Understanding Korea's Hydrogen Policy

How Should We Approach Hydrogen Policy in the Era of Energy Transition?

H_2

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Jeju Social Economy Network

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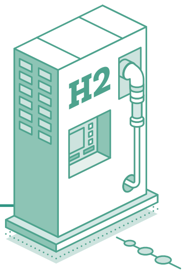
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Introduction

Is Hydrogen a Climate Solution or a Delay Tactic for Phasing Out Fossil Fuels?

The Rise of Hydrogen in the Energy Transition

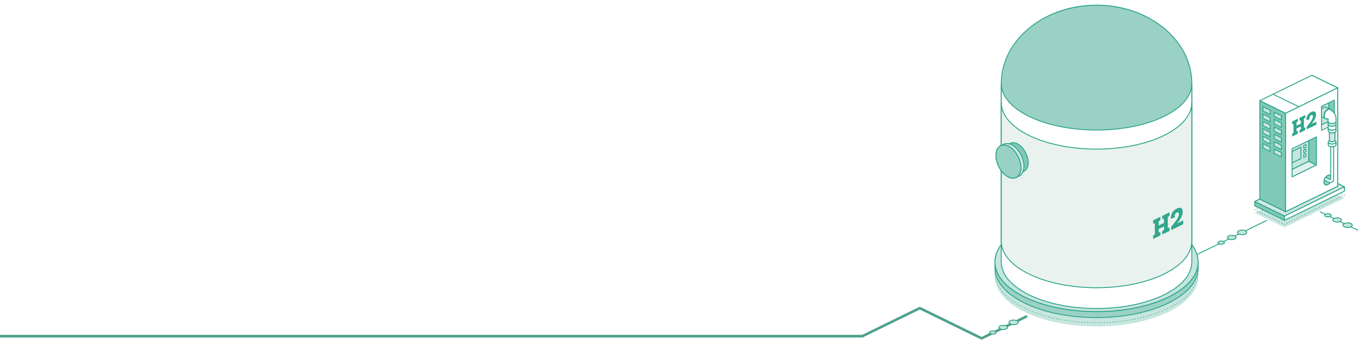
As the imperative to address the climate crisis intersects with the drive for energy sovereignty, the demand for eco-friendly energy is rapidly accelerating. Recently, hydrogen has garnered as much interest as renewable energy, with major nations increasingly prioritizing it within their national strategic frameworks. Low-emission hydrogen, in particular, is emerging as a critical transition tool for “hard-to-abate” sectors, sparking a simultaneous surge in both expectations and investments.

These hard-to-abate sectors primarily encompass heavy industries, such as steelmaking, and transportation, such as shipping and aviation. Despite this growing demand, the vast majority of hydrogen production remains reliant on natural gas-based “gray hydrogen.” While the current production of low-emission hydrogen is marginal, policy initiatives and early-stage investments aimed at scaling it are clearly gaining momentum.

The global supply chain, including trade and infrastructure development, is still in its infancy and relies heavily on a handful of pilot projects. Nevertheless, the strategic planning of major economies, alongside subsequent investments and technological advancements, is becoming increasingly visible. However, current investment levels fall short of climate targets, and a commercially proven production model for low-emission hydrogen has yet to be established. Against this backdrop, countries are fiercely competing to roll out policies and strategies aimed at producing low-emission hydrogen.

The Spread of Technocentrism and Greenwashing Concerns

As hydrogen’s prominence as a climate mitigation tool grows, so does the scrutiny surrounding it. Currently, hydrogen production is predominantly fossil fuel-based, resulting in significant



greenhouse gas emissions. Even the much-touted “low-emission hydrogen” faces skepticism regarding its viability as a climate solution when considering lifecycle emissions across both production and distribution.

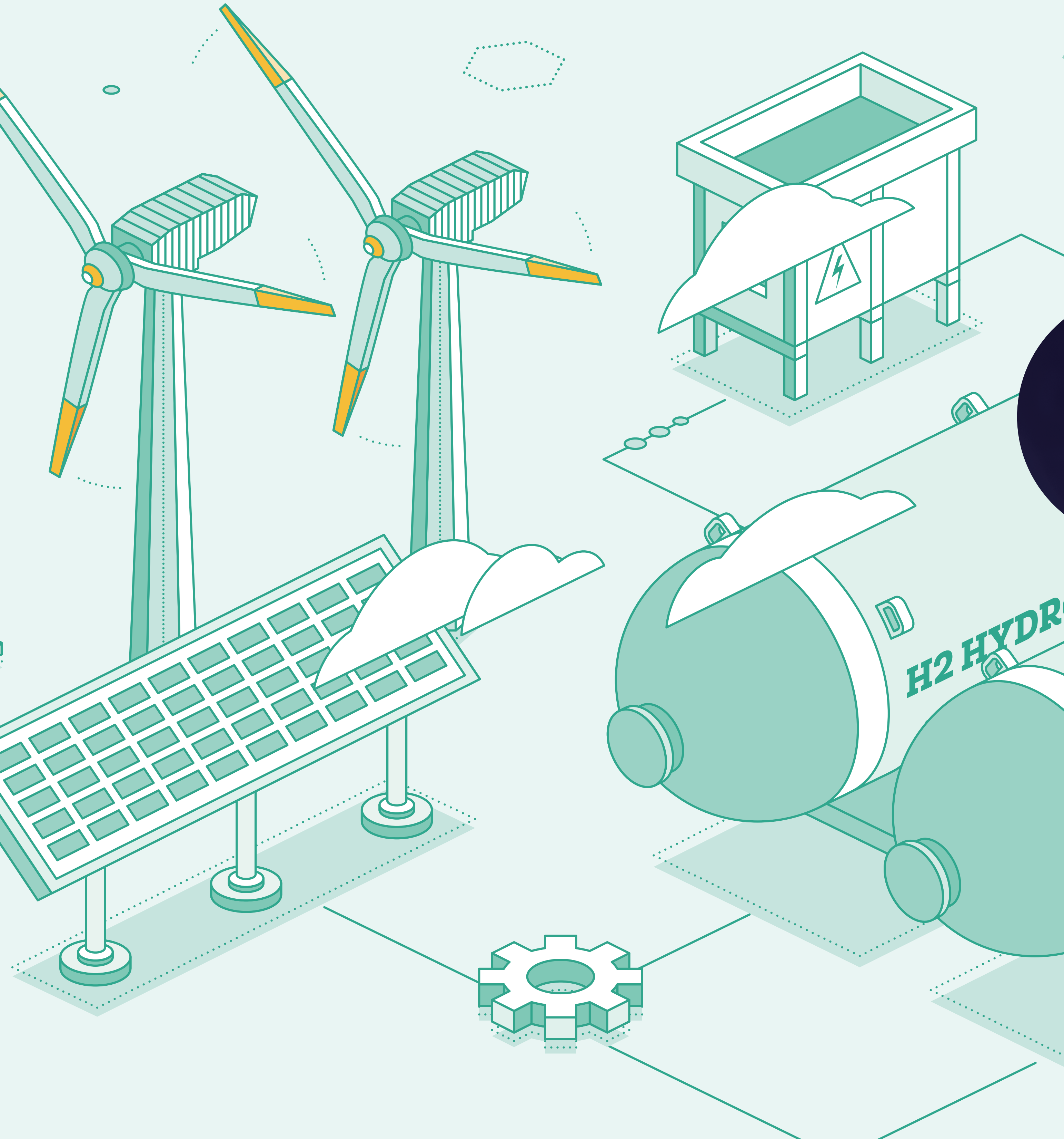
A primary point of contention is the ambiguous definition of “clean hydrogen” and the associated risk of greenwashing. Although labeled “clean,” its actual emission reduction benefits are often limited; instead, there is a risk that it may serve as a lifeline to prolong the existing fossil fuel industry. The term “hydrogen” does not inherently guarantee environmental benefits, and unchecked policy support could ultimately distort and delay genuine climate action.

Furthermore, scientific studies indicate that leaked hydrogen can indirectly hinder the atmospheric breakdown of methane, potentially resulting in a Global Warming Potential (GWP) up to 11 times greater than that of carbon dioxide. Debates regarding the feasibility of a hydrogen-centric transition remain robust, highlighting the exorbitant costs of infrastructure development, indirect emissions, and doubts over whether actual demand justifies these massive undertakings.

Seeking Solutions Amidst Necessity and Controversy

While hydrogen is undeniably necessary, its efficacy as a definitive climate solution remains highly debatable. Simultaneously, the lingering suspicion that current hydrogen policies merely represent a “fossil fuel life extension strategy” is difficult to dispel.

Therefore, this report reevaluates the definition and role of hydrogen, and assesses its future trajectory and policy direction. Furthermore, it reviews the broader landscape of Korea’s hydrogen policy and proposes a strategic redesign focused on addressing these core controversies.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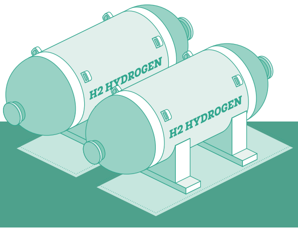
I What is Hydrogen?



