A white paper outlining the

HYDROGEN STRATEGY OF HONG KONG

思匯 CIVIC EXCHANGE

HONG KONG 2050 IS NOW

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EXECUTIVE SUMMARY

Being the most abundant element on earth, hydrogen is known for its extensive applications in the industrial sector for petroleum refining and chemical production. Meanwhile, hydrogen has emerged as a promising solution for mitigating climate change in the transport sector aspect.

The severity of the climate issue has steered people to explore hydrogen usage as an energy carrier to carry green electron. The increased interest to deploy hydrogen fuel has made governments around the world to incorporate hydrogen strategies into their own sustainability agenda, similarly with Asia, where many countries face challenges in rapid energy transition.

China is a forerunner in the hydrogen race, overlaying the nation with early-announced policies to comprehensively decarbonise various hard-to-abate sectors, in particular for transportation. As of now, it is the world's largest producer of hydrogen and has the entire hydrogen supply chains distributed in the Yangtze delta, the Greater Bay Area (GBA) and Beijing-Tianjin-Hebei area.

Hong Kong must undertake actions on integrating and leveraging the nation's strength to facilitate the energy transition. In November 2020, Hong Kong has announced the goal of carbon neutrality before 2050, as illustrated by the subsequent two government publications of "Climate Action Plan 2050" and "Hong Kong Roadmap on Popularisation of Electric Vehicles", broaching the concept of hydrogen as a fuel to reduce greenhouse gas emissions in Hong Kong's transport sector.

However, several challenges hinder the hydrogen development, including the i) unbearable cost of hydrogen fuel and its applications, ii) slowness in policy formulation spearheading hydrogen development, and iii) limited infrastructure in place.

To eliminate stakeholder uncertainty and drive demand in the hydrogen economy, the government must develop a hydrogen policy framework that reflects the most innovative approaches to address climate change, reduce emissions, and promote participation of all.

Hydrogen can store and carry energy produced from other energy source. Therefore, developing a transition pathway from grey hydrogen to ultimately procuring green hydrogen, with a portion being produced locally, is essential to align with the "*Climate Action Plan 2050*"'s goal and boost investor confidence to drive capital into Hong Kong.

Moving forward with building a comprehensive hydrogen policy, the white paper recommends four action areas for the government to undertake, based on extensive engagement and feedback from industries:

1. Establishing a hydrogen energy industry innovation system
2. Coordinating construction of the hydrogen infrastructure
3. Building a comprehensive hydrogen policy and regulation
4. Diversifying demonstration projects

The white paper advises the government and the commercial sector to coalesce on unleashing the full potential of hydrogen as a fuel in Hong Kong.

CHAPTER 1

Hydrogen and the World

1.1 Role in meeting net zero and Status Quo

The Paris Agreement is the first globally recognised climate treaty that has been comprehensively signed by 197 countries to keep global temperature increase to below 2ºC above pre-industrial levels and to increase efforts to limit the temperature increase to 1.5ºC.[1]

Since 2021, over 150 countries and regions have announced the target of achieving carbon neutrality by the middle of this century. Pathways to decarbonise include a holistic use of different fuels, such as electricity, hydrogen and biofuels. Sound technologies will play a critical role in meeting the net zero target. Among the outstanding carbon neutral technologies, hydrogen is one of the most important solutions to mitigate climate change.

The International Energy Agency (IEA) stated the global hydrogen demand reached 95 million tonnes in 2022, with an expected increase into requiring a substantial 450 million tonnes of low-carbon hydrogen demand by 2050, which the transport sector would be the largest consumer.[2] The use of low-emission hydrogen and hydrogen-based fuels would contribute to a larger carbon emissions reductions in the longer term, in comparison with the deployment of renewables and other reduction strategies.

The Hydrogen Council identified over 1,000 hydrogen project proposals being announced globally as of May 2023, 795 of which are expected to be fully deployed or partially deployed by 2030, with additional capital being poured into the investment of global hydrogen projects.[3] It is evident that demand for hydrogen has been increasing, largely due to decreasing renewable energy prices and expanding manufacturing capacity.

1.2 Hydrogen Fuel Basics

Hydrogen offers significant and promising opportunities in achieving carbon neutrality, especially for fast-growing Asia countries that face obstacles in matching energy demand with green and sustainable supply during its transition to a carbon neutral economy. It can be broadly classified into these categories: grey, blue, and green hydrogen. Grey hydrogen is produced from fossil fuels. Blue hydrogen is produced in a similar way, with most carbon emissions captured during the process. Green hydrogen is produced from renewable energy sources and is considered zero-carbon.

Hydrogen technologies has the potential to replace fossil fuels in hard-to-abate industries, including but not limited to:

Transportation

Hydrogen can be used as an energy carrier for transportation. As a fuel, hydrogen can be used in fuel cell vehicles and non-road mobile machineries, particularly in heavy-duty vehicles such as buses, trucks, and forklifts, due to its advantageous properties in terms of range, refuelling time, and energy density. The exhaust gas generated by the combustion of hydrogen is only water vapour, but creating it can be carbon intensive. Therefore, only the usage of green hydrogen in fuel cell vehicles can effectively reduce the carbon emissions of the transportation sector. Furthermore, the application of hydrogen in maritime and air mobility, including ammonia, e-methanol, and e-kerosene, has been actively developed and is expected to see widespread adoption in the long term.

Electricity Provision

Hydrogen can also be used in power generation. In generation sets at construction sites, hydrogen in a fuel cell reacts with oxygen to generate electrical power, emitting only water and heat. Adopting hydrogen fuel cell technology to produce electricity from hydrogen in replacing diesel generators help decarbonise the construction sector.

Industrial Processes

The primary uses of hydrogen today are as feedstock delivered to an energy system to enable large-scale industrial production, such as refinery, chemical and steel processing.

For instance, hydrogen can also be used in the chemical industry. In the production of many chemical products, hydrogen is an important raw material. The use of green hydrogen instead of fossil fuels in chemical production can significantly reduce greenhouse gas emissions. Moreover, the use of green hydrogen can be used in the steel-making process to reduce carbon emissions or in the production of ammonia for fertiliser.

Power Generation

One critical contribution of hydrogen is to maintain grid stability while ramping up renewable energy supply which is intrinsically volatile. Hydrogen can act as long duration energy storage (LDES) to balance volatile renewable energy input with stable energy demand.

As LDES, hydrogen energy technology can utilise the electricity generated from renewable energy sources (such as wind and solar) for hydrogen production, achieving green energy conversion. This not only promotes the coupling of hydrogen and renewable energy on the power supply side, but also facilitates the consumption and utilisation of large-scale renewable energy, effectively balancing the load of the grid and ensuring the stability of power supply.

Hydrogen energy has cross-seasonal and long-term energy storage characteristics, making it an excellent energy storage medium for optimal scheduling purposes. On the grid side, hydrogen energy can be used for peak shaving and frequency regulation, improving the safety, reliability, and flexibility of the power system. During periods of excess power supply, excess electricity can be converted into hydrogen for storage, and then during peak demand periods, the stored hydrogen can be converted back into electricity through hydrogen fuel cells, hydrogen gas turbines and other equipment to meet the power supply requirements of the grid. Taken into account the considerable round-trips energy loss incurred, the overall ability for energy storage and optimal scheduling of hydrogen can achieve optimal allocation of energy across regions and seasons.

1.3 Policy and Business Opportunities in Asia

1.3.1 Policy Opportunities

A growing number of governments have developed a national roadmap to facilitate the adoption and implementation of these strategies for deployment in the future. As of 2022, 32 governments around the world have established hydrogen strategies, with several major Asian economies announcing national roadmaps or strong commitments to reduce carbon emissions through the use of hydrogen in the future.[4] Figure 1 shows selected countries with published hydrogen strategies, specific hydrogen targets relevant to the production and its end-use application in the transport sector, as well as expected outputs in the economy.

FIGURE 1 Global development of hydrogen policy

	CHINA	THE UNITED KINGDOM	JAPAN	SOUTH KOREA
Policy framework, strategy and plan				
National Policy	**2020** Development Plan for the New Energy Vehicle Industry (2021-2035)	**2021** The UK Hydrogen Strategy	**2017** The Basic Hydrogen Strategy	**2019** Hydrogen Economy Roadmap
	2022 Mid-and-long term Development Plan for Hydrogen (2021-2035)	**2023** Hydrogen Production Delivery Roadmap	**2023** Revision on Basic Hydrogen Strategy	
Regional Strategy and Plan	**2022** The Action Plan for Accelerating the Construction of Fuel Cell Vehicle Demonstration City Clusters in 2022-2025	N/A	**2004** Fukuoka Hydrogen Strategy	**2019** Ulsan Future Energy Strategy
City Clusters	Five demonstration clusters in Beijing-Tian-Hebei, Shanghai, Guangdong, Henan and Hebei	Two low-carbon industrial clusters for deployment by the mid-2020s and four by 2030	Fukuoka, Fukushima	Hydrogen cities at Pyeongtaek, Namyangju, Dangjin, Boryeong, Gwangyang, and Pohang
Target				
Upstream target (Production)	Green hydrogen production using renewable feedstock resources, reaching 100,000-200,000 tonnes per year by 2025	Increase up to 5GW (1.8 million tonnes equivalent) of low carbon hydrogen production capacity by 2030 The recent publication of *Hydrogen Production Delivery Roadmap* in December 2023 doubled the UK's ambition to up to 10GW (3.6 million tonees equivalent) of low carbon hydrogen production capacity by 2030	Increase the domestic hydrogen supply by 50% over the current level to 3 million tonnes in 2030 and production to over 20 million tonnes by 2050	Produce up to 3.9 million tonnes of hydrogen by 2030
Downstream target (refuelling station and vehicles as end-use)	China targets to bring 50,000 hydrogen fuel-cell vehicles on the road by 2025 In Guangdong, targeting 1,200 hydrogen refilling station by 2025	N/A	Bring 800,000 hydrogen fuel cell vehicle units and 900 hydrogen fuelling stations by 2030	Produce 6.2 million fuel cell electric vehicles (FCEV) (30,000 trucks and 40,000 buses) and operate more than 1,200 refilling stations by 2040
Expected economic benefits				
Investment benefits (i.e. GDP)	Reach a 5 trillion RMB output value in the hydrogen industry by 2035; and a 12 trillion RMB output value by 2050, assuming a 10% hydrogen energy consumption scenario	Unlock over £11 billions of investment and over 12,000 jobs up to 2030 across the UK	The revised New Basic Hydrogen Strategy envisions investment to exceed 15 trillion Japanese yen by 2038	Deliver 43 trillion Korean won, 2% of national gross domestic product
Job Creation	N/A	Create 100,000 jobs and £13 billion under a high hydrogen scenario by 2050	N/A	Create over 420,000 jobs

Japan

Hydrogen, stored as a high-pressure gas, is currently governed under the High Pressure Gas Safety Act.[5] The Regulation on Safety of General High Pressure Gas covers the technical guidelines in terms of hydrogen leaks as specific guidelines for the temperature and position of storage vessels.

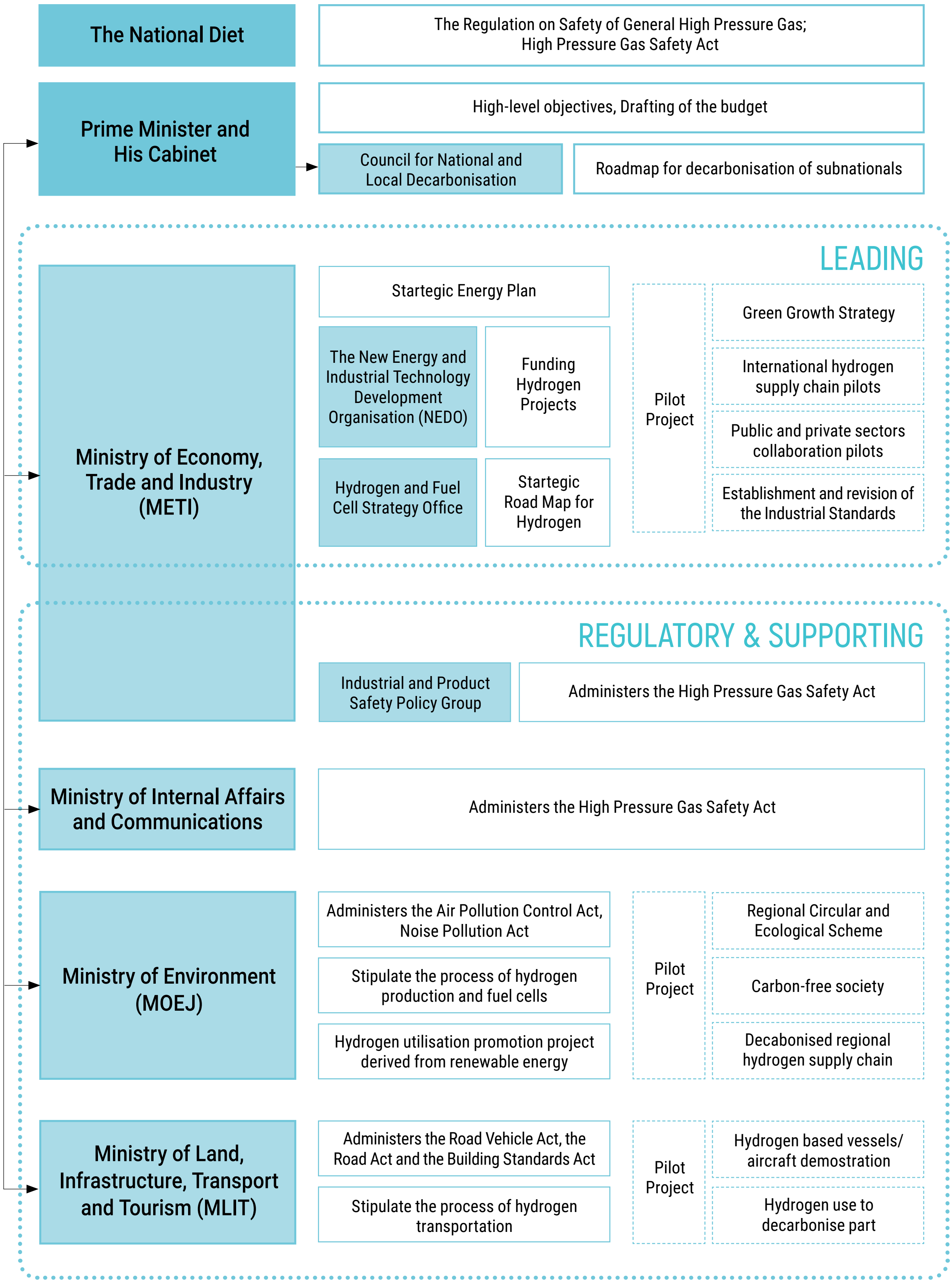
The established Carbon Neutrality Promotion Committee under the Prime Minister of Japan and His Cabinet coordinates efforts between central and local governments, and offers both tangible and intangible support to assist local governments in fulfilling their announced goals.

