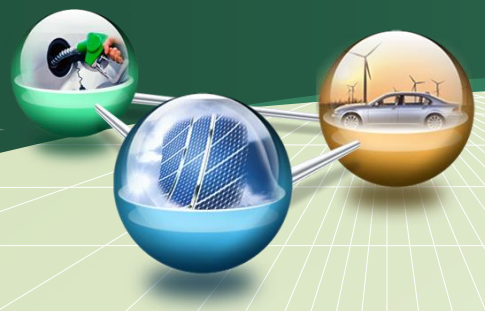

R&D and Trends of EV Industry in Korea

Nov. 14, 2019

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Kyungsung Univ.,Busan, KOREA

Contents

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

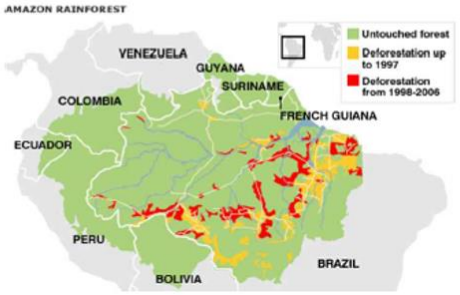
– Background and Regulation Enhancement

CO_2 gas emissions →

- Global warming acceleration and cold, arid
- Sudden increase in abnormal weather

Deforestation in the Amazon Rainforest

– 760,000 km² lost since 1988



* Source : Research of Paulista State University in Brazil

Irreversible Collapse of Antarctic Glaciers

– 130,000 ~ 200,000 km² lost

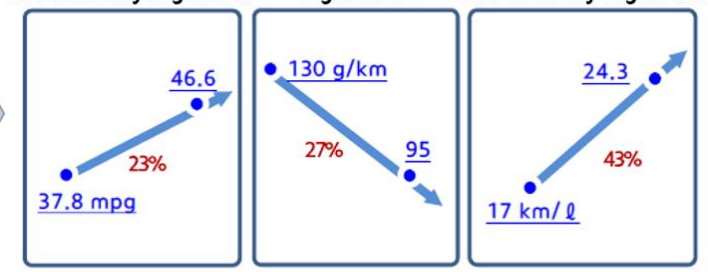
– Melting speed increase

* Source : IPCC, NASA etc.

Enhanced Environmental Regulations

(CO_2 regulation roadmap of each country)

"Ongoing reduction efforts in major markets"



* Reduction effect of CO_2 in EV

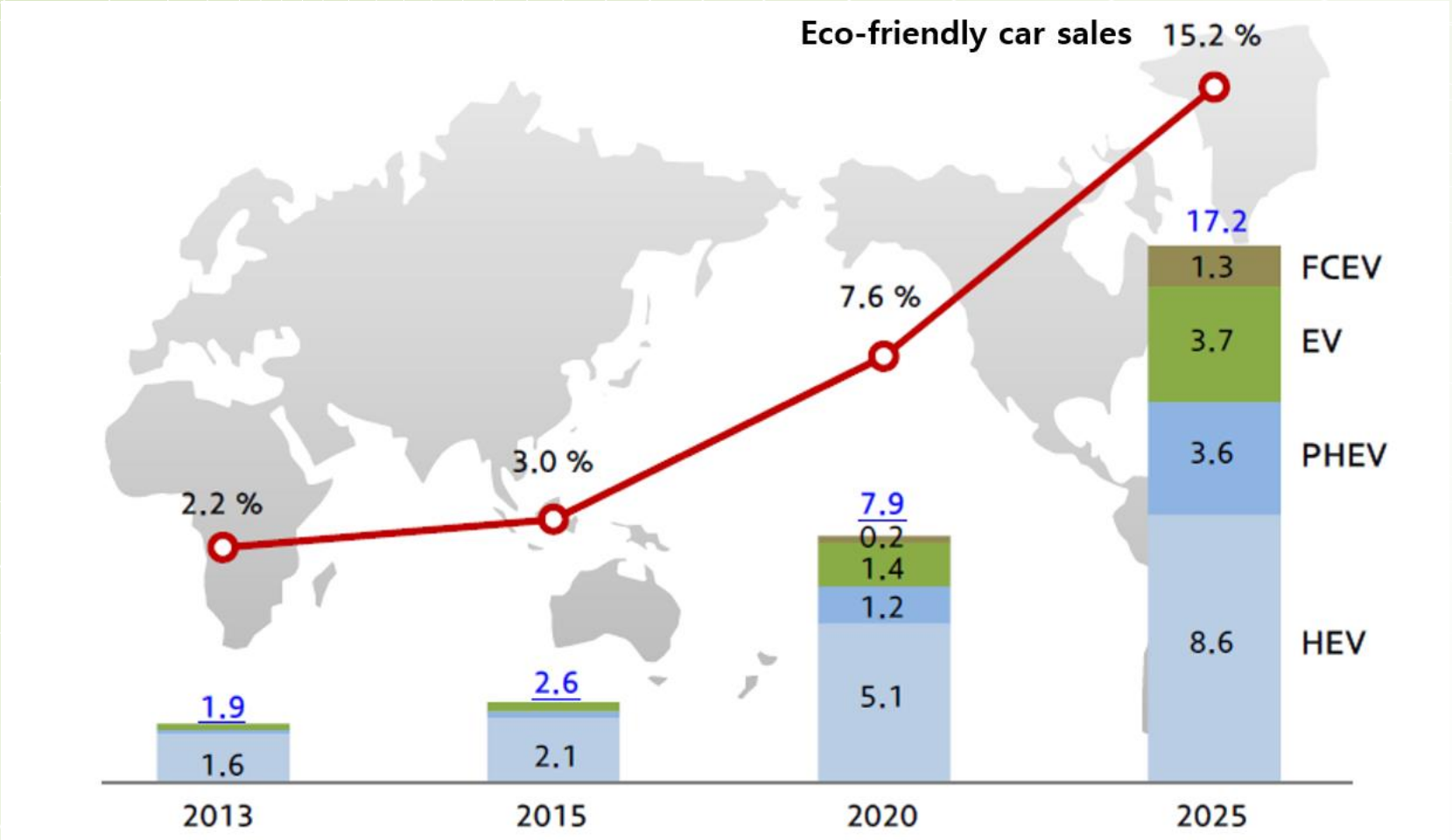
1,000 BEVs = 667,000 trees = 3,000 tons of CO2