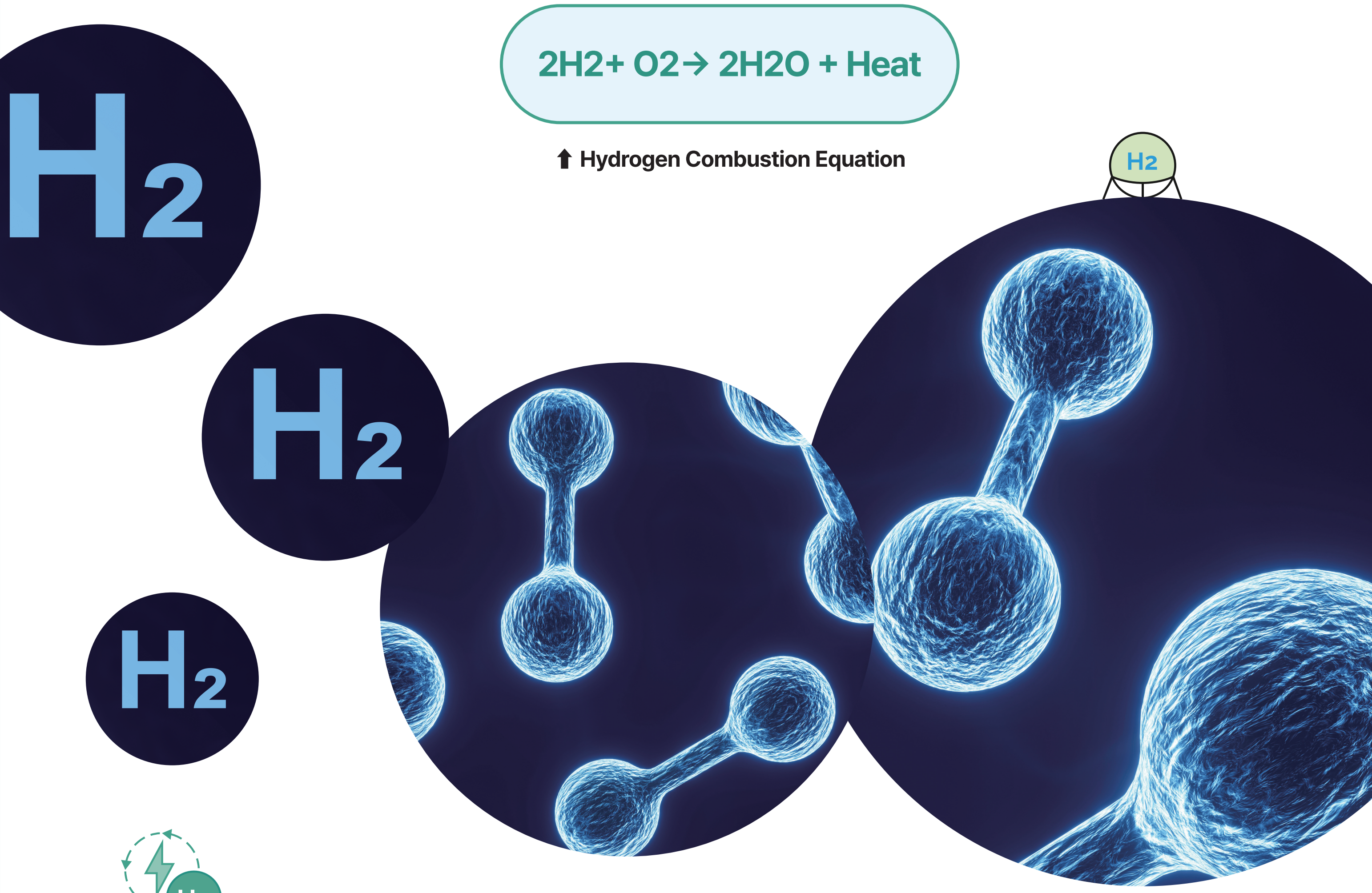
1. Definition and Physical Properties

Hydrogen (atomic symbol H) is the lightest and simplest element, holding atomic number 1 on the periodic table. It is the most abundant substance in the universe, constituting approximately 75% of all matter, and exhibits various distinct physical and chemical properties.

Under standard conditions, it exists as a diatomic gas (H_2) that is colorless, odorless, and tasteless. Hydrogen gas is about 14 times less dense than air, liquefies at -252.87°C (at 1 atm), and solidifies at -259.14°C. Hydrogen is highly combustible, reacting with oxygen to form water while releasing substantial heat. Its specific energy (higher heating value) is exceptionally high at roughly 120 MJ/kg, making it an ideal rocket fuel. These properties make it highly versatile for energy storage and transportation, industrial applications, and aerospace. [1]

$$2H_2 + O_2 \rightarrow 2H_2O + \text{Heat}$$

⬆ **Hydrogen Combustion Equation**



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[1] "Hydrogen | Properties, Uses, & Facts." *Encyclopædia Britannica*. https://www.britannica.com/science/hydrogen (Accessed June 2, 2025).

Recent studies show that while hydrogen does not directly absorb or radiate heat, it can induce an indirect greenhouse effect by extending the atmospheric lifespan and concentration of other greenhouse gases like methane. Consequently, research suggests that hydrogen's indirect GWP by mass could surpass that of carbon dioxide. [2] Strict leak prevention and management across the entire value chain—production, storage, and transport—are therefore imperative.

2. The Dominant Production Method : Gray Hydrogen

According to the International Energy Agency (IEA), global hydrogen demand surpassed 97 million tons in 2023 and is projected to reach 100 million tons in 2024. This growth is driven primarily by economic expansion in traditional sectors—such as oil refining, chemical manufacturing (ammonia, methanol), and steelmaking—rather than by new hydrogen policies. Following a brief pandemic-induced dip, demand has steadily recovered, yet low-emission hydrogen still accounted for less than 1% of the total 2023 demand.

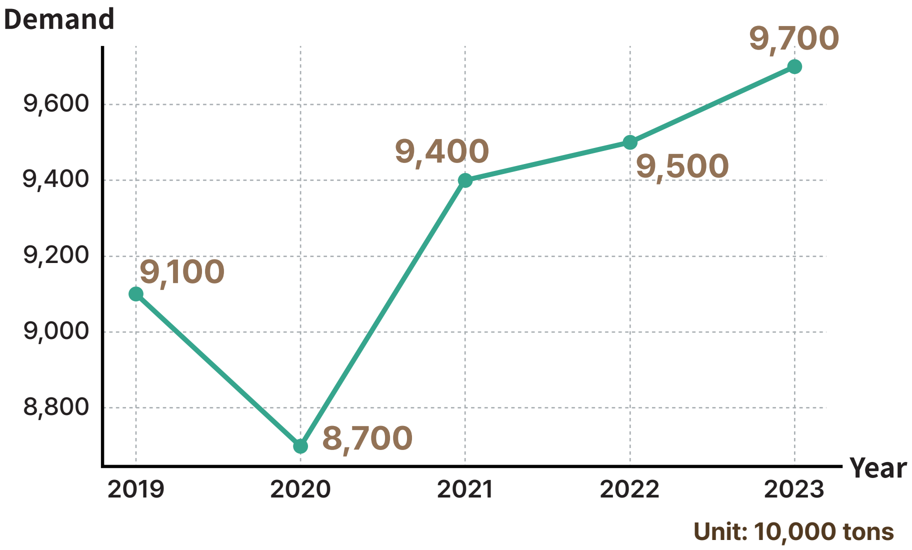
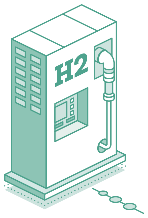


Figure 1. Global Hydrogen Demand (2019–2023)



China is the world's largest consumer, using approximately 33 million tons, followed by the United States (10 million tons) and the European Union (8 million tons). These three regions consume more than half of the global total. Other major consumers include India (6 million tons), Japan (2 million tons), and South Korea (1.5 million tons). 3)

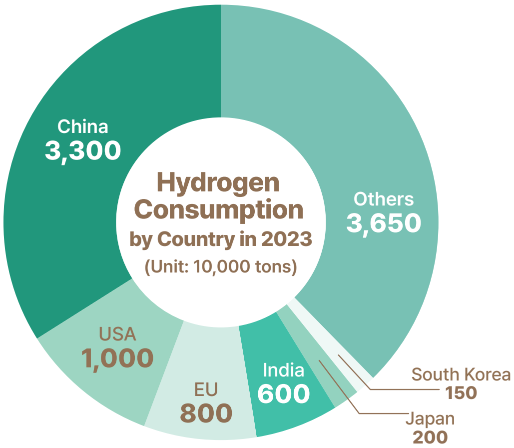


Figure 2. Hydrogen Consumption by Country in 2023

The greenhouse gas emissions resulting from this massive consumption are substantial. In 2023 alone, hydrogen production and usage emitted an estimated 920 million tons of CO2. To put this in perspective, this is comparable to the combined 2022 annual emissions of Indonesia and France. 4)

This massive carbon footprint stems directly from production methodologies. The vast majority of global hydrogen is extracted from fossil fuels, producing what is known as "gray hydrogen." Currently, about 6% of the world's natural gas and 2% of its coal are dedicated to gray hydrogen production.

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2) Ilissa B. Ocko and Steven P. Hamburg, "Climate Consequences of Hydrogen Emissions," *Atmospheric Chemistry and Physics 22*, no. 14 (2022): 9349–9368, https://doi.org/10.5194/acp-22-9349-2022 (Accessed May 30, 2025).GHAV

3) *International Energy Agency, Global Hydrogen Review 2024* (Paris: IEA, 2024), https://www.iea.org/reports/global-hydrogen-review-2024 (Accessed May 30, 2025).

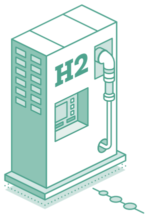
4) International Energy Agency. Countries and Regions. https://www.iea.org/countries (Accessed May 31, 2025.).

Gray hydrogen is primarily produced via two methods. The most common is Steam Methane Reforming (SMR), which accounts for 76% of gray hydrogen. 5) In SMR, methane reacts with high-temperature steam (700°C–1000°C) over a nickel catalyst to produce hydrogen and carbon monoxide. A subsequent water-gas shift reaction generates additional hydrogen and carbon dioxide. 6) Because one mole of methane produces one mole of CO2, generating 1 kg of hydrogen directly emits approximately 5.46 kg of CO2.

$$CH_4 + 2H_2O \rightarrow CO_2 + 4H_2$$

⬆ **SMR Hydrogen Reforming Reaction Equation**


〈Image of Gas Field〉



The second method, coal gasification, is far more complex. Pulverized coal reacts with oxygen (or air) and steam at 1400°C–1800°C to create syngas (carbon monoxide, hydrogen, and carbon dioxide). After cooling and purification, a shift reaction produces more hydrogen and CO2. Finally, high-purity hydrogen is extracted through a separation process. The critical flaw of this method is its extreme carbon intensity, emitting roughly twice as much CO2 as natural gas reforming. [7]

When evaluated via Life Cycle Assessment (LCA), natural gas-based hydrogen emits roughly 9–12kg [8] [9] of CO2 per kg of hydrogen, while coal-based hydrogen emits a staggering 15–20kg [10]. This demonstrates that utilizing gray hydrogen can be as carbon-intensive—or even more so—than directly burning fossil fuels, fueling the global push for low-emission alternatives.