The Ministry of Economy, Trade and Industry (METI), as the leading agency, drives the commercialisation of hydrogen and enacts strategies for social-technical transition. The *Green Growth Strategy 2050*, the key policy roadmap detailing decarbonisation pathways in Japan, was formulated under METI's leadership in collaboration with various ministries and agencies. The policy roadmap provides a comprehensive guideline for the development of hydrogen technologies, action plans on a large-scale hydrogen deployment over its supply chain that includes its use, generation, transportation, and storage system (e.g., liquefied hydrogen carriers). Besides, the METI oversees pilot projects with objectives to propagate a worldwide hydrogen supply chain, foster public-private partnerships and amend industrial standards on the hydrogen realm. Automobiles powered by fuel cells are considered essential in Japan's hydrogen discourse. Correspondingly, the Hydrogen and Fuel Cell Strategy Office is responsible for creating a strategic roadmap for the hydrogen application in the transportation sector, aligning visions and goals coined by the METI.

The New Energy and Industrial Technology Development Organization (NEDO) is an agency under METI to enhance the government's research capability on developing new energy and industrial technologies on the basis of expedience, managing green funds to advance technological development, promoting private sector involvement and collaboration between the public and private sectors (e.g., hydrogen use to decarbonise port operations via the Carbon Neutral Port initiative), as well as designing business policy for Japanese energy companies. The Industrial and Product Safety Policy Group under METI administers the High Pressure Gas Safety Act.

The Ministry of Land, Infrastructure and Transport and Tourism (MLIT), the Ministry of Environment (MOE), and the Ministry of Internal Affairs and Communications (MIAC) regulates the utilisation, production and application of hydrogen over its properties such as flammability, explosiveness, and environmental impact. These agencies also establish departmental hydrogen development plans as prescribed by the Prime Minister and the *Green Growth Strategy 2050*. Figure 2 illustrates the operational framework of government agencies and their corresponding responsibilities in Japan.

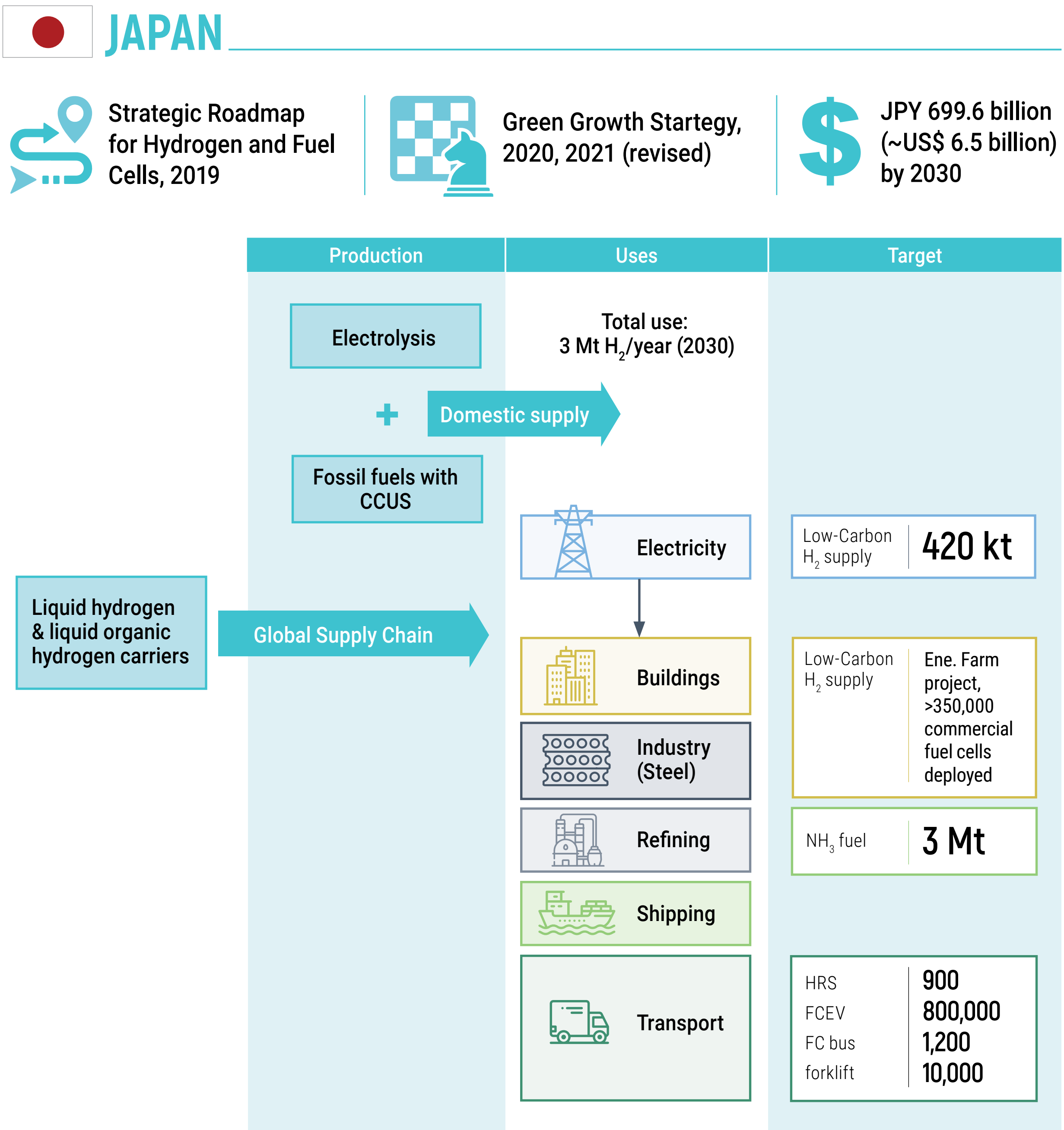
FIGURE 2 **National hydrogen development policies in Japan**



Japan is at the forefront of hydrogen development, given its internationally agreed status as a "hydrogen economy" and the active promotion of hydrogen use by its government. The country's hydrogen development is strongly charcterised by the "whole industrial chain" structure, which involves integrating hydrogen technologies into industry, transportation, energy, and their related sectors. The above-described structure also comprises a global supply chain for hydrogen and the development of hydrogen power generators.

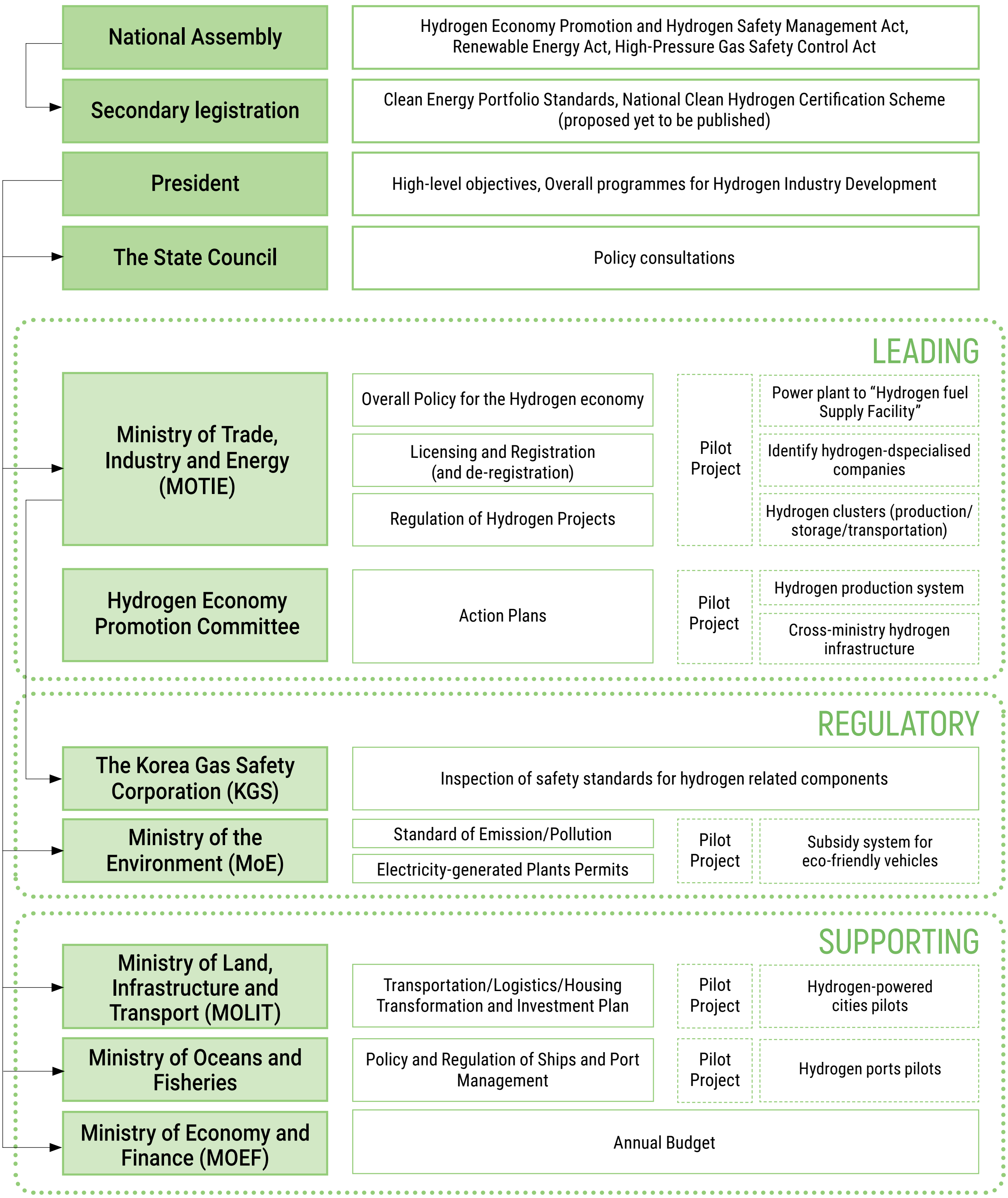
While hydrogen plays a vital role in Japan's transition to net-zero emissions, the hydrogen supply would be secured domestically from blue hydrogen, derived from natural gas with emissions with emissions captured and stored during production. In 2018, Japan achieved its target of generating around 3 million tonnes of hydrogen gas using its prime production methods such as LNG reforming and by-product hydrogen.

FIGURE 3 **Production, utilisation, and target for hydrogen economy in Japan**



South Korea
The regulatory framework governing South Korea's hydrogen industry is primarily determined by the Hydrogen Economy Promotion and Hydrogen Safety Management Act. The above-mentioned legislation, which took effect on February 4, 2020, serves as the principle guidance for the industry. In instances where this regulatory regime is deemed insufficient in providing comprehensive directions, the Renewable Energy Act, last amended in March 2017, shall suffice as the supplementary guidance. These two regulations focus on safety issues in hydrogen production, utilisation of hydrogen fuel cells, and manufacturing of hydrogen components.[6]

FIGURE 4 **National hydrogen development policies in South Korea**



South Korea has also been recognised as a global pioneer in developing hydrogen projects, reaching the frontier of using technology of hydrogen within the power, transportation, commercial, retail, and maritime sectors of the economy. South Korea aims to lead in the manufacture and distribution of fuel cell electric vehicles and large-scale stationary fuel cells to generate power in accordance with recent policy plans. Meanwhile, South Korea does not prioritise the use of hydrogen in heavy industries, including steelmaking and shipbuilding. South Korea's renewable portfolio standard (RPS) policy established in 2012 enables a large-scale stationary fuel cell energy production, as the policy requires a portion of the power companies' generation must come from renewable sources.[7]

