South Korea’s Experiences with Green Energy Transition

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Speaker: TAEIL KANG

- CEO and Chief Consultant, One Energy Island Co., Ltd., specialized in design and development of renewable energy distributed power systems
- (Former) Managing Director, Renewable Energy Business Division, KC Cottrell Co., Ltd., (www.kc-cottrell.com)
- (Former) CEO, KC-INVALL Co., Ltd., a Korean-Spanish JV specialized in wind power project development
- (Former) Chair of International Collaboration Committee, Korea Solar Photovoltaic Industry Association
- (Former) A member of board of Asia Solar Energy Forum
- Experiences:

(Utility scale RE project)

- Development, construction, and operation of more than 50MW solar PV projects including two solar PV power systems in global automaker's factories: 20MW solar PV system on parking yard and factory roof-tops at Renault Samsung Korea, and 6MW solar PV system on factory roof-tops at General Motors Korea
- Completion of a pre-feasibility study for development of a 100MW solar PV park in Cambodia. The pre-FS was funded and supported by the Korean government and ADB
- Completion of early-stage development of a 20MW wind power project in mountain area in South Korea

(Power grid optimization with BESS in power system environment with high share of renewable energy)

- Study of power grid optimization and stabilization using BESS at San Cristobal Island, Galapagos, Ecuador, hired by Korea Exim-bank, and Inter American Development Bank
- Study of integration and optimization of solar PV and wind power systems with BESS at Santacruz and Baltra Islands, Galapagos, Ecuador, hired by Korea Energy Agency and Inter American Development Bank

(Renewable energy microgrids in remote communities)

- Engineering design of solar PV, ESS, and diesel hybrid power system in Pitcairn island, Pacific, hired by The Pacific Community
- Design study of 2.5MW solar PV and 10MWh BESS power system at Manaung Island, Myanmar, hired by KOICA (Korea International Cooperation Agency)
- Design of solar PV and BESS microgrid project at village of Almirante Latorre, Chile, hired and supported by Korea Energy Agency and Inter-American Development Bank
- Design of solar PV and BESS hybrid electrification systems in 5 remote villages in Amazon forest, Bolivia, hired by Korea Exim-bank
- Design of solar PV, BESS, and diesel hybrid system at Spanish Wells St. George's Cay Power Station, Bahamas
- Design and development of solar PV, BESS and diesel hybrid system at the Peleliu Island, Palau, Pacific
- Design and development of solar PV and BESS microgrid project, Nahao and Navang villages, Khammouane province, Lao PDR

(Policy research)

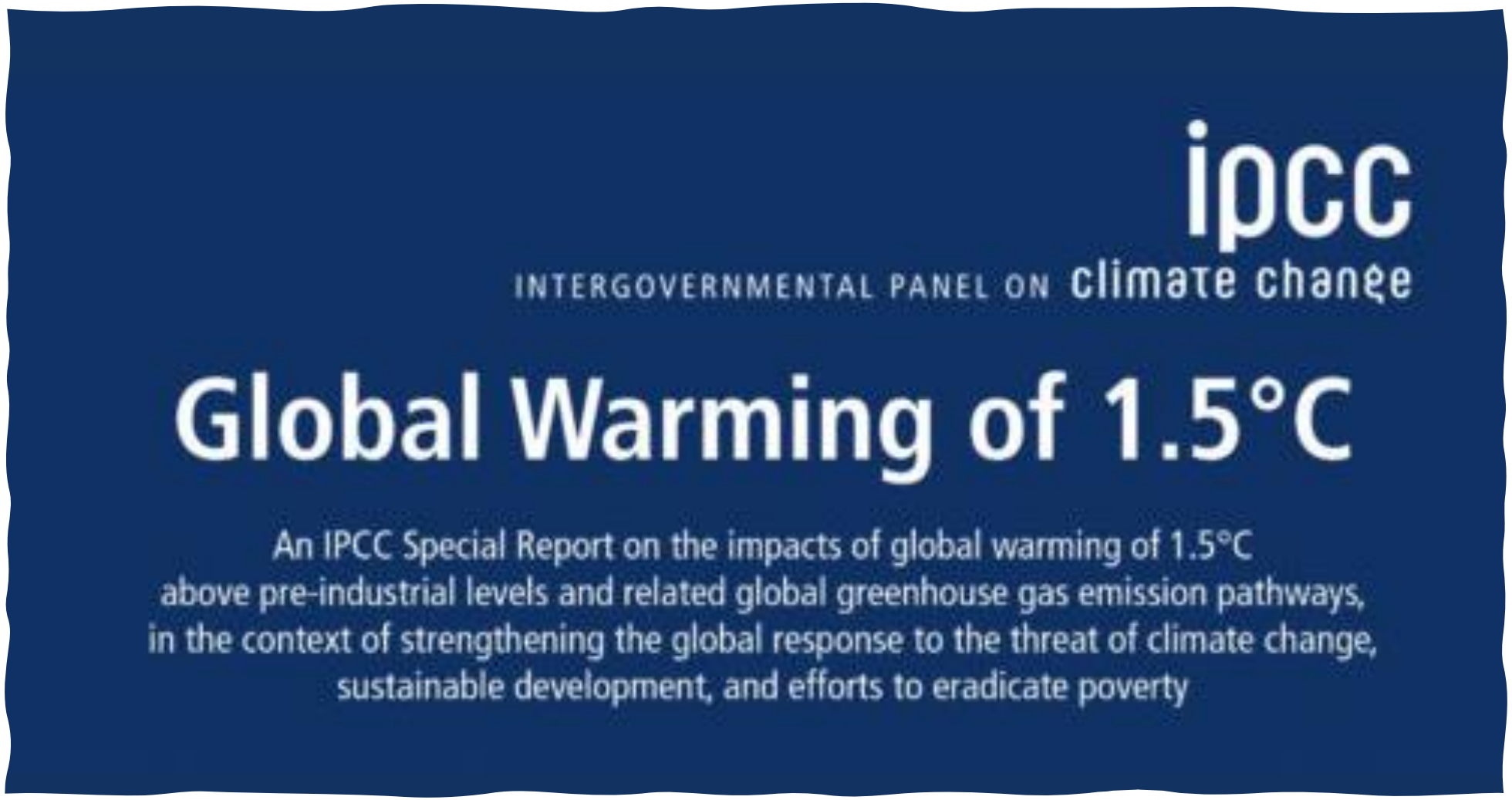
- Korean Experience with Smart Grid Development for Latin America and the Caribbean, Smart Grids, hired by Korea Development Institute and Inter American Development Bank
- Design of sustainable business model for renewable energy mini grids in remote communities in Honduras, hired by Korea Research Foundation
- Design of Sub-regional Renewable Energy Based Mini-grid Programme in the Pacific Island Countries and Territories, hired by United Nations Industrial Development Organization