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5) International Energy Agency. *The Future of Hydrogen: Seizing Today's Opportunities*. Paris: IEA, 2019. https://www.iea.org/reports/the-future-of-hydrogen (Accessed June 2, 2025).

6) Yong Yang et al., "*Hydrogen Production from Coal Gasification: A Review*," International Journal of Hydrogen Energy 50, no. 25 (2025): 12345–12360, https://www.sciencedirect.com/science/article/pii/S0360319925011991 (Accessed June 2, 2025).

7) U.S. Department of Energy. *Hydrogen Program Plan*. Washington, DC: Office of Energy Efficiency & Renewable Energy, 2020. https://www.hydrogen.energy.gov/docs/hydrogenprogramlibraries/pdfs/hydrogen-program-plan-2020.pdf (Accessed June 2, 2025.).

8) Hydrogen Council. *Decarbonization Pathways: Part 1 – Lifecycle Assessment of Hydrogen Pathways*. Brussels: Hydrogen Council, 2021. https://hydrogencouncil.com/wp-content/uploads/2021/04/Hydrogen-Council-Report_Decarbonization-Pathways_Part-1-Lifecycle-Assessment.pdf (Accessed June 2, 2025).

9) Spath, Pamela L., and Margaret K. Mann. *Life Cycle Assessment of Hydrogen Production via Natural Gas Steam Reforming*. Golden, CO: National Renewable Energy Laboratory, 2001. https://www.nrel.gov/docs/fy01osti/27637.pdf (accessed June 2, 2025).

10) Zhou, Yuanrong, Zhen Zhang, and Yan Li. L*ife-Cycle Analysis of Greenhouse Gas Emissions of Hydrogen, and Recommendations for China*. Washington, DC: International Council on Clean Transportation, 2022. https://theicct.org/wp-content/uploads/2022/10/China-hydrogen-report-A4_final-5.pdf (Accessed June 2, 2025).

3. Industrial Utilization of Hydrogen

As of 2023, the four largest hydrogen consumers are the refining, ammonia, methanol, and steel industries, which collectively account for the vast majority of total demand.

The oil refining sector leads consumption, utilizing around 43 million tons in 2023. Hydrogen is essential for Hydrodesulfurization (HDS), a process that removes sulfur from crude oil to enhance fuel quality.

Ammonia, methanol, and steel production collectively consumed 54 million tons. Of this, approximately 60% went to ammonia, 30% to methanol, and 10% to steelmaking. 11) Ammonia synthesis requires reacting hydrogen with nitrogen; over 70% of this ammonia is used to manufacture vital agricultural fertilizers. 12)

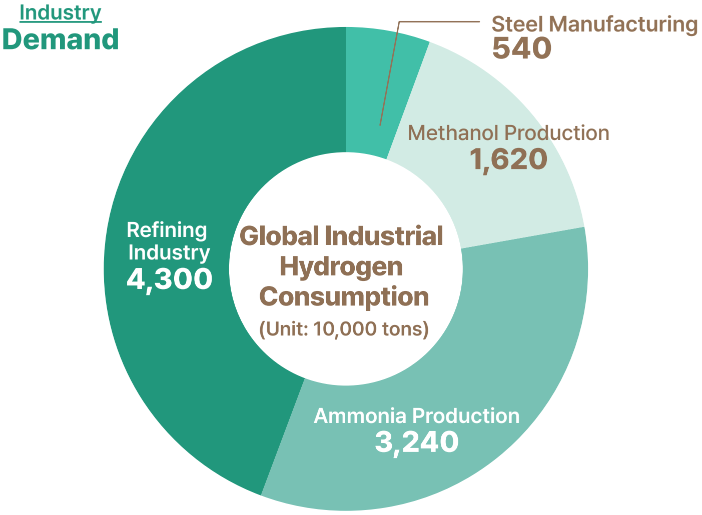

Figure 3. Global Industrial Hydrogen Consumption

〈Image of Refinery Industrial Complex〉

Methanol production requires synthesizing hydrogen (extracted from natural gas) with carbon monoxide or carbon dioxide under high heat and pressure using a catalyst. Methanol serves as a crucial chemical feedstock and fuel. 13)

In the steel industry, hydrogen sees limited use primarily in Direct Reduced Iron (DRI) processes. This method removes oxygen from iron ore in a solid state to produce reduced iron, which is then melted in an electric arc furnace to produce steel. 14)

In South Korea(as of 2023), total hydrogen production reached 2.48 million tons, with by-product hydrogen (generated during industrial or power processes) comprising 57% and reformed hydrogen accounting for 43%. 15) Based on 2020 data, 93% of the consumed hydrogen(2.186 million tons) was utilized in refining (61%) and chemicals(39%). The remaining 7% supported power generation and hydrogen vehicle charging. 16)

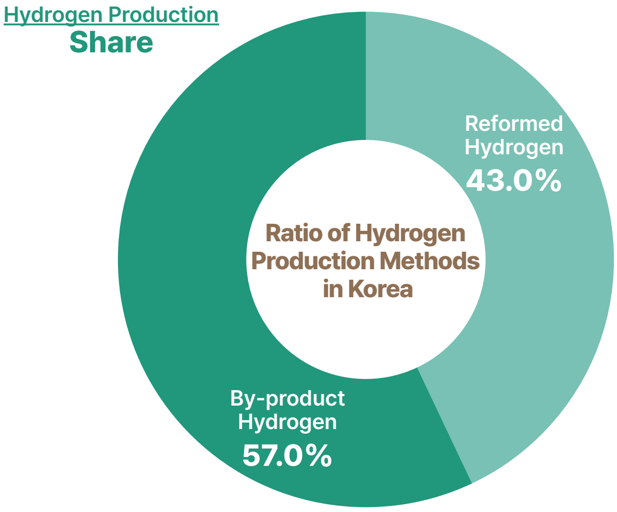

Figure 4. Ratio of Hydrogen Production Methods in Korea

〈Image of Stainless Steel Products〉

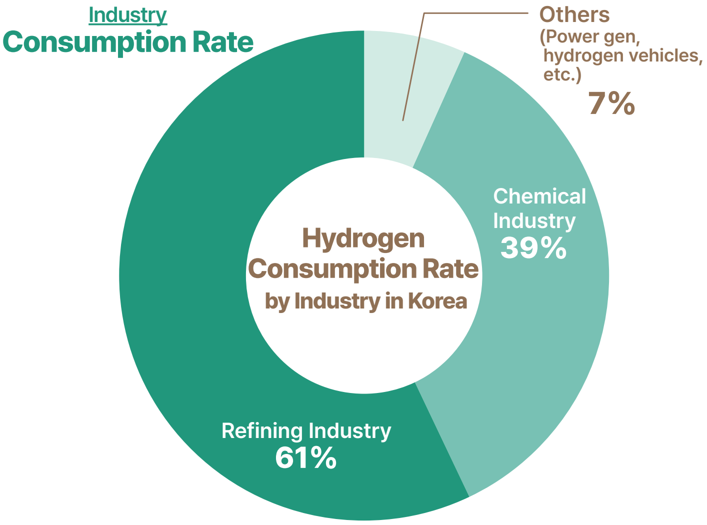

Figure 5. Hydrogen Consumption Rate by Industry in Korea

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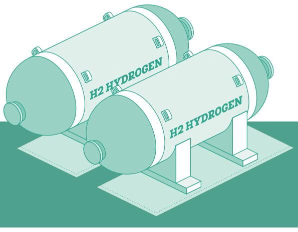
11) International Energy Agency, *Global Hydrogen Review 2024* (Paris: IEA, 2024), https://www.iea.org/reports/global-hydrogen-review-2024 (Accessed May 30, 2025).
12) International Energy Agency. *Ammonia Technology Roadmap: Towards more sustainable nitrogen fertiliser production*. Paris: IEA, 2021. https://www.iea.org/reports/ammonia-technology-roadmap (Accessed June 2, 2025).
13) Springer Nature Communities. "How to Make Methanol from CO_2 in the Most Efficient Way?" *Springer Nature Communities*. https://communities.springernature.com/posts/how-to-make-methanol-from-co2-in-the-most-efficient-way (Accessed June 2, 2025).
14) International Energy Agency. Low-Carbon Production of Iron & Steel: Technology Options, Economic Assessment, and Policy. Paris: IEA, 2020. https://www.energypolicy.columbia.edu/publications/low-carbon-production-iron-steel-technology-options-economic-assessment-and-policy/ (Accessed June 2, 2025).
15) "국내 수소 생산량(생산방식별)," 수소경제 종합정보포털 ((사)한국수소연합), https://h2hub.or.kr/main/stat/stat_product_method.do (Accessed June 23, 2025).
16) 한국에너지공단. "에너지온실가스 종합정보 플랫폼." EG-TIPS. https://tips.energy.or.kr/commonsystem/commonsystem_view_03.do?ch_code_num=QS03&code_num=QS (Accessed June 2, 2025).
17) International Energy Agency, *Global Hydrogen Review 2023* (Paris: IEA, 2023), https://www.iea.org/reports/global-hydrogen-review-2023 (Accessed June 4, 2025).
18) *International Energy Agency, Global Hydrogen Review 2024* (Paris: IEA, 2024), https://www.iea.org/reports/global-hydrogen-review-2024 (Accessed May 30, 2025).
19) National Grid, "The Hydrogen Colour Spectrum," National Grid, https://www.nationalgrid.com/stories/energy-explained/hydrogen-colour-spectrum (Accessed June 4, 2025).
20) 안지영, 김기환, 『국내 청정수소 생산 기반 확대 연구』, 기본연구보고서 2024-16 (울산: 에너지경제연구원, 2024), https://www.keei.re.kr/board.es?act=view&bid=0001&list_no=124844&mid=a10101020000 (Accessed June 4, 2025).

