Three Unseen Flaws of the Boryeong Blue Hydrogen Project in South Korea

Issue Brief

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Summary

The Boryeong Blue Hydrogen Project, led by Korea Midland Power Company (KOMIPO) and SK E&S, is the world's largest-scale project with a budget of over 5 trillion KRW aiming to produce 250,000 tons of blue hydrogen annually. Although the two companies promote the project as a means of achieving carbon neutrality, a detailed look into the project from the production and utilization of blue hydrogen perspective shows that it is far from carbon neutrality.

The production of natural gases, raw material for producing blue hydrogen, leads to massive GHG emissions, but the impact of such emissions is currently not properly considered. According to U.S.'s Institute for Energy Economics and Financial Analysis (IEEFA), the upstream methane emission rate is usually assumed to be 1% when calculating the carbon intensity for blue hydrogen, but the recent expansion of satellite-based research reveals that some regions have upstream methane emission rates as high as 9.4%, indicating that there is a significant hidden greenhouse effect from blue hydrogen. Furthermore, since methane's 20-year GWP amounts to 83 times that of carbon dioxide, when short-term impacts are also considered, the results may reverse efforts made toward 2050 carbon neutrality. **If a 4% upstream methane emission rate and 20-year GWP is applied to the blue hydrogen plant planned in Boryeong, an annual blue hydrogen production of 250,000 tons may emit GHGs equivalent to emissions by 770,000 to 1.28 million cars.**

Furthermore, KOMIPO's plan to use blue hydrogen produced in Boryeong for co-firing generation in gas combined cycle power generators is also far from carbon neutrality. **Even if 30~50% hydrogen is co-fired in gas combined cycle power generators, GHG emission is reduced only by 11~22% and using blue hydrogen in co-firing generation has almost no GHG reduction effect.**

Despite such underlying facts, the government continues its effort to firmly instate the blue hydrogen industry through the "Clean Hydrogen Certification System" and the "Clean Hydrogen Power Generation Bidding Market." Policy measures during the implementation process of the Clean Hydrogen Certification System such as setting the certification threshold to blue hydrogen produced in Korea and exclusion of shipping emissions for raw material (LNG) and captured carbon dioxide are policy decisions made with the Boryeong Blue Hydrogen Project in mind. If the Clean Hydrogen Power Generation Bidding Market opens under current circumstances, "non-environmentally friendly" blue hydrogen may receive sufficient reimbursement for fixed and variable costs while possibly causing a "lock-in effect" that prevents renewable energy transition.

To achieve carbon neutrality, the focus should be on green hydrogen production based on the expansion of renewable energy, not blue hydrogen production; the usage must not be focused in the power sectors but hard-to-abate sectors like the steel sector which face difficulties in replacing fossil fuels. Korea must not put itself in the "worst-case scenario" in which "blue hydrogen with significant GHG emissions" is produced and used in "co-firing generation causing GHG emissions".

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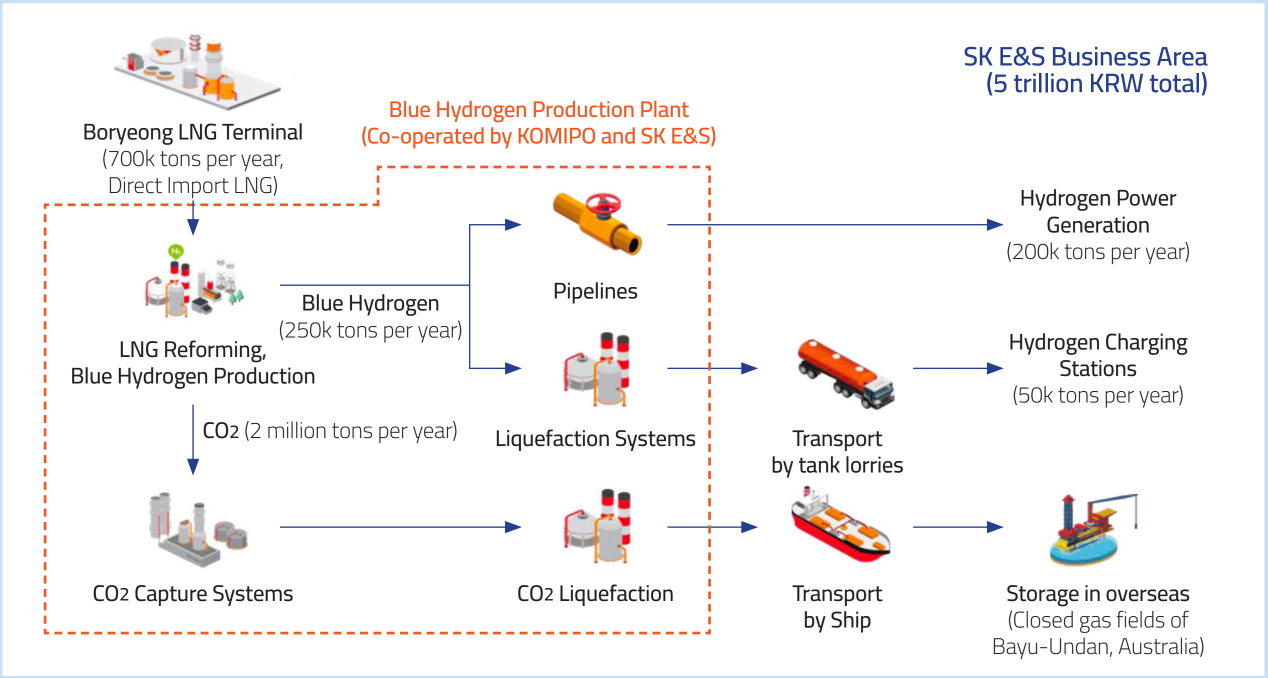
1. Background