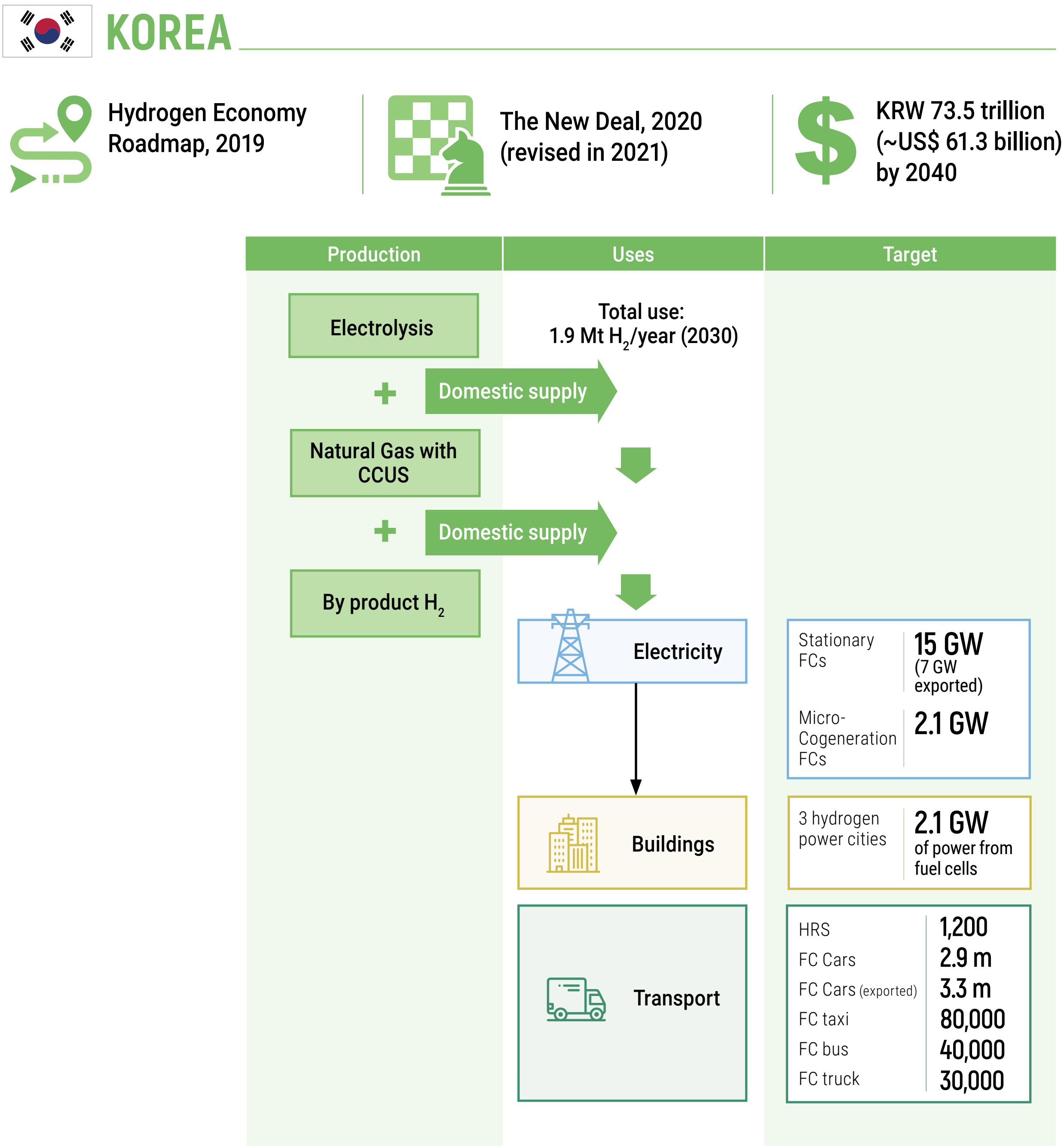
Following the official announcement of the *Hydrogen Economy Roadmap in 2019*, the Hydrogen Economy Promotion and Hydrogen Safety Management Law was enacted by the Korean National Assembly in January 2020. The law mandates the hydrogen industry crucial to the provision of R&D subsidies, loans, and tax breaks to hydrogen-focused enterprises. This statute lays a legal foundation for promoting hydrogen and executing safety regulations.

As part of South Korea's decarbonisation roadmap *New Deal* published in July 2020 and revised in a year later, an investment of 73.4 trillion Korean Won (nearly 61.3 billion USD) would be made with a purpose to increase the supply of hydrogen vehicles, develop hydrogen generation technology, and construct hydrogen towns.[8,9,10]

The 2022 Cabinet meeting formulated a production plan to position South Korea as a "first mover in the hydrogen economy". The above-described plan targets an annual 3.9 million metric tons of hydrogen production, which comprises 940,000 metric tons of grey hydrogen, 750,000 metric tons of blue hydrogen, and 250,000 metric tons of locally generated green hydrogen every year. The rest 1.96 million metric tons per year of green hydrogen will be imported from external sources. By 2040, South Korea endeavours to create a market reaching an annual hydrogen consumption of 5.26 million tonnes.

For the transportation sector, the New Deal has a goal of roughly 6.3 million domestically produced fuel cell vehicles by 2040, including 2.9 million for domestic use, 30,000 fuel cell trucks and 40,000 fuel cell buses, as well as 3.3 million of other vehicle types for export. Additionally, the New Deal includes plans to install 15 gigawatts of utility-scale fuel cells and increase the number of hydrogen refueling stations (HRS) to 1200.[11] Figure 5 presents the technical choice for hydrogen from production to application, as well as respective target for hydrogen deployment in South Korea.

FIGURE 5 **Production, utilisation, and target for hydrogen economy in South Korea**

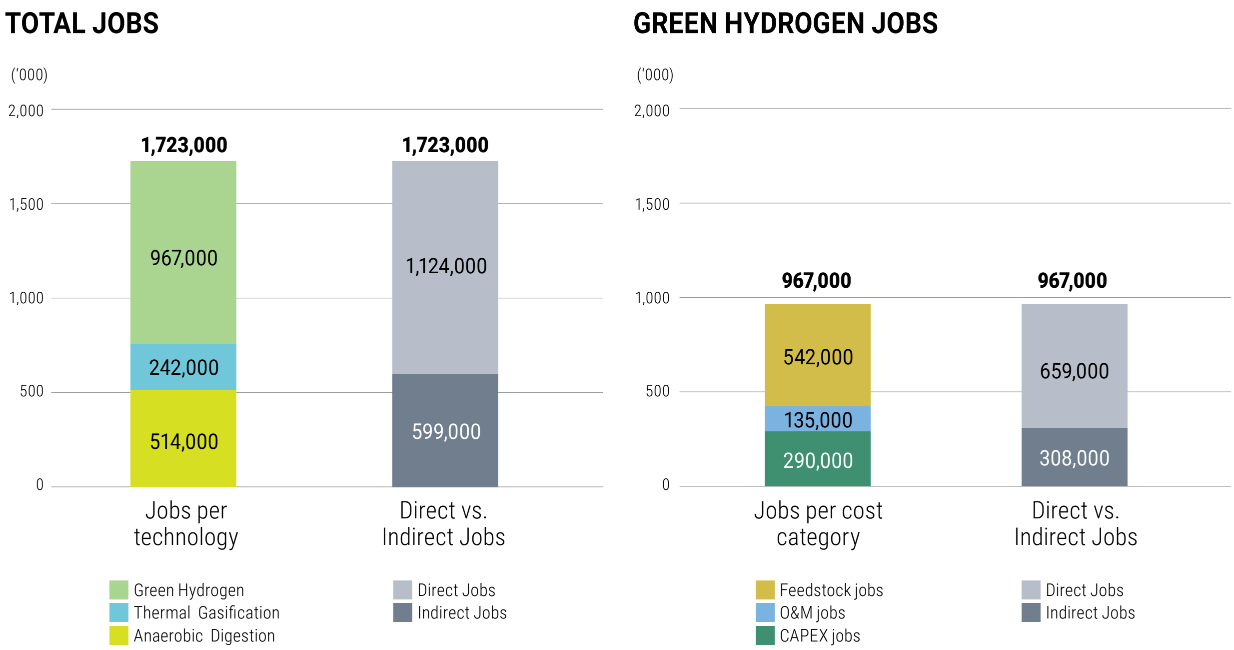


1.3.2 Business Opportunities

Efforts to increase energy efficiency, technology and cost effectiveness of hydrogen have been channeled through public-private partnership together with nationwide incentive policies to support hydrogen economic growth. Moreover, the hydrogen supply chain holds significance to create social benefits transitioning to net zero.

An analysis conducted by the Gas for Climate consortium group in Figure 6 revealed, in Europe, producing 1,710 TWh of green hydrogen by 2050 could create 300,000–450,000 high-skilled direct jobs and another 650,000–900,000 indirect jobs within supply chains.[12] For one terawatt hour of green hydrogen, 575–775 of both rural jobs and high-skilled technical positions would be created.

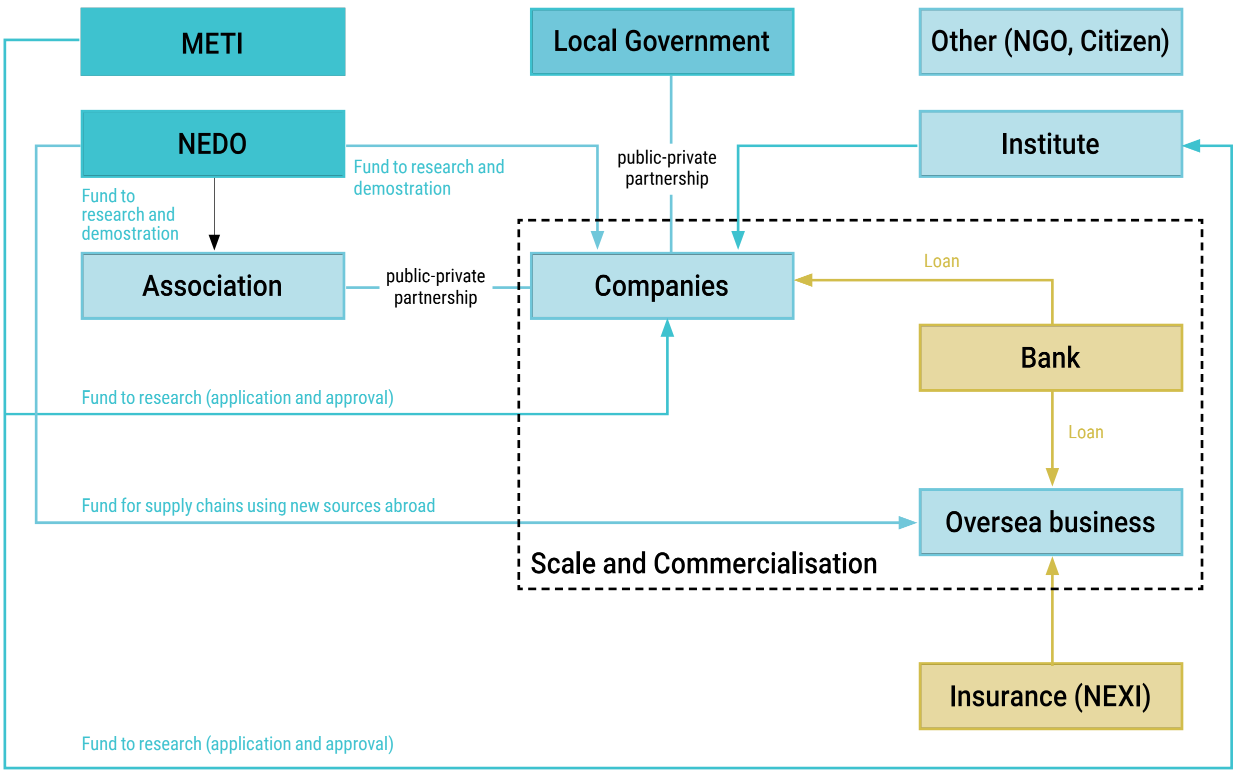
FIGURE 6 **Job creation potential in hydrogen sector 2050**



Country Cases

Case 1: Business model of hydrogen economy in Japan

FIGURE 7 **The co-operative arrangement for hydrogen economy in Japan**



The government of Japan takes on great significance to the growth of hydrogen technology in the country with the use of METI and NEDO, private firms, as well as financial and insurance institutions. The Japanese hydrogen economy prioritises funding research, development, demonstration, and deployment (RDD&D) of hydrogen and fuel cell technologies. The leading governmental agencies METI and NEDO work with various institutions, including private firms, industrial partners, financial and insurance institutions, to enhance the government's research capabilities in technological innovation and maintain a variety of choices in hydrogen production and application methods.

The commitment to RDD&D is evident. In 2020, the government of Japan invested around JPY 130 billion (nearly USD 1.2 billion) in the hydrogen sector. Concurrently, the private sector demonstrates robust interest in creating a hydrogen ecosystem for developing relevant technologies in Japan. On the policy side, the government has implemented a range of regulatory tools such as tax incentives, subsidies, and procurement policies to develop a favorable business environment for hydrogen development and encourage private sector investment. Besides, the government has set several research and development consortia to develop and demonstrate the novel hydrogen technologies, fostering a thriving R&D community in Japan.

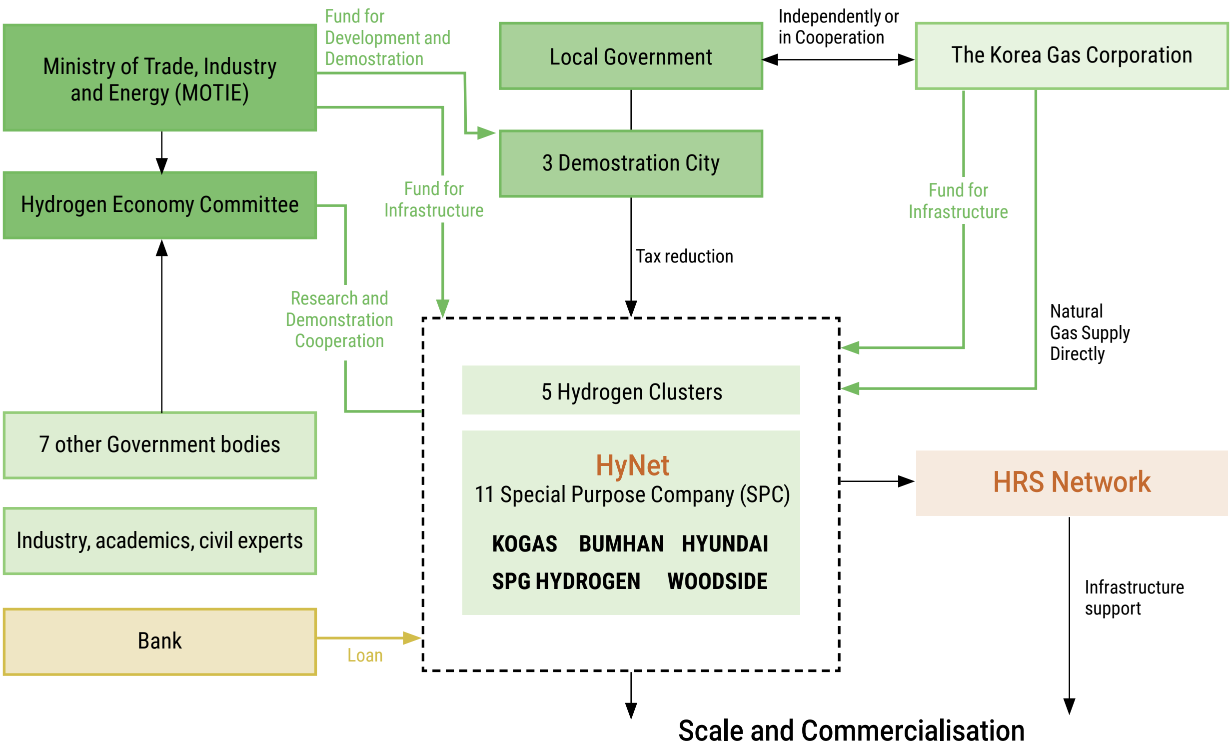
Interestingly, the Japanese government encourages the insurance sector participation, which specialises in providing end-to-end insurance solutions to domestic hydrogen companies. This strategic approach, with insurance sector involved, helps in securing access to hydrogen feedstocks and facilitates the export of Japan's leading hydrogen technologies and standards beyond its borders. This gesture sets Japan apart from the rest of the world, enabling risk-free participation and boosting confidence among domestic firms in international hydrogen trade. Figure 7 presents the relationship of various agencies and their collaborative bolstering hydrogen economy in Japan.

