

The role of DERs in Grid Resilience (Korean Power System Case)

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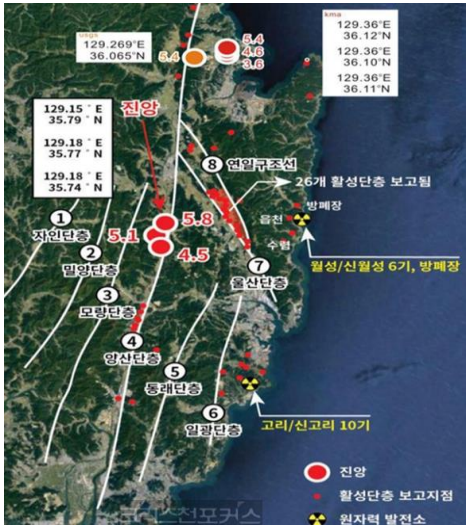
3. Future Plan & Suggestions

Characteristics of Korean Power System

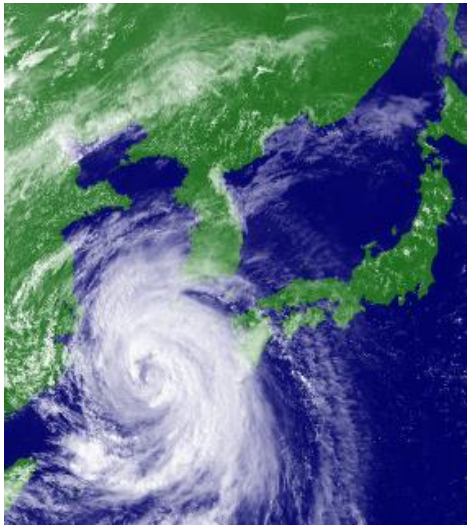
1. Isolated Power System (not interconnected with neighboring countries)
2. Centralized Power System (Bulk generation-transmission-consumption structure)
3. Continuous Electricity Demand Growth & Increase of Electricity Share in Final Energy Consumption
4. Recent Environmental Problems in Korea Peninsula (SMOG, PM/SOx/NOx, Global Warming, Earthquake, Flood, Typhoon, etc.)



Source: NASA

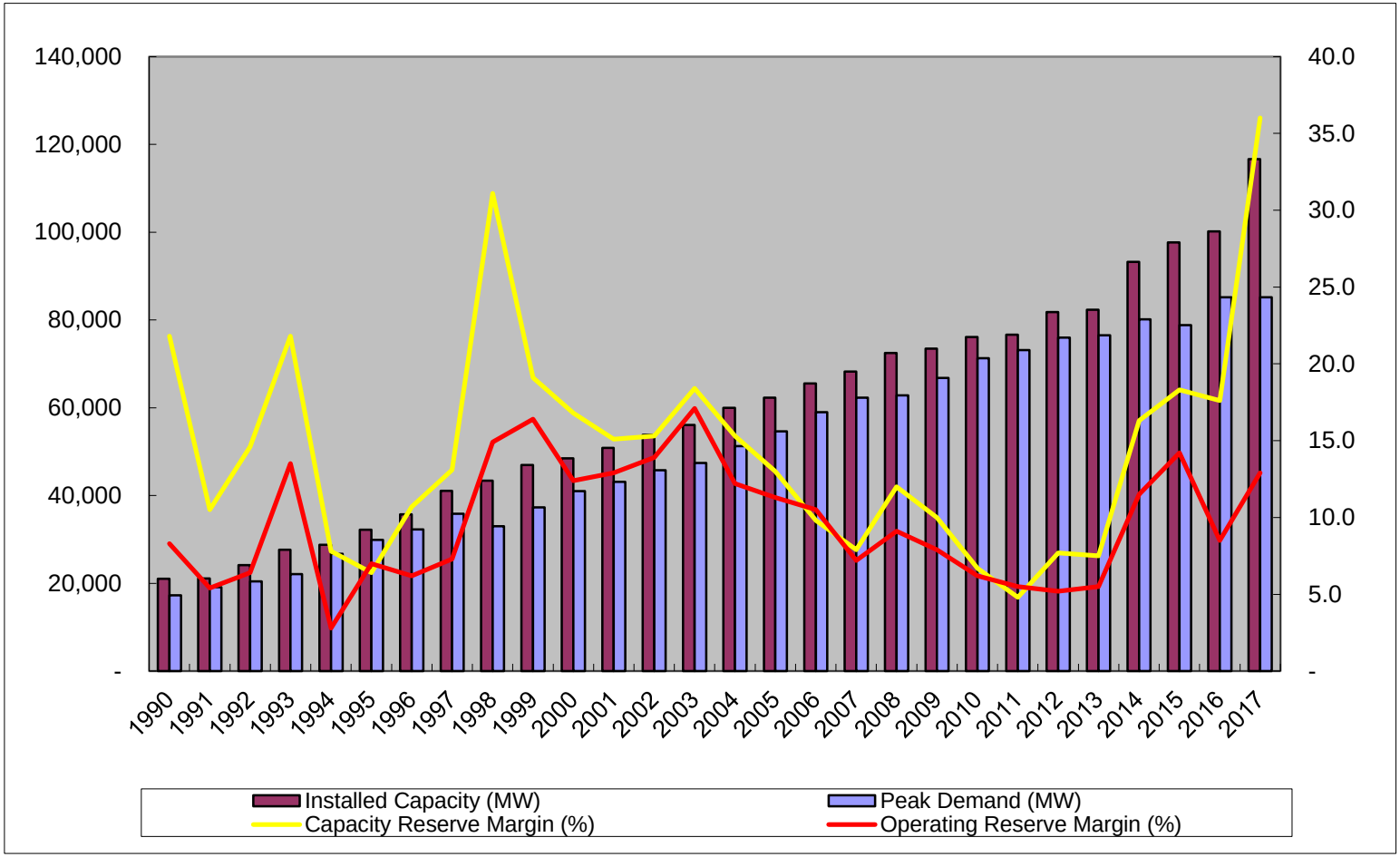


Source: 크리스천포커스



Historical Supply and Demand in Korean Power System

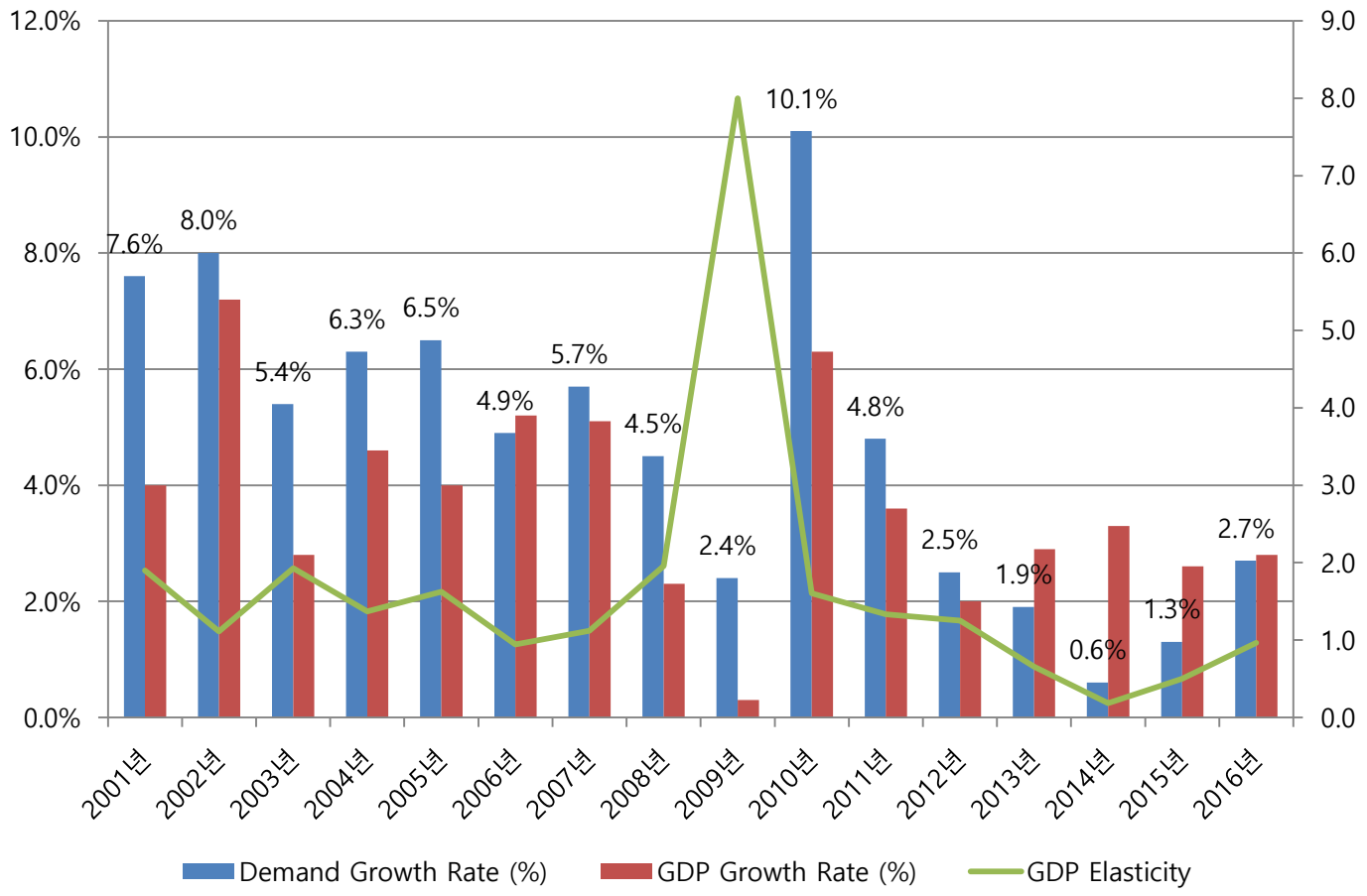
- Historical Supply and Demand in Korea (1990-2017)



