R&D and Trends of EV Industry in Korea

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Trends in Automotive Industry 2025

Social Trends
- Industrialization
- Information
- Aging Population↑
- Working-age population↓
- Environmental awareness↑
- Welfare awareness↑

Technological Environment Trend
- Environment
  - Eco-friendly/light-weight materials and recycle technologies to reduce carbon emissions
- Energy
  - Energy storage and conversion technology to increase energy efficiency
- Communication
  - Easy information access with the evolution of network technology and digital devices
- Cognitive Science
  - Increased intuition and safety by expanding human-device interaction
- Automation/Robot
  - Interaction between humans and devices through machine learning and A.I.

Future technology keywords of future vehicles in 2025

1. **Eco-friendly** (Low fuel consumption)
   - Electric vehicles (BEV, FCEV, HEV, etc.)

2. **Smart car** (autonomous driving, connectivity)

3. **Individualization & sharing**
   - Personal mobility, sharing
Eco-Friendly • Low Fuel Consumption
- Background and Regulation Enhancement

CO₂ gas emissions ➔
- Global warming acceleration and cold, arid
- Sudden increase in abnormal weather

Deforestation in the Amazon Rainforest
- 760,000 km² lost since 1988

Irreversible Collapse of Antarctic Glaciers
- 130,000 ~ 200,000 km² lost
- Melting speed increase

* Source: Research of Paulista State University in Brazil

Enhanced Environmental Regulations
(CO₂ regulation roadmap of each country)
“Ongoing reduction efforts in major markets”

CAFE
Corporate Average Fuel Economy regulation
- 37.8 mpg
- 23%

CO₂
CO₂ emission regulation
- 130 g/km
- 27%

2020
Corporate Average Fuel Economy regulation
- 17 km/8
- 43%

* Reduction effect of CO₂ in EV

1,000 BEVs = 667,000 trees = 8,000 tons of CO₂
* ICEV = 3 ~ 4 tons of CO₂/year

* Source: IPCC, NASA etc.
Eco-Friendly • Low Fuel Consumption

– Market Forecast of Eco-Friendly Cars

Eco-friendly car market 1.9 million units (2.2%) in 2013 →Rapid growth to 17.2 million units (15.2%) in 2025

Source: his, Fuji Keizai Group
EVs in Korea

- **Total**: 57,000 - early distribution mainly in Jeju island
- Expanding to main cities (Seoul, Gyeonggi, and Daegu)
- Significant increase after launching 400km-single-charging vehicles such as, Kona Electric and Niro, Chevrolet Bolt

Distribution of Electric Vehicles by Region (2011~2018)


2018, Ministry of Environment
EV Fast-Charging Infrastructure

Total: **1,700 units** by MoE, KEPCO and local governments (both rapid and slow)

**Rapid Charging Station Distribution**
(Ministry of Environment, 2011~2018)

- **Unit(s)**
  - 2011: 33
  - 2012: 85
  - 2013: 59
  - 2014: 60
  - 2015: 100
  - 2016: 154
  - 2017: 442
  - 2018: 766

*Source: Bing*

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Eco-Friendly Car Industry strategy – Korea

Trends

- EV industry + Hydrogen car for hydrogen economy
- Personal mobility, such as small/electric motorcycles/tricycles

- Distribution (subsidy): BEV, FCEV, micro EV, electric bi/tricycle
  (Some models have no limit on the number of grants available for business use.)

- Infrastructure: MOE, KEPCO, local government- charging infrastructure, mandatory charging facilities for multi-family houses

- User benefit: highway toll and public parking lot discounts

- Industry revitalization: 30 new technologies in roadmap for new industries
  → One of the five leading projects in the electric autonomous vehicle industry
Eco-Friendly Vehicle

Main technologies according to power source

- Downsizing
- Multiple gearboxes
- Weight reduction
- 48V system

- Engine is expected to become the main power source due to the evolution of ICE efficiency technology.

- High-output battery
- Electric motor
- Power control system
- Regenerative braking

- Expansion from the core market (US / Japan) to Europe and China.
- Generalization with high fuel efficiency option.

