# Scenario Planning of Hydrogen for South Korea Energy Policy

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## South Korea Hydrogen Vision

To become a zero carbon country and 100% Hydrogen based economy by 2050.

## South Korea Hydrogen Mission

To formulate South Korean energy policy that achieves one million tons per year of clean hydrogen of multiple resources in 2030.

To transform key energy intensive sectors of electricity, industry, mobility and heating to be clean hydrogen sectors.

## South Korea Hydrogen Scenario Planning

South Korea has four scenarios for clean hydrogen economy of the following colors:

**Blue, Yellow, Red, Green.**

Each color has advantages and disadvantages.

Combination of several colors is the realistic way in the formation of hydrogen policy.

# Blue Hydrogen Scenario:

Blue Hydrogen is the type of hydrogen generated from LNG (Liquefied Natural Gas) via a chemical process called SMR (Steam Methane Reforming) that produces Grey Hydrogen, for every 1kg of grey hydrogen, 10 kg of carbon dioxide is released, grey hydrogen counts for 76% of current hydrogen production in the world, however, in order to get clean hydrogen, Grey hydrogen should pass through CCS (Carbon Capture and sequestration) system that 90% arrests Carbon dioxide then stores it into natural caverns or manufactured storage tanks for several decades. KOGAS (Korea Gas Corporation) and MTRX (Matrix Service Company) has signed a collaboration agreement in 2022 to produce 1400 Tons per year of grey hydrogen as an initial project to cover the immediate surging demand of hydrogen in South Korea specially in the mobility sector; Kogas (Korea Gas Corporation) Grey Hydrogen production in South Korea is estimated to be 668,000 Tons per Year in 2030. There is no Blue hydrogen production in South Korea for the time being, however, Kogas Blue Hydrogen production in South Korea is estimated to be 167,000 Tons per Year in 2030.

South Korea does not have any natural gas resources or fossil fuel reserves; it depends on importing LNG from overseas suppliers which is a disadvantage for blue hydrogen.

KOGAS (Korea Gas Corporation) imports 90% of South Korea LNG; while power generation companies which are SK E&S and KOMIPO (Korea Midland Power) directly import 10% of South Korea LNG for their own business. In July 2021, KOGAS signed an agreement with Qatar Petroleum which is the main supplier of LNG to Korea by 27% of LNG imports, KOGAS will import 2 million tons per year of LNG from Qatar for 20 years from 2025 to 2045. South Korea imports approximately 59.8% of its LNG from the Middle East. USA is a main supplier of LNG to South Korea although most of US LNG goes to Europe, Russian supplies are approximately 6% of South Korea LNG imports, South Korea pays for Russian LNG via a Japanese bank which may be affected by sanctions over Russia because of Ukraine invasion. LNG prices are increasing in unrealistic and dramatic way, LNG overseas imports are putting South Korea in a weak position because they are affected by multiple economic and political factors as a result this will affect the national security and independence of South Korea Energy Sector.

The disadvantage of blue hydrogen is the increment of cost over grey hydrogen, it adds 50% to CAPEX (Capital Expenditures) and adds 100% to OPEX (Operating Expenditures); natural caverns like salt formations or depleted natural gas fields; and industrial storages of carbon dioxide are not 100% secured for decades, they are vulnerable to natural disasters like earthquakes and human-caused conflicts.

## Yellow Hydrogen Scenario:

Yellow Hydrogen is the type of hydrogen generated by the process of electrolysis which converts water molecules into hydrogen and oxygen by a utility called "electrolyzer", in case of yellow hydrogen, electrolyzers are powered by electricity generated from nuclear power plants by purchasing electricity from the public electricity grid by a specific tariff. South Korea nuclear industry is solid and well- established. Nuclear power in South Korea counts for 30% of current power generation in South Korea. South Korea has 24 nuclear power plants, 2 shut-off power plants, and 4 under construction. However, after Fukushima nuclear disaster which was a nuclear accident in 2011 at the Fukushima Daiichi Nuclear Power Plant in Japan; in 2012, South Korean leaders announced a policy called “One Less Nuclear Power Plant” to gradually shut off nuclear power plants and stop renewing old ones. Indeed the reality of this policy is diminishing after Russian invasion to Ukraine because of the dramatic increment of LNG (Liquefied natural gas) prices and the world hassle of finding strategic suppliers of importing LNG (Liquefied natural gas). South Korean policy makers are advised to review above 2012 anti-nuclear policy, not take down nuclear energy and reconsidering nuclear energy in the clean hydrogen transformation to produce yellow hydrogen while ensuring highest health and safety standards in nuclear power plants.