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

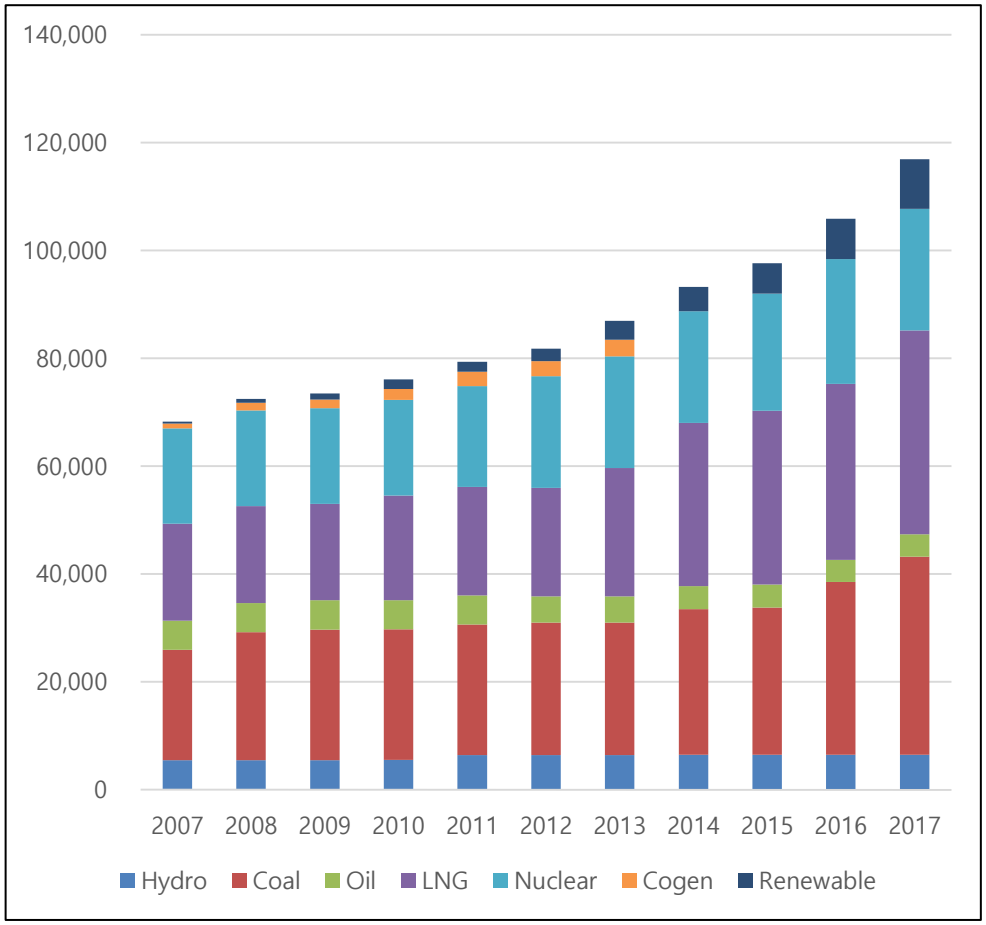
Historical Electricity Demand Growth Trends

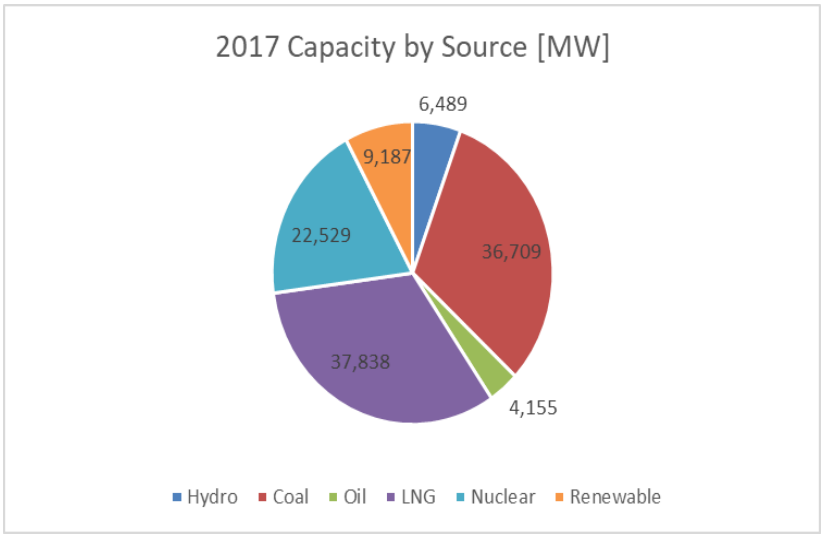
- Historical Demand Growth (2001-2016)

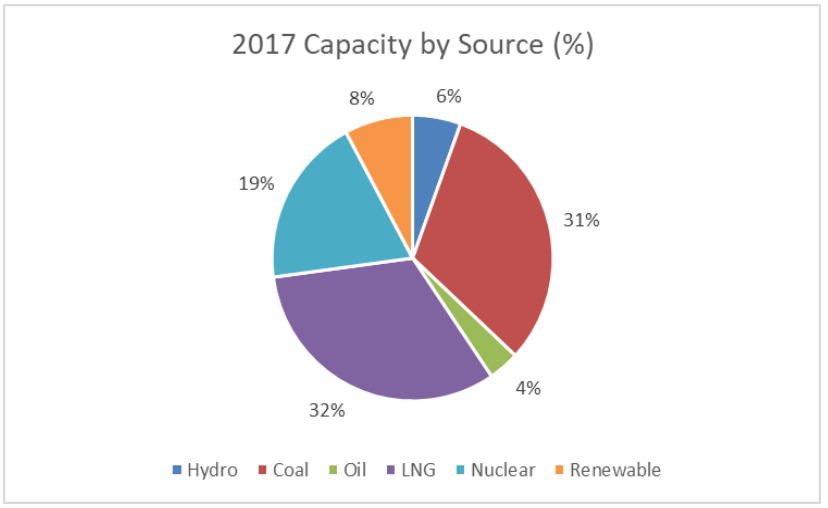


Composition of Generation Capacity by Source

- Installed Generating Capacity by Source (2007-2017)



