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캐나다 앨버타주의 수소산업 현황 및 전망

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The Present Condition and Outlook of Hydrogen Industry in Alberta, Canada

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요 약

한국의 수소경제 활성화 로드맵에 의하면 2040년 526만톤의 연간 수소공급이 필요하며 이 중 해외 생산 부분이 50%를 담당해야 할 것으로 설정하였으나 부생, 추출, 수전해 방식의 수소공급이 원활하지 않을 경우 해외 생산 비중이 당초 계획보다 증가될 수 있다. 따라서 국외 생산분에 대해 다양한 공급원의 확보가 필수적이며, 본 기술보고에서는 주요 공급후보국인 캐나다의 수소생산/수송 정책, 현황, 향후 전망에 대해 살펴보고 가장 현실적인 수소공급 방법으로 여겨지는 블루수소 프로젝트의 사례를 소개하고자 한다.

Abstract - Based on Korea's Hydrogen Economy Activation Roadmap, an annual supply of 5.26 million tonnes of hydrogen is required by 2040. But if the hydrogen production from by-product, extraction, and electrolysis of water is not able to meet the target which is 50% of total production, it would be necessary to increase the portion of imported hydrogen. Therefore, it is essential to secure a variety of sources for overseas production. In this technical report, hydrogen production/transportation policies, current condition, and future prospects of Canada, a major supply candidate, is examined and an example of blue hydrogen project which is considered the most realistic hydrogen supply method is introduced.

Key words : hydrogen, canada, blue hydrogen, production, transportation

I. Introduction

There are three categories of hydrogen based on how it is produced: 1) grey hydrogen, 2) blue hydrogen, and 3) green hydrogen. First, grey hydrogen is produced from oil, natural gas, and coal through thermochemical processes such as steam methane reforming(SMR) and coal gasification. Blue hydrogen is produced from the same steps but with carbon capture and storage (CCS) of CO_2 byproduct. Lastly, green hydrogen or also called renewable hydrogen is produced electrolysis of water with electricity from a renewable source (Fig. 1) [1]. Green hydrogen is the most environmental-friendly due to zero emission associated with its production, but it has the highest production cost. Currently, SMR is known as the most economical way of producing hydrogen but it has associated CO_2 production of 8~10 kg per 1 kg of H_2 produced, so the cost of

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Table 1. Hydrogen Roadmap of South Korea

Year		2022	2040
Hydrogen Car		810,000	6,200,000
Fuel Cell (MW)	Power (Domestic)	1,500 (1,000)	15,000 (8,000)
	Residential	50	2,100
Hydrogen Supply (Ton/year)		470,000	5,260,000
Hydrogen Price (KRW/kg)		6,000	3,000

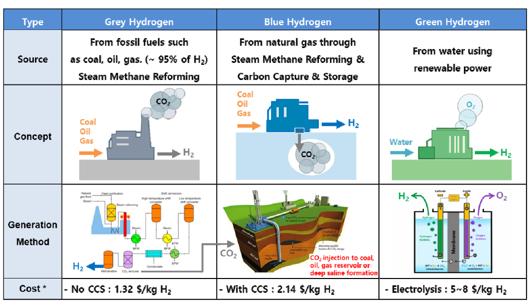

Fig. 1. Hydrogen Production Methods.

production increases if CCS is utilized to capture this CO_2 [2]. In addition, there are hydrogen produced as a byproduct of petrochemical process but there is a disadvantage that the amount cannot be controlled [3].

In January 2019, South Korea announced "Hydrogen Economy Activation Roadmap" to become the leading hydrogen economy country, setting aggressive targets of 6.2 million hydrogen powered cars, 15 gigawatts of fuel cells for power generation, with supply of 5.26 million tonnes of H_2 per year at 3,000 KRW/kg by 2040 (Table 1). This puts South Korea as the leader in hydrogen powered cars and fuel cell markets and allows transition from fossil fuel poor country to green hydrogen producer.

In Table 2 [4], the portion of overseas production accounts for 550,000 ton (28%) out of 1,940,000 ton by 2030, and 2,720,000 ton (52%) out of 5,260,000 ton by 2040, but the hydrogen productions from byproduct, extraction, and electrolysis are set excessively high, so the overseas production needs to increase unless the total hydrogen demand is reduced.