Content

I.

South Korea’s Experience with Green Energy Transition

What We Share Together with the Global Community



Energy Environment of South Korea

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A High Energy Intensive Economy with Vulnerable Energy Security

- The 8th largest energy consumer in the world
- 84% of its total primary energy supply (TPES) relying on imported energy sources
- Industry shares 55% of the country's total final consumption (TFC), the highest among IEA countries

	Global Rank	Note
TPES*	**8**	282 mil. Ton
Oil Import	**5**	109 mil. Ton
Power Consumption	**7**	544 TWh
CO2 Emission	**7**	589 MtCO2

* Source: International Energy Agency (IEA) 2018 data

Driving Factors for Green Energy Transition

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Need for Paradigm Shift

Respond to climate change

Voluntary goal to reduce green house gas (GHG) emissions by 40% compared to BAU by 2030.

Enhance energy efficiency

Energy efficiency as a key role in carbon emission reduction in the energy dense industry

Create a new growth engine

Need to find a new growth engine for the next generations

2050 Carbon Neutrality Strategy

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- **Achieving Net Carbon Zero by 2050**

- **Reduction of Carbon Emission by 2030**

  - 40% reduction from the year 2018 carbon emission
  - Reduction of CO2 from 727.6 million tons in 2018 to 436.6 million tons in 2030

- **Increase of Renewable Energy in Electricity Generation by 2030**

  - Replace coal-based power generation with renewable energies
  - Share of energy sources in electricity generation

    - Coal: from 41.9% (2021) to 21.8% (2030)

    - Renewable energy sources (solar PV and wind): from 6.2% (2021) to 30.2% (2030)

* New administration reviewing means to achieve goals with possibility of increasing contribution of nuclear energy

Major Achievements in Green Energy Transition

(Renewable Energy)

- **Development of various renewable energy projects** that aimed to utilize available renewable energy resources at scale while overcoming land availability constraint: roof-top solar PV in industrial complex, floating solar PV, and offshore wind power,

(Demand-side optimization)

- **A market-based demand response program for demand-side optimization**: securing 4.3GW demand-side energy sources to meet peak time loads in industrial segment

(Smart grid infrastructure)

- **Power grid stability with increasing renewable energy**: replacement of conventional thermal power plants with ESS which were tied up to frequency regulation purpose
- **2030 Jeju Carbon Free Island**: a showcase of green energy transition with integration of renewable energy and green mobility infrastructures
- **Renewable energy based mini grids** over 20 remote islands: testing technically and economic feasibility of renewable energy mini grids in order to displaces diesel generators

Interim Outcomes of Green Energy Transition

- **Renewable energy contribution not as fast enough**

  - Key hurdles to RE: land availability, local community's receptivity, power grid capacity

- **Various green energy technologies and applications being tested or entered the market**

- **Having shared goals and direction toward green energy transition**

South Korea needs to facilitate green energy transition in order to

- capitalize on its advanced ICT infrastructure in green energy transition and create a new growth engine,
- reduce its dependency on imported fossil energy, and
- achieve carbon emission reduction goal

Issues and Lessons from Green Energy Transition
Need for Paradigm Shift

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➢ Green Energy Transition: A transition that invites;

- Shift from government-driven development to private participation
- Coordination among different stakeholder groups who get impacted in different ways from transition
- Idea for optimal utilization of land which is limited and competing resource

➢ Green New Deal: a new socio-economic platform to align and coordinate interests of various stakeholders into shared goals

- A deal that needs to be agreed upon among different interest groups on each project as well as on the highest level of transition plan

✓ South Korea utilized '*2050 Carbon Neutrality and Green Growth Commission*,' a public and private joint committee as a vehicle to discuss and coordinate among different stakeholder groups, and arrive at shared goals on green energy transition

✓ It is important that the vehicle accommodates and balances interests of various stakeholder groups

Issues and Lessons from Green Energy Transition
Role of Government and Market

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Contributing Factors to Early-stage Green Energy Transition

- Government's initiatives to drive the change
- Active participants from private companies seeking a new business opportunity
- Advanced ICT infrastructure

Issues

- Creation of lively market environment that supports a new business models and new energy ventures is still on its way to advance
- Low electricity tariff and the conventional energy market structure becoming huddle to proving new technologies and new business models in the market

The government initiatives have been proven very effective in the early stage development and commercialization of technologies, but creation of new business is considered to become possible through a market environment that encourages the active participation of entrepreneurs

II.

