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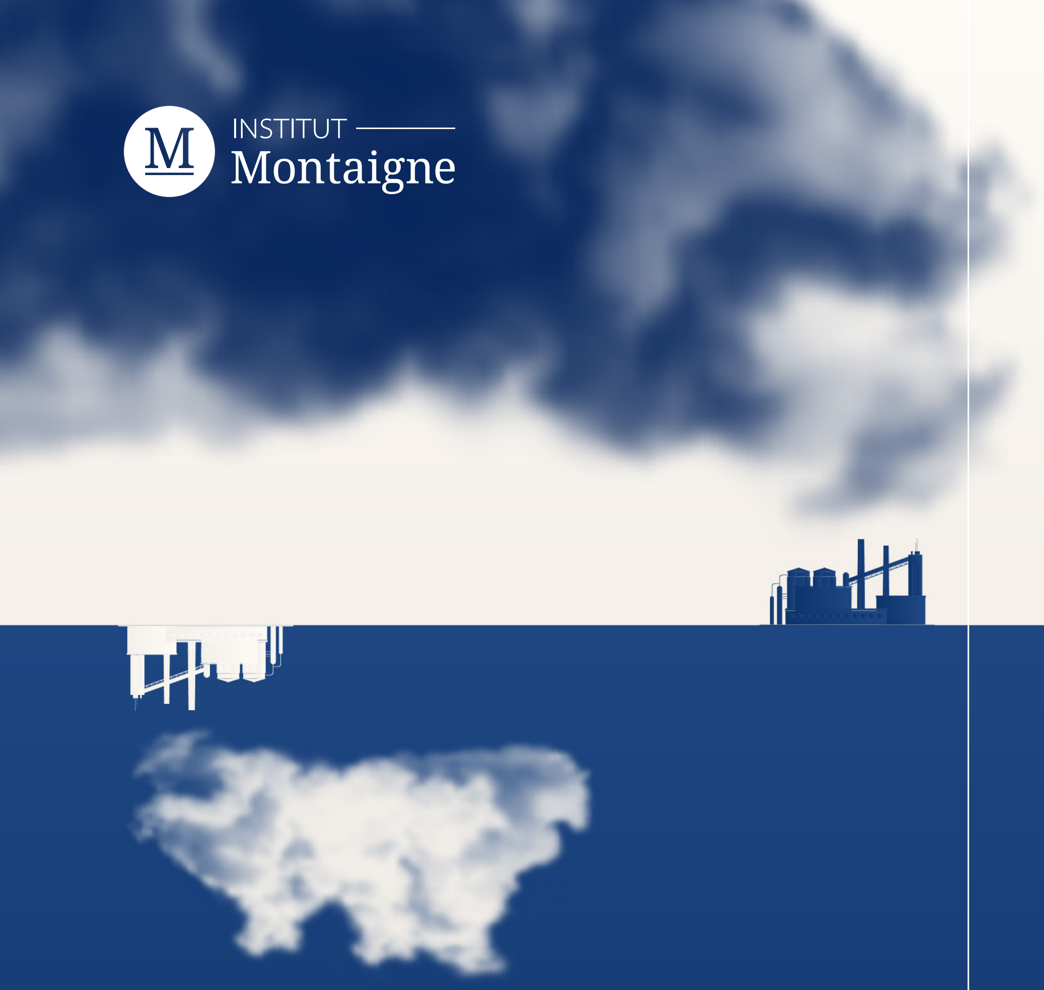

Forging a Post-Carbon Industry

Insights from Asia

OCTOBER 2024

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REPORT - October 2024

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Part 1

Shaping a Clean Industrial Strategy for Europe

Author

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Foreword

This report is divided into three parts. Part 1 seeks to address the multifaceted challenge of decarbonizing industry through a comparative analysis of the policies and strategies employed by Europe, China, Japan, and South Korea. By examining how these major industrial powers are navigating the shift from carbon-intensive production to a greener, low-emissions future, the report explores the intricacies of transitioning key sectors such as steel, aluminum, chemicals, and cement toward carbon neutrality.

Parts 2 and 3 explore sector-specific issues in decarbonizing the steel, aluminum, and chemicals sectors. They assess how the global landscape will be affected by decarbonization and offer a comparative perspective on how relevant policy is implemented and support is provided in Europe and Asia, respectively.

The report's first chapter provides a broad overview of what constitutes clean industrial policy, focusing on the experiences of Europe and Asia. The second chapter surveys the global landscape of industrial decarbonization, exploring the key technologies and processes that are fundamental to achieving this goal. Finally, the third chapter provides a comparative perspective on the risks, uncertainties, and opportunities that come with transitioning to a decarbonized industrial economy. It concludes by drawing on lessons from Asia to offer recommendations for how Europe can strengthen its clean industrial strategy while navigating competitive pressures from global industrial powers.

By synthesizing policy insights and technological trends from both Europe and Asia, this report aims to contribute to the development of a comprehensive and effective clean industrial strategy for the European Union. Through rigorous analysis, it seeks to set the stage for a deeper understanding of the critical elements required to decarbonize the most carbon-intensive sectors, thus ensuring their competitiveness in a post-carbon world.

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Introduction

The **industrial sector**[1] is a major contributor to global greenhouse gas emissions, accounting for **between a quarter and a third of all emissions**, taking all gases, sources, and countries into consideration. It is, thus, evident that it will not be possible to reach carbon neutrality without first decarbonizing industry.[2]

Globally, the industrial sector lags behind other sectors in several key areas of decarbonization. The pathway to carbon neutrality for the industrial sector is significantly less defined than it is for transportation or electricity, as decarbonization technologies are less advanced and decarbonization policies are less developed for industry than for other sectors.

In spite of the growing coalition-building activity focused on industrial decarbonization, new and effective business models for decarbonizing the industrial sector are only beginning to emerge. In the years since climate change became a matter of urgent international concern, little progress has been made in reducing industrial emissions. Industrial emissions have continued to rise in many regions over the past 15–20 years, driven largely by increased production to meet the global demand for higher living standards. Addressing these gaps will require concerted effort and innovative approaches to bring the industrial sector in line with the fight against climate change.

[1] *The industrial sector encompasses businesses involved in the manufacturing, processing, and production of goods, including heavy industries such as steel, chemicals, aluminum, cement, and machinery, as well as light industries such as food and electronics.*

[2] *Direct emissions, which are greenhouse gasses emitted directly from industrial processes, constitute about a quarter of global emissions. When including indirect emissions from electricity consumption, this figure comfortably exceeds a third. Other sectors' indirect emissions are actually the industrial sector's direct (scope one and two) emissions.*

THE COMING GREEN INDUSTRIAL REVOLUTION

The world stands on the brink of a transformative green industrial revolution. As the global industrial landscape undergoes a profound transformation, **the emergence of green industrial policies has become a pivotal element in steering the world toward a carbon-neutral future**.

This paper endeavors to analyze how several major industrial powers – **China, the European Union, South Korea, and Japan** – are navigating the shift from a carbon-intensive industrial base to carbon neutrality. The analysis focuses on the **steel, aluminum, cement**, and **chemicals sectors**, which are not only fundamental to modern civilization but also represent significant challenges in terms of decarbonization.

For years, certain industrial sectors were considered too “trade-exposed” or “technologically immature” to be integrated into decarbonization objectives. Others were tagged as “hard to abate” due to significant technological and economic gaps that make low-carbon alternatives both less viable and more costly. **The EU Emissions Trading System (ETS), for example, provided free allocations to emissions-intensive trade-exposed (EITE) sectors – most industries – highlighting the policy accommodations made to buffer competitive industries from the full cost of carbon pricing**.

However, this is changing rapidly due to the necessity of speeding up efforts to achieve carbon neutrality by 2050, and competitive industrial policies are emerging in many parts of the world. The importance of robust green industrial policies is underscored by their potential to significantly influence market transitions and reconfigure industrial value chains. This raises several critical questions: What defines an industrial decarbonization policy? How are these policies being formulated and implemented across the major industrial regions? How do these strategies align with the broader objective of achieving economic growth and carbon neutrality?

The transition toward green industrial policy is marked by varying approaches in different regions of the world. The European Union aims to integrate environmental concerns with market mechanisms and regulatory policies using the Emissions Trading System and the European Green Deal. In contrast, China leverages substantial planning to achieve a state-driven industrial policy that also scales up green technology and infrastructure, reflecting its unique governance and economic model. Japan, one of the birthplaces of contemporary industrial policy, needs to maintain its protected industrial bases while slowly advancing its decarbonization goals despite geographical and resource constraints. Finally, South Korea, a major industrial hub with heavily concentrated powerful industrial actors, is trying to adapt its innovation-based industrial strategy to reduce emissions.

The diversity of these strategies highlights not only the complexity of global industrial transformation but also the **disordered manner in which decarbonization is being approached worldwide**. This prompts the following further questions:

- How effective are clean industrial policies in fostering a unified global market for green goods?
- What steps can be taken to ensure these policies adequately support the rapid decarbonization of industrial goods?
- What are the risks and opportunities presented by the reorganization of industrial value chains, influenced by energy-cost considerations and geo-economic factors favoring more localized supply chains?

EUROPE IN THE POST-CARBON WORLD

Fueled by a world-beating ambition, Europe is now entering a phase of intense reflection on its green industrial strategy. In response to the competitive pressures posed by China's continental scale industrial policies and the United States' Inflation Reduction Act (IRA), the European Union is considering formulating a ***Clean Industrial Deal***[3] to address these challenges effectively.

This strategic pivot raises crucial questions: **What lessons can Europe draw from the policies implemented in China, Japan, and South Korea, the Asian industrial powerhouses? What avenues are available for international cooperation, and what are the potential areas of friction?** As Europe shapes its strategy, understanding these dynamics is critical for fostering a resilient and competitive green industrial sector that is aligned with Europe's climate goals and economic interests.

Methodology

To conduct this comprehensive analysis of industrial decarbonization across Europe, China, Japan, and South Korea, a rigorous academic methodology was applied, encompassing extensive documentary research, semi-structured interviews, and the organization of an international policy dialogue.

[3] *European Commission, "Statement at the European Parliament Plenary by President Ursula von der Leyen," July 2024, https://ec.europa.eu/commission/presscorner/detail/en/statement_24_3871.*

Policy Review

The foundational data for this study were collected through an exhaustive review of policy instruments implemented in the targeted regions. For China, policies from the National Development and Reform Commission (NDRC), the Ministry of Ecology and Environment (MEE), the Ministry of Industry and Information Technology (MITT), and the Ministry of Finance were examined, as well as the regulations of some provincial governments and industry associations. In South Korea, sources included the Ministry of Trade, Industry and Energy (MOTIE), the Ministry of Finance, the Presidential Committee on Net Zero, and the Ministry of Environment, among other governmental agencies. Japanese policy documents from the Ministry of Economy, Trade and Industry (METI) and the Ministry of the Environment were reviewed, along with policy documents from agencies such as the New Energy and Industrial Technology Development Organization (NEDO). European policies from various European Commission bodies, such as DG CLIMA, DG GROW, and DG TAXUD, and from national ministries in France and Germany were analyzed. Additionally, the ESG strategies of 154 companies across the steel, aluminum, chemicals, and cement sectors in the four jurisdictions were scrutinized with a view to understanding corporate approaches to industry decarbonization.

Semi-Structured Interviews

To enhance the understanding of the policy landscape, 523 semi-structured interviews were conducted with a diverse array of stakeholders in the four countries. Some of the interviews were conducted online, while others were conducted in-person in Europe, Japan, and South Korea, as well as at COP28 in Dubai. They included interactions with government officials from the relevant ministries, corporate stakeholders from the decarbonization and technology teams of industries in four sectors (steel, cement, chemicals, and aluminum), industry federation representatives, and delegates from international organizations such as the OECD, UNIDO, and the International Energy Agency (IEA).

EU–Asia Policy Dialogue

Further enriching the data, a high-level EU–Asia policy dialogue was organized in January 2024 with Japan's NEDO, featuring stakeholders from the EU, Japan, South Korea, China, and the OECD. This dialogue focused on discussing the four main challenges outlined in this paper: supporting decarbonization vectors, bridging the cost gap, standardizing green industrial goods, and analyzing the impact on international cooperation.

1 What Is Clean Industrial Policy?

1.1. EUROPEAN INDUSTRIAL POLICY

The European Union is at the forefront of the green transition, propelled by comprehensive strategies such as the European Green Deal and the Fit for 55 agenda. These initiatives aim to achieve a 55 percent reduction in CO_2 emissions by 2030 and net-zero emissions by 2050, positioning Europe as a leader in the global shift to a sustainable economy.

The new European Commission will need to implement this ambitious agenda and formulate a **genuine Clean Industrial Deal, reconciling future European competitiveness against the green objectives**. Faced with the massive challenge of energy costs, Europe stands at a crossroads and must maximize its own potential for clean electricity generation. For industrial sectors such as steel, aluminum, and chemicals, soaring energy costs pose an existential threat, compelling them to innovate and adopt green practices to remain relevant.

Explainer: "The Clean Industrial Deal"

A "Clean Industrial Deal" for Europe would be a comprehensive policy framework aimed at decarbonizing Europe's industrial sector while ensuring its global competitiveness. It would be aligned with overarching goals of the European Green Deal, fostering the transition to a low-carbon economy through innovation, investment in clean technologies, and the establishment of a circular economy. Such an initiative would emphasize the need for sustainable industrial transformation to ensure that European industries can reduce greenhouse gas emissions, utilize resources more efficiently, and create green jobs, all while maintaining their position in the global market. It would also include mechanisms for carbon pricing, support for green hydrogen, and measures to prevent carbon leakage to ensure that industries do not relocate to regions with lower environmental standards.

a. Challenges Facing Europe

Europe initially approached its decarbonization efforts through a market-based lens, exemplified by the ETS, which incentivized companies to internalize the cost of carbon emissions. This strategy has proven effective in reducing European emissions and is set to accelerate decarbonization as free allocations are phased out.

However, Europe lacks a comprehensive strategy to support the emergence of carbon-neutral technologies, processes, and industries. Although the current strategies reduce emissions, they do not sufficiently promote the rapid development of industrial alternatives, especially given the following factors:

- The emergency elsewhere of aggressive green industrial policies supporting clean technologies, particularly in the United States and China.
- The lack of urgency in decarbonization policies imposed on energy-intensive industries in other parts of the world.
- The timeliness of investing in Europe's heavy industries, given that significant investment is essential as much of the existing conventional capital stock is aging and nearing the end of its investment cycle.[4]

Against this backdrop, **decarbonizing Europe's industrial sector is not only an environmental imperative but also a strategic necessity**. Recent global shifts, exemplified by the US Inflation Reduction Act and China's aggressive cleantech trade strategies, highlight the growing competitiveness of global markets. **These countries not only benefit from financial and legislative support for their industries but also create conditions that have the potential to isolate European products if they fail to innovate toward greener solutions**.

In this context, European industry cannot undergo a clean transition without a comprehensive "verticalization" of industrial policy to financially support industrial sectors, promote their products, and shield them from "unfair" international competition that does not adhere to the same rules in terms of decarbonization.

Major industrialized countries are transitioning to this approach, which seeks to decarbonize while protecting their industries and enhancing strategic autonomy. This shift marks a paradigm change away from the previously dominant vision of liberalization and globalization, which prioritized economies of scale and efficiency at all costs. In this new industrial policy framework, **political and geopolitical factors supplement economic rationality, with the goal of creating new economic projects and employment opportunities that are not subject to offshoring**.

[4] *On this point, please see Agora Industry, Wuppertal Institute, and Lund University, "Global Steel at a Crossroads: Why the Global Steel Sector Needs to Invest in Climate-Neutral Technologies in the 2020s," 2021, https://static.agora-energiewende.de/fileadmin/Projekte/2021/2021-06_IND_INT_GlobalSteel/A-EW_236_Global-Steel-at-a-Crossroads_WEB.pdf.*

Explainer: "Vertical Industrial Policy" vs. "Horizontal Industrial Policy"

Vertical industrial policy targets specific sectors or industries with tailored interventions such as subsidies, tax incentives, or regulations to promote their development, often with the goal of creating competitive advantages or addressing market failures within those sectors. In contrast, horizontal industrial policy focuses on broad, cross-cutting measures that impact all sectors of the economy equally, such as improving infrastructure, education, or innovation systems, with the aim of enhancing overall economic efficiency, productivity, and competitiveness across the entire economy. Both approaches are used to foster economic growth, but they differ in scope and focus.

b. What Industrial Decarbonization Strategy for Europe ?

Europe stands at a crossroads in its industrial history, confronted with the imperative to not only sustain its industrial base but also to transform it in response to the climate crisis. The path to decarbonization is fraught with significant challenges. The transition demands a **profound overhaul of the industrial sector and particularly of carbon-intensive industries**, which are integral to Europe's economy but detrimental to its environmental goals.

Decarbonizing energy-intensive sectors such as steel, chemicals, cement, and aluminum is particularly challenging due to the complexity of their processes and significance of their energy requirements. **If Europe is unable to meet its decarbonization goals and produce or supply sufficient amounts of low-cost decarbonized energy, it may see entire**

historic sectors relocate to regions with abundant decarbonized energy.

For the European Union, this presents a **complex economic dilemma** that calls for political decisions about the future of Europe's industry. **Should Europe strive to preserve at any cost energy-intensive industries that will be difficult to decarbonize? Or should it take economic rationality into consideration and produce what can no longer be produced domestically without support policies elsewhere?**

Implementing industrial policies, coupled with intelligent "protectionist" measures, could allow Europe to decarbonize its industries while shielding them from competition by foreign products. This approach would be costly, and Europe must decide whether the benefits justify the expense, balancing economic autonomy and industrial rationality.

What is certain is that **the global resurgence of industrial strategies necessitates that Europe move beyond purely regulatory decarbonization policies**. It must reconsider and develop industrial support strategies. However, the complexities of European governance further complicate this process.

In response to the US Inflation Reduction Act (IRA), **Europe has not adopted a unified large-scale investment strategy**. Instead, it relaxed stringent single-market state aid rules,[5] a solution that favors fiscally strong, highly industrialized countries such as Germany[6] but creates significant disparities for smaller EU Member States lacking fiscal space to invest in industrial decarbonization. This disparity underscores the need for cohesive political choices.

[5] *More precisely, the Commission extended exceptions that had been introduced during the COVID-19 crisis.*

[6] *It is worth noting that the decision by the German Federal Constitutional Court in November 2023 significantly constrained the German government's fiscal capabilities to support German industries.*

The primary question concerns the future composition of Europe's industrial fabric. Will industry remain predominantly in traditional regions such as Germany or Czechia, or should Europe implement policies that promote a more balanced industrial distribution across the EU? **Should Europe deliberately align industrial production with clean energy production capacities and situate heavy, energy-intensive industries near clean energy sources?**

While this issue is distinctly European, it reflects broader challenges in industrial decarbonization policies worldwide. It pertains to the essence of the industrial endeavor in the post-carbon era. Industrial activities require abundant raw materials and energy, which explains why industries are often located either near these resources or in locations to which they can be easily transported in bulk, e.g., seaports and near large rivers. Higher-value or specialized industries may be situated where access to human skills, proximity to clients, or synergies and "network effects" that have emerged through the clustering of adjacent industries outweigh the importance of raw materials or energy resources.

For the European Union, as for other industrialized countries aiming for decarbonization, it is, therefore, **essential to reconsider the entire industrial fabric in light of the following new criteria imposed by decarbonization:**

- Where is clean energy available?
- Where can we manufacture clean hydrogen cheaply?
- Where can CO_2 be stored?
- Which locations are going to be economically efficient?
- Which industries are too strategic to be left to economic efficiency?

Thus, **the state's role in driving decarbonization and industrial policy must be redefined**. The need for a clean industrial policy also arises from the necessity of addressing persistent market failures, particularly coordination failures, which are pervasive in heavy and complex industries.

Coordination failures occur when the profitability of individual firms depends on complementary actions by others, but no single entity has the incentive to act first.[7] A clean industrial policy can correct these inefficiencies by aligning private incentives with broader social goals, thus ensuring the development of sustainable industries and technologies.

Therefore, beyond market policies, the state must guide the emergence of the clean industrial revolution. Like its competitors implementing clean industrial policies, Europe must redefine its trajectory to help its economy and industries decarbonize.

This cannot be achieved without a **mix of public policies**. These must be **market-based instruments**, such as the ETS, the phasing out of free allocation, and the implementation of the Carbon Border Adjustment Mechanism, as well as **regulatory measures** from the Green Deal. Additionally, a **more "directive" approach supporting specific sectors**, particularly energy-intensive ones, is necessary.

c. Europe's Current Clean Industrial Policy Landscape

At face value, the European strategies are designed to not only spur technological innovation but also **secure the existing industrial base by making Europe a more competitive energy provider**. This ambition extends beyond financial and regulatory adjustments – it seeks to fundamentally reshape market dynamics by **empowering consumers to choose net-zero and circular products** through transparent **environmental labeling** and fostering a competitive but sustainable **tax environment across Europe**.

[7] *For more on coordination failures, see: Réka Juhász, Nathan Lane, and Dani Rodrik, "The New Economics of Industrial Policy," Annual Review of Economics 16 (2024): 213–242, https://doi.org/10.1146/annurev-economics-081023-024638.*

One of the major challenges is coordinating the various levels of power. Industrial policies are enacted at the national, regional, and European levels, and actions taken by one government can significantly impact other areas. At the European Commission level, green industrial policies are primarily managed by the various directorates: GROW, Competition, Trade, Energy, Climate Action, and Research and Innovation. This creates a patchwork of policies at the European level that must be aligned with the various policies at the national and regional levels.[8]

Most research and development support policies within the European Union are led by Member States. The Horizon Europe project, with a budget of €95.5 billion, allocates about €15.1 billion to climate, energy, and mobility.[9] This is supplemented by the **Innovation Fund**, financed by **revenues from the EU ETS**. These revenues are expected to increase with the phasing out of free quotas, leading to more carbon revenue at the EU level.[10]

These aids generally stop at the early stages of prototyping and demonstration projects and do not extend further. However, **for industrial decarbonization policies to making it possible for green goods to compete with carbon-intensive goods, deployment, scaling up, and sometimes supporting operational costs are also critical**.

[8] *Reinhild Veugelers, Simone Tagliapietra, and Cecilia Trasi, "Green Industrial Policy in Europe: Past, Present, and Prospects," Journal of Industry, Competition and Trade 24, no. 1 (2024): 1–22, https://doi.org/10.1007/s10842-024-00418-5.*

[9] *European Climate, Infrastructure and Environment Executive Agency, "Horizon Europe: €163.5 Million Available to Fund Green, Smart, and Resilient Transport and Mobility," May 7, 2024, https://cinea.ec.europa.eu/news-events/news/horizon-europe-eu1635-million-available-fund-green-smart-and-resilient-transport-and-mobility-2024-05-07_en.*

[10] *The Directorate-General for Competition ensures that these R&D aids comply with single market rules and World Trade Organization regulations.*

In addition to R&D support, **European alliances** create cross-border projects and decarbonization technology value chains that are central to the energy transition. Some projects become **Important Projects of Common European Interest (IPCEIs)**, granting them access to substantial state aid, as seen with batteries and hydrogen.[11] This system allows for state aid significantly larger than typically permitted under EU internal rules. Development banks such as the **European Investment Bank (EIB)** also play a crucial role in supporting new sectors and cross-sectoral decarbonization projects that private finance actors find too risky to fund in their early stages.

d. The Net Zero Industrial Act

Like many other industrialized jurisdictions, Europe aims to couple decarbonization with a resurgence of industry. At a minimum, it aims to protect its existing industrial fabric, which has been strained by the continent's struggle to secure affordable energy. To advance this goal, the European Union has implemented the ***Net Zero Industrial Act* (NZIA)**,[12] considered an embryonic green industrial policy with specific targets for the production of green technology on European soil.

The act is a statement of Europe's intention of securing its industrial base by promoting the development and deployment of strategic net-zero technologies within its borders. By setting a **target of EU domestic manufacturing being able to meet at least 40 percent of the EU's annual clean tech deployment needs by 2030**, the NZIA aims to bolster Europe's technological sovereignty while driving significant reductions in carbon emissions.

[11] *European Commission, "Important Projects of Common European Interest (IPCEI)," accessed August 27, 2024, https://competition-policy.ec.europa.eu/state-aid/ipcei_en.*

[12] *European Commission, "Net Zero Industry Act," March 16, 2023, https://single-market-economy.ec.europa.eu/publications/net-zero-industry-act_en.*

The NZIA can be seen as an **embryonic form of EU industrial policy** because it marks a deliberate intervention by the EU to shape the direction of economic development, **emphasizing the need for state-driven support to build strategic industries**. Traditionally, industrial policy in the EU has been a controversial subject due to concerns about market distortion and competition within the single market. However, the NZIA indicates a shift toward a more active role for governments in ensuring the competitiveness of European industries in the global green economy. Beyond establishing targets for domestic manufacturing capacities, it **aims to provide streamlined permitting processes** and to **offer financial incentives for green technologies**. It also represents a theoretical move toward a more coordinated and strategic industrial policy.

Moreover, the NZIA reflects an acknowledgment that green technologies and industries are critical not only for achieving climate goals but also for maintaining Europe's economic sovereignty in an era of increasing geopolitical competition. **The NZIA represents an attempt to respond to industrial strategies seen in other global powers, such as the US Inflation Reduction Act or China's industrial policies**. It is the **first EU recognition that state support is necessary to compete globally in these sectors**. Hence, the NZIA serves as a foundation for what could evolve into a more coherent and ambitious EU industrial policy focused on fostering green industries, jobs, and innovation.

Table 1: The Main Pillars of the Net-Zero Industry Act

Pillar	Description
Boosting Domestic Manufacturing	Increase EU capacity to produce clean technologies (e.g., solar, wind, batteries, clean hydrogen) to reduce reliance on imports.
Streamlining Permitting Processes	Simplify and accelerate the approval process for clean technology projects to speed up infrastructure deployment.
Financial Incentives and Investment Support	Provide subsidies and access to funding to encourage public and private sector investment in net-zero technologies.
Skills Development and Workforce Training	Focus on reskilling and upskilling workers to meet the demands of the green economy and ensure a capable workforce.
Strategic Resilience and Diversification	Diversify supply chains for critical technologies to reduce reliance on non-EU countries and foster innovation in green tech.
Carbon Capture and Clean Hydrogen	Prioritize the deployment of CCS technologies and clean hydrogen production to help decarbonize heavy industries.
Circular Economy and Sustainability	Promote sustainable materials, recycling, and environmentally friendly practices in manufacturing processes.

Table 2: Overview of Green Industrial Policy in Europe

	Funding Mechanisms	Regulatory Instruments	R&D Projects
EU- Level			
*EU Green Deal (2019): • Green Deal Industrial Plan	**European Green Deal Investment Plan:** • €10 bn of Invest EU Fund. • €17.5bn Just Transition Fund. Funded by ETS: • Modernisation Fund. • €40 bn Innovation Fund. €225 bn of unused EU Covid recovery loans (RRF). €200 bn of Regional Development Fund (30%) & Cohesion Fund (37%). Framework Program: + € 15.1 bn Horizon for climate, energy. + European Investment Bank (EIB). + Connecting Europe Facility. + LIFE Programme.	**Fit for 55 Package (2021):** • European Emissions Trading System (ETS). • Carbon Border Adjustment Mechanism (CBAM). • Renewable Energy (RED) & Energy Efficiency Directives (EED) & Industrial Emissions Directive. • Circular Economy Action Plan.	**Horizon Europe:** • European Institute of Innovation and Technology Regulation. • Knowledge and Innovation Communities (KICs)s. **European Alliances.** • Important Projects of Common European Interest (IPCEI). • European Battery Alliance. • European Clean Hydrogen Alliance.
*New types of instruments post-IRA and China derisking	**Reform of State aid rules for net-zero technologies:** • The General Block Exemption Regulation (GBER). • Temporary Crisis and Transition Framework (TCTF).	**Net Zero Industry Act.** **Critical Raw Materials Act.**	**Strategic Technologies for Europe Platform (STEP).** • Helps channel funds from existing EU programmes towards cleantech (current budget allocated up to 2027).

Selected Member States	Funding mechanism	Relevant Policy instruments	R&D
France	€20 bn France Relance plan green investments. • 49 projects representing €596 million of investment in decarbonizing industry.	French Strategy for Climate and Energy: • Carbon budget for industry: 65 Mt CO_2eq (2024-2028). Climate and Resilience Law.	€20m Investment for the Future Program (PIA 4).

Germany	€49 billion Climate and Transformation Fund 2024. €17 billion Green Bond Framework Expenditure (2023).	Carbon Contracts for Difference (CCfD) mechanism. Renewable Energy Sources Act (EEG): feed-in tariffs systems to achieve 80% green energy use by 2030, EEG Levy for fossil energy consuming enterprises.	Exploration of hydrogen and electrification in steel, chemicals, aluminum, and cement. Billions in funding to convert steel production from coal to hydrogen, to implement the national hydrogen strategy and for other important hydrogen projects (Budget 2024).
Netherlands	National Energy and Climate Plan (INECP): • €60 million to €100 million (as of 2023 and including green hydrogen) is available each year from the Climate Budget.	SDE++ scheme National Climate Agreement: • €74.17 per tonne CO_2 for industrials. • Additional CO_2 levy (on top of ETS System).	Research into electrification and hydrogen use in steel, chemicals, aluminum, and cement sectors. Investment in offshore wind farms. MIDDEN project (Manufacturing Industry Decarbonisation Data Exchange Network).
Italy	National Energy and Climate Plan (NECP): • €20 billion (approx) by 2030 in large-scale solar and wind projects.	Ecobonus 65% energy efficiency: Tax credits and grants for renewable energy projects.	Exploration of carbon capture and storage (CCS) technologies in heavy industries.
Spain	National Integrated Energy and Climate Plan: • €625,075 M for improvement of technology in industrial equipment and processes; and implementation of energy management systems.	Circular Economy Strategy (España Circular 2030).	Extensive solar and wind energy projects supplying clean electricity to steel, chemicals, aluminum, and cement sectors (ex: EDP Renewables).
Nordic Countries	€7bn, Danish Green Investment Fund (Grøn Investeringsfond). €6,5 bn Climate investment Fund in Norway (not EU but in the single market).	Enova program (Norway) Klimatklivet initiative (Sweden).	Exploration of hydrogen use in steel, chemicals, aluminum, and cement production across Denmark, Finland, Norway, and Sweden.
Poland	Polish Energy Policy until 2040.	Green Technologies Project (Poland).	Hydrogen Valley (Poland).

Table 3: EU Regulations Applying to all Industrial Sectors

EU Policy/Directive	Specific Targets/Requirements	Description
EU Emissions Trading System (ETS) reformed by the Green Deal and the Carbon Border Adjustment Mechanism, 2023[13]	Gradual reduction in the cap on emissions allowances by 2.2% annually. End of free allocations on the EU ETS for emissions-intensive trade-exposed sectors. Introduction of Carbon Border Adjustment Mechanism (CBAM).	Applies to all energy-intensive sectors, setting a **framework for emissions reductions** and **preventing carbon leakage**.
Energy Efficiency Directive (EED), 2023[14]	Improve energy efficiency by 32.5% by 2030. + further increase its energy efficiency ambition by at least 11.7% in 2030 compared to the level of efforts under the 2020 EU Reference Scenario.	• Targets improvements in energy efficiency. • Most industries are obliged to implement a system of energy management.
Renewable Energy Directive (RED III), 2023[15]	Increase the share of renewable energy in the EU's energy mix to 42.5% by 2030 in all sectors.	Annual increase in the share of renewable energy in each sector by 1.6% until 2030.
Circular Economy Action Plan, 2020[16]	The plan aims to increase the recycling rate from 33% in 2020 to over 50% by 2050.	Applies to all sectors, promoting sustainable product design, increased recycling rates, and reduced waste.
Industrial Emissions Directive (IED), 2022[17]	Reduce industrial emissions through the application of Best Available Techniques (BAT).	Applies to all sectors, ensuring the application of Best Available Techniques to reduce emissions.
Strategic Energy Technology Plan (SET Plan), 2023[18]	Accelerate the development and deployment of low-carbon technologies.	Focuses on innovation in renewable energy, energy storage, CCUS, and coordination among Member States.

[13] *European Commission, "EU Emissions Trading System (ETS)," 2024, http://web.archive.org/web/20240321235259/https://climate.ec.europa.eu/eu-action/eu-emissions-trading-system-eu-ets_en.*

[14] *European Commission, "EU Energy Policy," accessed September 9, 2024, https://energy.ec.europa.eu/index_en.*

[15] *European Union, "Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023," https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:L_202302413.*

[16] *European Commission, "Circular Economy Action Plan," accessed September 9, 2024, https://environment.ec.europa.eu/strategy/circular-economy-action-plan_en.*

e. Three Issues: Coordination, Financing, and Technology Guidance

In essence, **the EU's present industrial policy resembles a patchwork of national climate and energy policies rather than a long-term strategy**. Foundational documents such as the ***Green Deal Industrial Plan***[19] and the ***NZIA*** were **introduced late in the legislative process** and **lacked sufficient political momentum to address the finance issue** – the crux of the challenge for Europe – and the **coordination issue between Member States' industrial policies**.

The present European strategy's main weakness is the **lack of new common European funds to achieve its decarbonization goals**. The Strategic Technologies for Europe Platform **(STEP)**,[20] with €10 billion, is the only real fund established to stimulate investment in this nascent EU green industrial policy. The NZIA does, however, permit actions typically prohibited by European rules, **allowing Member States to provide more support to green technology sectors**, fund entrepreneurs through tax rebates and loans, and **finance OPEX where there is a funding gap**. This situation represents a novel development at the EU level.

[17] European Commission, "Industrial and Livestock Rearing Emissions Directive (IED 2.0)," accessed September 9, 2024, https://environment.ec.europa.eu/topics/industrial-emissions-and-safety/industrial-and-livestock-rearing-emissions-directive-ied-20_en.

