Pioneering Hydrogen Energy Solutions in Cities

The Cases of Tokyo and Seoul

Background

Hydrogen has emerged as a key component in the global transition towards low-carbon energy systems. Acknowledged for its potential to drive sustainability, clean hydrogen is hailed as a promising solution capable of decarbonizing challenging sectors, facilitating the integration of renewable energy through robust energy storage mechanisms, and enhancing energy security. However, the current landscape reveals that clean hydrogen occupies only a marginal share in the broader hydrogen market, due to a constellation of challenges, including high costs, intricate technical barriers, and a lack of standardized protocols. Nonetheless, several governments across the world have unveiled comprehensive plans and funding initiatives intended to catalyze transformative progress in clean hydrogen technology by the end of this decade.

In this context, the role of cities is crucial in realizing the potential of hydrogen as a key component of clean energy systems. Several cities have launched pilot projects, aiming to advance the use of hydrogen. Among these cities, Seoul and Tokyo stand out as pioneers, having initiated hydrogen development strategies and actions. This article seeks to provide an analysis of how these two cities have pioneered hydrogen energy projects, offering valuable insights to other cities seeking to incorporate hydrogen in their decarbonization efforts.

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Tokyo: Establishment of a hydrogen town

Objectives

Tokyo, a global hub of technical innovation, has positioned itself at the forefront of hydrogen technology development and applications. An instrumental milestone transpired in 2016, when the Tokyo Metropolitan Government (TMG) unfolded its ambitions to cultivate a hydrogen-powered society, a vision interwoven within its environmental and sustainability blueprints. In 2022, TMG published the Tokyo Hydrogen Vision that further delineates the significant role of hydrogen in realizing Tokyo's commitments of attaining Carbon Half (50% emission reduction by 2030) and accomplishing Carbon Neutrality by 2050 (TMG, 2022). The groundbreaking Harumi Flag, a residential area functioning as a hydrogen-powered town post the Tokyo 2020 Olympic Games, stands as Japan's first practical foray into hydrogen on such a significant scale.

Actions

Policy framework and mechanism

Originally designed to serve as the Tokyo 2020 Olympic Village, Harumi Flag has evolved into a testing ground for sustainable and clean energy solutions. Following the city's vision to develop a hydrogen-centric society, noteworthy objectives, including doubling hydrogen power generation and usage by the Tokyo 2020 Games and deploying a comprehensive hydrogen supply system for the Olympic Village, were announced in 2016. This vision materialized through the establishment of temporary hydrogen stations within the Harumi district, providing hydrogen for fuel cell buses that transported athletes during the Tokyo Olympics. Simultaneously, the government introduced the Residential Development for the Olympic Village, with the aim to promote pivotal hydrogen technologies within Harumi Flag after the Tokyo 2020 Games. The plan envisions a hydrogen-dominant energy ecosystem delivering power and heat to 5,632 individually owned or rented residences and other public and commercial facilities within Harumi Flag by 2024 (Panasonic Group, 2019).

The journey of the hydrogen town project at Harumi Flag has been navigated through a collaborative process with different stakeholders. Conceiving Harumi Flag as a dynamic hydrogen hub, TMG has selected an implementing corporate group through an open solicitation procedure in 2016. Represented by Tokyo Gas, a private development operator, the group is a composite entity comprising six private enterprises. Charged with the practical execution of projects harnessing hydrogen technology, these enterprises cover various aspects of the hydrogen system, encompassing hydrogen stations, pipelines, and generators. Meanwhile, the government forged the Olympic Village Energy Committee in 2016, an entity collecting the insights of external experts and assessing the public and commercial feasibility of projects tendered by the corporate group. In the subsequent year, the Energy Infrastructure for Olympic Village Area project, which aimed to build a clean and reliable energy system within Harumi Flag, was formally affirmed (Bureau of Urban Development, TMG, 2022; Panasonic Group, 2019).

