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臺灣鋼鐵業低碳轉型政策組合研析

Policy Mix for Low-Carbon Transition of Iron and Steel Industry in Taiwan

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兩年多來投入本研究，源於先前工作與鋼鐵產業之間的一份特殊情誼。起初，我對研究主題的想像僅是出於對鋼鐵業減碳路徑的好奇；隨著研究逐步展開，關注也擴展至整體產業體系的去碳化與低碳轉型，並在過程中深刻體會工業去碳化研究的迷人之處。

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中文摘要

鋼鐵產業約占全臺灣溫室氣體排放量之十分之一，屬於典型的「難減碳排產業」。面對 2050 年淨零排放目標，鋼鐵業的低碳轉型不僅仰賴單一技術突破，亦涉及生產系統、基礎設施與市場機制等層面的結構性調整，需要政策組合促進並推動低碳轉型。

本研究結合量化的淨零減碳目標與質性的結構性因素，評估臺灣鋼鐵產業在低碳轉型過程中的關鍵落差。研究以符合淨零轉型路徑之轉型基準為分析起點，並引入涵蓋技術、基礎設施、市場需求、資本與政策等五大支柱的分析架構，透過文獻回顧與國內外專家半結構式訪談，系統性檢視臺灣鋼鐵業的轉型現況與限制條件。研究也進一步運用多層次視角理論(multi-level perspective, MLP)，分析外部地景壓力、體制鎖定與利基創新發展不足等因素，如何交互作用並形塑台灣鋼鐵低碳轉型瓶頸。

研究結果顯示，臺灣鋼鐵產業目前仍缺乏關鍵淨零基礎設施之跨架構整合規劃，且現行技術路徑規劃與長期淨零目標之間存在明顯落差。在體制層面，國營事業的治理結構使企業同時承受獲利要求與減碳期待，進而強化對既有高爐體系的路徑依賴，此舉也延伸產業供應鏈不穩定性形成產業安全的疑慮。體制內行動者對於轉型的基礎設施需求與國家策略連結低落，亦影響轉型策略積極度。此外，外部地景壓力雖已顯示轉型的機會之窗，但整體而言仍不足以有效鬆動既有體制，使利基創新得以突破制度鎖定並進入主流。

基於上述發現，本研究提出一套契合企業投資週期之具有時序性的政策組合，以支持鋼鐵產業之低碳轉型。政策建議聚焦於氫能為基礎的煉鋼技術作為核心轉型利基，優先推動關鍵基礎設施如氫能、再生能源的前期整合規劃，以及需求端機制建構如綠鋼定義、公共採購。於 2030 年後透過穩定的跨產業基礎設施制度架構，以及強化綠色公共採購與永續金融工具，引導低碳技術與制度向體制核心擴散。

整體而言，本研究不僅系統性呈現臺灣鋼鐵產業在低碳轉型過程中所面臨的結構性挑戰，亦提出具政策可行性之轉型路徑。研究結果顯示，鋼鐵業的低碳轉型不僅是回應全球淨零趨勢、更是推動產業升級並強化產業韌性的重要策略。

關鍵字： 工業去碳化、鋼鐵業、多層次視角、政策組合

Abstract

The iron and steel industry accounts for roughly 10% of national GHG emissions in Taiwan. As a hard-to-abate sector, achieving net-zero emissions by 2050 will require not only advances in low-carbon technologies but also broader structural transformations and a coherent policy mix.

This study draws from a transition benchmark aligned with net-zero trajectories and applies a five-pillar framework—technology, infrastructure, demand, capital, and policy—to assess Taiwan's iron and steel industry decarbonization progress. Based on literature review and semi-structured interviews with domestic and international experts, the research examines systemic barriers through the multi-level perspective theory, illustrating how landscape pressures, regime lock-in, and niche underdevelopment collectively limit transformative changes.

The findings show that Taiwan's steel industry lacks a cross-architecture integration plan for key net-zero infrastructures, and that current technology choices remain misaligned with long-term net-zero goals. Structural constraints linked to state-owned enterprise governance and an insufficiently opened window of opportunity further limit transformative change. Building on these findings, the study proposes a policy mix aligned with corporate investment cycles to support systemic reconfiguration—prioritizing hydrogen-based steel making technology, foundational infrastructure planning, and demand-side mechanisms, followed by post-2030 diffusion through stable hydrogen and CCS frameworks and strengthened green procurement.

Overall, this research provides a comprehensive evaluation of Taiwan's steel sector transition

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challenges and offers actionable pathways for accelerating decarbonization. It further highlights that low-carbon transition for iron and steel industry is not only a climate agenda but also a strategy for industrial upgrading and industrial resilience amid global net-zero restructuring.

Keywords: industrial decarbonization, iron and steel industry, multi-level perspective, policy mix

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1. Introduction

The iron and steel industry is widely recognized as one of the most hard-to-abate sectors, posing a significant challenge to global efforts toward achieving sustainable development goals. Globally, the sector accounts for approximately 7–9% of total greenhouse gas emissions. In Taiwan, the manufacturing sector is the primary source of national emissions, contributing 50.78% of total greenhouse gas emissions in 2023. Within manufacturing, around 20% of emissions originate from the metal industries, including the iron and steel sector. Consequently, decarbonizing the steel industry is essential for Taiwan's achievement of the 2050 net-zero target.

There are several features for this industry which make it classified as hard to abate sector: high heat requirements, using carbon as a process input, low profit margins, high capital intensity, long asset life, and trade challenges (Kim et al., 2022).

As figure 1 shows, according to the International Energy Agency (IEA), achieving net zero by 2050 requires significant changes in foundational industrial materials, including steel. By 2030, at least 10% of steel production must come from innovative pathways, and by 2050, the proportion of traditional processes should be reduced to less than 20%.

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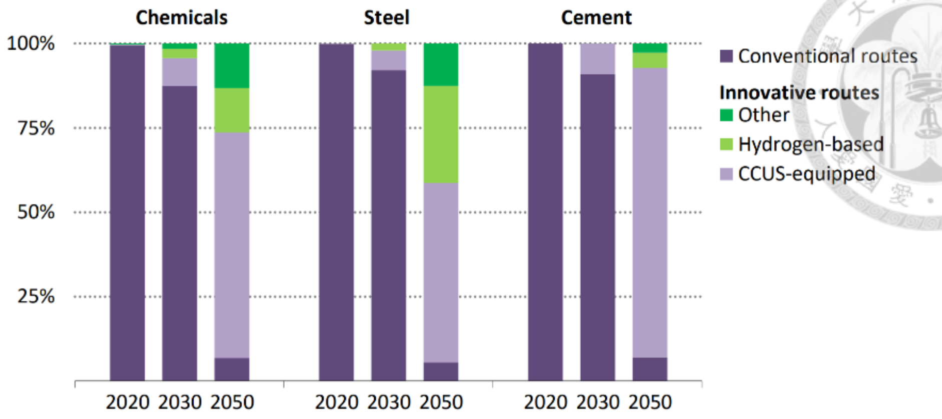

Figure 1: Industrial material production path allocation under the net-zero path

Source: International Energy Agency (2021)

Industrial decarbonization is technically possible on the mid-century horizon, but requires scale up of technology development and deployment, multi-institutional coordination, and sectoral and national industrial policies with detailed subsectoral and regional mitigation pathways and transparent monitoring and evaluation processes (Åhman et al. 2017; Wesseling et al. 2017; Bataille et al. 2018a; Rissman et al. 2020; Nilsson et al. 2021). In the IPCC AR6 Climate Change 2022: Mitigation of Climate Change report, several key themes are highlighted as essential considerations, including GHG pricing, GHG markets, technology and innovation, market demand, and public procurement, etc. For hard-to-abate sectors like iron and steel industry—characterized by high upfront decarbonization costs, long asset lifetimes, and exposure to open international competition, it requires a cross-system, comprehensive policy mix to overcoming decarbonization bottlenecks.

1.1 Research Objectives and Questions

This study aims to develop a comprehensive analysis of Taiwan’s iron and steel industry within the context of its low-carbon transition. Specifically, it examines the key pressures and structural challenges that constrain the sector’s decarbonization pathway and evaluates how existing policy instruments may be refined or expanded to more effectively accelerate transformative change.

To achieve the research objectives, the thesis will explore the research questions as follows:

RQ1. What pressures and challenges does Taiwan’s iron and steel industry face in its low-carbon transition under the national net-zero target?

RQ2. Based on the gaps identified in RQ1, what policy mix can effectively accelerate the industry’s low-carbon transition?

1.2 Research Scope

The steel industry can generally be divided into two production routes: the blast furnace–basic oxygen furnace (BF–BOF) system and the electric arc furnace (EAF) system. EAF-based steelmaking relies primarily on electricity and scrap, whereas the BF–BOF route depends heavily on coal as both an energy source and a reducing agent. As a result, greenhouse gas emissions from EAF-based steel producers are largely electricity-related,

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while emissions from BF–BOF steelmakers are mainly process-related. This distinction implies that technological transformation within the BF–BOF system can make particularly significant mitigation impacts. Owing to the substantial carbon emissions and high energy intensity associated with the BF–BOF process, this production route has become a center of both global and domestic decarbonization discussions. Accordingly, in this study, the scope of Taiwan's iron and steel industry is defined as producers operating BF–BOF steelmaking systems. In Taiwan, China Steel Corporation (CSC) and its subsidiary, Dragon Steel Corporation, are the only steelmakers that possess and operate blast furnaces. CSC operates four blast furnaces, while Dragon Steel Corporation operates two.

As Taiwan's steel sector decarbonization policies and industry developments remain ongoing, this study's data collection continued until November 2025. The research draws on semi-structured interviews, secondary data—including policy documents and publicly disclosed corporate information—as well as relevant academic and grey literature. Details on the research design and data collection procedures are presented in Chapter 3.

2. Literature Review

This chapter is structured into five parts. First, it outlines the current state of industry-focused research within sustainability transition theories (mainly focusing on multi-level perspectives) and identifies the research gap that this study seeks to address. The second part provides an overview of the structural characteristics of the steel industry, including issues of carbon lock-in and industrial structural challenges. The third part examines the technologies and definitions associated with low-carbon steel, while the fourth part reviews policy instruments and measures relevant to low-carbon transitions. Finally, the chapter offers an overview of the current status of Taiwan’s steel industry.

2.1 Sustainability Transition Research and industrial decarbonization

Sustainability transition research started to develop in 2000. After 2010, with the momentum of renewable energy technologies and the expanse of social, political influence, the research field gained a great attention since then. Among all the theories like Innovation Systems Theory, Transition Management, Strategic Niche Management, “Multi- Level Perspectives” (MLP) is one of the most used. The MLP suggests that socio-technical system transitions come about through the interplay between processes at niche, regime, and landscape levels (Geels, 2002, 2004). In a typical Multi-Level Perspective (MLP) analyzing framework, transitions emerge from dynamic interactions among niche innovations, socio-technical regimes, and the landscape. Stable regimes are typically

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resistant to change due to institutional lock-ins and path dependencies. However, landscape pressures—such as socio-political shifts, economic crises, or environmental concerns—can destabilize existing regimes and open “windows of opportunity.” When niche innovations mature technologically and socio-institutionally, they may exploit these windows to influence or replace the incumbent regime, leading to system reconfiguration and the formation of a new socio-technical order. Besides the public facilities, transportation, and energy, the MLP is commonly used to investigate a single, specific technology. For instance, Berkeley and Bailey, etc. (2017) set a MLP framework to analyze the electric vehicle and transportation transition in Europe.

The early model of MLP emphasized a bottom-up process of substitution, in which niche innovations replace (parts of) the existing system. Based on the types and sequences of multi-level interactions, the MLP has also developed several transition pathways. Geels (2005) categorizes them into several types－Transformation (in which incumbent actors gradually adjust the existing system and regime to accommodate landscape pressures), Reconfiguration (in which symbiotic niche innovations are incorporated into the existing system, followed by knock-on effects that gradually alter the system architecture), and De-alignment and Re-alignment (in which strong landscape pressures destabilize the system, creating space for multiple emerging niche innovations, followed by the re-alignment of a new system around one of them).

Geels and Turnheim (2022) found that, in the past decade, empirical research on low-carbon transitions shows that the transformation and reconfiguration pathways better reflect actual industrial transition processes. Transformation typically occurs under moderate external landscape pressures, where regime actors gradually initiate adjustments in response to environmental changes—for example, modifying regime rules and institutions such as innovation goals. Under this pathway, the existing system is gradually transformed through successive incremental innovation. In contrast, reconfiguration occurs when multiple niche innovations are incorporated into the existing system and subsequently trigger further changes. These changes often involve "architecture-level transformations", meaning the alteration of relationships among multiple system components.

System reconfiguration emphasizes the realignment and interaction of components within an existing system, a process referred to as "architectural change." As Andersen et al. (2023) observe, system architecture is shaped by both institutional logics and technological structures, which together guide how industries evolve through processes of reconfiguration rather than through wholesale replacement. Within this framework, "modular change" also plays a critical role alongside architectural change, representing the dynamics of individual core elements through processes of incremental adaptation or substitution. In a recent study on the industrial clusters of the United Kingdom, Herman

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et al. (2025) found that the system innovation requirements of hydrogen and carbon capture and storage (CCS) technologies reveal dynamic interactions between architecture and modular dimensions, which can better explain transformation dynamics within industrial clusters. As shown in Table 1, the combination of architecture change or unchange with modular reinforcement or substitution forms a framework, each reflecting different degrees of hydrogen and CCS adoption, as well as the extent of cross-system cooperation. For example, the creation of new hydrogen or CCS infrastructures that establish new linkages between firms from different industries constitutes a combination of modular substitution and architecture reshaping; conversely, the extension (and strengthening) of electricity grids to enable green hydrogen represents a combination of modular incrementalism and architecture stretching.

Table 1: Analytical framework for mapping system reconfiguration

Linkages between system components	**Core elements reinforced**	**Core elements substituted**
Architecture unchanged	*Modular incrementalism* Ex: replacing old gas pipes with plastic ones for H_2	*Modular substitution* Ex: adding on of carbon capture technology on industrial plants
Architecture changed	*Architectural stretching* Ex: extension (and strengthening) of electricity grids to enable green hydrogen	*Architectural reshaping* Ex: creation of new CCS or hydrogen infrastructures

Source: adapted from Herman et al. (2025)

This research demonstrates that industrial systems exhibit varying degrees of transition dynamics, where infrastructures such as hydrogen and CCS embody layered changes rather than direct displacement of existing facilities. The findings further emphasize that industrial decarbonization cannot be reduced to discrete system interactions. Instead, these cross-industry linkages converge into a broader meta-system, within which interdependent infrastructures, regulatory environments, and technological platforms collectively shape the long-term trajectories of system development.

At present, the application of sustainability transition perspectives to industries—particularly hard-to-abate sectors—is on the rise, yet studies focusing on the low-carbon transition of the steel industry remain limited. In Europe, a growing number of research has examined industrial decarbonization and related policy assessments. For example, Vogl et al. (2021) analyze the early commercialization phase of green steel production in the European Union, while Algers and Åhman (2024) examine phase-in and phase-out policy instruments in the context of the global steel transition. Despite these contributions, applications of sustainability transition theory to the steel sector remain limited. In Asia, existing research on steel decarbonization has predominantly focused on technological dimensions, with comparatively little attention given to the analysis of broader socio-technical systems.

In summary, although the Multi-Level Perspective (MLP) provides a valuable analytical

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framework for understanding the structural dynamics of sustainability transitions, its application to hard-to-abate industries such as steel remains limited—especially within the East Asian context. This study therefore seeks to address this gap by applying the MLP framework to analyze how socio-technical and governance structures interact to shape the low-carbon transition trajectory and policy discourse of Taiwan’s steel industry.

2.2 Socio-Technical Lock-in and Structural Challenges of the Steel Industry

Socio-Technical Lock-in

Industries such as steel, chemicals, and aviation are classified as hard-to-abate sectors, whose characteristics are closely tied to their sociotechnical systems, resulting in a strong phenomenon of carbon lock-in. Compared with other hard-to-abate industries, the steel industry occupies a particularly structurally dependent and pivotal position within the broader industrial value chain, serving as the foundation for metal and machinery manufacturing. The iron and steel sector is a globally extensive, and massive sociotechnical system with a significant impact on our modern life. Typically, end-users do not consume the iron and steel products—crude steel, slab, billet, or bloom—directly. These steel products are supplied to automobile, shipbuilding, plant, pipeline, and building and construction sectors as intermediate goods. Therefore, the iron and steel industry's decarbonization has great potential to reduce indirect emissions from those other industries (Kim et al., 2022).

Given its significant influence on society and the environment, the inherent challenges tied to the characteristics of the steel industry have also been examined. Algers and Åhman (2024) identified three specific phenomena that contribute to inertia—also known as barriers to exit—within the steel sector, which locks in the continued use of fossil fuels and inhibits the introduction of low-carbon technologies. These factors are high up-front investments, lumpiness, and societal embeddedness.

High up-front investment refers to the extensive infrastructure required for steel production, including plants, ports, and railways for transporting iron ore, coal, and natural gas. Combined with the industry's high energy consumption, this makes the cost of transitioning production systems in the steel sector extremely high. For many metals companies, it is extremely difficult to justify large upfront capital costs for decarbonization projects that have limited deployment and proven operational data.

Lumpiness arises from significant sunk costs that create risks for entering the sector and hinder competition within the industry. As more efficient firms avoid entering the sector at all, which discourages exit indirectly by shielding unproductive incumbents from competition, enabling them to remain in the market (Rimini et al., 2020).

Societal embeddedness is defined as strong links with local communities and

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governments which governments have historically supported domestic production of steel and capacity expansions for the purpose of economic development, job creation, and security of supply to drive growth. This blocks the exit of steel capacity, as it is supported by governments around the world, no matter its profitability (Rimini et al., 2020).

Ownership Dilemma

Beyond sociotechnical structural lock-in, ownership structure also significantly influences firms' low-carbon transition decisions. According to the OECD (2018), although only 22 of the world's top 100 steel companies are state-owned enterprises (SOEs), nearly 30% of global crude steel output originates from SOEs. Taiwan's largest steel producer, China Steel Corporation (CSC), is one such firm, with the government holding a 20% ownership stake.

State-owned steel enterprises generally exhibit lower profit margins and higher debt ratios than private firms and employ roughly twice as many workers, thereby fulfilling broader social responsibilities consistent with their societal embeddedness. However, SOEs often benefit from implicit government guarantees, including preferential financing, tax incentives, and bankruptcy protection. While these advantages can facilitate policy implementation and enable early transition efforts, they may also prolong the subsidization of high-carbon assets if policy execution lags behind strategic intent.

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Empirical research on the effectiveness of sustainability policies for SOEs remains limited. The OECD has noted that scholarly debate continues regarding the impact of market-based mechanisms, such as carbon pricing, on SOEs' transitions. Benoit et al. (2022) argue that such approaches may have limited impact on SOEs' behaviour due to the overall absence of competition where SOEs exhibit high market concentration, the existence of non-financial objectives, and their dependence on government subsidies, among other aspects. By contrast, research conducted at Loughborough University found that cap-and-trade schemes can still generate positive outcomes by mitigating coordination challenges across government entities, particularly where conflicting incentives exist.

