Sustainable Energy Mix and Renewables Plan in Korea Considering Roles of BESSs

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- **Summary of Energy Transition Plan of Korean Government**
- **Energy Vision 2040 of Korea**
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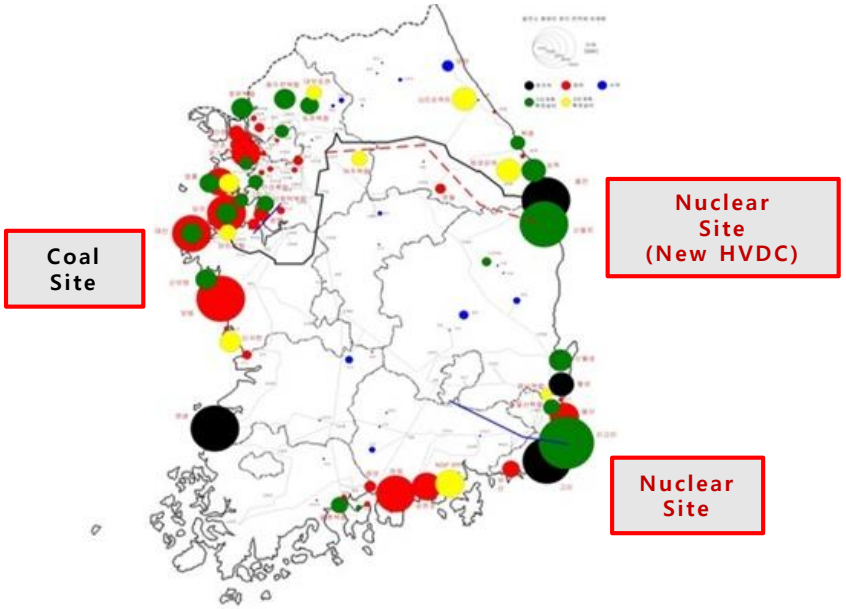
Characteristics of South Korean Power System

- **Centralized Bulk Power System (Generation, Transmission, Demand)**
  - Highly Concentrated Generation Sites for Massive Nuclear and Coal Plants (maximum 10 nuclear units in a site)
  - 765kV HVAC & 500kV HVDC (Bulk Transmission)
  - 40% electricity consumption in Seoul-metro and 30% of Busan-metro areas
- **Isolated Power System, Dependency for Fuel Import (94%, 100 BUS$/year)**



Issues of South Korean Power System

- **Implementation of De-centralized Power System**

  (Generation, Transmission, Demand)

- **Systematic Flexibility Enhancement for Active Renewable Penetration (DR, Interconnection, CHP, GT, BESS, etc)**

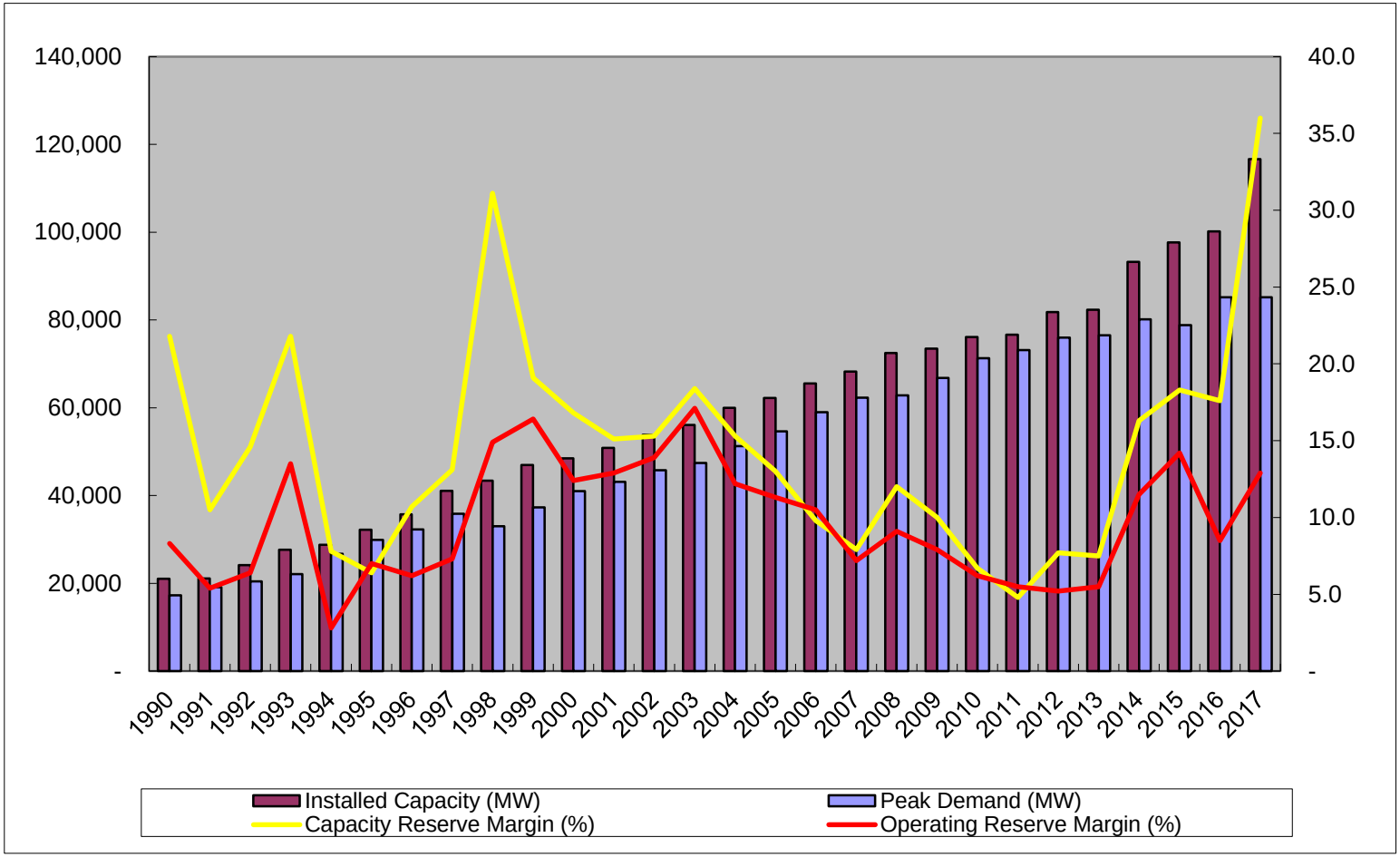
- **Increase of Reliability & Resilience**

- **Reduction of CO2 Emissions through Energy Mix Changes**

- **Reduction of SOx, NOx, PM2.5, PM10 for Air Pollution Mitigation**

Supply and Demand in Korean Power System

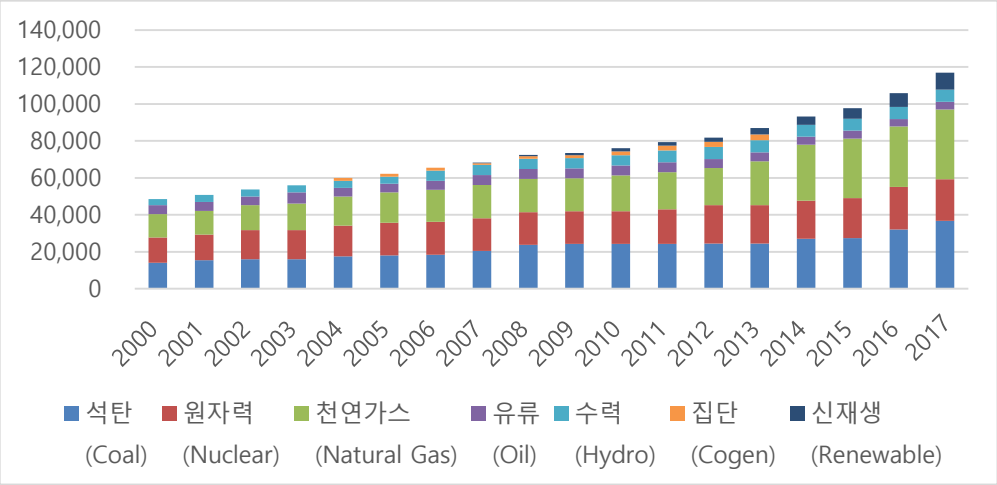
- **Historical Supply and Demand in Korea (1990-2017)**

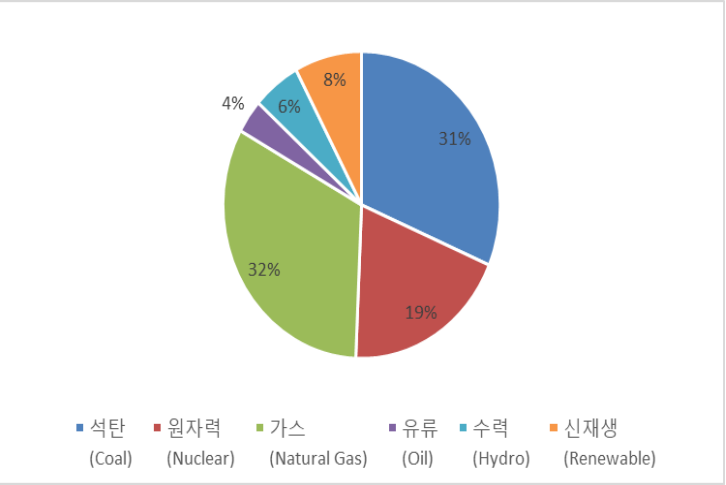


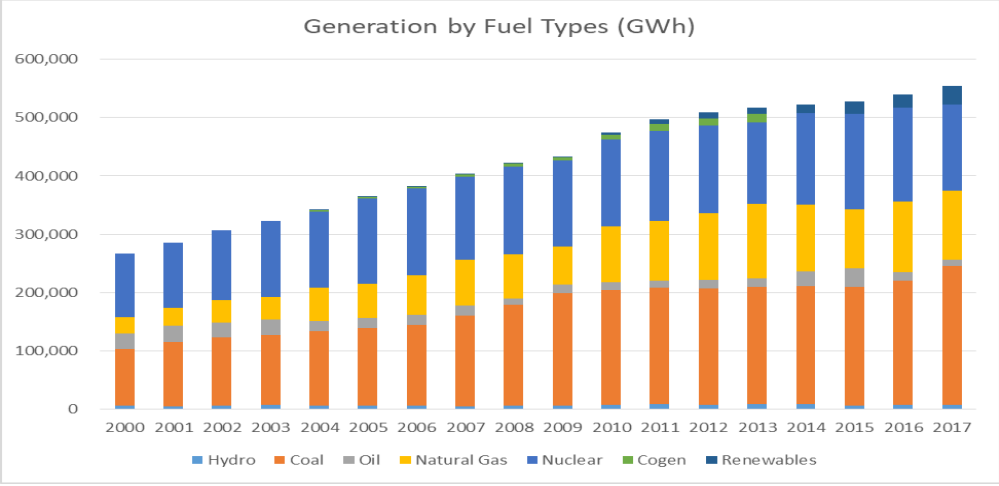
. Installed Capacity (117GW), Peak (85 GW), Operating Reserve Margin (13%) in 2017
. Experience of Rolling Blackout in 2011 (Low Reserve Margin, Demand Forecasting Error)

