Current Status of Hyundai's FCEV Development

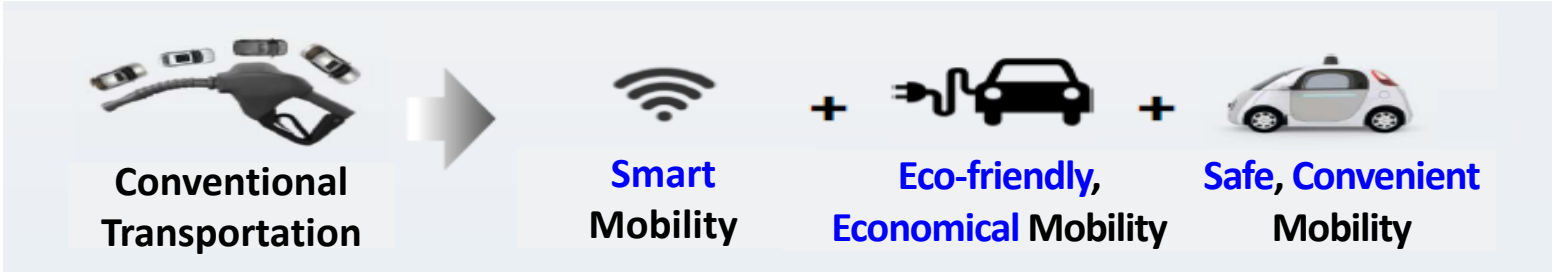
'19. 4. 3

Dr. SANGHO YOON

FUEL CELL Division, Hyundai Motor Company

INTRO – HMG's Key Directions for Future Mobility

- ***Paradigm shift*** in automotive industry has brought a new concept of mobility



Contents

Global Environmental Challenges

Economic Growth → *Environmental Issues* → Industry Adaptation

- Environmental Issues (Climate Change, Air Quality, Energy Security) drive automotive industry to change
- Increased attention for the use of low carbon energy resources

CLIMATE CHANGE

- Reducing CO2 emissions
- Global agreement
  ※ COP21, PARIS 2015
  - A goal of limiting global warming to less than 2°C compared to pre-Industrial levels

AIR QUALITY

- Regulation of NOx
- To restrict Combustion Vehicles
  ※ Norway, Netherland
  - Combustion Vehicles selling will not be allowed until 2025

ENERGY SECURITY

- Renewable Energy Development
- Diversification of energy sources
- Investment of alternative energy technology

“ The automotive industry is facing challenges & opportunities ”

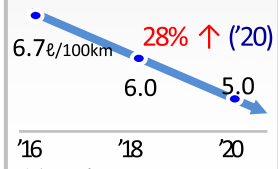
Environmental Regulations and Automotive Industry

Sales Mandates and Purchasing incentives expands *Zero Emission Vehicle* Market

Fuel Economy Regulation

CHINA

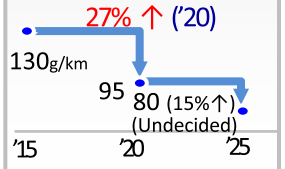
Fuel Economy Regulation



※ Penalty
: Certification Restrict
→ Vehicle Sales Restrict

EU

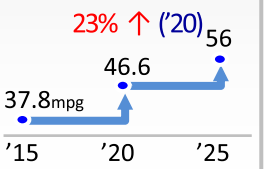
CO_2 Regulation



※ Penalty
: €95 × 1g/km × Total Sales Vol.

USA

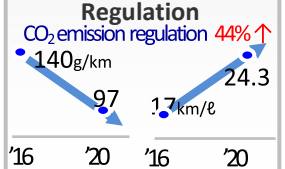
Avg. Regulation (CAFÉ)



※ Penalty
: $14/0.1mpg ×Total Sales Vol.

KOREA

CO_2 / Fuel Economy Regulation



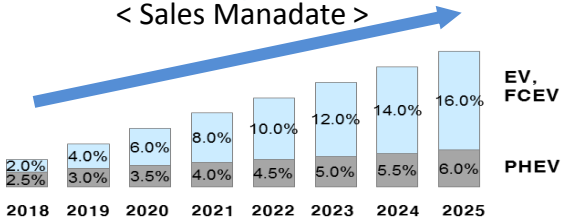
※ Selectable during CO_2 or fuel economy regulation

USA, ZEV*

◎ Target

- CA: 1.5 million vehicles by 2025
- $5,000 penalty per 1 credit
- It has been adopted by 10 states (California, New York etc.)