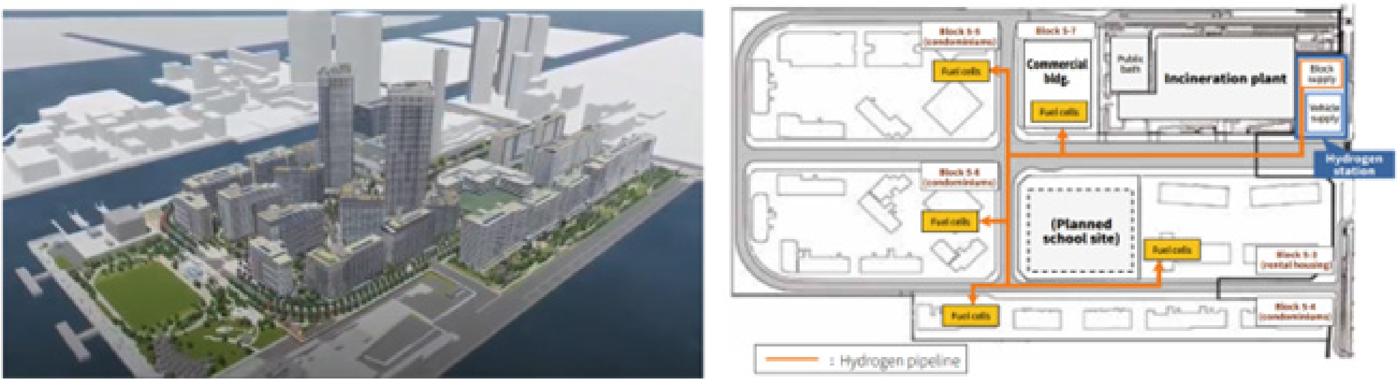

Figure 1: Harumi Flag after completion - bird's eye view and hydrogen supply conceptual schematic (Tokyo Updates, 2021)

Infrastructure development

The integral hydrogen system within Harumi Flag comprises a triad of components: a hydrogen station, underground pipelines, and fuel cell generators. The hydrogen station, positioned within proximity to the township, spans an expansive 4,800 square meters. The station supplies hydrogen to fuel cell vehicles and the fuel cell generators installed at residential clusters in Harumi Flag. Underground pipelines channel hydrogen from the station to fuel cell generators within residential blocks. The fuel cell generators generate both electricity and heat. This twin stream of energy powers residential clusters and communal facilities, including provisions for the elderly housing sector. Each residential neighborhood is endowed with 30 kW-capacity fuel cell generators. As illustrated by Figure 2, this integral power source is complemented by electricity generated from other power plants. This dynamic architecture is equipped with various types of monitoring instruments, from seismometers to pressure gauges, deployed to safeguard the integrity and resilience of the hydrogen supply system (Bureau of Urban Development, TMG, 2022; Panasonic Group, 2019).

In addition to the hydrogen infrastructure, Harumi Flag adopts an array of advanced technologies to forge a resilient renewable energy system. The energy management system, designed to monitor and control energy utilization, is deployed to predict energy demand and curtail peak demand. By decreasing the reliance on grid power, the system leads to a reduction in carbon emissions and electricity bills. Solar panels and storage batteries are also integrated to harness solar energy to meet the community's electricity demand (Bureau of Urban Development, TMG, 2022). Figure 3 shows the overall energy system in the Harumi district.