Regarding how ownership can drive transformation, Algers (2024) suggests that SOEs can incorporate the long-term social (and not commercial) goal of decarbonization in their strategies, without having to please shareholders whose main concern is to maximize short-term financial returns. The OECD further emphasizes that governments should not only set clear and ambitious sustainability expectations for SOEs but also establish monitoring and assessment mechanisms to evaluate their progress.

In summary, the challenges facing the steel sector's low-carbon transition stem from the deep structural and institutional inertia within its sociotechnical system. However, by reexamining the roots of carbon lock-in and integrating factors such as state ownership,

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public investment, and coordinated policy frameworks, these same structural conditions may be reconfigured as leverage points for transformation—opening new pathways toward low-carbon transition.

2.3 The rise of Low-carbon Steel

Low-carbon steel definition

International agreement on a joint definition for near-zero emissions steel (NZS) and the development of a global certification standard is a major priority for the near term (Mission Possible Partnership, 2022). International Energy Agency (IEA) published *Definitions for near-zero and low emissions steel and cement* in 2024, it offers clear criteria for "low-emissions steel" and "near-zero emissions steel." According to the IEA, near-zero emissions steel must meet the following emissions intensity thresholds:

- For 0% scrap input: less than 400 kg CO_2e per tonne of crude steel
- For 100% scrap input: less than 50 kg CO_2e per tonne of crude steel

Intermediate thresholds are defined progressively based on scrap content. In contrast, "low-emissions steel" does not have fixed carbon intensity values. It is intended as a transitional category that encourages ongoing emissions reductions without prescribing specific technologies.

The global certification initiative ResponsibleSteel develops the Decarbonization

Progress Level with four levels in their *Production Standard*. The highest level (Level 4) aligns with the IEA's near-zero emissions standard, requiring emissions intensity of less than 50 kg CO_2e per tonne of crude steel for 100% scrap input. The First Movers Coalition, an industry-led initiative for low-carbon procurement, has committed its members to ensure that at least 10% of their annual steel purchases by 2030 meet or exceed its definition of near-zero emissions steel, which also aligns with the IEA's standard.

Regional standards also exist. For example, the Low Emission Steel Standard (LESS), developed by the German Steel Association, defines five levels of steel decarbonization scales. The strictest level follows the criteria:

- For 0% scrap input: up to 450 kg CO_2e per tonne of crude steel
- For 100% scrap input: up to 170 kg CO_2e per tonne of crude steel

In China, the China Iron and Steel Association (CISA) and Baowu Steel Group jointly developed the China Carbon-Neutral Future-oriented Steel (C2F Steel) Evaluation Method. It also uses scrap input ratios to define five levels. For hot-rolled products:

- At 0% scrap input, the strictest level (Class A) must emit no more than 0.4 t CO_2e per tonne of hot-rolled product
- At 100% scrap input, the threshold is 0.05 t CO_2e per tonne of hot-rolled product

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Low-carbon steel technology

According to various international roadmaps for achieving net-zero emissions in the steel sector, the IEA's ETP Clean Energy Technology Guide identifies 25 low-carbon iron and steelmaking technologies across multiple domains. The Steel Sector Transition Strategy Model (ST-STSM) categorizes 20 key decarbonization technologies for the industry. The World Economic Forum (WEF), integrating insights from both sources, estimates that by 2050, in addition to scrap-based secondary steel production, hydrogen and CCS based primary steelmaking will account for around 20% of global output.

To better understand how these technologies compare to conventional steelmaking processes, it is essential to first grasp the basics of steel manufacturing.

Steelmaking can be broadly categorized into two main processes: the Blast Furnace–Basic Oxygen Furnace (BF-BOF) route and the Electric Arc Furnace (EAF) route. As the dominant method for primary steel production, the BF-BOF route accounted for 70.4% of global crude steel output, with an average CO_2 intensity of 2.32 tonnes per ton of steel produced. In contrast, the EAF route contributed 29.1% of global production and offers significantly lower CO_2 emissions—by 1.43 tonnes per ton when using the Direct Reduced Iron (DRI) route, or by 0.7 tonnes per ton when using the scrap-based EAF route.

Direct Reduction of Iron (DRI) as one of the common routes of ironmaking has been

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developed since the 1960s. Direct reduction involves the production of solid iron from iron ores and a reducing agent (e.g., natural gas). The solid product is called DRI and is mainly applied as feedstock in electric arc furnace (EAF). The DRI-EAF combination allows for higher electrification and lower emission if low-carbon feedstocks and electricity are used. (Fan et al., 2021) The production of steel from the DRI-EAF route exceeded 144 million tonnes in 2024 (7% global production). There are three main forms of Direct Reduced Iron (DRI): Cold DRI (CDRI), ideal for nearby EAFs; Hot DRI (HDRI), which retains heat to boost efficiency and cut costs; and Hot Briquetted Iron (HBI), a dense, stable form suitable for storage, transport. Due to its high density and resistance to reoxidation, HBI is an ideal feedstock for the BF-BOF process, while CDRI and HDRI are only suitable for use in EAF. Currently, over 80% of DRI production is CDRI, with merely 11% of HDRI and 8% of HBI.

Commercially developed Direct Reduced Iron (DRI) technology enables the substitution of fossil-based reductants with green hydrogen, potentially increasing its share in primary steel production from approximately 5% today to over 50% by 2050 (Mission Possible Partnership, n.d.). This hydrogen-based pathway is consistently emphasized across major decarbonization roadmaps for the steel sector (Deloitte, 2022; Bataille et al., 2021; Mission Possible Partnership, n.d.; NewClimate Institute, 2022; Yu et al., 2021). Low-carbon steelmaking technologies based on the Direct Reduced Iron–Electric Arc Furnace

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(DRI–EAF) route primarily use hydrogen or natural gas as the reducing agent. These pathways are referred to as H_2-DRI-EAF and NG-DRI-EAF, respectively.

Carbon Capture and Storage (CCS) can be used to address residual emissions from various net-zero technologies. However, the practical application of CCS is constrained by several factors, including the efficiency of carbon capture, the availability and scalability of utilization pathways, and the accessibility of nature-based sequestration alternatives (Birat, 2010). In addition, suitable storage locations are highly dependent on geological conditions and levels of social acceptance. These factors create considerable uncertainty around the deployment of CCS under current regulatory and institutional frameworks. Moreover, the implementation of CCS requires substantial investment in large-scale infrastructure, which further challenges its feasibility and public support. CCS is incorporated into various low-carbon steelmaking technology combinations, including BF-BOF-CCS and NG-DRI-EAF-CCS pathways.

According to the Global Iron and Steel Tracker (GIST), nearly half of the announced ironmaking capacity is based on the DRI route. However, due to the significant uncertainty surrounding hydrogen supply, natural gas is currently the most widely used reducing agent for DRI processes, with the majority of DRI plants adopting the NG-DRI-EAF configuration. Recently announced low-carbon steel projects from companies such as Thyssenkrupp and POSCO also plan to build DRI plants, with the intention of transitioning to green hydrogen in the future. However, these projects often rely heavily on substantial policy subsidies. Considering the technological breakthroughs required—such as in hydrogen and carbon capture and storage (CCS)—as well as the high investment uncertainty associated with major industrial transformations, policy guidance and support remain critical factors in enabling decarbonization in the steel sector.

2.4 Policy Mix for Industrial Decarbonization

Emerging low-carbon technologies in the steel sector face high infrastructure needs, investment risks, and underdeveloped markets, making it difficult for firms to act independently—thus requiring strong and targeted policy intervention. The deployment of mitigation options requires support from a mix of policy instruments, including GHG pricing coupled with border adjustments or other economic signals for trade-exposed industries; robust government support for research, development, and deployment; energy, material, and emissions standards; recycling policies; sectoral technology roadmaps; market pull policies; and support for new infrastructure (Flanagan et al., 2011; Rogge et al., 2017; Bataille et al., 2018a; Tvinnereim and Mehling, 2018; Creutzig, 2019; Bataille, 2020a; Rissman et al., 2020).

According to the IPCC's Sixth Assessment Report (AR6), including for climate change mitigation, have long been grouped into three main categories – (i) economic instruments,

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(ii) regulatory instruments, and (iii) other instruments – although the specific terms differ across disciplines and additional categories are common (Kneese and Schultze 1975; Jaffe and Stavins 1995; Nordhaus 2013; Wurzel et al. 2013). Economic instruments are designed to influence the GHG emissions by economic mechanism. Jeffrey Rissman, Chris Bataille et al. (2020) argue that policy interventions can reduce emissions through a variety of economic channels. Examples include carbon pricing (e.g., carbon taxes, emissions trading systems), fossil fuel taxes, and grants or subsidies. Economically efficient policies typically provide consistent incentives for decarbonization across sectors, thereby promoting optimal resource allocation in investment decisions. For instance, well-designed carbon pricing can induce cost-effective mitigation responses across all channels.

Regulatory instruments, by contrast, impose direct constraints on emissions through mandates and standards—such as performance or technology-specific requirements—often backed by penalties for non-compliance. Finally, other instruments encompass information-based and voluntary measures. These include information platforms that enhance transparency regarding mitigation efforts, energy efficiency labeling schemes, voluntary agreements between governments and industry, and green public procurement policies.

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To investigate industrial mitigation policies—particularly policy instruments for industrial decarbonization, which are the focus of this research—several international organizations and global climate think tanks have developed their own classification frameworks. The International Energy Agency (IEA) published the *Policy Toolbox for Industrial Decarbonization* in 2025, with the aim of providing governments with practical guidance for designing and implementing effective strategies to reduce industrial greenhouse gas (GHG) emissions.

The toolbox categorizes policy instruments into nine groups based on their core objectives: (1) establishing plans and policies for long-term GHG emissions reductions; (2) mobilizing finance and investment; (3) managing existing assets and near-term investment; (4) creating a market for near-zero emissions materials production; (5) developing technologies; (6) accelerating material efficiency and circularity; (7) international co-operation and a level playing field; (8) infrastructure planning and development; and (9) tracking progress and improving data. Designed to assist governments in the timely and effective application of these instruments, the toolbox outlines the appropriate stages for intervention along the decarbonization pathway. It also explains how each instrument contributes to deep emissions reductions and introduces four criteria for evaluating their implementation: effectiveness, simplicity, stakeholder acceptability, and economic efficiency.

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In addition to the global organization, climate think tanks also developed policy instruments framework to facilitate the decarbonization of hard-to-abate sectors. Agora Energiewende and the Wuppertal Institute—two prominent German energy and climate think tanks—jointly published a technology and transition pathway report aimed at advancing the European Union's climate ambition. With a particular focus on creating effective investment incentives in Europe's basic materials industries, the report adopts an industrial value chain perspective to identify the policy conditions required for upstream, midstream, and downstream transformation toward climate-neutral products, processes, and business models. As illustrated in Figure 2, the authors propose specific policy instruments combinations to create the conditions needed to achieve the overall goal of industrial decarbonization.

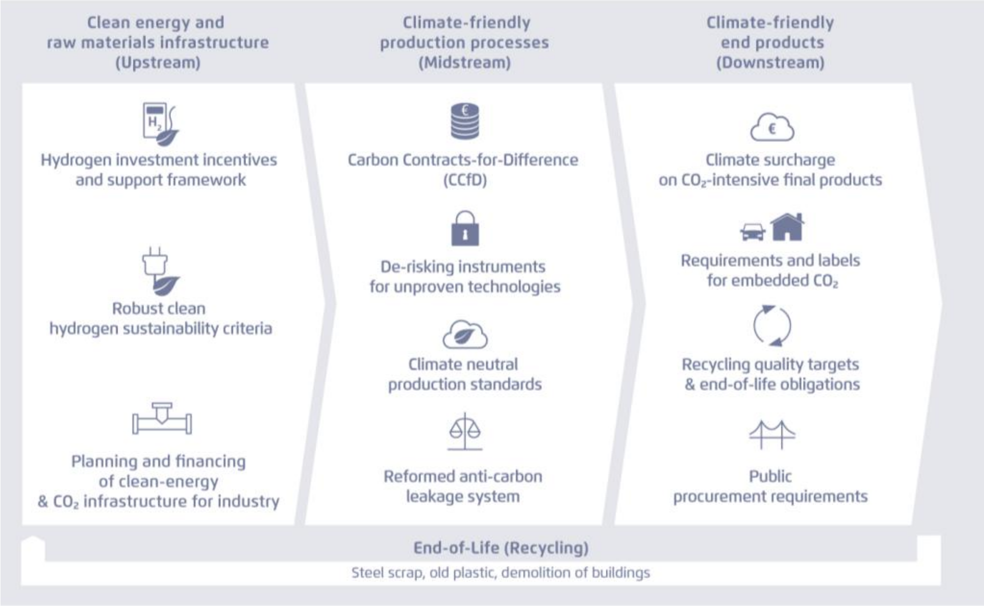
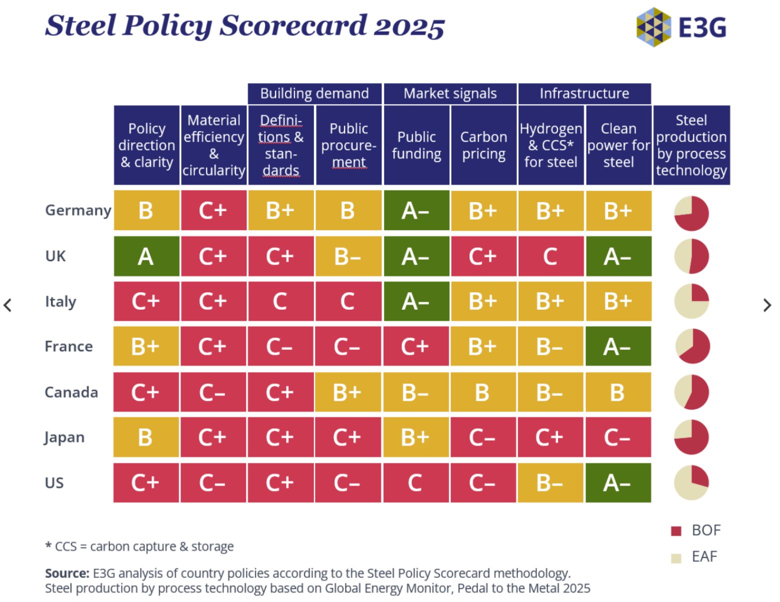


Figure 2: Policy needs at the different part of value chain

Source: Agora Energiewende and Wuppertal Institute (2020)

To focus more specifically on decarbonization policy instruments for the iron and steel industry, the international climate think tank E3G developed the Steel Policy Scorecard to evaluate the decarbonization performance of the steel sector in G7 countries as well as other major steel-producing nations, including China and South Korea for three years (2022, 2023, and 2025). The assessment covers several key policy dimensions: policy direction and clarity, market signals (such as funding mechanisms and carbon pricing), material efficiency and circular economy measures, demand creation (including definitions of green steel and public procurement strategies), and infrastructure investment. Using a set of detailed criteria under each indicator, the scorecard assesses the extent to which countries have implemented relevant policies. The results are visually represented using a three-color system to indicate different levels of progress.



Steel Policy Scorecard 2025

			Building demand		Market signals		Infrastructure		
	Policy direction & clarity	Material efficiency & circularity	Definitions & standards	Public procurement	Public funding	Carbon pricing	Hydrogen & CCS* for steel	Clean power for steel	Steel production by process technology
Germany	B	C+	B+	B	A–	B+	B+	B+	
UK	A	C+	C+	B–	A–	C+	C	A–	
Italy	C+	C+	C	C	A–	B+	B+	B+	
France	B+	C+	C–	C–	C+	B+	B–	A–	
Canada	C+	C–	C+	B+	B–	B	B–	B	
Japan	B	C+	C+	C+	B+	C–	C+	C–	
US	C+	C–	C+	C–	C	C–	B–	A–	

* CCS = carbon capture & storage

Source: E3G analysis of country policies according to the Steel Policy Scorecard methodology.
Steel production by process technology based on Global Energy Monitor, Pedal to the Metal 2025

Figure 3: Result of ESG Steel Policy Scorecard 2025

Source: E3G (2025)

Different institutions categorize policy instruments according to varying objectives, making it essential to understand these differences and restructure the classifications in a way that aligns with Taiwan’s specific industrial and policy context. The IEA’s Policy Toolbox provides broad recommendations on when and under what conditions policy instruments should be applied, based on distinct decarbonization objectives. In contrast, Agora Energiewende adopts an industrial value chain perspective tailored to European industrial conditions, identifying the policy requirements necessary to stimulate investment across upstream, midstream, and downstream stages of production. E3G, meanwhile, introduces a set of evaluation indicators to assess the alignment of national low-carbon steel policies with decarbonization goals, based on their implementation status.

Synthesizing insights from these three frameworks reveals four main functional categories of policy instruments relevant to industrial decarbonization:

I. Establishing Clear Climate and Emissions Targets

Clear long-term climate goals and sector-specific emissions reduction targets are critical for providing policy direction and investment certainty.

II. Supporting Decarbonization Along the Industrial Production Chain – Supply and Demand Sides

- Supply side: Development of low-carbon production technologies such as

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hydrogen-based steelmaking, carbon capture and storage (CCS), and renewable energy infrastructure.

- Demand side: Creation of markets for low-carbon materials through green public procurement and the establishment of low-carbon steel standards.

III. Addressing Technological Uncertainty and Investment Risks

Mechanisms such as Carbon Contracts for Difference (CCfDs), subsidies, and innovation funds play a crucial role in de-risking investments in novel technologies.

IV. Regulatory Instruments

Regulatory measures—including emissions performance standards and mandates—establish minimum compliance requirements and shape the competitive environment.

Notably, the Climate Club's Steel Policy Mapping report (2025) highlights that nearly half of the current steel decarbonization policy measures implemented by major steel-producing countries are non-binding and emphasize incentives rather than penalties—in other words, "carrots but not sticks." As the report notes, "Governments are opting to incentivize and publicly finance the transition rather than achieve this through regulation and pricing." The study further warns that in the context of a policy environment that lacks sufficient impetus on creating strong demand-side signals to produce low-carbon steel, progress towards decarbonization targets may be limited.

This observation underscores the importance of balancing supply-side and demand-side policy design when formulating decarbonization strategies. It is important to recognize that individual policy instruments alone are insufficient to drive systemic change. One of the important trends after the IPCC AR5 report was the necessity of enabling the low-carbon transition. As policy mix (or policy package) being seen as the enabler, literature on socio-technical transitions, rooted in innovation studies, highlights the need for different policy focus at different stages of a transition (Geels et al. 2017b,a; Köhler et al. 2019).

Empirical studies further illustrate these challenges. For instance, Lockwood and Herman et al. (2025), in their analysis of industrial decarbonization policy mixes in the United Kingdom, identify significant difficulties in achieving coherence, consistency, and comprehensiveness within industrial decarbonization policy packages. These challenges are closely linked to the inherent characteristics of industrial decarbonization, including its high degree of cross-sectoral policy coordination and persistent regulatory and informational gaps surrounding emerging low-carbon technologies.

Overall, the literature highlights that industrial decarbonization depends on well-designed policy mixes rather than isolated instruments. However, empirical studies show that achieving coherence and consistency across policy packages remains challenging due to the cross-sectoral nature of industrial transition and persistent regulatory and informational gaps.

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2.5 Iron and Steel Industry in Taiwan

This chapter provides an overview of Taiwan’s steel industry to establish a clear foundation for the research. It first outlines the industry’s scale, major products, and primary markets, then examines the annual production, corporate strategies, and current decarbonization measures of the leading blast furnace operator—China Steel Corporation (CSC). These discussions serve as the analytical and comparative basis for the subsequent sections of this study.