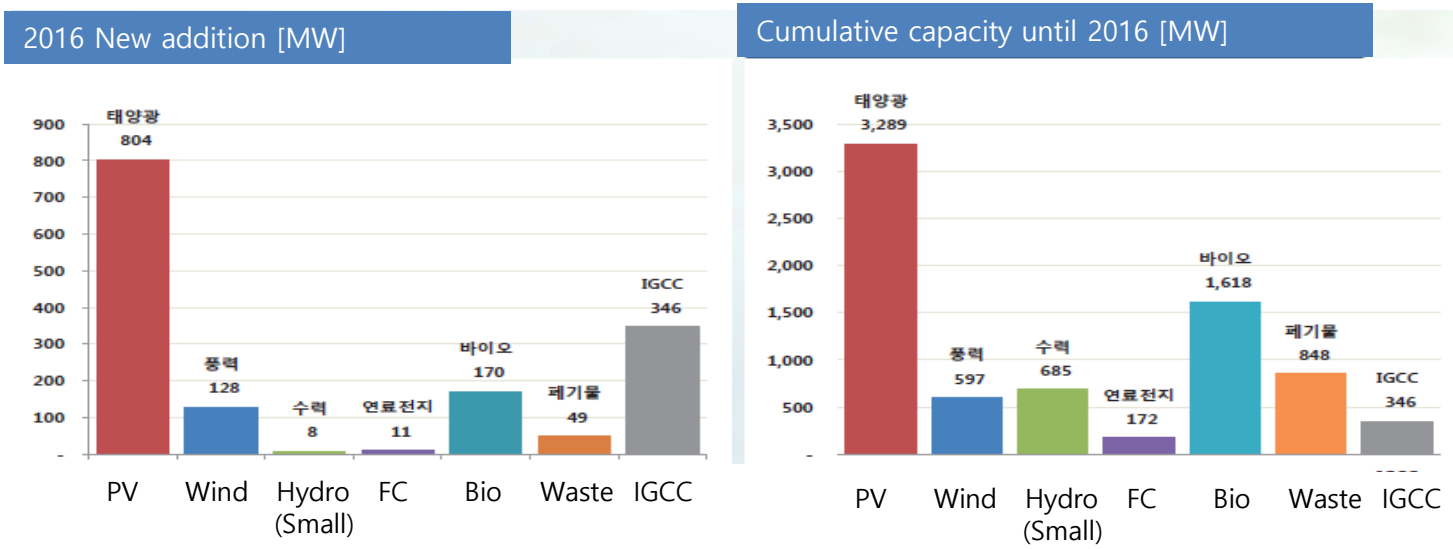




. Installed Capacity by Fuel (2017) : Hydro 6%, Coal 31%
Oil 4%, LNG 32%, Nuclear 19%, Renewable 8%
* LNG includes CCGT based CHP

Renewables in South Korea (2016)

- Installed Capacity by Renewable Type (2016)



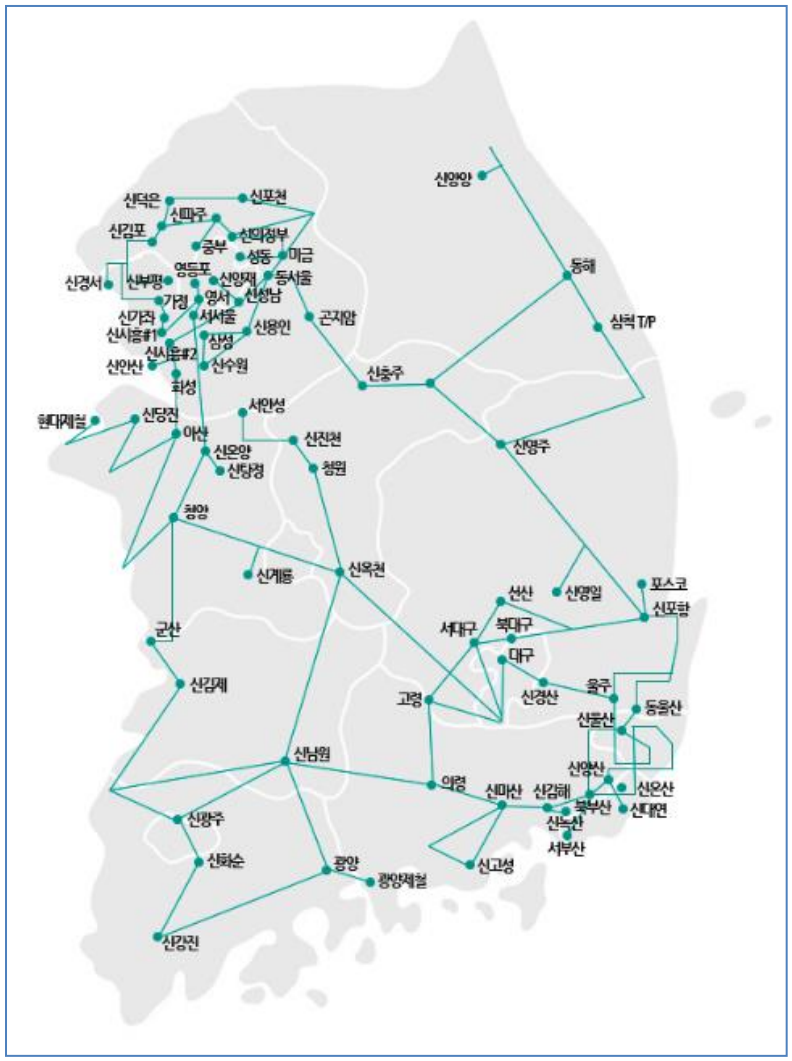
- Recent Renewables Investment

New Capacity (MW)		PV	Wind	Others	Total
2018	1/4	**446.2**	**69.1**	687.7	1,203.0
2017	4/4	**336.5**	**39.3**	40.2	416.0
	3/4	**331.0**	**45.3**	302.2	678.5
	2/4	**282.1**	**26.0**	14.7	322.8
	1/4	**261.3**	**18.9**	201.5	481.7

