40 min.

Smart grid & New Energy Business

Jun. 2017

KEPCO

agenda

I. 4th Industrial Revolution

II. Smart Grid Pilot Project in Korea

III. KEPCO's New business

IV. Challenges and Opportunities for the Future Grid

I. We are beginning at :
"The 4th Industrial Revolution"

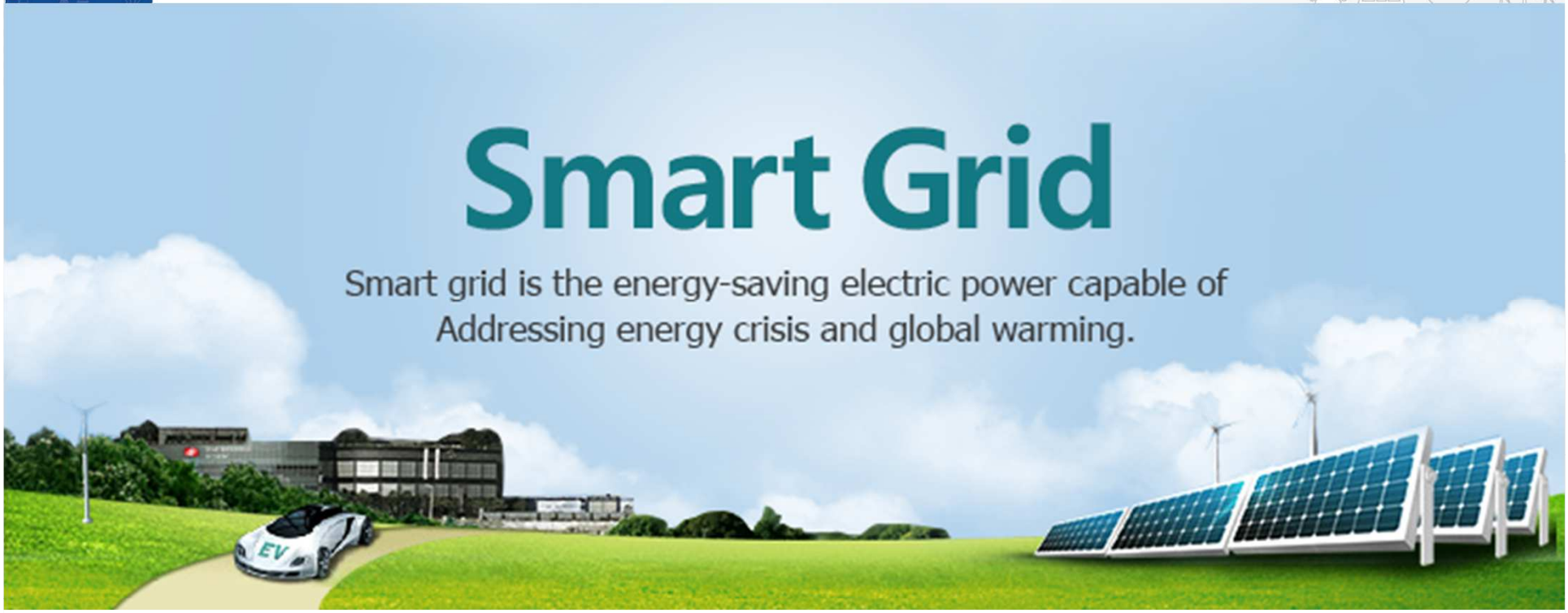
What is the "4th Industrial Revolution" ?

"The Fourth Industrial Revolution refers to the fusion of technologies across the physical, digital and biological worlds which is creating entirely new capabilities and dramatic impacts on political, social and economic systems."

- KLAUS SCHWAB, founder and executive chairman, The World Economic Forum

Perspectives of experts

Smart grid – 4th revolution in Power industry



Grid	+	ICT=Smart	=	Smart Grid
One-way flow of electric power and information		Real-time information exchange		Two-way flow of electric power and information

(ICT : Information Communication Technology)

Introduction to Korean Power System & Smart Grid

KEPCO in Brief

Government

(51%)

KEPCO

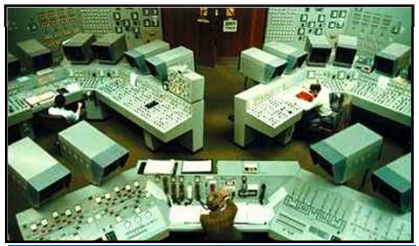
(1USD=1,144KRW)

Total Assets	$153 billion
Revenues	$51 billion
Customers	22,030,215
Employees	20,196

(As of Dec.31, 2015)

Domestic :
14 District Divisions
233 Branch Offices

Transmission



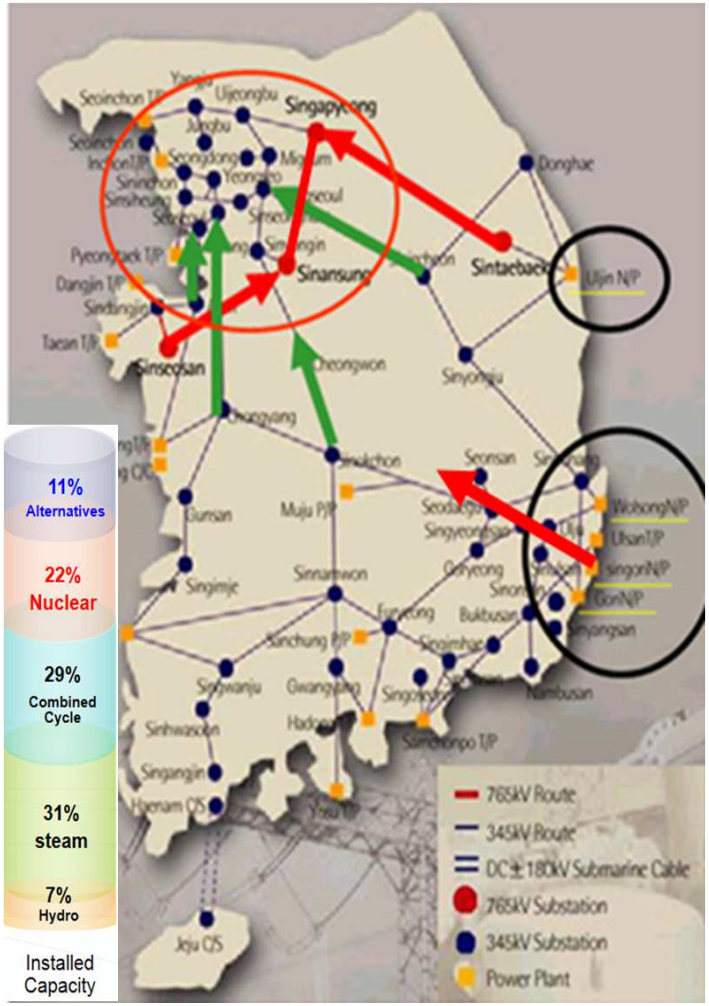
Distribution

Power Sales

Korean Power System

System Status

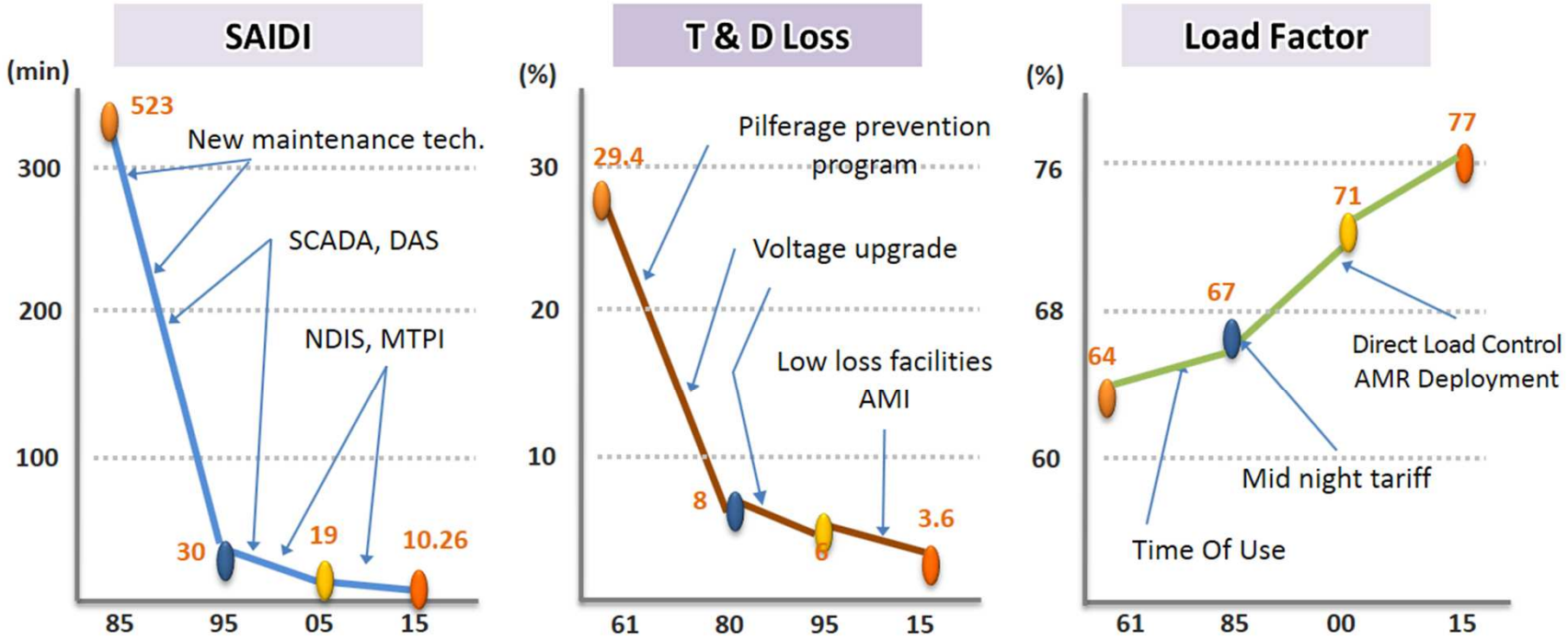
- Installed **Generation Capacity** : 101,399 MW
- **Maximum Power Demand** : 85,183MW('16.8.12)
- Capacity Reserve Margin : 23%
- Transmission Lines/Cables : 33,316 C-km
- Distribution Lines/Cables : 465,278 C-km
- Two **765kV** lines in Operation
- Backbone Grid : **345kV**, Others 154kV/22.9kV
- HVDC System : **DC±180kV, 250kV**, 101km
- Operating Frequency : 60Hz
- **Single Isolated** System



As of Dec.31, 2015

Korean Power System

[SAIDI : 10.26 min, T&D Loss : 3.6%, Load Factor 77% ('15)]



☞ **SAIDI : System Average Interruption Duration Index**
NDIS : New Distribution Information System
MTPI : Maintenance Technology without Power Interruption

KEPCO in Forbes 2000

#97 Korea Electric Power

Market Cap As of May 2016

$33.1 Billion

Industry	Electric Utilities
Founded	1915
Country	South Korea
Chief Executive Officer	Hwan-Eik Cho
Website	http://www.kepco.co.kr/eng/
Employees	20,603
Sales	$52.09 B
Headquarters	Seoul

Korea Electric Power on Forbes Lists

#97 Global 2000

- #139 in Sales
- #26 in Profit
- #179 in Assets
- #310 in Market value

Ranked as #1 in Electric Utility Sector

Leading New Energy Eco System

Paris Climate Agreement

- Paris COP 21 Agreed
- Korean government announced in Dec. 2015 Korea will reduce 37% CO2 (BAU levels) by 2030

Korean Government Policy

- US$ 42 Bil. Investment in 10 Selected Electric Energy Sector Projects
  - During 2016, US$6.4 Bil. Invested in New Energy Business Industry
- Target for Low Carbon Economy
  - Focus on Developing New Energy Industry

Industry/Technology Integration

- Ind./Tech. + Ind./Tech. → New Ind./Technology
  - R/E + ESS, EV + AI, etc.
- Electricity + ICT + Others
  - Smart Home, Smart Factories