As one of the nation’s fundamental industries, the steel sector is closely tied to national economic stability and defense autonomy. It has long received significant attention and protection from the government and is regarded as a strategic national industry. The characteristics of Taiwan’s steel industry include its strong industrial linkages, capital and technology intensity, high energy consumption, and heavy dependence on imported raw materials for steelmaking (Metal Materials Industry Yearbook, 2024). In 2024, Taiwan’s crude steel production reached approximately 19.18 million tonnes, accounting for about 1% of global output and ranking 13th worldwide.

Taiwan’s steel products can be categorized into two main groups: carbon steel (ordinary steel) and stainless and alloy steel, with carbon steel accounting for over 90% of total production. In terms of production processes, the industry can be divided into two main routes: the integrated blast furnace–basic oxygen furnace (BF–BOF) process and the

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electric arc furnace (EAF) process, which uses scrap steel as feedstock.

In terms of the industry supply chain, the upstream of the steel industry includes raw materials such as coal, iron ore, and scrap steel; the midstream segment covers the production of steel plates, coils, and bars—where stainless and alloy steels require additional cutting and processing; while the downstream segment encompasses diverse applications, including screws and bolts, industrial facilities, construction, transportation engineering, and machinery manufacturing.

Currently, around 60% of Taiwan's steel output serves domestic demand, with construction accounting for 25% and manufacturing industries (such as screw and bolt production, auto parts, and machinery) representing 35%. The remaining 40% of steel products are exported, primarily to the United States, Japan, and Belgium. Notably, Taiwan's screw and bolt manufacturing sector holds strong global competitiveness, with more than 1,600 factories nationwide, earning Taiwan the reputation of a "Kingdom of Screws." The industry is known for its high product quality and fast delivery and maintains a price advantage compared to Japan, South Korea, and China (Department of Statistics, Ministry of Economic Affairs, 2021). However, because the fastener industry is highly export-oriented—over 45% of its exports go to the United States and 9% to Germany, with other major destinations including the United Kingdom, the Netherlands, and Japan—it remains highly sensitive to the international trade environment.

This research focuses on the carbon steel sector within Taiwan's steel industry, particularly the BF–BOF production route. At present, only China Steel Corporation (CSC) operate such processes in Taiwan with four blast furnaces. Founded in 1971, CSC has an annual crude steel capacity of approximately 10 million tonnes. Its main products include steel plates, wire rods, hot-rolled and cold-rolled coils, galvanized steel coils, and electrical steel coils. About 60% of CSC's output is sold domestically, the remaining 40% is exported, mainly to Southeast Asia (40%), Japan (23%), and Europe (15%). Its subsidiary, Dragon Steel Corporation, operates two blast furnaces and one electric arc furnace, with an annual production of around 6 million tonnes. Together, the two companies account for over 80% of Taiwan's total crude steel output.

China Steel Corporation's (CSC) largest shareholder is the Ministry of Economic Affairs (MOEA) Taiwan. As of June 2025, the government held a 20% ownership stake, classifying CSC as a state-owned enterprise (SOE). In recent years, CSC has adopted the strategic framework of "Dual Cores and Three Transformation Strategies"（二軸三轉） as its core management and development direction. The "Dual Cores" refer to (1) the development of high-value-added, specialized steel production and (2) the advancement of the green energy industry. The "Three Transformation" involve (1) supply chain transformation, (2) digital transformation, and (3) low-carbon transformation.

With the typical character of a hard-to-abate industry, CSC's greenhouse gas emissions

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are primarily from Scope 1 (direct emissions). Based on data from the past three years, its direct emissions are approximately 18 million tonnes of CO_2-equivalent. According to the Ministry of Environment's data on greenhouse gas emissions across Taiwan, China Steel Corporation ranks among the top five companies in Taiwan in terms of emissions. The company has set a long-term goal of achieving carbon neutrality by 2050, with an interim target of a 25% emissions reduction by 2030, taking 2018 as the baseline year.

CSC’s major decarbonization measures include improving energy efficiency, increasing the use of renewable energy, adding low-carbon raw materials in blast furnaces, adopting hydrogen-enriched blast furnace injection, and raising the scrap steel utilization ratio. After 2030, the company plans to further pursue process electrification, carbon capture, utilization, and storage (CCUS) as part of its advanced decarbonization technology roadmap.

As a state-owned enterprise (SOE), China Steel Corporation (CSC) plays a leading role in Taiwan’s overall decarbonization policy. The company’s corporate carbon reduction strategy both reflects and supports the nation’s broader climate objectives. Since Taiwan officially announced its “2050 Net-Zero Emissions Pathway and Strategy Overview” in 2022, decarbonization and industrial transformation have gradually become central pillars of the country’s long-term development agenda. By 2025, under President Lai Ching-te’s “Green Growth and 2050 Net-Zero Transition” initiative, the Executive Yuan further

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formulated the Taiwan National Decarbonization Action Plan and aligned it with international standards by clearly defining the nation's Nationally Determined Contribution (NDC) targets (National Development Council, 2025). This action plan focuses on six major sectoral "flagship decarbonization programs" to promote systematic low-carbon transitions across industries.

Within this framework, the steel industry is incorporated under the category of "SOE-led decarbonization," with CSC serving as the primary demonstration enterprise. Building upon this policy foundation, CSC introduced its "CSC Flagship Decarbonization Action Plan," which outlines detailed strategies for research, development, and capital investment in decarbonization technologies through 2035. Compared with previous sustainability reports that merely provided a general decarbonization roadmap, this plan goes further by specifying the expected emissions reductions, investment budgets, and implementation timelines of various technologies. This development signifies CSC's transition from the stage of strategic declaration to that of technological implementation and financial commitment. The action plan not only highlights the experimental and catalytic policy role of state-owned enterprises in advancing Taiwan's national decarbonization strategy but also serves as an essential foundation for this study's analysis of CSC's decarbonization strategies and their alignment with national policy objectives.

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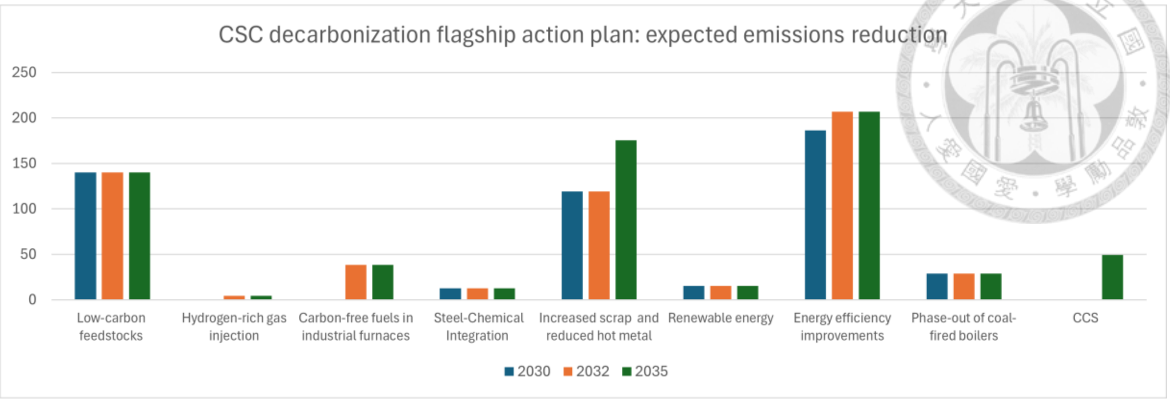

Figure 4: CSC Decarbonization Flagship Action Plan: expected emissions reduction

Source: adapted from China Steel Corporation (2025)

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3. Methodology

3.1Research Design

The research design is structured in two parts to address the first research question: What pressures and challenges does Taiwan's iron and steel industry face in its low-carbon transition under the national net-zero target? The first part clarifies the transition objectives and identifies key milestones to guide technological pathway choices. The second part evaluates the current stage of transition by examining the present conditions of Taiwan's iron and steel industry. By synthesizing insights from both components, the study develops an integrated response to the first research question through the analytical lens of multi-level perspective (MLP) theory. This approach enables a deeper understanding of the systemic constraints embedded in existing policy and institutional frameworks, and it provides a conceptual bridge to the second research question: What policy mix can effectively accelerate the industry's low-carbon transition?

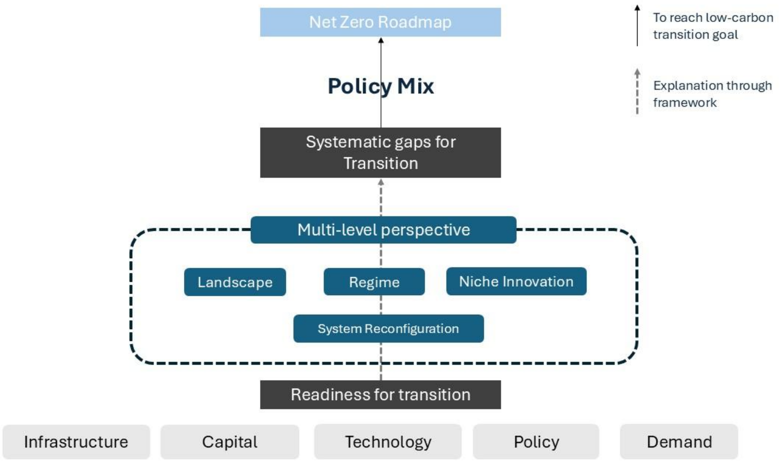

Figure 5: Research Design

Net-Zero Pathways for Taiwan's Iron and Steel Sector

As this thesis outlines a vision for the decarbonization of Taiwan's iron and steel industry, it is essential to clarify a clear goal for the sector, especially from the technology roadmap perspective. The thesis draws on the *Net Zero Industry* research project, coordinated by Dr. Chris Bataille in partnership with the Institute for Sustainable Development and International Relations (IDDRI) and Global Energy Monitor. Within this broader initiative, the Net Zero Steel project models decarbonization pathways for country's national steel sectors under 2050 net-zero vision. The model incorporates key variables such as projected steel demand, plant retrofit cycles, scrap availability, access to geological storage for carbon capture and storage (CCS), and renewable energy potential—including solar photovoltaics and surplus hydropower for hydrogen-based steelmaking. Further details of the model are provided in Appendix 2.

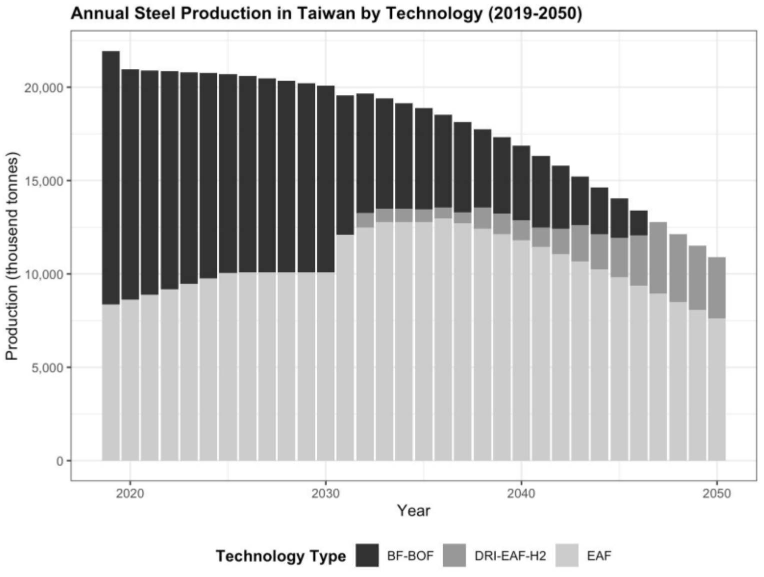

Figure 6: Taiwan's steel production based on technology

Source: adapted from Net Zero Industry (2021)

As figure 7 and table 2 show, Net Zero Industry's model shows under the scenario of net zero in 2050, by 2030 approximately 0.7 million tonnes of crude steel will come from hydrogen-based direct reduced iron (DRI) using the electric arc furnace (EAF) route. The production ratio between the blast furnace–basic oxygen furnace (BF–BOF) and EAF routes is projected to shift to approximately 2:3, reversing today's proportions. The share of H_2-DRI–EAF production is expected to increase steadily throughout the 2040s, while traditional blast furnace capacity is projected to be phased out by the early 2040s. By 2050, over 80% of production is anticipated to be from the EAF route, with the remainder from H_2-DRI–EAF processes.

Table 2: Taiwan's steel production details under net zero scenario

Time Point	**Net Zero Industry Pathway Model**		
Base Year	2020		
	Emission Reduction	**Total Crude Steel Production**	**Technology Pathway**
2030	45%	Decrease: 7%	BF-BOF: 40% EAF: 60% H_2-DRI-EAF: 0.7 million tonnes
2040	85%	Decrease: 26%	BF-BOF: 20% EAF: 70% H_2-DRI-EAF: 1 million tonnes
2050	Net Zero	Decrease: 50%	EAF: 80% H_2-DRI-EAF: 3 million tonnes

These projections provide quantitative foundation and framing for this thesis. They inform the subsequent analysis of steel demand and production trends, which are used to assess the low-carbon transition requirements for Taiwan's iron and steel industry.

Iron and Steel Industry Low-carbon Transition Readiness Evaluation

This section draws upon analytical frameworks to construct an evaluation system for assessing the current transition status of Taiwan's iron and steel industry. Specifically, it references the World Economic Forum's Net Zero Industry Tracker and the German climate think tank E3G's Steel Policy Scorecard, both of which provide structured indicators and assessment systems to evaluate a sector's readiness to achieve net-zero emissions. The research employs a policy scorecard framework to assess the current state of decarbonization policies in Taiwan's iron and steel sector. It also incorporates empirical data—for example, on hydrogen and electricity demand—to compare the *Net Zero Industry* scenario with existing conditions. The overall analytical framework is structured around five key pillars: technology, infrastructure, demand, capital, and policy. Building upon these two frameworks—while adapting them to Taiwan's specific context—this thesis develops a tailored evaluation framework.

This approach facilitates a comprehensive assessment of the sector's status, while also identifying critical bottlenecks and systemic challenges that hinder its transition to a low-carbon production system.

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Application of multi-level perspective theory

To understand the underlying factors shaping the current state of transition readiness, the research adopts the multi-level perspective (MLP) as the primary analytical lens, complemented by the extended perspective of system reconfiguration. The MLP facilitates an examination of how low-carbon transitions in Taiwan’s steel industry are structured by the dynamic interplay between niche innovations, entrenched regime configurations, and broader landscape pressures. Building upon this foundation, the perspective of System Reconfiguration helps tracing modular adaptations, incremental substitutions, and architectural shifts within Taiwan’s steel sector by mapping how existing steel production systems incorporate add-on solutions (e.g., energy efficiency upgrades, fuel-switching) versus more structural reconfigurations (e.g., electrification of furnaces or integration into renewable energy infrastructures).

Taken together, the integration of MLP with the reconfiguration dynamics enables the analysis of Taiwan’s steel decarbonization not only as a firm- or sector-specific transition, but as a meta-system transformation, shaped by cross-sectoral interdependencies, evolving infrastructures, and regulatory architectures. This framing allows the thesis to capture both evolutionary and disruptive dynamics in the steel sector’s decarbonization, thereby providing a more systematic explanation for the first step of evaluation and creating a coherent analytical bridge to the subsequent discussion on policy mixes in research question two. For the second research question: How Taiwan can accelerate the low-carbon transition in terms of the policy mix improvement? The thesis draws upon the first parts results and conducts the literature review as well as the first and secondhand data collection to formulate the policy mix suggestion.

3.2 Data Collection and Analysis

Semi-Structured Interview

This research employed semi-structured interviews to capture diverse perspectives from different actors and to inform the research questions. Given the rapid pace of change in decarbonization processes, interviewing stakeholders currently engaged in industry, research, or advocacy provided timely and practice-oriented insights into the transition within the steel sector. The interview guide was developed based on a review of relevant literature and policy documents, and was subsequently adapted to the interviewees' professional backgrounds, responses, and the natural flow of discussion.

Interviewees were categorized into two groups based on their backgrounds: steel producer and research-oriented experts. The study conducted interviews with both domestic and international participants. Domestic interviews focused on understanding the decarbonization bottlenecks and transition pathways of Taiwan's iron and steel industry, while international interviews aimed to gather insights on policy mix design that can

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effectively facilitate steel sector decarbonization. Further details are provided in the Appendix 1. All interviews were conducted either in English or Chinese, depending on the interviewees' preferences and time or location constraints. In total, eight semi-structured interviews were conducted, comprising four with domestic stakeholders and four with representatives from international organizations, including think tanks and NGOs based in Japan, Korea, Germany, and Sweden (see Table 3). Each interview lasted approximately 40 minutes to one hour.

Together with the materials provided by the interviewees, all transcripts were recorded verbatim and subsequently analyzed alongside secondary sources as part of the data analysis. This process allowed the study to further develop systematic explanations and descriptions in relation to the research questions. Further details of the interview guide are provided in Appendix 1.

Table 3: Interviewee list

Nr.	**Group**	**Role/Organization**	**Organization Nationality**
1	Industry Decarbonization Researcher	Researcher/Taiwan Climate Action Network	Taiwan
2	Industry Decarbonization /Energy Researcher	Senior Researcher/ Metal Industries Research & Development Centre	Taiwan
3	Industry Decarbonization /Energy Researcher	Senior Researcher/ Industrial Technology Research Institute	Taiwan
4	Steel Producer	Director & Leader / China Steel	Taiwan

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		Corporation Environmental Protection Department	
5	Industry Decarbonization Researcher	Team Leader/Transition Asia	Japan
6		Researcher/Solution for Our Planet	Korea
7		Team Leader/Agora Industry	Germany
8		PhD. Researcher/Lund University	Sweden

Literature Review

The literature review began with a keyword-based search focusing on decarbonization, iron and steel industry, net zero, low-carbon transition, and policy instruments. The selection of materials prioritized publications from the past five years. Sources were classified into domestic and international categories.

Domestic sources were primarily used to understand the current state of Taiwan’s iron and steel industry. These included publicly available materials from major steel companies (e.g., China Steel Corporation), such as sustainability reports, annual reports, shareholder meeting records, corporate websites, public statements at conferences, and press coverage. Policy-related information was mainly drawn from government documents, particularly from the Ministry of Economic Affairs and the Ministry of Environment. In addition, foundational data on Taiwan’s steel industry were collected from domestic research institutions such as Industrial Technology Research Institute and Metal Industries Research & Development Centre. International sources were consulted to identify global trends in steel decarbonization, including emerging low-carbon production technologies, policy mix recommendations, and net-zero transition assessments. These materials were obtained from international organizations and initiatives such as the United Nations (UN), Organization for Economic Cooperation and Development (OECD), International Energy Agency (IEA) and the World Economic Forum (WEF), etc. For country and region specific references, the review focused on the European Union (EU), Japan, and South Korea, given their relatively advanced progress in net-zero transitions and their industrial relevance to Taiwan.

4. Findings and Analysis

4.1 Decarbonization Readiness Assessment

To evaluate the readiness for decarbonization, this study adopts a hybrid approach that integrates two complementary assessment frameworks. First, the results based on the E3G Policy Scorecard criteria are illustrated in Table 4. Currently, Taiwan's steel industry policies for decarbonization are primarily situated in the mid-to-lower range, spanning Grades A, B, and C, with Grade C being the most prevalent.

