# Battery Technology for Clean Energy

# "Policy of Korea"

8th June 2018

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Korea Battery Industry Association

Battery R&D Association of Korea

# Contents

# 1. Introduction of Energy Storage System

# 1. Introduction of Energy Storage System

## “The current of ESS technology came from Rechargeable battery”

| 1950 | 1960 | 1970 | 1980 | 1990 | 2000 | 2010 |
|---|---|---|---|---|---|---|


**Lead-acid**
40Wh/kg


**Ni-Cd**
60Wh/kg


**Ni-Mh**
80Wh/kg


**LIB**
150Wh/kg


**NaS**
120Wh/kg

**Metal Air**
300Wh/kg

**Supercapacitor**
30Wh/kg

**Lithium ion Battery**

- High voltage, high energy density within light weight
  - → Various Applications as IT, xEV, ESS

# 1. Introduction of Energy Storage System

1,300mAh(1997) → 3,200mAh(2014) → 3,500mAh(2016)

**Cell capacity of 18650 cylindrical cell was 1,300mAh**

***"Theoretical limit would be 1800mAh"* by a Japanese expert (1997)**

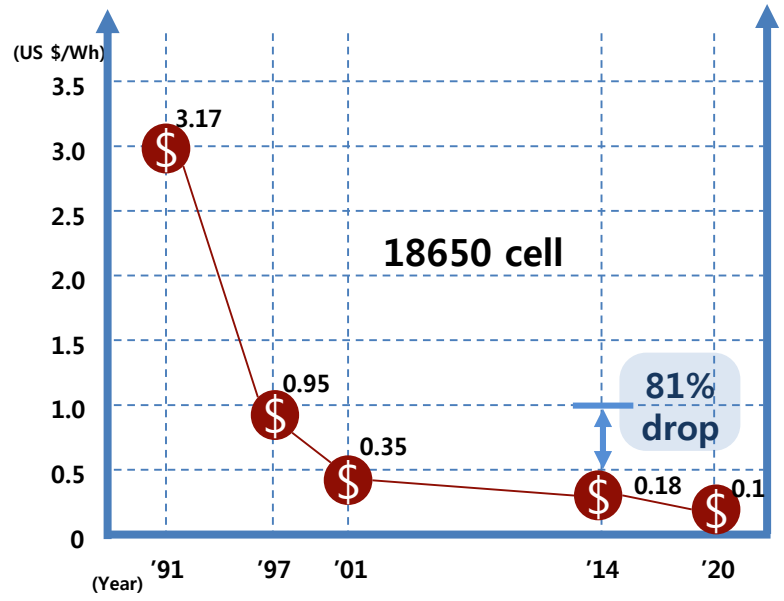
√ **3,200mAh (2014, without changing chemistry)**

**Energy density & Cost: 1997 vs. 2014**

√ **18650 : 292 Wh/L → 700Wh/L**
**$950/kWh → $180/kWh**

√ **BEV cell: 94Wh/L→ 320 Wh/L**
**>$1,000/kWh → <$200/kWh**

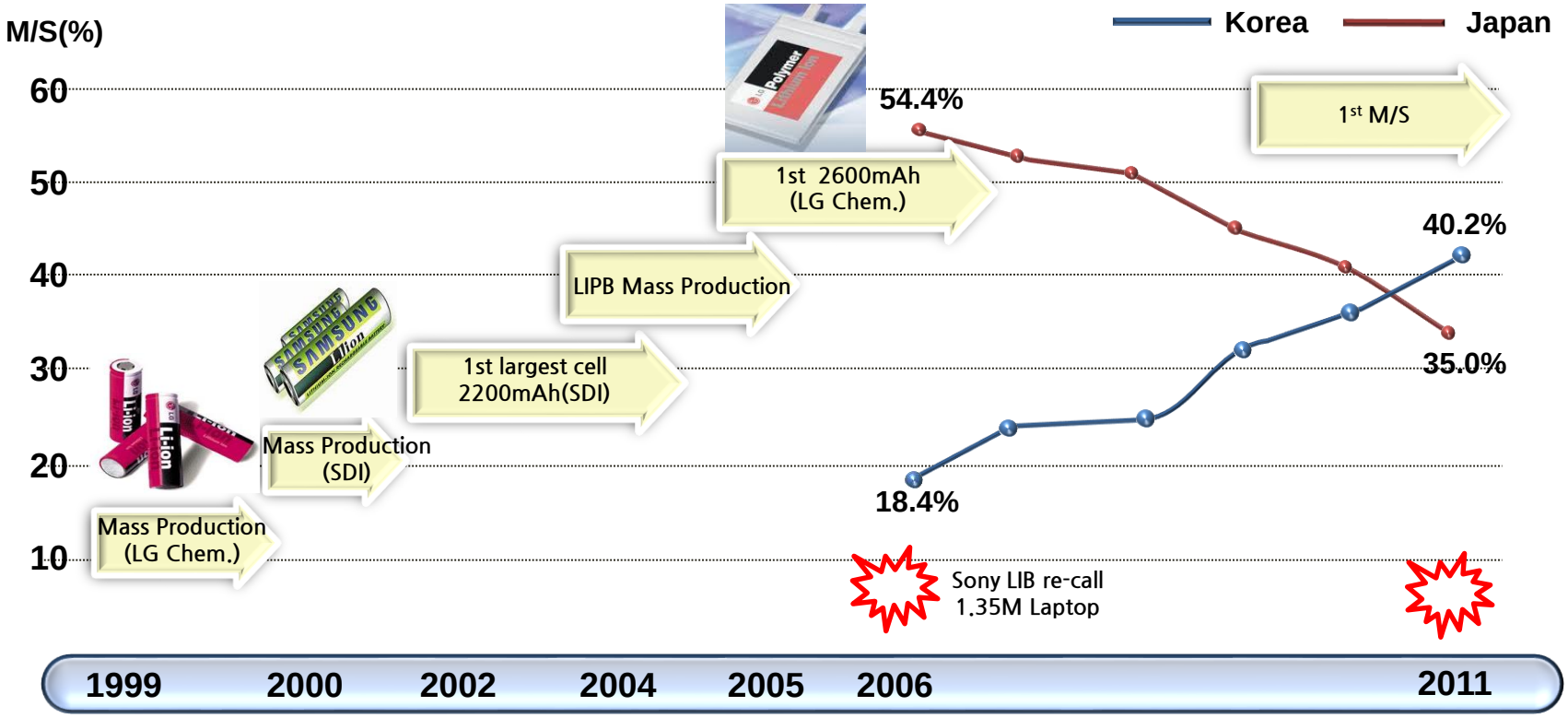
√ **Materials:**
**Anode material: >$40/kg → $5~10/kg**
**Separator: >$3.5/m² → $0.7/m²**




From. LG Chem 2014

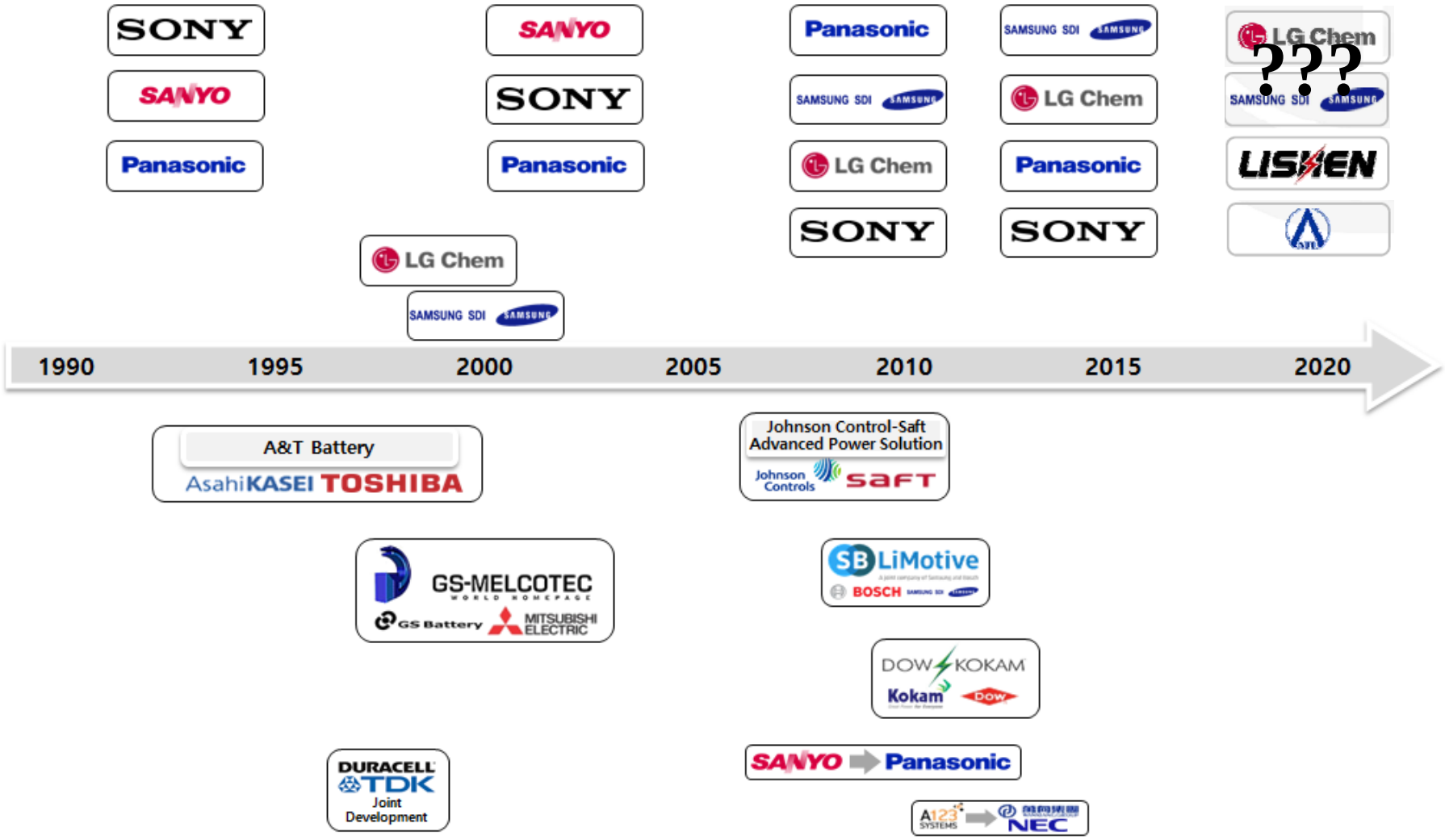
# 1. Introduction of Energy Storage System

## LIB Mass Production Start(1999), No.1 Market Share (2011)



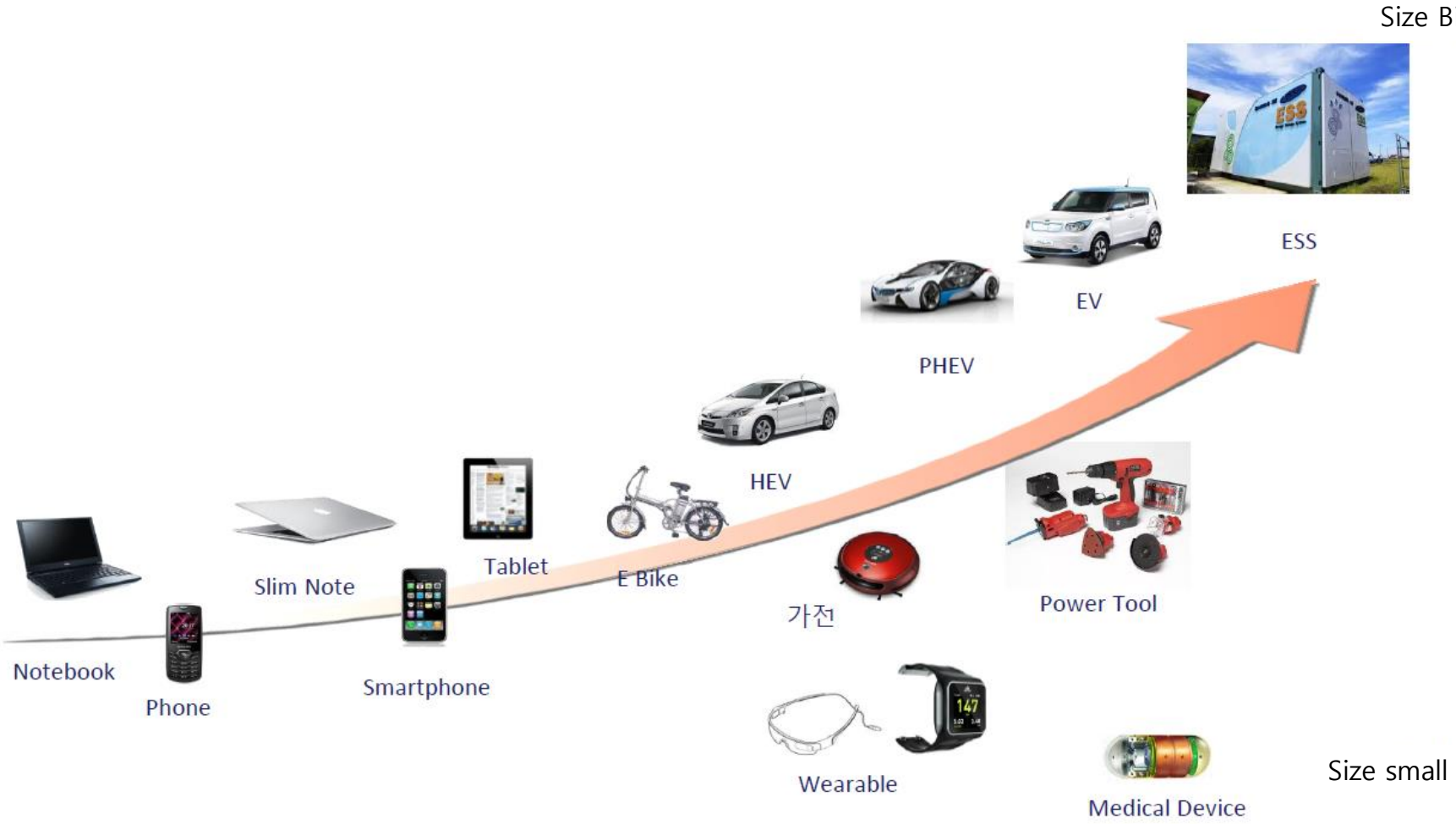
# 1. Introduction of Energy Storage System

