Development of Fuel Cell Electric Vehicle in Hyundai ·Kia Motors

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Energy Situation of Korea

- 10th Energy Consumption in the world(229.3 MTOE)
- 5th Crude Oil Importer in the world
- 2nd LNG Importer in the world

Data of 2005

Primary Energy Import
- **Oil, Natural Gas, Coal**
- **$66.7 Billion**
- **97% of Energy Consumed**

Energy Consumption
- **Coal: 84 MT**
- **Oil: 761 M bbl**
- **LNG: 23 MT**
- **Nuclear: 147 TWh**

Electricity Production
- **Hydro: 1.7 %**
- **Nuclear: 39 %**
- **Coal: 38 %**
- **Oil: 8 %**
- **LNG: 13 %**

- In 2008, 35.3 MTOE of energy is used by transportation sector which is 15% of total energy consumption in Korea

Eco-friendly Vehicle Strategy of Hyundai · Kia

blue drive

Preserving automobile mobility while creating a harmonious balance with our environment

World best eco-friendly vehicle

Low CO_2 ICE	Bio Fuel	Hybrid	Plug-In	FCV,EV
Continuous improvement of fuel economy	Respond to regional diversity of fuel use	Expanding line-up	Option for dedicated HEV	Early market penetration

CO_2 Emission

- Solution: EV & FCV
  - EV for compact car, limited driving cycle (city car, delivery car, and official car)
  - FCV for bigger car, unlimited driving cycle

Fuel Cell Vehicle Development

Small Scale Production

• 2012 ~

Validation Program
(2009.12 ~ 2011.11)

- Tucson iX FCV (100kW)

• 2008 ~ 2009

- Borrego FCV (115 kW)
- FC-BUS Gen II (200kW)

Domestic Monitoring Program
(2006.08 ~ 2010.07)

• 2007


i-Blue Concept car

- Tucson, Sportage FCV-II (100 kW)
- FC-BUS II (200 kW)

US DOE Fleet Program
(2004.09 ~ 2009.12)

• 2006

- Tucson, Sportage FCV (80 kW In House Stack)
- FC-BUS (160 kW In House Stack)

Member of CaFCP
(2000.11 ~ Present)

• 2004 ~ 2005

- Tucson FCV (80 kW)
- Sportage FCV (80 kW)

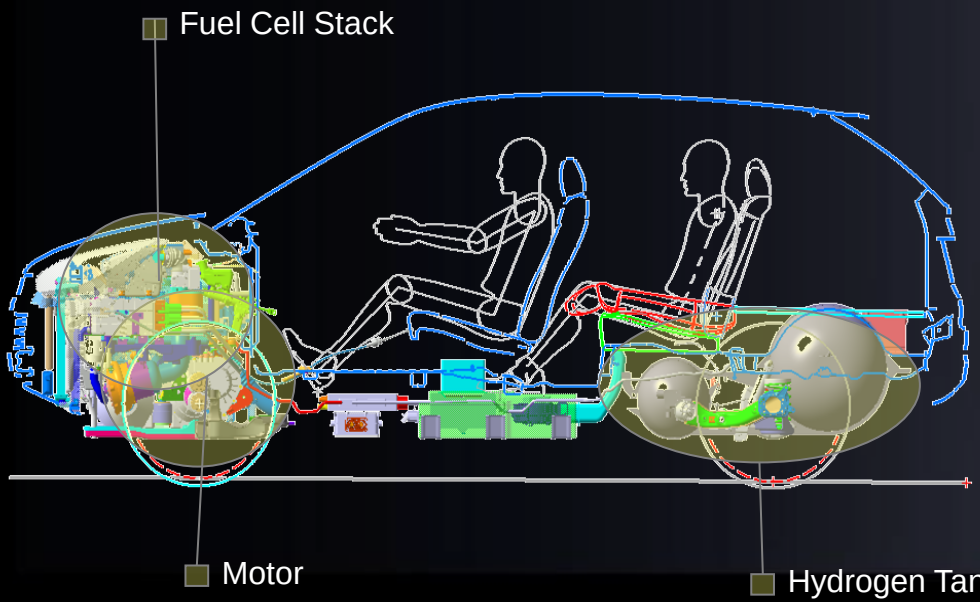
• 2000 ~ 2002

- Santa Fe FCV (75 kW)
- Sportage (10kW)

Fuel Cell Vehicle Development

Tucson iX Fuel Cell Vehicle (2012)

