Unveiling Fossil Greenwashing :

Hidden Emissions of Korea's Hydrogen Scheme

Solutions for Our Climate (SFOC)

2022. 09

—

Dongjae Oh Oil & Gas finance program lead, SFOC

Yongheum Yeon Methane program lead, SFOC

SFOC
Solutions for Our Climate

Solutions for Our Climate (SFOC) is a South Korea-based group that advocates for stronger climate change policies and transition towards a fossil-free society. SFOC is led by legal, economic, financial, and environmental experts with experience in energy and climate policy and works closely with domestic and overseas nonprofit organizations.

Unveiling Fossil Greenwashing : Hidden Emissions of Korea's Hydrogen Scheme

Publication Date	September 2022

Authors	Dongjae Oh (Oil&Gas finance program lead, SFOC) Yongheum Yeon (Methane Program lead, SFOC)
Design	Minji Kim (Designer, SFOC)
Edit	Jinny Kim (International Communications Officer, SFOC) Sooyoun Han (Private finance program lead, SFOC)
With Support of	Sejong Youn (Director, Plan 1.5) Sanghyun Hong (Senior Research Fellow, NEXT Group) Ana Maria Jaller-Makarewicz (Energy Analyst, IEEFA) Arjun Flora (Director of Energy Finance Studies, IEEFA) Joonhun Seong (Energy Decarbonization Analyst, EDF)
Contact	solutions@forourclimate.org dongjae.oh@forourclimate.org

Table of Contents

Unveiling Fossil Greenwashing : Hidden Emissions of Korea's Hydrogen Scheme

1 Executive Summary

The Hydrogen Economy Roadmap has rapidly emerged as a key energy plan in South Korea in recent years as a part of the Green New Deal policy under the Moon administration. In addition, the Hydrogen Economy Promotion and Hydrogen Safety Management Act was revised this March to facilitate support for clean hydrogen, and the new Yoon administration also identified hydrogen as a way to accelerate low-carbon growth. Hence, the government will likely continue to support the development of the hydrogen industry.

However, there are concerns about fossil hydrogen (grey and blue hydrogen), which accounts for most of the South Korean government and major companies' 2030 hydrogen supply plans. These concerns stem from the rapidly declining economic feasibility of fossil hydrogen compared to that of renewable hydrogen from rising prices of fossil gas with the post-COVID-19 economic recovery and the Russian invasion of Ukraine.

In addition, a recent study from Cornell and Standford University found that fossil fuel-based blue hydrogen, often called 'clean hydrogen', still emits 88-91% of greenhouse gas produced from grey hydrogen (Howarth et al., 2021), calling into question the validity of South Korea's hydrogen plan.

SFOC estimated the potential greenhouse gas emissions from South Korea's hydrogen scheme by applying assumptions from the Cornell-Standford study. Key findings show that if the Hydrogen Economy Roadmap is followed through, **the South Korean government will emit 30 million tons of additional greenhouse gases into the atmosphere in 2030. Regarding individual companies, Korea Gas Corporation ('KOGAS') is expected to emit 17.84 million tons in 2030, POSCO, 7.72 million tons in 2030 and SK E&S, 4.83 million tons in 2025**.

The South Korean government plans to produce up to 87% of hydrogen from fossil fuels in 2030. This goes to show that under the guise of clean energy, hydrogen actually extends the fossil fuel supply chain, especially gas. Given that the Hydrogen Economy Roadmap began as a response to the climate crisis and the rising greenhouse gas emissions, it is hard to escape the criticism that the plan contradicts its original purpose.

The Hydrogen Economy Roadmap may also conflict with the methane reduction target under the Global Methane Pledge which the South Korean government signed last year. Signatories to the Global Methane Pledge commit to collectively reducing global methane emissions by at least 30% from 2020 levels by 2030. However, South Korea's hydrogen scheme is expected to emit about 183 kilo tons of additional fugitive methane in 2030, adding up to almost half of the country's 2030 methane reduction target of 395 kilo tons. This is because fossil hydrogen mostly relies on fossil gas which releases methane throughout its entire lifecycle. With methane now being identified as an even more potent greenhouse gas than carbon dioxide, South Korea's hydrogen projects will likely face criticism from the global community.

South Korea's Hydrogen Economy Roadmap is justifying gas expansion in the name of creating a clean hydrogen economy. However, developing new gas fields at this given point in time will likely lead to a carbon lock-in for decades to come and endanger the Paris Agreement goal of 1.5°C and the 2050 carbon neutrality target.

Moreover, the price volatility and supply chain risks of gas could jeopardize hydrogen production in the future. This could ultimately result in blue hydrogen infrastructure becoming stranded assets as the competitiveness of fossil hydrogen wanes, as well as exposing the hydrogen distribution and consumption sectors to risk.

Hence, this report proposes: **1) a drastic reduction of fossil fuel reliance of the Hydrogen Economy Roadmap; 2) exclusion of fossil hydrogen from the 'clean hydrogen' certification and 3) the transition of public investments to renewable energy and green hydrogen businesses**.

2 Background

1. Promotion of the Hydrogen Economy

Hydrogen is recognized as a carbon-free energy carrier that can significantly contribute to achieving carbon neutrality since it does not emit greenhouse gases during combustion (KEIA, 2021).[1] With the worsening of the climate crisis and the acceleration of global efforts to reduce greenhouse gas emissions, hydrogen has started gaining traction as an energy carrier that can contribute by replacing fossil fuels.

The South Korean government has also made 'hydrogen economy', which focuses on the rapid expansion of production, distribution, storage and consumption of hydrogen, a crucial part of its policy to achieve carbon neutrality by 2050.

South Korea's hydrogen economy began with the announcement of the 'Hydrogen Economy Promotion Roadmap' in January 2019 and has materialized into 16 related policies and plans as of 2021 (NEXT, 2022).

Box-1 Categories of Hydrogen by the Method of Production

Fossil hydrogen

Fossil fuell-based hydrogen refers to hydrogen produced from, or based on fossil fuels. The types of fossil hydrogen are discriminated into 'extracted hydrogen' produced by reforming fossil gas and 'by-product hydrogen' from petrochemical/steel manafacturing processes. These two types of hydrogen are also referred to as 'grey hydrogen', and when the CO_2 generated from the above processes is captured and stored, it is referred to as 'blue hydrogen'.

Renewable hydrogen

This type of hydrogen is hydrogen produced by electrolysis of water utilizing electricity generated from renewable energy. It is also called 'green hydrogen'.

Nuclear hydrogen

This is hydrogen produced by electrolysis of water utilizing electricity produced by nuclear power generation. An other name of nuclear-based hydrogen is 'pink hydrogen'.

1 According to the public survey conducted by the Korea Energy Information Culture Agency in October 2021, hydrogen fuel cells (29.7%) surpassed solar/wind power (28.6%) and nuclear power (26.4%) to be acknowledged as the most suitable energy source for carbon neutrality.