[18] European Union, "Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions," October 20, 2023, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52023DC0634&qid=1698315020718.

[19] European Commission, "The Green Deal Industrial Plan," accessed September 9, 2024, https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/green-deal-industrial-plan_en.

[20] European Union, "Strategic Technologies for Europe Platform (STEP)," accessed September 9, 2024, https://strategic-technologies.europa.eu/index_en.

The NZIA also includes provisions to accelerate permit issuance and administrative procedures and coordinate private financing, **aiming for €92 billion in investments, with about 80 percent coming from private funds**.[21] Furthermore, it promotes the use of **public procurement** and auction systems with sustainability criteria.

Overall, the other major issue with current European industrial strategy is the **lack of coordination among different power levels, combined with the lack of European-level decision-making on funding**. Currently, industry funding is heavily focused on the national level, with sometimes contradictory goals and policies between different levels and countries. The NZIA is more focused on promoting various national approaches than on creating a strategic European agenda. This lack of common decision-making in financing **creates inequalities within the single market**, risking fragmentation due to different fiscal capacities among countries.

Another significant weakness frequently highlighted by industrial stakeholders is that the **European industrial strategy is not agnostic with respect to technology**. It tends to prematurely favor certain decarbonization technologies while excluding others, which hampers fair competition among different approaches to determine the most effective solutions. Industries would prefer greater freedom to choose their own paths to carbon neutrality and to be evaluated based on their outcomes. In this regard, the US Inflation Reduction Act is often seen as more "flexible" and favorable to industry.

It is true that the EU has made historical choices in favor of certain technologies – for example, prioritizing green hydrogen over low-carbon alternatives and excluding options like nuclear power or blue hydrogen.

[21] *European Commission, "Commission Staff Working Document: Investment Needs Assessment and Funding Availabilities to Strengthen EU's Net-Zero Technology Manufacturing Capacity," 2023, p. 26, https://single-market-economy.ec.europa.eu/system/files/2023-03/SWD_2023_68_F1_STAFF_WORKING_PAPER_EN_V4_P1_2629849.PDF.*

However, as this study suggests, the **Chinese example may indicate that the success of an industrial policy could be closely tied to a firm commitment to specific key technologies, executed without wavering or hesitation**.

With this in mind, the real issue in Europe is **not so much the lack of technology agnosticism but rather the lack of flexibility to adapt to technological advancements and allow new technologies to enter the market quickly enough**.

f. How Much Protection Is Needed?

The EU has lacked the political momentum to address the crucial issue of financing. It also lacked the momentum and, perhaps, the willingness to address the broader question of what kind of industrial policy it aims to pursue. This includes determining the level of protection Europe intends to provide to its low-carbon industries during the transition period, during which carbon-intensive and low-carbon industrial practices will coexist internationally. Addressing these challenges requires a dual approach: **Europe must foster innovation while ensuring that it does not cede its production capabilities**.

The ***Antwerp Declaration for a European Industrial Deal***[22] starkly emphasizes the necessity of a robust and clear industrial policy that **not only encourages innovation but also supports the retention and expansion of industrial production capabilities within the continent**. The declaration advocates for Open Strategic Autonomy, emphasizing the need to maintain and grow Europe's foundational industries – both basic and energy-intensive – within its borders to prevent overdependence on external sources for essential goods and technologies.

[22] *"The Antwerp Declaration for a European Industrial Deal," February 20, 2024, https://antwerp-declaration.eu/.*

Against this backdrop, and given the strategies implemented by industrial competitors and partners, the European Clean Industrial Deal should foster both decarbonization and the survival of the European industrial sector, which is no easy task. This is especially true because Europe itself is a big exporter and benefits from the open market in many segments of its economy.

Balancing industrial competitiveness against security concerns presents a complex challenge, particularly when considering the need to protect strategic industries as a safeguard against disruptions in international trade. **While it may be necessary to maintain certain uncompetitive plants as an "insurance" policy, the cost of sustaining these operations must be acknowledged**.

The key question is determining the minimum number of such plants required to serve as a nucleus for scaling up production in an emergency. However, there is a significant risk that these uncompetitive foundational industries could drag down the competitiveness of downstream industries, potentially undermining Europe's overall competitiveness. This could lead to a scenario in which industries within the EU are protected and are only competitive within the single market and struggle to compete globally. Such an outcome would be particularly detrimental to export-oriented economies in the EU, jeopardizing their ability to thrive in the global marketplace.

1.2. CHINA'S INDUSTRIAL POLICY

a. China's Gigantic Industrial Base

China's industrial policy has evolved significantly over the decades as it has transitioned from a Soviet-style planned economy to a highly strategic and technology-driven economic framework. This policy shift has transformed China into the world's largest manufacturer. However, although China's industrial sectors have propelled economic growth, they have also contributed heavily to environmental degradation, marking China as the **world's largest net exporter of embodied carbon**.

China's colossal industrial base is crucial to any discussion about decarbonizing industry globally. As the world's largest producer of steel, cement, aluminum, and chemicals, China accounts for about 51 percent of global cement production,[23] 57 percent of steel production,[24] and 56 percent of primary aluminum production.[25] Its chemicals industry also makes up about 44 percent of the global total.[26] These sectors are not only pivotal to the global supply chain but are also among the most carbon intensive, contributing substantially to the 28 percent share of global emissions that originates from China.[27]

Given that it is the largest global emitter of greenhouse gases, China's pace of decarbonization is critically important. Thus, the country's **"dual carbon" goals**, which aim for a **carbon peak by 2030 and carbon neutrality by 2060**, are central to global climate action. However, achieving these targets presents complex challenges. The sheer scale of China's industrial activity and its centrality in China's economic strategy complicate rapid transformation, and **unless its pace of decarbonization can be accelerated, there is a risk that global climate objectives will be derailed**.

[23] *International Cement Review, The Global Cement Report, 14th ed. (Tradeship, 2023), https://www.cemnet.com/Publications/Item/187049/the-global-cement-report-14th-edition.html.*

[24] *World Steel Association, Steel Statistical Yearbook 2023 (2023), https://worldsteel.org/publications/bookshop/ssy_subscription-2023/.*

[25] *International Aluminium Institute, "Primary Aluminium Production Statistics," accessed September 9, 2024, https://international-aluminium.org/statistics/primary-aluminium-production/.*

[26] *Cefic, "The European Chemical Industry: A Vital Part of Europe's Future, Facts and Figures 2023," December 2023, https://cefic.org/app/uploads/2023/12/2023_Facts_and_Figures_The_Leaflet.pdf.*

[27] *International Energy Agency, "CO2 Emissions in 2022," March 2023, https://www.iea.org/reports/co2-emissions-in-2022.*

b. The Architecture of China's Industrial Policy

China's approach to industrial decarbonization is intricately linked to its hierarchical governance structure, which mirrors the general organization of its industrial structure. The **central government establishes overarching rules and objectives**, while the **provincial and municipal governments are tasked with their implementation**. As a result of this multitiered arrangement, industrial policies in China, including those aimed at decarbonization, are implemented unevenly across different regions. Variations in adherence to central directives by provincial authorities can significantly affect the consistency and effectiveness of these policies.

At the national level, several key agencies play pivotal roles in shaping and enforcing China's industrial decarbonization efforts. The **National Development and Reform Commission** (NDRC), which oversees the country's broad economic planning, takes the lead in drafting most economic policies and endorsing stringent decarbonization measures. The **Ministry of Ecology and Environment** (MEE) focuses on establishing and implementing environmental regulations that also target industrial emissions. It collaborates closely with the **Ministry of Industry and Information Technology** (MIIT), which manages the specific industrial sectors. Additionally, the Ministry of Finance and the Ministry of Commerce indirectly influence decarbonization policies through their roles in fiscal and trade matters, respectively. **Industry associations**, which counterintuitively are government agencies, also play an important role in enforcing the rules in the various sectors.

The national structure is mirrored at the provincial and municipal levels through local departments such as the **Provincial Development and Reform Commissions and local environmental and industry agencies**. However, these local bodies often reflect the unique economic and industrial landscapes of their respective regions, along with differing local interests that may not always align with central directives. Each provincial government strives to attract economic growth, a priority that has historically overshadowed environmental concerns despite recent shifts in policy emphasis. This pursuit of growth is coupled with the imperative to maintain energy security, which in China often means continued reliance on abundant coal resources.

Despite the increasing importance attached to environmental policies and decarbonization among local officials, there is a noticeable **disparity between Beijing's ambitions and those of some local governments and companies**. Nonetheless, some provinces, leveraging competitive advantages such as renewable energy production or technological advancements, exhibit higher levels of ambition in this regard.

This dynamic creates a **competitive economic landscape among provinces**, significantly influencing the manner and capacity of both central and provincial governments to enact effective industrial decarbonization policies. Understanding this complex interplay is crucial for assessing China's overall strategy toward reducing industrial carbon emissions and its implications for global environmental goals.

Table 4: Example of "decarbonization specialization" between Chinese provinces

Sector	Specialized Province
Steel Industry	Hebei, Jiangsu, Shandong
Buildings Material Industry (including cement)	Fujian, Guangdong, Jiangsu, Anhui, Shandong
Textile Industry	Zhejiang, Jiangsu, Shandong, Henan
Petrochemical and chemical industry	Shandong, Jiangsu, Hebei, Tianjin

c. China's Strategic Planning and Government Intervention

To discuss Chinese industrial policy, it is necessary to acknowledge the **extensive role of government intervention in industrial affairs**, a feature that markedly distinguishes the Chinese system from those of liberal democracies. **In China, both national and local governments (provinces and municipalities) play pivotal roles in industrial affairs** and make interventions that are far more pronounced than in any other major economy. However, due to the sensitive nature of the topic for the Chinese regime, it is very difficult to know how much actual support China is providing to industries.

Such numbers as are available are massive. In 2020, the **financial support provided to industries** through subsidies, tax credits, and other mechanisms such as government procurement and various forms of indirect support may have been as high as RMB 6,402 billion (€813 billion), constituting about **5 percent of China's GDP**.[28] The total financial commitment to industry indicates a level of state involvement in the economy that is deeply woven into the fabric of national economic strategies.

These financial commitments are aimed at fostering domestic innovation and self-sufficiency, a goal that has become increasingly pronounced under the leadership of Xi Jinping. The **"Made in China 2025"** initiative and the recent emphasis on the **"dual circulation"** strategy reflect a deliberate focus on reducing dependency on foreign technology and enhancing internal capacity in strategic sectors.[29] **This strategy also encompasses the greening of China's industry, which is perceived as a substrategy of both China's economic independence and China's**

[28] *OECD, "Measuring Distortions in International Markets: Below-Market Finance," OECD Trade Policy Papers, no. 247 (2021), https://www.oecd.org/publications/measuring-distortions-in-international-markets-below-market-finance-a1a5aa8a-en.htm.*

[29] *State Council of the People's Republic of China, "Made in China 2025 Plan," 2016, accessed September 9, 2024, https://www.gov.cn/zhuanti/2016/MadeinChina2025-plan/.*

strategy for future growth. Furthermore, the expansive scale of government intervention underscores the Chinese authorities' capacity to steer industrial sectors toward major policy goals, including those related to decarbonization.

d. The "Dual Carbon" Objectives: Greening China's Industry

The introduction of the **14th Five-Year Plan** underscored a strategic pivot toward prioritizing technological innovation across a broad spectrum of industries in China.[30] This plan is the first to prioritize green and environmentally friendly products, at least on paper. This aligns with the broader vision encapsulated in the **"1+N" policy framework**, China's flagship climate objective, which was established to find a pathway for the country to peak its emissions in 2030.[31] While the "1+N" framework sets overarching climate goals, it **lacks specific emissions reduction targets for individual industrial sectors**.

Regarding industry decarbonization, the 14th Five-Year Plan yielded broader strategic initiatives to **optimize and adjust the industrial structure**, notably aiming to **address issues of overcapacity** and **enhance energy efficiency**. These initiatives notably promote recycling, improve energy conservation measures, and establish a robust green manufacturing system through diverse policy instruments from the national to the provincial and local levels. Additionally, this set of policies **introduces benchmarks that industries are expected to meet by 2025 and 2030**, with the goal of aligning with international efforts for energy

[30] *State Council of the People's Republic of China,* 中华人民共和国国民经济和社会发展第十四个五年规划和*2035*年远景目标纲要 *[Outline of the 14th Five-Year Plan for National Economic and Social Development of the People's Republic of China and the Long-Range Objectives for 2035], March 13, 2021, https://www.gov.cn/xinwen/2021-03/13/content_5592681.htm.*

[31] *"Working Guidance for Carbon Dioxide Peaking and Carbon Neutrality in Full and Faithful Implementation of the New Development Philosophy," Xinhua News Agency, October 24, 2021, http://www.news.cn/english/2021-10/24/c_1310265726.htm?bsh_bid=5645848472.*

conservation and carbon intensity. The approach includes **promoting "pioneers" (industry leaders)** and gradually expanding these standards to other sectors as technological maturity and economic viability evolve.

The Chinese government, through the Ministry of Ecology and Environment, **classifies steel, nonferrous metal smelting (aluminum), and chemicals and petrochemicals as "dual-high" industries** due to their high energy consumption and high emissions. Local environmental authorities are instructed to tighten the approval, pollution control, and monitoring of these projects. Since 2021, key environmental and climate authorities, including the NDRC, MEE, MIIT, and China Energy Engineering Corporation (CEEC), have been directed to "strictly contain the blind development of the dual-high industries."

China's Nascent Clean Industrial Strategy

Despite this set of policies, **China's path to industrial decarbonization is still in its infancy**. The country's heavy industries are not only massive in scale but also among the most carbon intensive globally. In 2020, China's CO_2 emissions per unit of GDP were more than double the global average, with profound disparities across provinces. This is exacerbated by the ongoing issue of overcapacity in industries such as steel and chemicals, which threatens to undermine efforts to reduce carbon intensity by creating economic incentives to maintain high levels of production.

Nevertheless, recent developments have seen a tightening of policies around high-emissions and high-energy-consumption industries. Since 2021, China has been more assertive in containing what are termed **"dual-high" projects**, with stringent controls over new projects and enhanced monitoring of existing ones. This included **suspending numerous projects that failed to meet dual-energy control targets** and initiating provincial pilots for carbon impact assessments in 2023.[32]

The national government also leverages interprovincial competition by **fiscally rewarding local administrations that have good results in terms of decarbonizatio**n.[33]

Although China's manufacturing strength is declining relative to its GDP, it remains a critical driver of both economic growth and environmental impact.[34] The **tension between industrial growth and environmental sustainability is a significant policy challenge for China**, reflecting the broader dilemmas faced globally. The shift toward electrification in industry and increasing demand for energy, particularly from coal-fired power generation, highlight the complex dynamics at play in China's industrial and environmental policies. As such, China's decarbonization strategy is not just a national issue but a critical component of global efforts to combat climate change.

When analyzing China's prospects for a turn toward clean industrial policy, it is essential to maintain a speculative outlook for key industries, as they face significant shifts in terms of both domestic demand and global competition. In sectors such as steel and cement, which have historically catered to a robust domestic construction industry, the recent real estate slump has led to a sharp decline in demand. This oversupply has already prompted a moratorium on new steel plants, highlighting the challenges of excess capacity.[35]

[32] *Ministry of Ecology and Environment of the People's Republic of China,* 关于加强高耗能、高排放建设项目生态环境源头防控的指导意见 *[Guiding Opinions on Strengthening Source Control of Ecological and Environmental Protection for High Energy Consumption and High Emission Construction Projects], May 31, 2021, https://www.mee.gov.cn/xxgk2018/xxgk/xxgk03/202105/t20210531_835511.html.*

[33] *State Council of the People's Republic of China,* 财政支持做好碳达峰碳中和工作的意见 *[Opinions on Financial Support for Achieving Carbon Peak and Carbon Neutrality], May 31, 2022, https://www.gov.cn/zhengce/zhengceku/2022-05/31/5693162/files/e4501d6e405f4f488f65ca910ac14dc3.doc.*

[34] *Qing Na, "China's Manufacturing Growth Hits Three-Year Peak, Caixin PMI Shows," Caixin Global, July 1, 2024, https://www.caixinglobal.com/2024-07-01/chinas-manufacturing-growth-hits-three-year-peak-caixin-pmi-shows-102210921.html; World Bank, "Manufacturing, Value Added (% of GDP) – China," accessed September 9, 2024, https://data.worldbank.org/indicator/NV.IND.MANF.ZS?locations=CN.*

Similarly, overcapacity looms large in many of the country's green tech industries, such as the solar photovoltaic and battery industries.[36] This could result in falling prices, followed by a wave of cancellations, mergers, and potentially bankruptcies in China's industrial sector. The global response to overcapacity, particularly from China, will be critical. **China currently seems to engage in aggressive market dumping rather than taking steps to retire some of its excess capacity. How these developments unfold will be pivotal in shaping the future landscape of industries in the country and setting an ambitious industrial decarbonization agenda**.

1.3. JAPAN'S INDUSTRIAL POLICY

Japan has a rich history of industrial policy that facilitated its status as the first Asian country to industrialize. Historically, this policy has supported the maintenance of robust capacities in energy-intensive sectors, despite geographic and energetic constraints that are generally unfavorable for industrial manufacturing. Japan's traditional industrial policy has been closely linked to providing cheap energy – which is highly valued by industrial producers – and a long-standing focus on innovation. However, sectors requiring high energy density, such as primary aluminum, have needed to relocate overseas to regions with accessible low-cost energy.

[35] *Ministry of Industry and Information Technology of the People's Republic of China,* 工业和信息化部办公厅关于暂停钢铁产能置换工作的通知 *[Notice from the General Office of the Ministry of Industry and Information Technology on Suspending Steel Capacity Replacement Work], August 22, 2024, https://www.miit.gov.cn/jgsj/ycls/wjfb/art/2024/art_beae9b1682de4457b555b42c5f839f4f.html.*

[36] *Recent data, such as those from Bloomberg New Energy Finance, suggest that the planned gigafactory expansions far surpass even the most optimistic demand projections. See: Yayoi Sekine, "Energy Storage: 10 Things to Watch in 2024," BloombergNEF, January 25, 2024, https://about.bnef.com/blog/energy-storage-10-things-to-watch-in-2024/.*

Japan emits approximately 1 billion tons of greenhouse gases annually,[37] with the **industrial sector accounting for about 36.5 percent of these emissions**. The steel industry alone contributes around 55 percent of these industrial emissions, followed by the chemicals industry at 14.6 percent and the cement industry at about 8 percent.[38] Despite a globally competitive market that sometimes surpasses the competitiveness of local production, Japan maintains a significant steel industry, which supports its automotive and machinery sectors. It also boasts major players in the chemicals industry and produces cement for both domestic use and export within the Pacific region.

Since the 1990s, Japanese industrial policy has been protective and supportive but much less intrusive than that of its neighbor, China. Japan is implementing various strategies to test its options for decarbonization, and the country's industrial future will be strongly impacted by the turn to a post-carbon world. The Japanese government establishes guidelines and coordinates policies with industrialists who **co-construct the rules imposed or sometimes voluntarily adopted to encourage compliance without coercion**. As Japan prepares to unveil a new national decarbonization strategy by the end of 2024, this paper will provide insights into the potential pathways and challenges facing the country in an increasingly diverse global landscape of industrial decarbonization.

[37] *Ministry of the Environment, Japan, "Japan's National Greenhouse Gas Emissions and Removals in Fiscal Year 2022," April 12, 2024, https://www.env.go.jp/en/press/press_02707.html#:~:text=Greenhouse%20gas%20(GHG)%20emissions%20of,is%20the%20reduced%20energy%20consumption.*

[38] *Ministry of the Environment, Japan, "Japan's National Greenhouse Gas Emissions and Removals in Fiscal Year 2022: Executive Summary," 2022, https://www.env.go.jp/content/000216745.pdf.*

a. The Shift toward Decarbonization: Policies and Innovations

Like other developed nations with energy-intensive industries, Japan needs to make low-carbon products competitive against their carbon-intensive alternatives. It must also foster research and development and implement innovations that achieve industrial decarbonization at the national level.

Until recently, Japanese industrialists viewed decarbonization as a burden. This perspective is slowly shifting as the country's energy security becomes increasingly fragile due to unstable fossil resources. The transition to less energy-intensive or decarbonized processes is increasingly seen by some industry leaders as a policy of good management. However, the pace of the decarbonization of energy-intensive industry, particularly if triggered by international pressure (such as the EU CBAM), is often considered too fast by Japanese stakeholders.

Despite its claim to have an industry that is less carbon intensive than that of some of its competitors, particularly China, **Japan was relatively late among developed nations in deploying decarbonization tools**. It only implemented binding climate policies on its industry very recently.

The timeline of Japan's industrial decarbonization strategy started around 2017, notably with work on the Basic Hydrogen Strategy, which was completed in 2023.[39] This was followed by a pledge from the Cabinet for *Carbon Neutrality by 2050*,[40] the *Green Growth Strategy* in December 2020,[41]

[39] *Ministry of Economy, Trade and Industry, Japan, "Basic Hydrogen Strategy," June 6, 2023, https://www.meti.go.jp/shingikai/enecho/shoene_shinene/suiso_seisaku/pdf/20230606_5.pdf.*

[40] *Prime Minister of Japan and His Cabinet. "Policy Speech by the Prime Minister to the 203rd Session of the Diet," October 28, 2020, https://japan.kantei.go.jp/99_suga/statement/202010/_00006.html.*

[41] *Ministry of Economy, Trade and Industry, Japan, "Green Growth Strategy through Achieving Carbon Neutrality in 2050," updated October 17, 2022, https://www.meti.go.jp/english/policy/energy_environment/global_warming/ggs2050/index.html.*

the ***Green Innovation Fund***[42] and the **6th *Basic Energy Plan*** in 2021,[43] and the ***Basic Hydrogen Strategy*** in 2023.[44] The ***Green Innovation Fund***, handled by the New Energy and Development Organization (Japan's industrial funding agency), is the centerpiece of the Japanese Research and Innovation architecture; it manages **JPY 2.9 billion (€18 billion) to support industrial decarbonization R&D projects in the country**.[45]

b. The GX Strategy

The first comprehensive decarbonization strategy for the industrial sector in Japan, the **GX League**,[46] was announced in 2022. It **combines "growth-oriented" carbon pricing with industry support to enhance the competitiveness of the Japanese economy**. This policy aims to drive the country's transition to carbon neutrality by fostering a collaborative framework among businesses.

Initially, the GX League included 568 companies that account for over 50 percent of Japan's greenhouse gas emissions. These companies have set voluntary emissions reduction targets for 2025 and 2030, aiming to reduce emissions by 620 million tons and 480 million tons, respectively. In 2024, a decision was made to **establish a mandatory national Emissions Trading Scheme to be implemented by 2026–28**, aligning with the official EU CBAM implementation.

[42] *Ministry of Economy, Trade and Industry, Japan, "Green Innovation Fund," updated February 3, 2023, https://www.meti.go.jp/english/policy/energy_environment/global_warming/gifund/index.html.*

[43] *Ministry of Economy, Trade and Industry, Japan, "Outline of Strategic Energy Plan," October 2021, https://www.enecho.meti.go.jp/en/category/others/basic_plan/pdf/6th_outline.pdf.*

[44] *Ministry of Economy, Trade and Industry, Japan, "Basic Hydrogen Strategy."*

[45] *Ministry of Economy, Trade and Industry, Japan. (n.d.). "Basic Policies for Green Innovation Fund (Summary)," https://www.meti.go.jp/english/policy/energy_environment/global_warming/gifund/pdf/20230111_000.pdf.*

[46] *Ministry of Economy, Trade and Industry, Japan,* グリーン・トランスフォーメーションリーグ運営事業費 *[Green Transformation League Operational Project Costs], March 22, 2024, https://www.meti.go.jp/policy/energy_environment/global_warming/GX-league/legalissuesofets.pdf.*

A substantial financial component of the GX policy is the issuance of **GX Transition Bonds**.[47] Japan plans to invest approximately **JPY 150 billion (€995 billion)** over the next decade, funded by **issuing around JPY 20 billion (€136 billion) in GX bonds**. This approach leverages one yen of public money to generate seven yen in private investment. The **GX bonds will be reimbursed using revenues from the carbon pricing mechanisms implemented in the country**.

This investment plan will support various initiatives, including the development of hydrogen, renewable energy, and industrial decarbonization. **The industrial strategy involves the initial funding of R&D projects, followed by financing deployment projects later in the decade using GX funds**. In June 2024, the first GX bonds were issued, raising JPY 700 billion (€4.4 billion), with the majority **– two-thirds – earmarked for industrial R&D projects**.

This legislative act came alongside the ***Basic Policy for the Realization of GX***, which aims to **promote thorough energy efficiency** and to **make renewable energy a major power source**, with the target of achieving 36–38 percent of renewables in the power generation mix by 2030. The Japanese government also updated its ***Basic Hydrogen Strategy*** in June 2023. This strategy seeks to **cultivate Japan's industrial technological advantage on hydrogen**, allowing it to reach 3 million tons per year of hydrogen consumption by 2030, 12 million tons per year (including ammonia) by 2040, and 20 million tons per year by 2050. The government has pledged to **support the launch of CCS projects by 2030** and to achieve **6–12 million tons** of annual CO_2 storage by **2030**.

[47] *Ministry of Economy, Trade and Industry, Japan, "Japan Climate Transition Bond Framework," November 2023, https://www.meti.go.jp/policy/energy_environment/global_warming/transition/climate_transition_bond_framework_eng.pdf.*

c. The Reality of Decarbonization and Economic Security

Japan is implementing supportive policies and innovations aimed at decarbonization, influenced by policies in Europe and the Inflation Reduction Act in the United States. The GX League, in particular, represents a dual approach of carbon pricing and support for innovation and industry decarbonization. The Japanese industrial policy is also closely linked to its energy policy, framed by the **"3 E's": energy security, economic security, and environmental sustainability**. The key government players in decarbonization include the Ministry of Economy, Trade, and Industry (METI) and the Ministry of the Environment (MOEJ), along with other ministries such as the Ministry of Finance and the Ministry of Information, which manage the decarbonization of the Japanese economy.

Japan's path to industry decarbonization is particularly complex, given the current technologies available. Consequently, **Tokyo is adopting a highly technology-agnostic approach**, which is prudent but may not always align with the goal of achieving carbon neutrality by 2050. Japan's policy approach allows the use of gas to replace more polluting activities that rely on resources such as coal and heavy oil, with ongoing evaluations of when these transitional policies will shift toward effective carbon neutrality. Crucially, Japan's ambitious hydrogen policy is not only focused on domestic production but also, significantly, on importing decarbonized hydrogen,[48] which is essential given Japan's insular nature and lack of sufficient local production potential.

[48] *It is important to note that Japan's vision for clean hydrogen entails blue hydrogen and even non-clean hydrogen options to "launch the market."*

1.4. SOUTH KOREA'S INDUSTRIAL POLICY

The Republic of Korea is an industrial behemoth, hosting major corporations in sectors including steel (POSCO) and chemicals (SK) that compete on the global stage alongside other prominent technology and machinery corporations (Samsung and LG). The South Korean industrial sector is characterized by its high energy intensity, with a substantial dependence on coal for both industrial processes and electricity production.

Similar to Japan, the principal architects of South Korea's industrial decarbonization policy are the **Ministry of Trade, Industry, and Economy** (MOTIE) and the **Ministry of the Environment** (MOEK). In addition, the Korean Presidential Committee on Net Zero plays a pivotal role, functioning as a consultative and coordinating body for the presidential action. Industrial conglomerates in South Korea, known as **chaebols** – which are perceived as controlling greater wealth than the state itself – have intricate connections with the government. This relationship enables them to exert **considerable influence on industrial policies**. Politically, advocating for substantial industrial strategies that would provide financial support for decarbonization efforts within these corporations has proven difficult.

The South Korean economy is notably driven by exports, with significant steel exports distributed among Europe (approximately 10 percent), the United States (approximately 10 percent), and Southeast Asia (20 percent).[49] Consequently, **international demand significantly influences South Korea's industrial activities**. The development of a global market for decarbonized products is considered crucial for South Korea. Rapid progression or inadequate adaptation to global market demands could lead to a substantial decrease in its industrial market share.

[49] *Korea Institute for Industrial Economics & Trade, 철강산업의 탄소중립 추진 전략과 정책과제 [Strategies and Policy Tasks for Promoting Carbon Neutrality in the Steel Industry], April 12, 2022, https://www.kiet.re.kr/research/paperView?paper_no=774.*

a. A Slow Shift toward Decarbonization

Overall, the government of South Korea remains disorganized in its approach to industry decarbonization, lacking comprehensive flagship legislation and integrated strategies for each sector. Additionally, much of the impetus for industry decarbonization comes from abroad, with the **EU's Carbon Border Adjustment Mechanism being a key incentive driving the government toward more action**.

Historically, South Korea's primary industrial policy has focused on providing low-cost energy to support its export sectors. Industrial decarbonization policy is still a very new concept in the country. To date, **support for decarbonization has largely been confined to research and development**, with comprehensive policies that mandate decarbonization remaining under deliberation.

South Korea's approach to industrial decarbonization is trailing behind comparable initiatives in countries such as Japan and, to an even great extent, the EU. In 2012, South Korea introduced the **Emission Trading System (SK ETS)**, inspired by the European model and established with assistance from the European Union. Despite the system encompassing over 88.5 percent of national emissions, its **efficacy in reducing these emissions has been limited**.[50] This limitation can be attributed to its foundational design around a "business as usual" trajectory, compounded by the ineffectual internalization of carbon costs by the industries it covers.

A significant challenge identified within South Korea involves the reform of the electricity sector. Similar to Japan, **securing an adequate supply of decarbonized energy** – whether through increased reliance on

[50] *International Carbon Action Partnership (ICAP), "Korea Emissions Trading Scheme," accessed September 9, 2024, https://icapcarbonaction.com/en/ets/korea-emissions-trading-scheme.*

nuclear and renewable energy sources, or even through hydrogen – remains a **critical concern**. In this respect, the two last administrations have established hydrogen strategies that seek to stimulate demand for decarbonized hydrogen and facilitate policies concerning its production and importation, with prospective imports from Australia and the Gulf countries.

During the administration of President Moon (2017–2022), South Korea initiated a ***renewable energy strategy***[51] and a ***national plan to reduce greenhouse gas emissions*** by 99 million tons through innovation and technology by 2030 compared to the 2019 level.[52] In 2019, a ***comprehensive roadmap for the hydrogen economy*** was launched, underscoring the role of hydrogen in industrial decarbonization.[53] This policy supported the utilization, importation, and production of hydrogen, irrespective of its source, aiming to establish a supply chain that would later be decarbonized.

In 2020, South Korea pledged to **achieve carbon neutrality by 2050**.[54] In the wake of the COVID-19 pandemic, a ***Green New Deal*** and green finance initiatives were introduced to support business transitions across various sectors.[55] In March 2022, the **Carbon Neutrality Act** was enacted to promote green growth.[56] This legislation aimed to **reduce carbon emissions**

[51] *Ministry of Trade, Industry and Energy, South Korea, "Korea's Renewable Energy 3020 Plan," October 2018, https://gggi.org/site/assets/uploads/2018/10/Presentation-by-Mr.-Kyung-ho-Lee-Director-of-the-New-and-Renewable-Energy-Policy-Division-MOTIE.pdf.*

[52] *Ministry of Environment, Republic of Korea, 2030 온실가스 감축 로드맵 수정안 및 2018~2020년 배출권 할당계획 확정 [Revised 2030 Greenhouse Gas Reduction Roadmap and Finalization of the Emissions Allowance Allocation Plan for 2018–2020], July 24, 2018, http://www.me.go.kr/home/web/board/read.do?menuId=286&boardMasterId=1&boardCategoryId=39&boardId=886420.*

[53] *Netherlands Enterprise Agency (RVO), "Hydrogen Economy Plan in Korea," January 18, 2019, https://www.rvo.nl/sites/default/files/2019/03/Hydrogen-economy-plan-in-Korea.pdf.*

[54] *Sohn Ji-ae, "Net Zero by 2050," Korean Culture and Information Service (KOCIS), December 2020, https://www.kocis.go.kr/eng/webzine/202012/sub08.html.*

[55] *Government of South Korea, "The Korean New Deal: National Strategy for a Great Transformation," July 2020, https://content.gihub.org/dev/media/1192/korea_korean-new-deal.pdf.*

by 35 percent by 2030 relative to 2018 levels and to enhance the national ETS, which had been operational since 2012 and covered 73 percent of national emissions.

Following the election of the conservative President Yoon, there was a notable pivot in decarbonization policy, especially with an expanded endorsement of nuclear energy. The inaugural ***National Plan for Carbon Neutrality and Green Growth*** was adopted, **revising down the greenhouse gas reduction targets to an 11.4 percent** decrease by 2030 compared to 2018.[57] Nevertheless, financial incentives for growth, particularly within green industries, have continued under the new administration.

Finally, in response to the European Union's Carbon Border Adjustment Mechanism (EU CBAM), Korea has committed to reforming its national carbon market to enhance the rigorousness and effectiveness of its industrial decarbonization efforts, aligning with European CBAM policies.