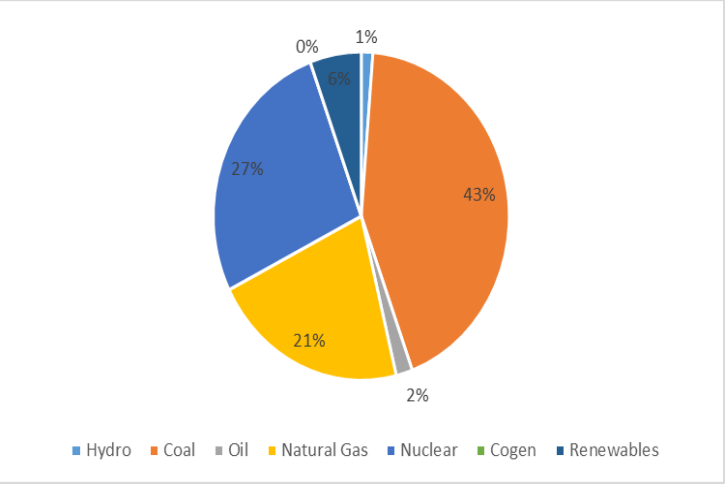
Capacity and Generation Mix in Korea (2017)

- **Capacity and Generation Mix (2017)**



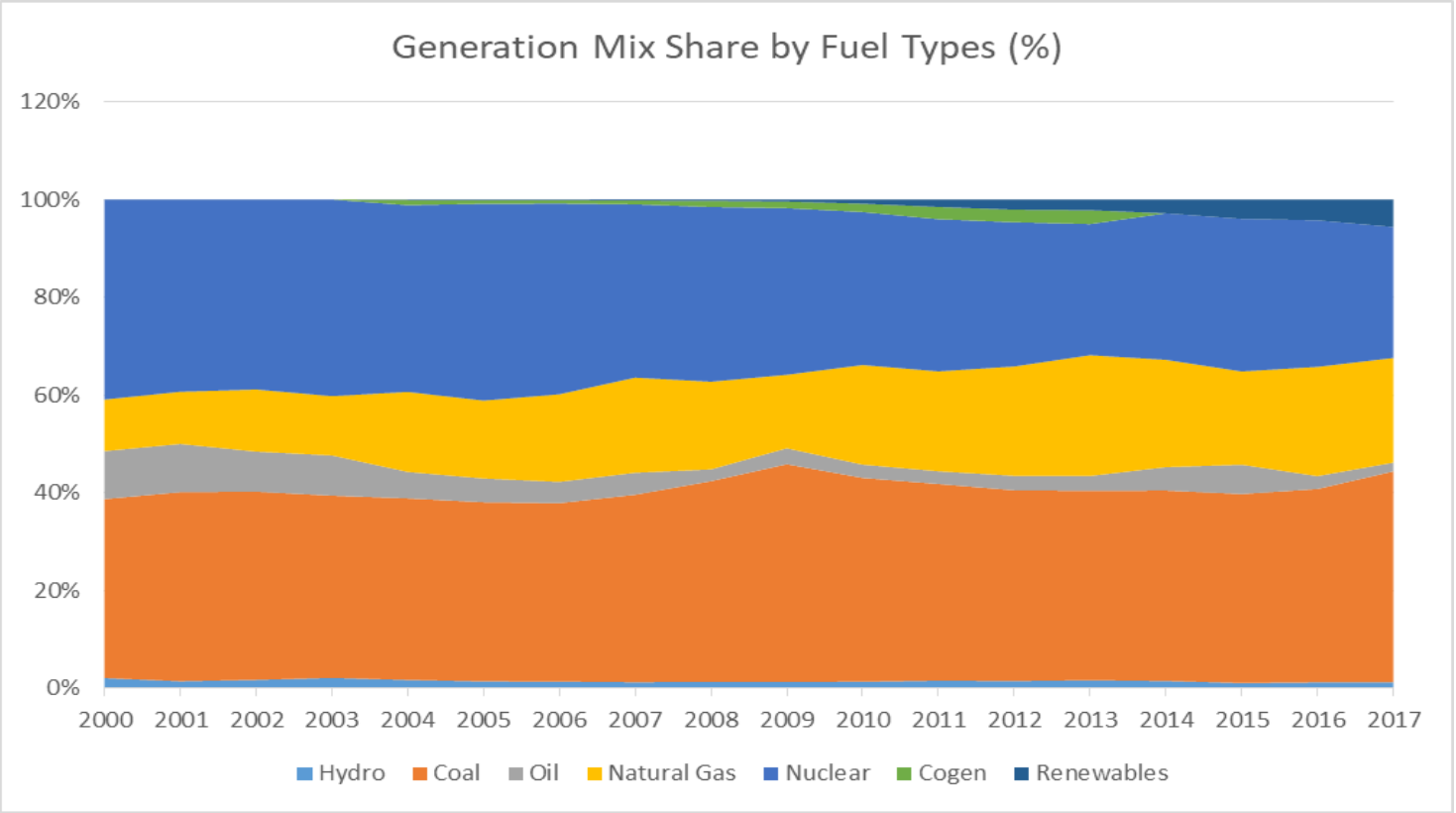






Generation Mix Trend in Korea

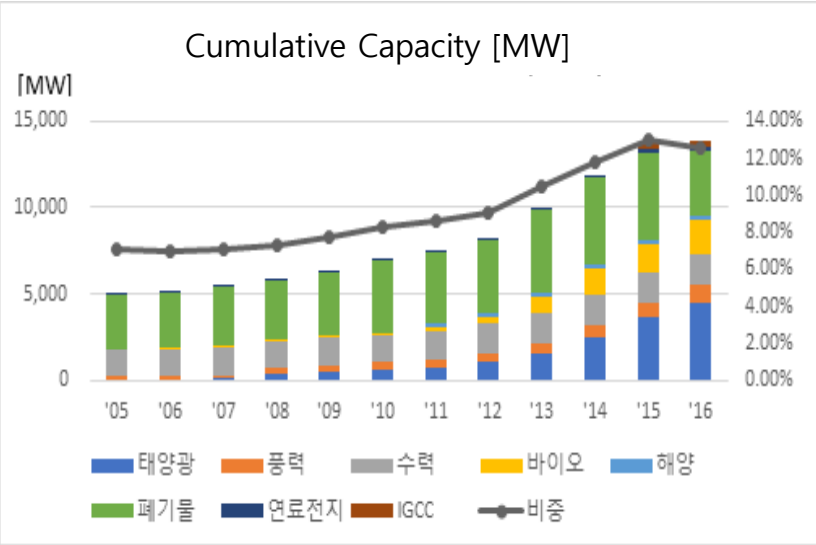
- **Generation Mix Trend in Korea (2000-2017)**

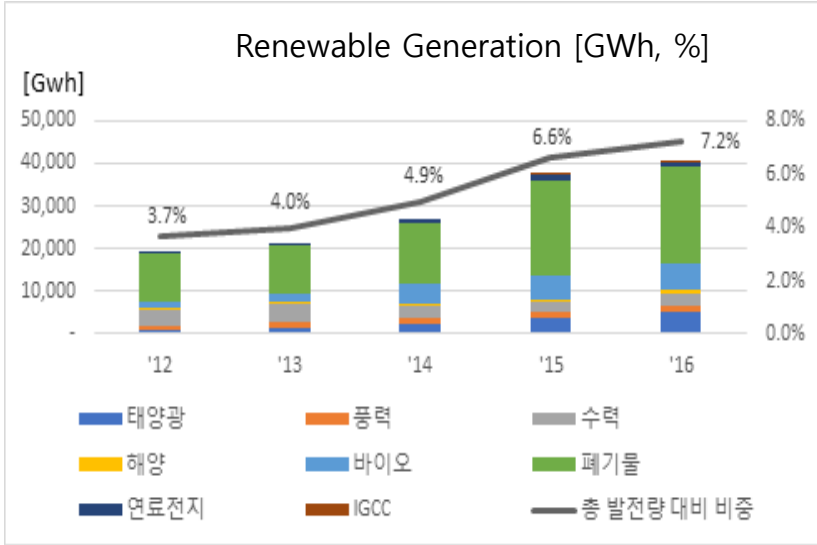


- 2000 : Nuclear (41%) > Coal (37%) > LNG (11%) > Oil (10%) > Hydro (2%)
- 2017 : Coal (43%) > Nuclear (27%) > LNG (21%) > Renewables (6%) > Oil (2%) > Hydro (1%)

Renewables in Korea (2016)