- Vehicle design considering small scale production
- Dramatic cost reduction through production technology
- Compact design of fuel cell system by modularization
- Extension of driving range by 70% compared to its previous version

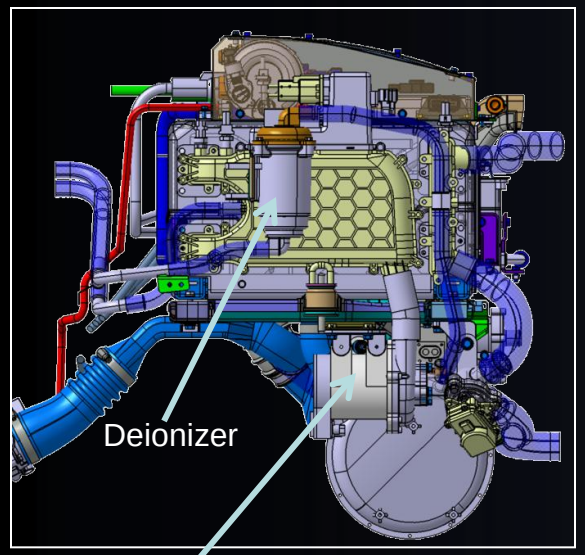


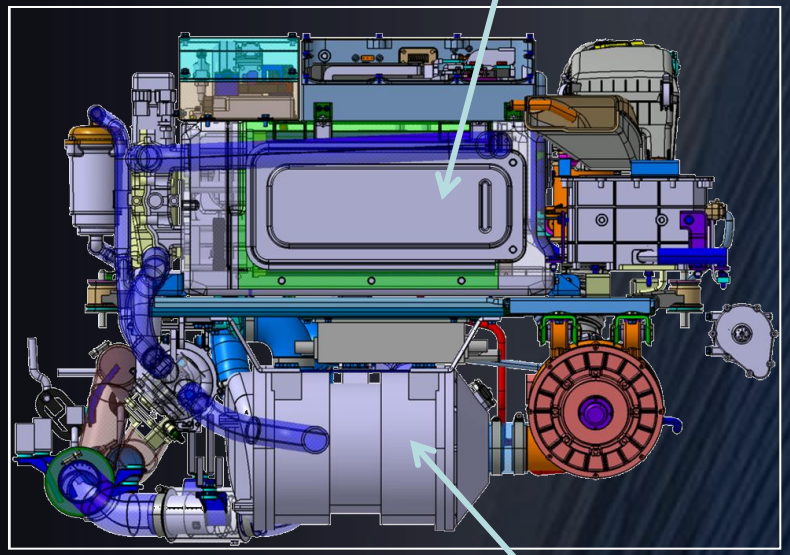
Fuel Cell Power	100 kW
Battery	34 kW
Motor System	100 kW
H_2 Tank	700 bar
Fuel Economy	31 km/l
Driving Range	650 km
Acceleration (0 → 100kph)	12.9 sec
Max. Speed	160 KPH

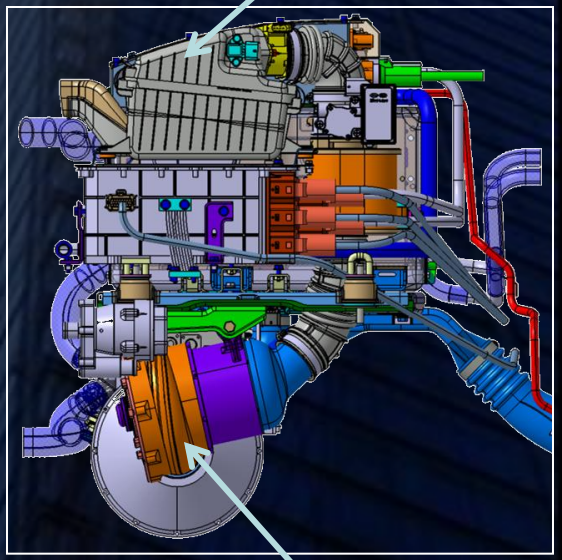
Fuel Cell Vehicle Development

Tucson iX Fuel Cell System (2012)

- Compact component design and system modularization
- System Power Density: over 620W/L (DOE Target: 650W/L)
- Gas/Gas Humidifier
- Cold Start Ability: -25ºC
- System max. Pressure: 1.45bara



