International Transport Forum

EXPERT WORKSHOP

Mapping standards for low- and zero-emission electric heavy duty vehicles

17-18 February 2020 – Paris, France

HYUNDAI MOTOR GROUP

Development Trends of Hyundai FCEV and Hydrogen Vision

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VICE PRESIDENT

✓ The automotive industry is facing challenges & opportunities

Global Environmental Challenges

CLIMATE CHANGE
Reducing CO_2 emissions

AIR QUALITY
Restriction on ICE vehicles

ENERGY SECURITY
Diversification of energy sources

COUNTRIES

NORWAY / NETHERLAND
ICE Vehicle sales to be prohibited from 2025

FRANCE / UK
Diesel Vehicle sales to be prohibited from 2040

CHINA
New conventional vehicle manufacturers (including HEV, PHEV) to be prohibited from entering the market from 2019

OEMs

VW plan to stop developing gasoline & diesel cars from 2026
'18. 12

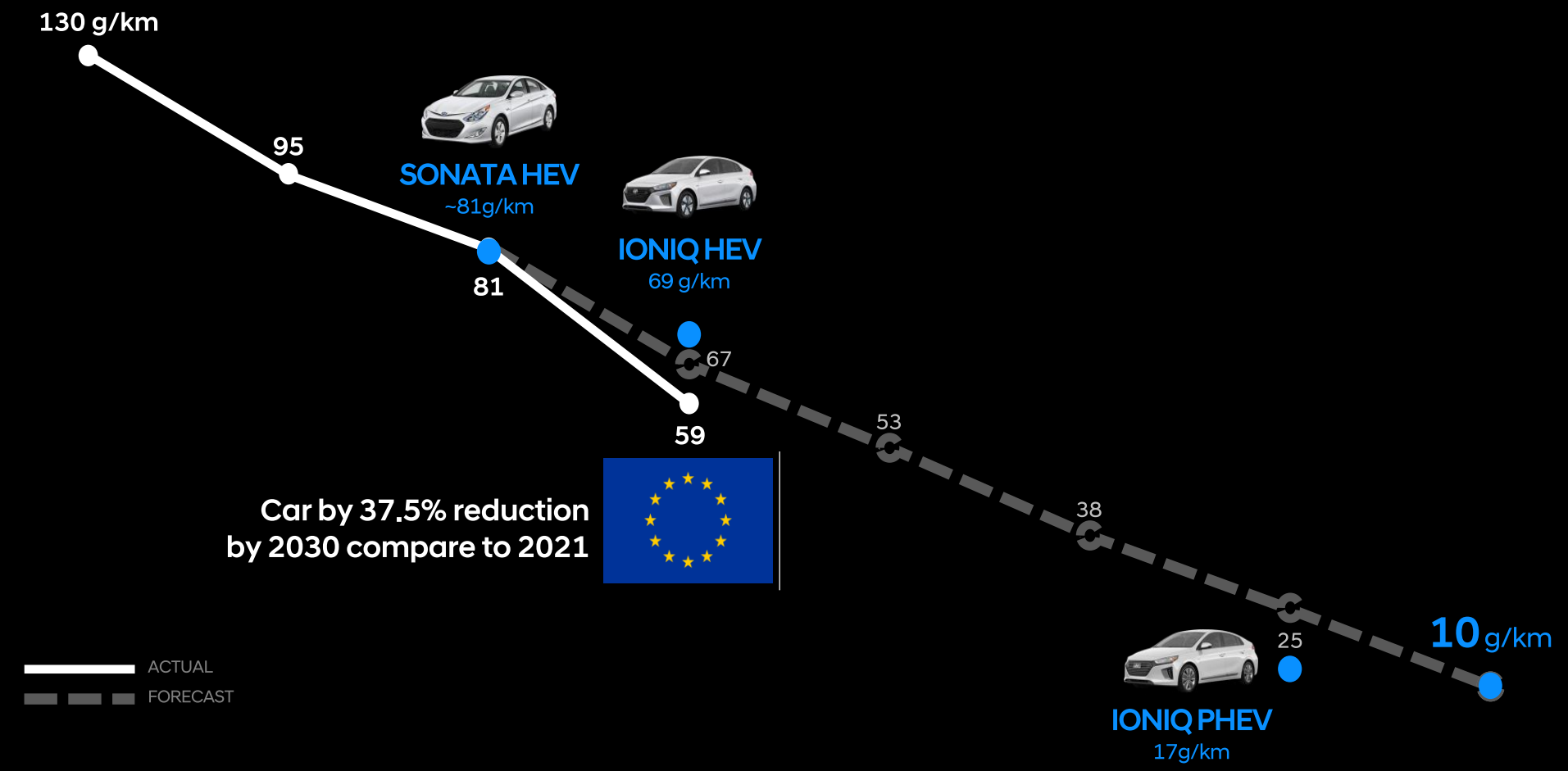
DAIMLER

Daimler to make its vehicles Carbon Neutral by 2039
'19. 5

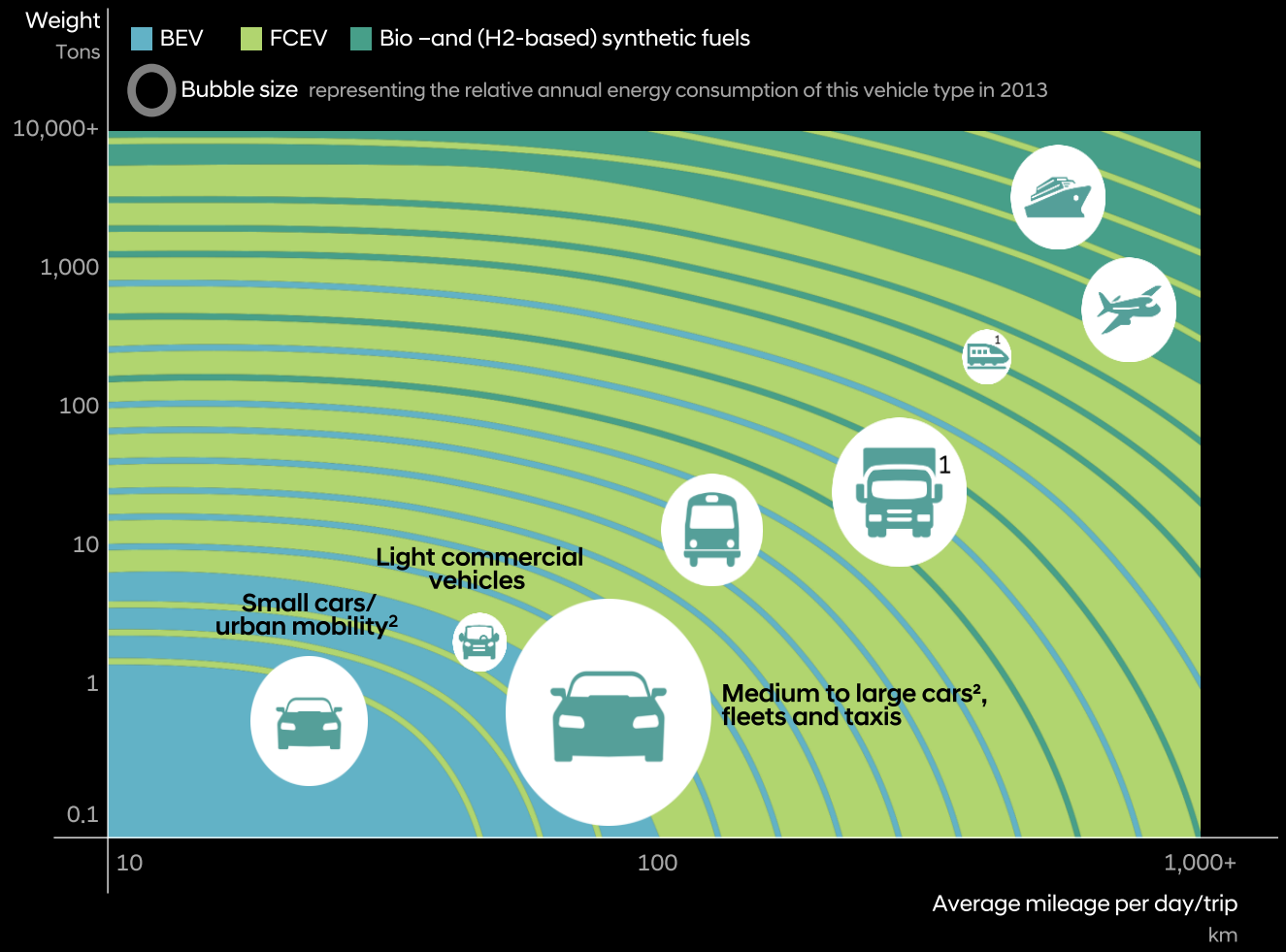
HYUNDAI MOTOR GROUP

HMG to produce 44 eco-friendly vehicles by 2025
'19. 1.

