The Hydrogen Economy South Korea

Market Intelligence Report

January 2021

INNOVATION IS GREAT

BRITAIN & NORTHERN IRELAND

Forewords

South Korea is setting out its stall to be a global leader in the development of a hydrogen-based economy. The Korean government has committed to net zero carbon emissions by 2050 and in July 2020, announced its Green New Deal, committing to £13bn fiscal investment by 2025 in green mobility. One of the key elements of that push is the development of hydrogen vehicles; South Korea hopes to produce 500,000 hydrogen fuel cell vehicles for export and domestic consumption by 2030.

As this report outlines, the hydrogen market in South Korea will almost double in size from £9.1bn in 2020 to £17.3bn by 2030, with the growth driven largely by investment from large local players such as Hyundai and Doosan.

The UK is expected to announce its own Hydrogen Strategy in early 2021. But there is already a growing awareness in South Korea that the UK is a world leader in the fields of basic science, advanced materials and fuel cells. This offers huge opportunities for UK fuel cell and hydrogen companies with both public and private sectors investing heavily in the nascent hydrogen economy.

We hope that this report, produced in partnership with Intralink, helps set out in more detail where these opportunities lie and the DIT team in Seoul stand ready to support UK companies looking to enter the South Korean hydrogen market.

Mike

Mike Welch
Director Trade and Investment
DIT Seoul, British Embassy Seoul

I wish to offer my sincere congratulations to the British Embassy Seoul on the release of the market report "The Hydrogen Economy South Korea" this year. I believe this will help to facilitate hydrogen cooperation between our two countries.

In Korea, the Hydrogen Economy Roadmap was announced in January 2019 and its goal is to make Korea become the world's leading hydrogen economy with world-class technologies including hydrogen vehicles and fuel cells technology. In addition, the Korean National Assembly passed the Hydrogen Law in February 2020 with a view to creating a legal framework for the realisation of the Hydrogen Economy Roadmap.

Furthermore, Korea announced its own version of sustainable recovery plan called the New Deal, with the Digital New Deal and Green New Deal being its two pillars. It is aimed at achieving sustainable economic recovery and creating green jobs by promoting a green transition in infrastructure, a low-carbon and decentralised energy supply, and innovation in the green industry.

Korea has indeed been playing a leading role in the field of hydrogen cars and fuel cells. In fact, Korea was the first country to successfully mass-produce hydrogen vehicles, and is currently working on the development of a hydrogen vehicle that has the longest driving range. In addition, we already have a portfolio of various fuel cells for utility power plants and buildings. The total installed power capacity of fuel cell in Korea is about 375 MW as of 2019, which accounted for 35% of global installed fuel cell capacity as of July 2020.

Currently, hydrogen for mobility and fuel cell power plants are obtained from the various refinery processes of fossil fuels or via natural gas steam reforming in Korea. However, in the foreseeable future, the hydrogen industry will deploy "water electrolysis" to electrolyze pure water and generate hydrogen. We need to advance technology in order to develop competency in the area of electrolysis.

In closing, international collaboration is essential for successful green energy transition and creating new industries and jobs across the entire cycle. To successfully build a hydrogen supply system, we need to work closely with countries like the UK who have advanced technology in electrolysis for example. I sincerely hope that "The Hydrogen Economy South Korea" will raise awareness of the importance of cooperation in the production, storage, transportation and utilisation of hydrogen.

Young Chul Choi
Head of Global Energy Cooperation Centre
Ministry of Foreign Affairs

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1. Introduction

South Korea (Korea) is betting big on hydrogen. Sustained public and private investment since the turn of the century has meant Korea is a key global market in the nascent hydrogen economy. The country accounts for fully one-third of the world's installed capacity of utility-scale stationary fuel cells and its largest automotive company, Hyundai Motors, launched the world's first commercial fuel cell vehicle in 2013 as well as the world's first fuel cell truck in 2020. Korea now plans to embark on a huge capital investment drive to build on these early successes, all of which should create strong opportunities for British firms in the space.

Korea's hydrogen industry is forecast to almost double in size from KRW 14.1 trillion (£9.1bn) in 2020 to KRW 26.8 trillion (£17.3bn) by 2030. This growth will be driven by investments from large local players such as Hyundai and Doosan who increasingly see hydrogen as a key growth engine. Hyundai Motors intends to spend KRW 7.6 trillion (£4.9bn) under its 'Fuel Cell Vision 2030' programme and looks well placed to capitalise on its early-mover advantage in fuel cells, both by selling its own vehicles and by licensing its fuel cell systems to OEMs around the world. With POSCO's recent retreat, Doosan now dominates Korea's large-scale stationary fuel cell market and with its growing portfolio of fuel cell technologies, the company looks set to become competitive in other stationary power applications, such as the residential and commercial markets.

This level of ambition is matched by a Korean government that sees hydrogen as part of the solution to the high carbon intensity of the country's economy. In 2017, President Moon announced his 'New and Renewable Energy 3020' policy which looks to increase the proportion of new and renewable energy in the overall generation mix to 20% by 2030. This difficult target - the current figure is 8.8% - reflects the action required to reduce emissions 37% against business-as-usual levels by 2030, a pledge Korea made at the United Nations Climate Change Conference (COP 21) in Paris in 2015.

Building on this, the Korean government announced its Hydrogen Economy Roadmap in 2019. The roadmap aims to deploy 15GW of utility-scale and 2.1GW of commercial and residential fuel cells by 2040. In terms of mobility, the goal is to have 5.9 million fuel cell cars and 60,000 fuel cell buses on the road by 2040 all supported by 1,200 hydrogen refuelling stations. The announcement of Korea's Green New Deal in July 2020 - a coronavirus stimulus plan outlining KRW 74 trillion (£47bn) in 'green' public-private capital investment by 2025 - should help the country on its way to achieving these aggressive long-term goals.

The hydrogen economy is of key strategic importance to Korea, a country lacking in both conventional and easily-exploitable renewable energy resources. Its industrial gases industry has long been influenced by Japanese, American and German technologies and standards, but as hydrogen begins to play a more transformative role in the broader economy, Korea is keen to ensure it has greater control over the technologies and standards that will underpin that transition. British companies with enabling technologies in the hydrogen economy will find a warm reception from Korean firms looking to establish themselves in this exciting and rapidly-developing industry.

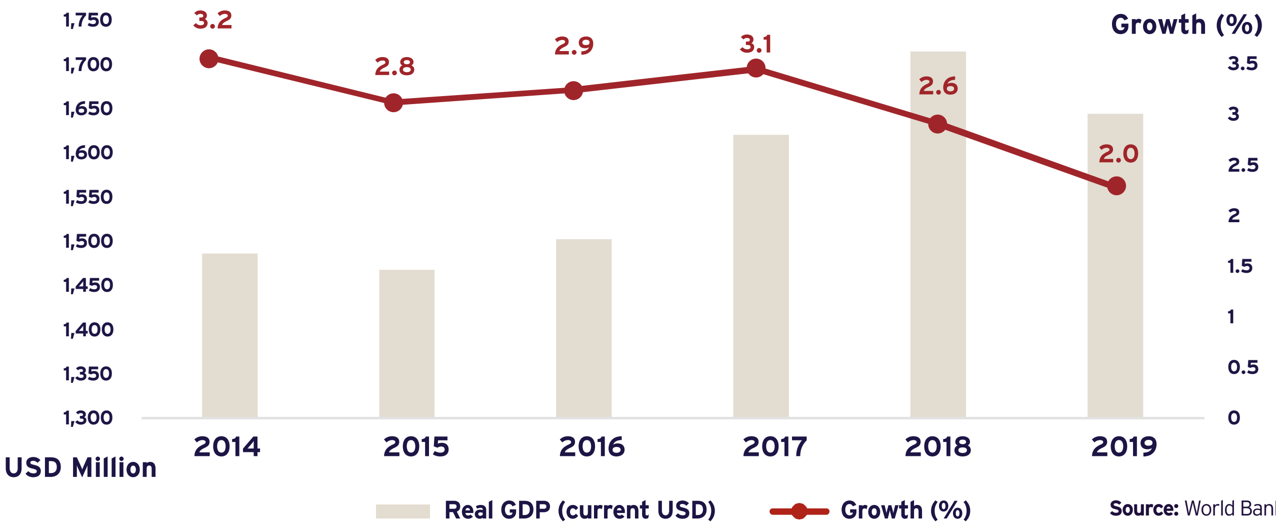
2. Korea: An Overview

In the space of just 60 years, Korea has transitioned from an agricultural economy to one driven by high-value industries such as automotive, shipbuilding and advanced manufacturing. Perhaps most remarkable of all is the country's success in the area of information communications technology where the country has become world class in terms of semiconductor, consumer electronics and ICT infrastructure.

