R&D and Deployment of EV charging infrastructure in KOREA: Progresses and Outlook

IERE CLP-RI Workshop - Smart Cities

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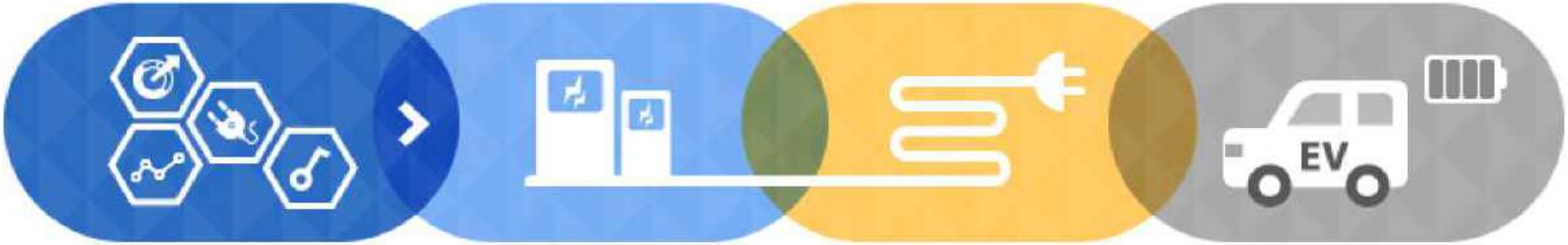
Introduction

❑ Components of EV charging infrastructure

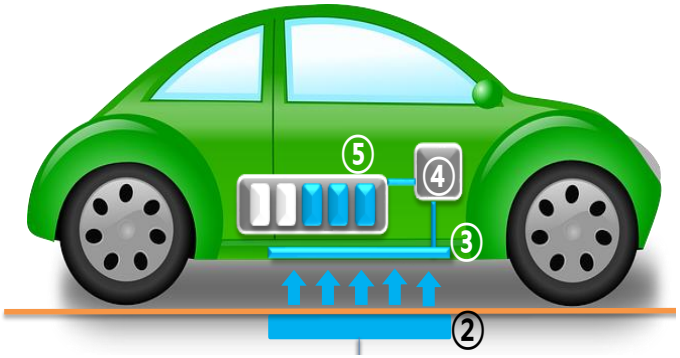


1. Power delivery 2. EVSE (Charger) 3. Charge Interface 4. Information system

❑ EV charging methods

Direct/Plug-in

Battery Exchange



Wireless Induction

❑ History of Plug-in type Electric Vehicle Supply Equipment (EVSE)

1st Gen. | 2nd Gen. | 3rd Gen. | 4th Gen.





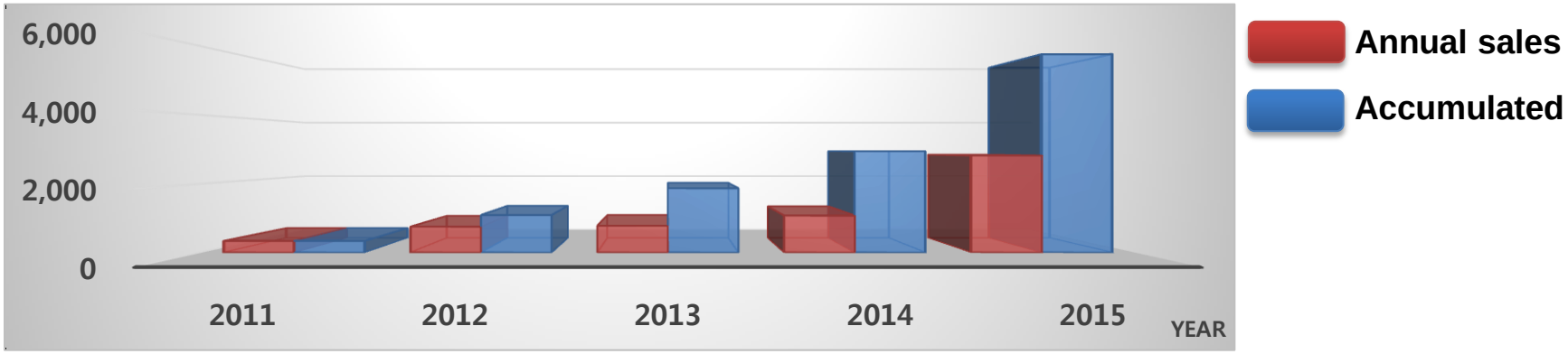


Application	Public Quick Charge	Home, Parking lot	Portable charge
Power rating	~50 kW	~7 kW	3.2 kW
Typical Charge Time*	20~30 min	4~6 hours	8~9 hours
Cost	70m	4~7m	<1m

*For EV with 28kWh battery, ie. IONIQ

Introduction

❑ EV sales in Korea



❑ Installed EVSEs (Fast & slow chargers)

- Slow chargers: 2,964 (2014)
- Quick chargers: 337 at Major cities and Highway (2015)
- KEPCO chargers: 131 at highways and business sites (52 in Jeju) ('15) ➔ 614 in 2016

YEAR	TOTAL	Highway	Major Cities	Other regions				
				Capital	Kyungsang	Jeolla	Chungchung	Kangwon
2011~2014	**237**	16	154	43	9	6	6	3
2015	**100**	30	5	11	18	25	7	4