In comparison with other major steel-producing countries with blast-furnace-based production accounting for more than 60% of total output—such as Germany and Japan. Germany has achieved higher scores across most dimensions, reflecting its earlier and more integrated development of hydrogen and renewable energy systems aligned with industrial demand. In addition, the recent implementation of Carbon Contracts for Difference (CCfDs) and the promotion of the Low Emission Steel Standard (LESS) have further strengthened Germany's policy framework. Japan's performance is primarily attributable to institutional developments under the Green Transformation (GX) policy agenda, including the establishment of dedicated working groups to define low-carbon steel, as well as the inclusion of low-carbon steel within electric vehicle subsidy criteria, thereby fostering demand-side market creation. In addition, the 2023 assessment includes China and South Korea, both of which demonstrate relatively stronger performance in specific dimensions. China performs particularly well in resource circularity, as it is among the few countries that explicitly integrate scrap demand in the steel sector with broader circular economy strategies. South Korea shows notable strength in policy clarity, following the announcement by the Ministry of Trade, Industry and Energy (MOTIE) in 2023 of the Strategy for the Development of Low-Carbon Steelmaking Transition. Further details of the evaluation are provided in Appendix 3.

Table 4: Steel policy scorecard result of Taiwan and other countries

Country /Criteria	Policy direction & clarity	Market Signals		Material Efficiency & Circularity	Building Demands		Infrastructure	
		Public Funding	**Carbon Pricing**		**Definitions & Standards**	**Public Procurement**	**Hydrogen & CCS for Steel**	**Clean power for steel**
Taiwan	B+	C+	C+	C	C-	C+	C-	C-
Germany	B	A-	B+	C+	B+	B	B+	B+
Japan	B	B+	C-	C+	C+	C+	C+	C-
China	B-	C+	C	B-	C+	C-	C+	C-
South Korea	A-	C+	C+	B-	C-	C-	C-	C-

Note: Data for China and South Korea are derived from the 2023 E3G Steel Policy Scorecard, while data for Germany and Japan are sourced from the 2025 E3G Steel Policy Scorecard.

To further interpret these results and understand the existing industry–policy gaps across the key pillars of technology, infrastructure, demand, and capital, the study also incorporates the indicator framework developed by the World Economic Forum's (WEF) Net-Zero Industry Tracker. This allows for a more comprehensive analysis and qualitative evidence of how far Taiwan's steel sector remains from achieving net-zero emissions under the current policy environment, as reflected in the Scorecard assessment.

I. Policy direction & clarity: Lack of ambition and sector decarbonization plan

Key Readiness Question: To what extent do Taiwan's current policy design and emission reduction targets effectively guide and incentivize the steel industry's decarbonization transition?

Clear and ambitious policies form the essential foundation for industrial transformation and serve as a precursor to other related measures such as finance, infrastructure, and carbon pricing. The key objective of establishing such policies is to provide various stakeholders—including industrial producers, consumers, intermediaries, trade partners, and society at large—with clarity and confidence regarding the intended long-term direction of transition. Within this evaluation framework, Taiwan received a B plus rating, primarily because it has adopted an industrial decarbonization policy that partially covers the steel sector—making it one of the relatively stronger areas among all assessed categories. However, simulations conducted under the Net Zero Industry research project indicate that, to align with a 2050 net-zero pathway, Taiwan's steel industry would need to achieve an emissions reduction of approximately 45% by 2030, relative to a 2020 baseline. While Taiwan has not established an explicit economy-wide emissions reduction target specifically for the steel sector, its third-phase greenhouse gas reduction target sets a cap of 117.377 $MtCO_2e$ for the manufacturing sector by 2030. Compared to total manufacturing emissions of 146.374 $MtCO_2e$ in 2020, this target corresponds to a

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reduction of only around 20%.

Similarly, China Steel Corporation’s Flagship Decarbonization Action Plan, approved in 2025, sets a 2030 emissions reduction target of 22.5% relative to the 2020 baseline. Both targets fall substantially short of the mitigation milestones required under a net-zero-aligned transition pathway, indicating that the current level of decarbonization ambition within Taiwan’s steel industry remains insufficient. This limited level of ambition has two main implications:

- Although China Steel Corporation (CSC) has been designated as the demonstration enterprise and launched its Decarbonization Flagship Action Plan in 2025, the absence of corresponding measures for other steel producers means that the policy does not yet constitute a comprehensive sector-wide strategy.
- The insufficient ambition of the national reduction target fails to create pressure or incentives to drive large-scale industrial transformation within the sector.

II. Public Funding: Uncertain Linkages Between Financial Allocation and Achieving Net-Zero Goals

Key Readiness Question: To what extent does public funding for low-carbon technologies support the steel sector’s decarbonization transition**?**

According to the Steel Policy Mapping report (Climate Club, 2025), nearly 40% of global decarbonization policy measures in major steel-producing countries take the form of

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direct public subsidies. In the E3G Scorecard, a threshold of 0.01% of GDP is used to assess whether the level of public funding is adequate. Taiwan receives a score of C+, primarily because it has established dedicated funding for technologies supporting net-zero steelmaking—notably China Steel Corporation's (CSC) "Decarbonization Flagship Action Plan," launched in 2025. As of November 2025, publicly available information indicates a total budget of approximately NT$69.5 billion, equivalent to 0.02% of Taiwan's 2024 GDP (NT$25.54 trillion). However, the Scorecard's definition of "net-zero steel" investment remains ambiguous, making it difficult to fully ascertain the appropriateness of the investment scope.

Investment allocation for mitigation measures should be evaluated based on the carbon abatement cost and efficiency of each technology, taking into account the marginal abatement cost (MAC) associated with adopting emerging technologies. The current budget documentation for CSC's flagship plan lacks annualized cost and emissions reduction data, preventing precise MAC analysis for each mitigation measure. Consequently, this study evaluates the allocation structure of the overall investment. Budget information indicates that the total investment up to 2035 amounts to approximately NT$69.5 billion, alongside projected emissions reductions through 2035 (see Table 5). Approximately 43% of total funding is allocated to the construction of new electric arc furnaces (EAFs), and nearly 30% to carbon capture and storage (CCS), both

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constituting major capital expenditures (CAPEX) and signaling CSC's current technological priorities. Additional CAPEX is dedicated to "hydrogen-enriched blast furnace injection," yet this measure yields only 42,000 tonnes of CO_2 reduction annually—representing merely 0.2% of CSC's yearly emissions. This indicates that the current configuration of public funding is misaligned with the relative mitigation potential of various technologies and warrants further scrutiny.

Table 5: Budget Allocation of CSC's Decarbonization Flagship Action Plan

Investment Target	**Capital Type**	**Total Funding (NT$ billion)**	**Annual CO_2 Reduction (ktonnes)**
Use of low-carbon raw materials in BF	OPEX	100	1,400
Hydrogen-enriched blast furnace injection	CAPEX	10	42
Increased scrap use (including new EAF construction)	CAPEX+OPEX	302	1,190
Use of carbon-free fuel in industrial furnaces	OPEX	77.7	382
CCS	CAPEX+OPEX	205.4	494

Source: adapted from CSC Decarbonization Flagship Action Plan, 2025

III. Carbon Pricing: Low-Ambition Carbon Pricing

Key Readiness Question: To what extent does the carbon pricing mechanism support the low-carbon transition?

Carbon pricing is one of the most widely adopted market-based instruments for shaping sustainability transitions. Taiwan receives a score of **C+** in this category. Although

Taiwan has already established a carbon fee mechanism—scheduled for formal payment beginning in 2026—its overall impact remains limited**.** Moving forward, Taiwan should progress toward establishing an Emissions Trading System (ETS) and take the European Union as a key reference case, particularly regarding the gradual tightening and eventual phase-out of free allowances for emissions-intensive sectors such as steel.

The assessment of "impact" is largely shaped by th**e** level of carbon price currently set under regulation. According to the *Climate Change Response Act*, the carbon fee is set at NTD 300 per ton (approximately USD 10 per ton). However, firms that participate in voluntary reduction programs may qualify for reduced rates of NTD 50 or NTD 100 per ton, further diminishing the mechanism's effective influence. When combined with additional rebates or subsidies associated with the carbon leakage risk coefficient, the effective carbon fee may be further reduced to as low as NTD 10 per ton, thereby substantially weakening the mechanism's overall regulatory impact.

This contrasts with previous analyses of Taiwan's carbon pricing needs. For example, Grantham Research Institute on Climate Change and the Environment and Vivid Economics (2020) argue that Taiwan's carbon price should start at USD 10 per ton of CO_2 and gradually increase to approximately USD 100 per ton after 2030.

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IV. Material Efficiency & Circularity: Lack of Sector-Specific Planning

Key Readiness Question: To what extent does scrap-steel strategy support low-carbon transition?

Taiwan receives a score of C in this category, primarily due to the absence of a sector-specific circular economy or material efficiency plan for the steel industry. Although previous national initiatives—such as the *Industrial Circular Economy Promotion and Guidance Program* and the *Action Plan for the Twelve Key Circular Economy Strategies*—have addressed resource circulation at a general level, they offer limited guidance for the steel sector, particularly regarding how to improve scrap-steel quality.

According to IRENA (2023), resource circularity, scrap reuse, and closed-loop material flows in the steel industry represent critical pathways for achieving net-zero emissions. In the *Net Zero Industry* scenario projections, EAF (Electric Arc Furnace) and H_2-DRI-EAF routes are identified as Taiwan's core decarbonization pathways, both of which depend heavily on a stable and large-scale supply of high-quality scrap steel.

As the *Net Zero Industry* model estimates indicate that EAF production will reach 11.5 million tonnes between 2030 and 2040, corresponding to approximately 12.76 million tonnes of scrap demand. By 2050, although EAF production is projected to decline to 9 million tonnes, scrap demand is expected to remain high at around 9.9 million tonnes.

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The model assumes continuous growth in global scrap availability, Taiwan could theoretically obtain additional scrap through international markets and address domestic supply shortages through imports.

In practice, Taiwan’s steel industry currently requires roughly 8.5 million tonnes of scrap annually, of which about 5 million tonnes is supplied domestically (Taiwan Steel & Iron Industries Association, 2023). To meet the projected peak scrap demand in 2040—representing an approximate 50% increase from current levels—improving scrap quality and ensuring stable supply will be essential.

Table 6: Comparison of scrap steel demand under the *Net Zero Industry* Scenario & current consumption in Taiwan

Unit: million tonnes

Net Zero Industry Pathway Demand		**Current Consumption in Taiwan**
2030	13.66	*2024 total consumption: 8.45
2040	12.88	
2050	9.99	

Source: Adapted from Net Zero Industry (2021) ; Taiwan Steel & Iron Industries Association (2025)

Note: Taiwan imports approximately 3.39 million tonnes of scrap, while around 5.05 million tonnes are supplied domestically.

Moving forward, Taiwan should establish a steel-sector-specific resource circularity strategy, with particular emphasis on scrap steel. This strategy should focus on enhancing scrap quality, strengthening domestic scrap collection and processing capacity, and improving self-sufficiency to supportw53 long-term low-carbon transition.

V. Definitions and Standards & Public Procurement: Meeting Only Minimum Requirements

Key Readiness Question: Has the market for low-carbon (green) steel begun to shape?

In the process of market formation, the E3G Scorecard identifies green steel definitions and green public procurement as two essential measures for initiating demand for low-carbon steel. Taiwan receives a C- for definitions and standards, and C+ for public procurement, indicating that efforts to develop a low-carbon steel market remain at an early stage. As Interviewees 3 and 4 noted, downstream customers in Taiwan's steel supply chain currently exhibit very limited awareness of low-carbon steel, with purchasing decisions still dominated primarily by price considerations. This underscores the importance of government-led green public procurement in stimulating early demand for low-carbon products.

Without a clear and agreed-upon definition of low-carbon steel, the market cannot develop a coherent standard or shared expectation. Taiwan has not yet launched a formal process for developing such standards. At present, the only related reference is provided by the Financial Supervisory Commission's Taxonomy for Sustainable Economic Activities, which designates specific processes in blast furnace production—namely hot metal, sinter, and coke—as contributing substantively to climate change mitigation. This

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taxonomy serves primarily as guidance for directing financial sector investments toward sustainable economic activities rather than setting an operational definition for low-carbon steel in the industrial or commercial market.

Regarding public procurement, the Ministry of Environment announced in 2024 that green procurement shall reach 10% of total government procurement by 2030. Complementary measures include the development of low-carbon public construction guidelines (2024–2025). Additional initiatives—such as the Low-Embodied-Carbon Building Label, which encourages the use of low-carbon and circular construction materials—also contribute to incentivizing the use of green steel.

Taken together, these efforts show that Taiwan has established a preliminary policy foundation in these two areas, though relevant institutional frameworks are still under development. As Interviewee 5 emphasized, establishing a clear and inclusive definition of green steel is essential, both for guiding future public investment and for shaping market expectations and demand patterns.

It is essential to acknowledge that infrastructure requirements are closely intertwined with the choice of low-carbon technologies. For this reason, the present study incorporates technology as one of the assessment dimensions. By doing so, it compares Taiwan's current technological trajectory and corresponding infrastructure deployment with those

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outlined in the Net Zero Industry net-zero scenario. This comparison enables a clearer identification of the discrepancies between Taiwan’s existing conditions and the infrastructure and technology configurations required under a net-zero pathway.

VI. Technology: Misalignment Between Current Technology Choices and Net-Zero Pathways

Key Readiness Question: What is the current level of availability (commercialization) of major technologies under development, and are they capable of delivering sufficient decarbonization depth?

In the assessment of decarbonization technologies for the steel sector, a clear distinction exists between incremental transitional optimization measures and fundamental process transformations. This distinction directly shapes strategic choices and long-term competitiveness. As illustrated in Table 7, the technologies currently adopted by Taiwan and China Steel Corporation (CSC) are predominantly partial retrofits, including hydrogen-enriched blast furnace injection, increasing the share of scrap in the burden mix, and improving energy efficiency. These measures typically deliver approximately 15–25% reduction in emissions. However, because such measures are not regarded as standalone decarbonization technologies, they lack clear classification in terms of Technology Readiness Levels (TRLs). If the industry does not adequately differentiate

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between these optimization measures and innovative technologies capable of enabling deep decarbonization, technological decisions may become biased toward short-term gains, overlooking the structural changes required to achieve long-term net-zero objectives.

In contrast, the Net Zero Industry scenario prioritizes Electric Arc Furnace (EAF) production—capable of achieving 70–80% emission reduction when paired with clean electricity. H_2–DRI–EAF are at TRL 5–6, with commercial viability expected before 2030, and offer over 95% potential emissions reduction. CSC's focus on CCS with blast furnace system remain limited by uncertainties in both technological performance and achievable capture rates. Although CCS is nominally associated with 70% or higher mitigation potential, its real-world effectiveness remains uncertain, and the technology availability might be later than 2030.

Overall, Taiwan's current technological deployment remains largely oriented toward extending the operational life of the BF–BOF system, through measures such as increased scrap use, fuel efficiency improvements, or the introduction of partial capture technologies. These represent medium-term optimization strategies rather than substantive technological transformation. The industry has yet to initiate a genuine shift

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toward the fundamental process innovations required for alignment with net-zero pathways.

Table 7: Comparison of technology pathway under the *Net Zero Industry* Scenario & current development by CSC

Scenario / Current Status	**Technology**	**Technology Readiness Level (TRL)**	**Availability**	**Mitigation Potential**
Net Zero Industry Pathway	H_2-DRI- EAF	5-6	2025-2030	>95% reduction
	EAF	Commercialized	Available	70–80% (with clean energy)
Technology Developed by CSC	Hydrogen-enriched blast furnace injection	-	-	15-25%
	BF-BOF-CCS	5	2030-2035	73% (or lower)

Note: Data on technology readiness levels (TRLs), availability mitigation potentials are compiled from the International Energy Agency-ETP Clean Energy Technology Guide, Agora Industry, while information on technologies developed by China Steel Corporation (CSC) is drawn from CSC Decarbonization Flagship Action Plan (2025).

VII.Infrastructure

Key Readiness Question: Has the supporting infrastructure or corresponding policy planning necessary for low-emission technologies been adequately established?

The critical infrastructure required to enable low-carbon transition in the steel sector includes clean electricity, hydrogen, and carbon capture and storage (CCS). Taiwan receives only a C- rating across all three categories. The primary reason is that the steel sector’s decarbonization needs are not meaningfully integrated into national infrastructure or energy planning. Each of these infrastructures constitutes a major niche that exhibits strong shared-use characteristics; none are used exclusively by the steel sector. Although Taiwan has its own national plans for each domain, such as renewable energy deployment, hydrogen development, and CCS roadmaps, the specific needs of the steel industry are not explicitly reflected in these plans. As a result, infrastructure planning does not provide sufficient certainty for the sector to “confidently transition,” leading to persistent concerns regarding “future power shortages, unclear hydrogen supply sources, and the lack of carbon storage sites after CO_2 capture” (Interviewee 4; Interviewee 5).

As shown in Table 8, under the Net Zero Industry Pathway, the total electricity consumption of the steel sector is in fact lower than Taiwan’s current level. More importantly, the scenario assumes that by 2050 the grid’s emission factor approaches zero, enabling highly electricity-intensive decarbonization technologies—such as electric arc furnaces (EAF) or hydrogen-based direct reduced iron combined with electric arc furnaces (H_2-DRI-EAF)—to fully realize their mitigation potential.

In contrast, Taiwan’s current and projected electricity mix diverges substantially from this requirement. According to government plans, renewable energy penetration will reach only about 30% by 2030, corresponding to a grid emission factor of 0.319 kg/kWh. Although this value falls to 0.241 kg/kWh by 2035, it still represents nearly 300 g/kWh, far from the near-zero-carbon grid assumed in international net-zero models. By 2050,

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Taiwan aims to increase renewable energy's share to 60–70%, but whether the grid can reach a near-zero emissions state remains uncertain.

These gaps indicate that the principal bottleneck for aligning Taiwan's steel sector with a net-zero technological pathway lies not in electricity demand, but rather in the carbon intensity of the power grid. Even if the sector adopts deep-decarbonization technologies such as EAF or H_2-DRI-EAF, the benefits will remain significantly limited as long as the electricity mix contains a substantial share of fossil fuels. In other words, the steel sector's ability to achieve net-zero emissions is fundamentally contingent upon the decarbonization of Taiwan's power system.

Table 8: Comparison of electricity demand under the *Net Zero Industry* scenario & status quo in Taiwan

Scenario / Current Status	**Electricity Demand**	**National Electricity Grid Emission Factor**
Net Zero Industry Pathway	2030: 8.07 TWh 2040: 10.3 TWh 2050: 7.05 TWh	Scenario assumption: public grid emissions near zero (< 50 gCO_2/kWh)
Taiwan's Status Quo	*11.2~18 TWh/year	Taiwan's target: 319 gCO_2/kWh by 2030 292 gCO_2/kWh by 2032 239 gCO_2/kWh by 2035

Note: Over the past five years, the steel sector purchased an average of 11.2 TWh per year of external electricity from Taipower ; the broader base metals manufacturing industry, including steel, aluminum, and copper, consumes 18 TWh annually.