- **Renewables in Korea (2016)**





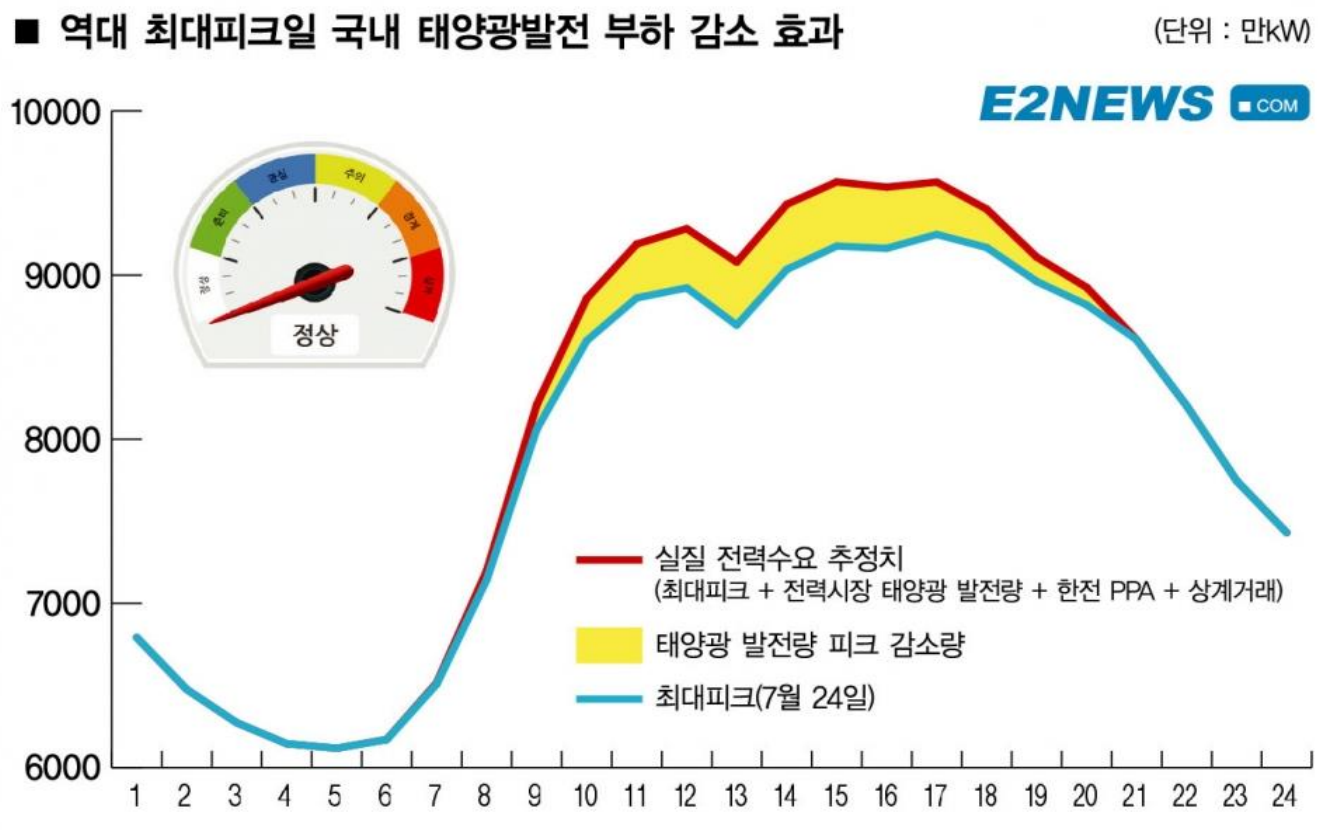
. Renewable Share in Capacity [MW] : 12.5% (PV 4.5GW, Waste 3.8GW, Bio 1.9GW Hydro 1.8GW, Wind 1GW, IGCC 0.34, etc)

. Generation [GWh] : 7.2%

. Share of PV and Wind Generation : 2.2% (Mostly by Waste and Bio)

PV's Contribution in 2018 Summer Peak

- **Historical Peak in 2018 Summer (July 24, 2018)**



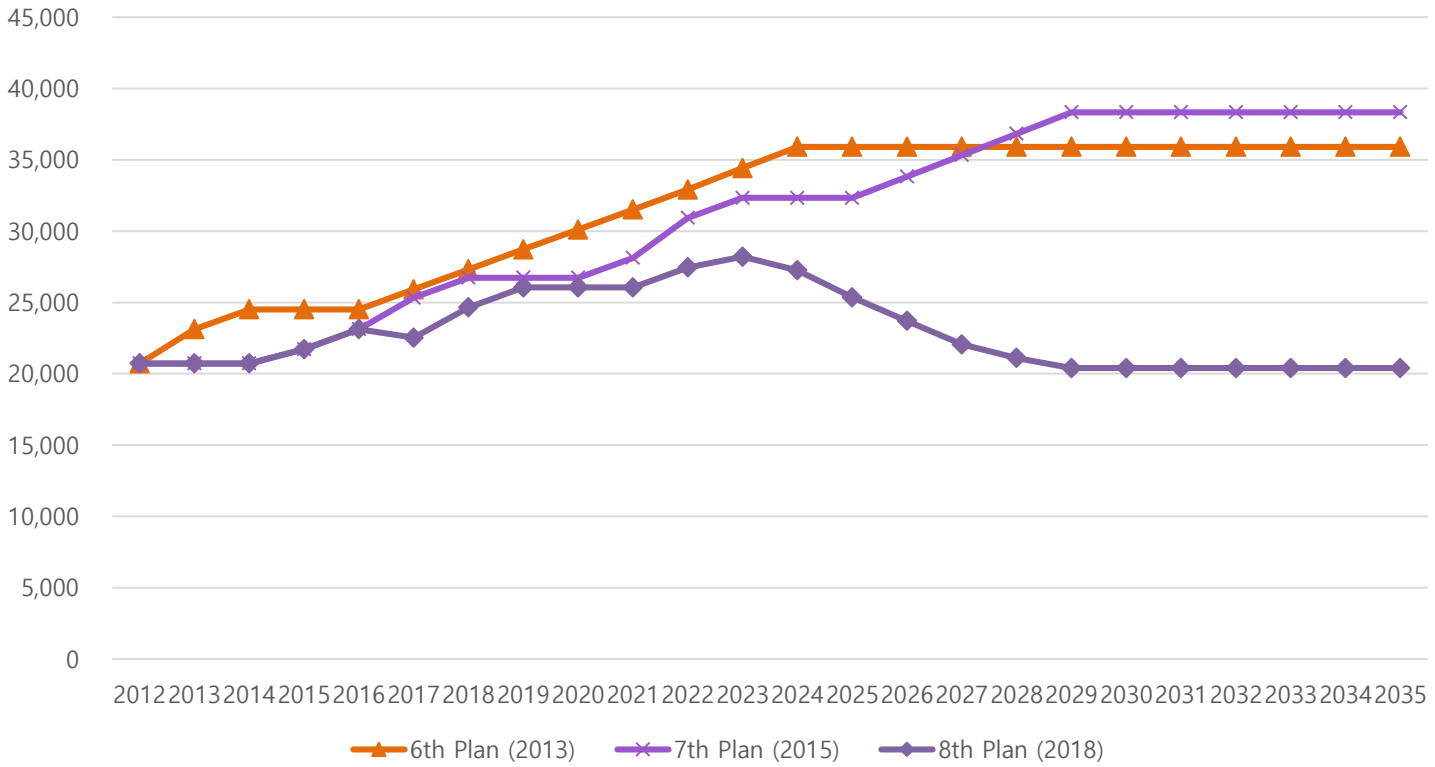
- 2018.7.24 pm 5 : 92,480 MW
- PV Capacity : 7,060MW including Self-generation
- PV Peak Cutting on July 24, 2018 : Around 4 GW
- Peak-time Shift due to PV Generation : pm 2 ➔ pm 5

New Government's Energy Transition Plan

- 8th Electricity Supply and Demand Plan (Dec. 2017)
  - Reduction of Nuclear & Coal Share
  - Increasing Renewable Generation by 20% until 2030
  - Electrification through E-mobility (1 Million Evs)
- 3rd National Energy Basic Plan (Under Process)
  - The Highest Government Energy Plan (Every 5 years)
  - Continuous Increase of Renewable in 2040 (25%~40%)
  - System Flexibility through Various Options (Including BESS)

8th Electricity Supply and Demand Plan - 1

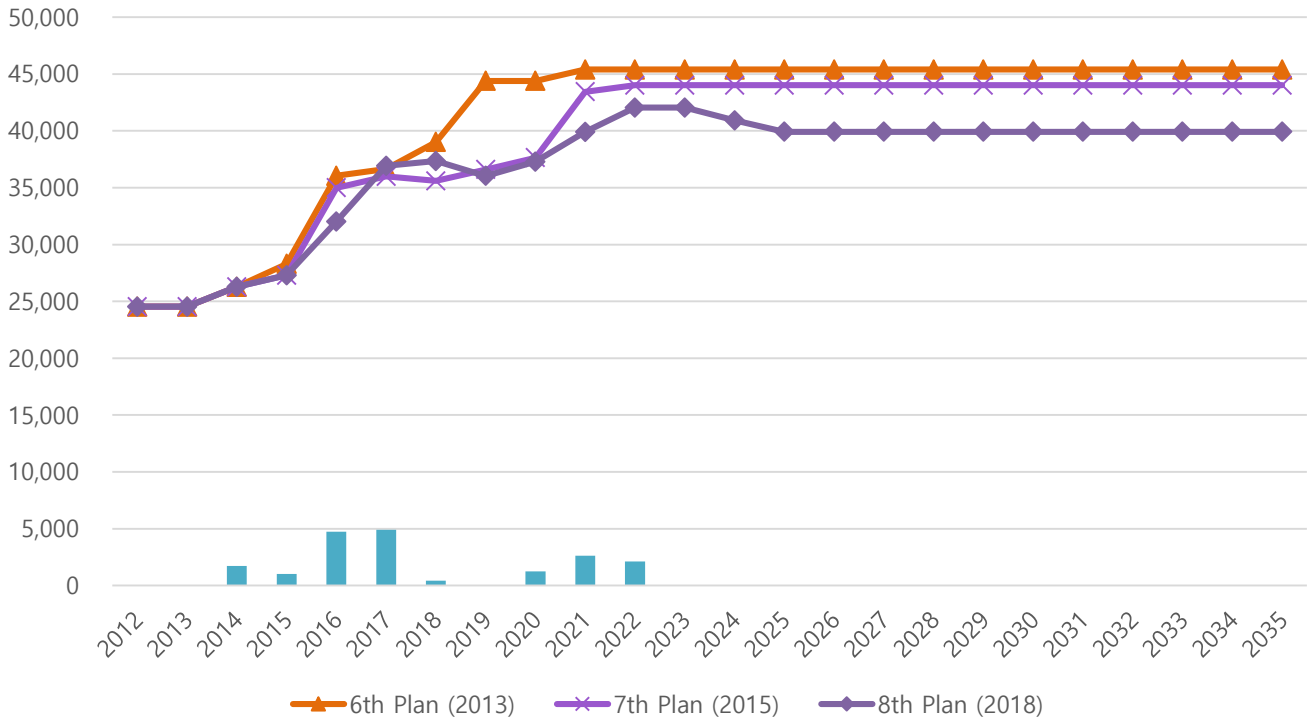
- **Nuclear Plan in 8th Electricity Plan (Dec. 2017)**



2017	2022	2030
24 Units (22.5GW)	27 Units (27.5GW)	18 Units (20.4GW)