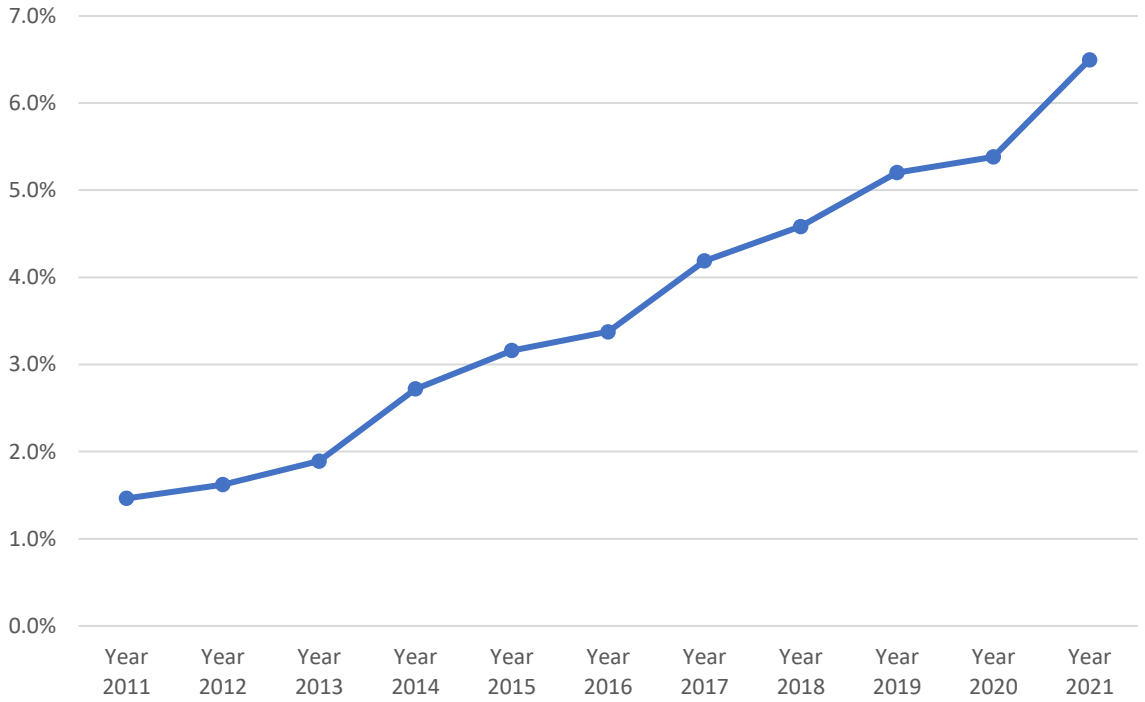
Case Presentation:

Renewable Energy Development at Scale

Share of Renewable Energy in Total Power Generation

- Total electricity generation in 2021 was 601,938GWh
- Renewable energy, mostly solar PV and wind, produced 39,102 GWh of electricity, sharing 6.5% in the total electricity generation
- Hydropower, which was not included in renewable energy category in the statistics, produced 7,148GWh electricity, adding additional 1.2% of clean energy contribution

Trend of New and Renewable Energy Contribution to Electricity Generation



Source: *Annual Electricity Statistics*, Korea Electric Power Corporation

Assessment of Available Renewable Energy Resource

	Solar PV	Wind (On-shore)	Wind (Off-shore)	Hydro	Geothermal	Ocean	Bio
Theoretical availability (GW)	102,455	499	462	28	22,235	438	12
Technical Availability (GW)	2,409	352	387	12	1,256	101	10
Commercial Availability (GW)	369	24	41	3	334	0	0
Installed Capacity (GW, Year 2020)	17.3	1.6	0.1 <	1.8	1.4	0.25	0.18
Resource Utilization (%)	4.7%	6.7%	n.a.	60.0%	0.4%	n.a.	n.a.

Source: *Korea Energy Yearbook 2020*, Korea Energy Agency

- Theoretical availability: total available energy resource measured from the theoretical perspective
- Technical availability: available energy resources within technical constraints
- Commercial availability: available energy resources that fulfill regulatory permits and commercial feasibility

Strategy of Renewable Energy Expansion with Increase of Site Availability

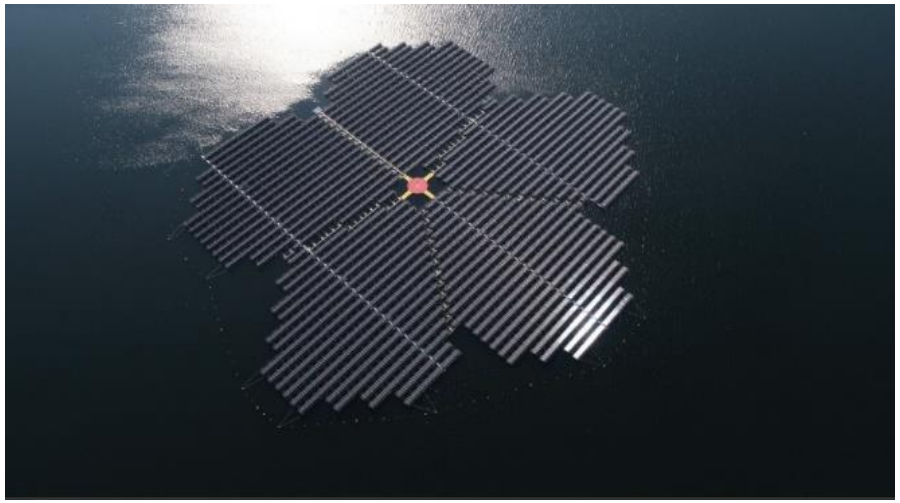
- Renewable power projects siting, particularly for large utility-scale projects, is one of the key barriers to promoting renewable power generation in Korea. Land is scarcity and competing resource in Korea where two third of land is mountainous terrain.
- For wind power, most of mountain hill areas with high wind energy resources are mostly in national parks.
- In order to overcome this challenge, the government encourages use of roof-tops of industrial complexes for roof-top solar PV and lakes and reservoirs for floating solar PV, and development of off-shore wind projects.
- The government grants higher REC (Renewable Energy Credit) for those projects:

Type of Project	Weight of Renewable Energy Credit
Roof-top Solar PV	1.5
Floating Solar PV	1.5
Offshore wind power	2.0 to 3.5 depending on grid-connection condition

Hapcheon Floating Solar PV Project

- the largest floating solar PV system in operation in Souht Korea

- Project location: Hapcheon Reservoir, Gyungsangnamdo province
- Capacity: 40MW
- Operation since 2021. 11.
- Managed by K-water



Tamla Offshore Wind Farm

- the 1st offshore wind power plant built in South Korea and in successful operation

- Project location: Hankyung-myeon, Jeju Island (500 m to 1,200 m off the coast)
- Capacity: 30MW (3MW Doosan Heavy Industry wind turbine * 10 units)
- Operation since 2017 producing 85,000 MWh of wind power annually
- Managed by Korea Southeast Power Co.

- Another offshore wind power project in Jeju Island, the proposed Hanlim offshore wind project with 100 MW capacity obtained environmental assessment approval in 2019, and is expected to be commissioned in June 2023.

Mega Size Renewable Energy Project Developments

- **Offshore Wind Power Project in Jeonnam Province** located in the south-western tip of the Korean peninsula
  - Currently in Phase 1, and KEPCO is taking the lead on developing the first 1.5 GW
  - The project ultimately targets to build 8.2 GW of wind power capacity by 2029 in the form of a public-private partnership

- **Offshore wind power development in Ulsan Metropolitan area** in the south-eastern coast of the Korean peninsular
  - plan to build a 6.0 GW floating offshore wind farm by 2030

- **Saemangeon Renewable Energy Cluster, Gunsan City, Jeonbuk Province** in the west cost of the Korean peninsular
  - Public land development on reclaimed land
  - Private power producers invited and selected through competitive biddings
  - plan to build a 2.4 GW solar PV farm including 2.1 GW floating solar PV

III.

Case Presentation:

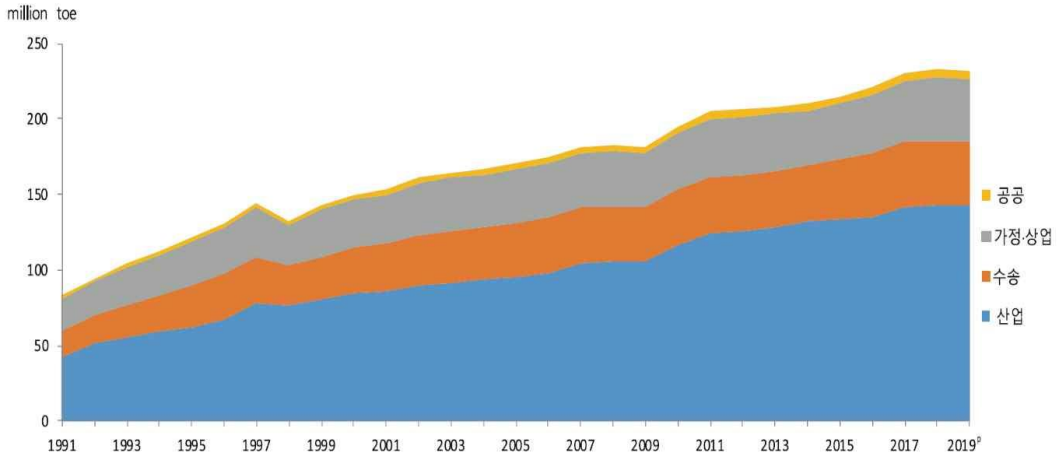
South Korea’s EE Policy &

Demand Response Program

Key Energy Efficiency Issue of South Korea

- **<u>Continued trend of increase of energy consumption especially in industry</u>**

Energy Consumption by Sector



* Source: Korea Energy Yearbook 2020, Korea Energy Agency

(Industry)

- Manufacturing sector is responsible for 90% of the industry's final energy consumption
- 30 largest industrial corporations in steel, petrochemical, and refinery, etc., each of whose annual energy consumption is more than 200,000 toe (2,300GWh), contributed 63% of the industry's total energy consumption.