**"No.1 company in the world"**



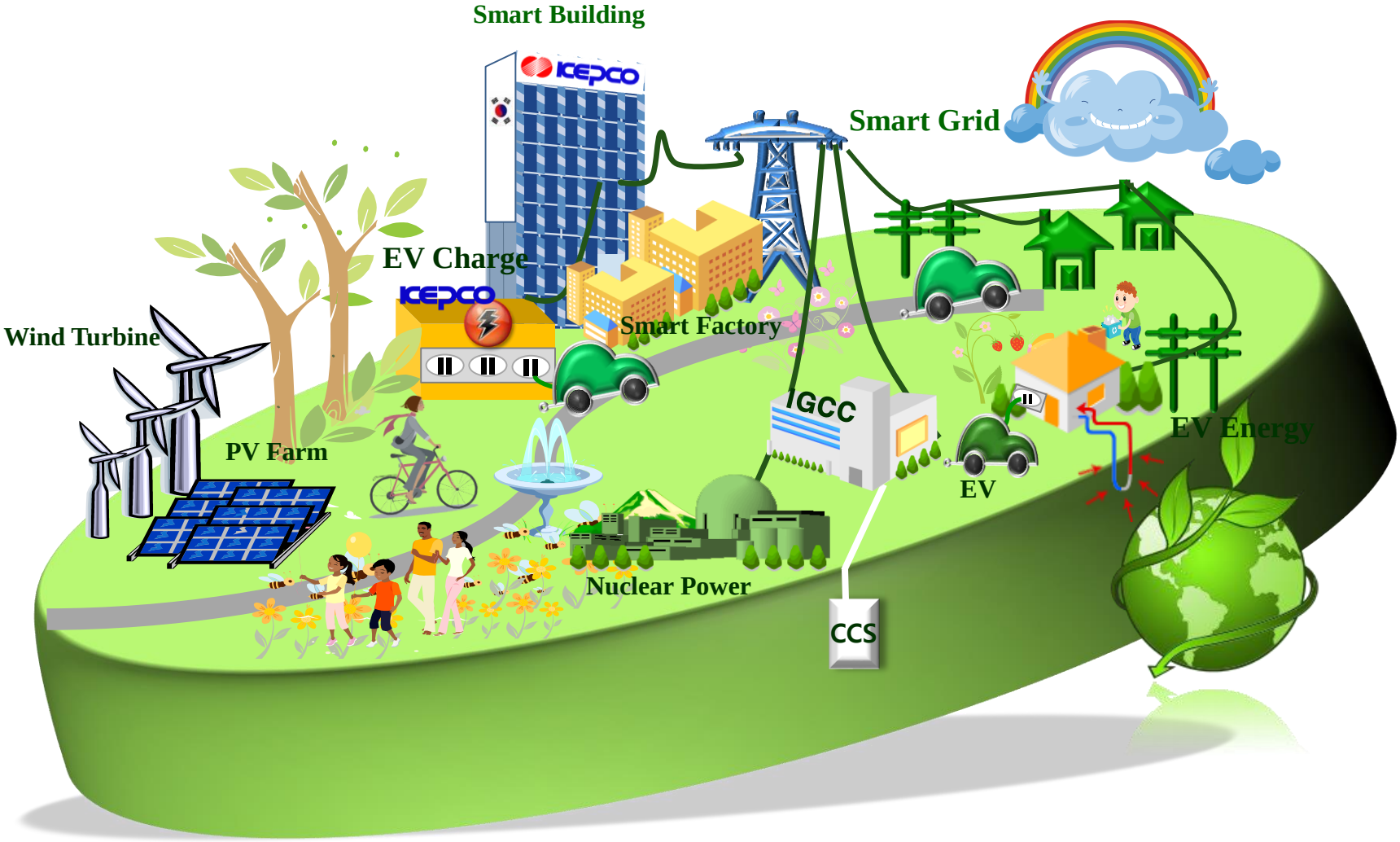
# 1. Introduction of Energy Storage System

**"IT → EV → ESS"**



# 1. Introduction of Energy Storage System

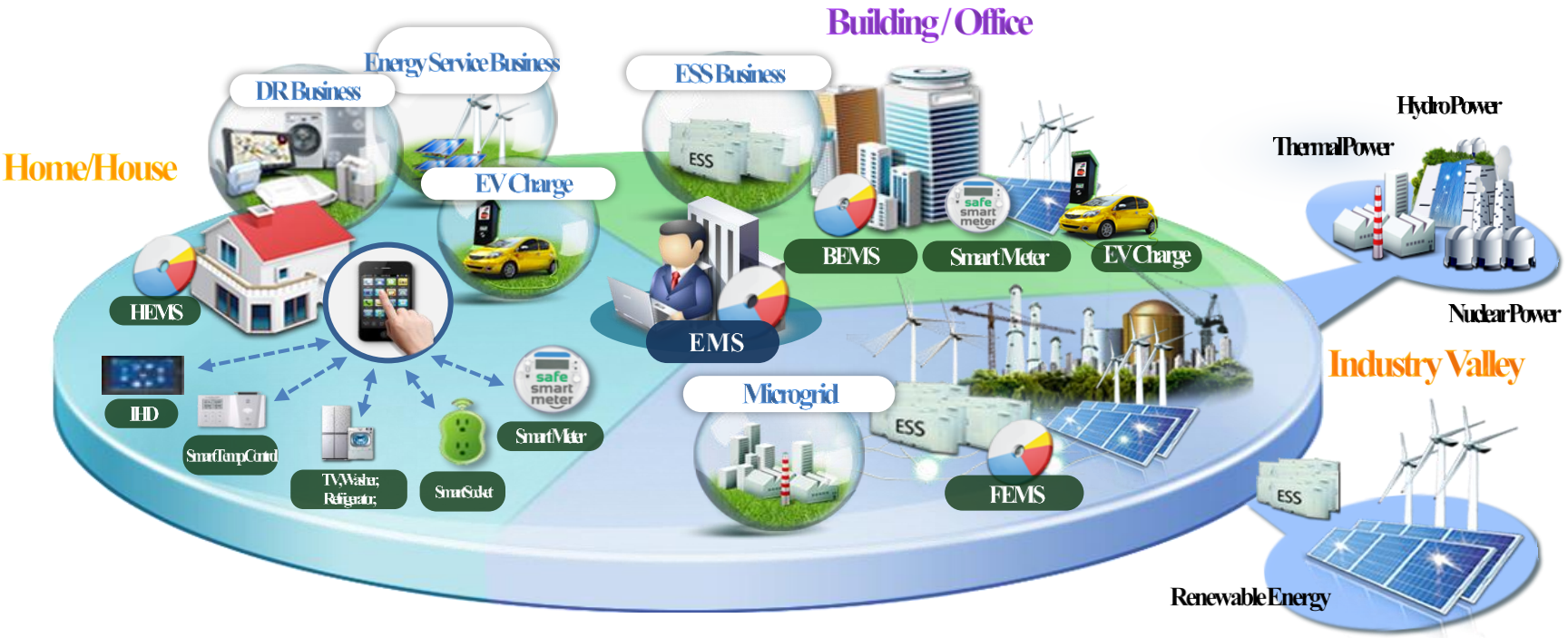
## 1st Phase of Smart grid Strategy in Korea (2009)



# 1. Introduction of Energy Storage System

## 2nd Phase Smart Grid Strategy in Korea (2012)

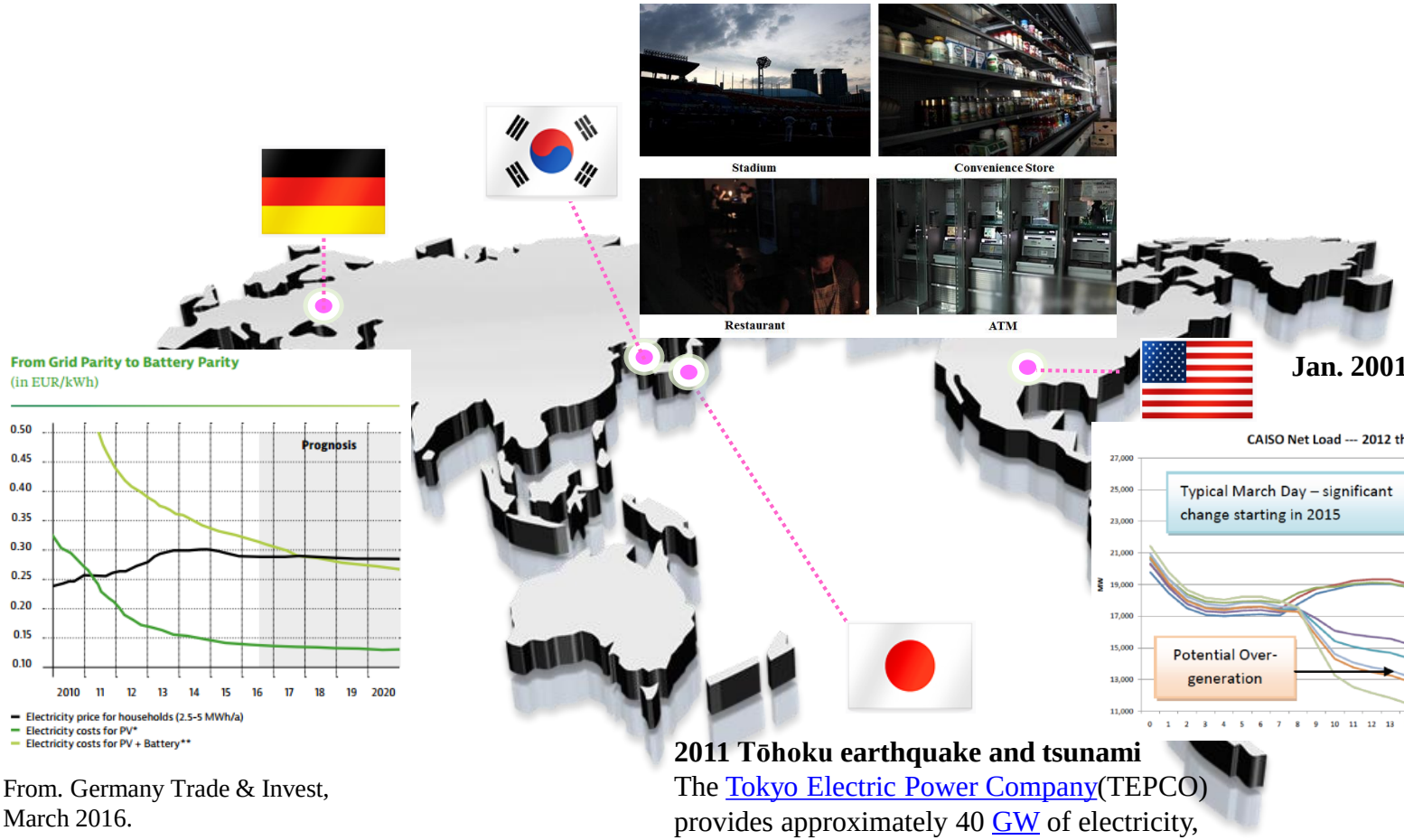
### The New Growth Engine in Korea




| Electrical Grid | + | IT Technology | = | Smart Grid |
|---|---|---|---|---|
| Mainly Provider<br>One-way communication<br>Closed Business Platform | | Real time information exchange | | Mainly Consumer<br>Both way communication<br>Open Business Platform |

# 1. Introduction of Energy Storage System

## ESS for E.F (Energy Efficiency), B R.E (Renewable Energy)




From. Germany Trade & Invest, March 2016.