Source: www.ev.or.kr

❑ EV charge rates for Home and Fast chargers

Class	Demand charge (krw/kW)	Energy charge (krw/kWh)			
		Time period	Summer (Jun.1~Aug.31)	Spring/Fall (Mar.1~May.31/ Sep.1~Oct.31)	winter (Nov.1~Feb.28)
Low Voltage	2,390	off-peak load	57.6	58.7	80.7
		mid-load	145.3	70.5	128.2
		peak-load	232.5	75.4	190.8
High Voltage	2,580	off-peak load	52.5	53.5	69.9
		mid-load	110.7	64.3	101.0
		peak-load	163.7	68.2	138.8
Fast Charger		off-peak load	284.2	285.2	301.6
		mid-load	342.4	296.0	332.7
		peak-load	395.4	299.9	370.5

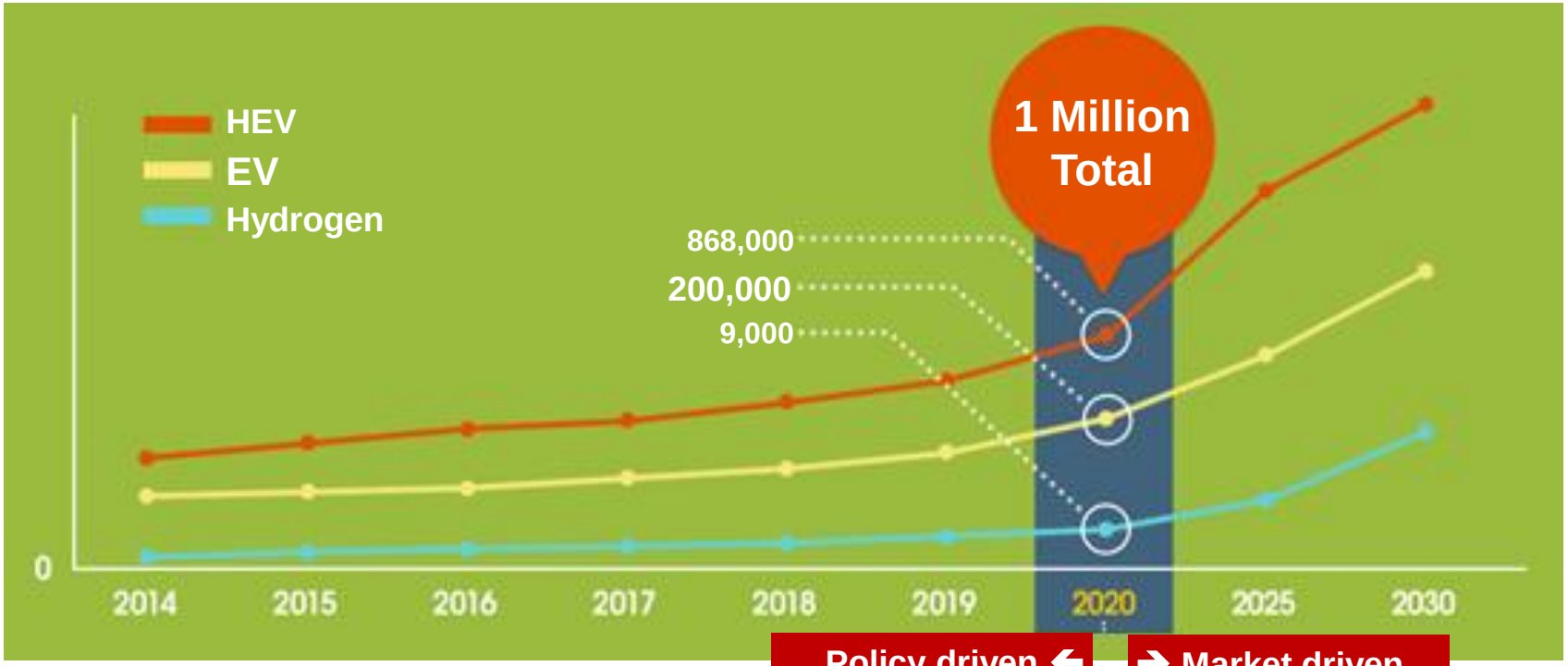
Category by season and time slot

Time slot	Summer, Spring and Fall (Mar. ~ Oct.)	Winter Nov. ~ Feb.
Off-peak load	23:00 ~ 09:00	23:00 ~ 09:00
Mid-load	09:00 ~ 11:00, 12:00 ~ 13:00, 17:00 ~ 23:00	09:00 ~ 10:00, 12:00 ~ 17:00, 20:00 ~ 22:00
Peak load	11:00 ~ 12:00, 13:00 ~ 17:00	10:00 ~ 12:00, 17:00 ~ 20:00, 22:00 ~ 23:00

Source: www.kepco.co.kr

Deployment goals

❑ Environmentally friendly cars deployment plan (Government Goals)



❑ Expectations and Outcomes

Deployment goals

❑ Plans to accelerate deployment of EVs and EVSE

- (Quick charger) 637 chargers at highways for long distance driving (~ 2017)

  ➔ Large scale public charge station (KEPCO)

- (Slow charger) Portable chargers and EVSE for Apartment complex (KEPCO)
- (Battery exchange) Demonstration project in Jeju Island