II. The Rise of Low-Emission Hydrogen and Its Technological Limitations



1. Defining Low-Emission (Clean) Hydrogen : Blue vs. Green

The IEA defines low-emission hydrogen as having a lifecycle greenhouse gas (GHG) intensity of less than 3.8 kg CO2eq per kg of hydrogen (based on lower heating value).

This threshold aligns with the EU's 2021 criteria for Renewable Fuels of Non-Biological Origin (RFNBOs) and roughly equates to SMR combined with a 90% carbon capture rate. 17) Recently, South Korea and other major countries have adopted the term "clean hydrogen" to describe this category.

Low-emissions hydrogen is broadly divided into a method that captures and stores carbon during the process of reforming methane to extract hydrogen (Carbon Capture and Storage, CCS), and a method of water electrolysis using electricity produced based on renewable energy. 18) According to these production methods, the former is called blue hydrogen, and the latter is called green hydrogen. It is not clear who started the classification by color or when, but hydrogen is classified by color to intuitively convey the hydrogen production method and greenhouse gas emissions. 19) However, since classification by color has aspects that make it difficult to normatively define hydrogen, there has been a recent tendency to collectively refer to it as low-emissions hydrogen or clean hydrogen.

2. The Limitations of Blue Hydrogen : CCS Uncertainty, Methane Leaks, and Low ROI

Blue hydrogen relies heavily on integrating SMR with CCS (SMR+CCS). Because SMR is mature and highly economical, retrofitting it with CCS is widely considered the most viable near-term option.

In this method, methane is burned as both the raw material for hydrogen and the fuel to produce high-temperature steam. In the early stage of the process, methane is input to generate high-temperature heat and steam to react with methane, but after the reformer is operating, it continuously supplies heat using waste heat generated from the reformer and process byproduct gas (off-gas) recirculated from the pressure swing adsorption process as fuel. Therefore, methane consumption for fuel is mostly characterized as occurring early in the process.

For this reason, when performing CCS on an SMR reactor, the gas emitted after fuel combustion is included along with high-purity carbon dioxide, which lowers the carbon dioxide concentration in the captured gas, thereby resulting in the disadvantage of relatively higher capture costs. Also, power consumption occurs during the process of capturing and compressing carbon dioxide, and massive facility investment and energy costs are incurred in transporting it for storage and operating and managing the storage site. 20)

Apart from the technical and financial problems of the SMR+CCS method, the uncertainty of CCS technology itself is an important issue. Commercially operating CCS facilities have never achieved a carbon dioxide capture rate of over 95%. Currently, in cases where carbon dioxide capture technology is applied among SMR-based hydrogen production facilities, the carbon dioxide capture rate stays at 70-80%. Even this is the result of selective capture from some streams where carbon dioxide exists in high concentration.

Facilities that actually capture carbon dioxide using currently operating SMR+CCS hydrogen facilities are ‘Shell Quest’ in Canada and ‘Air Products’ in Louisiana, USA; Shell Quest’s capture rate does not even reach half, and Air Products does not exceed 60%. The claim that a high level of CCS is possible with currently commercialized SMR technology is only theoretical and does not match reality.

Ultimately, CCS, the core technology of blue hydrogen, still shows a level of technological maturity that falls very short of being called carbon neutral, and imperfect and unverified technologies are packaged as if they are the future of hydrogen production, acting as an obstacle to responding to and overcoming the climate crisis.

Furthermore, to reform methane, methane must be used, but the problem of methane leakage is underestimated. For blue hydrogen, the methane leakage rate used in LCA analysis is assumed to be unrealistically low. The US Department of Energy (DOE) and some industries assume a methane leakage rate of 1.2% or less. However, the actual methane leakage rate in the US shale gas, LNG, and value chains can reach 3-5%. If the leakage rate is underestimated like this, the actual greenhouse gas emissions of hydrogen production are also minimized. This is because methane has a warming effect 28 times higher than that of carbon dioxide.

In addition to the indirect warming effect of hydrogen mentioned earlier, the volatility of natural gas prices due to instability in the international community such as wars, and the decrease in future hydrogen demand due to leaps in electrification and battery technology are raising many doubts about whether blue hydrogen is indeed a rational choice. Therefore, asserting that blue hydrogen is ‘clean’ or ‘low-carbon’ comes with many constraints. [21]

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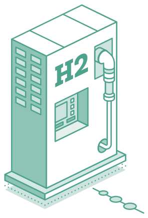
[21] David Schlissel, CCS and Blue Hydrogen: Unproven Technology and Financial Risk (Cleveland: Institute for Energy Economics and Financial Analysis, July 3, 2024), https://ieefa.org/resources/ccs-and-blue-hydrogen-unproven-technology-and-financial-risk (Accessed June 4, 2025).



3. Potential and Challenges of Green Hydrogen : High Costs, Reliance on Renewable Energy, and Supply Chain Issues

Green hydrogen is currently evaluated as the most desirable hydrogen production method from the perspective of climate crisis mitigation. Because it produces hydrogen using renewable energy, it emits almost no greenhouse gases during the production process, and its relative safety is a core factor driving interest in green hydrogen. In particular, the role of green hydrogen is sometimes emphasized as a means to secure flexibility resources for the power grid in tandem with the expansion of renewable energy. Hydrogen electrolysis technology is considered an effective alternative for addressing the intermittency of renewable energy and storing surplus electricity. This is why hydrogen is attracting attention as a supplementary measure to respond to the rapid expansion of renewable energy.

However, green hydrogen does not solely present a rosy future; primarily, the cost itself is significantly higher compared to other hydrogen production methods. Critics point out that due to high production unit costs, unless a country has sufficiently low renewable energy prices and an abundant supply, green hydrogen lacks economic viability, making mass production difficult. Currently, the power supply, storage and transportation infrastructure, and consumption base required for the large-scale production of green hydrogen are not yet adequately established. Furthermore, the energy loss during the conversion of electrical energy into hydrogen is substantial, resulting in a low amount of recovered hydrogen energy relative to the inputted electricity. The conversion efficiency of current electrolysis technology stands at around 60–70%, and overcoming this inefficiency, which causes significant power loss, remains a critical challenge.[22]

Naturally, these issues could be partially resolved if the expanded supply of renewable energy gains more momentum, and assuming a scenario where gray hydrogen faces heavier penalties for greenhouse gas emissions, the price competitiveness of green hydrogen could be addressed in the future. However, countries with abundant renewable energy resources and favorable geographical conditions—such as Northern Europe, China, the Middle East, Australia, and Chile—are highly likely to become the centers of green hydrogen production. Consequently, preparations must be made for the potential concentration of the supply chain in specific nations.

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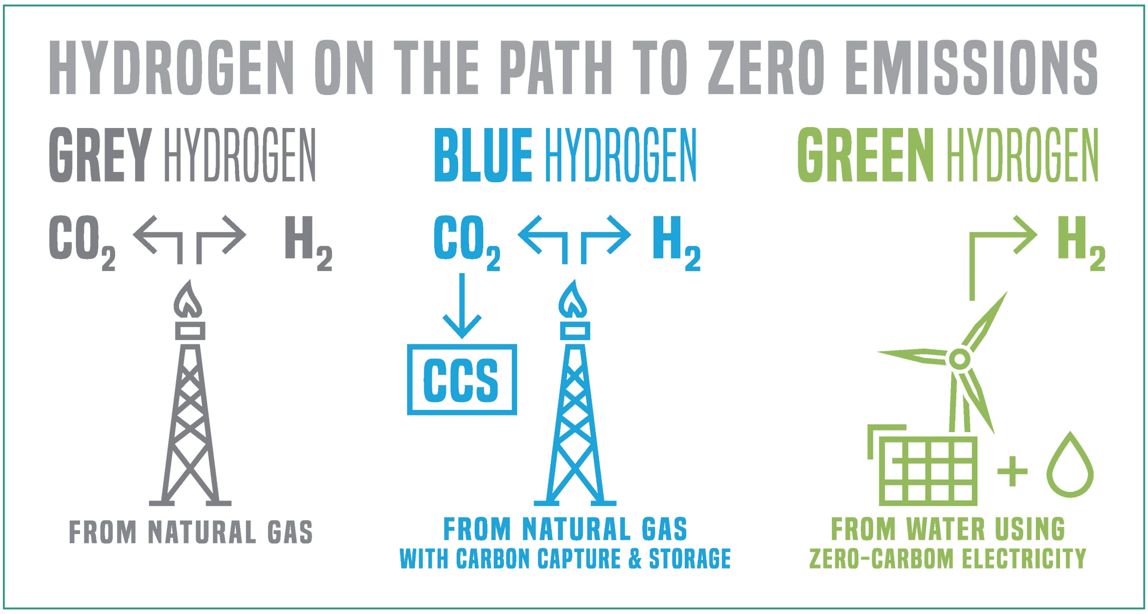
[22] International Energy Agency, The Future of Hydrogen: Seizing Today's Opportunities (Paris: IEA, June 2019), https://iea.blob.core.windows.net/assets/8ab96d80-f2a5-4714-8eb5-7d3c157599a4/English-Future-Hydrogen-ES.pdf (Accessed June 24, 2025).

Additionally, the IEA emphasizes that an adequate demand base is crucial for the successful proliferation of low-emission hydrogen. Yet, while hydrogen is abundantly present in nature, it must be extracted and produced by inputting energy; realistically, it is not an infinitely producible resource. Excluding the transition demand in the steelmaking industry, which can drastically reduce greenhouse gas emissions, another problem is that industrial sectors capable of stably securing hydrogen demand have not yet been distinctly identified. Accordingly, the possibility of excessive discussion and forceful implementation of technologies and policies whose necessity is hard to gauge, along with the subsequent socio-economic conflicts, must also be carefully considered. [23]



〈Schematic of Blue Hydrogen and Green Hydrogen〉

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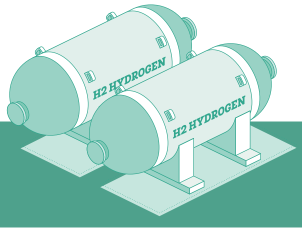
[23] International Energy Agency, *Global Hydrogen Review 2024* (Paris: IEA, 2024), https://www.iea.org/reports/global-hydrogen-review-2024 (Accessed May 30, 2025).