8th Electricity Supply and Demand Plan - 2

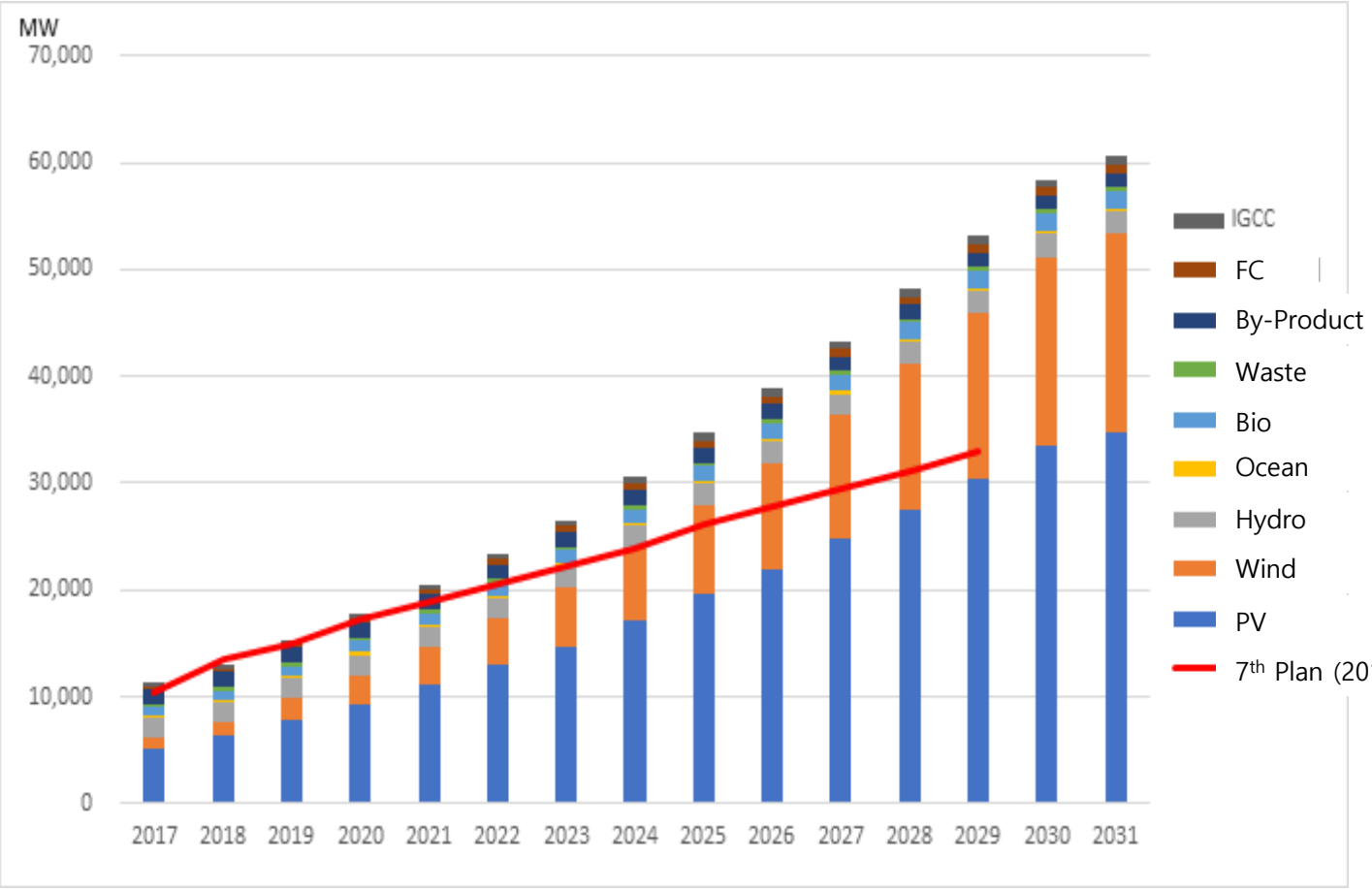
- **Coal Plan in 8th Electricity Plan (Dec. 2017)**



2017	2022	2030
61 Units (36.9GW)	61 Units (42GW)	57 Units (39.9GW)

8th Electricity Supply and Demand Plan - 3

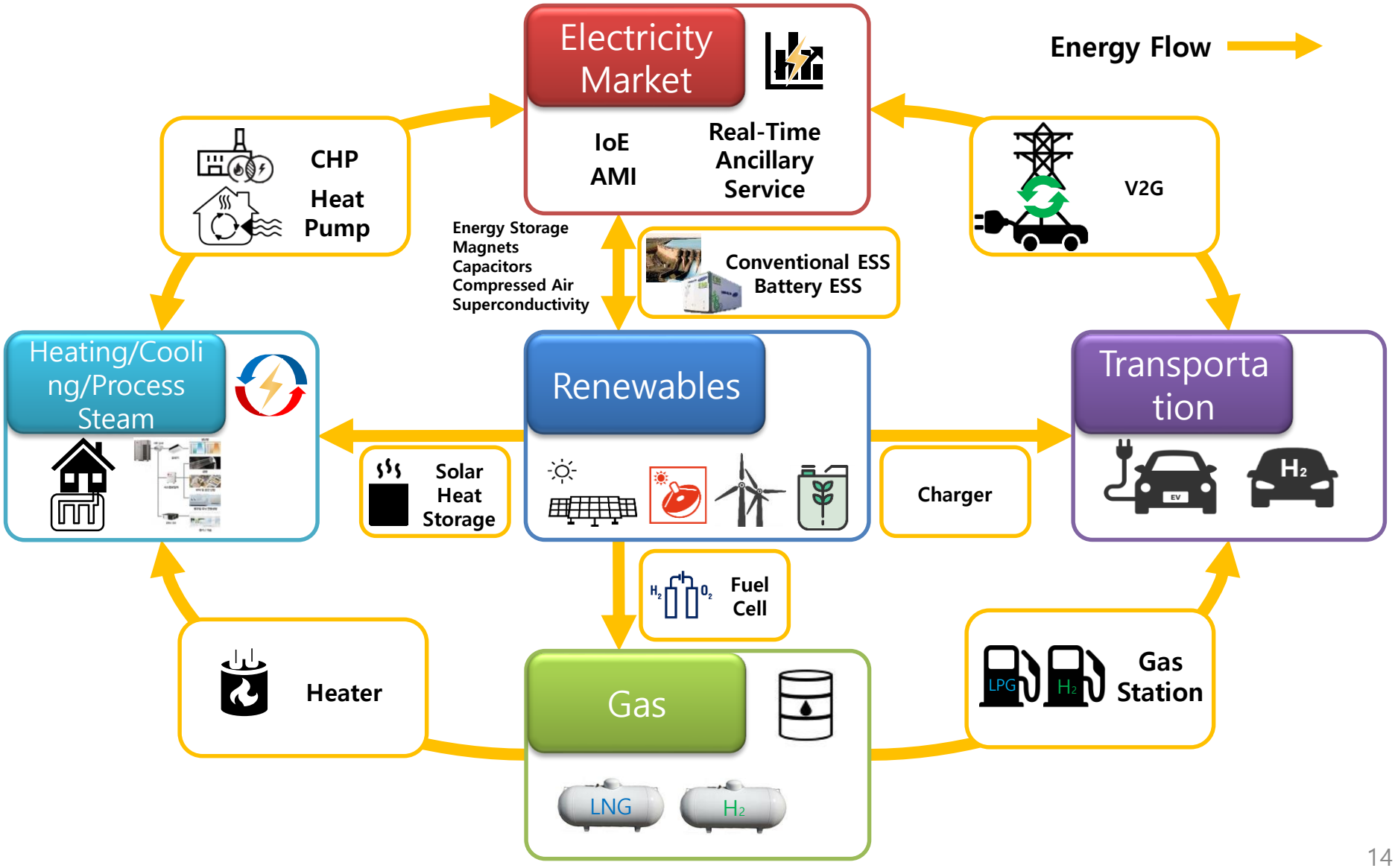
- **Renewable Plan in 8th Electricity Plan (Dec. 2017)**



- 20% Renewable Generation in 2030.
- PV and Wind Focused Renewable Capacity

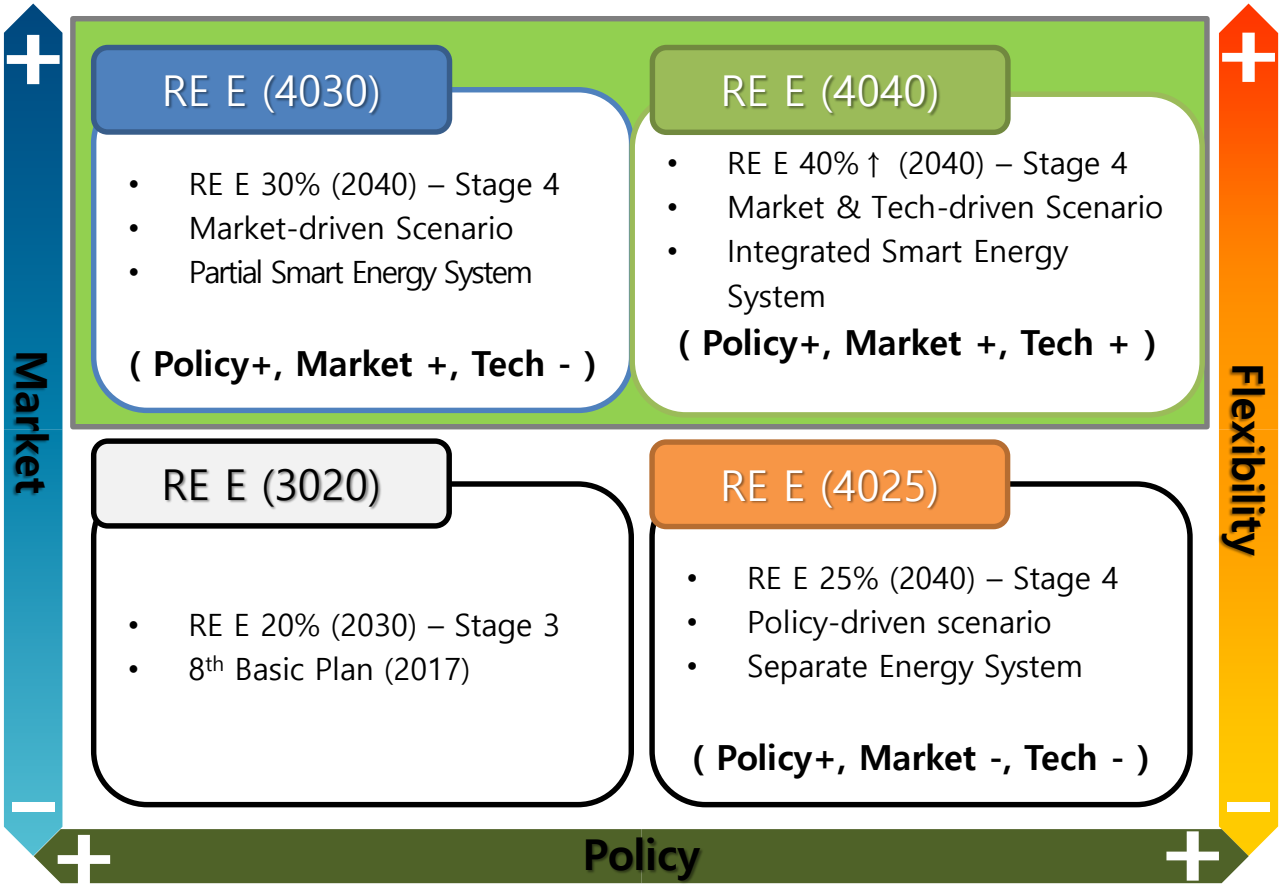
Integrated Smart Energy System (2040 Vision)