Korea Midland Power Company (KOMIPO) and SK E&S are jointly pursuing a project to establish blue hydrogen production plants in Boryeong. SK E&S has promoted the blue hydrogen production project as a "green portfolio", and as a blue hydrogen plant is planned for the first time in Korea, the industry is highly interested in the project. However, contrary to the hydrogen industry's ever-growing expectations, the Boryeong Blue Hydrogen Project has unseen aspects leading to massive GHG emissions and financial burden as well as some dubious aspects. This issue brief points out three major problems the Boryeong Blue Hydrogen Project has and proposes alternatives.

2. Outline of the Boryeong Blue Hydrogen Project[1]

- Purpose: Satisfy domestic demand of fuel cells, hydrogen co-firing generation, charging station supply, etc. through blue hydrogen production
- Investment: Approx. 2.6 trillion KRW (KOMIPO investment approx. 40 billion KRW)
- Production Scale: 250,000 tons of Blue hydrogen annually
- Hydrogen Usage: hydrogen power generation (200,000 tons/year), hydrogen charging stations (50,000 tons/year)
- Site: KOMIPO Boryeong Power Station Ash Processing Site (620,000m²)

[Figure 1] Boryeong Blue Hydrogen Project Concept (Source: KOMIPO)



1 Refer to environmental impact assessment, disclosed information, and National Assembly submissions by KOMIPO

3. 3 Major Problems

1) Clean Hydrogen Certification System: A policy measure with "special" considerations for Boryeong Blue Hydrogen

- Clean Hydrogen Certification System has 4 tiers based on GHG emissions; **domestically-produced blue hydrogen was set as the lower threshold of certification (under 4kg CO2eq per 1 kg of hydrogen)**
- Especially considering the government's indication that the key tier-4 technology is "blue hydrogen produced with 90%+ carbon capture" *, **the Clean Hydrogen Certification System can be said to have considered supporting the Boryeong Blue Hydrogen Project from the planning stages.**

  * A presentation during the 'Certification System Implementation Methods for Transition to a Clean Hydrogen Economy' seminar held on November 15, 2022, in the National Assembly Members' Office Building announced that domestically produced blue hydrogen was being considered as lower threshold for clean hydrogen certification

[Table 1] Clean Hydrogen Tiers and Corresponding Major Technology Groups[2]