❑ Goals for EVs and Fast charger deployment

Items	2014	2015	2016	2017	2018	2019	2020	2025
pHEVs (x1,000)		2	3	8	18	21	50	
EVs (x1,000)	3	6	16	46	86	136	200	500
Public Quick Chargers	232	432	487	637	830	1,000	1,400	3,300
Range (km)	160	200	230	230	270	270	300	

Deployment goals

❑ Incentives for home EVSE installation

Year	2013	2014	2015	2016	2017
EVSE Installation Incentives (million, krw)	8	7	6	4	-

❑ Other Incentives, subsidies and supports (2016, krw)

- EV Subsidies: **12m** (FCEV: 27.5m, HEV: 5m, HEV: 1m)
- EV Tax incentives: up to 4m
- Local Gov. subsidies: up to 8m (Suncheon)
- Specialty EV-only number plate design
- Mandatory EV-only parking lot and EVSE for new apartment complexes

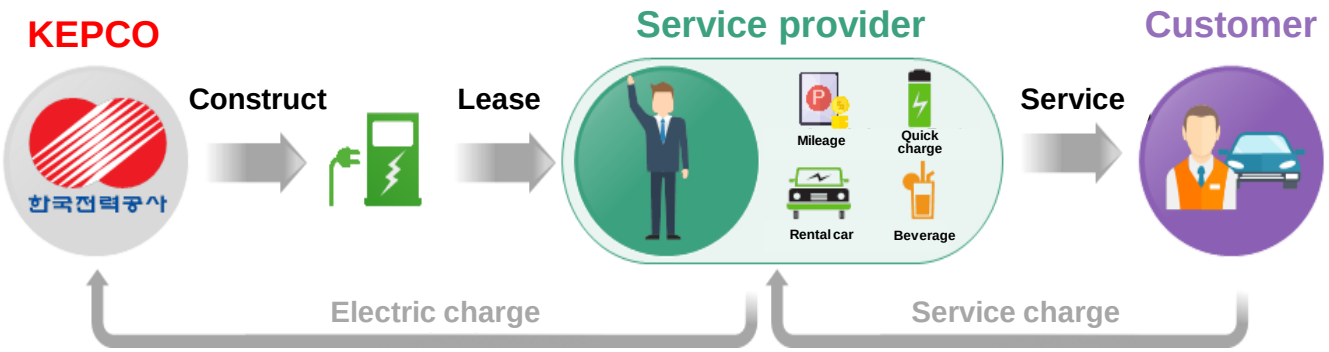
❑ R&D support plans (~ 2020)

- Improve EV performance: 150% (range: 200 km ➔ 300 km)
- Cost reduction of 40% for FCEVs
- Invest KRW 150bil. for 5 years in environment friendly car R&D

Promotion plans of KEPCO

Open type EV charging station construction

➔ To promote EV deployment and pave way to new business model



KEPCO: Construct infra, Lease to service provider
Service provider: Service development, customer interaction

- **Small scale public charging station construction**

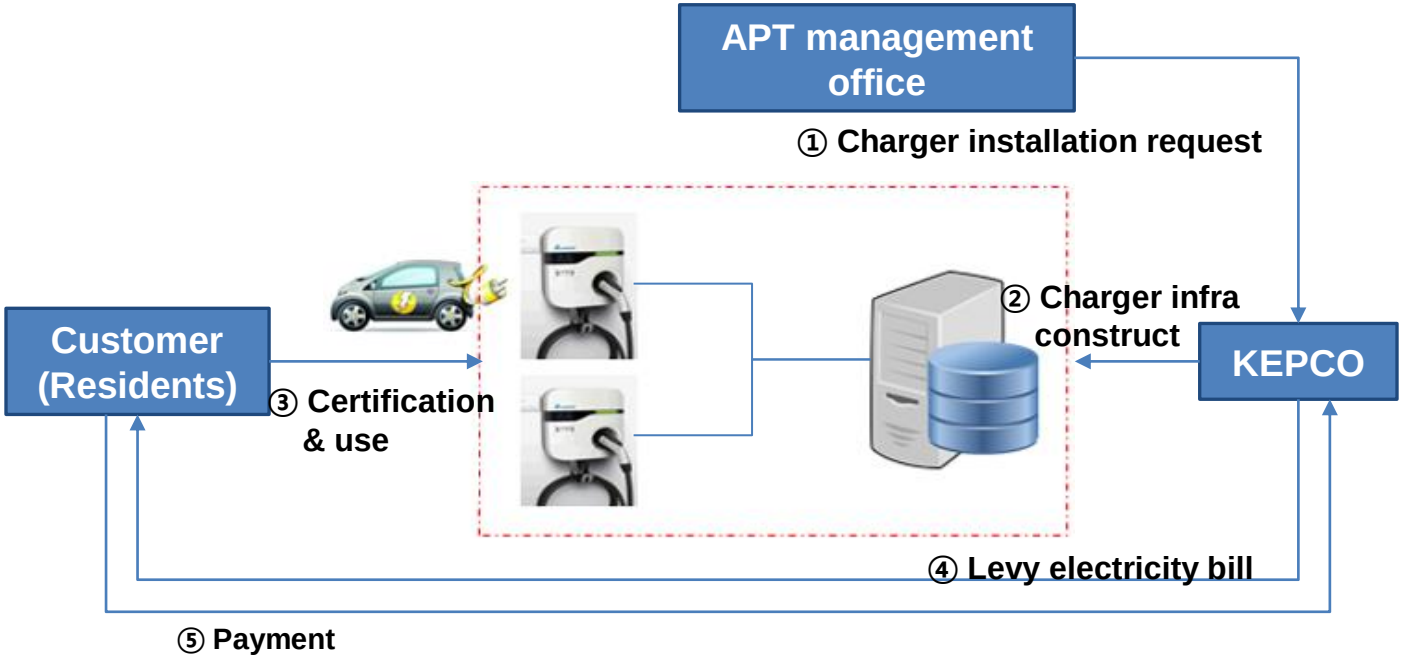
District	Seoul	Jeju	Daegu	Gwangju	Gyeongsang nam-do	Total
Station	60	60	12	12	6	**150**
Charger	100	106	34	44	16	**300**