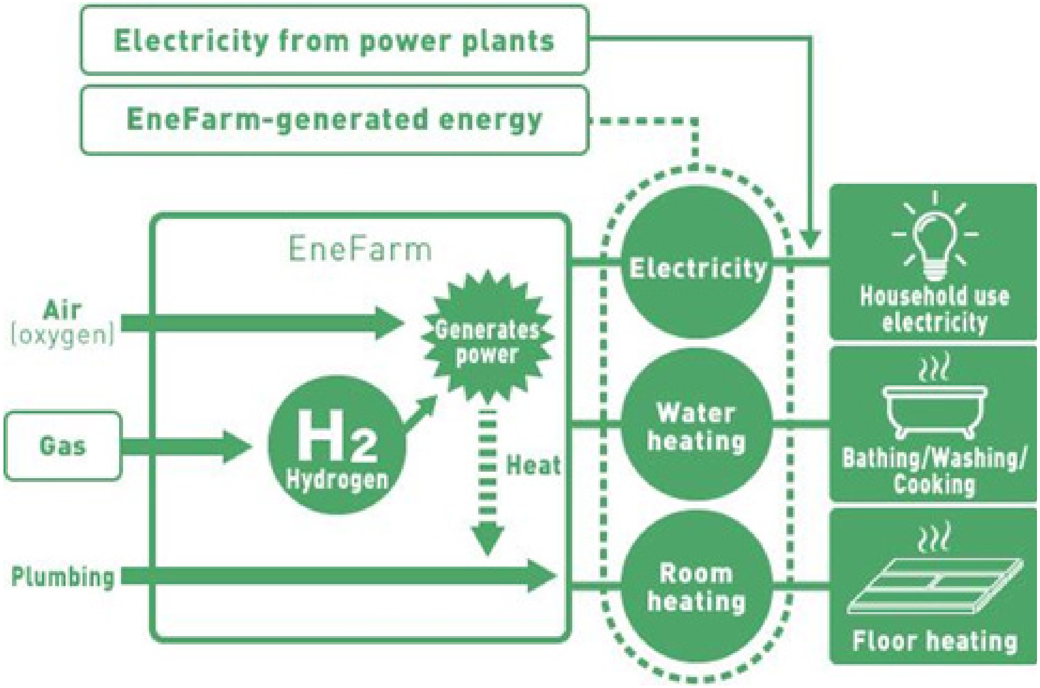

Figure 2: Working mechanism of the residential fuel cell generators (Panasonic Group, 2019)