Fuel Economy Regulation / EU



Decarbonization of Mobility

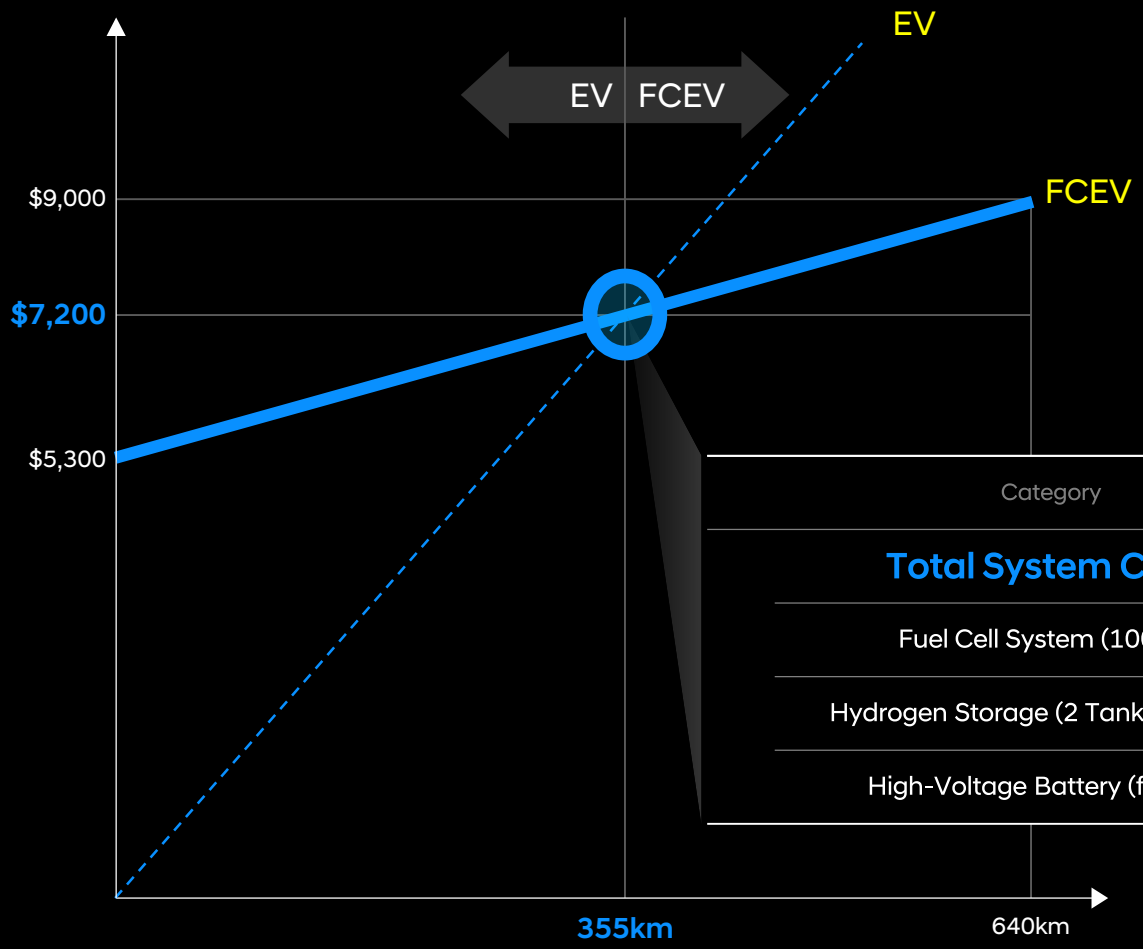


1 Battery-hydrogen hybrid to ensure sufficient power

2 Split in A- and B-segment LDVs (small cars) and C+-segment LDVs (medium to large cars) based on a 30% market share of A/B-segment cars and a 50% less energy demand