* ICEV = 3 ~ 4 tons of CO_2/year

Eco-Friendly・Low Fuel Consumption

– Market Forecast of Eco-Friendly Cars

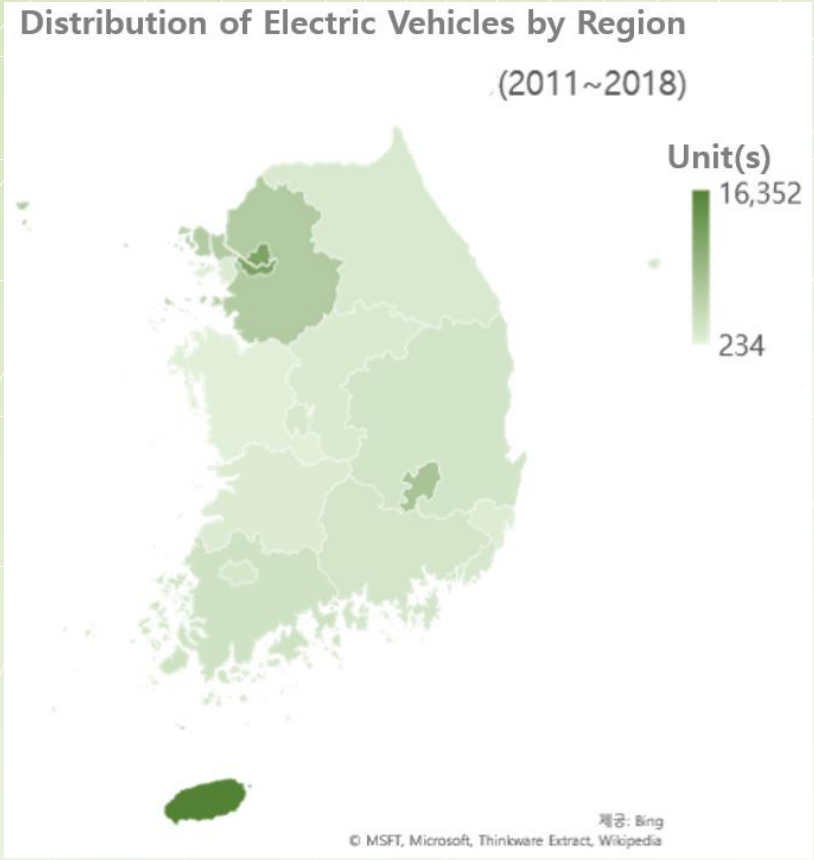
Eco-friendly car market 1.9 million units (2.2%) in 2013
→Rapid growth to 17.2 million units (15.2%) in 2025