< Sales Manadate >



* ZEV: Zero Emission Vehicle

CHINA, NEV**

◎ The Plan set a sales target
: 5 million vehicles by 2020
※500,000 vehicles by 2015

◎ NEV account for more than 30% of annual new vehicle purchases of central government, public institutions

◎ Sales Mandate for NEV

Year	2019	2020	2021
Case #2	10%	12%	14%

2022	2023	2024	2025
16%	18%	(undecided)	27%

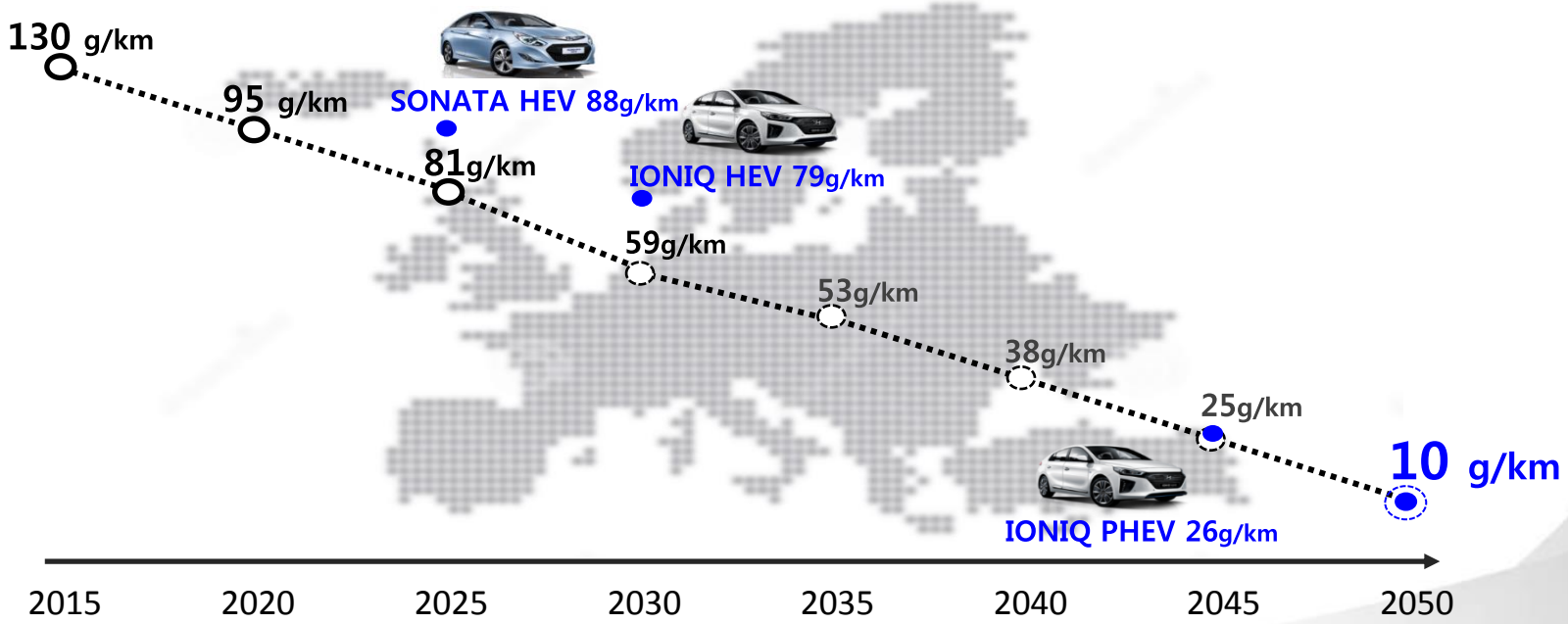
※ Sales ≥ 30,000 unit/year

** NEV: New Energy Vehicle

Environmental Regulations and Automotive Industry

Penalty is Reality for automotive OEMs.

- €95 × 1g/km × Total Sales Vol. (EU)



Enforcing Regulatory Policies for Internal Combustion Engines

Internal Combustion Ban Opens Up New Opportunities for ZEV's

EU

Agree to 30% cut of truck & bus CO_2 emissions by 2030
(Interim target of a 15% reduction by 2025, based on 2019 levels)

※ Car by 37.5% reduction, Van by 31% reduction (by 2030 compare to 2021)

NORWAY

Combustion Engine Vehicle's Sales Ban from 2025

CHINA

Restriction of newly established company with only conventionally fueled vehicles, including hybrids and plug-in hybrids from 2019 1/10.

GERMANY

German cities ban older diesel cars
(Frankfurt, Darmstadt, Berlin, Munich, Essen, Mainz, Hamburg etc.)

- **Darmstadt (The state of Hesse)**
  : To ban Euro 5 standard from mid-2019
- **Frankfurt**
  : Prohibited from entering the city center
  Euro 4 from Feb. 2019, Euro 5 from Sep.2019

UK / FRANCE

Diesel Engine Vehicle's Sales Ban from 2040

KOREA

Plan to ban Diesel Engine Vehicles from 2030

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OEM's Green Car Strategies

Preparation for ***Future Automotive*** Market already In-Motion

- Volkswagen to stop making gasoline & diesel cars in 2026 ('18. 12)

" In the year 2026 will be the last product start on a combustion engine platform."
- Michael Jost, VW strategy head

- Hyundai plans to introduce 38 eco-friendly vehicles by 2025 ('17. 8)
- HMG announced its long-term roadmap 'FCEV Vision 2030' plan ('18. 12)

- Toyota aims to eliminate gasoline cars by 2040 ('17. 10)

