Energy Storage System Technology and demonstration

5th June 2018

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Korea Battery Industry Association

Battery R&D Association of Korea

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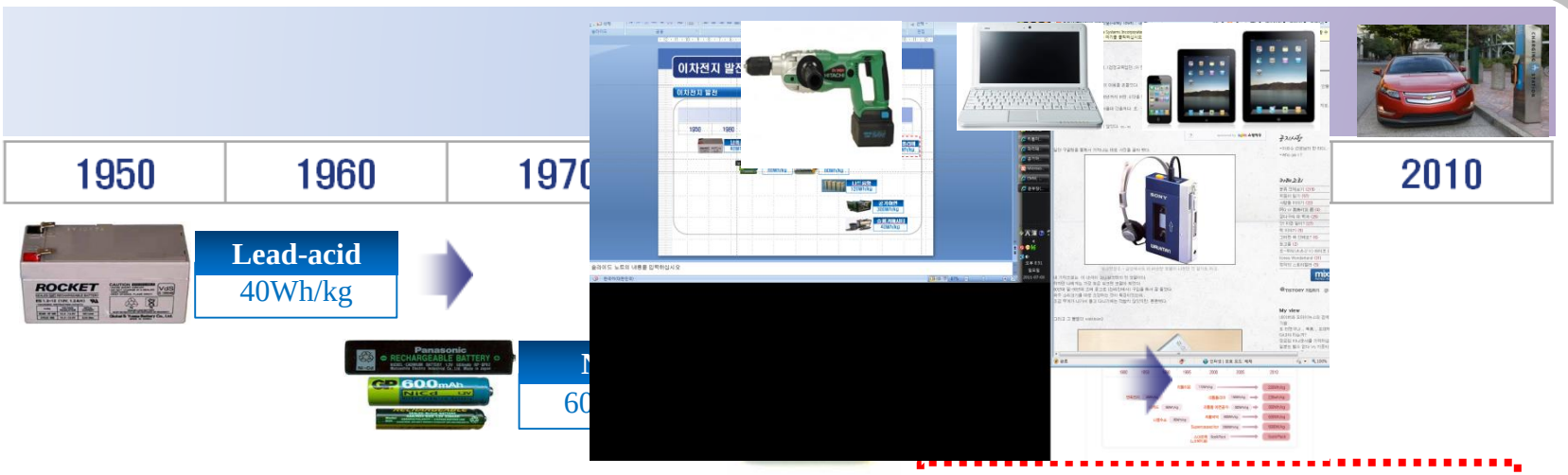
1. Introduction of Energy Storage System

1. Introduction of Energy Storage System

“The current of ESS technology came from Rechargeable battery”

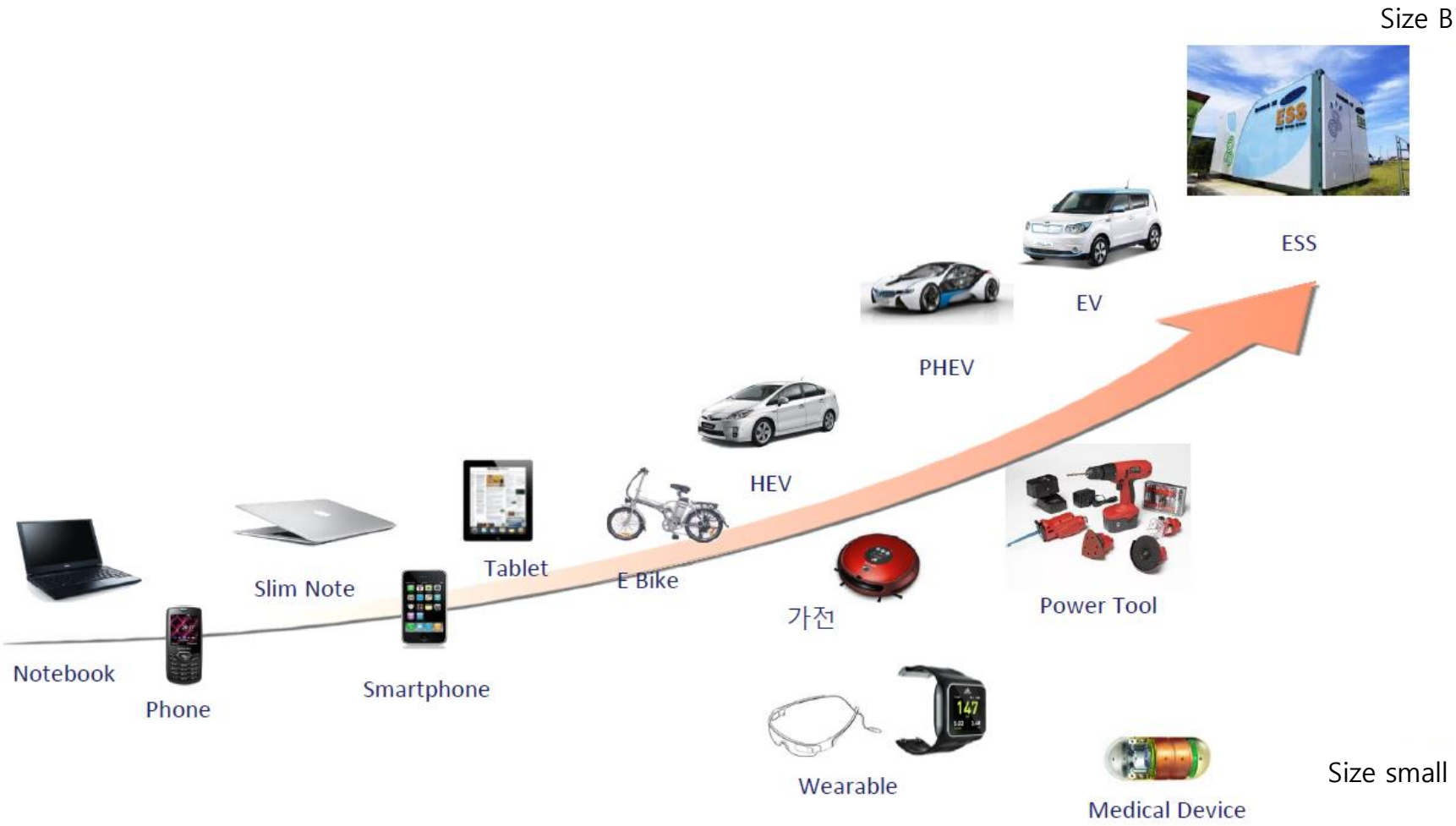


Lithium ion Battery

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

1. Introduction of Energy Storage System

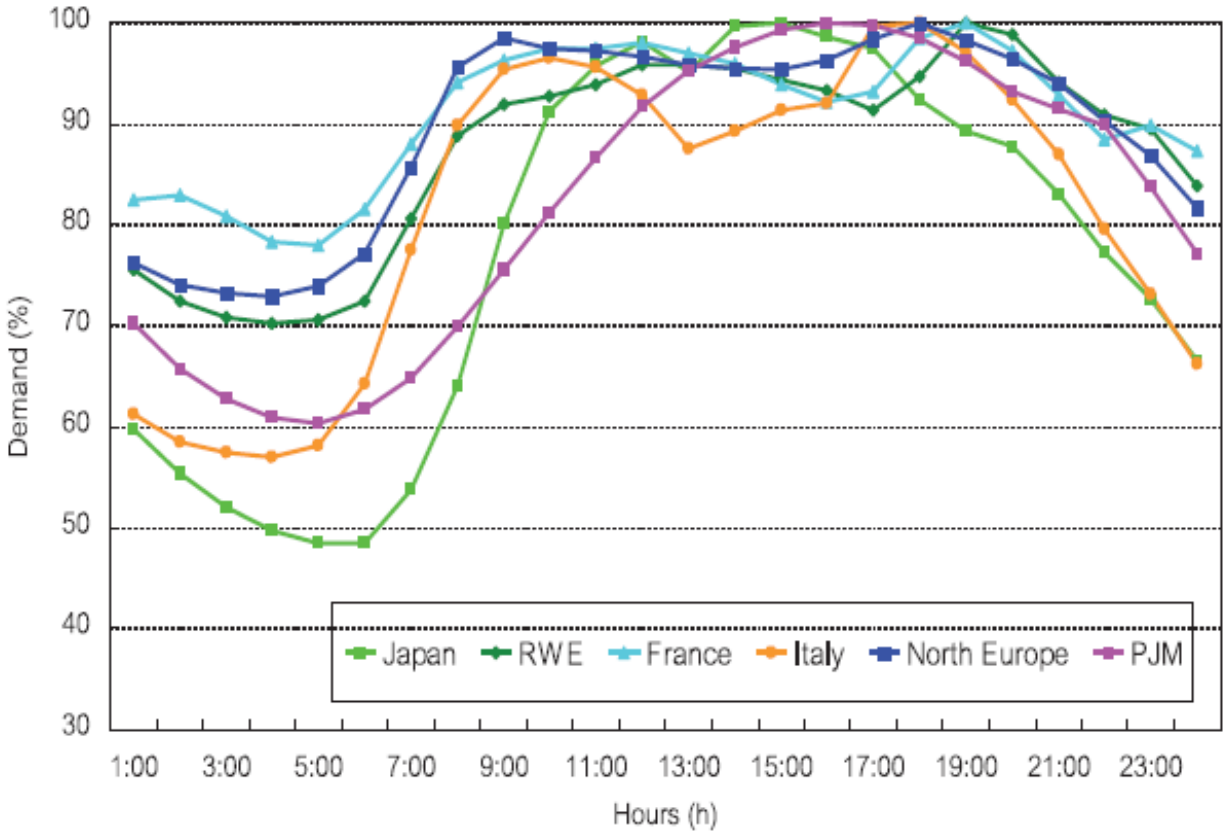
"IT → EV → ESS"



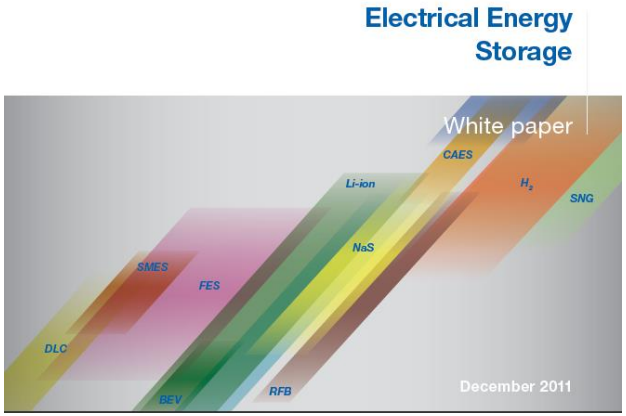
1. Introduction of Energy Storage System