With a population of 51 million people, Korea boasts the 12th largest economy in the world, a GDP of £1.2 trillion in 2019 and a per capita GDP of £21,841 that same year. Whilst no longer experiencing the dizzying growth rates that characterised its early growth phase in the second half of the twentieth century, Korea has maintained strong growth for a developed economy of close to 3% in recent years. The country has won recognition for its adept handling of the coronavirus pandemic which appears at the time of writing to have helped it fair better than many of the world's other major economies.

Korea's trade dependency ratio is high at over 80% and its economic performance is heavily affected by the economies of China, the US and Japan. Trade and investment flows between Korea and the EU are growing as a result of the FTA that came into effect in 2011. Trade between the UK and Korea has grown rapidly since 2011 and the two countries signed a continuity Free Trade Agreement in August 2019 which ensures that the trading framework remains largely unchanged from the end of the transition period into 2021.

Figure 1: GDP and Growth Rates (2014-2019)



Source: World Bank

3. The Hydrogen Industry

Korea is looking to build a society that harnesses hydrogen as a source of energy for mobility and power generation. According to the Korea Energy Economics Institute (KEEI), the hydrogen industry is worth KRW 14.1 trillion (£9.1bn) in 2020 and is forecast to reach KRW 26.8 trillion (£17.3bn) by 2030. While Korea already has a mature hydrogen industry, most of the growth and capital investment in the industry in the coming years is expected to come from mobility and power generation applications.

Ecosystem and Key Players

There are three large petrochemical complexes in Korea each centred around a large refiner: 1) Ulsan (SK Energy and S Oil), 2) Yeosu (GS Caltex) and 3) Seosan/Daesan (Hyundai Oilbank). About 90% of the local hydrogen production comes as a by-product from naphtha cracking which is cleaned and distributed to customers. Around 9% of the hydrogen produced in Korea comes from large-scale steam methane reformers (SMR) built to order and constructed on or next to customers' sites.

Deokyang is Korea's largest supplier of hydrogen. As with the other domestic hydrogen suppliers, Deokyang sources much of its hydrogen by taking by-product gas supplied at one of the three industrial complexes, cleaning it through pressure swing adsorption (PSA) equipment and distributing it to customers through pipeline or tube trailers.

Among the established international industrial gas companies Linde and Air Liquide are strong in Korea. Since 1996, Air Liquide has operated three industrial gas plants in Yeosu and recently began construction of a fourth plant specialised in hydrogen production from polyurethane. Linde established its Korean subsidiary in 1988 and is one of the largest industrial gas specialists in Korea.

Table 1: Key Hydrogen Suppliers

	Company Name	Capacity (Nm3/h)	Market Share (%)
1	**Deokyang**	150,000	50.1
2	**SPG Hydrogen**	65,000	27.1
3	**Air Liquide**	53,000	17.7
4	**SDG**	21,300	7.1
5	**Changshin**	5,200	1.7
6	**Linde**	3,200	1.1
7	**Daesung**	2,000	0.7

Source: Intralink Research

The broader hydrogen ecosystem consists of hydrogen producers and users, gas and power utility companies, gas and fuel cell equipment manufacturers and integrators, EPC companies, regulatory bodies and R&D institutions. It is estimated that there are almost 400 companies in the Korean hydrogen industry, of which the fuel cell sub-sector accounts for the highest share at around 30%.

Figure 2: Hydrogen Ecosystem

As hydrogen moves from being purely an industrial gas concern to a broader fuel to power and heat the economy, questions around the roll out of infrastructure come to the fore. For now, hydrogen is trucked via tube trailers to Korea's nascent HRS network, but this is not sustainable: of the 130,000 tons of by-product hydrogen produced in 2019, only 50,000 tons was available for hydrogen refuelling stations (HRS) or fuel cell power generation. Further, while the world's largest industrial fuel cell plant (50MW) was completed in July 2020 at Hanwha Energy's site in Daesan using Doosan's phosphoric acid fuel cells (PAFC), there is a limit to the transformation that can be achieved by relying purely on by-product hydrogen from petrochemical sites.

In the medium to long term, one of Korea's hydrogen strategies involves moving towards green hydrogen with renewable energy-powered electrolysis but for now, the strategy is to use the extensive natural gas pipeline as the main source of hydrogen for both power and mobility applications. This means the roll-out of fuel cells with in-built reformers for power generation and the roll-out of steam methane reformers (SMR) which reform the natural gas in to hydrogen for use in fuel cell vehicles. In this sense, Korea's strategy is to build out the most cost-effective hydrogen infrastructure in the short term and 'green' the supply of the hydrogen at a later point rather than trying to start with a green hydrogen strategy from the start.

In light of this, the natural gas industry is set to play a critical role in the early hydrogen economy. The industry is dominated by KOGAS which, with the exception of gas power plant operators, has a monopoly on the importation of natural gas. KOGAS distributes the gas to a network of 34 gas retailers that have the exclusive right to distribute the gas within their geographical region. The price of natural gas is heavily regulated and varies slightly by region and by application.

4. Hydrogen Policies

The first comprehensive hydrogen economy vision of Korea dates back to September 2005 when MOTIE announced the 'Masterplan for the Realisation of Hydrogen and New Renewable Energy Economy'. The early 2000s was characterised by optimism around the hydrogen economy and the plan's goals were ambitious: the production target of fuel cell vehicles (FCEVs) by 2020 was 2 million units, however, as of July 2020, the cumulative sales volume of FCEV was about 10,144 units (including exports). The target for total installed capacity of fuel cells for power generation by 2020 was 3,100 MW, whereas in fact the total installed capacity of fuel cell power plants in Korea is about is 375 MW as of 2019. Despite falling short of its early goals, Korea still accounted for fully 35% of global installed fuel cell capacity in July 2020.

Hydrogen Economy Roadmap

Over the last few years, optimism surrounding the hydrogen economy has returned and Korea finds itself well placed to drive that transition. In January 2019, the government announced the Hydrogen Economy Roadmap that set out its targets to 2040. The roadmap aims to increase the number of fuel cell cars to 79,000 by 2022 and to 5.9m units by 2040, and will support this growth with 310 HRS installed by 2022 and 1,200 HRS by 2040. It also aims to increase massively the installed capacity of utility-scale and residential fuel cells by 2040 to 15GW and 2.1GW respectively.