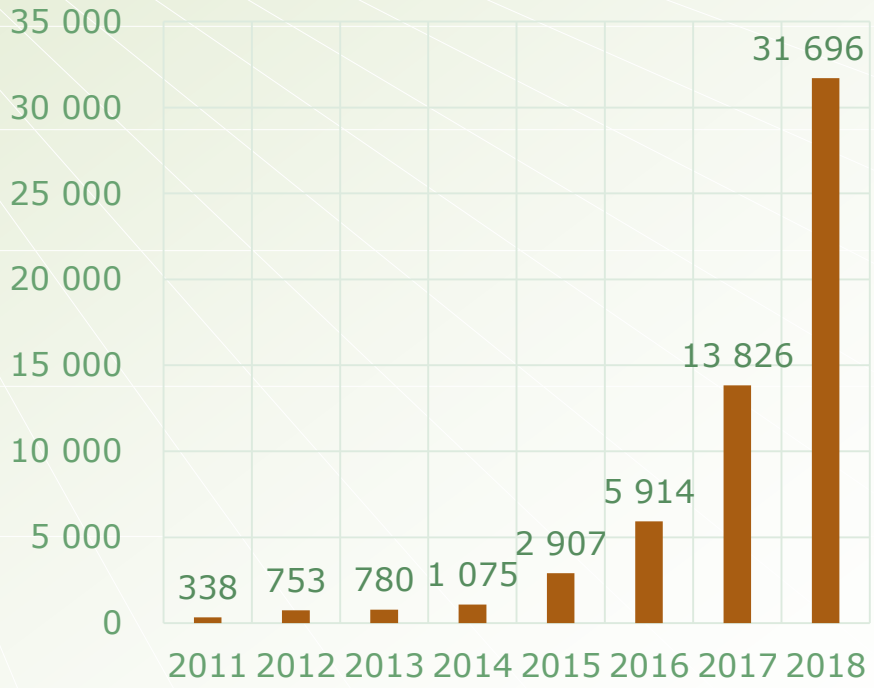


Source : his, Fuji Keizai Group

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

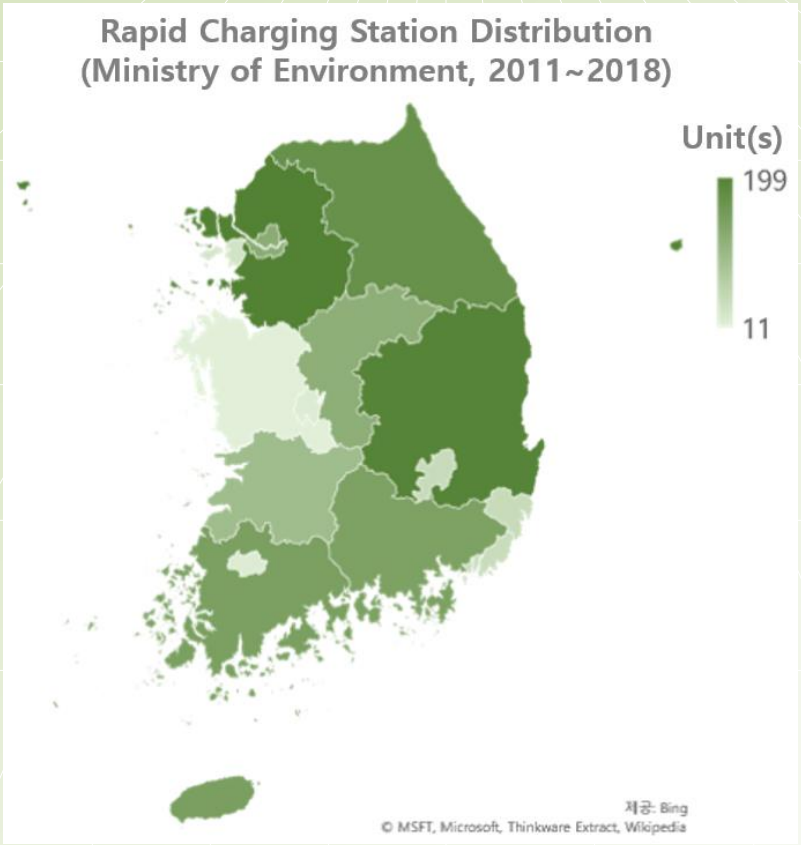


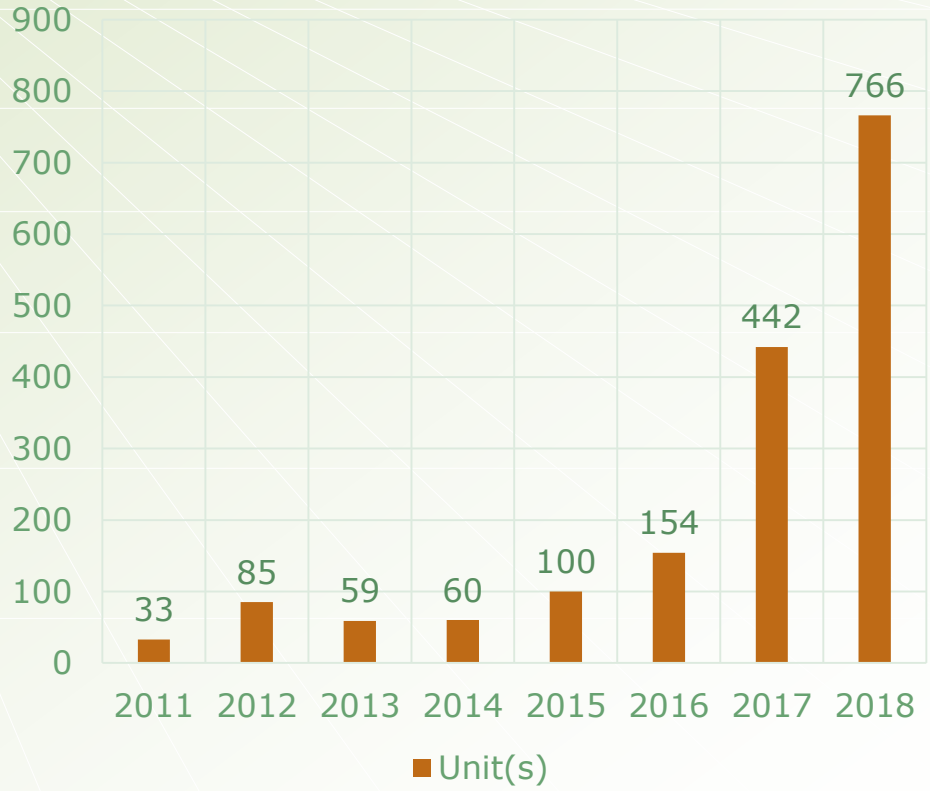


2018, Ministry of Environment

EV Fast-Charging Infrastructure

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



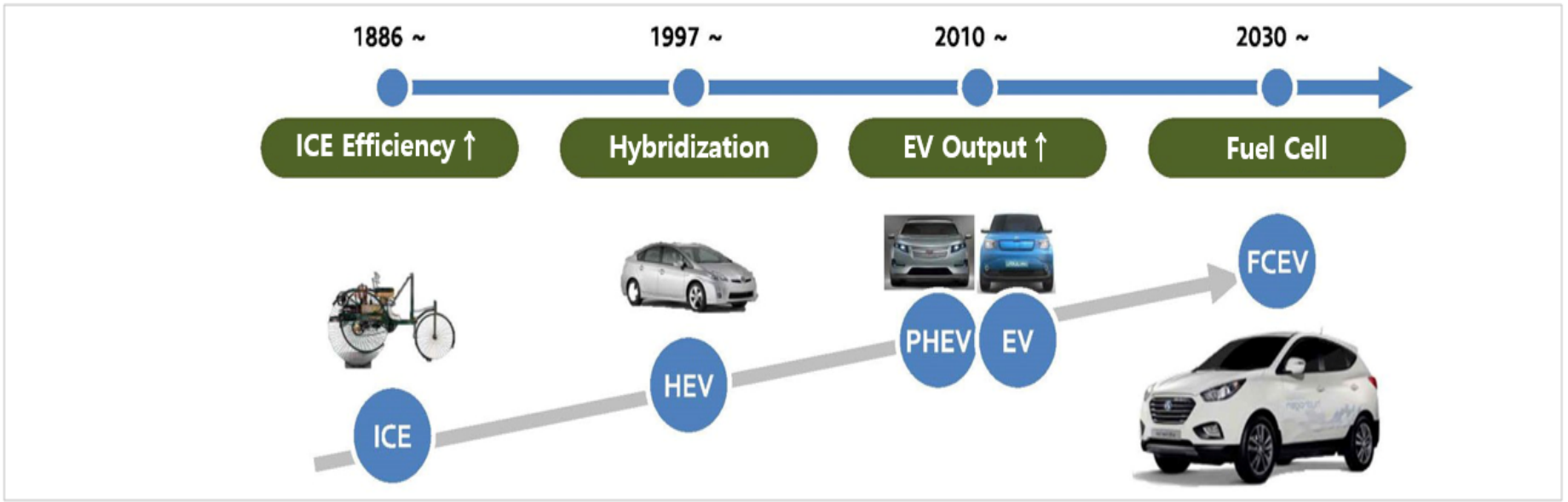


Eco-Friendly Car Industry strategy– Korea

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

ICE Efficiency ↑	Hybridization	EV Output ↑	Fuel Cell
Downsizing	High-output battery	High-capacity battery	Fuel cell stack
Multiple gearboxes	Electric motor	Battery management	Hydrogen tank
Weight reduction	Power control system	Power semiconductor	BOP (APS, FPS, TMS)
48V system	Regenerative braking	Fast charging	Hydrogen infrastructure

- Engine is expected to become the main power source due to the evolution of ICE efficiency technology.
- Expansion from the core market (US / Japan) to Europe and China.
- Generalization with high fuel efficiency option.
- PHEV is expanding to European premium companies
- EV is expected to grow centered on small cars
- 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

Electric car	Micro electric car	Electric car		Electric vans (busses)	
Max. $7,700	Max. $3,600	Light, $9,400	Small, $15000	Medium, max. $50,000	Large, max. $85,000