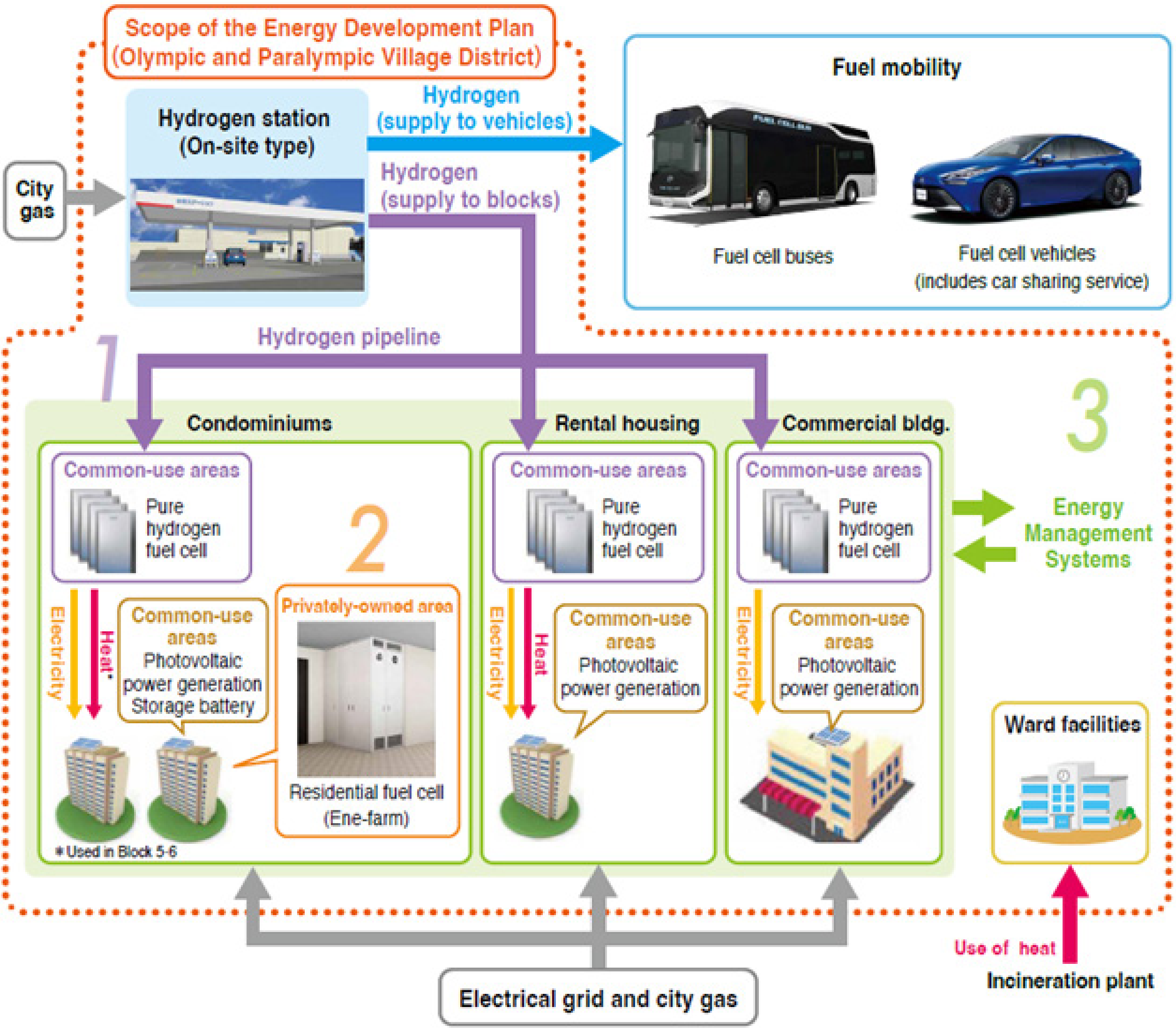

Figure 3: The energy system in the Harumi district (Bureau of Urban Development, TMG, 2022)

Outcomes

The significance of Harumi Flag transcends its physical dimensions, resonating with Tokyo's climate aspirations. The comprehensive development of the hydrogen energy infrastructure united with solar panels, energy storage mechanisms, and energy management systems can lead to a tangible reduction in the carbon footprint of this community nexus. Constructed within a residential milieu, this project bears the potential to increase public acceptance of hydrogen energy, an innovative concept that, for some, engenders trepidation due to its novelty.

Unveiling itself as Japan's inaugural community-scale hydrogen infrastructure, Harumi Flag embodies the potential to yield insights and expertise for the prospective expansion of hydrogen infrastructure. A key expectation for hydrogen is to be a reliable approach to energy storage. Due to the intermittency of solar and wind energy, the expansion of renewable energy requires significant energy storage capacity. The hydrogen infrastructure at Harumi Flag can contribute to exploring hydrogen's potential for energy storage. Another key contribution of Harumi Flag is the updated regulation framework and mechanism on hydrogen, which can provide reference for other governments.

Challenges

Within the Harumi Flag context, a notable challenge lies in the method of hydrogen production. Presently, the hydrogen station relies on natural gas, a process that generates carbon emissions and falls short of the optimal standard associated with hydrogen produced through renewable energy sources. Tokyo also needs to explore how to increase the share of green hydrogen in its hydrogen market. Additionally, once the hydrogen system at Harumi Flag is put into operation, TMG needs to assess the climate impact of this project and understand the potential of expanding hydrogen infrastructure in other circumstances such as old community complexes.

Seoul: Promotion of hydrogen vehicles

Objectives

In its 2050 Seoul Climate Action Plan, Seoul Metropolitan Government (SMG) has outlined two pivotal roles of hydrogen in its journey towards achieving net-zero by 2050. Firstly, hydrogen vehicles are positioned to replace internal combustion engine vehicles (ICEVs) alongside electric vehicles (EVs). Secondly, hydrogen's role extends to power generation, where hydrogen fuel cells, in conjunction with solar photovoltaics (PV), are slated to contribute to the city's power generation. With a focus on increasing operational efficiency and profitability, Seoul aims to increase the installed capacity of fuel cell power to 1 GW by 2050 (SMG, 2021).