III. Limitations of Korea's Hydrogen Policy and the Logic of Demand Expansion



1. Overview of Korea's Hydrogen Policy : Core Contents of the 1st Basic Plan for Implementation of the Hydrogen Economy[24]

Following the "Hydrogen Economy Promotion and Hydrogen Safety Management Act" (hereinafter the Hydrogen Act) enacted in February 2021, the government established the "1st Basic Plan for Implementation of the Hydrogen Economy (2021–2040)," the first statutory plan in the hydrogen sector. This plan sets the vision of "Realizing a Clean Hydrogen Economy" and outlines four major strategies and 15 execution tasks to create an ecosystem encompassing the entire lifecycle of hydrogen production, storage, transportation, and utilization.

The four major strategies are

① Expanding domestic and international clean hydrogen production bases
② Building distribution infrastructure, such as hydrogen storage and transportation networks
③ Expanding hydrogen utilization across diverse sectors, and
④ Strengthening the ecosystem's foundation through technology, regulatory frameworks, safety, and international cooperation.

The 15 tasks include expanding green and blue hydrogen production, securing overseas clean hydrogen, establishing distribution networks (pipelines, charging stations), utilizing hydrogen in power generation and mobility, driving hydrogen transition in the industrial sector, developing technology and training personnel, ensuring standardization and safety, creating hydrogen clusters and cities, and fostering global cooperation while improving public acceptance.

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24) 산업통상자원부, 제1차 수소경제 이행 기본계획 (세종: 산업통상자원부, 2021), https://h2hub.or.kr/main/info/policy-industry-techinfo.do?mode=view&articleNo=673&article.offset=60&articleLimit=10 (Accessed June 24, 2025).

In terms of expanding the clean hydrogen supply, the government set a target to establish an annual green hydrogen production capacity of 250,000 tons by 2030, scaling up to 3 million tons by 2050. This also includes a plan to lower the production cost of electrolyzed hydrogen from 3,500 KRW per kg down to around 2,500 KRW by 2030. For blue hydrogen, the plan specifies a timeline to establish a blue hydrogen cluster near LNG receiving terminals and commence production starting in 2025.

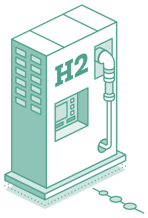
Carbon Capture, Utilization, and Storage (CCUS) technology is also targeted for early commercialization. Notably, there are plans to operate a CCS demonstration project capable of storing 400,000 tons annually for 30 years starting in 2025, utilizing the depleted Donghae gas field.

To build hydrogen distribution infrastructure, the government intends to construct pipeline networks centered around industrial and power generation complexes, and develop hydrogen ports, liquid hydrogen plants, and ammonia-to-hydrogen conversion facilities. The goal for hydrogen charging stations is to install 660 units by 2030 and 1,200 units by 2040, alongside support for converting existing gas and LPG stations, and introducing a hydrogen trading system to establish a market-based distribution framework.

In the utilization sector, the plan incorporates measures to use clean hydrogen as a power generation fuel. Initiatives include applying ammonia co-firing technology to coal power plants, hydrogen co-firing technology to LNG power plants, and integrating clean hydrogen power generation into the Renewable Portfolio Standard (RPS) mandate.

In the mobility sector, the strategy covers developing a full lineup of hydrogen passenger and commercial vehicles, transitioning intercity, transit, and express buses to hydrogen, promoting early adoption of special vehicles like garbage trucks, and commercializing future transport modes such as hydrogen-based ships, trams, and Urban Air Mobility (UAM). To support this, securing production capacity, expanding charging infrastructure, and implementing subsidy policies will be carried out concurrently.

⟨Image of Hydrogen Ecosystem⟩



In the industrial sector, foundational work for hydrogen transition is underway, including creating hydrogen industrial complexes, transitioning to hydrogen-reduced steelmaking, substituting petrochemical processes, and utilizing hydrogen as fuel in cement kilns. Concurrently, ecosystem-building efforts will proceed, covering technology development, workforce training, preempting international standards, ensuring hydrogen safety, expanding global cooperation, fostering specialized hydrogen companies, strengthening financial support, designating special regulatory zones, and establishing hydrogen cities.

Overall, the 1st Basic Plan for Implementation of the Hydrogen Economy aims to expand blue and green hydrogen production bases, construct a domestic supply system around them, and build the foundation for hydrogen utilization to facilitate a transition to a clean hydrogen-centric ecosystem. While the overarching plan covers the entire lifecycle—production, distribution, utilization, infrastructure, and R&D—its practical focus heavily prioritizes establishing massive production capacity and securing demand sources.

2. Expanding Supply Without Demand : The Premature Commercialization Plan for Blue Hydrogen CCS

As previously noted, substantial additional demand beyond existing industrial utilization has yet to materialize. Aside from a few commercialized applications, most remain in nascent technological phases, and it is uncertain whether these will actually translate into full commercialization. Therefore, the immediate need for massive volumes of low-emission hydrogen is currently lacking.

Furthermore, securing CCS technology is core to blue hydrogen, but as mentioned earlier, this carbon capture technology is far from perfect, and its drawbacks are increasingly overshadowing its climate mitigation benefits. Specifically regarding carbon utilization, the “National Strategy for Carbon Neutrality and Green Growth and the 1st National Basic Plan” announced by the government in 2023 explicitly acknowledges the low level of technological development. 25)

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25) 관계부처 합동, *탄소중립·녹색성장 국가전략 및 제1차 국가 기본계획*, 대한민국 정부, April 2023, p. 84.

Given this, is the government's flagship CCS policy for blue hydrogen production—planning to store 400,000 tons annually in the depleted Donghae gas field—truly feasible? In 2023, the government scaled up this plan to store 1.2 million tons annually, amending the project's scope and timeline to commence in 2025 with storage operations beginning in 2030. In essence, this implies they deemed the project viable.

It is true that depleted gas fields are considered highly suitable for carbon dioxide storage, given their natural geological structures that have trapped gas for millions of years. Indeed, SLB, a specialized CCS design and evaluation firm, assessed that the depleted Donghae gas field could store up to 1.2 million tons of CO2 annually without leakage or formation damage. [26]

Moreover, utilizing gas fields for storage aligns with international trends, as seen in the Netherlands' PORTHOS project [27] , and Eastern Europe's ANRAV project [28] However, these projects are also still underway and have not yet adequately verified their environmental impacts, safety, or economic viability.

The primary criticisms against gas-field CCS can be summarized into four points: ① Leakage risks and environmental impacts, ② Technological uncertainty and safety issues, ③ Lack of economic viability, and ④ Serving as a "greenwashing" tool rather than a fundamental response to the climate crisis.

The foremost criticism is the risk that injecting 1.2 million tons of CO2 into the geological formation could result in re-leakage through unidentified pathways, such as existing boreholes or fault structures. [29] Compounding this is the concern that pressure changes during injection could induce seismic activity (earthquakes), which would naturally escalate the probability of CO2 leakage. [30] Since perfect control over geological formations is impossible, absolute isolation cannot be guaranteed; furthermore, the impact on marine ecosystems should the leaked CO2 flow into the ocean has not been sufficiently examined.

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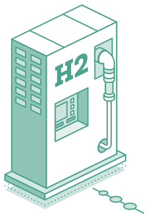
[26] SLB, CCS: KNOC Carbon Storage, Korea Case Study, SLB.com, https://www.slb.com/resource-library/case-study-with-navigation/sne/ccs-knoc-carbon-storage-korea-cs (Accessed July 8, 2025).

[27] Sunghyun Park, Insun Park, Woochan Lee, and Yutaek Seo, "Optimizing CO_2 Injection in Depleted Gas Fields off the East Coast of Korea: A Comprehensive Approach to Flow Assurance," Conference Paper, 17th International Conference on Greenhouse Gas Control Technologies (GHGT-17), Calgary, Canada, November 2024, via ResearchGate, https://www.researchgate.net/publication/385782972_Optimizing_CO2_injection_in_depleted_gas_fields_off_the_east_coast_of_Korea_A_comprehensive_approach_to_flow_assurance (Accessed July 8, 2025).

[28] European Commission, "ANRAV-CCUS – an innovative stakeholder supported CCUS value chain to realize the first CCUS cluster in Eastern Europe", Innovation Fund, December 2022, via EU Climate Action, https://climate.ec.europa.eu/system/files/2022-12/if_pf_2022_anrav_en.pdf (Accessed July 8, 2025).

[29] Pieter P. van der Meer, Thomas J. Hovorka, Thomas R. Winters, et al., "Fault Activation and Induced Seismicity in Geological Carbon Storage," International Journal of Coal Geology 234 (July 2022): 103645, via ScienceDirect, https://www.sciencedirect.com/science/article/abs/pii/S0012825221003500 (Accessed July 8, 2025).

[30] Mark D. Zoback and Steven M. Gorelick, "Earthquake Triggering and Large-Scale Geologic Storage of Carbon Dioxide," Proceedings of the National Academy of Sciences 109, no. 26 (2012): 10164–69 (published June 26, 2012),



Furthermore, the limitation in storage capacity poses a problem. The Donghae gas field's storage capacity is roughly 12 million tons, which is profoundly marginal compared to South Korea's total national greenhouse gas emissions of 724 million tons in 2022. [31]

From a national standpoint, only a negligible effect can be anticipated. The costs incurred to store such a minuscule fraction are also astronomical. Initial capital expenditures and operational costs are substantial, yet the revenue model remains nebulous, which could lead to a systemic issue of excessive dependence on government subsidies. [32] In reality, the Donghae CCS project requested approximately 2.9 trillion KRW from the government, but as of now, it has failed to pass the Ministry of Economy and Finance's preliminary feasibility study. [33]

The most fundamental issue is that technologies like gas-field CCS can obfuscate the true essence of climate crisis mitigation. Fossil fuel corporations can leverage CCS to window-dress their carbon reduction efforts while preserving their legacy business models (oil and gas production). This acts as a catalyst that delays the early retirement of coal and gas power plants and obstructs a structural transition to renewable energy. [34] Even the IEA explicitly states that CCS is merely an unavoidable interim measure during the phased phase-out of fossil fuels, not a core strategy for addressing the climate crisis. [35]

Under these circumstances, there is a pressing need to reevaluate whether funneling trillions of won in government funds into CCS for blue hydrogen production is a sound policy decision. What is urgently required now is not the forced mass production of blue hydrogen, but rather a renewable energy-based transition policy anchored in solar and wind power, as declared by the Lee Jae-myung administration.