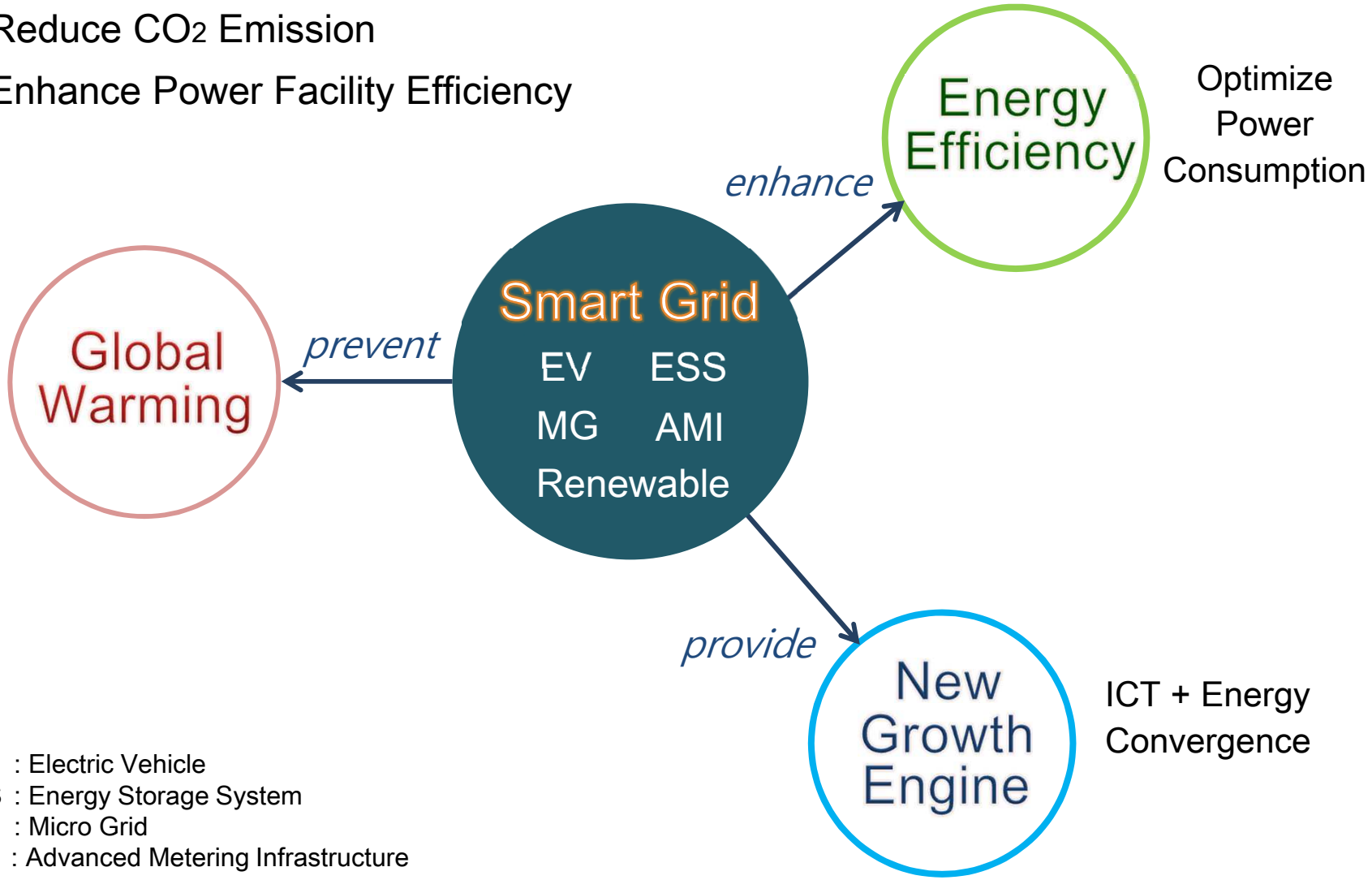
KEPCO's Change of Business

- From Conventional Business → New Energy Business
  - Electric+Non-Electric Power BMs
- Develop New Growth Engine
  - Env.-Friendly, Smart Energy

Ⅱ. Smart Grid Pilot Project in Korea

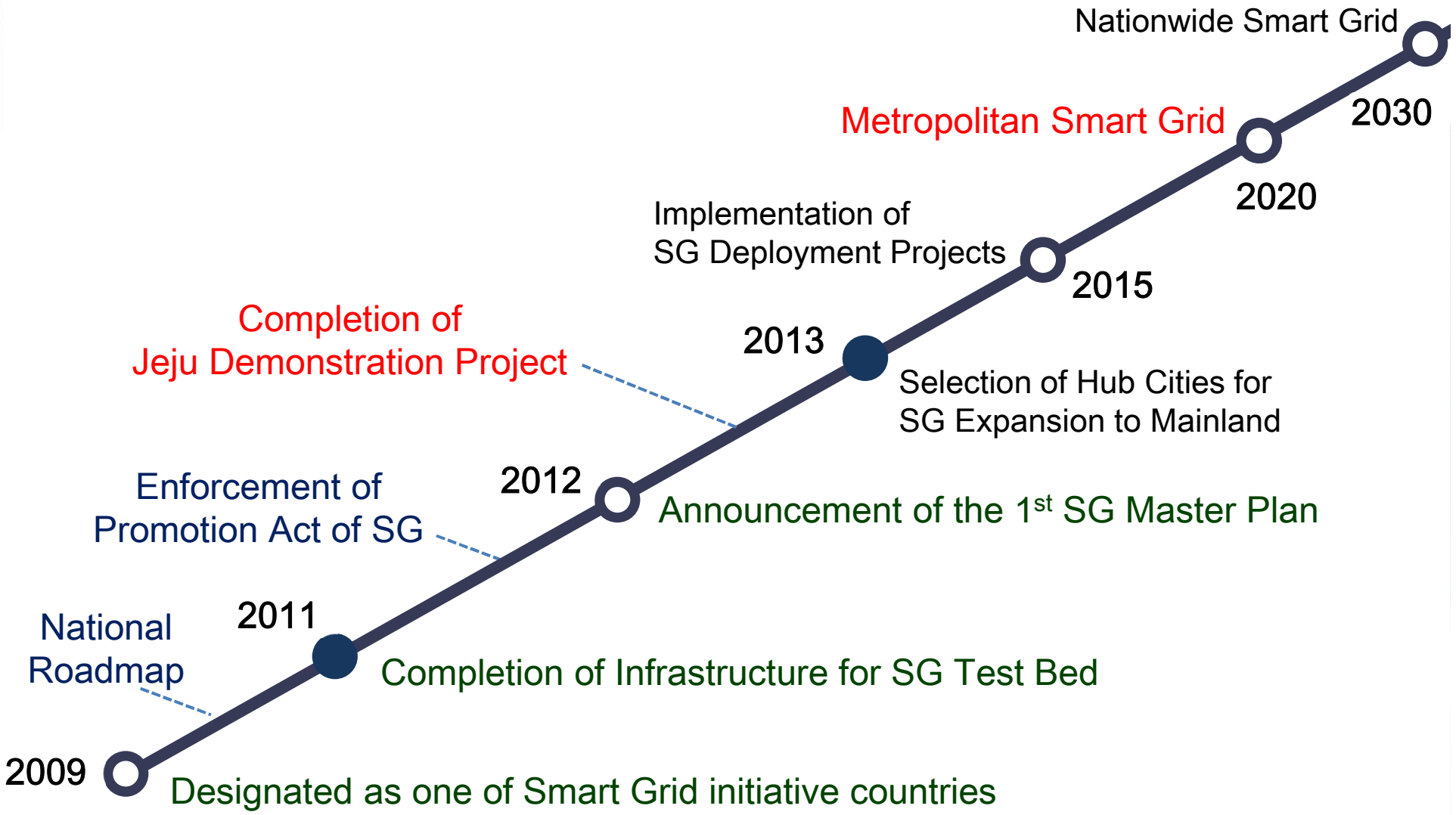
Benefits of Smart Grid

- To Reduce CO_2 Emission
- To Enhance Power Facility Efficiency



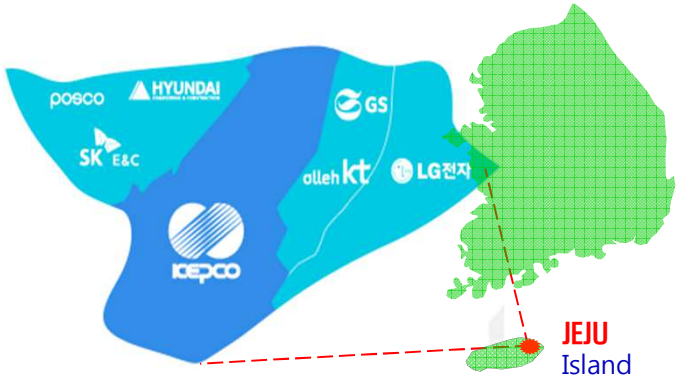
- EV : Electric Vehicle
- ESS : Energy Storage System
- MG : Micro Grid
- AMI : Advanced Metering Infrastructure

National Smart Grid Roadmap



SG Demonstration Project in Jeju

Location	Gujwa-eup, Jeju Island
Scale	5 Fields, 2 S/S, 4 D/L, 3,000 Households
Partner	12 Consortiums (168 Companies)
Duration	Dec. '09 ~ May '13 (42 Months)
Budget	Total $226.4 million (Government $67.9m, KEPCO $21.9m, Private $136.6m)



Participation Consortium of Each 5 Fields

Sector	Major Company	Partner	Budget (m$)	Sector	Major Company	Partner	Budget (m$)
Smart Power Grid	KEPCO	10	29.9	Smart Transportation	KEPCO	21	18.1
Smart Place	KEPCO	29	12.2		SK Innovation	10	17.4
	SK Telecom	23	25.6		GS Caltex	10	13.4
	KT	19	30.8	Smart Renewable	KEPCO	16	16.1
	LG Electronic	9	21.4		Hyundai HI	6	10.6
Smart Elec. Service	KEPCO/KPX	7	19.8		POSCO ICT	8	12.0
Total				5 Sectors		168	226.4

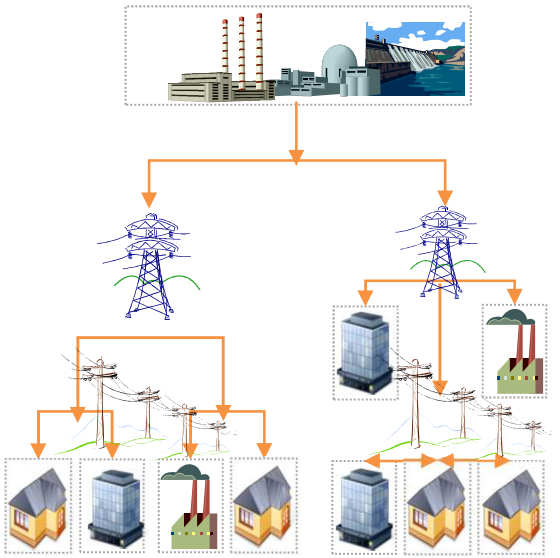
Result of SG Demonstration Project

- Development & Testing of 153 Technologies including AMI, EMS, Charging Infra, ESS
- Development of 9 Business Models including DR Management, EV charging Service

Smart Power Grid Devices	Smart Sensors, IED, Plug and Play Type Monitoring Devices for DG including Next Generation Power Grid Technologies	
ESS	Development of a Management Technology for Large Scale Battery combining DG with ESS	
EMS	Monitoring of Energy Flow and Verification of Optimal Control Technology	
EV Charging	Development of Quick/Slow Chargers and EV Communication Infrastructure	
AMI	Achievement of Real-time Demand Response	
Grid Integration Technology	Connection of Micro-grid, Renewable, Electric Car Battery to Power Grid for Two-way Electricity Transmission	

Change brought by Smart Grid

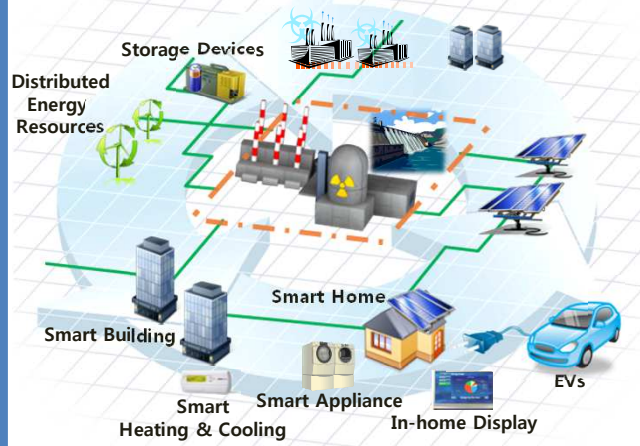
Current



Smart Grid

- Self-healing
- Grid Automation
- Customer participation
- Optimization
- Outage prevention
- Integrated network
- Information security

Future



- **Centralized** generation (Large-scale Generation using **fossil fuel**)
- **One-way** power & information flow
- **Supplier-oriented** facility operation

- **Centralized & distributed** generation (**Expansion of renewable** energy)
- **Two-way** power & information flow
- **Customer participation** in facility operation

Ⅲ. KEPCO's new Business

① Micro Grid (Gapa Island)