Regarding hydrogen vehicle promotion, Seoul has established both short-term and long-term targets. In the near term, Seoul aimed to subsidize 250 hydrogen vehicles by the first half of 2023 (SMG, 2023b). By 2026, Seoul plans to phase out 1000 public buses, 300 airport buses, and 100 cleaning trucks with hydrogen-powered counterparts (Hydrogen Central, 2023; SMG, 2022). By 2030, the city envisions deploying 300,000 hydrogen vehicles and establishing 660 charging stations (SMG, 2023a).

Actions

Policy framework and mechanism

Collaborating with the national government, Seoul aims to increase the profitability of hydrogen-generated power following updated regulations. The government is committed to revising regulations to promote hydrogen energy uptake, including legalizing the sale of power generated by fuel cells within buildings for commercial purposes and recognizing hydrogen as emergency power sources for medium or large buildings.

The city has also established incentive mechanisms to facilitate the hydrogen energy adoption and application. On the one hand, government subsidies are offered to communities residing near fuel cell power plants and private investment for fuel cell power projects at public facilities like water recycling centers and railway depots (SMG, 2021). On the other hand, as a demonstration project, SMG has selected Hyundai Motor's Nexo as the model to promote hydrogen-powered passenger vehicles. SMG provides substantial subsidies (approximately 32.5 million KRW, equivalent to around 24,000 USD) per vehicle, covering nearly half of the original price. Additional benefits include tax reduction and discount on parking fees, highway tolls, and certain congestion fees (SMG, 2023b). These regulatory and policy adjustments are intended to overcome historical regulatory challenges associated with hydrogen and promote its wider use with incentives.

Infrastructure development

Along with its effort on hydrogen vehicles, Seoul is also investing in the development of hydrogen charging stations. A noteworthy aspect of Seoul's efforts in constructing hydrogen charging stations lies in its diverse pilot projects, encompassing various types of stations, including urban charging stations and on-site production-generation stations.

The Seosomun Hydrogen Charging Station, which commenced operations in October 2022, stands as the first hydrogen station situated in the city center and accessible to the public in Korea. Seoul refers to it as an "urban hydrogen station". Its central location provides convenience to consumers seeking to charge their hydrogen vehicles, while its design harmonizes with the historical aesthetics of the neighborhood, showing the city's commitment to cultural heritage preservation.

Figure 4: Seosomun Hydrogen Charging Station in Seoul (SMG, 2023a)

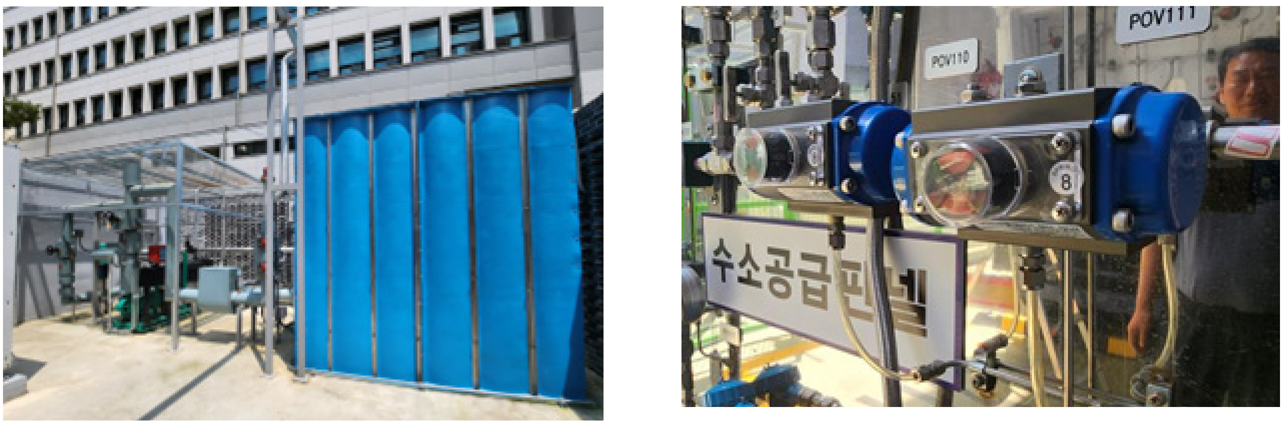

Figure 5: Emergency fire suppression tank and shut-down valve at the Seosomun Hydrogen Charging Station (SMG, 2023a)