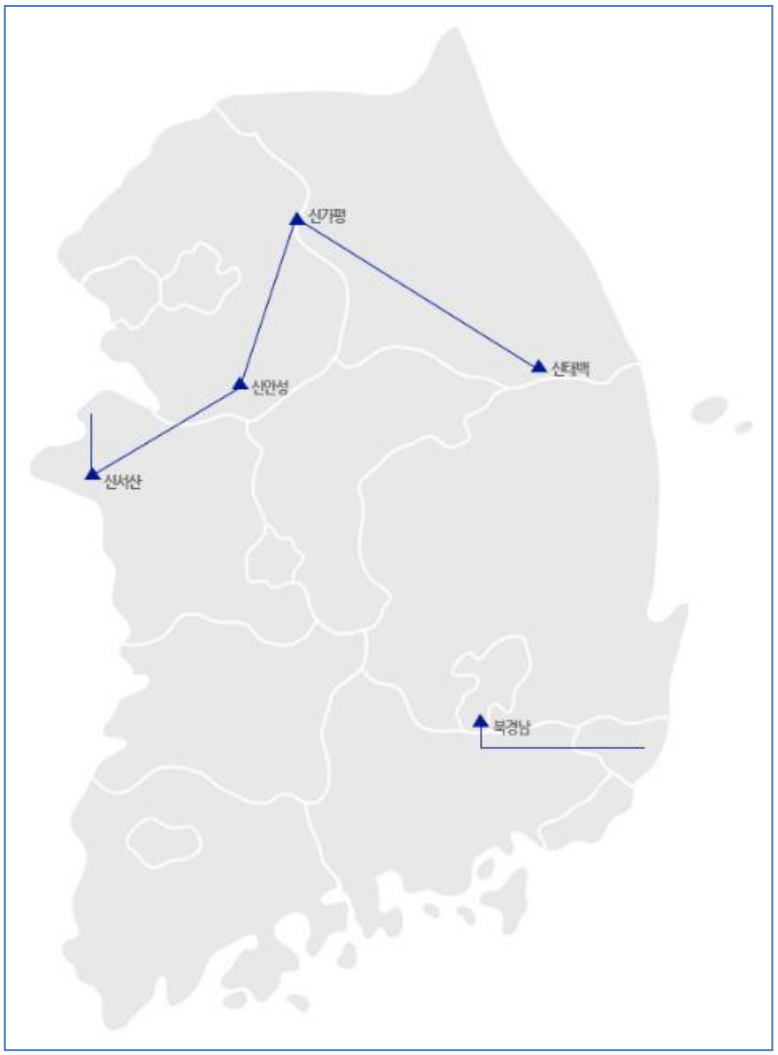
*KEMCO, RPS and In-house

Transmission System Configuration

- **T/Ls of 345kV and 765kV in South Korea**



345kV System

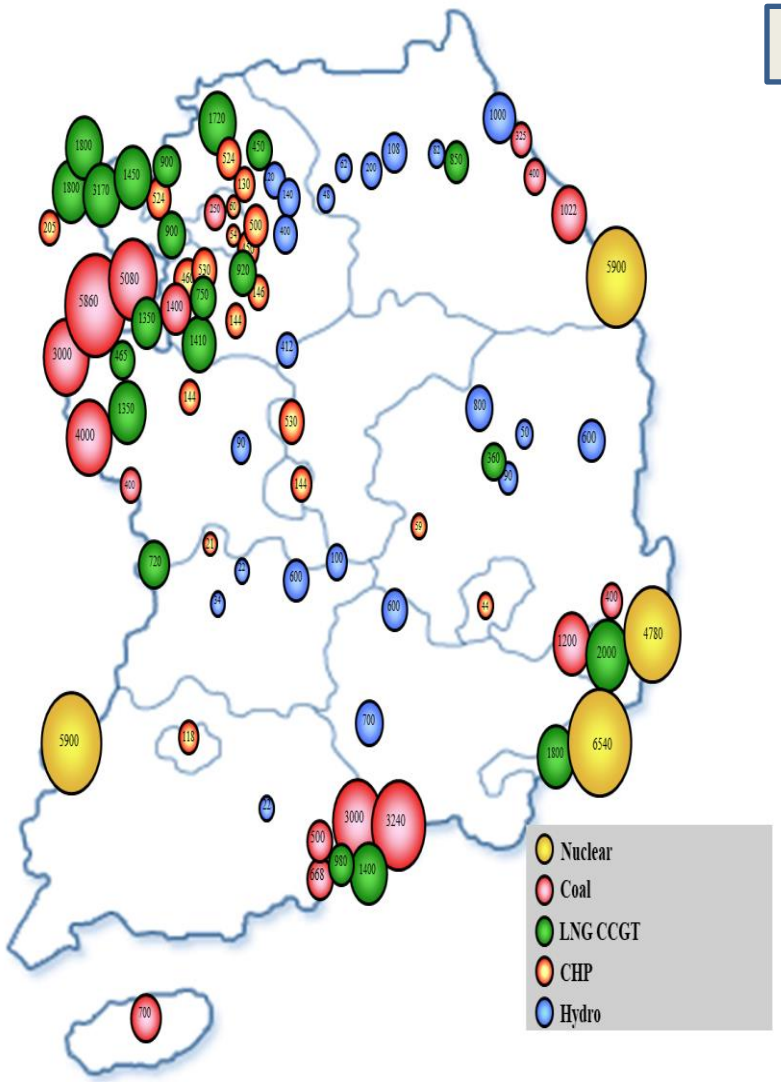


765kV System

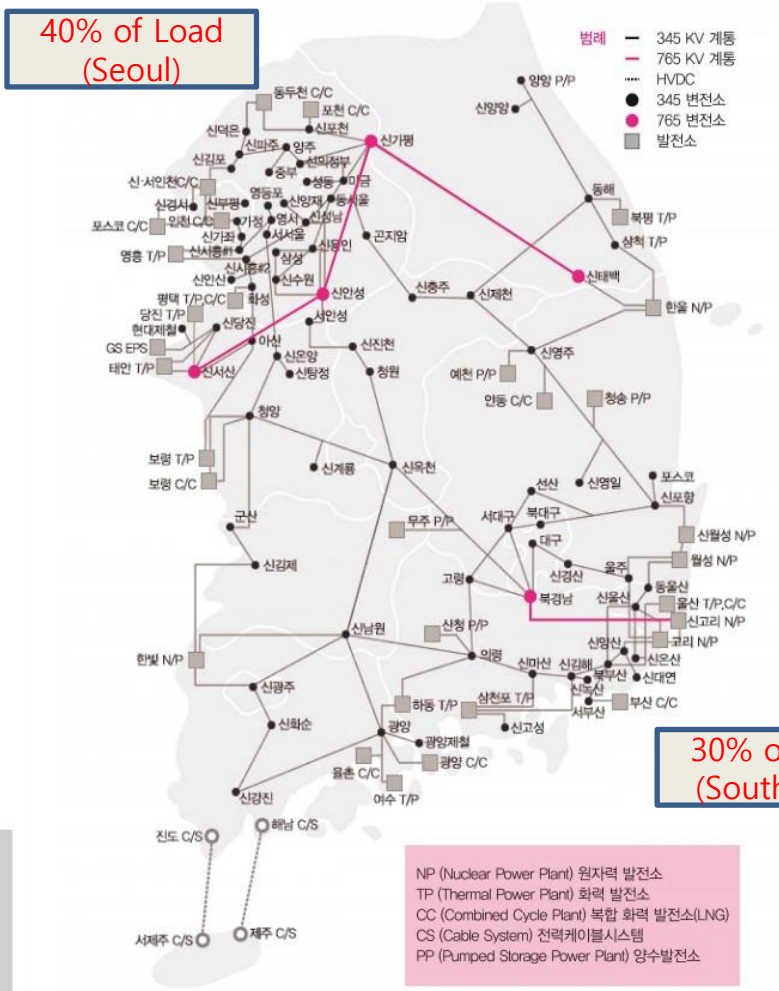
Source : KPX (Korea Power Exchange)

Locational Distribution of Central Dispatch Generators

- (Trunk) Transmission System – (Large) Generation Center – 2 Load Centers



40% of Load (Seoul)

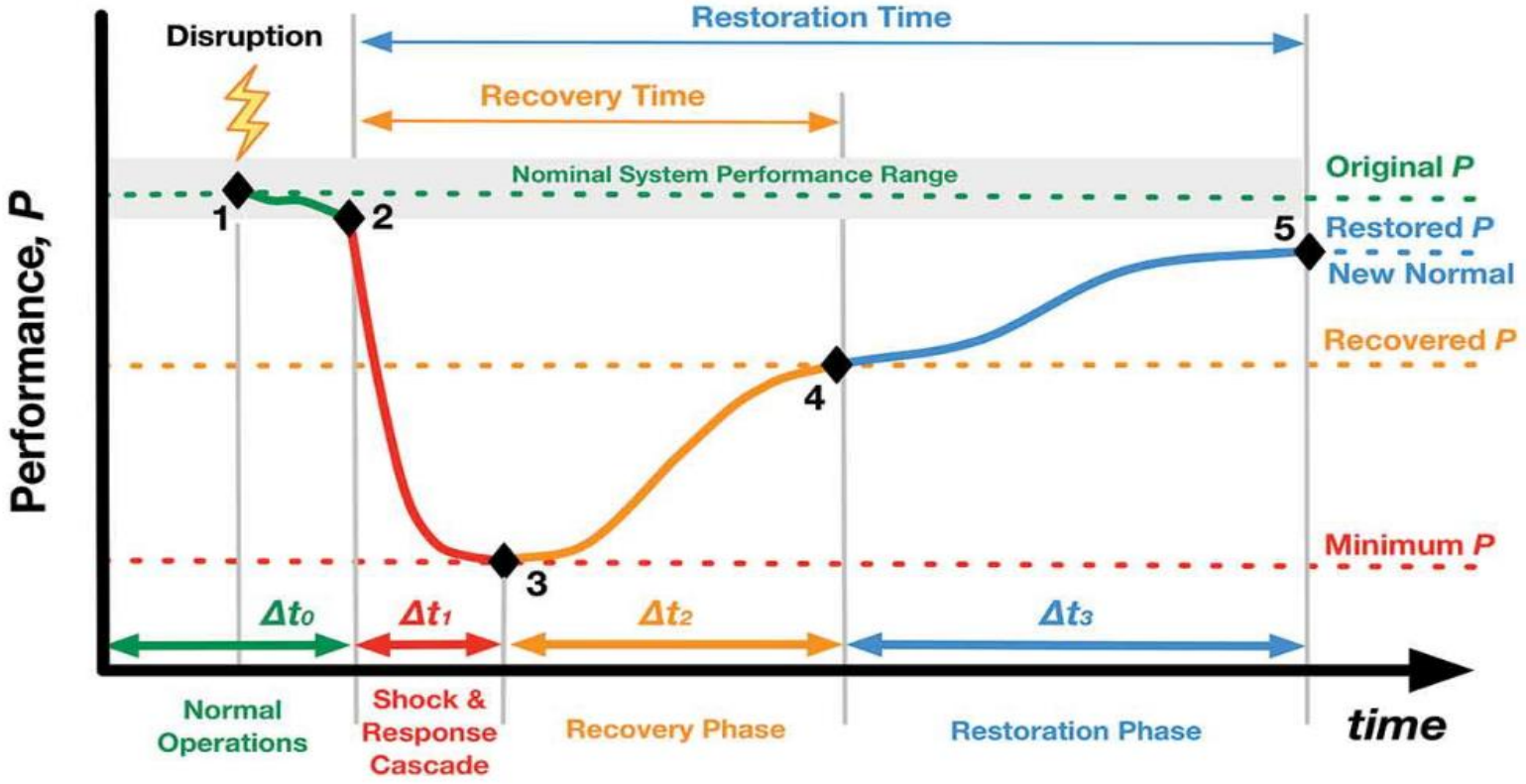


30% of Load (South East)

Grid Resilience Related Issues in Korean Power System

Power System Resilience Overview

- **Definition of Resilience**
  - The ability of the system which includes generating sources, transmission, and distribution to bounce back from high-impact, low-frequency events.
- **Generic System Resilience Curve**



Source : Sherrell R. Greene (2018) Are Current U.S. Nuclear Power Plants Grid Resilience Assets?, Nuclear Technology.