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

xEV Innovation & Growth Policy

1 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)**

EV user oriented charging station

HOME	ON THE ROAD	DESTINATION
Establish Slow & Fast charger In apartment complexes in Korea	EV charging system in the rest area of every highway & change to dual charging station (gas+electricity) for gas stations on highway	Focusing on railway station & big mart in urban living space

xEV Innovation & Growth Policy

2 EV/FCEV incentive & subsidy

Tax Exemption & subsidy

Income tax	Exempt Max. 2,800 € (approx..)
Acquisition tax	Exempt Max. 1,000 € (approx..)
Subsidy	Provide 6,400 € (expanding to private individual, beginning from 2018)

Driving Incentive (xEV)

Tollway	50% discount
Public Parking	50% discount

EV license plate

Example

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

xEV Innovation & Growth Policy

3 Technology development of EV's core components

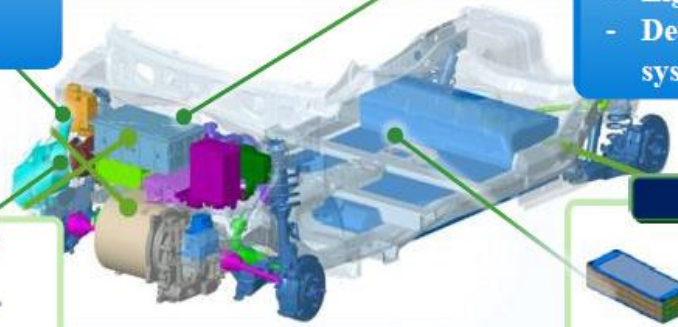
Motor / Reducer

- Increase driving motor efficiency
- Develop electro-magnetic multi stage gear for driving efficiency

Platform / HVAC

EV platform & Heating/Cooling control

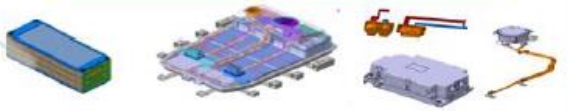
- Light weigh body using CFRP
- Develop EV optimized heat & cooling system