Despite the fact that nuclear energy is not considered a renewable energy, however, at the end of the day and in terms of climate change, nuclear energy power plants do not release any greenhouse gases and are considered an ideal clean energy resource that is generated to power up any electrolyzer and produce clean yellow hydrogen.

The projected Life-Time of the nuclear power plants are clear, they do not require too much maintenance, nuclear technology is matured in addition to the fact of high capacity factor which is 92% in nuclear power plants which determines the period that you can operate the power plant at the maximum output are the highest among all type of energy. This means that nuclear power plant will have its ROI (Return On Investment) in an accurate, defined and short time. Policies of easy Bankability in nuclear energy investments should be marching on, banks should be encouraged to take the final investment decision (FID) to finance new nuclear power plants because they have clear figure in the feasibility studies (unlike other renewable energy projects).

# Red Hydrogen Scenario:

South Korea currently depends on thermal energy power plants that generate electricity by a process called "Coal Combustion" that generates high level of heat and high level of carbon dioxide by reaction of oxygen from air with carbon from coal; heat generated in this process is utilized in boilers that converts water into high temperature steam and operates steam turbines that are connected to generators that produce electricity.

South Korea imports coal from the following countries: Australia, Indonesia and China; which are geographically close to its location, resulting in cheap transportation and shipping costs, they are coal-rich countries, diverse international suppliers, coal is a cheap commodity, high reserves and well-established value chains of suppliers that are always welling to export, despite recent increase in international coal prices because of the Russian-Ukraine conflict, Coal is less political-aligned commodity than other energy carriers unlike LNG (Liquefied natural gas) or Uranium. Several thermal power plants across South Korea are operating since decades, causing cheap operating costs, cheap maintenance costs of power plants, and cheap electricity prices.

However, the above method is a carbon-rich and not an environmentally-friendly way for generating electricity, according to the Carbon Dioxide Information Analysis Center, South Korea is among the top ten, the above traditional method of power generation should be replaced by a kind of hydrogen called "Black Hydrogen", the cheapest kind of hydrogen, it counts for 23% of total hydrogen production in the world, black hydrogen is generated from coal by a process called "Coal Gasification" which is not currently used in a commercial scale in South Korea, it can be commercialized and implemented in large scales taking the advantage of above reasons of low costs of Coal.
Coal gasification generates both black hydrogen and carbon dioxide, however, to be environmentally friendly and keeping in mind the above vision and mission of South Korea Hydrogen policy, black hydrogen should be converted to environmentally friendly "Red Hydrogen", by adding a process called CCS (Carbon Capture and Sequestration) to 90% arrest Carbon dioxide coming out of coal gasification and store it into natural caverns like salt formations or large scale industrial tanks for decades, however, the disadvantage of red hydrogen is the increment of cost in the production and cost of transforming the color of black hydrogen, it adds 50% to CAPEX (Capital Expenditures) and adds 100% to OPEX (Operating Expenditures), although, South Korean policy makers should take down black hydrogen and force new laws of CCS (Carbon Capture and Sequestration) to push red hydrogen industry forward.