Case 2: Business model of hydrogen economy in South Korea

The Ministry of Trade, Industry and Energy (MOTIE) and the Hydrogen Economy Committee are the two government agencies responsible for hydrogen energy matters in South Korea. These agencies led the development of a hydrogen economy business model and participated in by the government of South Korea. The government has the third-largest hydrogen fund in the world, following only Germany and Japan. To encourage private investment inflow, the government collaborates with major conglomerates and financial institutions, with five conglomerates planning to invest $38 billion in hydrogen technology by 2030.

Established in 2019, the Hydrogen Energy Network (HyNet) represents a joint venture among 13 prominent industrial companies in South Korea, with an initial investment of $119 million. HyNet functions as a strategic epicentre for South Korea's hydrogen energy application. It focuses on expanding the infrastructural base of the hydrogen economy, with the primary objective to install 100 hydrogen refueling stations by 2022 and upscales to 1,200 by 2040. Through an exclusive collaboration with HyNet, the government can effectively leverage social capital and integrate it with its limited fiscal budget to facilitate the construction of these stations, thus meeting the rising demand for fuel cell vehicles within South Korean society. Additionally, HyNet aims to create economies of scale by mutually promoting subsidies for end-users' fuel vehicles and refueling stations.[13, 14]

FIGURE 8 **The co-operative arrangement for hydrogen economy in South Korea**



Another critical aspect in South Korea's hydrogen economy would the production of hydrogen. The Ministry of Trade, Industry and Energy (MOTIE) has allocated 1.27 trillion Korean Won (equivalent to nearly USD$1.07 billion) for establishing hydrogen clusters across various regions, particularly to green and blue hydrogen. On the end-use node of the hydrogen cluster, South Korea is actively conducting research and development to reduce transportation costs and develop technologies for storing liquid hydrogen.

In tandem with the construction of hydrogen-receiving facility scheduled in 2022, the government has set a long-term goal of establishing a nationwide hydrogen pipeline network. While the import of liquefied natural gas (LNG) is forecasted to take up about a third of hydrogen consumption in 2040, the Korea Gas Corporation expects to provide natural gas directly to hydrogen production clusters via those pipelines.

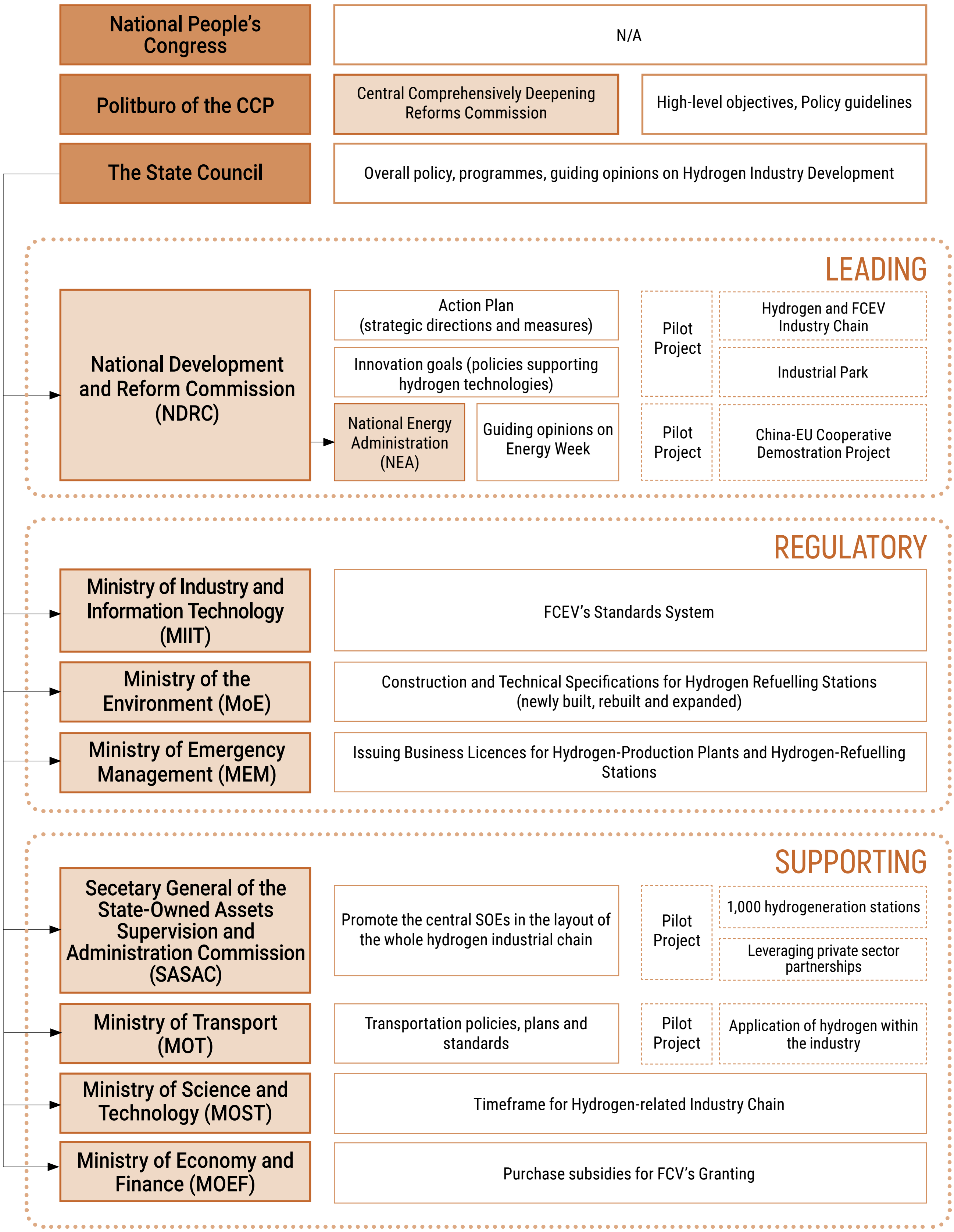
The government designated Ulsan, Ansan, and Wanju as "hydrogen pilot cities" in 2019 as a strategic step to power 10% of the country with hydrogen by 2030. In meeting this target, hydrogen will be utilised as a heating source for homes, factories, and vehicles beginning in 2022. Furthermore, the pilot city Ulsan sets to produce hydrogen from nearby petrochemical plants to provide energy for buildings and fuel for fuel cell electric vehicles and ships.[15, 16]

Commercial banks in South Korea offer private financing on hydrogen-related projects. For instance, Kookmin Bank, one of the largest retail banks in South Korea, along with five other financial institutions, participated in the project financing of an Incheon fuel cell facility with a capacity of 39.6 MW at USD$200 million. Additionally, the Export-Import Bank of South Korea established an ESG fund in February 2021 to assist South Korean firms in expanding internationally in industries (e.g., hydrogen). Not only does Export-Import Bank of South Korea supports hydrogen energy companies, it also insures Hanwha Solutions' green bonds. The arrangement of different actors and their cooperative pattern to boost hydrogen economy in South Korea is summarised in Figure 8.[17, 18, 19]

CHAPTER 2

The National State of Play

FIGURE 9 **National hydrogen development policies in Mainland China**



Key Players and Authorities in China's Hydrogen Strategy

In Mainland China, the hydrogen development program is an integral part of the Five-Year Plan (specifically China's 14th Five-Year Plan from 2021 to 2025) formulated and overseen by the Political Bureau of the Central Committee of the CCP. The State Council, serving as the top executive branch, has highlighted hydrogen as a key development strategy. The Council formulated overarching rules and programs to guide the implementation of more specific policies. The National Development and Reform Commission (NDRC) within the State Council plays a central role in promoting hydrogen progress, overseeing development plans, providing technology recommendations, and guiding pilot initiatives.

Regulatory documents for hydrogen management would be drafted by the Ministry of Industry and Information Technology (MIIT), Ministry of Housing and Urban-Rural Development (MoHURD), and Ministry of Emergency Management (MEM). Similarly, the policy framework for hydrogen development and demonstration is primarily influenced by the State-owned Assets Supervision and Administration Commission of the State Council (SASAC), Ministry of Transport (MOT), Ministry of Science and Technology (MOST), and Ministry of Finance (MOF). These government entities are also actively engaged in the national-level China Hydrogen Alliance.

Overview of Mainland China's Hydrogen Policy Framework

The policy structure of China's hydrogen development is paradigmatic and multi-layered. The structure encompasses four policy layers, by which it includes macro-policies, green technology and innovation policy, as well as tax and financial incentives. Alongside the release of the national hydrogen energy plan, provincial governments have been progressively issuing localised policies pertaining to the development of hydrogen energy and fuel cells.

FIGURE 10 **National Policy Framework for promoting hydrogen energy and fuel cell vehicles**

Layer	Macro Policy (comprehensive)	Green technology and innovation policy (bolster innovation)	Tax and Financial incentives (incentives)	Regional Policies (localised)
Policy Plan	Development plan for the new energy vehicle industry (2021-2035)	Energy technology innovation plan of action (2016- 2030)	Exemption of Vehicle Purchase Tax for New Energy Vehicles	Zhengzhou City introduces policies to support the demonstration application of fuel cell vehicles
	Energy Law of the People's Republic of China (draft for comments)	14th Five-year plan for energy technology innovation to propel green growth and digital transformation of the energy sector	Notice on the Demonstration Application of Fuel Cell Vehicles	Ningxia releases the draft of the Hydrogen Energy Industry Development Plan (Draft)
	Plan on the development of hydrogen energy for the 2021-2035 period 14th Five-year plan for renewable energy development		Notice by the Ministry of Finance, the Ministry of Industry and Information Technology, the Ministry of Science and Technology, and the National Development and Reform Commission of Improving the Policies on Government Subsidies for Promotion and Application of New Energy Vehicles	Action Plan for the Development of the Hydrogen Energy Industry in Ordos City (2022-2024)
				Action Plan for Promoting the Development of the Hydrogen Energy Industry in Nanhai District, Foshan City (2022-2025)
				The Medium- to Long-Term Development Plan for the Hydrogen Energy Industry in Shanghai (2022-2035)

In China, a macro policy support system has been established to promote the development of hydrogen fuel cell vehicles. The overarching layer includes the *Development Plan for the New Energy Vehicle Industry (2021-2035)* and the draft *Energy Law of the People's Republic of China*. It also includes specific plans like the *National plan for hydrogen energy development (2021-2035)* and the *14th Five-Year Plan for Renewable Energy Development*. Figure 11 shows the sectoral objectives associated with hydrogen technology outlined by the *14th Five-Year Plan for Renewable Energy Development document*.

FIGURE 11 Hydrogen Industry Innovation and Application Demonstration Project during the 14th Five-Year Plan period

Sector	Transport	Energy Storage	Power Generation	Industry
Description	Exploring the demonstration and application of fuel cell truck and the testing of 70MPa hydrogen storage cylinder vehicle applications, in mining areas, ports, industrial parks, etc.	Carrying out demonstration projects for renewable energy-based hydrogen production in regions abundant in renewable energy resources and with high demand for hydrogen.	Conducting demonstrations of hydrogen-electric integrated microgrids, and promoting the practical application of fuel cell combined heat and power (CHP) systems.	Exploring the application of renewable energy-based hydrogen production in industries such as synthetic ammonia, methanol, refining, and coal-to-liquid/gas, as a substitute for fossil energy sources.

To encourage green technology and innovation, there is the *Energy Technology Innovation Plan of Action (2016-2030)* and the *14th Five-Year Plan for Energy Technology Innovation*. Under this category, tax and financial incentives are provided to incentivise the adoption of environmentally friendly transportation options, including hydrogen fuel cell vehicles. The incentive mechanism, which is the exemption of "vehicle purchase tax for new energy vehicles" is subsidy-based and policy-led.

At the regional level, cities like Zhengzhou, Ningxia, Ordos, Nanhai District in Foshan, and Shanghai have introduced their own policies and plans to support the demonstration and development of fuel cell vehicles. These regional-level initiatives dovetail and support the State Council's goal to adopt hydrogen technologies in the transportation sector, allowing provincial governments find-tuning solutions compatible to territorial needs and circumstances, thereby ensuring flexibility and inclusivity at a regional level.

Demonstration Cities

In China, five Ministries and Commissions, including the Ministry of Finance, jointly promulgated *Notice of Launching Demonstration Applications of Fuel Cell Vehicles*, selecting five demonstration conurbations on launching fuel cell vehicle projects.

The cities clusters are Beijing-Tian-Hebei, Shanghai, Guangdong, Henan and Hebei, with each receiving up to 1.87 billion RMB incentive fund based on its achievement against certain stringent criteria for fuel cell vehicles and hydrogen development.

During the demonstration period, each cluster receives a minimum of 1,000 registered fuel cell vehicles with each vehicle having an average annual mileage of over 30,000 kilometers. Additionally, each city cluster is required to establish and operate at least 15 hydrogen refueling stations during the demonstration period. The annual production of vehicle-use fuel hydrogen in each city cluster must exceed 5,000 tons, and the carbon intensity of the fuel hydrogen used should be lower than 15 kgCO_2/kgH2 (equivalent to 125 gCO_2/MJ).