[56] *Korea Legislation Research Institute, "Framework Act on Carbon Neutrality and Green Growth for Coping with Climate Crisis," September 24, 2021, https://elaw.klri.re.kr/eng_mobile/viewer.do?hseq=59958&type=part&key=39.*

[57] *2050 Carbon Neutrality Commission, Republic of Korea, 국가 탄소중립·녹색성장 기본계획 (안) [National Carbon Neutrality and Green Growth Basic Plan (Draft)], March 2023, https://www.2050cnc.go.kr/download/BOARD_ATTACH?storageNo=1936.*

2 How to Decarbonize Industry Globally?

2.1. A VERY UNEVEN INDUSTRY GEOGRAPHY TO DECARBONIZE

Table 5: Industrial emissions In Europe and Asia

		China	Japan	South Korea	European Union	Sources
Steel	**Production**	1,019,080 kt	86,999 kt	66,683 kt	126,316 kt	All (2023)
	Carbon Emissions	2,100 Mt	150 Mt		221 Mt	China (2020), Japan (2019), EU (2021)
	Carbon Intensity	BF-BOF 2.1 t-CO_2/t, EAF 1.3 t-CO_2/t	1.796 t-CO_2/ t crude steel		1.15 t-CO_2/t	China (2023), Japan (2019), EU (2022)
Chemicals	**Production**	2,390 billion €	227 billion €	139 billion €	760 billion €	All (2022)
	Carbon Emissions	500 Mt of CO_2	CO_2, CH4, and N20: 3,709 (2020), 4,236 (2021), 3,786 (2022) kt-CO_2 eq.; F-gases: 322 (2020), 361 (2021), 186 (2022) kt-CO_2 eq.		121 Mt (2020), 124 Mt (2021)	China (2020), Japan (2020-2022); EU (2020-2021)
	Carbon Intensity	/	/		32.9 (2020), 31.8 (2021) GHG emissions per unit of chemicals production	EU (2020-2021)

		China	Japan	South Korea	European Union	Sources
Aluminum	**Production**	38.5 Mt (2021), 40.21 Mt (2022), 41.59 Mt (2023) of primary aluminum	0t (2015 onwards)	1.094 Mt of aluminum plates	1.226 Mt of primary aluminium	China (2021-2023) Japan (2024), Korea (2022), EU (2022)
	Carbon Emissions	550 Mt of CO_2	N/A (2015 onwards)		24 Mt CO_2 equivalent	China (2022), Japan (2024), EU (2021)
	Carbon Intensity	12.5 to 13 tCO_2/t	N/A (2015 onwards)		5.5 tCO_2/t	China, EU (2019), Japan (2024)
Cement	**Production**	2,110 Mt	53.2 Mt	51.06 Mt	182.1 Mt	China (2022), Japan (2022), Korea (2022), EU (2019)
	Carbon Emissions	763.4 Mt of CO_2	23.2 Mt of CO_2		104 Mt of CO_2	China, Japan, South Korea (2022), EU (2023)
	Carbon Intensity	0.58 $t\text{-}CO_2/t$	0.515 $t\text{-}CO_2/t$ (2020, 2021, 2022)		667 $k\text{-}CO_2/t$ of cement	China (2022), Japan (2020-2022), EU (2017)

Table 6: Emissions and Production Data for Key Industries in Europe and Asia

	China	Japan	South Korea	European Union	Sources
Steel	China Baowu Group	Nippon Steel Corporation	Posco Holdings	ArcelorMittal	
Production	131.84 Mt	44.37 Mt	38.64 Mt	68.89 Mt	(2022)
Carbon Emissions		63,397 kt CO_2	78.8 Mt (average between 2017 and 2019)	124.4 Mt CO_2e (scope 1&2)	Nippon Steel (2022), Posco, ArcelorMittal (2020)
Carbon Intensity	1.87 (2019)	1.92 t-CO_2/t (scope 1&2)	/	2.06 t-CO_2/t-steel (scope 1&2)	Nippon Steel (2022), ArcelorMittal (2018)
Chemicals	SINOPEC Group	Sumitomo Chemical	Lotte Chemicals	BASF	
Production	45.291 Mt (2023)	2,895,283 million yens	18.066 Mt (2022) (capacity)	€14,895 million	Sumitomo (2023), BASF (2022)
Carbon Emissions	172.56 Mt CO_2e, of which 148 Mt CO_2e in direct emissions (2021), 161.69 Mt CO_2e, of which 137.72 Mt CO_2e in direct emissions (2022), 168.64 Mt CO_2e, of which 142.28 Mt CO_2e in direct emissions (2023),	2.696 Mt CO_2e	3.896 Mt CO_2e	14,635 Mt CO_2e (2023), 15,797 Mt CO_2e (2022)	SINOPEC, Sumitomo (2022), Lotte (2023), BASF
Carbon Intensity	62.96 (2021), 48.76 (2022), 52.50 (2023) t-CO_2/RMB million (GHG emissions/revenue)	/	304 t-CO_2e/KRW Billion (Scope 1&2)	/	SINOPEC, Lotte (2023)

	China	Japan	South Korea	European Union	Sources
Aluminum	Chinalco	N/A	Lotte Aluminium	Norsk Hydro	
Production	6,700,000 t (2023)	N/A		2,030 kmt	Norsk Hydro (2023)
Carbon Emissions	61.3816 Mt of CO 2 e	N/A	1,084 t CO_2e	2.70 Mt CO_2e	Chinalco (2019), Lotte (2022), Norsk Hydro (2023)
Carbon Intensity	6.60 t-CO_2e/ RMB10,000	N/A	/	41.1 t-CO_2e/ NOK million	Chinalco (2019), Norsk Hydro (2023)
Cement	Anhui Conch	Taiheiyo Cement Corporation	Ssangyong C&E	Heidelberg Materials	
Production	395 Mt (capacity)	27,228 kt (of which 17,229 kt produced in Japan)	15 Mt (capacity)	176 Mt (capacity)	Anhui (2023), Taiheiyo (2023), Ssangyong
Carbon Emissions	175,889,434 t CO_2	20,065 Mt (of which 13,036 Mt in Japan) of CO_2	9.9 Mt (2020)	61.2 Mt CO_2	Anhui (2023), Taiheiyo (2023), Heidelberg (2022)
Carbon Intensity	0.8270 t-CO_2/t-clinker	0.698 t-CO_2/t-cementitious		0.551 t-CO_2/t-cementitious materia	Anhui (2023), Taiheiyo (2023), Heidelberg (2022)

2.2. TRANSITION TECHNOLOGIES AND PROCESSES

The concept of decarbonizing energy-intensive industries is well understood within the scientific community, and although it is challenging, it is far from unachievable. However, two main challenges remain:

- First, there are engineering hurdles that need to be resolved for certain technologies, as **some necessary technologies are known but not yet mature enough** for deployment or even demonstration. This creates **significant technology uncertainty, complicating investments and strategizing by industrials and policymakers**.
- Second, and most importantly, the **economic complexities associated with technological adoption** present significant obstacles that need to be resolved through policy and regulations. These obstacles originate in the **cost gap between decarbonized and carbon-intensive goods that is present during the transition phase**, giving rise to the question: How can customers be encouraged to choose the green alternative?

These two factors create **substantial uncertainty in industrial decarbonization policy**. A technology that seems suitable today might become obsolete in a few years, complicating policy decisions that must **encourage risk-taking while remaining open to the most appropriate future technologies**.

Fossil fuel use in industry can be categorized into two main areas: **heating** and **processes**. Heating typically involves boilers and furnaces powered by natural gas, coal, or oil, whereas processes use fossil fuels as feedstocks for chemical reactions and material production.

Substitution strategies for decarbonization include **transitioning to electric and clean hydrogen-based heating systems for heating needs**. For industrial processes, **replacing fossil-derived feedstocks**

with green hydrogen and bio-based alternatives presents a viable pathway. Additionally, using **alternative low-carbon raw materials** or **recycled materials** instead of those heavily reliant on fossil fuels is a crucial strategy for achieving decarbonization goals.

Beyond the substitution strategy, two additional decarbonization approaches are being considered by industries and governments to achieve carbon neutrality goals. The first strategy focuses on improving energy efficiency through process optimizations, policy implementations, and technological advancements. The second strategy involves **carbon capture, utilization, and storage (CCUS)**, which allows for the continued use of fossil fuels in processes that are difficult to decarbonize in the short term by capturing and storing the resulting carbon emissions.

Table 7: Substitution Strategies for Decarbonization

Category	Current use	Decarbonization Strategies
Heating	Uses boilers and furnaces powered by natural gas, coal, or oil.	Transition to electric heating systems or Use clean hydrogen-based heating systems
Processes	Uses fossil fuels as feedstocks for chemical reactions and raw material production.	Replace fossil-derived feedstocks with green hydrogen or Use bio-based alternatives or Utilize low-carbon or recycled materials
Energy Efficiency		Energy efficiency improvement through process optimizations, policy implementations, and technological advancements.
Carbon Capture, Utilization, and Storage (CCUS)		Allows for continued use of fossil fuels in difficult-to-decarbonize processes by capturing and storing carbon emissions. It may be useful in some countries to avoid stranded assets.

2.3. ELECTRIFICATION

Electrification is a crucial component of industrial decarbonization. Direct electrification offers many benefits, primarily regarding its efficiency in energy use, which surpasses alternatives such as fossil fuels, hydrogen, or ammonia. This approach involves replacing fossil-fuel-based systems with electric systems, thus leveraging clean energy sources to achieve decarbonization.

In practice, this means transitioning **from fossil-fuel-based heating to electric heating methods**. For **low-temperature** applications (below 100°C), **industrial heat pumps**, which utilize ambient or recycled waste heat efficiently, are highly effective. High-temperature heat pumps can handle output temperatures up to 160–180°C, with some innovative projects pushing this limit to around 200–260°C.[58]

For **higher temperature** requirements (above 200°C), **electric boilers** are efficient, converting electricity directly into heat at temperatures up to 500°C. **Electric arc furnaces (EAF)** are essential for applications requiring **extremely high temperatures**, such as steel production, where they can reach temperatures up to 3,500°C.[59]

Furthermore, electrification extends to **industrial processes**. For example, the steel industry can utilize EAFs powered by clean electricity to replace traditional coal-based blast furnaces in metallurgy processes. Finally, **electrolytic-process power**, which is common in the aluminum industry, is increasingly being considered as a solution to electrify other sectors such as steel and even the cement sector. If powered with clean electricity, the electrolytic process could become a key element of many future low-carbon industrial processes.

[58] *Agora Energiewende, "Breaking Free from Fossil Gas: A New Path to a Climate-Neutral Europe," May 4, 2023, https://www.agora-energiewende.org/publications/breaking-free-from-fossil-gas#downloads.*

[59] *Agora Energiewende, "Breaking Free from Fossil Gas."*

The increasing substitution of fossil fuels with low-carbon energy sources, mainly for **electrification of usages such as low to mid-level heat**, if essential to industrial decarbonization, still **suffers from lack of access to enough affordable clean electricity** due to the restricted resource availability.

Challenges for Industrial Electrification:[60]

- **Economic:**
  - high capital costs
  - process modification
  - long payback periods
  - high electricity-to-fossil-fuel price ratio
  - uncertain boundary conditions

- **Technological:**
  - limited number of manufacturers
  - long lifespan of existing equipment
  - limited number of examples
  - lack of compressors for high temperatures
  - lack of "plug and play" solutions[61]
  - bespoke designs instead of standardization and replication
  - significant capital investment required for new infrastructure and retrofitting induces high initial costs

[60] *Table compiled by the author and Dr. Lukas Hermwille, based on various sources cited in an X (Twitter) thread by Jan Rosenow (@janrosenow), March 10, 2024, https://x.com/janrosenow/status/1766795921495343523.*

[61] *This refers to the absence of easy-to-install, standardized, and ready-to-use technologies or systems that can be seamlessly integrated into existing industrial processes.*

- **Infrastructure:**
  - potential requirement for upgraded grid connection
  - long wait times for connections
  - need for robust electrical infrastructure to handle increased loads
  - increased vulnerability to power outages

- **Knowledge:**
  - Lack of capacity to manage energy consumption (particularly in SMEs)
  - Need for combined knowledge of both process and electrical technology
  - Lack of awareness of heat consumption in companies
  - Insufficient knowledge regarding available technologies and their capabilities

Table 8: Summary Table of electricity applications for industry decarbonization

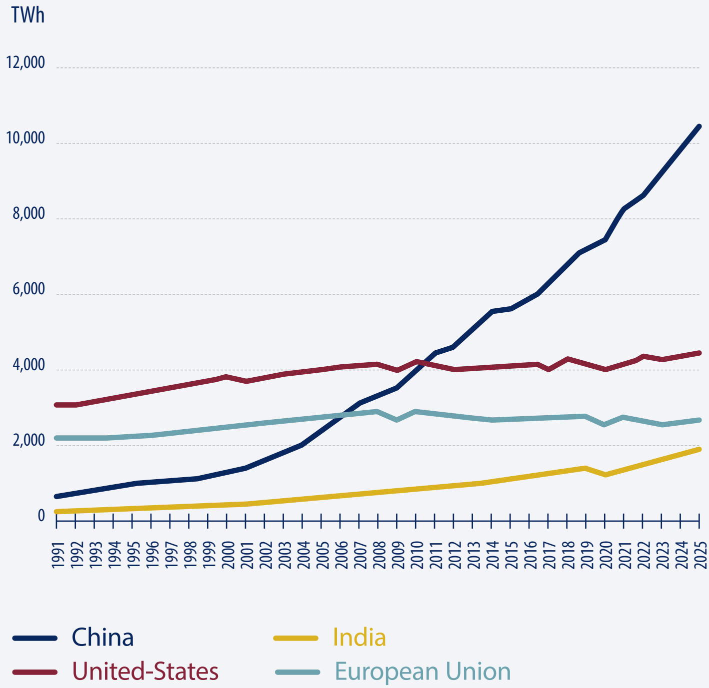
Sector	Current Use	Electrification Solution	Benefits
Cement	Fossil-fueled kilns	Electric kilns	Reduced emissions, efficiency
Steel	Coal-based blast furnaces	Electric Arc Furnaces	Lower emissions, renewables use
Aluminum	Electrolysis with fossil fuels-based electricity	Renewable-powered electrolysis	Emissions-free production
Chemicals	Fossil boilers	Electric boilers, heat pumps	Efficiency, lower emissions

China, the Future Electrostate?

Most countries that are genuinely committed to decarbonization tend to implement policy instruments that favor electrification where necessary. However, China lags behind Europe in electrifying its industry and remains heavily reliant on coal processes, despite the surge in clean electricity generation in China. Simultaneously, China is undergoing a renewable energy revolution, with massive installations of renewable capacity accounting for over 50 percent of the global total. This has led to a significant surplus of clean electricity generation at peak loads in some provinces, which the country still struggles to store or transfer to provinces with high demand.

To address these challenges, China is increasingly taking measures to promote the electrification of industrial processes. These efforts aim to support decarbonization and prevent the waste of renewable electricity in the future. Although these measures are not specifically targeted at the use of clean electricity, they encourage the adoption of electrification technologies. Relevant initiatives include promoting electric boilers, electric kilns, and electric heating and implementing high-temperature heat pumps, high-power electric storage boilers, and other electric energy substitutes in key industries.

Figure 1: Electricity Demand in Selected Regions, 1991–2025[62]



[62] *International Energy Agency, "Electricity Mid-Year Update," July 2024, https://iea.blob.core.windows.net/assets/234d0d22-6f5b-4dc4-9f08-2485f0c5ec24/ElectricityMid-YearUpdate_July2024.pdf.*

2.4. CLEAN HYDROGEN

Hydrogen is poised to be a pivotal element in the strategy to decarbonize industry, sometimes accounting for **approximately 40 percent of anticipated emission reductions**, complementing efficiency improvements and electrification efforts. Currently, the global industrial sector utilizes around 90 million tons of hydrogen, primarily derived from gray hydrogen processes that emit significant carbon dioxide.

To achieve comprehensive decarbonization, IRENA **projects that global demand for hydrogen will need to rise dramatically to 530 million tons**. This surge would necessitate a substantial increase in electrolyzer capacity, estimated at 5,700 GW based on current technologies.[63] However, **rapid advancements in direct electrification technologies may alter these forecasts**, potentially reducing future reliance on hydrogen.

Clean hydrogen, generated through electrolysis using renewable energy or nuclear power, plays a crucial role in industry decarbonization for industrial processes and high-temperature heating. Alongside this, blue hydrogen – produced from traditional fossil fuels with carbon capture, utilization, and storage technologies – also provides a viable alternative to the direct utilization of fossil fuels.

The positive aspect of hydrogen usage in industry is its relative versatility. Hydrogen can both serve as an energy vector that emits no greenhouse gases and be used in various processes. It can function as a reducing agent or combine with CO_2 to manufacture low-carbon chemicals. Additionally, its storage capacity provides flexibility.

An additional advantage from a political economy perspective is the potential to repurpose existing natural gas infrastructure, thereby

[63] *International Renewable Energy Agency (IRENA), "Green Hydrogen for Industry: A Guide to Policy Making," March 2022, https://www.irena.org/publications/2022/Mar/Green-Hydrogen-for-Industry.*

enhancing the value of current assets; however, this approach has certain limitations. These include material compatibility issues, increased leakage risks due to hydrogen's smaller molecular size, and the need for substantial modifications to existing storage facilities.[64]

A key challenge in this transition is access to renewable electricity. The **production of green hydrogen by 2050 will require an amount of electricity equivalent to current global electricity demand**, highlighting a significant infrastructural and logistic hurdle. Currently, Europe, South Korea, and Japan represent the most significant markets for hydrogen, reflecting strategic investments and policy frameworks aimed at fostering hydrogen adoption.

Hydrogen will be a central component of industrial decarbonization. However, clean hydrogen production is expensive in many regions due to the high costs associated with electrolysis and renewable energy storage. Electrolyzers are still in the process of being improved to scale up the hydrogen economy effectively. This presents a significant competitiveness challenge due to **the high cost of clean hydrogen, which will directly impact the competitiveness of industries**. Regions that successfully reduce the cost of low-carbon hydrogen will be in the strongest position to attract industrial investments and facilities.

Second, the infrastructure needed for hydrogen production, storage, and distribution is either lacking or underdeveloped, necessitating substantial investments and time to build an adequate support system. Last, there is a **mismatch between demand and supply** – ensuring consistent and sufficient access to clean hydrogen to meet industrial needs is one of the most uncertain aspects of integrating hydrogen as an industry decarbonization strategy nowadays.

[64] *Kornél Télessy, Lukas Barner, and Franziska Holz, "Repurposing Natural Gas Pipelines for Hydrogen: Limits and Options from a Case Study in Germany," International Journal of Hydrogen Energy 80 (2024): 821–831, https://doi.org/10.1016/j.ijhydene.2024.07.110.*

a. Consequences of the Future Hydrogen Economy for the Post-Carbon Industrial Landscape

The emerging hydrogen market is set to diverge markedly from traditional oil market dynamics. Unlike the oil market, which is dominated by a few sellers and many buyers, the **hydrogen market will likely feature a few buyers – primarily in energy-intensive industrial sectors – but numerous potential sellers**. This inversion necessitates the development of a robust and coordinated infrastructure for hydrogen transport and distribution.

This will have consequences. Access to abundant and affordable clean electricity is crucial for cost-efficient clean hydrogen production. Access to a cheap hydrogen supply will be instrumental for many industrial sectors if they transition to hydrogen for their processes or heating. Consequently, developing a clean hydrogen supply in traditional industrial regions will not be easy. **If industries rely heavily on affordable access to clean hydrogen, it may significantly impact the future geography of industry in the post-carbon economy**.

Hydrogen will always be a valuable resource. Nevertheless, if an industrial process can be electrified, it will likely transition to electrification for efficiency gains. This means that as technology evolves, decarbonizing heating below certain temperatures may become more feasible with electricity than with hydrogen (depending on technological innovation, above 600°C). This underscores that while hydrogen will be central to industrial decarbonization, it may not always be as central for all applications as initially envisioned, highlighting the crucial uncertainty in technological developments and their impact on global industrial decarbonization strategies. That said, **in many processes, hydrogen will remain essential as a reducing agent – such as in the steel industry and some aluminum processes – or as a feedstock in the chemicals sector to achieve decarbonization**.

Table 8: Summary of Green Hydrogen Applications for Industry Decarbonization

Sector	Current Use	Green Hydrogen Solution	Benefits
Cement	Natural gas for heat	Hydrogen-fired kilns	Zero emissions, high efficiency
Steel	Coal for reduction	Hydrogen-based Direct Reduction of Iron	Emissions-free primary steel production
Aluminum	Fossil fuel combustion	Hydrogen for high-temp processes, potentially as a reducing agent in the future (R&D)	Cleaner energy source
Chemicals	Fossil-derived hydrogen	Green hydrogen for feedstock, utilizing CO_2	Carbon-neutral chemical production

The Real Challenge for Hydrogen Use in the Industrial Sector

The large-scale commercialization of green hydrogen will require significantly **increasing the energy efficiency of infrastructure (electrolyzers and hydrogen uses)** and **securing large volumes of low-carbon electricity from renewable energies**. Considering that few countries have access to low-carbon electricity supplies, and even fewer have established low-carbon electricity markets, the feasibility of the large-scale **commercialization of green hydrogen will be limited by the low level of available low-carbon electricity generation capacity**. The deployment of green hydrogen must therefore be promoted strategically, using a **flexible approach**, with **priority given to sectors where there is no alternative**, such as in the **steel sector and some sections of the chemical sector**.

In Europe, the establishment of such infrastructure will require harmonized policies at the European Union level and beyond, fostering collaboration between governments and industry stakeholders. The **Hydrogen Bank**[65] is emerging as particularly crucial in this context, serving as a cooperative framework to align policy and industrial objectives. Despite the promise of hydrogen, the path to its widespread adoption is fraught with challenges. Hydrogen projects are highly capital intensive, and currently, only about 10 percent of proposed projects reach implementation. Scaling up existing electrolyzer technology is imperative to overcome these barriers and meet future demand.

Table 9: IPCEI projects for using Clean Hydrogen to decarbonize Industry in Europe

Sector	Project Name	Companies Involved
Chemicals	Iberdrole ES52	iberdola
Steel	HyCC-H2ermes	TataSteel
Chemicals	Orsted Haddock	Orsted
Chemicals	H2Enable	Bondalti
Chemicals	Green Ammonia Linz	Verbund, LAT Nitrogen
Lime Sector (cement)	Columbus	Carmeuse Engie
Cement	Pioneering Green Hydrogen for Industrial Cement Production in Greece	TITAN

[65] *European Commission (n.d.), "European Hydrogen Bank," accessed September 9, 2024, https://energy.ec.europa.eu/topics/energy-systems-integration/hydrogen/european-hydrogen-bank_en.*

Sector	Project Name	Companies Involved
Chemicals	Ver-Amonia	EDP, Fertinagro Biotech
Steel	Hydra IT06	RINA CSM
Chemicals	Barents Blue Project	Equinor, Var Energi
Steel	Hybrit H2-DR Demonstration	Hybrit Fossil-Free Steel
Chemicals	Neste FI05	Neste
Chemicals	Hydrogen Electrolysis	Air Liquide
Steel	Hydrogen Pipelines	Thyssengas
Steel	Hydrogen Electrolysers	Linde
Chemicals	Electrolyser & Storage	RWE

2.5. RAW MATERIAL SUBSTITUTION

Substituting traditional raw materials or feedstock with sustainable alternatives also plays a crucial role in the decarbonization of industrial processes. For example, in the cement industry, alternative materials such as fly ash and slag can be used in place of traditional raw materials, thus lowering emissions. In the steel industry, increasing the use of scrap steel in electric arc furnaces (EAFs) helps reduce reliance on carbon-intensive primary production methods. Similarly, the aluminum industry benefits from recycling aluminum, which is far less energy-intensive compared to producing aluminum from raw bauxite. The chemicals industry also sees reductions in emissions by using bio-based feedstocks instead of fossil-derived feedstocks.

The benefits of these substitutions are substantial. Emissions reduction is achieved through the decreased production of raw materials, which are often associated with high carbon emissions. Additionally, resource efficiency is enhanced by promoting the use of renewable and recycled materials, which supports a circular economy and leads to waste reduction.

However, these substitutions are not without their challenges. **The availability and cost of alternative materials can be a limiting factor**, and there may be a need for significant technological adjustments to accommodate these new materials in existing industrial processes. Furthermore, substituting fossil fuels with renewable feedstocks such as biomass presents its own set of challenges, including ensuring a consistent and sustainable supply of these materials.

Table 10: Table example of raw material substitution

Sector	Current Use	Raw Material Substitution Solution	Benefits
Cement	Traditional clinker	Fly ash, slag,...	Lower emissions, sustainable materials
Steel	Iron ore to pig iron and primary steel	Scrap steel	Resource efficiency, reduced emissions
Aluminum	Virgin aluminum	Scrap aluminum	Energy savings, lower emissions
Chemicals	Fossil-derived feedstocks	Bio-based feedstocks	Sustainable chemical production

2.6. CARBON CAPTURE, UTILIZATION, AND STORAGE

The final option for decarbonizing industry involves maintaining the use of fossil fuels in processes where decarbonization alternatives are not viable due to cost-efficiency, engineering constraints, or other factors such as geographical or political challenges that hinder complete reliance on decarbonized energy.

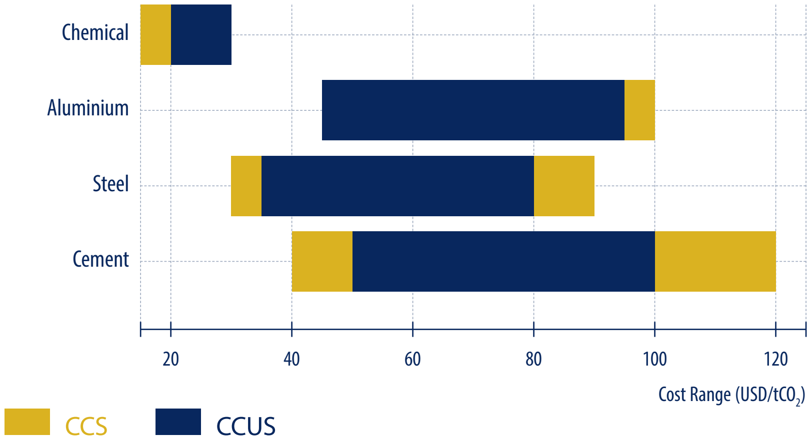
CCUS involves capturing CO_2 emissions from industrial processes and either utilizing them in other processes – such as in the chemicals sector – or storing them underground. Despite its potential for decarbonization, CCUS faces several significant challenges.

The first set of challenges is technical. Carbon capture and storage (CCS) requires suitable storage capacity, often found in old gas fields within impermeable geological layers, which are not available in many regions. Additionally, CCS necessitates the development of extensive CO_2 infrastructure, such as pipelines, to transport captured CO_2 to storage sites. In some cases, this CO_2 must be shipped to regions with greater storage capacity, complicating logistics, increasing costs, and **necessitating the creation of a CO_2 market**.

The second set of challenges revolves around the **cost of carbon capture technologies**, which vary depending on the point of capture within the industrial process. In some processes, greenhouse gases are sufficiently concentrated to be captured directly and stored efficiently. However, in other processes, capturing CO_2 requires more complex and energy-intensive methods, such as chemical absorption, making the operation significantly more expensive. Indeed, any industrial process would require additional energy to capture and store CO_2.

These economic hurdles often impede the widespread adoption of CCUS technologies, especially when compared to other decarbonization alternatives – such as changing processes to clean energy – that may be more cost-effective in the near future. Consequently, **the higher expenses associated with CCUS can be a major barrier to its implementation across various industries, especially as a long-term solution**. Countries are, however, increasingly considering CCUS as a potential solution to avoid stranded assets for carbon-intensive facilities that have not yet reached the end of their life cycle.

Figure 2: Chart of Carbon Capture cost-range in the four sector[66]



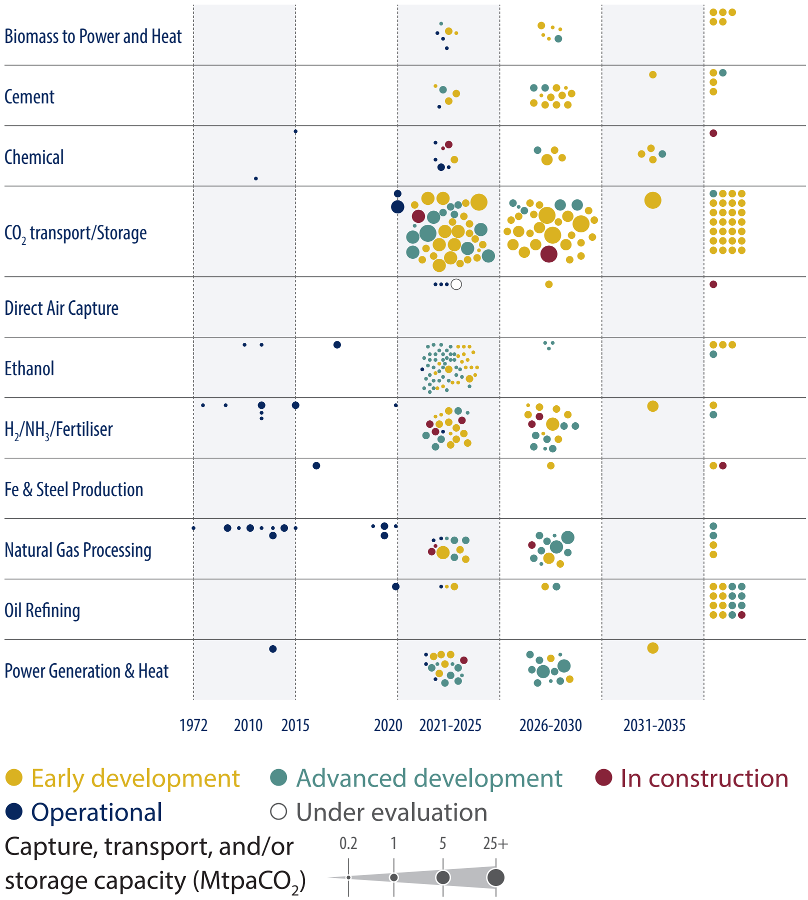
It is actually **very difficult to estimate the real cost of carbon capture** because the variables are extremely dependent on future technological developments, location, and energy requirements. **The costs associated with these technologies vary significantly by industry, concentration of CO_2 in emissions, and specific capture technology used**. The costs displayed in the previous chart do not take into consideration the cost of transporting CO_2 for sites that cannot store it in their immediate neighborhood. That being said, CCUS is still forecasted to play a significant role in industry decarbonization, particularly for the last chunk of industry decarbonization, close to or after 2050.

[66] *Adam Baylin-Stern and Niels Berghout, "Is Carbon Capture too Expensive?" International Energy Agency, February 17, 2021, https://www.iea.org/commentaries/is-carbon-capture-too-expensive; Brenna Casey, "CCUS Market Outlook 2023: Announced Capacity Soars by 50%," BloombergNEF, November 9, 2023, https://about.bnef.com/blog/ccus-market-outlook-2023-announced-capacity-soars-by-50/.*

Table 11: Challenges of Carbon Capture Methods

Sector	Technology	Notes	Where
Cement	**CCS**	High costs due to dilute CO_2 streams and process emissions	Capturing CO_2 from kilns and using it in concrete production or storing it underground
	CCUS	Utilization aspects can offset some costs, potential utilization in concrete.	
Steel	**CCS**	Costs vary with the integration level in existing processes	Capturing emissions from blast furnaces and converting CO_2 into chemicals - require industrial clustering
	CCUS	Utilization of captured CO_2 in steel production processes can reduce overall costs	
Aluminum	**CCS**	High costs due to energy-intensive capture processes	Capturing emissions from smelting processes (when using fossil fuels)
	CCUS	Utilization can provide economic benefits, reducing net costs	
Chemicals	**CCS**	Lower costs due to higher CO_2 concentration in emissions	Using captured CO_2 in chemical production
	CCUS	Utilization in chemical production can offset costs further	

Figure 3: Application of CCS Across Industries (CCUS Institute)



a. The Role of CO_2 Recycling in Industrial Decarbonization

Companies and governments around the world are increasingly prioritizing the development of CCUS technologies. Indeed, capturing carbon usually does not imply a change of process, and the timing behind the implementation of decarbonization technologies such as clean hydrogen processes or electrification may not be able to reach the climate objective.

Even if CCU technologies often remain more expensive than CCS, they are essential for industrial decarbonization as they allow the direct use of captured carbon. Thus, **the conversion of CO_2 captured using renewable energy into e-fuels, e-chemicals, or plastic will also play a role in industrial decarbonization, creating new markets and changing the cost equation of industrial decarbonization**. The key here is companies trying to generate benefits from their scrap CO_2.

That said, **most CCU processes require green hydrogen for converting CO_2 into valuable products**. Consequently, developing a **CCU market depends on the development of a clean hydrogen market, making CCU a secondary market of the hydrogen market**, to be developed in parallel with it.

Several **bottlenecks to the development of CCUS** remain, including the following:

- the need to **implement sufficiently high carbon pricing**
- the **high costs of e-fuel production and of CO_2 capture**
- the **adjustment of the tax system, subject to the political agenda**

b. Countries' Carbon Management Strategies

In Japan and South Korea, **governments currently expect CCS and CCUS to contribute to 14 percent of GHG emissions reduction by 2050**. In China, the expected figure is **up to 25 percent by 2060**. Europe has recently adopted a comprehensive industrial carbon management strategy.

Europe's Industrial Carbon Management Strategy

The *Net-Zero Industrial Act* encourages fossil fuel companies to create a market for industrial emissions. The European Union has also introduced a new directive focused on industrial carbon management, emphasizing the implementation and scaling of CCUS technologies across Member States. This strategy aims to reduce CO_2 emissions **by 50 million tons annually by 2030**, increasing to 280 million tons by 2040 and 450 million tons by 2050, contributing significantly to the EU's intermediate climate targets in the industrial sector.[67]

One of the directive's primary goals is to **address disparities in CCUS infrastructure and storage capacity across the EU**. Although some Member States have ample geological storage capacity, others do not, creating an imbalance that the directive seeks to rectify through cross-border cooperation and shared infrastructure projects.

To facilitate this, the EU is promoting the following key initiatives:

1. CO_2 Transport Networks: Establishing integrated pipelines and shipping routes for efficient CO_2 transport between regions with high emissions and those with available storage sites (with up to 7,300

[67] *European Commission (n.d.), "Industrial Carbon Management," accessed September 9, 2024, https://energy.ec.europa.eu/topics/carbon-management-and-fossil-fuels/industrial-carbon-management_en.*

km of pipelines costing €12.2 billion by 2030, expanding to 19,000 km and €16 billion by 2040). The directive sets a target of creating a trans-European **CO_2 transport network capable of handling 70 million tons of CO_2 per year by 2030**.