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- **Hydrogen**

As shown in Table 9, the net-zero industry scenario adopted in this study assumes the H_2-DRI-EAF route as the primary technological pathway. However, neither CSC’s Decarbonization Flagship Action Plan nor the Flagship Action Plan for Decarbonization of the Hydrogen (including Ammonia) Supply Chain provides an explicit estimate of the total hydrogen demand required for the steel sector. Instead, hydrogen demand is only indirectly referenced in a 2023 policy report, which outlines potential hydrogen requirements associated with blast furnace hydrogen injection and steel–chemical co-production. These approaches differ fundamentally from the H_2-DRI-EAF pathway in terms of both technological purpose and underlying system logic. Setting aside the differences in technological pathways, two clear trends can be observed in Taiwan’s current national-level hydrogen strategies:

- Hydrogen is primarily positioned as a fuel for power generation, serving as a substitute fuel within the electricity sector.
- Hydrogen supply is expected to rely predominantly on imports rather than domestic production.

These trends indicate that hydrogen for industrial applications in Taiwan is likely to depend on imported sources, creating a significant structural constraint for the steel sector’s long-term decarbonization options.

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Table 9: Comparison of hydrogen demand under the *Net Zero Industry* scenario & status quo in Taiwan

Scenario / Year	**Net Zero Industry Pathway**	**CSC's Plan**	**Government Planning**
2030	35.7 ktonnes	42 ktonnes	-
2040	51 ktonnes	264 ktonnes: steel–chemical co-production	-
2050	153 ktonnes	280 ktonnes	*3.67 million tonnes

Note: By 2050, approximately 65% of hydrogen demand is projected to be allocated to power generation, 34% to industrial use, and the remainder to the transportation sector. Domestic hydrogen production is expected to reach approximately 0.37 million tonnes, with the remaining 3.3 million tonnes supplied through imports. CSC's plan is referenced from the Status of Implementation of the Hydrogen Key Strategic Action Plan published by the Ministry of Economic Affairs (MOEA, 2023).

The demand assessment is based on the following sources: Status of Implementation of the Hydrogen Key Strategic Action Plan (Ministry of Economic Affairs, 2023); Taiwan 2050 Net-Zero Transition: Hydrogen Key Strategic Action Plan (Ministry of Economic Affairs, 2023); and Hydrogen (Including Ammonia) Supply Chain Decarbonization Flagship Action Plan (Ministry of Economic Affairs, 2025).

- **CCS**

Carbon capture, utilization, and storage (CCUS), while recognized as an important component of decarbonization strategies in the steel sector, continues to face substantial limitations related to technological maturity and deployment conditions. Challenges such as capture efficiency, the geological feasibility of long-term storage sites, and the construction of cross-sector CO_2 transport infrastructure have slowed global commercialization in recent years. The steel sector's CCUS investment pipeline also lags significantly behind hydrogen-based direct reduced iron technologies (Agora Industry, 2024). As demonstrated in the technical assessment of this study, the BF–BOF–CCS

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pathway achieves a maximum decarbonization potential of only around 73% under optimal conditions, falling short of the deep reductions required for long-term net-zero alignment. In the Net Zero Industry model, CCUS is not included among Taiwan's feasible net-zero technology options, primarily due to the absence of suitable geological formations for CO_2 storage near existing steelmaking sites, as well as the lack of CO_2 pipelines and shared industrial cluster infrastructure necessary for system-wide deployment.

Within the Taiwanese context, China Steel Corporation (CSC) has positioned "steel–chemical co-production" as the core direction of its CCUS development. The pilot plant was completed in 2022 and has verified basic technical feasibility; however, progress toward a full demonstration plant may currently be suspended, with an expected mitigation volume of roughly 125,000 tonnes CO_2 per year. In 2025, CSC incorporated CCS into its flagship decarbonization program, allocating investment beginning in 2032. Concurrently, the national CCS roadmap prioritizes CCU research and applications before 2030 and sets a target of achieving 6 million tonnes of annual CO_2 storage by 2035. Collectively, these developments indicate that although CCS retains mid- to long-term potential, it continues to face significant institutional, geographic, and technological constraints in Taiwan. Consequently, its strategic role remains secondary compared to the hydrogen-based DRI pathway.

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Table 10: Comparison of CCS plan under the *Net Zero Industry* Scenario & status quo in Taiwan

Scenario / Current Status	**Overview of CCS Planning**
Net Zero Industry Pathway	CCS has not been incorporated into Taiwan's technological options.
CSC's Plan	The steel–chemicals co-production pilot plant was completed in 2022, but the demonstration plant phase may be suspended. CCS has been included in the flagship program, with budget allocations beginning in 2032.
Government Planning	In the short term (before 2030), the focus is on CCU, with a target of storing 6 million tonnes of CO_2 by 2035.

Note: Reference from CSC Decarbonization Flagship Action Plan (China Steel Corporation, 2025), CCUS Decarbonization Flagship Action Plan (draft) (Ministry of Economic Affairs, 2025)

Structural Gaps in Taiwan's Steel Decarbonization: Infrastructure Shortfalls and Weak Market Formation

Based on the results of the readiness scorecard, the most significant gaps in Taiwan's low-carbon transition for the steel sector are concentrated in two key dimensions: infrastructure and demand-side market formation, including institutional mechanisms such as green-steel definitions and green public procurement. With respect to infrastructure, the gap does not merely stem from the misalignment between national-level energy and hydrogen strategies and the actual needs of the steel industry. More critically, it reflects the sector's strong path dependence in technological choices. Current technological deployment remains largely centered on extending the lifespan of the existing blast furnace system, resulting in limited urgency—both within government and industry—to plan for the clean electricity, hydrogen, and carbon storage infrastructure required for a net-zero transition. Conversely, the long-standing absence of such infrastructure planning undermines firms' incentives and confidence to adopt more transformative low-carbon technologies, thereby creating a condition of mutual stagnation.

This situation is further shaped by broader institutional and landscape-level factors, including the pace of the national energy transition, the strength of market signals, the degree of policy coordination, and pressures arising from global competition. To better capture these interdependencies, this study incorporates the Multi-Level Perspective (MLP) within sustainability transition theory, enabling a macro-level examination of the observed gaps and clarifying the structural barriers that constrain Taiwan's steel decarbonization. Through this analytical lens, the study demonstrates that the sector's delayed transition cannot be attributed to isolated policy shortcomings alone. Rather, it results from a combination of insufficient infrastructure development, conservative technological decision-making, and weak demand-side incentives—together constituting a system-wide impediment to deep decarbonization.

4.2 Narratives of Taiwan's Iron and Steel Industry Low-carbon Transition

Following the assessment in chapter 4.1 of the gaps between Taiwan's steel sector decarbonization trajectory and its national net-zero targets, this chapter employs

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Sustainability Transition Theory, drawing specifically on the Multi-Level Perspective (MLP) as the analytical framework. Supplemented by interview findings and secondary data, the analysis examines the major challenges currently constraining Taiwan's steel industry and identifies potential transition windows within the global low-carbon transition landscape.

According to the MLP framework, the decarbonization transition of Taiwan's steel sector is shaped by interactions among three analytical levels: the landscape, the regime, and niche innovations (see Figure 6). Based on interview data and secondary sources collected between September 2023 to November 2025, this study analyzes the dynamic developments associated with these three transition elements.

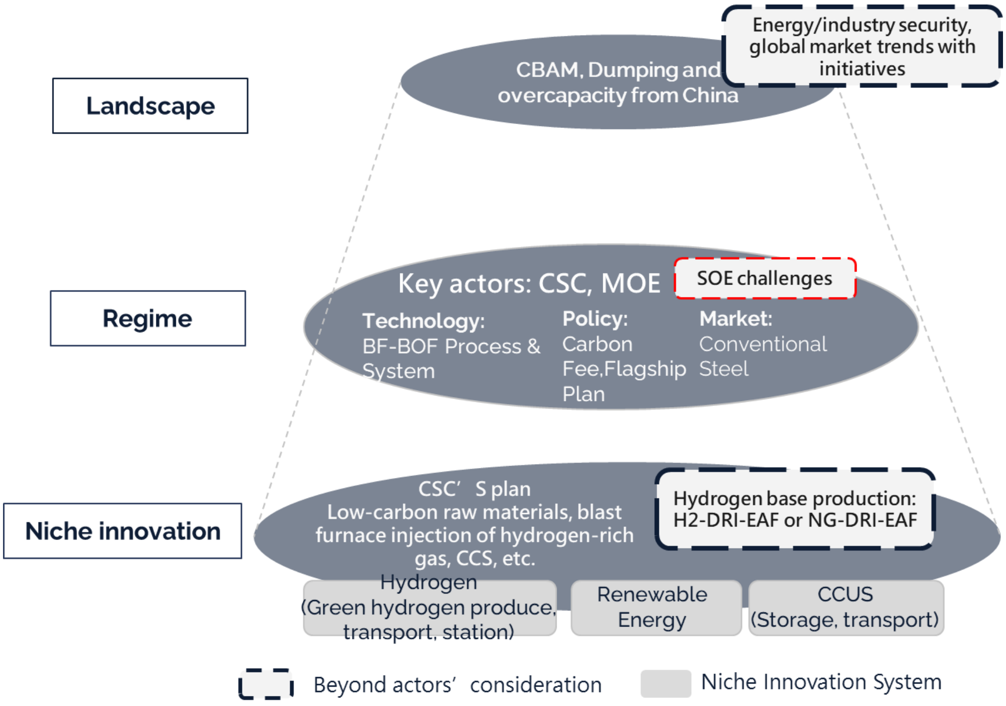

Figure 7: MLP structure of Taiwan's iron and steel decarbonization transition

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Landscape Level

The landscape context refers to external factors that interact with the regime, including oil prices, economic growth, wars, migration, broad political coalitions, cultural and normative values, and environmental problems (Geels, 2002). In this study, interviewees were directly asked to identify which external factors they perceived as influencing decarbonization strategies in the steel industry. In addition, secondary data were collected to further identify and substantiate relevant landscape elements.

Among the landscape factors highlighted by some interviewees were the European Union's Carbon Border Adjustment Mechanism (CBAM) and China's industrial overcapacity and dumping practices. However, two factors that received limited attention from industry respondents in Taiwan—despite their significance as landscape-level influences—were energy and industrial security, as well as global green procurement initiatives.

- EU Carbon Border Adjustment Mechanism

Taiwan's steel exports to the European Union consist primarily of fasteners and screws. When the EU announced the implementation of the Carbon Border Adjustment Mechanism in 2023, it generated substantial pressure on Taiwanese industries, prompting the government to launch the "Steel Industry Decarbonization Expert Service Program"

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to assist small and medium-sized producers in assessing their low-carbon transition needs. However, due to the lack of long-term incentives and financial support, this pressure did not translate into sustained momentum (Interviewee 2).

CBAM is nevertheless scheduled for full implementation in 2026, with importers required to surrender certificates starting in 2027. Although the current phase remains transitional with trial reporting, approximately 15% of China Steel Corporation’s exports are destined for Europe. Once free allowances for the steel sector under the EU ETS are gradually phased out, carbon-intensive products will face increasingly stringent market barriers. If CBAM coverage expands to include additional downstream steel products, the impact on Taiwan will intensify. Thus, landscape pressure for low-carbon transition remains significant and is tied to explicit time constraints.

- China’s long-term overcapacity and dumping

Persistent overproduction and dumping in China have distorted international steel prices, compressing profit margins for Taiwan’s steel industry and constraining its capacity to invest in green transition measures (Interviewees 3 and 7).

- Supply chains’ vulnerability and implication for industry security

Geopolitical developments and heightened concerns over energy and industrial security further contribute to landscape pressure, creating a structural tension for Taiwan between

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its dependence on high-carbon production routes and its vulnerability to imported energy and resources (Interviewee 8). The BF-BOF steelmaking system relies heavily on iron ore and coking coal as critical inputs. Given Taiwan’s lack of these resources, both must be imported, rendering the stability of upstream raw material supply chains a fundamental structural condition for industrial development. Coking coal, as a form of conventional fossil fuel, has attracted growing attention in the context of global energy transitions and geopolitical realignments due to its embedded risks of supply disruption, price volatility, and long-term sustainability. The strong dependence of the blast furnace regime on coal, in particular, exposes the steel industry to multiple supply chain vulnerabilities, including high export concentration, long transportation distances, and sensitivity to policy interventions and geopolitical disruptions.

The European Union provides a relevant comparative case. Since 2014, coking coal has been formally listed on the EU’s Critical Raw Materials list due to its high economic importance and significant supply risk. Influenced by geopolitical considerations, the EU has progressively reduced its reliance on Russian coking coal since 2018, while increasing imports from Australia, the United States, and Canada. This shift illustrates that coal remains a strategically sensitive material even under conditions of decarbonization. In 2024, the EU formally adopted the Critical Raw Materials Act (CRMA), explicitly identifying the reduction of external raw material dependence and

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the enhancement of supply chain resilience and industrial autonomy as core policy objectives underpinning competitiveness in green, digital, and defense-related industries. This was followed in 2025 by the launch of the *European Steel and Metals Action Plan*, which seeks to safeguard European steelmaking capacity and industrial competitiveness while responding to decarbonization targets by emphasizing affordable energy supply, carbon leakage prevention, market-shaping instruments, and public support to reduce investment risks associated with low-carbon steel technologies.

In Taiwan's blast furnace–based steelmaking system, coal inputs can be broadly categorized into thermal coal and coking coal. Thermal coal is primarily used for process energy supply, whereas coking coal functions as an indispensable reducing agent within the blast furnace. The global trade in coking coal is highly concentrated, with Australia as the dominant exporter, and Taiwan is correspondingly highly dependent on Australian imports. This dependence exposes Taiwan's steel industry to multiple potential risks, including rising costs driven by increasingly stringent environmental and safety regulations in coal mining, as well as growing pressure from Scope 3 emissions associated with substantial methane leakage during coal extraction.

In response to these intertwined supply chain and climate-related risks, certain low-carbon technological pathways have been framed as potential strategic alternatives. Among these, the hydrogen-based direct reduced iron–electric arc furnace (H_2-DRI-EAF)

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route theoretically eliminates the need for imported coal, thereby fundamentally reducing coal-related supply chain vulnerabilities. Although hydrogen procurement—whether through domestic production or international imports—may introduce new transnational supply chain configurations, hydrogen differs from coal in that it is not constrained by fixed natural resource endowments. Instead, it offers the potential to establish domestic production capacity through policy-driven investment and technological deployment. As such, hydrogen-based steelmaking may provide Taiwan with a strategic option to advance a national industrial and energy transition centered on localized low-carbon energy, while maintaining production stability and industrial security.

Table 11. Advantages and supply chain risks of low-carbon steelmaking technologies

Low-carbon technology	**Key imported inputs**	**Advantages**	**Key risks**
BF-BOF-CCS	Iron ore; coking coal; thermal coal	• Allows incremental decarbonization while utilizing existing BF–BOF assets • Lower short- to medium-term transition barriers compared to radical process change • Less stringent raw material quality requirements than H_2–DRI	• Continued dependence on imported coal, exposed to supply concentration, geopolitical risks, and price volatility • High Scope 3 emissions from coal mining, particularly methane
H_2-DRI-EAF	Iron ore (high-grade pellets); hydrogen (domestic or imported)	• Eliminates coal use and associated supply chain and Scope 3 emission risks • Offers the lowest process-level decarbonization potential consistent with net-zero pathways	• Dependence on high-grade iron ore may generate new upstream supply constraints • Limited availability of low-carbon hydrogen and electricity may create new

		• Enhances long-term energy and industrial autonomy through policy-enabled domestic hydrogen and power production	energy import dependencies • High upfront investment costs and ongoing technological and infrastructure uncertainty

- Emerging global coalitions and green procurement initiatives to accelerate low-carbon steel

International initiatives—such as the First Movers Coalition (FMC) and the Industrial Deep Decarbonization Initiative (IDDI)—indicate that both private and public sector actors are increasingly organizing around the development of a low-carbon steel market. These landscape-level changes signal a broader market trajectory that is likely to accelerate the maturation of the global low-carbon steel market in the near future.

Regime Level

Since its establishment in 1977, the steel production system centered on China Steel Corporation (CSC) has relied on an integrated blast furnace–basic oxygen furnace (BF–BOF) route, resulting in deep technological and infrastructural lock-in. Such lock-in extends beyond the smelting technology itself to encompass the broader energy structure, supply chain configuration, and market operations. As a result, major technological shifts and system-wide reconfiguration face substantial resistance. Although both the Ministry of Economic Affairs and CSC serve as key regime actors, current decarbonization policies—such as the carbon fee and the flagship decarbonization program—provide transition signals but lack clear and binding long-term targets. This absence of direction prevents critical cross-system resources such as renewable energy, hydrogen, and CCS from becoming effectively integrated. Furthermore, the lack of a clear definition for “green steel” and the absence of a mature green public procurement framework weaken market orientation and policy guidance for the sector.

Under relatively moderate landscape pressure, CSC’s current transition efforts remain largely at the level of modular substitution, such as hydrogen-enriched blast furnace injection or the use of lower-carbon raw materials. These measures indicate a focus on incremental improvements to existing core elements rather than system-level restructuring across architectural boundaries. Although CSC has initiated exploration of emerging options such as steel–chemical co-production, the absence of comprehensive national planning for hydrogen and CCS means that related infrastructures have not been incorporated into an integrated long-term blueprint. Industrial needs are likewise insufficiently reflected in government initiatives. This highlights insufficient policy coordination and ambiguity in regulatory direction, deepening existing path dependencies and structurally constraining more transformative decarbonization.

As a state-owned enterprise (SOE), CSC holds substantial legitimacy within the regime; however, it also confronts an ownership dilemma. On the one hand, its technical expertise leads regulatory institutions, such as the Ministry of Economic Affairs, to rely heavily on CSC’s professional judgment. On the other hand, as a semi–state-owned enterprise, CSC

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must balance profitability requirements with decarbonization targets. When "profitability pressures outweigh decarbonization pressures," transition momentum tends to stall (Interviewee 8).

Other actors within the regime, including government authorities and major customers in the steel market, exhibit differentiated dynamics within the transition system. In Taiwan's context, these actors include government agencies—most notably the Ministry of Environment and the Ministry of Economic Affairs—as well as key downstream steel users such as the construction sector, the fastener industry, and other downstream manufacturing customers. On the government side, the Ministry of Environment has advanced carbon fees and other climate-related regulations, while the Ministry of Economic Affairs has promoted flagship decarbonization initiatives and sectoral mitigation programs for the manufacturing industry, collectively signaling policy recognition of and commitment to low-carbon transition.

On the demand side, downstream customers that are exposed to international trade competition are more likely to be influenced by emerging low-carbon transition pressures, thereby contributing to the initial shaping of demand for low-carbon steel. Examples include fastener manufacturers exporting to the European Union and subject to CBAM-related requirements, as well as firms participating in international low-carbon procurement initiatives, such as Ørsted, while these actors demonstrate partial recognition

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of and engagement with low-carbon transition objectives, their positions and actions have not yet formulated the critical momentum or systemic openings necessary to facilitate niche breakthrough and challenge the regime.

Niche Level

Niche innovations in Taiwan’s steel decarbonization landscape currently exhibit a dual pattern. Domestically, CSC-led innovations remain centered on incremental improvements within the existing blast furnace system—such as hydrogen injection, increased use of low-carbon raw materials, and steel–chemical co-production. These belong to the category of modular substitution, rather than innovations capable of driving system reconfiguration.