After the enactment of the 'Hydrogen Economy Promotion and Hydrogen Safety Management Act' (the 'Hydrogen Act') in January 2020, which stipulated the framework of the hydrogen economy, in October 2021, power sector centered hydrogen utilization plan was embedded in South Korea's updated Nationally Determined Contribution (NDC).[2]

As the government's plans took shape, South Korean companies also began announcing plans to expand their hydrogen businesses. Five corporate groups, including SK, Hyundai Motor Group and POSCO, publicized plans to invest a total of KRW 43 trillion in all areas of the hydrogen industry by 2030. The announcements were followed by the launch of the Korea H2 Business Summit in September 2021. Moreover, there is growing anticipation that South Korea's hydrogen economy will gain further momentum with the updated Hydrogen Act, revised in March 2022, including the definition and support scheme for 'clean hydrogen'.

However, there are growing concerns that the hydrogen economy will fail to reduce greenhouse gas emissions as the hydrogen plans of the government and major companies begin to take further shape. This is because the hydrogen production plans announced so far rely on fossil fuel-based methods of production.[3] Recent research also shows that blue hydrogen, known as 'low-carbon' hydrogen, emits large amounts of greenhouse gases (Howarth et al, 2021).

Moreover, there is criticism around the declining competitiveness of fossil hydrogen, which accounts for most of the planned hydrogen from the government and corporates in the country. An issue brief from the South Korean think tank NEXT finds that behind the weakening competitiveness lie the price volatility of liquefied natural gas (LNG), which is the main source of fossil hydrogen, and the falling price of renewable hydrogen (NEXT, 2021). With the recent energy crisis and the skyrocketing price of fossil gas following the Russian invasion of Ukraine, fossil hydrogen is quickly losing its price competitiveness.

---

2 At NDC, Korea government targeted 1.94 million tons as demand for hydrogen in 2030. Among demand, 80%, or 1.57 million tons will be utilized for fuel cell power generation.

3 Hydrogen does not exist by itself in nature like other energy sources, such as solar, wind, and fossil fuels. Instead, hydrogen production requires massive amounts of energy.

2. Hydrogen Economy Plans of the Government and Major Companies

During the Moon administration's promotion of the hydrogen economy, the South Korean government and major companies announced roadmaps detailing how they would vitalize the entire hydrogen supply chain spanning from production to utilization.

- **South Korean government**

The South Korean government's hydrogen supply scheme is contained in the First Basic Plan for the Implementation of the Hydrogen Economy, which was announced at the end of the Moon administration's term in November 2021. The government plans to produce most of the domestic supply of hydrogen with fossil fuels (i.e., grey hydrogen and blue hydrogen) by 2030. The government aims to introduce renewable hydrogen more fully after 2030. Meanwhile, the government has yet to announce the specific make-up of imported hydrogen despite imported hydrogen accounting for 80% of the total planned supply of hydrogen.

Table 1. Korean Government's Hydrogen Supply Plan

Planned Hydrogen Supply by Year		2020	2030	2050
Domestic production		22	194	500
Fossil fuel	**Grey hydrogen**	22	94	
	Blue hydrogen		75	200
Renewable energy	**Green hydrogen**		25	300
Foreign import			196	2,290
Fossil fuel	**Grey hydrogen**	-	-	-
	Blue hydrogen	-	-	-
Renewable energy	**Green hydrogen**	-	-	-

Unit : 10 kilo tons

- **Major companies**

POSCO, Lotte Chemical, KOGAS and SK E&S are among the companies that have announced hydrogen economy plans and have also disclosed their hydrogen production plans. While the share of renewable hydrogen tends to be higher in the companies' long-term plans for 2050, the shorter-term supply plans for 2030 are oriented around fossil hydrogen. Also, POSCO and Lotte Chemical, which both aim to massively ramp up their hydrogen supply, still have not disclosed the share of fossil hydrogen in their planned supply, hinting at the vagueness of their plans.

Box-2 Hydrogen production plans of major companies

POSCO

'25 : 0.07 million tons (byproduct)
'30 : 0.5 million tons (blue, green)
'40 : 3 million tons (total)
'50 : 7 million tons (total)

Lottte Chemical

'30 : 1.2 million tons (clean)

SK E&S

'25 : 250 kilo tons (blue)
30 kilo tons (byproduct)

KOGAS

'30 : 0.835 million tons (grey 80%, blue 20%), 0.2 million tons (green)
'35 : 0.835 million tons (grey 40%, blue 60%), TBD (green)
'40 : 0.835 million tons (blue 100%), 1.21 million tons (green)

3 Last Stop for the Fossil Fuel Industry - 'Clean' Blue Hydrogen

1. Fossil Hydrogen, Where Does the Emission Take Place?

As noted earlier, hydrogen does not emit greenhouse gases during combustion, but it emits large volumes of greenhouse gas during production depending on the production method. Hydrogen extracted from fossil gas, which accounts for most of the currently planned hydrogen for supply and distribution, is known as a typical fossil fuel-based grey hydrogen.

Due to the concerning scale of greenhouse gas emissions from grey hydrogen, there is an ongoing discussion on having blue hydrogen as an alternative, which captures, and stores carbon dioxide (CO_2) generated in the process of production. At this time, blue hydrogen is also classified according to whether the capture occurs only for the CO_2 produced as a by-product in the fossil gas reforming process or also for the greenhouse gases emitted from power plants used to supply the energy required for the reforming process(w flue gas capture). The following graphs (Figures 1 and 2) provide an overview of the production process for grey and blue hydrogen.

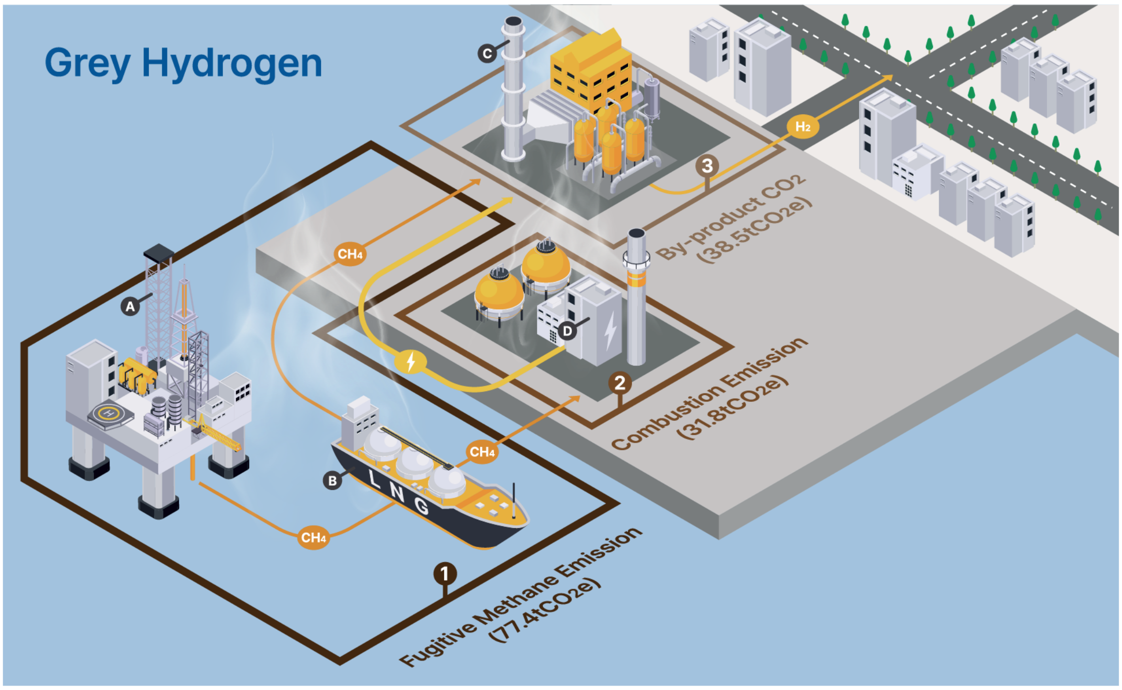
Box-3 Extracted (Reformed) Hydrogen

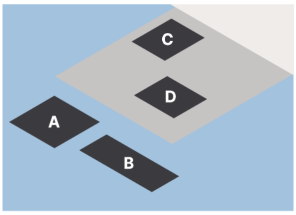
Extracted hydrogen, a typical fossil fuel hydrogen, is produced through a reforming process (Steam Methane Reforming, SMR) in which fossil gas, i.e., a main component of methane (CH_4), is made to react with water vapor (H_2O). In the process, carbon dioxide (CO_2) is separated and discharged as a by-product.