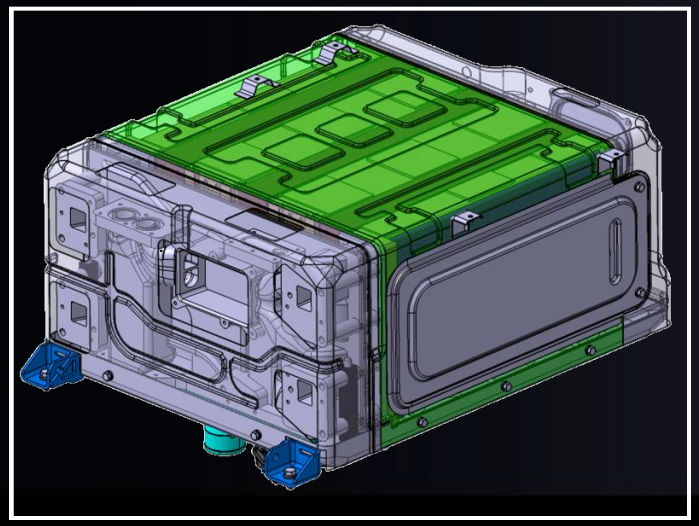


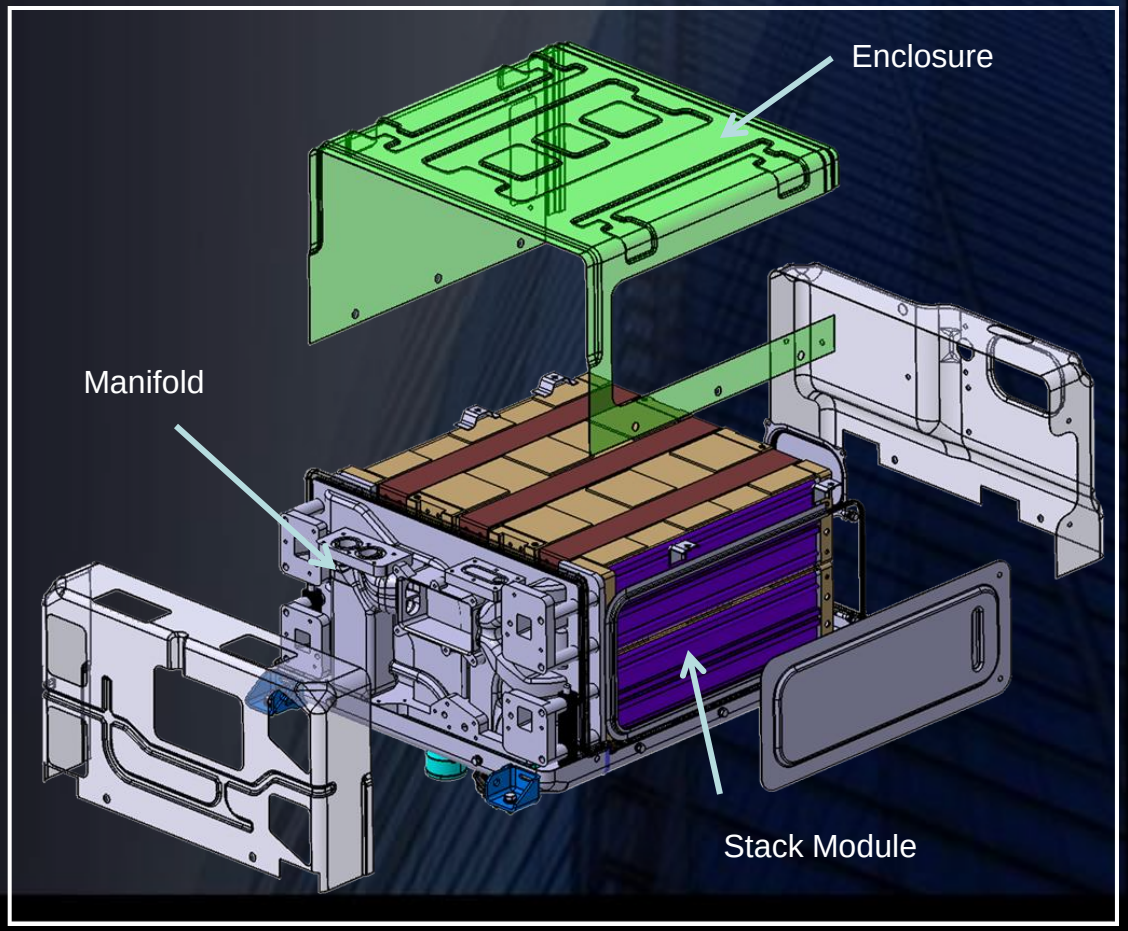


Fuel Cell Stack Development

Tucson iX Fuel Cell Stack (2012)