Source: Toyota, Hyundai, Daimler

Cost Parity / FCEV & EV



Comparison of Fuel Cell System and Battery System cost

Cost Parity at Approx. 355km

Category	Fuel Cell	Battery
Total System Cost*	**$7,200**	**$7,200**
Fuel Cell System (100kW)	$4522	(65.4kWh, $110/kWh* *)
Hydrogen Storage (2 Tank, H2 3.5kg)	$2058	
High-Voltage Battery (for HEV)	$620	

* : NEDO* & DOE* Cost Road map for Fuel Cell System

* * : Bloomberg New Energy Finance forecast (2017, “Lithium-ion Battery Costs and Market”)

HMG Green Car Line-up Strategy

Clean Mobility
Green energy system

Hybrid System
Electrification / Regeneration

Efficiency Technologies
IC improvement / CO_2 reduction

BEV — Battery Electric

HEV — Hybrid

FCEV — Hydrogen Fuel Cell

PHEV — Plug-in Hybrid

Gasoline

Diesel

R&D

HYUNDAI MOTOR GROUP

✓ Hyundai Motors has paid its devotion in developing FCEV

1998 — Initiated Fuel Cell development

2000 — First developed FCEV model (Santa Fe-based)

2004 — Independent development of stack

2005 — Independent development of Fuel Cell system

2007 — Independent development of FCEV powertrain

2013 — 1st generation FCEV (Tucson ix) "The world's 1st mass production"

2015 — US WardsAuto World "10 best engines in US market"

2018 — 2nd generation FCEV (NEXO) "Superior maximum range and energy efficiency"

✓ Hyundai Motors to mass-produce FCEV for the first time in the world

WORLD 1ST MASS-PRODUCED TUCSON FCEV ('13.2)

Deployed in 18 countries since 1st delivery to Copenhagen (2013)
Dedicated FCV assembly line in Ulsan Hyundai factory

France Eco - friendly Car of year from La Revue
Belgian 'Price FuturAuto'
Korea Silver Award
USA 2015 WARD's 10 Best Engine

FC stack	100 kW
Traction Motor	100 kW
Battery	24 kW
H2 Tank	700 bar
Driving Range*	415 km

* Fuel Economy Label:
70% Of EPA mode test results

✓ All-new dedicated FCEV, offering Hyundai's most advanced future technologies

1. Advanced Power Electric System

- The world-best driving range
- Refueled within 5 minutes
- System efficiency 60%
- In-house development for MEA, Metal Bipolar Plate

2. Durability & Storage

- Durability equivalent to conventional ICE : 160,000km /10 years
- The world-first 700 bar / Type4 3 tanks system : Cargo Volume Maximization

3. State-of-the-art ADAS Systems

[Contribution to the environment]

- AIR CLEANING EFFECT

The high-performance air filter can filter micro-particulates smaller than particulate matter (PM) 2.5

- FCV : SUPPLY ~ 10KW OF ELECTRIC POWER

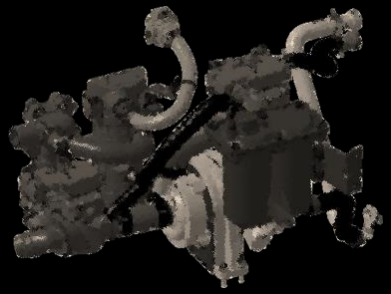
100,000 FCVs : Equivalent to a nuclear power plant (~ 1GW)

① Fuel Cell stack

- Stack performance improved by 12.5% compared to that of Tucson ix35 FCEV
  → Reduced weight by 14% and volume by 17%
- Improved low temperature control (-25℃ → -30℃)

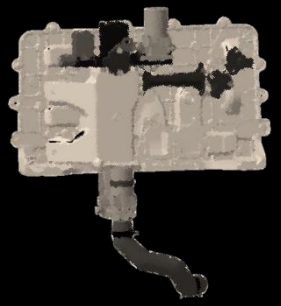
② APS (Air Processing System)

- Increased system performance and efficiency using variable pressure control
- Improved stack durability with tight air seal performance



③ TMS (Thermal Management System)

- Improved low-temperature start-up performance by applying multi-loop control
- Effective stack temperature management by improving valve response



④ FPS (Fuel Processing System)

- Single ejector recirculation system applied (Removal of blower & controller)
  → Reduced weight by 49% and power consumption by 90% (Compared to ix35 FCEV)