Table 2: Hydrogen Economy Roadmap

Application	Type	2018	Transition	2022	Transition	2040
Mobility	Passenger Vehicle	5,000	Localisation up to 100%	79,000	The same price as EV	5.9m
	Bus	2		2,000	Can run for 800,000 km	60,000
	Taxi	-	Expected to run in large cities from 2021		Expand across country	120,000
	Truck	-	5-ton truck development	10-ton trucks	Localisation up to 100%	120,000
	Hydrogen Stations	14		310	Localisation up to 100%	1,200
Energy	FC Power Plants	307 MW	Installation cost down to KRW 3.6m (£2,300)/kW	1.5 GW	Same generation	15GW
	Residential FC	7MW	Installation cost down to KRW 15.3m (£9,900)/kW	50 MW	cost as GTPP	2.1GW
Hydrogen Supply	Hydrogen Supply Amount	130,000 T/Y		470,000 T/Y	Installation cost down to KRW 7.1m (£4,600)/kW	5.26 M T/Y
		By-product / SMR	Large-scale production	Electrolyser		Green Hydrogen
Hydrogen Cost		KRW 8,800		KRW 5,500	Large-scale electrolyser	KRW 3,000
		(£5.6)/kg		(£3.6)/kg	KRW 3,500 (£2.4)/kg	(£1.9)/kg

Source: Ministry of Environment

The roadmap also identifies the National Core Technology Development Plan with respect to hydrogen production. Hydrogen is a strategic industry for Korea, and it has worked over the past two decades to ensure that it has access to the enabling technologies. While it has made great strides in developing or buying foreign fuel cell technologies, the country has not made the same the progress with hydrogen production or handling technologies. One of the key goals of the National Core Technology Development Plan is to ensure the country becomes globally competitive in small-scale SMR and electrolysis (both PEM and alkaline) technologies.

Table 3: National Core Technology Plan

Technology	Current Status	Short-Term						Mid-Term		Target
		2020	2021	2022	2023	2024	2025	~2028	~2030	
SMR	System design, small-scale system demonstration stage	Small-scale SMR system development								System Efficiency 78% (HHV) by 2030
			Medium-scale SMR system development							
Water Electrolysis	Design stage of the development of 1MW original technology and stack technology	Alkaline water electrolysis system development								100MW system; System Efficiency 50kWh/kg-H2; Dozens of MWs of P2H technology development connected to RE by 2030
		PEM electrolysis system development								
				Development of P2H technology connected to renewable energy						

Source: MOTIE

Hydrogen Law

The National Assembly passed the Hydrogen Law in February 2020 with a view to creating a legal framework for the realisation of Hydrogen Economy Roadmap. Although the law has passed parliament approval it will not enter into effect until February 2021. The Hydrogen Law makes provisions for hydrogen equipment safety requirements, certification processes and the roles and responsibilities of various government agencies.

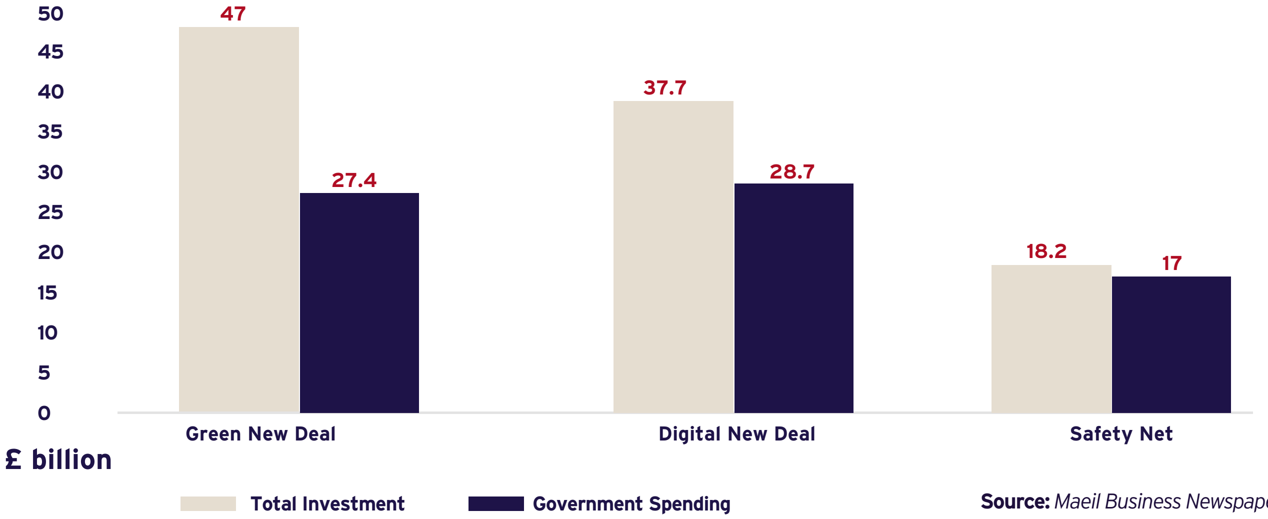
Green New Deal

In July 2020, the Korean government announced a Korean New Deal with the aim of providing 1.9m jobs by 2025. The New Deal consists of almost KRW 160 trillion (£102.5bn) worth of total fiscal investment in the digital, green economy and 'safety net' spaces. Central government expenditure will account for KRW 115 trillion (£73bn), while the remainder will be sourced from local governments and the private sector.

The Green New Deal is the term used to describe projects aimed at reducing the carbon intensity of the economy and hydrogen plays a key role in this. The government has selected 5 key areas of investment: Green Smart Schools, Smart Green Industrial Complexes, Green Remodelling, Green Energy, and Green Mobility. Out of the KRW 74 trillion (£47bn) of total capital investment under the Green New Deal, the largest portion, KRW 20 trillion (£13bn), will be used for green mobility, particularly hydrogen projects. Public organisations such as KOGAS, KEPCO and related ministries are now tasked with developing plans to channel the funds.

Green New Deal funding will be applied to overcome the lack of short-term profitability with hydrogen infrastructure. For example, operating a hydrogen refuelling station (HRS) is not yet profitable due to low volumes and the high price of delivered hydrogen through tube trailers so attracting investment has proven difficult. To remedy this, the government is considering adopting a Build-Transfer-Lease (BTL) model under the Green New Deal whereby the private sector builds the infrastructure, transfers the ownership to the government and then leases the infrastructure back from the government over a 30 or 50-year period.

Figure 3: Capital Allocation in New Deal Projects to 2025



Source: *Maeil Business Newspaper*

5. Hydrogen Economy Sectors

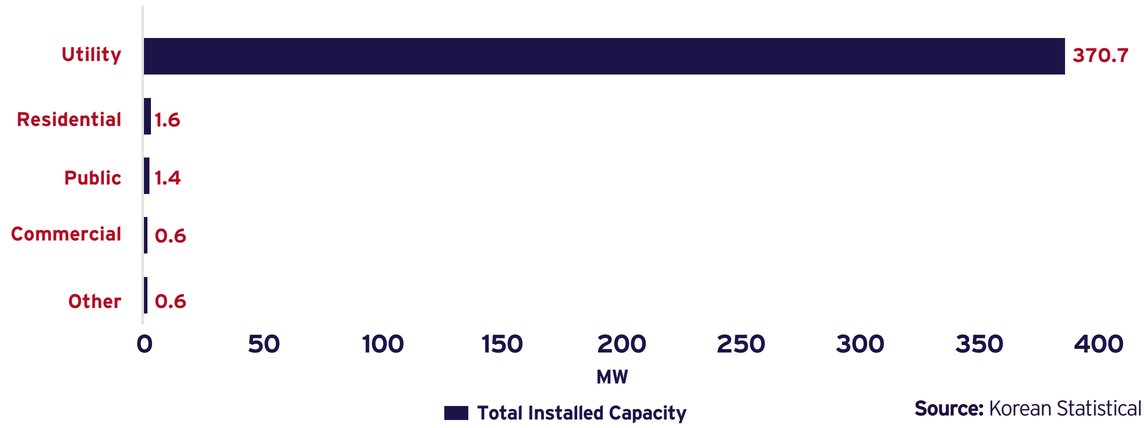
Stationary Power Generation

The primary instrument used to incentivise the roll-out of large-scale new and renewable energy – Korea uses the term 'new and renewable' precisely because natural gas-powered fuel cells cannot be considered a renewable energy resource – is the Renewable Portfolio Standard (RPS). Under the RPS, which replaced a Feed-in-Tariff (FiT) in 2012, power generators with installed capacity larger than 500MW are obliged to meet an increasing proportion of their power generation from new and renewable energy sources each year. The 22 obligators, both public utilities and IPPs, must source at least 7% of their total power production from such sources in 2020, a figure which rises by 1% each year up to 10% in 2023.

