EI (HKB) Position Paper on the Use of Hydrogen to Achieve Net Zero by 2050

Submitted by

Energy Institute (Hong Kong Branch)
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EI(HKB) Recommendations on Decarbonization Measures/Options for Achieving Net Zero by 2050

1. PURPOSES

1.1 This Paper presents the recommendations of Energy Institute (Hong Kong Branch) (hereinafter referred to as EI(HKB)) regarding the facilitation of more extensive utilization of hydrogen as an energy carrier and a clean fuel for Hong Kong to achieve the 2050 Net-Zero Carbon Target as enshrined in the Climate Action Plan 2050.

1.2 EI(HKB) has been advocating transition of Hong Kong economy towards a "Hydrogen Economy" for some years and for this we have organized a series of International Energy Conferences on energy efficiency/alternative energy once every two to three years since 2003. Each time our international conferences attracted overwhelming attendances from local and overseas professionals, policy makers, academia, and consultants in the energy sector to share the expertise and experiences in these topics. The most recent 7th international conference was co-organized successfully with City University of Hong Kong (CityU) and the Hong Kong Polytechnic University (PolyU) on 1 - 2 December 2022 at the campus of CityU and the main theme of this conference was dedicated specifically to various issues relating to the production, transportation, storage, conversion, and utilization of hydrogen.

1.3 During the preparation of the 7th International Conference on Hydrogen by the Organizing Committee of the Conference, a Technical Committee[1] was also formed to work out policy recommendations to the HKSAR Government in the form of this Paper which is submitted to the Secretary for Environment and Ecology for consideration. The purpose of this Paper is to render our strong support for the Government to promulgate effective and timely policies and to lay out a roadmap to facilitate faster and more extensive utilization of hydrogen as an energy carrier and a clean fuel for Hong Kong to achieve net zero by 2050.

1.4 This Paper comprises:

(a) A technical review of hydrogen safety and current technologies in production, transportation, storage, conversion, and utilization of hydrogen (As Annex A to this Paper)

(b) A summary of key messages delivered at the 7th International Conference on Hydrogen

[1] The Technical Committee members include: Ir Dr H.F. Chan (Chairman), Ir Jeffrey Kwok, Ir Professor Dennis Leung, Ir Professor Michael Leung, Ir Chris Chong, Ir Don Cheng, and Ir Raymond Fong.

Co-Organized by EI(HKB) and CityU held on 1-2 December 2022 (as Appendix A to this Paper)

(c) EI(HKB) policy recommendations to the HKSAR Government.

1.5 In addition to the submission of this Paper as our strong support to the Government in this hydrogen utilization policy area, EI(HKB) is willing to provide our technical expertise and extensive network to help the Government to reach out to various stakeholders in the society on taking forward this important decarbonization policy for the best benefit for Hong Kong. EI(HKB) is ready to give our contribution to the Government as and when it is deemed necessary.

2. TECHNICAL REVIEW OF HYDROGEN SAFETY AND CURRENT TECHNOLOGIES IN PRODUCTION, TRANSPORTATION, STORAGE, CONVERSION, AND UTILIZATION OF HYDROGEN

2.1 The Technical Committee has conducted an extensive technical review of hydrogen safety and current technologies in production, transportation, storage, conversion, and utilization of hydrogen and is attached as Annex A, entitled "Technical Review on Production, Transportation, Storage and Use of Hydrogen to Achieve Net Zero in Hong Kong" to this Paper. This review presents the current knowledge and experience in production, transportation, storage, and use of hydrogen in other economies of the world, especially those accumulated in Mainland China in recent years.

3. KEY MESSAGES DELIVERED AT 7TH INTERNATIONAL CONFERENCE ON HYDROGEN CO-ORGANIZED BY EI(HKB) and CityU HELD ON 1-2 DECEMBER 2022

3.1 **Appendix A** lists out the key messages delivered by various top-notch speakers at the 7th International Conference on Hydrogen Co-organized by EI(HKB), PolyU and CityU held on 1-2 December 2022 and cover the following areas:

(a) Policy Initiatives
(b) Power generation
(c) Towngas experience
(d) Safety standards
(e) Rail transportation

(f) Bus operation
(g) Airport operation
(h) Overseas experience

4. EI(HKB) RECOMMENDATIONS

4.1 Transition to more extensive use of hydrogen is a means to help Hong Kong achieve net-zero by 2050. However, in view of technical capabilities and local resources available, Hong Kong is not well positioned to produce hydrogen in bulk quantity. EI(HKB) proposes the following for the Government to consider:

(a) Production:

- Hydrogen in bulk quantities shall be produced in Mainland China or overseas and imported to Hong Kong [cf. China Roadmap on use of hydrogen]. Small quantities of grey hydrogen can be produced by The Hong Kong and China Gas Company Limited (hereafter called "Towngas").
- Green hydrogen or green hydrogen carrier shall be produced using renewable energy conversion technologies, such as solar photovoltaic thermal (PV/T) electrolysis systems or wind farms or Landfill gas.

(b) Delivery:

- Hydrogen shall be delivered to Hong Kong from Mainland China as high-pressure pure hydrogen gas or liquefied hydrogen or a chemical carrier e.g., ammonia, via:

    - Long-distant pipeline, decision shall be made in consultation with the Chinese Authority and industry partner(s) on the alignment of the pipeline from the nearest bulk hydrogen storage tank farms in China to connection points of the existing Towngas network. Towngas has confirmed the compatibility of its pipeline material with pure hydrogen to ensure safety, durability, reliability to carry hydrogen. Overseas experience in Australia shares similar outlook.

    - High pressure tanker trucks or by rail or by ships in large volume of hydrogen. Tube trailers for gaseous hydrogen and cryogenic trucks for liquid hydrogen. Standard high-pressure tanks are available for the delivery. Regulatory decision shall be made on whether special routing should be designated for the delivery to ensure safety in harbour and through tunnel crossing.

(c) Storage:

- Storage tanks shall be in place to receive and store the hydrogen or the chemical carrier of hydrogen. Safety code and standards shall be developed based on overseas experience and promulgated to ensure safety of the hydrogen tanks and the potential risks to the neighbors.
- For high demand end users, e.g., power stations, industrial estates, etc., storage tanks shall be set up there to facilitate the use of hydrogen. Alternatively, hydrogen gas can be supplied to these users by submarine gas pipeline, like natural gas.