Top Safety rated Car, 'NEXO'

IIHS vehicle safety rating	**Top safety pick+**	Highest Rating
Euro NCAP Test	★★★★★	Highest Rating
Korean Government Safety regulation	**All Pass**	14 items

Hydrogen Tank Extreme Test


Burst


Burn


Drop


Chemical


Gun shot


Cold Temperature

※ The hydrogen tank is completed through a number of verification tests

✓ 3rd Generation Fuel Cell Bus development completed and operating

- First Hydrogen Fuel Cell Bus has Produced (2006)
- Hyundai 3rd Generation Fuel Cell Bus has launched (2018)
- Test drive of the nation's first city bus powered by hydrogen (2019)

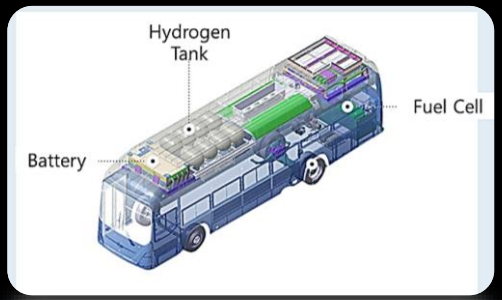
1st Generation
2006

2nd Generation
2009

3rd Generation
2018

PyeongChang 2018
'18 Winter Olympics

City Bus Pilot Program ('19)
- Busan
- Changwon



✓ Expanding line-up from 2020 such as Express Coach, Mid-truck

Coach Bus

Police force, Long distance bus

Mid duty Truck

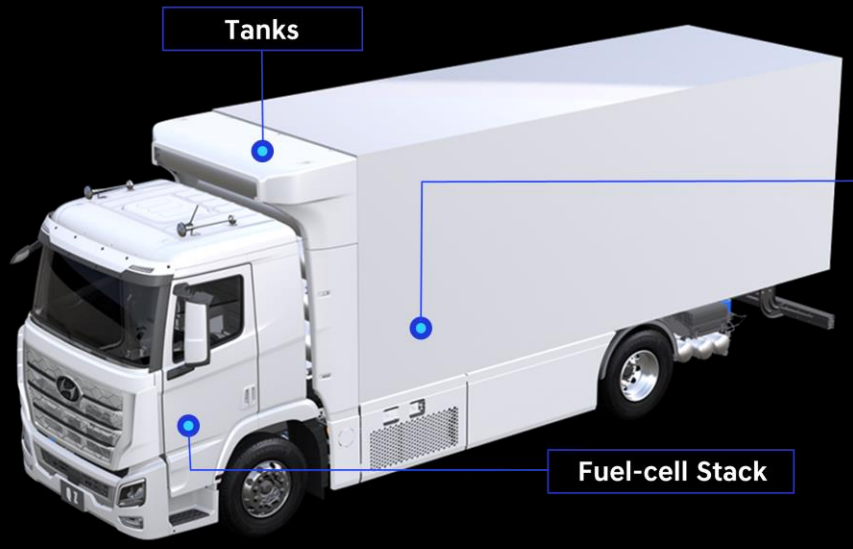
Trash truck, Road-cleaning truck

Heavy duty Truck

Full cargo

Swiss Distribution Truck Development

Supply 1,600 trucks to Switzerland by 2025



Stack	190 kW
Tank Capacity	34.5 kgH2 @ 350bar
Motor	350 kW
AER	400 km
GCW	34 ton

✓ The first hydrogen-only concept for HMC's commercial vehicles

- Next-generation fuel-cell electric truck : Emission Zero, Unique Experiences
- Human Machine Interface : Gesture Control, Eye-Tracking, Voice Command
- Four compressed-hydrogen fuel tanks : Driving range 600 to 800 kilometers
- Production truck based on the Neptune is targeted for around 2023/2024
- Liquid Nitrogen cooling containers system
- Exploring opportunities in the United States commercial vehicle market