Table 2. Hydrogen production plan of South Korea * Unit : 1,000 ton

Type	2022		2030		2040	
	Quantity	%	Quantity	%	Quantity	%
Byproduct (Factory)	280	60	280	14	280	5
Extraction (LNG)	170	36	970	50	1,580	30
Electrolysis (Water)	20	4	140	7	680	13
Overseas (Blue)	-	0	550	28	2,720	52
Total	470	100	1,940	100	5,260	100

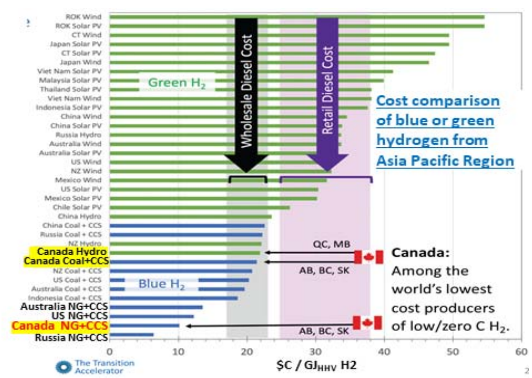

Fig. 2. Production Cost of CO_2 Free Hydrogen in APEC region.

The regions that are being considered for hydrogen import are North America, South America, Australia, Middle East, Russia, and Mongolia etc. Japan is currently progressing AHEAD (Advanced Hydrogen Energy Chain Association for Technology Development) project, which produces hydrogen from natural gas in Brunei and transporting it to Japan, and HySTRA (CO-free Hydrogen Energy Supply-chain Technology Research Association) project where hydrogen is produced in Australia from brown coal and transporting it to Japan. Korea is also building partnerships with Australian government, Woodside, and other Australian companies.

According to APERC's report in 2018, which is the Institute of Energy Economics of Japan, the production of blue hydrogen from natural gas through

SMR with CCS in Canada is the second most economical way of producing CO_2-free hydrogen next to Russia (Fig. 2) [4]. Therefore, it is necessary to investigate the potential of overseas hydrogen supply from the province of Alberta, which produces the most natural gas in Canada [5].

This study was conducted to examine the hydrogen production policy, supply status and commercialization potential, and CCS status to provide basic data for establishing hydrogen supply chain between Korea and Canada in accordance with Korea's hydrogen economy activation roadmap.

II. Overview of Hydrogen Production in Alberta, Canada.

2.1. Hydrogen Production Policy of Alberta

To revitalize from a period of unprecedented economic adversity, the government of Alberta announced "Natural Gas Vision and Strategy" in October 2020 which lays out a plan for Alberta to become a global supplier of clean [6], responsibly sourced natural gas and related products, including hydrogen. Canada is among the world's top five producers of natural gas, with about two-thirds of this production coming from Alberta [7]. One of the goals is large-scale hydrogen production with carbon capture, utilization, and storage (CCUS) and deployment in various commercial applications across the provincial economy by 2030 and exports of hydrogen and hydrogen-derived products to jurisdictions across Canada, North America, and globally by 2040. Deploying hydrogen into commercial applications such as transportation, home heating sectors, incorporating it as fuel for electricity generation, and industrial processes, is key to Canada's ability to meet greenhouse gas (GHG) emission reduction targets under the Paris Accord.

For short-term actions from the fall of 2020 to winter 2021, Alberta is planning to build alliances and map Alberta's hydrogen system to determine deployment pathways, partnerships, barriers and gaps (commercial, technology, and policy), technology development opportunities, and targets. Also, common interests and partnership opportunities with the Government of Canada will be established, including incorporating Alberta's interests into a federal hydrogen strategy, to accelerate hydrogen deployment in Alberta and other provinces.

Medium-term actions from 2021 to 2023 includes developing a Hydrogen Roadmap for Alberta detailing best deployment pathways, enabling policies, innovation strategy and funding support. During this term, Alberta plans to build support among western Canadian provinces to align policy to accelerate the deployment of hydrogen in western Canada, remove red tape to be inclusive of hydrogen deployment and pass enabling policy, legislation, and standards, work with industry, advance pilot projects and early demonstration projects, including supporting infrastructure, to build momentum, explore opportunity to accelerate joint federal/provincial private sector funding to stimulate initial build-out of the provincial hydrogen economy. Lastly, opportunities for hydrogen as part of overall approach to the LNG export value chain will be considered and investigated.

Long-term action for 2023 and beyond involves partnering with industry leaders to accelerate scaling up and commercial deployment, as well as infrastructure build-out, for key target end-use application, which includes exploring opportunities for broader hydrogen transportation utilizing existing natural gas infrastructure and pipeline corridors. To ensure hydrogen transmission across Canada is enabled along dedicated economic/resource corridors, Alberta will partner with other governments. Also, they plan to attract and secure a world-scale hydrogen for energy export project to Alberta.

