Session 4. National Experiences on Electrification of Public Transport
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FCEV for Public Transport in Korea

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1. Paradigm Shift to Green New Deal
2. Hydrogen Economy Roadmap of Korea
3. Hydrogen Public Transport in Korea
4. Hydrogen Bus (FCEV) of Changwon
5. Ride Quality and Comfort of FCEV & EV
6. Hydrogen Mobility of Incheon Int’l Airport
1. Paradigm Shift to Green New Deal

» Global Movement towards De-carbonization in the 21st Century

19c
- Network: Printing, Telegraphy
- Power Source: Coal
- Transportation: Railroads

20c
- Network: Phone, Radio, TV
- Power Source: Petroleum
- Transportation: ICE Vehicles

21c
- Network: IoT, 5G
- Power Source: Solar, Wind, Hydrogen
- Transportation: BEV, FCEV, Autonomous, PAV

Reference: Norway-Korea Hydrogen Seminar 2021/7
1. Paradigm Shift to Green New Deal

Transition to Hydrogen Society and Competing for Hydrogen Strategies

Hydrogen Activities Around the Globe

- National H2 Strategy: available (9), in preparation (11), etc.
- EU, Asia-Pacific, and Americas are particularly interested

Establishment of National Hydrogen Strategies

- In particular, each country’s competitive H2 strategy has been outstanding over the recent past year.

<table>
<thead>
<tr>
<th>Year</th>
<th>Country</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>2017</td>
<td>Japan</td>
<td>Dec 2017</td>
</tr>
<tr>
<td>2018</td>
<td>South Korea</td>
<td>Jan 2019</td>
</tr>
<tr>
<td>2019</td>
<td>Netherlands</td>
<td>Apr 2020</td>
</tr>
<tr>
<td>2020</td>
<td>Germany</td>
<td>Jun 2020</td>
</tr>
<tr>
<td>2021</td>
<td>France</td>
<td>Sep 2020 (Green H2 strategy)</td>
</tr>
<tr>
<td></td>
<td>Australia</td>
<td>Nov 2019</td>
</tr>
<tr>
<td></td>
<td>Norway</td>
<td>May 2020</td>
</tr>
<tr>
<td></td>
<td>Portugal</td>
<td>Jul 2020</td>
</tr>
<tr>
<td></td>
<td>Spain</td>
<td>Jul 2020</td>
</tr>
<tr>
<td></td>
<td>Russia</td>
<td>Nov 2020</td>
</tr>
<tr>
<td></td>
<td>China</td>
<td>In preparation</td>
</tr>
</tbody>
</table>

Timeline of analysed national hydrogen strategies publication

Source: International Hydrogen Strategies (20.9, World Energy Council)

International status of hydrogen activities of national governments (Aug. 2020)

Reference: Norway-Korea Hydrogen Seminar 2021/7
Benefit of Hydrogen Bus

ENVIRONMENTAL BENEFITS
- Air quality improvements: no toxic tailpipe emissions,
- Greenhouse gases emission reductions: with the potential to fully decarbonize public transport when hydrogen is generated from renewables
- Noise reduction: fuel cell electric buses are quiet

OPERATIONAL FLEXIBILITY
- Fuel cell electric buses have longest range (> 300 km)
- Short refueling times (< 10 min)
- Performance comparable (speed and acceleration)
- Regenerative breaking system
Benefit of Hydrogen Bus

» PASSENGERS AND DRIVERS COMFORT
- Fuel Cell buses are very comfortable for passengers and drivers due to the
  → lack of vibration & smooth driving experience
  → and for the drivers, the traction power allows a quick start of the bus, even when it is full
  → noise reduction: fuel cell electric buses are quiet

» BENEFITS AS EARLY ADOPTER
- Society is moving towards a low carbon future
- Receiving information on lessons learned from previous demonstration projects
- Improves the image of the transport operator
## 2. Hydrogen Economy Roadmap of Korea