Reformation process reaction formula

$$CH_4 + 2H_2O \xrightarrow[\uparrow \text{ Energy}]{} CO_2 + 4H_2$$

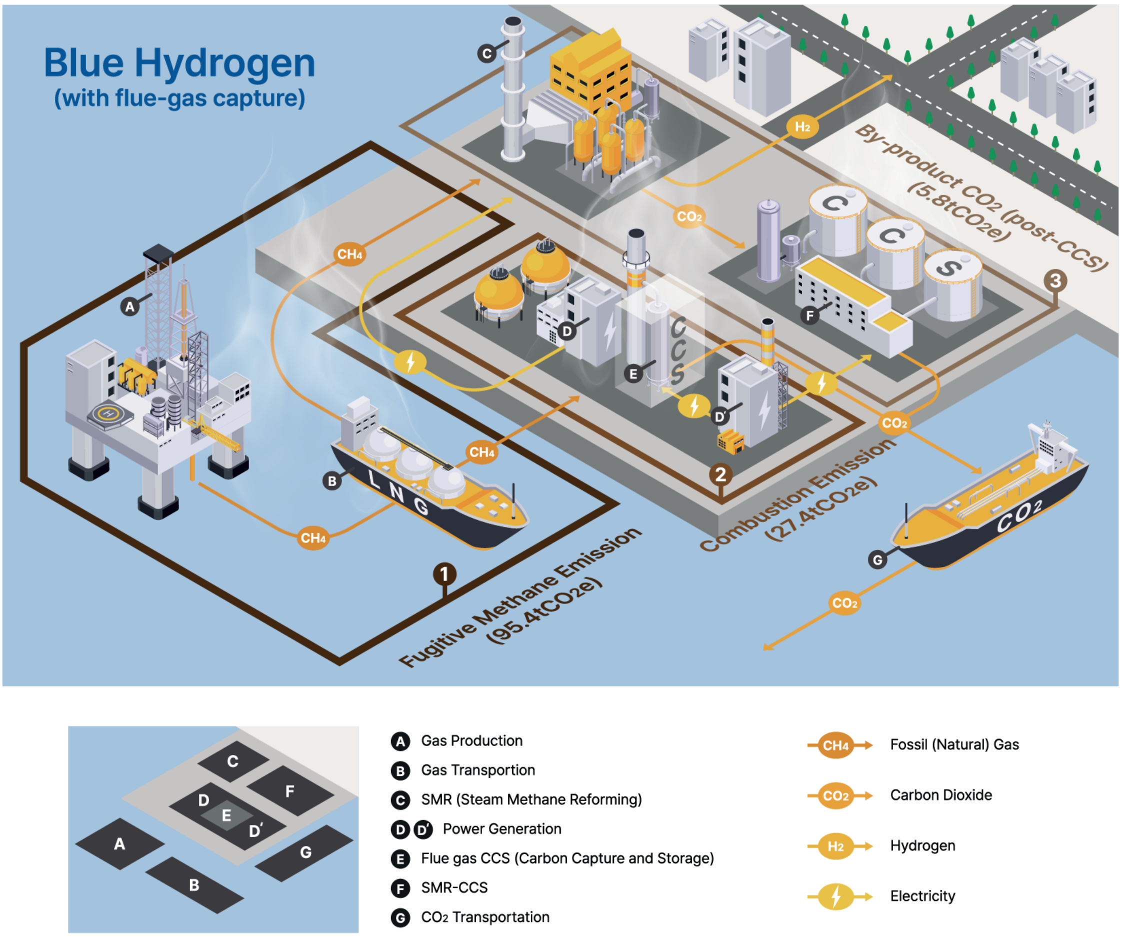
Figure 1. Value chain of grey hydrogen





Fossil gas, a raw material for extracted hydrogen, is produced from a gas field (A), liquefied, and then transported to the site of demand via an LNG carrier. Then, it is combined with water vapor at a reformer plant (C) to produce hydrogen (H_2), and in the process, carbon dioxide (CO_2) is emitted as a by-product. The energy necessary for operating the reformer plant is supplied by a power plant (D). **The largest amount of greenhouse gas (①) is emitted during the transportation of the fossil gas due to the leakage of methane (CH_4), followed by the amount of emissions released during the separation of CO_2 during the reforming process (③), and then finally, the amount of CO_2 emissions during power generation (②).**

Figure 2. Value chain of fossil blue hydrogen



In the case of blue hydrogen, a carbon capture and storage (CCS) system and a separate power generation facility are additionally installed. The CCS can either capture just the CO_2 released during the separation process at the SMR plant or also the flue gas released during electricity generation, which would require an additional CCS facility. Similar to grey hydrogen, blue hydrogen also emits the **largest amount of greenhouse gas from methane leakage which occurs throughout the entire process (①). This is followed by the amount of emissions produced from generating electricity for SMR and CCS (②). Lastly, this is followed by the remaining amount of CO_2 that is not fully captured during the CCS process (③)**.

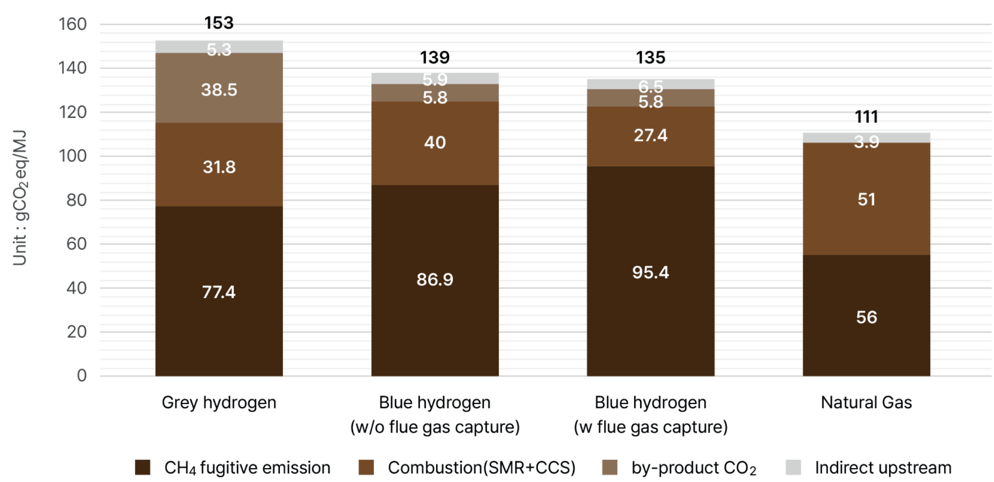
2. ‘Clean’ Blue Hydrogen? Greenhouse Gas Emissions Still Problematic