**2011 Tōhoku earthquake and tsunami**

The Tokyo Electric Power Company(TEPCO) provides approximately 40 GW of electricity, announced that it could only provide about 30 GW.

# 1. Introduction of Energy Storage System

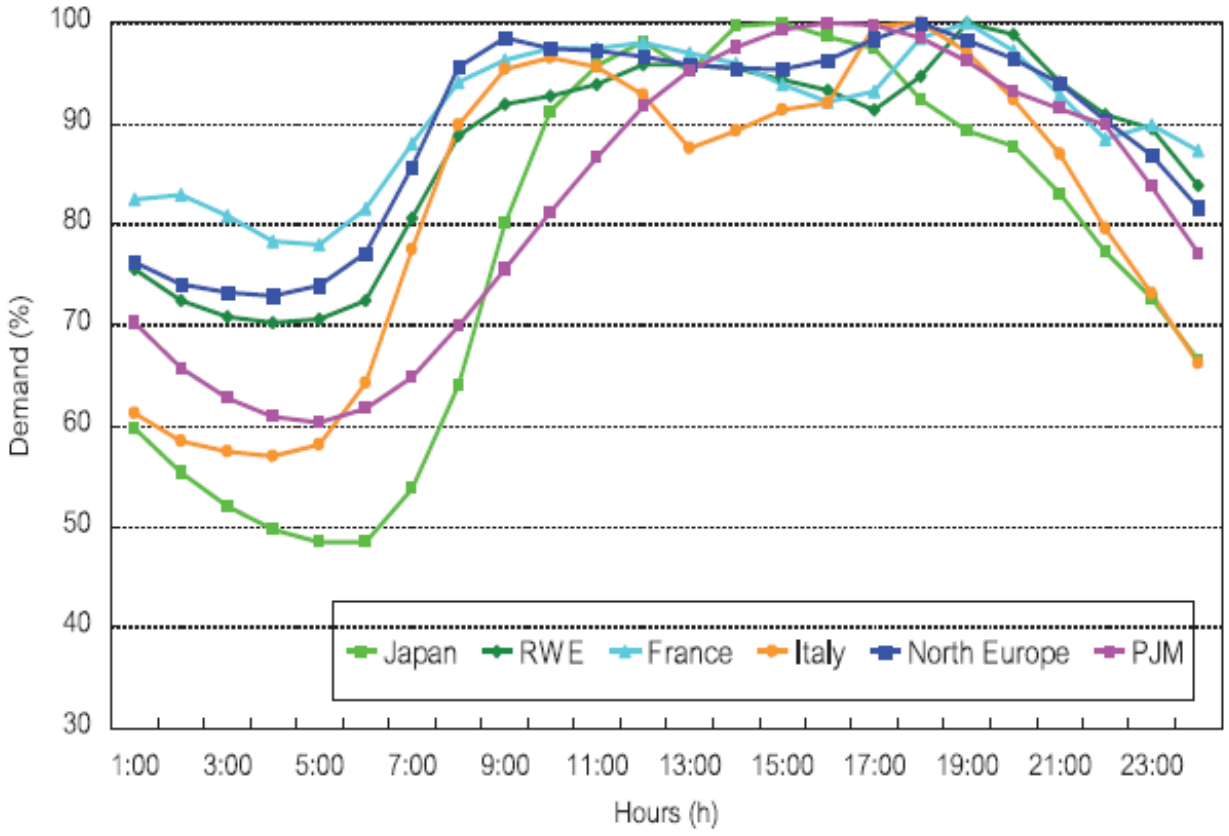
## Peak shift, Emergency, Renewable, Frequency Regulation,

| Nation | Initial Market | Potential ESS Market |
|---|---|---|
|  | Peak shift (2012) |  Commercial(Building) → FR, Transmission → Public side, Home |
|  | Emergency Power (2011) |  Home → Renewable → Transmission |
|  | Renewable Energy TOU, DR |  Transmission, TOU → Renewable → Home |
|  | Renewable Energy |  Renewable → Home |

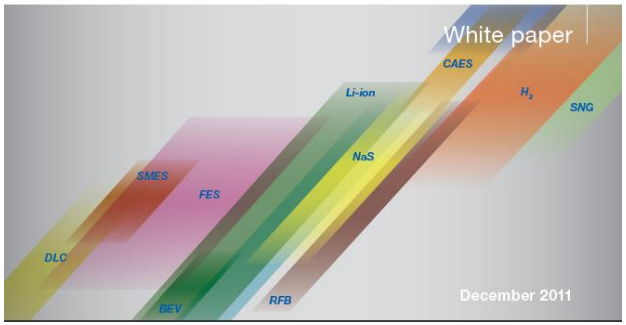
# 1. Introduction of Energy Storage System

## ‘IEC White Paper on December 2011’

**ESS(Electric Energy Storage), EESS(Electric Energy Storage System), BESS(Battery Energy Storage System)**




IEC



# 1. Introduction of Energy Storage System

Figure 2-2 – Pumped Hydro Storage
*(Vattenfall, IEC MSB/EES Workshop, 2011)*

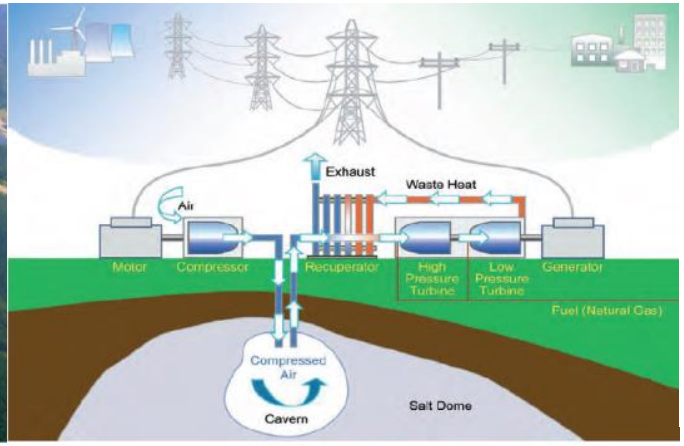



Figure 2-3 – Underground CAES
*[rid11]*

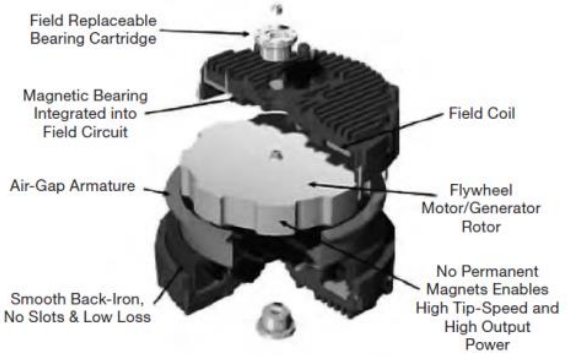



Figure 2-4 – Flywheel energy storage
*[act11]*

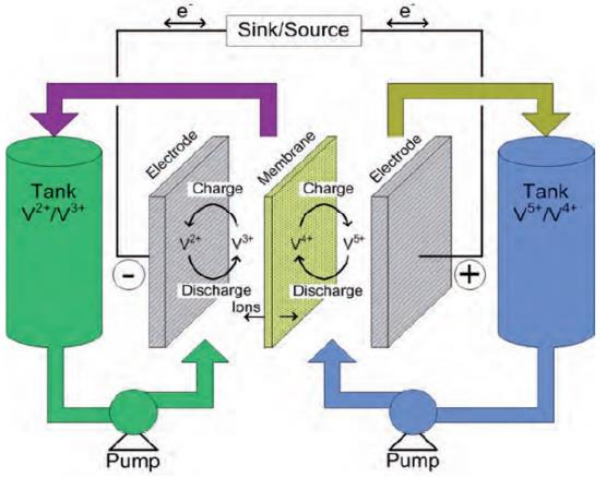



Figure 2-7 – Schematic of a Vanadium Redox Flow Battery
*(Fraunhofer ISE)*

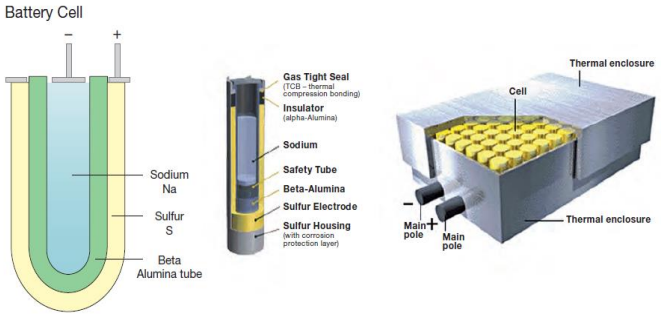



Figure 2-6 – NaS Battery: Cell design and 50 kW module
*(NGK, IEC MSB/EES Workshop 2011)*

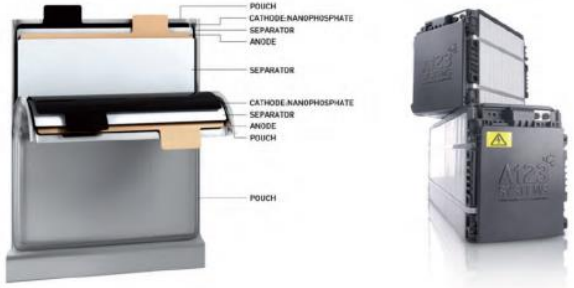
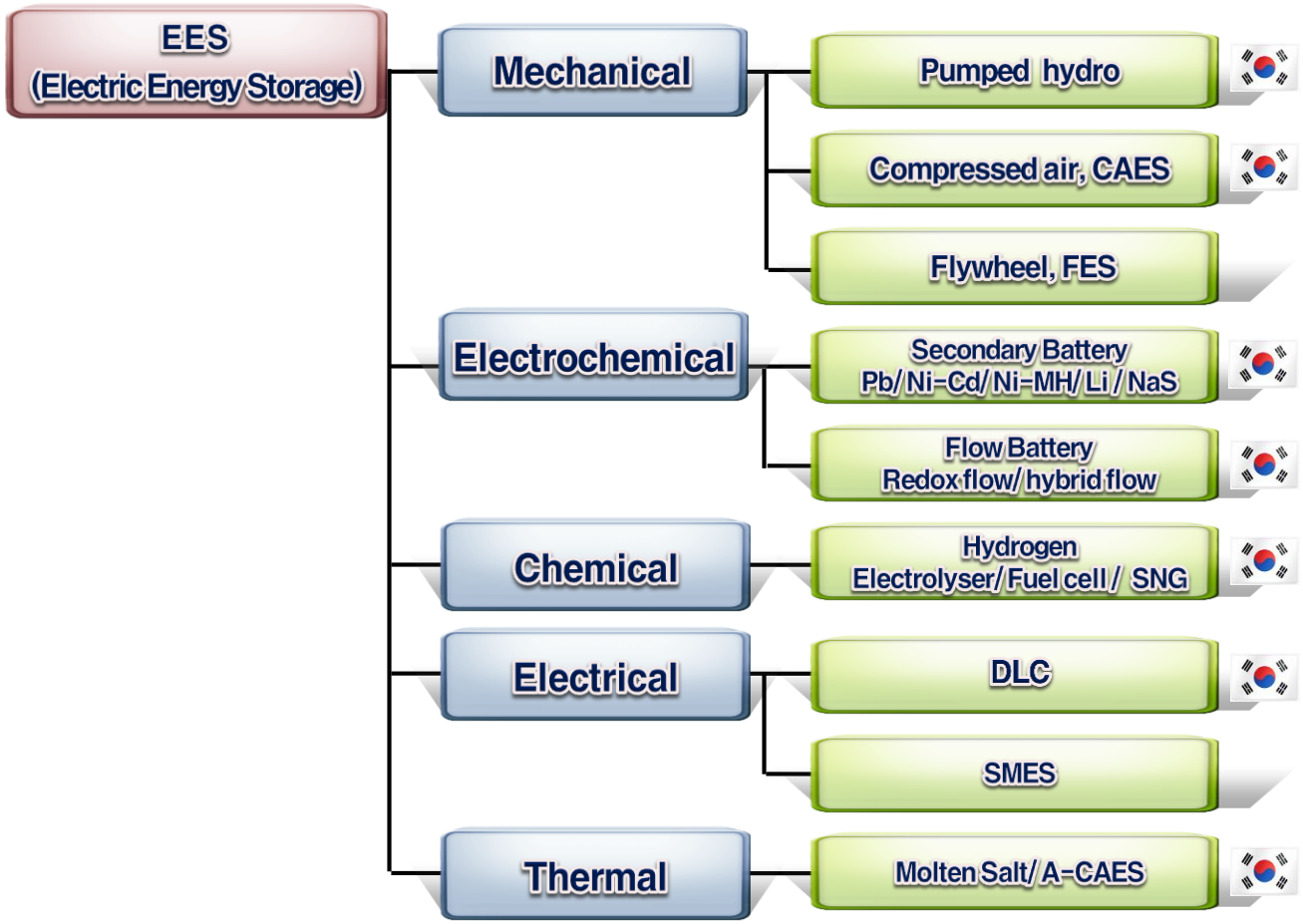
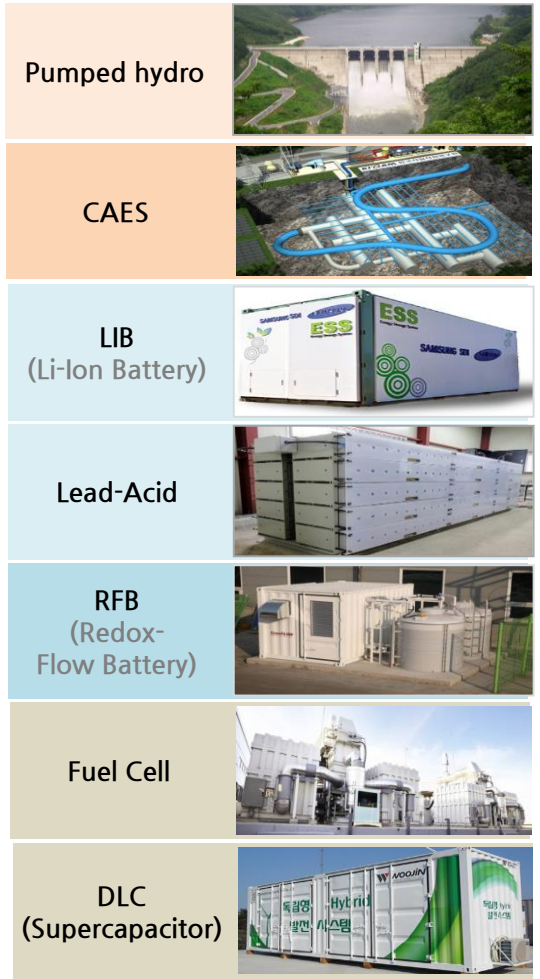