‘IEC White Paper on December 2011’

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

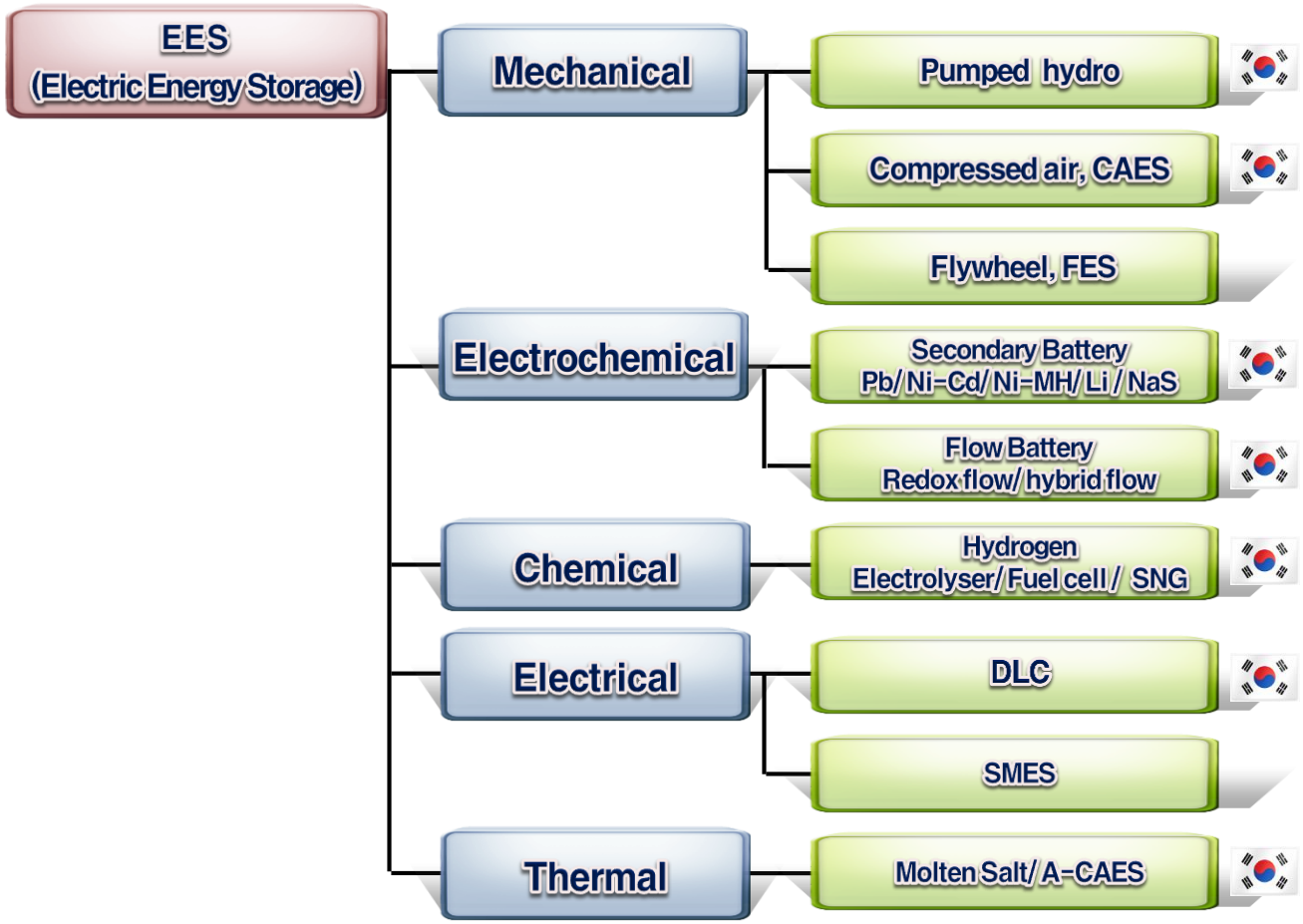


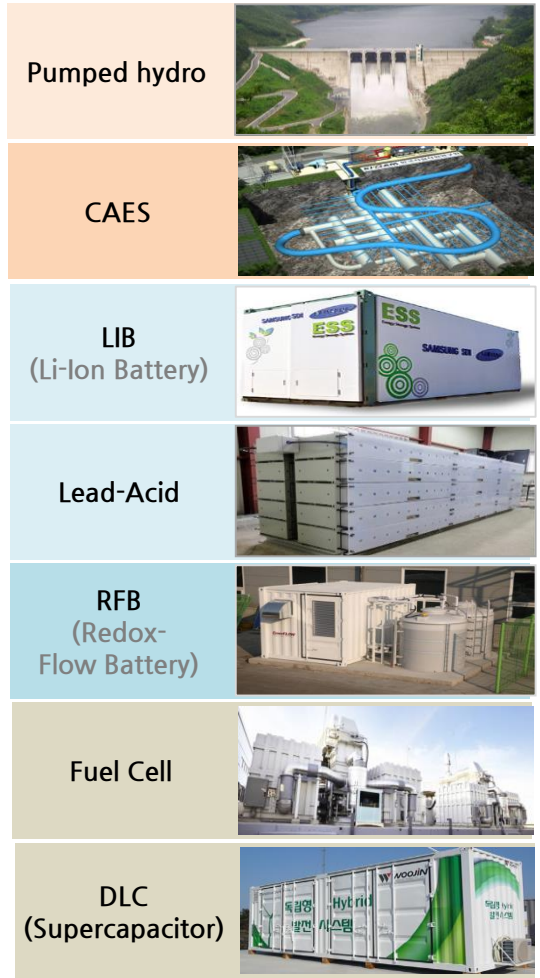
IEC



1. Introduction of Energy Storage System

Electrical Energy Storage technology in Korea

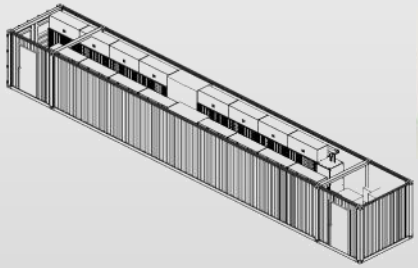




1. Introduction of Energy Storage System

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**

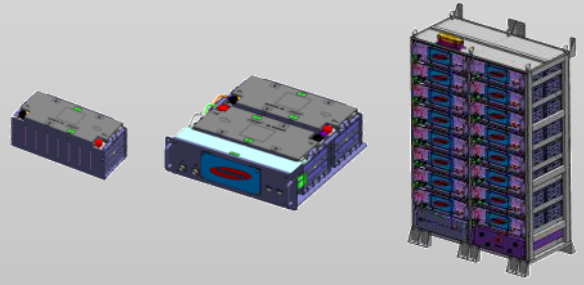
Cell

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

BMS

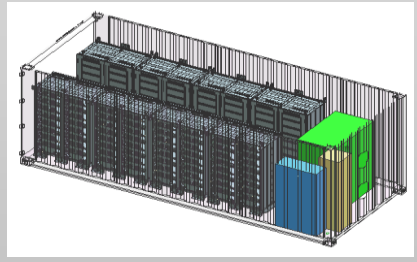
- **Master BMS**
- **Slave BMS**

Module / Tray / Rack



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

Containerization



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

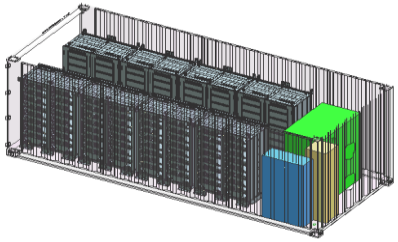
1. Introduction of Energy Storage System

BESS = Lithium Ion Battery + PCS + EMS, Value added by EMS

Grid Storage Solution

Energy Management System

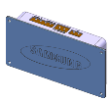
Grid Battery System (GBS)



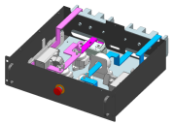
Power Conversion System

Cell

Module



BMS



J/B

Battery Rack

STANDARD SOLUTIONS

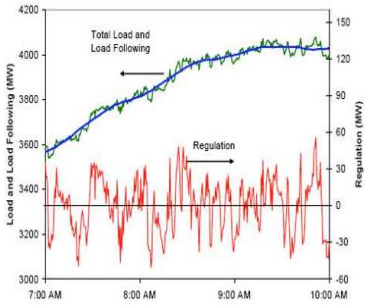
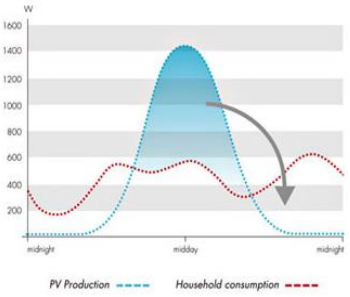
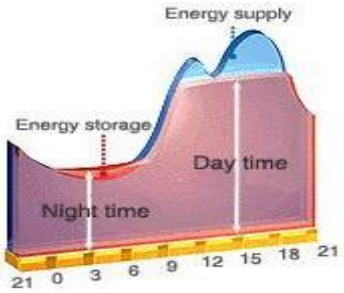
Container Type