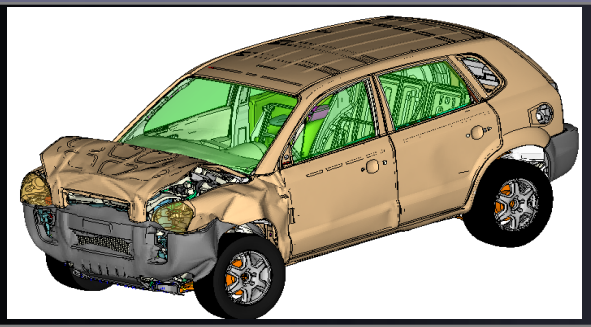
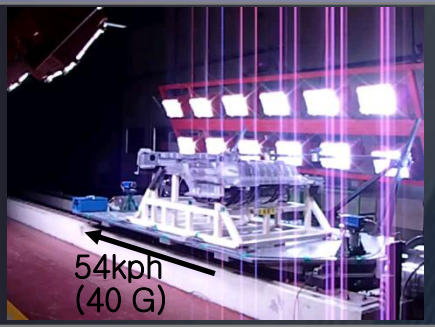
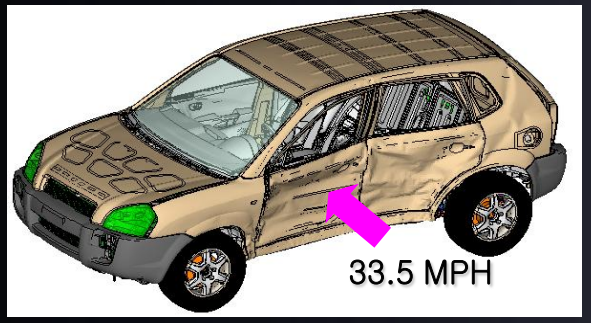
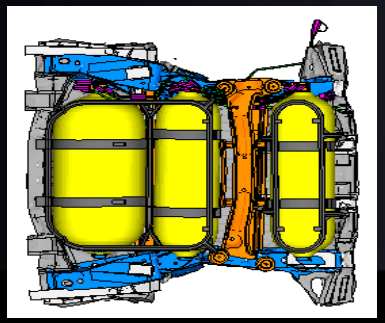
- Max. Power: 100kW
- Power Density: 1.65kW/L
- Operating Voltage: 250~450V
- Cold Start Ability: -30ºC
- Max. Air Pressure: 1.35bara
- Separator: Metal





Fuel Cell Vehicle Tests

Crashworthiness Evaluation

Test Item	Simulation	Vehicle Test
Sled Impact Test		 Before: He gas, 30bar No Leak Check the deformation of H_2 storage and delivery system
Side Impact Test (FMVSS 305)		 Before: He gas, 10bar No Leak Check the deformation of H_2 storage and delivery system. Check the H_2 tank burst pressure.
Rear Crash Test (FMVSS 301)		 Before: He gas, 30bar After: He gas, 350bar No Leak in the H_2 storage and delivery system

Fuel Cell Vehicle Tests

Start Up Test at -20°C

- Vehicle was stored at -20 ℃ for 24 hours in the environment chamber.
- Start up without external power supply → Ready to drive within 11 sec.

③ Cold-Drive ← ② Cold-Start ← ① Cold-Shutdown

Time (sec)	0	60	120	180
Logic	Start Up (11s) → Motoring → Full Power; Air Outlet Temp. 0˚C			

0 2 4 6 8 10

Check Valve | H_2 Supply | Air Supply → Ready!

Fuel Cell Vehicle Tests

Fire Test

	Gasoline Vehicle	FCV with Type 3 Tank
Test Condition	• Fire initiated from the ashtray	
Result	• Fuel tank exploded after 40 minute.	• PRD activated after 22 minutes.
Vehicle		

	CNG Tank (150bar)	Hydrogen Tank (350bar)
Test Condition	• Fire Source: LPG gas	
Result	• PRD activated : CNG vent • max. flame height 11m	• PRD activated : H_2 vent • max. flame height 8m
Vehicle		