Conversion System

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

Battery System



150 Wh/kg → 300 Wh/kg

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

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 → Up to $4,500
- Acquisition tax → up to $1,200
- Railroad bond → $2,100

Industrial Development Roadmap(BEV)

Goal

Single-charge mileage : 300 → 600km (2 times)

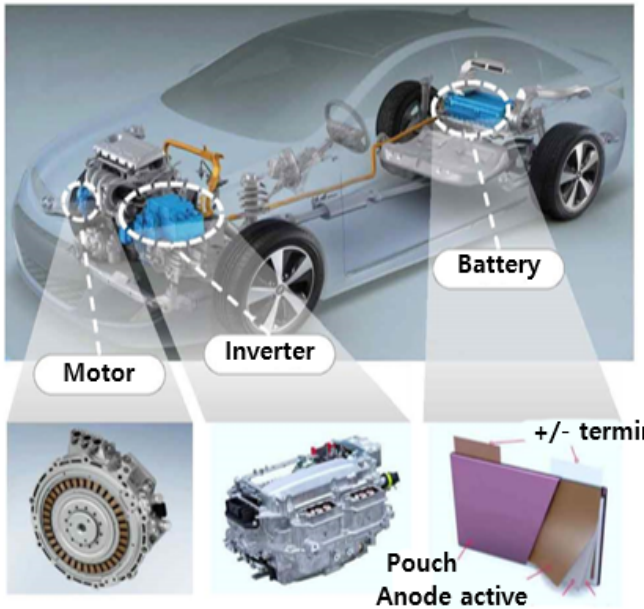
3x charging speed ⇨ Early popularization of electric vehicles

- **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.

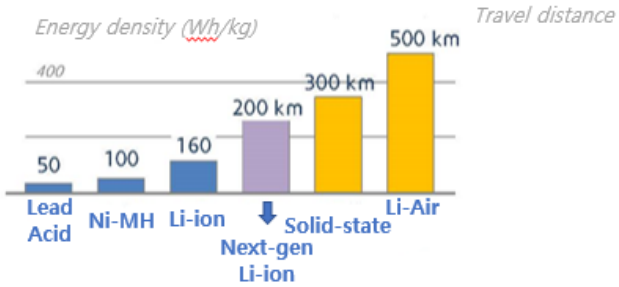
Core parts of a green car



Main parts technology

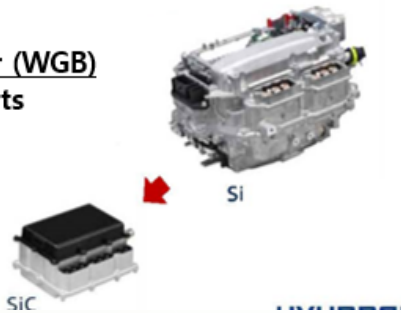
○ **Battery**

- 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.)



○ **SiC / GaN Power Semiconductor (WGB)**

- Fuel economy 5 to 10%, parts miniaturization 40% ↓



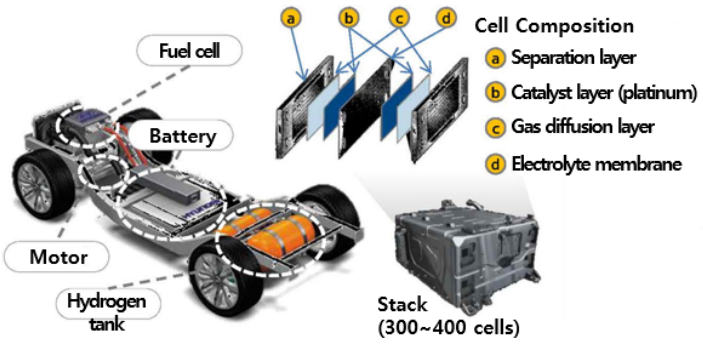
Industrial Development Roadmap (FCEV)

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 statio

Current Status

- Hyundai developed Tucsan 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

Under development

Garbage truck

Industrial Development Roadmap – Autonomous Vehicles

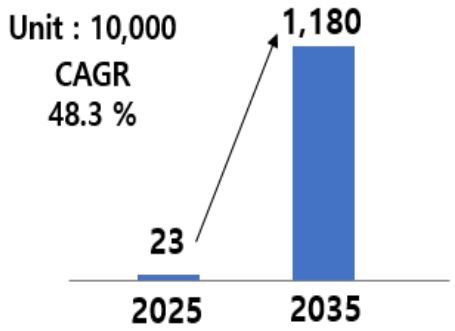
Goal	9 core technologies & components Autonomous driving on road (Lv 4.) in 2025

- **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 Vehicle-Road Map

Autonomous driving system commercialization in low-speed road section → highway → full autonomous driving

Market size forecast (annual sales)



'Rapid growth since commercialization in 2020'
(IHS Research)

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

Manual operation actuator

Electronically controlled actuator

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

Automation per function

Distance maintenance, automatic braking
ADAS feature integration control

Partial autonomous driving

Highway and low-speed
ADAS feature integration control

Section autonomous driving

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

Fully autonomous

Perfect Safety

1980 1990 2010 2015 2020 2030

Autonomous Vehicle – Technology Details

Category	Scope
Energy storage / management system	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
Power conversion system	Inverter, converter, onboard charger
Electric drive system	Permanent magnet motor, non-permanent magnet motor, SI-series inverter, non SI-series inverter
Electric Vehicle Charging Infrastructure	Electric vehicle charger (fast), infrastructure construction, wireless charging system
Camera for self-driving	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
Convenience system for drivers	Detection sensor, active safety system, driving support system, accident reduction system
Information system	Driver information, interface, and information generation technology
Eco-friendly lightweight parts	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