Figure 2-5 – Typical Li-ion prismatic cell design and battery modules
*(A123, IEC MSB/EES Workshop, 2011)*

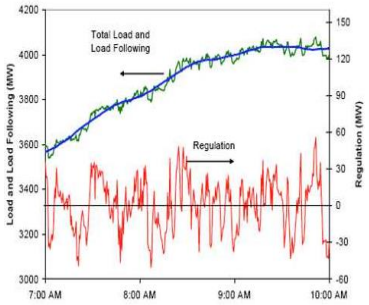
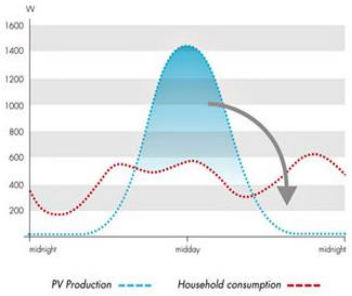
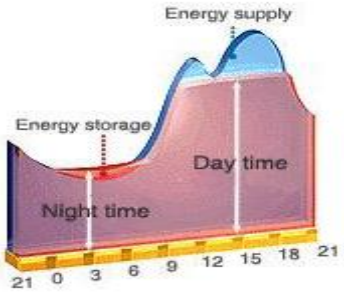
## Electrical Energy Storage technology in Korea



# 1. Introduction of Energy Storage System

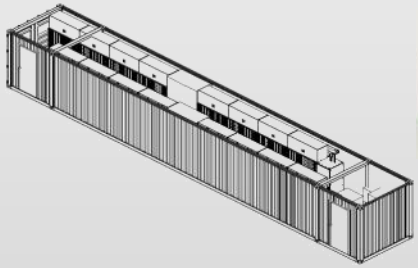
## General application and Use case of EES

| Frequency Regulation | Community Energy Storage | Residential Energy Storage | Peak Shifting | Load Leveling |
|---|---|---|---|---|
|  |  |  |  |  |
| · **Purpose**<br>- Maintain a constant grid frequency<br>- Grid stabilized back-up power (spinning reserve) | · **Purpose**<br>- Neighborhood back-up<br>- Local peak shifting<br>- Power quality | · **Purpose**<br>- Residential back-up<br>- PV integration | · **Purpose**<br>- Alternative to peaking gas power plant in urban areas<br>- Renewable peak shifting | · **Purpose**<br>- Energy arbitrage<br>- Renewable capacity firming |

# 1. Introduction of Energy Storage System

## 1MWh Lithium Ion Battery System

**= Cell + BMS → Module → Tray/Rack → Container**

| Specification | | | 1MWh Container |
|---|---|---|---|
| LIB system design | Power | 1MW |   |
| | Energy | 1MWh | |
| | Configuration | 256S 18P | |
| | Capacity | 1,022kWh (1MW) | |
| | Voltage | 768~1049.6V | |

❖ **Basic component**

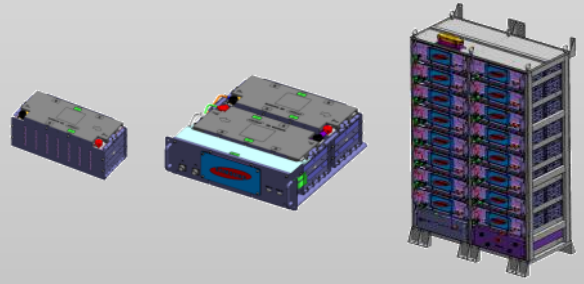
**Cell**

- **Large LIB cell**
- **High Power/Long life**

**BMS**

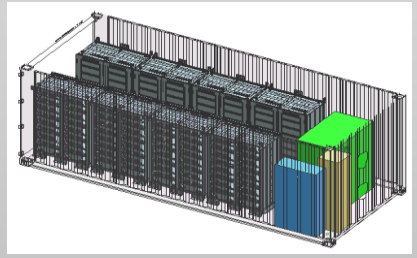
- **Master BMS**
- **Slave BMS**

**Module / Tray / Rack**



- **Modular Extend Design**
- **Reliability & Robust**

**Containerization**



- **HVAC**
- **Fire Suppression System**

# 1. Introduction of Energy Storage System

## 1MWh Lithium Ion Battery System

**= Cell + BMS → Module → Tray/Rack → Container**

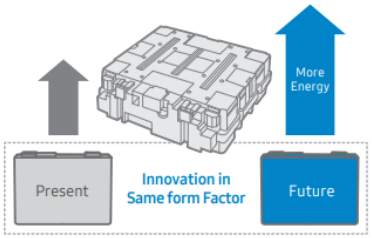
### Safety First

Multi-Layered
**Protection**


Safety first is Samsung SDI priority. Prismatic cell has multi-layered protection at the cell level resulting in best in class safety. In addition, the aluminum exterior has excellent thermal conductivity and cooling performance, and it releases high temperature safely and efficiently from the inside to the outside.

### Sustainable Design

**Easy to Upgrade**
Capacity without
Design Change




We are continuously innovating to increase the energy density while maintaining the same form factor and cell dimensions, thus facilitating future upgrades to higher capacity, higher energy density, ESS with no change to pack design.

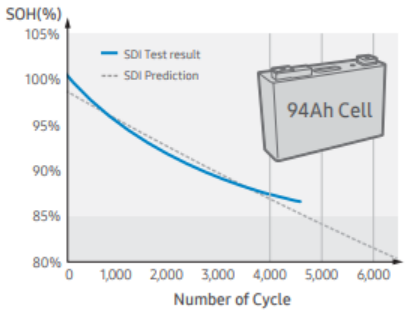
### Long Cycle Life

Industry Leading Cycle Life Performance

**6,000** Cycles

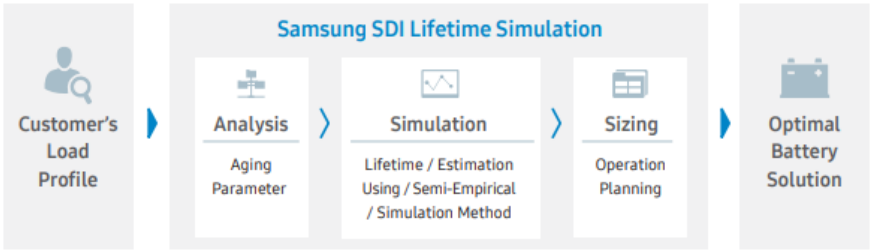
@continuous 1C /1C, SOH 80%

Samsung SDI ESS leverages our manufacturing experience in IT and automotive battery cells resulting in superior and adaptive technology. Samsung SDI ESS is recognized as the industry leader in the market, providing our customers with the safest and long lasting batteries.




(Test Condition at 25℃, 1C/1C, DoD 100%)
*Warranty condition could be different depending on the load profile

### Accurate Lifetime Simulation




Samsung SDI offers optimal battery solution with its superior lifetime prediction technology.
We design and propose a battery system with analyzing the various parameter such as purpose, operation period and installation environment.

# 1. Introduction of Energy Storage System

## 1MWh Lithium Ion Battery System

**= Cell + BMS → Module → Tray/Rack → Container**

### 1,500 High Voltage Platform New

- High Efficiency Battery Solution for 1,500V PCS

**Minimize Power Loss**
by Enabling High Power Output

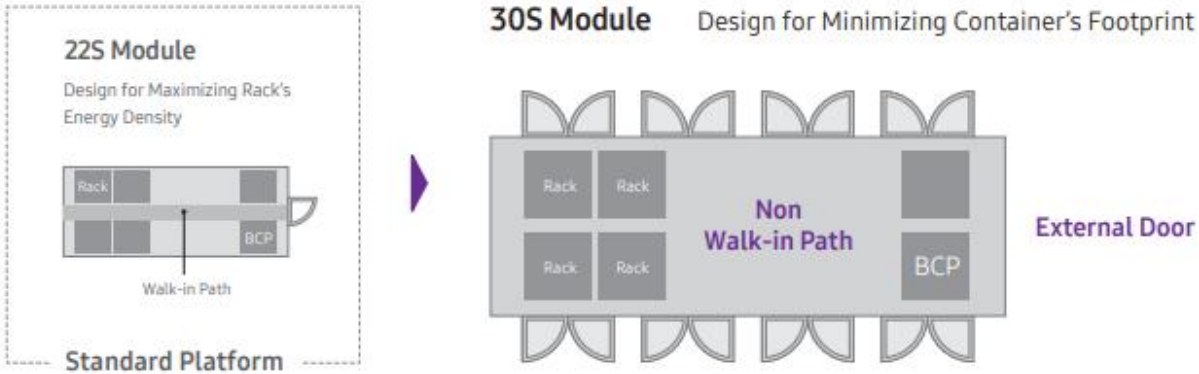
**Minimize Total Footprint**
by Reducing Footprint of
PCS and Battery System

**Maximize**
**Economics & Efficiency**

### 40FT ISO Container Platform New

- Optimized Solution for 40FT ISO Standard Container


**The Highest Capacity**
**at 40FT Container**



# 2. Policy of Energy Storage System in Korea

# 2. Policy of Energy Storage System in Korea

## "New Growth Engine in Korea"

| STEP 1 | STEP 2 | STEP 3 | STEP 4 | STEP 5 |
|---|---|---|---|---|
| K-ESS 2020 ('11.05) | ESS Supply Business ('12.07) ICT + ESS ('13.08) | New Energy Industry ('14.09) | New energy Industry For COP21 ('15.11) | Renewable Energy 3020 ('17.12) |
| **Research & Development Plan & Business strategy**<br>• ESS R&D Investment<br>• ESS demonstration<br>• Infra structure for ESS<br>• Policy for market | **Demand & Supply, ICT+ESS**<br>• ESS Supply business, create 2G Market (‘20)<br>• Demand Response<br>• Peak Shift | **New Energy Industry**<br>• ESS Service company<br>• EMS (Energy management system)<br>• FR(Frequency Regulation)<br>• DR market | **New Energy Industry**<br>• DR business, NegaWatt<br>• ESS-EMS business model<br>• Stand alone (Micro-Grid)<br>• PV Rental<br>• EV charge service provider<br>• Zero house, Clean energy town<br>• Smart Grid Business | **Renewable Energy 3020**<br>• Self Generator PV in city<br>• Small PV Power Plant<br>• Farm village PV<br>• Renewable Generation 5.0GW(~'22), 23.8GW('30) |

# Overview of Government Support

| Highlights of Policies | | |
|---|---|---|
| **Menus** | **Contents** | **Remark** |
| Procurement Target | ✓ Mandatory Procurement of Public Sector | |
| Rebate | ✓ Special Rate for Demand Charge<br>. 2~3 times Demand charge reduction by ESS<br>. Discounted fee for charging ESS<br>✓ ESS connected Renewable's increased REC<br>. W/T : 4.5(~2019) → 4.0(2020)<br>. PV : 5.0(~2019) → 4.0(2020) | Start @ 2016<br>Sunset year 2018<br><br>Start @ 2015 |
| Grant | ✓ Subsidy for C&I's ESS<br>. Has Supported X% of Installation cost in C&I<br>every year since 2012, x has been decreased from 75. | |
| Financing | ✓ Loan with special interest by KDB<br>✓ Financial company's investment<br>; a case of Samsung Card | |

