Challenges for the Power Industry and KPX's Initiatives Towards Net Zero

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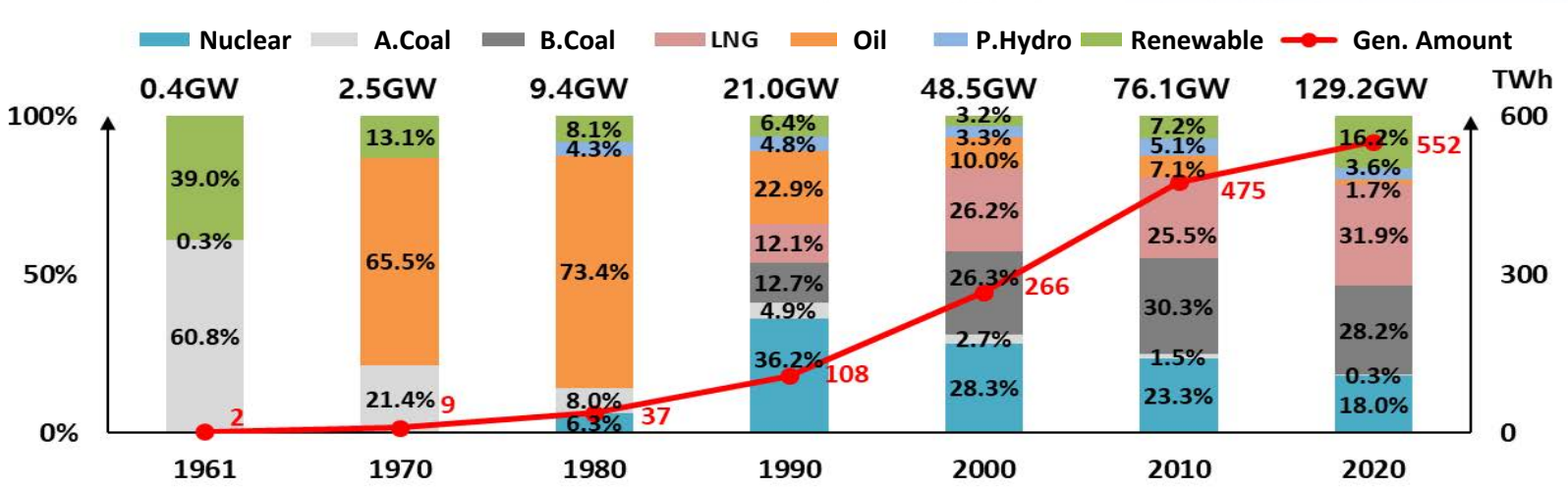
1. Advances in the Korean Power Industry

Korea's Generation Mix

- 1960~1970's : Mainly domestic coal & oil
- 1980's : Expand nuclear & coal * Oil shocks in 1973 & 1979 (Price 13.1x↑) → Oil phase-out policy
  → First nuclear (Kori #1, 1978) & bituminous coal (Samcheonpo #1, 1983) plants built
- 1990's : Rapid LNG expansion * Demand spike (e.g. 1988 Olympics) → Rapid additions near load centers
  → Seoincheon CC (1992), Anyang/Bundang/Ilsan/Bucheon CC (1993) built
- 2000~2010's : Nuclear-Coal-LNG balance (Portfolio) + Eco-friendliness (Climate)
- 2020's~Future : Rise of carbon-free focused energy transition

〈 Generation Mix Trends〉



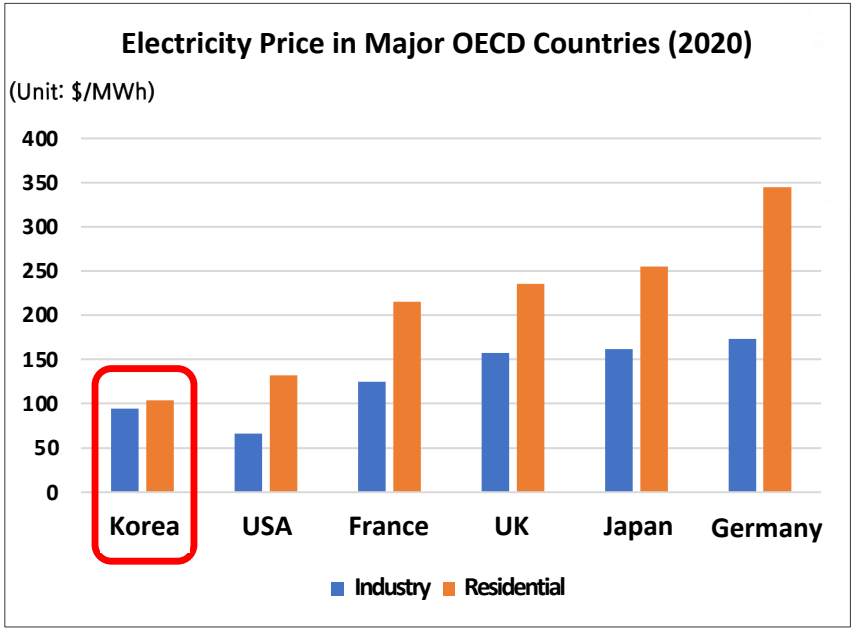
Low Price & High Quality

Korea provides low priced, high quality electricity stably

① **Low Price** : Kept prices low compared to other major countries

② **High Quality** : World-class frequency & voltage maintenance levels

③ **Stable** : One of the world's lowest per-customer outage time



* Source: KEPCO

Year	Freq. Maint. (%)	Volt. Maint. (%)
2002	99.45	99.88
2005	99.99	99.96
2010	100.00	99.99
2015	100.00	99.99
2020	100.00	99.99

* Source: KPX

Country	Per-Customer Outage (min/yr)	Country	Per-Customer Outage (min/yr)
Korea	8.9 (2020)	France	48.7 (2016)
USA	53.2 (2018)	UK	38.4 (2016)
Japan	7.0 (2017)	Italy	94.0 (2017)