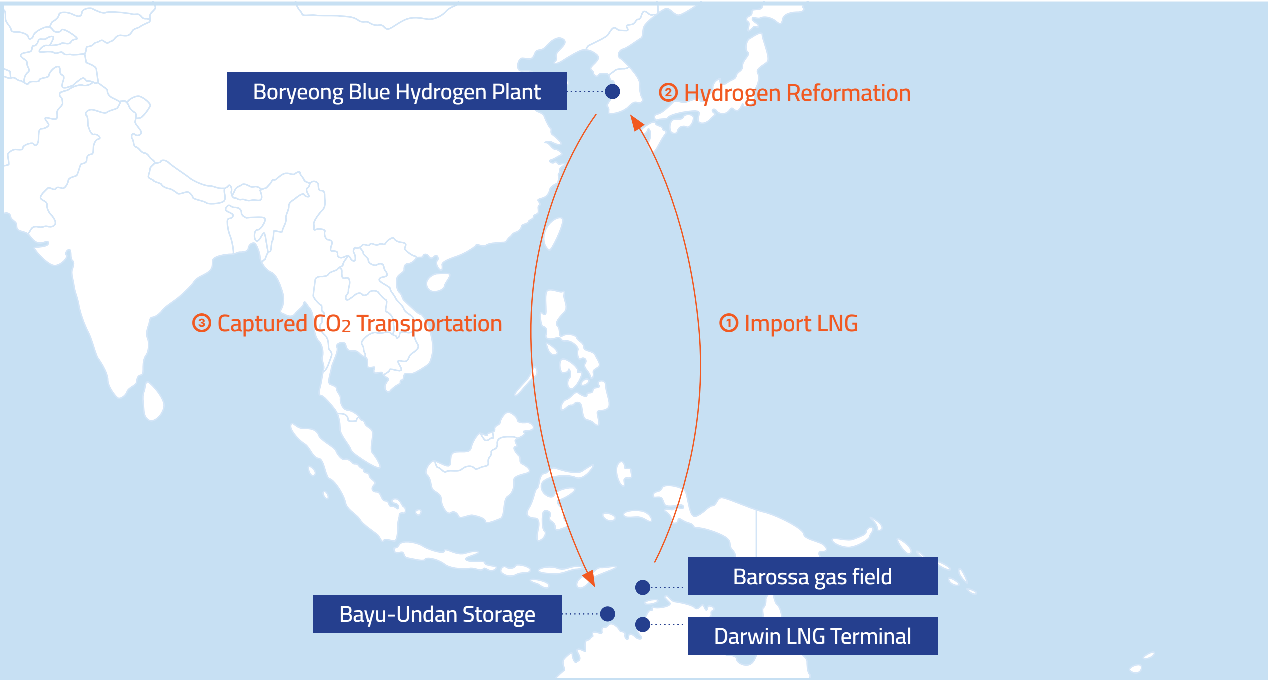
Tiers ($kgCO_2eq/kgH_2$)	Major applicable technologies by tier
Tier 1 (~0.1)	Domestic and overseas green hydrogen (100% renewable energy used for hydrogen production)
Tier 2 (0.1~1)	Domestic and overseas nuclear-produced hydrogen and overseas green hydrogen utilizing some grid power (Some power mix utilization for system stabilization)
Tier 3 (1~2)	Blue hydrogen from PNG with 90%+ carbon capture and with other additional emissions reductions (Reduction from fuel production, use of low-carbon electricity)
Tier 4 (2~4)	Blue hydrogen produced with 90%+ carbon capture (Utilizing average gas field + grid power)

- Furthermore, the government announced that it will consider the special nature of Korea and **exclude shipping emissions** from "acquiring raw material (LNG) for hydrogen production" and "transportation of carbon dioxide captured during production of hydrogen" **through the 'Public Notice on Operation of Clean Hydrogen Certification System (MOTIE Public notice 2024-39)**; [Figure 2] shows that Boryeong Blue Hydrogen Plant is the biggest beneficiary of such exclusions.

2 Korea Energy Economics Institute Presentation Material (Dec. '23.)

- The shipping emissions refer to the GHG emissions caused by shipping fuel combustion during transportation; considering the current zero carbon shipping technology and other factors, shipping emissions are expected to continue until 2050.
- According to the International Maritime Organization (IMO), shipping is responsible for 3% of the world's GHG emissions and is not a negligible source of emissions; thus, **providing incentives by going as far as excluding shipping emissions can be said to be favorable to blue hydrogen.**

[Figure 2] Boryeong Blue Hydrogen Project's LNG Acquisition-Hydrogen Production-CO_2 Transportation Process



◦ Despite long-distance Transportation (①Importing LNG, ③Transporting Captured CO_2) causing shipping emissions, the emissions are not considered for clean hydrogen certification calculations

2) Production and Utilization both Far From Clean: a Dangerous Project

◦ **(Production)** The LNG is extracted from gas fields in Barossa, Australia, then shipped to Korea, reformed, and used for blue hydrogen production in Boryeong. Methane (CH_4) is the main component of LNG, which may escape in large amounts during extraction and transportation phases, leaving the possibility of blue hydrogen production causing severe greenhouse effects open.

- The Korean GHG emission standards for Clean Hydrogen Certification System referred to examples from the U.S.; however, the Department of Energy's GREET model based GHG calculation method that Korea referred to has the following major flaws.

