agency's Industrial Leap program to support the establishment of a new H_2-DRI facility.	Significant proportion covered by owner companies
ArcelorMittal's H_2-DRI	Germany	No specific equity funding detailed.	None specified.	Benefited from a €1.3 billion state aid measure approved by the European Commission under the German Recovery and Resilience Facility (RRF), aligning with the EU's H_2 Strategy.	€1.3 billion
Thyssenkrupp's H_2-DRI Plant	Germany	Part of a broader €2 billion investment in decarbonization strategies by Thyssenkrupp.	Additional public and private funding expected to be raised to support the project.	None specified.	€2 billion+ expected
U.S. Department of Energy Project in Mississippi	USA	None specified.	None specified.	Swedish steelmaker SSAB plans to establish its commercial-scale HYBRIT facility with a green H_2 DRI in Perry County, Mississippi.	$500 million
U.S. Department of Energy Project in Ohio	USA	None specified.	None specified.	Cleveland-Cliffs' Middletown Works facility in Ohio is transitioning from coal-based ironmaking to hydrogen-ready DRI technology.	$500 million
POSCO's HyREX	South Korea	None specified.	None specified.	Technology development of HyREX, a fluidized bed reduction steelmaking with 100% hydrogen.	KRW 26.9 billion (USD 20.4 million) [2023-2025]

Source: (H_2 Green Steel, 2024; Salzgitter AG, 2023; Hybrit, 2023; European Commission, 2024; Thyssenkrupp, 2022; US DOE, 2024).



Funding for H2-DRI steelmaking projects is essential to drive project development, requiring an innovative combination of public and private funding sources, including subsidies, generous tax incentives, increased cost sharing to reduce private sector financial risk, and mutually beneficial private-private partnerships to create reliable demand for green steel products.

Example: H2 Green Steel (H2GS) is a good example of green steel development, with significant funding success for H2-DRI projects.

- ❑ In 2023, H2GS secured €1.5 billion through a fundraising drive to lay the foundation for the world's first green steel plant in Sweden.
- ❑ In 2024, over €4 billion in debt financing for Construction & Operations was secured.
- ❑ In 2024, the EU Innovation Fund also provided €250 million in subsidies.
- ❑ Strategic partnerships with major automotive companies such as Volvo and Scania, along with a supply agreement with Rio Tinto for high-grade iron ore. Ensuring strong demand and supply chain for H2 Green Steel's Green Steel products

Table 6.2 summarizes Green Steel related projects in various countries supported by investors, government funds and private sector collaboration.

ที่มา: Green Steel Economics - Comparing Economics of Green H2-DRI and Traditional Steelmaking Around the World โดย Global Efficiency Intelligent [Published: July 2024]

6.4) End market demand → Demand-side 'pull' mechanisms

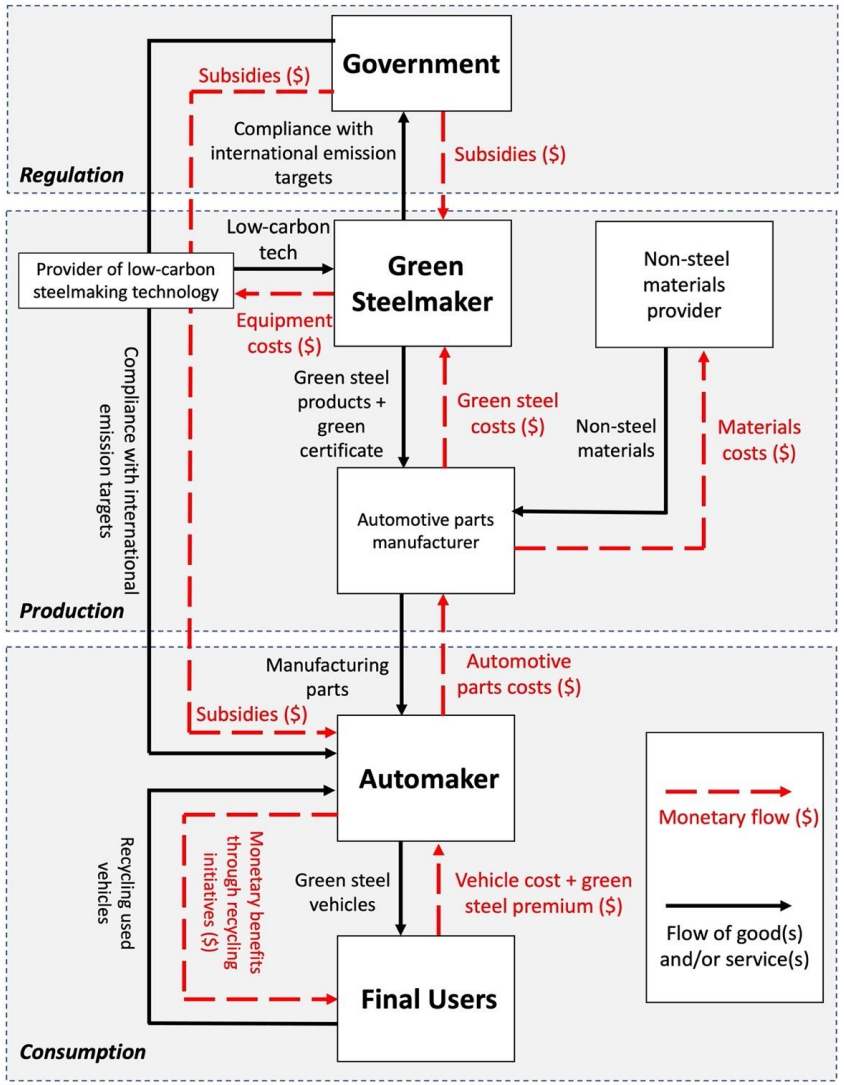


Figure 6.3: Business ecosystem of an automaker adopting green steel.

Demand-side pull mechanism: The green steel market is likely to be limited to environmentally conscious consumers who are willing to pay a premium for environmentally friendly products, which may be an opportunity for companies producing green steel products.