Since the rise of the hydrogen economy, ‘blue hydrogen’ has been promoted as clean hydrogen with near-zero greenhouse gas emissions as a result of capturing CO_2 from grey hydrogen emissions. However, **analysis shows that fossil fuel-based ‘blue hydrogen’ is capable of reducing merely 9~12% of grey hydrogen’s greenhouse gas emissions while emitting at least 20% higher levels of greenhouse gases than when fossil gas is directly burned** (Howarth et al, 2021). Furthermore, the following emission factors were pointed out by the researchers at Cornell and Stanford University regarding why blue hydrogen still emits a large volume of greenhouse gases despite capturing CO_2 (Figure 3):

1. Increase in fugitive emissions of methane (CH_4) throughout the entire value chain
2. Additional gas combustion emissions from producing the energy needed to power SMR and CCS
3. Residual CO_2 emissions due to the limited CCS capture rate (65~85%)

Ultimately, the fossil fuel-centered hydrogen supply plan, despite incurring astronomical costs to build the reforming plants and CCS, may end up producing more greenhouse gas emissions than if fossil gas, the raw material, were directly burned.

Figure 3. Greenhouse Gas Emissions by Type (gCO_2eq/MJ)



Reformulated the graph from the reference study (Howarth et al, 2021)

4 Estimated Emissions from Hydrogen Plans by Major Corporations and the Government

1. Methodology

In this analysis, SFOC estimates the amount of greenhouse gas emissions under the current hydrogen production plans of the South Korean government and major companies. The calculation is based on the following assumptions from research at Cornell and Stanford University.[4]

- **Methane leakage rate: 3.5%**

Methane leakages occur throughout the overall value chain of fossil gas, from production, storage to transportation. The Cornell-Stanford study uses a 3.5% methane leakage rate based on the mean value of top-down emission estimates from various studies that collected information from major gas fields through sources such as satellites or airplane flyovers.

- **GWP value of Methane: 86**

The 100-year GWP of methane, which is 21~34 times that of CO_2, has been commonly used. However, there are growing concerns that the world may exceed the 1.5℃ target of the Paris Agreement within the next few years. Hence, considering the urgent need to mitigate the short-term greenhouse effect of methane, this analysis also uses the 20-year GWP of methane, which is 86.

- **CCS capture rate**

The Cornell-Stanford study uses reported data to assume 85% CO_2 capture efficiencies from the SMR process and 65% capture efficiencies from the flue gases from gas combustion to run SMR (Howarth et al., 2021). The CO_2 capture rate for flue gases is assumed to be lower than for the SMR process because CO_2 is less concentrated in the flue exhaust.

4 Howarth RW, Jacobson MZ. How green is blue Hydrogen? *Energy Sci Eng*. 2021;9-1676-1687

2. Target Companies of Analysis

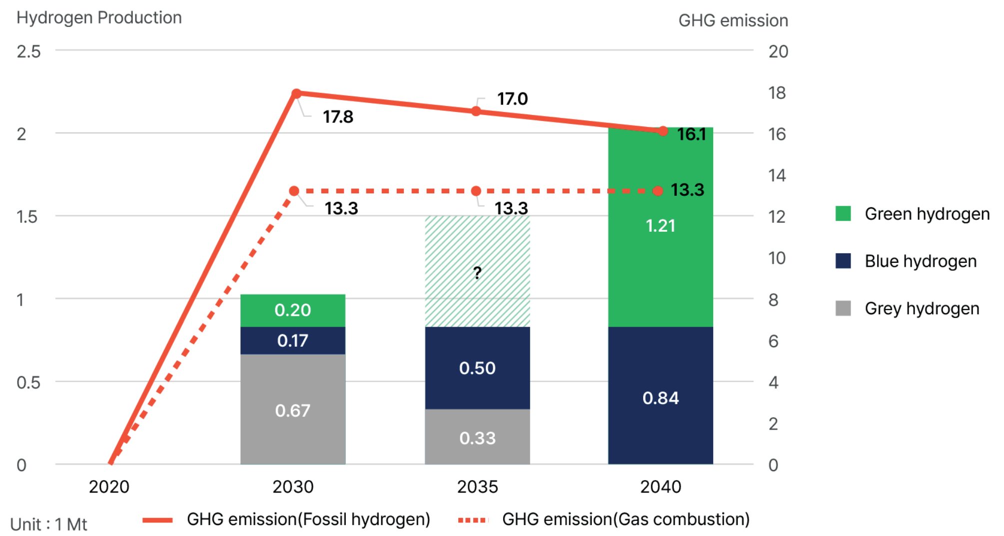
Today, many companies have established and are implementing hydrogen production plans. However, only KOGAS, POSCO, and SK E&S have disclosed their specific hydrogen production methods and timeline. Hence, our estimation of greenhouse gas emissions is based on the hydrogen production plans of these three companies.[5]

- **KOGAS**

KOGAS announced its plan to build fossil hydrogen infrastructure by 2030 in the 'KOGAS VISION 2030' plan published in September 2021 (KOGAS, 2021). According to the plan, 835,000 tons of fossil hydrogen are scheduled to be produced annually by 2030, of which the share of blue hydrogen will expand to 20% (0.16 Mt) by 2030, 60% (0.5 Mt) by 2035, and 100% (0.84 Mt) by 2040. Meanwhile, green hydrogen is planned to be expanded from 0.2 Mt in 2030 to 1.21 Mt by 2040.

However, the rapid increase of the fossil hydrogen production infrastructure within a short period until 2030 is estimated to add a large amount of greenhouse gas emissions rather than decrease the emissions. It was estimated that KOGAS will additionally emit about 17.8 million

Figure 4. KOGAS' Hydrogen Plan and Estimation of Greenshouse Gas Emissions under the Plan



5 Lotte Chemical, where planning to supply 1.2 million tons of 'clean hydrogen' by 2030, was excluded from the analysis as they didn't show up with concrete plan. However, considering Lotte Chemical's production plan is the biggest scale among other corporates, its plans afteraward should be looked through.

tons of greenhouse gases by 2030. Also, in 2040, when blue hydrogen will account for 100% of the fossil hydrogen production, KOGAS is predicted to still emit 16.1 million tons of greenhouse gases.

The current hydrogen plan of KOGAS is estimated to emit more greenhouse gases (4.59 million tons in 2030, 2.87 million tons in 2040) compared to when fossil gas is burned to obtain the same amount of energy (calorie). This means that additional 4.59 million tons of greenhouse gases will be emitted in 2030, and 2.87 million tons thereof will still be emitted in 2040.