Internationally, however, three major technological systems—hydrogen, renewable energy, and carbon capture and storage/utilization (CCS/CCUS)—are advancing rapidly. Among these, hydrogen-based direct reduced iron (H_2-DRI) is widely regarded as possessing the highest long-term decarbonization potential. As hydrogen and renewable energy costs continue to fall, the overall mitigation cost of the H_2-DRI pathway is expected to converge with that of the BF–BOF–CCS configuration (Agora Industry, 2025). Despite this trend, Taiwan currently lacks a clear national deployment plan or R&D investment strategy for H_2-DRI and related technologies. Therefore, niche innovations have not yet accumulated sufficient momentum to challenge the regime.

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Fast Changing Landscape create Windows of Opportunity

Although current landscape dynamics give only moderate pressure, most Taiwanese interviewees identify China’s dumping and global market instability as the primary external influences, generally perceiving them as factors that intensify barriers to low-carbon transition in the steel sector (Interviewees 3 and 4). It is also common for regime actors to perform resistance at certain degree toward change. However, as Geels (2014) argues, “Landscape-level cultural, political, and normative changes can undermine regime legitimacy, creating opportunities for niche alternatives.” If landscape-induced dynamics are reframed through alternative narratives that highlight the strategic value of transition—shifting from a discourse of “no urgency to decarbonize” to one of “a critical and timely opportunity”—societal and institutional actors may initiate new windows for transformation.

First, under the broader framing of energy and industrial security, continued reliance on fossil fuel–based blast furnace production deepens Taiwan’s exposure to import dependency risks. A transition toward renewable energy and hydrogen-based production pathways would not only support decarbonization but also strengthen industrial resilience. The European Union’s Action Plan for Steel and Metals released in early 2025, under the Clean Industrial Deal, places climate resilience at the center of industrial upgrading—illustrating the strategic importance of framing low-carbon transition as a pathway for strengthening industrial resilience. This approach offers a meaningful reference for Taiwan as it considers its own transition strategy.

Second, China’s persistent dumping and structural overcapacity continue to suppress global steel prices, constraining the financial space available for low-carbon investment. Yet this structural pressure could be reframed as a green-trade opportunity through policy design. Measures such as low-carbon steel certification or embedding green requirements into public procurement could, as Interviewee 8 notes, help transform these pressures into drivers of regime reconfiguration.

Finally, the formal implementation of CBAM places Taiwan’s fastener and downstream exporters at the forefront of compliance challenges. Although domestic institutions have begun initiating complementary measures, the broader regime still lacks comprehensive momentum for low-carbon transition. As free allowances in the EU ETS are gradually phased out for high-emission industries, the global steel market will accelerate its shift toward “clean steel.” Without timely strategic positioning, Taiwan’s export competitiveness will weaken further, making this an even more critical transition window for the domestic steel industry.

Transition Pathway: From Transformation to Reconfiguration

Over the past decade, empirical studies on low-carbon transitions have shown that the transformation and reconfiguration pathways most accurately reflect real industrial transition processes (Geels & Turnheim, 2022). Moreover, unlike many emerging sectors, the steel industry is experiencing transition pressures not through linear substitution but through reconfiguration (Geels & Schot, 2007). This study finds that the current trajectory of Taiwan's steel sector aligns primarily with the characteristics of transformation: under moderate landscape pressure and in the absence of mature niche innovations, regime actors such as China Steel Corporation (CSC) and the Ministry of Economic Affairs respond by adjusting institutional rules, investment directions, and innovation goals.

However, advancing toward reconfiguration—a pathway in which emerging technologies, energy systems, and governance arrangements become integrated into the regime—requires Taiwan's steel industry to overcome two major barriers:

(1) Regime lock-in.

The deep capital, infrastructural, and supply-chain integration of the existing blast furnace system creates strong path dependency, limiting the diffusion of alternative technologies.

(2) Policy uncertainty.

Both government and CSC exhibit limited ambition regarding the depth and pace of decarbonization, and the strategic direction for hydrogen-based steelmaking remains unclear. At the same time, insufficient coordination across key infrastructure systems and

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weak efforts to cultivate demand-side signals further exacerbate uncertainty, constraining the conditions necessary for deeper transition.

Taken together, Taiwan’s steel decarbonization remains at the stage of within-regime transformation: while early signs of technological substitution and policy signaling are emerging, they have not yet coalesced into cross-system, integrative reconfiguration.

This study argues that corresponding policy interventions must build upon Taiwan’s existing institutional architecture while creating opportunities for horizontal coordination that gradually loosen regime lock-in. By leveraging landscape-generated windows of opportunity and enabling niche innovations to enter the regime core, Taiwan can move from incremental transformation toward genuine system reconfiguration, thereby achieving the dual objectives of decarbonization and industrial upgrading.

4.3 Policy Mix

The final section of this study proposes a concrete policy mix based on identified transition gaps and the MLP analysis. Drawing on Sections 4.1 and 4.2, the key deficiencies and corresponding policy instruments are summarized in Table 11. The main gaps in Taiwan’s steel industry’s low-carbon transition lie in infrastructure development and demand-side formation. In line with transition theory emphasizing system reconfiguration, the study finds a lack of cross-architectural coordination and integrative

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planning. A central task of the policy mix is therefore to effectively leverage landscape pressures and facilitate the reorientation of incumbent actors (e.g., CSC and the Ministry of Economic Affairs), enabling niche innovations to overcome regime lock-in, enter the mainstream, and diffuse over the medium to long term.

Table 12. Mapping of transition gaps and corresponding policy instruments

No.	Key Gaps	Source	Policy Instruments	Reference Country Cases / Interview Sources
1	Insufficient deployment of infrastructure	Readiness assessment	National-level renewable energy and hydrogen strategies linked with industrial development	Japan (Interviewee 5)
2.	Insufficient deployment of demand-side formation	Readiness assessment	Definition of green steel, public procurement measures, etc.	Japan (Interviewee 5)
3.	Dependence on blast-furnace-based fossil resource supply chains	MLP – Landscape Dynamics of Coking Coal Reliance	Strategic deployment of hydrogen-based steelmaking pathways	Hydrogen-based steelmaking initiatives in Japan and South Korea (Interviewees 5, 6)
4.	Infrastructure development lacks reconfiguration characteristics	MLP – Reoriented Transition Pathway	Cross-industry planning of key infrastructure; private sector participation in public infrastructure projects	Literature, e.g., IEA reports on policy tools

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5.	Insufficient space for green investment	MLP – Landscape Dynamics of Investment Gap	Financial instruments: tax incentives, relaxed lending criteria, subsidy schemes such as CCfDs	Germany and Sweden (Interviewee 8), South Korea (Interviewee 6)

The timing of the policy mix should be aligned with technological and practical conditions, including the remaining lifetime of blast furnaces and the planning of technological transition pathways.

I. Lifespan and Investment Cycle of Blast Furnaces in China Steel Corporation

From a corporate operational perspective, blast furnaces are highly capital-intensive production assets. Decisions regarding the adoption of emerging low-carbon technologies involve long investment cycles and high-risk assessments. Therefore, when planning the transition timeline, it is essential to take into account both the lifespan of the furnaces and their investment decision cycles (Agora Industry, 2025; Interviewee 7).

Typically, each blast furnace can continue operating for approximately 15 years after undergoing relining, while investment decisions related to decarbonization technologies need to be determined three to five years prior to implementation to secure the investment direction and technological pathway.

Based on data from the Global Iron and Steel Tracker, which documents the commissioning dates and operational statuses of Taiwan's blast furnaces, this study estimates the remaining lifespan of each furnace and identifies the critical timing for corresponding investment decisions (see Table 11). The results indicate that China Steel Corporation (CSC) plans to reline two blast furnaces between 2028 and 2029, while its subsidiary Dragon Steel Corporation will need to reline one of its two furnaces before 2030.

Together, these three blast furnaces represent a total crude steel production capacity of approximately 7.5 million tonnes, accounting for about 46% of CSC Group's annual output. This schedule implies that the next two years will constitute a strategic window of opportunity for advancing low-carbon transition planning and investment decisions. The timing of these relining projects holds critical strategic significance for ensuring technological upgrading and alignment with the national carbon neutral pathway.

Table 13: CSC blast furnaces details

No.	**Status**	**Start date**	**Retired Date**	**Current Capacity(*ttpa)**	**Most recent relining**
China Steel Corporation					
BF 1.	operating pre-retirement	1977	2030	2100	-
BF 2.	operating	1982	-	2920	2021
BF 3.	operating	1988	-	3000	
BF 4.	operating	1996	-	3000	2014
Dragon Steel Corporation					
BF 1.	operating	2010	-	2500	2025
BF 2.	operating	2013	-	2500	

Source: Global Iron and Steel Tracker, Global Energy Monitor, 2025

II. Net-zero Achievement Potential: Insights from the "Net Zero Industry" Model

In designing the policy mix, this study adopts the achievement of net-zero emissions by

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2050 as the ultimate vision, and uses the deployment potential of decarbonization technologies as the core basis for strategic planning. To this end, the analysis refers to international model-based assessments developed for Taiwan's steel sector, particularly the Net Zero Industry Model, as a benchmark for policy recommendations. According to this model, the key technological milestones include: the introduction of 500,000 tonnes of hydrogen-based direct reduced iron (H_2-DRI–EAF) production capacity before 2030, followed by an expansion to 3.5 million tonnes before 2040.

These phased targets not only provide quantitative indicators for guiding the domestic steel industry's low-carbon technology transition, but also offer concrete direction for government decisions on resource allocation and policy instrument design.

First, the policy architecture must be grounded in a directive "Steel Sector Decarbonization Plan" that clearly articulates the government's commitment and long-term objectives for industrial decarbonization. Evidence suggests that clear and binding policy commitments play a decisive role in enabling low-carbon transitions—particularly in contexts involving state-owned enterprises (SOEs) (OECD, 2025; Interviewee 8). As a semi–state-owned enterprise, China Steel Corporation (CSC) must recalibrate its balance between profitability pressures and green investment under the policy guidance of the Ministry of Economic Affairs. This requires the government to share part of the financial performance burden so that CSC can allocate more resources toward low-carbon

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transformation (Interviewee 8).

On this basis, the policy framework should include phased timelines and the necessary complementary measures, while also demonstrating cross-architecture coordination, including clean electricity provision, hydrogen supply, CCS capacity, and scrap recycling systems.

In designing structure of the policy mix, this study takes into account the targets of establishing partial hydrogen-based DRI capacity by 2030 and 2040, the scheduled retirement of CSC Group’s blast furnaces, as well as the planning timelines of Japan and South Korea. Accordingly, the proposed policy mix distinguishes between actions required in the period “now to 2030” and those necessary “after 2030”, thereby establishing a transition pathway that is both technologically feasible and institutionally robust.

From Now to 2030: Direction-setting and Strategic Positioning

Core Objective: Establish hydrogen-based direct reduced iron (H_2-DRI) as the primary transition niche.

- Production Side: Clean Electricity, Hydrogen, and CCS

First, Taiwan must launch a national hydrogen strategy for the steel sector, identifying hydrogen-based DRI as the core of future industrial competitiveness and prioritizing its deployment alongside transitional applications of natural gas–based DRI. At the same time, the government should evaluate integrated solutions for both domestic hydrogen production and hydrogen imports, in order to reduce exposure to supply risks associated with a single source.

Key infrastructures—including clean electricity, hydrogen, and CCS—must be developed through a mutually reinforcing and symbiotic approach to overcome the current condition of architecture unchanged and to enable cross-system coordination. Hard-to-abate sectors have highly overlapping needs for renewable energy, hydrogen, and CCS infrastructure, underscoring the urgency of establishing inter-ministerial coordination mechanisms and prioritizing locations with industrial pipeline connectivity or spatial clustering as demonstration zones.

This process should proceed sequentially from architecture stretching to architecture reshaping: the former focuses on assessing the feasibility of repurposing existing infrastructure (e.g., natural gas pipelines, hydrogen transportation corridors), while the latter involves planning new pipelines and storage facilities.

In terms of clean electricity, the steel industry's high electricity demand should not be viewed as a burden; rather, it can serve as a stabilizing force for renewable energy and as a catalyst for expanding the PPA market. Thus, establishing long-term and predictable renewable energy supply mechanisms is essential. In parallel, circularity policies must

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be strengthened, including improving scrap quality and ensuring stable scrap availability, to support the development conditions of the EAF system.

- Demand side: green steel standards and green public procurement

According to the Steel Decarbonization Policy Mapping released by the Climate Club in 2025, 78% of existing policies among major steel-producing countries are supply-side oriented, with comparatively few demand-side measures. However, the Demand and Supply Measures for the Steel and Cement Transition report from Climate Club also emphasizes that demand-side policies are essential for generating market signals and increasing the adoption of green steel. Green steel standards and green public procurement constitute long-term institutional projects and must be initiated promptly. As Interviewee 7 notes, even in regions with mature low-carbon mechanisms—such as the EU—these systems require years of preparation. Therefore, to establish an initial low-carbon steel market by 2030, the definition of green steel and the design of green public procurement must begin immediately.

Regarding green steel definitions, Interviewee 5 emphasizes that their formulation must avoid favoring specific domestic producers, so as not to create unbalanced incentives or selective subsidies. Policy design must therefore account for the operational differences between BF–BOF and EAF producers, while referencing international standards—such as ResponsibleSteel and the EU’s Low Emission Steel Standard (LESS), which uses the "staircase" approach based on scrap input ratios—to avoid displacement effects and technological bias.

For green public procurement, beyond the current target of "10% green public procurement value by 2030," low-carbon steel must be incorporated into public construction requirements. A gradual shift from voluntary to mandatory mechanisms is needed. A reference model is the Industrial Deep Decarbonization Initiative (IDDI), which adopts a phased schedule and requires the use of low-carbon cement and steel in public projects no later than 2030. Taiwan's existing green steel definition in sustainable finance (referencing EU ETS benchmarks) can be integrated into public procurement standards to enhance embedded carbon management and strengthen market effects that reduce marginal abatement costs.

- Other policy instruments: carbon contracts for difference (CCfDs) and carbon fee increases

Because DRI facilities involve substantially higher initial capital and operating expenditures than traditional blast furnace routes, Carbon Contracts for Difference (CCfDs) can reduce firms' financial burdens and maintain the economic viability of climate-friendly steel before it becomes cost-competitive with high-emission steel (Agora Industry, 2022). International Energy Agency (2025) finds that CCfDs address both supply- and demand-side challenges: they provide firms with guaranteed price

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stability and predictable returns on low-carbon investments, while allowing governments to control fiscal expenditure and abatement costs through competitive bidding.

For example, Germany introduced CCfDs in 2024 as the core subsidy mechanism for low-carbon production in hard-to-abate sectors, committing EUR 2.8 billion to reduce approximately 17 million tonnes of CO_2 over 15 years. If Taiwan were to adopt CCfDs, preliminary estimates using Agora Industry's (2022) Steel Transformation Cost Calculator indicate that, for 0.5 million tonnes of crude steel and a carbon fee of USD 10 per ton, switching to natural gas–based DRI would require an annual subsidy of approximately NTD 3.2 billion, while hydrogen-based DRI would require approximately NTD 6.2 billion.

CCfDs typically have contract durations of 10–15 years, with subsidy amounts adjusting annually to reflect energy prices and carbon market fluctuations. They require firms to submit verified GHG and energy efficiency reports. When market carbon prices exceed the strike price, firms must return the difference. Additional design elements—such as mandatory technology sharing, subsidy caps, minimum abatement thresholds, and time-bound conditions—can maximize policy effectiveness and enhance niche diffusion.

In addition, gradually increasing the carbon fee is essential for strengthening the low-carbon transition (Interviewee 1). Taiwan's Ministry of Environment set the initial

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carbon fee at USD 10 in 2025; however, many studies indicate that a carbon price of around USD 100 by 2030 would help generate credible market signals and steer firms toward long-term low-carbon investments (Carbon Pricing Leadership Coalition, 2017; Burke et al., 2019; Kaufmann et al., 2020). Importantly, as carbon prices rise, CCfD subsidies will naturally decline, thereby reducing government expenditure and enabling a shift from subsidy-based mechanisms to market-driven incentives. By strengthening price signals and lowering fiscal burdens, this combined approach can create a virtuous cycle of policy incentives and market momentum, accelerating the deployment of low-carbon technologies.

Post-2030: Diffusion and Consolidation

Core Objective: To scale up and consolidate low-carbon production niche.

- Production side: institutionalization and stabilization of key infrastructure

In the post-2030 policy framework, the central task on the production side is to ensure the institutionalization and long-term stability of critical net-zero infrastructure. Hydrogen and CCS infrastructure are capital-intensive, cross-sectoral, and directly tied to public safety; thus, their development requires not only technological maturity but also robust legal systems and governance structures.

First, in the area of hydrogen, a long-term hydrogen contracting mechanism must be established to enable large industrial users—such as steel producers—to secure stable

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hydrogen supply and price certainty, thereby reducing investment risks associated with energy price volatility. In the CCS sector, it is necessary to accelerate the development of comprehensive regulations and oversight systems, including CO_2 transport pipeline standards, storage site permitting, liability frameworks, and long-term monitoring requirements, to ensure operational safety and clear responsibility allocation.

Furthermore, in building “net-zero utilities” such as hydrogen and CCS infrastructure, Taiwan may adopt Public–Private Partnership (PPP) models. According to the IEA (2025), long-term contractual arrangements allow private firms to contribute technological capabilities and financial resources that the government cannot shoulder alone, while enabling the construction of large-scale decarbonization infrastructure. Government participation, in turn, provides early-stage policy certainty in immature markets and facilitates the development of capital-intensive infrastructure—such as CO_2 transport and storage—that private firms would struggle to undertake independently. Such public–private collaboration not only enhances investment feasibility but also mitigates barriers arising from market failures.

- Demand Side

After 2030, beyond clearly defining “low-carbon steel,” a regular review mechanism must be established to respond to evolving international standards (e.g., ResponsibleSteel, LESS) and domestic market feedback. Dynamic adjustment prevents standards from

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becoming outdated or misaligned with technological advancements, ensuring that the green steel market remains competitive and coherent with broader policy frameworks.

Green public procurement should gradually shift from a voluntary mechanism to a mandatory requirement, accompanied by medium- and long-term targets for low-carbon steel usage in public construction projects. The government may progressively increase the mandated share of low-carbon steel in infrastructure, public buildings, and large-scale procurement projects, thereby providing clear market expectations and driving demand-side transformation.

- Other Policy Measures

After 2030, the contract price of Carbon Contracts for Difference (CCfDs) is expected to decline, largely due to anticipated reductions in hydrogen and energy prices as technologies mature and markets scale. This downward cost trend narrows the cost gap between low-carbon and conventional production routes, increasing firms' willingness to absorb the green premium. As low-carbon steel markets expand, rising demand will further enhance economies of scale, enabling niche technologies to overcome regime-level constraints and accelerate diffusion into mainstream production.

Beyond public funding, a stable and enduring low-carbon transition requires substantial private capital mobilization. The government should deploy tools such as green finance standards, transition finance guidelines, and low-carbon infrastructure bonds to channel private investment into key areas including low-carbon steelmaking, bioenergy, renewables, and CCS. By reducing financing risks, enhancing investment transparency, and strengthening market expectations, these measures can expand private-sector participation and foster a stable, long-term low-carbon investment ecosystem.