Although the development of the Green steel market is interesting, it may not be as successful as it should be due to the relatively high capital investment (CAPEX) and operating expenses (OPEX), making the cost of producing Green steel higher than general steel products (produced with Conventional technology) by about 20-50%. There should be significant supporting mechanisms and measures, including:

1) Policies/measures that promote and support some expenses for Green Steelmaker and Automaker that are sufficient for competitive business operations.
2) Transparent and reliable requirements and standards for Green steel product certification to build consumer confidence in the product and enable product traceability.
3) Using the concept of Circular Economy throughout the full lifecycle by creating a recycling mechanism after the end of its life, such as creating a mechanism for End users to return Used vehicles for recycling to Automaker, with the Automaker providing benefits to End users, etc.

Figure 6.3 summarizes some of the supply and demand mechanisms that support the adoption of green steel in the automotive sector.

Source: The Oxford Institute for Energy studies - Considerations for making green steel using carbon capture and storage (CCS) and hydrogen (H2) solutions [Published: May 2023]

6.4) End market demand → Demand-side 'pull' mechanisms

Table 6.3: Cross section of public green steel offtake agreements, as of October 2023

Company	Company headquarters	Sector	Steelmaker	Announcement date	Time supply commences	Destination of green steel
Bilstein Group	Hagen, Germany	Manufacturing	H2GS	Apr 2023	2026	Not disclosed
BMW	Munich, Germany	Automaker	H2GS	Aug 2022	2025	Not disclosed
BMW	Munich, Germany	Automaker	HBIS	Aug 2022	2026	Shenyang-made cars
Cargill	Minnesota, US	Multi-industry	H2GS	June 2023	Not disclosed	Not disclosed
Ford	Michigan, US	Automaker	TATA Steel Netherlands	Oct 2022	After 2030	Europe
General Motors	Michigan, US	Automaker	Nucor	Oct 2021	Q1 of 2022	Not disclosed
IKEA	Leiden, Netherlands	Retail	H2GS	Sep 2023	2026	Not disclosed
Mercedes-Benz	Stuttgart, Germany	Automaker	H2GS	June 2023	Not disclosed	Europe, North America
Mercedes-Benz	Stuttgart, Germany	Automaker	ThyssenKrupp	Apr 2023	2026	Not disclosed
Scania	Södertälje, Sweden	Automaker	H2GS	Jun 2023	2027	Not disclosed
Steel Processing Midlands (SPM)	Burntwood, UK	Steel processing	H2GS	Apr 2023	Not disclosed	UK
Volvo	Gothenburg, Sweden	Automaker	H2GS	Sep 2023	2026	Not disclosed
Volvo	Gothenburg, Sweden	Automaker	SSAB	May 2022	Q3 of 2022	Not disclosed
Zahnradfabrik Friedrichshafen (ZF)	Baden-Württemberg, Germany	Auto technology	H2GS	July 2023	2026	Not disclosed

Green steel offtake agreements

Offtake agreements, where consumers agree to buy unmanufactured material, have emerged as a key mechanism for driving demand for green steel and securing supply chains. Sectors including transport, automotive manufacturers and construction have shown significant interest in sourcing green steel using these agreements, demonstrating the depth and breadth of consumer demand (see Table 6.3).

These green steel offtake agreements, many of which are agreed by European companies, demonstrate the region's proactive stance on decarbonization, supported structurally by clear financial institutions and policies.

Countries with longstanding carbon emissions in particular need to take the lead and invest in green technologies.

Source: Forging pathways: Insight for the Green Steel transformation จัดทำโดย ACCR [Published in June 2024]

(7)

Guidelines for developing Thai steel industry towards "Green Steel"

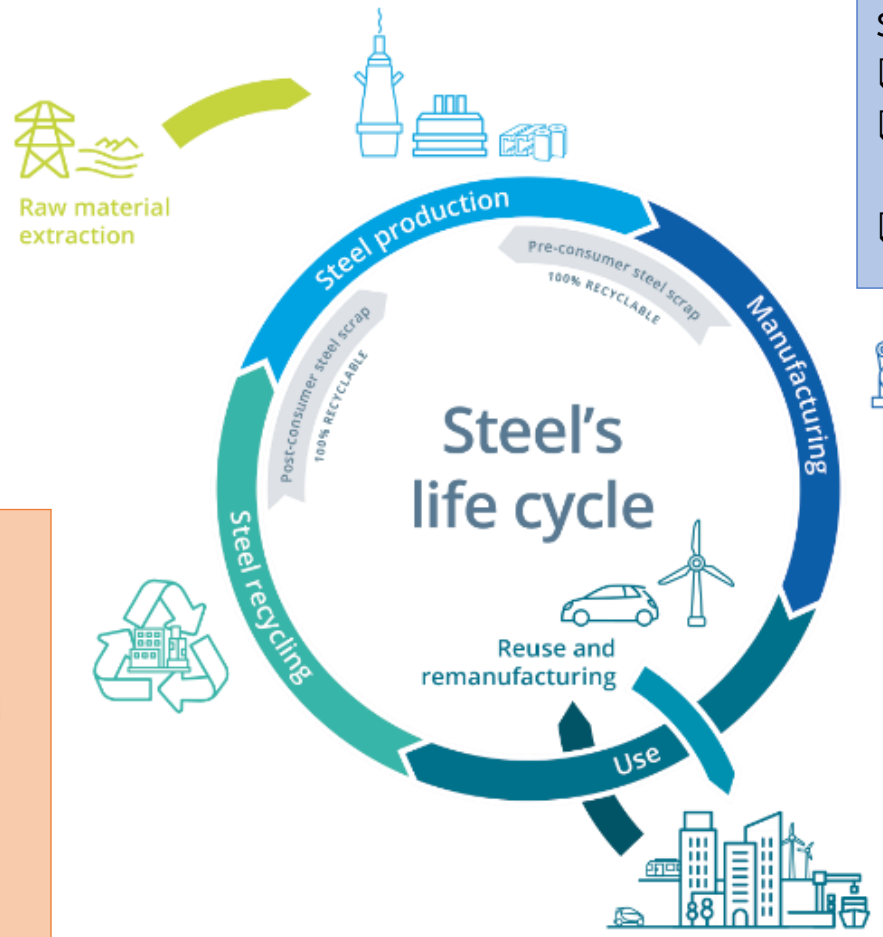
7.1) How to drive Green steel development

Development of the steel production process to Green Steel by promoting and supporting:

- ❑ Increasing energy efficiency of steel mills
- ❑ Applying BAT and Green steel technologies
- ❑ Energy transition to clean energy
- ❑ Using Green H2 in Steel mills
- ❑ Applying CCUS technology

Set up regulation to manage and control steel recycling,

- ❑ Establish guidelines/requirements for the management of steel scrap, equipment, and energy as a structure,
- ❑ organization/standards for components and scrap, and promote businesses that are important in the management of scrap such as cars, shipwrecks, etc.,
- ❑ establish standards for scrap steel.