Autonomous Vehicle

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

ACC ('92/'99)

LDWS ('92)

Automatic Parking ('03)

BSD ('07)

Future

Autonomous Vehicle

Partial autonomous cars (2014)

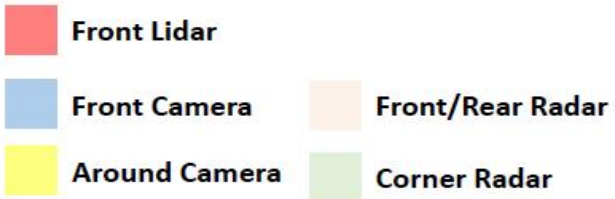
Fully autonomous cars (?)

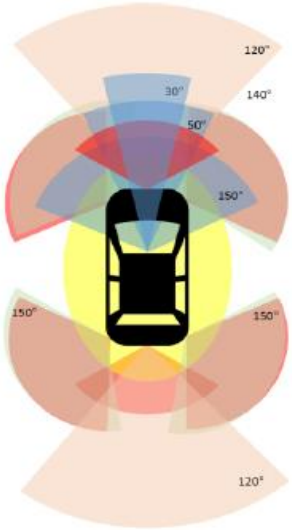
Autonomous Vehicle

☐ 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

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 1EV

- 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

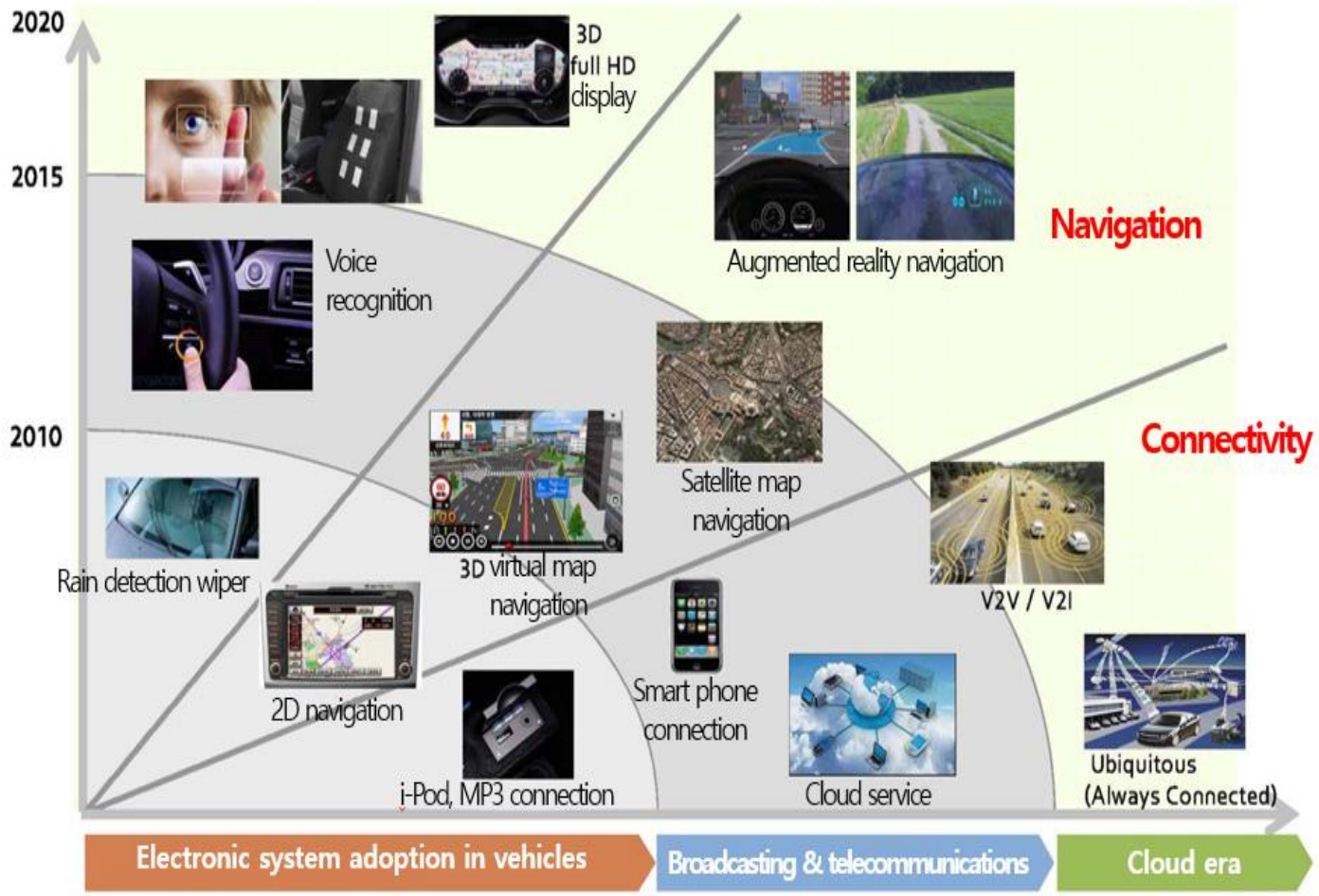
Seamless connection technology with mobile IT devices

