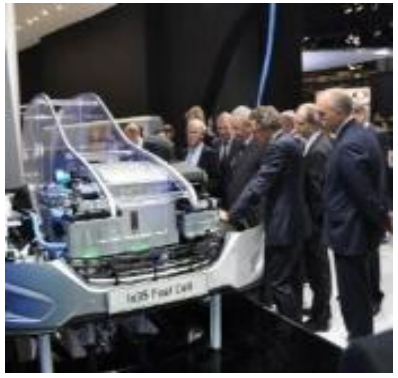
Hydrogen Fuel Cell Electric Bus Development and Dissemination Strategy of Hyundai



May 18, 2016

Bo Ki Hong

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History of Hyundai's Hydrogen FCEV* Development

> 600 SUVs & Buses (May, 2016)

Over 5 million km (3 million miles)

* Fuel Cell Electric Vehicle

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World's 1st Mass Production of Hydrogen FCEV

Tucson ix35 (Feb., 2013)

Ward's 10 Best Engines (2015)

First among FCEVs

Next Generation FCEV (2018)

Key Target Performances

Driving Range [km]	~ 800 km
Max. Speed [km/h]	> 170 km/h

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Lessons Learned: H_2 Infrastructure, Public Awareness & Cost

Expansion of H_2 infrastructure is very challenging ("Easier said than done")

- A Lack in Hydrogen Refueling Stations (HRSs)

  : North America (71), Europe (87), Japan (36), Korea (11) [Nov., 2014]

- A strong network of HRSs is required for deploying FCEVs in the world.

Public awareness on the benefit of H_2 energy and FCEV is still very low

- Over the last few years, general public awareness on electric vehicles has increased dramatically, but people still have little idea about the benefit of H_2 energy and FCEV.

  → This will cause weak public support for building the H_2 infrastructure.

- Improving the public awareness on the necessity of hydrogen and FCEV for the society is critical to the success of FCEV commercialization.

What's the next step?

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Current Status of Bus Business in Korea

Current Status

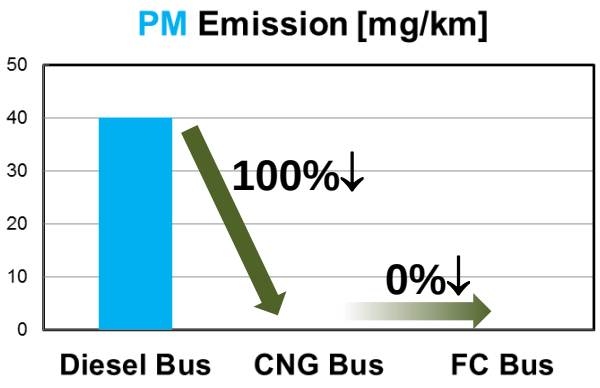
✓ **Air Pollution Issues**

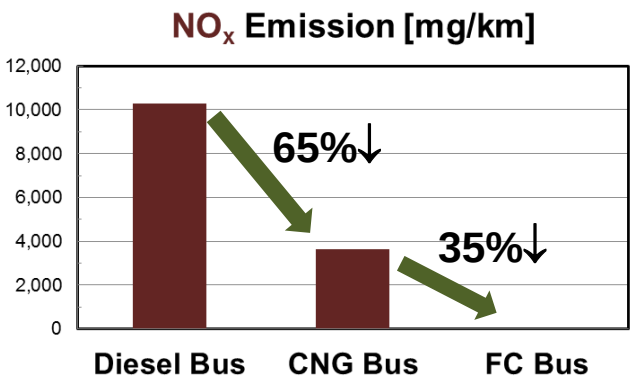
(NO_x, PM*, CO, CO_2 & HC)

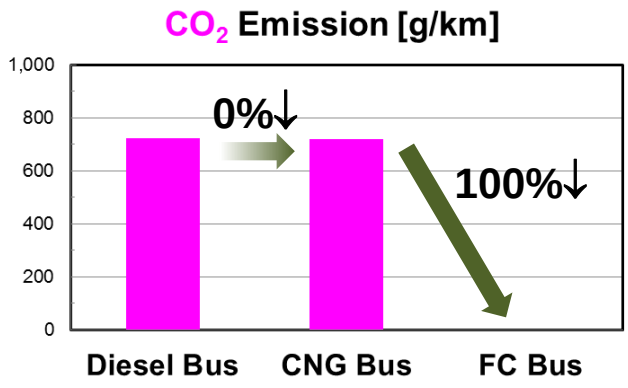
[Reference] Website of Chosun Media (www.chosun.com) (April 23, 2016).