Supporting Steel manufacturing by promoting:

- ❑ To use Green Steel as raw materials in steel manufacturers
- ❑ Increasing efficiency of steel material use in the steel processing
- ❑ Energy efficiency improvement and Energy transition

Maximize Green steel consuming and utilization by promoting:

- ❑ Green public procurement to consume Green steel and purchase Goods that were made by Green steel.
- ❑ Provide incentive to project developers to choose Green steel as a raw material for their projects such as construction works, infrastructure, etc.
- ❑ Set up regulation and standardize "End of life" management of scrap machinery, products, and others that contain steel as a component

Source: https://worldsteel.org/steel-topics/life-cycle-thinking/life-cycle-assessment-in-the-steel-industry/

7.2) Policy to promote and support Integrated energy transition

กลุ่มอุตสาหกรรมเหล็ก

Renewable energy & Bio-energy Ecosystem

Demand side

Electricity demand

Fuel
- HFO
- LPG
- Diesel
- Coal

Hydrogen (H2)

Infrastructure

Power grid and network
- ❑ National power grids system
- ❑ Private wire network system

Fuel Distribution Infrastructure
- ❑ Gas grid pipeline infrastructure
- ❑ Transportation systems such as Tube trailer, Truck

Limitation of Infrastructure to supply Fuel
- ❑ Gas grids are available only in Industrial estate
- ❑ For gas, there are several type and characteristic. For blending all together in gas line and separate at the end use that is costly and difficult

Supply side

Renewable Power supply

Green power from National grids (UGT, TPA, other..)

Renewable power generation (Solar, Wind, WTE and others)

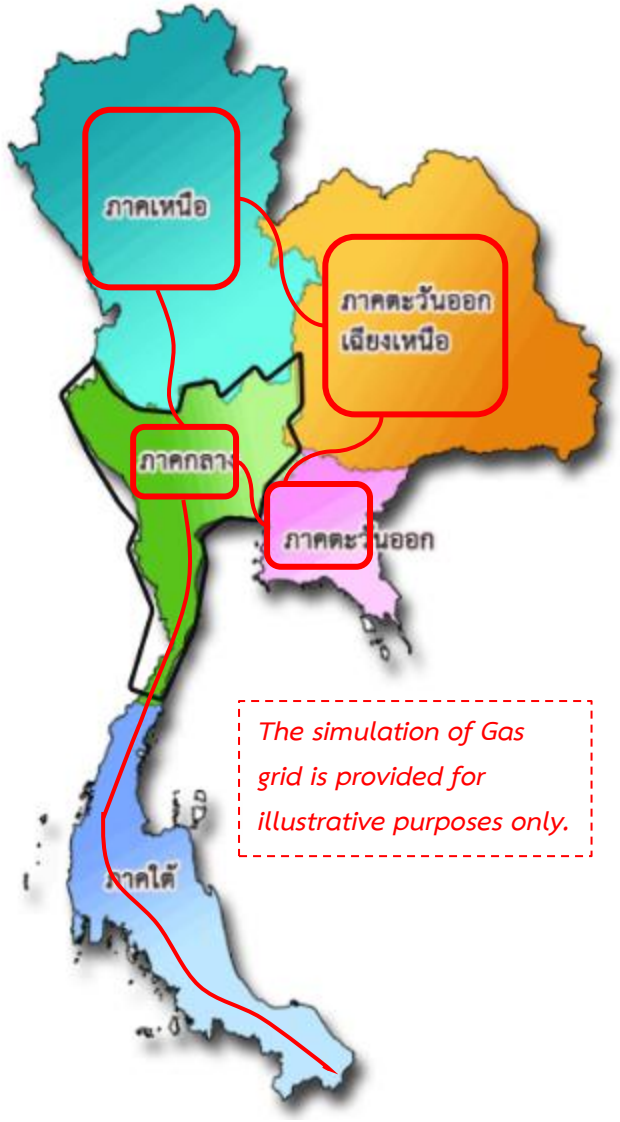
Bio-Energy & Alternative clean fuel supply

Biogas


Biomass


RDF or RDF Syngas

7.2) Policy to promote and support Integrated energy transition



Guidelines for promoting energy transition from fuels

- ❑ Long distribution: The development of “Clean fuel network infrastructure” that consists of gas grids for Bio-Methane and Green Hydrogen. The local gas producers of these fuels can produce fuels according to the quality of those gas grids and can be distributed to the system. Consumers who is located along gas grid can access to use clean fuel
- ❑ Local distribution: Promote the planting of energy crops, processing of agricultural waste and processing waste to energy for feeding to industrial sector, especially in areas near industrial plant areas (example in Saraburi Sandbox)

