Current Status of Hyundai’s FCEV Development

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.

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**Conventional Transportation**

<table>
<thead>
<tr>
<th>Smart Mobility</th>
<th>Eco-friendly, Economical Mobility</th>
<th>Safe, Convenient Mobility</th>
</tr>
</thead>
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**Connected Mobility**

**Clean Mobility**

**Freedom in Mobility**
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1. Environmental Challenges & Automotive Industry
2. HMC FCEV Development Status
3. Hydrogen Vision of Hyundai Motors
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

**CHINA**
- Fuel Economy Regulation
  - CO₂ Regulation: 6.7g/100km in 2016, 6.0g/100km in 2018, 5.0g/100km in 2020
  - Avg. Regulation (CAFÉ): 37.8mpg in 2015, 46.6mpg in 2020, 56mpg in 2025

**EU**
- CO₂ Regulation: 130g/km in 2015, 95g/km in 2020, 80g/km (15%↑) in 2025

**USA**
- CO₂ / Fuel Economy Regulation: 140g/km in 2016, 97g/km in 2020, 17.2mpg in 2025

**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.)

**USA: Sales Mandate**

< Sales Mandate >

**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

<table>
<thead>
<tr>
<th>Year</th>
<th>2019</th>
<th>2020</th>
<th>2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>Case #2</td>
<td>10%</td>
<td>12%</td>
<td>14%</td>
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</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>2022</th>
<th>2023</th>
<th>2024</th>
<th>2025</th>
</tr>
</thead>
<tbody>
<tr>
<td>16%</td>
<td>18%</td>
<td>(undecided)</td>
<td>27%</td>
<td></td>
</tr>
</tbody>
</table>

* 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

- **Agree to 30% cut of truck & bus CO₂ 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)

- **Combustion Engine Vehicle’s Sales Ban from 2025**
  - Restriction of newly established company with only conventionally fueled vehicles, including hybrids and plug-in hybrids from 2019 1/10.

- **Diesel Engine Vehicle’s Sales Ban from 2040**
  - **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

- **Plan to ban Diesel Engine Vehicles from 2030**
  - **Korea**
  - **China**
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)
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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

1. Hydrogen Storage System
2. Battery System
3. Fuel Cell PMC (PMC: Power Module Complete)
4. Motor
Sub-system of FCEV: Stack

Electricity generation using electrochemical reaction of hydrogen & oxygen

\[ \text{H}_2 + \text{O}_2 \stackrel{\text{Fuel cell}}{\rightarrow} \text{H}_2\text{O} + \text{Electricity} \]

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

- **Supply of air (oxygen)** for the electrochemical reaction within the fuel cell.
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**
- Hot Test
- Cold Test
- High Altitude
- Dynamo

**System Test**
- System Test
- Efficiency
- Dynamo
- Chamber
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.)

- Firing Test
- Drop Test
- Gunshot Test
- Extreme Environment Cycles
- Rear Crash Test (80kph)
- Front Crash Test (56kph)

ECE* R94.02: 56kph, 40% offset

* ECE: Economic Commission for Europe Regulations
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
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

<table>
<thead>
<tr>
<th>FC stack</th>
<th>100 kW</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traction Motor</td>
<td>100 kW</td>
</tr>
<tr>
<td>Battery</td>
<td>24 kW</td>
</tr>
<tr>
<td>H2 Tank</td>
<td>700 bar</td>
</tr>
<tr>
<td>Driving Range *</td>
<td>415 km</td>
</tr>
</tbody>
</table>

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

- [Belgian ‘Price FuturAuto’ Silver Award] (image)
- [Korea Silver Award] (image)
- [USA 2015 WARD’s 10 Best Engine] (image)
- [France Eco-friendly Car of Year from La Revue] (image)

* 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
**Hyundai Green Cars Development Status – NEXO**

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

<table>
<thead>
<tr>
<th></th>
<th>Tucson ix FCEV (`13)</th>
<th>NEXO (`18)</th>
</tr>
</thead>
<tbody>
<tr>
<td>System efficiency</td>
<td>55%</td>
<td>60%</td>
</tr>
<tr>
<td>Power</td>
<td>100 kW</td>
<td>120 kW</td>
</tr>
<tr>
<td>Cold Start</td>
<td>-20 °C</td>
<td>-30 °C</td>
</tr>
<tr>
<td>Range</td>
<td>415 km</td>
<td>609 km</td>
</tr>
</tbody>
</table>

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 in 10 years
   - *The world-first 700 bar / Type4 3 tanks system : maximize cargo volume*

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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2019 WARD’s
10 Best
Engine

2018 CES
EDITORS’
CHOICE

2018 CES ASIA
TOP TECH
Winner

Integration System
[Fuel Cell + Electric Motor]

Hydrogen storage system

WARD’S
10 BEST
ENGINES
2019

CES
ASIA
2018 TOP
TECH
WINNER
Hyundai Green Cars Development Status – commercial vehicles

I. 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)
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)
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"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
New Businesses Opportunities for Fuel Cell Systems beyond Automotive Industry
“Lifetime Partner in Automobiles and Beyond”