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The Cost of Delay

Socioeconomic Impacts of Steel Decarbonization in South Korea

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Socioeconomic Impacts of Steel Decarbonization in South Korea

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Solutions for Our Climate (SFOC) is an independent nonprofit organization that works to accelerate global greenhouse gas emissions reduction and energy transition. SFOC leverages research, litigation, community organizing, and strategic communications to deliver practical climate solutions and build movements for change.

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1. Introduction

As global efforts to achieve carbon neutrality accelerate, decarbonizing the industrial sector has emerged as one of the major challenges in addressing the climate crisis. The steel industry, in particular, is widely recognized as one of the hardest sectors to abate, and major steel-producing countries regard its decarbonization as a national policy priority.[1] This importance stems from the steel industry's role as a core industry deeply interconnected with other sectors across manufacturing value chains, while also being a significant source of carbon emissions, accounting for approximately 7% of global emissions.[2] Therefore, the low-carbon transition of the steel industry is essential for achieving national greenhouse gas reduction targets and ensuring the sustainability of the broader manufacturing value chain.

In Korea, the importance of steel decarbonization is increasingly evident as well. The domestic steel industry is the largest industrial emitter, accounting for approximately 40% of industrial greenhouse gas emissions and about 17% of total national emissions.[3] At the same time, it serves as a core supplier to key industries such as shipbuilding, automotive, construction, etc. Therefore, the low-carbon transition of the steel industry has far-reaching implications for the national economy, extending well beyond a simple environmental concern. In addition, global environmental regulations targeting carbon-intensive products are tightening. Given the export-oriented structure of the Korean economy, delays in steel decarbonization pose significant risks to national competitiveness. In this context, achieving carbon neutrality in the steel industry must be recognized as a national priority.

Recent policy developments reflect broad agreement on the necessity of steel decarbonization. The government's '*Steel Industry Advancement Plan*', announced last year, and the passage of the *'K-Steel Act'*[4] by the National Assembly indicate that a policy-level consensus on the need for transition has largely been established. Despite this policy direction, however, the pace of decarbonization within the industry remains slow. Many of carbon neutrality roadmaps of corporates set relatively conservative targets, citing uncertainties around the commercialization of low-carbon technologies, high upfront capital expenditures, and concerns about the stability

1 Climate Action Tracker. (2024). *Decarbonizing steel: national circumstances and priority actions*.
2 Worldsteel. (2025). *Sustainability Indicators Report 2025*.
3 Ministry of Environment. (2025). Greenhouse Gas Information Center.
4 「Special Act on Strengthening Steel Industry Competitiveness and Carbon Neutrality Transition」

of renewable energy supply. In addition, persistently low carbon prices under the Korean Emissions Trading System(K-ETS), combined with weak demand-side signals, provide insufficient economic incentives to accelerate the transition.

Furthermore, discussions surrounding the low-carbon transition tend to emphasize short-term burdens, such as increased production costs associated with the initial capital investment, employment adjustments resulting from industrial restructuring, and potential regional economic contraction. Particularly in regions highly dependent on the steel industry, such as Pohang and Gwangyang, concerns persist that the transition process could negatively impact the local economies and labor markets. However, many of these perceived risks arise not from the transition itself, but from the structural vulnerabilities that could emerge if the transition is delayed or insufficient. In fact, delayed action may expose the industry and the broader economy to greater long-term costs, including loss of competitiveness, heightened risks of stranded assets, and missed opportunities in emerging low-carbon markets.

Despite these significant implications, quantitative analysis remains limited regarding how different transition pathways in the steel industry affect the broader national economy. Given the industry's extensive interlinkages with other sectors, analyses confined to individual industries or short-term effects are insufficient to capture the full scope of the economic impact. To address this gap, this study compares two distinct low-carbon transition scenarios for the steel industry and evaluates their respective macroeconomic implications. By examining differences in transition speed, the analysis evaluates impacts on key economic indicators and estimates the opportunity costs associated with delayed action. Ultimately, the findings demonstrate that steel decarbonization should be understood not as a compliance burden, but as a economic opportunity capable of generation growth and employment nationwide.

2. Methodology and data

This study assesses the socioeconomic impacts of the steel industry's low-carbon transition on the domestic economy using input–output (I–O) analysis, comparing two transition scenarios to evaluate how differences in the pace of transition shape economy-wide outcomes. Input–output analysis is particularly suitable for analyzing future scenarios involving structural transformation, such as industrial decarbonization, as it enables the quantitative estimation of production-, value-added-, and employment-inducing effects arising from changes in final demand through inter-industry linkages. The low-carbon transition of the steel industry entails substantial structural shifts, including changes in energy demand, fuel switching, and the adoption of new production technologies. These transformations extend beyond the steel sector itself, affecting both upstream and downstream industries. Therefore, it is needed to analyze economy-wide impacts rather than changes confined to a single industry.

The main indicators derived from the I–O analysis are defined as follows[5]:

- **Production-Inducing Effect**: The total direct and indirect increase in gross output across all sectors, resulting from a one-unit increase in final demand.
- **Value-Added Inducing Effect**: The total direct and indirect increase in value-added generated throughout the economy in response to a one-unit increase in final demand.
- **Employment-Inducing Effect**: The total number of full-time equivalent (FTE) jobs directly and indirectly generated across all industries per 1 billion KRW increase in total output.