(Building)

- Commercial and public buildings, mostly in Seoul and Gyunggi Province contribute more than 50% of building energy consumption

(Transportation)

- Land transportation contribute 81% of energy consumption

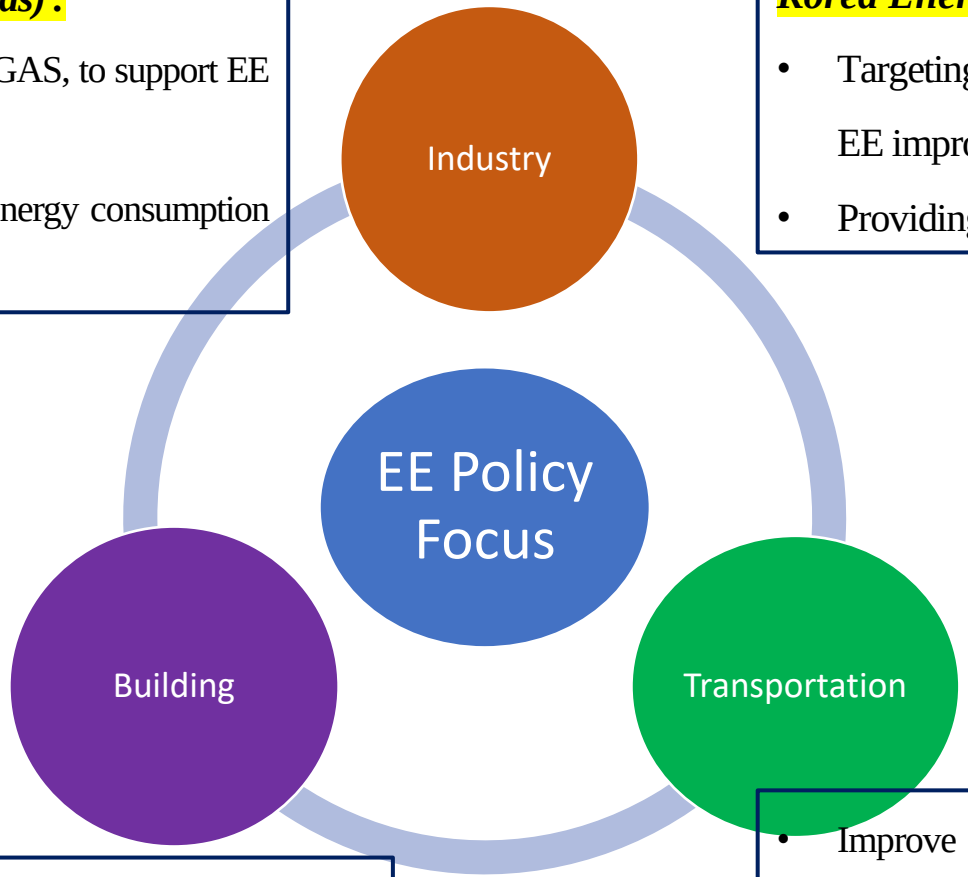
Direction of EE Policy and EE Program

EERS(Energy Efficiency Resource Standards) :

- Mandate energy suppliers, KEPCO and KOGAS, to support EE for large corporations
- Supporting clients' EE activities based-on energy consumption data

Korea Energy Efficiency Partnership 30

- Targeting 30 largest energy consuming corporations for EE improvement
- Providing incentives for EE improvement



- Revise policy in order to invite voluntary participation of building owners in improving EE
- Focus on 320,000 buildings (>3,000 m^2) nation wide

- Improve EE in transportation segment by promoting high fuel-efficient cars, and ITS (Intelligent Transportation System)
- Introduce energy efficiency rating on EV in order to deal with trend of heavier ESS and lowered energy efficiency of EV (EV energy efficiency from 5.9km/kWh ('16) to 4.3km/kWh ('21)

Market Base Demand Response (DR) Program

A program in which energy users paid for avoded peak energy demand

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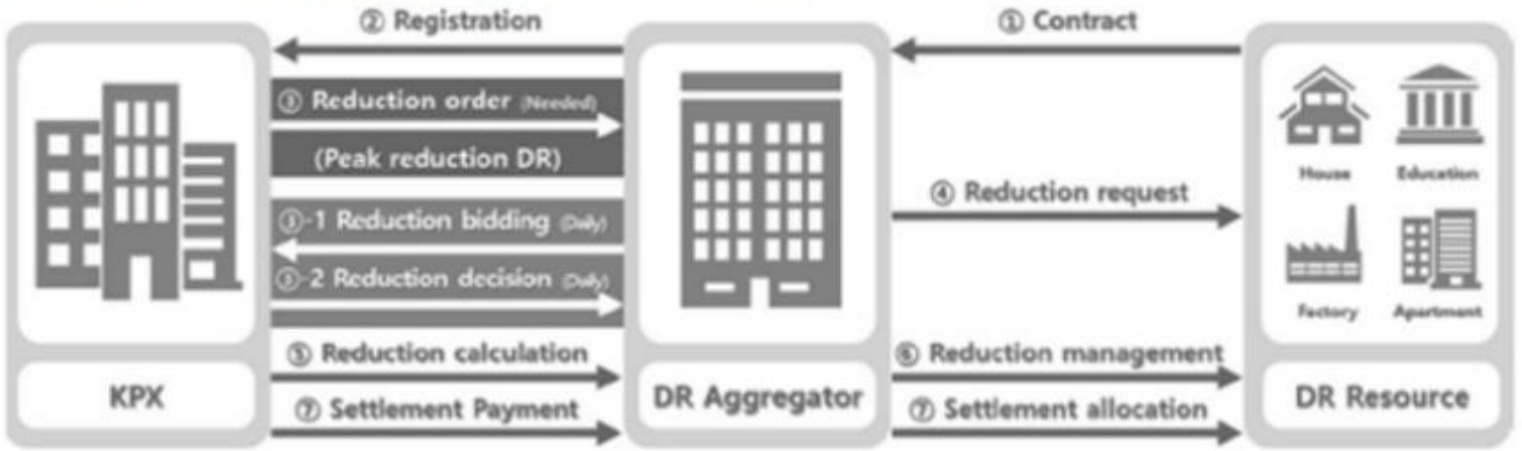
- Market-Based Demand Response Program was introduced in 2014. In the past, the demand management was implemented through the program operated by the Korea Electric Power Corporation (KEPCO).
- In the new demand response market, a third party called "aggregators" was allowed to participate as a deal broker. The aggregators recruits the demand response resources from customers who want to participate in the demand response business .
- Trades of demand response resources are arranged by the aggregators. Trading demand resource is required to come from more than ten users, and the power resource for trading should be at minimum 10 MW. The aggregators collect consumers to organize demand resources. After registration to the KPX (Korea Power Exchange), these resources are certified for trading. Demand resources are put on a bid to the power grid operator (KPX) on a daily base.
- When the bid is sold, demand curtailment begins. Once a curtailment order is issued by KPX, consumers are required to switch off on demand from the utility grid within an hour of dispatch order. During the curtailment, the consumers turn on their own power sources, which are mostly battery ESS, to meet their power demand.