(d) Refuelling Stations:

- Refueling stations shall be in place and distributed over Hong Kong for the transportation vehicles to refuel hydrogen. Safety code and standards including protocols shall be developed based on overseas experience, e.g., ISO TC197, NFPA Part 2, and promulgated to ensure safety of the hydrogen refueling stations and to minimize the potential risks to neighbors.
- Trial tests shall be carried out at Government/bus & utility companies' depots to demonstrate safe use of hydrogen

(e) Applications:

- Domestic use: Government shall permit Towngas through legislation to deliver more than the current 46.3% - 51.8% hydrogen to domestic premises. The current 3,700 km of pipeline may need to expand to cover new areas. Towngas shall consider whether the existing burners in domestic places are compatible with burning pure/higher percentage hydrogen.
- Commercial use: such as restaurants and caterers. Same as for domestic applications. Commercial buildings can consider use Trigeneration that generate air conditioning, heating and/or electricity..
- Power generation: As coal fired power plants will be phased out by 2035, Government shall work with power companies on the progressive use of hydrogen in gas turbine combined power and heating.
- Industrial use: Most of the industrial plants in Hong Kong are light industries that use mainly electricity and diesel for manufacturing. No high demand energy users, e.g., steel and cement manufacturing, are currently operating in Hong Kong.
- Transportation use: Government shall work with the two franchised bus companies to

progressively convert their double-decker buses to fuel cell driven buses. Trials are being carried out to test the performance of this hydrogen technology over the battery-based technology under Hong Kong unique topography, long range and routes with frequent services, and climate. Commercial/industrial type medium and heavy vehicles, e.g., lorries, trucks, forklifts, etc. shall be encouraged to convert their diesel vehicles into fuel-cell driven.

- Large data centre: Hydrogen/ammonia powered fuel cell (FC) shall be used as back-up power for large data centres.

(f) Investment and R&D Support:

- Investors or private sectors shall be invited to participate in the development of the hydrogen infrastructure under Green Bond Programme.
- R&D shall be funded to support the whole value chain to produce a low cost, affordable, durable, and sustainable hydrogen operation using Green Tech Fund.
- Hong Kong Government shall set up polices to support investment in the development of hydrogen technology and the hydrogen economy.

(g) Legislative Support:

- Legislation shall be in place in due course to require the switching of light-duty vehicles, e.g., passenger cars to electric and the medium to heavy duty vehicles, off-road machinery, forklifts, etc. to fuel cell driven.
- Government shall negotiate with the two bus companies in Hong Kong to switch to hydrogen buses.
- Government shall negotiate with ferry companies in Hong Kong to switch to hydrogen ferries.
- Government shall ban or limit the import and sales of fossil fuel in Hong Kong in phases.
- Government shall ban the use of fossil fuels in marine or oceanic ships to enter Hong Kong ports in phases.
- Government shall treat hydrogen as fuel and not as dangerous goods for energy/transportation applications and to amend the appropriate legislation accordingly.

(h) Action Plan:

- Government shall set up an Action Plan with targets and milestones for the achievement of each of the targets in the Action Plan in full consultation with the industry, research communities, bus companies, ferries companies, end users, and all relevant stakeholders.

- Government shall appoint an independent advisory committee to review and monitor the progress on a regular basis the implementation of the Action Plan and advise on further action to be taken.

4.2 EI (HKB) hereby proposes several decarbonisation measures/options with technical support to achieve net zero by 2050, which are in line with the following Policy Initiatives as outlined in Climate Action Plan 2050 by the HKSAR Government, i.e.:

- Net zero electricity generation
- Energy saving and green buildings
- Green transport
- Waste reduction

Details of the proposed decarbonization measures are given in **Appendix B**.

4.3 EI (HKB) is willing to advise/assist in the policy formulation and implementation of the Climate Change Action Plan.

Appendix A: Key messages delivered at 7th International Conference Organized by EI(HKB) and held on 1-2 December 2022[2]

Conference precedence and presentation material can be downloaded at http://www.energyinst.org.hk/

<u>On Policy Initiatives</u>:

- The Government targets to achieve net zero by 2050 through 4 initiatives as described in the Climate Action Plan 2050, i.e., (a) Net zero electricity generation, (b) Energy saving and green buildings. (c) Green transportation, and (d) waste reduction.
- Phasing out of all coal fired power plants for base load power generation by 2035
- Increasing RE to 7.5-10% for electricity generation by 2035 and gradually increase to 15%
- Exploring the potential for hydrogen-fuelled power generation and trial of new energy and regional cooperation by 2035
- Reducing energy consumption in commercial buildings by 15-20% and residential buildings by 10-15% by 2025 as compared with the consumptions in 2015. Subsequently, the energy consumption would be reduced by 30-40% in commercial buildings and 20-30% in residential buildings
- Ceasing new registration of fuel-driven and hybrid private cars in 2035 or earlier
- Promoting wider adoption of electric private cars EV and provision of sufficient charging facilities
- Trials on single-decker e-buses and subsidy of operators to replace the current fleets with longer service life to e-buses through the NET Fund, starting from 2023. Introducing about 700 electric buses by end of 2027.
- Trials on e-taxis and replacement of LPG taxis with longer services life with e-taxis through the NET Fund. Introducing about 3000 e-taxis by 2027.
- Trials on e-PLB and installation of quick charging facilities by 2023 and devising a concrete and feasible roadmap for electrification of PLBs with more operation data from green minibus operators and charging service providers by around 2025.
- Progressive conversion of petrol/LPG filing stations to quick charging stations for EV.
- Provision of 7000 parking spaces with EV chargers in Government building between 2023-2026.
- Launching of EV-charging at Home Subsidy Scheme (EHSS) as from October 2022 to subsidize the EV charging infrastructure in car parks of existing private residential buildings.
- Trials on hydrogen fuel cell-driven double decker buses and heavy vehicles in 2023.

[2] The following messages do not cover all those that were delivered at the Conference.

- Assessing the operational feasibility and safety risk of hydrogen refiling stations, the arrangement of hydrogen supply, and the HFCEVs on roads, etc.
- Trials on electrification of in-harbour ferries starting from 2024 and the use of LNG which complies with the International Maritime Organization Tier III emission standards in hybrid vessels and subsidy to operators on the construction and trials of electric ferries and the associated charging facilities.
- Improving the overall energy performance in Government buildings by more than 6% by 2024-2025
- Using district cooling system in Northern Metropolis
- Zero carbon emissions from transport sector before 2050
- Implementing municipal solid waste charging
- Developing adequate waste-to-energy facilities by 2035
- Reducing carbon emissions by 50% before 2035 and achieving carbon neutrality by 2050, as compared to that in 2005.
- Government has set up a Government Green Bond Programme in 2018 to fund sustainable development and projects to combat climate change by issuance of a US$2.6 billion, the world largest retail green bond.
- Government has set up a HK$400 million Green Tech Fund in 2020 to support R&D on decarbonization technologies. Priority is given to projects on net-zero electricity generation, energy saving, and green buildings, green transport, and waste reduction.
- Setting up a new Council for Carbon Neutrality and Sustainable Development to advise on decarbonization strategies and to publicize public understanding and awareness, among others.