- **Large scale flagship station: KRW 29.6 billion (3 stations, 100 chargers)**
- **Gas station type: KRW 80.0 billion (5 stations, 100 chargers)**

Promotion plans of KEPCO

- **EVSE deployment for apartment complex (krw 100b, 2016)**
  - **Apartment home accounts for >60% of residences in Cities**
  - **To promote EV sales for residents of apartment complex**
  - **Expansion of L2 charger number to 30,000 (MOTIE)**

Quick charger: 1 per 1,500 household
L2 charger: 3 per 1,000 household



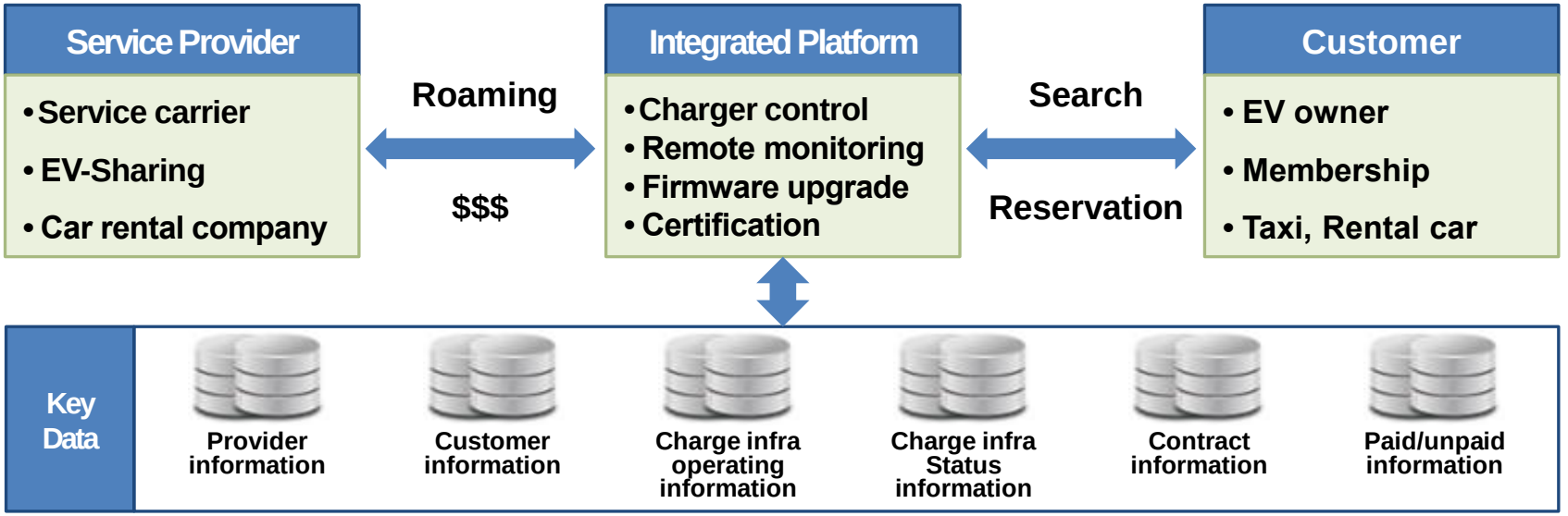
Promotion plans of KEPCO

Integrated operation platform for EV charger infrastructures

Background

- Nationwide Star-Network and Large-scale public/Flag-ship station construction
- Opening of charge station to the public and billing of charged electricity

- Remote control, self-diagnosis, reservation function
- Charger availability, roaming of charge service carrier, payment transaction
- Control of charge demand to reduce peak load



Promotion plans of KEPCO

Smart grid based carbon free island - Jeju

- **Switching to EV and 100% of Energy independence**
- **CO_2 reduction of 90%↓**
- **Job creation : 50,000 positions**

Category	As-Is (2016)	To-Be (2030)
Infra Construction	▪ AMI - 70 thousand units (19%) ▪ **EV - 2,366 cars (0.6%), EVSE: 486 units**	▪ AMI – 360 thousand units (100%) ▪ **EV: 377,000 (100%), EVSE: 4,300 units**
Power grid expansion	▪ HVDC #1, #2 - 400 MW ▪ Renewable energy - 282 MW ▪ ESS - 19.3 MW	▪ Additional, HVDC #3 - 200 MW ▪ Renewable energy - 4,311 MW ▪ ESS - 1,300 MW
Consumption effectiveness	▪ Delay of efficiency solutions for customers ▪ Absence of integrated management of energy information	▪ AMI based optimization of power consumption ▪ Integrated E-information management center