The station, located in a bustling area, also incorporates additional safety measures, including emergency fire suppression tanks and emergency shut-down valves. With a daily capacity of 200 kg or 25 cars per day (SMG, 2023a), this station represents a milestone in promoting public acceptance of hydrogen energy.

Sangam H2 station, originally constructed in 2011, underwent a significant upgrade in 2020. The upgrade resulted in a substantial increase in hydrogen fuel generation capacity, from 75 kg to 160 kg per day, and raised the fueling pressure from 350 bar to 700 bar. These improvements enabled the hydrogen station to serve a larger number of vehicles. The Sangam H2 station represents an “on-site type” charging station, where hydrogen is produced at the station. This on-site hydrogen production approach offers benefits such as transportation cost reduction and environmentally sound solutions for managing landfill methane. Additionally, the station also produces hydrogen from liquefied natural gas (LNG), resulting in a combination of hydrogen generation methods at the facility (SMG, 2020).

Figure 6: Sangam Hydrogen Station in Seoul (SMG, 2020)

These pilot projects serve to consolidate Seoul’s knowledge and expertise in hydrogen station deployment, positing the city to expand its network of hydrogen charging stations in the future.

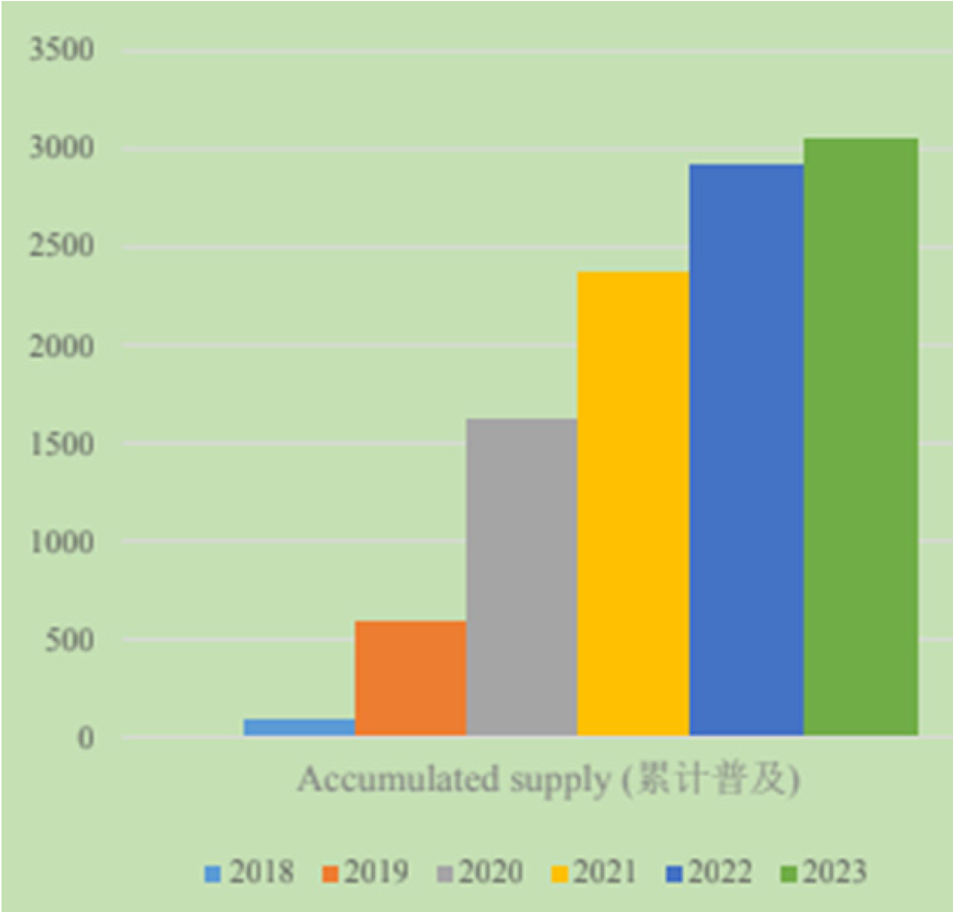

Figure 7: Accumulate supply of hydrogen vehicles in Seoul (SMG, 2023a)