✓ **Diesel Bus → CNG** Bus**

→ **Hydrogen FC Electric Bus**







[Reference] The emission test data for diesel and CNG buses under NIER test mode reported by Korean Ministry of Environment in 2012 were cited from the Website of Korean Association of Natural Gas Vehicles (www.kangv.org) (May 13, 2016).

*Particulate Matter; **Compressed Natural Gas

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Current Status of Bus Business in Korea

- ✓ Approximately 31,000 CNG buses are currently in operation in Korea.

  → Lots of operation experience of CNG buses and refueling stations (196 CNG stations).

Methane
CH_4

- ✓ In spite of the improved air quality by using CNG buses for the past decades, there are still strong needs for "greening" cities further to improve quality of living.

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Pros and Cons: CNG Bus *vs.* Hydrogen FC Electric Bus

Item	CNG Bus	Hydrogen FC Electric Bus
Zero-Emission Capability	-	+
Energy Independence from Fossil Fuels	-	+
Noise/Vibration Mitigation	-	+
Driving Range	+	+
Refueling Time	+	+
Route Flexibility	+	+
Technological Maturity	+	-

(+) Good; (-) Poor.

[References]
1) ″Necessity for Governmental Support for Hydrogen Infrastructure″, Korean Gas News (April 15, 2016).
2) ″Fuel Cell Electric Buses – Potential for Sustainable Public Transport in Europe″, FCH-JU (December, 2015).
3) ″Challenges and Solutions of CNG Bus″, Korean Gas News (March 25, 2013).
4) ″Fuel Cell Market Survey: Buses ″, Fuel Cell Today (November, 2003).

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Pros and Cons: Hydrogen FC Electric SUV* *vs.* Bus

Item	Hydrogen FC Electric SUV	Hydrogen FC Electric Bus
Consumption Amount of Fuel Cell Components	-	+
Vehicle Package Layout	-	+
H_2 Refueling Infrastructure	-	+
Public Awareness (Attracting People's Attention)	-	+
Conventional Market Size	+	-

(+) Good; (-) Poor.

✓ **FC electric bus needs a larger amount of FC components than FC electric SUV → Useful to boost an initial market of unique FC components**

✓ **Easier to fit a fuel cell system into a bus.**

✓ **Hydrogen FC electric buses are refueled at bus depots**

→ **Less requirements for H_2 infrastructure on the operation route.**

* Sports Utility Vehicle

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Hydrogen FC Electric Bus Development of Hyundai

FC Bus – 1st Generation (2006)

Fuel Cell Power	160 kW
Power Assistance	Super Capacitor
Motor System Power	240 kW
H_2 Tank	40 kg H_2 (@ 35 MPa)
Max. Speed	74 km/h

FC Bus – 2nd Generation (2009)

Fuel Cell Power	200 kW
Power Assistance	Super Capacitor
Motor System Power	300 kW
H_2 Tank	40 kg H_2 (@ 35 MPa)
Max. Speed	103 km/h

Driving Range: ~ 370 km
(Local City Mode)

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Next Generation Hydrogen FC Electric Bus of Hyundai

Current Status

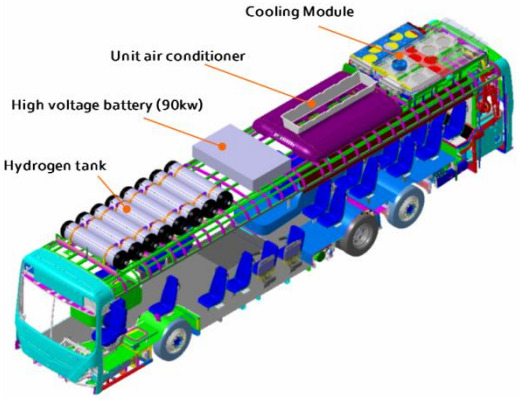
▣ **5 FC Buses in Operation**

- Total Mileage > 300,000 km
- Verified Durability

Next Generation FC Bus

▣ **Next Generation FC Bus (~ 2019)**

- Improved Power Train
- Cost-Effective Components
- Enhanced Durability



- New Announcement of Governmental Project for FC Bus Development (MOTIE*, May 2016)

*Ministry of Trade, Industry and Energy (Korea)

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Summary - Impact of Hydrogen FCEVs on Society

Energy paradigm shift continues ⇒ Hyundai's FCEVs will prove it to the public

- "The stone age did not end for lack of stone, and the oil age will end long before the world runs out of oil[1)]"

[1)]**Sheikh Zaki Yamani, Oil Minister, Saudi Arabia**

Benefit of FCEV Commercialization

✓ **Opportunity of New Job Creation and Employment**

✓ **Power Grid Stabilization and Blackout Mitigation through V2G* Technology**

✓ **Increased Energy Independence from Fossil Fuels**

✓ **Air Cleaning (like running the "Vacuum Cleaners" on the road)**

*Vehicle to Grid

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