From. KETEP, ADB-KOREA ESS Workshop '18.5

# Overview of Government Support

## Highlights of R&D Support

✓ **Application Technologies : $80millions**

- **BM/Function Development, Demonstration in Overseas Area**
- **FTM : 2, BTM : 12, MG : 1, Ship : 1, Common : 2 Projects**

✓ **Product Technologies : $60millions**

- **Battery : LIB $18, RFB $19, NaS $10, others $5 millions**

  LIB : Life 10 → 20 years, RFB : MW scale product of ZnBr, VRB

- **PCS & System : $8millions**

  PCS : 2MW product, Modularization

  System : Improvement of EMS-SW, Validation Technology

From. KETEP, ADB-KOREA ESS Workshop '18.5

# Overview of Government Support

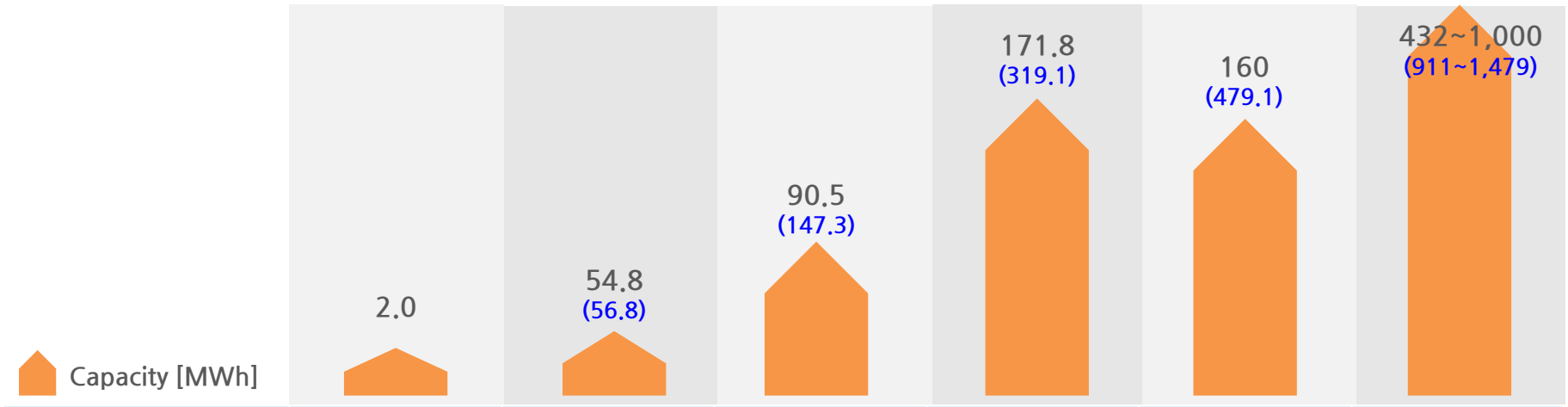
## Map of Projects

| Applications | | Area | Demonstration | | Deployment |
|---|---|---|---|---|---|
| | | | Domestic | overseas | |
| On -Grid | Generation | - Defer Asset Investment<br>- Load Leveling | | | |
| | | R.E. Time shift | | Australia | |
| | | R.E. Smoothing | | EU | |
| | System Operator | Energy time shift | | | |
| | | FR | | USA, EU | |
| | | Other Ancillary service | | | |
| | T&D Utility | Defer T&D Investment | | | |
| | Customer | Demand management ,UPS | | USA, Asia | |
| Off -Grid | MG | Island | | Asia | |
| | | Data Center, Campus | | | |
| | Others | Ship, off-shore plant | | | |
| | | Mine, Oil Field | | | |

From. KETEP, ADB-KOREA ESS Workshop '18.5

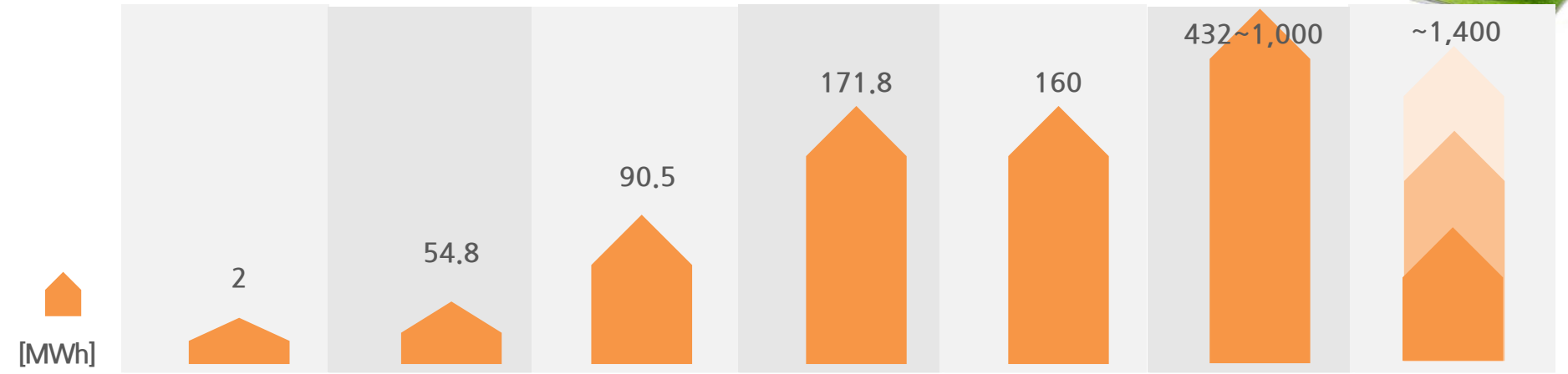
# 2. Policy of Energy Storage System in Korea

## ESS Installation in Korea




| 구분 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|---|
| Peak reduction | 1 | 13.9 | 63.2 | 26.7 | 20.1 | 192 |
| **Frequency Regulation** | | | 19.0 | 46.0 | 35.0 | 12 |
| Wind | | | | 95.8 | 90.4 | 90 |
| PV | | | | | | 102 |
| Distribution | | | | | 10.0 | 35 |
| R&D | | 8.3 | 6.5 | | 4.5 | |
| Island Micro grid | | 3.9 | 1.8 | 3.3 | | |
| Public Building | | | | | | |
| Self Generation | 1 | 28.7 | | | | |
| Total | **2.0** | **54.8** | **90.5** | **171.8** | **160** | **432~1,000** |

# 2. Policy of Energy Storage System in Korea




| Year | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 |
|---|---|---|---|---|---|---|---|
| Total | 2 | 54.8 | 90.5 | 171.8 | 160 | 432 | ?? |

ESS Subsides Program '13 ~ '17 (Smart Grid, Korea Energy Agency)

Renewable energy + ESS (Korea Energy Agency)

Frequency Regulation ESS '14~ (KEPCO)

Wind Turbine with ESS(REC +) '15~ (Korea Energy Agency)

Transformation ESS '16~ (KEPCO)

New Energy industry for Province (KEA)

ESS Emergency Power

Public Building '17~

PV +ESS REC+ '17 ~

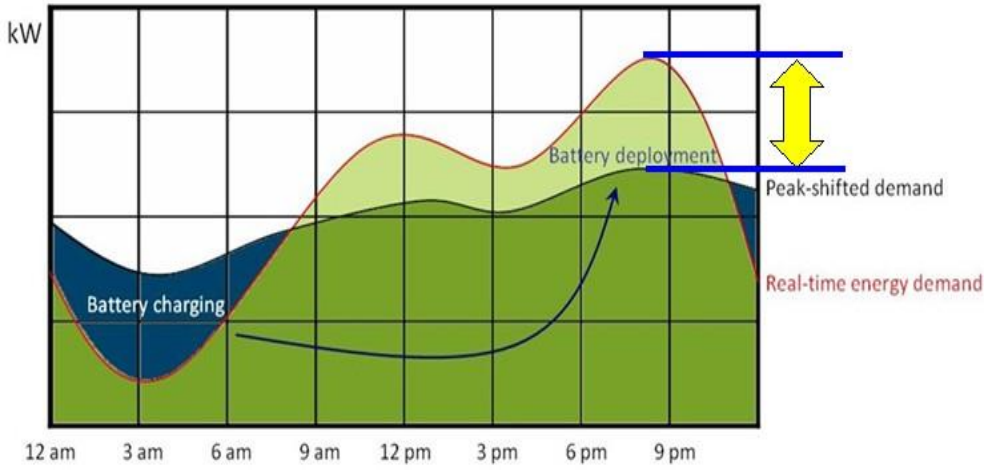
From Subsidies, Incentive program to Regulation

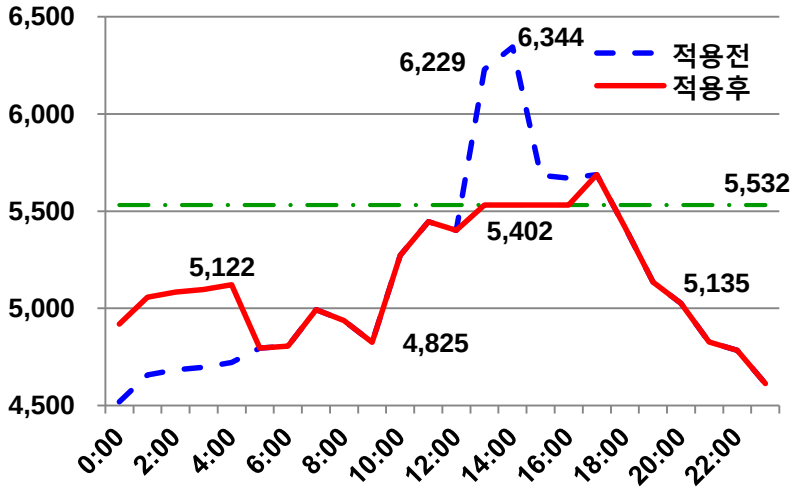
# 2. Policy of Energy Storage System in Korea

## 1. ESS Subsides Program '13 ~ '16 (Smart Grid, Korea Energy Agency)

### Energy Hybrid & Complex Subsides Program '16 ~ (Korea Energy Agency)

1) Application : Peak Cut during Peek hours
   Summer 12:00~14:00
   Winter 9:00~11:00 and 15:00~17:00
   * Performance : 2hours Charge
2) Subside : 75% for Total installation (US$ 13.6 millions)
3) Benefit : Peek tariff save
4) Social Benefit
   '12, US$ 1,500,000/1MWh → '14. US$1,000,000/1MWh

# 2. Policy of Energy Storage System in Korea

## 1. ESS Subsides Program ‘13 ~ ’16 (Smart Grid, Korea Energy Agency)

### Energy Hybrid & Complex Subsides Program ‘16 ~ (Korea Energy Agency)


Dezon(‘13) Data Center,

LIB 500kW

(1.7MWh) Peak Control

Save $ 40,000/year


KMW(‘15) Peak save,

Lead-Acid

500kW(1.0MWh) Peak control

Save $ 45,000/year

# 2. Policy of Energy Storage System in Korea

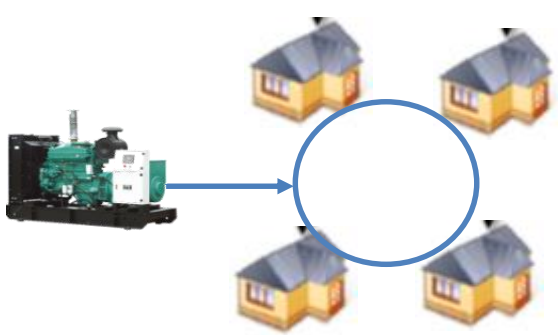
## 2. Renewable + ESS Subsides Program '13 ~ (Korea Energy Agency)

1) Application : Renewable Energy + ESS for islands Power System

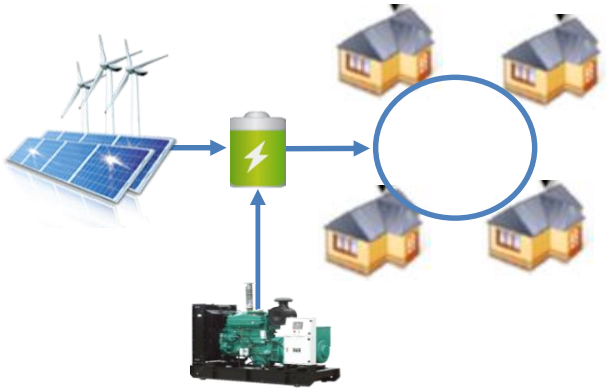
2) Subside : 50% for ESS Total installation