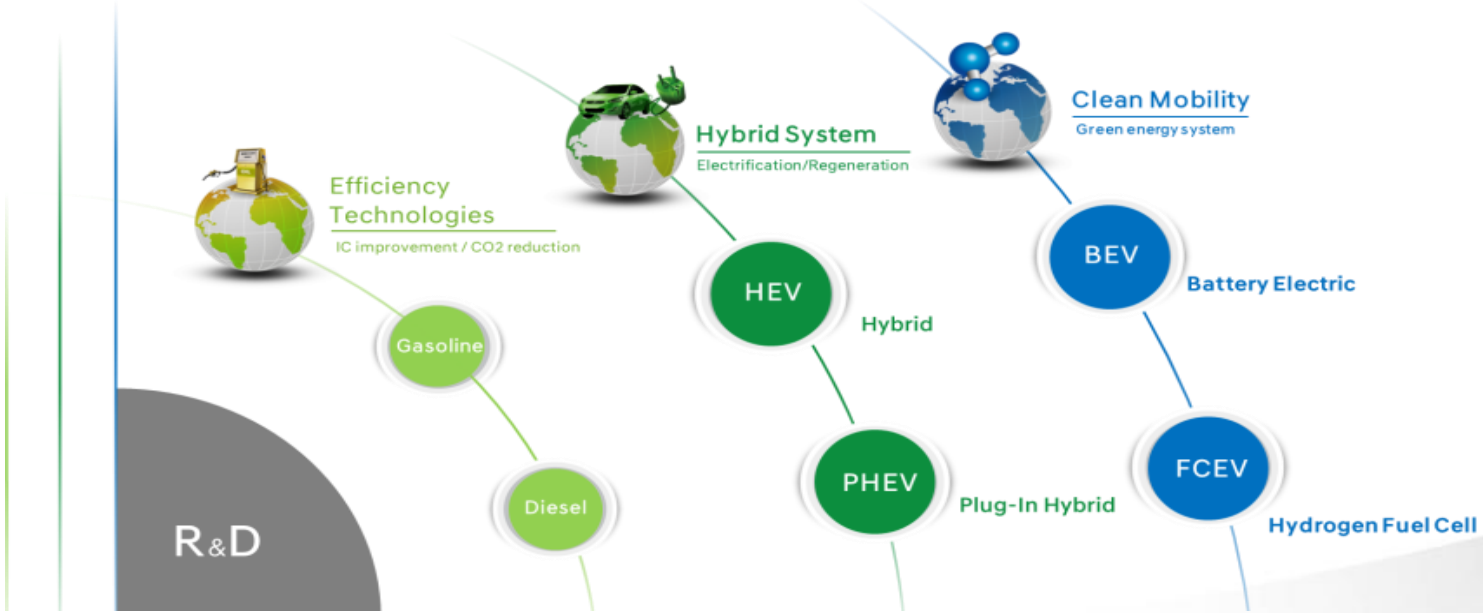
- Volvo to use electric motors in all cars from 2019 ('17. 7)