<table>
<thead>
<tr>
<th></th>
<th>2018</th>
<th>2022</th>
<th>2030</th>
<th>2040</th>
</tr>
</thead>
<tbody>
<tr>
<td>Units</td>
<td>1,800 units</td>
<td>81,000 units</td>
<td>850,000 units</td>
<td>6.2 million units</td>
</tr>
<tr>
<td>Capacity</td>
<td>14</td>
<td>310</td>
<td>660</td>
<td>1,200</td>
</tr>
<tr>
<td>Power</td>
<td>307 MW</td>
<td>1.5 GW</td>
<td>2.0 GW</td>
<td>15 GW</td>
</tr>
<tr>
<td>Capacity</td>
<td>130,000 tons/year</td>
<td>470,000 tons/year</td>
<td>1,940,000 tons/year</td>
<td>5,260,000 tons/year</td>
</tr>
<tr>
<td>Price</td>
<td>8,000 won/kg</td>
<td>6,000 won/kg</td>
<td>4,000 won/kg</td>
<td>3,000 won/kg</td>
</tr>
<tr>
<td>Source</td>
<td>By-product hydrogen</td>
<td>By-product hydrogen</td>
<td>By-product hydrogen</td>
<td>By-product hydrogen, Hydrogen extraction (LNG reforming), Water electrolysis, Overseas production</td>
</tr>
</tbody>
</table>

### Green Hydrogen
- Development of Efficiency Improvement Techniques for Water-Electrolysis
- Development of Long Term Storage Technology for Hydrogen High Capacity

### Overseas Import
- Imports in earnest from 2030
- Construction of old takeover base for imported hydrogen
- Development, demonstration and commercialization of hydrogen transport ship

Reference: H2Korea, 2021/6
2. Hydrogen Economy Roadmap of Korea

» Transition of Hydrogen Economy in Korea

- **2019**
  - Hydrogen economy roadmap
  - Hydrogen economy standards roadmap

- **2020**
  - Regulatory improvement plan for new industries
  - Establishment strategy for Hydrogen infrastructure
  - Hydrogen Economy Committee launched
  - Hydrogen technology development roadmap
  - Hydrogen Safety Roadmap
  - Hydrogen Economy Act Enacted
  - Announcement of Korean New Deal

- **2021**
  - The 3rd Hydrogen Economy Committee
  - Strategy for future vehicle expansion & Market pre-occupation
  - 2050 Net-Zero declared
  - The 2nd Hydrogen Economy Committee
  - Hydrogen Economy Act enforced

» Reference: H2Korea, 2021/6
2. Hydrogen Economy Roadmap of Korea

Current Hydrogen Stations (112 as of August ’22)

Reference: www.ev.or.kr
3. Hydrogen Public Transport of Korea

Hydrogen Transport Complex in Korea

- (Transport Hub) Transit Center, Railway Station, Bus Depot with Hydrogen Station
- (Plan) - Pyungtek(2021), Chuncheon/Ansan/Changwon/Tongyoung (2022)
3. Hydrogen Public Transport of Korea

Hydrogen City Pilot Project

» In October 2019, MOLIT announced that by the end of the year it would select three cities, which will set up several hydrogen pilot projects.

» On December 30, these cities were announced: Ansan, Ulsan and Jeonju/Wanju.

» MOLIT additionally selected Samcheok as a hydrogen R&D city.
## 3. Hydrogen Public Transport of Korea

### Hydrogen Buses in Korea

Hydrogen buses are 163 unit as of June 2022, for city bus, airport shuttle, police, others

* Total Hydrogen cars are 24,119 units, *4,733(Gyeonggi), 2,665(Seoul), 2,393(Ulsan)...*

<table>
<thead>
<tr>
<th>Hydrogen Bus</th>
<th>Seoul</th>
<th>Busan</th>
<th>Incheon</th>
<th>Gwangju</th>
<th>Ulsan</th>
<th>Sejong</th>
<th>Chungnam</th>
<th>Jeonbuk</th>
<th>Gyeongnam</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2018.12</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>2019.06</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3</td>
</tr>
<tr>
<td>2019.12</td>
<td>2</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>2020.06</td>
<td>2</td>
<td>5</td>
<td>-</td>
<td>-</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>5</td>
</tr>
<tr>
<td>2020.06</td>
<td>9</td>
<td>13</td>
<td>-</td>
<td>6</td>
<td>6</td>
<td>-</td>
<td>9</td>
<td>8</td>
<td>24</td>
<td>75</td>
</tr>
<tr>
<td>2020.12</td>
<td>20</td>
<td>36</td>
<td>15</td>
<td>12</td>
<td>9</td>
<td>2</td>
<td>16</td>
<td>18</td>
<td>32</td>
<td>163</td>
</tr>
</tbody>
</table>

![Graph showing the increase in Hydrogen Buses from 2018.12 to 2021.12](image)
3. Hydrogen Public Transport of Korea

Hydrogen taxi pilot project

» 2019. Seoul operates 10 hydrogen taxis for the first time in Korea
» 2020. Additional 10 units were added, * total 20 hydrogen taxis in Seoul