Major Issues Related with Grid Resilience in Korea

1. National Energy Policy Perspective
   - National Energy & Power Planning Policy focused on Bulk Generation (Nuclear and Coal) and Bulk Transmission (765kV, 500kV HVDC) Based on Scale-of-Economy
   - Environmental and Conflict Costs are not actively considered until 2016
2. Generation Perspective
   - Large-scale Units and Huge Generation Station far from Load Center(s)
   - Small Share of DERs and Self Generation of Large Industrial Customers
3. Transmission Perspective
   - 765kV and/or 500kV Trunk Transmission Lines to Load Center
   - (N-2) Contingency Application & SPS-based Load Shedding Scheme
4. System Operation Perspective
   - Lack of System Flexibility and Resilience (Generation & Transmission)
   - Black-start Related Issues
5. Others

National Energy Policy and Grid Resilience in Korea (1)

- **National Energy Policies**

  - National Energy Basic Plans (NEPs)

    . Highest Level of Energy Policy and Long-term Plan (Every 5-yr for 20 yrs)

    . 1st Plan (2008) : Nuclear 40% ➔ 2nd Plan (2014) : Nuclear 29% in Capacity [MW]

    . Both plans are based on high oil and fuel prices.

  - Electric Power Supply and Demand Basic Plans (EPBPs)

    . Electricity Demand, Generation, Transmission, and DSM Plan (Every 2-yr for 15 yrs)

    . 6th Plan (2013) : Active Addition of Coals and Nuclears

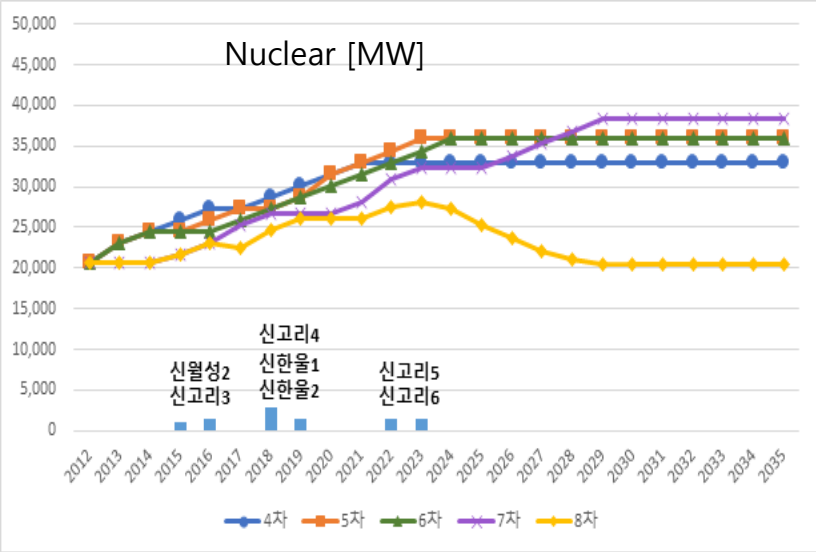
    . 7th Plan (2015) : Cancellation of 4 Coals, Increase of Renewables

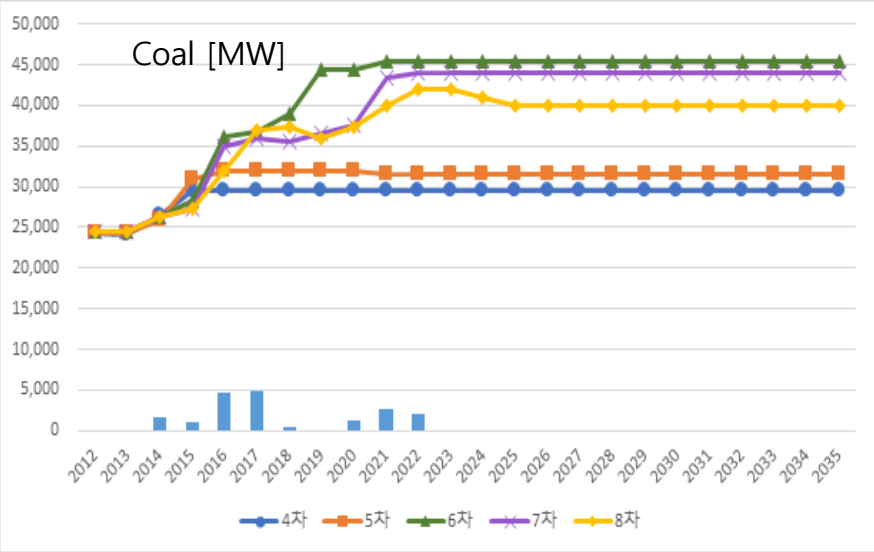
    . 8th Plan (2017) : Low Demand Forecasting. Renewables 20% in 2030.

    DERs Based Plan (Decommissioning of Nuclears. No Additional Construction of Coals and Nuclears)

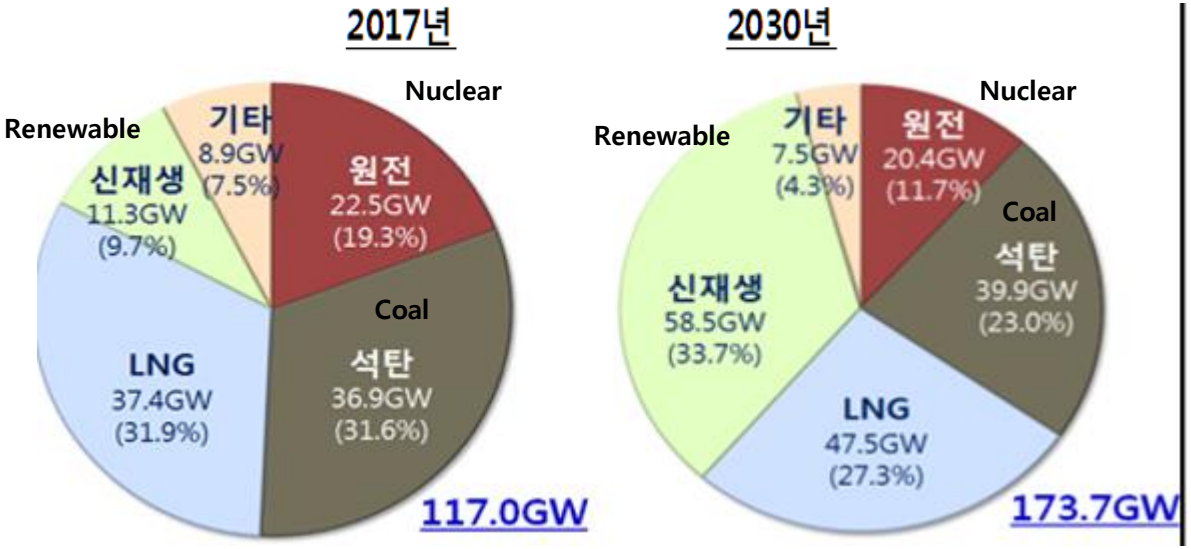
National Energy Policy and Grid Resilience in Korea (2)

- **Nuclear, Coal, and Renewable in EPBPs**





8th EPBP (DER focused Plan)



Generation Issues Related with Grid Resilience (1)

- **Large-scale Units and Stations**

  - Maximum 10 Nuclear or Coal Units in a Station/Site (5-6 GW Size)

- **Size Distribution of Generation Types (2016)**

		No. of units	2016 Capacity(MW)
Nuclear	500~750 MW	6	4,016
	750~1000MW	6	5,700
	1000MW above	13	13,400
	Total	**25**	**23,116**
Coal	100~500	10	2,294
	500~750	38	19,240
	750~1000	8	6,940
	1000 above	2	2,072
	Total	**58**	**30,546**
LNG CCGT (CHP)	0~100	8	355
	100~500	42	14,616
	500~750	17	9,750
	750~1000	12	10,379
	1000 above	0	0
	Total	**79**	**35,100**