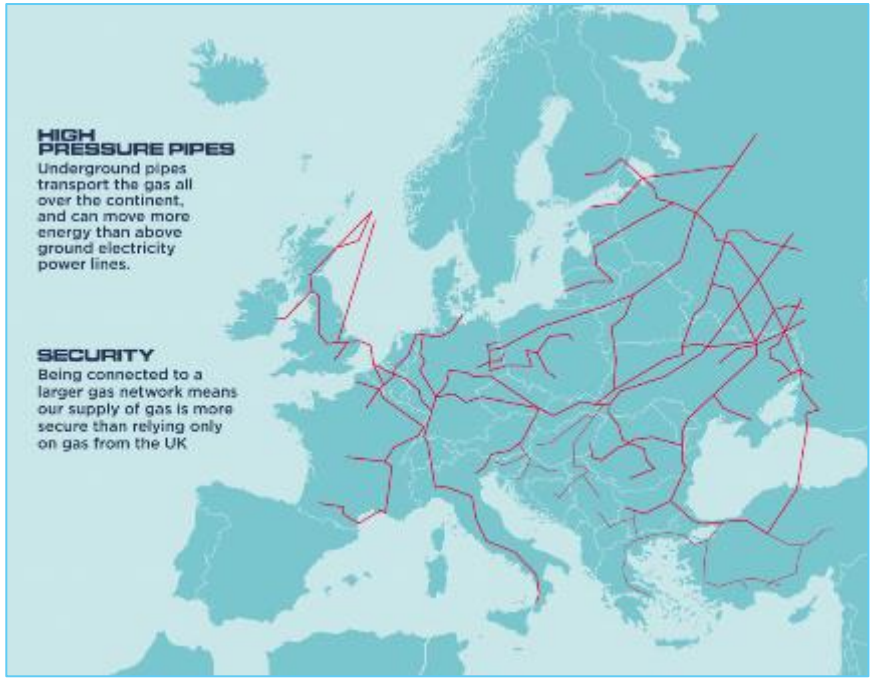
Guidelines for promoting the transition of electricity

- ❑ Promote and encourage the private sector and the public sector to produce renewable energy into the National power grid system and have a fair-trading system for all sectors.
- ❑ Promote the production of renewable energy by the industrial sector for its own use and purchase excess power, including unlocking various restrictions to promote the industrial sector to be a prosumer.
- ❑ Promote investment in energy storage systems for the industrial sector to maintain the stability of renewable energy, including promoting energy storage/storage businesses.

7.2) Policy to promote and support Integrated energy transition

The example of Gas grid development to serve Clean fuel for Industry

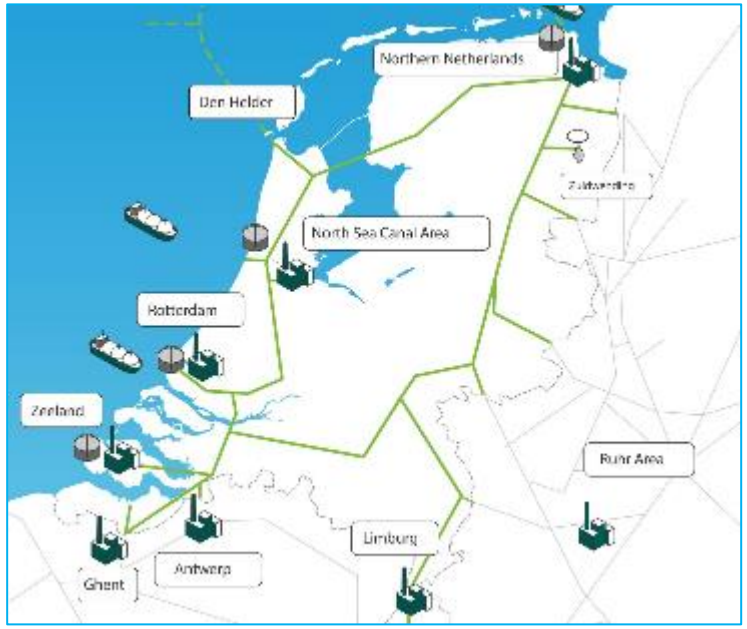
Gas Grid in Europe and UK



Source: https://ourfuture.energy/how-it-works/gas-grid/

The figure shows the main gas pipelines and gas transport routes across Europe. Sharing natural gas resources in this way makes for greater energy security, as every country can access as much energy as it needs, using resources available not only at home but also abroad.

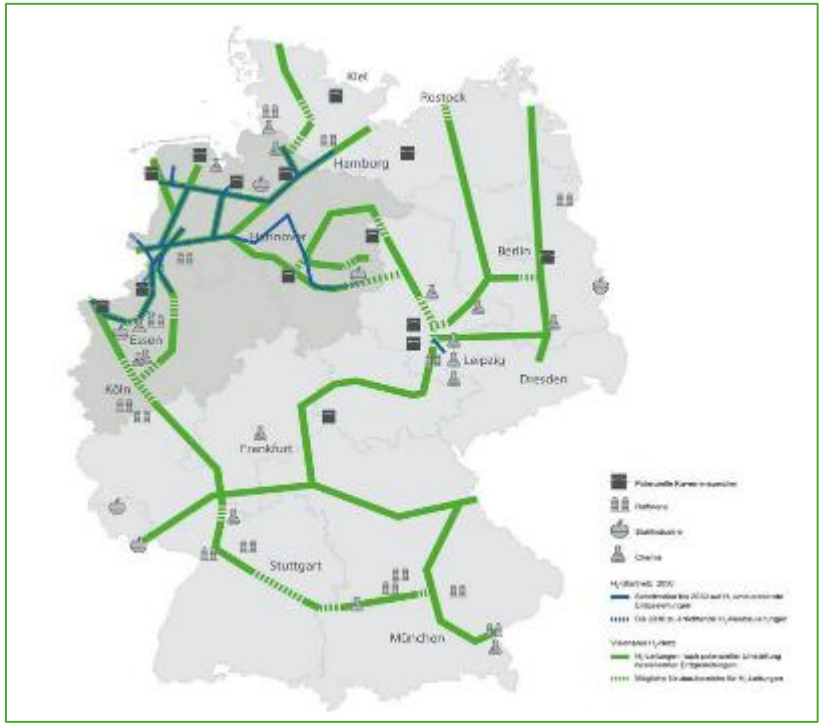
Hydrogen network Netherlands



Source: https://www.gasunie.nl/en/projects/hydrogen-network-netherlands

The H2 Network will provide hydrogen infrastructure to all industrial sectors and make the Netherlands the H2 Hub of Europe. The network is being built in phases, with a target of completion by 2030. The development of the network will mainly use existing NG pipelines. These pipelines will be ready for use, as natural gas transport is expected to continue to decline over the coming years, and only a few areas may be able to build new pipelines.