2. Public–Private Partnerships: Encouraging collaboration between industry leaders, research institutions, and governments to drive innovation in CCUS technologies and their applications. The EU aims to **establish at least 20 large-scale public–private partnership projects by 2025, focusing on various aspects of the CCUS value chain**.
3. Financial Incentives: Offering **grants, subsidies, and tax breaks to companies investing in CCUS projects**, particularly those demonstrating high potential for scalability and impact. The EU has allocated **€10 billion in funding to support CCUS initiatives through the Innovation Fund until 2030**.
4. Research and Development: Funding research initiatives to advance CCUS technology, improve capture efficiency, and explore new utilization pathways for captured carbon dioxide, such as in the production of synthetic fuels and building materials. The directive includes goals of increasing R&D funding for CCUS by 50 percent, reaching €3 billion annually by 2025, and developing platforms for CO_2 demand assessment and investment atlases for storage sites.

By 2040, regional carbon value chains should be economically viable, **making CO_2 a tradable commodity within the EU**. Several European countries are already making strides under this directive. For example, Norway's Northern Lights[68] project is a pioneering effort to create a full-scale CO_2 capture, transport, and storage chain, while the Netherlands is developing the Porthos project[69] to store captured carbon from the Rotterdam port area in depleted North Sea gas fields.

[68] *Northern Lights, "What We Do," accessed September 2, 2024, https://norlights.com/what-we-do/.*

[69] *Porthos, "CO2 Reduction through Storage under the North Sea," accessed September 2, 2024, https://www.porthosco2.nl/en/.*

A key element for the future of CCUS in Europe is the **integration of carbon removal into the EU Emissions Trading Scheme (ETS)**. Including carbon removal within the ETS framework would give companies predictability, allowing them to plan and invest with confidence. However, this integration raises the following critical questions:

- What is the appropriate timing for implementation?
- Which technologies should be included?
- Which industries should be allowed to utilize these technologies?
- How can the environmental effectiveness of the scheme be preserved?

It is essential to design this integration carefully to ensure that it does not compromise the overall emissions cap, thus maintaining the scheme's effectiveness in reducing greenhouse gas emissions.

CCUS Strategy in Japan

The Japanese government recently adopted the ***Carbon Capture Bills***,[70] establishing a regulatory framework for the exploration and storage of CO_2. This legal framework aims to facilitate the implementation of carbon capture projects, integrating environmental safeguards and public safety measures. Japan faces unique challenges due to its geographical and industrial landscape, necessitating innovative approaches to carbon removal. The strategy outlines the following key targets and initiatives to overcome these obstacles:

1. Domestic CO_2 Storage Capacity: Japan aims to identify and develop domestic geological storage sites, with a target of **storing 6–12 million tons of CO2 domestically per year by 2030**. This involves

[70] *Ministry of Economy, Trade and Industry, Japan,* 二酸化炭素の貯留事業に関する法律案 *[Bill Concerning Carbon Dioxide Storage Projects], 2024, https://www.meti.go.jp/press/2023/02/20240213002/20240213002-6.pdf.*

extensive geological surveys and feasibility studies to pinpoint suitable storage locations within Japan.

2. Cross-Border CO_2 Transport and Storage: Recognizing the limitations of domestic storage, the government aims to **establish agreements with neighboring countries – or countries further away – to store CO_2**. Current efforts include partnerships with Australia, Malaysia, and Indonesia.
3. Public–Private Collaboration Using a Decarbonization-Hub Approach: The Japanese government tries to foster collaboration between the private and public sectors to accelerate the development and deployment of CCUS technologies. **By 2025**, Japan aims to **launch 15 large-scale CCUS demonstration projects involving key industry players and research institutions**.
4. Financial Support and Incentives: Japan has allocated **JPY 2 billion** (approximately €15 billion) in funding to **support CCUS initiatives over the next decade**. This includes grants, subsidies, and tax incentives for companies investing in CCUS projects.
5. Research and Development: The Japanese government is committed to increasing **R&D funding for CCUS technologies,** with a target of **JPY 200 billion** (approximately €1.6 billion) **annually by 2025**. This funding will support research on improving capture efficiency, developing new utilization methods for CO_2, and exploring innovative storage solutions.

Several Japanese companies are actively engaging in CCUS projects. For instance, J-Power is developing a large-scale carbon capture and storage project in the Tomakomai area, while Mitsubishi Heavy Industries is collaborating with international partners to advance CO_2 capture technologies and explore storage options in Southeast Asia.[71]

[71] *Mitsubishi Heavy Industries, "CO_2 Plants and Project Records," accessed September 2, 2024, https://www.mhi.com/products/engineering/co2plants_projectrecords.html.*

CCUS Strategy
in Korea

The Korean National Assembly has adopted a ***CCUS Framework Act***, with the aim of **decreasing GHG emissions by 11.2 million tons via CCUS**. However, the government is faced with different challenges related to **South Korea's limited storage capacities**, as it is estimated that **South Korea can store only about 1 million tons domestically**, and identifying relevant sectors for the utilization of captured carbon dioxide remains difficult.[72]

Accordingly, MOTIE is attempting to **secure additional CO_2 storage facilities abroad**, as it concluded a MoU promoting CCS cooperation with Indonesia in September 2023[73] and is currently in talks with Australia and several Middle Eastern countries.

The South Korean government is also attempting to reinforce cooperation between the private and public sectors through the establishment of a committee discussing clean hydrogen and CCUS technologies' development, utilization, and pilot projects. Additionally, in view of the country's difficult geological location, the government has **provided policy support for South Korean companies' exploration of business opportunities to find carbon dioxide storage facilities abroad**. For instance, SK E&S has concluded a MoU with the Australian company Santos,[74] and POSCO International has pursued transport and storage of domestically captured carbon in East Timor, Malaysia, and Australia.[75]

[72] *Kim & Chang, "Announcement of National Basic Plan for Carbon Neutrality and Green Growth," July 6, 2023, https://www.kimchang.com/en/insights/detail.kc?sch_section=4&idx=27488.*

[73] *Japan Petroleum Exploration Co., Ltd. (JAPEX), "JAPEX Signed MOU with SKK Migas on Joint Collaboration toward Realization of CCS/CCUS Hub & Clusters in Indonesia," September 21, 2023, https://www.japex.co.jp/en/news/detail/20230921_01/.*

[74] *Santos, "Santos and SK E&S Sign MoU to Develop CCS projects in Australia," February 28, 2022, https://www.santos.com/news/santos-and-sk-es-sign-mou-to-develop-ccs-projects-in-australia/.*

CCUS in China

China's carbon capture, utilization, and storage strategy is a cornerstone of its industry decarbonization strategy, with **the goal of removing 20 million tons of CO_2 annually by 2025 and 60 million tons by 2030 (although the actual figure by that date may reach 100 million tons)**.[76] Central to this strategy is the 1+N Policy, overseen by a dedicated **Committee on CCUS**, which underscores **the regulatory-driven nature of China's approach to carbon management**.

In contrast to countries without suitable carbon-storage sites like Japan and South Korea, China estimated a **potential storage capacity ranging between 1.2 and 4.1 billion tons of CO_2** in 2022. This vast storage potential underscores the critical role China intends to give CCUS in its decarbonization strategy, particularly for some key sectors in some regions that are well endowed with fossil fuel.

China's carbon capture strategy is **primarily propelled by regulations on total energy consumption and intensity**. This policy engine is gradually transitioning toward a dual-control system that targets both carbon emissions and their intensity. This regulatory framework contrasts with the approaches of the US and the EU, where tax credits and carbon pricing, respectively, serve as primary drivers for CCUS adoption.

Key Projects and Technological Milestones

The inauguration of the world's largest post-combustion CO_2 capture facility in 2023 at the Huaneng Longdong Energy Base, with a capacity of **1.5 million tons per year**, marked a significant technological milestone

[75] *Petroleum Sarawak (PETROS), "PETROS signs deal with Korean POSCO Group for development of CCS business in Sarawak," December 12, 2022, https://www.petroleumsarawak.com/news-media/news-and-events/2022/12-dec-2022-petros-signs-deal-with-korean-posco-group-for-development-of-css-business-in-sarawak.*

[76] *Interview with Xie Zhenhua at COP28.*

for China. Currently, there are **six major CCUS projects across the country**, reflecting the strategic importance of this technology **in provinces with substantial fossil fuel resources**.

Provinces with significant fossil fuel resources – as is the case in Shaanxi Province's Yulin City – have integrated CCUS into their developmental philosophy. Through a project led by Ma Jinfeng, Shaanxi already practices commercial CCUS, while Yulin City relies on CCUS to sustain its oil-dependent economy. This approach underlines China's thinking regarding CCUS, which stresses **mitigating the risk of stranded assets in regions with younger infrastructure that are heavily reliant on fossil fuels**.

Challenges and Limitations

Logistic challenges in transporting CO_2 to suitable geological storage sites, especially from steel plants in southern and central China, further complicate the implementation of CCUS. High initial costs and the absence of strong market incentives also dampen enthusiasm for CCUS investments. **Unlike regions with robust market signals such as carbon pricing, China's regulatory-driven approach may not sufficiently stimulate private sector investment without substantial policy support and financial incentives**.

The Role of SOEs as CCUS Project Hubs

The steel sector plays a key role in the development of CCUS in China, particularly by testing CO_2-recycling technologies (projects by BAOTU, Baowu, and Delong Steel) – even if most national guidelines for the steel sector hardly mention this technology compared to hydrogen, for instance. However, in China, it is the chemicals sector that is the most prone to invest in CCUS, with Sinopec taking a central role.

Sinopec's involvement exemplifies the crucial role of major industrial players in China's CCUS landscape. With a 1-million-ton CCUS project, Sinopec aims to **cover the entire value chain, from capture to storage, positioning itself as a leader in the industry**. The company's investment of **RMB 2 billion in 2023** (approximately €254 million) and development of a high-efficiency CO_2 pump highlight its commitment to technological innovation and scaling up operations.[77]

Standardization as China's Main Carbon Capture Strategy

Finally, China is actively **developing national standards for carbon removal[78] for almost any kind of industrial sector in the energy and industrial sectors**. Additionally, the country is also seeking to develop an international standard for carbon capture, leveraging its perceived comparative advantage in this technology. By promoting these standards globally, China aims to influence the international CCUS framework, aligning it with its technological strengths and regulatory philosophy while also promoting Chinese technologies around the world.

[77] *Interview with Chunping Liu, SINOPEC CCUS project director, at COP28.*

[78] *State Council of the People's Republic of China,* 关于印发《碳达峰碳中和标准体系建设指南》的通知 *[Notice on Issuing the "Guidelines for the Development of the Carbon Peak and Carbon Neutrality Standardization System"], April 1, 2023, https://www.gov.cn/zhengce/zhengceku/2023-04/22/content_5752658.htm.*

3 Clean Industrial Policy – Comparative Perspectives

3.1. DEFINING CLEAR OBJECTIVES

There are many difference in how countries understand the nexus between industrial policy and decarbonization. The primary difference in how countries approach their industrial decarbonization strategy lies in the emphasis placed on each sector within their economies. Supporting innovation or acquiring relevant technology is a common challenge, but the **level and type of support vary considerably depending on the sector and the country**. Countries that are well established in certain sectors may either see rapid decarbonization as detrimental or, on the contrary, see it as advantageous and aim to be first movers. In reality, most countries strive to create conditions that support their industries, aligning with market demand.

This is where differences arise, not only between Europe and Asia, but also more concretely between heavily industrialized regions/countries and those aiming to use decarbonization as a means to reindustrialize. There are also significant differences in approaches within countries, between different regions, between Chinese provinces, and among EU Member States. The fact is, **approaches toward the technological transition to carbon neutrality vary greatly depending on the existing industrial fabric, perceived theoretical competitive advantages, and the desire to preserve an industrial base**.

Beyond rationality, and even beyond decarbonization, industrial policy in Europe and Asia reflects different concepts of protectionism and state intervention. This is evident in **industry decarbonization strategies that are still nascent** and diverge between countries, which **often struggle to define concrete objectives**.

3.2. DIFFERENT TYPES OF RISKS AND UNCERTAINTIES

a. The Risk of Stranded Assets

Analyzing clean industrial policies cannot be done uniformly across all regions. Postindustrial nations, such as most Western countries, differ significantly from China. China operates a continental scale industrial policy where public actors, including state-owned enterprises, play crucial roles in its industrial framework – 39 percent of industrial assets are state-owned in China. **SOEs not only receive significant government support but can also provide support**.

For example, state banks often offer industrial companies loans at below-market rates, state utilities may supply energy inputs at below-market prices, and industrial SOEs in the manufacturing sector assist in "clustering" large projects, sometimes related to decarbonization efforts such as CCUS and hydrogen integration. This practice is a crucial element in China's overall industrial strategy and significantly influences its industrial decarbonization strategy, primarily by favoring companies that benefit from the lower costs charged by SOEs.

The dominance of Chinese manufacturing in sectors such as steel, aluminum, and, increasingly, chemicals provides an advantage in terms of scale compared to most competitors. However, this also means that China has a vast carbon-intensive industrial base that it must address.

The issue of stranded assets will become a significant concern for most countries but particularly for the Chinese industrial sector, which has a very young median age of its assets – around 10 years, depending on the sector, while most industrial plants have life cycles of 30–50 years. This means that the **current deployment plans for the industrial sector could leave China with a substantial number of stranded assets by the 2050s**.

Therefore, **to achieve total carbon neutrality by 2060, China must not only drastically reduce the construction of new carbon-intensive industrial processes but also consider decommissioning assets that are not at the end of their life cycle**.[79] This problem is currently being managed with reference to carbon capture, utilization, and storage, suggesting that capturing carbon will help avoid stranded assets in the future.

The issue of stranded assets due to decarbonization is not unique to China; most industrial actors in South Korea, Japan, and even Europe consider CCUS a way to avoid the risk of stranded assets as their carbon budgets diminish. This presents a significant challenge for Europe, as aging industrial plants require substantial reinvestments, presenting companies with a dilemma. Although investing in green technologies is fraught with risks due to the uncertain availability of infrastructure and markets, reinvesting in conventional plants is equally problematic, as these assets are likely to become stranded in the near future.

This issue will play a central role in the speed of technological adoption of other carbon-neutral processes in the industrial sector and is likely to influence decisions based on economic viability and practicality. It seems that **CCUS is likely to play an extensive political role in industry decarbonization – particularly in the cement and chemicals sectors – allowing carbon-intensive assets to remain in the market longer than expected and sustaining some industrial regions, even as the carbon-neutral transition makes them less competitive**.

[79] *See the chapter of this report on steel. For example, where global steel is concerned, retiring particularly inefficient plants (especially in China) is key for achieving global goals. See: Chris Bataille, Seton Stieberg, and Francis G. N. Li, "Facility Level Global Net-Zero Pathways under Varying Trade and Geopolitical Scenarios: Final Technical and Policy Report for the Net-Zero Steel Project, Part II," Global Energy Monitor, June 30, 2024, https://netzeroindustry.org/wp-content/uploads/pdf/net_zero_steel_report_ii.pdf; Xu Ruocheng et al., "Plant-by-Plant Decarbonization Strategies for the Global Steel Industry," Nature Climate Change 13 (2023): 1067–1074, https://www.nature.com/articles/s41558-023-01808-z.*

b. The Risk of Locking in Capital-Intensive Facilities in an Uncertain Technological Environment

By nature, an industrial policy aims to support the domestic sector, ensure the production of needed goods or preserve a domestic supply chain, and gain global market shares. The post-carbon industrial landscape will be vastly different from the current situation. In most sectors, **the importance of clean energy costs will be central in determining what can be achieved in certain locations – a challenge that most countries have yet to perfectly understand**. Many countries face the critical question: **Does it make sense to decarbonize this specific industrial sector in our country/region, or should it be left to regions better suited for it?**

What is the objective of an industrial decarbonization policy beyond decarbonization? This is a question that policymakers and industry leaders must address. Some, thinking as global industrialists, may respond to government concerns about decarbonization without genuinely giving the future location of their activities any consideration. Indeed, **the current state of industrial decarbonization is more of a test phase than a concrete, large-scale deployment of technologies that will decarbonize existing industrial sites without challenging the rationality of their locations**.

The necessity of decarbonizing their activity also poses a critical question for industrialists: **Should we lock in very capital-intensive investments in their current locations, sometimes for many decades?** Or should we proceed slowly until the future market for green goods becomes clearer? The reality is that most countries in Europe, as well as Japan and South Korea, fear that their positions in the global industrial supply chain will be affected by this transition. This amplifies risk perception and complicates the management of technological uncertainty.

c. Fear of Taking Risks

Another significant challenge is the economic and financial restructuring required to support the transition of existing assets. The **initial costs of green technologies**, especially in industries such as steel, cement, chemicals, and aluminum, **can be prohibitively high compared to carbon-intensive processes**. Additionally, there is another **risk of stranded assets** if you bet on the wrong technology and it becomes obsolete. This situation leads to a challenging **second-mover advantage:** The second generation of green plants is likely to be more efficient and easier to build. This creates a potential free rider problem, whereby companies may delay their investments, hoping to benefit from their competitors' efforts in overcoming initial learning curves.

Policymakers must, therefore, design financial incentives and support mechanisms that not only promote initial adoption but also sustain long-term investment in green technologies. This will include subsidies, grants, favorable loans, and mechanisms like carbon pricing to internalize the environmental costs of brown technologies, making clean alternatives more competitive. However, these **measures tend to be spread unevenly among the top industrial players, leading to uneven playing fields and posing risks for trade and cooperation**.

Industrial policy plays a particularly significant role in **sectors where returns on investment for decarbonization are hardest to achieve** or where **investment risks are highest**. Determining which sectors and projects to support is crucial in shaping an effective industry decarbonization policy.

The countries analyzed in this study exhibit varying levels of policy deployment to address the challenges associated with transitioning their industrial sector to carbon neutrality. However, the overall level of action remains similar across Europe and Asia and relies on the following three pillars:

- **Mitigating risk and bridging the cost gap**
- Implementing an **innovation–demonstration–scaling-up-based strategy**
- **Demand-side creation**

3.3. MITIGATING THE RISK OF THE CLEAN TRANSITION

The transition to a decarbonized industry is fraught with risks, including **technological change, policy instability, and technology uncertainty, all of which can be difficult to foresee**. Given the natural risk aversion among economic actors, industrial policy should aim to **mitigate these risks while not removing them completely**, thereby accelerating the necessary investments for decarbonization.

The **uncertainty associated with investing in decarbonization technologies**, especially in the early stages of process changes, presents a significant challenge. Therefore, it **is crucial to promote risk-taking**. Taking risks inherently involves the possibility of errors and losses, making it essential to establish systems that **distribute risks among various stakeholders to prevent losses from disproportionately impacting a single actor**.

The level of understanding and commitment to promoting risk-taking for decarbonization varies between Europe and Asia. European companies, although more experienced in their decarbonization efforts, remain hesitant to fully commit to the technology transition. This reluctance **stems from technological uncertainties and challenges in accessing clean energy sources such as clean hydrogen**.

In Asia, the primary concern is the **potential lack of market demand for green products**. This is particularly evident among South Korean and Japanese companies, which do not face the imminent prospect of high carbon prices. Additionally, there is apprehension that the EU's Carbon Border Adjustment Mechanism may not generate sufficient demand to justify a complete shift to carbon neutrality because if demand is partially European, **demand coming from other important markets such as China, the US, or Southeast Asia may not follow the same trends at the same speed**.

Mitigating the Risk in South Korea

South Korea follows a model in which the state currently plays a less prominent role in directing and managing risk-taking among actors. The central role is played by some chaebols whose integration of carbon-neutral innovation will be crucial for the country. Most actors believe they have sufficient resources to absorb a large part of the risk by themselves. However, the entire industrial ecosystem in Korea is highly integrated for economic efficiency reasons, leading to concerns that the system may be too rigid to adapt to and integrate the transition to carbon neutrality. This complexity makes it challenging to manage risk-taking and process transitions among actors effectively. Partnerships between the government and industrial conglomerates seem to be the chosen direction. The government rewards decarbonization investments through financial mechanisms and, depending on the sector, demand-side measures.

a. The Necessity of Covering the Green Premium

Governments have access to a **diverse array of instruments** to help decarbonize industry and promote risk-taking. Depending on their position within the value chain, these instruments can facilitate the transition by overcoming various barriers, which may **financial, insurance-related, or nonfinancial**. The approaches vary significantly between countries, and **most regions currently lack effective utilization of such instruments in their industrial policies**.

A green industrial policy must promote and lead the creation of markets for green goods. The price differential between green goods and their carbon-intensive counterparts is called the green premium. The green premium varies between sectors and is, of course, dependent on many factors, including the efficiency of the greener process, to be as cost-competitive as the carbon-intensive one.

What are countries currently doing or considering doing to cover the green premium? They are mainly acting on two fronts: **carbon pricing** and **providing cheap clean energy**. If other types of instruments are available, they are still far from mainstream. The key questions are: **How to pass the cost to end users, despite their unwillingness to pay? How to move the carbon cost down the value chain?** In these respects, depending on the sector, the main issue does not always concern the end user but rather the intermediary actors who are suffering profound change of business model.

The Example of the Cement Sector

In the European cement sector, the green premium for end users could eventually be relatively low, estimated at an additional cost of up to €400 for a 100-square-meter apartment – an overcost that is considered manageable for end users.[80] The greater challenge lies with intermediary buyers of cement, who may struggle to absorb the green premium and thus require support. Conversely, in Asia, the cement industry views CfD as a viable option, especially to remain competitive when selling goods to emerging Southeast Asian economies.

b. Carbon Pricing Alone Is Not Enough

To compensate for the green premium, **carbon pricing is an essential component of industry decarbonization policies**. It is also the most efficient instrument to facilitate risk-taking, as it makes green goods more competitive. Europe has the most established Emissions Trading Scheme globally, which prices carbon in industrial sectors and plans to phase out free allocations by 2026 with the implementation of the Carbon Border Adjustment Mechanism. Korea also has an ETS, which it aims to improve following the EU's implementation of the CBAM. Japan is adopting an ETS for 2028, and China has a national intensity-based scheme that is forecast to eventually transform into a real cap-and-trade system by 2030.

[80] *See Tomas Wyns, Harri Kalimo, and Gauri Khandekar, "Public Procurement of Steel and Cement for Construction: Assessing the Potential of Lead Markets for Green Steel and Cement in the EU," Brussels School of Governance, 2024, https://www.brussels-school.be/sites/default/files/2024-06/Public%20procurement%20construction%20steel%20and%20cement%20EU%20FINAL.pdf.*

However, carbon pricing alone is not sufficient to decarbonize industry. The primary reason is that the **cost of carbon is not high enough to completely de-risk the transition for industrial sectors**. The second reason is that **the marginal abatement cost of carbon varies considerably across sectors**, making it impossible to rely solely on carbon pricing as a general industry decarbonization policy.

Figure 4: Planned Phasing Out of Free ETS Allowances and CBAM implementation

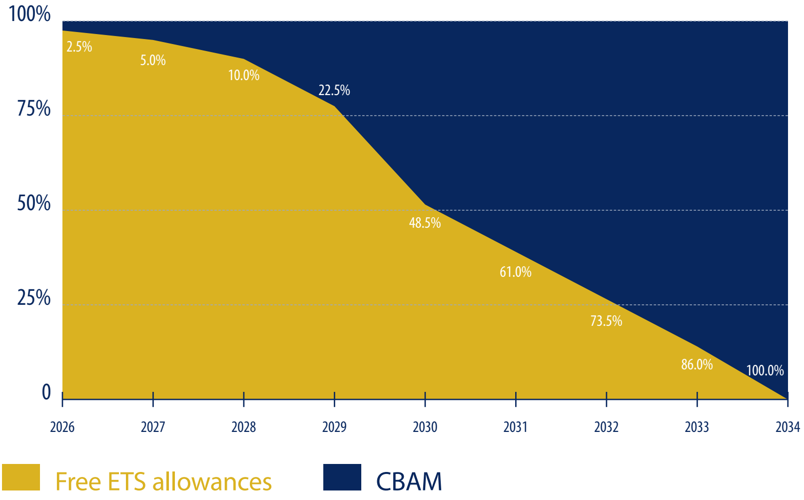


Table 12: Approaches to Carbon Pricing and CBAM in Europe and Asia

	Carbon Pricing	CBAM	Average cost of carbon in 2024
Europe	ETS 1 reform with end of free allocation for industrial sectors from 2026	Gradually Implemented from 2026	$60\text{-}70\$/tCO_2e$
	Some Memberstates have additional instruments (carbon taxes)		
Japan	Implementation of a carbon levy from 2028 and GX ETS from 2030[81]	Consider the implementation of a carbon border adjustment mechanism from 2030ies - TBC	/
Korea	ETS in place with free allocation for industrial sectors, potential reform coming by 2026.	High costs due to energy-intensive capture processes	$7.2\$/tCO_2e$
China	National ETS - intensity based (no absolute reduction of emissions). Currently, only the power sector. Potentially expanded for a test-phase to some industrial sectors from 2025 (Steel, Aluminum, Cement)	Against CBAM, in favor of ETS linkage	$8\$/tCO_2e$

[81] *Ministry of Economy, Trade and Industry, Japan,* グリーントランスフォーメーションの推進に向けて *[Towards the Promotion of Green Transformation], May 29, 2023, https://www.meti.go.jp/shingikai/sankoshin/sangyo_gijutsu/chikyu_kankyo/ondanka_follow_up/pdf/2023_001_05_00.pdf.*

Moreover, the **disparity in carbon prices between Europe and other regions of the world** will eventually become problematic. While the issue of **carbon leakage** can be **addressed by a well-functioning Carbon Border Adjustment Mechanism**, the competitiveness of European products remains a concern. **European products**, faced with rising carbon prices, **may struggle in the global market, as WTO provisions do not allow for the reimbursement of ETS costs for exported goods**. This could have significant consequences for European industrial products exported outside the EU market.

The EU Carbon Border Adjustment Mechanism and Industry Competitiveness

The European Union's Carbon Border Adjustment Mechanism (CBAM) is designed to prevent carbon leakage and encourage global climate action by imposing a carbon price on imports of certain goods from countries with less stringent climate policies. CBAM specifically covers sectors that are both carbon-intensive and at high risk of carbon leakage, including cement, iron and steel, aluminum, fertilizers, electricity, and hydrogen. These sectors were chosen because they are significant contributors to carbon emissions and are heavily exposed to international competition.

The CBAM complements the EU ETS by extending carbon pricing to imports, ensuring that imported goods are subject to the same carbon costs as domestically produced goods within the EU. This level playing field helps maintain the competitiveness of EU industries while encouraging non-EU producers to adopt cleaner technologies and align with EU environmental standards. The CBAM will be gradually phased in from 2026, aligning it with the removal of free allocation in the EU ETS.

The Carbon Border Adjustment Mechanism was introduced to level the playing field for carbon pricing in the EU market. While it is necessary, it is also a highly technical instrument that will be extremely challenging to implement. Specifically, regarding electricity consumption, most industry stakeholders in Europe advocate using "country average" carbon intensity rather than facility-level metrics. This approach would help European industries remain competitive against companies that might direct their most low-carbon production assets to Europe while reserving their more carbon-intensive operations for other markets, which would give them an unfair advantage.

This **CBAM dilemma** is well understood in Europe and is equally crucial in countries such as Japan and South Korea that have planned to implement higher carbon prices in the next few years. These countries face the same challenge as Europe: the **necessity of a high carbon price to drive industry decarbonization, coupled with the fear of being a first mover in this transition**.

In particular, South Korean and Japanese industries have significant markets in China and Southeast Asia, which are very likely to be impacted by a rise in carbon costs due to regional competition. Against this backdrop, **Japan's METI and Korea's MOTIE share a similar approach: the increase in carbon prices will be slow and incremental, following regional trends, particularly those set by China, to avoid being outcompeted by the Chinese industrial machine**.

Additionally, **the emergence of competition-based industrial policies – from outside Europe – complicates relying solely on carbon pricing**, as many countries, particularly China and the United States, now actively support their industries with various financial and nonfinancial instruments.

Therefore, **carbon pricing must be complemented by other instruments, such as subsidies, tax reductions, standards, and regulations, during the transition period**. It is crucial to bridge the cost differential between carbon-intensive and greener versions of the same good and to address the increasingly uneven playing field emerging at the global level. The biggest question faced by all jurisdictions is the same: **How can the budget necessary for these instruments be found if carbon prices cannot be raised sufficiently?**

d. Providing Cheap Clean Energy in the Long Term

The primary discriminatory factor is the **price of clean energy, particularly clean electricity**, which represents the **most significant industrial policy advantage a government can provide to its transitioning industrial sectors**. For instance, one of the main pillars of China's overall industrial policy is to invest heavily in providing the cheapest energy possible to its industrial sector through practical cost-reduction and financial and nonfinancial policy instruments. This is achieved partly through the low cost of energy in some Chinese provinces as well as through price advantages given to certain industrial sectors for using green energy.

A green industrial policy must be successful in providing cheap clean energy, particularly electricity and increasingly hydrogen, to its industrial sector. During the transition period, this is no easy task – as seen with the infrastructure and financial hurdles regarding hydrogen. Beyond the need to produce clean electricity and meet future demand, there is also the question of instruments to entice industrial companies to invest in buying or producing the energy needed themselves. The four regions studied for this paper have all conducted experimental trials of various instruments to support clean energy consumption in their industrial sector.

Feed-in Tariffs

Some countries have implemented **feed-in tariffs (FiTs)**. These are an instrument used in many countries, such as Germany, to support clean energy consumption in industrial sectors. **China and Japan are also employing this strategy**, and South Korea is considering adopting it to support industry decarbonization, alongside electricity market liberalization. FiTs play a crucial role by **guaranteeing a fixed premium price for energy generated from renewable sources over a specified period**. This mechanism provides long-term financial security and encourages investment in renewable energy projects by ensuring a stable revenue stream.

For industries with high energy consumption, such as steel, aluminum, cement, and chemicals, **FiTs can reduce the cost barriers associated with integrating clean energy into their operations**. By offsetting the initial investment and operational costs of renewable energy systems, FiTs help industrial sectors transition to greener energy sources, enhance energy security, and reduce carbon emissions.

Tax Incentives

Tax incentives such as **accelerated depreciation** and **tax credits** are also used for investments in renewable energy and energy efficiency improvements for industrial sectors in many countries, including **Japan** and **South Korea**.

China also employs these incentives on a provincial and sectoral basis, tailored to local conditions and availability of renewable resources. For instance, there are **value-added tax exemptions for energy management contracts and renewable energy products. Corporate income tax reductions** are available for companies engaged in pollution prevention and control, as well as for energy-saving. Additionally, **specific**

consumption taxes are exempted – for example, for the production of pure biodiesel from waste animal and vegetable oils.

The overall strategy includes **ensuring a cheap long-term price for renewable energy, sometimes using over-the-counter partial reimbursement mechanisms** at the local level.[82] These incentives aim to reduce the financial burden on companies investing in sustainable energy solutions, thereby encouraging more widespread adoption of green technologies.

Table 13: Summary of Tax incentives for clean energy production and consumption concerning industry in China[83]

Tax Incentive	Description
VAT Exemptions and Reductions	• VAT exemptions for energy management contracts, renewable energy products, drip irrigation products, reclaimed water.
Corporate Income Tax (CIT) Reductions	• CIT reductions for companies engaged in pollution prevention and control, energy-saving, and water-saving projects. • CIT exemptions for income derived from CDM Fund projects.
Consumption Tax Exemptions	• Exemptions for the production of pure biodiesel from waste animal and vegetable oils
Long-term Stable Pricing and Reimbursement Mechanisms	• Ensuring long-term, stable pricing for renewable energy, sometimes using over-the-counter reimbursement mechanisms at the local level.

[82] *From interviews in China.*

[83] *National Development and Reform Commission, China.,* 关于印发“十四五”可再生能源发展规划的通知 *[Notice on Issuing the “14th Five-Year Plan” for Renewable Energy Development], June 1, 2022, https://www.ndrc.gov.cn/xwdt/tzgg/202206/t20220601_1326720.html?code=&state=123; State Council of the People’s Republic of China,* 工业和信息化部等七部门关于加快推动制造业绿色化发展的指导意见 *[Guiding Opinions from the Ministry of Industry and Information Technology and Six Other Departments on Accelerating the Green Development of Manufacturing], February 5, 2024, https://www.gov.cn/zhengce/zhengceku/202403/content_6935684.htm.*

Green Certification

Green certificates, such as Renewable Energy Certificates, are market-based instruments that certify the generation of a specific amount of renewable energy. Industries can purchase these certificates to meet regulatory requirements or corporate sustainability goals, thereby promoting the use of clean energy without having to generate it themselves. **Japan** and **South Korea** are **utilizing these instruments across various industries** and plan to expand their use during all transition phases to facilitate industrial decarbonization.

Similarly, **China is leveraging this mechanism to generate sufficient demand for its renewable electricity supply in various provinces**. This strategy is a crucial component of the country's dual carbon goal initiative. In 2023, 120 billion kilowatt-hours of clean electricity were traded through green certificates in China.

Renewable Energy Mandates

A key question is **how to entice energy-intensive industries to consume more clean energy**, even when it may not be economically efficient to do so. To address this, Europe has implemented the **RED III directive**, which aims to increase the use of clean electricity across all sectors, including the industrial sector. The directive mandates an **annual increase of 1.6 percent in the share of renewable energy in each sector until 2030**, promoting greater integration of renewables in the industrial sector.[84]

A similar approach is to use **renewable portfolio standards (RPS)** which **mandate a certain percentage of electricity to come from renewable sources. South Korea** has implemented such an instrument for power

[84] *European Union, "Directive (EU) 2023/2413 of the European Parliament and of the Council," October 31, 2023, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:L_202302413.*

producers, using a supply-side approach. It mandates power producers with facilities over 500 MW – which are sometimes also big industries – to produce 17 percent of their total electricity output from renewables. This figure is set to increase to 25 percent by 2026.[85]

For energy-intensive industries, there is **no direct mandate to consume renewables** under the RPS. However, there are mechanisms like the K-RE100 initiative, which encourages both industrial and general consumers to transition to 100 percent renewable energy.[86] This initiative allows companies to purchase Renewable Energy Certificates or make additional payments to be recognized as users of renewable electricity. Companies participating in K-RE100 can also engage in **corporate Power Purchase Agreements to procure renewable energy indirectly through the Korea Electric Power Corporation** (KEPCO).