Each MWh of new and renewable energy produced secures one Renewable Energy Certificate (REC). To secure RECs, obligators can develop projects themselves, invest in projects developed by third parties, sign REC contracts with third party developers or buy RECs on the spot market. To control the direction of the market and incentivise certain technologies, a multiplier is used. For example, solar farms under 100kW capacity receive 1.2 RECs/MWh whereas solar farms over 3MW receive 0.7 RECs/MWh. For fuel cells the multiplier is 2.0, so a fuel cell plant receives 2 RECs per MWh of energy produced on top of the value of the electricity.

The REC price and the system marginal price (SMP) for electricity fluctuate, but the RPS usually ensures fuel cells generate revenues in excess of KRW 200 (£0.13)/kWh. This policy has led to 370MW of utility-scale fuel cells being installed across the country or approximately 0.3% of the total domestic power generation. This is a long way from the 15GW target by 2040 set out by the Hydrogen Roadmap but it has made the Korean utility-scale fuel cell market one of the most competitive in the world.

Figure 4: Fuel Cell Stationary Power Generation by Application (2019)



Source: Korean Statistical Information Service

The residential and commercial fuel cell markets in Korea have not been so successful and stand in contrast to Japan's success in these sections of the market. Buildings with a total floor area over 1,000m^2 are required to generate at least 30% of their energy consumption from new or renewable energy. MOTIE provides subsidies for 5 types of installations for residential and commercial building end-users: solar power, solar heat, fuel cells, geothermal and wind. For fuel cells, 80% of the installation cost is covered up to a maximum of £9,900/kW. Similar subsidies apply to residential fuel cells up to a maximum of £10,000/kW.

The majority of residential and commercial buildings to date have been proton exchange membrane (PEM) fuel cells supplied by local players. However, according to a survey conducted by Korea Energy Agency in 2019, utilisation rates of residential fuel cells were low and the consumer satisfaction rate was only 10.6%. While there have been quality concerns, the agency found that the biggest reason for consumer dissatisfaction was high city gas utility prices. In response, the government recently announced a separate price for natural gas used for residential fuel cells which is 6.5% less than the standard price. The new tariff applies not only to residential but also to commercial and utility-scale fuel cells.

The Uninterruptible Power Systems (UPS) market for commercial and public buildings in Korea is dominated by battery-based energy storage systems (ESS), unsurprising as Korea has three of the world's largest lithium-ion battery manufacturers. Nonetheless there is interest in using fuel cells for UPS applications and Hyundai Mobis, for example, recently developed a 450kW UPS unit by combining 5 of Hyundai Motor's 95kW fuel cells.

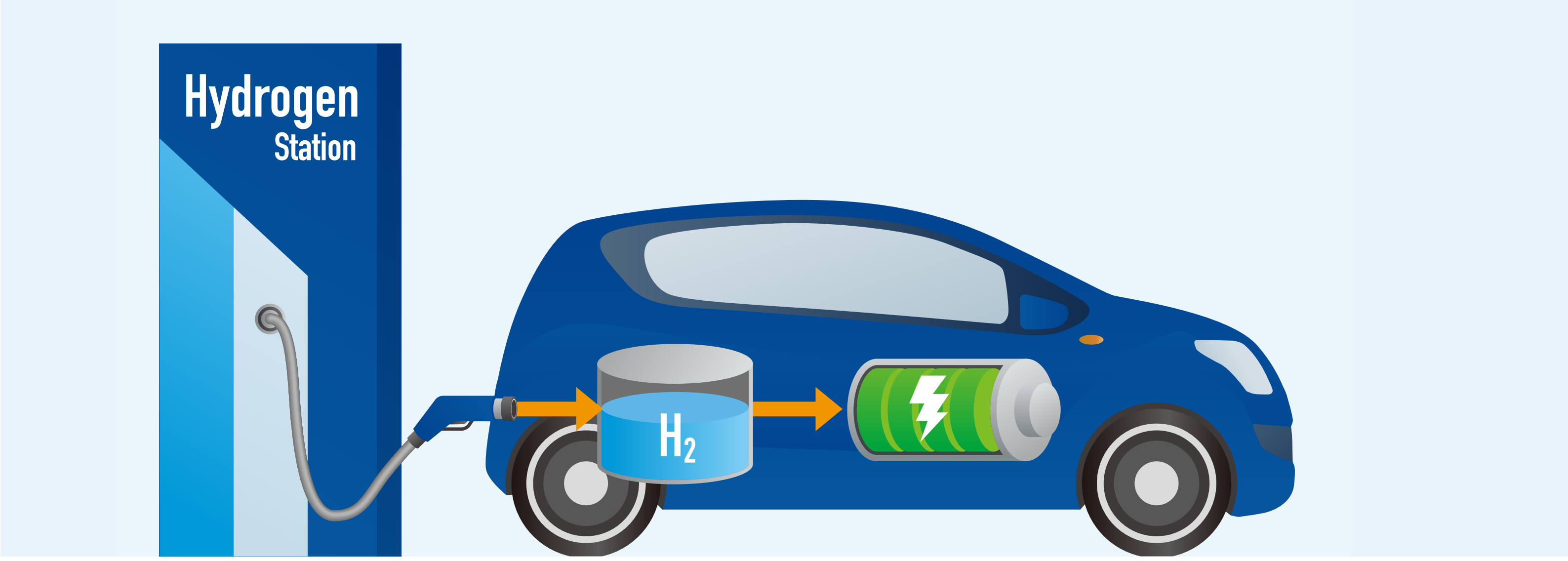
Research, development and commercialisation efforts in Korea have now shifted to higher efficiency, fuel-flexible solid oxide fuel cell (SOFC) systems which promise to be more competitive than earlier technologies. As with other fuel cell types, while there are domestic firms aiming to develop competencies in the field, much of the core technology around SOFC systems has been sourced from abroad, often from the UK and the USA. One such example is Ceres Power, a UK SOFC technology specialist who signed a Collaboration and License Agreement with Doosan Corporation in 2019 and a further agreement in October 2020 which broadened collaboration between the two companies to include manufacturing. This deal means that Doosan will have offerings across three types of fuel cell technologies (PEMFC, PAFC, and SOFC). Similarly, in 2017 SK E&C signed a distribution agreement for Bloom Energy's SOFC system and then announced a joint venture with Bloom Energy in 2020 to manufacture the systems in Korea.

Table 4: Key Players - Power Generation Market

Company	Product Type	Capacity	Original Technology	Application Field
POSCO Energy	MCFC	300kW, 2.5MW	FuelCell Energy	Utility
Doosan	PEMFC	600W, 1kW, 5kW, 10kW	Fuel Cell Power	Residential/ Commercial
	PAFC	400kW	Clearedge Power	Utility
	SOFC	5~20kW	Ceres Power	Commercial
S-FuelCell	PEMFC	1~10kW	CETI, GS Fuel Cell	Commercial
	PAFC	100kW	S-FuelCell	Utility
SK E&C	SOFC	300kW	Bloom Energy	Utility

Source: Intralink Research

While there have been successes with this approach, such as with Doosan's acquisition of Clearedge Power and its phosphoric acid fuel cell (PAFC), there have also been difficulties. POSCO Energy's tie-up with Fuel Cell Energy to manufacture and distribute its molten carbonate fuel cells (MCFC) led to a strong initial roll-out in Korea but the relationship turned acrimonious largely in relation to what POSCO claims was defective equipment supplied by Fuel Cell Energy. Separately, in 2012, LG Group acquired 51% of Fuel Cell Systems, a subsidiary of Rolls-Royce with a view to developing its SOFC system but couldn't make it work. In another case, in 2014, the Kolon Group established a joint venture with Canadian firm Hydrogenics to develop the Korean market for the latter's PEMFC products but sold out and withdrew from the market in 2020.



Industry Insider's Thoughts

We expect the Korean fuel cell market to continue growing as it is backed by enormous public and private capital investments as well as environmentally-friendly policies. In terms of technology, there is increasing demand for low-cost, efficient catalysts for SOFC and PEMFC systems. We know the UK is active in this area which leaves room for R&D and commercial opportunities between the UK and Korea.