FIGURE 12 **Current situation and Goals for Five Fuel Cell Vehicle Demonstration Application City Clusters**

	Year 2022	Target by 2025
Beijing	Fuel cell electric vehicles: 1000 Hydrogen station: 20	Fuel cell electric vehicles: 5300 Hydrogen station: 49 Fuel hydrogen refueling demand (tons/year) 21,000
Guangdong	Fuel cell electric vehicles: 2212 Hydrogen station: 51	Fuel cell electric vehicles: 10000 Hydrogen station: 200 Fuel hydrogen refueling demand (tons/year) 79,160
Henan	Fuel cell electric vehicles: 317 Hydrogen station: 14	Fuel cell electric vehicles: 5000 Hydrogen station: 86 Fuel hydrogen refueling demand (tons/year) 40,000
Hebei	Fuel cell electric vehicles: 563 Hydrogen station: 16	Fuel cell electric vehicles: 7710 Hydrogen station: 809 Fuel hydrogen refueling demand (tons/year) 22,000
Shanghai	Fuel cell electric vehicles: 1963 Hydrogen station: 32	Fuel cell electric vehicles: 5000 Hydrogen station: 57 Fuel hydrogen refueling demand (tons/year) 13,800

2.1 Hong Kong Policy with a focus on the transport sector

Hydrogen technologies are particularly important to Hong Kong for realising the 2050 carbon neutrality strategy. Being a cleaner and efficient alternative to fossil fuels, its versatile ability to store and convert energy, applications in fuel cell vehicles in the transportation sector, and cleaning the industrial processes makes it a key component of a sustainable energy future. Hydrogen has a high potential in the power generation in the long term and transports sector from a technological perspective, which is responsible for 82% of total greenhouse gas emissions in Hong Kong.[20] Hong Kong's government and business sector must co-create a clear direction and build a strong policy alignment among all stakeholders for a sustainable future.

Insights to Hong Kong embracing China's masterplan

Mainland China and global counterparts have instituted overarching policies, delineating clear objectives and timelines for hydrogen fuel cell vehicles and industry advancement. Hong Kong can adopt a similar strategic approach by setting time-bound targets specifically to hydrogen technology advancement, drawing from Mainland China's model.

Furthermore, Mainland China has introduced plans and initiatives to support the technicalities of hydrogen technologies, including regulatory standards for vehicle registration, minimum mileage requirements, certification on mechanics, construction of refuelling infrastructure, and carbon intensity limits for fuel hydrogen. Hong Kong can use these initiatives to supplement the technical perspective of a unified framework for industry expansion.

Mainland China offers robust financial incentives and support mechanisms, such as tax concessions and government subsidies, to spur the uptake of fuel cell vehicles and hydrogen usage, fostering investment and innovation. Hong Kong can emulate strategies coupling impactful financial incentives and support mechanisms to further catalyse economic growth in the hydrogen market.

While learning the best practice from Mainland China, Hong Kong should position itself as a leader not follower in Greater Bay Area. In the renewable energy sector, hydrogen is still a relatively new area compared to some other clean energy industries such as solar, wind and batteries. As a global hub of financial and technology, Hong Kong is a premier place to introduce cutting-edge Chinese technologies to international markets and vice versa, reinforcing its role as a pivotal player in the global hydrogen ecosystem.

Status Quo

Hong Kong is at its preliminary stage on formulating policy prototype and making concerted efforts in aligning with national hydrogen strategies. China's potential as a major producer and consumer of hydrogen energy has enabled Hong Kong to join the global trend of decarbonising the city with hydrogen technology.

Up until March 2024, the Inter-departmental Working Group on Using Hydrogen as Fuel, comprising thirteen bureaux (hereinafter the Working Group), have given agreement-in-principle to a total of fourteen valid applications. Led by the Environment and Ecology Bureau, trial projects have ranged from electricity generation for construction sites to fuel cell vehicle utilisation of hydrogen energy, ensuring prior preparation in place for future hydrogen development based on operational data and experience from the trials. Figure 13 shows a timeline and cateogorisation of hydrogen technology applications approved as of 22nd March, 2024.

FIGURE 13 Trial Projects approved under the Working Group

Refuelling | Delivery
Fuel cell vehicles | Electricity

2023

24 Mar

- **Citybus** (Refuelling): Try out a hydrogen refuelling facility at a bus depot of the company
- **Towngas** (Refuelling): Try out a hydrogen extraction facility at its Tai Po plant
- **Citybus** (Fuel cell vehicles): Try out one hydrogen fuel cell double-deck bus

8 June

- **Sinopec** (Refuelling): Try out a hydrogen refuelling station at Au Tau, Yuen Long
- **MTR** (Fuel cell vehicles): Conduct a test run with a hydrogen fuelled light rail vehicle in Tuen Mun as a non-revenue train
- **Linde** (Delivery): Try out the use of a hydrogen tube trailer to deliver hydrogen to a hydrogen fuelled light rail vehicle

20 Aug

- **Citybus** (Fuel cell vehicles): Setting up of a hydrogen refuelling facility at its bus depot in Chai Wan and the operation of five hydrogen fuel cell double-decker buses

13 Oct

- **China State Construction Engineering**, **Sinoenergy**, **Sinopec** (Electricity): Providing electricity for a site office at a construction site in Lok Ma Chau with hydrogen fuel
- **Towngas** (Electricity): Extracting hydrogen from the existing towngas network at the site of the latter in Sai Kung to generate electricity for charging electric vehicles

2024

22 Mar

- **Epro Advance Technology Limited** (Electricity): The use of silicon to produce hydrogen for power generation set to provide electricity for a public housing construction site in Tung Chung
- **Waihong Environmental Services Limited** (Fuel cell vehicles): Try out two hydrogen fuel cell refuse collection vehicles
- **Food and Environmental Hygiene Department** (Fuel cell vehicles): Try out three hydrogen fuel cell street washing vehicles on hire for street washing
- **China State Construction Engineering (Hong Kong) Limited**, **Hong Kong Nation-Synergy International Hydrogen Power Technology Co. Limited** (Electricity): Provision of electricity with hydrogen power generation equipment for the operation of electric machinery at a construction site in Sheung Shui
- **Veolia Hong Kong Holding Limited** (Refuelling): Production of hydrogen by using landfill gas and installation of related hydrogen refuelling facilities at the South East New Territories Landfill Extension

FIGURE 14 Additional effort from the Working Group

Award the leasing contracts for three hydrogen fuel cell street washing vehicles	Conduct consultancy study on business environment impact assessment	Accept Code of Practice and Guidance Note	Listen to the results of the consultancy study on the use of tunnels by HFC vehicles
• Following up closely on subsequent issues, including future procedures such as testing, delivery, and acceptance	• Help establishing the relevant guidelines and legislative framework for the long-term application of hydrogen in Hong Kong	• Formulated by the Electrical and Mechanical Services Department (EMSD) after consultation with the trades • Code of Practice for Hydrogen Fuelled Vehicles and Maintenance Workshops; for Hydrogen Filling Stations, and Guidance Note for Quantitative Risk Assessment Study for Hydrogen Installation	• Reviewed the design storage capacity, operating pressure and various safety devices of hydrogen fuel cell vehicles • Hydrogen fuel cell vehicles can travel in tunnels if they comply with the relevant guidelines, excluding tube trailers

Note: The hydrogen refuelling facility in operation is built from private capital investment without government funding. The two successful applications on hydrogen refuelling station constructions are also driven by private capital investment, instead of government subsidies.

Thus far, Hong Kong has capitalised on the unique strength it possesses. Not only has the city got fourteen trial projects running, but it has also achieved a record high of six electric vehicles for every ten newly registered vehicles in 2023. The Policy Address same year further picked up the city's momentum and heightened sectoral excitement with the government's announcement to promote green transformation of hydrogen in sea, land and air transport.[21]

The Hong Kong government earmarked $200 million under the New Energy Transport (NET) Fund for subsidising hydrogen vehicle trial projects. However, the NET Fund has yet to disclose an eligibility criterion of the funding scheme, resulting an absence of platform for interested parties to apply for project fundings.

Figure 15 reveals subsidies thresholds for Mainland China's demonstration cities to meet on par with comparing Hong Kong's known policy areas on hydrogen development.

FIGURE 15 Comparison of criteria in policy areas between city clusters and Hong Kong

Policy Areas	The five demonstration clusters in Beijing-Tian-Hebei, Shanghai, Guangdong, Henan and Hebei	Hong Kong
Hydrogen Supply	Baseline incentive entry of 5,000 tonnes hydrogen production for vehicles annually with carbon emissions below 15 $kgCO_2$/kg hydrogen. Additional clean hydrogen incentive of 3RMB/kg with carbon emissions below 5$kgCO_2$/kg hydrogen.	N/A
Promotion and Application of Fuel Cell Vehicles	4 cumulative years of operating a fuel cell vehicle reaching its mileage of 7,500 km, 15,000 km, 22,500 km and 30,000 km respectively. Subsidised vehicles must follow fuel cell standard vehicle conversion method, vehicle incentive points standard, and heavy truck incentive coefficients.	Procurement, construction or renting of hydrogen fuel cell vehicles
R&D Industrialisation of Key Components	Develop 8 key components: electric stack, membrane electrode, bipolar plate, proton exchange membrane, catalyst, carbon paper, air compressor and hydrogen circulation system. For a maximum of 5 products, each subsidised component will be awarded up to 1,500 points.	Green Tech Fund on providing funding support to developing cost-effective and efficient technologies for producing green hydrogen, as well as demonstration system to promote public awareness of green hydrogen technologies.

2.2 Hong Kong's role in the hydrogen value chain

Exploring the city's niche in a rapidly changing world across the entire value chain is a prerequisite for its long-term policy planning for hydrogen development.

In consideration of production capacities, Hong Kong exerts minuscule advantage in manufacturing its own hydrogen. Given space constraints, it limits the provision of available land to install production facilities for renewable energy such as solar panels and wind farms, let alone hydrogen. Also, the city is currently importing nuclear power from Mainland China to meet energy demands. Hong Kong is affixing its hydrogen supply from the neighbouring cities.

In terms of hydrogen transportation, the operating gaseous pipeline system that carries 49% hydrogen constituent across Hong Kong Island, Kowloon and New Territories assures extensive delivery of hydrogen underground. Alternatively, tube trailers carrying hydrogen either in compressed gas or liquid form could make deliveries at small quantities. The compact city makes fuel transportation on road feasible over short distances.

In the end-use perspective, hydrogen fuel cells are a promising technology in especially for zero-emission transportation in respective to other purposes within the local context. Hydrogen fuel allows vehicles to travel longer distances with less hydrogen refuelling time, which is especially ideal to accommodate the diesel-reliant inter-city bus and heavy duty road vehicles traveling hundreds of kilometres at a time. As of 2021, electric buses and trucks accounted for less than 0.2% of the total. Given Hong Kong's hilly terrain, hydrogen becomes a more favourable option compared to battery electric vehicles due to its higher energy density. Moreover, hydrogen has the potential to greatly contribute to decarbonising industries such as ports, airports, and logistics operations in Hong Kong. Applications like forklifts have proven to be economically viable compared to other low-carbon alternatives like battery-powered counterparts. Hydrogen-powered forklift also offers advantages such as extended operational time, reduced space requirements, and lower safety risks.

At this stage, a key factor that prevents wider hydrogen application is high cost, including capital cost of hydrogen infrastructure and vehicles, and cost of hydrogen. This is not uncommon in the early phase of any new technology development. Government funding to subsidise both capital and operating cost of hydrogen applications is crucial at this stage to encourage the adoption in Hong Kong to allow industry experience and knowledge to be built up, solutions to be developed for Hong Kong environment, and private capital to be motivated to invest in this clean energy sector in the city. In developing hydrogen technologies and applications, Hong Kong should aim to be a leader in Greater Bay Area to contribute to the national strategy instead of being a follower. Hong Kong is well positioned to introduce global leading technologies from both Mainland China and overseas and adapt them to the highly visible Hong Kong environment supported by high quality regulation of an international standard. During this process, Hong Kong has the opportunity to rise as a hydrogen clean energy technology hub to introduce high quality Chinese hydrogen companies to overseas market and international top-tier technology solutions to China, fulfilling a role in hydrogen clean energy industry that Hong Kong successfully delivered as a financial centre.

CHAPTER 3

Hydrogen Scalability in the Economy

The world stands at a critical juncture to leverage hydrogen as a fuel driving transformative solution in decarbonising the transport sector. As seeds to be sown today, more and more nations develop policy framework outlining crucial targets, resources allocation and progress assessment works pertaining to the production, storage, transportation and application of hydrogen technology.

3.1 Workshop Events

In the beginning of 2024, with the support from the Strategic Public Policy Research Funding Scheme administered by the Chief Executive Policy Unit, the project team held two workshops providing the exclusive window of opportunity to assist policymakers in understanding the needs of the industry when shaping future visions and acquiring foreknowledge in the local hydrogen policy framework, while aligning with national developments and policy directives that are sustainable and impactful.