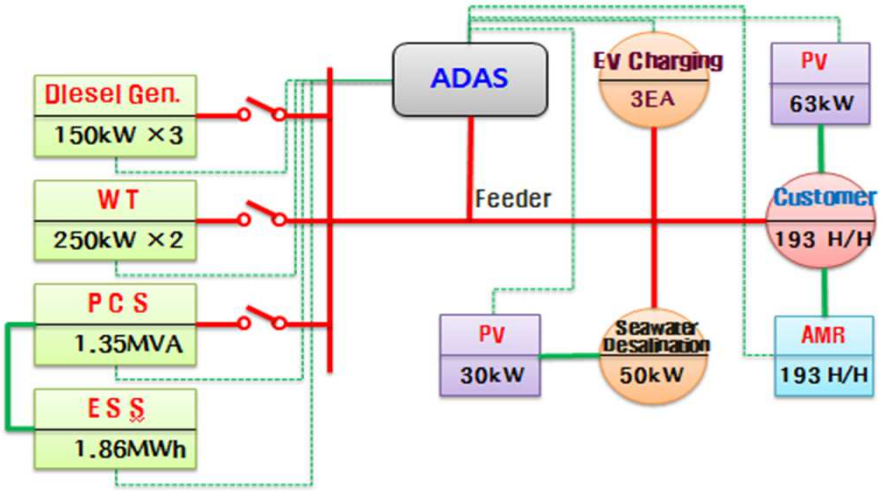
- **Goal**

  To Replace Diesel Generation Power with Renewable Energy and Smart Grid

- **Duration** : Nov. 2011 ~ Oct. 2013 (2 years)
- **Partners**

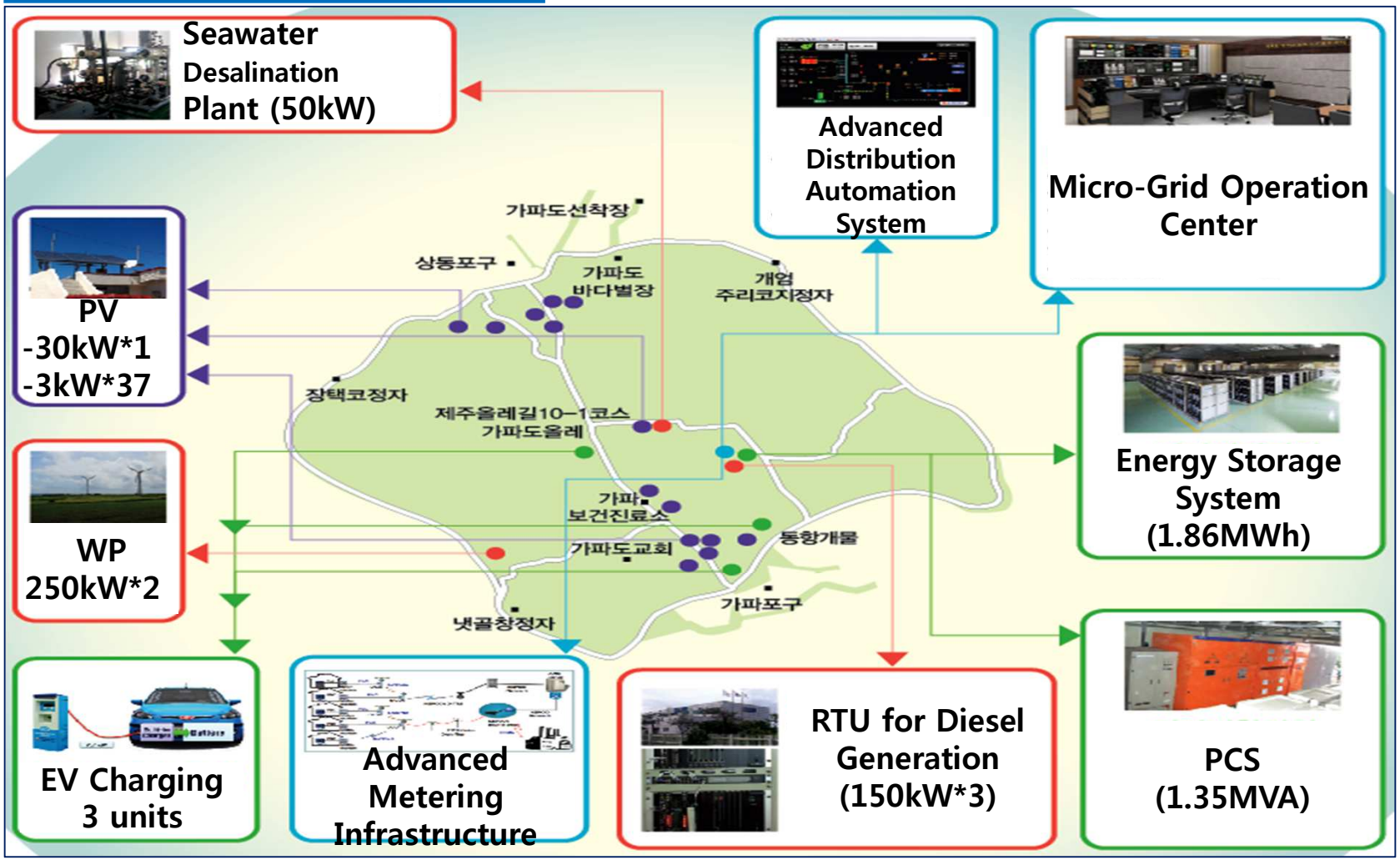
  KEPCO, Jeju, KOSPO, Woojin, Shin-kobe co.

- **Location** : Gapa Island in Jeju
- **Configuration**

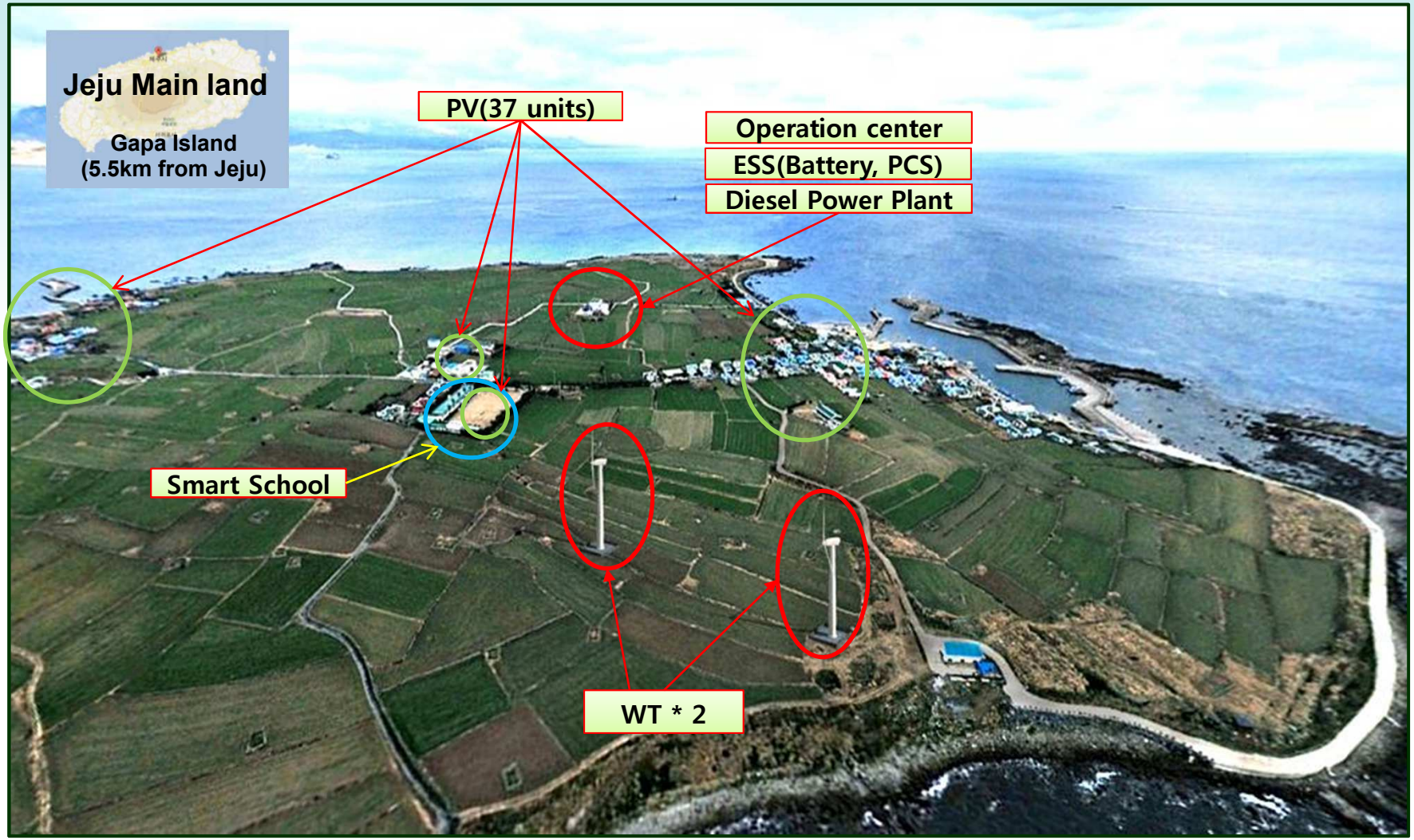


Micro Grid (Gapa Island)

Components

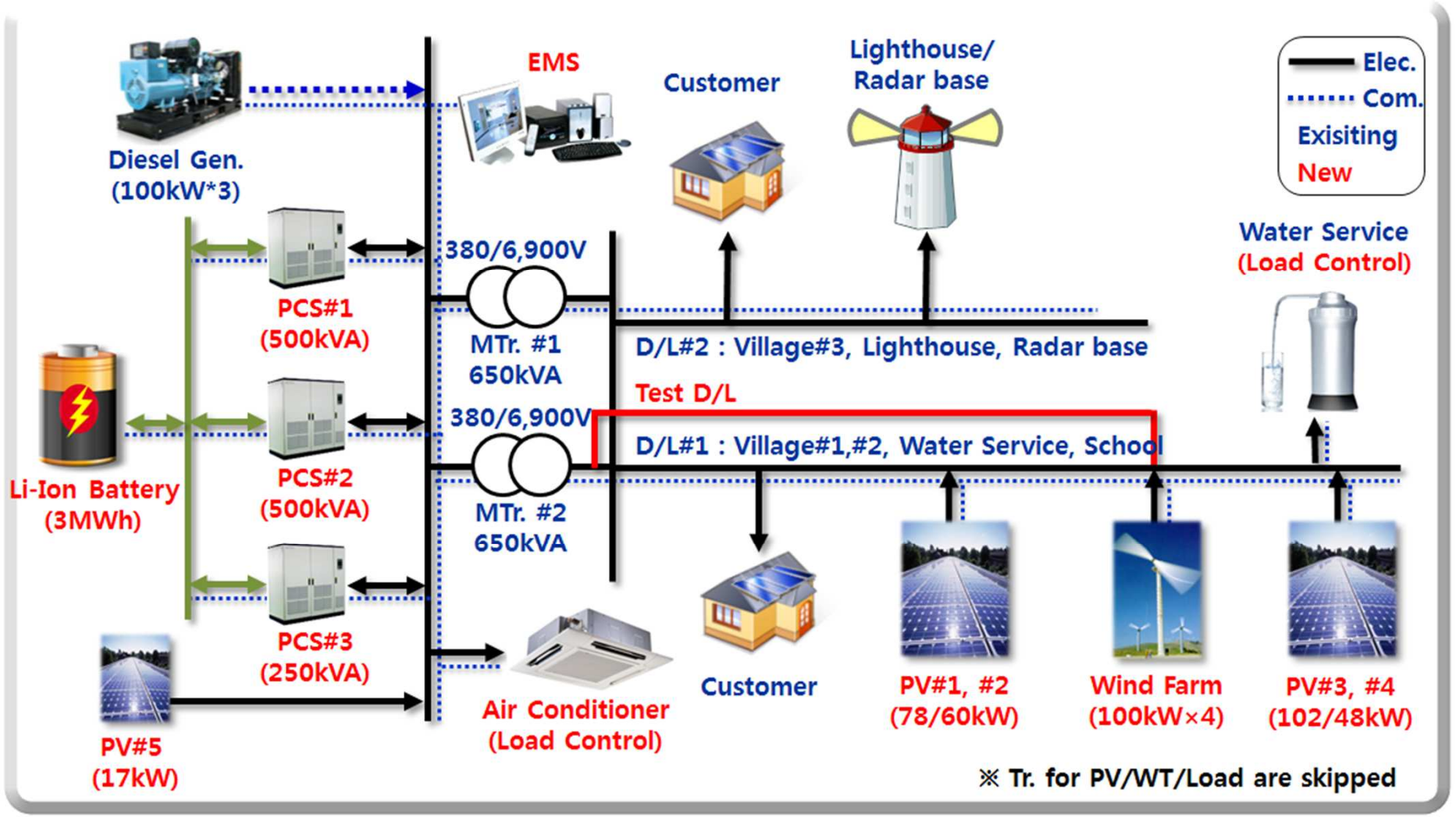


Micro Grid (Gapa Island)



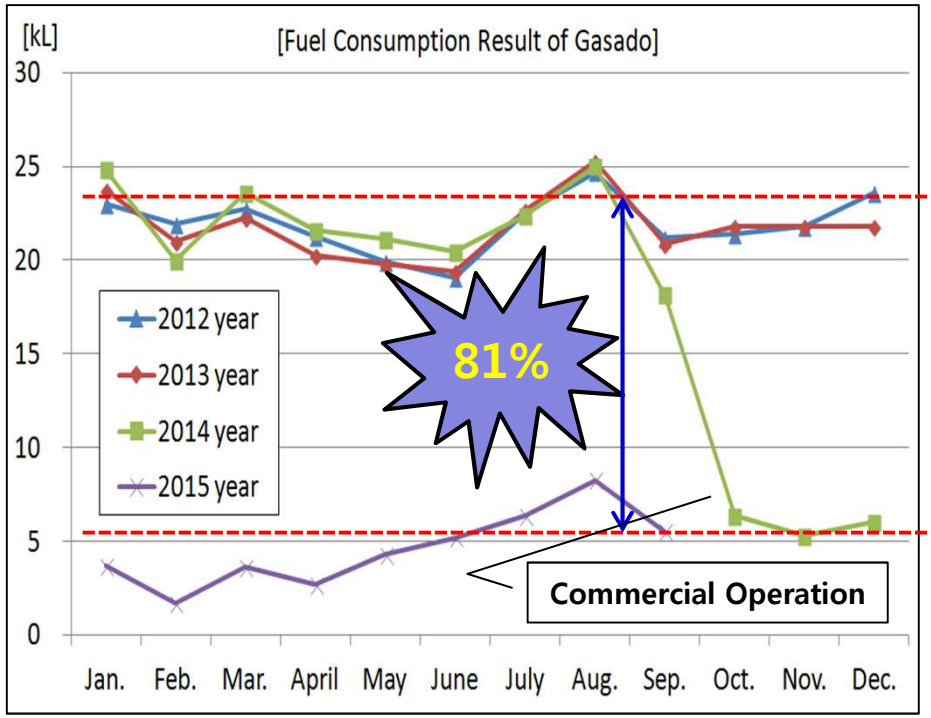
Micro Grid (Gasa Island)

Micro Grid (Gasa Island)