Fuel Cell Stack Development

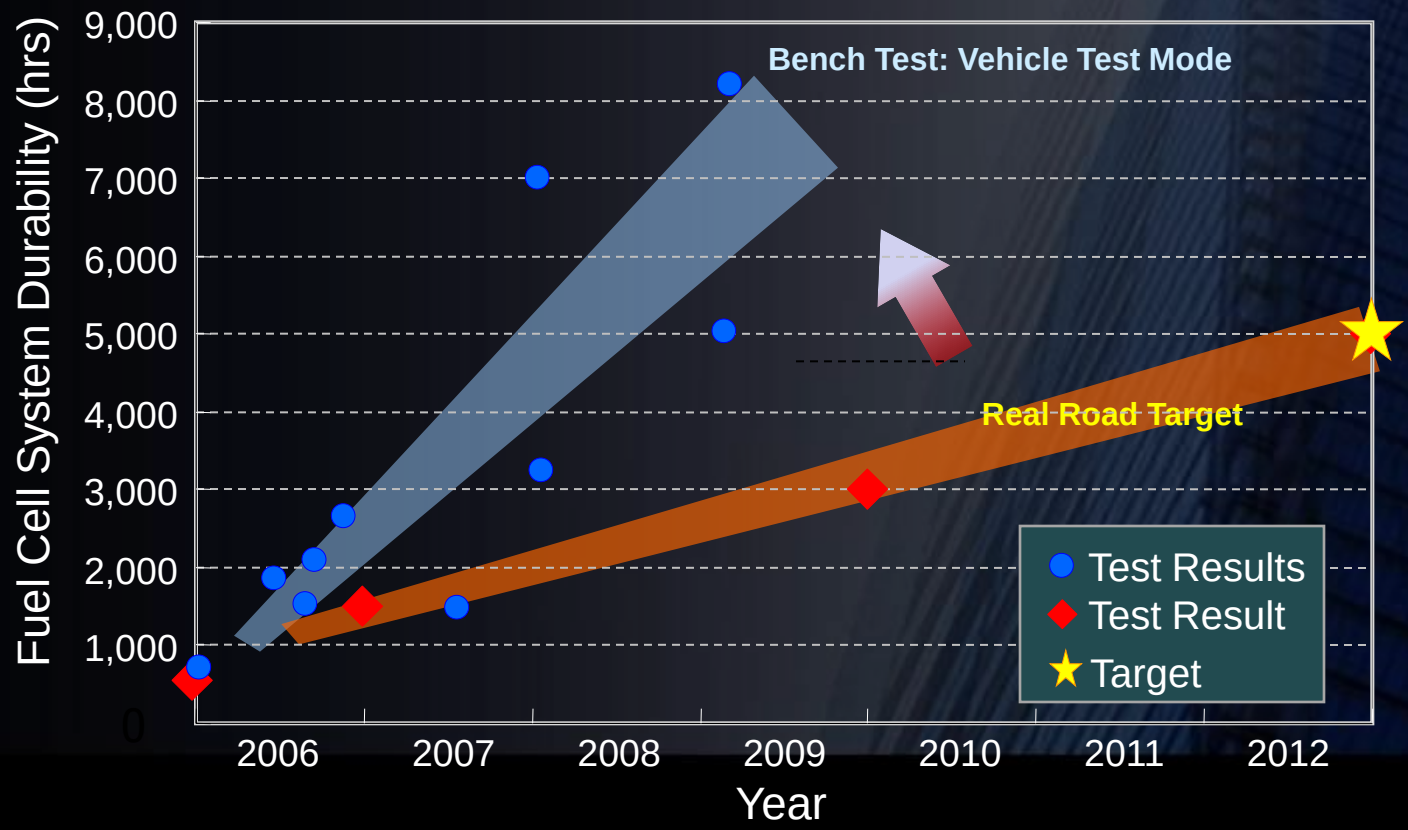
Durability

Durability = f(operation parameters, driving mode, environmental effects)

- Verification of Degradation Mechanism

  (Start Up / Shut Down / Cold Start Up / High Temperature Operation)