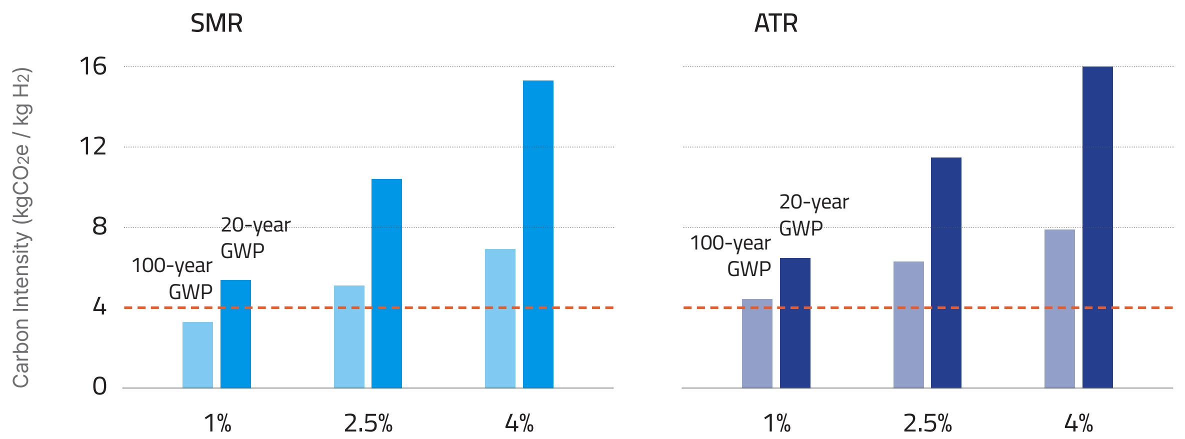
Methane's Global Warming Potential (GWP) is Underrated

The GREET model calculates GWP on a 100-year basis; the 100-year GWP of methane is 28 times that of carbon dioxide, but the 20-year GWP is 83 times that of carbon dioxide.

The U.S.'s institute for Energy Economics and Financial Analysis (IEEFA) pointed out the limitations of the GREET model in September 2023, further pointing out that not considering the 20-year GWP of methane led to underestimating the greenhouse effect caused by methane emissions.[3]

The figure below was included in the report; **a sharp rise in GHG emissions following methane emissions can be seen if 20-year GWP is applied,** and even on the assumption that methane emissions are at minimal levels (1%), **the carbon dioxide equivalent (kgCO2eq/kgH2) per 1 kg of hydrogen exceeds 4kg, which falls outside of clean hydrogen standards.**

[Figure 3] Blue Hydrogen Carbon Intensity Changes by GHG Life Cycle (Source: IEEFA)



Therefore, if 100-year GWP is applied to domestic Clean Hydrogen Certification Tiers, blue hydrogen will qualify for tier-4, but if the short-term impact focused 20-year GWP is applied, it can be expected that blue hydrogen will not qualify as clean hydrogen as it causes much more emissions.

The problem is that the world is in an urgent situation and cannot wait 100 years for carbon neutrality in order to overcome the climate crisis; if blue hydrogen plants are operated according to the current plan, the massive amounts of GHG emissions not considered by Korea will prevent achieving carbon neutrality by 2050.

3 IEEFA, Blue Hydrogen: Not Clean, Not Low Carbon, Not a Solution (2023)

Underestimation of Upstream Methane Emission Rate

The scope of "upstream" production includes exploring, developing, and producing from gas fields; methane, the major constituent of gas, can be released into the atmosphere when extracting gas from reservoirs, so most methane emissions occur during upstream production.

Upstream methane emissions can have various causes and can be classified into intentional releases (~52%), incomplete combustion during flaring (~1.4%), and unintentional releases (~42%).[4]

Intentional releases happen mainly for safety and maintenance; flaring happens when salvage value is low or when gas cannot be distributed; and unintentional releases happen randomly due to faulty equipment or randomly during drilling.

Due to such causes, **upstream gas field methane emissions cannot be completely controlled, and large amounts of methane is released into the air; along with the development of satellite observation technology, it is expected that observed methane emissions are likely to continue to rise.**

The issue is that the American GREET model applies **a very underestimated methane emission rate (1%)**, and as recent satellite-based research found **areas where methane emission rates reached 9.4%, a more realistic methane emission rate needs to be adopted in determining whether something is "clean."**

[Table 2] Methane Emission Rate by Region in Recent Research (Source: IEEFA)

Research	Published in	Region	Emission Rate
Alvarez et al.	2018	U.S.	2.3%
Peischl et al.	2018	Bakken Shale, ND	5.4%
		Barnett Shale, TX	1.5%
		Denver Basin, CO	2.1%
		Eastern Eagle Ford Shale, TX	3.2%
		Western Eagle Ford Shale, TX	2.0%
Ren et al.	2019	Marcellus Shale	1.1%
Schneising et al.	2020	Permian Basin	3.7%
		Bakken Shale, ND	1.3%
		Eagle Ford Basin, TX	1.4%
		Anadarko Basin, OK	3.9%
		Appalachia	1.2%
Zhang et al.	2020	Permian Basin	3.7%