- High-capacity battery
- Battery management
- Power semiconductor
- Fast charging

- PHEV is expanding to European premium companies
- EV is expected to grow centered on small cars

- Fuel cell stack
- Hydrogen tank
- BOP (APS, FPS, TMS)
- Hydrogen infrastructure

- Korean, Japanese automakers lead the FCEV popularization technology
- Need to expand hydrogen charging infrastructure
Korea's Eco-Friendly Car Policy (EV)

**Goal**

42,000 electric cars and 300 electric buses in 2019

Expansion of charger (national led and private assistance)

- Distribution target → Individuals, public institutions, local governments, etc. (excluding Central Administrative Agencies)

- Subsidy satisfied "Regulations on Evaluation System on Supply of EV"

- Subsidy is paid to perform. and config. (single charge mileage, battery capacity, etc.)

- Classification → passenger, subcompact, vans, buses, 2/3-wheeler

- Total subsidy → Governt. + local = $3,600 ~ 85,000

**Government subsidies**

<table>
<thead>
<tr>
<th>Electric car</th>
<th>Micro electric car</th>
<th>Electric car</th>
<th>Electric vans (busses)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. $7,700</td>
<td>Max. $3,600</td>
<td>Light, $9,400</td>
<td>Small, $15,000</td>
</tr>
<tr>
<td>Light, $9,400</td>
<td>Light, $9,400</td>
<td>Medium, max.</td>
<td>Large, max.</td>
</tr>
<tr>
<td>Small, $15,000</td>
<td>Small, $15,000</td>
<td>$50,000</td>
<td>$85,000</td>
</tr>
</tbody>
</table>
Korea’s EV Innovation & Growth Policy

Goal

430,000 EV on the road by 2020

Strategy

- Build charging system in all places ➤ Remove Inconvenience
- Provide EV purchasing incentive ➤ Improve merits for buyer
- Develop Various models & Tech ➤ Boost global market share

Implement 3 Projects

- Increase Charging Infra
- Expanding Incentive
- Developing Technology
**Increasing charging Infra**

**Goal:** Establishing 10,000 EV fast chargers by 2022 “Anytime & Anywhere”

- 3,800 Fast Chargers were installed till 2018, over 1,500 F.C will be established each year

  * Number of F.C (accumulative): (`15) 523 → (`16) 1,050 → (`17) 2,531 → (`18) 3,800

- Charging electricity cost for EV dropped from 0.25 → 0.14 €/kwh (`17.1.12)

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**EV user oriented charging station**

**HOME**
- Establish Slow & Fast charger
- In apartment complexes in Korea

**ON THE ROAD**
- EV charging system in the rest area of every highway & change to dual charging station (gas + electricity) for gas stations on highway

**DESTINATION**
- Focusing on railway station & big mart in urban living space
### EV/FCEV Incentive & Subsidy

<table>
<thead>
<tr>
<th>Category</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Income tax</td>
<td>Exempt Max. 2,800 € (approx..)</td>
</tr>
<tr>
<td>Acquisition tax</td>
<td>Exempt Max. 1,000 € (approx..)</td>
</tr>
<tr>
<td>Subsidy</td>
<td>Provide 6,400 € (expanding to private individual, beginning from 2018)</td>
</tr>
</tbody>
</table>

### Driving Incentive (xEV)

- **Tollway**: 50% discount
- **Public Parking**: 50% discount
- **Example**: ![License Plate](52가 3108)

### Obligatory Purchase by Public Institute

- Public institute **Should purchase green cars over 70% for new purchase or rent vehicles**
  - EV & FCEV are more than 80% of green car
  - Upswing to 100% by 2022
3 Technology development of EV’s core components

**Motor / Reducer**
- Increase driving motor efficiency
- Develop electro-magnetic multi stage gear for driving efficiency

**Platform / HVAC**
- Light weigh body using CFRP
- Develop EV optimized heat & cooling system

**Conversion System**
- Develop motor integrated high density inverter with power semiconductor (IGBT)

**Battery System**
- Develop technology to double up the density of Lithium Ion battery
- Optimized BMS

Additional Note: 150 Wh/kg → 300 Wh/kg
Korea's Eco-Friendly Vehicle Policy (FCEV)

Grant Support

- (Hydrogen car) Government subsidy $20,000 + local (up to $11,000)
- (Charging station) Government $130,000 + local 130,000 (same)
- (Hydrogen bus) Government $170,000 + local 170,000 (same)

Tax Reduction

- Individual consumption and education tax $4,500
- Acquisition tax up to $1,200
- Railroad bond $2,100
Industrial Development Roadmap (BEV)

Goal

Single-charge mileage: 300 → 600km (2 times)
3x charging speed → Early popularization of electric vehicles

- Energy density and capacity of battery packs (200Wh/kg)
- Intensive development - High voltage (800V class) drivie system to improve energy efficiency
- Reduced charging time to 1/3 of present in 2022
- Charging output (120kW → 400kW) for super fast charging system
- 400A high-current charging coupler (charger-car connector)
Hybrid EVs

- Common key components for HEV to FCEV → **battery, motor, inverter**.
- Core technology of motorization is 'high energy battery' and the **power semiconductor** to control it.