CUSTOM SOLUTIONS

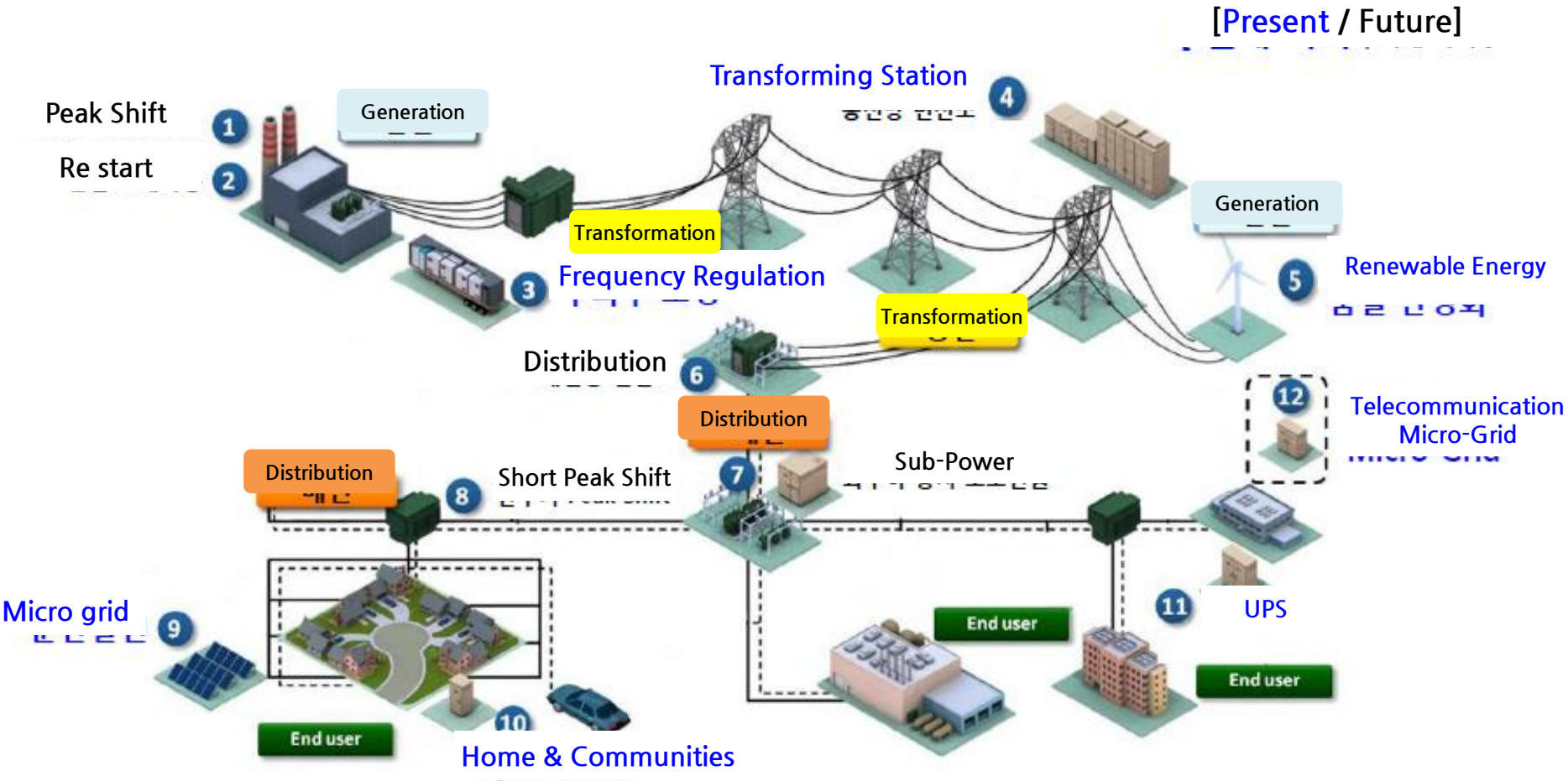
Temporary Building Type

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 - Maintain a constant grid frequency - Grid stabilized back-up power (spinning reserve)	**· Purpose** - Neighborhood back-up - Local peak shifting - Power quality	**· Purpose** - Residential back-up - PV integration	**· Purpose** - Alternative to peaking gas power plant in urban areas - Renewable peak shifting	**· Purpose** - Energy arbitrage - Renewable capacity firming

Energy Storage in Grid



2. Technology of Energy Storage System

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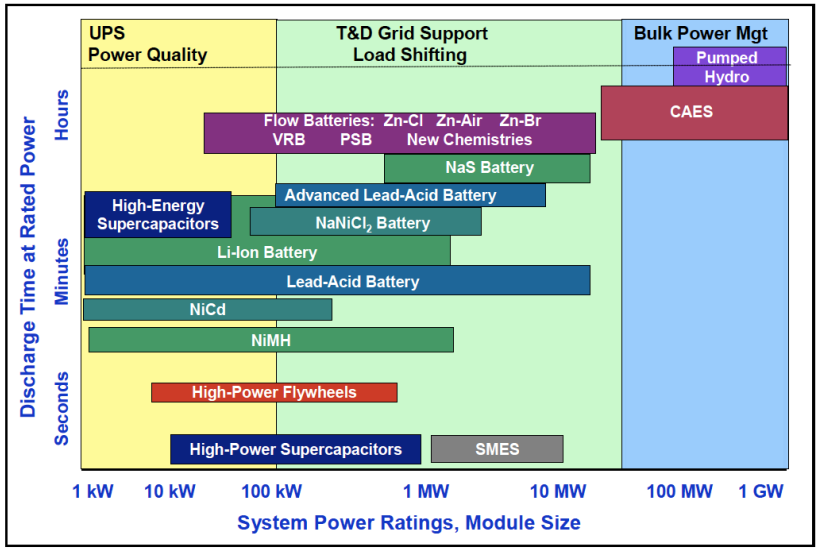
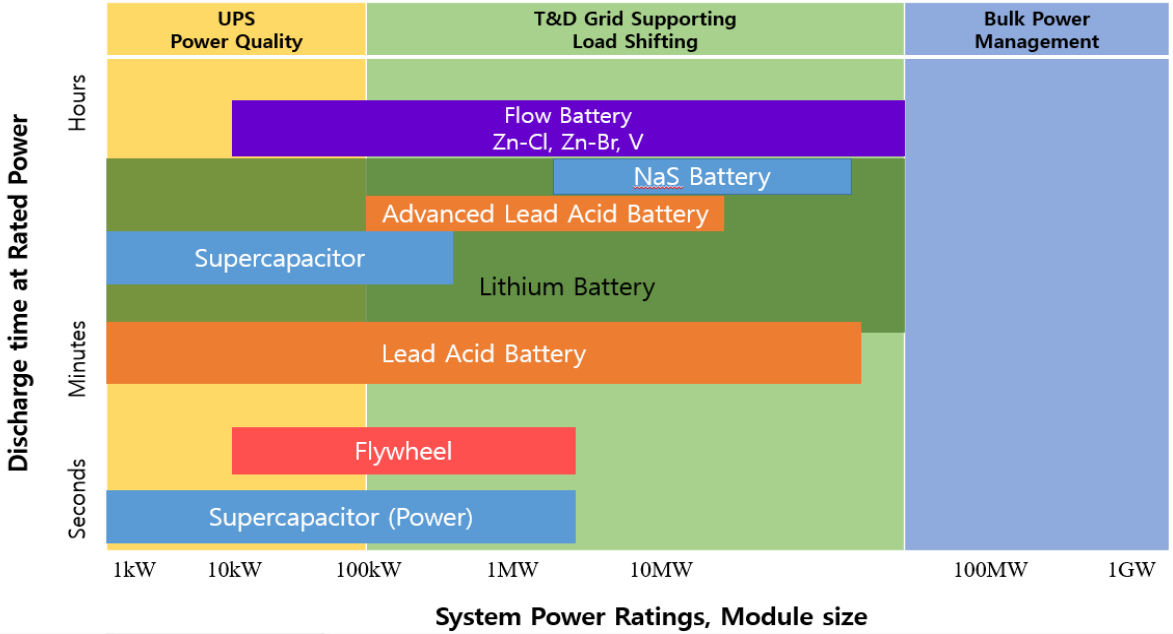


From. EPRI



2. Technology of Energy Storage System

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

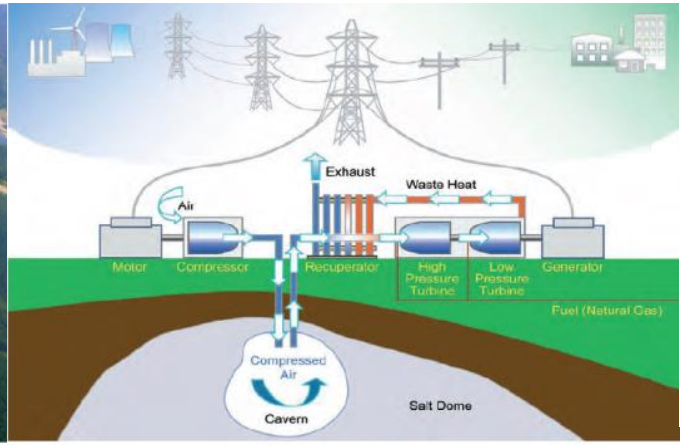


Figure 2-3 – Underground CAES
[rid11]

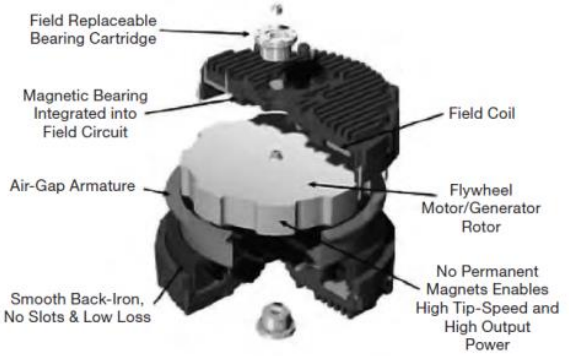


Figure 2-4 – Flywheel energy storage
[act11]

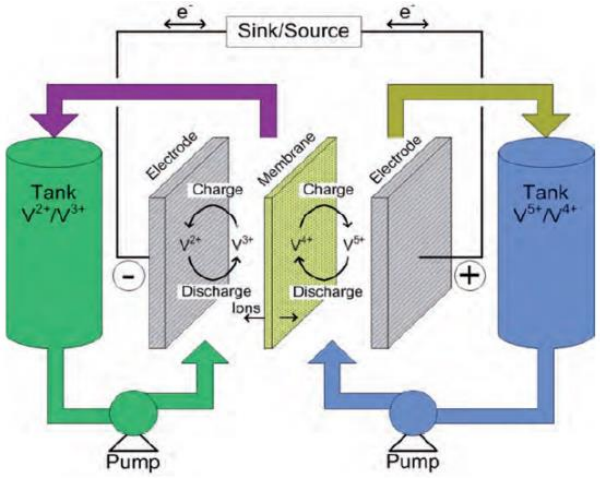


Figure 2-7 – Schematic of a Vanadium Redox Flow Battery
(Fraunhofer ISE)