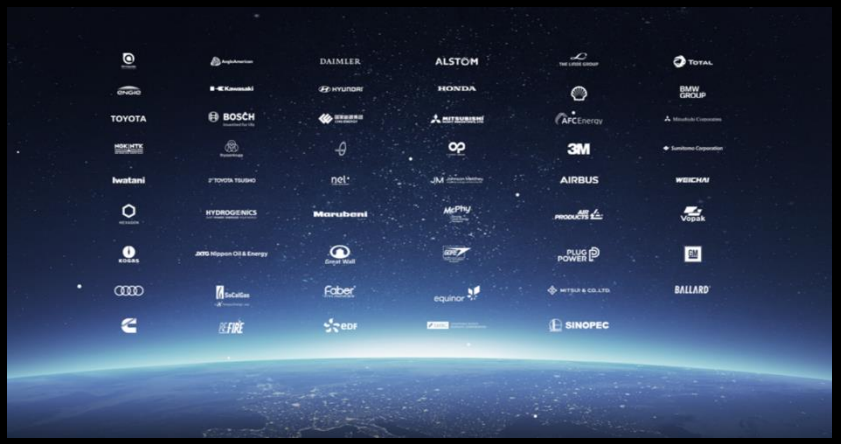
NEPTUNE CARGO

NEPTUNE TRACTOR

Strategic Partnership

✓ Collaborations with Business Partners to Expand & Lead FCEV Market

✓ **81 leading energy, transport and industry companies with a united vision and long-term ambition for hydrogen to foster the energy transition**



Hydrogen Council

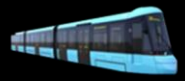
Co-chaired
by Air Liquide & Hyundai Motors since 2018

A global CEO-level initiative,
launched
at the World Economic Forum 2017,
in Davos, January 2017

✓ Announcement of HMG's long-term roadmap 'Vision 2030' plan (11.DEC.2018)

- Plans to produce **700,000 fuel-cell systems annually by 2030** including 500,000 units for FCEVs
- **New Businesses Opportunities for Fuel Cell Systems beyond Automotive Industry**

Forklift

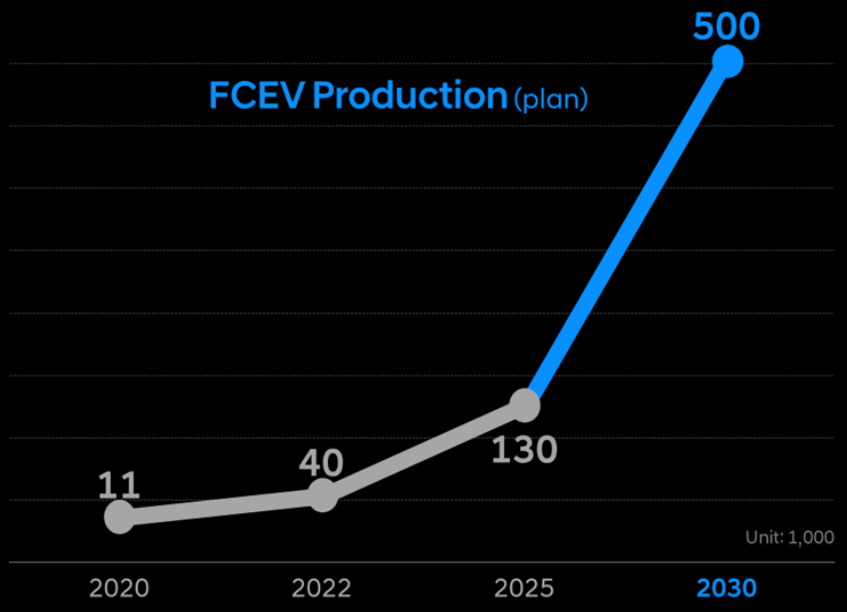


Trams / Trains

Manufacturers Of Automobiles

Power generator

Vessels



✓ A Proposal on the regulation and standard for expanding the supply of FCEV

① Deregulation on conformable and multiple tanks [GTR No.13]

Category	Contents
Current regulation	Any shut-off valve, and TPRD shall be mounted directly on or within each container.
Request	The hydrogen storage system may be equipped with a single shut-off valve in a multiple tank.

[Current regulation]

[Request]

② Establish standards for certification of modifications in tank size [GTR No.13]

Category	Contents
Current regulation	A complete certification test is required for any changes in length and diameter of the tank
Request	In EC79 Regulation, only some of the evaluation tests are required when the tank is modified. [Diameter change, Length change, Nominal working pressure change] Request to reduce the number of evaluation tests for the modifications in the size of tank.