Contents

HMC Green Car Line-up Strategy

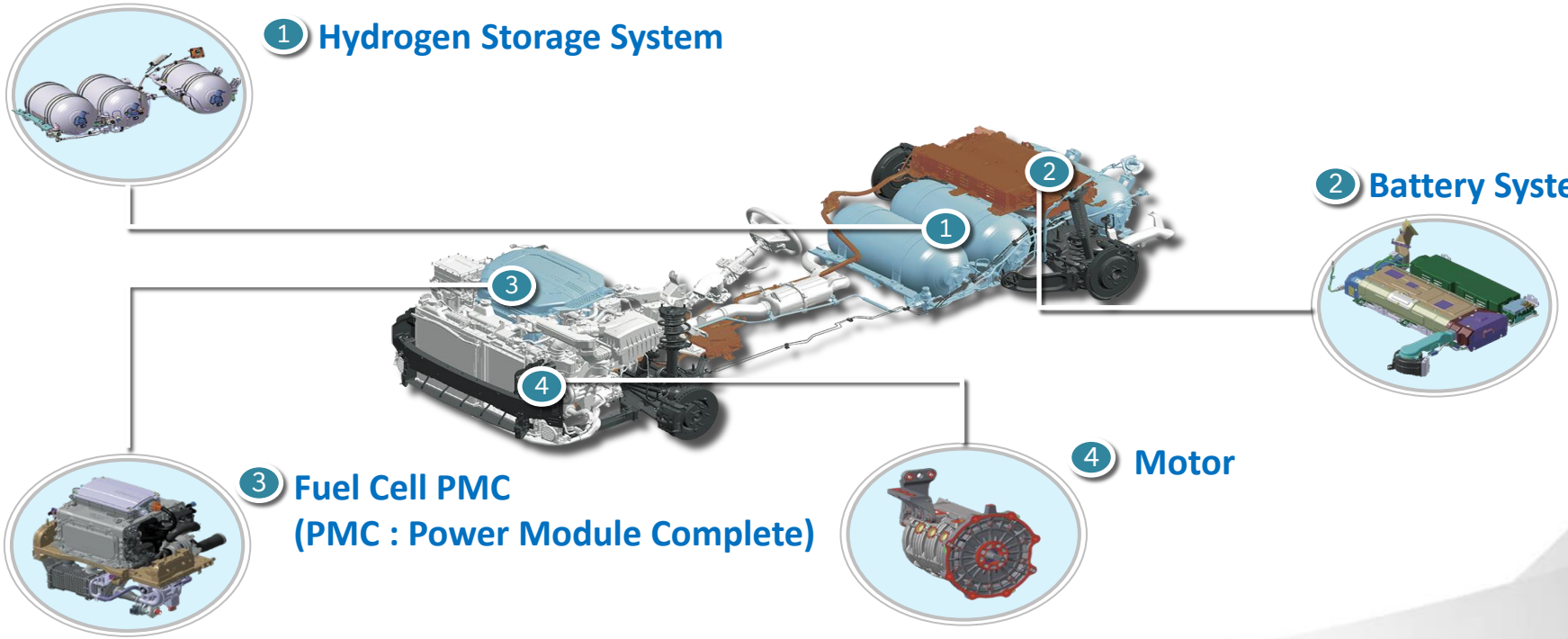
Green Car Strategy

- Fuel economy improvement (New engine & T/M technologies, Weight reduction)
- Hybridization : Combustion + Electrification (HEV, Plug-in HEV)
- Electrification : Hydrogen & Electricity (FCEV, BEV)



Fuel Cell Electric Vehicle

FCEV : ***Fuel cell system + Hydrogen storage system*** + Battery / Motor system

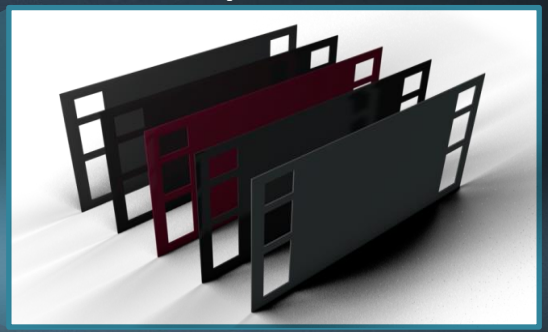


Sub-system of FCEV : Stack

- ***Electricity generation*** using electrochemical reaction of ***hydrogen & oxygen***

$$H_2 + O_2 \underset{\text{Electrolyzer}}{\overset{\text{Fuel cell}}{\rightleftharpoons}} H_2O + \text{Electricity}$$