Outcomes

Following the initiation of pilot projects on hydrogen projects in 2018, Seoul witnessed a rapid increase in the number of hydrogen vehicles. As indicated in Figure 7, the number of hydrogen vehicles in Seoul reached 2,889 by 2022, starting from a low number in 2018. Furthermore, the city has successfully erected 13 hydrogen charging stations across the city (SMG, 2023a), establishing robust infrastructure to support the widespread adoption of hydrogen vehicles.

Challenges

Despite the rapid increase in the number of hydrogen vehicles in Seoul thanks to the support and investment by the SMG, the city faces substantial challenges in meeting its 2026 target of 35,000 hydrogen vehicles, particularly considering that there were only 2,889 hydrogen vehicles in Seoul as of 2022.

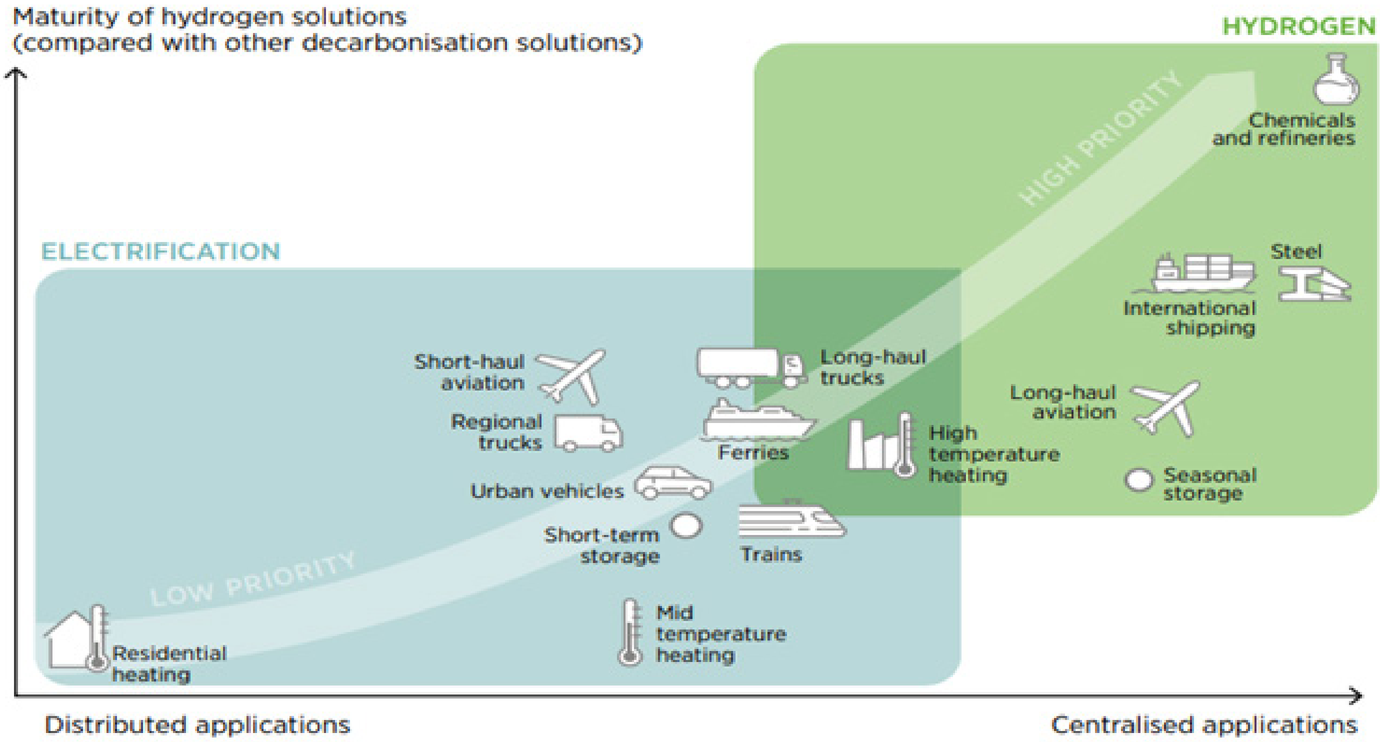

Figure 8: Clean hydrogen policy priorities (Source: IRENA, 2022)

Cost-effectiveness and economic efficiency remain the two major challenges facing Seoul during its development and development of hydrogen power in the transportation sector. The city has predominantly selected hydrogen vehicles manufactured by Hyundai Motor, a local Korean brand, for subsidy support. For instance, the Hyundai Motor Nexo serves as the sole hydrogen passenger vehicle eligible for subsidies, and a similar pattern is observed in the case of hydrogen buses. In Seoul's plan to deploy hydrogen buses, Hyundai Motor remains the sole supplier (Hydrogen Central, 2023). This lack of competition and limited choice has resulted in diminished economic efficiency in Seoul's hydrogen vehicle pilot projects.

More importantly, it is uncertain whether Seoul's hydrogen vehicle project can lead to meaningful decarbonization impacts. According to the International Renewable Energy Agency (IRENA), in the current stage, hydrogen applications of high priority should focus on steel, seasonal energy storage, and international shipping, relegating urban vehicles to a lower priority status, as depicted in Figure 8 (IRENA, 2022). The low priority accorded to hydrogen application in urban transportation is primarily due to the competitive alternative presented by EVs, which offers cost-competitive, reliable and sustainable options.

Summary