- **Market-based Smart Energy System. Flexibility through all Energy Sector.**



Scenario-Based Renewables Initiative in 2040

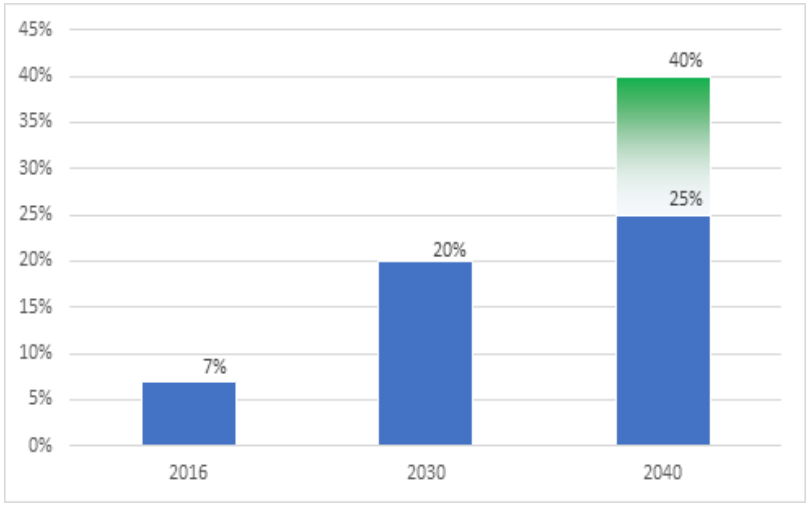
- **Renewables Penetration Based on the Conditions of Policy, Market, and Technology(Flexibility)**



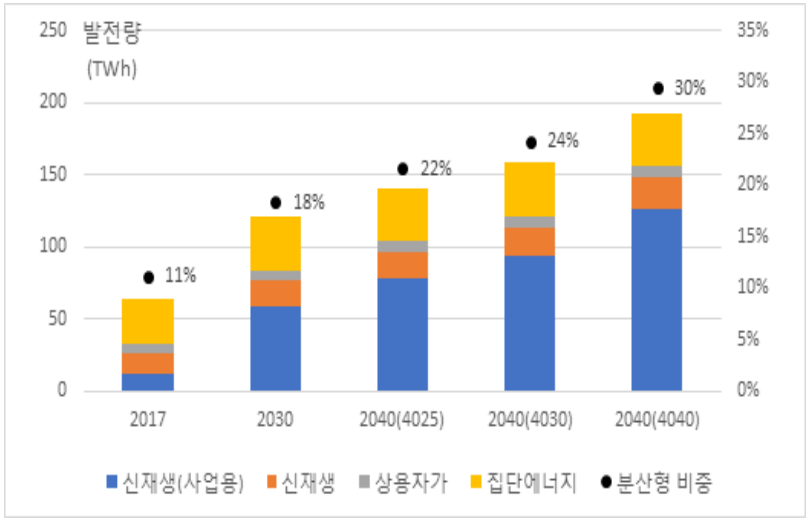
IEA Classification of Renewable Portion. Stage1: ~3%, Stage2: 3~15%, Stage3: 15~25%, **Stage4: 25%↑**

Major Outcomes of 2040 Energy Vision

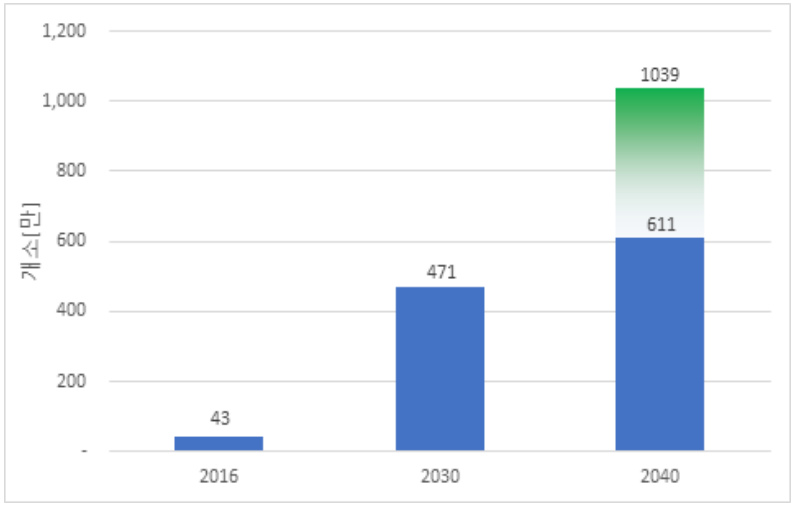
- **Major outcomes of Korean Power System through 2040 Energy Vision**



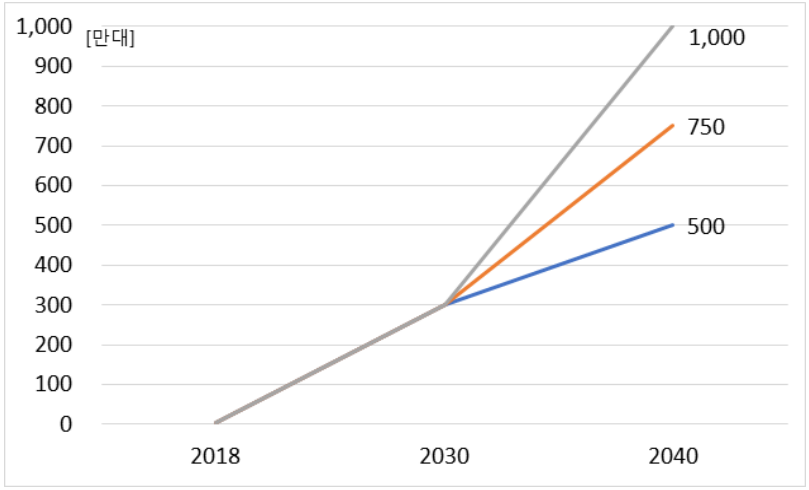
< % of Renewable Generation >



< % of Distributed Generation >



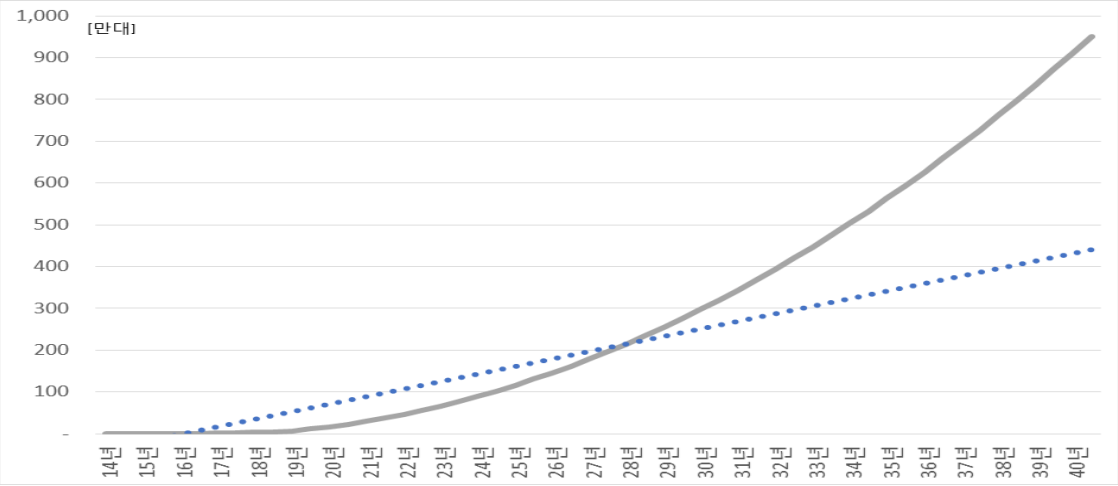
< Market Participant of Renewables (10^4) >



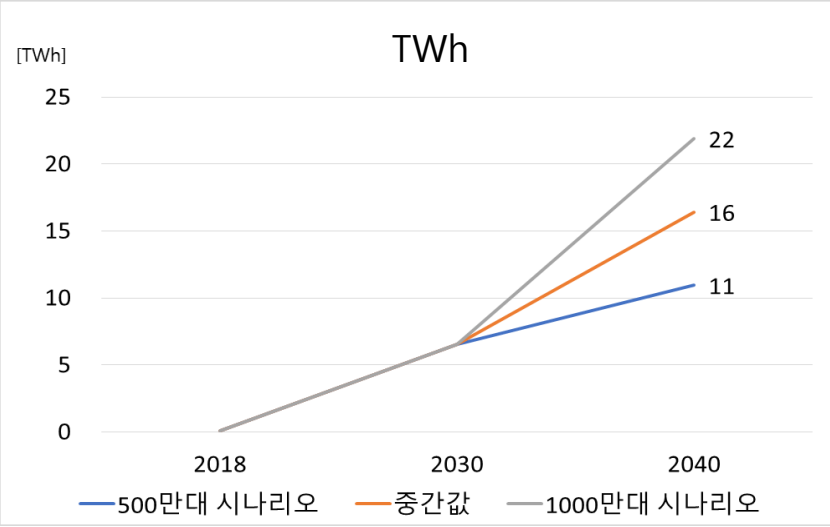
< E-mobility (10^4) >

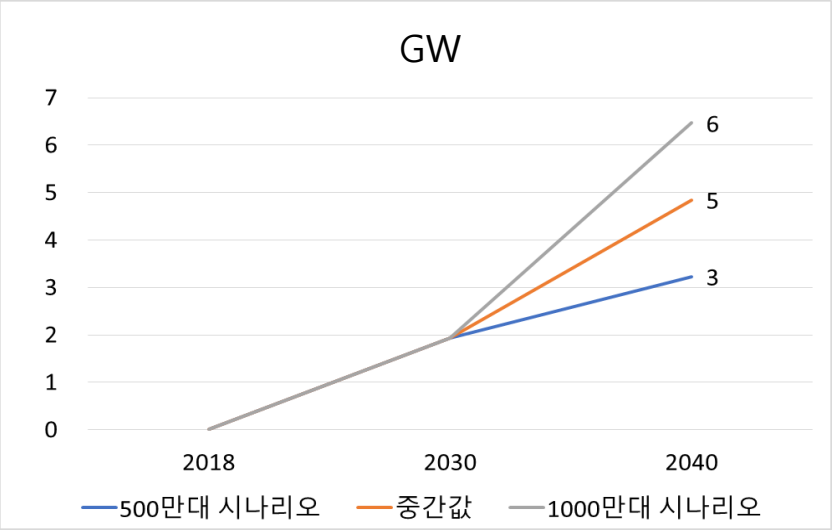
E-mobility Scenarios in 2040

- **E-mobility : 3 Millions in 2030 (CO2 Mitigation Plan in Transportation. 2018)**