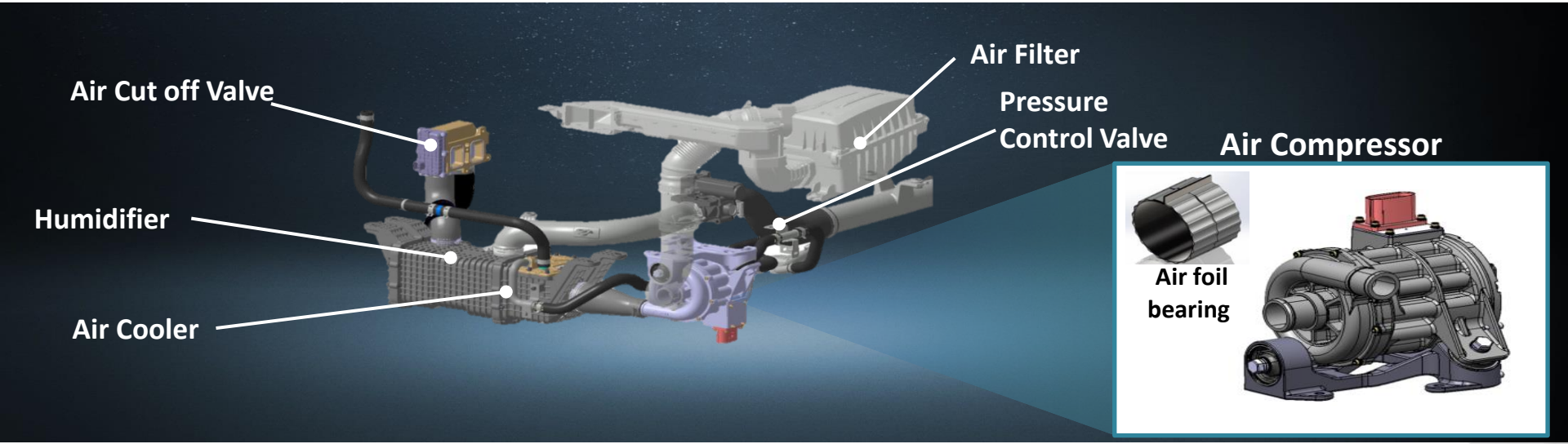
MEA* / 3D porous flow field



* MEA : Membrane Electrode Assembly

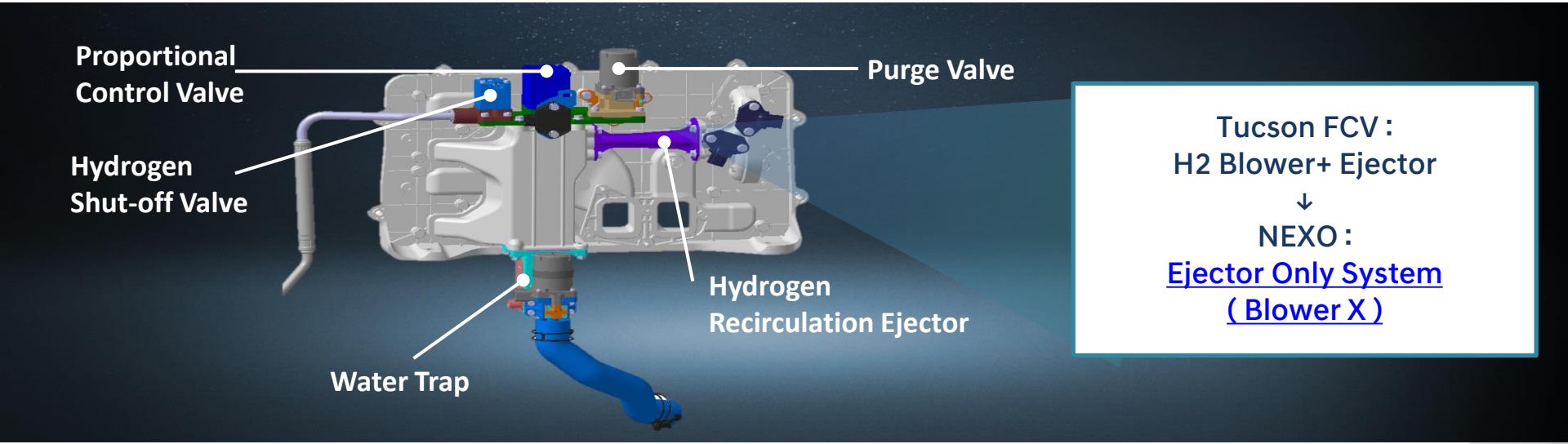
Sub-system of FCEV : APS (Air Processing System)

- ***Supply of air (oxygen)*** for the electrochemical reaction within the fuel cell



Sub-system of FCEV : FPS (Fuel Processing System)

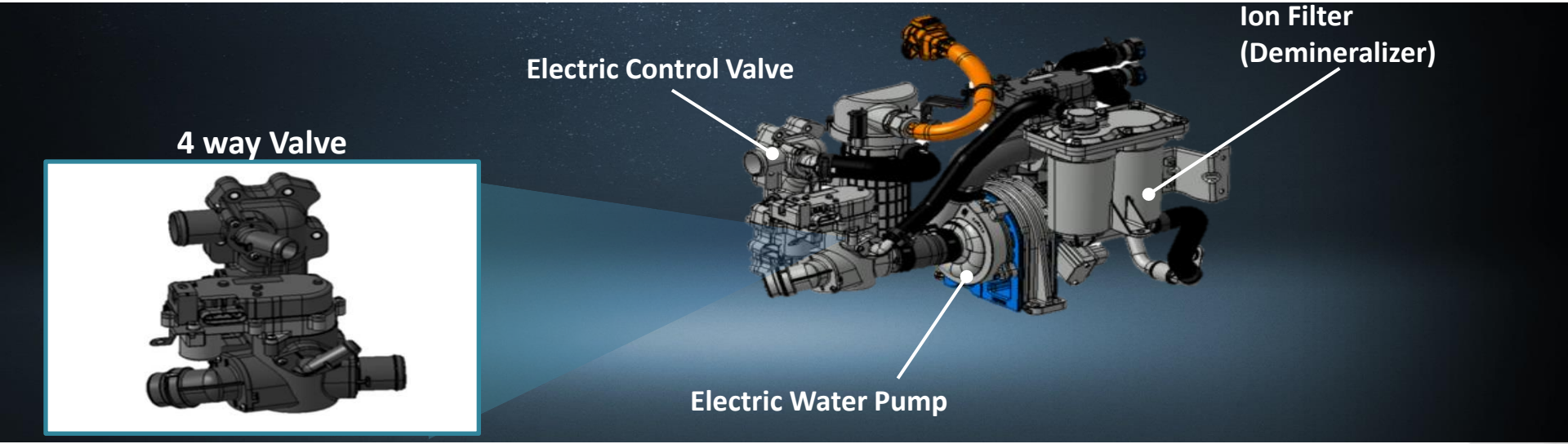
- ***Supply of hydrogen*** for the electrochemical reaction within the fuel cell



Tucson FCV :
H2 Blower+ Ejector
↓
NEXO :
Ejector Only System
(Blower X)

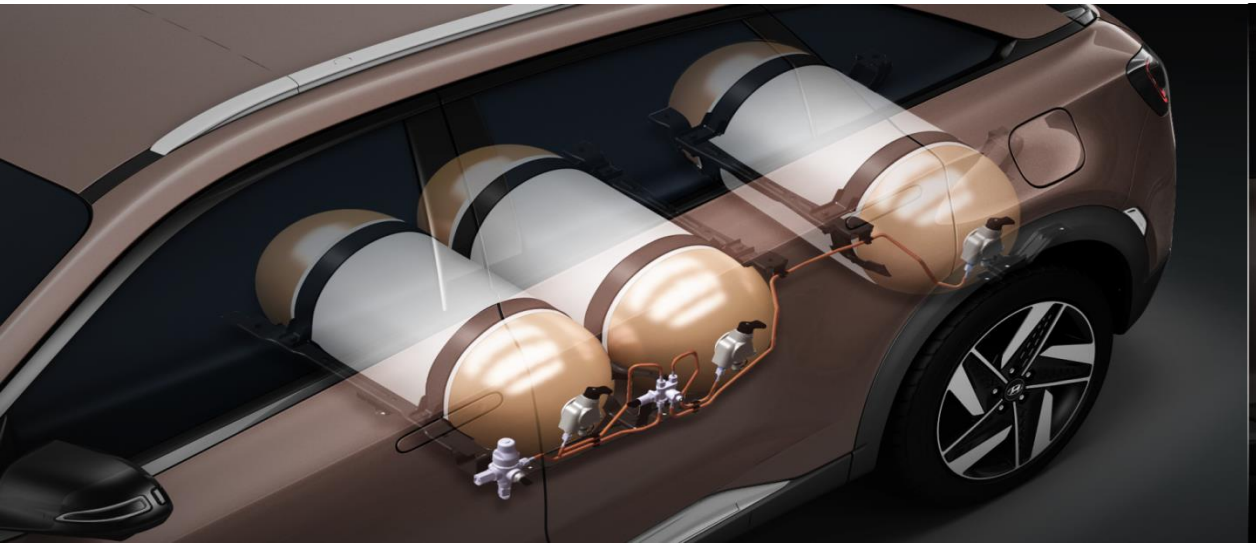
Sub-system of FCEV : TMS (Thermal Management System)