Mr H.K. SHIN, Vice President – Bumhan Fuel Cell

Passenger Mobility

Consumer Fuel Cell Electric Vehicles (FCEV)

From January to October 2019 more than half of the FCEVs sold globally were made in Korea and Hyundai Motors surpassed Japan's Toyota and Honda to achieve the world's top FCEV sales. In the domestic market, FCEV sales are growing more rapidly than battery electric vehicles (BEV), albeit from a much smaller base, thanks to government subsidies.

Table 5: Domestic Consumer FCEV and BEV Sales Comparison

Vehicle Type	1Q 2019	1Q 2020	Growth Rate (%)	Total
FCEV	188	1,044	455.3	6,124
EV	5,348	7,828	46.4	96,737

Source: GasNews Newspaper

The central and local governments allocate subsidies for consumer FCEVs and while the subsidies apply to any make, almost all FCEVs in Korea are supplied by Hyundai. The starting price of Hyundai's most recent FCEV model 'Nexo' is KRW 72m (£47,000). The central government offers a subsidy of KRW 22.5m (£14,000) and local governments offer subsides ranging from KRW 10~20m (£6,300-13,000). In Seoul, after subsidies the consumer pays around KRW 32.5m (£21,000) for the basic Nexo model. Apart from the end-user subsidies the government provides further incentives in the form of tax exemptions benefits. As Type 1 low-emission vehicles, FCEVs are also eligible for up to a 50% discount on public parking spaces. The Korea Expressway Corporation (KEC) also provides a 50% discount on highway tolls.

Fuel Cell Electric Buses (FCEB)

Hyundai Truck & Bus is the only fuel cell bus OEM in the market. The original price of its FCEB is around KRW 630m (£406,000) but this receives subsidies of around KRW 150m (£97,000) from the central, and KRW 150m (£97,000) from local governments, bringing the price down to KRW 330m (£212,000). At the time of writing there were only 11 FCEBs on the road in Korea, but as Hyundai's FCEB is ready for mass deployment, this number is expected to rise rapidly. Budget has already been secured by local governments for 815 FCEBs for delivery in 2021 and the country aims to have 2,000 units on the road by 2022. The Hydrogen Economy Roadmap aims to have 60,000 units in operation by 2040.

There are four bus OEMs in Korea: Hyundai Truck & Bus, Edison Motors, Woojin Industrial Systems and Zyle Daewoo. While Hyundai and Edison already have battery (BEV) bus lines and are focusing on the zero-emission vehicles, Woojin IS and Zyle Daewoo plan to keep their current CNG buses as their main product lines for now. In terms of the domestic BEV bus sales, Hyundai Truck & Bus is the largest player with 32% market share in 2019 followed by Edison Motors with a 29% market share.

In 2019, Hyundai Motors announced that as well as supplying Hyundai Bus & Truck, they would also supply fuel cell systems to other bus manufacturers. However, there is suspicion among the bus OEMs as to whether Hyundai will deliver its systems on terms that would allow them to compete with Hyundai Truck & Bus.

Industry Insider's Thoughts

Hyundai is indeed well-positioned to become a fuel cell system supplier to the bus OEMs in Korea. However, we cannot deny the fact that this might put us at risk of becoming dependent on our competitor when it comes to the critical technology. Therefore, we are also considering the option of a foreign supplier for the development of our own fuel cell bus.

Mr Chihwan KIM, Director of Purchasing Division – Edison Motors

The purchase of FCEBs is organised by local government bodies, such as municipalities and technoparks, who announce subsidies for public transport operators and the operators apply and compete for those subsidies.

Table 6: Fuel Cell Bus Supply Plan by Region

Region	Target by 2022	Budget Secured by 2020	Remaining
Seoul (Capital)	650	436	214
Busan (South Gyeongsang Province)	400	194	206
Daegu (North Gyeongsang Province)	50	0	50
Incheon (Gyeonggi Province)	531	87	444
Gwangju (South Jeolla Province)	265	0	265
Daejeon (South Chungcheong Province)	322	78	244
Sejong (North Chungcheong Province)	20	19	1

Source: *Ministry of Environment, EV portal*

Industry Insider's Thoughts

It's costly and time-consuming to develop PEMFC independently, especially on a small scale. We can engineer and customise fully-built PEMFC once we have the core technology, particularly, polymer membranes. In this regard, we are keen to partner with local and foreign suppliers.

Mr Suk-won KIM, Technical Division Chief – Contech Mobility

Freight Mobility

FC Trucks

Hyundai Truck & Bus recently began mass production of the world's first FC trucks – XCIENT Fuel Cell. The trucks are powered by 190kW FC stacks (2 x 95kW Nexo FC stacks) with a combined hydrogen storage capacity of approximately 32kg. In 2019, Hyundai Motors formed Hyundai Hydrogen Mobility (HHM), a joint venture with Swiss company H2 Energy, which will lease the trucks to commercial truck operators on a pay-per-use basis. Following delivery of the initial 10 units of its FC trucks to Switzerland, Hyundai signed an agreement to provide two test-run FC garbage trucks to the Korean city of Changwon from 2021. The Ministry of Environment plans to announce end-user subsidies for FC trucks beginning 2022.

There are two local domestic OEMs in the market: Hyundai Truck & Bus and Tata Daewoo. Although Hyundai is currently the only supplier of FC trucks in Korea, Tata Daewoo also has medium to long-term plans to develop FC trucks. According to a representative at Tata Daewoo, the company is closely monitoring the potential government subsidies for FC trucks and potential demand in the market.

FC Drones

Korea has more than 3,300 islands and delivering goods to these rural areas is challenging and drones are seen as one solution for this. In April 2020, Doosan Mobility Innovation (DMI) distributed protective masks to three islands using its FC drone. Apart from 'last mileage delivery' services, FC drones are also being used in the plant inspection (industrial, power generation), solar farm monitoring as well as for military and agriculture purposes.

Industry Insider's Thoughts

Our current fuel cell drone models have 350 bar hydrogen tanks. We are currently developing 700 bar tanks with a view to making refuelling easier and allowing the drones to carry more hydrogen in a smaller space. Although it is not our immediate focus, we are also considering the option of providing a 'full solution' with a small scale on-site SMR for our customers.

Mr Doo-soon LEE, CEO – Doosan Mobility Innovation

There are over 20 UAV companies in Korea and apart from DMI, Giantdrone is known to have FC-based product line at the R&D stage. The company recently developed a 2kW FC drone with a 2-hour flight time. Current regulations in Korea allow drones with a total weight up to 25kg (including FC system and storage tank) to fly over residential areas. Drone taxis are also on the government's long-term agenda which will require much broader regulations.

Under the National Hydrogen Technology Roadmap (NHTR), the government aims to achieve 1kW/kg for general purpose drones, and 2kW/kg power density for drone taxis by 2040. The largest FC drone currently available in Korea has a 5kW air-cooled PEMFC system but local drone manufacturers such DMI are open to licensing technology for larger scale, liquid cooled systems and are keen to secure or develop light-weight, cost-effective hydrogen storage tanks for those drones.

FC Water Vessels

Korea is currently the world's second largest shipbuilder after China and boasts major shipbuilding companies such as Hyundai Heavy Industries, Daewoo Heavy Industries & Machinery and Samsung Heavy Industries. Despite enjoying this great success, Korea lags in terms of adopting clean technologies in water vessels compared to the UK.

Korea currently requires only Tier II marine standards (less strict control of CO2 and NOx emissions) rather than Tier III, meaning vessel operators have no obligation to electrify the vessel engines. Korea's Ministry of Environment recently established a task force group with a view to proposing new regulation draft to the National Assembly, which if passed will require vessel operators to introduce clean water transport within the ports across the country.