  ∗Full-time equivalent (FTE) employment measures total labor input by converting part-time and non-standard working hours into equivalent full-time positions based on standard full-time working hours

As the steel industry transitions toward low-carbon production, the share of blast furnace operations declines, leading to recuded coal consumption. At the same time, the expansion of low-carbon production routes, including electric arc furnaces and hydrogen-based direct reduction, increases demand for renewable electricity and hydrogen. To assess the effects of these changes on industries linked to steel production, the "Coal Products" and "Renewable Energy" sectors[6] in the input–output table were utilized. In the case of renewable energy, prior research[7] indicates that differences in value-added and employment-inducing coefficients

5 Bank of Korea. (2014). *An Introduction to Input-Output Analysis*.
6 Coal: Basic Sector 1610; Renewable Energy: Basic Sector 4506
7 Kim, G. & Seo, Y. (2019). *An Analysis of the Macroeconomic Impacts of Renewable Energy Expansion (1/4)* Korea Energy Economics Institute.

between wind and solar power are minimal. Accordingly, renewable energy is treated as a single aggregated sector without distinguishing among specific technologies.

Hydrogen, however, is not currently classified as an independent sector in the government's input–output table, which limits the direct application of conventional input–output (I–O) methods. To address this limitation, this study draws on prior research[8] that analyzed the industrial linkage structure of the hydrogen economy and projected its growth through 2050. Based on this framework, the hydrogen value chain is divided into stages of production, storage and transportation, and utilization. In addition, the economic effects arising from green hydrogen production are assumed to be already reflected in the renewable energy sector, while the effects of hydrogen utilization are confined to the steel industry. Accordingly, among the stages of the hydrogen value chain presented in **[Table 1]**, only the economic effects associated with hydrogen storage and transportation are incorporated into the analysis.

[Table 1] Hydrogen Industry Value Chain Classification

Category	Production	Storage and Transportation	Storage and Transportation
Fossil fuels	• Industrial Process → Byproduct Hydrogen • Natural/Biogas → Reformed Hydrogen	• Pipeline • Tube Trailer • Liquid Hydrogen Tank Truck • Hydrogen Refueling Station (* when used for transportation)	• Fuel cell (Residential and Industrial) • Transportation (bus, taxi, ship, train, unmanned aerial vehicle) • Gas turbine • Hydrogen-based ironmaking (steel)
Renewable Energy	• Renewable Energy → Electrolysis		
Import	• Overseas Hydrogen Production → Imported Hydrogen		

The analysis covers the period from 2026 to 2050, the target year for achieving national carbon neutrality. As a baseline, the 2023 extended input–output table published by the Bank of Korea was used for the coal and renewable energy sectors. For hydrogen-related sectors, the analytical framework proposed in the aforementioned prior study was adopted. Future input–output projections were generated by incorporating price scenario assumptions for key energy inputs into the input coefficient matrix. In formulating these assumptions, coal prices were assumed to remain constant, reflecting the view that the coal industry is mature and has limited

8 Choi, S., Kim, J., & Yoo, S. (2023). *Measuring the Economic Impacts of the Hydrogen Economy in South Korea: An Input–Output Approach*. Journal of Hydrogen and New Energy

potential for structural transformation. By contrast, the costs of hydrogen and renewable energy were projected based on prior research, including the renewable generation mix outlined in the 11th Basic Plan for Electricity Supply and Demand, renewable energy cost projections from Bloomberg New Energy Finance (BNEF), and electrolyzer operating cost projections from the International Energy Agency (IEA).

Scenario setting

This study develops two transition scenarios to examine how differences in the pace of decarbonization and technology adoption pathways in the steel industry affect economy-wide outcomes. The first scenario reflects the transition pathway currently articulated by industry, while the second represents an alternative pathway derived from considerations of technological feasibility and economic efficiency. By comparing these scenarios, the analysis assesses how variations in transition strategy influence key socioeconomic indicators, including production, value-added, and employment.

Scenario 1: Conservative Transition Scenario

The first scenario reflects the transition pathway disclosed by POSCO in its 2024 Sustainability Report.[10] Under this scenario, the share of coal-based production processes, such as blast furnace and FINEX operations, declines gradually over time, while the share of electric arc furnaces (EAFs) increases progressively. Hydrogen-based ironmaking, which is widely regarded as offering the greatest potential for greenhouse gas reduction in the steel industry, is projected to account for approximately 50 percent of total steel production processes by 2050. The share of EAF production is assumed to reach roughly 30 percent in the same year.

POSCO has also announced plans to introduce Carbon Capture, Utilization, and Storage (CCUS) beginning in 2038. However, due to significant uncertainties regarding investment requirements and operating costs, as well as prior research raising concerns about the technical and economic feasibility of CCUS deployment in steel production[11], this study excludes CCUS from the I-O analysis.