2.2. Status and Prospects of Hydrogen in Alberta

Canada ranks in the top 10 of global hydrogen producers and produces about 3 million tonnes of hydrogen (4%) annually for industrial use out of the global total which is 69 million tonnes per year. Most hydrogen in Canada is produced by the chemical industry from fossil fuels (53%) and the oil and gas sector (47%). Geographically, most hydrogen is produced in Western Canada (76%), followed by Central Canada (17%) and Atlantic Canada (7%) [8]. Currently, the majority of hydrogen is produced from fossil fuels through processes such as SMR and is being produced and used by companies who produce fertilizers or upgrade bitumen. It is pro-

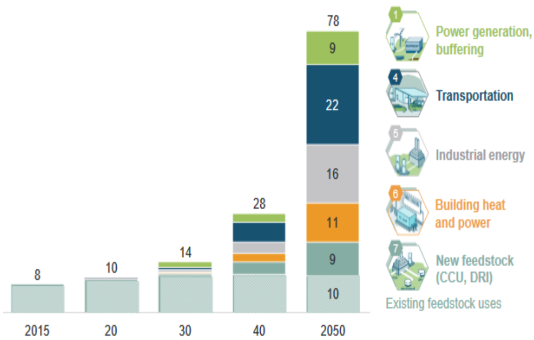

Fig. 3. Forecast of Global Hydrogen Demand.

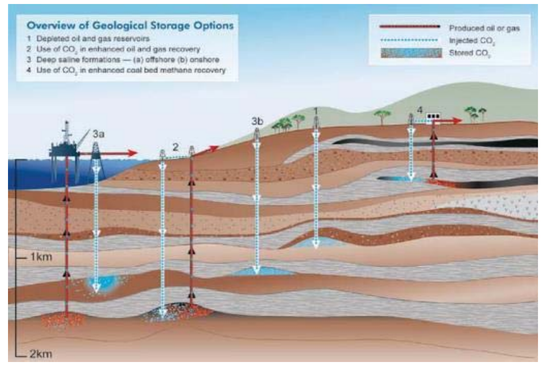

Fig. 4. The Conceptual Diagram of CCS.

duced only enough for the company's need currently, so there will be no issue increasing the production amount.

In 2019, natural gas production in Alberta reached 11.9 Bscf/d and is expected to increase the production to 13 Bscf/d by 2025 for LNG projects [9]. Approximately 1,000 tonnes of H_2/d can be produced from 170 MMscf/d of natural gas feedstock [10], so if 1.2 Bscf/d or 10% of Alberta's natural gas is used for hydrogen production then 8,000 ton/d (2.9 million ton/y) of hydrogen can be produced. In addition, given the trend that the majority of countries are trying to switch from fossil fuels to hydrogen, the reduction in natural gas demand can be used for more hydrogen production. According Hydrogen Council, global hydrogen demand is expected to reach 28 EJ (2.8 x 1010 GJ) which is equivalent to 197 million ton/y (Fig. 3) [11]. Therefore, assuming that 10 to 50% of natural gas produced in Alberta is used for hydrogen production in the future, Alberta can provide 1.5 – 7.5% of the global hydrogen demand in 2040 which means Alberta will play an important role in the global hydrogen supply.

2.3. CCS in Alberta

When 1 kg of hydrogen is produced through SMR, 8 to 10 kg of CO_2 is produced as a by-product, so it is essential to utilize an effective CCS technology to meet the GHG reduction goal while producing hydrogen with abundant natural gas resources in Alberta. As shown in Fig. 4 [12], there are four methods of CCS: storage in depleted oil and gas reservoirs, use in enhanced oil recovery(EOR), storage in deep saline formations, and use in enhanced coal bed methane recovery. In Canada, the captured CO_2 is typically stored in depleted reservoirs or used for EOR.

Alberta is considering CCS as the key technology in response to CO_2 emissions that is continuously increasing and expects that up to 70% can be reduced by 2050. A common feature in CO_2 storage options is the presence of a caprock which prevents the CO_2 from migrating back to the surface. Reservoir depths are recommended to be at least 800 m below ground, so the CO_2 can be stored as a supercritical fluid. This is desirable, as CO_2 is about 200 times denser as a supercritical fluid than a gas, allowing considerably more CO_2 to be stored in each reservoir [12]. In Alberta, there are many depleted reservoirs that meet the conditions since oil and gas production has been active for a long time. The Government of Alberta has conducted a study in 2013 which states that 139 million tonnes of CO_2 must be sequestrated per year by 2050 to meet the GHG emission target, and Alberta will have approximately 330 years of sequestration capacity at that rate.