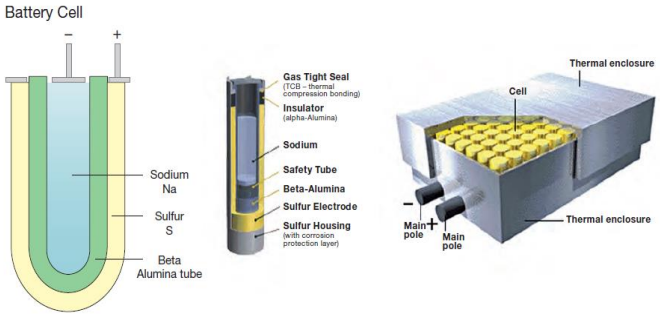


Figure 2-6 – NaS Battery: Cell design and 50 kW module
(NGK, IEC MSB/EES Workshop 2011)

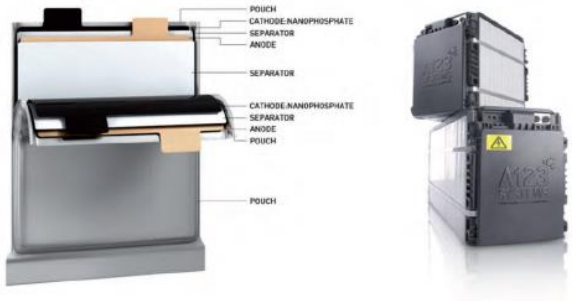


Figure 2-5 – Typical Li-ion prismatic cell design and battery modules
(A123, IEC MSB/EES Workshop, 2011)

2. Technology of Energy Storage System

	1st	2nd	3rd	4th	5th
Energy Density (Wh/kg)	Li	NaS	Flow	Ni-Cd	Lead-Acid
	150 ~ 250	125 ~ 150	60 ~ 80	40 ~ 60	30 ~ 50
Round Trip Efficiency (%)	Li	NaS	Flow	Ni-Cd	Lead-Acid
	95	75 ~ 85	70 ~ 75	60 ~ 80	60 ~ 70
Life Time (yrs)	Li	NaS	Ni-Cd	Flow	Lead-Acid
	10 ~ 15	10 ~ 15	10 ~ 15	5 ~ 10	3 ~ 6
Eco-friendly Aspect	Li	NaS	Ni-Cd	Flow	Lead-Acid
	O	X	X	X	X

Lead Acid

Sealed → AGM → PbC, Ultra-battery

Lead-Acid batteries consist of two electrodes: Le ad and lead-dioxide immersed in sulfuric acid.

Lead Acid

HITACHI Inspire the Next

Rolls BATTERY ENGINEERING

LEOCH

Shin-Kobe Electric Machinery Co., Ltd.

HBL BATTERIES

EXIDE

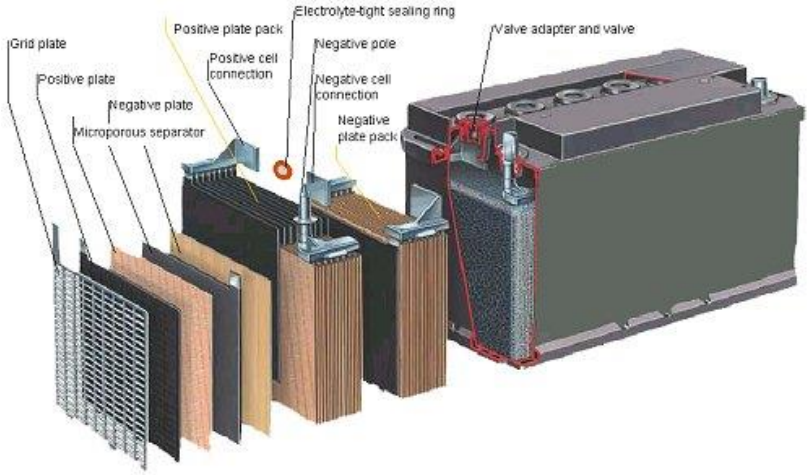
ecoult energy storage solutions

EASTPENN

AXION POWER™ INTERNATIONAL INC.

energypower SYSTEMS

EnerSys Power/Full Solutions™



Performance measure	Cycle Life	Energy Efficiency (%)
Market leader	1200	80
Best in class	2000	85

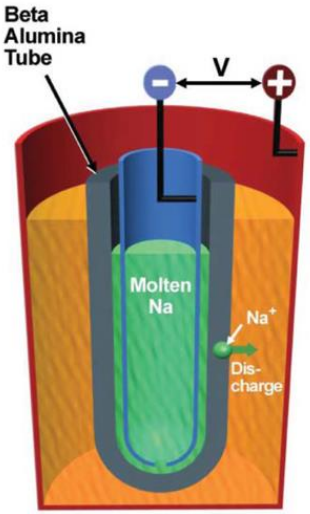
Sodium based battery - NAS

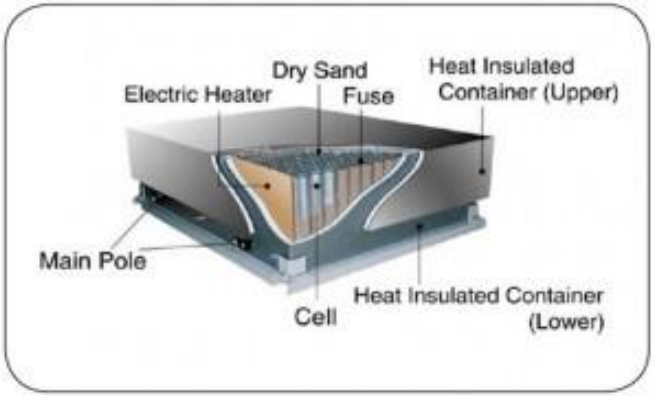
Sodium-sulfur (NaS) batteries use molten sodium and sulfur electrodes separated by a ceramic electrolyte

Sodium Based

NGK, FIAMM, GE, SHARP, AQUION ENERGY

Performance measure	Cycle Life	Energy Efficiency (%)
Market leader	4000	70
Best in class	6000	85





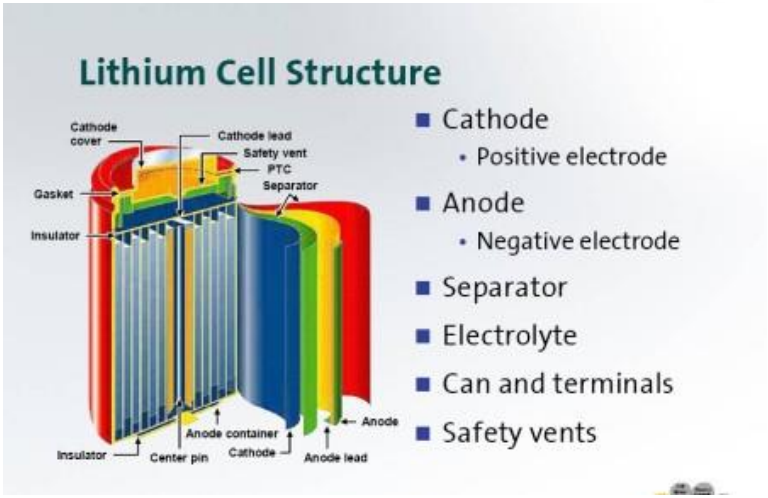
$2Na^{+} + 2e^{-} \underset{Dis}{\overset{Ch}{\rightleftharpoons}}$

Li-ion Battery Technology

Li-ion battery uses graphite as the anode material and $LiFePO_4$ or $LiCoO_2$ or Lithium titanate or lithium nickel manganese cobaltate as the cathode.

Li-Ion Batteries

AES Energy Storage, HITACHI, MITSUBISHI, LG Chem, Panasonic, BYD, TESLA, electrovaya, SAMSUNG, altairnano, microvast, SAFT, TOSHIBA, ATL, LG Chem, NEC, Kokam



Performance measure	Cycle Life	Energy Efficiency (%)
Market leader	2000	90
Best in class	10,000+	95

2. Technology of Energy Storage System

From. LG Chem 2014

2. Technology of Energy Storage System

From. LG Chem 2014

2. Technology 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)**

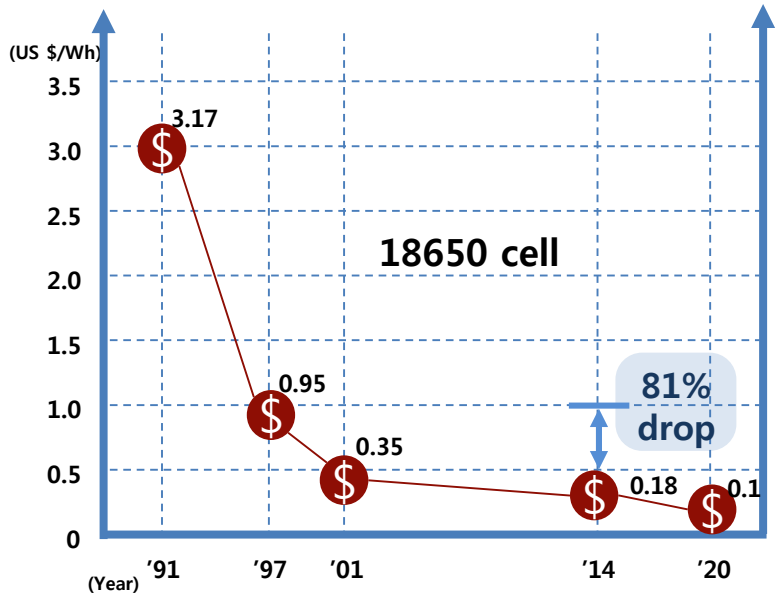
√ **3,200mAh (2014, without changing chemistry)**

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



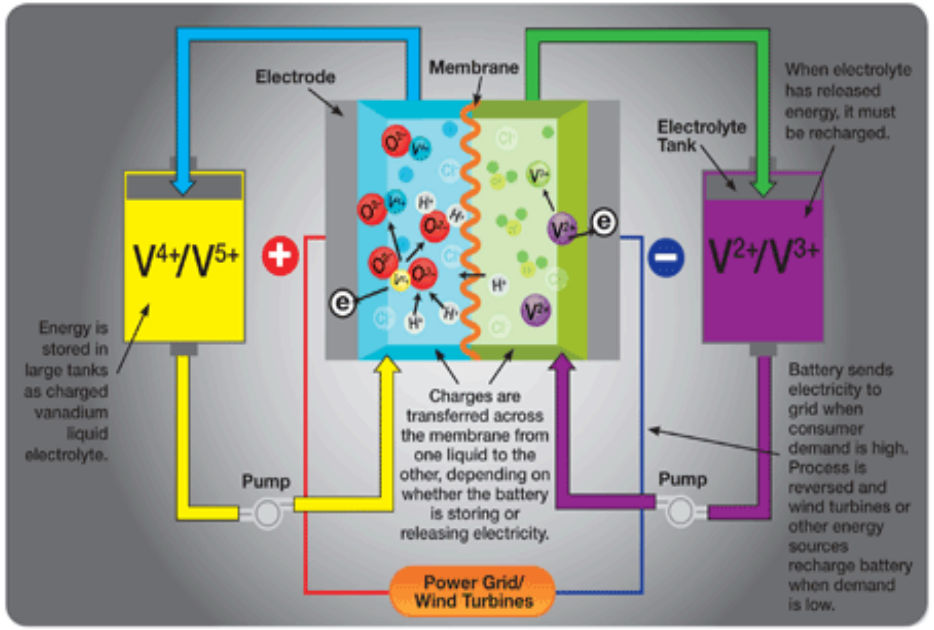
From. LG Chem 2014

Flow Battery Technology

Flow batteries use liquid electrolytes with fixed cells to store and regenerate power. Various flow battery chemistries exis t such as vanadium redox, zinc-bromine, iron - chromium etc.