10 POSCO. (2025). *2024 POSCO Sustainability Report*

[Table 2] Changes in the share of steelmaking processes (scenario 1)

Year	Blast Furnace/FINEX	H2-DRI	Electric arc furnace
2026	80%	0%	20%
2030	78%	0%	22%
2040*	42%	30%	20%
2050*	0%	50%	30%

* CCUS share: 8% in 2040, 20% in 2050

Scenario 2: Accelerated Transition Scenario

The second scenario builds on the Marginal Abatement Cost Curve (MACC) analysis presented in a prior study,[12] which evaluated the emissions reduction potential and unit abatement costs of major decarbonization technologies in relation to the greenhouse gas reduction targets of POSCO,[13] to identify the most cost-effective transition pathway. Building on these findings, this study designed an accelerated transition scenario. While the previous analysis assumed that hydrogen-based ironmaking facilities would be introduced beginning in 2033, this study advances it to 2030 to provide a clearer contrast with the conservative transition scenario (Scenario 1).

Under this pathway, the share of high-carbon production processes, specifically blast furnace and FINEX operations, declines more rapidly. The hydrogen-based ironmaking process expands to approximately 87 percent of total steel production by 2050. This represents a significantly higher deployment rate and scale of hydrogen-based technology compared with Scenario 1. Also, consistent with the conservative scenario, industrial linkage effects associated with CCUS are excluded from the analysis due to persistent uncertainties regarding cost-effectiveness and implementation feasibility. Accordingly, carbon neutrality by 2050 in this scenario is achieved exclusively through the expansion of hydrogen-based ironmaking and electric arc furnace processes.

[Table 3] Changes in the share of steelmaking processes (scenario 2)

Year	Blast furnace/FINEX	H2-DRI	Electric arc furnace
2026	94.4%	0%	5.6%
2030	70.4%	16.2%	13.4%
2040	21.4%	65.2%	13.4%
2050	0%	86.6%	13.4%

11 Nicholas, S., & Basirat, S. (2024). *Carbon capture for steel?*. Institute for Energy Economics and Financial Analysis (IEEFA).
Nicholas, S., & Basirat, S. (2024). *Steel CCUS update: Carbon capture technology looks ever less convincing*. Institute for Energy Economics and Financial Analysis (IEEFA).

12 Kim, D. & Kweon, Y. (2025). *Driving Hydrogen-Based Steelmaking in South Korea: Focus on Hydrogen Sourcing*. Solutions for Our Climate (SFOC).

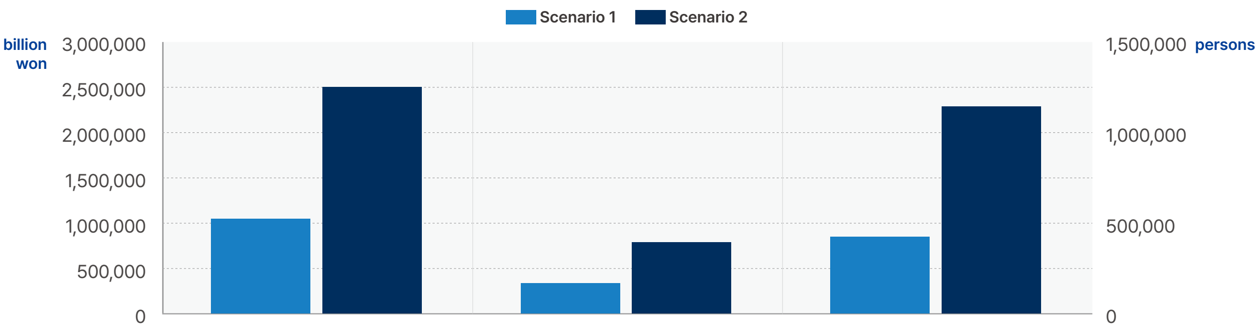
13 10% by 2030, 30% by 2035, and 50% by 2040 (relative to the 2017–2019 baseline), achieving carbon neutrality by 2050.

3. Key findings

Economic costs of delayed transition

The results of the input-output analysis indicate that the accelerated transition (scenario 2) generates substantially greater cumulative economic benefits across all indicators than the conservative transition pathway (scenario 1). These findings underscore that the pace and design of decarbonization strategies affect not only greenhouse gas reduction levels, but also broader macroeconomic performance. The cumulative socioeconomic impacts over the period 2026–2050 are presented in **[Figure 1]**.

[Figure 1] **Comparison of cumulative socioeconomic effects between scenarios (2026-2050)[14]**



Scenario	Production-inducing effect (billion won)	Value-added inducing effect (billion won)	Employment inducing effect (persons)
Scenario 1	1,046,792	331,375	424,043
Scenario 2	2,501,437	785,615	1,143,129

Over the full analysis period, the cumulative production-inducing effect under Scenario 1 amounts to approximately KRW 1,046 trillion. In contrast, Scenario 2 generates approximately KRW 2,501 trillion, rougly 2.4 times greater. This gap reflects the earlier commercialization of low-carbon steelmaking processes under the accelerated scenario which stimulates demand in related industries sooner. As a result, the accelerated transition yields substantially greater cumulative production gains over time.