4. Hydrogen Bus (FCEV) of Changwon City

Status of hydrogen Bus Pilot City in Changwon

- Nov 2018, Selected as Hydrogen Bus Pilot City by the government
- Jun, 2019, Changwon operates 5 hydrogen buses for the first time in Korea
- Aug, 2022, A total of 28 hydrogen buses are currently in operation in Korea
4. Hydrogen Bus (FCEV) of Changwon City

Hydrogen Bus defect maintenance & quality improvement

» Hydrogen buses stopped operating due to failure of key components
» Hydrogen bus performance improvement
  - Stabilize fuel cell stacks / Improve motor output / Increase hydrogen tank capability
» Launched operating a demonstration in Changwon (April~June, 2020)
4. Hydrogen Bus (FCEV) of Changwon City

Building a World-class Commercial Vehicle Hydrogen Charging System

Promoted the construction of large-capacity hydrogen charging stations
Support demonstration of charging system manufactured by Changwon-based companies
5. Ride Quality and Comfort of FCEV & EV

» Data Collection
- Noise, vibration, and electromagnetic radiation collected on 2 buses per each type (CNGB/BEB/HFCB)

» In-Bus Noise Level – Idling Condition
- FCEB: 57.9 dB
- BEB: 59.7 dB
- CNGB: 66.7 dB
5. Ride Quality and Comfort of FCEV & EV

» Noise by Speed on Bus Types

- Noise value of BEB was 4.1 % higher than FCEB
- Boise value of CNGB was 18 % higher than FCEB

<table>
<thead>
<tr>
<th>Speed Range (km/hour)</th>
<th>Average Noise (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FCEB</td>
</tr>
<tr>
<td>0</td>
<td>57.95</td>
</tr>
<tr>
<td>1–10</td>
<td>59.89</td>
</tr>
<tr>
<td>11–20</td>
<td>60.29</td>
</tr>
<tr>
<td>21–30</td>
<td>61.36</td>
</tr>
<tr>
<td>31–40</td>
<td>63.63</td>
</tr>
<tr>
<td>41–50</td>
<td>65.71</td>
</tr>
<tr>
<td>51–60</td>
<td>67.57</td>
</tr>
<tr>
<td>61–70</td>
<td>69.30</td>
</tr>
</tbody>
</table>
5. Ride Quality and Comfort of FCEV & EV

» Average Vibration Velocities on Bus Types
  - FCEB: 1.10 mm/s
  - BEB: 1.16 mm/s
  - CNGB: 2.43 mm/s

» Average Electric Fields on Bus Types
  - FCEB: 8.84 V/m
  - BEB: 17.24 V/m
  - CNGB: 15.13 V/m
6. Hydrogen Mobility of Incheon Int’l Airport

» Building Green Airport Infrastructure

- First hydrogen vehicle charger (250kg) in T1 (Jan 2020)
- Hydrogen vehicle charger (1,000kg) in T2 (July 2020)
- Equipped with the charging capacity of 180 units/day
6. Hydrogen Mobility of Incheon Int’l Airport

» Green Airport – Mobility Transition
- Transition of all vehicles into Electronic & Hydrogen

» Status of eco-friendly vehicles – Incheon Airport

<table>
<thead>
<tr>
<th>Phase in adoption of eco-friendly vehicle (2021)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric Car</td>
</tr>
<tr>
<td>Hydrogen Car</td>
</tr>
<tr>
<td>Hybrid Car</td>
</tr>
<tr>
<td>Electric Bus</td>
</tr>
<tr>
<td>Hydrogen Bus</td>
</tr>
<tr>
<td>CNG</td>
</tr>
</tbody>
</table>

100% Transition of Office Cars (164 Units)
Up to 10 Hydrogen Shuttle Buses (until year 2025)

* Except Fire Fighting and special purpose vehicle
Appendix - Hydrogen Colors

**Brown Hydrogen**
- H2 production from coal with emitted CO₂
- Chemicals & Energy

**Gray Hydrogen**
- H2 production from natural gas with emitted CO₂
- Existing end-uses

**Blue Hydrogen**
- Grey cycle with CO₂ removal, storage or re-use
- New end-uses with Gray H₂ in transition
- All end-uses

**Green Hydrogen**
- Electrolysis powered by Renewable Energy with zero CO₂ emissions
- All end-uses

Clean Hydrogen

» Reference: Norway-Korea Hydrogen Seminar 2021/7