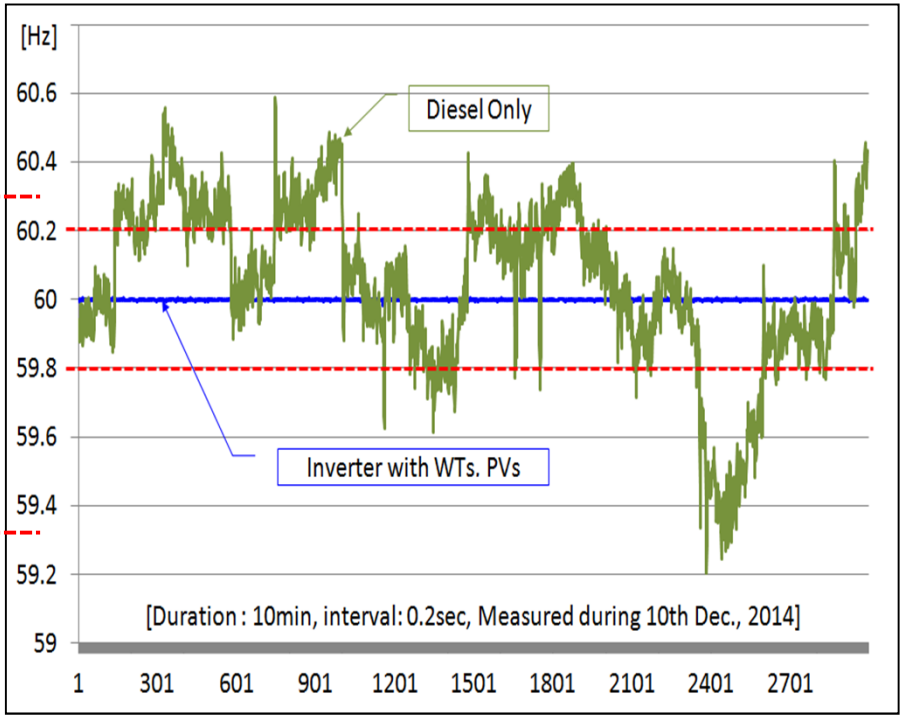


Benefits of Gasa Island M/G

❖ Reduction rate of fuel amount



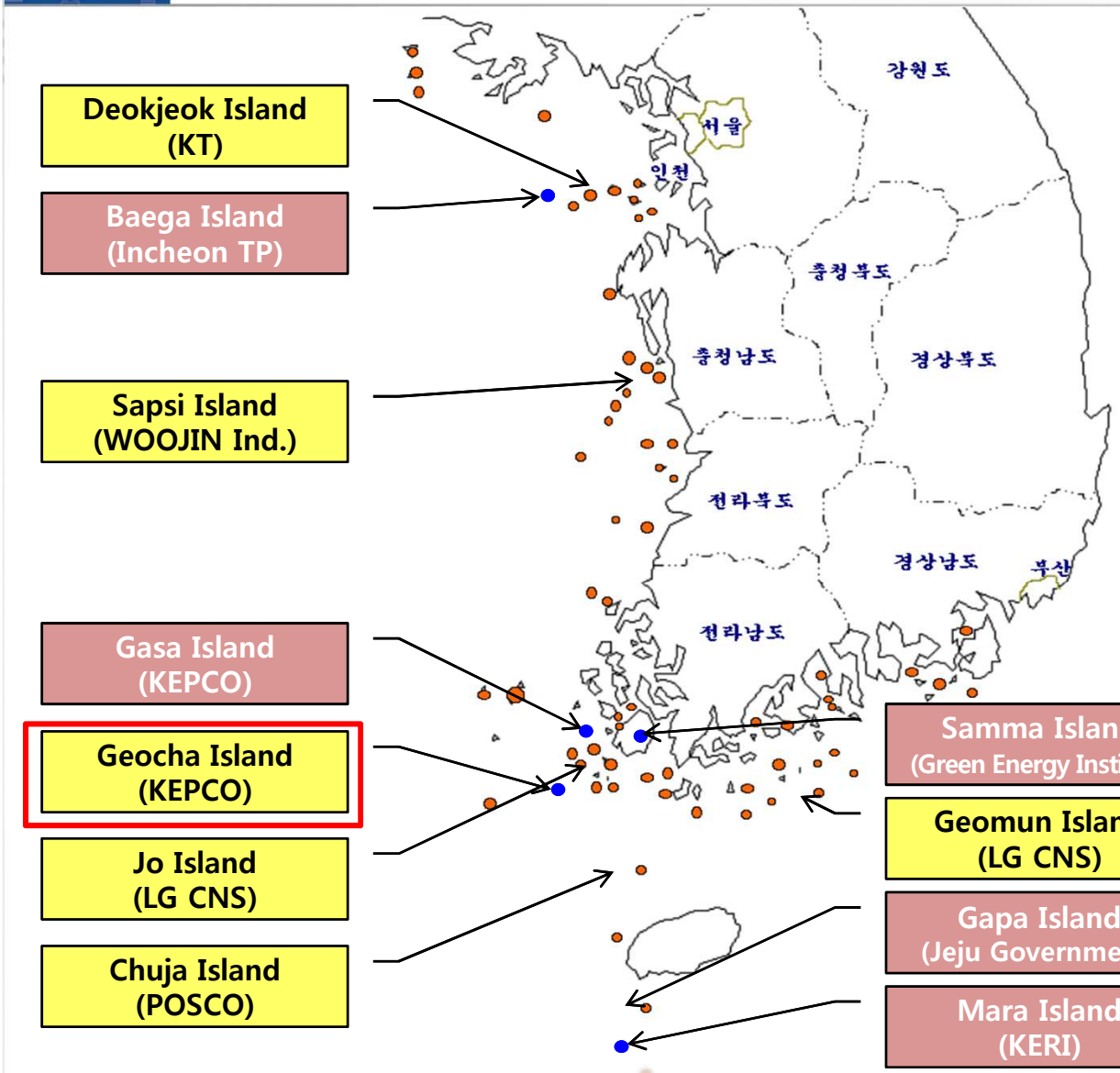
❖ Frequency regulation rate



Fuel reduction (After commercial Operation)
: 81% (≒ 143,000 liter, $170,000/yr)

Diesel Only : 57%
With Microgrid : 100%

Domestic Expansion of Island M/G



- Deokjeok Island (KT)
- Baega Island (Incheon TP)
- Sapsi Island (WOOJIN Ind.)
- Gasa Island (KEPCO)
- Geocha Island (KEPCO)
- Jo Island (LG CNS)
- Chuja Island (POSCO)
- Samma Island (Green Energy Institite)
- Geomun Island (LG CNS)
- Gapa Island (Jeju Government)
- Mara Island (KERI)

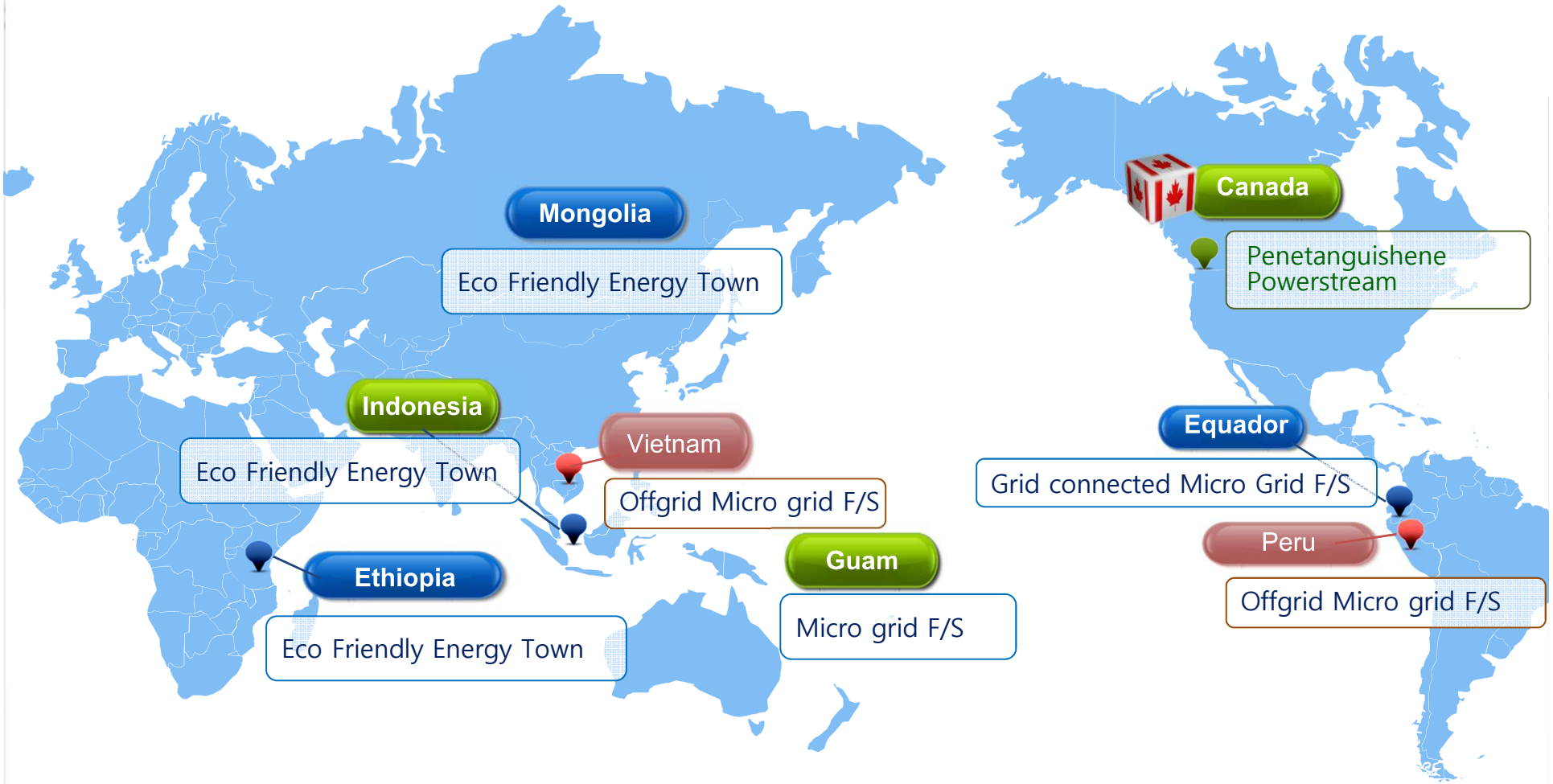
Ulleung Island (KEPCO&LG CNS)

Residents : 10,300
Current Gen. Set : 19.2MW
Max. Power : 10MW

Hydro, PV : 1.2MW
Wind : 6MW
Geo Thermal : 16MW
Diesel : 3.7MW
ESS : 19.5MWh

KEPCO
Local government
Completed
Planned

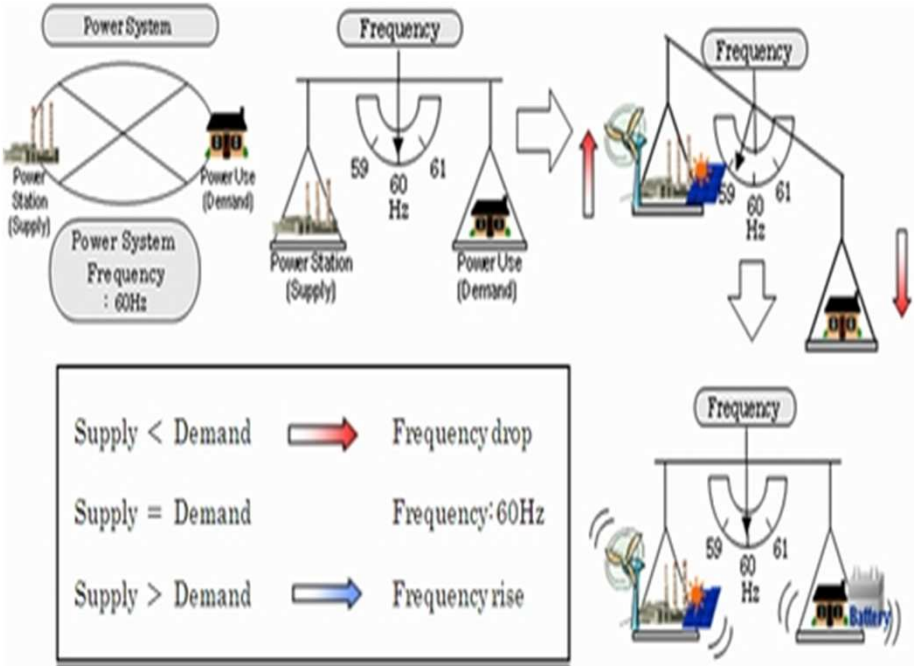
Overseas MG projects



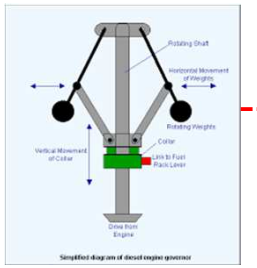
② Frequency Regulation ESS

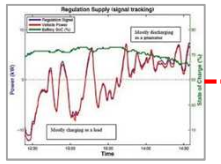
Frequency Regulation(FR)

- To maintain the power frequency (50 or 60Hz) constantly caused by discrepancy of Supply and Demand to a standard



How to maintain the frequency



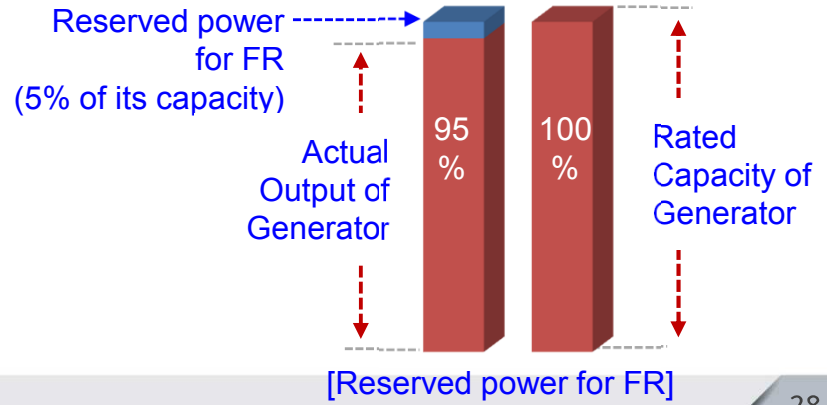


<Governor Free>

<System Operator>

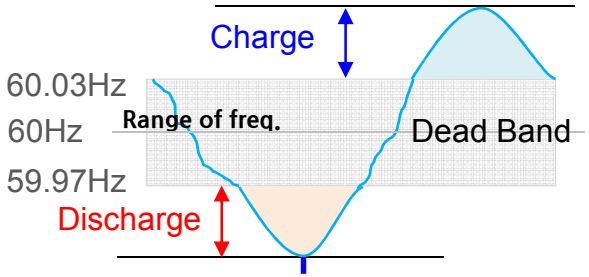
Response

Control

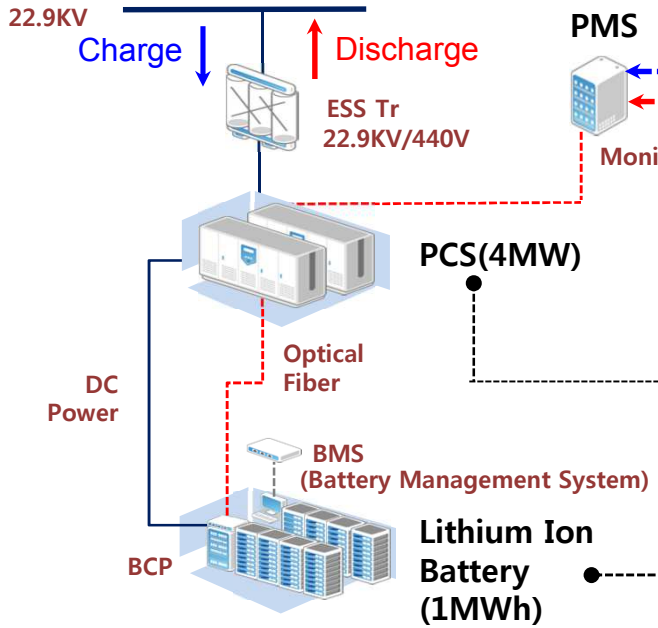


[Reserved power for FR]

Frequency Regulation



[ISO's EMS]



Power Management System
Acquires the frequency and control charge/discharge

Power Conditioning System
Convert AC/DC from battery to grid

Battery
Storage the electricity with DC

Why ESS for Frequency Regulation?