14 For the coal and renewable energy sectors, total employment-inducing effects (including both wage and non-wage workers) are estimated, whereas for the hydrogen sector, wage employment-inducing effects (wage workers only) are applied. To ensure comparability and avoid potential overestimation due to definitional differences, final results are reported as wage employment-inducing effects.

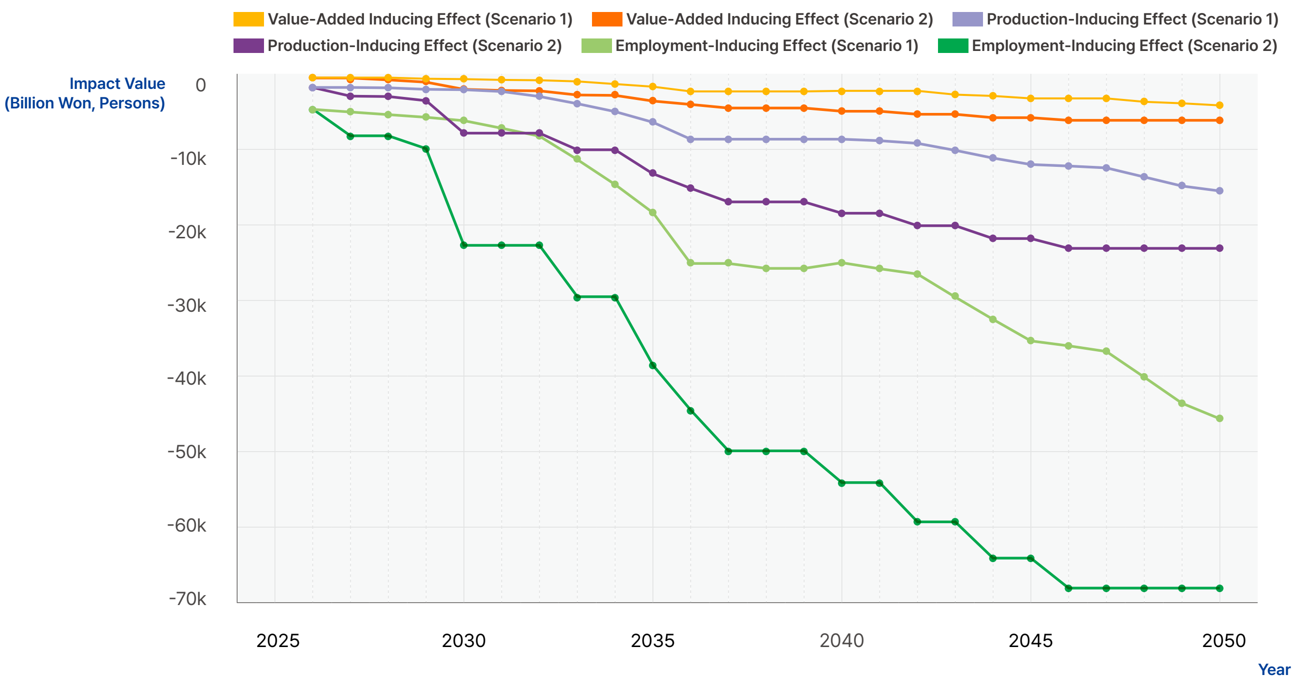
A similar pattern is observed in value-added inducing effect. Scenario 2 generates approximately KRW 786 trillion in cumulative value-added effects, compared to KRW 331 trillion under Scenario 1, roughly 2.4 times greater. Earlier structural transformation enables the expansion of low-carbon technologies, higher value-added production processes, and related service sectors, thereby strengthening the economy's overall capacity to generate value-added. Conversely, delayed transition entails significant opportunity costs by constraining long-term socioeconoimc effects.

Employment outcomes show the greatest divergence between scenarios. Over 25 years, the accelerated transition (scenario 2) generates roughly 1.14 million cumulative jobs, which is about 2.7 times more than the 420,000 jobs created under Scenario 1. These results indicate that the low-carbon transition of the steel industry does not lead to net job losses at the national level. Rather, it has the potential to generate significant employment gains through investment in new production technologies, expansion of clean energy infrastructure, and growth in related industries. Importanty, the accelerated transition amplifies these effects by allowing employment gains to accumulate over a longer period, thereby generating a more sustained and structurally beneficial impact on the national labor market.