Germany's gas grid operators present concept for 2030 green hydrogen grid

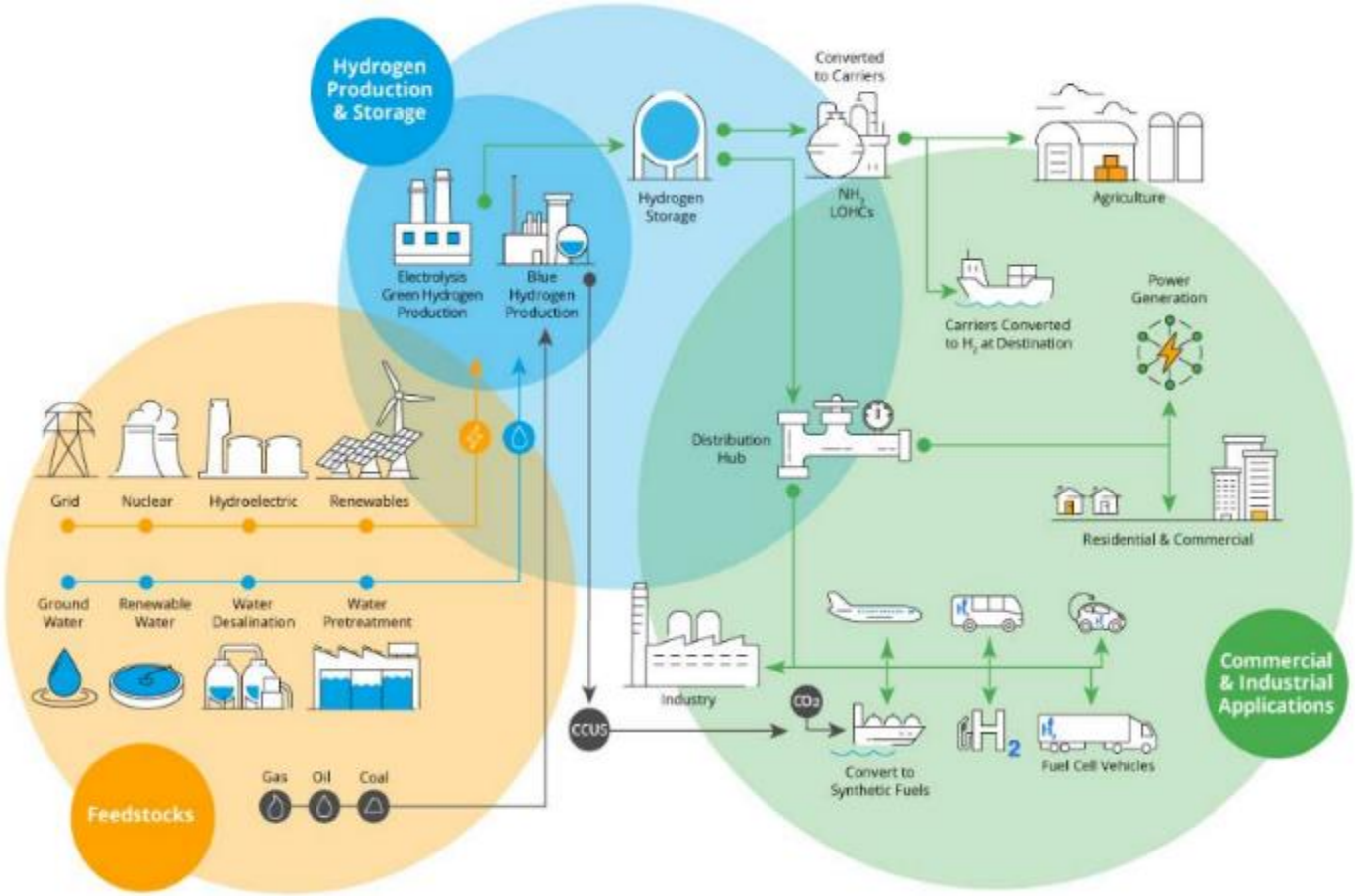


Source: https://www.cleanenergywire.org/news/germanys-gas-grid-operators-present-concept-2030-green-hydrogen-grid

Germany is developing a Gas grid for the transport of Green H2 by 2030. The network covering 1,200 km. will consist mainly NG pipelines(old) and will be built for new pipeline with a budget of EURO 660 million. Supporting industries such as steel or Chemical industry.

7.2) Policy to promote and support Integrated energy transition

Overview of Hydrogen Ecosystem



Source : https://www.bv.com/solutions/hydrogen/

Hydrogen ecosystem development policy

Based on H2 production from Water electrolysis and SMR and H2 value chain has a variety of hydrogen colors and many routes to produce and use hydrogen. Therefore, the preparation of hydrogen policies for Thailand shall consider the potential of Thailand's feedstocks and primary energy sources that are suitable in both quantity and quality, the infrastructure system for transporting/distributing hydrogen gas, and the application in each sector.

7.3) Promoting products/goods which are made by Green steel

Pain point

1) Definition of Green steel is not yet defined.

2) Conversion cost of Green steel would be raised or higher than conventional products that will be effect to end user.

3) Developers of infrastructure projects such as bridges, buildings, gas/fuel pipelines, renewable energy production structures such as wind turbines, solar farms still lack awareness of the sources of steel materials.

The concept of promoting the use of steel products and Green steel products

1) Establishment of Green Steel Standards and Requirements
   - ❑ Establishment of international standards and definitions of Low emission, Net zero steel or Green steel products
   - ❑ Identification of Green steel certification organizations/agencies
2) Development of marketing mechanisms for Green products
   - ❑ Green public procurement: Support/promote the government sector to use and purchase low emission and net zero steel in current and future projects.
   - ❑ Green material promoting: Support/promote the private sector to purchase/buy Green products in project development or product production, such as the construction industry, automotive industry, etc.
   - ❑ Encourage various business sectors to assess and report GHG emissions related to product production and have a plan to reduce GHG emissions to encourage the use of Green steel to reduce GHG emissions Scope-3

7.4) Promoting steel scrap management policy

Pain Point

- Exporting steel scrap abroad still carry on, even though domestic demand for steel scrap is high, and the availability of steel scrap is not enough to meet demand
- Policy and regulation of management process for metal scrap from machinery, vehicles, products that contain steel, including metal scrap from various infrastructure systems such as bridges, buildings, gas/oil pipes, etc. Some of these things that are collected and sorted for recycling, but some do not have clear processes and regulations to regulate and control in collection process to the sorting process for recycling.
- Recycling businesses related to the upstream process of steel crap, such as Decommissioning, Ship breaking, ship recycling businesses, are still few and some do not yet exist.