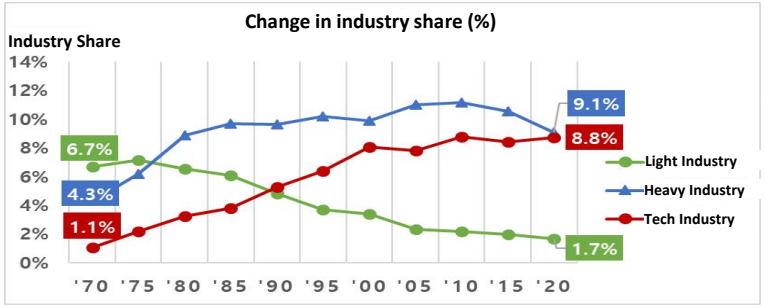
* Source: KEPCO

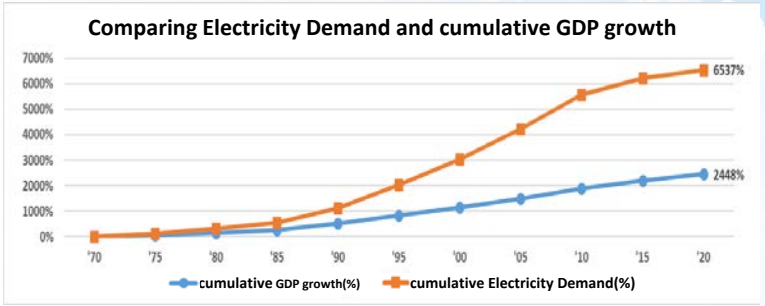
Power Industry's Economic Contributions

Advancement of industrial structure

- From low added value light industries → Provided basis for transitioning to high added value tech & heavy industries

  In 50 years (1970~2020), GDP grew 25-fold and electricity demand rose by 66 times

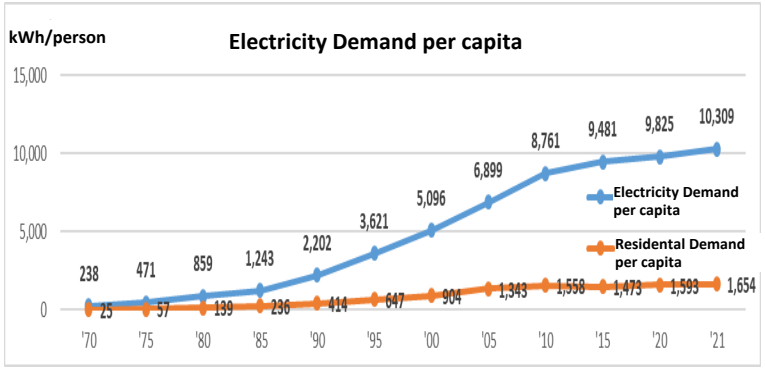


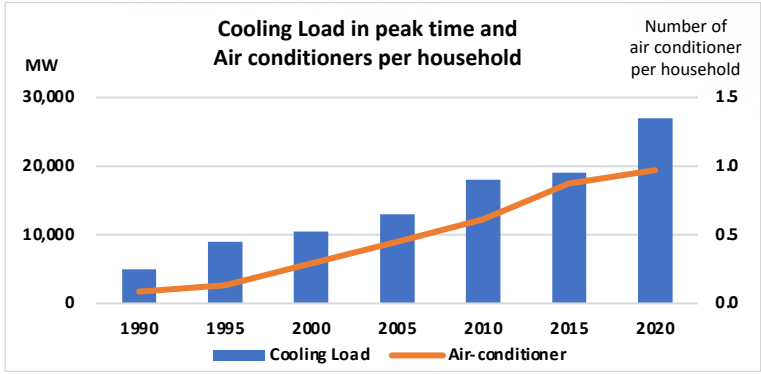


* Sources : Bank of Korea, KEPCO

Enhancement of people's quality of life

- Compared to 1970, per capita electricity demand in 2020 rose by 43x, with residential demand by 67x





* Sources : KEPCO, KPX

Factors in Korean Power Industry's Success

(Gov't) Set up & pursue consistent, persistent energy policies

- Create legislative structure for stable electricity supply - EUA, EPS DPA
- Enact proactive laws with stability & economy in mind - 5-year EPS development plan, BPLESD
- Actively promote local development & production of power equipment
  * Electric Utility Act / Electric Power Source Development Promotion Act / Basic Plan for Long-term Electricity Supply and Demand

(Industry) React timely to changing industrial environment

- Big nuclear & coal investments in cheap oil era of 80's built basis for low electricity price
- Standardization & mass adoption of nuclear & coal plants saved build costs
- Single-company structure until 90's enabled rapid expansion during demand spikes
- Restructuring since early 2000's boosted private investments in power industry

(People) Support & cooperate with national energy policies

- Eager cooperation for building generation/transmission/distribution
  * Residential customers : (1961) 770,000 → (1990) 8,400,000 → (2020) 15,610,000
- Active participation in national energy conservation policies
  * Consumer price inflation 1990~2020 : 160%, Electricity price increase 1990~2020 : 29%

2. Korea's Net Zero Efforts

Korea's Net Zero Efforts So Far

Historical efforts to reduce greenhouse gases

- (Nov. '09) Set 'Mid-term (2020) Goals for National GHG Reduction' ⇒ 30% reduction from 2020 BAU
- (Dec. '09) Legislate 'Basic Act on Low Carbon Green Growth'
- (Jun. '15) First to set 2030 NDC for the Paris Agreement ⇒ 37% reduction from 2030 BAU
- (Dec. '20) Announce 'Amended 2030 NDC', submit to UN ⇒ 24.4% reduction by 2030 from 2017 results
- (Aug. '21) Legislate 'Framework Act on Carbon Neutrality and Green Growth to Confront Climate Crisis'
- (Oct. '21) Announce '2050 Net Zero Scenario' & 'Increased 2030 NDC' ⇒ 40% red. by 2030 from 2018 results