China has implemented an RPS mechanism aimed at achieving a minimum of 20 percent of total energy consumption from non-fossil sources by 2025. The RPS mechanism in China is transitioning from a traditional supply-side measure to a demand-side approach. This is because the industrial sector operates many captive, coal-based, and carbon-intensive power plants that supply power to an industrial plant.[87]

For a country like China, where some regions produce significant amounts of clean electricity without the capacity to consume it at peak levels, it becomes increasingly crucial to go beyond price incentives like time-of-use pricing and actually mandate renewable energy consumption

[85] *Korea Energy Agency, "Renewable Portfolio Standards (RPS)," April 28, 2024, http://web.archive.org/web/20240428002315/https://dco.energy.or.kr/renew_eng/new/standards.aspx.*

[86] *Climate Group RE100, "The Rise of South Korea: Is the Market Open for Business?" August 3, 2021, https://www.there100.org/our-work/news/rise-south-korea-market-open-business.*

[87] *National Development and Reform Commission, China,* 关于加强绿色电力证书与节能降碳政策衔接大力促进非化石能源消费的通知 *[Notice on Strengthening the Integration of Green Power Certificates with Energy Conservation and Carbon Reduction Policies to Vigorously Promote Non-Fossil Energy Consumption], February 2, 2024, https://www.ndrc.gov.cn/xxgk/zcfb/tz/202402/t20240202_1363856.html.*

for heavy industrial consumers. Under these mandates, **high-emitting industries must either purchase green power or acquire a substantial number of green certificates**. In some provinces, green power costs more than brown power, prompting industries to either contract with local green power generators or request green power content from their power retailers at a premium. The objective remains consistent: to ensure sufficient consumption of renewable energy to support its production.

Before attempting to implement a genuine electricity market reform, China has initiated pilot programs for **green power trading, enabling renewable energy producers to sell electricity at competitive rates – slightly above the coal benchmark price** – thus incentivizing the use of clean energy over fossil fuels in some industrial sectors.[88]

[88] *State Council of the People's Republic of China, "Pilot Direct Trading of Green Power Launched," September 8, 2021, https://english.www.gov.cn/statecouncil/ministries/202109/08/content_WS6137ee2bc6d0df57f98dfd3d.html.*

Table 14: Summary of Instruments to Support the Use of Clean Electricity in Industry in Europe and Asia

	Type of instrument to support the use of clean electricity in industry
Europe	Feed-in-Tariffs in some member states
	Tax rebate
	Renewable Energy Directives III
China	Proposal to reform electricity market
	Feed-in-Tariffs
	Direct Grant (sectoral) in some provinces (for clean electricity consumption, production, and energy storage)
	Tax rebate in most provinces
	Renewable Portfolio Standards (Consumption mandate of clean energy for some industrial sector) + Green Power Trading
	Differentiated electricity price: • Favorable pricing for clean electricity access in the Steel, Chemical, and Aluminum sector • Punitive pricing for polluting entities
Japan	Feed-in-Tariffs and Feed-in-Premium
	Tax credits and accelerated depreciation
	Renewable Energy Certificates
South Korea	Tax rebate and Tax credits
	Renewable Portfolio Standards

e. Carbon Contracts for Difference vs. Direct Subsidization:

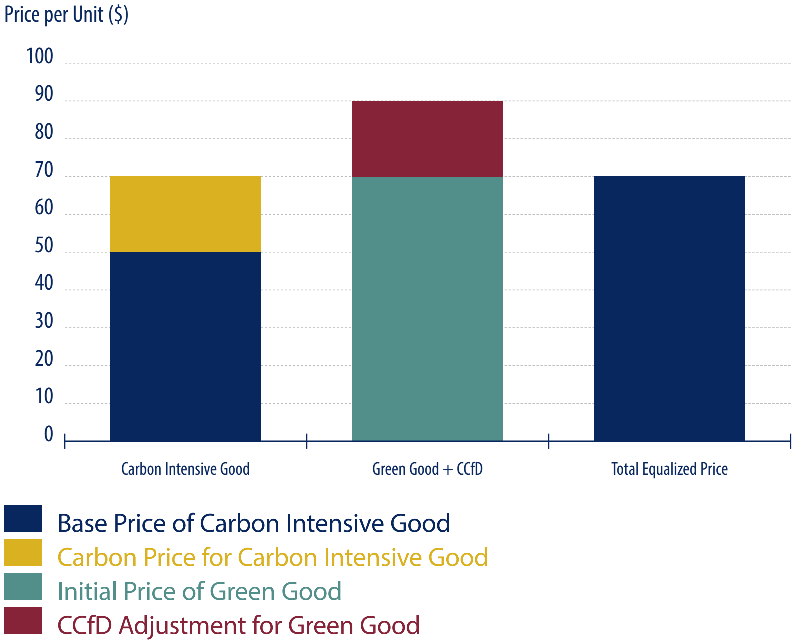
To mitigate risks in industry decarbonization, it is essential to support industries in choosing clean feedstocks, utilizing clean energy, and adopting cleaner production processes. Two main types of instruments are emerging in this context:

1. **De-risking Instruments:** Instruments such as carbon contracts for difference (CCfDs) are becoming increasingly popular in Europe, Japan, and even South Korea.
2. **Direct Financial Support Instruments:** These include direct subsidies, grants, and operational expenditure funding, which are notably available in China and are under consideration in other regions.

For some sectors, the use of **carbon contracts for difference** has become a serious option. These can be used as an instrument to provide cheap energy or cheaper clean hydrogen to industrial sectors. In the production process, this tool can also be used to **guarantee a fixed price for carbon-neutral products, compensating producers if market prices fall below this level, thereby reducing financial risk and incentivizing the adoption of greener technologies**.

In Europe, the contracts are **awarded through a competitive bidding process,** where companies propose the amount of government support needed to avoid one ton of CO2 emissions. **The lowest bids receive the subsidies, encouraging cost-efficient decarbonization**.

Figure 5: . Example of How CCfDs Equalize the Prices of Green Goods and Carbon-Intensive Goods



- **Carbon Intensive Good:** The base price is $50 per unit, with an additional $20 per unit carbon price, making the effective price $70 per unit.
- **Green Good + CCfD:** The initial price is $90 per unit, with a $20 subsidy through CCfD, making the effective price $70 per unit.
- **Total Equalized Price:** Both goods have an equal total price of $70 per unit after the carbon price and CCfD adjustment are applied, promoting competitiveness and the adoption of green technologies.

Carbon Contracts for Difference for Hydrogen

In Germany, **contracts for difference are emerging as a pivotal mechanism for supporting the adoption of clean hydrogen**, particularly in the industrial sector. These financial instruments provide a guaranteed price for hydrogen, thereby mitigating market volatility and making it a more attractive alternative to fossil fuels.[89] The steel industry, a major carbon emitter, stands to benefit from this policy. By securing a stable and competitive price for clean hydrogen, steel manufacturers are encouraged to take the risk and adopt hydrogen-based direct reduction of iron. Following the German example, the **EU has also decided to promote clean hydrogen using CCfD**, financed by the Innovation Fund.[90]

In 2024, Japan has also decided to test CCfDs for hydrogen. First, there is the ***Hydrogen Society Promotion Act***,[91] which introduces carbon contracts for difference for hydrogen production, favoring domestic production, **using money from the GX League bond scheme**. This new law aims to facilitate Japan's transition to a decarbonized economy by promoting the use and supply of low-carbon hydrogen that meets specific CO_2 emissions criteria – including blue hydrogen – across various industries. Businesses

[89] *Federal Ministry for Economic Affairs and Climate Action, Germany, "Press Release: First Round of Carbon Contracts for Difference Launched," March 12, 2024, https://www.bmwk.de/Redaktion/EN/Pressemitteilungen/2024/03/20240312-first-round-of-carbon-contracts-for-difference-launched.html.*

[90] *European Commission, "Press Release: REPowerEU: A Plan to Rapidly Reduce Dependence on Russian Fossil Fuels and Fast Forward the Green Transition," May 18, 2022, https://ec.europa.eu/commission/presscorner/api/files/document/print/en/ip_22_3131/IP_22_3131_EN.pdf.*

[91] *Ministry of Economy, Trade and Industry, Japan,* 脱炭素成長型経済構造への円滑な移行のための *[For a Smooth Transition to a Decarbonized Growth-Oriented Economic Structure], 2024, https://www.meti.go.jp/press/2023/02/20240213002/20240213002-1.pdf.*

involved in the hydrogen supply chain must submit plans to METI for approval, demonstrating economic rationality and contributions to international competitiveness.

Beyond the promotion of clean hydrogen through CCfD, they **can also be used to directly promote green steel, cement, or aluminum**. For the steel industry, this is particularly useful, as transitioning to carbon-neutral production methods – such as using hydrogen instead of coal – incurs significant costs. The predictability and stability provided by CCfDs may accelerate the decarbonization process in steel production. However, they may not be as applicable in other sectors such as chemicals, aluminum, or cement, where the cost structures, technological pathways for decarbonization, and market dynamics differ. For example, in the chemicals sector, which is characterized by its diversity of processes and products, the uniform application of CCfDs might be complex and less effective.

Due to its **potentially high cost for the public budget**, the role of contracts for difference is to establish small, compartmentalized lead markets. It must remain a temporary measure. CCfDs should, then, **be complemented by other instruments to sustain the lead market** and expand beyond the initial financial support.[92]

[92] *The economic advisory council of the German BMWK has argued quite forcefully in this direction – see: Bundesministerium für Wirtschaft und Klimaschutz, Germany, "Transformation zu einer klimaneutralen Industrie: Grüne Leitmärkte und Klimaschutzverträge," February 8, 2023, https://www.bmwk.de/Redaktion/DE/Publikationen/Ministerium/Veroeffentlichung-Wissenschaftlicher-Beirat/transformation-zu-einer-klimaneutralen-industrie.html.*

Carbon Contracts for Difference in Europe and Asia

Many industry stakeholders interviewed in this study are advocating for the implementation of carbon contracts for difference in their sectors across Europe, Japan, and South Korea. Germany, in particular, is the first country trying to pioneer the utilization of CCfDs in its steel and cement industries.[93]

Inspired by Germany's example, the **South Korean authorities are exploring the feasibility of adopting CCfDs for their steel and chemical industries** as well. However, they face the issue of insufficient budgets to dedicate to such instruments, especially in a situation of low revenues from the SK ETS. **In Japan, METI has currently ruled out CCfDs for anything other than hydrogen**.

Table 15: Summary Table of CCfD for industry decarbonization

	Europe	China	Japan	Korea
Steel	Yes (Germany)	No	No	Considered
Aluminum	No	No	No	No
Cement	Considered (Germany)/ Supported by EU	No	No	No

[93] *The first round of bids has been completed, but the winners have yet to be announced. According to the BMWK, some 20 bids were placed, including some from large companies as well as SMEs. The total requested volume exceeded the 4 billion available in the first round. The contract winners are supposed to be announced in October 2024. See Bundesministerium für Wirtschaft und Klimaschutz, Germany, "Funding Programme for Carbon Contracts for Difference," March 12, 2024, https://www.klimaschutzvertraege.info/lw_resource/datapool/systemfiles/agent/ewbpublications/fe0f6dc4-f70e-11ee-8b39-a0369fe1b6c9/live/document/0276-24_EN_Lav_Pressepapier_F%C3%B6rderprogramm_Klimaschutzvertr%C3%A4ge.pdf.*

	Europe	China	Japan	Korea
Chemicals	Considered (Germany)/ Supported by EU	No	Considered	Considered
Hydrogen	Yes	No	Yes	No

The Chinese Industrial Support System

The debate on contracts for difference is currently largely absent in China. This may be related to the complexity of the instrument. This criticism can be found elsewhere, saying that it does not prevent uncertainties for companies due to the difficulty of predicting carbon prices on a market-based instrument such as an ETS. Instead, **China relies on other measures that are often more direct, such as grants and subsidies, to achieve similar goals**.

China utilizes both demand-side and supply-side subsidies as key instruments to enable its industrial companies to demonstrate and scale up quickly and to incentivize industries to invest in new technologies. While these subsidies are not exclusively aimed at decarbonization, they do contain provisions that can promote greener industrial processes when supported by local or national governments. These provisions include the following:

- **OPEX subsidies or operational grants:** These are allocated for projects deemed critical in sectors such as steel, aluminum, chemicals, or cement, particularly those utilizing hydrogen, electrification, or carbon capture and storage.
- **Government below-market debt and equity:** Offering financial support at below-market rates.
- **Subsidized feedstock prices:** Lowering costs for essential materials.
- **Reduced prices for key inputs:** Achieved through government subsidies or regulations in related industries.

How to Finance Such Instruments?

CCfDs can be sustainably financed through carbon pricing revenue or other mechanisms that transfer the costs to carbon-intensive goods. However, **they are transitional support instruments and should not serve as a permanent industrial model**. They should be phased out once the lead market is established.

There is a kind of schizophrenia regarding the question of how to fund industrial instruments such as carbon contracts for difference. In most cases, countries plan to finance these through carbon revenues, alongside various other support mechanisms for capital expenditures or even operational expenditures for decarbonization. However, they simultaneously fear raising carbon prices due to competitiveness concerns, creating a genuine funding dilemma.

This is particularly true for South Korea and Japan, where carbon revenues are essential but politically difficult to obtain. In Japan, direct subsidies financed through Green Bonds – coming from future carbon revenues – seem to prevail over contracts for difference. In Korea, the current pathway to finance CCfDs involves removing free allocation within the SK Emissions Trading System while keeping control over increases in the carbon price. In practice, this would mean raising more revenue than in the current situation while avoiding unwanted carbon price levels. Meanwhile, other budgets – possibly related to fossil fuel subsidies – would be cut to transfer funds to support CCfDs.

Table 16: De-risking and support instruments to decarbonize industry[94]

	Raw Materials & Energy	Production Processes	Product Use	End-of-Life
High upfront costs	Viability Gap Funding			
	Tax Rebates			
	Concessional Loans			
	Subsidized prices			
Cost of capital	Sustainability-linked instruments (financial)			
		Capital Refinancing		
		Energy Savings Insurance		
		Securisation and aggregation		
Higher costs of operations	Carbon pricing			
	Feed-in tariff	Revenue guarantee		
	Contracts for differences			
	Direct OPEX subsidies[95]			
Revenue uncertainty	Contracts for Differences	Contracts for Differences	Green Premium	Landfilling Taxes & negative recycling taxes
	Feed-in tariff		Tradable Certificates	
			Offtake Agreement	

Pure de-risking | Financing | China

[94] *Original figure from the Climate Club, Chinese inputs from the author.*

[95] *Direct OPEX subsidies are not just used in China, but the country uses this instrument widely compared to its competitors.*

3.4. INNOVATION, DEMONSTRATION, AND SCALING UP

There is a significant **difference in approach between the EU and the rest of the world regarding tech adoption strategies**, particularly in terms of timing. **Europe**, as a decarbonization leader, has chosen to **simultaneously implement stringent carbon regulations**, such as a high carbon price, **while promoting technological transitions for industrial actors**.

In Asia, particularly in **South Korea and Japan**, this strategy is largely rejected in favor of a more cautious approach that **prioritizes technological "certainty."** These countries prefer to see which technologies prove effective before committing to substantial investments in decarbonization.

On the other hand, **China's strategy** is more comprehensive or "aggressive," and could be characterized as **"everything, everywhere, all at once."** China focuses on **building new technologies before discarding the old**, and although decarbonization is an important factor in its industrial strategy, it is not the primary criterion. **New technologies or processes must therefore prove themselves to be efficient and competitive before they are spread widely across a sector**.

This philosophy, which underpins **China's technological adoption strategy** in the industrial sector, also allows it to **benefit from the "second-mover advantage,"** a strategy that may prove to be the most practical in the context of industrial decarbonization. Unlike traditional technological breakthroughs, where the first-mover advantage offered significant economic and strategic benefits to the actor developing and industrializing the new technology, **the high level of uncertainty surrounding decarbonization technologies in most industrial sectors creates a critical advantage in waiting for others to test new low-carbon innovations and potentially make costly mistakes**.

a. How to Create First Movers?

One of the primary challenges in decarbonizing heavy industries lies in the fact that while some sectors have begun to see viable alternatives to fossil-fuel-based processes, truly sustainable options for steel, aluminum, chemicals, and cement manufacturing are still in their nascent stages and remain more expensive than their carbon-intensive counterparts.

Most of this is due to a lack of infrastructure (such as for hydrogen, or for sequestering CO_2), expensive clean energy costs, and economic gains that have yet to materialize. Innovations like carbon capture and storage, hydrogen-based steel production, and electrification of heat processes are promising but **still require substantial investment in research, development, and infrastructure scaling**.

The pace of technological progress and the ability of industries to adopt these technologies are critical yet uncertain factors. Currently, these challenges are managed through the following **three-step strategy:**

- support for **development**
- **demonstration** of new technologies and processes
- support to enable the **scaling up** of these early-stage innovations

To implement their post-carbon industrial policy, most national strategies implement this three-phase approach in addition to **supporting cooperation and clustering by technologies** – sometimes even cross-sectorally – for innovation, demonstration, and deployment. While this is a common trend across Europe and Asia, **the speed of deployment and the criteria for determining which technologies to support vary considerably between countries**. These differences can be attributed to the distinct regional industrial fabrics and the specific agendas each country enforces on their industrial sectors. **A key difference is the level**

of technology agnosticism, which is more pronounced in Asia than in Europe.

Adopting a **clusterization approach facilitates the exchange of information and learning about decarbonization techniques both within and across industries**. This strategy promotes cooperation not only within the same sector but also between different sectors. The EU's Important Projects of Common European Interest (IPCEI) system is built on this idea, helping companies develop large-scale projects through a cluster-based approach. The EU supports a range of proposed technologies by providing funding for projects of "Common European Interest" while leaving the rest to national governments. This has led to initiatives such as the hydrogen IPCEI. However, it has yet to effectively create post-carbon cross-sectoral clusters. This is largely because the instrument is heavy to navigate. It also lacks support for different types of technology, and it does not provide long-term support for these complex, large-scale projects. Overall, they still do not compensate for the potential "first-mover disadvantage" that most industrial companies fear.

The Japanese system similarly aims to develop industrial clusters, with NEDO, led by METI, planning to establish CCUS-oriented clusters. Much of Japan's hydrogen use in the industrial sector also seeks to cluster existing industrial bases or regions to provide alternative fuels or feedstocks to industries. However, these initiatives remain largely theoretical. While some funding is available through the Green Innovation Fund, it is primarily directed toward research and development rather than demonstration projects.

China has a long-standing tradition of clusterization in its industrial policy, and the country is now actively promoting industrial concentration to enhance economic efficiency, address overcapacity, and simultaneously reduce emissions. The scale of clusterization in China is unparalleled globally. State-owned enterprises (SOEs) play a pivotal role in this process, as most industrial clusters, whether sector-based or cross-sectoral, are led by SOEs or built around them. These SOEs provide funding and reliable demand, attracting private industrial actors to establish themselves within the newly formed clusters. However, this still misses the decarbonization objective, and these Chinese clusters are not really oriented toward decarbonization but rather toward economic efficiency.

Finally, to address the financial challenge of moving from innovation to demonstration and then to scaling up, one must support investment in decarbonization vectors and projects with the greatest potential impact on decarbonization. Beyond the industries themselves, **investment funds (public and private)** and **public investment banks have a significant role to play**, particularly in the early stages of green technology development and increasingly in **scaling up and deploying decarbonization technologies**. This dimension is particularly well understood by most industrialists in Europe and Asia and is widely believed to be at the heart of the Chinese industrial strategy.

b. Europe

Although cooperation and information exchange regarding decarbonization occur in Europe between industries, the **vertical integration and concentration of "carbon-free industrial hubs"** have yet to materialize on a large scale and **remain organized at the national level due to the lack of EU-level coordination**.

Furthermore, the European strategy still lacks a strategic compass for the new realities of industry in a post-carbon economy (technologically speaking, the geopolitical evolution of each sector and the new geography of industry). **The focus remains on decarbonizing existing assets rather than considering the broader picture of where these industries should be located and how they should be organized at the continental scale**.

The EU Innovation Fund

The **EU Innovation Fund** is one of the world's largest funding programs for the **demonstration of innovative low-carbon technologies**. It aims to **support the commercial demonstration of industrial solutions** that can decarbonize Europe and facilitate its transition to climate neutrality by 2050. The fund, which operates from 2020 to 2030, **has a total budget of approximately €40 billion**.[96]

In 2024, the Innovation Fund has allocated €4 billion for its call for proposals, aimed at supporting the deployment of innovative decarbonization technologies. This funding is sourced from revenues generated by the EU ETS. The fund covers up to 60 percent of the relevant costs of projects, including both capital expenditure (CAPEX) and operating expenditure (OPEX), across various project sizes:

1. **Large-scale projects** (CAPEX > €100 million): €1.7 billion available
2. **Medium-scale projects** (CAPEX €20–100 million): €500 million available
3. **Small-scale projects** (CAPEX €2.5–20 million): €200 million available
4. **Cleantech manufacturing:** €1.4 billion available for projects focusing on manufacturing components for renewable energy, energy storage, heat pumps, and hydrogen production
5. **Pilot projects:** €200 million available for deep decarbonization projects

The EU Innovation Fund's support is structured through **grants awarded via competitive calls for proposals**, which may **limit the accessibility and immediacy of operational funding for ongoing costs beyond initial demonstration phases**. Unlike support given in the US by the IRA or even in China, which includes **mechanisms such as tax incentives that**

[96] *European Union Innovation Fund, "The Innovation Fund," accessed September 2, 2024, https://www.euinnovationfund.eu/.*

provide predictable, ongoing financial benefits tied directly to operational metrics like production levels, making it easier for companies to plan and secure OPEX funding over longer periods.

Competitive Bidding: The Right Instrument for Selecting Projects in a Green Industrial Policy?

Competitive bidding, or auctioning, is increasingly used by the Commission to complement the Innovation Fund's existing grants program for low-carbon technologies. This competitive bidding is designed as a novel financial instrument at the EU level, offering significant advantages. It aligns with the Innovation Fund's objectives by supporting innovative low-carbon technologies, which often struggle to penetrate the market due to the lower costs of incumbent fossil-based technologies and high risk perceptions in financial markets. The scheme aims to award support cost-efficiently, minimizing public expenditure while maximizing the leverage of private capital. This way of awarding support is increasingly being considered by other actors such as Japan or South Korea as they look to design their own systems.

Competitive bidding is now central in supporting hydrogen production and adoption within industry in the EU. The Commission is currently considering several support types to be awarded through competitive bidding to hydrogen producers or purchasers, including carbon contracts for difference and fixed premium contracts.

While **competitive bidding** is an effective instrument for selecting candidates based on cost-efficiency – a prudent approach to utilizing public funds – it **may overlook other important criteria if not supplemented with additional benchmarks**. This method could potentially **disregard factors crucial to a more "directive" or "political" industrial policy, such as the origin of the technologies used in the project, the projected cost evolution of the proposed feedstock, and other political considerations**.

Table 17: Table about EU Level funding mechanisms to support industry decarbonization

EU Funding support	Specific Targets /Requirements	Description
Horizon Europe[97]	EU's key funding program for research and innovation.	Provides significant funding for projects aimed at reducing emissions and developing sustainable technologies in various industrial sectors.
Innovation Fund[98]	Support for innovative low-carbon technologies and processes.	Provides substantial funding for the development of innovative technologies that can help reduce emissions in energy-intensive industries like steel, aluminum, etc.
European Regional Development Fund (ERDF)[99]	Financial support for regional development projects, including sustainability and decarbonization efforts.	Funds projects aimed at improving sustainability and reducing emissions at the regional level, affecting various industrial sectors.
Just Transition Mechanism (JTM)[100]	Supports regions most affected by the transition to a low-carbon economy.	Provides financial and technical support to regions and industries most impacted by the transition, ensuring a fair and inclusive shift to sustainability.

[97] *European Commission, "Horizon Europe: EU Funding Programmes," on September 9, 2024, https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/programmes/horizon.*

The EU and Member States Coordination Strategy

Beyond the EU-level mechanism, individual **Member States** are primarily responsible for funding industrial support, leading to **significant variations based on their fiscal capacities**. This results in considerable disparities in investment capabilities and causes **substantial non-coordination**, which can be highly counterproductive for implementing a cohesive industrial policy across Europe.

The **European Strategic Energy Technology Plan (SET Plan)**, the **Important Projects of Common European Interest (IPCEI)**, and particularly the **Strategic Technologies for Europe Platform (STEP)** are helping foster collaboration among EU Member States, industry, and the research community to advance industrial decarbonization technologies.

The **SET Plan** aims to accelerate the development and deployment of low-carbon technologies in the **energy sector** by **enhancing coordination and cooperation among EU countries**.[101] It focuses on several key areas, including the integration of renewable energy sources, the development of smart energy systems, and the improvement of energy efficiency in industries, including the steel sector. The SET Plan plays a role in aligning national research agendas and leveraging public and private funding to drive the innovation and technological progress necessary for the transition to a low-carbon economy.

[98] *European Commission, "Innovation Fund," accessed September 9, 2024, https://climate.ec.europa.eu/eu-action/eu-funding-climate-action/innovation-fund_en.*

[99] *European Commission, "European Regional Development Fund," accessed September 9, 2024, https://ec.europa.eu/regional_policy/funding/erdf_en.*

[100] *European Commission, "The Just Transition Mechanism: Making Sure No One Is Left Behind," accessed September 9, 2024, https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/finance-and-green-deal/just-transition-mechanism_en.*

[101] *European Commission, "Strategic Energy Technology Plan," accessed September 2, 2024, https://energy.ec.europa.eu/topics/research-and-technology/strategic-energy-technology-plan_en.*

Issues with the SET Plan:

The main problem with the SET Plan lies in the fact that **energy, along with financial services and information and communication technologies, is not yet fully integrated into the EU single market**. This lack of integration limits the effectiveness of the SET Plan by creating barriers such as fragmented regulations and limited cross-border cooperation. Addressing this by incorporating these sectors into the single market, as recommended by Enrico Letta's report,[102] would enhance the plan's success and bolster the EU's energy and climate goals.

Therefore, the SET Plan still faces significant challenges in helping to create a coherent European industrial policy:

- **Lack of integration and coordination in national research agendas and funding mechanisms:** This is making it difficult to achieve the desired low-carbon technology advancements uniformly across Europe.
- **Insufficient funding and investment:** The plan relies heavily on **leveraging both public and private funding**, but securing adequate investment remains a persistent issue. The financial mechanisms currently in place are often seen as insufficient to support the ambitious targets set by the plan, particularly in scaling up new technologies and bringing them to market.
- **Slow market uptake of innovations:** Despite advances in research and development, the transition from innovation to market-ready products and services is slow. This delay can be attributed to regulatory barriers, market acceptance issues, and

[102] *Enrico Letta, "Much More Than a Market – Speed, Security, Solidarity: Empowering the Single Market to Deliver a Sustainable Future and Prosperity for All EU Citizens," European Council, April 2024, https://www.consilium.europa.eu/media/ny3j24sm/much-more-than-a-market-report-by-enrico-letta.pdf.*

the high costs associated with deploying new technologies. As a result, the benefits of research and innovation are not realized as quickly as needed to meet the EU's climate goals and are sometimes even achieved outside the EU's border by actors leveraging easy access to support such as the US's IRA.

- **Regulatory and policy hurdles:** Varying national policies and regulations can create obstacles for the implementation of low-carbon technologies, further complicating the path to a unified energy strategy – an issue that is supposed to be handled by the NZIA but that has yet to be implemented by Member States.
- **Non-technology agnostic:** The plan's focus on certain technologies and sectors over others has led to imbalances – an issue some find problematic. For instance, while renewable energy sources and smart energy systems receive significant attention, other critical areas like carbon capture and storage or energy efficiency in less prominent industries may not get the same level of support.

The **IPCEI**, on the other hand, provides a framework for **large-scale, cross-border projects that are deemed crucial for the EU's strategic interests**. These projects can receive state aid, which is normally restricted under EU competition rules, to support significant investments in research, development, and innovation that would otherwise be challenging to finance. In the context of steel sector decarbonization, IPCEI initiatives often involve the development of technologies such as hydrogen-based steel production, carbon capture, and utilization technologies, and the creation of integrated energy systems that utilize renewable energy sources efficiently.

Issues with the IPCEI system

Similarly to the SET Plan, there are many issues facing the IPCEI system that hinder it from genuinely helping to integrate a European industrial policy:

- **Complex and lengthy approval process:** One of the primary criticisms is the cumbersome and lengthy process required for project approval, which is **distinctly more complex than what other countries have implemented so far**. This complexity can delay the start of crucial projects, making it difficult to respond swiftly to emerging technological and economic needs. Industry stakeholders often find the bureaucratic hurdles a significant barrier to timely project implementation, as it **sometimes take more than 18 months for them to receive an answer**.
- **Does not help newcomers to emerge:** Although the IPCEI system aims to facilitate substantial investments through state aid, there are concerns about the equitable distribution of funds. Smaller Member States and smaller companies (SMEs) may struggle to compete with larger countries and corporations for funding, potentially leading to an uneven playing field across the EU. This imbalance can limit the participation of diverse actors that is crucial for holistic industrial and technological development.
- **High administrative costs:** The administrative burden of managing and reporting on IPCEI projects is substantial, often resulting in high operational costs. These costs can detract from the funds available for actual research, development, and innovation activities. Companies need to invest significant resources into compliance and administration, with **up to a year's worth of resources sometimes mobilized to submit an IPCEI project**. This is primarily due to the extensive criteria required to obtain support, which are significantly more demanding than

in other regions of the world, where projects tend to reach the "political stage" much more quickly than Europe.

- **Coordination and integration issues:** Ensuring effective coordination among multiple countries and stakeholders involved in IPCEI projects can be challenging. The varying national regulations, priorities, and capacities of Member States can complicate the integration and smooth functioning of these large-scale projects. This is of course due to the supranational nature of any European instrument, but this lack of seamless coordination hinders the potential impact and efficiency of the projects.

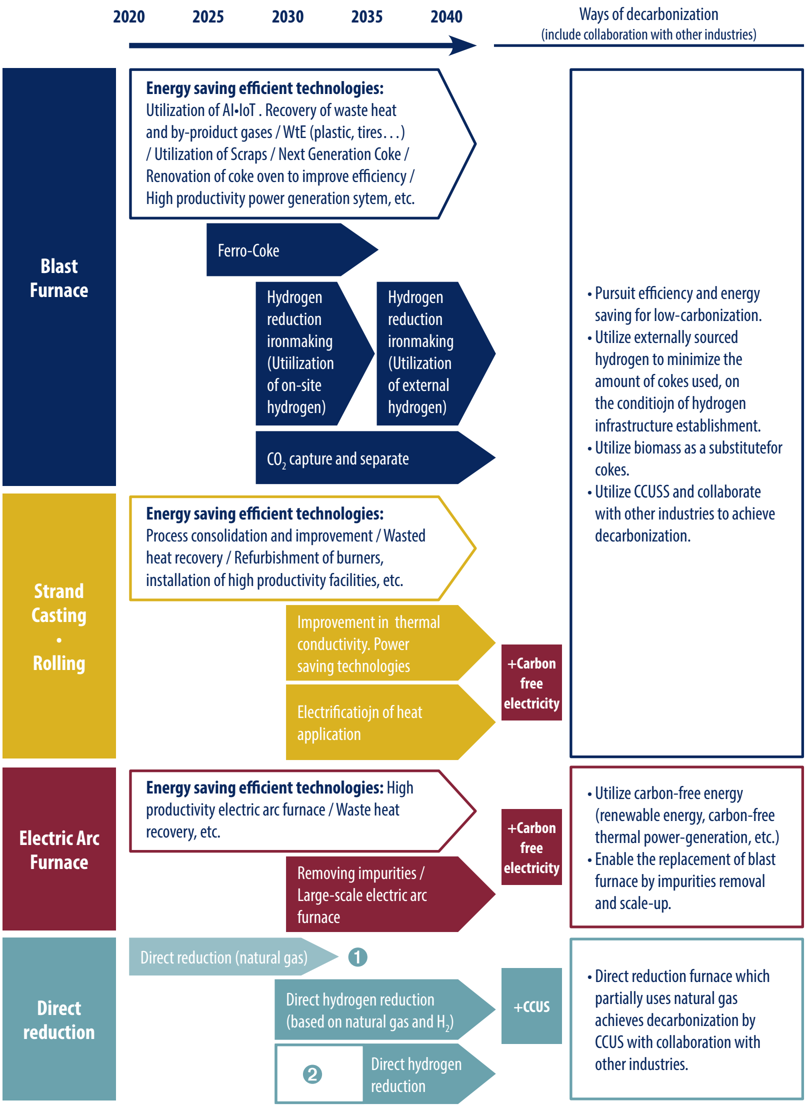
Finally, the **main coordination instrument specifically for industry decarbonization – and one of the embryonic instruments of an EU industrial policy – is the Strategic Technologies for Europe Platform (STEP)**. This platform started out as an ambitious "EU Sovereignty Fund" but was later significantly scaled back to something much more modest. It aims to enhance industrial competitiveness and sovereignty by focusing on critical technological sectors. STEP targets investments in digital technologies, deep-tech innovation, clean and resource-efficient technologies, and biotechnologies. A key advantage of this platform is its **aim of pooling resources from multiple EU programs, driving innovation and technological advancements**.