- **POSCO**

POSCO announced its plan to secure up to 0.07 million tons of by-product hydrogen by 2025 and 0.5 million tons (including 0.1 million tons of green hydrogen) of blue and green hydrogen by 2030 (POSCO Holdings, 2022). POSCO has also established a plan to massively ramp up its hydrogen production after 2030; however, the specific shares of hydrogen per production type have not been disclosed. The report, therefore, estimated greenhouse gas emissions of producing 0.4 million tons of fossil hydrogen (excluding green hydrogen) under POSCO's 2030 hydrogen production target with the assumption that all fossil blue hydrogen is extracted from gas.[6]

POSCO's hydrogen scheme is estimated to emit up to 7.72 million tons of additional greenhouse gases by 2030. This indicates that for the same amount of energy, POSCO's hydrogen plan emits even more greenhouse gases than fossil fuel combustion, by 1.37 million tons.

According to POSCO Holdings' sustainability report, a large amount of hydrogen supplied in 2030 is expected to be distributed to non-steel sectors (POSCO Holdings, 2022).[7] Considering that POSCO aims to commercialize hydrogen-based DRI (Direct Reduction Iron) technology-the key to reducing greenhouse gas emissions in the steel industry-around 2050 (POSCO, 2022), POSCO's 2030 hydrogen scheme will likely end up emitting more greenhouse gases than it reduces.

---

6 POSCO announced to increase its hydrogen production to 7 million tons by 2050. As it's the largest among Korean corporates, it should be noted that the plan could cause massive greenhouse gas emission if fossil hydrogen consists majority.

7 POSCO anticipates distributing its hydrogen production to fuel cells (0.04 million tons) and to the power sector (0.16 million tons) in 2030.

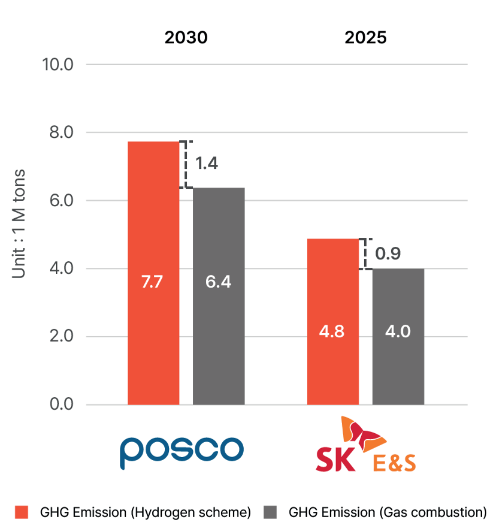
- **SK E&S**

Last year, SK E&S announced its plan to produce blue hydrogen at a scale of 280 kilo tons (250 kilo tons of blue hydrogen and 30 kilo tons of byproduct hydrogen by 2025) (SK E&S, 2021).[8] SK E&S' blue hydrogen plan is estimated to emit about 4.83 million tons of additional greenhouse gases by 2025. This means 0.86 Mt more greenhouse gases will be emitted than if fossil gas were to be burned for the same amount of energy.

Additionally, the blue hydrogen-centered hydrogen supply plans of SK E&S and POSCO would face criticism on energy efficiency. Considering that 4.1~4.5 tons of fossil gas are required to produce 1 ton of blue hydrogen, both companies' hydrogen plans would bring 37~42% of inefficiency compared to securing energy by burning fossil gas. Consequently, even with additional costs needed to install SMR plants and CCS facilities, blue hydrogen may end up failing to secure energy efficiency or mitigate greenhouse gases.

Figure 5. Blue Hydrogen Production Plan

Figure 6. Estimation of Greenhouse Gas Emissions under Hydrogen Plans



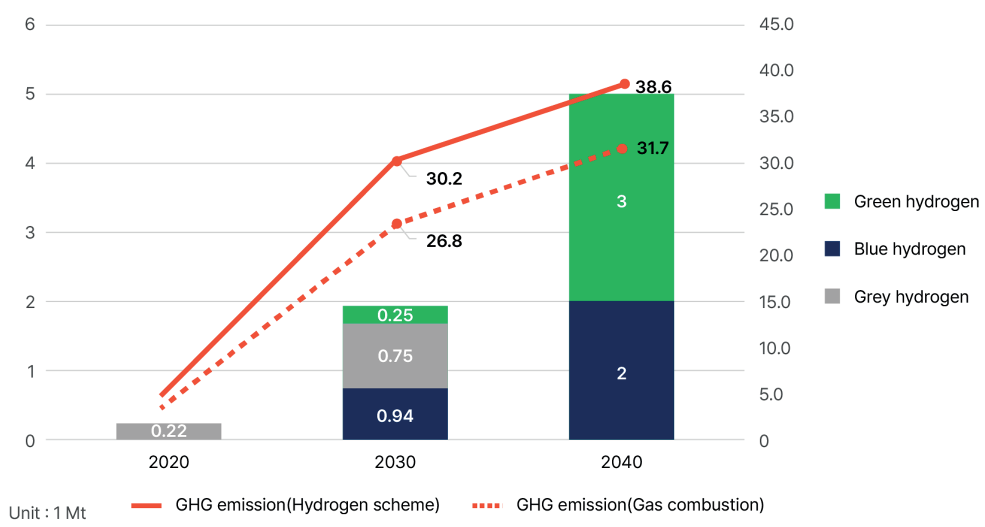
8 Gross calorific value of hydrogen (1g) is 0.143 MJ, whereas heat value of fossil gas (4.1~4.5g) needed to produce blue hydrogen (1g) is 0.226~0.248 MJ.

3. Estimation of Greenhouse Gas Emissions from Implementation of the Korean Government's Hydrogen Roadmap

Lastly, the greenhouse gas emissions arising from the implementation of the Korean government's hydrogen economy have been estimated. The analysis was performed only for hydrogen produced in Korea, which accounts for 18% (5 million tons in 2050) of the total quantity in the long term supply plan. Imported hydrogen, which accounts for 82% (22.9 million tons in 2050), was excluded from the analysis as the hydrogen production types were not specified. Thus, this estimation represents a part of the greenhouse emissions from the implementation of the hydrogen roadmap, and it is hereby noted that emissions may further increase depending on the reliance of imported hydrogen on fossil fuels.

As shown in Figure 7, a considerable amount of greenhouse gases is expected to be additionally emitted in the short run with the implementation of the Korean government's hydrogen economy. This is because most of the hydrogen to be supplied by 2030 relies on fossil hydrogen. If the hydrogen economy proceeds in its current form, our analysis finds that about 30.2 million tons of greenhouse gas will be additionally emitted by 2030. Compared to emissions of burning fossil gas to gain same amount of calorific energy of fossil hydrogen, Korea's hydrogen plan may even emit 3.4 million tons of additional emissions than burning fossil gas.[9]

Figure 7. Greenhouse Gas Emissions projection of the Korean Government's Hydrogen Roadmap



9 For grey hydrogen in 2020, based on reported hydrogen supply under government's 'Hydrogen Economy Promotion Roadmap', the entire amount was assumed as extracted hydrogen. Considering that the byproduct hydrogen is consumed within the production process as a fuel in 2030, only 230,000 tons of byproduct hydrogen that can be externally utilized was excluded and entire amount remaining was calculated as extracted hydrogen.

- **Methane Emissions**

SFOC also separately analyzed potential methane fugitive emissions from the Korean government's hydrogen roadmap. Given that the global average temperature has already increased by 1.1˚C since pre-industrialization (IPCC, 2021), the immediate reduction of methane is necessary to meet the Paris goal. This is because methane has a potent global warming potential in the short-run, reaching over 86 times that of CO_2.