Finally, the carbon fee should continue to increase after 2030 so that its price level gradually converges with international benchmarks (e.g., the EU), establishing a more predictable and coherent low-carbon market structure. By that time, Taiwan’s Emission Trading System (ETS) is expected to become more mature, enabling the domestic carbon pricing mechanism to gradually transition from a fee-based system to a market-based trading system. This structural shift will strengthen the economic signals associated with emissions, support market-oriented abatement behavior, and sustain the deepening and expansion of industrial low-carbon transition.

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5. Discussion and Conclusion

5.1 Discussion

Based on its research objectives and methodology, this study provides an integrative assessment of multiple dimensions of the low-carbon transition—including technology, infrastructure, finance, market demand, and policy. While each of these themes contains substantial complexity and numerous sub-issues that merit detailed investigation, the present study focuses on identifying the most urgent areas requiring improvement. Future research may therefore explore each dimension more deeply.

Among these topics, the selection of low-carbon production technologies and the broader debates surrounding hydrogen application in steelmaking represent particularly rich areas for scholarly dialogue. These issues can be further examined through comparative analysis and cross-engagement with emerging studies in related fields and international contexts.

This study identifies hydrogen-based Direct Reduced Iron (DRI) as the primary niche for advancing low-carbon transition in Taiwan's steel sector, drawing on international research, emerging technological trends, and investment patterns among global steelmakers. Nevertheless, multiple pathways remain possible for hydrogen utilization, including the domestic production of hydrogen and DRI, or the importation of Hot

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Briquetted Iron (HBI) produced overseas using renewable or low-carbon hydrogen. As a high-density, easily stored and transported intermediate product that can be directly used in electric arc furnaces, HBI provides an alternative route that may avoid some infrastructural constraints associated with domestic hydrogen production.

Li et al. (2025) find that in scenarios where international HBI trade is available, imported HBI becomes cost-competitive with blast furnace production as early as 2030, while domestically produced DRI does not become cheaper than blast furnace routes until around 2034—and even then, imported HBI remains the lower-cost option. The analysis further indicates that, when comparing major East Asian steelmaking countries—namely South Korea, Japan, and Taiwan—under scenarios involving imported hot briquetted iron (HBI), Taiwan exhibits two notable cost advantages. First, the production cost of domestically produced direct reduced iron (DRI)–based steelmaking in Taiwan is expected to reach cost parity with, and potentially become lower than, domestic BF–BOF steelmaking earlier than in Japan and South Korea. Second, owing to its comparatively favorable renewable energy potential, Taiwan demonstrates significantly lower production costs than Japan and South Korea under both domestically produced DRI and imported HBI steelmaking scenarios.

On the other hand, modeling by Korea’s climate think tank Solutions for Our Climate (2025) shows that, in the Korean context, importing hydrogen for DRI production is more

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expensive than producing hydrogen domestically. Taken together, existing studies and models evaluating the cost-effectiveness of hydrogen self-production versus importation (especially HBI and hydrogen) in East Asian steel-producing countries do not yet offer a consistent conclusion. However, the literature converges on one point: high dependence on imported hydrogen (or hydrogen-derived products) may pose significant supply-chain risks and energy-security uncertainties, underscoring the need for careful strategic evaluation when planning long-term decarbonization pathways.

Reflection on Research Limitations

I. Model-related Limitations

This study's use of the Net Zero Industry model introduces inherent constraints. While the model provides a useful reference for estimating Taiwan's 2050 steel decarbonization milestones and production pathways, any single model is inevitably shaped by its embedded assumptions, scenario framing, and parameter selection. For instance, the model assumes a gradual decline in global steel demand and, based on Taiwan's geological and energy conditions, presumes "relatively abundant renewable resources but limited feasibility for CCS deployment." Such assumptions may predispose the model toward specific technological outcomes. If key parameters were modified—such as energy mix, CCS availability, or hydrogen import strategies—significantly different pathways and cost structures could emerge. Therefore, the transition trajectory presented

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in this thesis reflects only one modeled scenario, rather than the full spectrum of potential futures.

II. Interview-related Limitations

Due to constraints on time and resources, the number of interviewees was relatively limited. Moreover, as China Steel Corporation is Taiwan’s only blast furnace operator, industry-side perspectives may be particularly narrow. Interview responses may also reflect individual biases. Furthermore, several international interviewees provided insights based on the industrial conditions, policy frameworks, and technological developments of their respective countries; despite efforts to contextualize these viewpoints within Taiwan’s circumstances, structural and energy-system differences may still lead to limited applicability.

III. Directions for Future Research

Overall, future studies could employ multiple models to conduct cross-scenario comparisons, examining how different assumptions—such as energy portfolios, hydrogen sourcing strategies, or CCS deployment—affect Taiwan’s steel decarbonization pathways. Such analysis would help identify the feasibility and trade-offs of diverse technological combinations. Likewise, expanding interview samples to include additional domestic industry actors, government officials, and non-state-owned enterprises, as well as comparing steel, hydrogen, and CCS policies across countries, would deepen understanding of alternative governance models and enabling conditions.

Lastly, given the rapid evolution of international politics, economy, energy markets, etc., all analyses and policy recommendations in this thesis reflect the conditions at the time of writing. Future research should continue to adapt dynamically to emerging global and domestic developments influencing the low-carbon transition landscape.

5.2 Conclusion

This thesis evaluates the gaps in Taiwan’s iron and steel sector’s low-carbon transition by examining both quantitative net-zero targets and qualitative structural factors. To further interpret the sector’s current transition status and identify the missing elements in its progression, the study employs a sustainability transition theoretical lens to purpose the strategic direction and guiding principles for the proposed policy mix. Finally, drawing on secondary data, and insights from interviews with stakeholders in Taiwan and abroad, the study develops a timeline-based policy mix that accounts for corporate investment cycles and the sector’s potential pathways toward achieving net-zero emissions.

In response to RQ1: What pressures and challenges does Taiwan’s iron and steel industry face in its low-carbon transition under the national net-zero target?

According to the study findings, external landscape pressures—including CBAM,

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international market competition, and China's persistent dumping—remain insufficient to exert strong transformative force on the regime. Nonetheless, these pressures have created partial windows of opportunity: they have raised awareness of the need for low-carbon transition, yet profit compression has simultaneously constrained firms' capacity to invest in green technologies.

Within the regime, innovation is further limited by ownership-related constraints: as a state-owned enterprise, CSC faces pressures between profitability requirements and decarbonization expectations, while deep technological lock-in reinforces a preference for incremental adjustments over systemic change.

Niche development is similarly constrained. Strong regime lock-in has resulted in niche innovations that are neither aligned with long-term net-zero objectives nor capable of challenging the dominant regime with the BF-BOF production system. Current efforts remain largely at the stage of within-regime and minor transformation, characterized by modular substitution centered on the blast-furnace system. Due to the underdevelopment of multiple cross-system niches—such as clean electricity and hydrogen—there is a lack of architecture-level reconfiguration actions. Overall, these conditions have not yet produced sufficient momentum to disrupt the incumbent regime or initiate a more profound system reconfiguration.

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Addressing RQ2: How can Taiwan accelerate the low-carbon transition in terms of the policy mix improvement?

This study identifies five key transition gaps: insufficient deployment of infrastructure; inadequate formation of demand-side mechanisms; continued dependence on blast-furnace-based fossil resource supply chains; infrastructure development that lacks system reconfiguration characteristics; and limited space for green investment.

Building on these insights, this study proposes a temporally sequenced policy package spanning the pre-2030 and post-2030 periods. This policy mix is grounded in: (1) the projected technological pathways and production configurations of Taiwan's steel industry under a 2050 net-zero scenario; and (2) the blast furnace retirement schedule and investment decision timeline of China Steel Corporation (CSC).

Stage 1: Orientation and Strategic Positioning (Present–2030)

The first stage centers on direction-setting and foundational deployment. Strengthening policy signals is essential, particularly through the explicit identification of hydrogen-based Direct Reduced Iron (DRI) as the primary niche pathway for transformation.

On the production side, the government must accelerate integrated planning for renewable energy, hydrogen, and CCS. Through industrial demonstration zones and cross-ministerial coordination, these measures can gradually loosen the lock-in surrounding the blast furnace system. Architecture stretching and subsequent architecture reshaping should guide the transition of natural gas/hydrogen pipelines, storage systems, and industrial infrastructure.

On the demand side, immediate action is required to establish green steel standards and green public procurement mechanisms, thereby generating clear long-term market expectations. To address the initial cost gap between low-carbon and conventional production routes, subsidy instruments like Carbon Contracts for Difference (CCfD) could be introduced, complemented by a steady annual increase in the carbon fee. These measures can provide credible, directional policy signals that encourage long-term low-carbon investment.

Stage 2: Diffusion and Consolidation (Post-2030)

The second stage emphasizes the diffusion and stabilization of low-carbon production niches.

On the production side, hydrogen and CCS—both critical net-zero infrastructures—must be institutionalized through long-term hydrogen contracting schemes, comprehensive legal and regulatory frameworks, and public–private partnership (PPP) models. These measures are essential to ensure supply security, investment stability, and risk-sharing across stakeholders.

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On the demand side, green steel standards should be periodically reviewed to align with evolving international frameworks (e.g., ResponsibleSteel, LESS), while green public procurement should transition from voluntary to mandatory application. Sustainable finance instruments should be leveraged to expand private capital participation in low-carbon steel and related technologies.

As carbon prices rise and Taiwan's Emissions Trading System (ETS) matures, market signals will strengthen, facilitating the movement of niche technologies toward the regime core. This long-term trajectory can support the steel industry's shift from incremental transformation toward genuine system reconfiguration.

Enhancing Industrial Decarbonization to Form Industrial Upgrading and Security

Throughout the research period, Taiwan's steel industry has faced heightened volatility in international markets. This turbulence has been driven primarily by persistently weak steel demand in China, coupled with structural overcapacity and continued dumping practices. At the same time, rapid expansions of steel production capacity in Southeast Asia and the Middle East have further increased global steel overcapacity. In response, major economies have strengthened trade policy measures, including the United States' imposition of additional tariffs on steel and aluminum starting in 2025, as well as the European Union's extension of its steel import safeguard measures.

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As countries increasingly deploy trade strategies to counteract the impacts of tariffs and dumping, green transition has simultaneously emerged as a central focus of the steel industry's policy agenda. As discussed in Chapter 4.2, policy initiatives such as the European Union's European Steel and Metals Action Plan and South Korea's K-Steel Act (the Special Act on Strengthening the Competitiveness of the Steel Industry and Advancing Carbon Neutrality) explicitly integrate green transition objectives with industrial competitiveness considerations.

In line with this policy orientation, this study suggests that the low-carbon transition of the steel industry is not only a matter of climate governance but also a strategic imperative for industrial security and national competitiveness. In the context of Taiwan's heavy dependence on imported energy and the ongoing restructuring of global steel trade, positioning decarbonization as a core industrial upgrading strategy would enable Taiwan to reduce reliance on fossil fuels-based production route.

By restructuring production systems around renewable energy and hydrogen, and by leveraging policy incentives and green public procurement, the steel sector can reorient from reactive regulatory compliance toward proactive innovation as a source of long-term industrial advantage. Ultimately, embedding low-carbon transition within the broader trajectory of industrial upgrading can enhance Taiwan's international competitiveness and ensure industrial security amid accelerating global net-zero transitions.

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Appendix 1. Interview Guide

【Domestic Interview－For Researcher】

1. **Transition Pressures**

   Which international and domestic policies constitute the most significant drivers of decarbonization for Taiwan’s steel industry, and why?
   (e.g. CBAM, GASSA, domestic carbon pricing, supply chain requirements.)

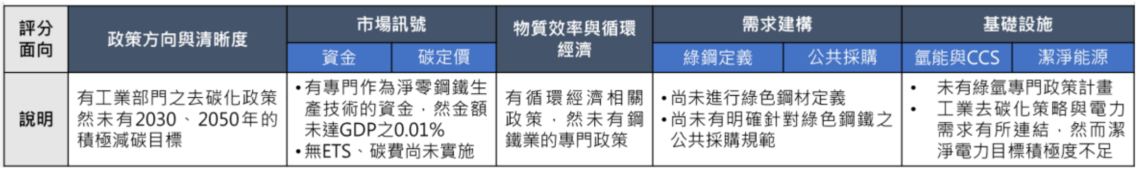
2. **Identification of Transition Challenges and Bottlenecks**

   Based on E3G’s steel decarbonization assessment framework, how do you assess the current implementation and key challenges of Taiwan’s steel decarbonization policies across the five dimensions? (See table 1 and table 2)

Table1. Steel Scorecard Categories

Topic	**Criteria**
Policy direction & clarity	Decarbonization policies specifically for the steel industry and ambitious carbon reduction targets.
Market Signals	Carbon Pricing, Public Funding
Material Efficiency & Circularity	Circular economy policy for steel sector
Building Demands	Definition, Standard for green steel
Infrastructure	Hydrogen, CCS, Renewables

Table2. Result of Taiwan’s Steel Scorecard (2024)



評分面向	政策方向與清晰度	市場訊號		物質效率與循環經濟	需求建構		基礎設施	
		資金	碳定價		綠鋼定義	公共採購	氫能與CCS	潔淨能源
說明	有工業部門之去碳化政策然未有2030、2050年的積極減碳目標	•有專門作為淨零鋼鐵生產技術的資金，然金額未達GDP之0.01% •無ETS、碳費尚未實施		有循環經濟相關政策，然未有鋼鐵業的專門政策	•尚未進行綠色鋼材定義 •尚未有明確針對綠色鋼鐵之公共採購規範		• 未有綠氫專門政策計畫 • 工業去碳化策略與電力需求有所連結，然而潔淨電力目標積極度不足	

1. **Effectiveness of Existing Policies**

   To what extent do current or forthcoming decarbonization policies in Taiwan’s steel or industrial sectors effectively incentivize the industry’s low-carbon transition, and where could these policies be strengthened?

2. **Additional Policy Instruments and Policy Mixes**

   Which policy instruments or policy mixes would be most effective in accelerating steel decarbonization in Taiwan, and why?
   (e.g. CCfDs, carbon pricing, standards, green public procurement.)

【Domestic Interview－For Producer】

1. **Transition Pressures**

   Which international and domestic policies constitute the most significant drivers of decarbonization for Taiwan's steel industry, and why?

   (e.g. CBAM, GASSA, domestic carbon pricing, supply chain requirements.)

2. **Decarbonization Pathways for Blast Furnace–Based Steelmaking**

   How do you assess:

   (a) short- to medium-term options before 2030 (e.g. hydrogen injection, reduced iron, increased scrap use), and

   (b) long-term pathways towards net-zero by 2050 (e.g. hydrogen-based steelmaking vs. blast furnaces with CCS),

   in terms of emissions reduction potential, costs, and key constraints?

3. **Product Strategy and Low-Carbon Transition**

   How does the strategy of developing high-quality, value-added steel products interact with the low-carbon transition? Are there trade-offs or synergies between product upgrading and decarbonization?

4. **Enabling Conditions**

   How do you evaluate the current policy support, infrastructure readiness, and implementation status of renewable energy, hydrogen, and CCS in relation to the steel sector in Taiwan?

5. **Market Demand**

   What is the current level of market demand for low-carbon steel, and how might low-carbon public procurement influence the industry's decarbonization transition?

6. **Transition Strategies and Policy Mix**

   From the perspective of industry stakeholders, what short-, medium-, and long-term strategies are needed to advance steel decarbonization, and which policy instruments should accompany them?

   (Examples: CCfDs, R&D support, carbon pricing, standards, green public procurement.)

【International Interview】

[Support for Low-Carbon Steel Production]

With reference to the country case researched by the interviewee:

1. The relationship between renewable energy policies and the decarbonization of the steel industry.
2. The relationship between hydrogen policies and the decarbonization of the steel industry.
3. The relationship between carbon capture and storage (CCS) policies and the decarbonization of the steel industry.

[Green Markets and Demand Development]

With reference to the country case researched by the interviewee:

1. The policy progress regarding the definition of low-carbon or green steel.
2. Public finance strategies supporting low-carbon or green steel.
3. Public procurement strategies promoting low-carbon or green steel.

[Other Country-Specific Questions]

Additional questions specific to the national context studied by the interviewee.

Appendix 2. Net Zero Industry Methodology

The Net Zero Industry research project is supported by the Institute for Sustainable Development and International Relations (IDDRI) and is led by Dr. Chris Bataille, Lead Author of the IPCC Sixth Assessment Report (AR6), Working Group III, Industry Chapter.

The steel module of the Net Zero Industry project develops a set of spatially explicit, facility-level pathways for the global steel sector, outlining alternative scenarios through which net-zero steel production could be achieved by 2050. The primary objective of the project is to capture the granular impacts of the transition at both facility and national levels, and to identify the infrastructure requirements and policy conditions necessary to enable such pathways.

The following section summarizes the key modelling foundations of the study. Further methodological details and related materials are available at: https://netzeroindustry.org/。

- Year of analysis: 2019
- Databases: The model is primarily based on the Global Energy Monitor (GEM) database and integrates additional data from the Global Infrastructure Emissions Database (GIEDS), production statistics from the World Steel Association, and the OECD national steel capacity database. These sources are cross-referenced to construct detailed energy consumption and emissions profiles at the facility level. In total, the dataset identifies 835 steel production facilities, classified by technology, across 94 countries, representing global steel production in 2019.
- Key Modelling Assumptions
    - ■ Future steel demand projections: Future demand is projected under three convergence scenarios, drawing on historical demand-use statistics from the World Steel Association Steel Statistical Yearbook (2020) and informed by

assessments from the International Energy Agency (IEA), including the World Energy Outlook (WEO). The model assumes that per-capita steel demand across countries converges toward 200, 250, and 300 kg per capita by 2080, respectively. For reference, Taiwan’s per-capita steel demand was 726 kg (World Steel Association, 2023). These demand trajectories are subsequently used to estimate future steel production levels.