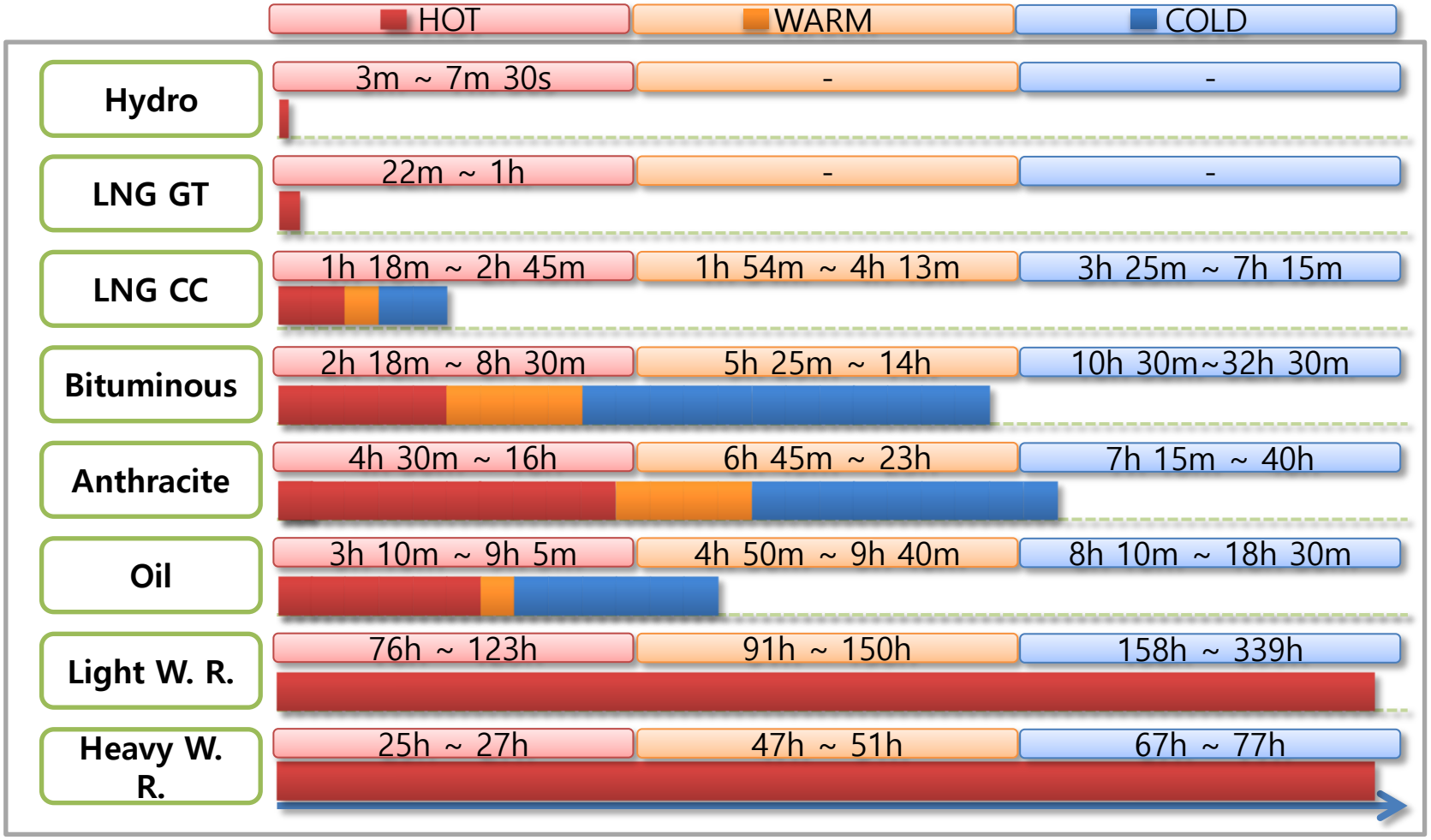
Large Central Generators

		2016 Capacity (kW)	2016 Capacity (MW)
PV	1kW below	4,568	4.6
	1~10kW	240,762	240.8
	10kW~1,000kW	3,134,476	3,134.5
	1,000~10,000kW	989,552	989.6
	10,000kW above	132,294	132.3
	Total	**4,501,652**	**4,501.7**
Wind	1kW below	32	0.0
	1~10kW	321	0.3
	10kW~1,000kW	6,085	6.1
	1,000~10,000kW	177,850	177.9
	10,000kW above	850,350	850.4
	Total	**1,034,638**	**1,034.6**
Hydro	1kW below	-	
	1~10kW	29	0.0
	10kW~1,000kW	40,056	40.1
	1,000~10,000kW	162,211	162.2
	10,000kW below	1,587,600	1,587.6
	Total	**1,789,896**	**1,789.9**

Small Renewable DERs

Generation Issues Related with Grid Resilience (2)

- **Start-Up Time of Generators**



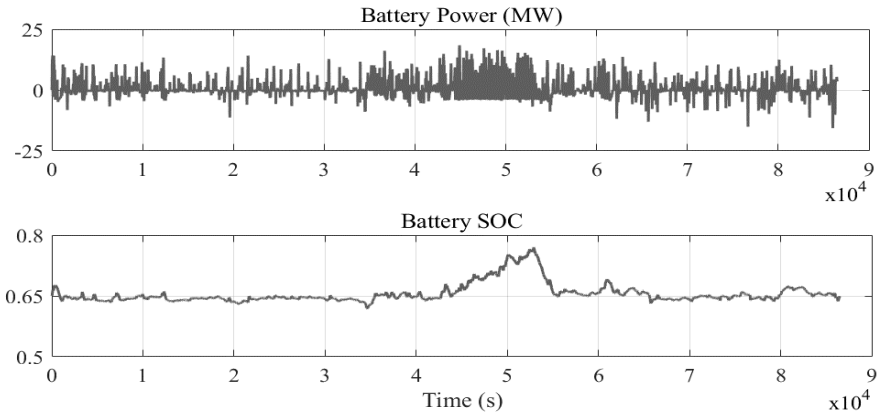
Source : KPX/KEPCO, "The status of installed capacity of power generation in Korea", 2016

Generation Issues Related with Grid Resilience (3)

- **Battery Energy Storage System for Frequency Regulation**

	Capacity (MW)	Cumulative Capacity (MW)	Substation (No.)
'14년	52	-	2
'15년	184	44	7
'16년	140	236	4
'17년	124	376	4

Source : KEPCO, 17 Sites, Total Cumulative Capacity 376MW





➔ **Increase Resilience and Flexibility (Short-term Perspective)**

Generation Issues Related with Grid Resilience (4)

● Self-Generation of Large Industrial Customers

Self-Generation in Korea(2016)



Total Generation Capacity		109,789 MW
Self-Generation Capacity	**Total (4%)**	**3,924 MW**
	Market Participation	2,956 MW
	Market non-participation	967 MW

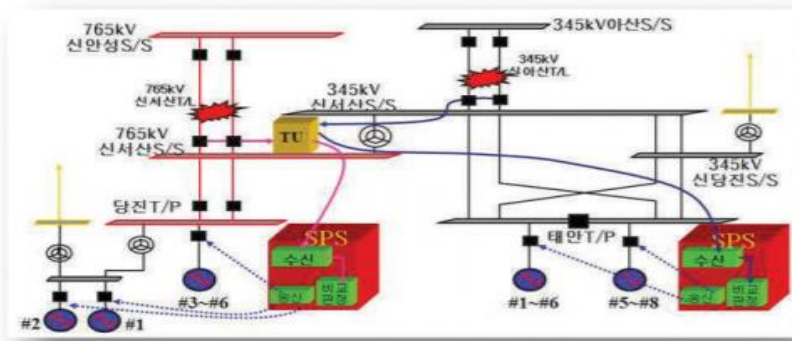
Total Generation Capacity		560,985 GWh
Self-Generation Capacity	**Total**	**20,627 GWh**
	Market Participation	13,722 GWh
	Market non-participation	6,904 MW

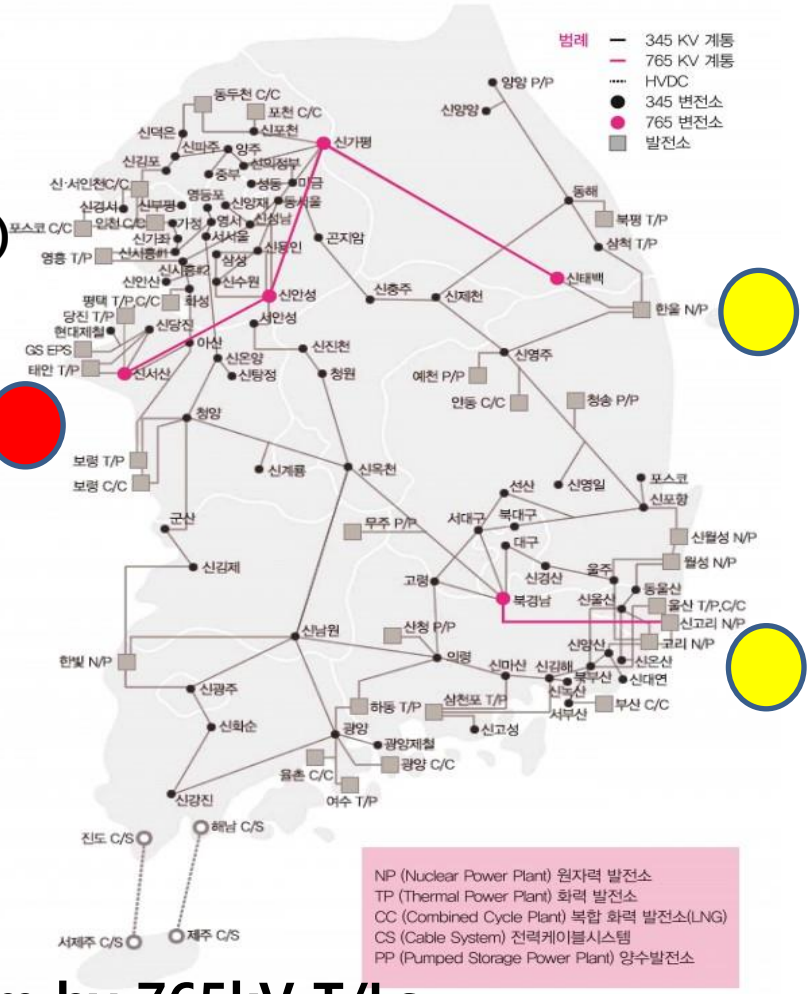
※ Source : Korea Power Exchange (2016)