However, the estimate shows that Korea's hydrogen scheme would emit a massive amount of fugitive methane throughout the overall value chain of fossil gas. The fugitive methane emissions from the hydrogen production process were estimated to reach up to 212 kilo tons by 2030 and 317 kilo tons by 2050. This would possibly contradict the methane reduction targets under the 'Global Methane Pledge' signed by Korean government in 2021. Further details are to be discussed in the following section.

Table 2. Volume of fugitive methane emssions under the Korean hydrogen supply plan

Hydrogen Supply Plan		2020	2030	2050
Domestic Production		2.8	21.2	31.7
Fossil fuel	**Grey hydrogen**	2.8	9.3	0
	Blue hydrogen	0	11.9	31.7
Renewable energy	**Green hydrogen**	0	0	0

Unit : 10 kilo tons

5 Risks of Implementing a Fossil Fuel-Centered Hydrogen Economy

1. Carbon lock-in effect from additional gas field development

With the South Korean hydrogen scheme being planned around fossil hydrogen, gas industries are pushing new gas field development. Considering its average 30-year lifetime, a new gas field would operate beyond the time point for carbon neutrality, leading to a carbon lock-in.

To meet the 2030 fossil hydrogen production target (grey: 0.94 Mt, blue: 0.75 Mt) set by the Moon administration, fossil gas-which accounts for 15% (6 million tons) of current fossil gas supply of Korea-should be additionally secured by 2030.

This is serving as a justification for companies pursuing new gas field developments. Major companies are promoting blue hydrogen as 'clean hydrogen' and new gas field developments as 'clean businesses.' Recently SK E&S received hundreds of millions of dollars from public finance on developing Australian Barossa gas field by advertising it would utilize those gas on producing blue hydrogen domestically. Also, POSCO International announced to triple Senex Energy's fossil gas production (POSCO, 2022) after acquiring this Australian gas producer for the sake of pursuing its hydrogen scheme.

Developing new gas fields at the point can only have a fatal impact on the climate crisis. USA based environmental group, Oil Change International (OCI), warned that the 1.5℃ target set by the Paris Agreement will not even be achievable with the operating fossil fields and those under development (OCI, 2020). Furthermore, in 'Net Zero by 2050: A Roadmap for the Global Energy Sector' published last year, the International Energy Agency (IEA) also emphasized that the approval of new oil and gas field development should be stopped to achieve carbon neutrality.

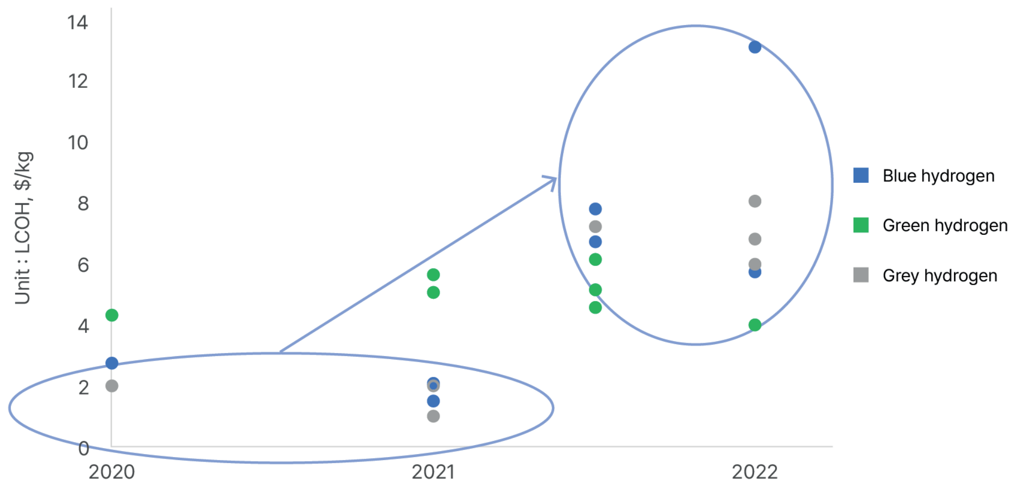
Given that the hydrogen economy began as a way to respond to the climate crisis, the current hydrogen economy plan is reprehensible for justifying overseas fossil fuel development and long-term greenhouse gas emissions.

2. Risk of Korean 'Blue Hydrogen' Assets being Stranded

Even if large-scale fossil fuel-based infrastructure facilities are built under the current plan, losing competitiveness of fossil hydrogen would make those facilities become stranded.

A major factor that contributed to current fossil fuel centered Korean hydrogen scheme was the perception that the price of fossil hydrogen is cheaper than that of green hydrogen. But it has been pointed out that this perception could be made because it was based on a period when the price of LNG was unprecedentedly low (NEXT, 2021). This means that, if the skyrocketing price of fossil gas is reflected, fossil hydrogen is highly likely to lose its price competitiveness compared to green hydrogen.

Figure 8. **Fossil hydrogen is no longer Economical in Europe : Levelised Cost of Hydrogen Estimates (2020-2022)**



Source : IEEFA based on estimates published by (BNEF, Energy Flux, ICIS, IEA, GCCSI, KPMG, Lazard, Rethink Energy, Rystad)

Fossil hydrogen already lost its price competitiveness compared to green hydrogen due to recent upsurge of gas price in Europe. According to the Institute for Energy Economics and Financial Analysis (IEEFA), the Levelized Cost of Hydrogen (LCOH) of green hydrogen over the past two years has become cheaper, within the range of 4~6$ per kg, while the cost of grey hydrogen and blue hydrogen has been showing high volatility by skyrocketing from 1~3$ to 6~12$ per kg (IEEFA, 2022).

Even with analysis that the current rise in gas prices is temporary, stemming from the post-COVID-19 economic recovery and the Russian invasion of Ukraine, its price volatility is expected to worsen as carbon emission regulations are tightened and the energy transition to renewables accelerates (IEEFA, 2021a). Even if gas prices do fall, it is predicted that green hydrogen will secure price competitiveness in most countries (including Korea) by 2030 following the decline in renewable energy prices (BNEF, 2021).

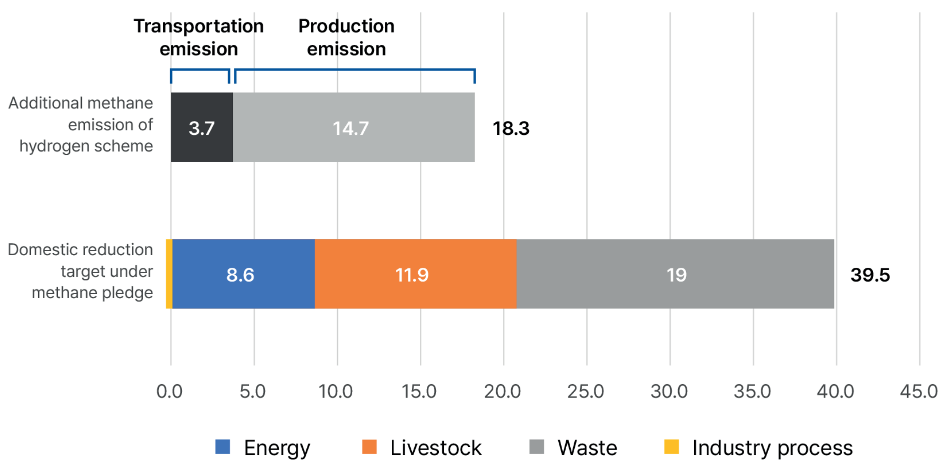
Under the current hydrogen roadmap of Korea, 87% of the hydrogen production infrastructure will be constructed to be fossil fuel-based by 2030. Korea's high reliance on fossil fuels could extend to the risk not only for the competitiveness of the hydrogen production side but also in the hydrogen distribution and consumption sector which will also likely grow along with production, as wholesale production price affects retail price.