- Scrap availability: Scrap steel availability is derived from global and regional forecasts. Under the model assumptions, scrap-based electric arc furnace (EAF) production increases from 0.42 Gt in 2019 to approximately 1.0 Gt by 2050.
- Blast furnace lifetime and investment cycles: Blast furnaces are assumed to have a technical lifetime of 25 years. Facilities that have exceeded their investment lifetime are considered eligible for retrofit or reinvestment in the current modelling years (e.g., 2020, 2021, 2022).
- Power sector decarbonization: The model assumes that the electricity sector is subject to policy interventions that drive grid electricity emissions toward near-zero, enabling low-carbon electrification and hydrogen production.
- Country-level capacity–demand balancing: If existing facilities are sufficient to meet national steel demand, the model adjusts country-specific capacity utilization factors such that production equals demand. Where existing capacity is insufficient, additional facilities are constructed. The technological pathway for new capacity follows a sequential decision logic (see Figure below):
  (1) expansion of scrap-based EAF capacity where incremental scrap is available;
  (2) post-combustion carbon capture and storage (CCS) retrofits for coal-based blast furnace–basic oxygen furnace (BF–BOF) and direct reduced iron–EAF (DRI–EAF) facilities, subject to proximity to CO_2 storage sites, with transport distance thresholds of 100 km, 200 km, and 300 km assessed;

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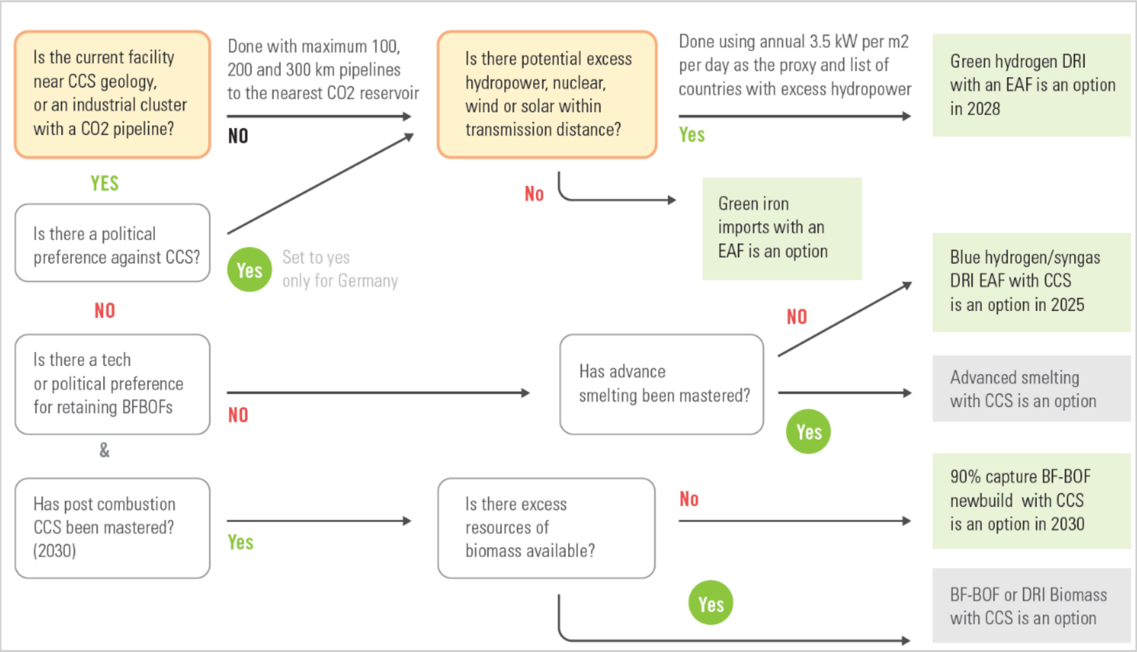
(3) deployment of hydrogen-based DRI–EAF (H_2-DRI–EAF) where low-cost clean electricity is available for electrolytic hydrogen production;

(4) where none of the above options are feasible, construction of non-spatially allocated new facilities or reliance on imports of green iron or green steel to meet demand.



Source: Bataille et al., 2021

Based on the model outcomes described above, Taiwan's steel sector under the 2050 net-zero scenario exhibits the following technological pathway characteristics:

1. A decline in total steel demand leads to a corresponding reduction in overall production volumes.
2. The transition pathway is dominated by electric arc furnaces (EAFs) and hydrogen-based direct reduced iron–electric arc furnace systems (H_2-DRI–EAF). The model identifies limited feasibility for carbon capture and storage (CCS) in Taiwan, due to the absence of suitable geological storage sites and established CO_2 transport infrastructure within industrial clusters.

Appendix 3. Steel Policy Scorecard Methodology

Since 2022, climate policy think tank E3G has published the Steel Policy Scorecard, which provides an assessment framework to track and compare how G7 countries—as well as major steel-producing countries beyond the G7—are addressing the challenge of phasing out coal-based steelmaking over time.

The Steel Policy Scorecard focuses exclusively on the development of public policies and does not take into account the emissions intensity of steel production in each country.

Scoring methodology:

1. The scorecard consists of eight assessment categories:
   (1) clarity of policy direction,
   (2) material efficiency and circular economy,
   (3) definitions and standards for green steel,
   (4) public procurement,
   (5) public finance,
   (6) carbon pricing,
   (7) hydrogen and CCS, and
   (8) clean energy.

2. Each category comprises several indicators. Countries receive between 0.25 and 1 point for each indicator achieved. The total score is then aggregated and translated into a letter grade, ranging from C−, C, C+, B−, B, B+, A−, A, to A+.

The correspondence between total scores and letter grades is presented in the following table.

Aggregated Score	**Color/Grade**	–		+
0<Score≤1	Red／C	0–0.25	0.5	0.75–1
1<Score≤2	Orange／B	1.25	1.5	1.75–2
2<Score≤3	Green／A	2.25	2.5	2.75–3

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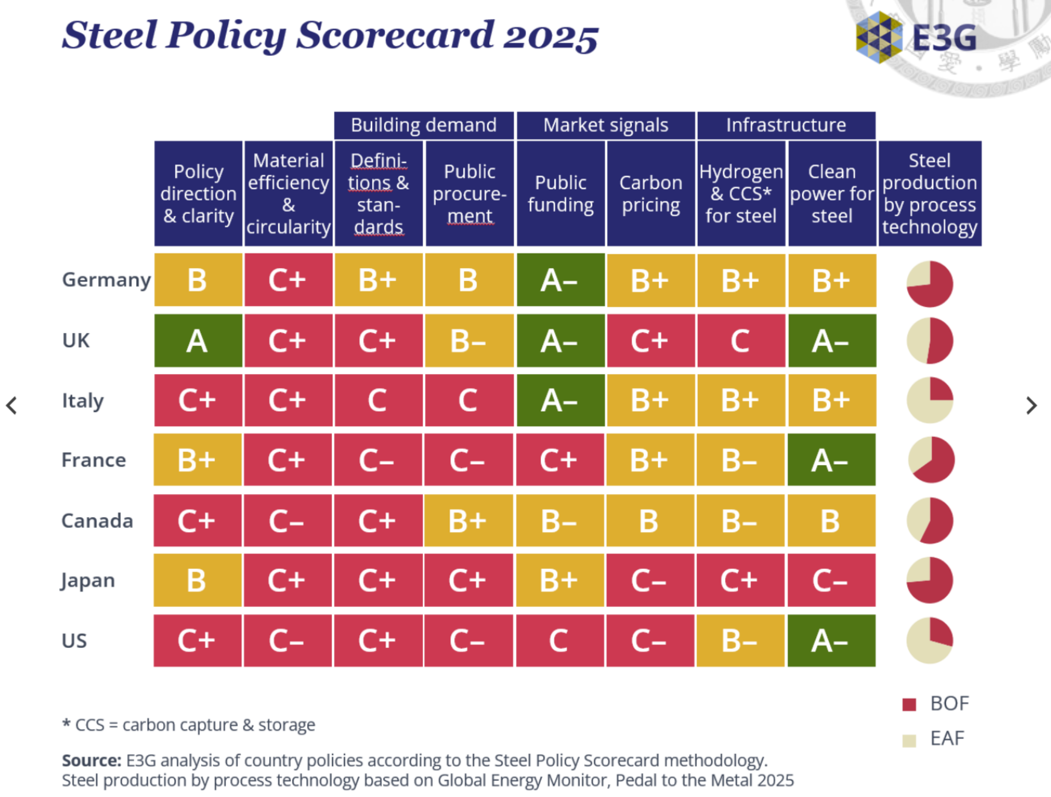
The 2025 results covering all major steelmaking countries are shown in following figure.



Steel Policy Scorecard 2025

E3G

			Building demand		Market signals		Infrastructure		
	Policy direction & clarity	Material efficiency & circularity	Definitions & standards	Public procurement	Public funding	Carbon pricing	Hydrogen & CCS* for steel	Clean power for steel	Steel production by process technology
Germany	B	C+	B+	B	A–	B+	B+	B+	
UK	A	C+	C+	B–	A–	C+	C	A–	
Italy	C+	C+	C	C	A–	B+	B+	B+	
France	B+	C+	C–	C–	C+	B+	B–	A–	
Canada	C+	C–	C+	B+	B–	B	B–	B	
Japan	B	C+	C+	C+	B+	C–	C+	C–	
US	C+	C–	C+	C–	C	C–	B–	A–	

🟥 BOF

🟨 EAF

* CCS = carbon capture & storage

Source: E3G analysis of country policies according to the Steel Policy Scorecard methodology.
Steel production by process technology based on Global Energy Monitor, Pedal to the Metal 2025

This study uses this framework to evaluate Taiwan's steel industry policies. For a detailed description of the assessment framework, see: https://www.e3g.org/publications/raising-ambition-steel-decarbonisation-2023-steel-policy-scorecard/

The evaluation results are as follows:

1. Policy direction & clarity: (Grade: B+)

Policy focus and priority	**Score**	**Taiwan Score**	**Relevant Policy**
Has a climate policy with focus on industrial decarbonization	0.25		
Has a climate policy with focus on industrial decarbonization, including steel	0.5		

Has a steel strategy with some focus on decarbonization	0.5		
Has an industrial decarbonization strategy	0.75		
Has an industrial decarbonization strategy with a focus on steel	1	1	Manufacturing Sector 2030 Net-Zero Pathway; Flagship Action Plan
Has a steel decarbonization strategy	1.5		CSC plan applies only to China Steel Corporation
Targets	**Score**	**Taiwan Score**	**Relevant Policy**
Regionally (transnationally) enforced target	0.25		
Outlines an emissions reduction pathway for steel	0.25		
Is exploring a target for steel	0.25		
Has an unambitious* target for industry	0.75	0.75	Third Phase GHG Control Target: 2030 −28±2%
Has an unambitious target for steel	1		
Has an ambitious* target for industry	1.25		
Has an ambitious target for steel	1.5		
Aggregated Score		1.75	
Grade		B+	

2. Material Efficiency and Circular Economy (Grade: C)

Clear national policy direction	**Score**	**Taiwan Score**	**Related Policy**
Dedicated circular economy plan/strategy/roadmap	**0.5**	**0.5**	**1. 2019 國發會 5+2 產業創新計畫-循環經濟計畫>>產業循環經濟推動輔導計畫** **2. 12 關鍵戰略：資源循環零廢棄關鍵戰略行動計畫**
Dedicated circular economy plan/strategy/roadmap with a	**1**		

steel focus			
Dedicated circular economy plan/strategy/roadmap with a steel focus, including steel scrap[116]	**1.25**		
Dedicated steel reuse and scrap recycling targets/policy framework	**2**		
Clear regional (transnational) policy direction	**Score**	**Taiwan Score**	**Related Policy**
Dedicated regional circular economy plan/strategy/roadmap	**0.25**	**-**	
International circularity initiatives	**Score**	**Taiwan Score**	**Related Policy**
Partnership in circularity initiatives	**0.25**	**-**	
Initiation of circularity initiatives[117]	**0.5**	**-**	
Aggregated Score		**0.5**	
Grade		**C**	

3. Green Steel Definitions and Standards (Grade: C−)

Recognizing the importance of adopting definitions with emissions intensity thresholds and measurement standards (Countries may score on all indicators.)	**Score**	**Taiwan Score**	**Related Policy**
Is a member of IDDI	**0.25**	**-**	
Is a member of FMC	**0.25**	**-**	
Is part of an intergovernmental forum/coalition (e.g. G7, G20, EU) that has formally expressed a movement towards the adoption of a definition	**0.25**	**-**	
Movement towards national adoption of a definition	**Score**	**Taiwan Score**	**Related Policy**

Working group, or other official process in place for adopting a green steel definition123	**1**	**-**	
Adopting and implementing a definition (If a country scores on this section, it automatically erases scores from previous sections.)	**Score**	**Taiwan Score**	**Related Policy**
Have a formally adopted definition of green steel, with related emissions intensity thresholds and measurement standards	**2.5**	**-**	
Have a formally adopted (ambitious) definition, with related emissions intensity thresholds and measurement standards, which has been integrated into reporting and national industrial and climate policy	**3**	**-**	
Aggregated Score		**0**	
Grade		**C-**	

4. Public Procurement (Grade: C+)

Green public procurement (GPP) (Countries may only score on one of the indicators below.)	**Score**	**Taiwan Score**	**Related Policy**
Has a mandatory or voluntary GPP that does not explicitly cover steel	**0.25**	**0.25**	**2024 環境部：綠色採購金額2030年達10%；低碳公共工程在2024-2025年間訂定公共工程減碳指引，輔助機關建立低碳採購需求**
Has a voluntary GPP that explicitly covers steel	**0.25**	**-**	
Has a mandatory GPP that explicitly covers steel	**0.5**	**-**	
Membership of global initiatives and related procurement commitments (Countries may only score on one of the indicators below.)	**Score**	**Taiwan Score**	**Related Policy**
Is a member of IDDI	**0.25**	**-**	
Has committed to a pledge	**0.5**	**-**	

under the IDDI120			
Has committed to the most ambitious pledge under the IDDI121	**0.75**	**-**	
Intention-setting	**Score**	**Taiwan Score**	**Related Policy**
Has announced its intention to set an explicit green steel PP target or requirement	**0.5**	**0.5**	**2024 環境部：綠色採購金額 2030 年達 10%; 低碳公共工程在 2024-2025 年間訂定公共工程減碳指引，輔助機關建立低碳採購需求**
Explicit green steel public procurement and pre-purchase agreements (If a country scores on this section, it automatically erases scores from previous sections.)	**Score**	**Taiwan Score**	**Related Policy**
Has a mandatory GPP with ambitious GPP target or requirements for steel	**2.5**	**-**	
Pre-purchase agreements (Points awarded independently from scores in the sections above.)	**Score**	**Taiwan Score**	**Related Policy**
Has entered into pre-purchase agreements on steel	**0.5**	**-**	
Aggregated Score		**0.75**	
Grade		**C+**	

5. Public Funding (Grade: C+)

R&D funding (Countries receive one score, for the highest indicator that they qualify for.)– volume as a percentage of GDP	**Score**	**Taiwan Score**	**Related Policy**
Has funding that could be used for R&D of net zero steel production methods	**0.25**		
Has funding explicitly earmarked for R&D of	**0.5**		

net zero steel production			
Has funding explicitly earmarked for R&D of net zero steel production methods which constitutes > 0.01% GDP	**0.75**	**0.75**	「中鋼減碳旗艦行動計畫」預算編列約 **695** 億元，約佔 **2024** 年台灣 **GDP 25.5** 兆的 **0.02%**
Has funding explicitly earmarked for R&D of net zero steel production technologies which constitutes > 0.05% GDP	**1**		
CAPEX funding (Countries receive one score, for the highest indicator that they qualify for.)– proportion of country´s BF-BOF capacity supported112	**Score**	**Taiwan Score**	**Related Policy**
Has funding that could be used for capital investment support for steel plants trying to decarbonize	**0.25**	**0.25**	**“CSC Decarbonization Flagship Action Plan” (國營事業減碳-中鋼減碳旗艦行動計畫)**
Has funding explicitly earmarked to support decarbonization of specific plants awarded to at least one-third of the country's BF-BOF plants	**0.5**		
Has funding explicitly earmarked to support decarbonization of specific plants awarded to at least one-third of the country's BF-BOF plants, as well as significant additional national funding for capital investment support for industry decarbonization	**0.75**		
Has significant funding explicitly earmarked to support decarbonization of specific plants decarbonization awarded to the majority of the country’s BF-BOF plants	**1**		
OPEX funding	**Score**	**Taiwan Score**	**Related Policy**
Has funding dedicated to supporting operational costs of companies transitioning	**1**	**-**	

to net zero steel production113			
Aggregated Score		1	
Grade		C+	

6. Carbon Pricing (Grade: C+)

Low ambition carbon pricing (Countries may score on one of these indicators.)	**Score**	**Taiwan Score**	**Related Policy**
ETS with free allowances	**1**		
Insignificant carbon tax	**1**	**1**	
Medium ambition carbon pricing (Countries may score on one of these indicators)	**Score**	**Taiwan Score**	**Related Policy**
National ETS with free allowances and a set phase-out date	**2**	**-**	
Significant carbon tax with some steel exemptions	**2**	**-**	
High ambition carbon pricing (Countries may score on one of these indicators.)	**Score**	**Taiwan Score**	**Related Policy**
ETS up and running and no free allowances	**3**	**-**	
Significant carbon tax without exemptions	**3**	**-**	
Aggregated Score		1	
Grade		C+	

7. Hydrogen and CCS (Grade: C−)

Hydrogen and/or CCS as a dedicated policy priority (Countries may receive points for one or both indicators for either hydrogen with CCS, or green hydrogen. If aspects of both are in place, the hydrogen score is counted.)	**Score**	**Taiwan Score**	**Related Policy**
Where hydrogen is a policy priority through inclusion and focus in national plans or through a dedicated plan, there is nuance provided in terms of CCS application	0.25	**-**	
CCS for hydrogen for steelmaking and/or CCS on natural gas for DRI is a policy priority through inclusion in national plans or through a	0.25	**-**	

dedicated plan			
or			
Where hydrogen is a policy priority, there is emphasis on green hydrogen	0.5	-	
Where there is emphasis on green hydrogen, there is emphasis on its use for steel	0.5	-	
Hydrogen and CCS infrastructure for steel already being implemented (Countries may receive points for either CCS, or hydrogen. If both are in place they are scored on hydrogen.)– differentiated by number of pilot facilities relative to BF-BOF capacity	**Score**	**Taiwan Score**	**Related Policy**
CCS infrastructure for hydrogen production for steel and/or CCS on natural gas for DRI is being rolled out	0.75	-	
or			
Green hydrogen production facilities for use in steel sector are being rolled out	1	-	
Final stage – hydrogen and CCS infrastructure for steel are available at commercial scale (Countries may receive points for either CCS or hydrogen. If both are in place the hydrogen score is counted.)	**Score**	**Taiwan Score**	**Related Policy**
CCS infrastructure is available and in use in the production of hydrogen for steel and/or natural gas for DRI	2.5	-	
or			
Green hydrogen is available and in use in steel production	3	-	
Aggregated Score		**0**	
Grade		**C-**	

8. Clean Energy (Grade: C−)

Ensuring clean electricity infrastructure to meet growing electrified steel demand (Countries	**Score**	**Taiwan Score**	**Related Policy**

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may only score on one of the indicators below, which will be the highest they qualify for.)			
National industrial decarbonization strategies connect the needs of power system decarbonization with rising power demand due to industrial electrification	**0.5**	**-**	
National industrial decarbonization strategies connect the needs of power system decarbonization with rising power demand due to industrial electrification, with specific policies to achieve it	**1**	**-**	
National industrial decarbonization strategies connect the needs of power system decarbonization with rising power demand due to industrial electrification, with specific policies to achieve it and detail on the steel sector	**1.5**	**-**	
National industrial decarbonization strategies connect the needs of power system decarbonization with rising power demand due to industrial electrification, with specific policies to achieve it, including clear timelines on clean electricity infrastructure roll-out for all steel-producing sites	**2**	**-**	
Ambition on cleaning up the power grid135 (Countries may only score on one of the below)	**Score**	**Taiwan Score**	**Related Policy**
Has a 95–100% 2030 clean power target136	**0.25**	**-**	
Has a >25% change between 2022 share of clean power generation and 2030 target	**0.5**	**-**	
Enabling corporate renewable power procurement– policy and market	**Score**	**Taiwan Score**	**Related Policy**

environment			
Relatively well developed PPA market	**0.25**	**-**	
Highly developed PPA market	**0.5**	**-**	
Aggregated Score		**0**	
Grade		**C-**	