Meaning of legislating the Framework Act on Carbon Neutrality

- 14th country to legislate 2050 net zero vision & implementation
- Set mid-level goal towards realistic net zero (legislating 35+% reduction by 2030 from 2018 results)
- Get realistic policy tools for implementing net zero (GHG reduction measures, Climate Crisis Fund)

Korea's Net Zero Goals (1) : 2050 Net Zero Scenario

2050 net zero goals

- Two scenarios to get domestic net emission (emission-capture) to zero announced
  - * (A) Maximize emission reduction - stop thermal power, produce hydrogen from 100% electrolysis, etc.
  - * (B) Expand CCUS as emissions rise - retain thermal power, produce hydrogen from byproduct & extraction

2050 goals for transition (generation) sector

- Emissions (Million Ton CO_2eq) : (2018) 269.6 → (2050) [Plan A] 0(△100%), [Plan B] 20.7(△92.3%)
- Methods : Sharp reduction of thermal power, expansion of renewables & hydrogen-based power
  - * (A) Stop all thermal power to reduce sector emissions to zero
  - * (B) Retain some thermal power (LNG) to have some emissions left

〈 Generation and Emissions by Sources 〉

(Unit : TWh)

Type		Nuclear	Coal	LNG	Renew.	Fuel Cell	Asian Grid	No-Carbon Gas Turbine	Byproduct Gas, etc.	Total	Emissions (Million Ton)
Transition	A	76.9	0.0	0.0	889.8	17.1	0.0	270.0	3.9	1,257.7	0
		(6.1%)	(0.0%)	(0.0%)	(70.8%)	(1.4%)	(0.0%)	(21.5%)	(0.3%)	(100%)	
	B	86.9	0.0	61.0	736.0	121.4	33.1	166.5	3.9	1,208.8	20.7
		(7.2%)	(0.0%)	(5.0%)	(60.9%)	(10.1%)	(2.7%)	(13.8%)	(0.3%)	(100%)	

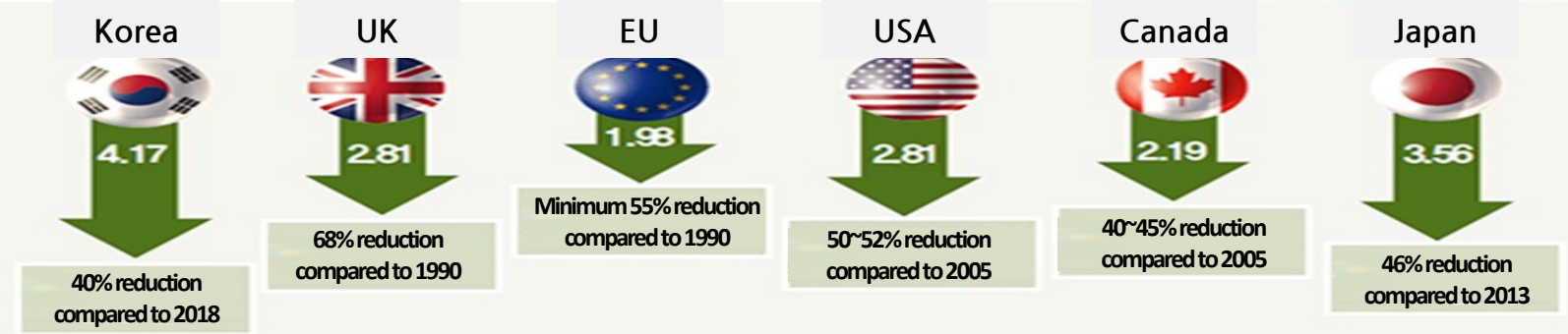
* Source : 2050 Net Zero Scenario (Oct. 2021)

Korea's Net Zero Goals (2) : Increased 2030 NDC

2030 - Nationwide

- Emissions (Million Ton CO_2eq) : (2018) 727.6 → (2030) 436.6 (△40%)
- Levels : Speed of reduction is one of world's fastest

< Yearly Average Reduction Goals by Major Countries (%/Year) >



2030 - Transition (generation) sector

- Emissions (Million Ton CO_2eq) : (2018) 269.6 → (2030) 149.9 (△44.4%)
- Methods : Reduce coal & LNG, expand renewables - use eco-friendly & no-carbon sources

Type	Nuclear	Coal	LNG	Renew.	Ammonia	P.H. & Others	Total
Results (2018)[1)]	23.4%	41.9%	26.8%	6.2%	-	1.7%	100%
Prev. Gov't (2030)[2)]	23.9%	21.8%	19.5%	30.2%	3.6%	1.0%	100%
New Gov't (2030)	Considering generation mix that balances nuclear & renewables						

* Sources : 1) KEPCO, 2) Increased 2030 NDC (Oct. 2021)

Evaluating Korea's Net Zero Goals

Aggressive goals that consider importance & urgency of net zero

- **Necessity** — Minimize damages from climate abnormalities, confront climate crisis as a responsible member of int'l community, maintain national competitiveness with timely actions
- **Aggressiveness** — Manufacturing-heavy industry structure considering GDP, short time from peak emissions to net zero, higher rate of reduction than major countries

⇒ Hard goals under local circumstances, but recognizes need for net zero to solve climate crisis

Worries about the process towards net zero

- **Economy & Industry** — Increased cost to companies & lowered GDP have economic impacts
- **Energy** — Renewables-heavy generation mix (70%) & reliance on imported hydrogen (80%)
- **Environment** — Reliance on unproven future tech (e.g. CCUS, hydrogen turbine)
- **Labor** — Needs to deal with job stability & transition due to changing industry structure

⇒ Necessity of net zero is agreed upon, but opinions diverge on the speed & method