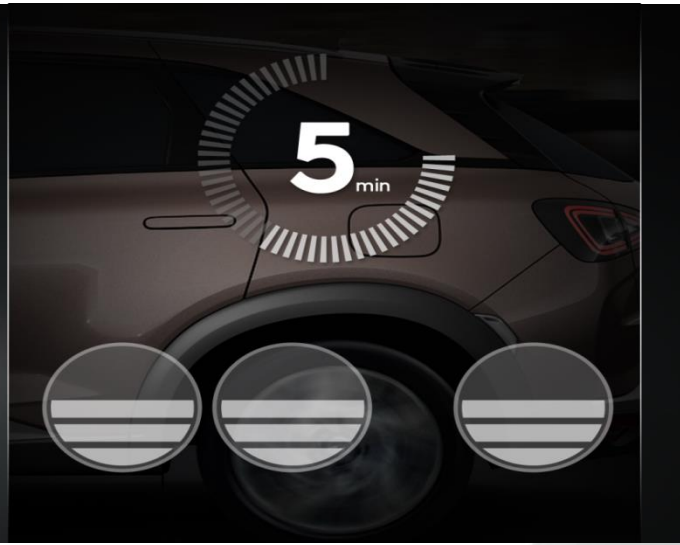
- ***Control of the coolant temperature*** for FC stack



Sub-system of FCEV : Hydrogen Storage

- ***High pressure hydrogen (350 or 700 bar)*** is stored in carbon fiber tank
  - Certification (EC No.79/406, EVE R-134) : VCA (Vehicle Certification Agency) & KGS (Korea Gas Safety corporation)
  - Test : 14 items in KGS, EC No. 79/406, 5 items in GTR No.13





Performance Test of FCEV

FCEV & FC System *Test*

- Hot & Cold Test : Environmental Chamber & On-site Test
- Durability Test : Real Driving & Simulation Test for FCEV & FC System
- Performance Test : Fuel Economy, System Efficiency, Power Test

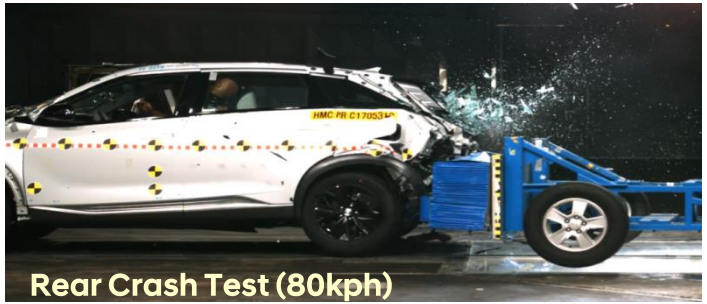
FCEV Test

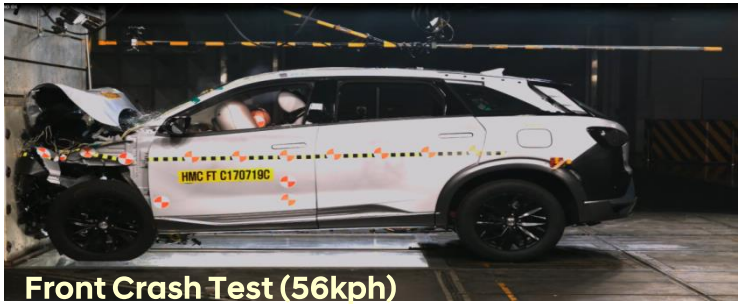
System Test

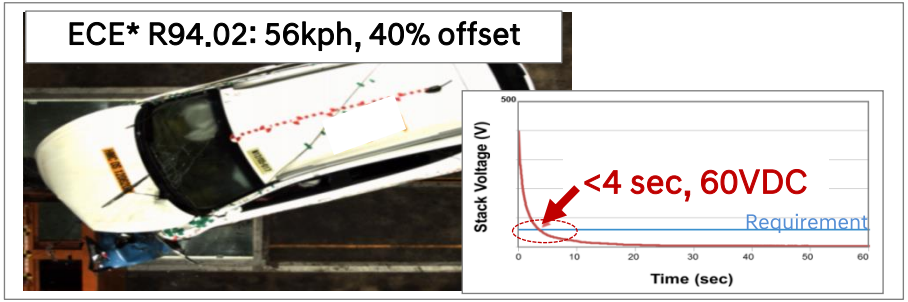
Safety Test of FCEV

Electrical & Hydrogen ***Safety***

- Crash test : High voltage safety and no hydrogen leakage
- Electrical safety : After collision 60V or less within 4 seconds (standard within 60sec.)