Phase I (~2018)	Phase II (~2025)	Phase III (~2030)
▪ Infra construction (AMI, EVC) ▪ Integrated management system	▪ Renewable energy & ESS expansion ▪ Early construction of HVDC #3 ('25→'21)	▪ Completion of Smart Grid ▪ Jeju CFI completion

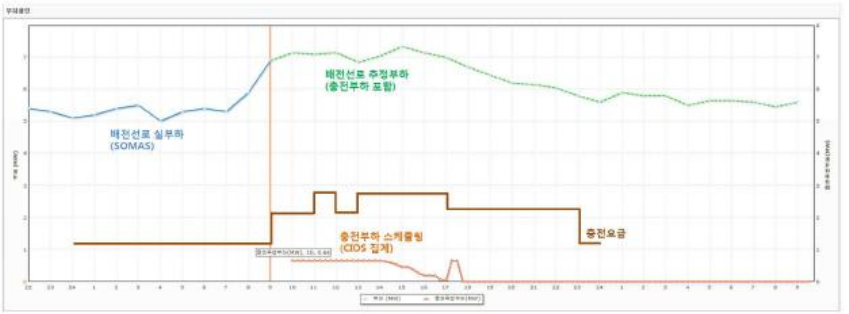
R&D Project Highlights

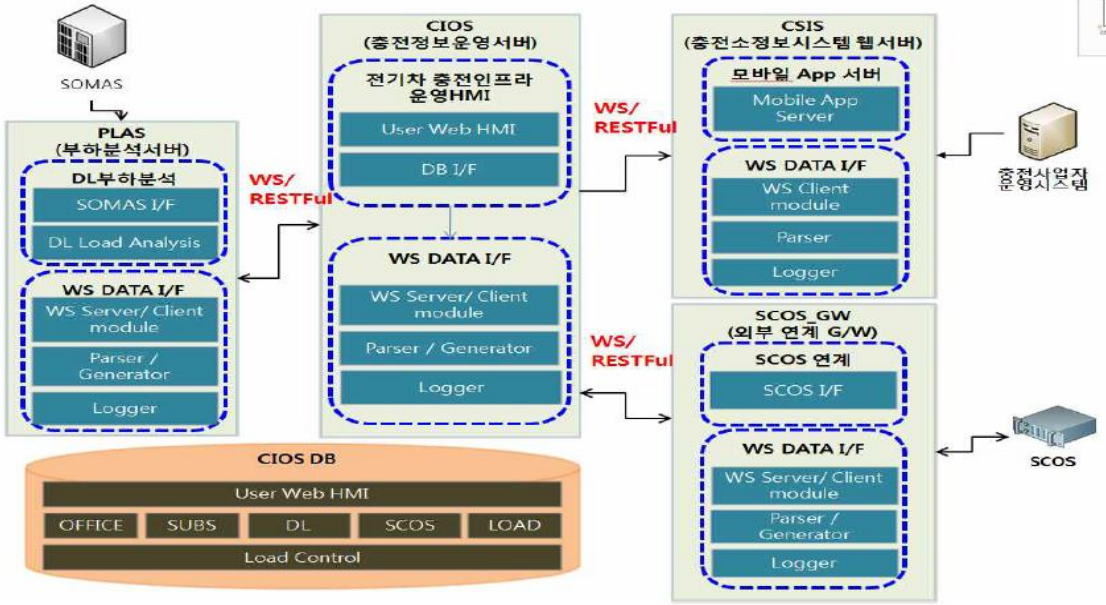
❑ Development of EV charging information system

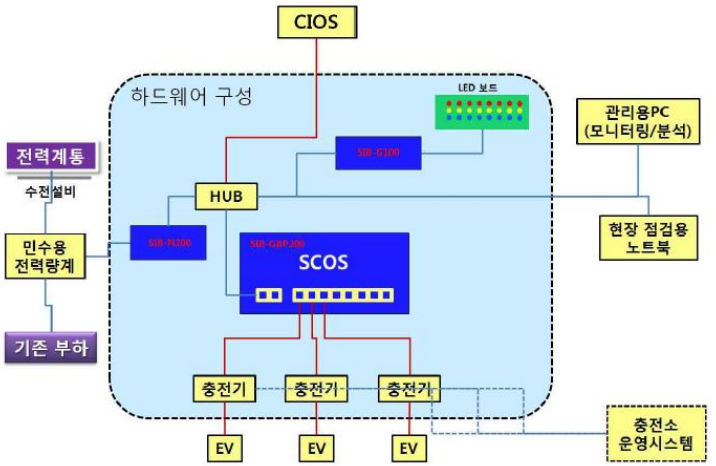
- **Period: Nov. 2012~ Oct., 2014**
- **Budget: 1,450M (krw, KETEP & KEPCO)**

OUTCOMES:

- **EV charging information contents & HMI**
- **Smart Charging Operation System (SCOS)**
- **Charging infrastructure Operation System(CIOS)**
- **EVSE – SCOS - CIOS Protocol & standards**