New Government's Power Industry Policy Directions

New Government's Policy Roadmap for the Power Industry

Proactively Use Nuclear Power	· Proactively use nuclear power as means for energy security & net zero · Resume Sinhanul #3,4 construction & continue operating expired NPP
Adjust the Energy Mix	· Rationally adjust energy mix, balancing between nuclear & renewables · Amend NDC achievement process for energy, industry, and transport
Create New Energy Industries	· Elevate PV & wind industries, foster new industries linked to 4th Ind. Rev. · Build clean hydrogen production-supply infrastructure for world #1 hydrogen industry
Establish Rational Electricity Market	· Enhance independence & professionalism of market, rate, and regulatory governance · Establish electricity market based on competition & market principles
Secure Next Generation Nuclear Technologies	· Develop indigenous SMR design, link hydrogen production to fusion/fission · Invest R&D to secure future nuclear reactor technology
Reduce Fine Dust	· Optimize energy mix to reduce coal+LNG proportion (40% range in 2027) · Promote BEV & FCEV adoption, find ways to reduce charging costs

* Source: Roadmap of 110 Major Policies for Yoon Administration (May 2022)

3. Challenges in the Net Zero Era

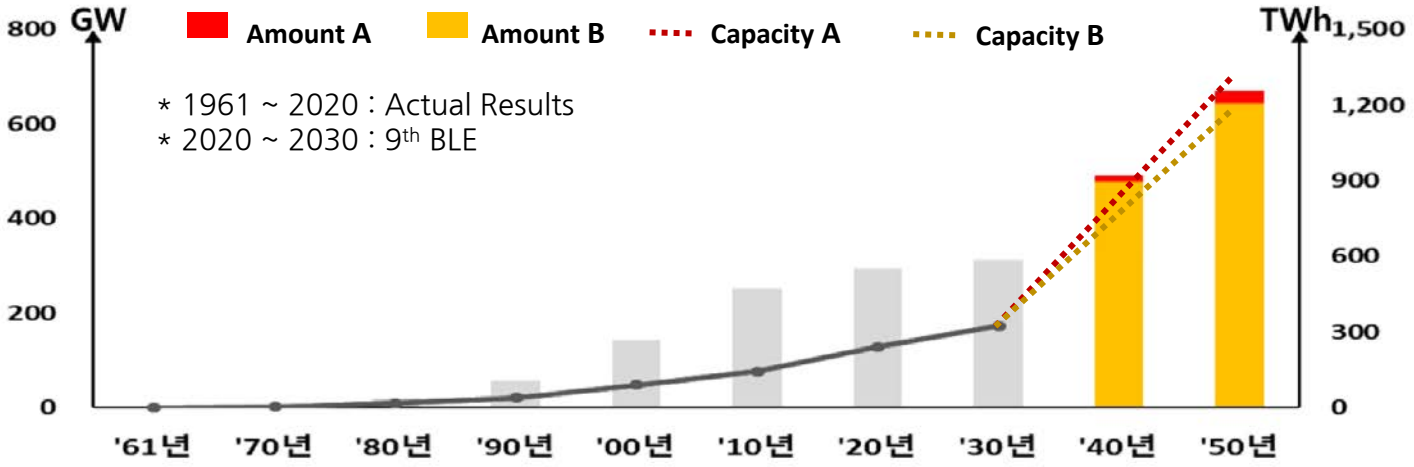
(For the Power Industry)

Challenges : ① Electrification of Energy Use

- (Past) Slow electrification based on econ. development, quality of life, & energy price
- (Future) Rapid electrification of other sectors to achieve net zero in short time (2022-2050)

* (Ex.) EV's proportion of power demand in 2050 to be 14~24% (KPX-Bloomberg Joint Seminar, Nov. 10, 2021)

⇒ Domestic demand in 2050 (1,209~1,258TWh) to be 2.2~2.3 times that of 2020 (552TWh)
Much of the increase comes from electrification demand



Challenges : ② Diversification of Power Sources

(Past) Slow change to main source based on econ. develop., tech advances, & oil price

1960's	1970's	1980's	1990-
Anthracite Coal	Oil	Nuclear, Coal, Oil	Nuclear, Coal, LNG

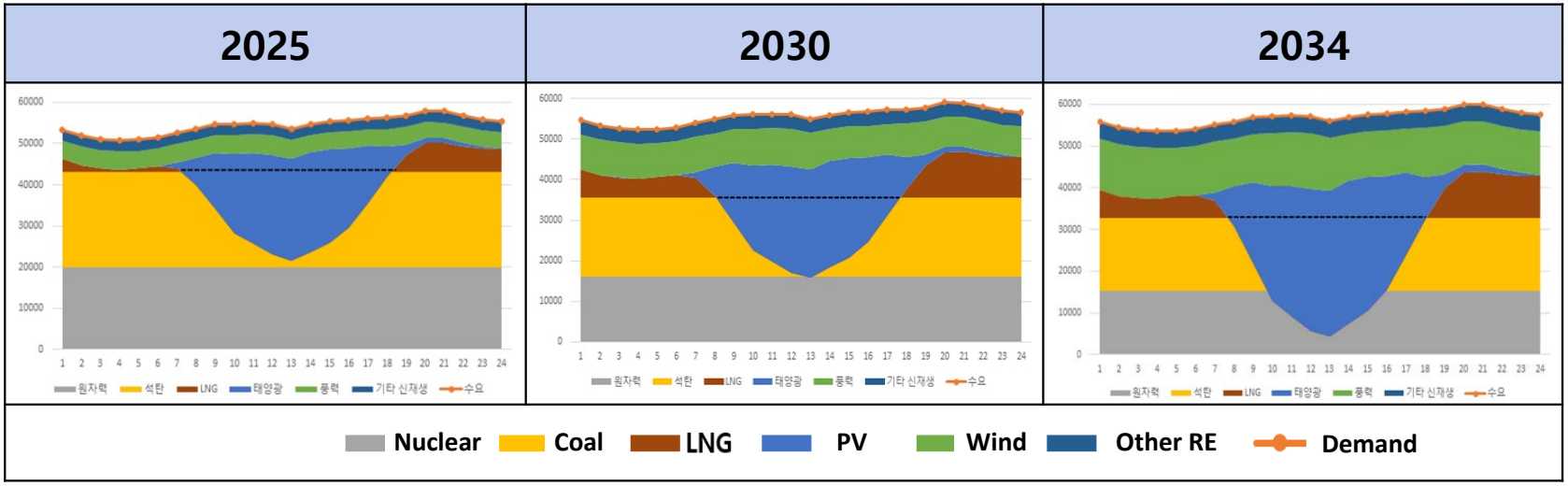
(Future) Existing coal power rapidly replaced to no-carbon sources (PV, wind, hydrogen) to achieve net zero in short time (2022-2050)