# Green Hydrogen Scenario:

Green Hydrogen is the type of hydrogen generated by the process of electrolysis which converts water molecules into hydrogen and oxygen by a utility called "electrolyzer", in case of yellow hydrogen, electrolyzers are powered by electricity generated from renewable energy source mainly: PV (Photovoltaic) Solar Power, CSP (Concentrated Solar Power), Offshore Wind Power and Onshore Wind Power. In 2022, three South Korean companies have signed a collaboration agreement to build a 1 billion USD green hydrogen and ammonia production plant in United Arab Emirates. Korea Electric Power Corporation, Samsung C&T Corporation, Korea Western Power, and Petrolyn Chemie will build a plant that can produce up to 200,000 Tons per Year of green ammonia; green ammonia is the ideal hydrogen carrier of hydrogen for overseas shipments to South Korea because of the long distance and the advantages of ammonia in high density of energy and easier storage conditions (no need for very cold tanks or high pressure, unlike pure hydrogen), however, ammonia has the disadvantage of being a toxic material and can cause a disaster to marine life if maritime accidents happen, highest safety policy should be ensured. When green ammonia arrives to South Korea, it will be transformed back to green hydrogen and used in land, Sempra (USA) is having a collaboration agreement with Kogas to establish large scale green ammonia infrastructure in South Korea, MCDermott CB&I (USA) is having a collaboration agreement to establish (LH2) liquid hydrogen facilities in terminals and shipyards.

In 2022, specifically after the Russia-Ukraine conflict, mass production of electrolyzers are marching on and resulting in dramatic reduction LCOE (Levalized Cost of Energy) of green hydrogen production, economy of scales where increment of quantity reduce the cost is the reason, this will push green hydrogen because the cost is falling to produce each one kg of green hydrogen, in USA for example, the US Department of Energy has a goal that is creating policies for, which is called (1.1.1) which means: one decade for one KG of Hydrogen for One USD only, this motto is a reality in 2030.

The biggest electrolyzer producer in the world is NEL (Norway), it has opened a new factory of a planned capacity of 2 GW at Heroya, Norway, this plant currently has 500 MW of production capacity; Siemens (Germany) also promised a cheaper electrolyzer prices especially after the opening of its new " Silyzer 300" factory in Erlangen, Germany, Siemens has a planned capacity of 3 GW of electrolyzer production by 2025.

Green hydrogen production requires high amounts of demineralized water and a location that is rich of water resources, for example, newest Siemens electrolyzer which is called " Silyzer 300" requires 10 Liters of demineralized water to produce 1 KG of hydrogen, this high consumption of water is a disadvantage of green hydrogen production because clean water resources are declining, also the location of the electrolyzer is not flexible, it should be near high-volume water resources .

PV (Photovoltaic) Solar Power Plants, the renewable energy source of green hydrogen production has a disadvantage side, unrealistic warranty of 25 years, which is over estimated by most feasibility studies that leads investment decision of funding banks, indeed PV solar panels should be calculated for 10% annual deterioration and not more than 10 years life-time, despite the risk of destruction of the weak structured silicon surface of PV solar panels that may be caused by natural disasters and human-caused conflict, PV solar power plants are vulnerable to damages unlike other power plants.

Among the disadvantages of green hydrogen is the low capacity factor of 25% in PV (Photovoltaic) Solar Power Plants, and 34% in Wind Power Plants, which means that theoretical peak power of the above main resources of renewable energy are not the real output power generated from the power plant; indeed 75% of time in PV (Photovoltaic) Solar Power Plants, and 66% of time in Wind Power Plants are not meeting peak power which cause long time to achieve the ROI (Return On Investment) in feasibility studies of green hydrogen funding investments. Currently, renewable energy is only 3% of the energy mix in South Korea, and policy makers are not advised to emphasize too much in advancing large- scale construction of PV (Photovoltaic) Solar Power Plants.

South Korea is advised to focus on a policy of purchasing overseas green hydrogen rather than building new expensive solar energy power plants; the reason behind this policy advice is that South Korea is not a good location of PV (Photovoltaic) Solar Power Plants; South Korea has a low solar irradiation which is a disadvantage.

South Korea is advised to focus on Wind energy because it has a high wind potential, in 2021, President Moon Jaein announced a planned 8.2 GW offshore wind farm that will be the largest in the world. Kogas (Korea Gas Corporation) which is the main gas supplier in South Korea plans to import green hydrogen in 2027, policy makers should encourage Kogas (Korea Gas Corporation) and other companies to import green ammonia and green hydrogen, reduce importing taxes for the benefit of the environment, and commit to purchase all the generated power from wind farms.