### Core parts of a green car

#### Main parts technology

- **Battery**
  - To expand the range of electric vehicles (above 300km)
  - Mainly develops Li-ion battery electrode material
  - Developed beyond Li-ion battery (Li-S, li-Air, solid-state battery, etc.)

![Battery technology chart](chart)

- **SiC / GaN Power Semiconductor (WGB)**
  - Fuel economy 5 to 10%, parts miniaturization 40% ↓
Industrial Development Roadmap (FCEV)

**Goal**
- Doubled the durability of hydrogen car
- Reduced price by 30%
- Secured high-capacity and rapid hydrogen charging system
→ Distribution of Hydrogen Vehicles

- Entered the initial stage of commercialization
- The ultimate eco-friendly car driven by the electric energy generated by hydrogen – oxygen reaction
- High component prices and hydrogen production & construction infrastructure are obstacles in the short run

**FCEV core parts**

**Commercialization issues**

- **High-price**
  - Initial purchase price of 100 million won
  → Need to secure the economy and develop expensive platinum substitutes (platinum 80% reduction)

- **Hydrogen charging infrastructure**
  - Charging infrastructure is insignificant
  → (12,330 gas stations / 18 hydrogen charging stations, 2015)
  - Reduction of charging station construction cost
  → (Gas station 300 million KRW / Hydrogen station 3 billion KRW)

**Hyundai Motors’ first mass-produced FCEV**

2013 → the only mass production system in the industry
2014 → started sales to local governments, Lease Sales to US Consumers
2020 → Popularization
FCEVs

**Strategy**
Developing FCEV core technology continuously & establishing more hydrogen charging station. Implementing demonstration projects for public service (bus, taxi)

- **Target**: Distributing 65,000 FCEVs by year 2022 & Establishing 310 hydrogen charging stations.

**Current Status**
- Hyundai developed Tucson IX FCEV in 2013 → **NEXO SUV, 2018.3**
- 198 FCEV were distributed to public institutes in Korea.
- 15 hydrogen refueling stations are in operation by 2018.

**Demonstration Pilot Project**
- KTX fast railway station Car sharing service
- Taxi service at Ulsan
- Bus service at Pyung Chang olympic
- New NEXO SUV

**Under development**
- 5 ton truck
- Garbage truck
9 core technologies & components

Goal

Autonomous driving on road (Lv 4.) in 2025

9 core parts: High performance radar and LIDAR sensor, Image sensor, sensor fusion technology, V2X module, vehicle control processor, etc.

Commercialize service technology related to autonomous driving in 2022

Multi-purpose autonomous-driving service vehicle
→ Demonstration of promising service models such as autonomous shuttle service
Autonomous driving system commercialization in low-speed road section → highway → full autonomous driving

"Continuous research on advancement system is required for commercialization such as high price, sudden response, and related system maintenance”

Market size forecast (annual sales)

<table>
<thead>
<tr>
<th>Year</th>
<th>Unit</th>
<th>CAGR</th>
</tr>
</thead>
<tbody>
<tr>
<td>2025</td>
<td>23</td>
<td>48.3%</td>
</tr>
<tr>
<td>2035</td>
<td>1,180</td>
<td></td>
</tr>
</tbody>
</table>

‘Rapid growth since commercialization in 2020’
(IHS Research)

Manual operation actuator

Electronically controlled actuator

Electronically controlled ECU
Auto TM, ESC, MDPS (1980~2000)


Automated per function

Partial autonomous driving

Highway and low-speed
ADAS feature integration control

Distance maintenance, automatic braking
ADAS feature integration control

Section autonomous driving

Limited section autonomous driving
Information convergence (location-based + communication + new sensor)