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https://www.researchgate.net/publication/227343678_Earthquake_triggering_and_large-scale_geologic_storage_of_carbon_dioxide (Accessed July 8, 2025).

[31] 환경부 온실가스종합정보센터,「2024 국가 온실가스 인벤토리 (1990–2022)」, 2025년 1월 3일, https://www.ctis.re.kr/ko/selectBbsNttView.do?bbsNo=314&key=1694&nttNo=1136849 (Accessed July 8, 2025).

[32] Greenpeace, Selling Hot Air: How the European Union's Carbon Trading Scheme Fails to Deliver Real Emissions Cuts (Amsterdam: Greenpeace International, February 2024), https://www.greenpeace.org/static/planet4-canada-stateless/2024/02/4b010c8b-en-selling-hot-air-report.pdf (Accessed July 8, 2025).

[33] 김정환, “동해가스전 CCS 실증사업, 예타 지연 ‘장기 표류’,” 경상일보, 2025년 5월 2일, https://www.ksilbo.co.kr/news/articleView.html?idxno=1025796 (Accessed July 8, 2025).

[34] Friends of the Earth International, Nature-Based Solutions: A Wolf in Sheep's Clothing (November 2021), https://www.foei.org/wp-content/uploads/2021/11/Nature-based-solutions_a-wolf-in-sheeps-clothing.pdf (Accessed July 8, 2025).

[35] International Energy Agency, Net Zero Roadmap: A Global Pathway to Keep the 1.5 °C Goal in Reach – 2023 Update (Paris: IEA, September 2023), via IEA website, https://iea.blob.core.windows.net/assets/8ad619b9-17aa-473d-8a2f-4b90846f5c19/NetZeroRoadmap_AGlobalPathwaytoKeepthe1.5CGoalinReach-2023Update.pdf (accessed July 8, 2025).

3. Extending Lifespans Instead of Phasing Out Fossil Fuels : The Issue of Hydrogen and Ammonia Co-firing

A notable aspect of the government's plan is its emphasis on co-firing power generation, which involves blending and combusting hydrogen and ammonia with LNG or coal. Initially, the goal is to implement 20% ammonia co-firing in coal power generation by 2030, targeting generators based on their remaining design lifespan and economies of scale derived from large-scale coal power complexes. Factoring in the NDC, [36] the plan dictates that 21GW out of the 32.6GW of coal power capacity must adopt co-firing by 2030. The government's ultimate trajectory is to eliminate coal entirely and achieve 100% ammonia mono-firing power generation before 2050.

For LNG power generation, the objective is to co-fire up to 50% hydrogen. The government proposed early commercialization of hydrogen co-firing by 2031 at low investment costs by retrofitting mid-sized gas turbines whose depreciation has already been fully recovered. It also raises the prospect of repowering retired coal power generators. Regarding 100% hydrogen mono-firing—eliminating gas entirely—the policy dictates completing demonstrations before 2040 and subsequently determining the commercialization timeline by assessing the proportion of renewable energy and hydrogen supply and demand.

Furthermore, to execute its power sector plans, the government intends to introduce a Clean Hydrogen Portfolio Standard. The mandatory entities are being considered to include power generation businesses and electricity sales operators, and the stance also involves restructuring taxes and public charges, extending to downward adjustments or even refunds for clean hydrogen. Currently, ammonia is not permitted for power generation, but the policy includes reviewing deregulation to lift this restriction.

At first glance, these strategies read as a viable blueprint to cut greenhouse gas emissions. This is because injecting zero-emission fuels into facilities that previously burned 100% fossil fuels theoretically reduces emissions proportionally. Indeed, the government underscores this narrative. However, contrary to the government's perspective, there is intense criticism that this scheme effectively delays the phase-out of fossil fuels.

For ammonia co-firing in coal generation, the commercial power plant demonstration by Japan's JERA and

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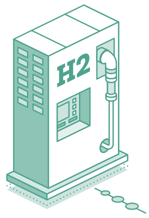
[36] Nationally Determined Contribution, 각국이 기후변화에 대응하기 위해 유엔기후변화협약(UNFCCC) 하에서 자발적으로 설정한 온실가스 감축 목표

[37] E3G. Explained: *Why Ammonia Co-Firing in Coal Power Generation Is a Flawed Approach*. Last modified February 27, 2024. https://www.e3g.org/news/explained-why-ammonia-co-firing-in-coal-power-generation-is-a-flawed-approach/ (Accessed July 17, 2025).

[38] Koons, Eric. "Ammonia Coal Co-firing: Solution Or Distraction?" Energy Tracker Asia, June 12, 2024. https://*energytracker.asia*/ammonia-coal-co-firing/?utm_source=chatgpt.com (Accessed July 17, 2025).

[39] Kennedy, Seb, Jacqueline Tao, and Joo Yeow Lee. "Japan's Toxic Narrative on Ammonia Co-firing." *TransitionZero*, April 13, 2023. https://www.transitionzero.org/insights/japans-toxic-narrative-on-ammonia-cofiring?utm_source=chatgpt.com (Accessed July 17, 2025).



IHI is frequently cited. A 20% ammonia co-firing demonstration at a 1GW-class plant from April 1 to June 19, 2024, verified a 20% reduction in direct CO2 emissions.

Based solely on this, one might anticipate a revolutionary transition, but the reality diverges. Fundamentally, ammonia co-firing policies stall the phase-out of coal and contradict the 1.5°C scenario, which demands a rapid and sweeping transition to renewable energy. [37] Analysis indicates that a 20% blend emits five times more greenhouse gases than the IEA's 2030 Net Zero benchmark, and elevating the blend to 50% still results in emissions three times higher than that benchmark. [38]

Critics also note that fuel costs for a 20% blend soar to approximately double those of current coal, making it up to four times more expensive than renewable energy. [39] A more profound issue is that, unless it is green hydrogen-derived ammonia, the process could generate higher greenhouse gas emissions than simply burning raw coal. Certain LCA-based studies conclude that emissions can actually surpass those of traditional combustion. [40] Ultimately, generating power by blending ammonia with coal stifles the deployment of renewables like solar and wind, inducing the systemic problem of delaying coal phase-out.

Gas power generation fares no better. For gas power generation, hydrogen is mixed in, and the most advanced current technology is the hydrogen co-firing demonstration project partnered by US-based GE and NYPA (New York Power Authority). Operating with hydrogen blended with LNG at a 5% to 44% ratio (by volume), the project confirmed greenhouse gas reductions, showcasing the potential of hydrogen co-firing technology.

Yet, despite this potential, assessments invariably highlight that the actual reduction in greenhouse gases is meager. Their project results demonstrated that a 15% hydrogen blend yielded a mere 5% reduction in direct CO2 emissions; a 25% blend yielded 10%; and a 35% blend yielded 14%. This explicitly illustrates that the actual abatement of greenhouse gases is disproportionately low relative to the volume of hydrogen blended. [41]

Economic viability issues are also flagged; according to a report by Newstapa, hydrogen intended for gas co-firing consumes immense amounts of energy during its reforming, cooling, and transportation phases. They point out that passing through these intermediate stages incurs an approximate 80% energy loss compared to the raw feedstock. [42] In conclusion, while technological complexity and costs surge dramatically, the mitigation effects remain comparatively constrained, exposing a stark lack of efficiency as a greenhouse gas reduction technology.

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[40] Lee, Hoon, Ha Eun Lee, and Sang Mun Jeong. “An Environmental Impact Assessment of Ammonia Co-Combustion in a 1 GWe Coal-Fired Power Plant.” *Proceedings of the 2025 AIChE Spring Meeting & Global Congress on Process Safety*, Environment Division, 2025. https://proceedings.aiche.org/conferences/aiche-spring-meeting-and-global-congress-process-safety/2025/proceeding-521?utm_source=chatgpt.com (Accessed July 17, 2025).

[41] Electric Power Research Institute (EPRI), New York Power Authority (NYPA), and General Electric (GE). *Hydrogen Cofiring Demonstration at New York Power Authority's Brentwood Site: GE LM6000 Gas Turbine*. Report no. 3002025166. Palo Alto, CA: EPRI, December 2022. https://www.epri.com/research/products/000000003002025167 (Accessed July 17, 2025).

[42] 조원일. “수소 혼소 발전, 에너지 80% 낭비’… 국민 비용 전가 우려.” *뉴스타파*, August 18, 2025. https://newstapa.org/article/rcxvO (Accessed October 1, 2025).

Furthermore, depending on the hydrogen's origin, applying an LCA can reveal greenhouse gas emissions exceeding those of conventional LNG power generation. Analyses also exist indicating that blue hydrogen's LCA emissions could eclipse those of methane. 43) Additionally, escalated nitrogen oxide levels and the generation of nitrous oxide during mono-firing are cited as severe drawbacks.

The overarching peril is that this approach—mirroring the critique of ammonia co-firing—threatens to retard the transition away from fossil fuel-based generation. It warns that hydrogen co-firing decelerates the pace of transitioning to net-zero and acts as a potential loophole to dodge rigorous investments. 44) This issue has already surfaced domestically; utilizing hydrogen co-firing as a pretext to expand new gas power plants on Jeju Island sparked fierce backlash from the local community. 45)

Among power generation methods utilizing hydrogen, hydrogen fuel cell power generation boasts the highest technological sophistication and stability. However, stubbornly pushing an irrational co-firing policy can ultimately only be explained as a contrived strategy to secure demand to justify the massive production plans for low-emission hydrogen.