Flow Batteries

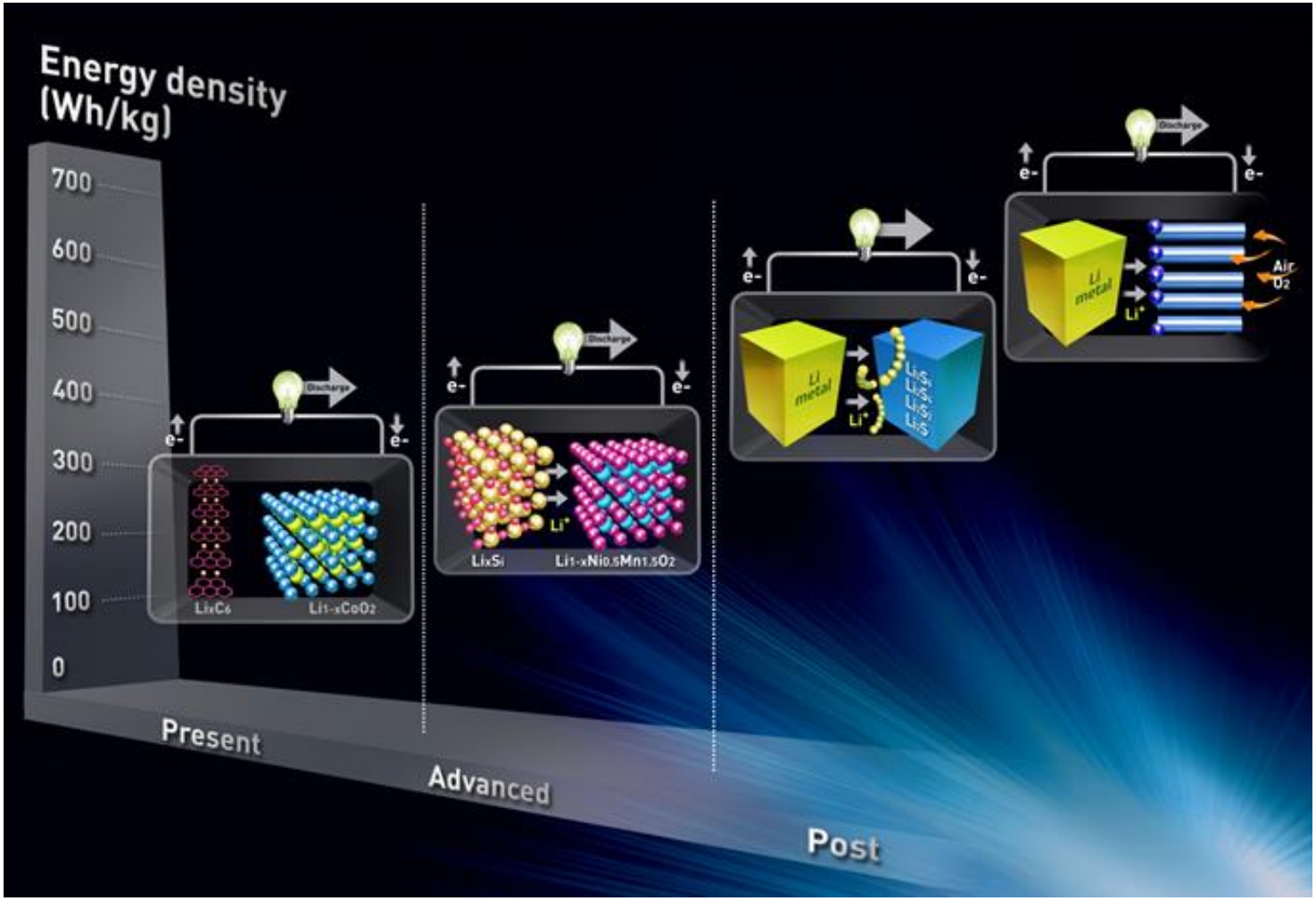
Premium Power
IMERGY POWER SYSTEMS
United Technologies
GILDEMEISTER
ZBB energy corporation
PRIMUS POWER
SUMITOMO ELECTRIC
UET UniEnergy Technologies
EnerVault
H2 The Advanced Energy Storage Company
融科储能 RONGKE POWER
VANADIS POWER
REDT Renewable Energy Storage
redflow advanced energy storage
Prudent Energy



Performance measure	Cycle Life	Energy Efficiency (%)
Market leader	5000	60
Best in class	10,000+	70

2. Technology of Energy Storage System

LiB (NaiB)→ Li/S Battery → Li/Air



3. Demonstration of Energy Storage System

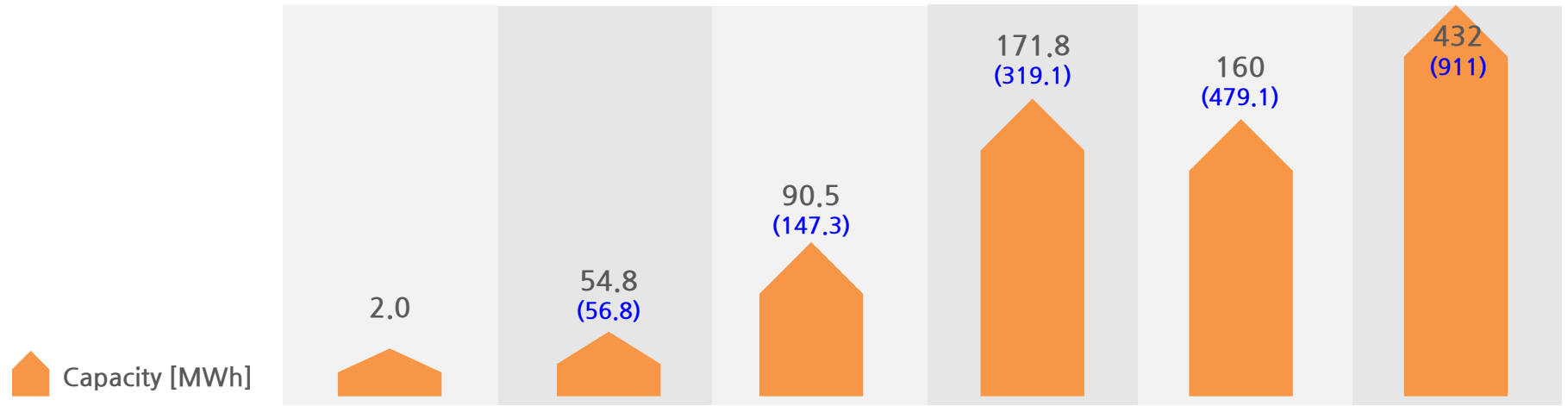
3. Demonstration of Energy Storage System

"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, '15.11)	Renewable Energy 3020 ('17.12)
Research & Development Plan & Business strategy • ESS R&D Investment • ESS demonstration • Infra structure for ESS • Policy for market	**Demand & Supply, ESS industry promote** • ESS Supply business, create 2G Market ('20) • Construct Infra Structure • Tax cut	**ICT+ESS, Demand & Response business** • ESS Service company • EMS (Energy management system) • FR(Frequency Regulation) • DR market	**New Energy Industry** • DR business, NegaWatt • ESS-EMS business model • Stand alone (Micro-Grid) • PV Rental • EV charge service provider • Zero house, Clean energy town • Smart Grid Business	**Renewable Energy 3020** • Self Generator PV in city • Small PV Power Plant • Farm village PV • Renewable Generation 5.0GW(~'22), 23.8GW('30)

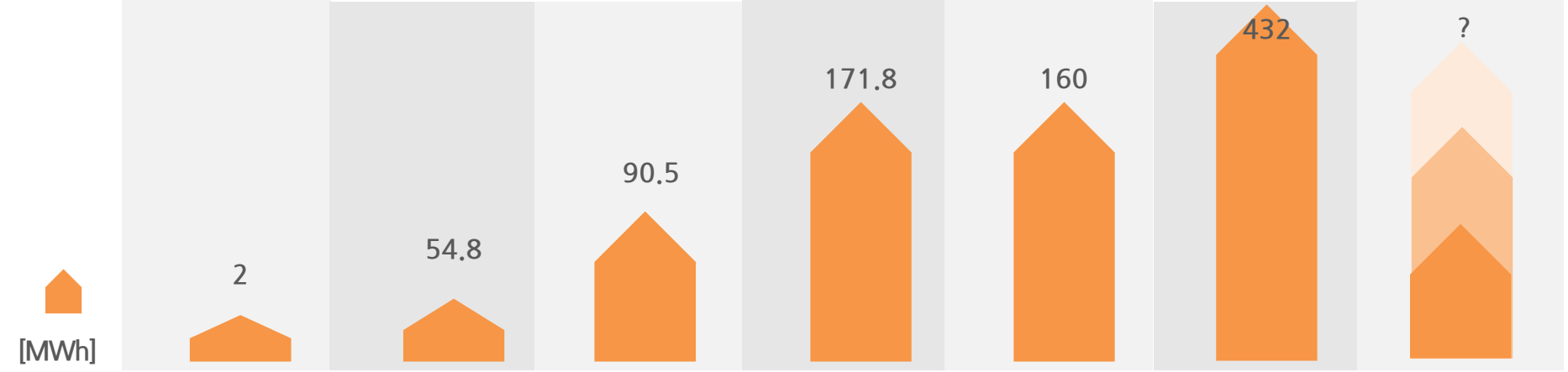
3. Demonstration of Energy Storage System