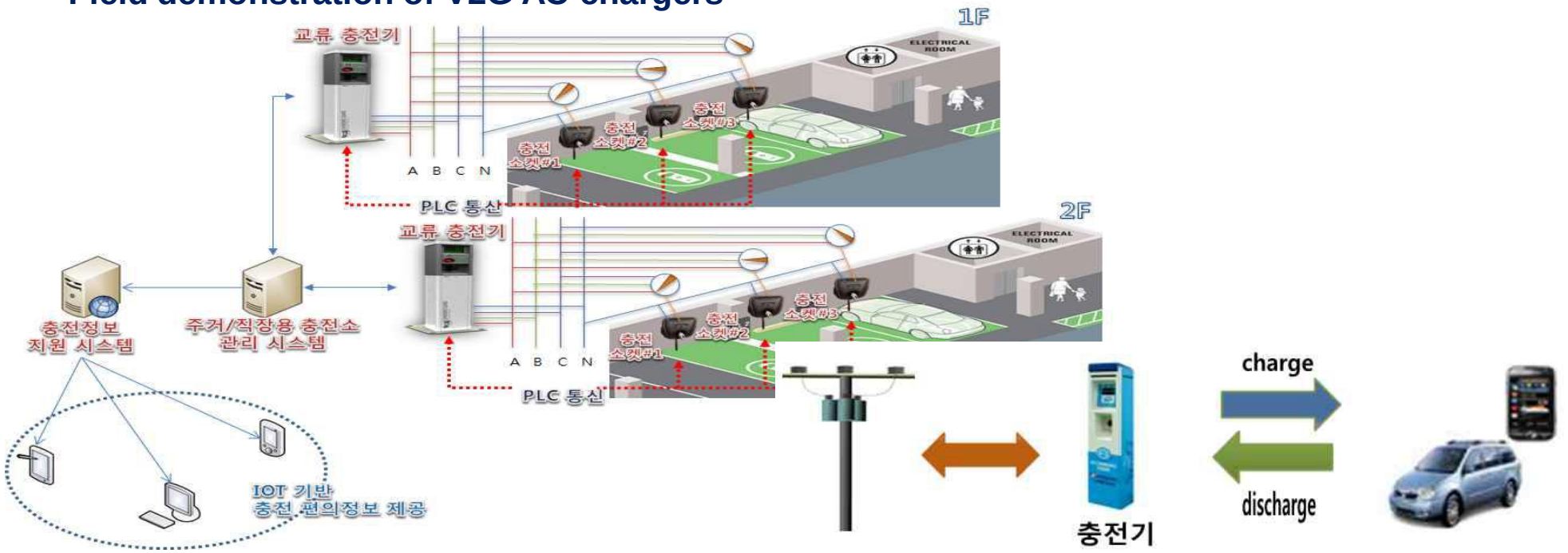


❑ Development of the V2G AC charging system

- Period: January, 2015 ~ December, 2017
- Budget: 2,010M (krw, KEPCO)
- Partners: KEPCO KDN, PNE, KAIST

OBJECTIVES:

- Development of V2G charge infra operation algorithm and system plans
- Development of 1:N socket type V2G AC charger
- Field demonstration of V2G AC chargers



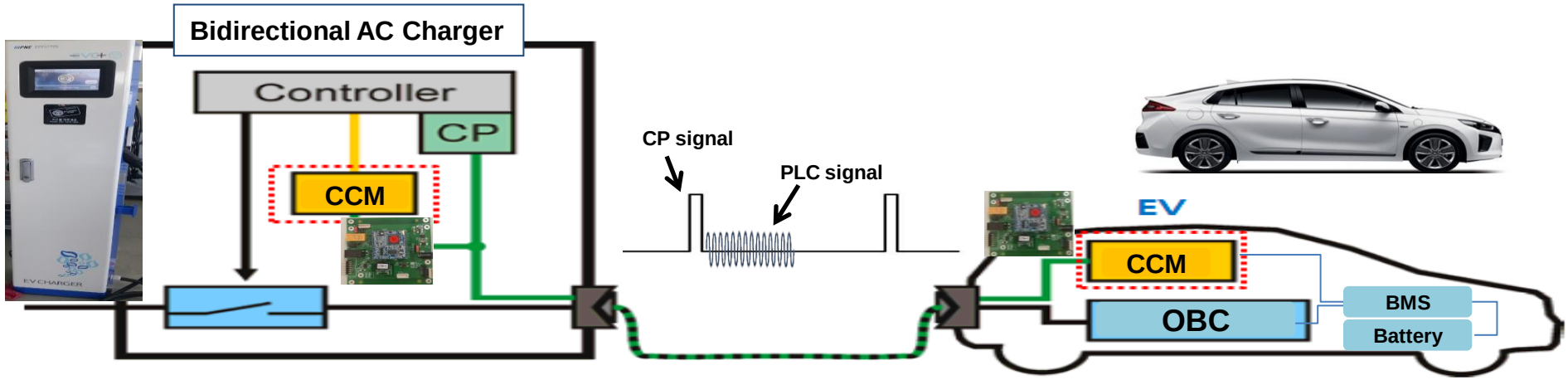
❑ Service integrated V2G development & demonstration

- Period: June, 2015 ~ May, 2017
- Budget: 4,774M (krw, KETEP & KEPCO)
- Partners: HMC, MOBIS, KEPCO KDN, PNE, I&CT, Nemo, Nextel

OBJECTIVES:

- Development of V2G business model and policy
- EV and bi-directional charger technology for V2G application
- Field demonstration of V2G EV, bi-directional chargers, operation system

❖ AC Charge and Discharge test



R&D Project Highlights

❑ Construction of Security infrastructure for Smart Grid vulnerability test & analysis

- Period: March, 2015 ~ December, 2017
- Budget: 4,570M (krw, KETEP & KEPCO)
- Partners: KSGI, NSR, KEPCO KDN, KOIST, JejuEVS, etc.