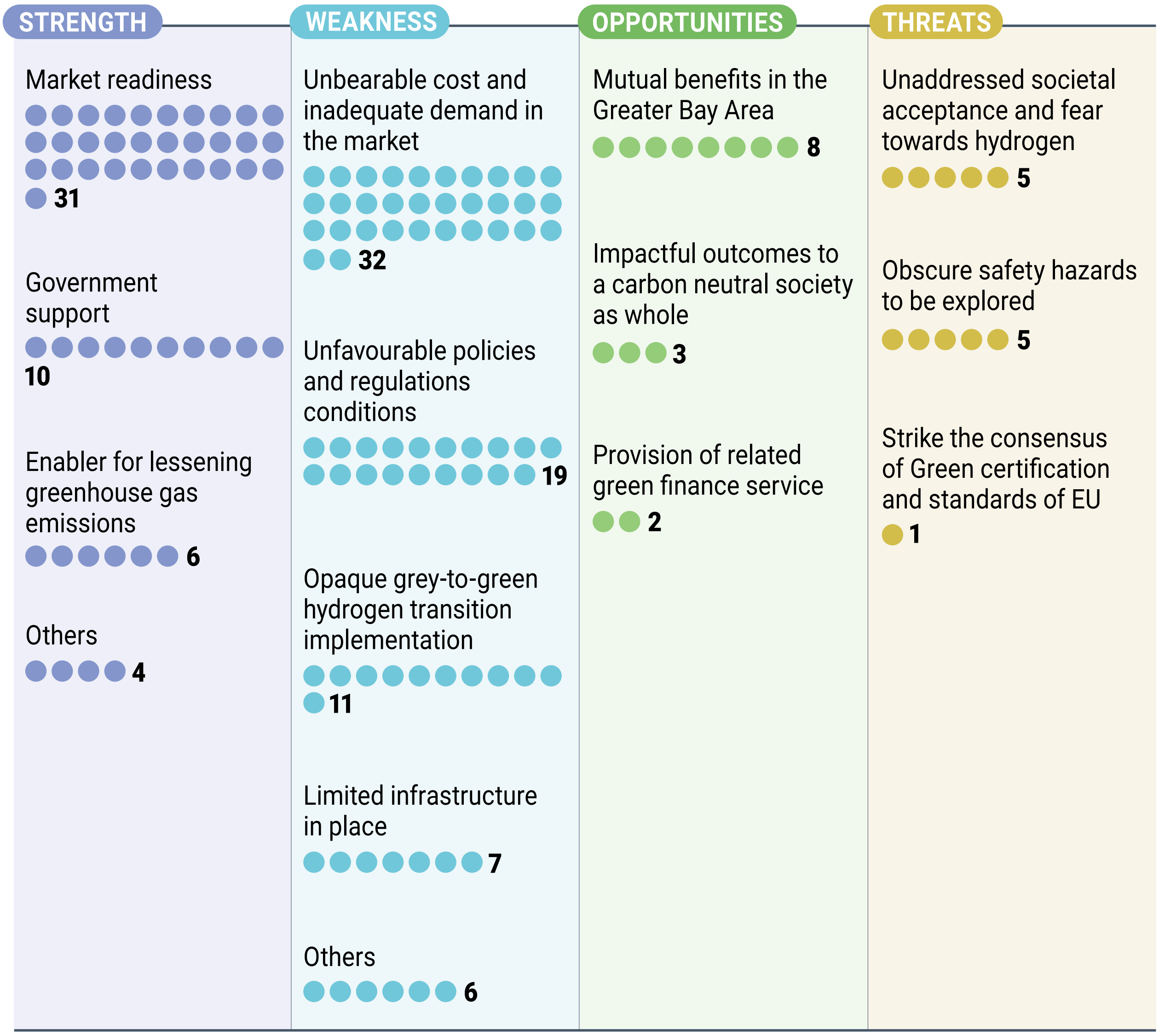
Over 80 key industry players spanning the entire hydrogen supply chain were gathered for an in-depth discussion on the dynamic aspects of hydrogen. Workshop were conducted with relevant government departments, public road transport operators, fleet owners, duty vehicle manufacturers, non-profit organisations, airline companies, shipping companies, and energy suppliers.

The purposes of these workshops were to unveil the potentiality of hydrogen use as a fuel in the transport sector, identify solutions to address the weaknesses and threats pertaining to current hydrogen development, and curate a hydrogen-leading decarbonisation strategy for the mobility sector in Hong Kong by 2050. In particular, these workshops used a SWOT analysis as a framework to create an attendee-friendly and interactive environment to spark the discussion.

Following with discussion, participants have built consensus on advantages, flaws, and possible resolutions enabling the scaling up of hydrogen energy penetration into all sectors.

3.2 Synthesis and Recommendations

FIGURE 16 **Participant's perception on Strength, Weakness, Opportunities and Threats of Hydrogen Development Status-quo**



Strength

Market readiness: Stakeholders are open and adaptive to hydrogen technologies. Particularly, the business sector expresses their keen interest in playing a role in the hydrogen economy. It is noticeable that some businesses are investing in the construction of hydrogen refuelling stations, resulting having at least one refuelling station strategically located in each of the three areas in Hong Kong in near future. Hydrogen fuel cell use to generate electricity for electric vehicles charging is also another upcoming practical example.

Enabler for decreasing greenhouse gas emissions: It is commonly agreed that hydrogen fuel cell vehicles have the profound potential to substitute diesel vehicles, as the former emits no vehicular emissions, leading to an improvement in roadside air quality without the long term concern of battery related metal mining and battery disposal.

Government support: Besides giving green lights to agreement-in-principle trial projects by the working group, other departments also exert their professionalism and have taken the lead in propelling hydrogen in Hong Kong. The Environment and Ecology Bureau (EEB) has hosted briefings to the trade, gas, energy, waste management companies regarding the production of hydrogen. The EMSD has also approached the gas, energy, and automotive industry for a briefing session on supporting the study of Gas Safety Ordinance (Cap. 51) amendment. The consultation exercise seeks to cover hydrogen as a fuel, and consequently, introduce the proposed legislative amendment to the Legislative Council in due course.

Weakness

Unbearable cost of hydrogen and inadequate demand in hydrogen market: Businesses express hesitancy in fully investing hydrogen-related projects, due to absence of policy framework on deploying hydrogen technologies that has deterred both local and foreign vehicle manufacturers from entering the Hong Kong hydrogen fuel cell vehicles market, affecting firms who wish to seize durable first-mover advantage and gain competitive advantage. High cost and low demand generally go hand in hand and is a vicious cycle that has to be broken to enable a healthy growth.

Unfavourable policy and regulation condition: It is time-critical for an integrated policy to take shape, in tandem with updates and amendments in regulations and legislation. Industry players have expressed the hostile business environment and the lack of 'carrot-and-stick' measures to improve commercial competitiveness of green hydrogen, have discouraged off-takers from taking action at this stage.

Limited infrastructure in place: As of early 2024, there is only one hydrogen refuelling station in place to cater for the hydrogen fuel cell double decker bus, with two more refuelling stations being built by the end of the year. The Food and Environmental Hygiene Department has submitted an application to the working group for three additional hydrogen fuel cell street washing vehicles, where the first truck would start operation in mid 2024. Closing the infrastructure gap has been deemed pivotal to ensure the smooth operation of heavy duty mobility on road in a foreseeable future.

Opaque grey-to-green hydrogen transition implementation and the availability of green hydrogen: There is a lack of transparency in the policy framework that encompasses the injection proportion of green hydrogen into grey hydrogen at a particular interval. This hinders the stakeholders' ability to fully understand and participate in the local grey-to-green transition. Given Hong Kong's proximity to Mainland China, the government can reference Mainland's hydrogen mix requirements to necessitate the switch and further explore how GBA could further support Hong Kong in the supply of green hydrogen.

Opportunity

Provision of green finance service: Given the recent market expansion of sustainable initiatives, Hong Kong's financial market has been driving force in this development. Experts have found that with the use of professional green financial services, such as certification under the green taxonomy, insurance, and loan services alongside the appropriate funding model backed by the government and private sector, Hong Kong's hydrogen development can play a larger role in reaching carbon neutrality.

Mutual benefits between Hong Kong and Mainland China: As per Hong Kong's commitment to carbon neutrality and China's national direction towards a greener future, the alignment stresses for a proportional response to increase demand for hydrogen technologies, thus creating a shared common value and fostering regional collaboration between Hong Kong and Mainland China. However, there is a need to gain a deeper understanding of China's policies and regulations to effectively navigate the advancement for both regions.

Impactful outcomes to a carbon neutral society: The establishment of a global trading and transport hub presents a significant opportunity for Hong Kong to transition into a net-zero city. By facilitating hydrogen trade, Hong Kong can contribute significantly to achieving a carbon-neutral society on a global scale.

Threat

Unaddressed societal acceptance and fear towards hydrogen: Participants expressed reluctance from the public to embrace change and a tendency to rely on traditional energy systems. Addressing these perceptions through education on safety protocols would be a powerful tool to eradicate concerns that hydrogen is inherently dangerous and assuage apprehension on hydrogen refuelling.

Obscure safety hazards to be explored: Participants displayed uncertainties in safety issues of hydrogen usage and cost-related concerns regarding preventing injuries and minimising risk for large-scale hydrogen applications. On manoeuvring hydrogen technology that is not fully developed, the government has used consultancy study outcomes to create interim standards for its 14 trial projects, such as the safety guidelines for vehicle hydrogen fuel systems and filling stations.

Striking a consensus on green certification and standards with the European Union (EU): A participant raised the issue on the interoperability of a green taxonomy as it is paramount to attracting foreign direct investment of hydrogen technology and to acquire sufficient capital funds. For instance, Japan's hydrogen policy framework considers that grey and blue hydrogen are low carbon, while the EU does not opt for grey hydrogen, as it does not reign renewable electricity through electrolysis. Green certification and standards worldwide must come to a consensus for business to follow.

Workshop resolutions

Experts in the second workshop have delved into weakness and threats to facilitate better integration of these attributes into the hydrogen economy. Preliminary solutions were offered to usher in a new era of hydrogen integration into our transport systems. The answer to effectively using hydrogen to decarbonise the sector is not just a transformative step, but rather a lasting solution to meet future energy needs.

- Encourage shared use of hydrogen infrastructure
  - Using the example of government refitting gas stations into e-charging stations, commercial vehicle owners still found it difficult to recharge electric vehicles due to insufficient charging spots and overloading the power grid, let alone recharging hydrogen fuel cell buses and heavy duty vehicles in the future. To foster the extensive adoption of fuel cell commercial vehicles, road transport operators in the discussion urged the Lands Department and Town Planning Board to re-evaluate land lease conditions for other business activities and explore more possibilities to allocate space for hydrogen refuelling infrastructure on these privately owned areas. In other words, the Lands Department and Town Planning Board must buy-in the Environment and Ecology Bureau and the Working Group's effort on hydrogen projects.
- Establish government policies that address the "chicken and egg" issue
  - A well-established "chicken and egg" conundrum arises in lieu of the diffusion of new technologies in emerging industries. As a central binding force, the participants believed that the government could take lead in initiating policy changes. For instance, there is a lack of clear tonnage classifications for heavy-duty vehicles from government departments in Hong Kong. This issue presents a window of opportunity for policy to set and align the classifications. The participants urge stakeholders across infrastructure, investment, and end-use sectors to coalesce interests and streamline the implementation timeline for hydrogen projects. Subsequently, the business sector could manifest market mechanism to deliver consumables, stimulate development in hydrogen technology and obtain economies of scale with lowered long run average cost for hydrogen businesses.
- Create incentives and funding models to address operational capacity
  - A fleet operator demonstrated their willingness to transition by introducing hydrogen fuel cell vehicle into their fleet. However, the operator has found the transition not economically viable from both the capital expenditure and operational expenditure perspective. Being aware that hydrogen fuel cell vehicle cannot be subsidised entirely by the government, relying solely on the operator's current business model is insufficient for this transition. Therefore, it is believed that the government should spearhead these discussions with road transport operators to create a viable funding model that ensures success in the transition. For instance, a bus-plus-property development model could be considered with franchised bus companies in new development areas under prudent commercial principles, in order to create affordable and level-playing field among hydrogen end-users who wish to operate hydrogen-powered vehicles in their fleet.

- Characterise demand for hydrogen in Hong Kong
  - Experts expressed that the demand for hydrogen for Hong Kong's transportation remains ambiguous. Despite hydrogen's potential as a clean energy solution, many corporations are still evaluating the viability and benefits of integrating hydrogen into their operations. However, recent trends show growing indications that more and more business are partaking in trial projects facilitated by the working group. The government can work on a **demand forecast analysis** to learn Hong Kong's hydrogen demand base, in tandem with creating policy directives as a multiplier effect to increase demand base in future.

- Diffuse hydrogen knowledge for better public acceptance
  - As the working group is working on commercial test-run cases, it is crucial to enhance understanding and acceptance of hydrogen as a viable and sustainable energy solution among the general public. By disseminating and communicating the benefits, safety measures, and potential applications of hydrogen technology, this can build trust, address misconceptions, and encourage constructive dialogue, ultimately garnering public support for upcoming initiatives.

- Indicate present and future green-versus-grey ratio for hydrogen mix.
  - The production of grey hydrogen emits greenhouse gases and is considered unsustainable. The government must assess and develop a pathway to facilitate the transition from importing grey hydrogen to ultimately procuring (with a locally producing portion) green hydrogen. In particular, experts suggested the Hong Kong government can preliminarily refer to the Guo Biao standard on green hydrogen blend ratio into natural gas pipelines as a requirement for businesses to meet when applying for incentives.

Drawing upon the synthesis of two stakeholder workshops, the upcoming Strategy of Hydrogen Development in Hong Kong should focus on creating a robust framework that mobilises all-participation and drives impactful climate action.

A Need to Formulate Policy Framework

China has developed a comprehensive framework that encompasses various sectors and sets clear targets and guidelines for emissions reduction, renewable energy promotion, and sustainable development. Hong Kong should learn from China's experience and adapt its successful strategies on **developing a framework that reflects the best and most innovative approaches to address climate change, reduce emissions, and promote participation of all**.

In precedence to establishing a hydrogen strategy for Hong Kong, evaluating the status quo of hydrogen as a fuel, its unique positioning within the hydrogen value chain help strengthen policy design and implementation. Based on analysis explicated in Chapter 2 and 3, Hong Kong needs to establish a cohesive and proactive strategy to foster growth of hydrogen industry and fuel cell vehicles. This should include the formulation of an overarching policy, clear targets, and support measures such as financial incentives. By doing so, Hong Kong can catch up with Mainland China and create a conducive environment for the development of a sustainable hydrogen ecosystem.