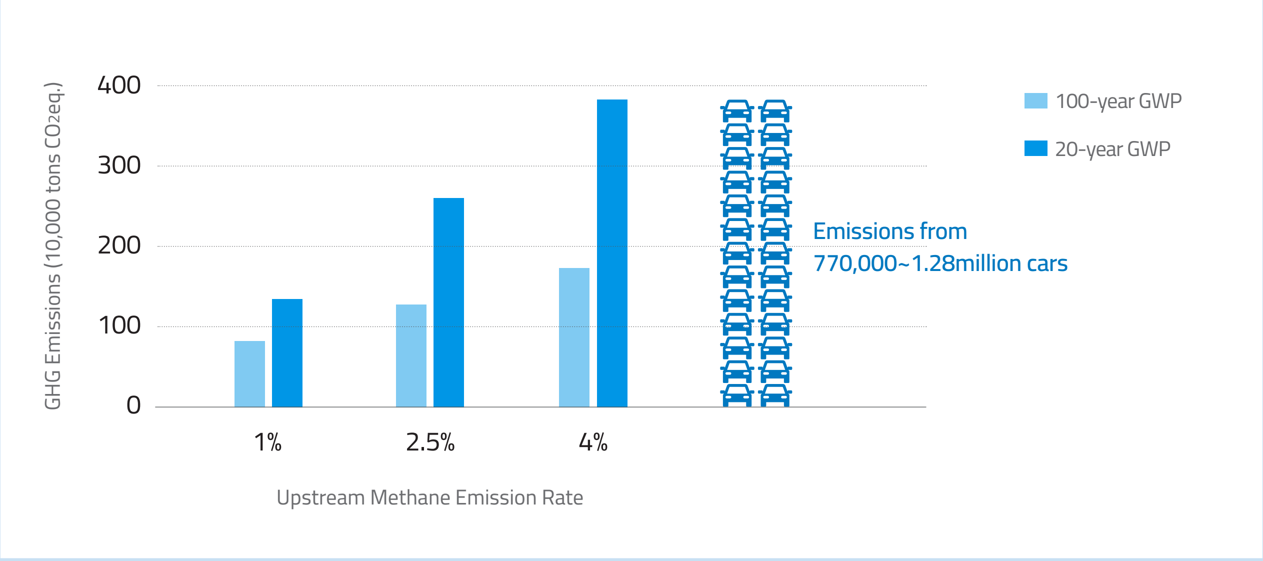
4 Katlyn MacKay et al. Methane emissions from upstream oil and gas production in Canada are underestimated (2021), Nature.

Lyon, et al.	2020	Permian Basin	1.9%-3.3%
		U.S.	2.5%
Chen et al.	2022	Permian Basin	9.4%
Shen et al.	2022	U.S.	2.0%
		Permian Basin	3.5%-4.6%
Howarth	2022	U.S.	2.6%
Lu et al.	2023	U.S.	3.7%
		U.S.	2.5%

IEEFA organized the findings of 10 recent researches analyzing the methane emission rates in 21 areas across the U.S. ([Table 2]), and analyzed the respective carbon intensity for blue hydrogen production assuming conditions with average methane emission rates (2.5%), low methane emission rates (1%), and high emission rates (4%) (see [Figure 3]).

When the analysis results are applied to Boryeong blue hydrogen production plants [Figure 4], an annual production of 250,000 tons of blue hydrogen may lead to 3.85 million tons CO_2eq emissions; this means that **blue hydrogen production in Boryeong may cause GHG emissions equivalent to emissions by 770,000~1.28 million cars.** (Based on annual emission of 30,000~50,000 tons per car)

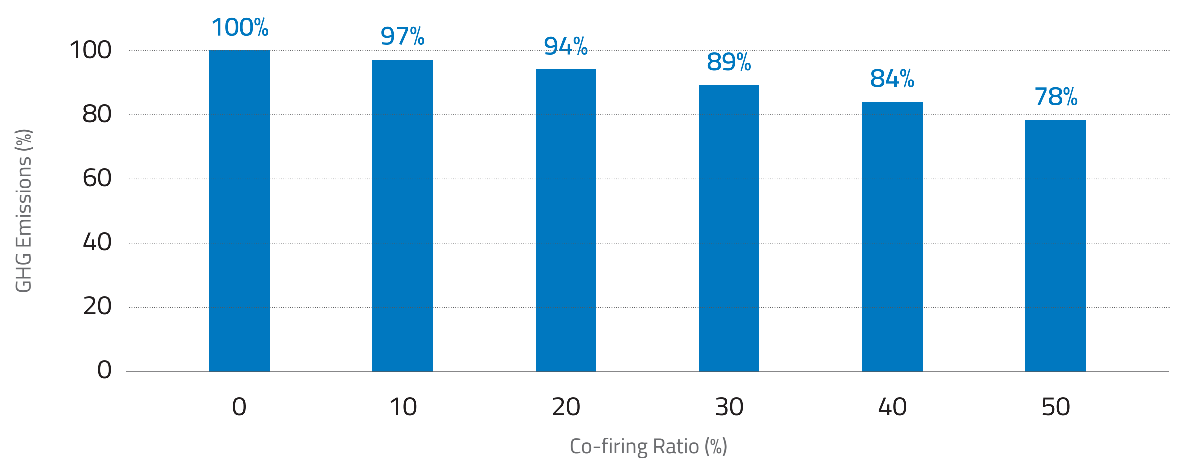
[Figure 4] Estimated Annual GHG Emissions for Planned Blue Hydrogen Production in Boryeong (250,000 tons annually)