However, the shipbuilding industry is global in nature and the large Korean shipbuilders are already working on early-stage projects with fuel cell providers, as shown by the agreement signed between Samsung Heavy Industries and Bloom Energy in 2020 to develop a fuel cell system to replace the main engines and generators on LNG carriers. The Korean government's aim is to encourage the domestic development of a fuel cell system for marine applications by 2030 at a price point of KRW 0.5m/kW (£322/kW).

Material Handling and Heavy Equipment

Forklift subsidies from central government are expected in 2022 but current subsidies are only available at the local government level and differ by region. For instance, in 2019, South Chungcheong Province announced a 50% end-user subsidy for up to 10 units of FC forklifts to be used at warehouses, while South Gyeongsang Province announced a tender with 70% end-user subsidies in March 2020. The largest port in Korea, Busan Port is looking to make FC and BEV handling equipment mandatory within the port from 2023. According to the Port Authority, a subsidy proposal has been submitted for review by the government.

Korea's domestic forklift OEMs such as Soosung Lift and Doosan Industrial Vehicles (DIV) have electrified most of their product lines with lithium-ion batteries and plan to develop FC forklifts once the government announces relevant subsidies. Government-funded FC forklift development began in 2018 when Gaon Cell won a project to develop two FC forklifts with a budget of KRW 3.6bn (£2.3m). Although there are cost-of-ownership benefits with fuel cells due to increased uptime, it was concluded that huge subsidies would be needed to ensure FC forklifts compete with their battery counterparts that can cost as little as KRW 30m (£19,000) per unit.

Although construction equipment has not gone through battery electrification yet, it is generally agreed that fuel cells are perhaps most suited to this type of vehicles. Local OEM Hyundai Construction Equipment (HCE) recently announced plans to develop FC excavators and signed an MOU for the joint development of this machinery with Hyundai Motors and Hyundai Mobis. Other OEMs such as Doosan Infracore are monitoring the market and subsidies before expanding into the fuel cell segment. There are no end-user subsidies for FC construction equipment and such vehicles are not yet available in the market.

Hydrogen Refuelling Stations (HRS)

Currently, there are 38 HRS operating in Korea. The vast majority of these are 'truck-in' stations whereby the hydrogen is trucked in by tube trailer from a hydrogen supplier such as Deokyang or SPG. There is only one operational HRS with an on-site SMR commissioned in April, 2020. In terms of capacity, HRS are divided into two broad categories: regular HRS with 650kg/day and bus HRS with 1,000kg/day refuelling capacity. Due to the low profitability of HRS operation, almost all HRS are being operated by the municipalities. HRS are often built close to CNG stations (most Korean buses run on CNG) or LPG stations (most Korean taxis run on LPG) as permits are easier to secure and some costs, such as safety protocols, can be shared across the stations.

The hydrogen price at HRS falls within the range of KRW 7,100 and KRW 8,800/kg (£4.6 and £5.7/kg) which includes 10% VAT. Hydrogen is substantially cheaper than gasoline, diesel, or LPG on a cost/km basis. While there is no government-mandated ceiling for the price of hydrogen that the end-user pays, 8,800 KRW/kg (£5.7/kg) has become the standard price that HRS operators are reluctant to go beyond. This price makes it difficult to attract operators into the HRS industry, an issue the government is looking to address.

Comparisons

- Petrol: KRW 1,250 (£0.81) per litre
- Diesel: KRW 1,060 (£0.68) per litre
- LPG: KRW 730 (£0.47) per litre

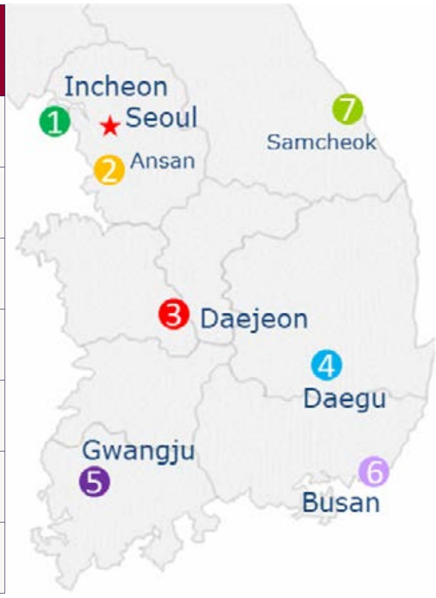
Table 7: HRS CAPEX Subsidies

Subject	Type	Original Cost (£)	Subsidy (£)	Details (£)
HRS	Regular	1.8m	900,000	*ME: 900,000 *MOLIT: 467,000 in 2019 and 620,000 in 2020 for highways
	Bus	3.8m	2.7m	ME: 2.7m

There are three public procurement authorities for HRS in Korea: The Ministry of Trade, Energy, and Industry (MOTIE), KOGAS and the Ministry of Environment (ME). MOTIE and KOGAS aim to roll out ‘base stations’ or ‘mother stations’ whereby an SMR is installed in a large regional station and hydrogen produced there is both used to refuel vehicles at that site and is transported to other nearby HRS, either by truck or eventually by pipeline. MOTIE often conducts these bids through technoparks that announce tenders after receiving budget from the ministry.

Table 8: MOTIE-sponsored Projects

	Tender Name	Capacity (NM3/h)	Status
1	**Incheon Hydrogen Cluster**	460	Planned
2	**Ansan Refuelling Station**	300	On-going
3	**Daejeon Refuelling Station**	300 x 2	Planned
4	**Daegu Hydrogen Facility**	460 x 2	Planned
5	**Gwangju Hydrogen Facility**	300	Planned
6	**Busan Hydrogen Station**	300 x 2	Planned
7	**Samcheok Hydrogen Facility**	300	On-going



Source: Intralink Research

KOGAS organises tenders either independently or in cooperation with local governments. KOGAS projects, however, are fully sponsored by KOGAS only, whereas some technoparks allocate certain amount of capital in addition to the MOTIE funding for base station projects. Local governments provide land or ease of permitting, tax, or other administrative assistance to attract KOGAS hydrogen facilities. Tenders specify that SMRs with a minimum lower heating value (LHV) efficiency of 70% qualify.

Table 9: KOGAS-sponsored Projects

	Tender Name	Capacity (Nm3/h)	Status
1	**Ansan Hydrogen Facility**	460	Planned
2	**Pyeongtaek Hydrogen Facility**	3,000	On-going
3	**Daejeon Hydrogen Facility**	460	Planned
4	**Jeonju Hydrogen Facility**	460	Planned
5	**Gwangju Hydrogen Facility**	1,830	Planned
6	**Changwon Hydrogen Facility**	1,830	On-going
7	**Gimhae Hydrogen Facility**	300	Planned
8	**Busan Hydrogen Facility**	460	Planned
9	**Ulsan Hydrogen Facility**	1,830	Planned

Source: Intralink Research

The Ministry of Environment is not directly involved in the hydrogen production space unless the method of production is electrolysis connected to a renewable energy source. ME supports the roll-out of HRS with truck-in hydrogen through CAPEX subsidies (rather than running tenders) which are up to 50% of regular HRS and 70% of bus HRS.

HyNet

In 2019, 13 hydrogen companies with interests in the hydrogen space established a special purpose company (SPC) with the goal of building 100 HRS by 2022. Those companies were KOGAS, Hyundai Motors, Woodside, Nel, Valmax, Bumhan, SPG Hydrogen, JNK Heaters, Kolon Industries, Hyosung Heavy Industries, Air Liquide, Deokyang and Ecobio Holdings and together they invested a total of KRW 135bn (£87m) into the SPC. However, Deokyang and Ecobio withdrew from the SPC in 2020, leaving 11 companies in the consortium.

HyNet started building 20 HRS in 2019 and plans to build a further 20 in 2020 and 30 more in 2021 and 2022. Despite a degree of government involvement, HyNet acts as a private sector player investing 50% CAPEX on top of the government's 50% subsidy for HRS. There are now plans to copy this model with the formation of another SPC, called BusNet, to build HRS for FCEBs.