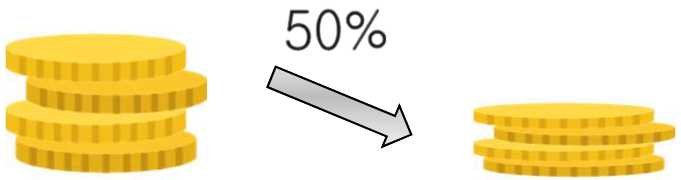
Power Demand Increase and T&D Construction Delay

- High Cost of Generator for F/R Margin
- Increasing Social Cost for Building New Power Plant and T&D Facility
- Maintaining the Power Quality with Bulk Renewable Energy

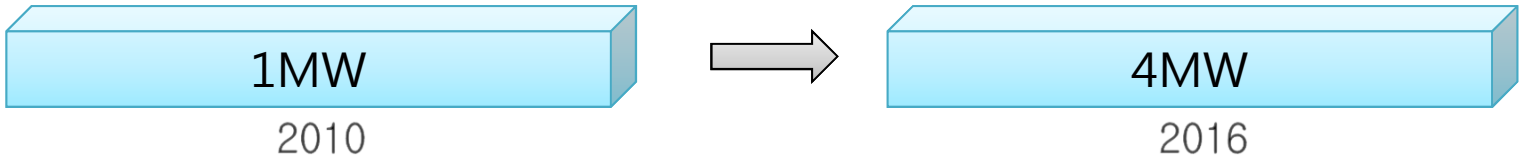
Cost Down of Battery for ESS

Li-ion Battery Cost (estimated)

- $1,000/kWh in 2010
- $500/kWh after 2016



Capacity of ESS Container



KEPCO's F/R ESS Project

Item	Primary Frequency Control (Governor Free)	Secondary Frequency Control (Automatic Generation Control)
Main Purpose	Prevent from freq. drop at an early stage	Increase its output at a signal from ISO's Energy Management System for grid
Operation Type	Respond by itself based on freq. status	Ramp up/down by the signal from ISO
Pilot Project (52MW) 2 sites	28MW FR ESS (Battery : 12MWh, PCS : 28MW) 	24MW ESS (Battery : 18MWh, PCS : 24MW) 
Energy Capacity	15 min-Li battery	30 min-Li battery
System Provider	(PCS) LS, WOOJIN Industrial Systems Co., Ltd. (Battery) Kokam Great Power for Everyone, LG Chem	(PCS) EN TECHNOLOGIES, LG CNS (Battery) SAMSUNG SDI, SAMSUNG SDI

Benefits of F/S ESS

Cost Reduction

- Base load power plant can generate power. **(95% → 100%)**
- **Spinning reserves can be reduced** due to the fast and accurate response.

Power Quality

- Be able to **respond** to frequency regulation requirement **in milliseconds**
- Capable to accept even more renewable generation to the system

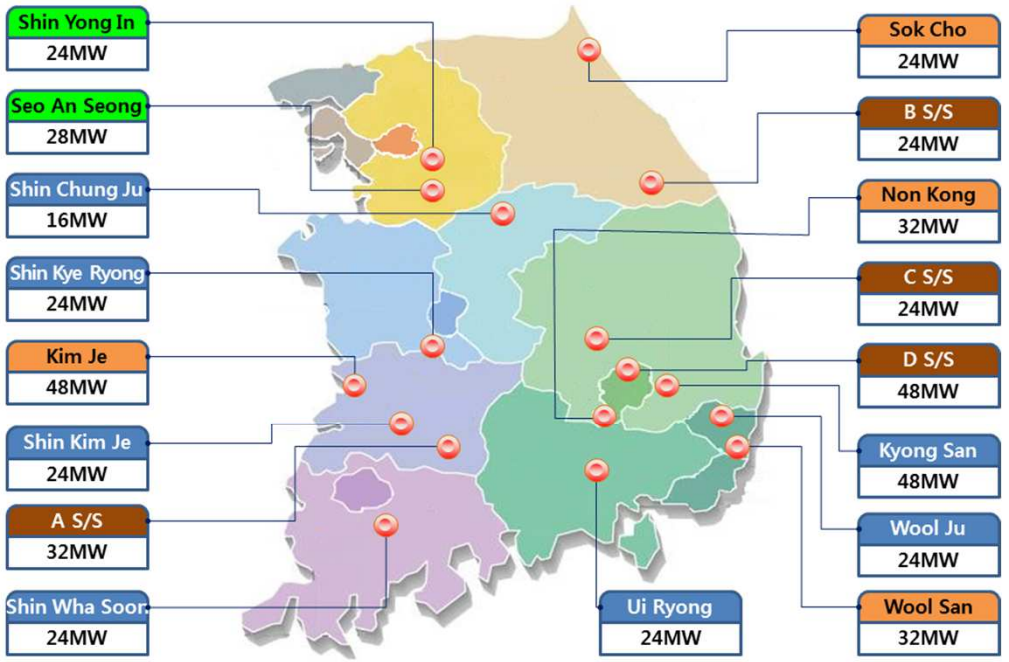
Grid Reliability

- Can **ramp up much faster than conventional P/P** in transient situation
- Provide enormous flexible ramping capacity

World largest F/R ESS operation

Item	2014	2015	2016	2017	Total
Capacity	52MW	184MW	140MW	124MW	500MW
Status	Commercial Operation(376)			Under Const.	






Remark	'14	'15	'16	'17

③ BEMS(SGS) Projects

Definition

Smart Grid
Future Power Grid with information exchange and diverse services through converging ICT with existing power grid

+

Station
Platform Buildings providing diverse services

Smart Grid Station
Places providing smart power grid services

Functional Definition

Renewable Energy

+

Energy Storage System

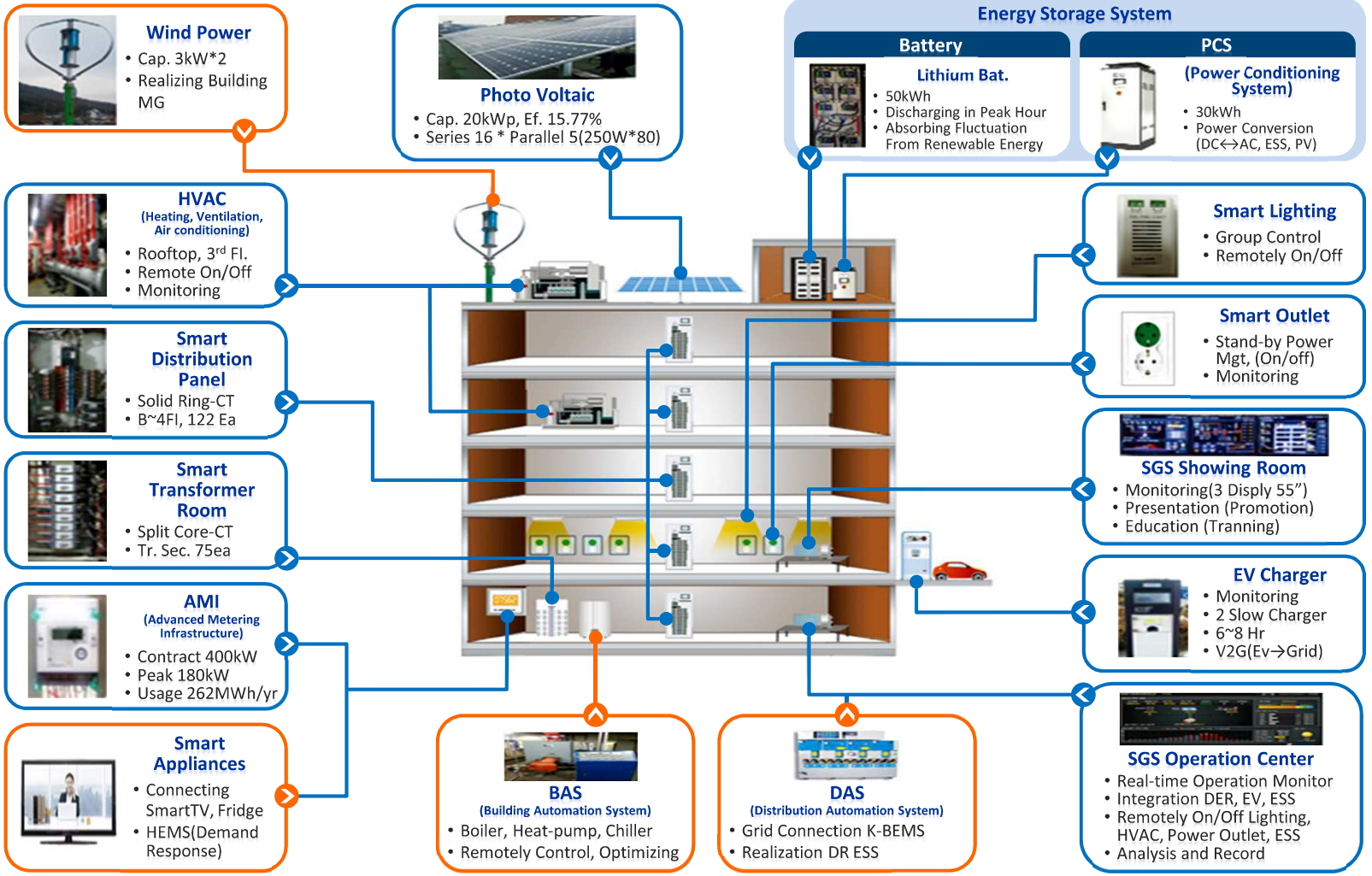
+

Building Automation System

Integrated Operation Center

Components of K-BEMS

K-BEMS Diagram



Background & Achievement

The Latest Achievement

2014 ~
- Energy consumption 10% ↓, Peak shaving 5% ↓
- Visualize electricity consumption in real time, Auto Demand control etc.

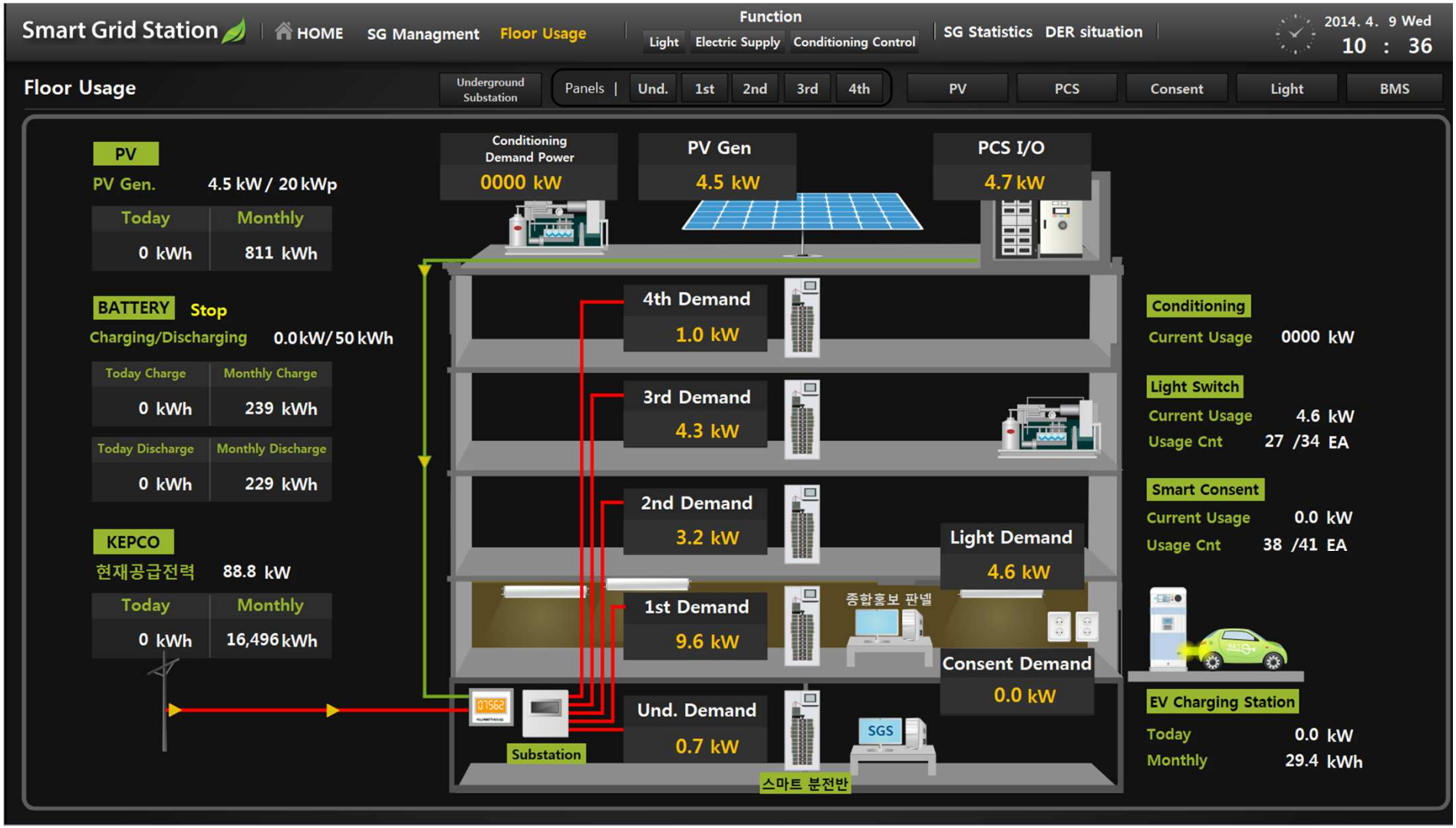
2015. 5
- SG International Conference Award
  – K-BEMS Model(ISGAN, GSGF)