Drivers of differences in outcomes

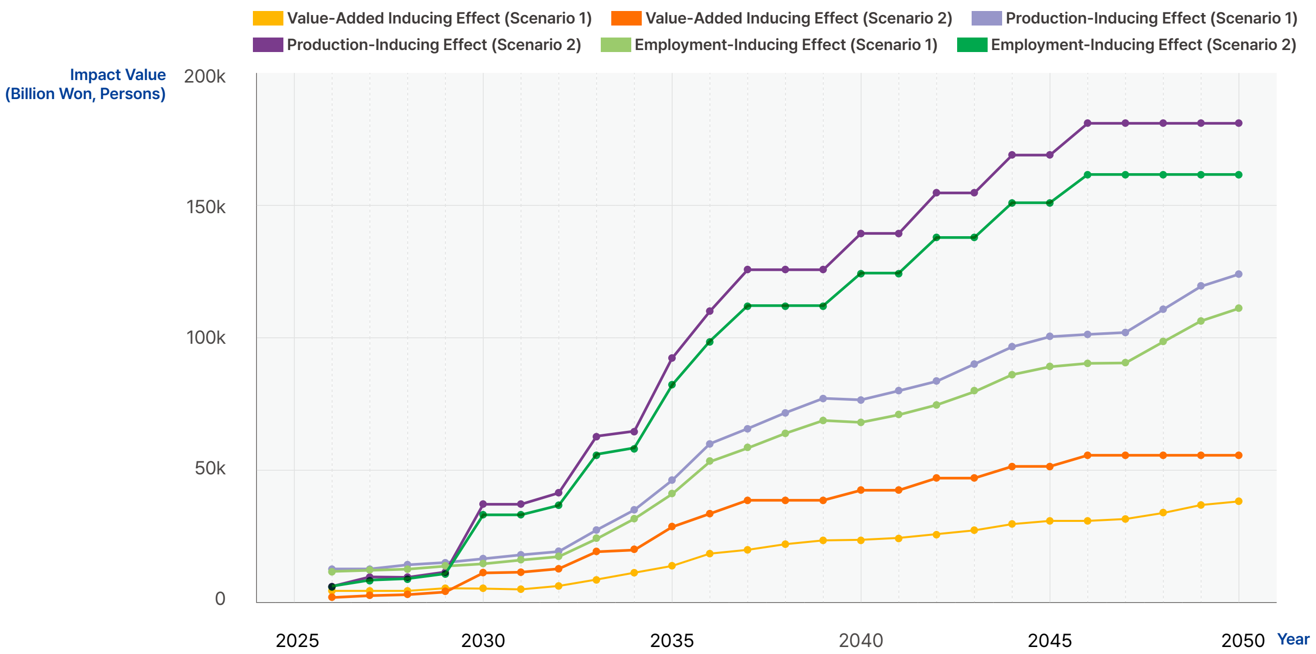
The socioeconomic impacts of the low-carbon transition are driven by two main factors. First, the reduction of carbon-intensive production processes generates contractionary effects in fossil fuel–related industries. As illustrated in **[Figure 2]**, scaling back blast furnace–based production leads to a decline in coal (coke) consumption. Electricity generation from coal-fired power plants also decreases. These shifts generate negative effects on production, value-added, and employment in coal-related industries.

[Figure 2] **Socioeconomic effects of reduced coal consumption**

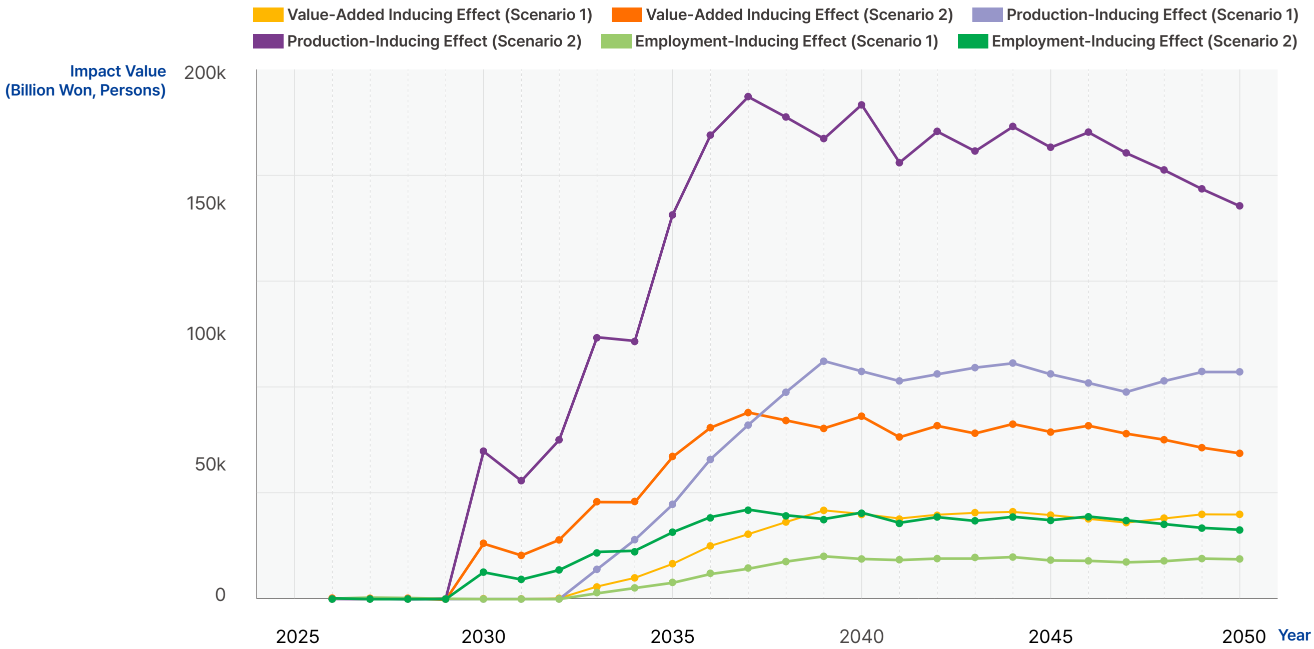


Second, positive effects arise from the expansion of low-carbon production processes and the deployment of renewable energy. As the share of wind and solar power increases in line with the national plan, and as hydrogen-based ironmaking is commercialized, demand for renewable electricity and green hydrogen rises significantly. These changes generate substantial economy-wide socioeconomic effects, particularly in industries related to hydrogen and renewables (see **[Figures 3, 4, and 5]**).