4. Expanding Hydrogen Utilization in the Transportation Sector : Can It Overturn the Dominance of Electrification?

Even examining the government's own plans, the immediate hydrogen demand required in the transportation sector is highly limited. For passenger cars and commercial vehicles like buses, current priorities are overwhelmingly skewed toward battery electrification rather than hydrogen. Indeed, the

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43) Howarth, Robert W., and Mark Z. Jacobson. "How Green Is Blue Hydrogen?" *Energy Science & Engineering 9*, no. 9 (2021): 1676–1687. https://doi.org/10.1002/ese3.956 (Accessed July 17, 2025).

44) Organisation for Economic Co-operation and Development. *Mechanisms to Prevent Carbon Lock-in in Transition Finance. Paris*: OECD Publishing, 2023. https://www.oecd.org/en/publications/mechanisms-to-prevent-carbon-lock-in-in-transition-finance_d5c49358-en.html (Accessed July 17, 2025).

45) 김태홍. "막대한 탄소배출 불러오는 수소 혼소 LNG복합화력발전소 건립계획 철회하라." *제주환경일보*, January 12, 2023. https://www.newsje.com/news/articleView.html?idxno=266811 (Accessed July 17, 2025).

46) 관계부처 합동, *탄소중립·녹색성장 국가전략 및 제1차 국가 기본계획, 대한민국 정부*, April 2023, p. 50.

47) 장병극. "영도·우암감만·씨베이선 합친 '부산항선' 건설…수소전기트램 도입." 철도경제신문, March 21, 2025. https://www.redaily.co.kr/news/articleView.html?idxno=11727 (Accessed July 17, 2025).

48) International Energy Agency. *International Shipping. In Energy System and Transport*. Updated May 2023. https://www.iea.org/energy-system/transport/international-shipping (Accessed July 17, 2025).

49) Urban Air Mobility, 도시 및 도시 주변 지역에서 전기 구동 수직 이착륙(eVTOL, electric Vertical Take-Off and Landing) 항공기를 활용하여 사람이나 화물을 수송하는 새로운 교통 시스템

50) Grand View Research. *Drone Market Size, Share & Trends Analysis Report By Type (Military, Consumer, Commercial, Enterprise), By Platform (Fixed Wing, Rotary, Hybrid VTOL), By Application, And Segment Forecasts, 2024–2030*. Published March 2024. https://www.grandviewresearch.com/industry-analysis/drone-market-report (Accessed July 17, 2025).

51) 대한민국 국토교통부. "*한국형 도심항공(K-UAM), 14일 고흥에서 첫 비행 실증*." 정책뉴스, December 13, 2024. https://www.molit.go.kr/USR/NEWS/m_71/dtl.jsp?id=95090478 (Accessed July 17, 2025).

Korean government's 2023 "National Strategy for Carbon Neutrality and Green Growth and the 1st National Basic Plan" targets the deployment of 4.2 million electric vehicles by 2030, compared to a mere 300,000 hydrogen vehicles. 46)

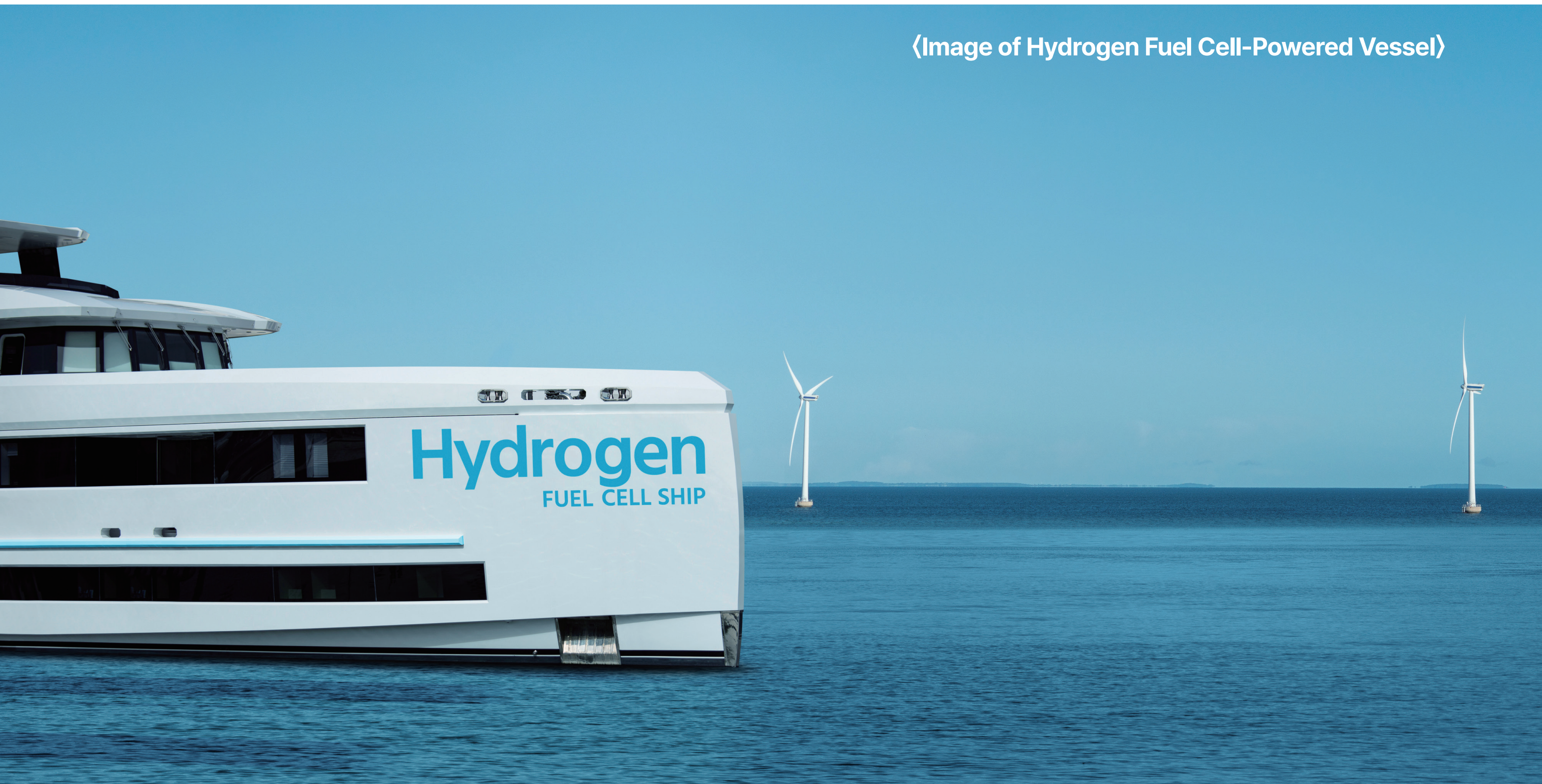
Beyond hydrogen vehicles, plans outline transitioning the fuel for transit modes like hydrogen trams and hydrogen ships to hydrogen or ammonia. Commercialization targets are set post-2028 for hydrogen trams and post-2030 for ships, with hydrogen trams holding the highest probability of realization since route construction is actively progressing alongside commercialization efforts.

However, only a minority of local governments have actually initiated construction. Daejeon and Ulsan have reached completion or pre-completion stages, while Jeju Island remains in the feasibility study phase, and Busan is stagnant in the planning stage. 47) For hydrogen ships, empirical research is still confined to small vessels, making the generation of substantial demand an unrealistic prospect at present. 48) Consequently, hydrogen demand within the transportation sector is extremely restricted.

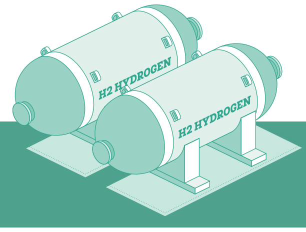
While hydrogen drones and Urban Air Mobility (UAM) are frequently mentioned, 49) electric battery-based drone technology has already advanced significantly, leaving little market demand for hydrogen drones 50). As for UAM, despite ongoing prototype demonstration tests, mass production, commercial certification, and related infrastructure integration remain in primitive stages, making it arduous to secure adequate demand by 2030. 51)

To be sure, technological innovations in transportation are unlocking potential applications for hydrogen fuel cells or ammonia-based fuels, albeit restricted to small-to-medium aircraft, large international aircraft, large passenger ships, and cargo vessels. However, given that commercialization for these technologies is broadly projected post-2040, the current policy aggressively driving radical expansions in hydrogen production without recognizing this timeline is deeply flawed. Accordingly, a sweeping recalibration of hydrogen-related supply and infrastructure strategies is imperative.

〈Image of Hydrogen Fuel Cell-Powered Vessel〉



IV. Policy Recommendations : Appropriate Utilization of Hydrogen and Approaches for Energy Justice



1. Hydrogen policy must not be divorced from fossil fuel phase-out strategies; it must be cohesively structured within the overarching consistency of the carbon neutrality roadmap.

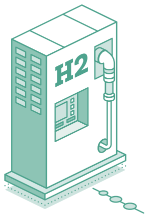
To artificially inflate demand, Korea's current hydrogen policy champions a power generation model that co-fires green hydrogen and green ammonia. Yet, as previously critiqued, this trajectory inherently delays fossil fuel phase-out and effectively perpetuates legacy fossil fuel-based generation facilities. This policy egregiously fails to reflect the accelerating reality of the climate crisis. Therefore, co-firing plans must be thoroughly reevaluated, and policy must pivot toward expediting the deployment of solar, wind, and other renewable energy sources, concurrent with the reduction of legacy power facilities.

2. Efficiency policies and demand management strategies designed to curb energy demand itself must take precedence; expanding supply in a vacuum of demand triggers structural waste.

In drafting the "Basic Plan for Electricity Supply and Demand" and the "National Strategy for Carbon Neutrality and Green Growth," the Korean government routinely overestimates power demand, perpetuating plans to expand power generation facilities to match. Hydrogen or ammonia co-firing power generation is merely a subset of the strategies propelled by these inflated demand forecasts.