⇒ Demand for electrification in other sectors & current low utilization of RE mean that installed capacity in 2050 may be over 5 times that of 2020 (129GW)

Features	Past (1961-2020)	Future (2020-2050)
Capacity	About 130GW added (in 60 years)	More than 500GW (5x) added (30y)
Sources	Progressive changes to main source (A.Coal→Oil→Nuclear→B.Coal →LNG)	Focused in renewable energy (PV, wind)
Auxiliaries	Unnecessary	Energy Storage (ESS, P. Hydro, H_2)

Challenges : ③ Intensification of RE Variability

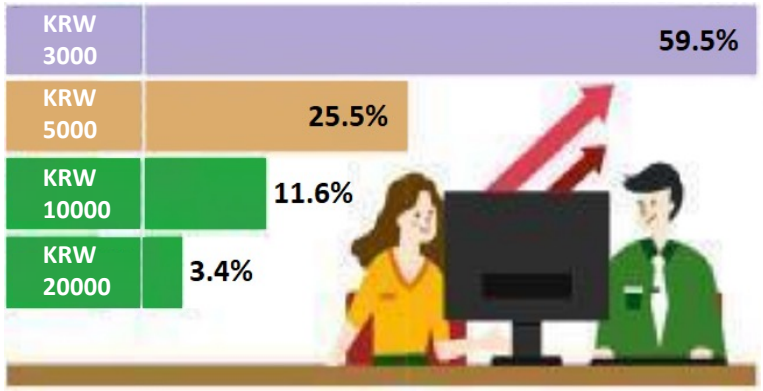
- (Past) RE's proportion in the mix is small, and consist mostly of hydro power with easily adjusted output ⇒ **No RE variability problem**
- (Future) RE such as PV & wind are projected to rise rapidly ⇒ RE variability problem to intensify with weather conditions
  - Significant daytime PV generation leads to supplying in excess of demand
    Solar, wind changes exceeding prediction causes power excess or shortage



Challenges : ④ Supplying Stable, Economic, HQ Electricity

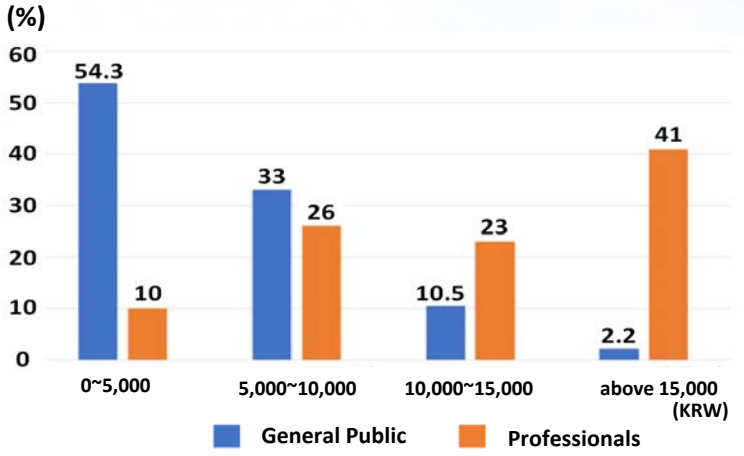
- Future expectation (goal) is still supplying high quality electricity stably at reasonable price
  - Electricity backs the success of 4th Industrial Revolution & is necessary for improving quality of life, as well as being the driver towards net zero society
  - Price hike needed for net zero (e.g. to expand RE) is poorly accepted by citizens

< Reasonable E. Price Increase for Energy Transition >



Source: Electric News & RealMeter (Dec. 2018)

< Acceptable E. Price Increase Range for Net Zero >



Source : Climate Change Center & KEI (Dec. 2021)

4. KPX's Initiatives for Net Zero Goals

Net Zero and KPX's Roles

Main Duties of KPX	KPX's Roles for Achieving Net Zero
Establish Basic Long-term Supply-Demand Plan	· **Establish Basic Plan that expands no-carbon sources** · Set optimal energy mix that is feasible & economical · Include energy storage plans for supporting no-carbon sources
Operate Electric Power System	· **Improve system operation to better suit nuclear & RE** · Make operational flexibility plans for supply stability · Transmission-distribution cooperation to optimize grid operation
Operate Electricity Market	· **Drive new investment & system flexibility thru market innovation** · Set up new markets to entice participation of new, future sources · Revise compensation structure for supply stability

KPX's Actions : ① Reconfigure Energy Mix

Supply structure changes in fossil fuel era

- (Main Source Shift) A.Coal → Oil → Nuclear → B.Coal → LNG in gradual steps

  ⇒ **Output is certain and controllable - economic generators are operated in response to demand changes (load-follow)**