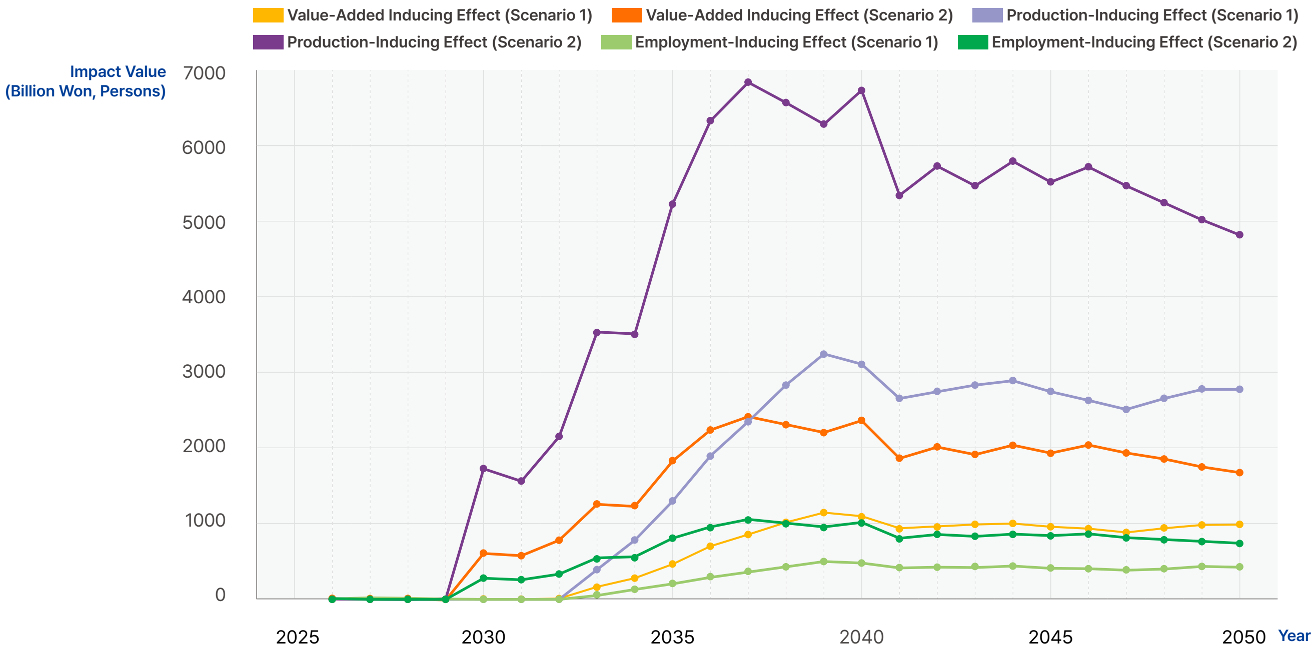
[Figure 3] **Socioeconomic effects of renewable energy expansion**



[Figure 4] Socioeconomic effects of hydrogen industry expansion (storage)



[Figure 5] socioeconomic effects of hydrogen industry expansion (transportation)



When these offsetting effects are considered together, the analysis shows that in both scenarios the positive effects of the low-carbon transition outweigh the negative effects. The key factor explaining the difference between the two scenarios is the pace of transition. Although both scenarios aim to achieve carbon neutrality by 2050, accelerating the transition extends the period over which positive socioeconomic effects accumulate. This longer accumulation period amplifies total impacts on production, value-added, and employment. In other words, given that the transition is structurally inevitable, advancing its timeline creates stronger long-term socioeconomic gains.

Differences in the ratio of hydrogen-based ironmaking also contribute to the differences in outcomes. Scenario 1 assumes a limited expansion of hydrogen-based processes and includes the eventual introduction of CCUS. However, because this analysis does not incorporate the inter-industry linkage effects associated with CCUS, the potential contribution was not translated into measurable socioeconomic impacts. Therefore, If CCUS generates significant industrial linkages, the gap between the two scenarios could narrow. However, current assessments of the technical and economic feasibility of CCUS deployment in the steel industry remain highly uncertain. Moreover, limited empirical evidence makes it difficult to reliably incorporate CCUS-related ripple effects into the input–output framework.