On Power generation:

1. ***CLP Pledge***

- Targeting to attain 0.3 kg CO_{2e}/kWh by 2030. 0.1 kg CO_{2e}/kWh by 2040 and net zero by 2050.
- Taking action to phase out coal asserts, promoting energy efficiency, investing in clean energy, strengthening targets every 5 years, and pursuing opportunities in transition enablers.
- Delivering decarbonization with high reliability and a reasonable tariff.
- Targeting using 60-70% zero carbon fuel and generating 7.5-10% renewable energy by 2035
- Exploring pumped storage and battery energy storage to balance intermittent RE
- Exploring more nuclear power from Mainland China to achieve net zero.
- Powering gas turbines on pure hydrogen by 2030 according to manufacturers' view.

- Free energy audit services to identify energy management opportunities of customers
- Subsidy to energy improvement works in commercia areas of building
- Subsidy to business customers for e-purchase of energy efficient electrical equipment
- Educating the next generation to decarbonise

2. ***Hong Kong Electric Pledge***

- Targeting to reduce greenhouse gas emission per unit of electricity generated by more than 68% from 2019 level in 2035.
- Striving to achieve coal to gas transition and expects to further increase the gas-fired generation to over 50% of total output in 2022.
- Cease using coal for daily power generation by 2035.
- Subsidy to HK Electric customers to enhance their buildings energy efficiency under the Smart Power Building Fund
- Subsidy to the needy to adopt low-carbon living styles, and improving living environment and electrical safety under the Smart Power Care Fund
- Feed-in Tariff (FiT) Scheme for HK Electric customers to install RE power systems connecting to HK Electric's power grid
- Promoting Energy Efficiency & Conservation (EE&C), low carbon lifestyle and the application of renewable energy through different educational and promotional activities under Smart Power Education Fund.
- Exploring the development of a 150 MW class offshore windfarm at South West Lamma Island.
- Exploring the feasibility of switching to hydrogen-fueled power, by using green hydrogen to generate electricity at Lamma Power Station Extension

Town gas Experience:

- Existing Towngas already contains 46.3% - 51.8% hydrogen.
- 3,700 km network reaching virtually every part of the territory.
- Two product plants providing non-stop & reliable gas supply.
- 160 years of engineering experience dealing with hydrogen rich gas system with excellent safety record.
- Hydrogen transport by pipeline is safe using the tough steel pipeline (with material API 5L Grade X52 or below), and with 100 ppm oxygen and 2% CO or 2% SO_2 against embrittlement.
- Hydrogen is safe as it can dissipate rather than accumulate quickly.
- Towngas has set up a pilot plant at its Taipo plant to extract hydrogen from Towngas with purity > 99.9% through (a) gas compression from 2 to 7 bars, (b) sulfur removal to < 1

ppb, (c) Rotary Pressure Swing Adsorption (rPSA) and (d) Gas compression for storage.
- The produced hydrogen complies with ISO 14687: Hydrogen Fuel Quality.

Safety Standards:

- Safety standards are needed to identify the best practices to protect the public, and to identify bad actors who put public at risks. They provide solutions to make the industry safer, and shape positive perception of hydrogen and fuel cell technologies. They provide guidance to authorities having jurisdiction and facilitate approval and adoption of hydrogen and fuel cells technologies.
- Recent development in the setting of safety standards means that they result in a higher standard of safety for hydrogen than many legacy fuels like gasoline or diesel.
- IEC TC105, clauses AG1, AG2, AG3 and AG4, set standards on fuel cell safety and performance.
- ISO TC197 sets standards for hydrogen technologies, including hydrogen quality, filling stations, and filing protocols, pressure vessels and component requirements and electrolyzers.
- American Society of Mechanical Engineers (ASME) B31.12 sets standards on hydrogen piping and pipeline.
- National Fire Protection Association (NFPA) standards, Part 2, sets standards for hydrogen system and fuel cell installation in North America. NFPA 55 sets standards on storage, use and handling of compressed gases and cryogenic fluids in portable and stationary containers, cylinders, and tanks.
- Compressed Gas Association (CGA) Publication G5.5 sets standards on hydrogen vent system, and Publication H3 on cryogenic hydrogen storage, and H5 on installation standard for bulk hydrogen supply system.
- UN Registry on Global Regulations ECE-TRANS180a13 sets global technical regulations for hydrogen -powered vehicles
- Society of Automotive Engineers SAE sets industry-based standards for fuel cell vehicles
- ISO TC 197 sets standards for hydrogen quality, filling stations and filling protocols, pressure vessels, and component requirements, electrolyzers, fuel tanks, and component standards
- ANSI/CSA HGV (Hydrogen Gas Vehicle) sets a series of standards for hydrogen gas vehicles in North America [3]
- IEC TC9 JWG 51 Parts 1, 2 and 3 set standards for hydrogen fuel cell trains
- International Maritime Organization (IMO) IGF Code sets interim draft guidelines for fuel

[3] HyTunnel-CS project has performed pre-normative research for safety of hydrogen driven vehicles and transport through tunnels and similar confined spaces.

cell and hydrogen installation aboard ships

- No standards have yet been set on hydrogen release in road vehicle tunnels and large-scale hydrogen releases aboard ships as no solutions have been found on the issues.
- Hand-held or fixed gas sensors/detectors can be used to protect the safety of people in domestic premises, factories, and facilities.
- Detectors can provide a great variety of safety functions: including pollution detection, domestic fuel gas leakage detection, gas concentration detection, gas detection, etc.
- In China, standards/specifications have been established for the management and operation of hydrogen filling stations. Technical specifications are also in place for hydrogen filling stations.

<u>On Rail Transportation</u>:

- Replacement of diesel vehicles with E-vehicle/clean fuel vehicles
- Introducing regenerative braking
- On-site renewable energy
- Introducing new rolling stock
- Station HVAC and E&M systems optimization
- China announced its roadmap on the use of hydrogen
  - By 2025 establish a hydrogen energy supply chain with industry collaboration. Annual hydrogen production from renewable energy is expected to reach 100,000 tonnes to 200,000 tonnes. Establish carbon reduction of 1 million to million tonnes per year
  - By 2030 increase the use of hydrogen generated by renewable energy to reach national carbon goals.
  - By 2035 wider application of hydrogen generated from renewable energy. Application in various industries including transportation, energy storage industry, etc.
- MTR would begin to explore possibilities to adopt hydrogen fuel for its trains.

<u>On Bus Operation</u>:

- CityBus has upgraded its existing Euro 5 fleet to Euro 6 fleet
- CityBus has launched its world's first tri-axle electric decker bus on 19 April 2022 and began operation on 19th June 2022
- Trials of operating electric double decker buses on three routes: Route 5B, Route 20/20A/22M and Route 962 series
- Installation of 3 mid-day charger at Hong Kong Station, Central Pier, and Kai Tak Cruise Terminal.