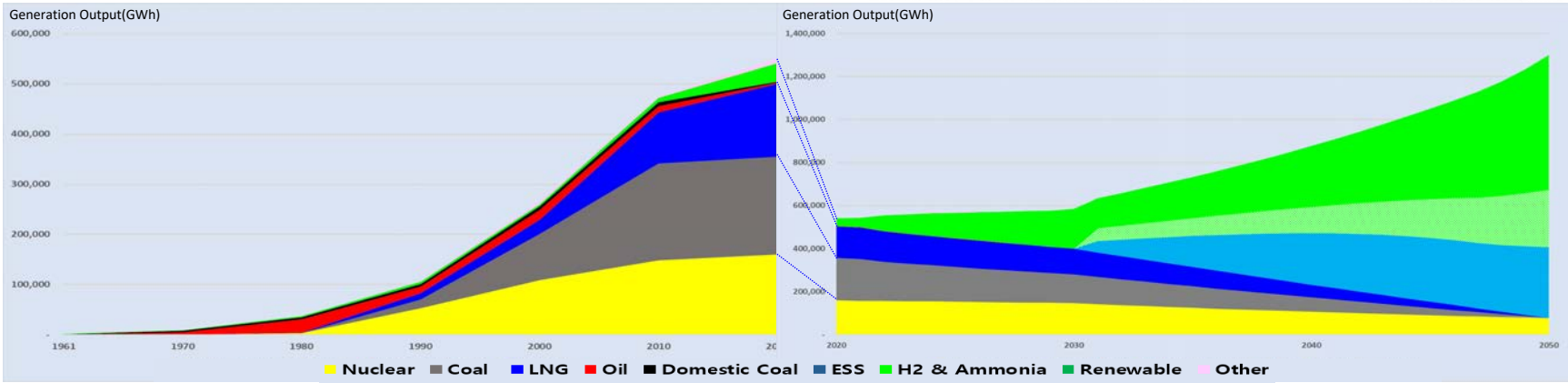
Reconfiguring supply structure in net zero era

- (Main Source Shift) Reduce traditional sources → rapidly replaced with no-carbon sources (RE, H_2)

  ⇒ **Evaluate nuclear-RE proportion & mix with cost, competitiveness in mind**

- (Plan for RE Variability) Make use of storage (ESS, H_2 e, H_2 CC, Gravity Generator)

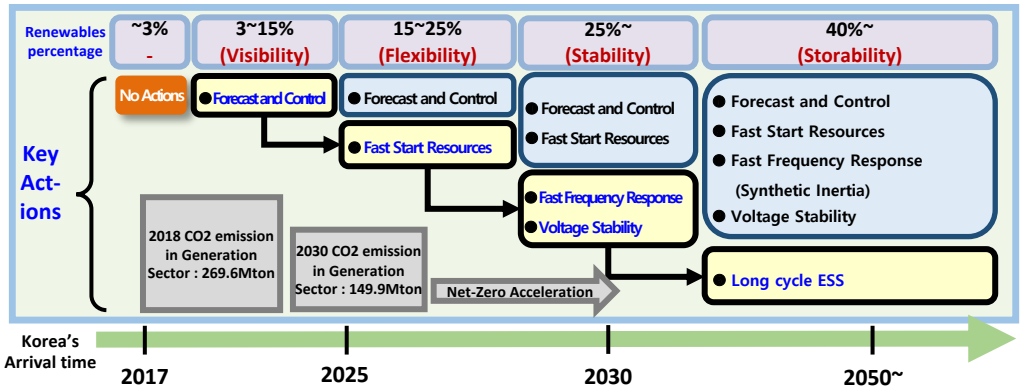
  ⇒ **Considering RE's variability & uncontrollability, respond to both demand & supply (of RE) to focus on stable generator operation (load-follow + gen.-follow)**



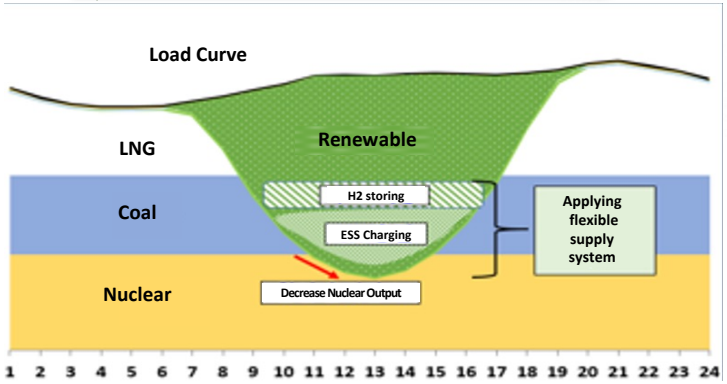
KPX's Actions : ② Improve System Operation

- Proactively secure more flexible supplies - flexible nuclear tech, STATCOM, etc.
  - Apply scheduled load following to large nuclear & consider using SMR tech
  - Reuse soon-to-retire aging thermal generators for use as STATCOM
- Improve system operation standards to better suit nuclear & RE centric mix
  - **Re-establish standards for freq. maintenance & reserve operation, and optimize gen. maintenance**
- Reinforce transmission lines and optimize transmission-distribution operation
  - Make transmission reinforcement plans based on regional RE location & power flow
  - Set up cooperative environment between TSO and DSO