Industry Insider's Thoughts

Although dozens of UK companies are active in the power generation sector in Korea, we don't see as much activity in the HRS space. HyNet is open for partnering with UK companies, especially those that have mobile refuelling solutions – an area in which HyNet is interested in expanding its business.

Mr Won Sik KIM, Head of Infrastructure Department - HyNet

Distributed Hydrogen Production

Steam Methane Reformers (SMR)

Korea ultimately aims to secure its hydrogen from renewable energy-powered electrolysis or to ship in hydrogen from, for example, Australia. But it is recognised that doing this safely, cheaply and at scale is still some way off. In the meantime, the government has identified on-site natural gas reformation through SMRs as a good 'bridging' technology for the next decade or so. In order to encourage the roll-out of on-site SMRs MOTIE announced in July 2020 there would be a separate and lower price for gas used on-site SMRs. Local companies are racing to develop on-site SMR offerings but currently only have pre-commercial units.

Table 10: Local on-site SMR Manufacturers

Manufacturer	Model	Capacity (kg/day)	H2 Purity (%)	Remarks
JNK Heaters	HIIS-250	250	99.97	Only track record opened in Seoul in March 2020. However, operation is currently suspended
	HIIS-500	500	99.995	
Hyundai Rotem	HYSERVE-200	640	99.999	Signed licensing agreement with Osaka Gas Engineering (OGE)
Wonil T&I	HyPU-100	200	99.999	Set to commercialise technology developed by Korea Institute of Energy Research (KIER)
	HyPU-200	500	99.999	
Bumhan	H-300	300	99.999	Has military ties and developed on-site SMR under a public-funded program
Tricin	H2-150	340	99.999	SMR is able to reform LPG. Originally developed by Yonsei University and still at R&D stage

Source: Intralink Research

Japanese companies such as Osaka Gas Engineering (OGE) and Mitsubishi Kakoki Kaisha (MKK) are well-known in Korea but with one exception - there is no domestic track record for Japanese on-site SMR makers. Hyundai Rotem signed an agreement to license OGE's 650kg/day equipment and aims to target the regular HRS market with this product. Air Liquide has on-site SMR equipment with 115 kg/day, 174 kg/day and 584 kg/day capacities, but as yet no use case in Korea and competes against Linde's SMR equipment which boast 110 kg/day–2,200 kg/day capacities.

Electrolysis

Korea is clearly behind the international competition in terms of both PEM and alkaline electrolysis competency and while the government and industry see renewable energy powered electrolysis as an important component of its long-term hydrogen production strategy, it does not see this production method making a large contribution – at least to HRS – in the near term.

A small percentage (<1%) of hydrogen is currently produced through electrolysers, at 5 locations across the country. Investment is being made into electrolysis both by the private and public sector. Elchemtech, which spun out from EM Solution in 2018, has a PEM electrolysis solution in the market and large players such as Hyundai Motors and Hanwha are also looking at electrolysis technology. In December 2020, Hanwha Solutions signed an MOU with Gangwon Province and KOGAS-Tech to build an electrolysis complex connected with wind power capable of producing 290 tons of hydrogen per year. Other players such as Acro Labs and Wespe are developing PEM and AEM (Anion Exchange Membrane) technologies with a view to bringing units to the market by 2022. By 2030, the government aims to have a domestic champion with a high-efficiency (50kWh/kg), large-scale (up to 100MW) electrolysis technology.

Table 11: Electrolysis Stations

Operator	Capacity (Nm3/h)	Location	Remarks
Jeju City Government	5	Jeju Island	2 R&D, 1 Commercial
EM Solution	15	Daegu Metropolitan City	Commercial
	12	Buan-gun (North Jeolla Province)	Commercial

Source: Intralink Research

As 'green' hydrogen from electrolysis is on the longer-term agenda of the government, only three cities – Ansan (Gyeonggi Province), Naju (North Jeolla Province), Boryeong (South Chungcheong Province) – have been selected as the cities for large-scale water electrolysis installations. As an initial step, state-owned power utility companies such as KEPCO in Naju and Korea Midland Power Company (KOMIPO) in Boryeong are conducting R&D projects for water electrolysis installation connected to renewable energy sources. One issue is the high cost of producing renewable energy in Korea which means green hydrogen is often uncompetitive.

Industry Insider's Thoughts

Although Korea is currently focusing on grey and blue hydrogen solutions as a short-term strategy, I believe we need to start a large-scale implementation of green hydrogen technology. European economies, especially the UK have immense experience in this field which opens great opportunities for companies in both countries.

Mr Seunghoon LEE, General Manager – Hydrogen Convergence Alliance (H2Korea)

Hydrogen Handling and Transportation

Hydrogen handling equipment for mobility such as compressors, storage tanks and dispensers are largely sourced from abroad. The high-pressure methane and propane/butane gas compressor supply chain is mature as most of Korea's bus and taxi networks use CNG and LPG fuels respectively. However, as the new hydrogen economy is in its infancy, local companies currently rely on foreign core hydrogen compressor equipment. Ionic liquid and hydraulic piston compressors were mainly used in the early HRS, but diaphragm compressors are increasingly being used in more recent stations. Key players in the hydrogen compressor market include Hyosung Heavy Industry, Kwangshin, EM Solution and Nel Korea.

In the hydrogen storage field, although local companies like NKTECH and Iljin are gaining strength, the majority of equipment continues to be imported from abroad and JSW (Japan) and Fibatech (the US) control almost 50% of the hydrogen storage equipment market. Due to space constraints, Korea recently allowed the installation of bundle-type hydrogen storage tanks instead of cartridge-type tanks, which generally have a larger footprint. However, owing to increased weight and safety concerns, bundle-type storage is allowed only with Type 3 or 4 storage tanks, which are strengthened with non-metallic fibre liners.

Japanese companies partnering with local firms dominate the hydrogen dispenser market. A local company called Saemchan has succeeded in developing a domestic hydrogen dispenser but customers maintain a preference for foreign equipment with stronger track records – industry experts believe this will continue as dispensers and compressors account for 20% and 40% of station downtime respectively ensuring that reliability is critical. One such domestic integrator is MS ENG which sources the core technology from Japan's Tatsuno and integrates that into a dispenser. Another local company, Valmax, recently signed a licensing agreement with Japan's TOKICO to manufacture dispensers under the brand name of 'Valmax Neorise'.

In terms of transportation, hydrogen is mainly carried through tube trailers at 200~300 bar and there are about 558 trailers in operation across the country

Hydrogen is also transported to refineries and other end-users through a total of 200 km hydrogen pipelines mainly around Ulsan Metropolitan City. It is generally recognised that a 200 km round trip is as far as it is feasible to transport hydrogen as a gas.

Most of the research around Liquid Organic Hydrogen Carriers (LOHC) in Korea is led by R&D institutes and state-owned companies. Korea Institute of Science and Technology (KIST) developed a new LOHC with the support of MOTIE in 2017. The LOHC is a liquid in which biphenyl and diphenylmethane are mixed in a specific ratio. A ruthenium catalyst is used to store the hydrogen at 50 bar and a palladium catalyst is then used at atmospheric pressure to extract the hydrogen. Although KEPCO also claims to have developed LOHC technology that can store 20Nm3/h hydrogen, most of the research in Korea remains at the basic R&D stage.

As mentioned, one of Korea's main strategies for rolling out hydrogen infrastructure is to build a hub and spoke network whereby hydrogen is produced at a centralised site and then transported to nearby HRS. Tube trailers are currently the only available option but ultimately the plan is to build a hydrogen pipeline network linking the hub and the spokes where this is feasible. Korea already has a total of 200km of hydrogen pipelines mainly around the petrochemical complexes in Ulsan and Yeosu. This network is based on metallic pipes which operate at 60 bar but demand is expected for flexible, low pressure (<40 bar) hydrogen pipelines.