- CityBus introduced the world's first tri-axel hydrogen fuel cell bus on 21 June 2022, aiming to run an estimated range of over 400 km during 2023.
- Electric buses are more suitable for short routes and moderate schedule while hydrogen fuel cell buses are more suitable for long range and routes with frequent services.
- Charging time for electric buses longer than 3 hours, while refilling time for liquid hydrogen is about 10 min.
- Hydrogen buses can operate on all weather, but electric buses are better suited for warm and moderate temperature
- KMB planned to have electric single decker buses between 2016-2030 and electric double decker buses between 2023 – 2050

On Airport Operation:

- HKIA 's carbon reduction target is: 55% absolute carbon reduction (from 2018 level) and net zero carbon emission by 2050
- HKIA 2021 carbon footprint: 70% aircraft related emissions. And 30% from ground emissions
- No emission growth from 2024 and linear decrease of carbon emission from 2028
- HKIA decarbonization roadmap incl:
    - Electrification of vehicles and ground services equipment
    - Use of renewable diesel
    - Use of low GWO refrigerants
    - Zero carbon on-site energy generation
    - Energy efficiency measures
    - Grid decarbonization

Overseas Experience:

- Northern Gas Network (NGN) under Project H21 launched a safety study between 2018 – 2022 at three sites within the NGN network (West Yorks, Teesside, Humber), i.e., Buxton, Spadeadam and South Bank to test the safety of supplying hydrogen to homes in these locations. The purpose was to demonstrate 20% by volume of blending hydrogen into existing gas network safely and with public acceptance.
- The demonstration was completed in June 2022. The houses are a typical pair of semi-detached houses fitted with 100% hydrogen appliances with minimal disruption to their current gas supply system. It also demonstrates maturity of hydrogen supply chain by showcase "market-ready" technologies.
- NGN is proposing to Government to supply 2,000 homes in Redcar with 100% hydrogen for 2 years and is expected to have decision by 2023.

- NGN has launched in November 2022 a Customer Energy Village project consisting of one 1919 terrace, one 1830 semi-detached, one 1950 bungalow, one 1970 flats and one 1990 detached houses. All included natural gas and hydrogen networks alongside with electricity and water supply.
- In Japan, Panasonic, with over 13 years of experience in manufacturing residential fuel cells, and more than 220 K units' installations as at March 2022, provides 5kW natural gas-powered fuel cells for home applications. The Company is developing pure hydrogen fuel cells using same technology as for natural gas fuel cells. Since October 2021, the company has installed its first fuel cell models in in Shanghai Baoshan District and Wuxi Factory. A pilot test was carried out in Foshan Nanhai Hydrogen town.
- In Japan, Iwatani Corporation handles all business from procurement, transportation, and supply of hydrogen in Japan. The hydrogen market has expanded from the conventional industrial applications, incl iron manufacturing, petroleum refinery/Petrochemical, glass, optical fibre, semi-conductor, ammonia production, metallurgy, fuel for rocket, electronic component, and solar panels, to household FC cogeneration system, FC buses, power plants, FCVs. Iwatani has 80 years of experience for safety and takes a dominant market share in Japan.
- Iwatani has 3 plants for LH2 production in Japan.
- The Green Growth Strategy focuses on 14 sectors covering: Energy, Transport/Manufacturing and Home/Office [Source: Green Growth Strategy with carbon neutrality by 2050]
- Iwatani future hydrogen supply chain will focus on (a) acquiring target amounts of inexpensive CO2-free hydrogen sources, (b) shifting from production to import /storage functions, and (c) creating hydrogen energy demands
- A Green Innovation Fund with a total investment of 300 billion yen of which 200 billion yen comes from and Government support to demonstrate large scale liquefied hydrogen supply chain. The participants are Kawasaki to develop technics of H2 transportation, Iwatani to study H2 utilization in and near seaside areas, and ENROS to study H2 utilization in seaside areas.
- Iwatani produces hydrogen from waste plastic through gasification
- Iwatani is working with other corporations to produce the world 's largest hydrogen system (0.1 GW) using renewable energy at Fukushima
- Iwatani is working to convert 500 ton/year of wood pellet to hydrogen through gasification and shift reaction to produce 700 Nm3/h of hydrogen
- Iwatani has established and operated 53 hydrogen stations and 15 are under construction in Japan.
- Iwatani will establish a total of 83 (+30) H2 refueling stations by 2023, targeting on medium-heavy duty users and working with logistic and FC truck manufacturers.

- The existing gas networks of Australia Gas Network can carry 100% hydrogen
- Existing gas appliances in Australia can use blends of hydrogen and 100% hydrogen
- Australian Gas Infrastructure Group (AGIG) has established five operational /advanced projects or studies including
    - DBP feasibility study – a A$0.45 technical feasibility study for regulatory roadmap
    - Hydrogen Park South Australia - a A$14.5M project with 1.25MW electrolyser supplying <5% blend to > 700 homes and to industry via tube trailer. Expansion: >3000 homes online Q1 2023
    - Australia Hydrogen Centre – a A$4.15M virtual centre for a hydrogen blending feasibility study in SA and VIC.
    - Hydrogen Park Murray Valley – a A$44M project with 10MW electrolyser supplying <10% blend to > 40,000 homes and businesses in 2024
    - Hydrogen Park Gladstone – a A$4.2M project with 0.175MW electrolyser supplying <10% blend to >800 homes and businesses as from 2023

Appendix B: EI (HKB) Recommendations on Decarbonisation Path to Achieve Net Zero by 2050

EI (HKB) proposes that the Government considers adopting the following decarbonisation measures to achieve net zero by 2050 or earlier:

Sector	Total CO_{2e} emissions in 2020 (kTon)	Decarbonisation Measures to be Adopted in 2035+	Associated Reduction in CO2 emissions in 2035+ (kTon)	Total CO_{2e} emissions in 2035+ with the measures (kTon)	Reference to Appendix C
Electricity generation	20,400	Phasing out of all coal-fired power generation plants	6,244	14,156	Sub-option A1
Transport	6,650	Electrification of all gasoline vehicles	928	4,163	Sub-options B1, B2, B3, & B4
		Electrification of all LPG vehicles	374		
		Conversion of 50% of buses and 30% of medium /heavy vehicles to fuel-cell driven	934		
		Conversion of 50% of in-harbour ferries to fuel cell driven	251		
Other end use of fuels (inc. comm, ind., domestic)	1,970		Partly included below		
Waste	2,960	Use of gasification-to energy, closure of some of the landfills, and waste reduction	1,480[2]	1,480	Option D
Industrial processes and product use	1,780		Partly included below		
Agriculture, forestry, and other land use	35			35	
Consumption	Included	Energy saving &	6,904		Option C

of electricity[1]	above	green buildings			
Total	33,800			7,102	

Note:

1. In heavy & light rail, residential sector, commercial sector, industrial sector, and others
2. Assuming 50% reduction due to the adoption of gasification of municipal solid waste, closure of some of the landfills and waste reduction

Hence, with the proposed measures, it can be anticipated that the total CO_{2e} emissions by 2035+ would come down to 7,102 kTon, at a reduction as compared to 2020 by about 80%, though the associated carbon emissions from the production and delivery of Hydrogen to Hong Kong have not been considered for lack of information. Further reduction may be achieved with other options assessed in **Appendix C.**

On the other hand, it is anticipated power consumption due to the use of EV would increase but on the other hand energy saving and green buildings would reduce power consumption, leading to a net mild increase in power consumption by about 1%, as compared to 2020 scenario, as shown below:

Year	Total Power Consumption (M-kWh)	Power consumption from electrification of gasoline vehicles (M-kWh)	Power consumption from electrification of LPG vehicles (M-kWh)	Energy saving and green buildings
2020	44,097			
		+1,923		
			+766	
				-2,285
2035+	44,5018			

EI (HKB) is willing to advise/assist in the policy formulation and implementation of the Climate Action Plan.

Appendix C: Feasible Decarbonization Options to Achieve Net-Zero for Hong Kong by 2050

According to Climate Change Plan 2050, the total CO_{2e} emissions (kilotonnes) in 2005, 2020 and target emissions in 2030 and beyond and the total CO_{2e} emissions by sector in 2020 (kilotonnes) are as shown in **Table C.1** and **Table C.2** below:

Table C.1

Year	2005	2020	2030 (climate action 2050)		2050
			L-limit	U-limit	
Total CO_{2e} emissions (kts)	41,300	33,800	26,432	30,562	Net zero

Table C.2

Sector	Total CO_{2e} (kTon)	% of Total CO_2e
Electricity generation	20,400	60.4
Transport	6,650	19.7
Other end use of fuels (inc. comm, ind., domestic)	1,970	5.8
Waste	2,960	8.8
Industrial processes and product use	1,780	5.2
Agriculture, forestry, and other land use	35	0.1
Total	33,800	100%

CO2 emissions arose from the consumption of electricity and burning of fossil fuels. The energy end-use by sector in 2020 according to the Hong Kong Energy End-use 2020 in TJ are shown in **Table C.3**

Table C.3

Type/Secor	Residential	Commercial	Industrial	Transport	Total (TJ)
Electricity	46,675	102,171	7,383	2,871	159,100
Towngas and LPG	19,726	11,844	1,470	11,155	44,195
Oil and Coal Products	15	498	3,309	65,373	69,195
Total end-use	66,416	114,513	12,162	79,399	272,490

Decarbonization Options for Achieving Net Zero by 2050 or Earlier

In order to achieve net zero by 2050 or earlier, EI (HKB) has examined five options, some with sub-options, of decarbonization measures and the associated CO_{2e} reduction for Government to consider. These options are in line with the policy initiatives as described in Climate Action Plan 2050 as below:

Option A: Net Zero Power Generation

1. ***Sub-option A1: Phasing out of Coal-fired Power Plants***

Power generation has become the single largest source of energy consumption and CO_{2e} emission in Hong Kong. In line with the Government policy initiative and the commitment of two power companies to phase out coal-fired power plants by 2035, and replace them by gas turbine power plants, the total CO_{2e} emissions by 2035 would be as below, assuming the same total electricity demand:

Year	Unit sold/Coal (M-kWh)	Unit sold/Gas (M-kWh)	Nuclear & others (M-kWh)	CO_{2e}/Coal (kTon)	CO_{2e} /Gas (kTon)	Total CO_{2e}/kTon	Average Carbon intensity (kg/kWh)
2020	10161	21369	12,471	10329	8,590	18,919	0.42
2035	0	31,531	12,471	0	12,675	12,675	0.29

* Assuming electricity demand unchanged and same generation efficiency in 2035 c/w 2020 and enough gas fired power plant capacity

In terms of the energy use in power generation, the scenarios in 2020, 2035 and 2050+ would be as below:

Type of Generation /Consumption	2020	2035	2050 & beyond
Total power consumed (M-kWh)	44,097	44,097[1]	??
Estimated Energy Consumed by Coal fired Plant (TJ)	97,310	0	0
Estimated Energy Consumed by Gas Turbines (TJ)	124,416	243,411	??
Estimated Energy Consumed by Nuclear Plant (TJ)	45,716	45,716	??
Average Energy Intensity (kJ/kWh)	7,580	6,557	??
Average Carbon Intensity (Ton CO_2/TJ)	59.12	43.84	??
Average Carbon Intensity (kg CO2/kWh)	0.42	0.29	??
Total CO_{2e} emission (kTon)	18,919[2]	12,675	Net zero
Total reduction in CO_{2e} emissions (kTon)		**6,244**	??

Note:

(1) This figure may increase due to other decarbonization actions

(2) This figure which is derived from the operation of local power plants deviates slightly from the Government figure of 20,400 kTon, probably because the latter may have included emissions from other non-power plant operations

2. ***Sub-option A2: Hydrogen Blending in Gas Turbines***

The total CO_2 emission can be further reduced if the natural gas is blended with 20%, 30% or even higher concentrations of hydrogen in the gas mixture as below, assuming the total electricity demands remain unchanged:

Hydrogen Blending	Unit sold from Gas Turbine (M-kWh)	CO_2 emissions from Gas Turbine (kTon)	Carbon intensity (kg/kWh)
20%	25,225	10,140	0.23
40%	18,918	7,605	0.17
60%	12,612	5,070	0.11
80%	6,306	2,535	0.06
100%	0	0	0

Option B: Green Transport Initiative

1. ***Sub-option B1: Electrification of Gasoline Vehicles***

According to the emission statistics and energy end-use, transport is the second major source of CO_2 emissions. Green transport has become another major policy directive to decarbonize Hong Kong. In line with the Government initiative to electrify all passenger vehicles with a pledge to cease registration of all gasoline vehicles no later than 2035, EI (HKB) proposes that all gasoline vehicles be converted to EV. The total CO_{2e} emissions in 2020 and after the conversion would be as below:

Year	Gasoline Consumed (kLitre)	Total km-Travelled by Gasoline Vehicles (km)[1]	Energy Consumed by Gasoline Vehicle (TJ)	Energy Consumed by EV		Total CO_{2e} emissions from Consumed gasoline/Petrol (kTon)[3]	Total CO_{2e} Emission from EV (kTon)
				(TJ)	(M-kWh)[2]		
2020	640,994	9,614,912,281	21,922	?	0	1,481	0
2035 +	0	0	0	12,608	1,923	0	553
Total reduction in CO_2 emissions (kTon) =							928

Note:

1. Assume average mileage of an average gasoline vehicle @ 15 km/L
2. Assume average power consumption of EV @ 5 km/kWh (which is conservative)
3. Based on emission factor of gasoline/petrol @2.31 kg CO_{2e}/L

2. ***Sub-option B2: Electrification of LPG vehicles***

The Government further initiates progressive conversion of all LPG taxis to e-taxis and all light-duty commercial vehicles to e-PLB. In line with this initiative, EI (HKB) proposes that all existing LPG taxis and LPG buses be converted to EV. The total CO_2 emissions and the associated reduction would be as below:

Year	Total Qty of LPG Consumed (Ton)[1]	Total km-Travelled by LPG Vehicles (kM)[2]	Energy Consumed by LPG Vehicle (TJ)	Energy Consumed by E-Vehicles		Total CO_2 Emissions from LPG consumed (kTon)	Total CO_2 Emissions from EV (kTon)
				(TJ)	(M-kWh)[3]		
2020	182,519	3,832,896,466	11,155	?	0	594	0
2035 +	0	0	0	5,026	766	0	220
Total reduction in CO_2 emissions (kTon) =							374

Note:

1. Assume energy density of LPG @ 116 MJ/m^3 (from EMSD website) as gas or 61.1 MJ/kg as liquid and the gravimetric density of LPG as gas @ 1.898 kg/m^3 or 495 kg/m^3 as liquid
2. Assume average mileage of LPG vehicles @ 21 km/kg
3. Assume average power consumption of EV @ 5 km/kWh (which is conservative)

3. ***Sub-option B3: Fuel-cell Driving Medium and Heavy Vehicles***

It is understood that the Government is working with franchised/non-franchised bus companies to convert their diesel driven buses to fuel-cell driven buses and that trials are in progress at KMB and CityBus to examine the technical feasibility and the performance of the system under the Hong Kong environment.

In 2020, buses consumed 12,358 TJ of diesel and goods vehicles consumed 23,261 TJ of diesel. EI (HKB) proposes that 50% of the buses and 30% of the goods vehicles including off-road vehicles to be converted to fuel cell driven, the CO_{2e} emissions and the associated reduction would be as below:

Year	Total Energy Consumed by Buses (TJ)	Total Energy Consumed by Goods Vehicles (TJ)	Diesel Oil Consumed by Buses (kLitre)[1]	Diesel Oil Consumed by Goods Vehicles (kLitre)	CO_{2e} emissions (kTon)[2]
2020	12,358	23,261	332,204	625,296	2,528
2035 +	6,179	16,283	166,102	437,707	1,594
Total reduction in CO_{2e} emissions (kTon) =					934

Note:

1. Based on energy density of diesel @37.2 MJ/L
2. Based on emission factor of diesel oil @2.64 kg CO_{2e}/Litre

4. ***Sub-option B4: Fuel-cell Driving In-harbour Ferries***

In line with the Government initiative to electrify in-harbour ferries, EI (HKB) proposes that 50% of the in-harbour ferries to be driven by fuel cells and the CO_{2e} emissions and the associated reduction would be as below.

Year	Total Energy Consumed by in-harbour ferries (TJ)	Diesel Oil Consumed by in-harbour ferries (kLitre)[1]	CO_{2e} emissions (kTon)[2]
2020	7,094	190,699	503
2035 +	3,547	95,350	252
Total reduction in CO_{2e} emissions (kTon) =			251

Note:

1. Based on energy density of diesel @37.2 MJ/L
2. Based on emission factor of diesel oil @2.64 kg CO_{2e}/Litre

Option C: Energy Saving and Green Buildings

In line with the Government initiative to conserve energy in Government buildings and the promotion of the use of electrical appliances with energy labels and the development of green buildings, the total CO_{2e} emissions can be expected to drop due to reduced electricity demands and consumptions. EI (HKB) proposes as a minimum 10% in use by heavy and light rail and 5% for other uses in 2035 and beyond. The associated carbon reduction would be as shown below:

Type of Use by Sector	Electricity Use in 2020 (TJ)	Energy Efficiency	Measures To be Adopted	Reduced Electricity Use	Electricity Use in 2035 & beyond (TJ)
Use by heavy & light rail	2,726	10%	Use of regenerative braking; Use of new rolling stock; Optimization of HVAC performance; Use of on-site RE	10%	2,453
Use in Residential Sector	46,675	5%	Use of energy efficient electrical appliances, Use of green building design	5%	44,341
Use in commercial sector (inc. rail station operation)	102,171	5%	Retro-commissioning of HVAC and energy systems; Use of energy efficient electrical appliances	5%	97,062
Use in industrial sector	7,383	5%	Retro-commissioning of HVAC and energy systems; Use of energy efficient electrical appliances: Process improvement	5%	7,014
Others	145	5%	ditto	5%	138
Total Energy Use (TJ)	159,100	NA	NA	NA	151,008
Total CO_{2e} emissions (kTon)	18,961	NA	NA	NA	12,057
				Total reduction in CO_{2e} emissions =	6,904 kTon
				Total reduction in electricity use =	8,092 TJ
					2,285 M kWh

Option D: Municipal Solid Waste to Hydrogen

The current practice in managing municipal solid waste, comprising solid wastes from households, commercial and industrial sources, is landfilling in 3 strategic landfills in Hong Kong, i.e., NENT Landfill, SENT Landfill and WENT Landfill. In response to concerns and complaints from residents living near the SENT Landfill, all municipal waste has been diverted to NENT Landfill and WENT Landfill since January 2016. The proposed Integrated Waste Management Facilities which comprise a 3,000 ton/day waste incineration facility in Phase 1 is being built at Shek Ku Chau and is expected to be fully commissioned by 2025.

As landfilling produces methane, which is more than 28-36 times more potent in global warming potential than carbon dioxide from anaerobic digestion of organic matters in the waste, in addition to its impacts on air, water and land quality, it is understood that the Government intends to develop adequate waste-to-energy facilities to move away from reliance on landfills by 2035, according to Climate Action Plan 2050. However, waste-to-energy facilities produce carbon dioxide from full combustion of the organic matters in the waste. On this aspect, EI (HKB) proposes that the Government considers gasification of the municipal solid waste to produce syngas for power generation and hydrogen for other uses and use landfill gas to produce green hydrogen.

Gasification is a partial oxidation process[4] which requires only 25%-40% of the oxygen needed for full combustion to generate enough heat to break up the chemical bonds in the feedstock and gasify the feed to produce syngas (CO and H_2), which can be used for power generation through gas turbines or steam turbines or can be used in chemical production or can be separated and purified to produce hydrogen for various applications. The slag can be used as construction material.