Guidelines for promoting scrap metal management for recycling

1) Shall have policies & regulations to prohibit or limit the export of steel scrap abroad while the demand for steel scrap in the country is still insufficient.
2) Shall have policies and regulations related to the management and separation of scrap metal for recycling, or a "scrap metal recycling policy", by promoting the user and consumer sectors of steel products to have efficient management from the beginning, along with creating a process to ensure that steel can be easily collected and recycled.
3) Promote the development of businesses that collect scrap metal and separate it for recycling, such as ELV vehicle scrap management businesses, Ship recycling businesses, Decommissioning businesses (emphasizing the quantity and quality of scrap metal).

7.4) Promoting steel scrap management policy

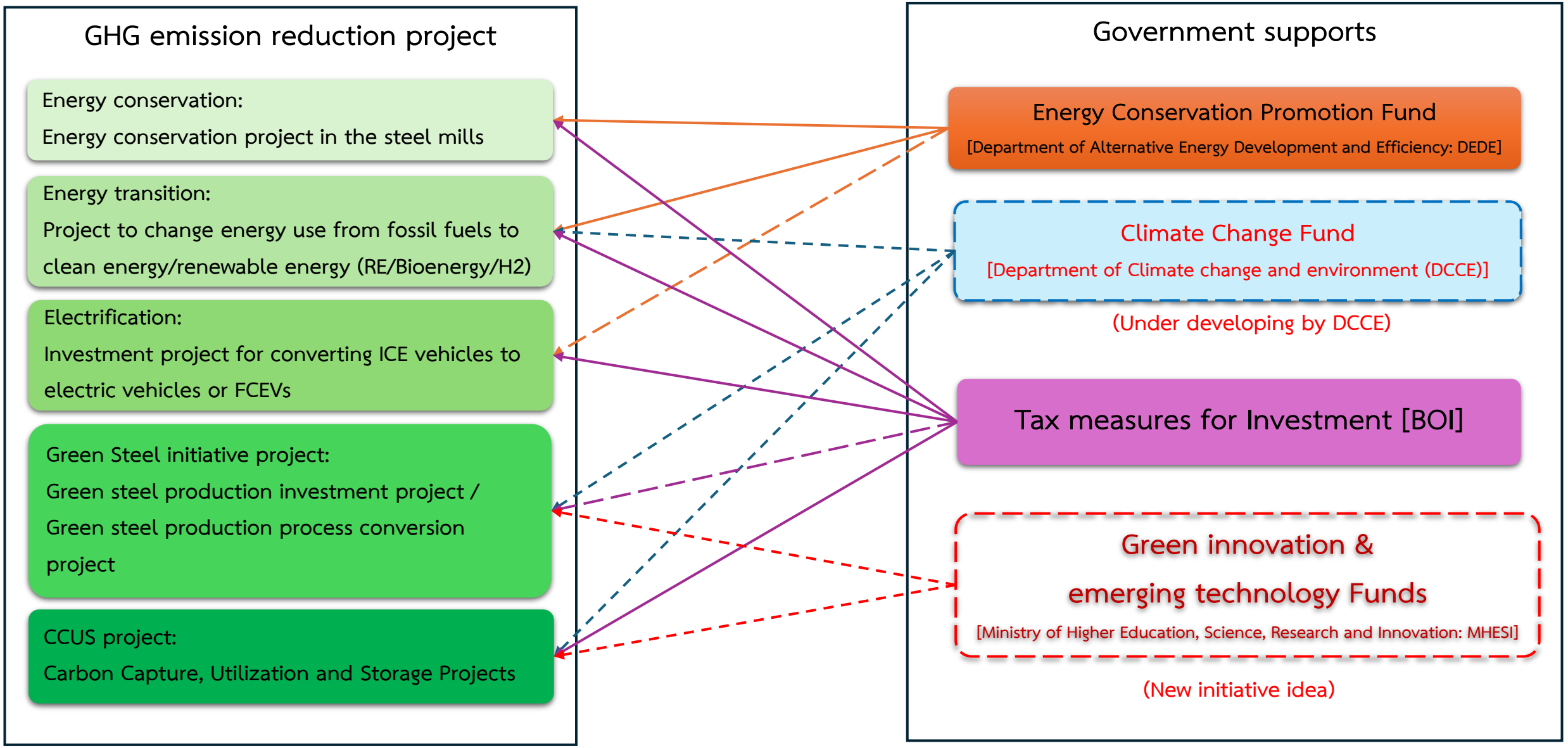
There are 43 countries around the world have restricted the export of ferrous scrap abroad.

The scope of the scrap export restriction policy has expanded, currently (as of 2022) in force in 43 countries, with the revision of the Waste Shipment Regulation in the European Union in January 2023, and related measures in Mexico, which will result in approximately 71 countries or developing countries worldwide.

Countries that have banned or restricted the export of scrap abroad, there are now 43 countries worldwide, including India, China, Russia, Indonesia, Malaysia, Vietnam and most countries in the Middle East. Currently Thailand, there is no policy and measures to restrict the export of ferrous scrap.

Source: https://gmk.center/en/infographic/43-countries-of-the-world-limit-the-export-of-scrap-metal-and-every-third-of-them-prohibits-it/

7.5) Funds/financial to support investment in Green technology



7.6) Promoting the development and investment of CCUS

Obstacles and limitations in project development of CCUS

Carbon capture technology is quite proven and has been applied in industrial scale, but the cost of capturing CO2 is quite high at around 50 USD/ton.CO2