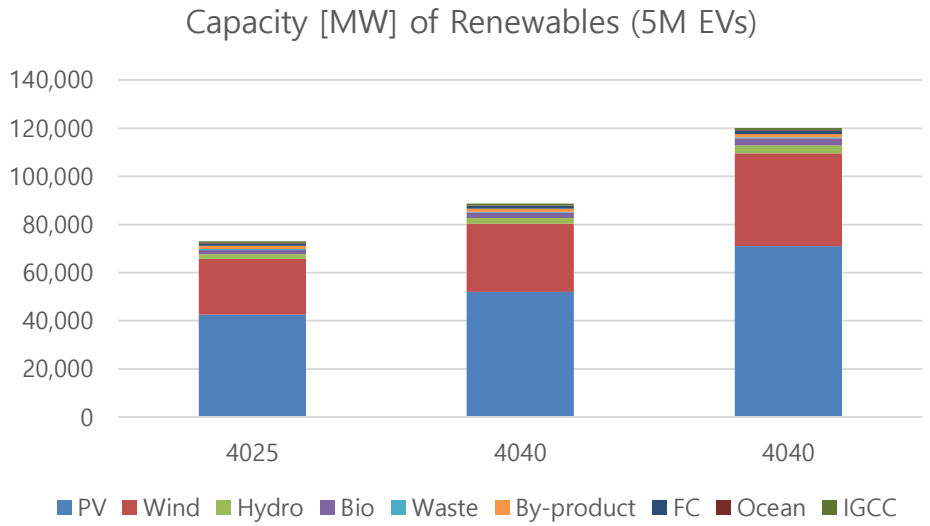
- **Peak & Energy Increase in Electricity Sector in 2040 (5M, 7.5M, 10M)**



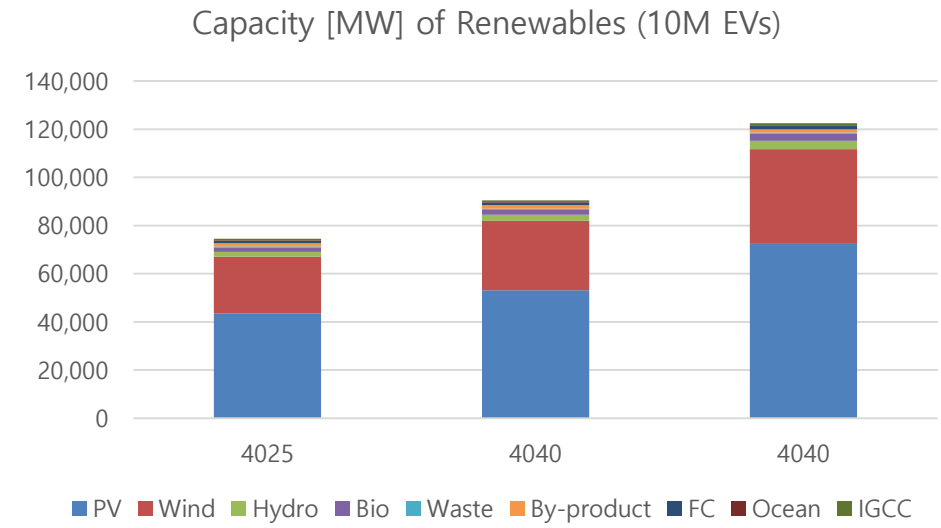


Renewables Capacity by Scenarios in 2040

- **Renewable Capacity in 2040 by Scenarios (EVs 5M) : 73GW ~ 120GW**



- **Renewable Capacity in 2040 by Scenarios (EVs 10M) : 75GW – 123GW**

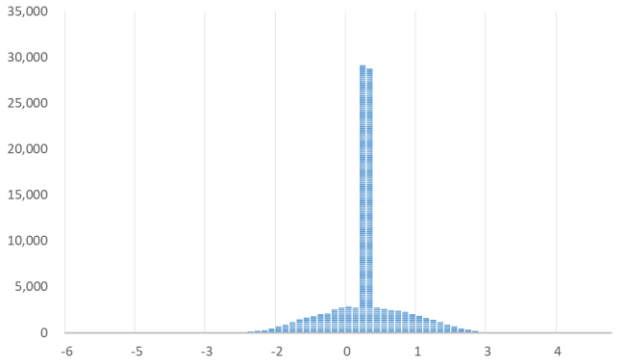


Flexibility Increase to Overcome Volatility and Uncertainty of Renewables - 1

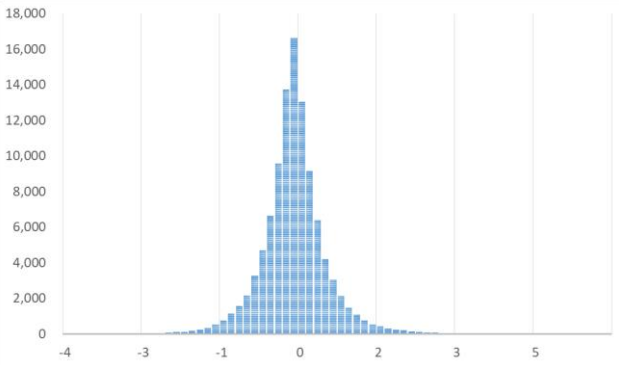
- **Flexibility – The Critical Component for Massive Increase of Renewable Generation**

- **Volatility Analysis of Winds and PVs in Korea (2017)**

	Wind		PV	
CF (%)	Avg. : 22.45	Max. : 74.83	Avg. : 15.99	Max. : 86.94
Output Volatility (%p)	5 Mins : -4.38 ~ 6.02 30 Mins : -9.43 ~ 12.83 1 hr : -13.36 ~ 17.49 2 hrs : -21.13 ~ 25.99		5 Mins : -6.37 ~ 5.22 30 Mins : -14.24 ~ 15.95 1 hr : -29.09 ~ 29.26 2 hrs : -51.41 ~ 52.60	



5 Mins Volatility of PV



5 Mins Volatility of Wind

Flexibility Increase to Overcome Volatility and Uncertainty of Renewables - 2

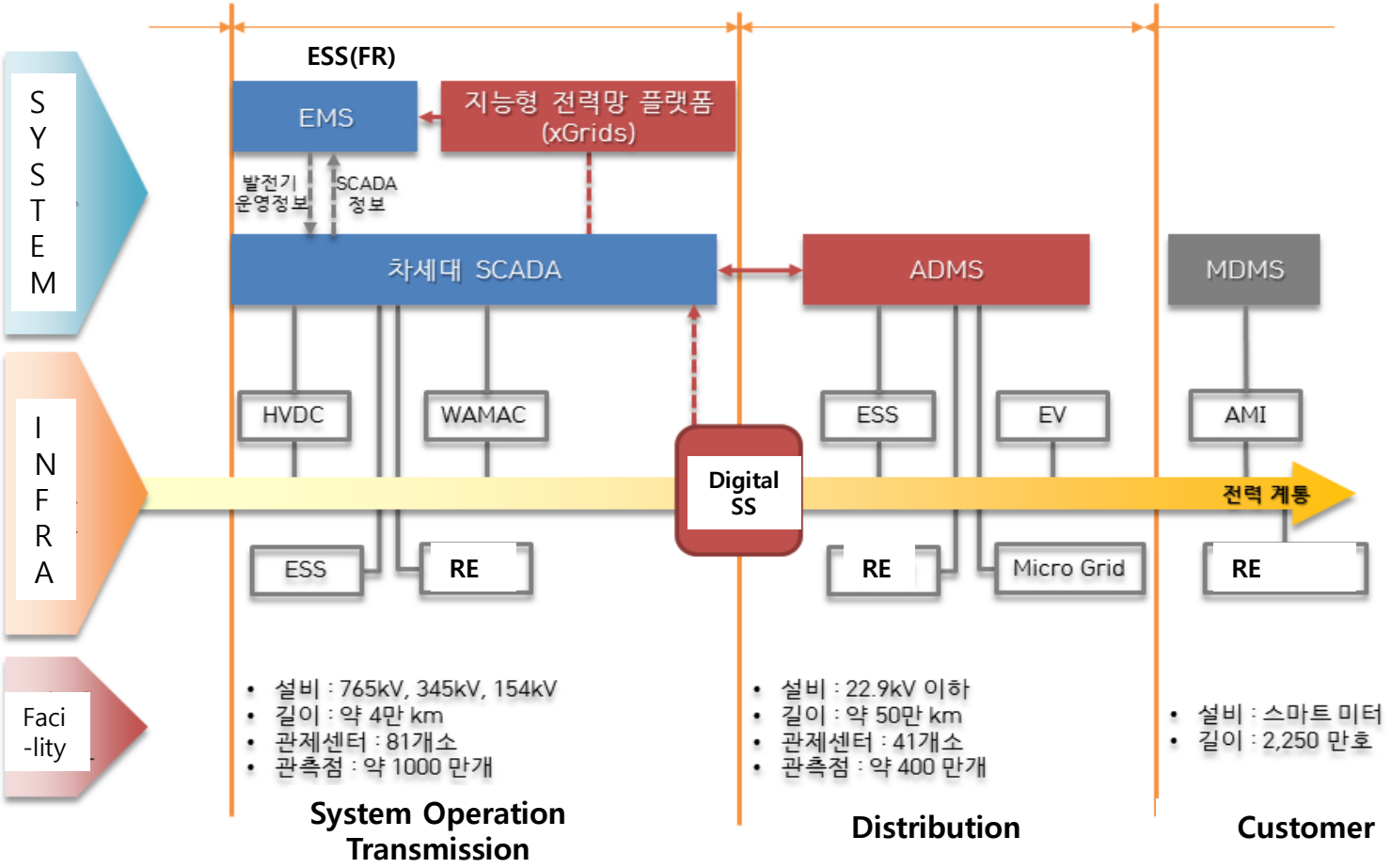
- **Volatility Forecasting of Winds and PVs (2016, 2030, 2040)**

Volatility [MW]			2016	2030	2040	
					25%	40%
PV [MW]	5 Mins	-(Dec)	- 415	- 2,136	- 2,771	- 4,713
		+(Inc)	340	1,750	2,271	3,862
	1 hour	-(Dec)	- 1,896	- 9,754	- 12,654	- 21,524
		+(Inc)	1,907	9,811	12,728	21,649
Wind [MW]	5 Mins	-(Dec)	- 53	- 770	- 1,035	- 1,760
		+(Inc)	73	1,058	1,422	2,419
	1 hour	-(Dec)	- 162	- 2,348	- 3,156	- 5,368
		+(Inc)	212	3,074	4,131	7,027

- **Flexibility Options: Market Structure including Reserves, Supply Options, Demand Options, Storage Options (BESS), Infrastructure, etc.**
- **BESS(Li-B) focused Presentation**