CO_2 EOR, which increases oil productivity by injecting CO_2 into the oil reservoir, is also one of the key techniques to reduce CO_2 emissions from the production of hydrogen by SMR. Alberta has been supporting this method since 2000, as it is an economical way to increase production in low-productivity wells while sequestering carbon. Fields

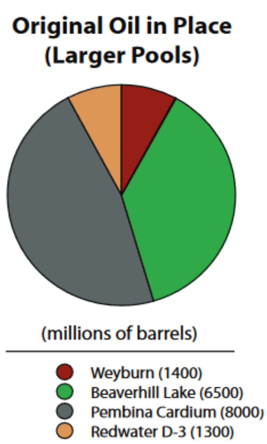

Fig. 5. Original Oil in Place and Recoverable Amounts of Oil for CO_2 EOR in Alberta.

where CO_2 EOR have been used to date are Weyburn, Beaverhill Lake, Pembina Cardium, and Redwater, and it is estimated that 2 billion barrels of additional oil can be received with EOR (Fig. 5) [13].

In Alberta, there is a 240 km pipeline that transports CO_2 from Alberta's Industrial Heartland to central Alberta where CCUS is actively carried out, with the capacity of 14.6 million tonnes of CO_2 per year. There are other CO_2 EOR projects of various sizes including AlphaBow Energy's CCS project.

Ⅲ. Hydrogen Project in Alberta

According to studies by companies such as Mitusi and Zen, SMR with CCS technology is the most economical method of producing CO_2-free hydrogen in British Columbia and Alberta which has abundant natural gas resources (Fig. 6) [1].

There are three methods for transporting hydrogen produced in Alberta to Korea: liquid hydrogen(LH2), ammonia(NH3), and methylcyclohexane(MCH) (Table 3) [14]. Of these three methods, transporting hydrogen in the form of MCH is rated as the best in technical maturity, long distance, long-term, environmental impact, and economics. Chiyoda Corporation of Japan is utilizing this technology in a demonstration project where hydrogen produced in Brunei is shipped to Japan.

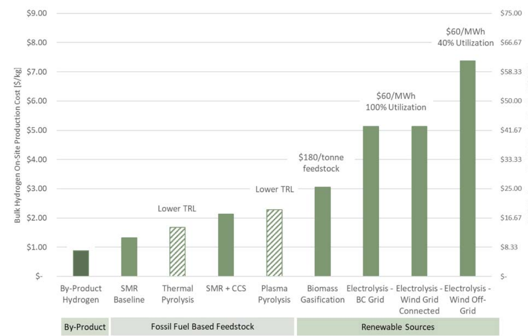

Fig. 6. Cost of On-site Hydrogen Production in Alberta and BC.

Table 3. The Comparison of Three Hydrogen Transportation Methods

Method	Technical maturity	Long distance transport	Long term storage	Transport amounts per 1 trip	Environ-mental impact	Economics
MCH	Base Application	Unlimited	Unlimited	6,000~30,000 ton (100,000~450,000 tankers)	Low	Excellent
LH2	Base	Good	Days~weeks	700~10,000 ton (1~15 m^3)	None	Fine
NH3	Base Application	Unlimited	Unlimited	3,000~8,000 ton (3~8 m^3)	Severe	Excellent

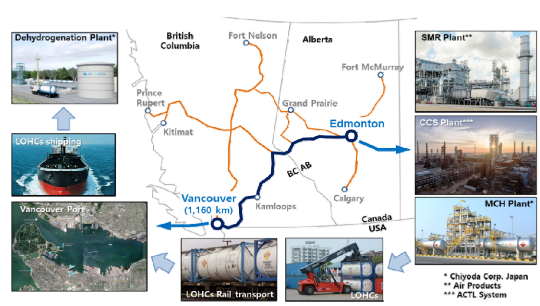

Fig. 7. Blue Hydrogen Projects in Alberta.

Currently, the Government of Alberta is actively encouraging hydrogen projects, and so various projects are being planned (Fig. 7) [15]. One of those projects is Hydrogen Canada project which is planning to produce and export 300 ton/d of blue hydrogen in Alberta by 2026. The project location will be near Edmonton in Alberta's Industrial Heartland.

Ⅳ. Conclusion

The study was conducted to review the potential of hydrogen supply in Alberta, Canada, which is expected to be responsible for a significant portion of overseas production in order to secure hydrogen supply in accordance with Korea's Hydrogen Economy Activation Roadmap. The Government of Alberta has announced a policy of strategically supplying hydrogen and other natural gas-related products to the world, and has a global competitiveness in the production of hydrogen based on a significant amount of natural gas reserves and CCS capacity. In particular, it is expected to be able to take advantage of the huge natural gas production to be responsible for a significant portion of the world's hydrogen demand. And when an appropriate transportation method is used, it can contribute considerable amount of hydrogen to Korea's overseas production portion of the Roadmap.

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