✓ A Proposal on the regulation and standard for expanding the supply of FCEV

③ Deregulation on container service life extension [GTR No.13]

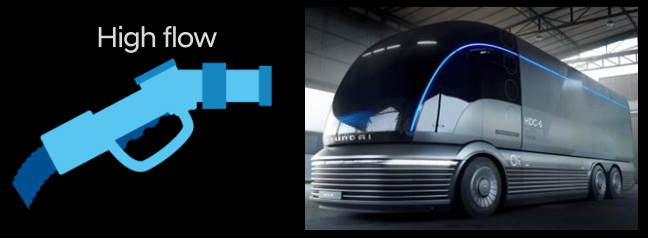
Category	Contents
Current regulation	The maximum service life of the container is 15 years.
Request	The maximum service life of the tank in EC79 regulation is 20 years. In order to spread FCEV expansion, suggest criteria for the extended service life of the tank

④ Development of hydrogen fueling protocol for heavy duty vehicles [SAE Interface task force]

Category	Contents
Current standards	Only hydrogen fueling protocol for the light duty vehicle exists. (SAE J2601, max flow rate < 60g/s)
Request	High flow fueling protocol for heavy duty vehicle needs to be developed to reduce refueling time, which is essential for commercialization of the heavy duty vehicle.

[Current standard]

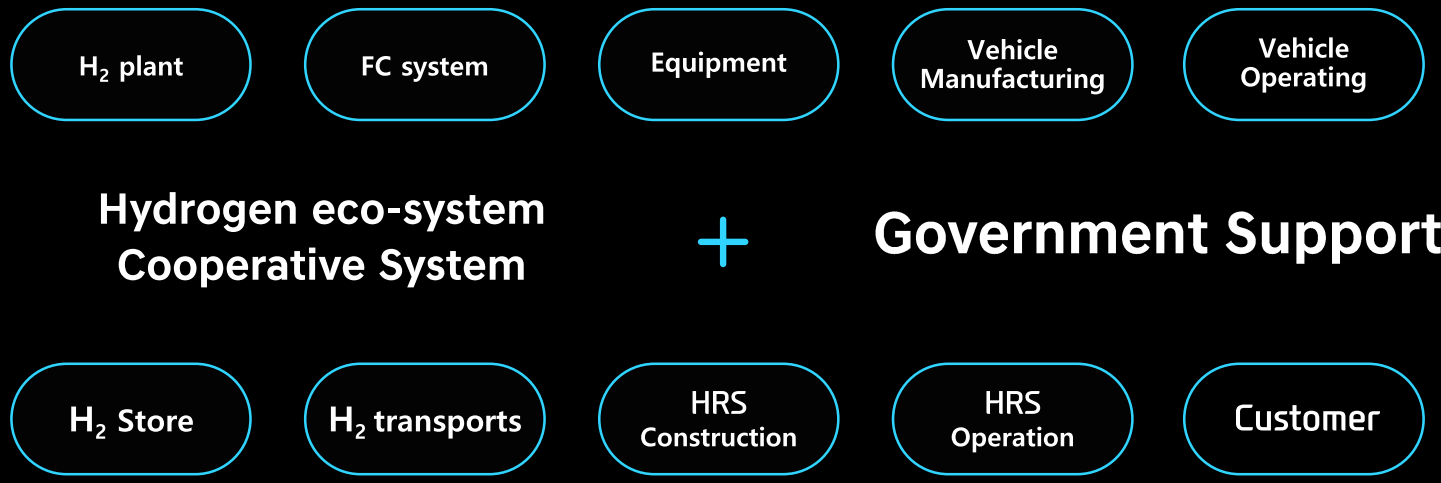
High flow

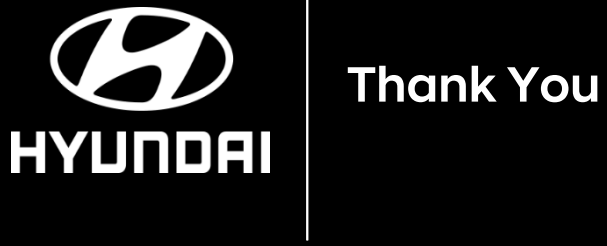


[Request]

✓ Establishing a Cooperative System for the Development of Hydrogen Industry

- Key to the success of Hydrogen economy is the active support and aid from the government
- To develop technology and invest continuously in the hydrogen production, distribution, and operation of applications




HYUNDAI
Thank You