* ECE: Economic Commission for Europe Regulations

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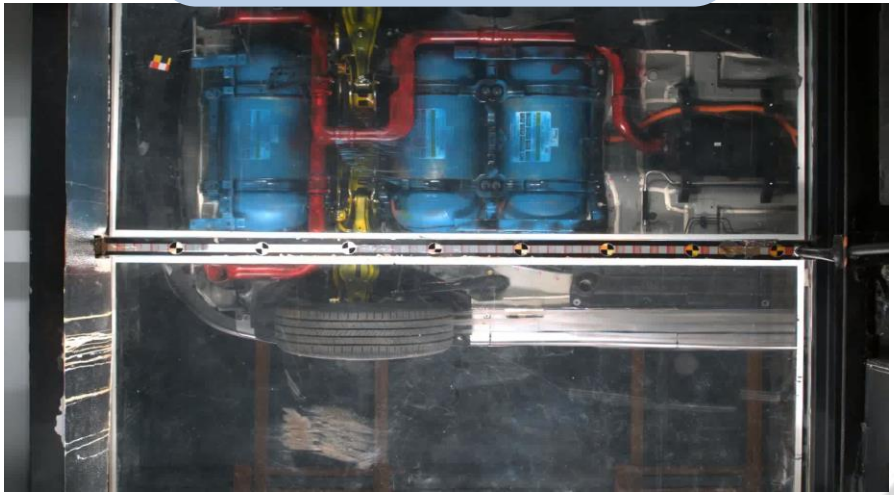
Crash Test_Movie

Front Crash

Rear Crash



Hyundai Green Cars Development Status – NEXO

- The maximum ***Five-star*** overall safety rating from ***Euro NCAP****
  - NEXO has been awarded ‘Best in Class’ of 2018 in the ‘Large Off-Road’ category

** Euro NCAP : the European New Car Assessment Programme*

TEST RESULTS

EURO NCAP FOR SAFER CARS

Hyundai NEXO
Standard Safety Equipment

2018 ★★★★★

Adult Occupant	Child Occupant
94%	87%

Vulnerable Road Users	Safety Assist
67%	80%

Hyundai Green Cars Development Status – Tucson FCV

World 1st Mass-produced Tucson FCV ('13.2)

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

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

Belgian
'Price FuturAuto'

Korea
Silver Award

USA
2015 WARD's
10 Best Engine

France
Eco- friendly Car of
year form La Revue

※ **Wards 10 Best Engines** : An annual list of the ten "best" automobile engines available in the U.S. market, that are selected by Ward's AutoWorld magazine

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Hyundai Green Cars Development Status – NEXO

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

	Tucson ix FCEV (`13)	NEXO (`18)
System efficiency	55%	**60%**
Power	100kW	**120kW**
Cold Start	-20℃	**-30℃**
Range	415km	**609* km**

2019 WARD's 10 Best Engine

2018 CES EDITORS' CHOICE

2018 CES ASIA TOP TECH Winner

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

Integration System
[Fuel Cell + Electric Motor]

2. Durability & Storage

- Durability equivalent to conventional ICE
: 160,000km in 10 years
- **The world-first 700 bar / Type4 3 tanks system : maximize cargo volume**

Hydrogen storage system

3. State-of-the-art ADAS Systems

Blind-spot View Monitor

Highway Driving Assist/
Lane Follow Assist

Remote Smart Parking Assist

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Hyundai Green Cars Development Status – commercial vehicles

- Expand Application of hydrogen fuel-cell systems to ***Commercial Vehicle classes***
  - The hydrogen bus pilot project will put a total of 30 Hyundai FCEV Buses into operation
    7 in Seoul, 6 in Gwangju, 3 in Ulsan, 5 in Changwon, 4 in Asan and 5 in Seosan (Nov. 2018)
  - HMC to supply 1,000 hydrogen fuel cell trucks to the Swiss commercial vehicle market over next five-year period, starting in 2019 (Sep. 2018)

New hydrogen fuel cell bus

Fuel cell truck

Strategic Partnership

Collaborations with Business Partners to Expand & Lead FCEV Market

- Hyundai and Audi agreed to share Fuel Cell Patents and some FC components & its suppliers (June. 2018)
- Hyundai Motor, Air Liquide and ENGIE sign MOU to supply 5,000 units of FCEVs (Oct. 2018)