- When annual GHG emission is estimated for each upstream methane emission rate and 20-year/100-year GWP, blue hydrogen production (250,000 tons annually) may lead to 850,000 tons to 3.85 million tons CO2eq. (on a 96.2% CCS efficiency basis)

- **(Utilization)** Almost half of the blue hydrogen produced in the Boryeong plant is planned to be used for co-firing in gas combined cycle power generators at KOMIPO Boryeong Power Plant site; the usage of the hydrogen also shows results far from GHG reduction.
  - KOMIPO Boryeong Power Plant has three (#1~3) gas combined cycle power generators in operation; co-firing for the generators are planned with 30% hydrogen in the future. The Boryeong new combined generator #1 is planned to use 50% hydrogen for co-firing.[5]
  - Regarding the three Boryeong gas combined cycle power generators: the three generators were expected to reach end of design life in 2027[6]; however, considering KOMIPO's plan to use Boryeong-plant produced blue hydrogen for co-firing in the three generators, the old generators' design life is likely to be extended.
  - However, GHG reduction from hydrogen co-firing in gas combined cycle power generators is mediocre, and even if the hydrogen ratio is increased to 50%, only 22% GHG reduction occurs in the generation process (see [Figure 5]).
  - **If blue hydrogen is used, practically no reduction effect is observed; KOMIPO and SK E&S's promotion campaign of achieving carbon neutrality through blue hydrogen production and co-firing can thus be said to be exaggerated.**

[Figure 5] GHG Reduction Trends by Hydrogen Co-firing Ratio (Only Considering Co-firing)



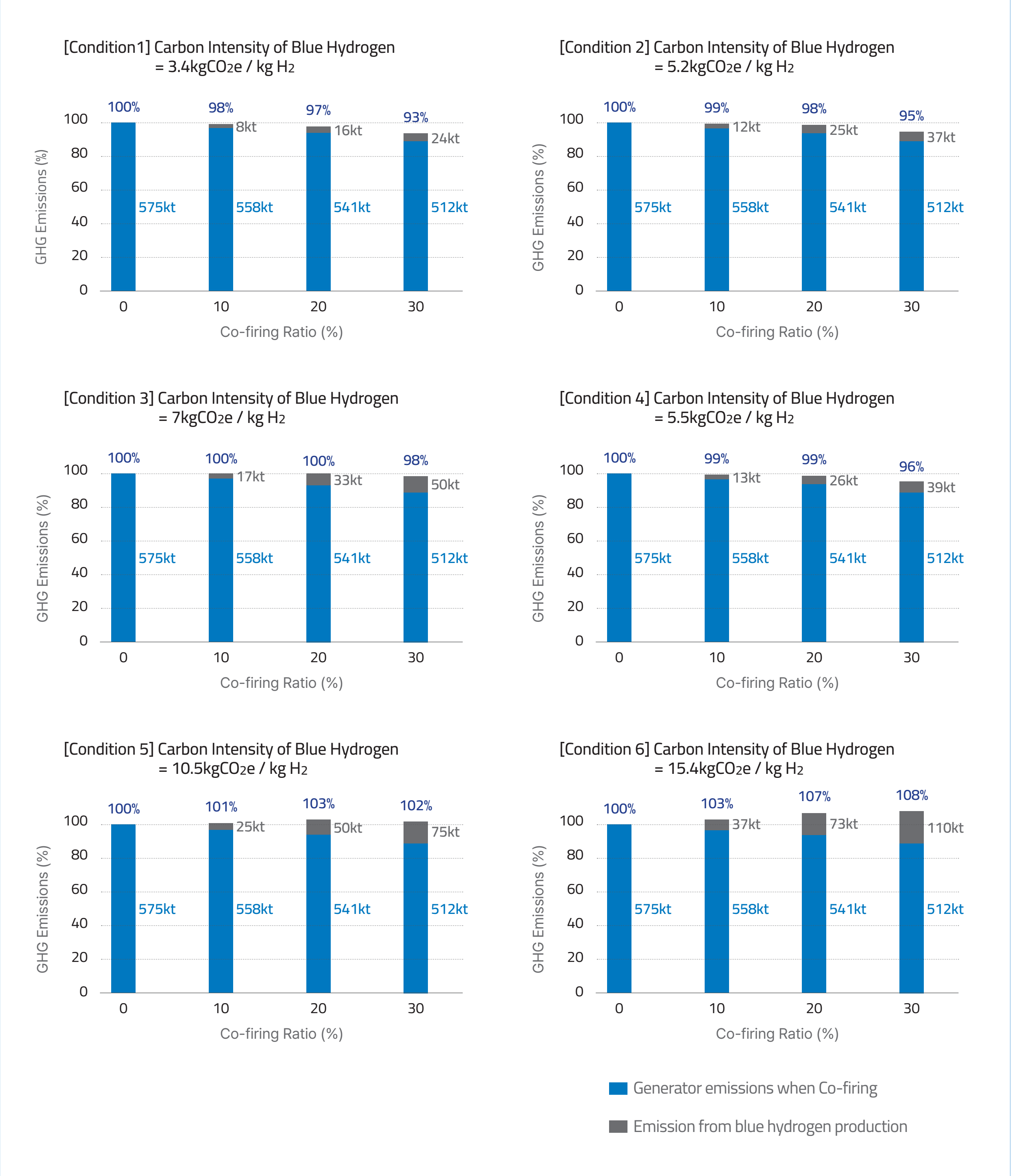
- Hydrogen's heat value per unit volume is smaller than that of LNG; thus, GHG reduction is not proportional to co-firing ratio. Even a 50% hydrogen ratio only results in 22% reduction[7]