As compared with conventional waste incineration[5] which requires high temperature (850~1200 °C) to fully combust the waste into CO_2, H_2O, and heat plus other air pollutants e.g., SO_2, NO_x, HCl, PCDD/F, and particulate, gasification only combusts part of the waste with limited oxygen at temperatures varying between 550 – 900 °C depending on the gasifier type) to produce heat needed to turn the waste into syngas with high calorific values such as CO, H_2 and a small amount of CH_4 plus other air pollutants e.g., H_2S, HCl, NH_3, HCN, tar, alkali, and particulate.

As compared with landfilling, gasification produces much less greenhouse gases, e.g., 0.1% methane and 15% carbon dioxide and releases much fewer toxic compounds, as compared with landfilling. The released CO_{2e} can be further captured to reduce its emissions.

Given that the gasification-to-energy cost @ US$306 - $4,012[1] per ton at this moment may be

[4] Apinya Chanthakett, M.T. Arif, Mohammad Masud Kamal KhaU "Hydrogen production from municipal solid waste for cleaner environment" Bioenergy Resources and Technologies

[5] Arena, U, (2012), "Process and Technological Aspects of Municipal solid waste gasification". Waste Management, 32 pp625-639

higher than the incineration cost, which is typically US$680 - $1,026 per ton[6], it is still a promising option and alternative to be considered by the Government with the coming improvement/advancement in the technology which will drive down the cost for waste management and energy recovery from municipal solid waste.

There is existing Landfill gas, which can be used as feedstock for producing Hydrogen as it contains methane. Using reforming, hydrogen can be split through reforming from the biomethane to become Hydrogen and CO2. The CO2 can be captured before it is released into the atmosphere.

Option E: Replacement of Towngas and LPG by Hydrogen for Cooking and Heating

The production and burning of Towngas for cooking and heating at domestic premises and for commercial use emit CO_{2e} at 0.06225 kg CO_{2e}/MJ and the burning of LPG at 1.61 kg CO_{2e}/L. By the time when the hydrogen infrastructure is in place and hydrogen stoves and appliances that burn hydrogen are widely available, the Hong Kong and China Gas Company Limited (HKCG) and the Government may consider supplying hydrogen to replace the existing Towngas supplied by HKCG and cylinder LPG supplied by various gas distributors for cooking and heating. The associated reduction in CO_{2e} emissions would be as below:

Year	Use of Towngas/LPG in Residential Sector (TJ)[1]	Use of Towngas/LPG in Commercial Sector (TJ)[1]	Estimated CO_{2e} emissions from Residential Sector[2] (kTon)	Estimated CO_{2e} emissions from Commercial Sector[2] (kTon)
2020	19,726	11,844	982 + 210	590 + 126
2035+	0	0	0	0
Total reduction in CO_{2e} emissions (kTon) =				1,906

Note:

1. Assume 80% of the TJ consumed as Towngas, i.e., 15,781 TJ in residential sector and 9,475 TJ in commercial sector and 20% consumed as cylinder LPG. The total energy consumed as Towngas in residential sector and commercial sector would become 25, 256 TJ. This is in line with the naphtha usage in HCG of 11,329 TJ for Towngas production in 2020.
2. Based on emission factor from production and combustion of Towngas as supplied by The Hong Kong and China Gas Company Limited @ 0.6225 kg CO_{2e}/MJ

[6] Waste to Energy International, Cost of Incineration Plant, https://wteinternational.com/news/cost-of-incineration-plant/

Appendix D: International Safety Codes and Standards

China Codes and Standards 国家标准

用氢相关标准

- GB 50516—2010《加氢站技术规范》
- GB 4962-2008《氢气使用安全技术规程》
- GB/T 37244-2018《质子交换膜燃料电池汽车用燃料氢气》
- GB/T 26779-2011《燃料电池电动汽车加氢口》

燃料电池车辆相关标准

- GB/T 24548-2009《燃料电池电动汽车术语》
- GB/T 37244-2018《质子交换膜燃料电池汽车用燃料氢气》
- GB/T 24554-2009《燃料电池发动机性能试验方法》
- GB/T 24549-2020《燃料电池电动汽车安全要求》
- GB/T 26991-2011《燃料电池电动汽车最高车速试验方法》
- GB/T 29123-2012《示范运行氢燃料电池电动汽车技术规范》
- GB/T 29124-2012《氢燃料电池电动汽车示范运行配套设施规范》

Vehicles - System Design/Testing

- GB/T 23645-2009 Test method of fuel cell power system for passenger car (China)
- GB/T 25319-2010 Fuel Cell test system used for motor vehicles - Technical specification (China)
- GB/T 28183-2011 Test methods of fuel cell power system for bus (China)
- GB/T 33978-2017 Proton exchange membrane fuel cell module for road vehicle (China)
- GB/T 36288-2018 Fuel cell electric vehicle fuel cell stack safety requirements
- United Nations Working Party 29 Global Technical Regulations (GTR) on Pollution and the Environment Hydrogen Vehicles (International)
- EC No.79/2009 Type-approval of hydrogen powered motor vehicles (Europe)
- UN/ECE134 Uniform provisions concerning the approval of motor vehicles and the components with regard to the safety performance of hydrogen fuelled vehicles (HFCV) (Europe)

Vehicles – Safety

- SAE J1766 Recommended Practice for Electric and Hybrid Electric Vehicle Battery Systems Crash Integrity Testing (United States & Other Locales)
- SAE J2990/1- Hydrogen and Fuel Cell Vehicle First and Second Responder Recommended Practice (United States)
- SAE J2578 Recommended Practice for General Fuel Cell Vehicle Safety (United States & Other Locales)
    - *ISO 6469 Electrically propelled road vehicles – Safety Secifications* (International)
    - ISO 6469-1 Part 1: On-board rechargeable energy storage systems (RESS)
    - ISO 6469-2 Part 2: Vehicle operational safety means and protection against failures
    - ISO 6469-3 Part 3: Protection of persons against electric shock
    - ISO 6469-4 Part 4: Post crash electrical safety requirements
- ISO 23273:2013 Fuel Cell Road Vehicle – Safety specifications - Protection against hydrogen hazards for vehicles fueled with compressed hydrogen (International)
- *KS R ISO 2273 Fuel cell road vehicles – safety specification* (Korea)
    - KS R ISO 23273-1 Part 1: Vehicle functional safety (Korea)
    - KS R ISO 23273-2 Part 2: Protection against hydrogen hazard for vehicles fueled with compressed hydrogen (Korea)

- KS R ISO 23273-3 Part 3: Protection of persons against electric shock (Korea)

- *CNS 15499 Electrically propelled road vehicles – Safety specifications* (Taiwan)
    - CNS 15499-1 Part 1: On-board rechargeable energy storage systems (RESS) (Taiwan)
    - CNS 15499-2 Part 2: Vehicle operational safety means and protection against failure (Taiwan)
    - CNS 15499-3 Part 3: Protection of persons against electric shock (Taiwan)