4.1 Recommendations

FIGURE 17 **Proposed Policy Framework on hydrogen strategy of Hong Kong**

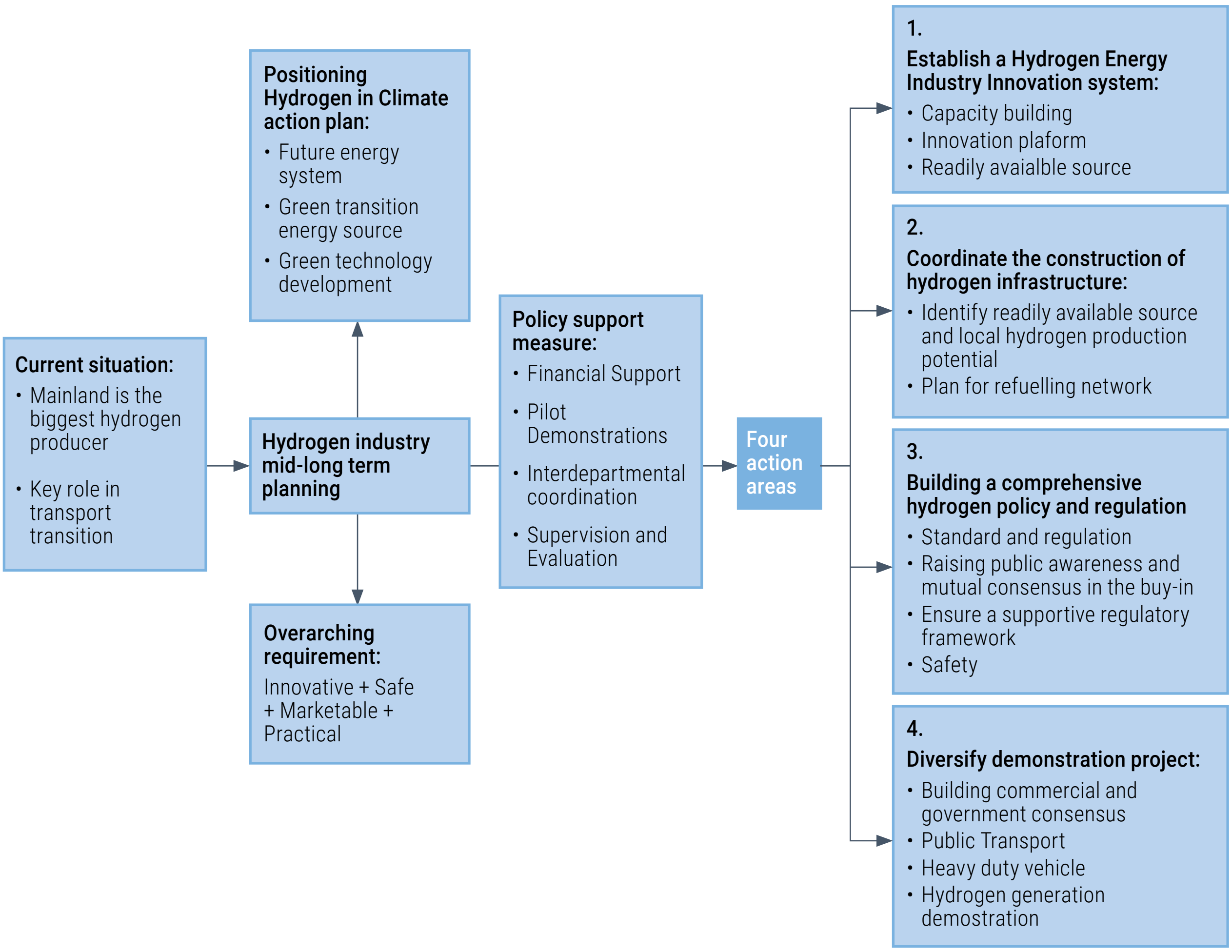


Figure 17 presents a proposed policy framework for Hong Kong, which is adopted from the national *Mid-and-long term Development Plan for Hydrogen (2021-2035)*. The Hong Kong framework should incorporate the three segments, including i) Positioning hydrogen in Climate Action Plan; ii) Overarching requirement; and iii) Current situation. The three segments are the pillars supporting the making up of the policy skeleton of a hydrogen industry mid-to-long term planning.

i) Positioning hydrogen in Climate Action Plan &

ii) Overarching requirement

These two segments are the policy focuses Hong Kong is required to follow through in order to achieve necessary hydrogen objectives.

iii) Current Situation

The segment entails the comparative advantages Hong Kong currently displays. With the Mainland being the biggest producer of hydrogen in the world, Hong Kong can easily secure and import its hydrogen supply from Mainland to accelerate usage of hydrogen technology in mobility.

Policy Support Measure acts as the catalyst accelerating the three core policy structures to achieve four action areas. Financial support reassures business confidence in regards to fuel prices and capital expenditure for fuel cell vehicles, thereby affecting hydrogen vehicle adoption rates and facilitating the advancement of the hydrogen economy as a whole.

4.1.1 Establish a Hydrogen Energy Industry Innovation System

Capacity building

Education and training underpin the innovation system by developing new knowledge and training skilled workers. To prepare for the operation and maintenance of any hydrogen system, **the government has been soliciting support and collaboration opportunities with the Vocational Training Council (VTC)** to ensure the safe use of hydrogen as a fuel with qualified personnel handling those facilities.

Given that Hong Kong's abundant workforce that is competent and talented, it is imperative **to design a comprehensive curriculum and provide hands-on training** to upskill workers' adaptability in managing hydrogen technology. This would enhance coordination on the construction of hydrogen infrastructure between workers and infrastructural developers.

Innovation Platform: Creating market levers to affect cost and demand

The existing business model for hydrogen fuel cell vehicles is inadequate to meet the growing demand and potential of the market. Previous analysis underscores the necessity to collaborate with academia and industry in developing a business fitting the prospering hydrogen technology deployment.

Specifically, a multifaceted approach must be adopted when formulating strategies for both the supply and demand sides of the hydrogen market.

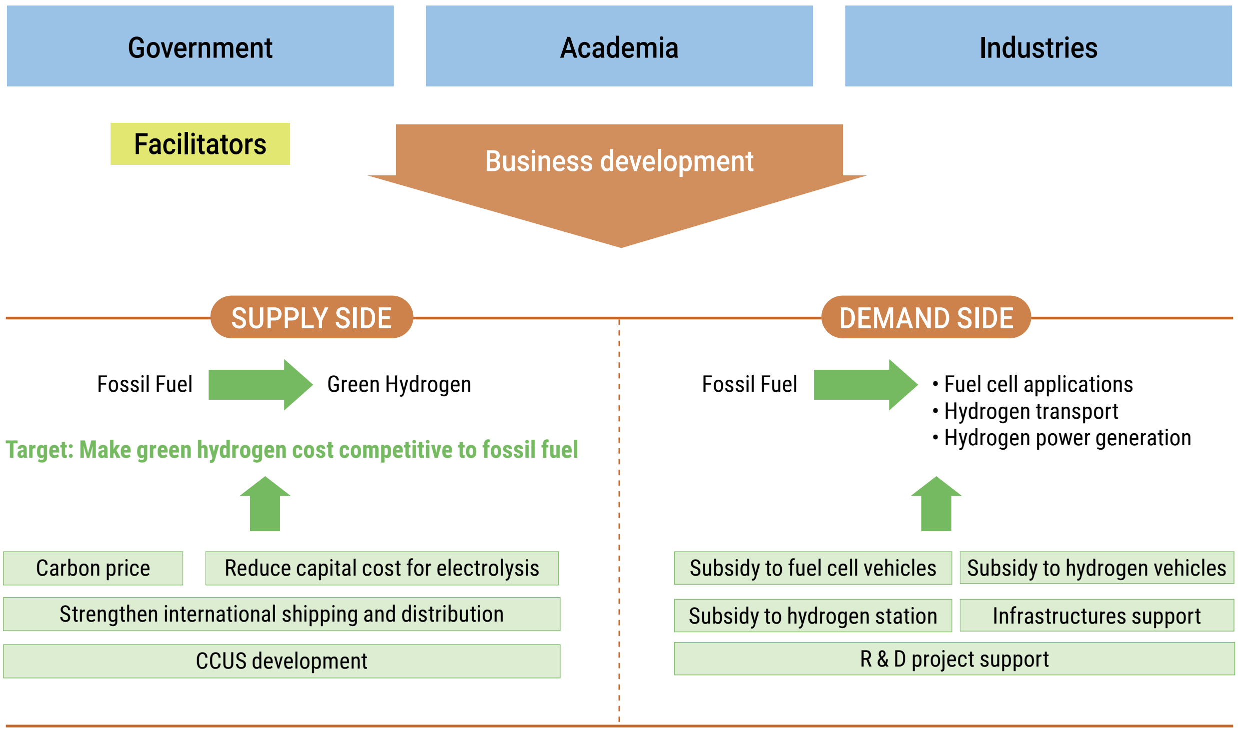
On the supply side, increasing the cost for fossil fuel while reducing the cost for green hydrogen will be essential through measures such as carbon pricing scheme and CCUS technologies. The mechanism would internalise the environmental cost of fossil fuels and make green hydrogen more competitive. Additionally, the development of policies aimed at reducing capital costs associated with green hydrogen production, coupled with robust international collaboration to decrease shipping and distribution expenses, would significantly contribute to mitigating hydrogen costs.

- Hydrogen vehicle manufacturers: Around two-thirds of the world population live in areas which adopt right-hand traffic. Manufacturers in the United States, Continental Europe and Asia primarily focus on producing vehicles for right-hand traffic. Given that Hong Kong ascribes to a left-hand traffic system, the market for left-hand-traffic hydrogen vehicles is relatively restricted. Manufacturers need a clear domestic demand to enter the Hong Kong market. Without adequate production volume to share the fixed cost, manufacturers could not drive down the average cost of hydrogen vehicles. Price-competitiveness of hydrogen vehicles is crucial in lowering the capital cost of potential users.

On the demand side, effective subsidies on infrastructural support and end-user application to fuel cell vehicles plays a pivotal role in promoting the market share of green hydrogen.

- Hydrogen refuelling stations: As in the electric vehicle market, private companies play an important role in supplying hydrogen refuelling services. The installation of refuelling facilities involves substantial fixed costs. In order to attract private companies to enter the market, there must be an adequate expected demand for their refuelling services; otherwise, the average cost would be too high to sustain the business model. On the other hand, the availability of these refuelling services directly affects the attractiveness of hydrogen vehicles. Inadequate supply of hydrogen refuelling services would raise the operating cost of potential users of hydrogen vehicles.

FIGURE 18 **Opportunities of promoting green hydrogen in supply and demand side**



Because of these "chicken and egg" dilemmas, industry players in the demand and the supply sides may end up in a coordination failure where both are deterred from entering the market. Therefore, the government has a crucial role in market coordination. Transport companies and other players in the value chain are risk averse and would benefit from more clarity of the potential costs and benefits of adopting hydrogen vehicles. To unleash the economies of scale, the Hong Kong government could provide forward guidance by:

FIGURE 19 **Four aspects to unleash economies of scale**

Financial benefits Incorporating hydrogen activities in the Hong Kong taxonomy to reduce the capital cost of different players in the hydrogen value chain.	**Non-financial benefits** Charting the roadmap of transition to green hydrogen to reduce the uncertainty about the environmental contribution of hydrogen vehicles.
Financial costs Allocating space for hydrogen refuelling infrastructure and creating viable funding models to reduce the capital and operating expenditure.	**Non-financial costs** Developing safety standards around hydrogen vehicles and raising awareness of the public to reduce their safety concerns of the technology.

The provision of 'carrot-and-stick' measures is also crucial. The government could consider increasing subsidy support in dissolving the upfront cost of hydrogen-powered mobility and development of hydrogen infrastructure (e.g., refuelling stations) to fast forward the scale of adoption. Additionally, the government could also shift to using more stick-based policy mechanisms such as speeding up bans enactment on the purchase of diesel commercial vehicles and the imposition of carbon tax as a lever.

Key players of the hydrogen industry have conveyed concerns regarding the coordinative efforts pursued by various governmental governments. This unawareness, combined with the absence of policy guidance, have coupled together to form a ripple effect that impacts other members of the supply chain, creating an atmosphere of hesitancy to invest in hydrogen technology. It is imperative for both businesses and the government to pursue their respective roles concurrently and synergistically to eradicate the 'chicken-and-egg' dilemma.

A tipping point could be reached where market mechanism overrides the government to play a fundamental decisive role and drive the changes. This could be illustrated as the government creates an enabling environment and establishes clear long-term strategies for hydrogen buses to operate on road. With hydrogen infrastructure in place, the market can decide the viability of hydrogen technology and benefit the early movers by efficiently allocating resources to the right businesses.

To upscale the hydrogen market, the government must investigate the full picture of the hydrogen economy in order to unleash its undiscovered potential. For instance, the government could formulate policy framework to progressively move to using green hydrogen. It is of paramount importance for decision makers take a step back and engage in the entire hydrogen value-chain. While reaching deep decarbonisation at source with use of green hydrogen, a comprehensive policy framework facilitates cross-sector collaboration and coordination with a competitive cost advantage.

4.1.2 Coordinate construction of the hydrogen infrastructure

Identify readily available source and local hydrogen production potential

In terms of supply, one of the barriers is Hong Kong's limited ability to produce green electricity and therefore green hydrogen domestically. Several local hydrogen production projects are emerging, but Hong Kong will have to develop a hydrogen import supply chain to meet its demand, whether it be through pipelines connected to Mainland China or tankers supplying hydrogen from other countries. This infrastructure development consisting of storage reservoirs, pipelines, refuelling stations, etc. will certainly be capital-intensive.

In the near term, Hong Kong can leverage its **existing infrastructure**, undergo minor modifications to serve hydrogen, fast-track infrastructure deployment, and save up transportation costs of hydrogen to efficiently accommodate rising hydrogen consumption. Nevertheless, the utilisation of relevant infrastructures depends on whether the upstream hydrogen sources are to be secured.

Beyond Hong Kong's geographical borders, the Greater-Bay-Area has the great potential to help smooth out Hong Kong's hydrogen supply, with readily available hydrogen sources in various types detailed in Figure 20.