Fully autonomous
Perfect Safety
<table>
<thead>
<tr>
<th>Category</th>
<th>Scope</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy storage / management system</td>
<td>Core raw material, battery cell, battery module / pack, BMS, PRA, cooling system, VIT measurement, cell balancing, protection circuit, VIT precision, SOC and SOH output, cell balancing, thermal management, communication, diagnosis</td>
</tr>
<tr>
<td>Power conversion system</td>
<td>Inverter, converter, onboard charger</td>
</tr>
<tr>
<td>Electric drive system</td>
<td>Permanent magnet motor, non-permanent magnet motor, SI-series inverter, non SI-series inverter</td>
</tr>
<tr>
<td>Electric Vehicle Charging Infrastructure</td>
<td>Electric vehicle charger (fast), infrastructure construction, wireless charging system</td>
</tr>
<tr>
<td>Camera for self-driving</td>
<td>Rear view, around-view monitoring, mirrorless camera, camera module, lane recognition, vehicle recognition, pedestrian recognition, light source recognition, road sign recognition, distance information detection, video record of incident</td>
</tr>
<tr>
<td>Convenience system for drivers</td>
<td>Detection sensor, active safety system, driving support system, accident reduction system</td>
</tr>
<tr>
<td>Information system</td>
<td>Driver information, interface, and information generation technology</td>
</tr>
<tr>
<td>Eco-friendly lightweight parts</td>
<td>PCM material, unpainted/plated material and processing, foam material, bio-based eco-friendly material, transparent material, homogeneous composite material, heterojunction material, natural fiber material, sandwich and hollow section layers, flame retardant material</td>
</tr>
</tbody>
</table>
Accelerate the development of an intelligent safety technology that pursues safety and driving convenience simultaneously.

**Past**
- Automated Manipulation
  - Power Window (‘40)
  - A/T (‘40)
  - Automatic Headlamp (‘60)
  - Rain Sensing Wiper (‘96)

**Present**
- Advanced Driver Assistant System
  - LDWS (‘92)
  - ACC (‘92/’99)
  - BSD (‘07)
  - Automatic Parking (‘03)

**Future**
- Autonomous Vehicle
  - Partial autonomous cars (2014)
  - Fully autonomous cars (?)
Technology development & standard adoption for autonomous driving

Early self-development of core technology for autonomous driving

- Localization of core parts that are highly dependent on foreign countries
  - Developing 9 core parts such as Lidar (2017-2021)
  - Localization of AI, vehicle semiconductor (~2023)

- Development of 5G-based autonomous mobile communication technology
  * Real-time high-speed communication module and SW

Connected Automated Vehicle
Autonomous Vehicle

- Securing world-class autonomous vehicle competitiveness

**Construct a world-class demonstration complex**

- Review to designate the autonomous driving regulation sandbox special zone (Amendment of Industrial Convergence Promotion Act, ’18)
  - Within this year, two autonomous driving demonstration complexes will be designated

- Smart City is designed as an electric car and autonomous car-friendly type from the development stage

**Pilot project that citizens can experience**

- First real road-based college student autonomous car contest was held (18.10)
  * Promote the interest of the public by proceeding on actual roads in the city (Daegu)

- Implementing demonstration projects based on autonomous driving
  
  ![Diagram of demonstration projects]

  - Autonomous courier service
  - Traffic abbreviations calls and moves
  - Autonomous speech recognition Secretary
Autonomous Vehicle

- Create new industries & job based on future vehicle

Creating a new service market

- Developing service models through the Connected Services Alliance (2018)
  - A variety of companies, including car makers, IT, and telecom, participate to discover promising business models

- Build big data to support commercialization of SME service (2019)
  - Predictive maintenance of automobile parts, analysis of driving propensity, insurance design, etc.

Demonstration of new EV service industry

- Energy: Connect electric cars to the power grid (V2G, 2018)
  - Enhancing V2G technology such as 2-way charging
    - Meeting 1 day electricity demand of 3 households with 1 EV

- Environment: Wasted battery recycling system
  - Utilizing wasted battery of electric car as ESS
  - Recycling after recovering minerals such as lithium
    - Establishment of Jeju waste battery recycling center (2017 ~ 2019)
Smart Car – Connectivity

- Synchronization with mobile IT devices in vehicles including CarPlay, Android Auto
- Provides personalized contents and personalized & intelligent services through wireless Internet network using cloud computing technology

Seamless connection technology with mobile IT devices

Car cloud

- Real-time data storage/analysis
- Large server infrastructure
- Data processing platform
- Car software – wireless upgrade