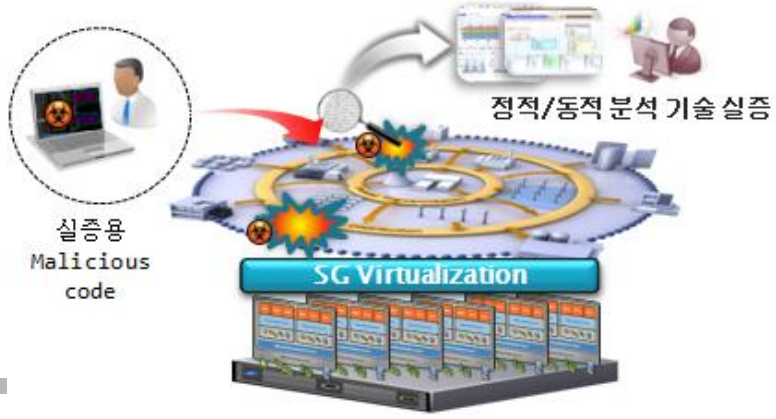
OBJECTIVES:

- Vulnerability analysis for EV charge infra cyber security
- Development of Smart-grid virtualization system and vulnerability analysis automation
- Construction of EV charge infra cyber security analysis test-bed

```
02 19 70 01 01 00 01 03  27 10 02 30 30 30 30 30
30 30 31 30 31 63 31 00  19 00 05 00 00 00 00 03
fd ff 74 00 00 00 00 19  70 01 01 00 01 03 10 00
31 50 5f c2 03
```

```
memset((char *)v5 + 0x824, v7, 0x81Cu);
*((_BYTE *)v5 + 0x824) = *vMsgBuffer;
memcpy((char *)v5 + 0x825, vMsgBuffer + 1, 7u
memcpy((char *)v5 + 0x82C, vMsgBuffer + 8, 3u
memcpy((char *)v5 + 0x82F, vMsgBuffer + 11, 8
memcpy((char *)v5 + 0x837, vMsgBuffer + 19, 2u);
memcpy((char *)v5 + 0x839, vMsgBuffer + 21, 2u);// cmd
memcpy((char *)v5 + 0x83B, vMsgBuffer + 23, 2u);// length field (big endian)
v9 = *((_BYTE *)v5 + 0x83C);
vLen = v9 | (*((_BYTE *)v5 + 0x83B) << 8);
memcpy((char *)v5 + 0x83D, vMsgBuffer + 25, v9 | (*((_BYTE *)v5 + 0x83B) << 8));// data field: [length] bytes
memcpy((char *)v5 + 0x103D, &vMsgBuffer[vLen + 25], 2u);// CRC field
v11 = *((_BYTE *)v5 + 0x824);                 // start tx byte (should be 0x2)
v12 = vMsgBuffer[vLen + 27];
*((_BYTE *)v5 + 0x103F) = v12;
if ( v11 != 2 )
{
  qDebug("Debug : stx error");
  return 0;
}
if ( v12 != 3 )
{
  qDebug("Debug : etx error");
  return 0;
}
```

```
v13 = 0xFFFF;
v14 = 1;
do
{
  v15 = vMsgBuffer[v14++];
  v13 = CRC16_TABLE[(unsigned __int8)(v13 ^ v15)] ^ (v13 >> 8);
}
while ( v14 - 1 < vLen + 24 );
if ( v13 != (*((_BYTE *)v5 + 0x103E) | (*((_BYTE *)v5 + 0x103D) << 8)) )
{
  qDebug("Debug : crc error");
  return 0;
}
return Protocol::DataProc(v5);
```