Tokyo and Seoul have launched their efforts on hydrogen application in energy generation and transportation. This case study provides an overview of the key initiatives undertaken by these two cities. Below, we distill the insights garnered from Tokyo and Seoul’s hydrogen development projects, emphasizing the potential significance of their progress for other municipalities seeking to expand their hydrogen initiatives.

- Recognizing the nascent nature of hydrogen technology, both cities have underscored the pivotal role of public and private collaboration in advancing hydrogen projects. In Tokyo, TMG has fostered a strategic partnership with a corporate group led by Tokyo Gas for the Harumi Flag project. Augmenting this dynamic alliance is the formation of the Olympic Village Energy Committee, composed of external experts who provide critical insights and oversight. In Seoul, a similar synergy has emerged as a cornerstone, with the city collaborating with hydrogen vehicle manufacturers.
- The development of urban spaces offers good opportunities for the application of cutting-edge technologies. Tokyo leveraged the opportunity presented by the Tokyo 2020 Olympic Games to incorporate renewable energy solutions. In Seoul, an innovative approach was adopted by repurposing an old landfill site for the establishment of a hydrogen production and charging station. These successful endeavors underscore the potential for other cities to embrace a clean energy ethos when designing new urban spaces or revitalizing existing areas. This forward-thinking approach unveils a pathway toward the proliferation of sustainable and innovative energy systems on a global scale.
- Cities must exercise caution and diligence in assessing the sustainability impacts of hydrogen projects. It is imperative for cities to carefully evaluate their approaches to hydrogen production and utilization to unlock the low-carbon potential of hydrogen initiatives. Seoul, for instance, should conduct a thorough assessment of the carbon footprint associated with hydrogen vehicles, especially when compared to EVs. Tokyo, on the other hand, should focus on expanding the production of green hydrogen, given that the hydrogen currently utilized in the Harumi Flag project is sourced from gas. By addressing these sustainability challenges, both cities can maximize the environmental benefits of their hydrogen projects and contribute to a cleaner energy future.

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