3) Benefit : Power generation cost reduction US$ 0.36/kW →US$0.3/kW

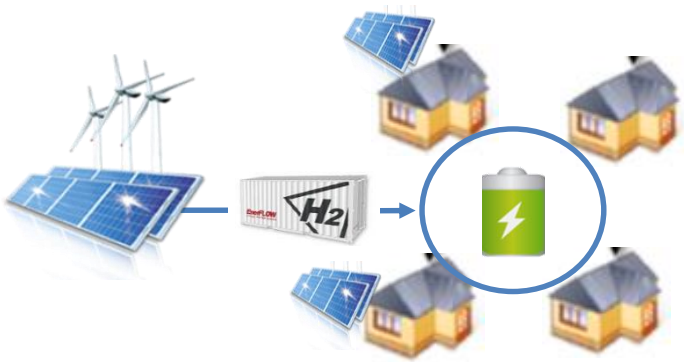
4) Social Benefit : '12, US$ 150,000,000 will be down around 10~20% in Short period



Island Power System



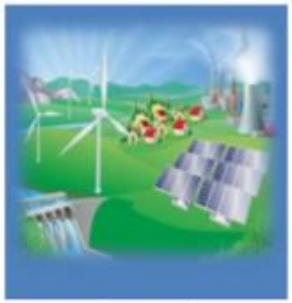
Hybrid Power System




100% Renewable system

# 2. Policy of Energy Storage System in Korea

## 2. Renewable + ESS Subsides Program '13 ~ (Korea Energy Agency)

| |  |  Gapa Island |  Gasa Island |  Deokjeok Island |  Ulleung Island |
|---|---|---|---|---|---|
| Area/ Population | | 0.85km² / 281 | 0.85km² / 281 | 22.97km² / 1,919 | 72.9km² / 10,673 |
| Customers | | 193 | 168 | 1,000 | 7,932 |
| Configuration | | WT+PV+ESS+AMI | WT+PV+ESS | WT+ PV+ ESS + EMS+ Geotherm | WT + PV+ Hydro + Geotherm + ESS + EMS |
| Main Characteristics | | Carbon Free Island (Korea's First) | Carbon Free Island | Ecology Energy Independent Island(Stailization, Optimization) | Green Energy Independence Island |
| Status | | Operating | Operating | Project Started | Planning |

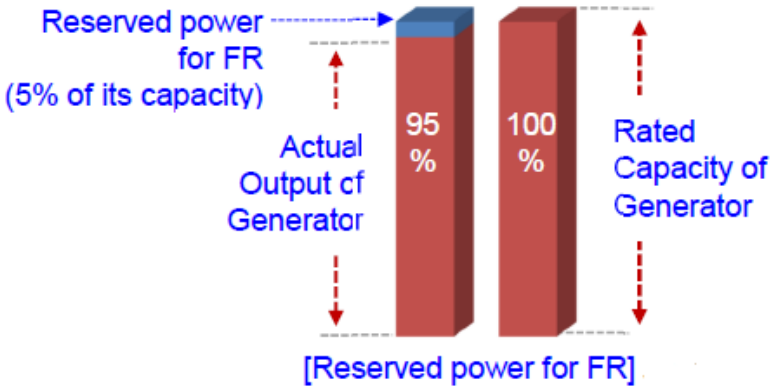
## 3. Frequency Regulation Program '14 ~'17 (KEPCO)

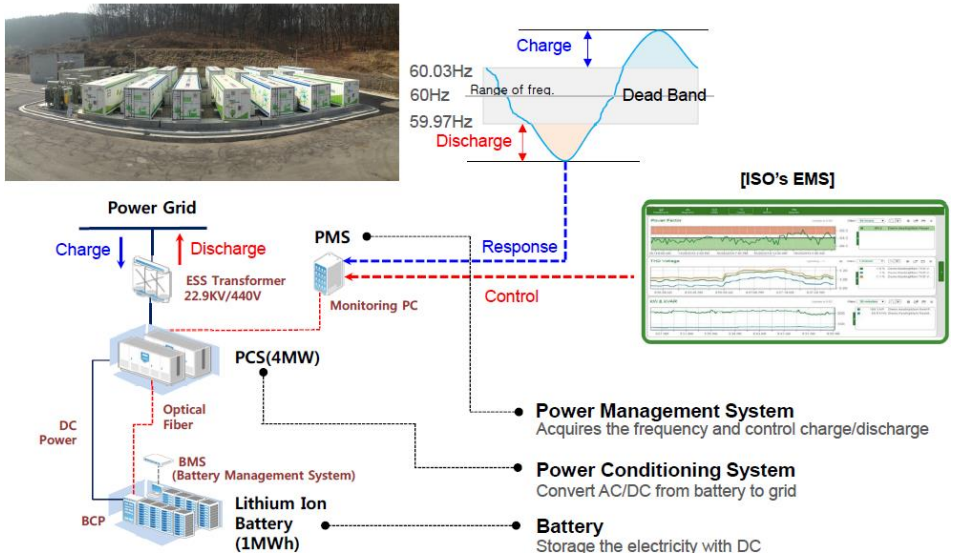
1) Application : Frequency Regulation

2) No Incentive or Subside which is economically possible applications for ESS

3) Benefit : To reduction compensation cost of 5% standby power from Coal fired Power plant

4) Social Benefit : Power from Coal fired US$ 50,000,000 or US$ 150,000,000 from LNG

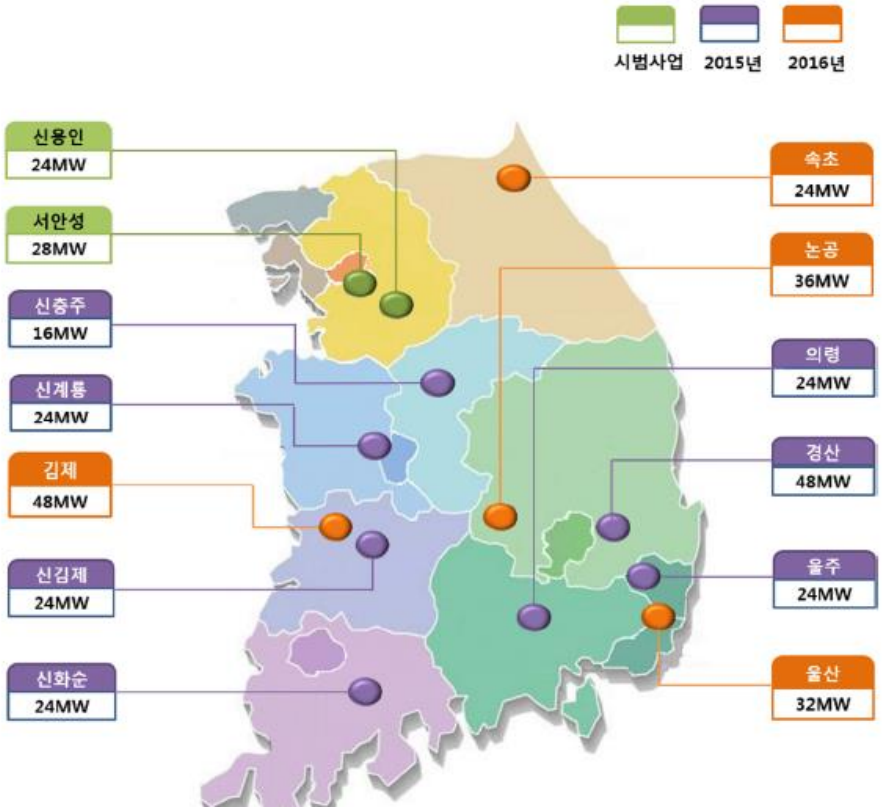


## 3. Frequency Regulation Program '14 ~'17 (KEPCO)

| Item | 2014 | 2015 | 2016 | 2017 | Total |
|---|---|---|---|---|---|
| Capacity | 52MW | 184MW | 98MW | 48MW | 376MW |
| Status | Commercial Operation(376MW) | | | | 13 Sites |







## 4. Renewable Energy + ESS, Additional REC '15 ~ (Korea Energy Agency)

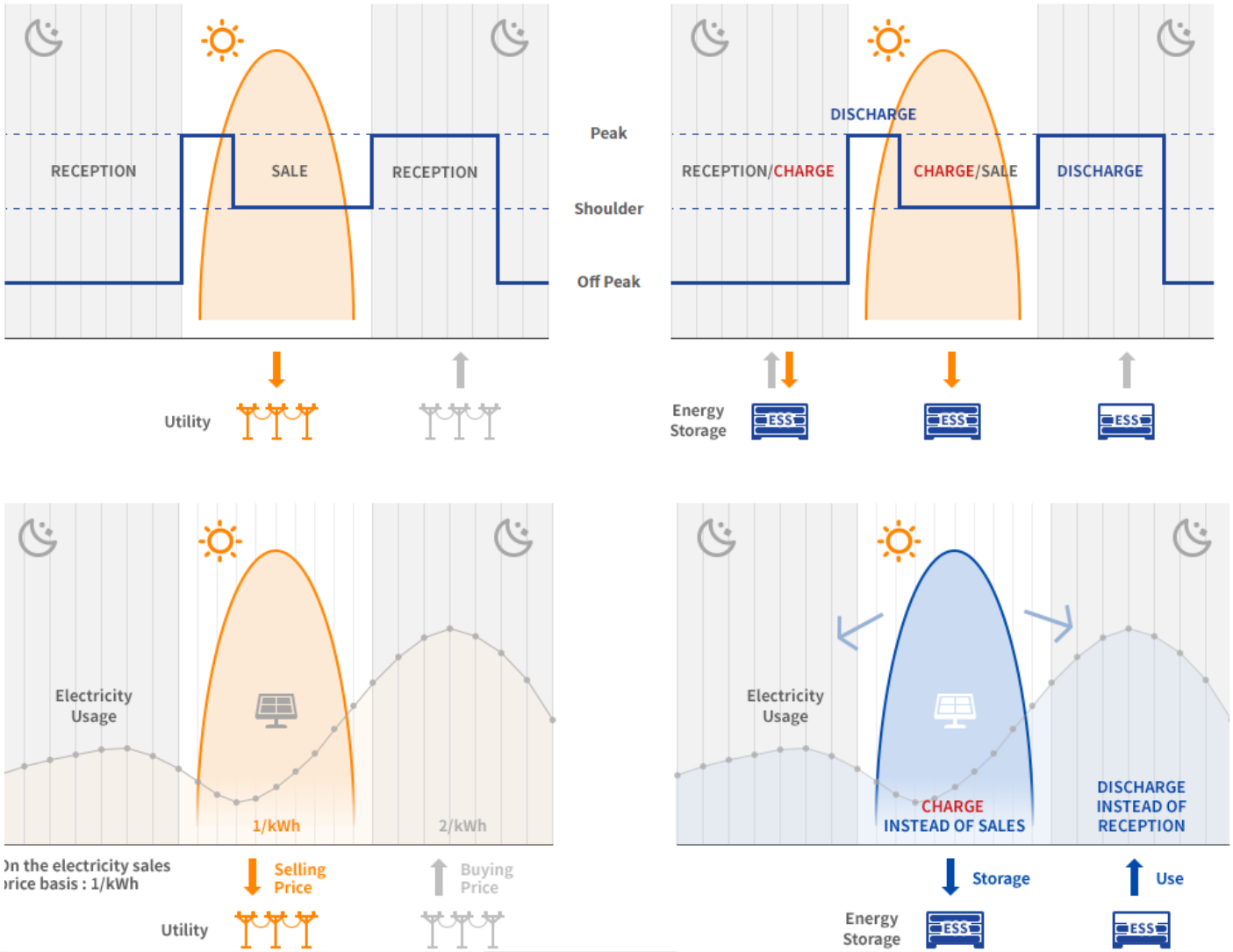
1) Application : Renewable Energy + ESS of Additional REC(Renewable Energy Certificate)
Wind Turbine : 5.5('15), 5.0('16) ~ 4.0('20)
PV : 5.0('16) ~ ~ 4.0('20)

2) Incentive : SMP + REC(1.0~5.5)

3) Benefit : To increase power quality from W.T
To increase using efficiency for grid connection line with PV

4) Social Benefit : To reduction construction & upgrade cost of grid connection system

## PV+ESS REC


RECEPTION
SALE
RECEPTION
Peak
Shoulder
Off Peak
Utility
DISCHARGE
RECEPTION/CHARGE
CHARGE/SALE
DISCHARGE
Energy Storage
ESS
Electricity Usage
1/kWh
2/kWh
Selling Price
Buying Price
Utility
CHARGE INSTEAD OF SALES
DISCHARGE INSTEAD OF RECEPTION
Storage
Use