The platform also facilitates coordination among governments, industry leaders, research institutions, and the private sector, addressing funding challenges and promoting market-ready innovations. Despite its ambitious objectives, STEP faces significant **challenges in securing adequate funding** and ensuring the swift market uptake of innovations. Indeed, a total allocation of **€10 billion has been designated for STEP's objectives** within the entire Multiannual Financial Framework. However, this amount is relatively modest compared to the scale of the IRA or China's industrial policy interventions. Regulatory barriers and varying national policies also complicate the uniform implementation of new technologies across the EU. Additionally, integrating different national agendas and funding mechanisms remains a critical issue, potentially hindering the platform's overall efficiency and effectiveness.

c. Japan

The Japanese government is focused on supporting innovation and demonstrating decarbonization technologies for industry decarbonization but lags in scaling up projects, reflecting a **cautious approach to the uncertainties these technologies entail**. The situation in Japan highlights the significant technological uncertainties associated with decarbonizing the industrial sector, particularly given the complicated nature of Japanese industry. To address these challenges, Japan has implemented a **technology guidance strategy**. This strategy aims to provide a clear technology roadmap of what is supported, facilitating risk-taking and validating investments in decarbonization efforts. The capacity of this approach to be efficient and fast enough to reach carbon neutrality by 2050 remains to be seen.

Figure 6: Example of Technology Roadmap for the Steel Sector



❶ Has not been implemented domestically due to several conditions (production scale & quality, cost, etc.) unmet.

❷ IEA estimates the technology be available in 2030, however the Technology Roadmap determine the implementation year in consideration with the establishment of hydrogen infrastructure.

The Green Bonds Approach

Since December 2020, with the release of the **Green Growth Strategy (GGS)**, the Japanese government has pledged to achieve carbon neutrality by 2050, by dedicating **JPY 240 billion** (approximately €1.5 billion) to Japanese companies and by *establishing an environment-related investments for employment and growth fund* – the **Green Innovation Fund**, launched in March 2021 – with a budget of JPY **2,000 billion** (approximately €12.6 billion).[103]

The Japanese government has introduced various tax incentives and subsidies to encourage companies to invest in decarbonization. These include **raising the upper limit on tax deductions to 10 percent, offering a 50 percent special depreciation option for companies investing in decarbonization technologies**, and providing **performance-based interest subsidies**.

In May 2023, the ***GX Promotion Ac***t established the ***GX Transition Bonds*** – a funding instrument of approximately **JPY 20 billion** (approximately €126 billion) of public money over the **next 10 years – with the expectation of raising a total of JPY 150 billion** (approximately €947 billion) **once combined with private investments**. These funds aim to be used as cost measures to promote the green transition and accelerate the transition toward decarbonization.

[103] *New Energy and Industrial Technology Development Organization (NEDO), "Overview of the Green Innovation Fund Projects," accessed September 9, 2024, https://green-innovation.nedo.go.jp/en/about/.*

Table 18: Allocation of the Funds of the GX Investment Bonds[104]

	Sector	Funding	Subsector (Example of Fund Allocation)	Funding
R&D	Bioeconomy	JPY 3 trillion (approximately €18.9 billion)		
	Carbon capture and storage	JPY 4 trillion (approximately €25.22 billion)	Producing cement using CO_2	J PY 56.78 billion (approximately €358.4 million)
			Tech for CO_2 separation	JPY 38.23 billion (approximately €241.2 million)
End Use	Next-ge-neration automobiles	JPY 17 trillion (approximately €107.2 billion)		
	Housing/ building	JPY 14 trillion (approximately €88.3 billion)		
Manu-facturing Processes	Energy efficiency in manufacturing	JPY 8 trillion (approximately €50.45 billion)		
	Digitalization to decarboni-zation	JPY 12 trillion (approximately €75.67 billion)		
	Battery industry	JPY 7 trillion (approximately €44.14 billion)		
	Ship and air-craft industry	JPY 7 trillion (approximately €44.14 billion)		

[104] *Source: METI (2024).*

	Sector	Funding	Subsector (Example of Fund Allocation)	Funding
Power Source/ Fuel Transition	Renewable energy	JPY 31 trillion (approximately €195.51 billion)		
	R&D on new nuclear power	JPY 1 trillion (approximately €6.3 billion)		
	Hydrogen/ Ammonia	JPY 7 trillion (approximately €44.14 billion)	Large-scale supply-chain hydrogen establishment	JPY 300 billion (approximately €1.9 billion)
			Hydrogen production (Electrolysis)	JPY 70 billion (approximately €441.5 million)
			Hydrogen utilization in Steelmaking process	JPY 193.5 bil-lion(approximately €1.2 billion)
			Ammonia supply-chain establishment	JPY 68.8 billion (approximately €433.9 million)
	Carbon recycling fuels (e-methane, e-fuels, SAF…)	JPY 3 trillion (approximately €18.9 billion)	Specific tech for plastic using carbon recycling Tech for producing fuel	JPY 126.2 billion (approximately €796 million)
				JPY 115.28 billion (approximately €727 million)

The Selection Process

The Japanese strategy is relatively simple: **entice industries to support decarbonization through voluntary action and support from the government, mostly aimed at innovation and demonstration up to 2030**. The **2030s have been set as the target for large-scale demonstration and first deployments of projects**.

In Japan, **the concentration approach**, which allows risk-sharing among various actors – not only state-funded agencies like NEDO but also private entities – is **central to the strategy**. The intention to integrate innovation and demonstration among actors is a tangible aspect of the strategy. However, carbon-neutral industrial hubs remain largely theoretical, with few concrete implementations in the country's traditional industrial regions. Concrete application is lacking, and the ecosystem of many sectors still needs to be built to genuinely aim for carbon neutrality. **In the short and mid-term, most actors are focused on preserving their current processes**, delaying the transition to carbon neutrality and associated risk-taking until later, when the viability of new approaches has been demonstrated by first movers.

The selection of projects under Japan's GX Green Bond scheme is based on an application process rather than a bidding system. The GX Acceleration Agency, established by METI, sets the standards for which projects are eligible for financial assistance. Businesses and organizations that have projects aligning with the GX goals can apply for funding by submitting proposals that demonstrate how their projects meet these criteria.

The agency evaluates these applications based on several factors, including alignment with government policy, promotion of innovative technologies, risk factors that private financial institutions cannot mitigate, and the sustainability and management capacity of the project. Although this process involves the submission of applications, it is competitive, as only those projects that best meet the selection criteria and contribute most effectively to Japan's Green Transformation objectives are funded.

NEDO's role is to manage the implementation of these projects once selected, ensuring they are aligned with technical and strategic goals and facilitating collaboration between industry, academia, and government. Thus, while there is no formal bidding system, the process is rigorous, requiring detailed applications and thorough evaluations to determine the best projects to support.

Japan's **Green Innovation Fund**, managed by NEDO, **selects projects based on their potential to contribute to the national goal of achieving carbon neutrality by 2050**. The selection process focuses on innovative and impactful technologies across key sectors such as offshore wind power, hydrogen, ammonia, and carbon recycling. Projects must demonstrate strong potential for long-term societal implementation, innovative R&D, and scalability.

To ensure effective outcomes, **applicants are required to submit a long-term business strategy** outlining their vision and commitment to achieving ambitious carbon reduction targets. NEDO **prioritizes projects involving public–private partnerships and encourages the participation of SMEs, universities, and research institutions**. There is also a system of incentives and regular assessments to ensure that projects meet their targets. **Projects that do not meet expectations may be canceled, and funding may be withdrawn**.

d. South Korea

South Korea **has yet to establish a comprehensive innovation and deployment policy specifically targeting industrial decarbonization**. The government still needs to develop dedicated mechanisms and a distinctively South Korean approach to transitioning its industries to a post-carbon economy. Currently, the government's efforts are primarily concentrated on supporting R&D within key industrial sectors. However, these efforts are constrained by relatively limited funding and a narrow range of instruments.

The South Korean government currently offers three primary types of support to industries committed to decarbonization:

- **Low-Interest Loans:** Preferential rates provided through the National Bank and Korea Development Bank.[105]

- **Targeted Subsidies:** Financial assistance aimed at specific decarbonization efforts.
- **Tax Rebates:** Incentives designed to reduce the tax burden on companies investing in decarbonization technologies.[106]

Technology Roadmaps and Limited Funding

These instruments, overseen by the Ministry of Trade, Industry and Energy, are primarily **focused on research and development**. At present, they **do not extend to deployment or large-scale demonstration projects, nor do they offer OPEX support**.[107] However, as mentioned above, MOTIE envisions introducing carbon contracts for difference in the coming years. This means that any kind of demonstration happening in South Korea at the moment mostly originates from private-company initiatives.

In collaboration with specific industrial committees, **MOTIE has identified 52 key technologies for decarbonization across various sectors:**

- **7 related to carbon capture, utilization, and storage**
- **13 focused on integrating renewable energy technologies**
- **13 innovations in sub-sectors such as steel, chemicals, and semiconductors**
- **13 energy efficiency technologies applicable across various industrial sub-sectors**

[105] *Korea Development Bank, 녹색·사회적·지속가능채권 표준 관리체계 [Standard Management System for Green, Social, and Sustainability Bonds], 2020, https://www.kdb.co.kr/wcmscontents/pdf/Green%20Social%20Sustainability%20Bond%20Principle.pdf.*

[106] *Example of texts establishing these tax rebates: Ministry of Science and ICT, South Korea, "Establishment of the Strategy for Technology Innovation for Carbon Neutrality," accessed September 9, 2024, https://www.msit.go.kr/eng/bbs/view.do?sCode=eng&mId=4&mPid=2&pageIndex=&bbsSeqNo=42&nttSeqNo=495&searchOpt=ALL&searchTxt=.*

[107] *Interview with MOTIE.*

Despite this targeted list, the Korean government maintains a relative technology-agnostic approach, providing technology roadmaps primarily for large corporations. Small and medium-sized enterprises are not yet subject to stringent decarbonization policies, aside from the relatively modest Korea Emissions Trading Scheme. The current strategy emphasizes R&D and innovation tailored to specific sectors:[108]

- **Steelmaking:** Electrification and clean hydrogen processes (HyREX)
- **Cement:** CCUS and recycling technologies
- **Chemicals:** Transition from NAFTA to biofuels

The government evaluates project proposals based on several factors, including technological feasibility, potential for emissions reduction, and contribution to the national carbon reduction targets. POSCO's use of hydrogen-reduction steelmaking (HyREX) is typical of the kind of projects that contribute to the commercialization of green technologies. The level of public investment remains relatively modest in relation to the scale of the challenge. Supporting large corporations, which often have access to substantial financial resources, is politically sensitive in South Korea. This sensitivity stems from the disparity between corporate wealth and the limited availability of public funds.

Indeed, South Korean companies have expressed concerns that the available funding is insufficient by international standards. The total support for industrial sector R&D in decarbonization **in 2023 amounted to KRW 1.259 billion** (approximately €846 million), allocated as follows:[109]

- **Steel:** Around KRW 269.2 billion (approximately €189 million);
- **Petrochemicals:** Around KRW 255.8 billion (approximately €171.9 million);

[108] *See: Presidential Committee on Carbon Neutrality, South Korea,* 국가 탄소중립·녹색성장 기본 계획 의결 *The 1st National Basic Plan for Carbon Neutrality and Green Growth: 2050 Carbon Neutrality Commission, March 2023, https://www.2050cnc.go.kr/download/BOARD_ATTACH?storageNo=1936.*

[109] *Interview with the Carbon Neutrality Team of the Korean Chamber of Commerce and Industry.*

- **Cement:** About KRW 403.8 billion (approximately €271.4 million);
- **Semiconductors:** Around KRW 336.5 billion (approximately €226.2 million).

This level of funding is perceived as limited by industry stakeholders, who are advocating for increased financial support to remain competitive on a global scale.

South Korea, in-between Two Models

South Korea's approach to financing its clean industrial policy appears to be oscillating between the Japanese model, which emphasizes Green Bonds, and the European model, which relies on direct carbon revenue. However, the country is likely to adopt a hybrid approach that includes the following elements:

- **Reducing free allocations** in the South Korea Emissions Trading Scheme.
- Introducing **carbon contracts for difference with new funding sources**, potentially reallocated from fossil-fuel-related budgets.
- Establishing **agreements with major companies to encourage private investment**.
- Emphasizing a **Green Taxonomy that would be more stringent and binding**.

e. China

China has not yet set explicit targets for absolute emissions reductions in its industrial sector and is unlikely to do so before 2030. However, this does not mean the country lacks a "clean industrial strategy," particularly for innovation and project demonstrations. China's timeline for industrial decarbonization differs significantly from those of developed countries, with the country often viewing the technology transition more as a driver of future growth than as an immediate burden.

China has significantly increased its R&D spending over the past few years, with both public and private investments contributing to this surge. By 2023, China's total R&D expenditure exceeded RMB 3.3 billion (around €419 billion), marking an 8.1 percent year-on-year increase.[110] This has brought **China's R&D spending close to matching that of the US and the EU**, demonstrating the country's commitment to closing the gap in global research and innovation.

Large Chinese corporations, particularly those in advanced industries and SOEs, are also playing a key role by allocating substantial budgets to R&D, often surpassing those of European companies. **In 2021, China overtook the EU in R&D spending among major global companies**.[111]

China's approach integrates R&D as a core element within its broader industrial strategy, rather than isolating it as a separate initiative. This is also true for decarbonization innovation. This system fosters collaboration between the public and private sectors to enhance technological capabilities across industries. **Often centered around**

[110] *State Council of the People's Republic of China, "China's R&D Expenditure Exceeds 3.3 Trln Yuan in 2023: Minister," March 5, 2024, https://english.www.gov.cn/news/202403/05/content_WS65e6ff4dc6d0868f4e8e4b66.html.*

[111] *"EU Private R&D Investment Grows in Record Year – But Remains Short of US and China," Science | Business, January 4, 2024, https://sciencebusiness.net/news-byte/industry/eu-private-rd-investment-grows-record-year-remains-short-us-and-china.*

state-owned enterprise-led clusters, it attracts private initiatives – including foreign companies – by driving demand and leading breakthrough innovations in its vicinity.

The Chinese industry decarbonization strategy varies across sectors, and stranded assets remain a genuine concern for China's industrial base. Nonetheless, **Chinese stakeholders appear confident that the scale of the country's industry, combined with its strong industrial policy support, will allow them to navigate the challenges and uncertainties associated with technology adoption**.

China's Technology Guidance

As with all of China's industrial plans, policies aiming to promote innovation in and demonstration of decarbonization technologies are conceived centrally by the government and then disseminated to the provinces and state-owned economic entities that have to implement and create the conditions for them to emerge. **These initiatives primarily aim to achieve a "technological breakthrough" as the key solution for decarbonization**, rather than imposing strict regulations, although some constraints do exist.

The government sets extensive guidelines outlining technologies to promote and those to phase out within the industrial sector. **These lists**, which range from advisory to more binding, **determine what can be supported by provincial governments and industrial funds**, influencing the development strategies of both private and state-owned companies.[112]

[112] *State Council of the People's Republic of China,* 工业领域碳达峰实施方案 *[Implementation Plan for Carbon Peak in the Industrial Sector], August 2022, https://www.gov.cn/zhengce/zhengceku/2022-08/01/5703910/files/f7edf770241a404c9bc608c051f13b45.pdf; National Development and Reform Commission of the People's Republic of China,* 产业结构调整指导目录 *(2024* 年本*) [Guiding Catalogue for Industrial Structure Adjustment (2024 Edition)], December 2013, https://www.ndrc.gov.cn/xxgk/zcfb/fzggwl/202312/P020231229700886191069.pdf.*

Comprehensive in scope, these lists are designed to "guide" industries and companies in the desired direction or "oblige" them to take certain actions – depending on the "legal strength" of the text. Most of them serve as tools for the state to maintain, or in some cases, to try to regain control over the industrial apparatus. **In the selection process, local and national industry associations (a type of government body) play a significant role, alongside provincial industrial authorities**.

When it comes to implementation, China adopts a different approach to mitigate risk-taking and stimulate industrial transition or to create "first movers." **Vertical integration between private companies and SOEs** is typically the modus operandi, directed by **state and provincial government interventions** to ensure appropriate location and substantial financial support. This support spans from the innovation phase through demonstration and scaling up and even extends to price guarantees for the goods produced. This **"hubification" or "clusterization" of China's industrial strategy transcends the sole issue of decarbonization**. Indeed, decarbonization is part of a broader agenda aimed at keeping industrial sectors thriving – or reforming them – thus enhancing competitiveness, advancing technology, and managing overcapacity.

In this sense, the Chinese strategy, at least at the national level, adopts a pragmatic approach toward industry decarbonization. It does not focus on transitioning existing carbon-intensive assets (or those still being built) but rather on **creating entirely new green industrial hubs in appropriate locations. Thus, the risk is shared and mostly absorbed by state policy**, with a **clear direction to create parallel industrial supply chains: a green supply chain alongside a carbon-intensive supply chain**.

The Chinese "Green" Industrial Policy – or rather energy efficiency – can be looked at within the context of broader industrial strategies like Made in China 2025,[113] which aims for innovation-driven development and technological self-sufficiency, heavily supported by substantial industrial subsidies. In 2019, these subsidies were estimated at RMB 1.7 billion (approximately €221 billion), or 1.73 percent of China's GDP, significantly higher than those in major EU and OECD countries.[114] The opaque nature of Chinese public finance makes it particularly challenging to estimate the real extent of public money provided to industries to decarbonize.

What is evident, however, is that China's financial support to its industry, **including both demand-side and supply-side subsidies**, enables Chinese firms that acquire new technologies to **rapidly scale operations, dominate the domestic market, and expand into international markets**. This means that in China, the value of company money invested in innovation – or in acquiring innovation from a third party – is amplified by massive state support, leading to visible differences in the effectiveness of the Chinese strategy.

The extensive subsidization has strengthened China's industrial capabilities, including in emerging industrial green technologies such as hydrogen. This has also raised concerns about global trade dynamics and market fairness in future green markets, highlighting potential competitive imbalances that may prompt policy responses from other economies and be potentially detrimental to overall global decarbonization goals.

The current fall in Chinese domestic demand stemming from the downturn in the infrastructure and real estate sectors has now increased the overcapacity issue in key sectors such as steel and cement. For the steel sector, this now creates the significant issue of exporting this overcapacity to Europe. In the future post-carbon industrial landscape, China's industrial strategy could provoke additional tensions, particularly

[113] *State Council of the People's Republic of China, "Made in China 2025 Plan," 2016, https://www.gov.cn/zhuanti/2016/MadeinChina2025-plan/.*

[114] *Frank Bickenbach, Dirk Dohse, Rolf J. Langhammer, and Wan-Hsin Liu, "Foul Play? On the Scale and Scope of Industrial Subsidies in China," Kiel Policy Brief no. 174, April 2024, https://www.ifw-kiel.de/fileadmin/Dateiverwaltung/IfW-Publications/fis-import/bc6aff38-abfc-424a-b631-6d789e992cf9-KPB173_en.pdf.*

if "green industrial sectors" are developed for international markets while carbon-intensive industries continue to dominate domestically or through Chinese investments in third countries – for example, in Southeast Asia – where they might utilize remaining carbon budgets. This approach could provide China with a competitive edge over regions with stricter industrial emissions regulations, potentially exacerbating international trade frictions.

Chinese Industrial Funds

China has a vast array of industrial funds designed to support its industrial base. These funds are integral to the country's broader industrial policy and also played a role in early efforts to decarbonize the industrial sector and promote greater energy efficiency.

Among these industrial funds, the **Chinese Industry Innovation Fund** is a major initiative whose objectives encompass advancing industrial decarbonization efforts. It plays a role in promoting the development and adoption of clean energy technologies and reducing carbon emissions across various sectors. One of the fund's primary goals is to **support projects that enhance energy efficiency and drive green technology innovation**. However, as is often the case in China, this fund serves not only decarbonization goals but also functions as a "dual-use" instrument, funding energy efficiency initiatives alongside other priorities of the Chinese authorities. For instance, the fund supports the **China Integrated Circuit Industry Investment Fund, which *focuses on advancing semiconductor technologies that are key to low-carbon solutions in industrial processes***.[115]

[115] *State Council of the People's Republic of China, "China Pledges to Support Central SOEs in Issuing Sci-Tech Innovation Bonds," November 12, 2022, https://english.www.gov.cn/statecouncil/ministries/202211/12/content_WS636ef0cbc6d0a757729e2f1a.html.*

The fund is also integral to China's broader decarbonization strategy, as outlined in the 14th Five-Year Plan Plan. By providing financial support for research and development, the fund aims to **bridge the gap between technological innovation and practical implementation. It facilitates collaboration between large SOEs and small and medium-sized enterprises (SMEs)**, promoting a cohesive approach to achieving the nation's environmental goals.[116]

The second phase of the ***National Industry Innovation Fund*** has a registered capital of RMB 315 billion (approximately €40 billion), primarily focused on technological innovation and the transformation of SOEs in strategic sectors. **This fund is structured to attract further investment from central and local enterprises, boosting growth in key industries such as advanced manufacturing, new materials, and green technologies**. Additionally, the *National SME Development Fund* has invested in numerous projects, accumulating investments totaling RMB 1,500 billion (approximately €190.6 billion) across nearly 200 projects by mid-2023.[117]

Chinese Green Funds

Green funds were introduced in China to address the shortage of long-term financing options in the industrial sector. Although **green credit remains the dominant funding source**, largely because it was established earlier,[118] **green funds have emerged to encourage technological innovation by offering long-term financial stability**. Industries such

[116] *State Council of the People's Republic of China, "China to Create 1m Innovative SMEs by 2025," December 18, 2021, https://english.www.gov.cn/statecouncil/ministries/202112/18/content_WS61bd149fc6d09c94e48a2643.html.*

[117] *2023年产业基金研究报告 [2023 Industrial Fund Research Report], 21st Century Business Herald, April 24, 2023, https://www.21jingji.com/article/20230424/herald/1b00f548b076252f0839f2a9f9367553.html; Zhu Yanran, 315亿规模基金助力，国资央企加大战略性新兴产业布局 [A 31.5 Billion Yuan Fund Supports the Expansion of State-Owned Central Enterprises in Strategic Emerging Industries], Yicai Global, July 29, 2023, https://www.yicai.com/news/101822055.html.*

as semiconductors have already successfully leveraged innovation funds, with the *National Integrated Circuit Industry Investment Fund* serving as a notable example.[119] Green funds aim to replicate this success by supporting similar advancements in decarbonization technologies in industrial sectors.

China's green funds can be categorized into four main types:[120]

- ***Green Guidance Funds Initiated by the Government:*** These funds aim primarily to guide and leverage social capital, investing in industries, projects, and technologies that are pivotal to green development. The ***National Green Development Fund*** exemplifies this category, with additional support from provincial and local funds such as the Beijing Municipality Green Development Fund. These funds **play a crucial role in incubating industries and promoting green technologies that align with long-term sustainability goals**.[121]
- ***Public–Private Partnership (PPP) Model Green Funds:*** This category of funds **aligns closely with government priorities**, benefiting from the involvement of public actors, which enhances their credibility among private investors. **Typically reserved for more mature projects**, these funds have supported efforts such as sewage treatment, waste incineration, and ecological restoration. The PPP model facilitates collaboration between the public and private sectors, ensuring that political priorities are reflected in investment choices while providing stability and risk mitigation.

[118] *More detailed information available here (in Chinese): Dong Ruihua,* 中国绿色产业基金发展现状分析 *[Analysis of the Current Development Status of Green Industry Funds in China], ThePaper.cn, June 22, 2021, https://m.thepaper.cn/baijiahao_13263114.*

[119] *Zhang Guoguo and Zheng Shilin, "National Industrial Investment Fund and Corporate Innovation," Journal of Finance and Economics 47, no. 6 (2021), https://qks.sufe.edu.cn/mv_html/j00001/202106/f43f288f-fe54-4f7d-adb9-8918b6cf4b4b_WEB.htm.*

[120] *Dong Ruihua, "Analysis of the Current Development Status of Green Industry Funds in China."*

[121] *International Center for Science & Technology Information, China.* 北京绿色科创基金成立 *[Analysis of the Current Development Status of Green Industry Funds in China], December 27, 2021, https://www.ncsti.gov.cn/kjdt/xwjj/202112/t20211227_54261.html.*

- ***Industrial Development Green Funds:* Established by large industrial companies – including SOEs** – these funds align with corporate strategies and focus on green projects that suit the company's business model. **The investment approach revolves around incubation or mergers and acquisitions, with strong integration into the company's industrial platform**. This allows for smoother exit strategies for green projects, while also enhancing the company's social reputation.
  - A notable example is the ***Baowu Low-Carbon Metallurgical Innovation Fund*** (中国宝武低碳冶金创新基金), established in 2021 with an annual allocation of RMB 35 million (approximately €4.4 million), which focuses on fostering innovation in low-carbon technologies.[122]
- **Green Private Equity (PE) and Venture Capital (VC) Funds: Initiated by financial institutions or private individuals**, these funds operate under a market-oriented model, similar to traditional private equity funds. They involve market-driven fundraising, investment, management, and exit strategies. One prominent example is the *Carbon Neutrality Technology Fund*, established by Sequoia China and Envision Technology Group, which has a total scale of RMB 10 billion (approximately €1.3 million).[123]

[122] *Baowu Group, 2022年度中国宝武低碳冶金创新基金项目指南和申报通知 [2022 Annual China Baowu Low Carbon Metallurgy Innovation Fund Project Guidelines and Application Notice], November 18, 2022, https://www.baowugroup.com/glcmia/detail/260423.*

[123] *远景和红杉中国合作成立100亿碳中和基金 [Yuanjing and Sequoia China Collaborate to Establish a 10 Billion Yuan Carbon Neutral Fund], November 12, 2021, https://startup.aliyun.com/info/102038.html.*

[124] *National Green Development Fund, 基金公司的股东背景 [Background of Shareholders in Fund Companies], accessed September 9, 2024, https://www.ngd-fund.com/shareholder.*

In July 2020, China's Ministry of Finance, Ministry of Ecology and Environment and the Shanghai Municipality, alongside 11 provinces along the Yangtze River Economic Belt, initiated the **National Green Development Fund**. With participation from most big Chinese financial institutions and large enterprises, this fund has 26 shareholders and is aimed at promoting sustainable development across the region.[124] The first phase, sized at RMB 88.5 billion (approximately €11.25 billion), is focused on projects within the Yangtze River Economic Belt.[125] Some of the key objectives of the fund are directly related to industrial decarbonization:[126]

- **Green Industry Development:** The fund promotes the development of green industries that respond to market demand, stimulating growth in sectors that contribute to environmental sustainability.
- **Green Technology R&D:** Research and development in "green" technologies is a core focus, focusing on energy efficiency and the integration of green energy.
- **Industrial Support for Ecological Initiatives:** The fund systematically supports industrial efforts aimed at enhancing ecological and environmental quality.

[124] *National Green Development Fund, 基金公司的股东背景 [Background of Shareholders in Fund Companies], accessed September 9, 2024, https://www.ngd-fund.com/shareholder.*

[125] *Dong Ruihua, "Analysis of the Current Development Status of Green Industry Funds in China."*

[126] *International Energy Agency, "Launching of the National Green Development Fund," April 5, 2022, https://www.iea.org/policies/12360-launching-of-the-national-green-development-fund.*

Table 19: Summary Table of green industrial funds in China[127]

Fund Type	Initiator	Fund Investment
Green Industry Guidance Fund	Governments at all levels	Oriented towards public welfare industries with long-term significance, critical technologies, key areas, important domains; long investment return cycle, relatively high risk.
PPP Green Project Fund	Local governments or construction units	Public welfare nature, limited investment period, low investment return rate, but stable cash flow.
Industry Development Green Fund	Large enterprise groups	Combination with certain green industries of the same business, focus on ecological development and economic returns, while laying out green industry, taking industry responsibility.
Green PE/VC Fund	Financial institutions, individuals	Market-oriented projects, promising industries, green equity projects with relatively good investment returns.

3.5. GREEN STANDARDIZATION AND DEMAND-SIDE CREATION

There are three main instruments for driving demand-side creation for industrial decarbonization that are used or considered by policymakers examined in this study: **public procurements, green standardization**, and **green purchasing mandates**. These instruments can work hand-in-hand with each other.

a. Green Standardization

The necessity of standardizing green goods emerges as a pivotal aspect of industrial decarbonization policies. Standardization is a very broad concept. For this paper, it refers to establishing (internationally)

[127] *Created by the author from the Chinese sources cited above.*

recognized specifications and criteria for what constitutes "green" products. This process is essential to ensure that goods labeled as sustainable meet a certain threshold of environmental impact, which facilitates clearer consumer choices and aids in preventing "greenwashing" – where products are misleadingly marketed as more environmentally friendly than they are. They are also **crucial for making industrial goods comparable**, internationally or domestically.

Standards for green goods also enable fair competition among producers and help regulatory bodies enforce compliance. However, establishing these standards can be challenging due to different regional priorities and technological capabilities. Without some alignment in standards, there can be significant variations in how green goods are defined and evaluated, potentially leading to trade barriers and market fragmentation.

International bodies and agreements play a crucial role in harmonizing these standards, ensuring that the transition toward green industries is both effective and equitable on a global scale. Big industrial players and big buyers also have a central role to play in defining and harmonizing these standards as they structure the value chain. This harmonization not only supports environmental goals but also enhances economic cooperation and development worldwide. **However, most current initiatives seem to have given up on harmonization for a larger concept of "interoperability." This suggests that clean industrial standards will likely develop in Europe alongside other regions, potentially leading to friction and necessitating greater interoperability in the future**.

The EU Sustainable Product Regulation

The European Union introduced the Ecodesign for Sustainable Products Regulation on July 18, 2024 as part of its broader initiative to foster a circular economy. This regulation replaces the former Ecodesign Directive and significantly expands the scope of products it covers. While the former directive focused mainly on energy-related products, the ESPR aims to **regulate a diverse range of goods, enhancing their durability, reusability, repairability, and recyclability**.[128]

One of the key features of the ESPR is the introduction of the **Digital Product Passport (DPP), a measure that has been heavily criticized by Asian industrial stakeholders**. It acts as a digital identity card for products, storing vital information to support their sustainability and circularity. The DPP will include data on a product's technical performance, materials, repair activities, recycling capabilities, and life-cycle environmental impacts. By making this information accessible to consumers, manufacturers, and regulatory authorities, the DPP aims to facilitate informed decision-making and enhance compliance with sustainability standards.

The regulation also includes provisions for green public procurement, **enabling public authorities to prioritize the purchase of sustainable products**. This policy is projected to significantly boost the demand for sustainable goods and incentivize companies to invest in eco-friendly products, further supporting the EU's circular economy objectives.

China vs. the West: International Standards for Green Industrial Goods

The emergence of green standards is a reality that will have significant impacts, not only on decarbonization efforts but also because **these standards have the capacity to lock in certain technologies in the global market. This can provide some companies or countries with a competitive advantage**.

[128] *European Commission, "Ecodesign for Sustainable Products Regulation," accessed September 9, 2024, https://commission.europa.eu/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/sustainable-products/ecodesign-sustainable-products-regulation_en.*

There are two key phenomena at play in the realm of green standards. The first is the tendency of some countries to use international standards agencies to **establish standards that are not ambitious enough to genuinely decarbonize the industrial sector**. The second phenomenon is the strategy of key players such as China of **imposing their own standards at the global level to support their industrial strategy and market share**.

China has a comprehensive international standardization strategy aimed at **spreading Chinese standards for industrial goods globally**.[129] In this context, the **Belt and Road Initiative acts as a vehicle** to export and promote these standards abroad and to establish green supply chains with international partners.

China's Approach to Green Standards

Standards in China play a **crucial role in the country's industrial strategy** and are a powerful instrument for upgrading the industrial sector. Currently, China has around **500 standards related to decarbonization**, including 18 national standards for carbon emissions and over 380 for energy savings. Notably, **50 percent of these standards are mandatory**, encompassing industries such as steel, aluminum, chemicals, and cement.

A key characteristic of China's approach to green standardization is its **rejection of the product-based model. Instead, China favors a technology-based approach (process-based approach)**, preferring standards for "CCUS-steel" over "green steel." This approach allows for the

[129] *State Council of the People's Republic of China,* 关于印发《碳达峰碳中和标准体系建设指南》的通知 *[Notice on the Issuance of the "Guidelines for the Establishment of a Carbon Peak and Carbon Neutrality Standard System"], April 1, 2023, https://www.gov.cn/zhengce/zhengceku/2023-04/22/content_5752658.htm.*

preservation of the market for various types of infrastructure, including those based on fossil fuel. It also **uses standards strategically to foster competition and validate low-carbon technologies in the Chinese system.**[130]

Some standards pertain to the upcoming expansion of China's national carbon markets and cover various sectors, including cement, steel, aluminum, and certain chemicals. **These standards are also used as a tool for determining which projects to invest in for decarbonization**.

They are also a central instrument for the government to **gather data related to the decarbonization of the industrial sector**. Most of these standards are enforced by provincial governments and **industry associations, which, although they are also government bodies, are intended to act as independent third parties**.

Overall, Chinese industrial standards are not genuinely aimed at achieving carbon neutrality but are instead focused on reducing the emissions intensity of industrial production, aligning with the country's dual carbon goals. Beijing's objective in establishing so many standards simultaneously is also highly political, preparing for upcoming international discussions on standardizing green industrial goods.