3. Fossil hydrogen scheme contradicts 'Global Methane Pledge'

At the 26th UN Climate Change Conference of the Parties (COP26) held in November last year, South Korea signed the Global Methane Pledge with more than 100 other countries, aiming to reduce global methane emissions by at least 30% by 2030 compared to 2020 levels. South Korea pledged to reduce its domestic methane emissions by 0.39 Mt (from 1.33 Mt to 0.94 Mt) by 2030 in its Nationally Determined Contribution (NDC) submitted during COP26.

However, South Korea's hydrogen scheme is estimated to emit at least 183kilo tons of additional fugitive methane emissions in 2030 compared to 2020. This is equivalent to half of Korea's methane reduction target under its NDC and is twice as much as the reduction target of the domestic energy sector (86 kilo tons).

Figure 9. Methane emission projection and reduction target comparison



Unit : 10 kilo tons

If additional fugitive emissions from imported hydrogen of 2030 (1.96 Mt out of 3.9 Mt in total) are included in the analysis, the amount of emissions is expected to increase even further.

Eventually, domestic efforts to reduce methane emissions could turn to nothing if the South Korean government proceeds with its hydrogen economy. The Global Methane Pledge demands signatories not only to reduce domestic methane emissions but also to work together to collectively reduce the global anthropogenic methane emissions. If South Korea promotes its efforts to reduce methane domestically while emitting an enormous amount of methane emissions from its overseas fossil fuel projects, the government will be criticized for violating the Global Methane Pledge.

6 Recommendations

1. Fossil oriented hydrogen supply scheme should be revised

The recent surge in energy prices clearly shows problems with high dependence on fossil fuels. Major countries are establishing mid- to long-term plans to quickly shift away from fossil fuels due to their uncertainty.

Similarly, renewable hydrogen is already becoming competitive with fossil hydrogen worldwide. There are currently 161 green hydrogen projects being pursued (at the feasibility assessment stage) globally, outnumbering the number of grey hydrogen projects by 6 times (IEEFA, 2022; IEA, 2021).

The forecast on hydrogen production facilities to be introduced by 2030 is also consistent. A report published by the Hydrogen Council, a global hydrogen initiative, with McKinsey & Company in July 2021, estimates that about 70 % of low-carbon hydrogen, which will reach 10 million tons in 2030, will likely be procured from renewable energy-based hydrogen. Blue hydrogen is to account for merely the remaining 30% (Hydrogen Council, 2021).

Fossil fuel-centered hydrogen production will not only slow down South Korea's renewable hydrogen from becoming competitive, but also expose the country's hydrogen industry to various risks related to fossil fuels. Therefore, South Korea's hydrogen economy roadmap must drastically cut down its reliance on fossil fuels and set realistic mid-term goals.

2. Fossil hydrogen must not be certified as 'clean' hydrogen

'Clean hydrogen' is expected to receive more support with the Hydrogen Act, amended in March 2022, introducing clean hydrogen portfolio standards (CHPS) that mandate the sale and usage of 'clean hydrogen,' which includes zero-carbon and low-carbon hydrogen. Fossil hydrogen may be classified as 'clean hydrogen' if it emits less than a specified amount of greenhouse gases, depending on a later decision to be made under the Presidential Decree.

However, if the Hydrogen Act only includes CO_2 as a target greenhouse gas for the emission reduction certification, it may end up benefitting fossil hydrogen, leading to failure in reducing greenhouse gas emissions while blocking the expansion of renewable hydrogen.

CO_2 emitted during steam methane reforming (SMR) only consists of a quarter of the total amount of greenhouse gas emission from grey hydrogen. If the scope of emission reduction for clean hydrogen certification is set restrictively, it could potentially ignore major components of grey hydrogen emissions, including fugitive methane emissions as well as combustion emissions during SMR and CCS. Hence, emission-intensive fossil hydrogen may receive similar benefits as renewable hydrogen by being considered a 'clean hydrogen.' Thus, fossil hydrogen must not be classified as 'low-carbon hydrogen' considering all of its greenhouse gas emissions.

3. Public financiers must transition their investment from fossil fuels to renewable energy

The long-term direction of the energy transition - shift from fossil fuels to renewables - will remain the same, even if the speed may be affected by internal and/or external circumstances. With the worsening energy insecurity from our persistent reliance on fossil fuels, the role of public finance is becoming more critical. Hence, investment in domestic and international renewable businesses via public finance can significantly contribute to reducing South Korea's overreliance on fossil fuels. Especially considering that overseas renewable businesses can support future overseas renewable hydrogen projects, related investment must quickly be expanded.

However, major South Korean public financial institutions, including the Export-Import Bank of Korea (KEXIM) and Korea Trade Insurance Corporation (K-SURE), have invested up to $27.6 billion per year (2018-2020) in overseas oil and gas projects, ranking first among the G20 countries (OCI, 2021). On the contrary, public finance for renewable energy projects remains meager. During the parliamentary audit in 2021, KEXIM received criticism that its investment toward renewables amounts to only 1/33 of its financing toward fossil fuels (MoneyToday, 2021). Despite the urgent need for South Korea to convert its public finance from fossil fuels to renewable energy, the country's hydrogen economy is justifying more public finance into new gas fields, as well as corporate greenwashing.

Expanding public finance in fossil fuels not only threatens the financial stability of public finance from stranded asset risk but also further heightens the transition risk of the South Korean economy that heavily relies on its fossil fuel-based manufacturing industry. Hence, South Korea needs to swift its public finance to secure competitiveness within the rapidly expanding low-carbon industry.