Flexibility Increase (Smart Grid Infrastructure)

- **Smart Grid Infrastructure (~2022)**

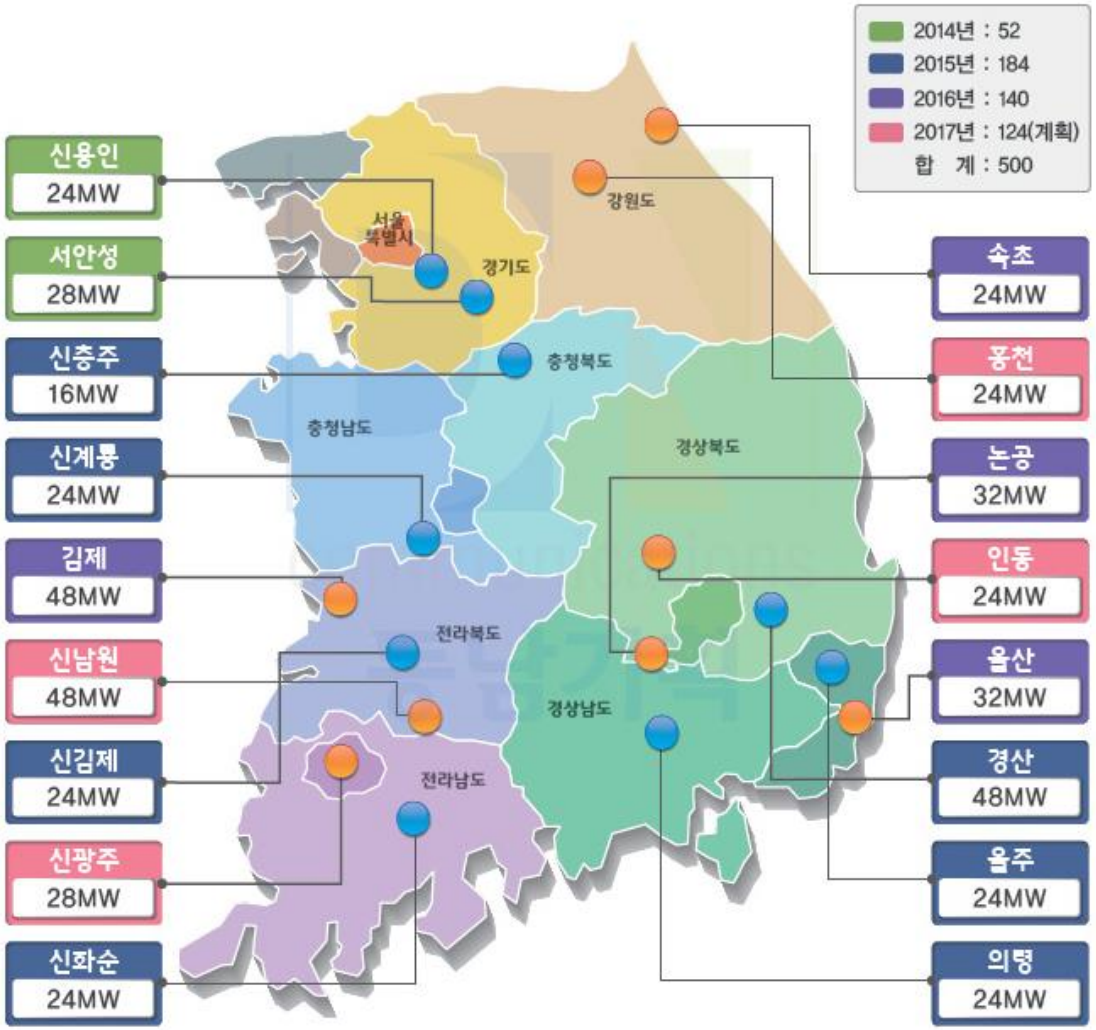


BESS Applications in Power System

- **Active Application of LiB BESS for Power System Stablization in South Korea**
- **Frequency Regulation (Primary, Secondary Reserve)**
- **Renewable Integration (PV and Wind through REC Compensation)**
- **Peak Cutting of Industrial Customers through Incentive Mechanism (TOU)**
- **Around 3GW~4GW in Total LiB BESS Under Operation or Construction**

BESS Applications for Frequency Regulation in Korea

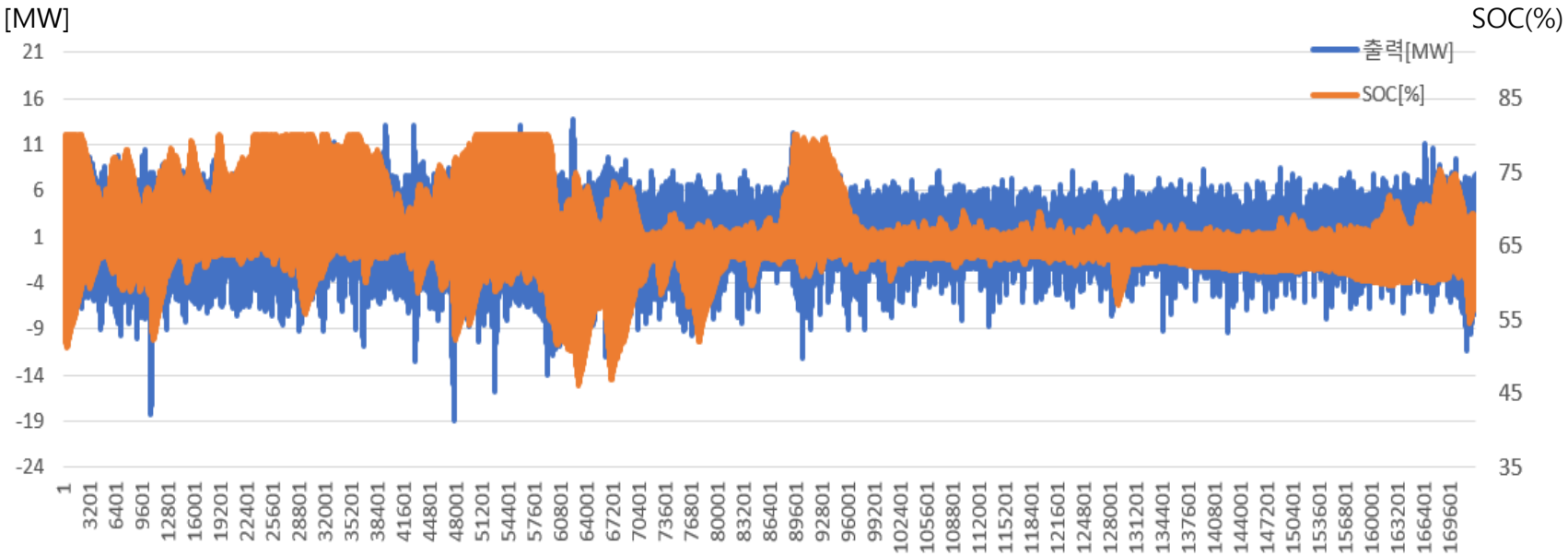
- **Total 360MW BESSs for FR in Operation (2018)**



- LiB BESS for FR by KEPCO's S/S
- Replacing Coal's Primary Response

Frequency Regulation Operations - 1

- **Operation Characteristics of FR ESS (Aug. 18, 2016)**

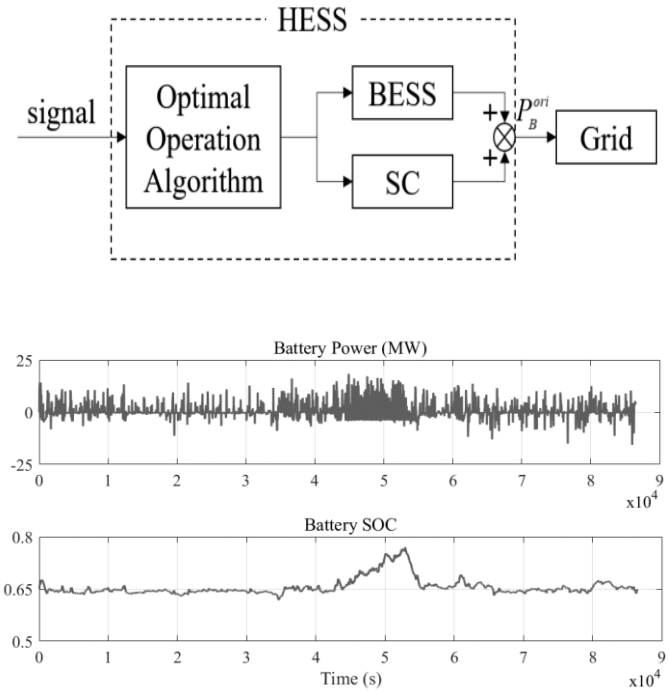


- ESS Power/Energy : 24MW/6MWH
- BESS Operation Range : 60Hz ± 0.03
- SOC Operaton Range : 20 ~ 80%

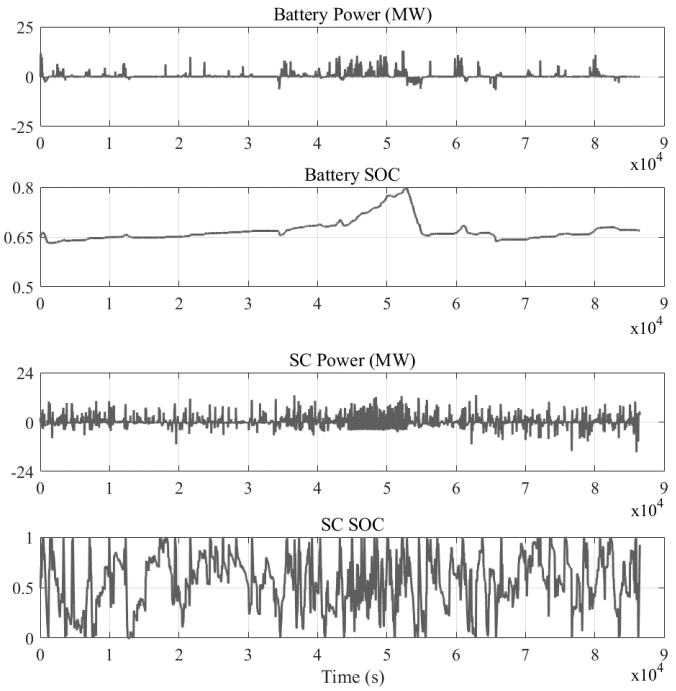
➔ **Frequent Operation and Depth-of-Operation Shorten Lifespan of BESS(LiB)**

Frequency Regulation Operations - 2

- **Hybrid (LiB + Supercapacitor) Operation of FR ESS Considering Wearing Cost (Under Research)**