<Figure> Trading Mechanism of Demand Response Market



Market Base Demand Response (DR) Program

- Since the introduction of the new demand response market, the number of consumers who participated in the market grew from 90 to 3,592 and curtailed energy amounts to 175,771 MWh, up by 342.6 times from 513 MWh.
- The demand response market program helped KEPCO, the national power system operator, secure 4GW demand side power resources to meet peak demand of industrial segment

<Table> Number of Consumers and Curtailed Power Before New DR Market

YEAR	2010	2011	2012	2013	2014
NO. OF CUSTOMERS	90	119	158	159	159
CAPACITY AVAILABLE FOR CURTAILMENT (MW)	2,219	3,049	3,612	3,615	3,615
CURTAILED POWER (MWH)	513	690	785	556	682

<Table> Number of Consumers and Curtailed Power After New DR Market

YEAR	2014.12~2015.11	2015.12~2016.11	2016.12~2017.11	2017.12~2018.05
NO. OF AGGREGATOR	15	15	17	20
NO. OF CUSTOMERS	1,323	1,970	3,195	3,580
CAPACITY AVAILABLE FOR CURTAILMENT (MW)	2,444	3,272	4,352	4,271
CURTAILED POWER (MWH)	208,109	392,853	175,771	121,206

Source: Case Study of Demand Response Operation using Management Program in South Korea

IV.

Case Presentation:

Smart Grid Infrastructure

To Support Renewable Energy Expansion

ESS With RE Project:
Dongbok-Bookchon Wind Power Plant

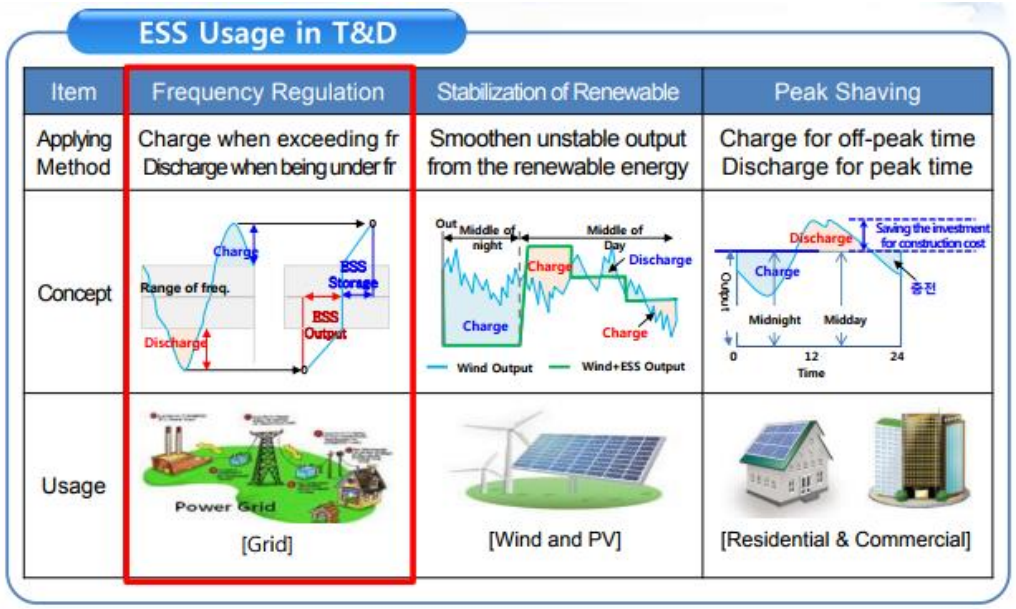
Dongbok-Bookchon wind power plant achieves high operational performance thanks to data-driven operation and maintenance and ESS's role of time shifting of energy dispatch

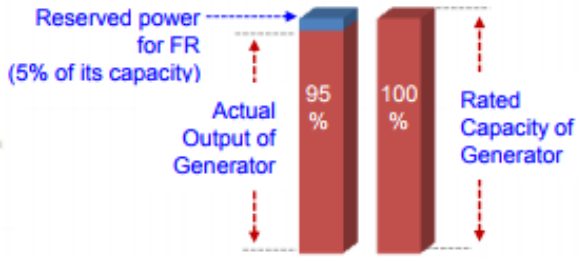
- Project location: Goojua-eup, Jeju Island (closed landfill site)
- Capacity: 30MW (2MW * 15 units) and 18MWh ESS
- Operation since 2015
- Managed by Jeju Energy Corporation