Actions for Each RE Adoption Level

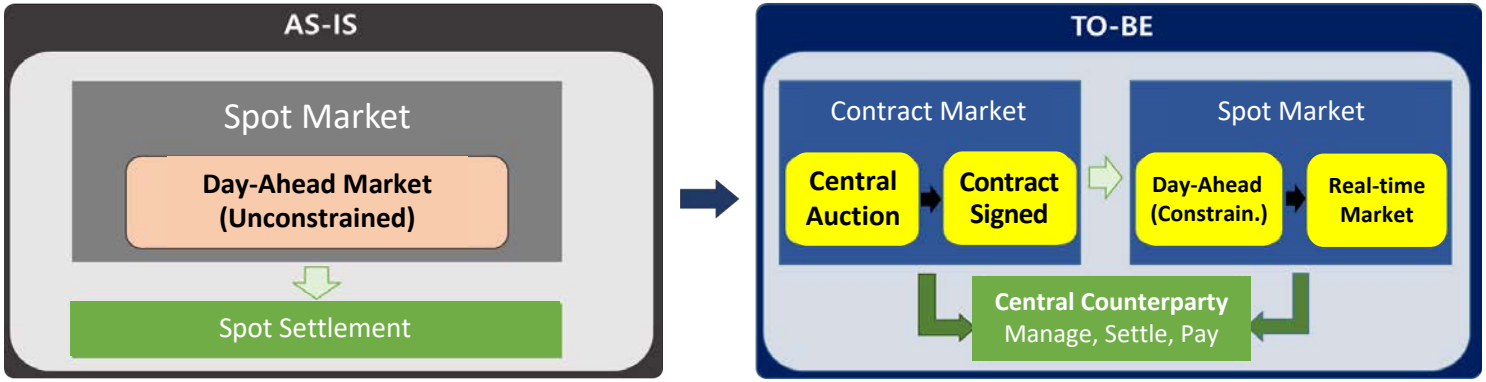


Flexible Supply Operation



KPX's Actions : ③ Improve Market Structure

- **To ① reconfigure energy mix & ② improve system operation, dramatic changes to market compensation system need to come first**
- **Plan : Spot (day-ahead) → Contract (central auction) + Spot (real-time)**
  - Low-carbon contract market : set up central contract market for new low-carbon sources to join in
    * New low-carbon source examples : ESS, hydrogen generation, CCS, new AS
  - Price-bidding : In place of rigid cost evaluation (CBP), price bidding (PBP) is used to allow more autonomy of participants and enhance market price function
  - Real-time & AS markets : Using near real-time trading to cost-effectively & efficiently solve RE variability problem ☞ market price reflects real-time supply-demand condition
  - Vitalize demand resource market : Expand participation of new DR such as Citizen DR, Fast DR, and Plus DR to manage variability & increase utility of RE




Thank You
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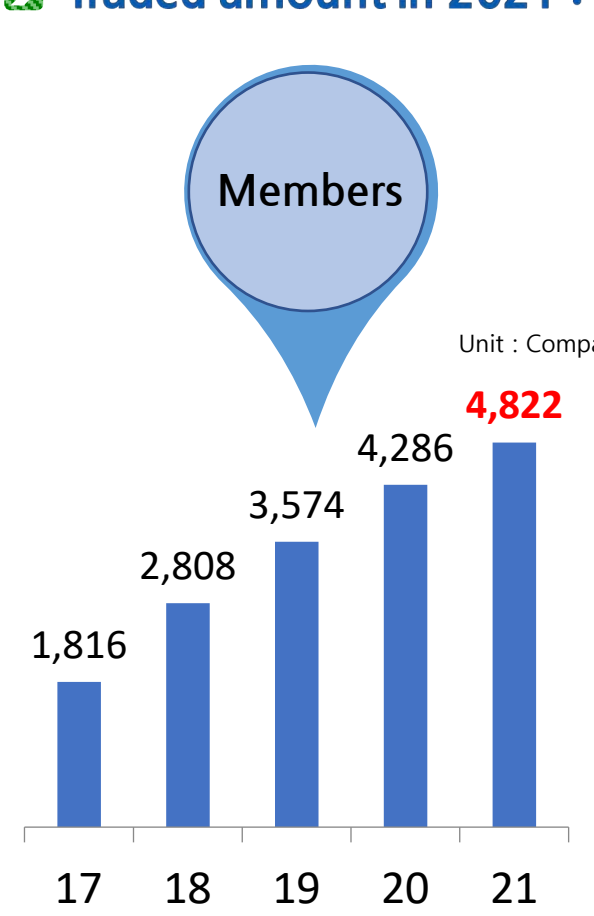
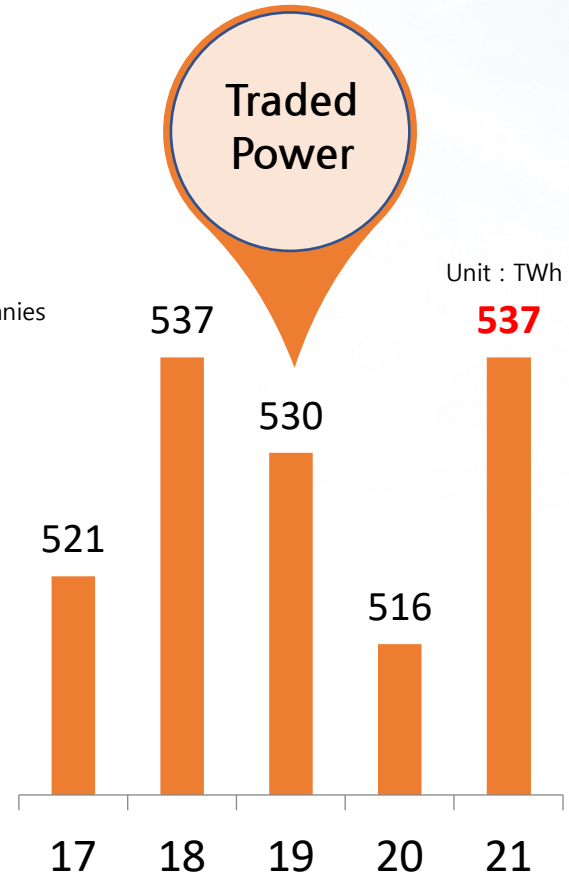
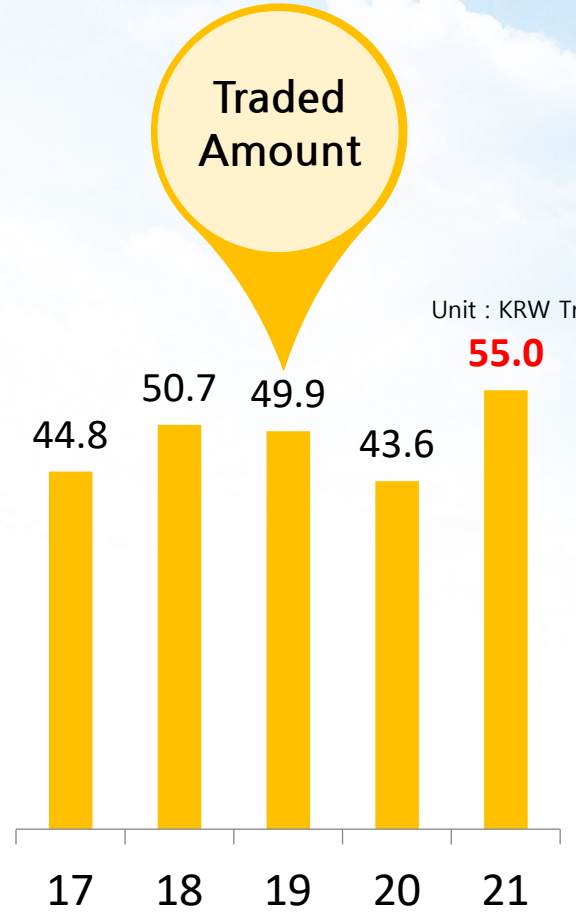
[Ref] Wholesale Market Operation Trends