Vehicles - Performance - efficiency, emissions, durability

- SAE J2572 Recommended Practice for Measuring the Exhaust Emissions, Energy Consumption and Range of Fuel Cell Powered Electric Vehicles Using Compressed Hydrogen (United States & Other Locales)
- ISO 23828:2013 Fuel Cell Road Vehicle- Energy Consumption Measurement Part 1: Vehicles fuelled with compressed hydrogen (International)
- ISO/TR 11954 Fuel Cell Road Vehicles- Road Maximum Speed Measurement (International)

Vehicles - Hydrogen Sensors

- SAE J 3089 Technical Information Report (TIR) for Vehicular Hydrogen Sensor Test Method (United States)

Vehicles - Fuel Systems

- ISO 12619 Road vehicles – Compressed gaseous hydrogen and hydrogen/methane blends fuel components
    - ISO 12619-1 - Part 1: General requirements and definitions
    - ISO 12619-2 - Part 2: Performance and general test methods
    - ISO 12619-3 - Part 3: Pressure regulator
    - ISO 12619-4 - Part 4: Check valve
    - ISO 12619-5 - Part 5: Manual cylinder valve
    - ISO 12619-6 - Part 6: Automatic valve
    - ISO 12619-7 - Part 7: Gas injector
    - ISO 12619-8 - Part 8: Pressure indicator
    - ISO 12619-9 - Part 9: Pressure relief valve

- ISO 12619-10 - Part 10: Pressure relief device
- ISO 12619-11 - Part 11: Excess flow valve
- ISO 12619-12 - Part 12: Gas-tight housing and ventilation hoses
- ISO 12619-13 - Part 13: Rigid fuel line in stainless steel
- ISO 12619-14 - Part 14: Flexible fuel line
- ISO 12619-15 - Part 15: Filter
- ISO 12619-16 Part 16: Fittings

- CSA HGV3.1 Fuel System Components for Hydrogen Gas Powered Vehicles
- ISO 19887 Gaseous hydrogen – Land vehicle fuel system components
- CGA PS31 Cleanliness for PEM Hydrogen Piping / Components

Fuel Cells - Performance - efficiency, emissions, durability

- SAE J2615 Performance Test Procedure for Fuel Cell Systems for Automotive Applications (United States & Other Locales)
- SAE J2617 Performance Test Procedure of PEM Fuel Cell Stack Subsystem for Automotive Application (United States & Other Locales)
- 20173719-T-604 Test evaluation method for the life of the fuel cell reactor with proton exchange film (Evaluation method for lifetime of proton exchange membrane fuel cell stack in vehicle operation) (China)

Fuel Cells – Recyclability

- SAE J2594 Design for Recycling Proton Exchange Membrane (PEM) Fuel Cell Systems (United States & Other Locales)

Fuel Processors – Performance

- SAE J2616 Performance Test Procedure of Fuel Processing Subsystem for Automotive Applications (United States & Other Locales)

Fuel Tanks

- ISO 13985 Liquid Hydrogen - Land Vehicle Fuel Tanks (International)
- ISO 19881 Gaseous hydrogen – Land vehicle fuel containers (International)

- KS B ISO 19881 Gaseous hydrogen – Land vehicle fuel containers (Korea)
- ISO 19882 Gaseous hydrogen – Thermally activated pressure relief devices for compressed hydrogen vehicle fuel containers (International)
- KS B ISO 19882 Gaseous hydrogen – Thermally activated pressure relief devices for compressed hydrogen vehicle fuel containers (Korea)
- AS ISO 19881:2020 Gaseous hydrogen – Land vehicle fuel containers (Australia)
- CSA HGV2 Standards for Hydrogen Vehicle Fuel Containers (United States)
- CSA HPRD1 Basic Requirements for Pressure Relief Devices for Compressed Hydrogen Vehicle Fuel Containers (United States)
- CSA SPE 2.1.3 Best practices for defueling, decommissioning, and disposal of compressed hydrogen gas vehicle fuel containers (North America)
- CGA Publication C6.4 Methods for External Visual Inspection of Natural Gas Vehicle (NGV) and Hydrogen Vehicle (HV) Fuel Containers and Their Installation (United States)

  EC No.79/2009 Type-approval of hydrogen-powered motor vehicles (European Union)
- KS B ISO 13985 Liquid hydrogen - Land vehicle fuel tanks (Korea)
- CNS 16078 Test methods of onboard low pressure hydrogen storage devices for small fuel cell vehicles (Taiwan)

Refuelling / Dispensing Connections

- SAE J2600 Compressed Hydrogen Vehicle Fueling Connection Devices (United States & Other Locales)
- SAE J2601 Fuelling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles (United States & Other Locales)
- SAE J 2601/2 Fuelling Protocols for Heavy Duty Gaseous Hydrogen Surface Vehicles (buses) (United States & Other Locales)
- *ISO 19885 Gaseous hydrogen – Fuelling protocols for hydrogen-fuelled vehicles* (International)
  - ISO 19885-1 Part 1: Design and development process for fuelling protocols
  - ISO 19885-2 Part 2: Definition of communications between the vehicle and Dispenser control systems
  - ISO 19885-3 Part 3: High flow hydrogen fuelling protocols for heavy duty road vehicles

- ISO 17268 Gaseous Hydrogen Land Vehicle Refuelling Connection Devices (International)
- ISO 13984 Liquid hydrogen Land vehicle fueling system interface (International)
- SAE J2799 70 MPa Compressed Hydrogen Surface Vehicle Refuelling Connection Device & Optional Vehicle to Station Communication (United States & Other Locales)
- EC No.79/2009 Type-approval of hydrogen-powered motor vehicles (European Union)
- KS B ISO 13984 Liquid hydrogen - Land vehicle fueling system interface (Korea)
- KS B ISO 17268 Compressed hydrogen surface vehicle refueling connection devices (Korea)
- SAE J 2601/4 Ambient Temperature Fixed Orifice Fuelling (United States & Other Locales)
- JIS B 8576 Hydrogen Metering Systems for Motor Vehicles (Japan)

Fuel Specifications

- SAE J2719 Hydrogen Fuel Quality for Fuel Cell Vehicles (United States & Other Locales)
- SAE J3219 Hydrogen Fuel Quality Screening Test of Chemicals for Fuel Vehicles (United States & Other Locales)
- ISO 14687 Hydrogen Fuel - Product Specification (International)
- AS ISO 14687:2020 Hydrogen fuel quality – Product specification(Australia)
- ISO 21087 Gas analysis – Analytical methods for hydrogen fuel -PEM fuel cell applications for road vehicles (International)

State of California Regulations Hydrogen Fuel Standard (California)

US Department of Commerce (NIST) Uniform Fuels and Automotive Lubricants Regulation-Retail Sales of Hydrogen Fuel Standard Specification (United States)

Other international safety codes and standards can be found in the following website http://fuelcellstandards.com/