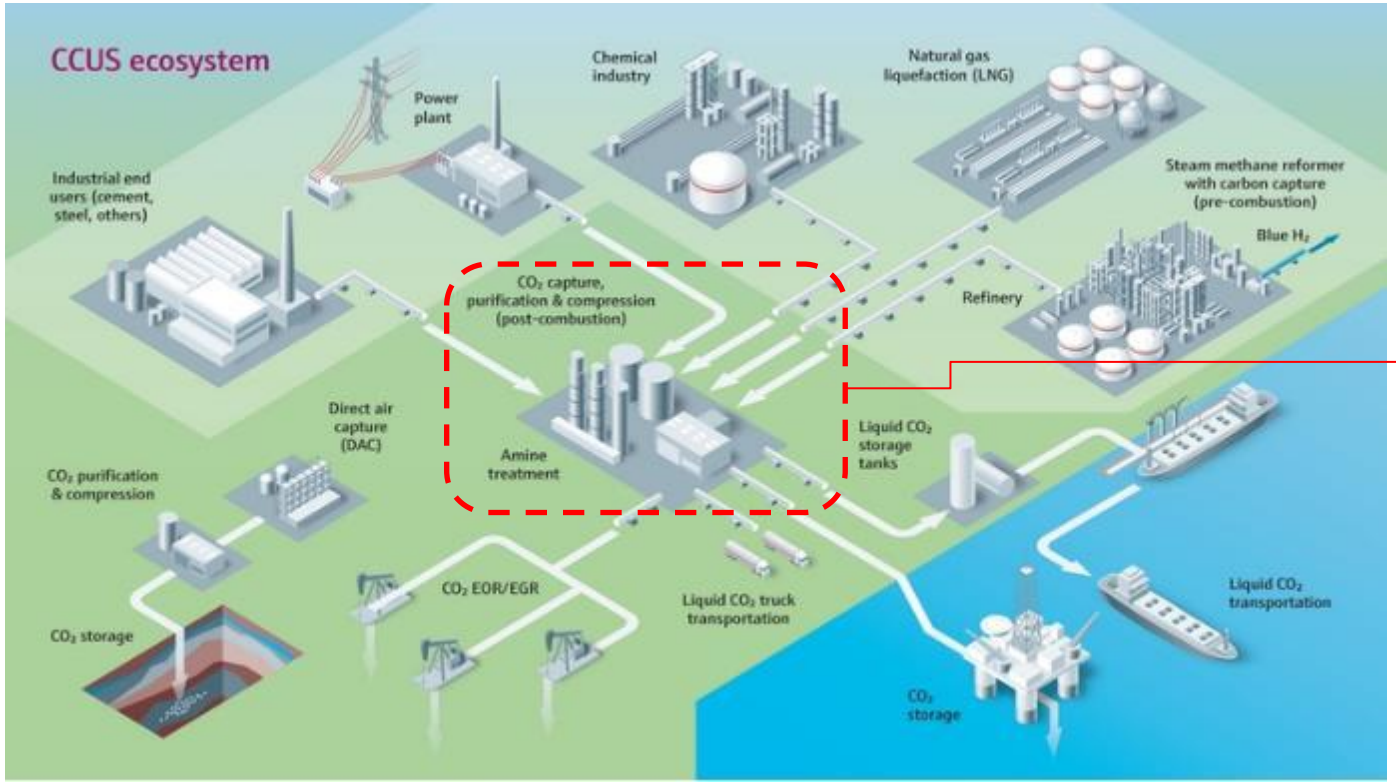
CCU: CO2 utilization technology is quite diverse, depending on the context of the company who develops project to convert CO2 into what type of Carbon recycled product, such as Building materials, Synthetic fuel, e-fuel, etc., but the production cost is still higher than conventional products.

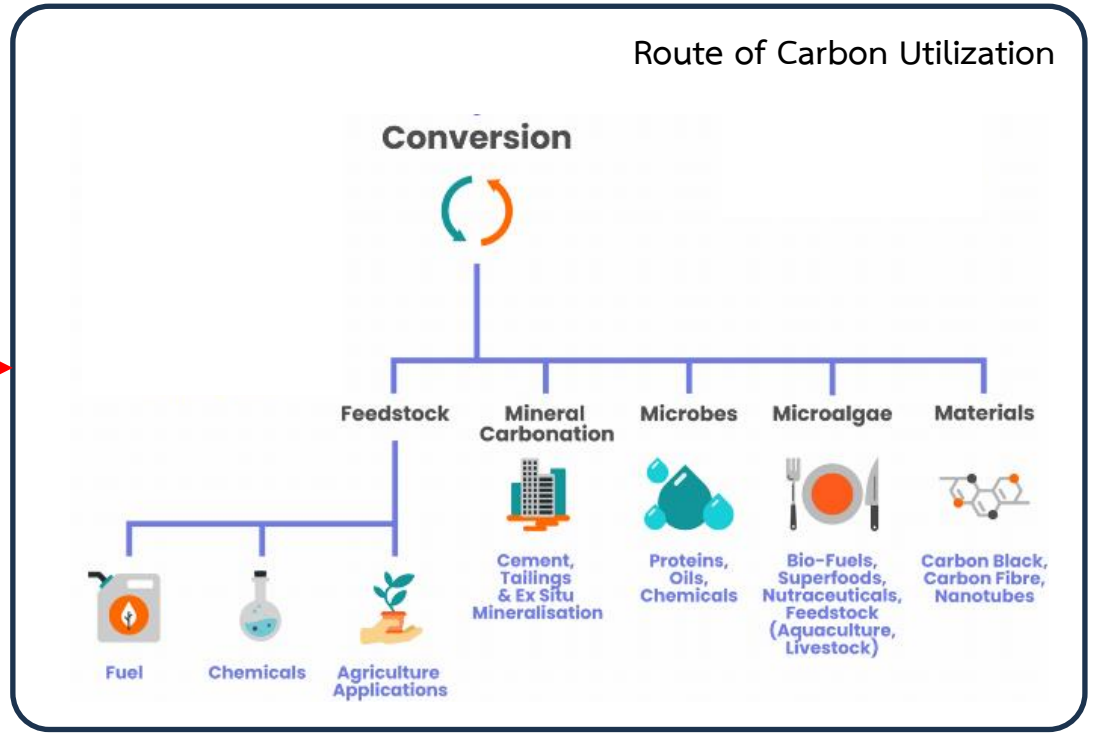
CCS: The technology of CO2 storage in underground rock formations or old underground oil wells is considered to have begun commercial use. However, there is a spatial limitation that must be close to the well used to store CO2. Therefore, there must be an infrastructure to transport CO2 to the point where the CO2 storage service is provided.