HMC - AUDI

HYUNDAI

Cross-license agreement
Share component

Audi

HMC - Air Liquide - ENGIE

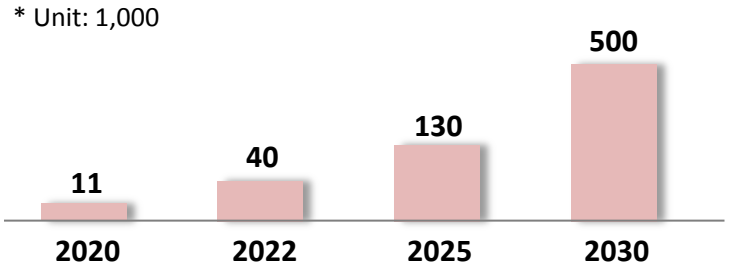
Contents

FCEV Vision 2030 for Hyundai Motor Group

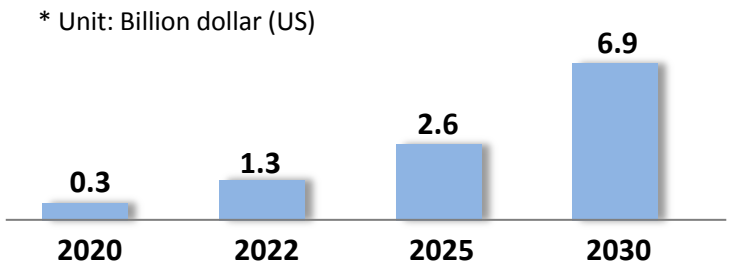
- Announcement of HMG's long-term roadmap '***FCEV Vision 2030***' plan (11.Dec.2018)

  Plans to produce 700k fuel-cell systems annually by 2030 including ***500k units for FCEVs***

FCEV Production (plan)



Investment



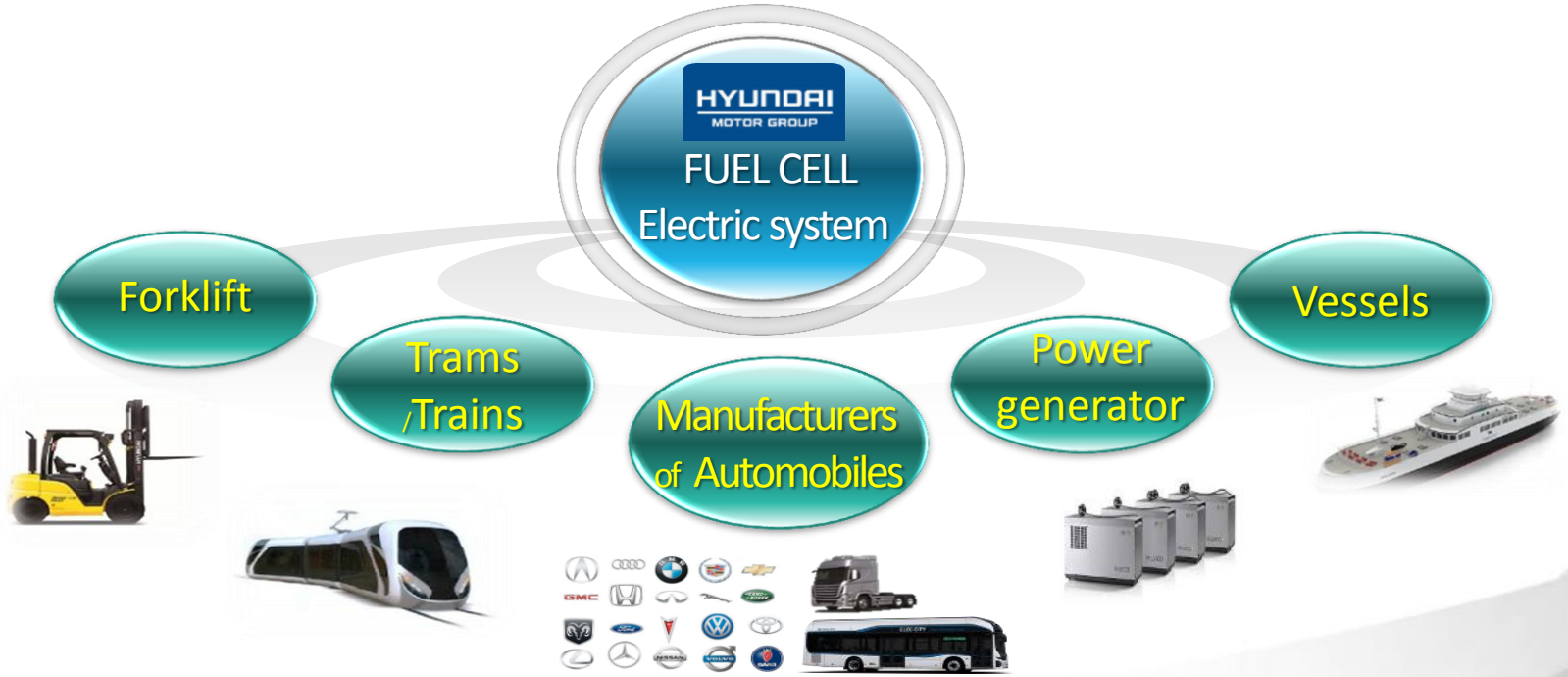
"***As a first mover*** in the forthcoming hydrogen economy, we will ***lead a society that uses hydrogen*** as its main source of energy."

Euisun Chung,

Executive Vice Chairman of Hyundai Motor Group

FCEV Vision 2030 for Hyundai Motor Group

- ***New Businesses Opportunities for Fuel Cell Systems*** beyond Automotive Indust



NEXO

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“Lifetime Partner in Automobiles and Beyond”
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NEW THINKING.
NEW POSSIBILITIES.