5 Refer to documents provided by the National Assembly Member's Office

6 Refer to "Generation Facilities" section of KOMIPO's website

7 Refer to Korean academic literature and KOMIPO's National Assembly submissions

[Figure 6] Gas Generator GHG Emission Trends by Blue Hydrogen Co-firing Ratio



- Considering, the GHG emissions from co-firing hydrogen (up to 30%) in Boryeong combined generators 1~3 (in blue) and the emissions from blue hydrogen production (in grey) result in no practical reduction effect.

* The LNG input record for Boryeong combined generators is difficult to confirm, so emissions were calculated for generator; blue hydrogen emissions according carbon intensity conditions in [Figure 3] were applied for calculation

- The graph above illustrates the GHG emission of Boryeong combined generators 1~3 if 30% blue hydrogen co-firing is applied according to KOMIPO's plan; **analysis shows that GHG emissions from blue hydrogen production offsets any reductions from co-firing, leading to no practical GHG reduction effect.**

- **Even the Boryeong new combined generator #1 for which 50% hydrogen co-firing is planned,** the GHG reduction from power generation is only at 22%, and considering the impact of GHG from blue hydrogen production as illustrated in [Table 3] below, **no practical reduction effect exists.**

[Table 3] Expected Annual GHG Emissions for Boryeong New Combined Generator #1 Co-firing at 50% Hydrogen Ratio

Total GHG Emissions (10,000 tons)				
Gas Generator Emissions*	Emissions at 50% Co-firing Ratio (A)	Blue Hydrogen Carbon Intensity ($kgCO_2e/kgH_2$)	Blue Hydrogen Emissions (B)	Total (A+B) (Ratio vs Status Quo %)
163.3 (100%)	127.3 (78%)	3.4	11.0	138.3 (85%)
		5.2	16.9	144.2 (88%)
		7	22.7	150.0 (92%)
		5.5	17.8	145.1 (89%)
		10.5	34.1	161.4 (99%)
		15.4	50.0	177.3 (109%)

* Calculations based on GHG emissions detailed in Boryeong new combined generator #1 construction environmental impact assessment

- **(Other factors that increase blue hydrogen emissions)** The analysis above focuses on blue hydrogen's upstream emission rates and impact of GHG occurrence by GWP life-cycles, **but there are additional factors that increase emissions which are stated below:**

  - **(Midstream/downstream methane emissions)** LNG related methane emissions can occur during transportation, handling, and utilization of LNG, so actual emissions can be higher than the analysis in the report.

  - **(Carbon Capture Efficiency)** The report set the CO_2 capture efficiency during blue hydrogen production at the ideal target level (96.2%) when calculating GHG emissions; currently, there are no cases with a capture efficiency higher than 80%, so the actual emissions can be at higher levels.

- **(Greenhouse effect from direct release of hydrogen)** Recent research suggests[8] that hydrogen released into the atmosphere causes considerable greenhouse effects (100-year GWP: 11, 20-year GWP: 33); if large amounts of hydrogen is released into the air during production and handling, actual GHG emissions may increase.