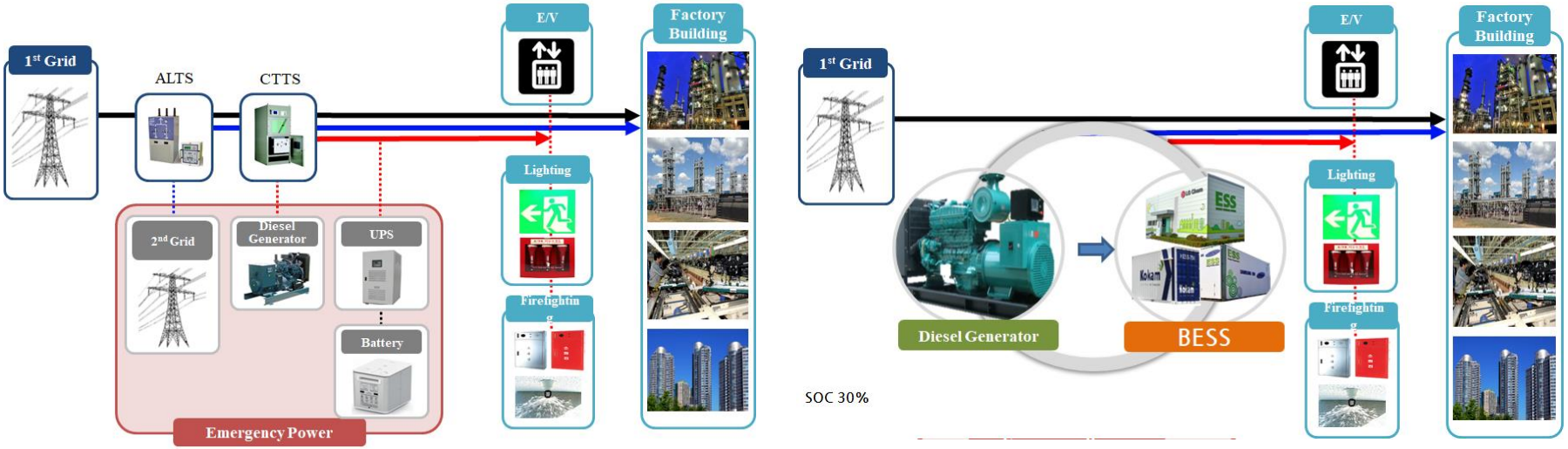
## 5. Emergency Power from ESS '16~ (Korea Energy Agency)

1) Application : Emergency Power for Fire suppression equipment and left

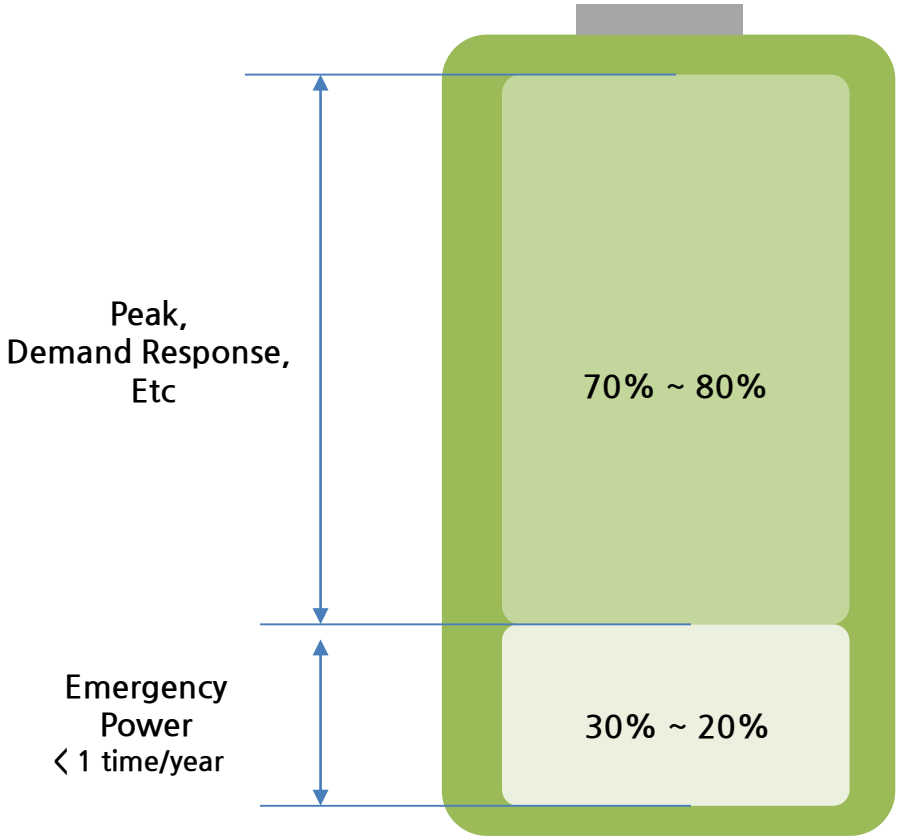
2) Incentive : 50% for ESS installation Cost

3) Benefit : Replace Diesel Generator

4) Social Benefit : Reduction CO2 for pre-operation about 30 mins per month

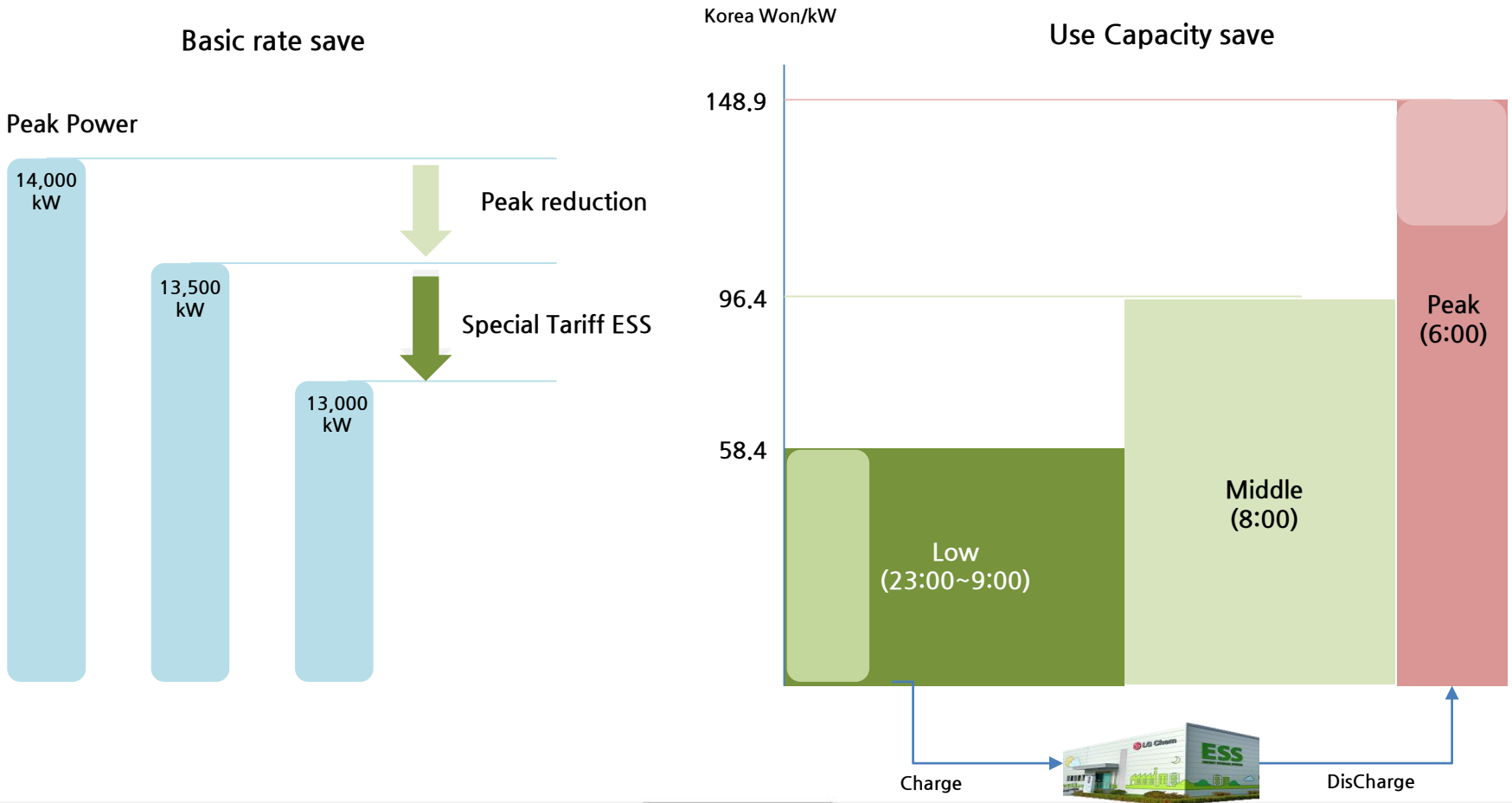


## 5. Emergency Power from ESS '16~ (Korea Energy Agency)



## 6. Special Discount for Charge tariff '16~ (Korea Energy Agency)

1) ESS charge tariff discount about 50% during night time



## 7. ESS installation in Public Building '17~ (Korea Energy Agency)

1) 5% ESS capacity for Contract Electricity Capacity until ~ 2020

| Contract Capacity(KW) | Date |
|---|---|
| Over 10,000 | ~ 2017.12.31 |
| 5,000~10,000 | ~ 2018.12.31 |
| 2,000~5,000 | ~ 2019.12.31 |
| 1,000~2,000 | ~ 2020.12.31 |

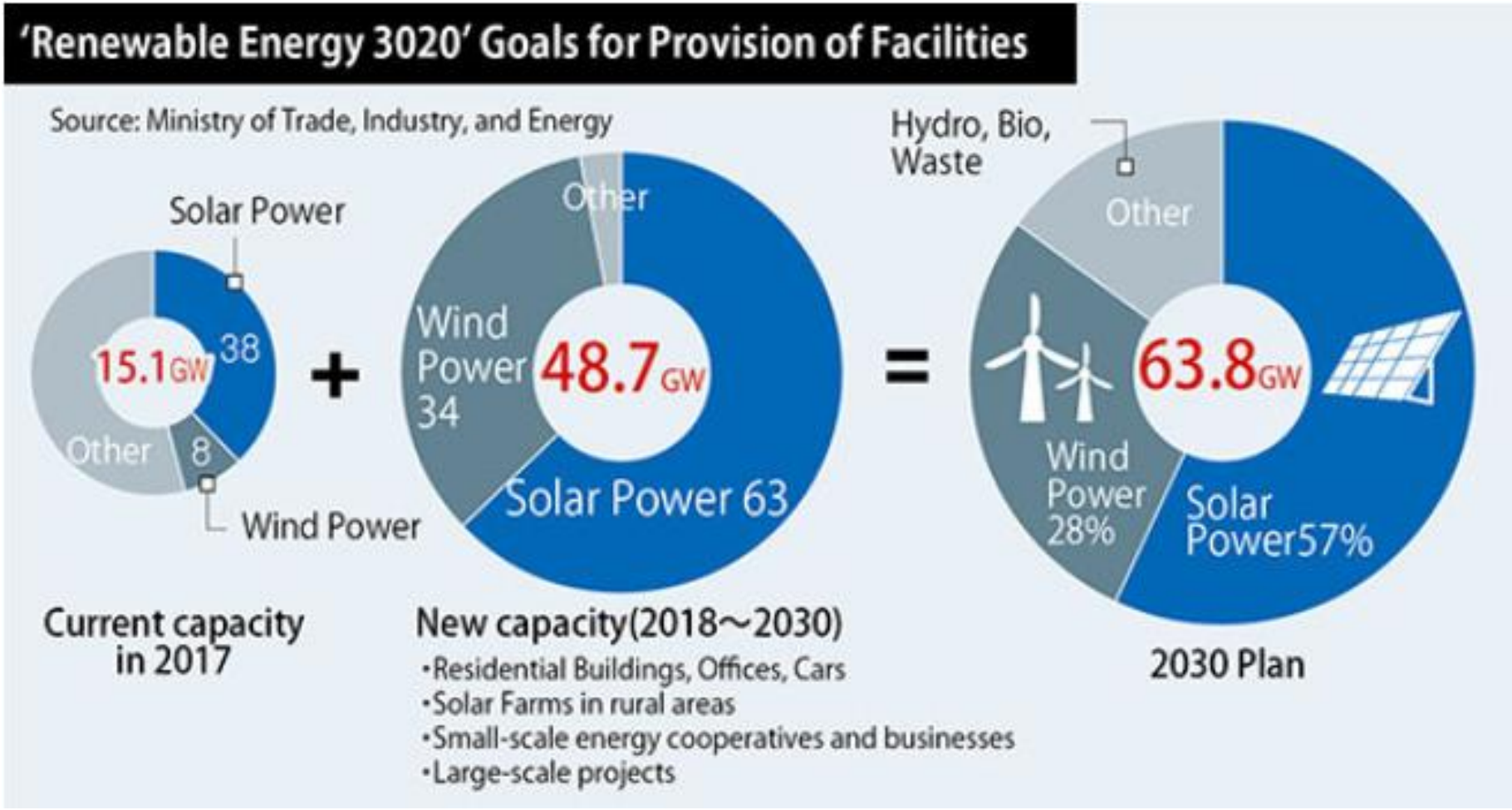
### Guide line of ESS Capacity for Public building