The crux of the energy transition is not merely scaling renewables, but actively slashing demand itself via energy efficiency enhancements and rigorous demand management strategies. However, bloated demand forecasts inevitably spawn artificial demand creation—such as scaling hydrogen production and developing co-firing tech—absorbing staggering amounts of fiscal and administrative resources in the process. Consequently, this precipitates profound structural waste, meaning prioritizing efficiency enhancements and demand management strategies to curtail energy demand is paramount.

〈Image of Solar and Wind Energy〉



3. As a supplemental tool for renewable energy expansion, hydrogen must be deployed at an appropriate scale in the 'right places'—such as energy storage, hydrogen fuel cells, and targeted industrial sectors.

In Korea's drive to expand renewable energy, securing grid flexibility has emerged as a paramount challenge. Consequently, Power-to-Gas (P2G) technology, which converts electricity into hydrogen for storage, is gaining traction as a vital flexibility resource. P2G utilizes electrolysis to convert and store surplus renewable electricity as hydrogen, making it a critical technology for pushing past grid limitations to further expand renewable energy.

Green hydrogen produced in this manner should be strictly confined to 'essential applications' vital for decarbonizing the industrial sector—such as fuel cell power generation, transitioning legacy ammonia and methanol production, hydrogen-reduced steelmaking, cement kiln fuel transition, and substituting naphtha in petrochemicals—and utilized at appropriate scales.

4. Blue and clean hydrogen yield more harm than good; a phased trajectory must be established to exclusively recognize renewable-based green hydrogen.

Among low-emission variants, blue or clean hydrogen harbors massive technological, economic, and environmental liabilities. Crucially, when assessed against LCA metrics, these hydrogen variants can register CO2 emissions virtually indistinguishable from gray hydrogen. Pumping disproportionate technological and financial resources into producing these variants can become a critical bottleneck, delaying the overarching transition to renewable energy.

Therefore, even if the short-term utilization of blue hydrogen is deemed unavoidable, policy frameworks must enshrine the transition to renewable-based green hydrogen as the ultimate endgame, devising and executing a lucid, phased implementation pathway.

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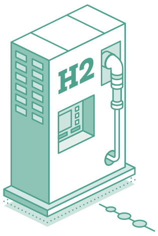

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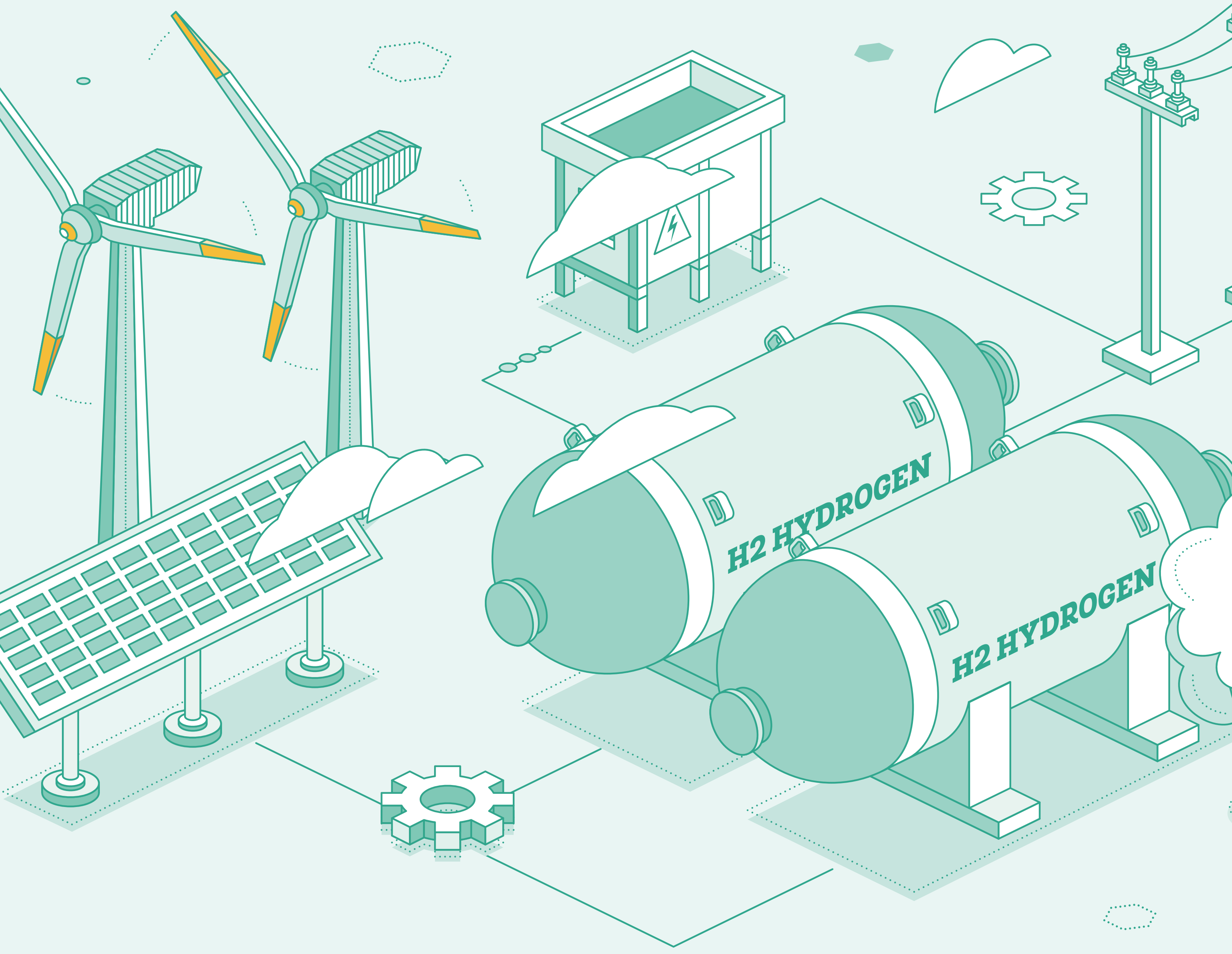
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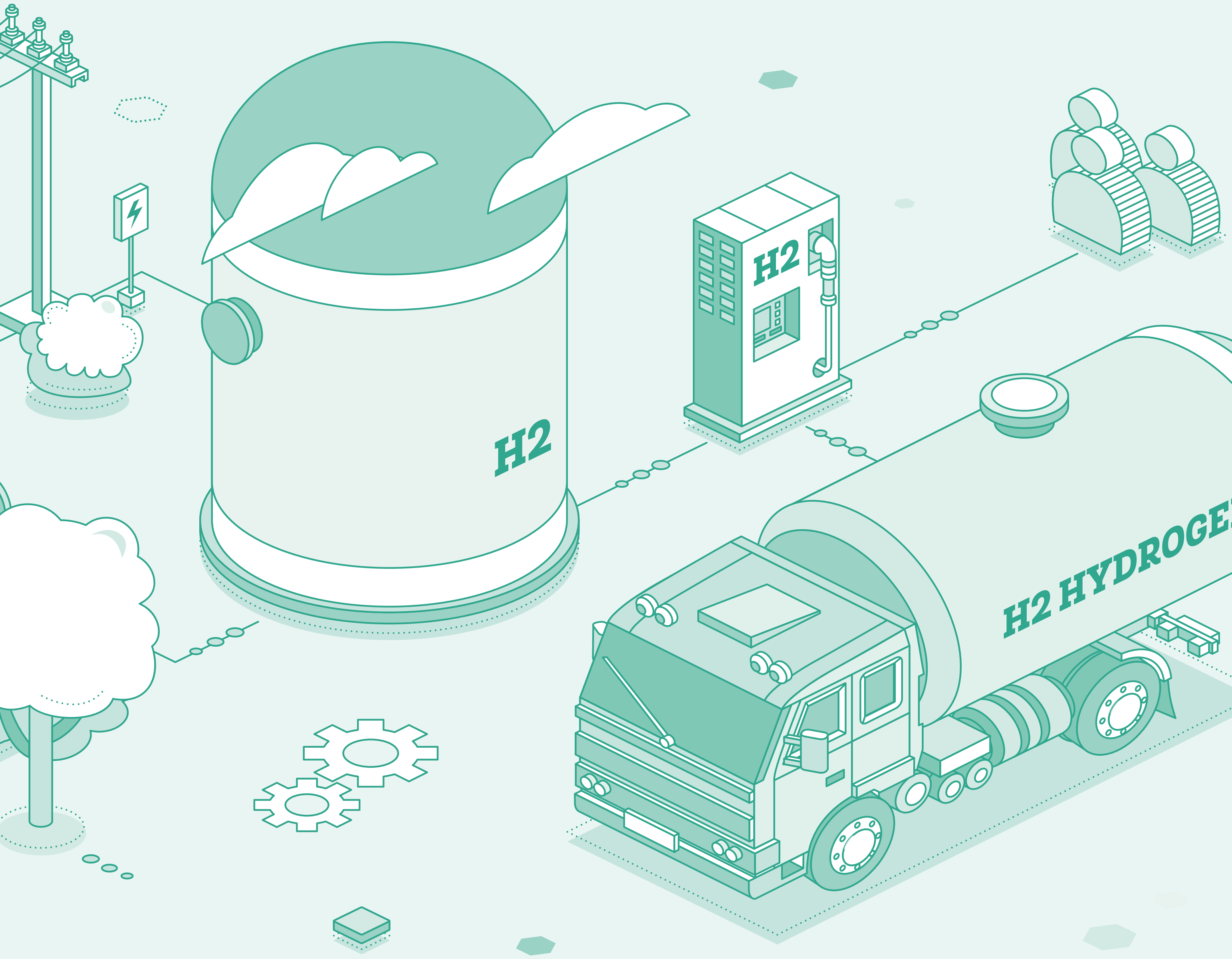
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Understanding Korea's Hydrogen Policy

How Should We Approach Hydrogen Policy in the Era of Energy Transition?

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- This English translation of the report is intended to differ from the Korean version in content.
- In case of an unforeseen conflict, the Korean original will prevail.