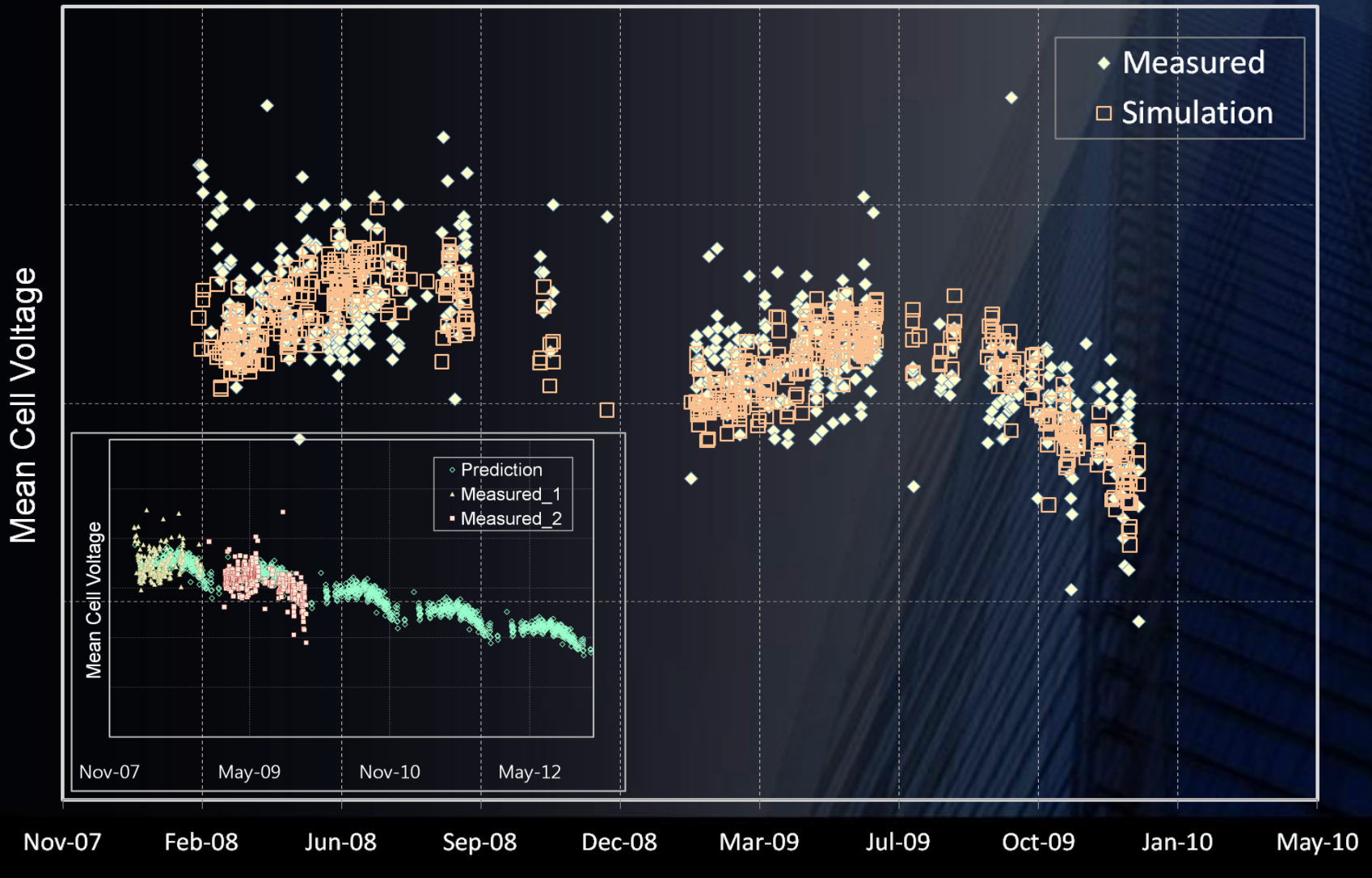
- Development of New Material (Catalyst / Membrane)



Fuel Cell Stack Development

Theoretical Study

- Vehicle Level Performance and Durability can be predicted till End of Life (EOL)



Fleet Program

1. US DOE

- Period : 2004. 12 ~ 2009. 12 (5years)
- Budget : $105 million
- Vehicles : Tucsan/Sportage FCEV Total 32 vehicles
- 721,654 km / 21,284hr / 71,839 Start up
- Average Fuel Economy: 16.3km/l (gasoline eq.)