- Number of members in 2021 : 4,822 (Rapid rise of RE companies)
- Traded power in 2021 : 537 TWh
- Traded amount in 2021 : KRW 55.0 Trillion



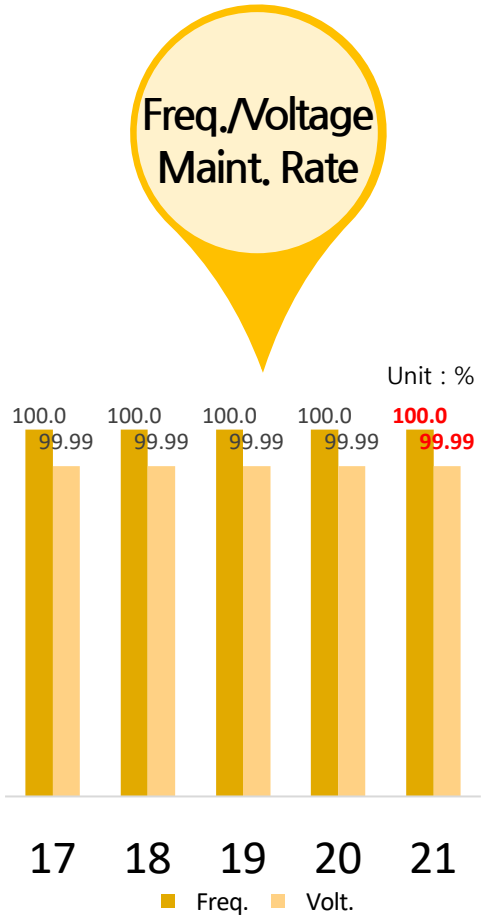


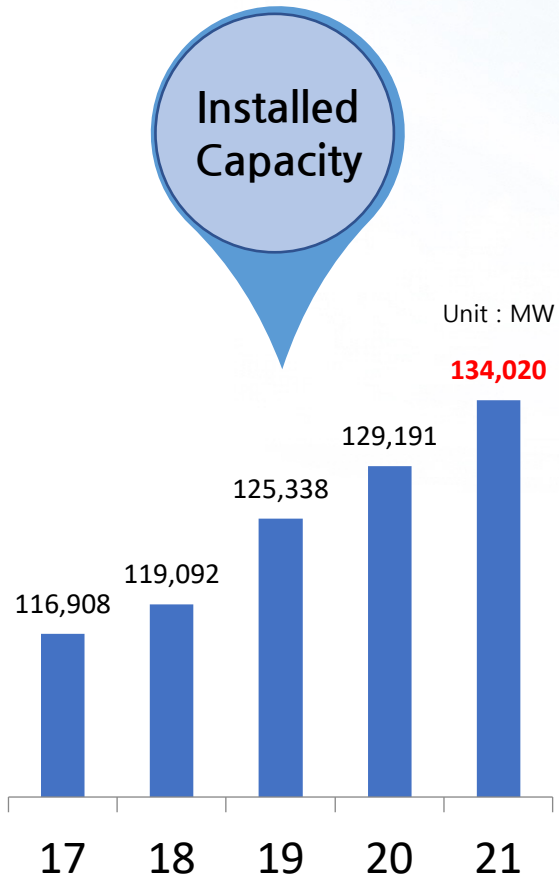


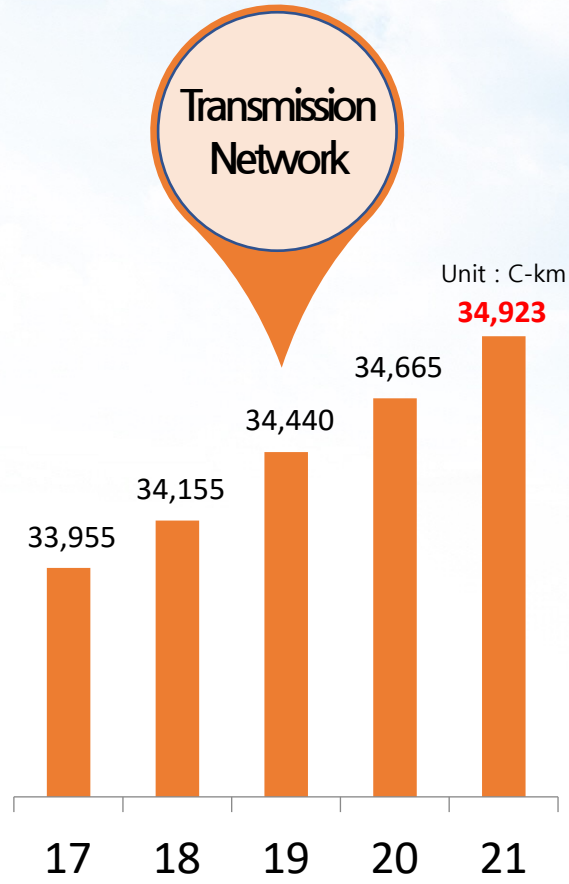
※ As of Dec. 2021

[Ref] Power System Operation Trends

- Maintenance rate in 2021 : Frequency 100.00% / Voltage 99.99%
- Installed capacity in 2021 : 134,020 MW
- Transmission network in 2021 : 34,923 C-km







※ As of Dec. 2021