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**

3. Demonstration of Energy Storage System



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

3. Demonstration of Energy Storage System

1) Peak Shaving and Carbon Free Island

ESS Supply Business — **Save Charge** — **Carbon Free Island**

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

Gasa island ('14) Carbon Free Island
1MW, 250kW (3MWh) '14.10~'15.3 commercial operating

Fuel cost $ 0.128 Mil Save, 80% ↓

2) Frequency regulation

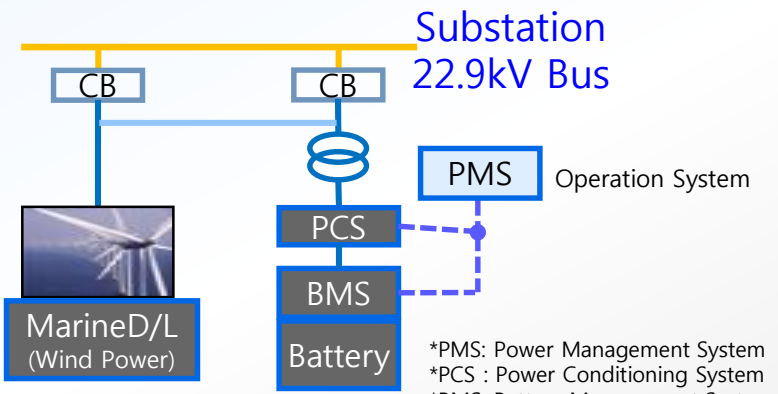
Installation Sites

2014	Site #1 Seo-Anseong S/S	Site #2 Shin-Yongin S/S	Total
Installed Capacity (MW)	28(10MWh)	24(18MWh)	52(28MWh)
Participating Companies	PCS : 2 Battery : 2	PCS : 2 Battery : 1	7

3) Renewable Energy with ESS

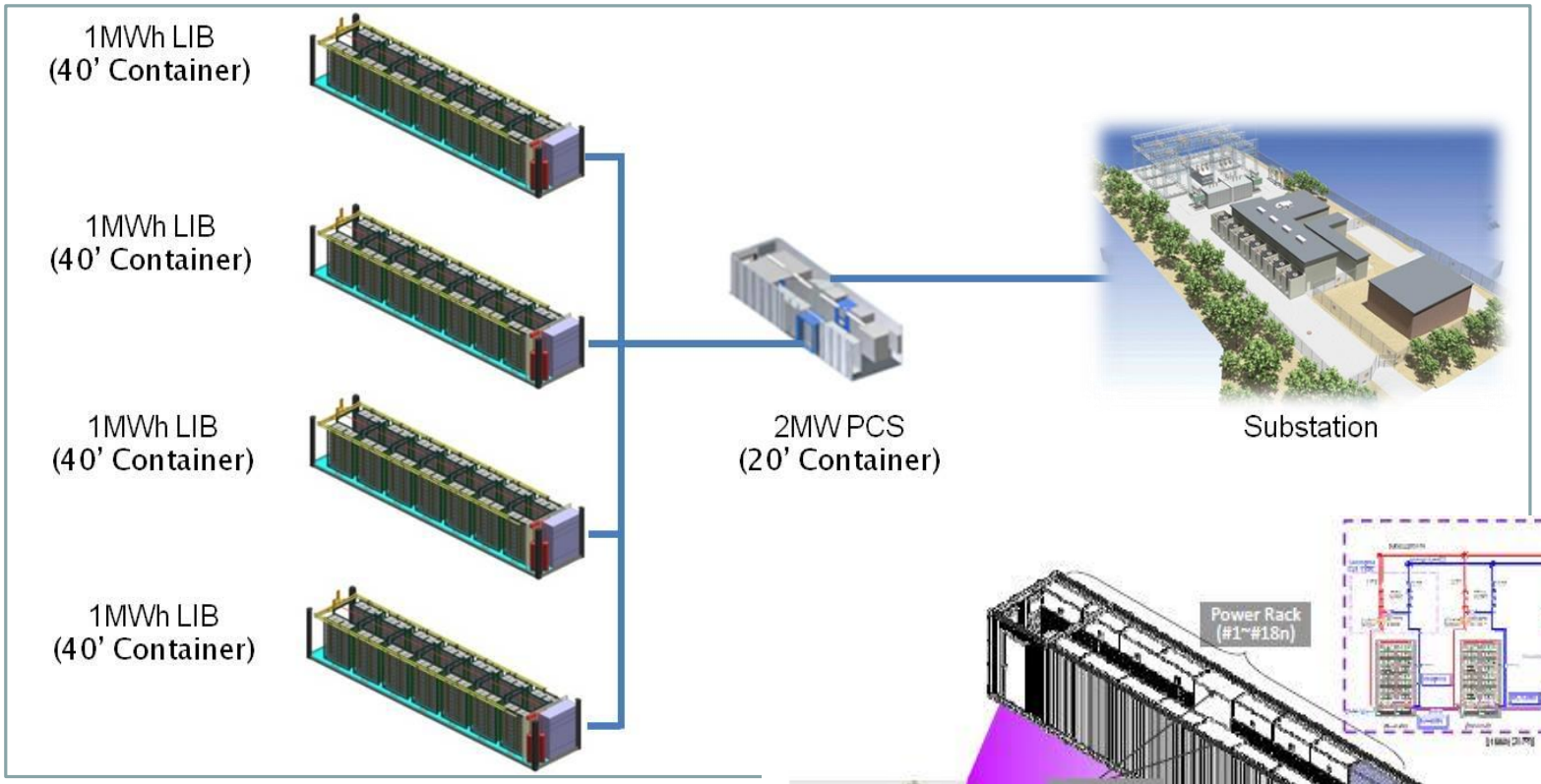
Goal	**Load leveling, Stabilization with Renewable Energy**
Scale	**4MW/8MWh Li-ion Battery**
Site	**Jeju 154kV Jocheon Substation**