2015. 10
- Contract a $3 million K-BEMS in Dubai Electricity & Water Authority

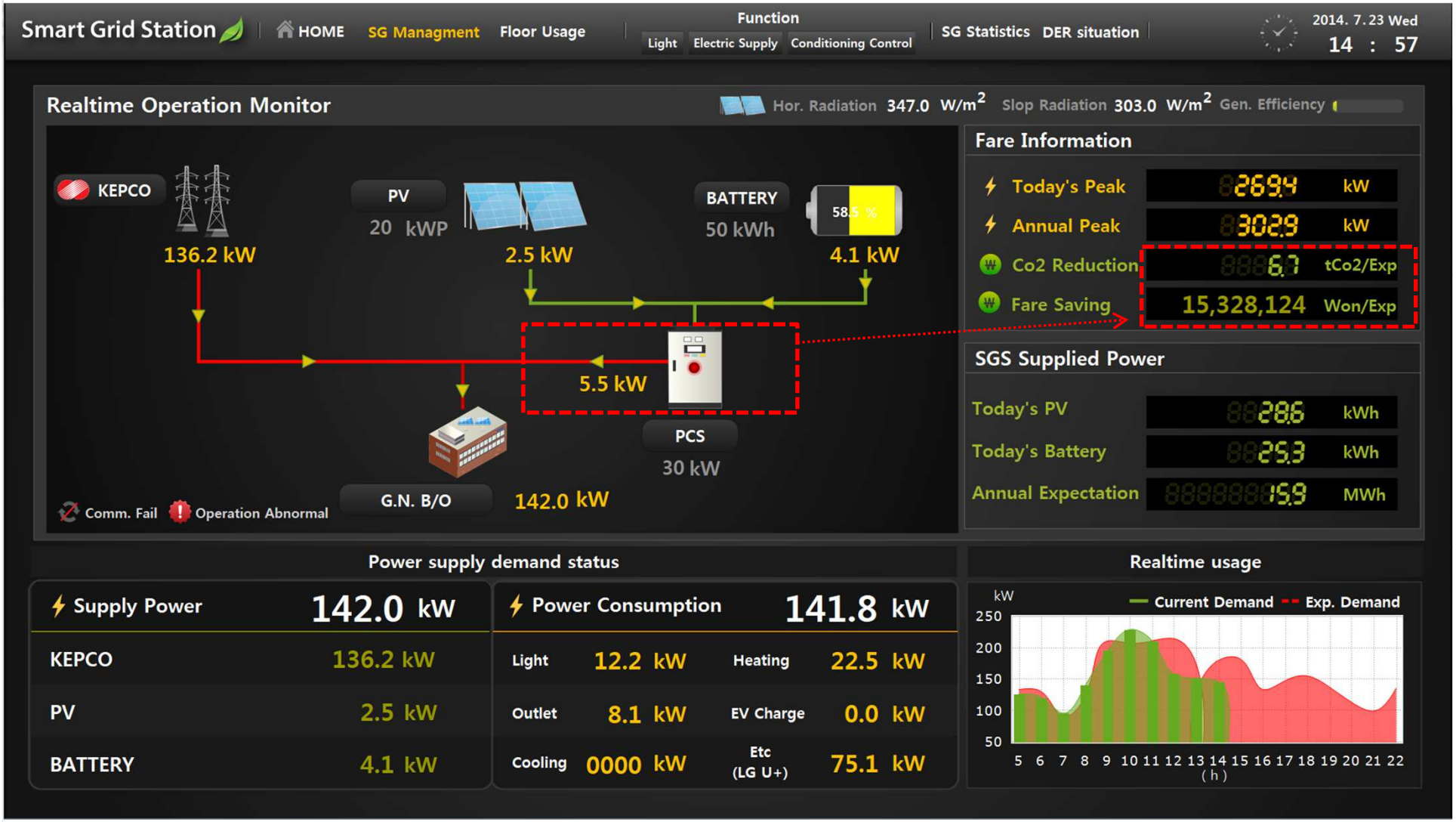
2015. 11
- KEPCO's K-BEMS Operating Contest
  - Max. Peak shaving : 23% (Dongulsan District office) ↔ Avg. 5%
  - Max. Energy consumption : 22% (Jincheon District office) ↔ Avg. 10%

Expand internally all over KEPCO, externally to the factory(building) ➡ CO_2 ↓

K-BEMS Snapshot

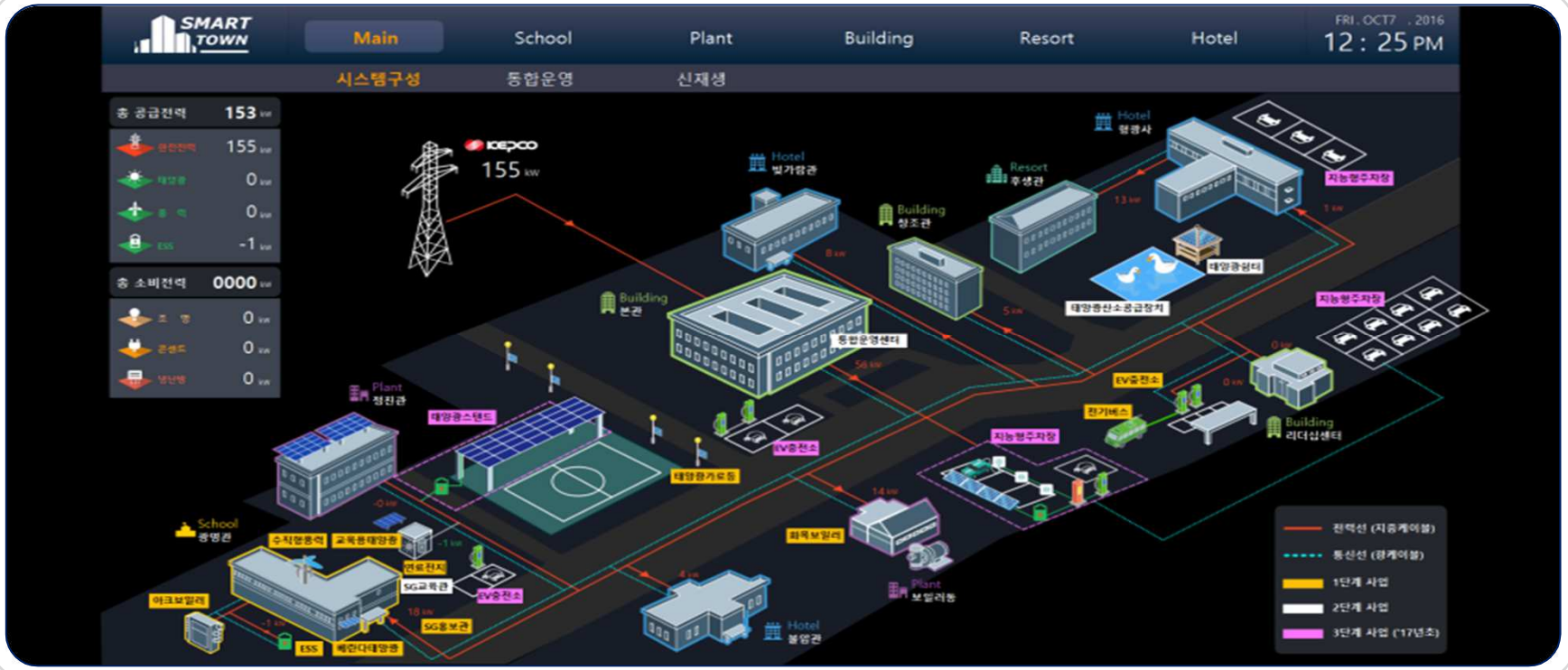


K-BEMS Snapshot



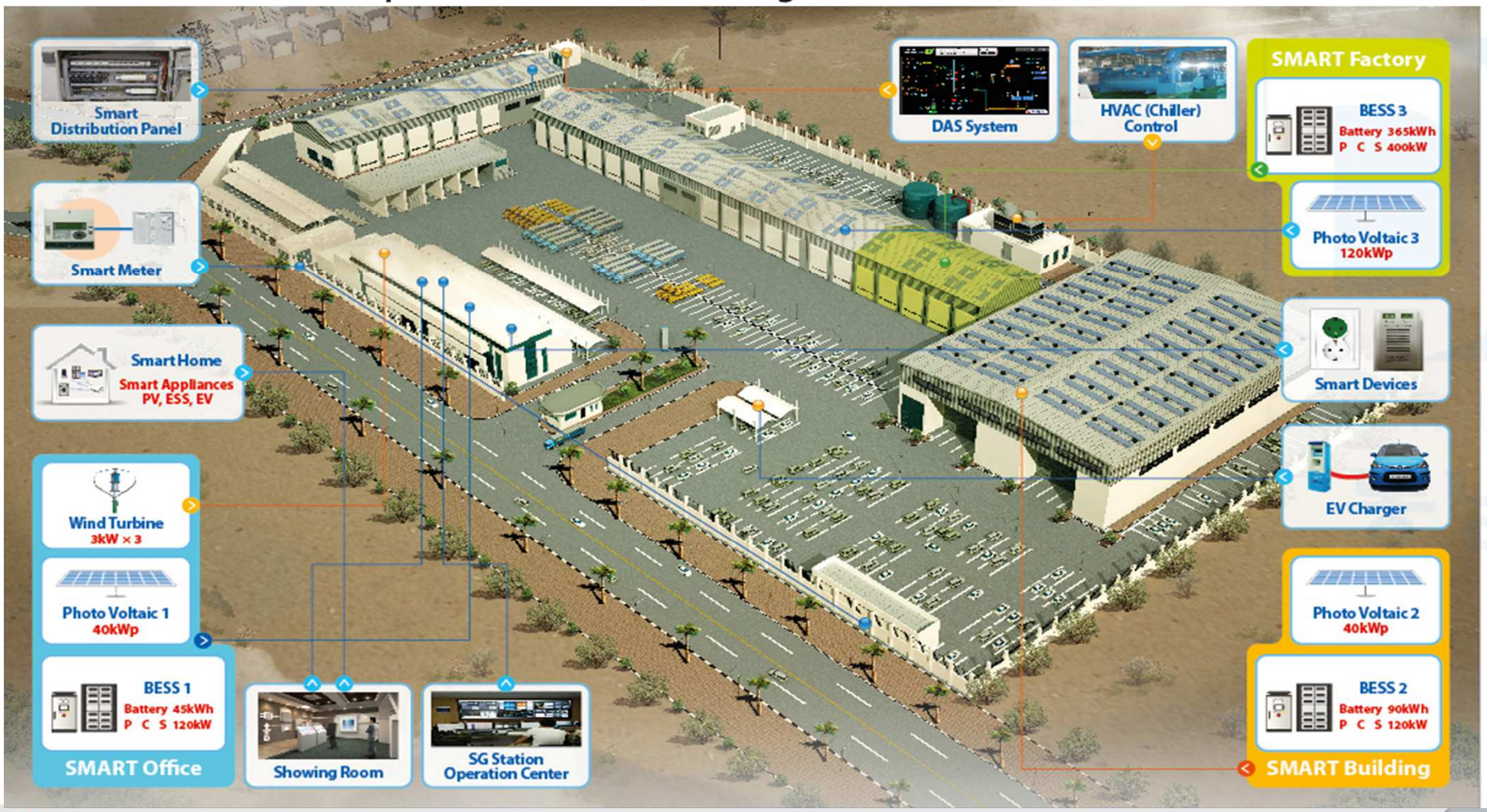
K-BEMS expansion – Smart Town Project

Purpose	Improving energy efficiency by installing SG facilities in each building and operating all K-BEMS system implemented.
Duration	DEC 2014 ~ MAR 2015 (1st Stage) , DEC 2015 ~ OCT 2016 (2nd Stage)
Goal	Reduce Power Consumption by 15%, Peak Load by 10%, CO2 by 15%



Dubai Smart Town Project

- Target : Energy Saving and Peak Cut Rate 8%
- Duration : 2015.10 ~ 2017. 2
- Device : PV 200kWp, ESS 500kWh(Including PCS 640kW)



④ EV charging infrastructure building project

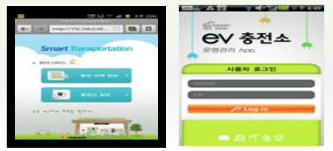
Jeju Smart Transportation Test bed Development

- Goals: Development an optimal EV charging & commercialization business model
- Duration: '09.12~'13. 5(42month)
- Participations: KEPCO Consortium(21 Companies)

SG Information Center

ST Operation Center

Smart Phone App



I-Park APT

ST Information Center

EV Navigation

Div.	Stations	Chargers					EVs		
		Quick	Normal	Wireless	Others	Total	High-speed	Others	Total
Qty	18	13	29	4	6	52	14	4	18

EV charging infrastructure building project

Charging System for power trade (B2G, V2G)