3) Clean Hydrogen Power Generation Bidding Market Entrenching Blue Hydrogen Production

◦ The Boryeong Blue Hydrogen Project has a massive budget of 2.6 trillion KRW, and considering everything from acquisition of fuel to utilization, a total expense of 5 trillion KRW is expected for the project.

◦ The invested cost for hydrogen production is reflected in the hydrogen price and the cost burden shifts to parties using the hydrogen. As most of the hydrogen produced in the Boryeong plant (80%) is used for power generation, most of the production cost is reflected in the generation costs through the Clean Hydrogen Power Generation Bidding Market.

- The Clean Hydrogen Power Generation Bidding Market is operated by the Korea Power Exchange (KPX) like the Electricity Market, and is designed in a structure in which **MOTIE posts annual bidding volumes (in case of 2024, 3,500GWh) and hydrogen power generation businesses participates in the bid to sell to the hydrogen power buyers (Korea Electric Power Corporation and others).**

[Table 4] Bidding Volume in the Bidding Market by Year (Public Notice on the Calculation of the Purchase Quantity Per Year for the Hydrogen Power Generation Bidding Market, etc.)

Bidding Market Opening Year	2024		2025	
	Commercial Operation Commencement	Volume (GWh)	Commercial Operation Commencement	Volume (GWh)
Clean Hydrogen Power Generation Market	2027	3,500	2028	3,000

* Generation facilities winning bids deliver the bid volume 3 years later when commercial operation starts

- Only clean hydrogen (determined through emissions calculated from publicly certified data and design data) may participate in the bid, and **blue hydrogen planned to be produced in Boryeong is expected to participate in the bid as it is guised as “clean hydrogen”.**

- Power generation projects winning bids in the market receive reimbursements for their fixed costs and fuel costs; **in case of blue hydrogen, LNG implementation costs, blue hydrogen production cost, CCS costs, domestic transportation pipeline costs, generator modification costs and other costs are granted in the form of CfD (contract for difference).**

8 Warwick, et al. Atmospheric implications of increased hydrogen use. (2022)

- Ultimately, as most of the massive cost required for blue hydrogen production and utilization is compensated through the Clean Hydrogen Power Generation Bidding Market, **it can be said that systematic conditions have become available for non-clean hydrogen to guise as "clean hydrogen" and conduct stable business in the market.**

- Such systematic incentives "entrenches a blue hydrogen industry that is accompanied by unavoidable GHG emissions" and may "hinder the expansion of renewable energy unaccompanied by GHG emissions".

  <In her paper published in the academic journal Nature Energy, German economist Claudia Kemfert stated that dependence on gas must not increase further as **"the sustained use of natural gas interacts with fossil-fuel based systems, making the phase-out difficult and interferes with carbon reduction as well as renewable energy transition" and this implies that the government's intent of "using blue hydrogen as a transitional method" may cause lock-in effects.**>

4. Conclusion and Proposal

◦ The Boryeong Blue Hydrogen Project is a large-scale project with investments of 2.6 trillion KRW; despite KOMIPO, a government-owned company, participating in the project, the project was exempt from feasibility studies because KOMIPO invests only 40 billion KRW; 2.2 trillion KRW, 85% of the entire investment, is planned to be funded through project financing, and large-scale public funds investment is expected.

◦ Furthermore, considering that the project was granted special cases for demonstration status by MOTIE on grounds of clean hydrogen production without proper judgement regarding blue hydrogen's GHG reduction effects, the project is open to controversy regarding preferential policy treatment and may pose reputational risks for participating companies (SK E&S, KOMIPO, etc.).

◦ Therefore, the project plan must be withdrawn without delay before active capital input is made and a genuine "green portfolio" based on renewable energy and green hydrogen must be adopted.

  - Through renewable energy expansion, we must focus on green hydrogen production using surplus electricity, and the produced hydrogen in should be used in hard-to-abate industries that cannot substitute fossil fuels.

◦ The underestimated global warming effects of blue hydrogen (life cycle, impact on methane emission rate, etc.) needs to be reviewed in detail, and blue hydrogen needs to be fundamentally excluded from the government's "Clean Hydrogen Certification System".

- Furthermore, using hydrogen for steam power generation not only continues traditional fossil fuel power generation, but also leads to great energy loss (60% loss) and is cost-inefficient[9]; therefore, as the "Clean Hydrogen Power Generation Bidding Market" firmly consolidates hydrogen/ammonia co-firing and combustion for steam power generation, the policy feasibility of the bidding market needs to be reviewed.

9 Paul Wolfram et al., Helping the climate by replacing liquefied natural gas with liquefied hydrogen or ammonia? (2024), Environmental Research Letters

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in 2016 for more effective climate action and energy transition.
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