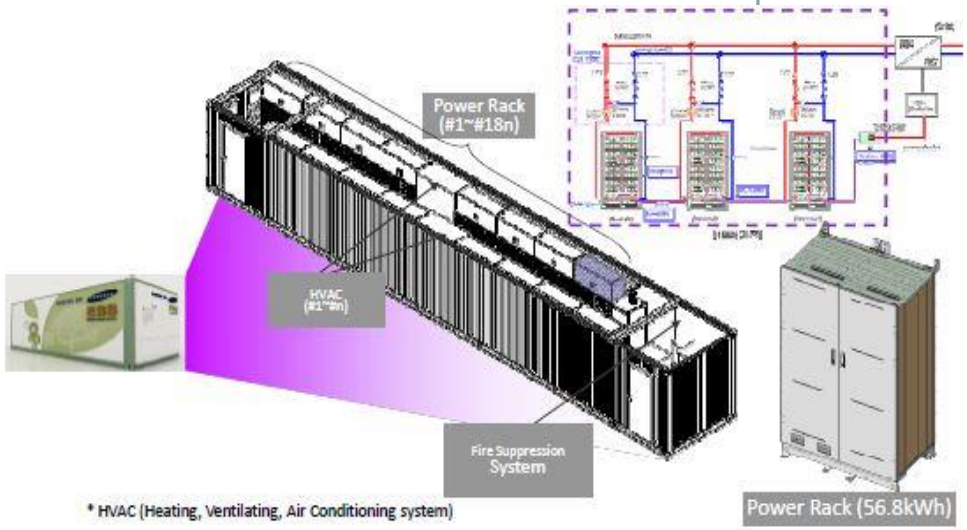
Configuration



Installation Image

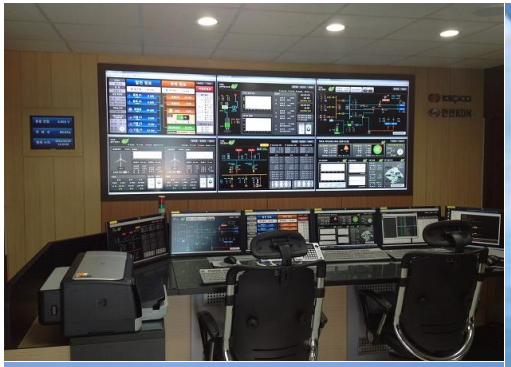
3) Renewable Energy with ESS



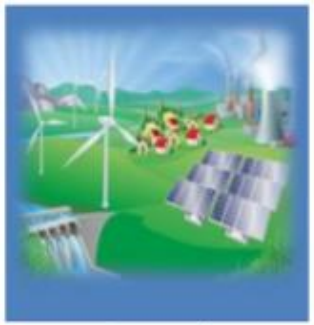


4) Island Micro-Grid or Carbon Free Island

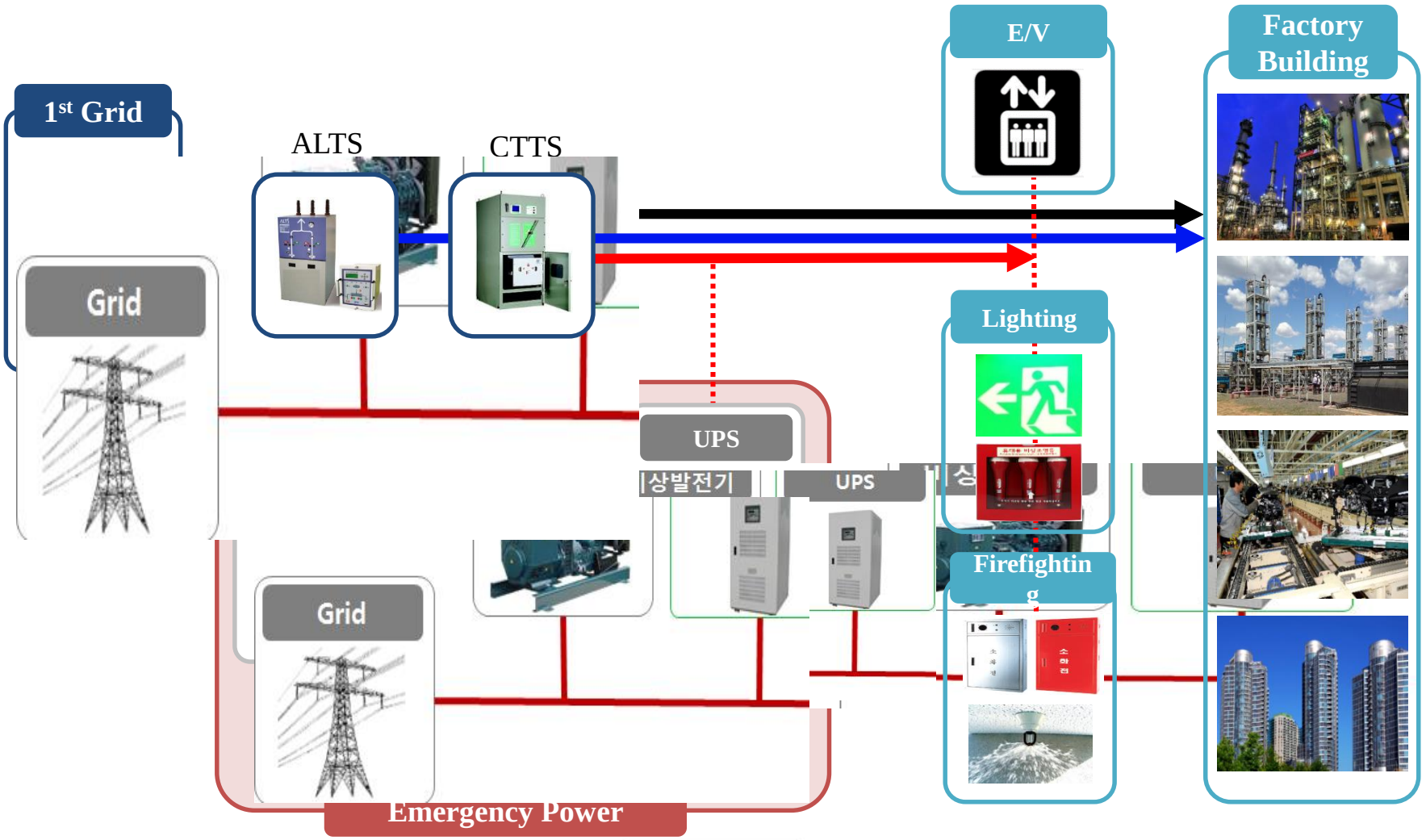
Goal	Renewable(PV, Wind) Energy with ESS Self Generation
Scale	1MWh Li-ion Battery
Site	Gapa island in Jeju



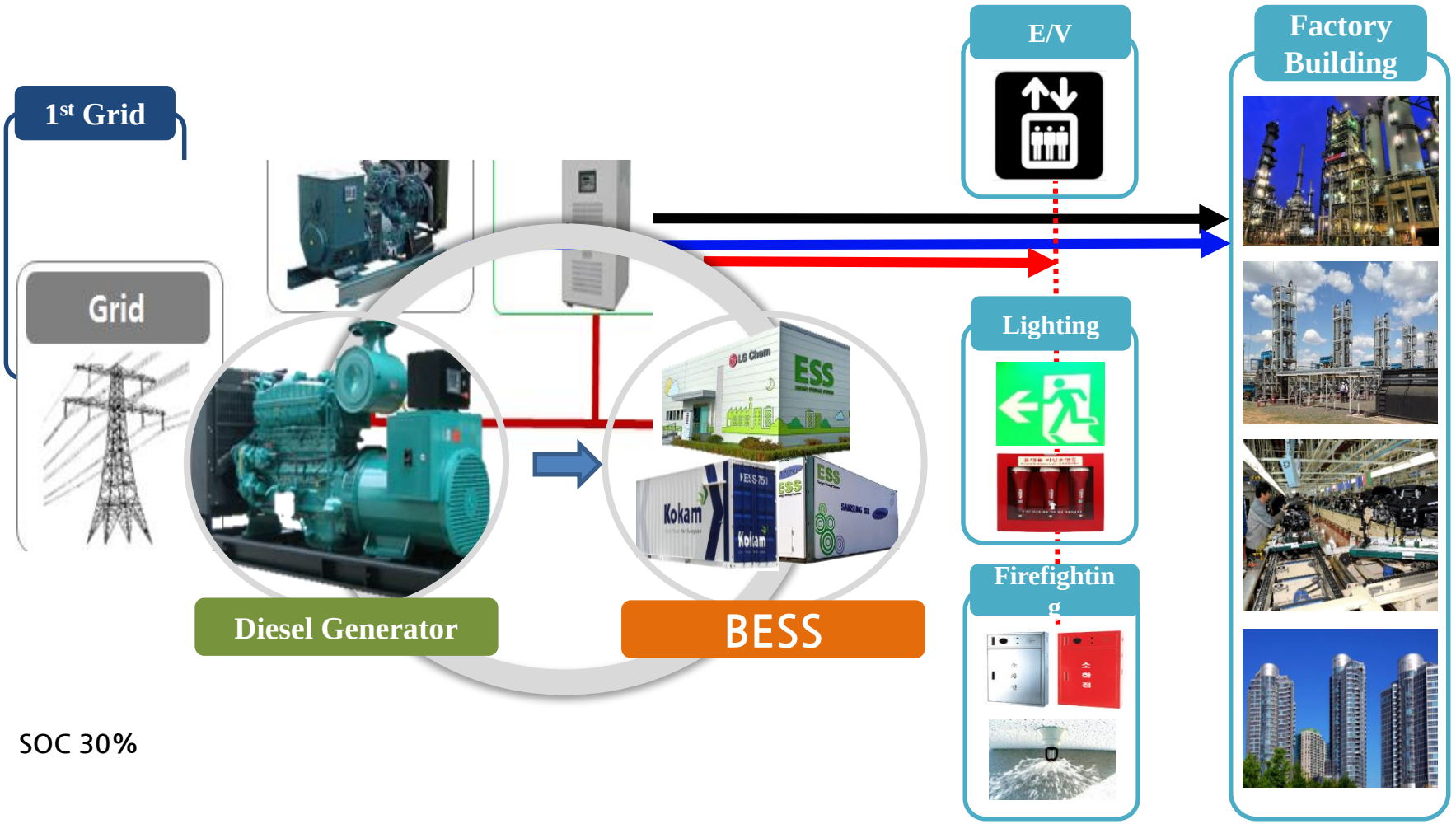
4) Island Micro-Grid or Carbon Free Island