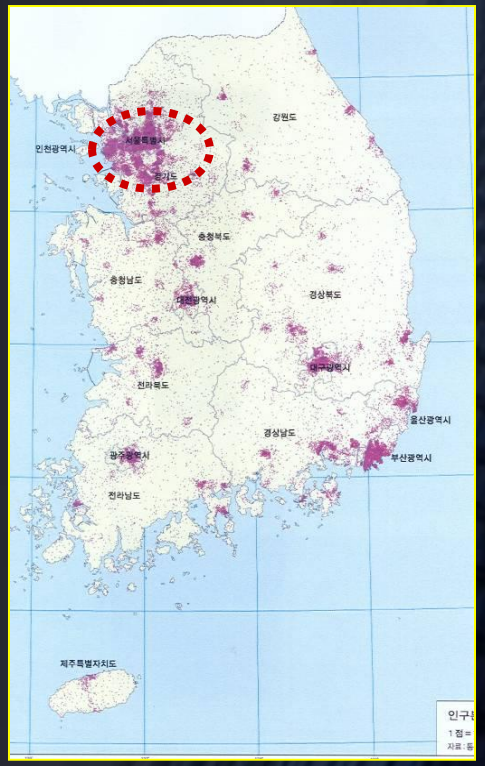
2. 1st Stage Domestic

- Period : 2006. 8 ~ 2010. 7 (4 years)
- Budget : $46.6 million
- Vehicles : 30 Passenger cars, 4 Buses
- 743,500km (including Bus)
- Average Fuel Economy: 19.2km/l (gasoline eq.)

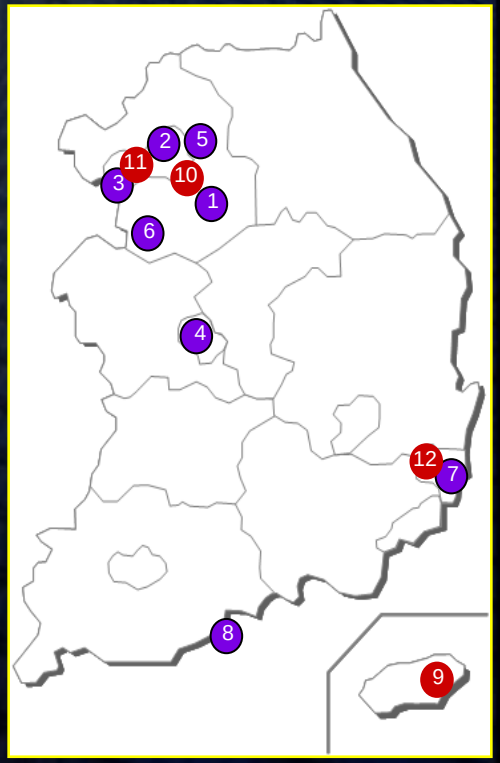
3. 2nd Stage Domestic

- Period : 2009. 12 ~ 2011. 11 (2 years)
- Budget : $17.6 million
- Vehicles : 80 Passenger cars

1st Vehicle for Demo Fleet Program
(2005. 12.16)



(•): 1,000 persons



■ 700bar Station: #1, #6, #12

*Ref.: National Geographic Information System (2005)

FCEV Roadmap of Hyundai · Kia

1st Stage (~'03)

Preliminary Research

- Member of CaFCP ('00)
- Santa Fe FCEV ('00)
  - Award in Michelin Challenge Bibendum

2nd Stage ('04~'11)

Prototype Development

- Tucson, Sportage FCEV ('04)
- DOE Project, US ('04~ '09)
- Fleet Demonstration ('06~)

3rd Stage ('12~)

Small Scale Production

- The 3rd Generation FCEV
- Establish Core Technology for Mass Production

※ CaFCP : California Fuel Cell Partnership
DOE : Department of Energy

Korean Vision of Hydrogen Economy (2008, MKE)

MKE: Ministry of Knowledge Economy

2003 ~ 2012
R&D and Demonstration

. Demonstration and Supply under government Support

. Hydrogen Energy Market Share

▶ 0.03%

’03-’05	’06-’08	’09-’12

R&D ▶ Demo ▶ Market Intrusion

- **Decentralized (250-1000kW) 400 MW**
- **Industrial (10-50kW) 80 units**
- **Residential (under 3kW) 10,000 units**
- **Hydrogen Station 10 units**
- **Fuel Cell Vehicle 500 units**
- **Fuel Cell Bus 20 units**

2013 ~ 2020	2021 ~ 2030	2031 ~ 2040
Market Formation	Market Expansion	Initial Phase of Hydrogen Economy