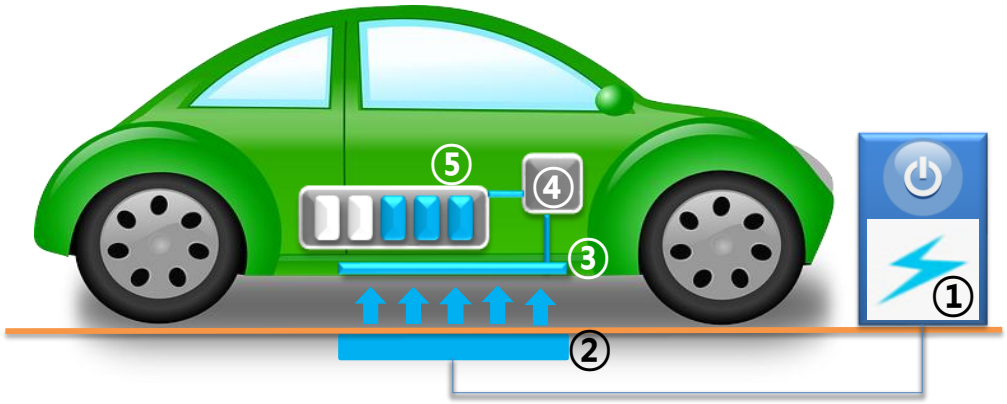
R&D Project Highlights

❑ Development of 6.6 kW Wireless Power transfer EV charger

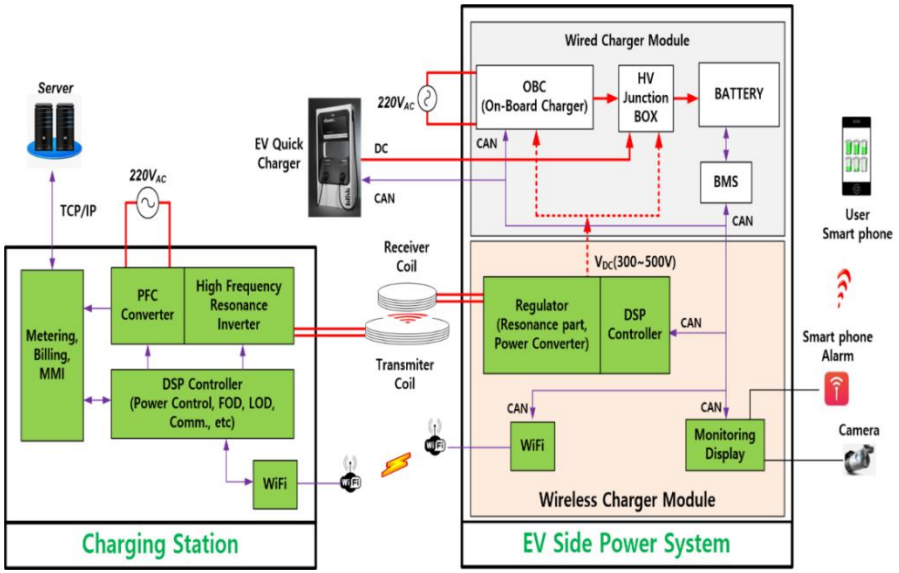
- Period: June, 2015 ~ May, 2018
- Budget: 6,300M (krw, KEIT & KEPCO)
- Partners: Green Power, KAIST, KATECH, BNS soft

OBJECTIVES:

- Dev. of 6.6 kW resonant type WPT system (>90% @20cm Air gap)
- EV WPT charger characterization system (SAE & IEC std.)
- WPT-EV integration and field demonstration of WPT EV and charger



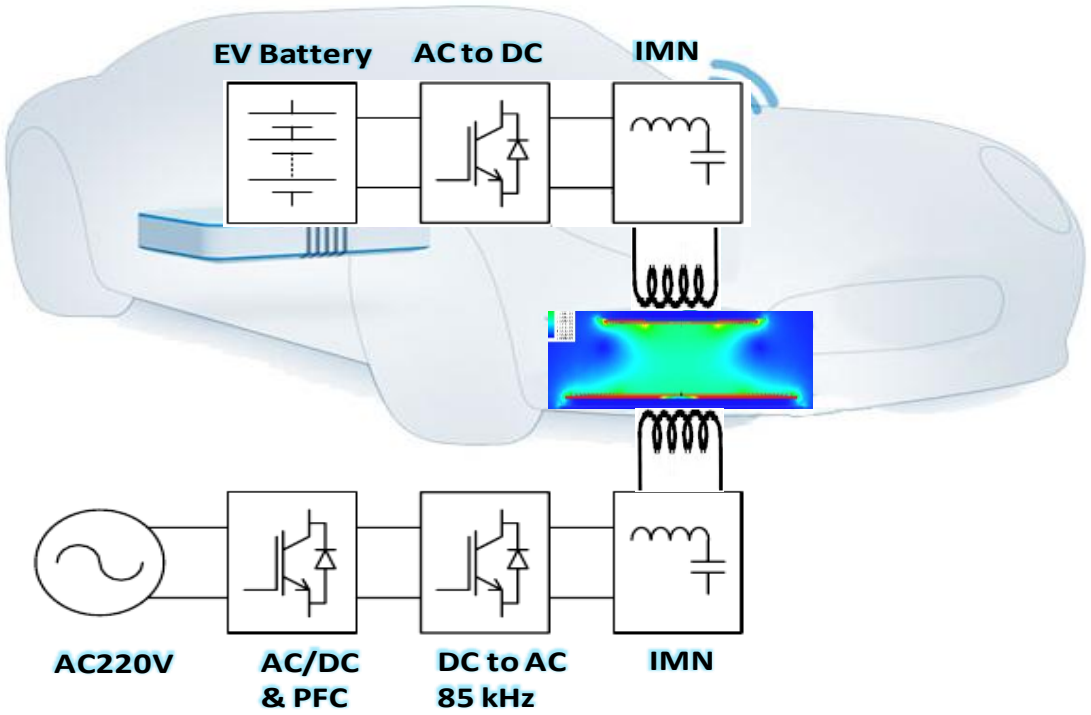
① Power Conversion , Control, Billing, ② Wireless Power Transmitter pad, ③ Wireless power receiver pad, ④ Power conversion and charging control, ⑤ EV Battery



R&D Project Highlights

❑ Development of 6.6 kW Wireless Power transfer EV charger

- **Wide range of air gap:** Z = 150 ~ 200 mm
- **High Efficiency:** > 90% (AC to Battery), > 95% (coil to coil)
- **Wide range of tolerance:** X = ±75mm, Y = ±100 mm
- **Interoperable :** Compatible with 3.3 kW RX pad



CONCLUSION

- Not only incentives but also customer friendly policies and technology should be integrated with the EV charging infrastructure deployment plans.
- EVs will become a sizable part of utility customers as the number of EV increases and the capacity of the battery increases.
- V2G and V2x technology will play a role as DER for utility operation and home-grid integration.
- Wireless charging technology will be a standard option for upper class EVs and autonomous e-vehicles.