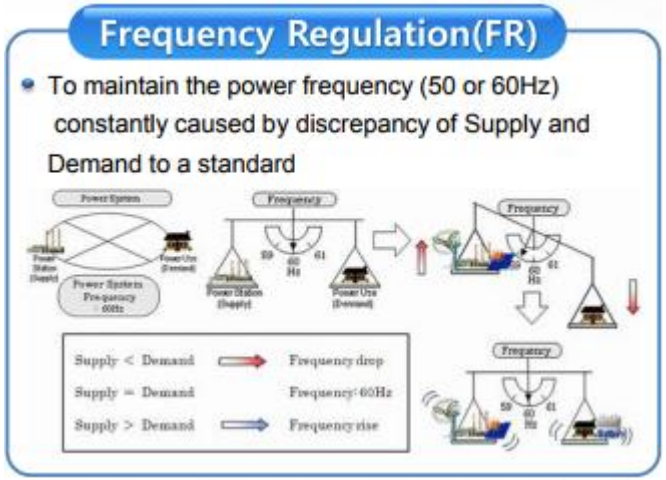
ESS For Frequency Regulation (FR ESS)

From 2014 to 2017, KEPCO installed total 376MWh ESS for frequency regulation (FR ESS) at KEPCO's major substations nationwide. The new frequency regulation mechanism with ESS enabled fast and precise response to abnormal events of frequency deviation in the power grid. The FR ESS provided KEPCO with great flexibility in power grid operation with high penetration of intermittent renewable energy sources. The KEPCO's FR ESS program helped save the reserve thermal power generation capacity which accounted for 5% of the country's power generation capacity.

In the ESS industry for frequency regulation, South Korea is among the frontrunners worldwide, following the US in the number of projects and installed ESS capacity. Based on successful implementation of the ESS for frequency regulation, KEPCO plans to install additional 1.4GWh ESS with multiple applications for power grid reliability as more renewable energy sources come into play on the country's power grid.







ESS For Frequency Regulation (FR ESS)

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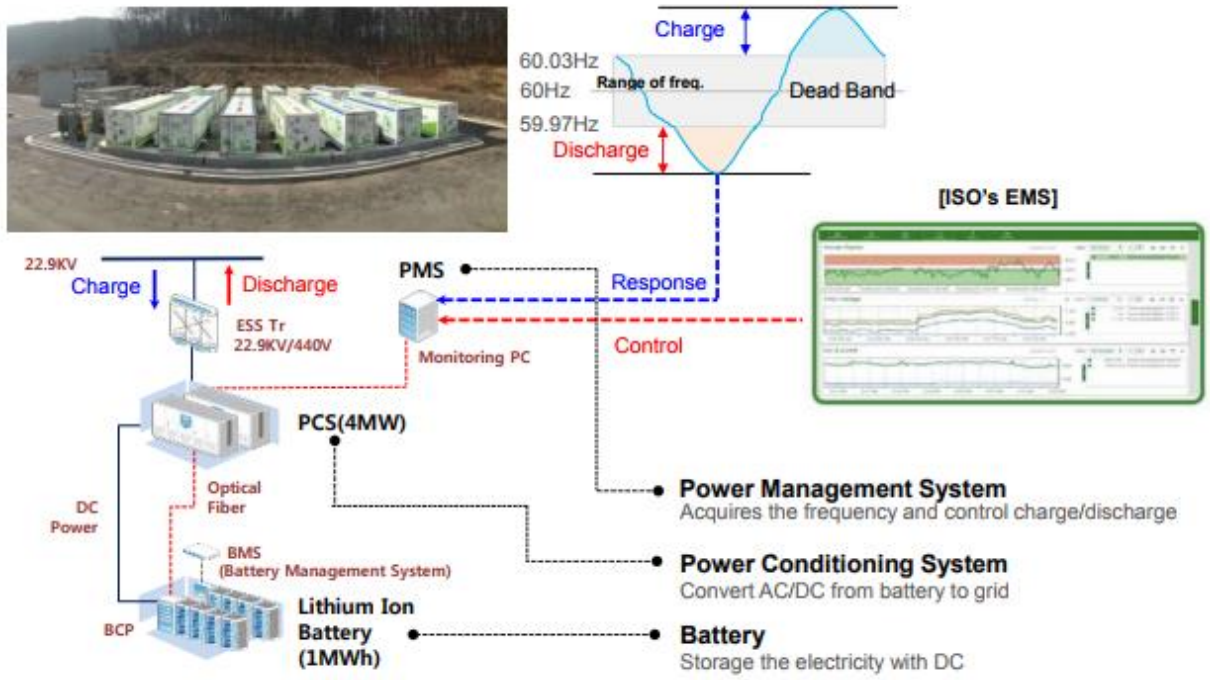
- Composition and Role of ESS in Frequency Regulation



- Two Types of FR ESS

Item	Primary Frequency Control (Governor Free)	Secondary Frequency Control (Automatic Generation Control)
Main Purpose	Prevent from freq. drop at an early stage	Increase its output at a signal from ISO's Energy Management System for grid
Operation Type	Respond by itself based on freq. status	Ramp up/down by the signal from ISO
Pilot Project (52MW) 2 sites	28MW FR ESS (Battery : 12MWh, PCS : 28MW) 	24MW ESS (Battery : 18MWh, PCS : 24MW) 
Energy Capacity	15 min-Li battery	30 min-Li battery