In 2019, the Korea Institute of Machinery and Materials (KIMM) launched a liquid hydrogen technology research group with the aim of developing domestic liquification technology. Until then, Korea has no option but to use foreign technology. In April 2020, Hyosung Corporation announced a partnership with Linde Group for a 13,000 tons/year capacity hydrogen liquification plant which will be the world's single largest liquid hydrogen facility. One month prior to the Hyosung-Linde project announcement, Doosan Heavy Industries & Construction (DHIC) announced a 5 ton/day capacity project with Changwon Industry Promotion Agency. DHIC is currently considering several options for the liquification technology supplier.

Industry Insider's Thoughts

The hydrogen economy requires a fully-developed production, storage and transportation ecosystem. It is too early to say but we are heading in the right direction for scaling up hydrogen production. However, hydrogen storage especially in its liquid form remains one of the biggest challenges we face.

Mr Jin-kyung KIM, Head of Technical Sales Division – NKTECH

Hydrogen for Industry

The industrial hydrogen market in Korea is dominated by established players. Many of the applications are 'mission-critical' so commercial track records are extremely important for customers. On average, the oil refineries in Korea consume about 3,000~5,000 Nm3/h of hydrogen while steel manufacturers use between 1,000 Nm3/h and 2,000 Nm3/h. By-product hydrogen is limited as it is directly linked to the load capacity of petrochemical complexes so industrial users of hydrogen tend to install large-scale SMRs to guarantee supply.

One of the most common applications of hydrogen is fertiliser production through ammonia. About 853,000 tons of chemical fertiliser was produced in Korea in 2018. However, the key component in producing fertilisers, ammonia, is largely imported from abroad rather than being produced domestically. Korea imported ammonia at about KRW 408,000 (£263)/ton price in 2018. Even when using the cheapest hydrogen purified from by-product hydrogen, 177kg of hydrogen would cost about KRW 507,000 (£342) meaning that importing ammonia at KRW 408,000 (£263)/ton is clearly more competitive.

Other applications of hydrogen such as for semiconductors, glass manufacturing and power generation (generator cooling) are dominated by the incumbent large-scale hydrogen suppliers. Unless there is a revolutionary new technology or business model that is able to deliver much cheaper, reliable hydrogen to these end users, these areas do not appear to offer easy opportunities for new entrants.

Although injecting hydrogen into the natural gas grid can be very effective as a decarbonisation strategy, Korea is not currently working on blending hydrogen into the gas grid. According to one local KOGAS official the natural gas pipeline could take no more than a 3% blend of hydrogen, so it's not a major focus for the organisation.

Opportunity Areas

It should be noted that the UK and Korea signed a Memorandum of Understanding in fuel cell and hydrogen technology which may be a useful starting point for British companies in the space looking at the Korean market. Beyond this, there are many opportunities for British companies in Korea such as:

- Hydrogen Production: On-site SMRs, energy-efficient water electrolysis solutions
- Hydrogen handling and transportation: Solutions for hydrogen storage, compressor/dispenser technologies, liquification technologies and LOHC solutions
- General gas equipment: Control valves, filters and pumps, water flow sensors, flow controllers, desulpherisers, heat exchangers
- Material science: Advanced materials with properties related to thermal and pressure management, fibre composites, materials for cryogenic liquid storage of hydrogen, graphene solutions
- Passenger mobility: Efficient fuel cell systems, polymer membranes, modular air filters
- Material handling and heavy-duty equipment: Efficient fuel cell stacks, liquid cooled PEMFC systems, hydrogen tanks and enabling materials
- Fuel cells: Efficient fuel cell stacks and systems, SOFC is of particular interest
- Fuel cell supporting technologies: ceramics and coating technologies, gas diffusion layers, process improvement technologies, 3D printing for prototype manufacture

And there are many areas for collaboration between the UK and Korean governments such as :

- Bilateral cooperation and knowledge sharing between the UK and Korean governments in terms of hydrogen policies, plans and roadmaps
- Collaboration on hydrogen production and infrastructure technologies
- Bilateral government support for pilot and R&D projects in the UK and Korea
- The UK and Korean governments signed an MOU in 2013 on the fuel cell technology collaboration (https://www.imperial.ac.uk/news/134607/uk-korea-sign-agreement-today-advance/) and now as the further step of this agreement, there could be more opportunities around hydrogen generation and infrastructure

Table 12: Technoparks and Research Institutes

Organisation		Specialty
1.	Seoul Technopark	ICT, IT training, Bio Science
2.	Gyeonggi Technopark	Electronics, Auto-parts, IT
3.	Incheon Technopark	Aviation, Green Energy, IT
4.	Daejin Technopark	Green Energy, Bio Science, IT
5.	Chungnam Technopark	Hi-tech, ICT, Auto-parts, Bio Science
6.	Sejong Technopark	IT manpower training
7.	Daejoen Technopark	IT, Bio Science, Mechatronics
8.	Chungbuk Technopark	Bio Science, Semicon, Fuel Cells
9.	Gyeongbuk Technopark	IT, Machinery, Life Science
10.	Daegu Technopark	Nano, Bio Science, Green Energy
11.	Pohang Technopark	Advanced Materials
12.	Jeonbuk Technopark	Machinery, Bio Science, ICT
13.	Gwanju Technopark	LED, Optical Communication
14.	Jeonnam Technopark	Bio Science, Materials, Logistics
15.	Gyeongnam Technopark	Machinery, Robotics, Bio Science
16.	Ulsan Technopark	Automobiles, Shipbuilding
17.	Busan Technopark	Marine, Machinery
18.	Jeju Technopark	Health, Beauty, Tourism
19.	Korea Institute of Science and Technology	Green Energy, Life Science
20.	Korea Institute of Energy Research	Renewable Energy
21.	Korea Institute of Energy Technology Evaluation and Planning	Energy Technology Evaluation
22.	Korea Energy Economics Institute	Energy Economics Evaluation
23.	Incheon Hydrogen Cluster (planned)	Hydrogen and Fuel Cell Equipment

6. Regulations and Certifications

Korea Gas Safety Corporation (KGS) is the central government authority that tests and certifies high-pressure gas equipment. Currently there is no specific law that regulates the certification of hydrogen producing and handling equipment such as SMRs and compressors, storage tanks, etc. Instead the 'High-pressure Gas Safety Law (HPGSL)' is temporarily applied for the certification of these equipment. KGS and MOTIE are currently working on the Hydrogen Safety Act which is expected to be announced in 2022. According to the HPGSL, all hydrogen-related equipment rated at over 10 bar design pressure is considered a high-pressure gas equipment and will need to be certified by KGS. On the other hand, equipment below 10 bar design pressure is considered low-pressure gas equipment. Low-pressure gas equipment and fuel cells certification process is regulated by Korea Occupational Safety and Health Agency (KOSHA).

Table 13: High-pressure Equipment Certification Process

No.	Steps	Time	Contents
1.	**Factory Registration**	1~2 weeks	• KGS inspects foreign manufacturer's capability to manufacture equipment to sufficient quality • After factory registration of a certain product, the foreign manufacturer will be eligible to supply the product to Korea
2.	**Product Inspection**	2~3 months	• Each component of the equipment is subject to a separate certification (high-pressure or low pressure) • If the components are certified in accordance with ASME, product inspection will be conducted according to the ASME standards rather than the Korean standards • After ASME inspection KGS reviews the inspection results – the process will be simplified
3.	**Facility Inspection**	2~3 weeks	• KGS conducts facility inspection after which the installed equipment will be allowed operate

Industry Insider's Thoughts

Korea is the first country in the world to adopt a 'Hydrogen Law' and the biggest task ahead of us now is creating robust safety standards for hydrogen equipment. We are analysing and bench-marking the hydrogen gas safety regulations of the US and the EU while reflecting Korean public opinion on safety.

Mr Dong-woo CHOI, Gas Safety Management Executive Director – Korea Gas Safety Corporation

For more information on the KGS regulations please visit:

http://www.kgs.or.kr/kgsmain_eng/kgs_services/manufactural_sys.jsp

Exchange rates used in the report: £1 = KRW 1,550

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Front cover: Financial data monitor

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Published April 2021 by Department for International Trade