[Korean]

- The Government of the Republic of Korea(2019). “Hydrogen Economy Promotion Roadmap”.
- The Government of the Republic of Korea(2021a). “The First Basic Plan for the Implementation of the Hydrogen Economy”.
- The Government of the Republic of Korea(2021b). “The Republic of Korea’s Enhanced Updated 2030 NDC”.
- The Government of the Republic of Korea(2022). “The New Government’s Energy Policy Direction”.
- POSCO(2020). “Business Strategy on Hydrogen”.
- POSCO HOLDINGS(2022). “POSCO HOLDINGS Sustainability Report 2021”.
- POSCO(2022). “POSCO Corporate Citizenship Report 2021”.
- KOGAS(2021). “KOGAS VISION 2030”.
- Sanghyun Hong, Seungwan Kim(2022). “Development of Korea hydrogen scheme: from Hydrogen Economy Roadmap to the Basic Plan for the Implementation of the Hydrogen Economy”.
- Sanghyun Hong(2021). “Blue hydrogen, Carbon Neutral or Carbon Bomb?”.
- Sanghyun Hong(2022). “Hydrogen Act revision, the first step toward clean hydrogen economy”

[English]

- Government of Alberta(2020). “Quest CO2 Capture Ratio Performance, Quest Carbon Capture and Storage (CCS) Project”.
- European Commission, United States of America(2021). “Global methane pledge”.
- IPCC(2021). “Sixth Assessment report Working Group 1: The Physical Science Basis”.
- Collodi G, Azzaro G, Ferrari N, Santos S(2017). “Techno-economic evaluation of deploying CCS in SMR based merchant H2 production with NG as feedstock and fuel”. Energy Proc. 2017;114:2690-2712.
- Jacobson MZ(2019). “The health and climate impacts of carbon capture and direct air capture.” Energy Environ Sci. 2019;12:3567-3574. https://pubs.rsc.org/en/content/articlelanding/2019/EE/C9EE02709B

- Plant G, Kort EA, Floerchinger C, Gvakharia A, Vimont I, SweeneyC(2019). “Large fugitive methane emissions from urban centers along the US east coast”. Geophys Res Lett. 2019;46:8500-8507. https://agupubs.onlinelibrary.wiley.com/doi/10.1029/2019GL082635
- Oil Change International(2020). “Big oil reality check 2020”. http://priceofoil.org/content/uploads/2020/09/OCI-Big-Oil-Reality-Check-vF.pdf
- Howarth RW(2020). “Methane emissions from fossil fuels: Exploring recent changes in greenhouse-gasreporting requirements for the State of New York”. J Integr Environ Sci. 2020;17(3):69-81. https://doi.org/10.1080/19438 15X.2020.1789666
- Petra Nova Holdings(2020). “W.A. Parish Post-CombustionCO2 Capture and Sequestration Demonstration Project(Final Technical Report). https://www.osti.gov/servlets/purl/1608572/
- Howarth RW, Jacobson MZ(2021). “How green is blue hydrogen?”. Energy Sci Eng. 2021;9:1676-1687. https://doi.org/10.1002/ese3.956
- Oil Change Internaiontal(2021). “Past last call: G20 Public Finance Institutions are still Bankrolling Fossil Fuels”. https://priceofoil.org/content/uploads/2021/10/Past-Last-Call-G20-Public-Finance-Report.pdf
- IEEFA(2021a). “Gas and LPG Price Volatility to increase in 2021”. http://ieefa.org/wp-content/uploads/2021/01/Gas-and-LNG-Price-Volatility-To-Increase-in-2021_January-2021.pdf
- IEEFA(2021b). “Boundary Dam 3 Coal Plant Achieves Goal of Capturing 4 Million Metric Tons of CO2 but Reaches the Goal Two Years Late”. https://ieefa.org/wp-content/uploads/2021/04/Boundary-Dam-3-Coal-Plant-Achieves-CO2-Capture-Goal-Two-Years-Late_April-2021.pdf
- Howarth RW(2021). “Methane and climate change”. In: Stolz JF, GriffinWM, Bain DJ, editors. Environmental Impacts from Development of Unconventional Oil and Gas Reserves. Cambridge, UK:Cambridge University Press; 2021, in press.
- IEEFA(2022). “Russia Sanctions and Gas Price Crisis Reveal Danger of Investing in “Blue” Hydrogen”. https://ieefa.org/sites/default/files/2022-05/Russia%20Sanctions%20and%20Gas%20Price%20Crisis%20Reveal%20Danger%20of%20Investing%20in%20Blue%20Hydrogen_May%202022.pdf

[Websites&Articles]

- SFOC(2021). “Korea became the largest provider for International oil and gas finance among G20 countries”. Search date: Aug 9, 2022. https://forourclimate.org/en/sub/news/view.htmlidx91

- MoneyToday(2021). “KEXIM provided fossil finance 33times more than renewables…”Additional fossil fuel finance should be prohibited”. Search date: Aug 9, 2022. https://news.mt.co.kr/mtview.php?no=2021101316173275355
- International Energy Agency. “Hydrogen Projects Database”. Last Updated: Oct 2021. https://www.iea.org/data-and-statistics/data-product/hydrogen-projects-database
- Korea Energy Information Culture Agency(KEIA)(2021). “Key findings of public survey on Carbon Neutrality”. Search date: Aug 9, 2022. https://www.keia.or.kr/news/01.php?admin_mode=read&no=462&make=&search=&selecVal=
- BNEF(2021). “‘Green’ Hydrogen to Outcompete ‘Blue’ Everywhere by 2030”. 검색일: 2022.08.09.
https://about.bnef.com/blog/green-hydrogen-to-outcompete-blue-everywhere-by-2030/
- SK E&S(2021). “[Press Release]SK E&S, Aims to Achieve “Corporate Value of 35 Trillion Won By 2025” by becoming the World’s Leading Hydrogen Provider”. Search date: Aug 9, 2022. https://www.skens.com/sk/press/view.do?seq=3305&page.head=ALL&page.keyword=&page.type=&page.bc=ALL
- Lotte Chemical(2022). “[Press Release] LOTTE Chemical Pursues Hydrogen Energy Business and Battery Materials Business in Earnest for 2030 Future Growth”. Search date: Aug 9, 2022. https://www.lottechem.com/ko/media/news/525/view.do?page=1
- POSCO INTERNATIONAL(2022). “POSCO International, Expands Gas Fields and Makes Headway into Energy Conversion Business with Australia’s Senex Energy”. Search date: Aug 9, 2022. https://www.poscointl.com/eng/pressReleaseView.do?u_id=6119&now_page=1&temp_num=9&page_name=pressReleaseView.do
- POSCO INTERNATIONAL(2022). “POSCO International to Acquire an Australian Natural Gas Company to Lay the Basis for Blue/Green Hydrogen Business in Preparation for Energy Transition”. Search date: Aug 9, 2022.
https://www.poscointl.com/eng/pressReleaseView.do?u_id=6058&now_page=1&temp_num=8&page_name=pressReleaseView.do
- POSCO HOLDINGS(2022). “Areas of business-Hydrogen”. Search date: Sep 13, 2022. https://www.posco-inc.com:4453/poscoinc/eng/business/s91e2000500c.jsp
- Hankyoreh(2022). “800billion won support from public finance on Australia’s Barossa gas field, will the ‘low-carbon promise’ be kept?”. Search date: Aug 9, 2022. https://www.hani.co.kr/arti/economy/marketing/1045459.html

1. Greenhouse gas emissions per unit

Type	Emissions (gCO_2eq per MJ)	Heat value (MJ /g)	Emissions (gCO_2eq /g)
Grey hydrogen	153	0.143	21.879
Blue hydrogen (w/o flue gas capture)	139	0.143	19.877
Blue hydrogen (w flue gas capture)	135	0.143	19.305
Fossil gas	111	0.055	6.105

2. Gas needed for hydrogen production per unit

Type	Fossil gas needed (gCH_4 /MJ)	Fossil gas needed (gCH_4/gH_2)
Grey hydrogen	25.6	3.66
Blue hydrogen (w/o flue gaas capture)	28.6	4.09
Blue hydrogen (w flue gas capture)	31.6	4.51

Note : The gross calorific heat content of hydrogen is equivalent to 3.5 moles H_2 per MJ.