Mobile app

- Electric vehicle remote management system (battery/vehicle information)
Smart Car – Connectivity

- Convenience technologies (safety, intuition, conciseness) to understand consumer sentiment
- Additional services through driver monitoring and enhanced security with biometrics
Personal E-Mobility

Micro Mobility: MM
- Two-wheeled
- Three-wheeled
- Bicycle
- Scooter
- Kickboard
- Balancing
- Wheel
- Board

Personal Mobility: PM
- Walking Farming Carrier
- Riding Farming Carrier

Agricultural Electric Vehicle: AEV
- Wheelchair
- Transportation for the mobility impaired

Mobility Scooter: MS
- Cargo
- Passenger Flight

Special Electric Vehicle: SEV
- Multi-purpose
- Facility management
- Leisure

Sedentary Smart mobility
- One wheel
- Two wheel
- Three wheel
- Four wheel

Standing Smart mobility
- One wheel
- Two wheel
- Three wheel
- Four wheel

SEAT ➔ WHEEL ➔ MOTOR

- Mini: ~590 [W]
- Light: 591~1,000 [W]
- Small: 1,001~5,000 [W]
- Medium: 5,001~11,000 [W]
- Large: 11,001 [W]
Vehicle classification by top speed

- **Max. Speed 80km/h** (MOTOR VEHICLE MANAGEMENT ACT)
  - No max. speed limit
  - High-speed EVs

- **Max. Speed 30km/h** (AGRICULTURAL MECHANIZATION PROMOTION ACT)
  - Max. speed limit = 80km/h
  - Mini EVs
  - Electric motorcycles (Min. speed: above 25km/h)

- **Max. Speed 25km/h** (ELECTRICAL APPLIANCES AND CONSUMER PRODUCTS SAFETY CONTROL ACT)
  - Max. speed limit = 30km/h
  - Agricultural power cars
  - Max. speed limit = 25km/h
  - Electric motorcycles

- **Max. Speed 15km/h** (MEDICAL DEVICES ACT)
  - Max. speed limit = 25km/h
  - Electric scooters, bikes, kickboards, wheels
  - Max. speed limit = 15km/h
  - Electric wheelchairs, medical scooters
Electric Drive System Development – Motor Aspect

Electric motor
- Performance (efficiency, output, etc.) + lightweight → IPMSM → most common
- Large capacity + cost competitive + rare earth magnet → high-efficiency IM, Wound field sync. motor (WFSM)
- SRM, PMA-SynRM + spoke-type ferrite motor → under development.

Efficiency
- Winding: Fill factor improvement and copper loss reduction;
  sub-issue → automation and durability → Hairpin winding + core,
  concentrated winding + split core, star winding + split core
- [IPMSM] Core loss, eddy current loss reduction: V or Δ shape, permanent magnet split or laminated
- [IM] Conv. aluminum or copper fabrication → copper die-casting
Development of Traction Motors

Concept
- High Power & Brushless with PM
  - DCM
  - IM

High Power & Brushless without PM
  - Magnetic torque
  - SRM
  - SynRM

Reduced Nd
- Layered IPMSM
- PMASynRM
- PMASRM

Without Nd
- Wound Field Synchronous Motor
- High Efficiency IM
- CFSM

Hybrid: Reduced & Winding
- HEPMSM
- Series HEPMSM
- HEPMSM
Electric Drive System – Driving System Aspect

- **Mechanical or electrical multi-gear application**
  - Mechanical multi and continuous transmission
  - Electric multi-gear

- **Cooling technology** (cooling is a key factor for high power density)
  - Stator: Water cooling or end-coil direct cooling
  - Rotor: Cooling flow path through shaft

- **Integrated motor, inverter and reducer**
  - Connected by bus bar w/o harness: minimizing copper loss and electromagnetic noise
  - Housing sharing improves power output density with optimal cooling
Power Converter Trend

- **Small, lightweight / high density**
  - Low sw. loss and high heat dissipation → WBG semiconductor (SiC, GaN, etc.)
  - Self or water-cooled heat dissipation structure for miniaturization.

- **High efficiency**
  - Application of soft switching techniques such as ZVS, ZCS and high efficiency topology

- **Integrated structure**
  - Eliminate spatial constraints in vehicles, wire harness reduction, maintenance, cooling structure sharing
  - Motor + inverter, inverter + LDC, LDC + OBC, Low voltage battery + LDC, etc.
THANKS