Car cloud

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


Renault Samsung 'SM3 Z.E'


Hyundai 'Ionic EV'


Kia 'Soul EV'


GM Korea 'BOLT'

Micro Mobility : MM

Personal Mobility : PM


Two-wheeled, Three-wheeled, Bicycle, Scooter, Kickboard, Balancing, Wheel, Board

Agricultural Electric Vehicle : AEV


Walking Farming Carrier, Riding Farming Carrier

Mobility Scooter : MS

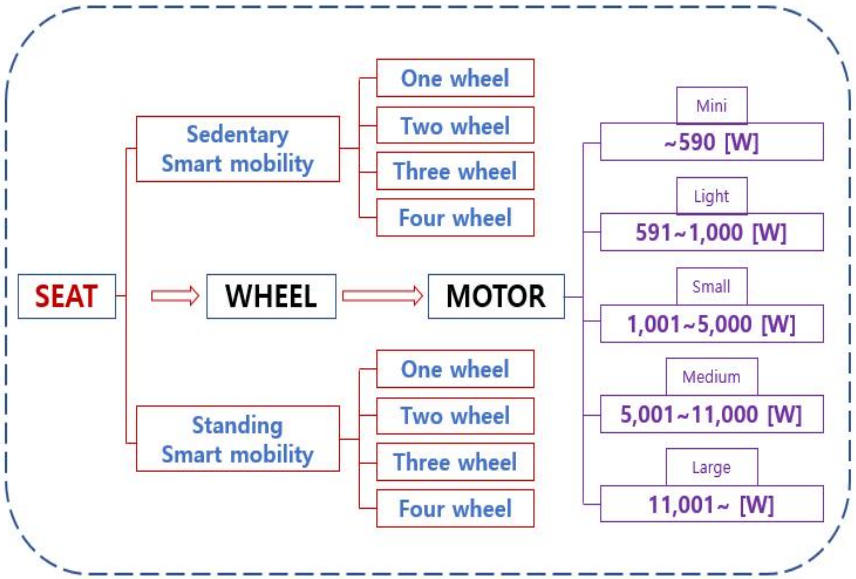

Wheelchair, Transportation for the mobility impaired

Drone


Cargo, Passenger flight

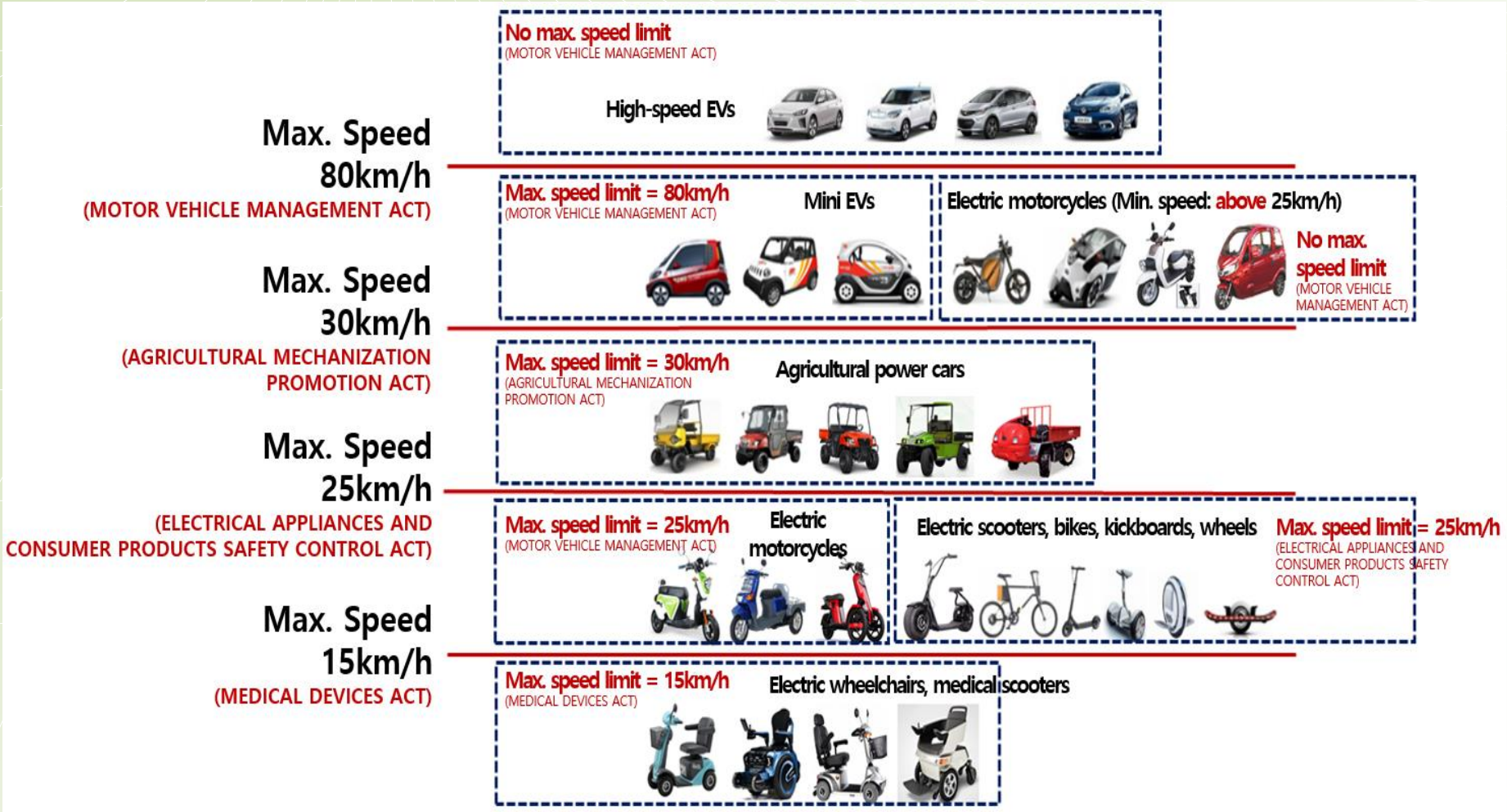
Special Electric Vehicle : SEV


CoCo (Yakult Electric Cart), Multi-purpose, Facility management, Leisure



Personal E-Mobility

☐ Vehicle classification by top speed