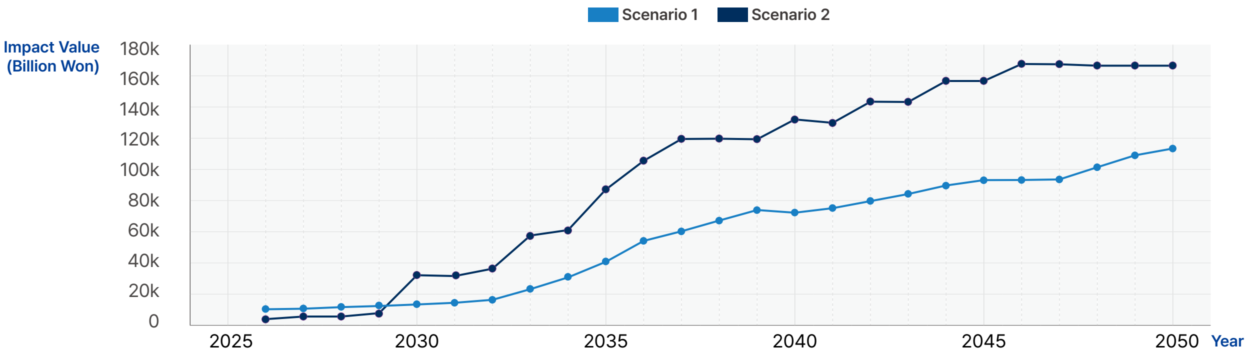
Temporary reversal in early transition phase

A year-by-year analysis reveals that during the initial phase of the transition, the conservative scenario temporarily generates stronger positive socioeconomic effects than the accelerated scenario (see **[Figures 6, 7, and 8]**). This short-term reversal reflects the differences in the timing of structural transformation.

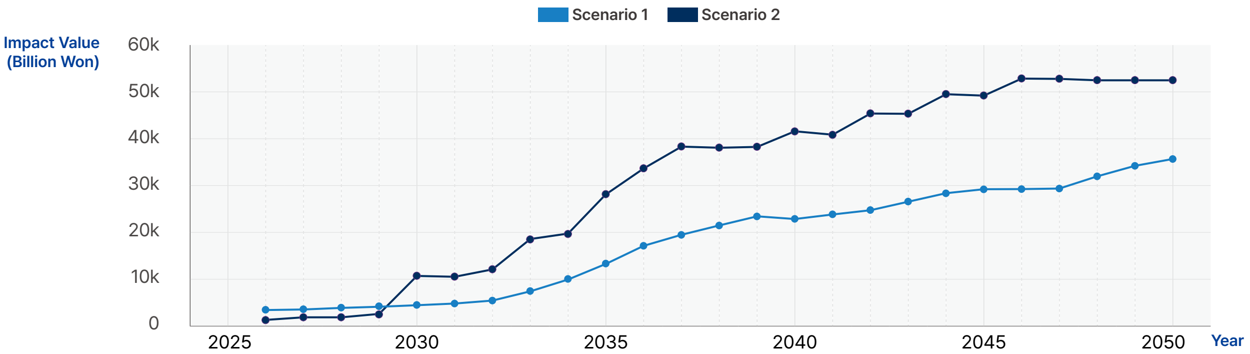
Under the accelerated transition scenario, blast furnace operations and coke consumption decline earlier and more rapidly. As a result, the economic outcomes associated with fossil fuel–based industries contracts sooner. By contrast, hydrogen-based ironmaking, along with the expansion of renewable energy and hydrogen demand, does not scale up until after 2030. The positive ripple effects therefore emerge with a time lag. In the conservative scenario, blast furnace production remains at higher levels for a longer period, sustaining fossil fuel–based industrial activity in the short term. Consequently, production and employment effects appear relatively stronger during the years of the transition.

However, this reversal is temporary. As hydrogen-based ironmaking expands and renewable energy deployment accelerates, the positive effects in the accelerated scenario grow progressively larger. Over time, cumulative gains in production, value-added, and employment significantly exceed those under the conservative pathway.

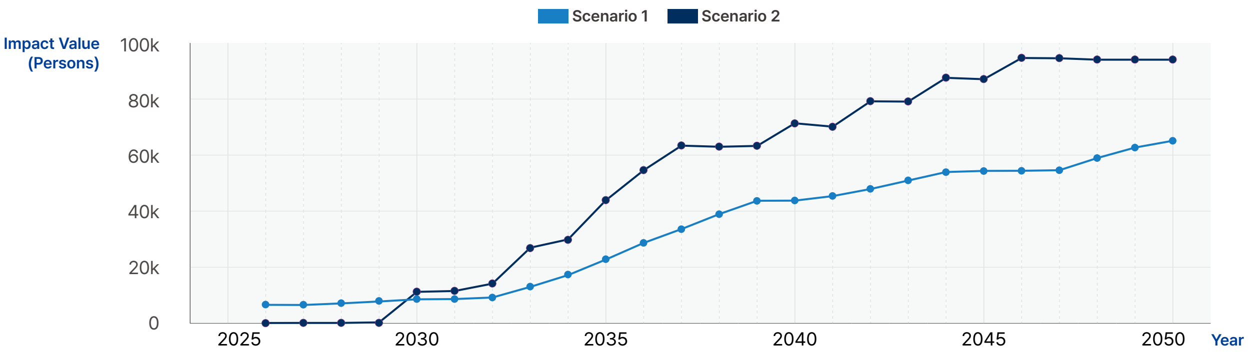
[Figure 6] Annual production-inducing effects