➔ Increase System Resilience by Off-grid Operation (Only 4%)

Transmission Issues Related with Grid Resilience

- **Heavy Reliance on 765kV & 345kV T/Ls for Seoul-metro Energy Transfer**
  - **(N-2) Contingency Standard for Trunk Lines (Isolated System)**
  - **SPS Installation for Nuclear/Coal Plants & Load-shedding in Load Centers (KERI)**

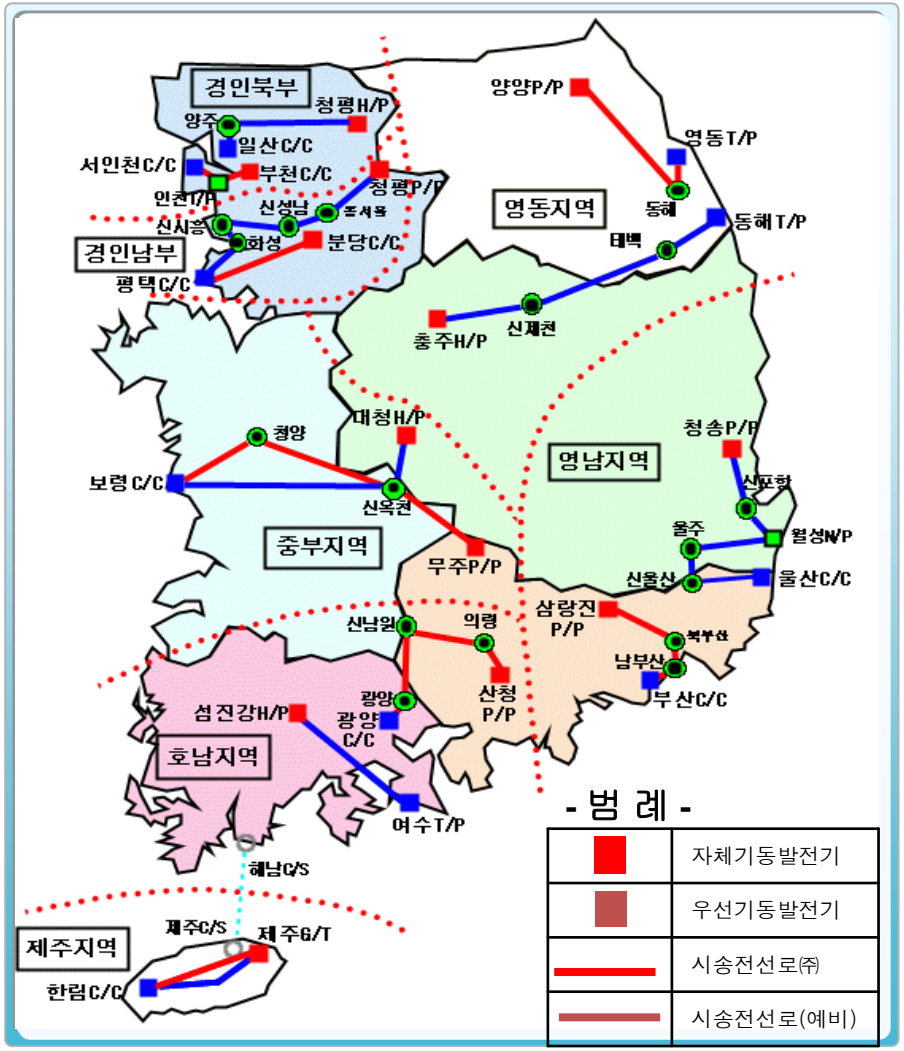


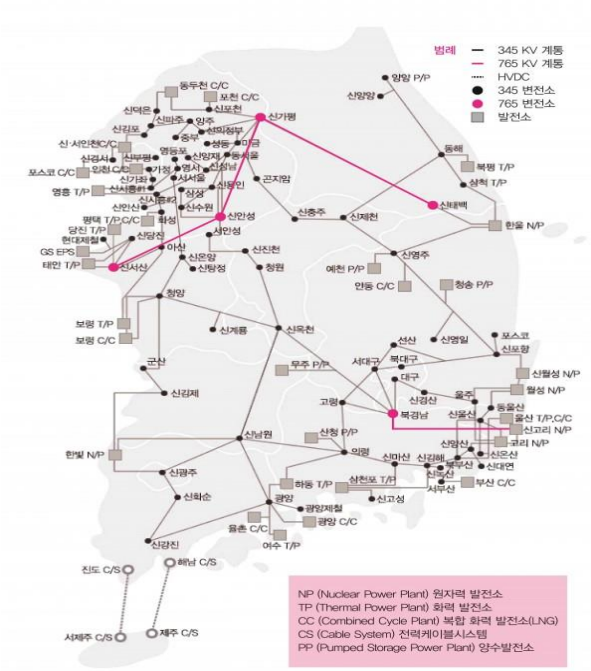


➔ **Transmission Resilience Problem by 765kV T/Ls**

System Issues Related with Grid Resilience

- **Black-start Problem in Some Areas Due to High Portion of Nuclear and Coal**





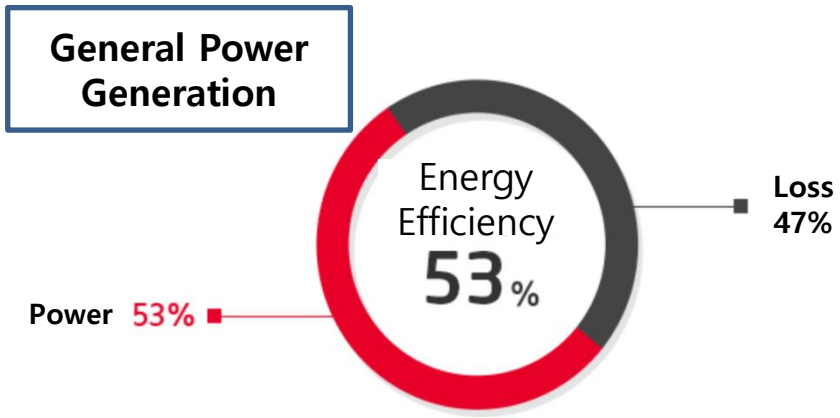
Restoration Time

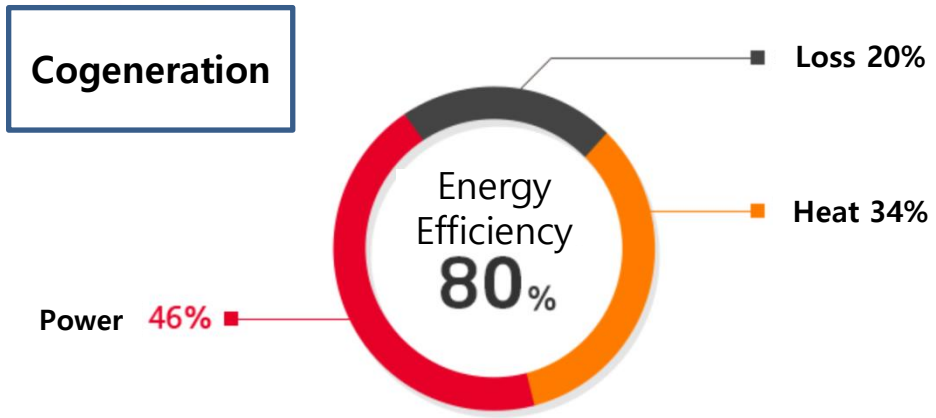
- 1st Generators : 2 Hrs
- Start Source Supply for all Generators : 4Hrs
- 80% of Load Restoration : 24Hrs

Benefits of CHPs in Power System Resilience (1)

- **CCGT-based CHP Characteristics**

GT Gas Turbine	HRSG Heat Recovery Steam Generator	ST Steam Turbine
Generation by gas expansion	Recovery of waste heat to produce steam	Generation by steam expansion