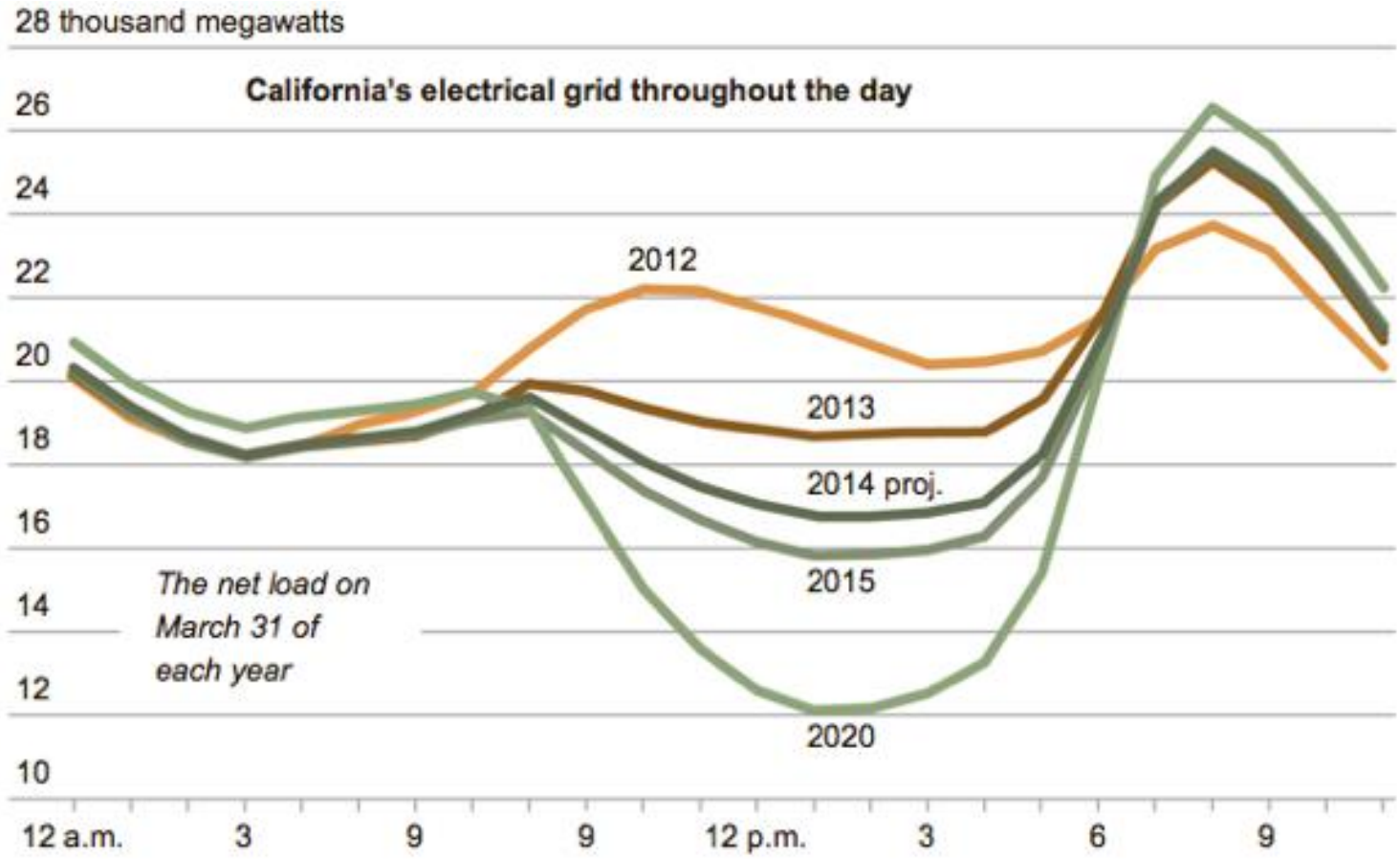
| Type | ESS Capacity | Contract Power (kW) | Peak Power (kW) |
|---|---|---|---|
| A | 500 kW | 5,000 ~ 10,000 | 1,000 ~ 5,000 |
| B | 1 MW | 10,000 ~ 20,000 | 5,000 ~ 10,000 |
| C | 2 MW | 20,000 ~ 50,000 | 10,000 ~ 20,000 |
| D | 5 MW | 50,000 ~ | 20,000 ~ |

# 3. Energy Storage System for Clean Energy

## Renewable Energy 3020



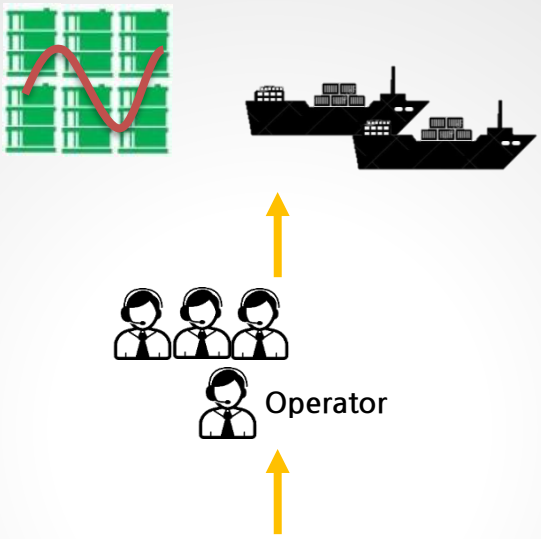
## Renewable Energy 3020




Source: CalISO

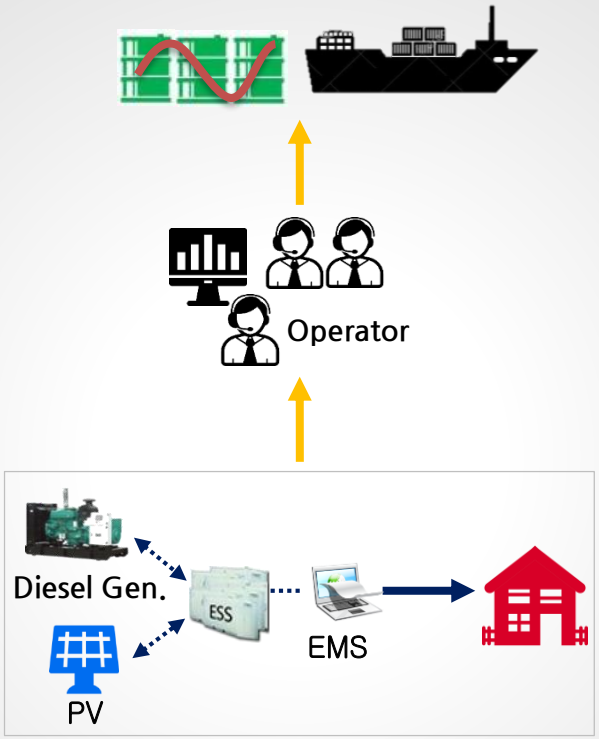
# 3. Energy Storage System for Clean Energy

## Micro-gird for Island



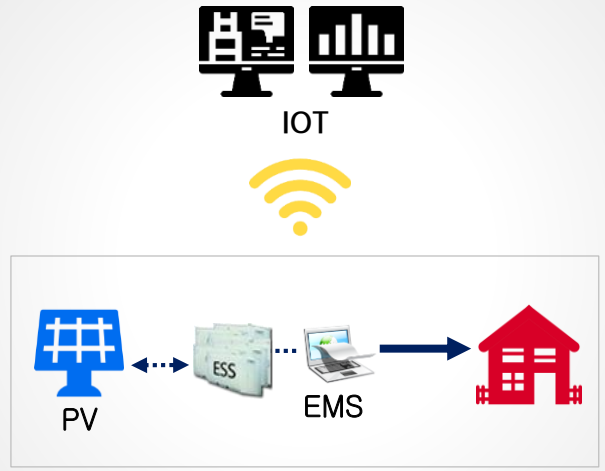

**STEP 1**
**Diesel Gen.**

Diesel Gen. 100%




**STEP 2**
**Hybrid System**

Diesel Gen. + PV + ESS + EMS

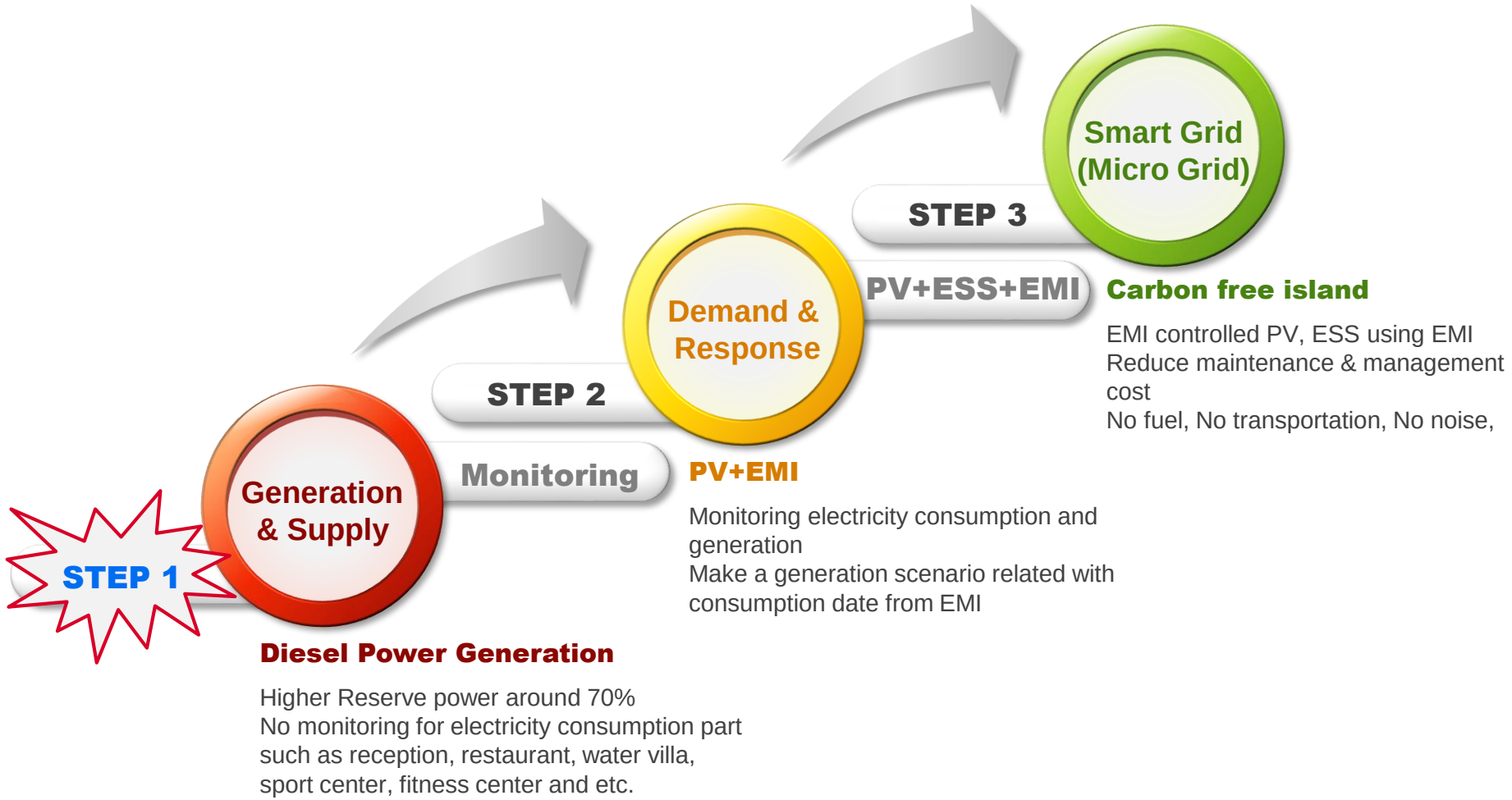



**STEP 3**
**Renewable Energy**

PV + ESS + EMS

# 3. Energy Storage System for Clean Energy

## Micro-gird for Island




**Diesel Power Generation**

Higher Reserve power around 70%
No monitoring for electricity consumption part such as reception, restaurant, water villa, sport center, fitness center and etc.

**PV+EMI**

Monitoring electricity consumption and generation
Make a generation scenario related with consumption date from EMI

**Carbon free island**

EMI controlled PV, ESS using EMI
Reduce maintenance & management cost
No fuel, No transportation, No noise,

# 4. Prospect of Futures

# 4. Prospect of Futures

# Thank you!!

KORBA Battery R&D Association of Korea

KBIA Korea Battery Industry Association