Guidelines for promoting the development and investment of CCUS projects

1) Shall have a policy to promote and support investment in CCUS development projects, such as:
   - ❑ Promoting research/development of CCU projects
   - ❑ Promoting pilot projects/demonstrating the application of CCU
2) Shall have policies to promote the development of CCUS infrastructure and ecosystems, such as:
   - ❑ Promoting the development of carbon capture and storage infrastructure (CCS)
   - ❑ Promoting the CCU ecosystem to support the production of products from CO2 recycling
3) Participate in the study and preparation of the White Paper of "Thai Industrial CCUS Development Plan" through the Thailand CCUS Alliance (TCCA) network.

7.6) Promoting the development and investment of CCUS





Above simulation of an industrial group that can bring waste gas or polluted air from various processes into a centralized CO2 capture system to capture or utilize the CO2, which allows for the cost sharing of capturing and utilizing or storing large quantities of CO2.

- ❑ Carbon Capture & treatment Technology solution center – A center for capturing and treating CO2 before sending it to storage or utilization.
- ❑ Carbon Utilization solutions: Receiving CO2 to transform it into Carbon recycled products that are appropriate for the market demand in the area, such as Synthetic fuel, Building materials, etc.

Source : https://www.us.endress.com/en/industry-expertise/oil-gas-marine/ccus-technologies-in-oil-gas-industry

7.7) Promoting investment of Green Steel production projects

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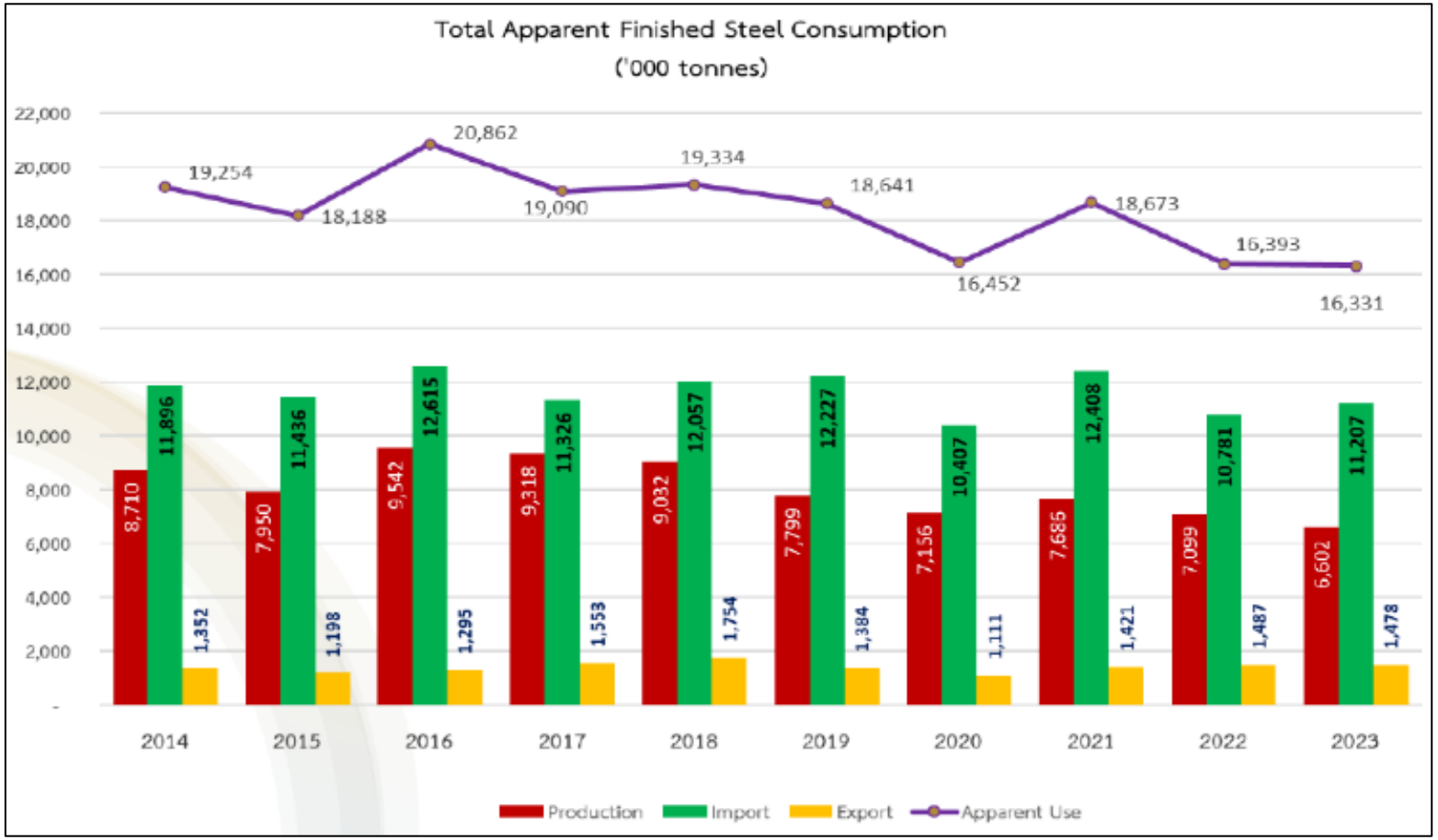
The consumption demand of steel products in Thailand over the past 10 years



Guidelines for promoting investment in Green Steel development projects

1) Shall build up policies to promote and support investment in Green steel
2) Shall have a policy to promote the production and use of Green Hydrogen, including a plan to develop the infrastructure of the Hydrogen ecosystem.
3) Shall have measures to promote the ability of domestic steel producers to change the steel production process from the traditional to the Green steel production process.
4) Create cooperation between the public and private sectors and the research/development unit sector in studying the "Green Steel development roadmap in Thailand" to be a White paper to drive the steel industry towards carbon neutrality.

Scrap base steel production is not enough to meet consumption demand in Thailand. At present, the amount of scrap steel that can be collected for recycling is only 20-25% of total steel consumption, or about 4-4.5 million tons. There should be a new steel production process using Green Steel technology.

Source: Iron and Steel Institute of Thailand (ISIT)

Acknowledgments

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Thank you for your kind attention