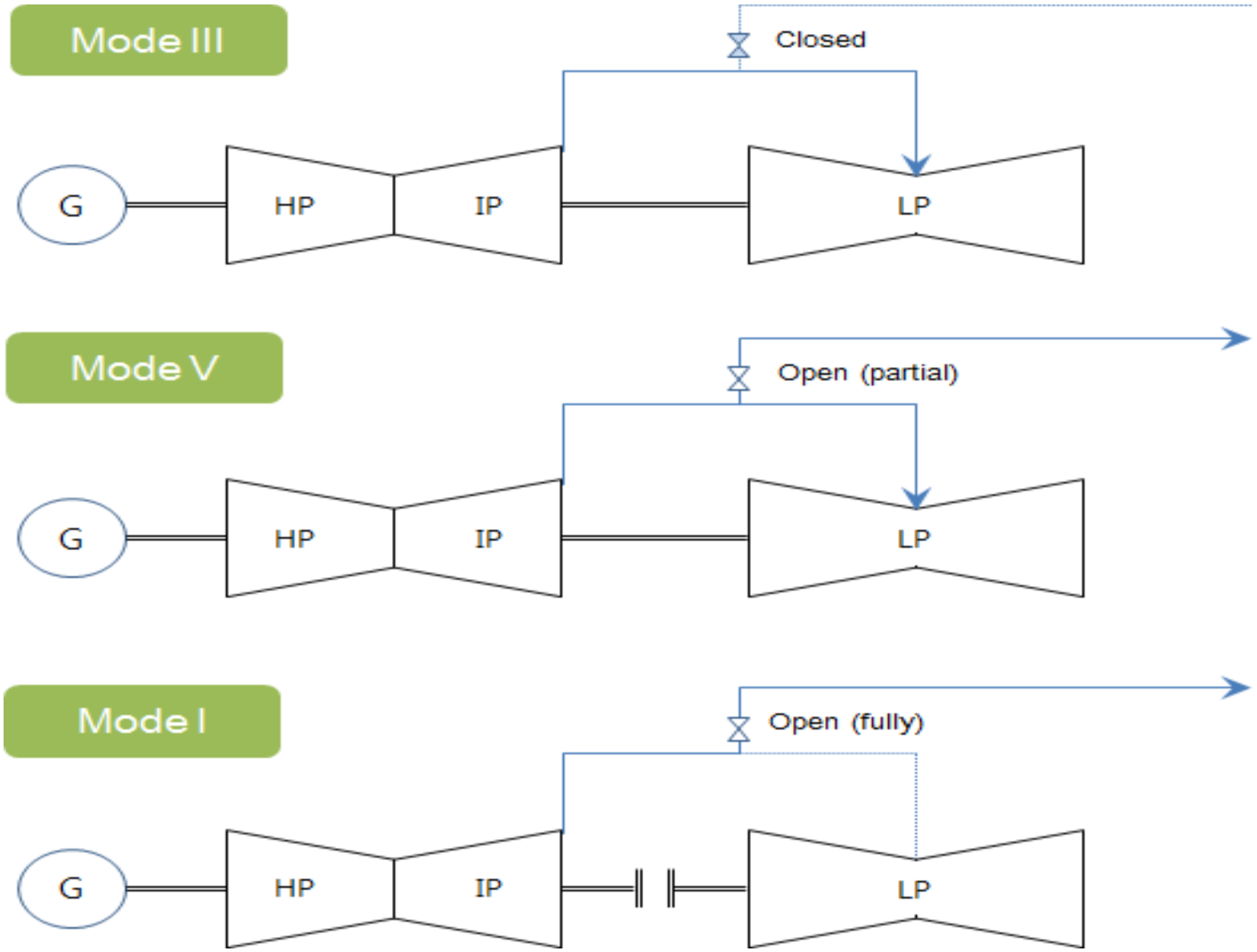




* Reference : https://www.skens.com

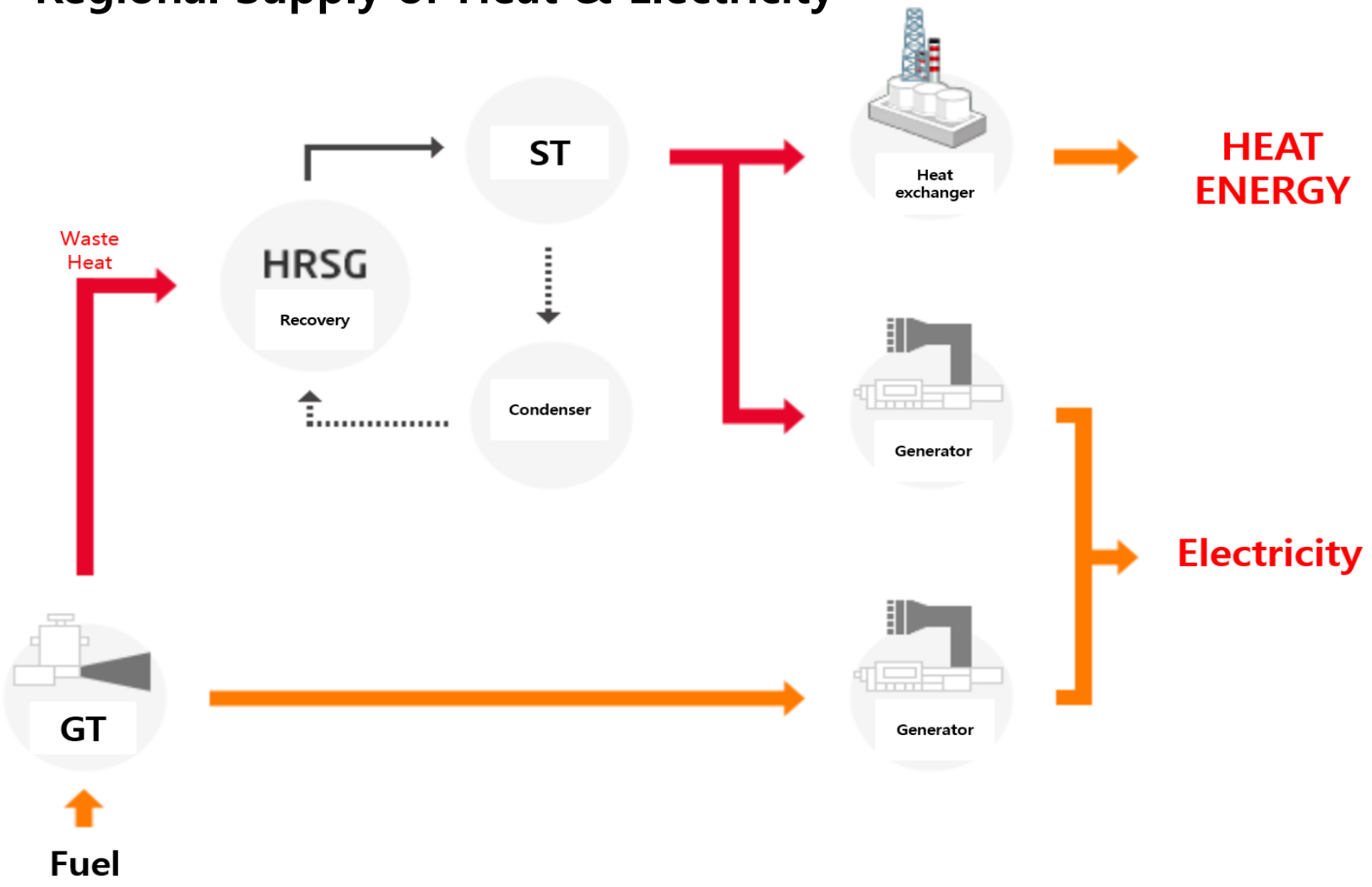
Benefits of CHPs in Power System Resilience (2)

- **Operational Flexibility (Heat & Electricity)**



Benefits of CHPs in Power System Resilience (3)

- Regional Supply of Heat & Electricity



Future Plan & Suggestions

DER Expansion Plan in 8th EPBP

- **Outlook of Long-term DER supply [TWh]**

Type			2017	2022	2030	2031
Annual Amount of DER Generation (TWh)	Renewable(for business)		12.2	27.3	59.3	61.8(9.4%)
	Self-generation	Renewable	13.9	14.9	17.1	17.1(2.6%)
		others	7.3	7.3	7.3	7.3 (1.1%)
	District Heating/Cooling Business		31.0	37.3	37.3	37.3(5.6%)
	Total		64.4	86.7	120.9	123.4
Share of DER			**11.2%**	**13.8%**	**18.4%**	**18.7%**

Source : The 8th Basic Plan of Long-term Electricity Supply and Demand in Korea (2017 ~2031)

- **More Active Support on the Future National Energy Plan**
- **Positive Impact on System Resilience**

National Energy/Electricity Policy Changes for Resilience

- **Traditional Planning and Operational Scheme**

  - Least-cost Operation and Planning with Reliability Constraints

- **Present Planning and Operational Scheme**

  - Least-cost Operation and Planning with Reliability, Safety, Environmental Constraints

- **Future Planning and Operational Scheme**

  - Least-cost Operation and Planning with Reliability, Resilience, Safety, Environmental Constraints (DERs can be added)

- **How to determine the resilience standards and index in each power system just like as reliability standards?**