Renewable Energy Microgrid Test-bed:
Gasado Renewable Energy Microgrid

Project

- 286 inhabitants in 168 households
- Electricity supply from two 100 kW diesel generators
- Diesel fuel consumption: 285,000 liters/year.
- Constructed by KEPCO in 2014
- Investment of 9.2 billion Korean won (US$7.67 million)
- To replace diesel power with renewable energy sources

Purpose of Project

- Provide a testbed to apply technologies of a stand-alone renewable energy microgrid
- Verify techno-economic feasibility of a renewable energy microgrid system
- Test EMS (Energy Management System) developed by KEPCO to monitor, predict, and real-time control of energy flows among different energy sources

Gasado Microgrid (Continued)

- **Key Components of Gasado Microgrid**

Category	Quantity	Description
Solar PV	314kW	Ground-mounted and roof-top (266 kW) Floating system on a lagoon (48kW)
Wind Turbine	100kW x 4	
BESS	3 MWh	Lithium ion ESS, life span: 4,000 cycle
BESS Inverter	500kVA x 2 250kVA x1	Frequency and Voltage Control
EMS (Energy Management System) & PMS (Power Management System)	1 unit	Monitoring and control of energy flows among various energy sources and demands
Diesel Generator	100kW x 3	Existing diesel generators




Gasado Microgrid (Continued)

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- **Performance of Gasado Microgrid**

- Clean and reliable electricity supply to residents
- Reduced dependency on diesel fuels and carbon emission

Annual Diesel Fuel Consumption in Gasa Island

Year	Annual Diesel Fuel Consumption (Liter)	Saved Diesel Fuel from 2013, (Liter)	Rate of Diesel Fuel Saving from 2013, (%)
2013	260,847		
2014	214,921	50,797	19.5
2015	60,194	205,524	77.3
2016	72,416	193,302	72.7
Total		449,623	

- **Lessons and Implication of Gasado Microgrid**

- A renewable energy microgrid proves to be technically feasible and reliable
- Replacing diesel generators 100% with renewable energy penetration is not financially justifiable at this moment
- The renewable energy microgrid is going to be popular in a near future as the prices of ESS decline and knowledge and experience of renewable energy microgrids accumulate.

V.

Outline of Program to Share with GMS Countries Knowledge and Experiences with Green Energy Transition

Program Outline

- Program period: Aug. 2022 to Mar. 2023
- Program modality: 6 Web-Seminars and Study Tour
- Topics:
  i. Building renewable energy infrastructure
  ii. Enhancing power grid stability and flexibility for increased RE
  iii. EE policy and project cases
  iv. Green transportation
  v. RE mini-grids in remote areas/islands
  vi. Green financing

Web-based Seminars

Session	Topics
Session 1: Building RE infrastructure (Tentative schedule: a half day between Aug. 9 to 11)	1. Policy presentation: South Korea's 2050 Carbon Neutrality Plan 2. Policy presentation: South Korea's renewable energy policy 3. Case Presentation: Hapcheon floating solar PV project 4. Case Presentation: Tamla off-shore wind power project
Session 2 : Grid stability and flexibility with in creased RE (Tentative schedule: a half day between Sep. 6 to 7)	1. South Korea's national power grid and Achieving power grid stability and flexibility with increasing RE penetration 2. Case presentation: ESS for frequency regulation 3. Case Presentation: ESS with renewable energy
Session 3: Energy Efficiency (Tentative schedule: a half day between Oct. 4 to 6)	1. Policy presentation: South Korea's EE policy and achievement 2. Case presentation: FEMS (Factory Energy Management System) 3. Case presentation: Energy auditing in Vietnamese industrial segment 4. Case presentation: Market-based demand response program
Session 4: Green Transportation (Tentative schedule: a half day between Nov 8 to 10)	1. Policy presentation: South Korea's EV policy and EV status 2. Case presentation: V2G (EV to Grid) pilot project 3. Case Presentation: Recycling/Reusing EV ESS
Session 5: Community Carbon Neutrality and RE Mini-grids in remote Island (Tentative schedule: a half day between Jan 17 to 19, 2023)	1. Case presentation: Community carbon neutrality partnership program of Seoul Metropolitan government 2. Case presentation: RE mini grid in a remote island
Session 6 : Green Financing (Tentative schedule: a half day between Feb. 14to 16, 2023)	1. Policy presentation: South Korea's green financing programs 2. Case presentation: Green financing of carbon emission reduction with electric motorcycles in Cambodia 3. Program presentation: South Korea's green ODA program 4. Program presentation: South Korea's green EDCF program

Study Tour Plan

Day	Activity	Location
Day 1	• Visit a KEPCO's substation for FR ESS (Frequency Regulation Energy Storage System) operation • Visit a demand response aggregator	Gyeonggi Province
Day 2	• Visit Korea Energy Agency for a half-day seminar and discussion on EE programs • Visit an industrial factory for energy efficient project	TBD Gyeonggi Province
Day 3	• Visit a floating solar PV project site	Gyeongsangnam Province or Chungchungbuk Province
Day 4	• Visit Korea Power Exchange Jeju Regional Office • Visit Dongbook wind power and ESS project site	Jeju Island
Day 5	• Tamla offshore wind farm • Visit V2G (Electric Vehicle to Power Grid) project site • Future Energy Exhibition Hall	

Two options for study tour schedule in order to avoid CODIV19 travel restriction and cold winter season:

i) Option 1: mid of October to mid of November, 2022

ii) Option 2: March 2023

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Thank You!