Bi-directional DC Charger for Quick V2G

- **To develop the power trade system for V2G model**

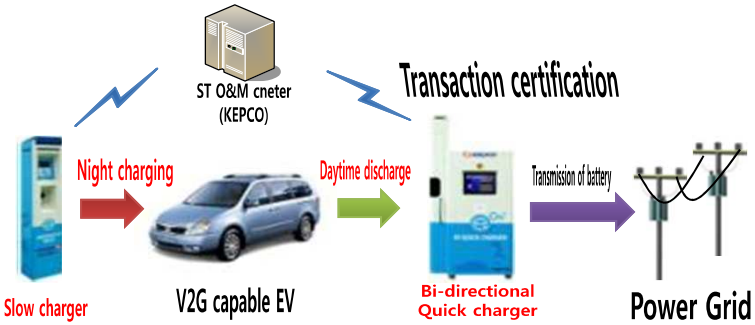
Contents

- **Development of bi-directional DC quick charger**
  - Bi-directional control algorithm development
  - Vehicle interface protocol development for V2G

<Remodeled car & charger for V2G>

<Bi-directional DC charger>

- **Define Quick V2G protocol, service process**



※ B2G : Building to Grid, V2G : Vehicle to Grid

[select Sales & Charge] [reverse power transmission]

EV charging Star Network

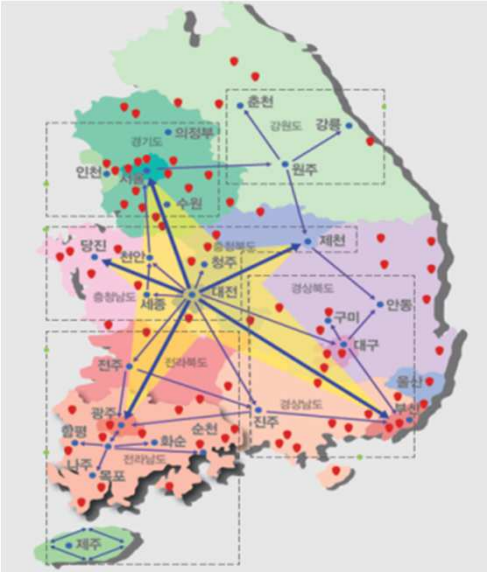
EV Expansion Plan (Nation Wide)

Unit : EA

2015	2020	2030
4,945	200,000	1,000,000

Installed EV Charging Infra(2016)

Classification	EV	Charging Infra		
		Quick	Slow	Total
National-Wide	4,775	2,964	337	3,301
KEPCO	170	185	465	696



• Star Network

Plan for EV implementation in 2017

Item	Quantity (unit)	Budget (thousand US $)
Quick	519	13,485
Normal	266	691

• EV Charging Station

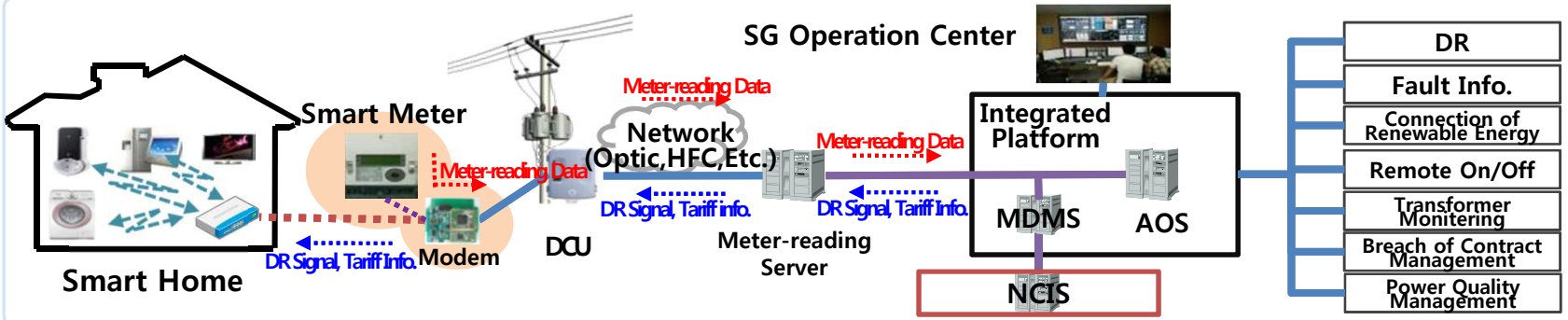
• Expanding Public Flagship Charging Infra Starting with Seoul & Jeju
• Establishing Star Network through nationwide KEPCO Branch Offices

⑤ AMI project

Key Performances

- **Controlling** Power Demand through Sending Demand Response Signals by Bi-directional Communication Network
- **Supporting** Utility's Main Businesses in Power Distribution, Sales, etc.

Configuration



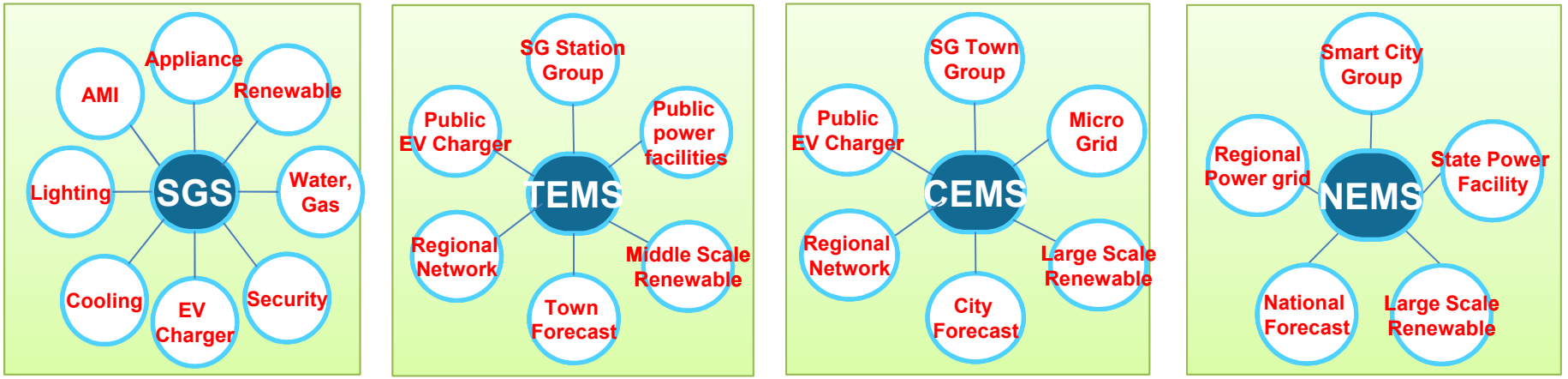
Installation Plan

Item	'13	'14	'15	'16	'17	'18	'19	'20
Installation (10 thousand unit)	200	230	250	257	250	250	330	364
Cumulative Installation (10 thousand unit)	263	493	743	1,000	1,250	1,500	1,830	2,194

IV. Challenges and Opportunities For the Future Power Grid

Towards Nationwide Smart Grid

Step 1 (Point)	Step 2 (Region)	Step3 (Hub)	Step 4 (Nation)
SG Station	**Smart Town**	**Smart City**	**Smart State**
AMI, Smart Home Appliances, EV, EMS, Renewable, Operation Sys.	SG Station Group , Common EV Charging, MG, Middle Scale R/E	SG Town Group , Weather monitoring, City Power Grid, Large Scale R/E, CCTV	Smart City Group, Local Electric Power Network, National Grid, Super Large Scale R/E



Smart City Project

Goal : To Enhance the Quality of Life and Sustainability of the City

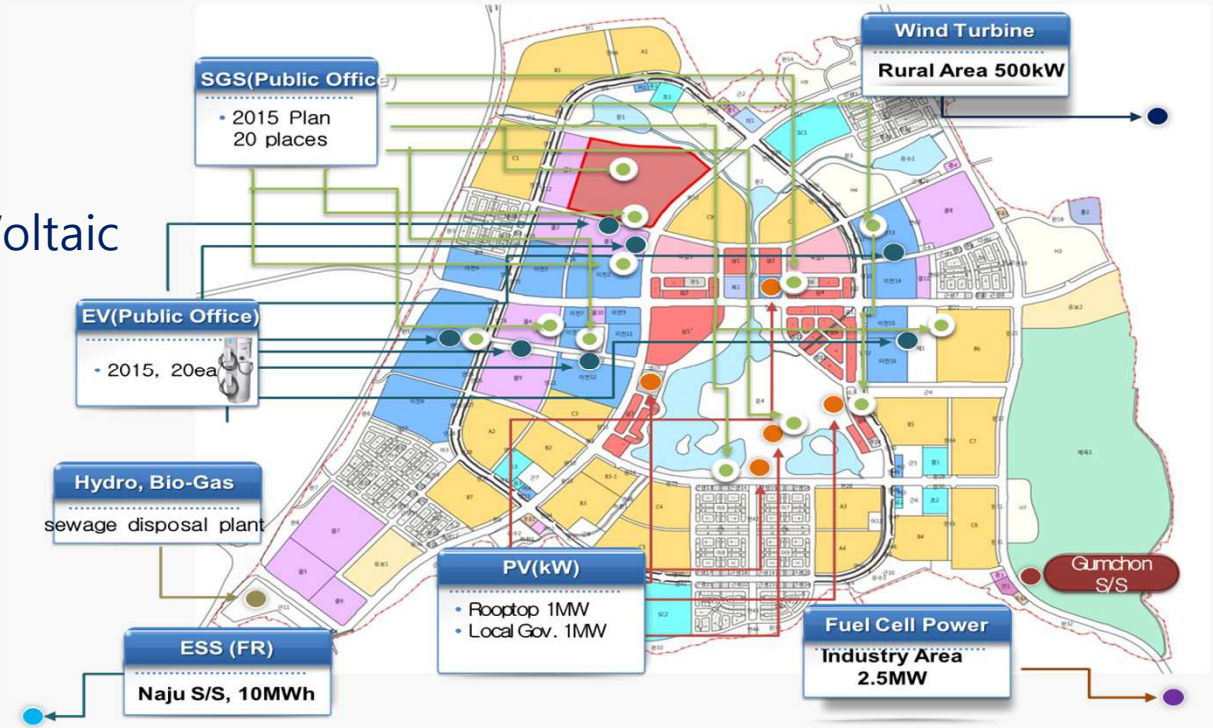
- Establishing The Smart City with Advanced Smart Solutions to Reduce CO_2 and Enhance Energy Efficiency

** Energy Self-Supporting 30%, Utilization Efficiency Enhancement 15%, CO_2 Reduction 30%*

Duration : 2015~2017

Contents :

- SG Station
- Wind Power, Photo Voltaic
- Fuel Cell, Bio Energy
- EV Charger
- BESS
- Total Integrated Operation System for Smart City



Super Grid : Mutual Growth with Connection

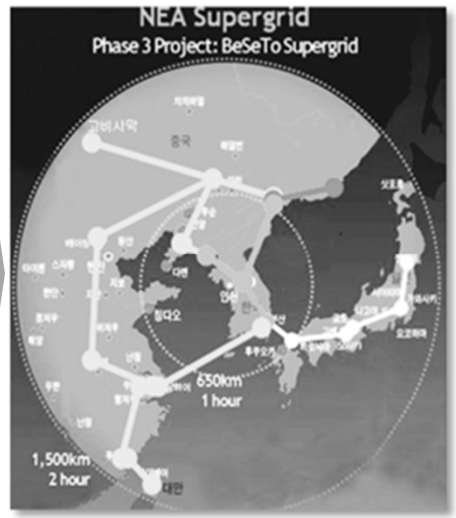
Targets

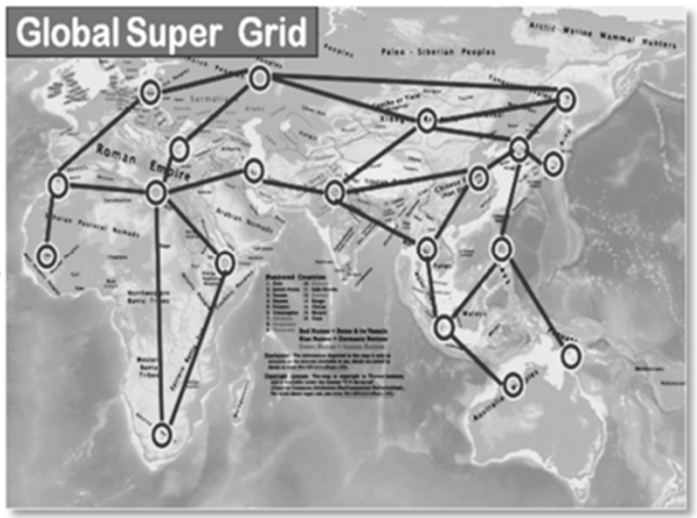
- ✓ **Grid Stability and Reliability**
- ✓ **Effective Use of Renewables**
- ✓ **Economies of Scale and Size**

Issues

- **Large Scale HVDC**
- **Wide Area Monitoring & Control System(WAMAC)**
- **Energy Development (Oil, Gas, Electricity)**
- **Plant and Grid Construction**

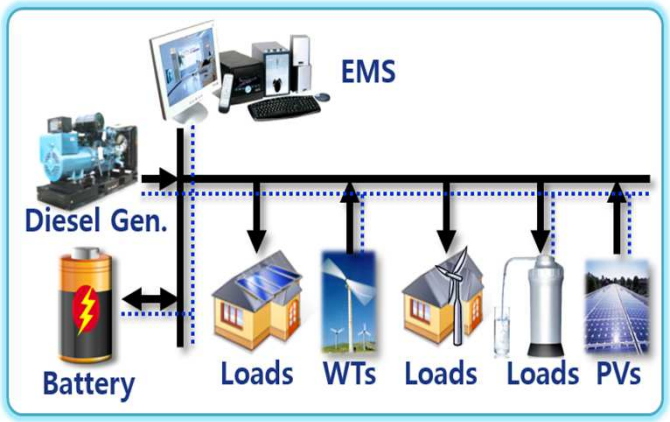
→ Through regulation of power supply and demand by Super Grid, reduction of CO2 emission would be finally achieved





Energy Self-sufficient Islands

- After COP21 in Paris, need for anti-climate change tech. is sharply increased
- To reduce energy supply cost at Korean islands : COE at island is 4 times expensive vs. Mainland
- To adopt more renewables into the previous power system
- Renewables provide the electricity instead of diesel generators
- Surplus energies are stored at ESS and that are used when not enough energy from renewables



Conceptual Diagram

e-self sufficient island – GASA island

- Cost of Energy ↓ : more than 10%
- Power Quality a↑ : up to 100% (before 70~90%)
- CO2 Emission ↓ : up to 90% (depends on the capacity of renewables)

Carbon-free Island

Budget : USD 7 bil.