[Figure 7] Annual value-added Inducing effects



[Figure 8] Annual employment-inducing effects



Long-term economic benefits determined by transition pace

Taken together, the findings of this study indicate that the pace of the low-carbon transition is a decisive determinant of its socioeconomic outcomes. Although short-term reversal effects are unavoidable, particularly due to declining coal use and the early-stage deployment of low-carbon technologies, delaying the transition in order to avoid these initial burdens results in substantially greater cumulative losses in production, value-added, and employment. In the short term, postponing transition may appear to preserve economic stability and reduce immediate cost pressures. However, over the medium to long term, such delay translates into significant forgone economic gains. By contrast, the accelerated transition generates sustained economic benefits through the expansion of renewable energy and hydrogen industries, along with the growth of related sectors.

To ensure that these potential benefits are realized rather than lost as opportunity costs, national policy support must complement in addition to industry-led efforts to accelerate the transition. The decarbonization of the steel industry is not a choice but an unavoidable structural transformation. Assuming the achievement of carbon neutrality by 2050, long-term economic performance will depend critically on how quickly coal-based production processes are phased down and how early renewable energy and hydrogen utilization are scaled up.

4. Policy recommendations

The analysis demonstrates that differences in the pace and pathway of the steel industry's low-carbon transition lead to markedly different economy-wide outcomes. While an accelerated transition generates significantly larger long-term gains in production, value-added, and employment, it may entail higher economic pressures during the early stages. These findings underscore that effective transition strategies must align the pace of technological transition with well-calibrated public policy support. Drawing on the results of this study, the following three policy recommendations are proposed.

Accelerating the steel industry's transition through national strategic planning

The findings clearly indicate that an accelerated transition yields substantially greater long-term socioeconomic benefits. Steel decarbonization should therefore be understood not merely as a climate mitigation measure, but as a core component of a national growth strategy. As global markets increasingly shift toward low-carbon products, Korea's export-oriented industrial structure faces rising competitiveness risks if transition efforts are delayed. Although delaying the transition may temporarily ease short-term pressures, it ultimately raises long-term opportunity costs, including reduced access to overseas markets, slower technological improvements, and widening competitiveness gaps.

Accordingly, the government should establish a comprehensive national strategy to accelerate the transition of the steel industry, including a clear and time-bound roadmap for the expansion of hydrogen-based steelmaking. If the current conservative industry pathway persists, the scale of long-term, nation-wide economic gains may be significantly constrained.

Such a strategy should combine expanded public investment and strengthened support for low-carbon steel technologies with accelerated infrastructure development for hydrogen and renewable energy integration. At the same time, regulatory clarity and credible long-term transition signals are essential to reduce investment uncertainty and mobilize private capital at scale. A coordinated national framework that aligns industrial policy, energy planning, and climate objectives will not only facilitate domestic industrial transformation but also enhance Korea's long-term competitiveness in emerging global low-carbon markets.

Strengthening policy support to mitigate initial transition burdens

Although the accelerated transition generates substantially stronger long-term outcomes, the analysis indicates that short-term pressures may be more pronounced during the early phase. These initial burdens may include higher capital expenditures, operational restructuring costs, temporary productivity fluctuations, and labor market adjustments. Without adequate and timely policy support, such pressures could weaken industry acceptance and undermine the momentum of the transition.

To facilitate a smooth and stable transition, the government should implement phased and targeted support measures designed to alleviate these short-term constraints. This includes providing tax incentives and direct subsidies to offset upfront investment costs, establishing transitional financing mechanisms to ease capital constraints, and strengthening comprehensive workforce retraining and job transition programs. In addition, tailored regional support initiatives could effectively assist steel-dependent communities in managing economic restructuring and maintaining local stability. By mitigating short-term adjustment pressures, these measures can help sustain political and industrial commitment to the transition while preserving the substantial long-term economic gains identified in this study.

Securing a stable green hydrogen ecosystem

The accelerated transition scenario relies heavily on the rapid deployment of hydrogen-based ironmaking and assumes the availability of domestically produced green hydrogen. A substantial share of the projected long-term economic gains is driven by the expansion of domestic renewable energy and hydrogen-related industries. This highlights that the success of an accelerated transition depends not only on technological adoption within steelmaking, but also on the timely expansion of renewables and green hydrogen-related industries. Also, if domestic supply remains insufficient, reliance on imported hydrogen would increase, heightening exposure to external price volatility and weakening supply security for hydrogen-based ironmaking. Such dependence could erode both economic resilience and the projected socioeconomic benefits of the transition.

Accordingly, securing a stable green hydrogen ecosystem is essential to fully realize the long-term socioeconomic benefits identified in this study. This requires scaling up renewable energy deployment to support green hydrogen production, expanding investment in hydrogen storage and transportation infrastructure, and establishing long-term procurement frameworks and market stabilization mechanisms to reduce investment uncertainty. A robust domestic hydrogen ecosystem will not only underpin steel decarbonization but also catalyze broader industrial development across renewable energy and hydrogen value chains, reinforcing Korea's long-term competitiveness in emerging low-carbon industries.

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