FIGURE 20 **Hydrogen source locally and in close proximity to Hong Kong**

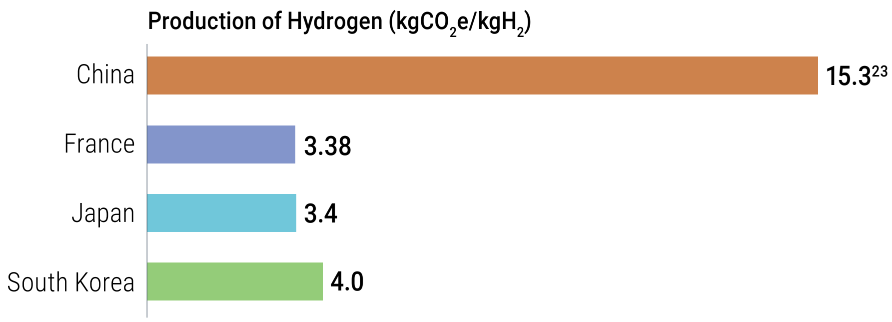
	GREY HYDROGEN	GREEN HYDROGEN
Hong Kong	**Underground pipeline network** A utility company's infrastructure spans 3,700 kilometers over all territories in Hong Kong. The town gas used by every household in Hong Kong contains as much as 49% hydrogen. Remarkably, among global civilian gas infrastructures, only those in Hong Kong and Singapore boast such elevated levels of hydrogen concentration. Other countries, such as the United Kingdom and Australia, are currently exploring and researching how to incorporate small amounts of hydrogen into urban natural gas pipelines.	**Landfill gas** A waste management company responsible for hydrogen supply through the capturing of landfill biogases. The content (i.e. methane) would be harnessed and converted to green hydrogen with high-heat thermal processing.
	Hydrogen electrolyser There is currently an operating hydrogen electrolyser production plant in Tseung Kwan O, which can carry a production capacity of approximately 100 cubic meters of hydrogen at an energy consumption rate of approximately 5.5kW/hr per cubic metre of hydrogen.	**Food waste and sludge** To transform 2.8 million cubic meters of food waste and sludge collected every day from sewage treatment plan of the Hong Kong Government's Drainage Service Department into hydrogen in a form of biogas, through anaerobic co-digestion.
The GBA	**Guangzhou** The first public hydrogen station in Au Tau, Yuen Long is expected to be completed by 2025. Primitively the hydrogen would be sourced and delivered from Guangzhou to Hong Kong through cylinder trucks, with a capacity of 385 kilograms each ride.	**Nanhai, Foshan**[22] A waste resources utilisation project targets over 9,100 standard cubic meters of green hydrogen produced daily. It is scheduled to be put into operation by the end of 2024.

4.1.3 Building a comprehensive hydrogen policy and regulation

Standards and regulation: Life cycle emission vs end pipe emission

The purpose of adopting hydrogen fuel cell technology is to mitigate greenhouse gas emissions and roadside air pollution in the transportation sector. In Mainland China's demonstration city cluster projects, the current national carbon intensity threshold for hydrogen fuel has been set at 125 gCO_2/MJ, and considers only carbon dioxide emissions during the hydrogen production process. Interestingly, this threshold is higher than the carbon intensity of diesel, which is 90g CO_2 equivalent/MJ when accounting for greenhouse gas emissions throughout the fuel life cycle.

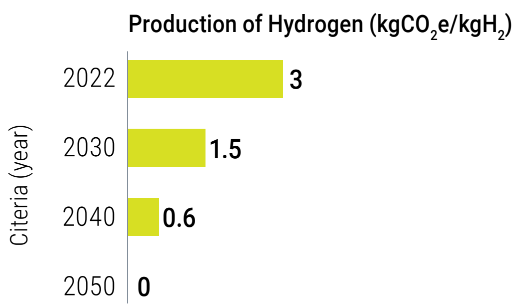
FIGURE 21 **Current carbon intensity standards for low hydrogen production from other countries**



Setting a relatively high carbon intensity threshold for hydrogen fuel at the early stage is in fact compatible with international practices, as long as there are plans to gradually tighten the threshold over time. For instance, in the Singapore Taxonomy, the carbon intensity threshold of hydrogen production is initially set at 3 kg CO2e/kgH 2, and is expected to decline over the years until reaching zero in 2050.

This reveals that China and Singapore are adopting an infrastructure-first approach while aiming to gradually reduce the carbon intensity of hydrogen. However, this approach may misalign with the expectations of community members. Therefore, it is imperative for the government to effectively manage public expectations from the early stages of implementation, provide standard definitions and explain the rationale behind adopting hydrogen as a fuel.

FIGURE 22 **Hydrogen carbon intensity thresholds from Singapore Taxonomy**



To systematically boost the green credential of hydrogen fuel cell vehicles, the government should concert standards and regulations around its value chain through developing relevant criteria in its emerging taxonomies; see Figure 23 for similar efforts from other markets. The "Prototype of a Green Classification Framework for Hong Kong" derives its credibility by referencing the EU Taxonomy and China's Green Bond Endorsed Project Catalogue (2021 Edition) in proposing metrics and thresholds for classifying economic activities as "green". For instance, the prototype framework "aligns with other international taxonomies wherein the operation of vehicles with zero tailpipe emissions, or close to zero tailpipe emissions, is automatically eligible as it supports the decarbonisation of the transport sector." Meanwhile, inputs from local industry experts have been incorporated in developing the thresholds to ensure their relevance to Hong Kong. This points to the importance of striking a balance between alignment with other taxonomies and catering for the local contexts to maximising policy effectiveness.

FIGURE 23 **Hydrogen development criteria in green and sustainable taxonomy across markets**

EU Taxonomy	China Green Bond Endorsed Projects Catalogue (2021 Edition)	ASEAN Taxonomy	Singapore Taxonomy
Energy: Storage of hydrogen	1.6.1.2 The Manufacture of Facilities for Charging, Battery Replacement and Hydrogenation	352[030] Storage of renewable and low-carbon gases (include 3 tiers)	1.8 Transmission and distribution of renewable and low-carbon gases
Manufacturing: Manufacture of equipment for the production and use of hydrogen	3.2.2.8 The Construction and Operation of Hydrogen Energy Exploitation Facilities	352[010] Transmission and distribution networks for renewable and low-carbon gases (include 3 tiers)	1.10. Storage of hydrogen or its derivatives
Manufacturing: Manufacture of hydrogen	5.5.4.1 The Construction and Operation of Power Charging, Battery Replacement, Hydrogen Refueling and LNG Refueling Facilities (for vehicles)		1.11. Electricity generation from hydrogen or its derivatives (e.g. ammonia)
			1.12. Electricity generation from fossil gaseous fuels
			2.5. Low-carbon transport infrastructure
			4.4. Manufacture of hydrogen
			4.9. Manufacture of equipment for the production of hydrogen through electrolysis

In line with international best practices such as the EU and Singapore taxonomies, the emerging local taxonomy should adopt a dynamic carbon intensity threshold which declines over time to facilitate different stages of hydrogen economy transition in Hong Kong.

To address the present challenge of industry coordination failure which hinders the economies of scale, the Hong Kong government should create a preliminary framework that prioritises reducing capital cost, avoiding excessive stringency in standards and focusing on feasibility for businesses investment in the short term. This approach serves to expand the domestic hydrogen market at the early stage while providing flexibility for the local business sectors to discuss how the society can transition from grey hydrogen to green hydrogen.

To facilitate a smooth transition towards clean hydrogen, the government should also develop a comprehensive transition roadmap. This roadmap should include a phased approach for transitioning from grey-to-green hydrogen, considering the availability of renewable energy sources and the infrastructure required for hydrogen production, storage, and distribution. Like other thresholds in the prototype taxonomy, the roadmap should be developed in conjunction with local industry experts to ensure its feasibility and suitability to the local context. Conducting a scenario analysis will help assess opportunities and risks associated with different hydrogen types, enabling informed decision-making.

After the domestic hydrogen market has matured, Hong Kong should consider adopting the European Union's standard, which demands a 70% reduction in greenhouse gas emissions throughout the life cycle of hydrogen fuel. This would result in a carbon intensity limit of 28gCO_2 equivalent/MJ or 3.5kgCO_2 equivalent/kgH2. By implementing such stringent requirements, Hong Kong can ensure that the hydrogen fuel used in the transportation sector contributes significantly to reducing overall carbon emissions in the long term.

Key businesses in Hong Kong have demonstrated a readiness to pay a premium for green hydrogen. Implementing this grey-to-green transition roadmap will provide assurance of future green hydrogen availability in Hong Kong. This, in turn, will boost businesses' confidence in investing in hydrogen-related projects, both in terms of supply and demand.

Raising public awareness and mutual consensus in the buy-in

To advance in this direction, the government must implement strategies aimed at **educating the public about hydrogen technologies, addressing safety apprehensions**, and **highlighting their environmental and economic advantages**. It is crucial to engage with local communities, non-governmental organisations (NGOs), and industry associations to foster mutual consensus and encourage the widespread adoption of hydrogen technologies.

Moreover, showcasing successful case studies and pilot projects can effectively demonstrate the feasibility and benefits of adopting hydrogen technology, thereby promoting social acceptability and trust in these advancements.

Ensuring a supportive regulatory framework with use of demonstration projects

In response to its carbon neutrality goal by 2050, the government is actively exploring a wide array of decarbonisation measures to radically lessen greenhouse gas emissions in due course, including the Working Group's fourteen agreement-in-principle trial projects to use and test hydrogen fuel technology.

When developing a supportive regulatory framework, dilemma arises where businesses await for government to implement policies, and vice versa, wherein the government waiting for business's actions to be taken. The stalemate situation leads to a lack of swift progress in implementing necessary policy measures for hydrogen technology development. Consequently, the government **can effectively streamline procedures on approving projects, organise visits to demonstration sites, and regularly share trial findings to the public.** These actions can showcase progress, raise awareness, and ultimately eradicate confusion within public policy.

Moreover, the government could diversify demonstration projects to show the capability of hydrogen technology to the general public, in which trial projects could be in various locations and scales.

4.1.4 Diversify demonstration project

Hydrogen generation and transport demonstration
It is important to validate emerging technology in a real environment. A plan must be devised to efficiently allocate sets and responsibilities to maximise societal decarbonisation impacts, particularly on a sectoral level which resources must be given to facilitate hydrogen fuel cells vehicles adoption on a fair ground. The government should also progressively amplify support of research and trial projects regarding local green hydrogen production.

Building commercial and governmental consensus
The lack of a clear timeline and upfront indication of costs is a common source of contention during policy implementation. Resolving several key constraints can expedite hydrogen development:

- hydrogen technology approval process required for trial examination within the bureaucracy.
- legislation amendment consultations.
- inclusion of hydrogen technologies in any interoperable green and sustainable taxonomy.
- cost of building public-private partnerships and citizen-government engagement
  - Legislative Members from the Panel on Environmental Affairs and the Panel on Transport arranged visits to a local hydrogen refuelling station and three GBA cities to obtain first-hand information on and understand practices of the neighbouring cities about adoption of hydrogen transport respectively[24]. The frequency of site visits can be augmented to facilitate Member's deliberations on policy formulation supplementary to creating an enabling environment for hydrogen technology.

To develop a fuller awareness, a **time-cost analysis** should be done to quantify investment amount, provide guidance to relevant stakeholders, and ensure level-playing field for business owners in the hydrogen market. The white paper calls for relevant authorities to **devise a comprehensive strategy for creating a market for hydrogen, including measures to impact cost and stimulate demand.**

ENDNOTES

1. United Nations Framework Convention on Climate Change (UNFCC) (2016), *The Paris Agreement*. Retrieved at https://unfccc.int/process-and-meetings/the-paris-agreement
2. International Energy Agency (IEA) (2023), *Global Hydrogen Review 2023*. Retrieved at https://iea.blob.core.windows.net/assets/cb9d5903-0df2-4c6c-afa1-4012f9ed45d2/GlobalHydrogenReview2023.pdf
3. Hydrogen Council (2023), *Hydrogen Insights 2023*. Retrieved at https://hydrogencouncil.com/wp-content/uploads/2023/05/Hydrogen-Insights-2023.pdf
4. International Energy Agency (IEA) (2024), *Hydrogen*. Retrieved at https://www.iea.org/energy-system/low-emission-fuels/hydrogen
5. Japanese Law Translation, 2022. High Pressure Gas Safety Act in Japan, High Pressure Gas Safety Act (Act No. 73 of 2022)
6. Hyungna, O.I., HONG; and Ilyoung OH, 2021. South Korea's 2050 Carbon Neutrality Policy. East Asian Policy 13(01), 33-46.
7. Sgarbossa, F., Arena, S., Tang, O., Peron, M., 2023. Renewable hydrogen supply chains: A planning matrix and an agenda for future research. International Journal of Production Economics 255.
8. Choi, W., Yoo, E., Seol, E., Kim, M., Song, H.H., 2020. Greenhouse gas emissions of conventional and alternative vehicles: Predictions based on energy policy analysis in South Korea. Applied Energy 265.
9. Sulich, A., Sołoducho-Pelc, L., 2022. Changes in Energy Sector Strategies: A Literature Review. Energies 15(19).
10. Youngok, K., Eunkyung, Y., Hyunik, S., 2022. Russia's policy transition to a hydrogen economy and the implications of south korea–russia cooperation. Energies 15(1).
11. Gielen, D., Saygin, D., Taibi, E., Birat, J.-P., 2020. Renewables-based decarbonization and relocation of iron and steel making: A case study. Journal of Industrial Ecology 24(5), 1113-1125.
12. https://www.euractiv.com/section/energy-environment/opinion/renewable-gases-bring-european-jobs-that-cannot-be-outsourced/
13. Ibid.
14. Lee, D., Kim, K., 2021. Research and Development Investment and Collaboration Framework for the Hydrogen Economy in South Korea, Sustainability.
15. Nakano, J., 2021. South Korea's Hydrogen Industrial Strategy.
16. Stangarone, T., 2021. South Korean efforts to transition to a hydrogen economy. Clean Techn Environ Policy 23(2), 509-516.
17. Aditiya, H.B., Aziz, M., 2021. Prospect of hydrogen energy in Asia-Pacific: A perspective review on techno-socio-economy nexus. International Journal of Hydrogen Energy 46(71), 35027-35056.
18. Fan, L., Tu, Z., Chan, S.H., 2021. Recent development of hydrogen and fuel cell technologies: A review. Energy Reports 7, 8421-8446.
19. Lee, D., Kim, K., 2021. Research and Development Investment and Collaboration Framework for the Hydrogen Economy in South Korea, Sustainability.
20. https://cnsd.gov.hk/wp-content/uploads/2023/12/Greenhouse-Gas-Emissions-in-Hong-Kong-by-Sector.pdf
21. https://www.policyaddress.gov.hk/2023/public/pdf/policy/policy-full_en.pdf
22. The greenness of waste-to-hydrogen depends on what constitutes municipal solid waste. As plastic waste subjects to high-heat thermal processing such as gasification or pyrolysis, carbon dioxide would be released as a by-product when producing hydrogen.
23. Conversion rate would be 90 gCO_2e/MJ (equivalent to11 $kgCO_2e$/kg H2) https://theicct.org/wp-content/uploads/2023/07/ISO_blue_hydrogen_GHG_ICCT_DNV.pdf
24. https://www.legco.gov.hk/yr2023/english/counmtg/motion/cm-mfollowup-2023-e.pdf

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