Duration : 15 years

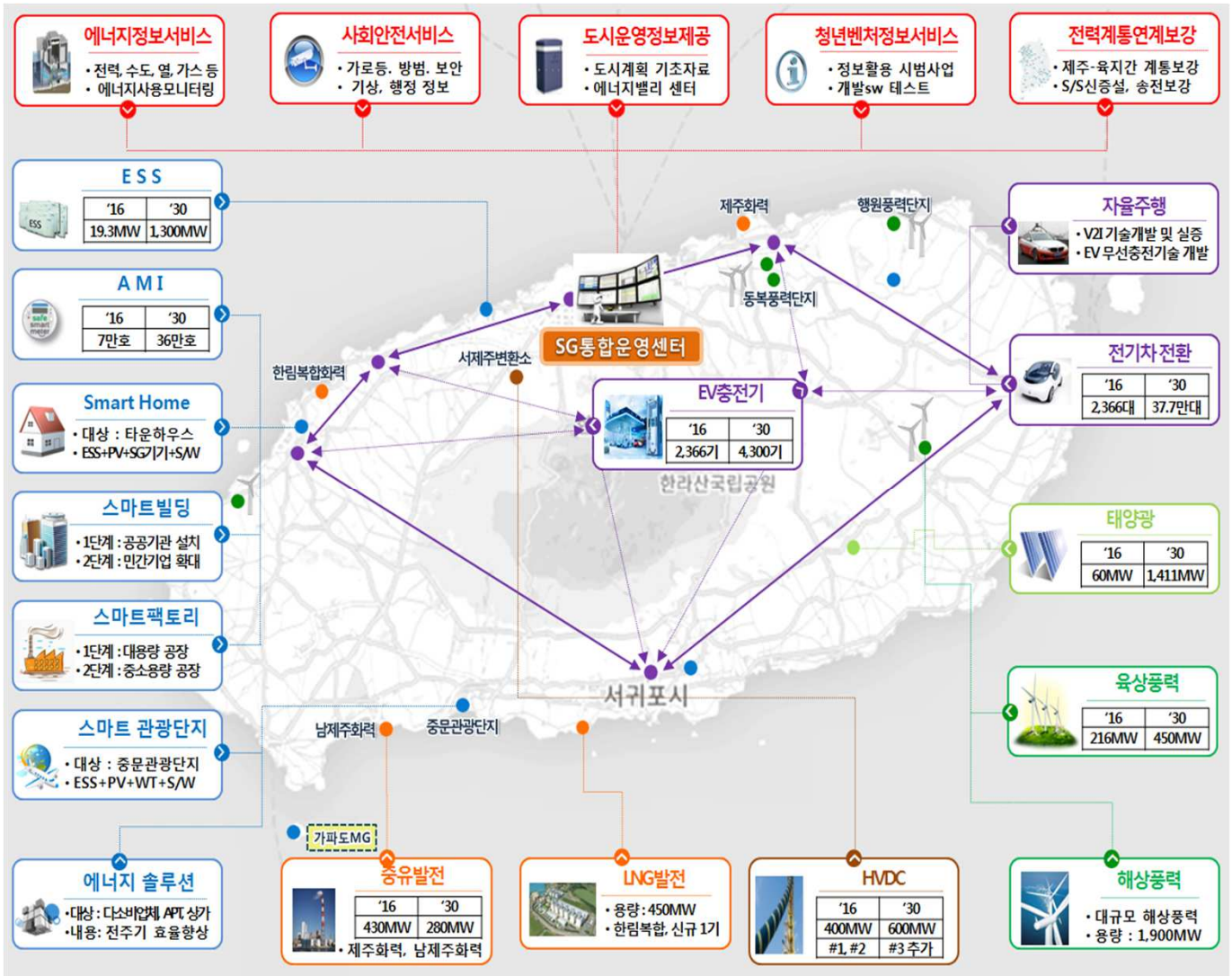
- 2016~2030

Project Details

- AMI
- EVC
- Renewable Energy
- EMS
- ESCO

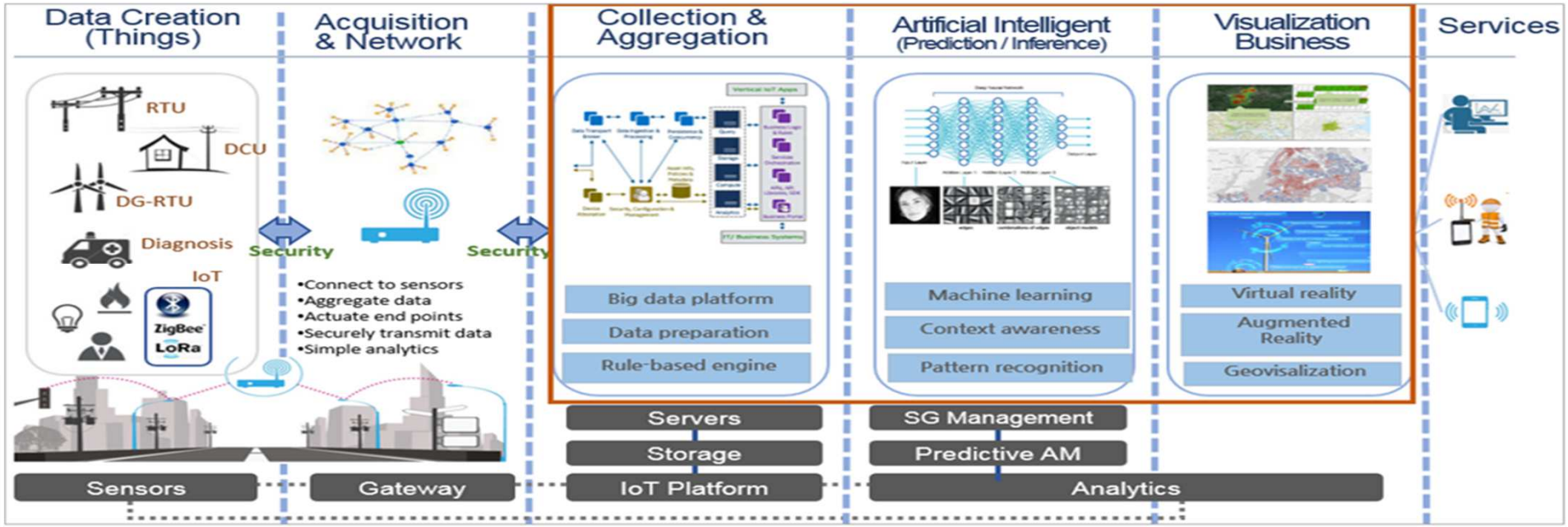
Expected benefits

- EV 100%
- CO_2 Reduction 90%
- 500,000 jobs



(big data & IoT) e-IoT Platform verified Interoperability

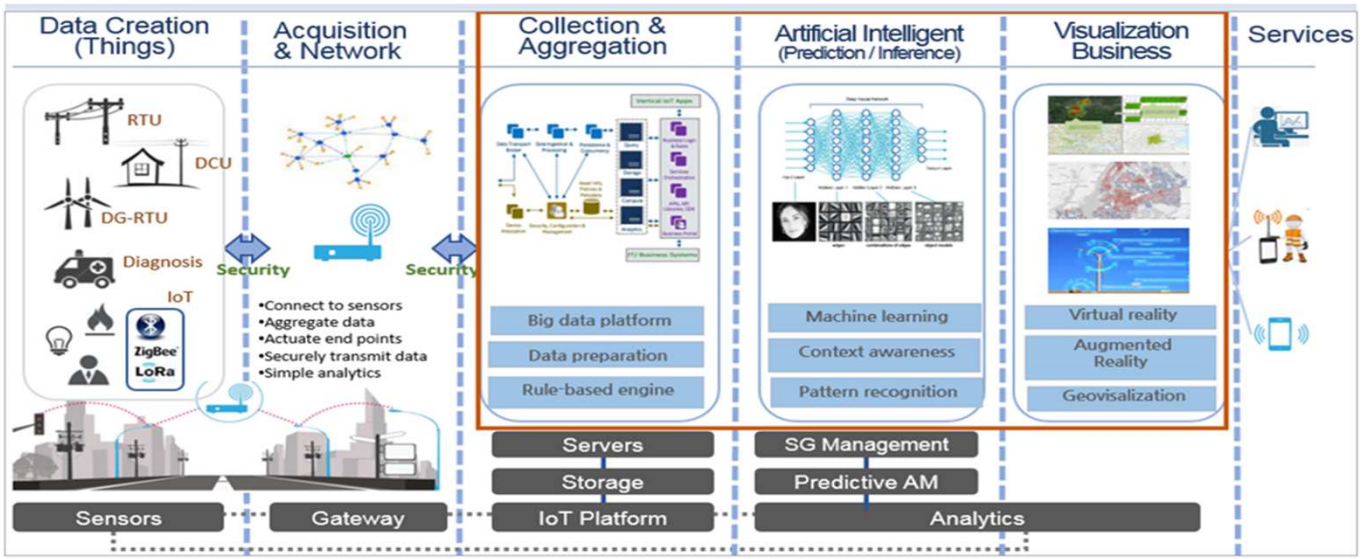
- Develop an ecosystem for vitalizing power-IoT and procure new service infrastructures based on Big data
- Sensor-gateway-platform information exchange message and communication standard
- Standard platform and gateway for interoperability
- Award of TTA certification(World's first in Electric Power sector)



❖ (AI) Machine Learning-based Predictive Engine

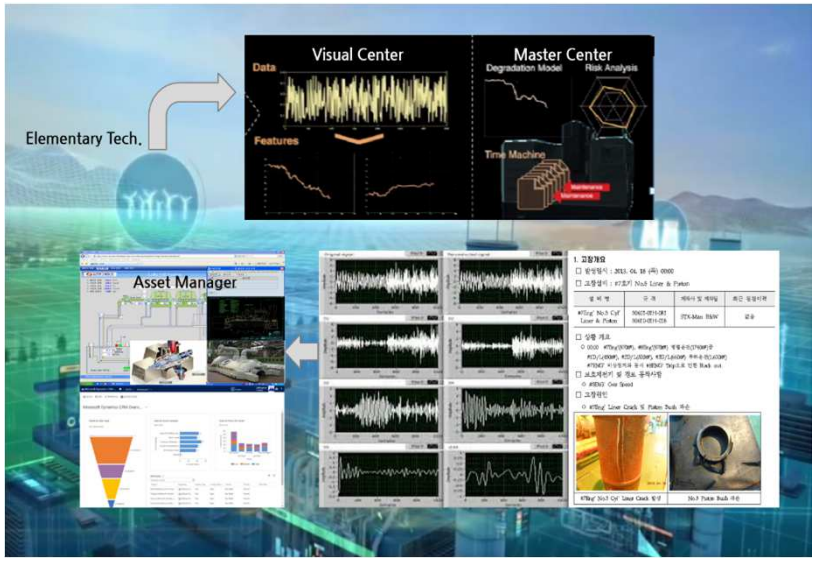
- Aggregate and federate data to understand the state of distribution assets
- Expand scope of predictive maintenance using data
- Use machine learning to improve prediction accuracy

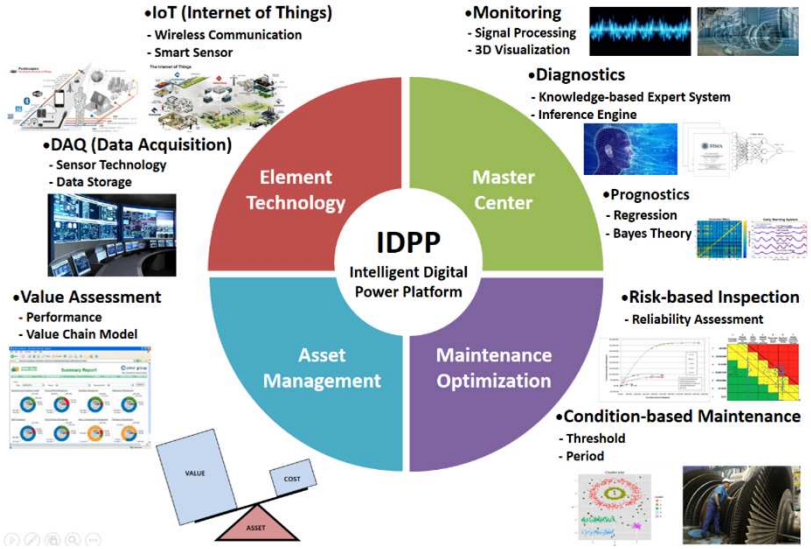
  → Improve distribution system reliability through machine learning
- The predictive engine integrates data from legacy systems (SCADA/NDIS/AMI) as well as novel systems (IoT, weather information etc.)
- Leverage variety analytic algorithms to effectively manage the asset in real-time



Machine Learning-based Predictive Engine

❖ Intelligent Digital Power Plant (IDPP)





- Huge amount of operation data which is not utilized because of its limitation of data size, signal processing technology and computer performance in power plant
- Develop future intelligent power plant operation platform to meet the demands of power company
- ET and MC monitor main components of plant with domain knowledge and machine learning algorithm
- Risk-based Inspection will be applied to optimize maintenance schedule for power plant assets
- Finally, the best solution for managing power plant assets will be supplied to users
- This solution will be included power plant facilities health and economical efficiencies

* ET : Elementary Technology, MC : Master Center (confer to the right picture)

Thank you!


Wind Farm
Commecial & Residentail Complex
(Underground Substation)
Superconductor
All Electrified House
Intelligent Substation
EV Charging Station
IGCC Power Plant
Smart Factory
Photovoltaic Power Plant
LED Streetlight
All Electrified House
EV
EV(Electric Vehicle)
Nuclear Power Plant
Heat Pump
CCS
HVDC
Power Control Center
Smart Grid
(Self healing)