Electric Drive System Development – Motor Aspect

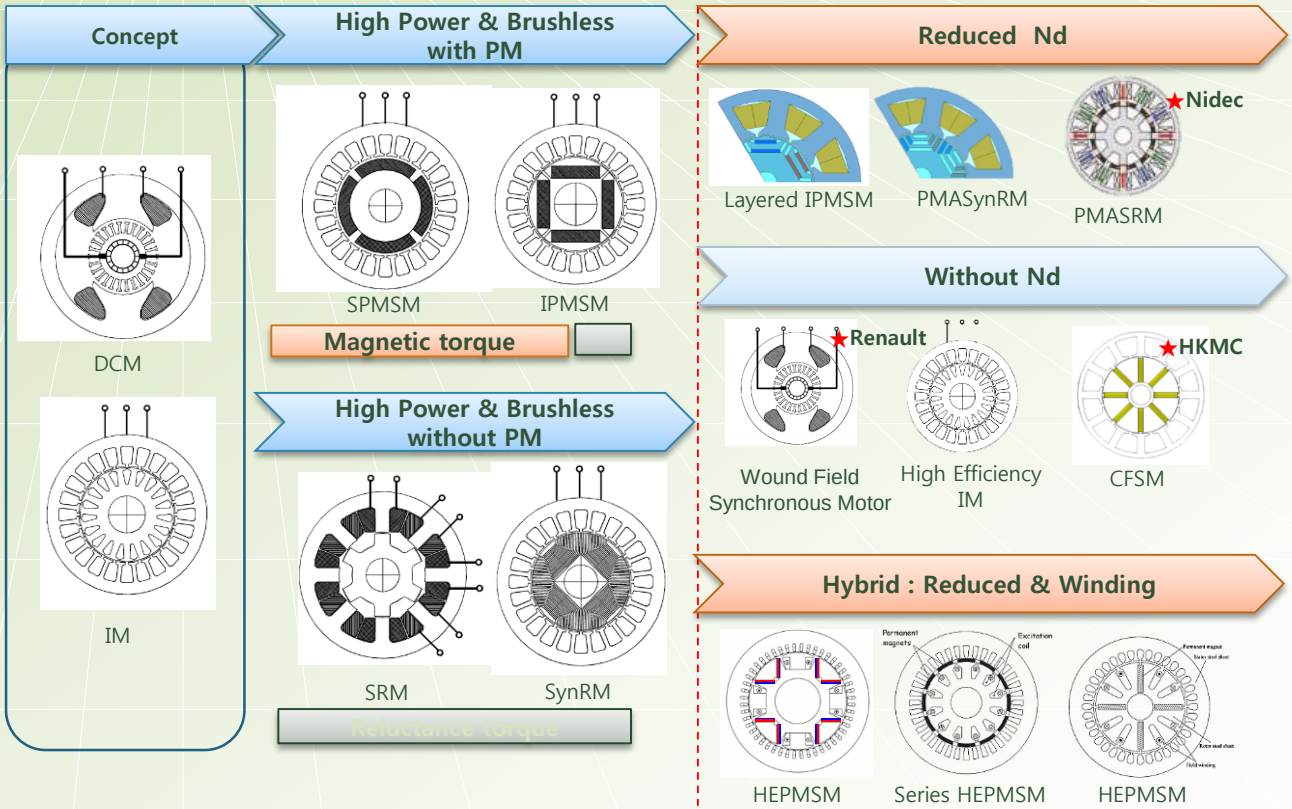
Electric motor

- 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 △ shape, permanent magnet split or laminated
- [IM] Conv. aluminum or copper fabrication → copper die-casting

Development of Traction Motors



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

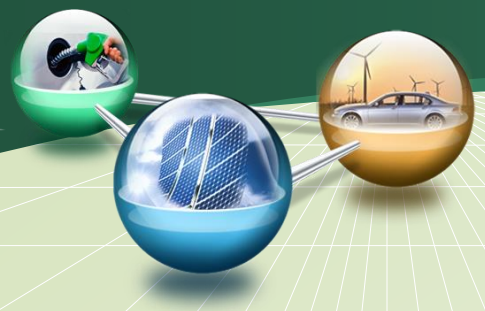
- **Integrated motor, inverter and reducer**
  - Connected by bus bar w/o harness: minimizing copper loss and electromagnetic noise
  - Housing sharing improves power output density with optimal cooling

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

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