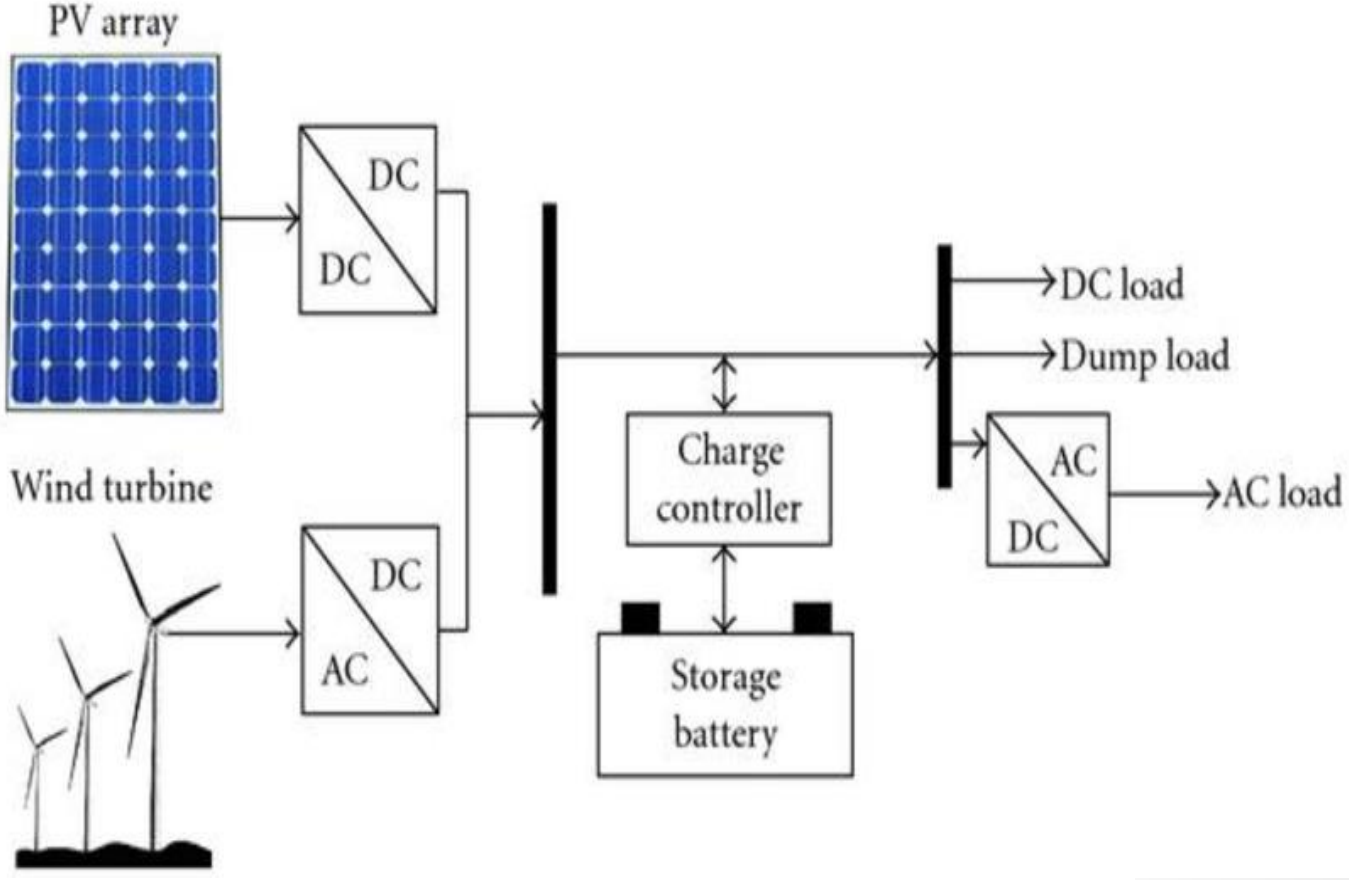
(a) LiB BESS single operation

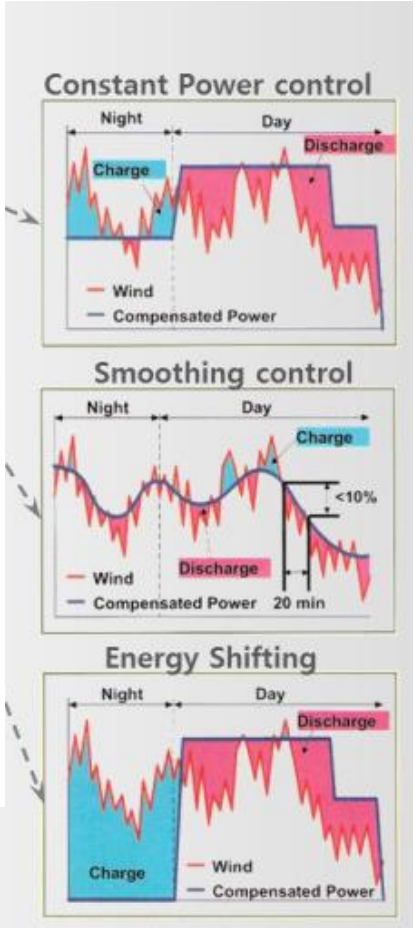


(b) HESS operation

Multi-purpose Operations of BESS

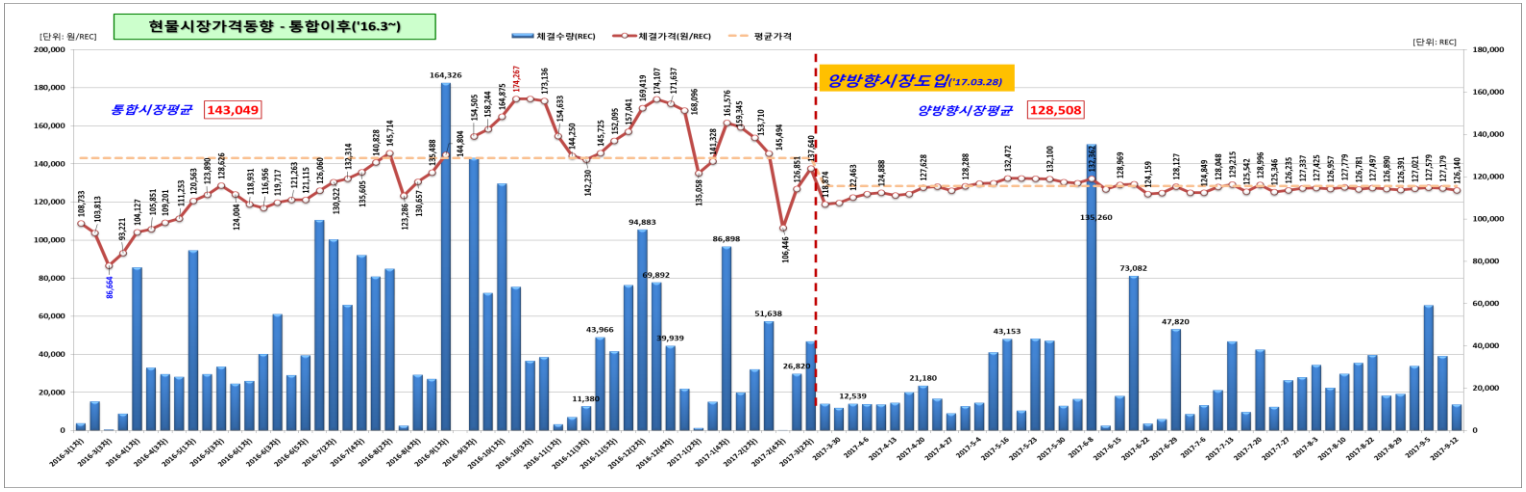
- **Renewable (PV, Wind) + BESS : Constant Power Control, Smoothing, Energy Shifting**



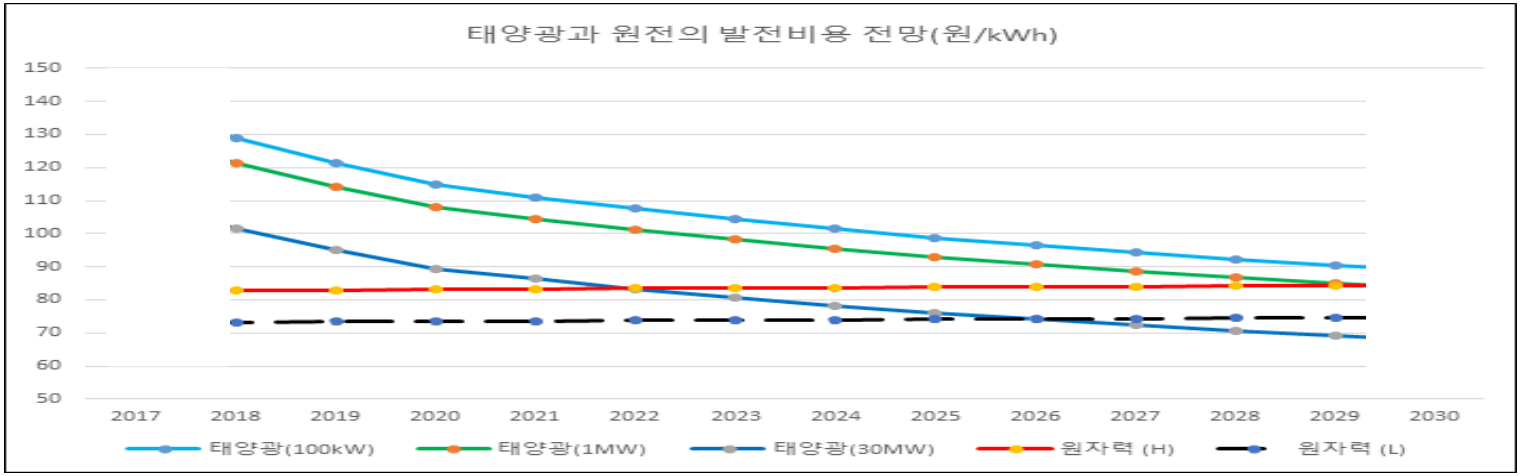


Cost Reduction of Renewables

- **Historical REC Spot Price Trend**



- **LCOE Estimation (PV vs Nuclear)**



Conclusions and Suggestions

- **Massive Renewables Capacity Increase Plan of New Government until 2030 and 2040**
  - **60GW in 2030 (20% in 2030)**
  - **70GW~120GW in 2040 (25%~40% in 2040)**

- **Systematic and Cost-effective Flexibility Increase Strategy**
  - **Platform and Infrastructure Implementation including Interconnection**
  - **BESS Contribution (Cost Reduction Required)**
  - **Successful Implementation of Market-based Smart Energy System including EV, Gas(P2G), Thermal, etc**

- **International Collaboration & Sharing of System Operation Experience**