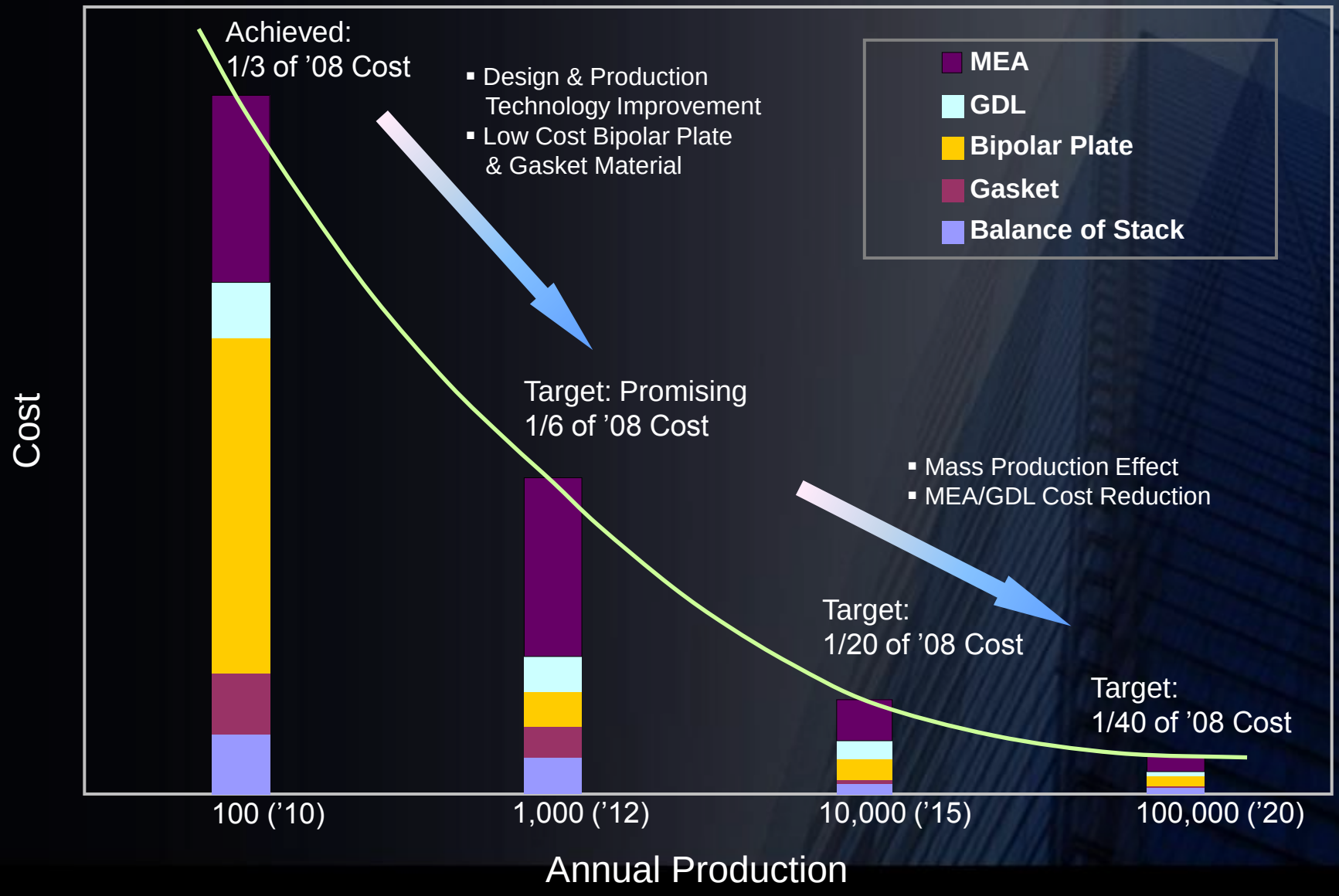
. Accomplishment Of Technical Development

. Expansion of Hydrogen Infra

. Self-Growing Market

Fuel Cell Generation Market Share		
●Decentralized 1,000 MW ● Industrial 2,000 units ● Residential 100,000 units	10%	15%
Fuel Cell Vehicle Market Share		
● Hydrogen Station 500 units ● Fuel Cell Vehicle 50,000 units	15%	50%

Cost Estimation



Conclusion

- Cost
  - FCV Price should come down to $50,000 in order to win in the Free Competition
  - Proper Increase in Production Volume should be secured to adopt Mass Production Technology
    : Carbon Fiber Products (GDL, Hydrogen Tank), BOS / BOP / E-Drive Components

- Durability
  - High Level Quality Control of Repeated Fuel Cell Components
  - Fine Engineering and Control of the Fuel Cell System
  - Break through Materials: Non-Carbon Catalyst Support, Highly durable Membrane/Gasket

- Commercialization
  - Vehicle OEMs, Oil/Energy Company and Government must cooperate under concrete Roadmap in order to provide sufficient Hydrogen Infrastructure in right time
  - At least 50 H_2 Refueling Stations are need to start small scale FCV Production in Korea


Thank You