	 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

5) Emergency Power ESS

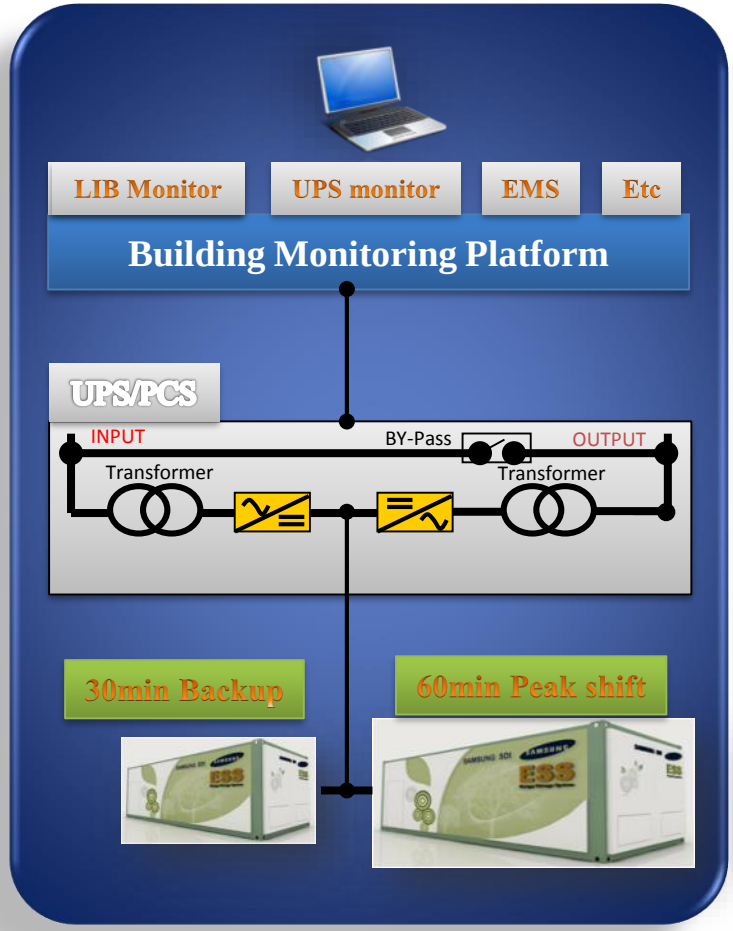


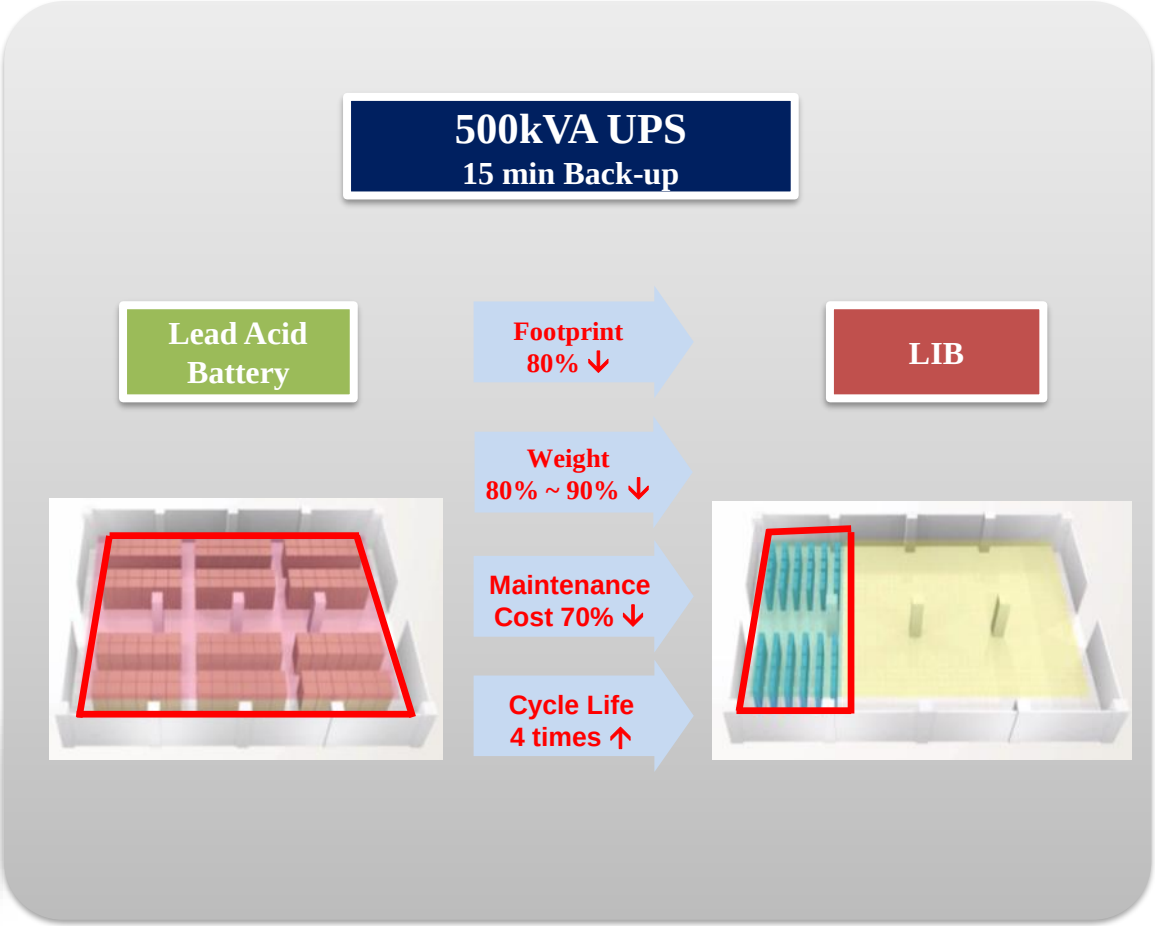
5) Emergency Power ESS



SOC 30%

6) UEPS(Uninterrupted Energy Power System)





4. Prospect of Futures

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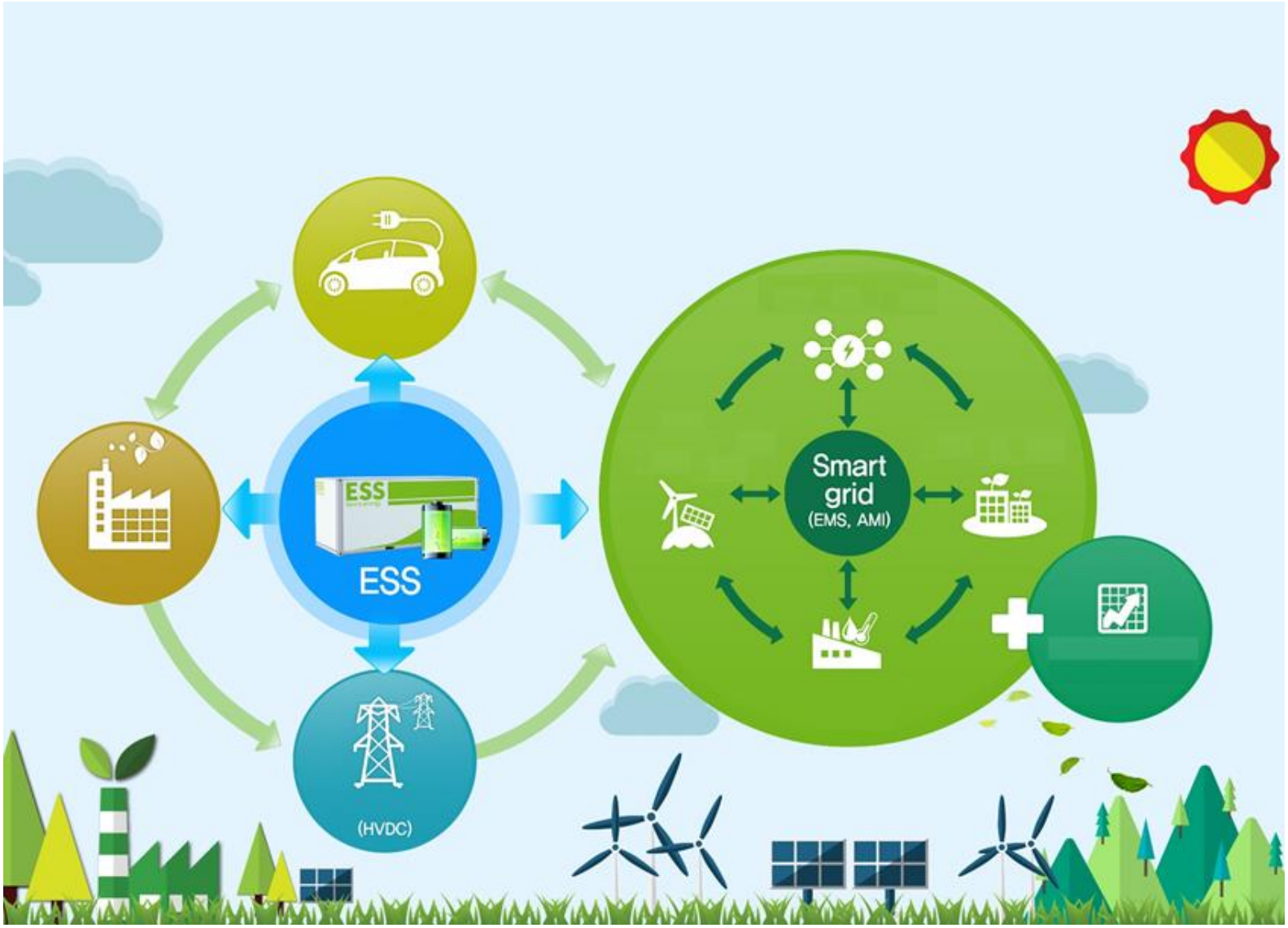
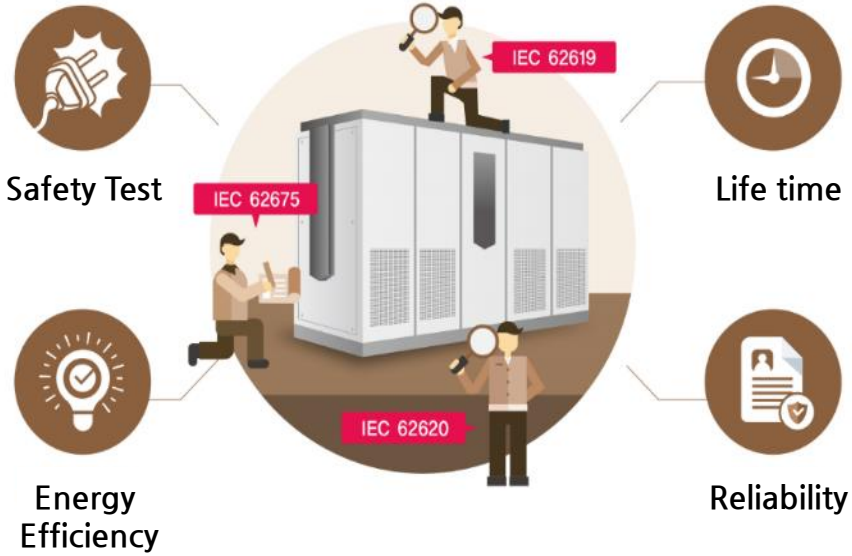
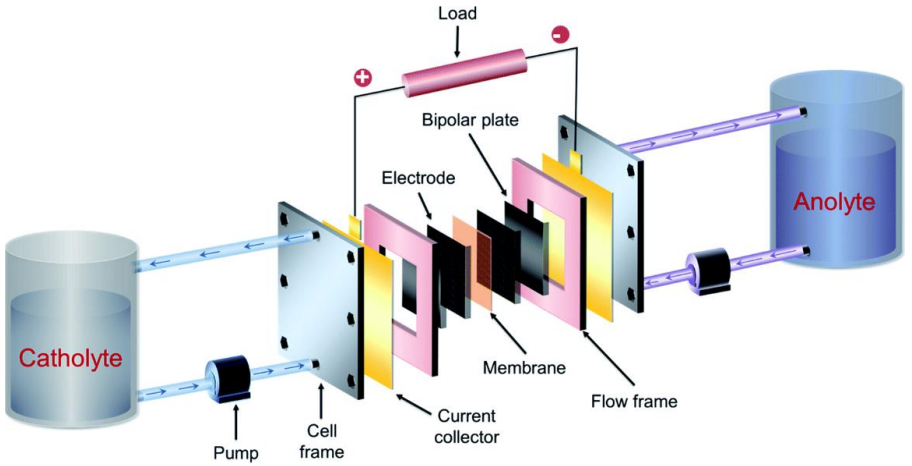


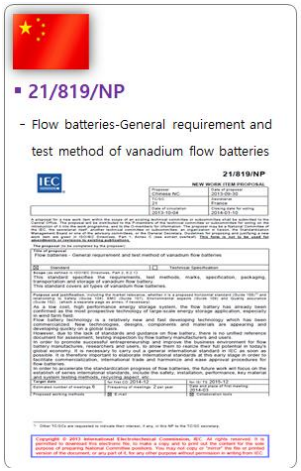
4. Prospect of Futures

Li Battery



Redox Flow Battery



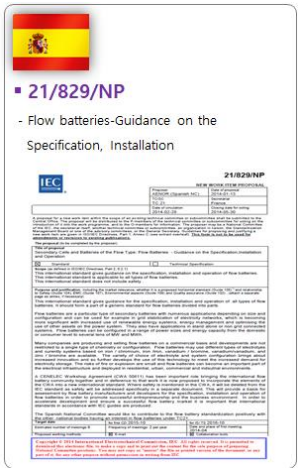


▪ 21/819/NP

- Flow batteries-General requirement and test method of vanadium flow batteries

▪ 21/823/NP

- Flow Battery Technology-Safety



▪ 21/829/NP

- Flow batteries-Guidance on the Specification, Installation

Thank you!!

KORBA Battery R&D Association of Korea

KBIA Korea Battery Industry Association