[130] *Interview with China's Standardization Administration at COP28.*

The Global Arrangement on Steel and Aluminum

Table 20: Table of initiatives to standardize and promote green steel demand

Initiative	Description
OECD Steel Committee[131]	Focuses on creating policies and frameworks for decarbonizing the steel industry and promoting sustainable practices.
Responsible Steel[132]	Provides certification for steel producers based on environmental, social, and governance criteria.
Industrial Deep Decarbonization Initiative (IDDI)[133]	Develops methodologies and protocols for evaluating embedded carbon emissions in steel products.
Green Procurement Pledge (GPP)[134]	Encourages governments to use low-emission materials in public construction projects.
First Movers Coalition[135]	Aims to drive demand for zero-carbon technologies by committing to purchase green steel and other low-carbon products.
SteelZero[136]	An initiative for businesses to make commitments to procure 100% net-zero steel by 2050.
Global Steel Climate Council (GSCC)[137]	Advocates for a single global standard for measuring and reducing carbon emissions in steel production.
Global Arrangement on Sustainable Steel and Aluminum (GASSA)[138]	Aims to create a sectoral trade deal between the US and the EU to lower carbon emissions in the steel and aluminum industries and address "non-market excess capacity" (particularly Chinese).
Low Emission Steel Standard (LESS)[139]	Proposed by the German Steelmakers Association in the realm of an EU Standard proposal, which they are actively advocating for adoption at the EU level. This standard builds on key conceptual advancements developed during the BMWK stakeholder consultation process and is aligned with the framework outlined in the IEA's 2022 report for the G7. The proposal seeks to harmonize industry practices across Europe, leveraging these insights to drive innovation and sustainability in the steel sector.

International standards discussions are happening in different forums, and private initiatives are followed by international institutions, particularly in the OECD and the IEA. The negotiation of **the *Global Arrangement on Steel and Aluminum* between the US and the EU is intended to create the world's first sectoral trade deal focused on reducing carbon emissions in the steel and aluminum sectors**. The primary goal is to incentivize low-carbon production and consumption while penalizing higher-emissions alternatives.[140]

The agreement does include provisions aimed at standardizing and promoting green steel production. It emphasizes the importance of establishing a unified emissions standard that is technology and production method agnostic. This means that **the standard would focus on the actual carbon emissions of the steel production process rather than**

[131] *OECD, "Multilateral Guidelines (Extract from the Annex to the Decision establishing a Steel Committee)," accessed September 9, 2024, https://legalinstruments.oecd.org/en/instruments/OECD-LEGAL-5007.*

[132] *ResponsibleSteel, accessed September 9, 2024, https://www.responsiblesteel.org/.*

[133] *United Nations Industrial Development Organization (UNIDO), "Industrial Deep Decarbonization: An Initiative of the Clean Energy Ministerial," accessed September 9, 2024, https://www.unido.org/IDDI.*

[134] *Green Procurement Pledge, "Turning the Tide on Climate change," accessed September 9, 2024, https://www.industrialenergyaccelerator.org/gpp-pledge-campaign-landing/.*

[135] *World Economic Forum, "First Movers Coalition," accessed September 9, 2024, https://initiatives.weforum.org/first-movers-coalition/home.*

[136] *Global Alliance for Buildings and Construction (GlobalABC), "SteelZero," December 12, 2022, https://globalabc.org/index.php/sustainable-materials-hub/resources/steelzero.*

[137] *Global Steel Climate Council, accessed September 9, 2024, https://globalsteelclimatecouncil.org/.*

[138] *European Commission, "Joint EU-US Statement on a Global Arrangement on Sustainable Steel and Aluminium," October 31, 2021, https://ec.europa.eu/commission/presscorner/detail/en/ip_21_5724.*

[139] *Wirtschaftsvereinigung Stahl, "LESS: Low Emission Steel Standard," accessed September 9, 2024, https://www.stahl-online.de/less_en/.*

[140] *Global Steel Climate Council, "Press Release: New Steel Coalition Promotes a Transparent and Climate-Focused Standard to Measure and Reduce Carbon Emissions," November 17, 2022, https://globalsteelclimatecouncil.org/newsroom/press-release-standard/.*

how the steel is produced. This approach aims to level the playing field among steel producers and encourage the adoption of cleaner technologies across the industry.

The EU has expressed caution in response to the US proposal for the GASSA. One key concern is that the US approach heavily favors its domestic steelmakers, who have a robust secondary steel production base, in a manner that is potentially disadvantageous to European producers. Additionally, the US request for broad exemptions from the EU CBAM has been met with resistance. The EU remains reluctant to grant such exemptions, viewing them as undermining the bloc's climate goals and competitive fairness within the steel and aluminum sectors. These points of contention have slowed progress on the agreement.[141]

The arrangement also seeks to **address the global overcapacity of steel production**, particularly targeting the carbon-intensive steel produced by countries like China. The agreement tried to implement a common approach to carbon border adjustments – a measure Europe has moved on alone so far and unsuccessfully. The primary issues delaying the agreement include the following:

- **differences in how to address carbon intensity and global overcapacity**
- the application and removal of tariffs imposed under the Trump administration's Section 232 measures
- desire on the part of the US to be exempted from the EU CBAM
- the **compatibility of the proposals with World Trade Organization (WTO) rules**
- **political uncertainty in the US**

[141] *For more on the GASSA negotiations, see: Andrei Marcu, Michael Mehling, Aaron Cosbey, and Sara Svensson, "Options and Priorities for the EU-U.S. Global Arrangement on Steel and Aluminium (and Implications for the CBAM)," November 22, 2023, https://ercst.org/options-and-priorities-for-the-eu-u-s-global-arrangement-on-steel-and-aluminium/.*

Even though no Asian countries participated in this discussion – but could theoretically join later – **most stakeholders in Korea and Japan believe that such an agreement would significantly impact their approach to decarbonization**, potentially accelerating their actions. However, given the challenges in reaching an agreement between the US and Europe and the slow progress at the plurilateral level within the OECD platform, **Japanese and Korean stakeholders are also looking to Brussels for a potential first "European Green Steel Standard."** This standard could set a precedent and shift political momentum in their own countries.

Challenges in Establishing and Monitoring Green Industrial Standards

Implementing standards is a multifaceted process that **requires time** due to the variety of standards that exist:

- There are **standards that define the specific attributes of products**, such as composition, shape, and compliance requirements.
- There are **standards focused on processes** (like ISO 50001, which pertains to energy management systems), as well as **standards governing practices**, including energy efficiency and environmental sustainability practices.

A company's compliance with certain standards does not automatically equate to energy efficiency. **Compliance indicates adherence to the specified criteria of the standard**, which may or may not directly relate to **improving energy efficiency**, let alone carbon neutrality. **Additionally, for many industrial products, due to the significant technology uncertainty that still remains, it may be too early to standardize**.

The complexity in differentiating between **low-carbon and high-carbon products stems from the fact that they can be chemically and physically identical, despite being produced through vastly different**

processes. This poses a significant **challenge in accurately measuring and comparing products' carbon footprint**. When products emerge from the production line with the same specifications, the distinction in their environmental impact **relies entirely on the nuances of their production methods** – ranging from the energy sources used to the efficiency of the processes involved. This complexity underscores the **importance of developing sophisticated assessment tools and methodologies. This also presents a broader challenge of recognition under established frameworks like WTO rules, which require the equal treatment of "products that are alike."**

Once a standard is established for broader implementation, a crucial review process begins, reflecting on the processes defined (such as what qualifies as low emissions or green). As the scope of application evolves, these **standards require regular updates to remain relevant and effective**. Decarbonization, being an evolving trajectory, introduces additional complexities that need to be addressed continuously.

Finally, **delegation issues** arise when a **dominant player in an industrial sector is reluctant to delegate international standardization talks to the government**, turning this into a highly political matter. For example, in South Korea's steel sector, POSCO's dominance creates such a scenario. Consequently, there is no single point of contact in the country, complicating negotiations with international partners.

Table 21: Challenges to resolve to establish international Green Industrial Standards

Initiative	Description
Variety of Standards	Implementing standards is multifaceted due to different types of standards (product attributes, processes, practices).
Time-Consuming Process	The standardization process is very long.
Compliance vs. Efficiency	Compliance with standards doesn't necessarily equate to energy efficiency or carbon neutrality.
Technology Uncertainty	Significant technology uncertainty makes it too early to standardize many industrial products.
Identical Products, Different Processes	Low-carbon and high-carbon products can be chemically and physically identical, making it hard to measure and compare carbon footprints.
Complex Measurement	Differentiating environmental impact relies on nuanced production methods, requiring sophisticated assessment tools.
Continuous Review and Updates	Standards need regular updates to stay relevant as decarbonization efforts and technologies evolve.
Evolving Scope	Standards must adapt to the evolving scope of applications and practices in decarbonization and sustainability.
Certification companies (MRV)	Establishing certification companies to monitor standards application - Monitor, Report and Verify - is one of the most difficult tasks for some countries that are less advanced than Europe.
Data confidentiality	Companies are usually unwilling to share their energy-related data internationally, asking for a domestic verification system and Mutually Recognized Agreement.

Toward Performance-Based Standards: The Need for an Open-Technology Approach that Enables Newcomers

To trigger faster decarbonization of the cement sector, Europe could overhaul its **current restrictive standards for cement manufacturing**, which are predominantly shaped by incumbent industry players. These standards impose stringent limits on permissible carbon levels and approved technologies, often marginalizing smaller companies with innovative low-carbon solutions. The existing regulatory framework creates an unrealistic barrier for these smaller players, stifling competition and innovation. By shifting toward performance-related standards that prioritize the end performance of cement rather than its composition or production process, **the industry can foster greater flexibility and innovation, enabling the use of alternative low-emissions materials in cement recipes**. This change would enable new technologies and methodologies to emerge, thus accelerating the sector's transition to low-carbon solutions.

Moreover, **the pace of standardization must be expedited to facilitate quicker adaptation of new technologies and practices**. The current standardization process, which can take up to six years, is significantly hindered by resistance within the sector and regulatory capture. This slow pace does not just delay the adoption of innovative practices. Reducing the timeframe for implementing new standards would allow the industry to keep pace with technological advancements and regulatory changes, thus supporting faster decarbonization. Europe must adopt a more dynamic and responsive regulatory framework to drive the cement industry toward sustainable practices and meet its climate goals effectively.

b. Green Public Procurement

Public procurement is an element of the post-carbon industrial policy toolbox. It also plays a crucial role in de-risking industry decarbonization by **guaranteeing a stable minimal demand for low-carbon products**, thereby reducing financial and operational risks for manufacturers. Governments can create a reliable market for sustainable goods by committing to purchase them, thus incentivizing companies to invest in green innovations and production methods. This consistent demand helps scale up new technologies, reduces production costs through economies of scale, and signals market confidence, which can attract further private investment.

In Europe, **the Net-Zero Industry Act seeks to promote green public procurement across the EU by establishing minimum environmental sustainability requirements for the procurement of net-zero technologies**.[142] Public tenders must meet specific ecological and social criteria related to dimensions such as resilience and sustainability, unless they result in a significant cost increase. Additionally, the act includes a resilience criterion that limits dependence on imports from non-EU countries, encouraging procurement within Europe to foster local production and reduce strategic dependencies.[143]

This instrument is also particularly supported by industrial sectors in Asia. **Japan and South Korea have already established public procurement policies** for certain industrial goods related to energy efficiency or the use of recycled materials. Governments are now exploring potential public procurement campaigns for products such as "green cars"

[142] *European Commission, "Proposal for a Regulation of the European Parliament and of the Council on Establishing a Framework of Measures for Strengthening Europe's Net-Zero Technology Products Manufacturing Ecosystem (Net-Zero Industry Act)," March 16, 2023, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52023PC0161.*

[143] *Miriam Russ, Anna Leipprand, and Lukas Hermwille, "Der Net Zero Industry Act: Zusammenfassung und Einordnung in die aktuelle europaïshe Debatte," SCI4climate, August 2024, https://sci4climate.nrw/wp-content/uploads/2024/08/Russ_Leipprand_Hermwille_2024_Der-Net-Zero-Industry-Act_SCI4climate.pdf.*

made with green steel and aluminum. The Ministry of Economy, Trade, and Industry and the Ministry of Environment in Japan are considering adopting a mandate to use decarbonized (or increasingly decarbonized) cement for public infrastructure. Furthermore, a call has been made for the procurement of cars manufactured with green steel and aluminum, in collaboration with Toyota.[144]

Similar approaches are being designed in South Korea for products related to the infrastructure sector. Specifically, South Korea is considering **Advanced Market Commitment** as a policy tool used to drive the development and adoption of innovative green technologies by guaranteeing a future market. In South Korea, this could involve the government defining specific criteria for green goods, such as carbon removal technologies, and forming a **coalition with large companies to promise a certain amount of funding for these products**.[145] This commitment ensures that companies have a financial incentive to invest in and produce these technologies, as they know there will be a guaranteed buyer once they meet the prescribed standards.

Whatever form it may take, a **green public procurement strategy cannot address the needs of all sectors**. For instance, the chemicals sector does not experience sufficient demand from the public sector to be supported in this way. Green public procurement for steel also presents a particular challenge due to the mismatch in product demand and production methods. Public demand mainly involves low-quality long products used in construction, typically made from recycled scrap via the secondary steel route. However, the primary steelmaking route, which faces the most significant decarbonization hurdles, produces high-quality flat products for industries like automotive manufacturing. This creates a gap between the supply of green steel from decarbonized primary production and the lower-quality demands of the public sector.

[144] *Probably utilizing mass balance green certificates.*

[145] *Interview with MOTIE.*

Public procurement is also a way for the government to **promote domestic goods rather than imported ones**. Beyond protectionist measures like tariffs, public procurement allows for easier control over sourcing and serves as a significant tool in industrial policies. It is closely related to the implementation of green standards, which is another crucial aspect of green industrial policy.

c. The Green Purchasing Mandate Approach, or "Green Quota"

Beyond standardization and public procurement, governments could also **implement a "mandate to buy green" policy**. This approach involves **requiring companies to purchase an increasing share of carbon-neutral goods**. However, such a policy must be designed with caution, as it could potentially create an influx of cheaper foreign goods. When combined with standards and local production requirements, it can become a powerful tool in the green industrial policy toolbox.

Nevertheless, this policy **could represent a significant market disruption** and might have inflationary consequences if not managed carefully, making it unsuitable for all types of products. Many companies interviewed for this analysis, particularly in Japan and South Korea, are in favor of this approach. The governments of South Korea and Japan are considering it. China has used this policy for a long time to favor some types of product over others in their massive infrastructure projects.

The Challenges of Using a Mass Balance Approach

The mass balance approach is a chain-of-custody model that is widely used in industrial decarbonization to promote the gradual substitution of fossil-based feedstocks with renewable or recycled alternatives. In this approach, conventional and low-carbon raw materials are mixed into existing carbon-intensive production systems, with the sustainable portion being allocated to specific products through a certification process. This enables companies to account for the renewable content in their products, even when physical separation is not feasible. The key benefit of this method is that it allows industries to decarbonize incrementally without needing new infrastructure right away.[146]

The support for the use of **green certification through the mass balance approach** with third-party verifiers is gaining traction in Asia, primarily due to its ability to **integrate sustainable materials into existing production processes**. This method allows a product to be labeled as "green" even if it is not entirely derived from sustainable sources by attributing a proportion of sustainable material to the final product through an accounting system. However, this approach has been criticized for its potential to facilitate greenwashing. Some argue that the mass balance method lacks transparency, leading to exaggerated environmental claims and misleading consumers about the actual sustainable content in the products.

[146] *It also helps industries make sustainability claims based on established standards such as ISO 22095.*

Another major issue is the flexibility in allocation rules, which can undermine the credibility of the certification. Some current schemes allow for the transfer of credits between different products and geographical locations, diluting the true impact of decarbonization efforts. The lack of globally standardized methods for applying mass balance also leads to inconsistencies, making it difficult to verify the true environmental benefits. Calls for stricter standards and traceability emphasize that only the actual recycled or renewable content should be credited to products to foster genuine improvements.

New standards, such as the proposed LESS standard for steel, are moving in this direction. These standards **allow for limited use of the mass balance approach as a transitory solution**, particularly in cases where both green and conventional production facilities feed into the same converter or subsequent process steps, making it impossible to distinguish between green and conventional steel batches. However, the scope of mass balancing is quite restricted beyond these specific scenarios, limiting its broader application in the certification of green steel.

3.6. RECOMMENDATIONS: CLEAN INDUSTRIAL STRATEGY FROM A COMPARATIVE PERSPECTIVE

a. Technology Choices: Strategic Investment, Priorities, and the Need to Remain Technology Agnostic

All the industrial decarbonization strategies analyzed in this report emphasize the need to mobilize decarbonization tools that enable the **simultaneous deployment** of a **multiplicity of vectors**. This includes access to **affordable clean electricity**, the massive commercialization of **clean hydrogen**, and the production and use of biofuels, both for energy supply and stocks for industrial use.

While some industrial strategies in China, Japan, South Korea, and Europe emphasize specific decarbonization vectors, **maintaining technological openness is crucial across the board due to uncertainties, varying access to clean alternatives across regions, and the diverse contexts in which industries operate**. This means that support should not favor one technology over another, as long as it achieves the goal of decarbonizing a sector. However, this does not preclude a clean industrial strategy from being consistent in heavily supporting a particular technology, such as clean hydrogen or electrification, especially for processes in which it proves particularly effective.

Adapting high-emissions industries to decarbonization processes will demand **strengthened partnerships between the private sector and governments to streamline and expedite technological advancements**. It is vital for all stakeholders involved to accelerate progress in technology, policy-making, and investment strategies and implement them swiftly to meet environmental targets. **Governments have a critical role to play in this transition by providing clear guidelines and establishing definitive financial support mechanisms to aid industries in their decarbonization efforts**.

Therefore, to move toward carbon neutrality and ensure access to CO_2-free energy, significant investment in clean hydrogen and electrification needs to be prioritized as a key strategy to drive industrial decarbonization. Additionally, CCUS technologies will play a role, particularly in the transition period, and should help preserve some industrial assets necessary for European sovereignty until fully clean alternatives are available. **Despite efforts to reduce fossil fuel consumption by 2050, the challenge of completely eliminating its use underscores the necessity for carbon-intensive sectors such as steel, cement, chemicals, and aluminum to intensify collaborative efforts in developing low-carbon technologies**.

b. The Role of Industrial Clusters

Cooperation across industries is essential in order to decarbonize carbon-intensive sectors, as **carbon emissions are embedded in the interconnectivity of the different sectors**. This "clusterization strategy" is becoming central in pilot and demonstration projects in Europe and Asia. For example, products generated by the chemicals industry are deeply embedded in the world's largest value chains, such as manufacturing and construction. As a result, **the level of deployment of low-carbon technologies will be dependent on cross-industrial collaboration**.

Europe and Asia need to anticipate future demand and foster synergies across sectors. For example, CO2 captured from steel production could be repurposed for nearby chemical applications. This **clustering approach is gaining traction in China, particularly around SOEs**, with significant backing from the central and provincial authorities. The strategy leverages SOEs' capacity to drive substantial demand and provide financial support to private actors.

The need to anticipate new challenges and cooperate across sectors will arise from multiple fronts. For example, electrification will bring additional electricity demand, and changes of processes will also affect industries, meaning that they will need to find new synergies to comprehensively anticipate new challenges. This includes anticipating challenges such as the following:

- The **loss of the excess heat generated by fossil-fuel-based industrial processes, which was** traditionally **redistributed toward other sectors**.
- The **increase in peak loads that heat pumps impose on the grid**.
- Finding **funding sources for the construction of electrification-related infrastructure**.

c. First-Mover Risk vs. Second-Mover Advantage

In **Europe**, the Green Deal and the Fit for 55 package provides significant clarity for European actors and international suppliers, signaling a carbon-neutral future. Nonetheless, investing in new decarbonization technologies still requires substantial support. **Risk-taking remains culturally complicated for some actors unless it is significantly backed by financial and nonfinancial support from the state**.

The main challenge facing many European industries is the risk that **a first-mover advantage may not materialize in the realm of industrial decarbonization**. Countries such as **Japan, South Korea, and especially China are positioning themselves to capture a probable second-mover advantage**. In contrast to the approach taken with emerging sectors such as batteries, their main strategy for traditional industries involves closely monitoring and testing what works in first-mover regions – particularly Europe, with its more stringent policies – and scaling up once the leading technology becomes evident. As a result, the European strategy must tackle both fronts: supporting first movers who are willing to take risks and quickly anticipating competition from regions that are not bound by the same regulatory constraints.

Europe's strategy toward achieving industry decarbonization hinges on three key policy mechanisms:

- The use of an **emissions trading system and Carbon Border Adjustment Mechanism that are generating revenues**
- **National subsidies**
- A long list of EU-level support mechanisms for R&D, demonstration, and deployment such as the **Innovation Fund**, the **IPCEI, STEP, and legislative packages such as the Net-Zero Industry Act and Net-Zero Europe Platform**

This is a starting point, but it is insufficient to both achieve decarbonization and address the emerging uneven playing field created by national industrial policies and diverging decarbonization priorities. **Europe must recognize the need for pragmatic trade measures during the transition period**, which will intensify around 2028 with the gradual phasing-out of free allocations in the EU ETS.

There is, therefore, a need to **coordinate industrial policy with trade policy, not only politically but also organically. If an emissions-intensive trade-exposed sector is under strict decarbonization regulations in Europe, this should be considered in EU trade policy**.

To safeguard its industries, Europe should therefore **expand the Carbon Border Adjustment Mechanism, implement green procurement policies that favor European-made green goods**, and **provide financial support to lead markets**. If the industry decarbonization agenda aligns with that of other global actors, green trade will become feasible. However, there is a significant risk that industrial decarbonization efforts may not proceed at the same pace across trade partners, necessitating protective measures. This dilemma is also abundantly clear in the cases of Japan and South Korea.

d. Combine Regulation with Industrial Strategies

A Clean Industrial Strategy Requires a Demand-Side Approach

Given the high costs of investment and the significant risks that industrials face due to technological uncertainty, it is **crucial that green industrial policies supporting the decarbonization of the most polluting industries address risk-taking**.

- Europe addresses risk mitigation through a mix of financial and nonfinancial instruments, including regulations.

- China is establishing a support network with technology guidance and is enabling large industrial players to test new technologies before full-scale implementation has been achieved and any stringent measures have been implemented.

- Japan focuses on R&D and demonstration projects and is implementing sectoral agendas for deployment but has yet to promote widespread implementation across most industrial sectors.

A critical question that remains across all jurisdictions is **how to generate sufficient demand for green goods to justify the significant investments required for carbon-neutral processes**. Europe has primarily relied on rising carbon pricing to stimulate this demand – a strategy increasingly being adopted by other nations, including Japan, South Korea, and, to some extent, China.

There is a growing **need to implement demand-side measures, such as green public procurement and mandatory green purchasing requirements, as part of a broader industrial strategy**. These approaches are already being explored in Japan and South Korea, while public procurement and purchasing mandates have long been integral components of China's industrial policy framework. Demand-side measures should be part of the European industrial strategic playbook, and the Clean Industrial Deal must have a demand-side dimension.

A Strategic Selection of the Right Clean Technology

A key challenge in designing an effective industrial strategy is determining which technologies to support, as governments cannot operate as typical market participants. This issue remains one of the most contentious among stakeholders and policymakers in both Europe and Asia. **While industries should ideally have the freedom to select their own best technologies, governments inevitably play a role in shaping those choices**.

In China, the government's consistent support for massive deployment of renewable energy is effectively influencing some industries' decisions. Governmental intervention is particularly the case in some heavily industrialized provinces that intervene more directly in industry than others, or in sector specialists provinces. Despite this, **the Chinese authorities maintain sectoral open lists of technologies that are eligible for support through green industrial funds**. These lists (sometimes provincial-based) are updated regularly due to industry demand (notably through industry associations – which are actually public governmental agencies) and eventually enable many technologies or approaches to be supported.

In Japan, technology selection is approached with caution, as the government strives to remain as technology-neutral as possible, although the availability of clean energy vectors imposes certain limitations. NEDO plays a central role in technology selection, in co-construction with industries. South Korea, although still in the early stages, appears to be following a similar path.

Europe, on the other hand, needs a system that **combines** vertical interventionist measures – **guiding and promoting decarbonizing technologies** – and horizontal **market-based regulations** (e.g., carbon pricing) to ensure competition among companies and technologies to identify the best options for each geographical area.

Moreover, a critical element of a successful green industrial policy is its **ability to adapt quickly to the changes and technological advancements** that inevitably arise in the market. **China, in this respect, is adept at being technologically flexible until it becomes clearer which technology will dominate the market**. In practice, this means that **the policy should not only focus on market leaders but also promote the emergence of new, often smaller, players** who have developed technologies closer to market needs for decarbonization.

Public–private partnerships are also essential in this context. Government agencies, industries, and even civil society should collaborate to select projects supported by the community to decarbonize industries. This collaborative approach ensures that the projects selected are aligned with broader societal goals and contribute effectively to decarbonization efforts while also being open to newcomers.

The European strategy should therefore offer technological guidance on decarbonization, particularly for the most hard-to-abate sectors, **without limiting support to any single type of technology**. This requires **regularly reviewing the basis for technology guidance, with the primary criterion being carbon abatement in the most cost-efficient manner while upholding the sovereignty objectives of the Net-Zero Industry Act**.

Easy Financing of OPEX Becomes Essential

The need for operational expenditure (OPEX) financing during the transition period has become evident for most industrial sectors. This will be a critical element in establishing lead markets. **Financing OPEX** can be justifiable under certain conditions. Primarily, it should be **considered for bridging temporary gaps**. However, if these gaps become persistent, continuing to finance them is not justifiable and becomes a waste of resources. It is crucial to assess the sustainability and long-term impact of such financing to ensure it contributes to economic stability rather than perpetuating inefficiencies.

Carbon contracts for difference are a promising tool that could indeed be extended to support industry decarbonization in more sectors, such as steel or cement. European countries, Japan, and South Korea are considering adopting them. However, in Europe, **CCfDs face significant limitations due to a lack of visibility regarding the long-term cost of carbon on the EU ETS**, making them challenging to implement. To function effectively, CCfDs require a perfect Carbon Border Adjustment Mechanism and a predictable carbon price. In the current situation, this instrument is complex and risks being restricted to a specific sector, such as hydrogen or CCUS, if no better predictability of carbon price is established. That said, using European CCfDs for green goods such as steel or green aluminum may be the best option available in the toolbox.

Direct OPEX subsidies should also be included in the playbook. China is using OPEX subsidies as a way to reshape its industrial apparatus and may well continue to do so for decarbonization when the time comes. In Europe, state aid for **financing operational expenditures presents significant challenges, particularly within the framework of EU market competition rules**. These rules make the implementation of such aid complex and often restrictive. To overcome these challenges, **a shift toward a European-level approach is essential**.

One critical question arising in Europe and Japan is whether state aid should cover expected or actual OPEX. Understanding the necessary conditions to trigger investment decisions is key to effectively addressing this issue. **A sector-based approach employing a production-based discriminatory factor could provide the necessary framework for this evaluation.** This approach would ensure that aid is distributed fairly and effectively, targeting the sectors where it is most needed and likely to stimulate growth.

In Europe, this also means **perennializing exemptions to competition law – like the IPCEI – for industry decarbonization, allowing industries to receive the necessary support to establish green lead markets**. This is especially crucial during the transition period, which will involve numerous tests, failures, and attempts by external market actors to capture market share.

e. The Importance of Green Industrial Standards

Establishing international standards for green industrial goods is crucial, especially during the transition period. Regional and national conditions will differ significantly, and technological uncertainty will be influenced by specific geographical factors.

The first mover on standard setting could well be the one that defines the global standard – this should encourage the EU to move fast. **China is actively positioning itself to shape global industrial standards, as it recognizes that standardization can promote certain technologies on the global market**. If a country succeeds in embedding technologies that it dominates into global standards, it can gain a considerable competitive advantage over other nations.

To develop effective green standards, **a period of experimentation is essential to determine which approaches work best**. However, such experiments must be thoroughly evaluated, with the goal of eventually consolidating standards to avoid fragmentation.

Considering the great political difficulties and diverse national tactics on standard setting, interoperability could well be the best obtainable version of an agreement on low-carbon industrial standards. Each country or bloc could thus develop its own standards based on local conditions, considering other instruments implemented globally, particularly among trade partners. This approach can be used to initiate discussions on making these standards interoperable, using science-based criteria such as **carbon intensity, processes, tailored emission calculation methods, and carbon pricing**.

However, this should not sidestep difficult political decisions that are crucial for resolving power dynamics and achieving true progress. In the context of industrial decarbonization, China presents a key challenge due to its dominance across many sectors. While dialogue with China on standards is necessary, it will always be influenced by geopolitical considerations, given the country's industrial dominance and policy support. **This underscores the need for Europe to lead in developing its own standards – ideally in cooperation with like-minded partners and countries engaged in the Clean Industrial Deal – before pursuing a truly global set of clean industrial standards**. A clear, consolidated set of European green standards will ensure stronger alignment and commitment across the industry and Member States, fostering more decisive action toward sustainability.

f. Preparing for the Coming of Age of an Uneven Playing Field

Despite Europe's significant strides toward decarbonization through stringent regulatory policies such as carbon pricing, it is not the only region advancing in this area. **Governments worldwide are encouraging industries to accelerate their transition to better position themselves in the emerging post-carbon economy**. This effort is particularly evident in the evolving interactions and policy frameworks within and among major industrial and trade blocs, including the EU, China, the US, South Korea, and Japan.

However, these **governments are adopting very different approaches and timelines**, and this trend is likely to continue. These varied strategies **can lead to issues such as market distortions**, where goods are priced differently across borders, causing competitive imbalances.

Without international coordination, such discrepancies can result in "carbon leakage," where industries relocate to countries with less stringent regulations, thus undermining global decarbonization efforts. This is why the EU has implemented the Carbon Border Adjustment Mechanism as it phases out free allocations in the EU ETS. However, **the CBAM may not be sufficient to shield these sectors due to various ramifications of the value chain**, and the complexity of transitioning these sectors **may lead to the simultaneous existence of "green" and "brown" economies during this transformative phase**. As nations develop their transition timelines and policies, effectively managing this coexistence becomes crucial.

Beyond the Carbon Border Adjustment Mechanism, a significant challenge is the **relative absence of a cohesive political trade policy at the European level**, which hinders the use of industrial policy to support European sectors. For example, cooperation on carbon pricing has been a key aspect of China–EU relations, but it is evident that further progress in this area will not lead to significant convergence, particularly regarding ETS linkage. Access to relevant data for CBAM from China, and even from the Chinese ETS itself, also remains doubtful. Additionally, the US Inflation Reduction Act has changed the landscape by providing financial support for both CAPEX and OPEX to a level unseen in Europe. China's continental scale and relatively opaque industrial policy further exacerbate the absence of a unified political approach to trade policy in Europe.

Coordinating industrial strategies at an international level is, therefore, imperative to ensure a level playing field and foster a global market for green goods that is both fair and competitive. Support for initiatives such as the Climate Club and a demonstrated European willingness to share knowledge with potential partners is also crucial. In this context, Europe's neighborhood becomes critical, particularly for industries such as steel and chemicals, which require access to substantial amounts of clean energy and hydrogen. **There is a need to make the EU Clean Industrial Deal an international instrument, not only for Europe's decarbonization and competitiveness but also for international partners exchanging industrial goods with Europe** (e.g., Mozambique and aluminum).

If this collaborative approach does not emerge quickly, green markets for industrial goods could become more localized, with trade limited to countries that transparently share the same practices. This would result in higher costs for industrial goods and could ultimately hinder the clean transition's popularity among populations already facing inflationary pressures.

g. A Streamlined Sectoral Green Industrial Strategy for Europe

Currently, **there is no perfect industrial policy or strategic management framework globally**. However, certain practices from other jurisdictions could significantly enhance Europe's approach.

Europe has implemented various instruments such as the IPCEI, SET Plan, and STEP to coordinate a nascent common industrial policy. Despite these efforts, they are insufficient.

Unlike **Japan, which has the Green Innovation Fund under NEDO coordinating investment, technology guidance, and policy support across different levels of power**, Europe still lacks a similar agency. Additionally, **unlike China, Europe does not have a centralized approach to technology guidance and cannot efficiently promote the allocation of resources where it makes the most sense** – for instance, where renewable or low-carbon energy resources are abundant or where clean hydrogen will be cheapest to obtain.

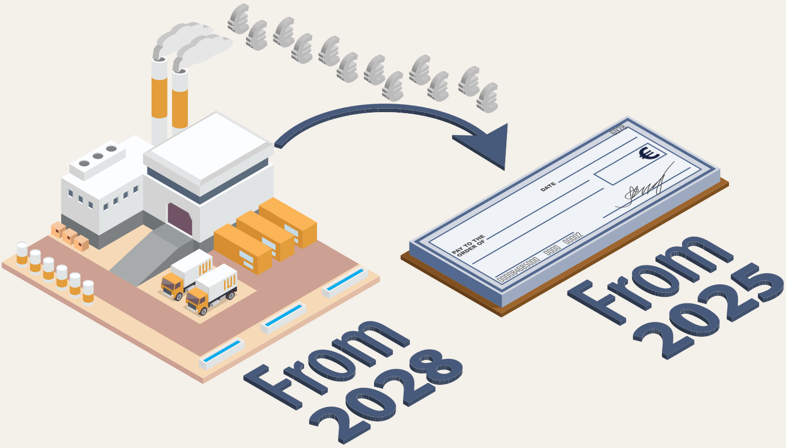
Moreover, **securing long-term support for OPEX remains challenging due to overly complex procedures** that need to be streamlined to meet objectives. Consequently, Europe's industrial policy related to innovation, demonstration, and scaling up faces numerous obstacles.

Beyond the lack of funding in the EU for developing a green industrial policy, one critical aspect is that the European **funding landscape is highly fragmented**, posing significant challenges for companies seeking financial support. Obtaining the necessary funds often requires about a year's worth of resources, a burden many find excessive. To address this, there is a **pressing need for a streamlined Clean Industrial Fund tailored to each sector**, complete with a **more open list of supported technologies and objectives at both the EU and Member State levels where appropriate**.

The EU should adopt a Clean Industrial Deal incorporating the following elements:

Recommendation 1

Establish EU-level common funding through a European Green Bond – or a Clean Industry Investment Debt of €100 billion per year, repaid by anticipating portions of future carbon revenues starting in 2028 and through the removal of free allocations in the ETS.



Recommendation 2

Use the base of the European Climate, Infrastructure, and Environment Executive Agency CINEA Platform and STEP to create an EU Clean Industrial Strategy Agency under the Executive Vice-President for Industrial Strategy and the Executive Vice-President for Clean, Just, and Competitive Transition. A dedicated European agency should not be an end in itself, but rather a strategic tool to structure and accelerate the green transition, provided it operates with clear priorities and objectives. The agency should be responsible for the following areas:

a. **Providing technology guidance** with direct and organic cooperation of industrial stakeholders and the participation of civil society. It should **regularly review the basis for technology guidance**, using carbon abatement in the most cost-efficient manner as the primary criterion while upholding the sovereignty objectives of the Net-Zero Industry Act.
b. **Analyzing existing projects**, identifying key success factors, and determining how these can be replicated while avoiding loopholes, redundancies, and inefficiencies.
c. **Coordinating EU-level funds** and support mechanisms with Member State–level funds.
d. **Merging existing instruments** such as the EU **IPCEI**, **STEP**, and **SET Plan**, and **perennializing them**.
e. **This agency should function as a one-stop European financing hub, centralizing funds and streamlining access for clean industrial projects**. Its role would be to facilitate the implementation of the objectives of the NZIA, ensuring that **financial support is directly tied to the achievement of decarbonization targets and other NZIA objectives**.
f. Implementing **a cluster-based distribution of funds** that promotes competition among Member States when beneficial and fosters cooperation when possible. This approach will enable local and regional authorities to be involved in projects at the earliest stages of the process.

Recommendation 3

Embrace a demand-side approach with instruments such as a **Made-in-Europe Green Public Procurement Policy** for clean industrial goods.

Recommendation 4

Use trade policy as an instrument of industrial strategy based on two elements:

a. **Trade policy should consider scrap as a carbon asset**, and its status as such should be preserved within the European market during the transition period. This would avoid many circumvention issues in the Carbon Border Adjustment Mechanism.

b. **Favor trade with regions and countries adopting similar industrial decarbonization agendas and/or cooperating under the Clean Industrial Deal or member countries of the Climate Club.**

Recommendation 5

Beyond further electricity market integration, **there is a need to support and anticipate the demand for industry electrification**. The European Commission should **<u>establish a comprehensive monitoring framework to track electrification progress in industry</u>:**

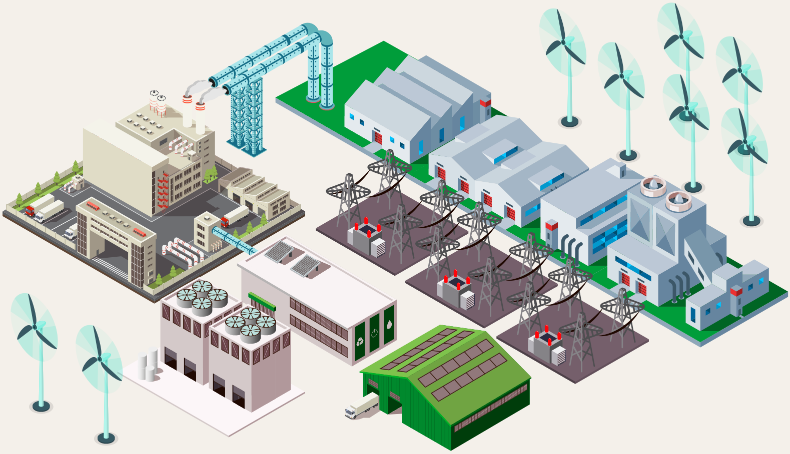
a. Ensuring **coordination among Member States and enforcing electrification targets**.

b. Closely monitoring technological and industrial advancements in this field to ensure that the electrical infrastructure can support the transition.

c. Proactively anticipating future needs and the potential impacts of increased demand resulting from electrification.

Recommendation 6

Adopt a **Cross-Sectoral Technology-Hub Strategy:**



a. Cross-sectoral and within-sector collaborations are crucial for fostering technological innovation, essential for the mass production and market introduction of carbon-neutral technologies and processes such as green hydrogen, as well as for advancing CCS and CCUS technologies to **practical application levels**.

b. Promoting mutualization of clean electricity generation in locations where this is easily achievable.

Recommendation 7

Follow two principles to **establish clean industrial standards:**

a. **Break technology path dependency** – Standards often evolve from earlier technologies and practices, meaning that the history of prior standards heavily influences the design and adoption of new ones. Once a standard becomes widely accepted, it can lead to inertia, making it difficult for newer technologies to break through, even if they are more efficient or innovative.

   i. In the case of industry decarbonization, there is a need to **enable emerging technologies to enter the market**. This requires **reviewing standards on a rolling basis**, preventing the lock-in of old technologies, and allowing newcomers to compete. This approach is relevant for most industrial products.

b. Adopt and promote a product-based approach and accelerate the implementation of ecodesign regulations:

i. The European Union should promote a product-based approach to standardizing green industrial goods to **ensure a uniform, high standard of environmental sustainability across the market**. This approach would facilitate the creation of products that are not only carbon neutral but also competitive on a global scale, reinforcing the EU's position as a leader in green technology and sustainability. By **focusing on the end products**, the EU can more effectively regulate the environmental impact of goods, ensuring they meet strict sustainability criteria **regardless of the manufacturing processes used**. This also enables avoidance of technological lock-in.

ii. This method would also drive innovation as manufacturers seek cost-effective ways to meet these standards, ultimately benefiting the economy and the environment. Additionally, it would **accelerate the implementation of ecodesign requirements and the promotion of sustainable products through standards set by the Ecodesign for Sustainable Products Regulation**, fostering a greener market and driving the shift toward a circular economy.

Appendix 1
Korean policy toward industry decarbonization

Korean policy towards industry decarbonization

Text	Industry Decarbonization measures
The 2030 Basic Roadmap for Achieving the National Greenhouse Gas (GHG) the Reduction Target (2030 Roadmap (June 2018)[147]	Specific GHG reduction plans for 8 sectors and 30 sub-sectors by 2030.
	Framework for the operation of **K-ETS from 2018 to 2020**.
	In the industrial sector to **reduce emissions by 56.4 MTCO$_2$e** through energy **efficiency improvements**, gas development through environmentally friendly processes, refrigerant replacement, innovative technologies, and waste resource use by 2030 compared to 2016 level. In the industrial sector, the *roadmap* scopes to **reduce GHG emissions by 99 million tons**, including **11 million thanks to the improvement of industrial processes** and of energy efficiency and **10 million with the spread of innovative reduction technologies**, primarily CCUS technology and waste recycling system.
Hydrogen Economy Roadmap[148], 2019	Ensure the growth of the domestic hydrogen market in the long-term in order to establish an **ecosystem of hydrogen industry**, encompassing energy production, storage, transportation, safety and mobility. Vast majority of planned hydrogen production mainly focuses on fossil-fuel generated blue and gray hydrogen, which is expected to represent up to **87%** of the total hydrogen production by **2030**, while the government only seeks to make clean hydrogen accounts for **7.1%** of the nation's energy mix by 2036. Additionally, as part of this target to seed the development of a hydrogen economy, Yoon administration announced in January 2023 that it would invest a total of **KRW 240 billion** won (US$193 million) in pilot projects for hydrogen cities (Pyeongtaek, Namyangju, Dangjin, Boryeong, Gwangyang and Pohang).

[147] *Ministry of Environment, South of Korea, 2030 온실가스 감축 로드맵 수정안 및 2018~2020년 배출권 할당계획 확정 [Revised 2030 Greenhouse Gas Reduction Roadmap and Finalization of the Emission Allowance Allocation Plan for 2018–2020], July 24, 2018, https://www.me.go.kr/home/web/board/read.do?menuId=286&boardMasterId=1&boardCategoryId=39&boardId=886420.*

[148] *Netherlands Enterprise Agency (RVO), "Hydrogen Economy Plan in Korea," January 18, 2019, https://www.rvo.nl/sites/default/files/2019/03/Hydrogen-economy-plan-in-Korea.pdf.*

Korean policy towards industry decarbonization

Text	Industry Decarbonization measures
Korean Green New Deal[149], **July 2020**	In synergy with the **2050 Carbon Neutral Strategy** to move towards a carbon-neutral society, the Korea's **Renewable Energy 3020 Plan**, it has three main areas: 1. Green transition and infrastructures. 2. Low-carbon and decentralized energy supply. 3. Innovation in the Green industry.
	Invest **KRW 73.4 trillion (approximately €49 million), of which KRW 42.7 trillion** is from the Treasury (approximately €28.7 million), in green finance to support business investments in green transition and create 659,000 jobs by **2025, mostly for energy and infrastructure, but also for the following:** • To secure innovation in the green industry, it is expected that by 2025, the government will invest **KRW 7.6 trillion (approximately €5 billion)**, including KRW 6.3 trillion (approximately €4.2 billion) from the Treasury and will create 63,000 jobss.
	On innovation in the green industry: • **promote small businesses** to lead the green industry and the establishment of low-carbon and green industrial complexes, through the support of 9,000 small businesses in setting fine dust facilities, of 100 smart ecological plans and 1,750 clean factories and to set a green-integrated cluster for technological development, including **resource recycling** and **biomaterial** development. • It also aims to lay down the **foundation for green innovation** through active **investments in the R&D and financial sectors**. The government plans to provide a loan of KRW **1.9 trillion (approximately €1.3 billion)** in the green sector, mainly to support the commercialization of large-scale **CCUS technologies** by 2023 and promote **resource recycling**.
2050 Carbon Neutral Strategy of the Republic of Korea: Towards a Sustainable and Green Society[150], **Dec 2020**	Korean carbon neutrality strategy as published to the UNFCCC: 1. **The expansion of the use of clean power and hydrogen across all sectors** through the application of CCUS technologies when coal and other fossil fuel/LNG-powered energy are used and the expanding use of renewable energy sources, like solar, wind and hydro for energy supply. 2. **The improvement energy efficiency to a significant level**, considered as a more cost-effective option compared to ESS and hydrogen technologies. 3. **The Commercial deployment of carbon removal and other future technologies**, meaning to further investments in the development and commercialization of CCUS technologies and hydrogen. 4. **The Scaling up the circular economy to improve industrial sustainability**. 5. **The enhancement of carbon sinks**.
	The government plans to facilitate industry sector's transition to low-carbon production through 3 key means: • (1) To combine ICT and technologies 4.0 within industries' existing structures to favor the transition a high-value-added • (2) To use a combination of measures and incentives measures to stimulate energy efficiency • (3) To reinforce the commitment of policies and technology **development for waste and resources recycling**, that could drastically **diminish the utilization of raw materials and fuels**.

Korean policy towards industry decarbonization

Text	Industry Decarbonization measures
Establishment of the [Strategy for Technology Innovation for carbon neu-trality], March 2021 (press release)[151]	The technology innovation strategy aims to drive to achieve carbon neutrality by 2050, through the support of technology innovation and inter-ministerial cooperation, which should be realized by focusing on five main actions plans: • The development of **ten core technologies** for carbon-neutral technology innovation: - **solar and Wind Power, Hydrogen, Bioenergy, Steel and Cement, Petrochemical Industrial Process Advancement**, Transport Efficiency, Building Efficiency, Digitalization and **CCUS**; - **differentiated** depending on their related issues, expected contributions to reduce GHG emissions and industrial demands, based on the Long-term low greenhouse gas Emission Development Strategies (LEDS). • The planning and promotion of carbon-neutral-**sector-focussed R&D projects** engaging all ministries. • The government's proactive support for the creation of **new green and/or digital industries**. • The emphasis on a private-led low-carbon conversion. - ***roadmap* for the successful commercialization and market settlement** of low-carbon technologies; - **establishing a standard/certification system** to regulate technology development; - **implementing tax exemption measures to incite private investments on low carbon, thus reducing the technology fee burden**. • The establishment of **sustainable research** foundations.
한국판 뉴딜 **2.0** 추진계획 **(Korean New Deal 2.0**[152]**, July 21**	• Creates both a **Green New Deal Fund of KRW 350 billion (approximately €235 million)** and a **Future Fund of KRW 142.6 billion** (approximately €96 million). • Additionally, the MOTIE announced its goal to scale up investments in the private sector up to **KRW 43 trillion (approximately €29 billion)** in the hydrogen sector and **KRW 36 trillio**n (approximately €24 billion) (through a public–private investment plan) for floating offshore green power by 2030 • Additionally, as part of the Green New Deal , the MSS and the MOE pledged to invest a total of **KRW 200 billion (approximately €134.5 million)** in R&D for green growth and low-carbon transition for a total of 70 companies in 2021 • Finally, the document reiterates the government's commitment to move toward a net-zero society and industry, principally by expanding the scope of its support for R&D investments in CCUS technology's development (**KRW 159 billion** – approximately €107 million – to be invested by **2025**), as well for hydrogen production and the expansion of resource recycling facilities in the industry sector.

[149] *Government of South Korea, "The Korean New Deal: National Strategy for a Great Transformation," July 2020, https://content.gihub.org/dev/media/1192/korea_korean-new-deal.pdf.*

[150] *Government of South Korea, "2050 Carbon Neutral Strategy of the Republic of Korea: Towards a Sustainable and Green Society," December 2020, https://unfccc.int/sites/default/files/resource/LTS1_RKorea.pdf.*

Korean policy towards industry decarbonization

Text	Industry Decarbonization measures
국가 탄소중립 · 녹색성장 기본계획 의결 **The 1st National Basic Plan for Carbon Neutrality and Green Growth (2023)**[153]	Updates the reduction target at **45.9%** by 2030 compared to 2018 levels, representing an additional 4 million tons reduction compared to the target set by the 2030 *roadmap* and also adapts reduction and absorption/removal targets by sector. Yet, **in the industrial sector the NCD target was lowered to 11.4% reduction by 2030 compared to 2018 levels, which represents a decrease of 8.1 million tons against previous NDC target**.
	In the industrial sector, this national strategy aims to foster low-carbon transition in the industry structure, primarily through technology development and an overhaul of systems such as the K-ETS by taking the following measures: • increasing the ratio of paid allocation of emission permits up to **75%** of total emissions. • adjusting to a **higher level of Benchmark Allocation**, based on emissions efficiency standards • **reinforcing tax support for low-carbon technologies**. • providing carbon neutrality-related policy financing, loan projects, and standards development. Additionally, this Basic Plan emphasizes the government's **support for CCUS technology development and commercialization**, as the main vector for decarbonization across all sectors, with an NDC target of GHG absorption/removal set at **11.2 million ton**s by 2030, entailing an increase of 900,000 tons against the previous NDC target.
제**3**차 국가 기후변화 적응대책 수립**...** 기후안심 국가 구현 **(The 3rd National Climate Change Adaptation Plan (2020) strategic plan for the period 2021-2025)**[154]	In the industrial sector, the main adaptation measures suggested implied: • improving the **energy efficiency** and maintenance of power system facilities; • **diversifying energy sources** to entail climate-resilient energy systems; • establishing a better energy management system, **including through smart grids** (target of building up to 5 million by 2025 vs. 150 in 2020); • developing **energy storage** capabilities.

[151] *Ministry of Science and ICT, South Korea, "Establishment of the Strategy for Technology Innovation for Carbon Neutrality," 2021, accessed September 10, 2024, https://www.msit.go.kr/eng/bbs/view.do?sCode=eng&mId=4&mPid=2&pageIndex=&bbsSeqNo=42&nttSeqNo=495&searchOpt=ALL&searchTxt=.*

[152] *Joint Ministry of Related Departments, South Korea,* 한국판 뉴딜 *2.0 -*미래를 만드는 나라 대한민국 *-* 관계 부처 합동 *[Korean New Deal 2.0 – A Country Creating the Future], 2021, https://outlook.stpi.narl.org.tw/pdfview/4b1141007f9b57d9017fc0093b374d74.*

Korean policy towards industry decarbonization

Text	Industry Decarbonization measures
The 10th Basic Energy Plan for Electricity Supply and Demand (Feb 2023 [155]	The 2030 and 2036 targets for the proportion of renewable energy is lower against the 9th Basic Plan.
	Introduction of a long-term contract market for low-carbon power sources, mainly hydrogen and ESS. It also plans to support the development of ammonia co-firing and blue hydrogen in order to reduce GHG emissions and to **invest up to KRW 48.4 trillion (approximately €32.6 billion) in the accommodation of renewable energy storage**.
Factory Energy Management System [156]	This strategy aims to **maximize the productivity and improve the energy efficiency of the industrial sector**, by: • establishing a comprehensive plan for the management of factories production and non-production facilities in order to reduce GHG emissions. This strategy is in line with the 2030 Roadmap published in 2018 and the implementation of the K-ETS. • relying on **efficient energy management** using energy modeling benchmarking.

[153] *2050 Carbon Neutrality Commission, South Korea, 국가 탄소중립 • 녹색성장기본계획(안) [National Carbon Neutrality and Green Growth Basic Plan (Draft)], 2023, https://www.2050cnc.go.kr/download/BOARD_ATTACH?storageNo=1936.*

[154] *Joint Ministry of Related Departments, South Korea, 제3차 국가 기후변화 적응대책 [3rd National Climate Change Adaptation Plan], http://www.climate.go.kr/home/cc_data/policy/3_nation_climate_change_adaptation_step_summary.pdf.*

[155] *2050 Carbon Neutrality Commission, South Korea, [제10차 전력수급기본계획(2022~2036)] 확정 [Confirmation of the 10th Basic Plan for Electricity Supply and Demand (2022–2036)], 2023, https://www.2050cnc.go.kr/base/board/read?boardManagementNo=43&boardNo=1242&searchCategory=&page=1&searchType=&searchWord=&menuLevel=2&menuNo=73.*

[156] *Korea FA Systems, "Factory Energy Management System," accessed September 10, 2024, http://www.kfa.co.kr/en/sub/solution/solution.asp?idx=17.*

Appendix 2
Japanese Policy toward Industry Decarbonization

Japanese policy towards industry decarbonization

Text	Industry Decarbonization measures
Green Growth Strategy Through Achieving Carbon Neutrality in 2050[157] **(Dec 2020)**	Funding: • Total of **JPY 240 trillion** (approximately €1.5 trillion) for Japanese companies. • The **Green Innovation Fund** with a budget of **JPY 3,000 trillion (approximately €19 trillion)**. • **JPY 2 trillion** (approximately €12.6 billion) at the New Energy and Industrial Technology Development Organization (NEDO).
	Object: 1. To establish a **new set of industrial policies** to create such a "virtuous cycle of economy and environment," setting high goals in 14 Industrial fields to realize the 2050 Carbon Neutrality goal. 2. In Industrial fields other than the power sector, **to decarbonize** through the promotion of **electrification** and form the basis of industrial competitiveness. 3. To build **resilient green and digital infrastructures** so as to nurture the growth of semiconductor/information and communication industrial fields. 4. To **expand R&D tax system, by raising the upper limit of tax deduction up to 30%** so as to foster investment in carbon-neutral innovation. 5. To develop s**ector-specific action plans** for 2050.
	Measures: • development of hydrogen reduction steelmaking; • promoting the **use of hydrogen**, the **methanation process**, **synthetic fuel** and **biomass**, as **energy sources**; • **establishing a sharing system for used products and materials to foster resource circulation**; • **increasing the use of biomass and recycled materials** and the development of recycling technology • CCUS: CO2-SUICOM for cement, artificial photosynthesis for chemicals.

[157] *Ministry of Economy, Trade and Industry, Japan, "Green Growth Strategy through Achieving Carbon Neutrality in 2050," December 25, 2020, http://web.archive.org/web/20240218065813/ https://www.meti.go.jp/english/press/2020/pdf/1225_001b.pdf.*

Japanese policy towards industry decarbonization

Text	Industry Decarbonization measures
Environment Innovation Strategy[158] **(Jan, 2020)**	**Innovation Action plans** - estimate the technology's specific target cost and the extent to which they can contribute to GHG emissions reduction: • **increasing use of renewable energy and CO_2-free hydrogen**, through the development of zero-carbon steel with hydrogen reduction steelmaking technology, the improvement of metal resource circulation and the advancement of plastic resource circulation; • the development of **Carbon recycling technologie**s to **use CO_2 as a material and fuel source** through the production of plastics by artificial **photosynthesis technology**, the use of cement made from CO_2, **low-cost methanation**.
	Acceleration Plan: • establish an **inter-agency chain of command** through the inauguration of a Green Innovation Strategy Meeting; • **promote private ESG-related investments** through the promotion of green finance, so as to facilitate the dissemination of information on climate change among industrial companies.
Strategic Energy plan[159] **(Oct, 2021)**	Diversify the manufacturing process, including through the **introduction of hydrogen-reduction iron- and steelmaking** and highly functional **hydrogen-fired boilers**.
Clean Energy Strategy[160] **(May 2022)**	**Funding:** GX 150 billion in 10 years
	Measures: • tightly **monitoring supply and demand of energy**; • on **hydrogen/ammonia**, the government has planned to implement **support measures** by supporting the difference between the strike price and the reference price for hydrogen/ammonia *vis-à-vis* conventional fuels; • in the **steel industry**, the government scopes to support the development of innovative technologies, primarily hydrogen-reduction steelmaking, but also to promote investment in **energy efficiency** and **electrification**; • **CCUS technologies**, the government seeks to implement public support policy and to **improve the legislative framework for the commercialization of CCS technologies by 2030**.

[158] *Government of Japan, "Environment Innovation Strategy," January 21, 2020, https://unit.aist.go.jp/gzr/zero_emission_bay/en/images/kankyousenryaku2020_english.pdf.*

[159] *Ministry of Economy, Trade and Industry, Japan, "Outline of Strategic Energy Plan," October 2021, https://www.enecho.meti.go.jp/en/category/others/basic_plan/pdf/6th_outline.pdf.*

[160] *Ministry of Economy, Trade and Industry, Japan, "Clean Energy Strategy Interim Report (Outline)," 2022, https://www.meti.go.jp/english/policy/energy_environment/global_warming/pdf/clean_energy_strategy.pdf.*

Japanese policy towards industry decarbonization

Text	Industry Decarbonization measures
The Basic Policy for Realization of GX- A *roadmap* for the next 10 years[161] **(Feb 2023)**	**Restructuring the manufacturing industry**, primarily **through fuel and feedstocks transition**, will allow for moving away from dependency on fossil energy sources
GX Promotion Act (May 2023)	**Funding:** • JPY 150 trillion (approximately €946.5 billion), of which JPY 20 trillion (approximately €126.2 billion) is public and the rest is private over 10 years. • Establishes **GX Transition Bonds**, with a total investment amount of approximately **JPY 20 trillion (approximately €126.2 billion)** over the **next 10 years**. • **GX League ETS**. • The GX Transition Bonds will be **funded by the Fossil Fuel Levy and the Specified Business Contributions**.
	Objectives: reduce GHG emissions by **46% by 2030** compared to 2013 levels.
	Measures: • vrequires the government to define a **strategy for the structural transition towards decarbonization**. **Government should support:** • investments on business projects which aim to reduce GHG emissions; • while improving industrial competitiveness and fostering sustainable economic growth; • risk decreases: and support private companies which seeks to develop technological innovation, **but yet remain hesitant due to the uncertainty** surrounding technological innovation.

[161] *Ministry of Economy, Trade and Industry, Japan. "The Basic Policy for the Realization of GX – A Roadmap for the Next 10 Years," 2023, http://web.archive.org/web/20231010040239/https://www.meti.go.jp/english/press/2023/pdf/0210_003a.pdf.*

Japanese policy towards industry decarbonization

Text	Industry Decarbonization measures
Basic Policies for Green Innovation Fund (May 2023)[162]	**Funding: Green Innovation Plan: JPY 2 trillion fund launched in March 2021** as part of the NEDO plan for the achievement of carbon neutrality by 2050 to give support for business R&D projects that aim to significantly reduce GHG emissions.
	• R&D projects with an **average size of JPY 20 billion (approximately €126.2 million)**. • functions on a project-by-project basis. • regular **cross-sectoral monitoring of funds** based on the projects' International Competitiveness Commercialization and its potential to attract FDIs.
Basic Hydrogen Strategy[163] **(June, 2023)**	**Funding:** • The government aims to invest more than **JPY 20 trillion (approximately €126.2 trillion)** in green transformation-related investment over the next **10 years (GX)**. • Total investments (from the private and public sectors) dedicated to hydrogen and ammonia supply chains are expected to reach **JPY 15 trillion** (approximately € 94.7 billion) in the next **15 years**.
	uce GHG emissions by 46% by 2030 compared to 2013 levels.
	Objectives: This strategy, according to the **S (Safety) + 3 E (Energy Security, Economic Efficiency, and Environment) principles**, sets out the following director for the country's hydrogen policy: • to **cultivate Japan's industrial technological advantage on hydrogen**, allowing to reach 3 million tons per year of hydrogen consumption by 2030, 12 million tons per year (including ammonia) by 2040, and 20 million tons per year by 2050; • **to set low-carbon targets** in line with international standards for hydrogen production and supply. **Focus on:** **Hydrogen price reduction:** • consideration of a market design with incentives for consumer payment of some cost for low-carbon hydrogen; • establishment of regulatory guidance measures for low-carbon hydrogen; • support domestic firms to invest in the introduction of **CCUS and Carbon Recycling** technologies for Hydrogen; • achieve **6-12 million tons** of annual CO_2 storage by **2030**.

[162] *Ministry of Economy, Trade and Industry, Japan, "Basic Policies for Green Innovation Fund (Summary)." 2023, http://web.archive.org/web/20230125144842/https://www.meti.go.jp/english/press/2021/pdf/0312_002a.pdf.*

[163] *Ministry of Economy, Trade and Industry, Japan, "Overview of Basic Hydrogen Strategy," June 2023, https://www.meti.go.jp/shingikai/enecho/shoene_shinene/suiso_seisaku/pdf/20230606_4.pdf.*

List of All Interviewees and Stakeholders Consulted

This report builds on research interviews and consultations with about 500 European, Japanese, South Korean, and Chinese policymakers and stakeholders held between June 2023 until July 2024. The following tables provide an overview of the affiliation of the individuals interviewed or consulted (during working groups) as part of the research process for this report. These semi-structured interviews were conducted to gather expert insights and firsthand perspectives relevant to the topics discussed. They were conducted online or in-person during research trips in Europe, Japan, South Korea, and the UAE (COP28).

INTERVIEWS WITH CHINESE STAKEHOLDERS

Institution

- EDF Beijing Representative Office
- Energy Foundation China
- Environmental Defense Fund
- Chinese Academy of Science
- Chinese Academy of Social Science (CASS)
- Shanghai Institute for International Studies
- Research Institute for Carbon Neutrality of Beijing Da Xing
- WRI China
- National Center for Climate Change Strategy and International Cooperation
- Energy Research Institute
- The Administrative Center for China's Agenda 21 (ACCA21), Ministry of Science and Technology
- China Building Materials Federation (CBMF)
- China National Institute for Standardization
- Deep Rock

- Delong Steel
- Shanghai GEIT Co.
- Renewable Energy Development Center, Energy Research Institute, NDRC
- SINOPEC
- Baowu
- Greenovation: Hub
- National Development and Reform Commission (NDRC)
- Ministry of Industry and Information Technology (MIIT)
- Ministry of Ecological Environment (MEE)
- Shanghai Greenment
- China Beijing Green Exchange
- China Standardization Administration
- China National Institute of Standardization
- CNPC Research Institute of Safety and Environmental Technology
- Clean Energy Research Institute
- Chinalco
- Institute for Climate Change and Sustainable Development – Tsinghua University
- Biosphere 3
- Carbontrust China
- China Environmental United Certification Center
- Sinocarbon

INTERVIEWS WITH JAPANESE STAKEHOLDERS

Institution

- Mitsubishi Chemical Group Corporation
- New Industry and Technology Development Organization (NEDO)
- Global Environmentally Conscious Research Group
- Sumitomo Osaka Cement Co.

- Climate Change Task Force Department
- National Graduate Institute for Policy Studies (GRIPS)
- Ministry of Economy, Trade and Industry (METI)
- Ministry of the Environment of Japan (MOEJ)
- Sumitomo Osaka Cement Co., Ltd
- Sumitomo Chemical, Co., Ltd.
- UACJ – Aluminum
- Research Center for Advanced Science and Technology (RCAST)
- JFE Steel Corporation
- Mitsui Global Strategic Studies Institute
- Mitsui Chemicals, INC
- Taiheiyo Cement Corporation
- NEDO Representative Office in Europe
- Research Institute of Innovative Technology for the Earth
- The Central Research Institute of Electric Power (CRIEPI)
- Waseda University
- IGES
- Graduate School of Public Policies, REITI / University of Tokyo
- Toyota Motor Corporation
- Japan Aluminum Association
- Nippon Steel
- Marunouchi Innovation Partners
- Shizen Energy
- The Institute of Energy Economics
- Daichi Life
- Mitsubishi Heavy Industry
- CRIEPI

INTERVIEWS WITH KOREAN STAKEHOLDERS

Institution

- Presidential Committee for Net Zero
- Korea National Cleaner Production Center, Korea Institute of Industrial Technology (KNCPC/KITECH)
- Korea Institute for International Economic Policy (KIEP)
- Kim & Chang
- KB Kookmin Bank
- National Center for APEC Studies and the Pacific Economic Cooperation Council at Korea Institute for International Economic Policy (KIEP)
- KIEP (Korea Institute for International Economic Policy)
- Center for International Development Cooperation
- Seoul National University of Science and Technology (Seoultech)
- Korea Chamber of Commerce and Industry (KCCI)
- Korean Environmental Law Association
- Korean Institute of Energy Research Center
- Korean Advanced Institute of Science & Technology & Solution for Our Climate
- Korean Institute for Industrial Economics and Trade
- National Assembly Research Service (NARS)
- Ministry of Environment (ROK)
- Ministry of Trade, Industry and Energy
- Korean Presidency
- People's Party
- Korea Environment Institute
- Korea Chemicals Association
- Korea Energy Economic Institute (KEEI)
- Korean Cement Association
- Korea Testing & Research Institute
- Ministry of Strategy and Finance
- Carbonco

- Division of International Studies of Korea University in Korea
- Yonsei University
- CSDLAP
- Yulchon LLC
- VEOLIA Korea
- International School of Urban Sciences, University of Seoul
- POSCO Research Institute
- POSCO
- Eugene Corp Research Institute
- SK Chemicals
- Samsung
- Korea Cement Industry Association
- Delegation of the European Union to the Republic of Korea

INTERVIEWS WITH EUROPEAN STAKEHOLDERS

Institution

- European Commission
- DG Grow, European Commission
- DG Clima, EC
- DG Trade, EC
- DG Taxud, EC
- DG Energy, EC
- DG Grow, EC
- EEAS
- French Ministry of Economy and Finance
- French ministry of Industry
- Cleantech for Europe
- Institut du développement durable et des relations internationales
- (IDDRI)
- CEA (French Atomic Energy and Alternative Energies Commission)

- Institut Montaigne
- Wuppertal Institute for Climate, Environment and Energy
- Breakthrough Energy
- Ecocem Materials, Ltd.
- AFYREN
- ArcelorMittal
- German Federal Chancellery
- Renault
- BMWK
- BMW
- Airliquide
- Ardian
- Mitsubishi Electric, France
- The Boston Consulting Group France
- Copenhagen Infrastructure Partner
- OPmobility
- MEDEF
- Kéa
- VICAT
- Orano
- Ministry of Energy Transition, France
- Accenture France
- Archery Strategy Consulting
- Airbus
- Accuracy
- Hitachi Energy France
- Groupe Amundi
- Chubb France
- Bessé
- SGS, France
- EDF
- Schneider Electric
- ENEDIS
- TotalEnergies

- ArcelorMittal
- Evolen
- Solvay
- Thyssenkrupp Steel Europe
- BASF
- EUROFER (European Steel Association)
- Cembureau
- CEFIC (chemical federation)
- Holcim
- Siemens
- GTT (Gaztransport & Technigaz) SA
- Agora Energiewende
- The Climate Group
- L'Oréal Groupe
- IFP School / Laboratoire de Génie Industriel de CentraleSupélec
- Association française des Economistes de l'Energie
- VUB
- College of Europe
- IDDRI
- Clean Hydrogen Joint Undertaking
- Plastic Omnium
- Pergamon
- Engie
- E3G
- Enagas
- EnBW
- Hy24
- SNAM
- Climate Leadership Council
- European University Institute
- European Institute on Economics and the Environment
- International Institute for Sustainable Development
- Ministry of Ecological Transition, Italy
- Department for Business, Energy, and Industrial Strategy, UK

- Atlantic Council Global Energy Center
- Department for Energy Security and Net Zero, UK
- Resources for the Future
- Hydrogen Europe
- Transformation Factory
- Jeantet
- Suez
- Vulog
- Hogan Lovells France
- Breakthrough Energy
- Wavestone
- Gide Loyrette Nouel
- RTE
- ABB France
- I4CE
- iQo
- Natural Grass
- Federal Ministry of Economy Climate Protection, Germany
- Carbios
- Cimpor
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- Global Cement and Concrete Association
- ADEME
- Secrétariat Général à la Planification écologique (France)
- Wupperthal Institute
- H2 Green Steel
- French Ministry of Europe and Foreign Affairs
- SIS
- The Directorate General for Enterprise (DGE), Industry Service: Industrial Policies, France
- Advisor to the Green Group at the European Parliament
- Aluminum Dunkerque
- Delegation of the European Union to the Republic of Korea
- Delegation of the European Union to China

- EDF
- AXA
- Thyssenkrupp
- German State Secretariat for Energy
- Adelphi
- AgoraEnergiewende

OTHERS

Institution

- UNIDO
- OECD
- IEA
- International Organization for Standardization
- Climate Club
- World Bank
- Global CCS Institute
- Rio Tinto
- World Economic Forum
- International Sustainability Standard Board
- IRENA

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Moelis & Company
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Natixis
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