탄소없는 섬, Carbon Free Island, Jeju

Renewable Energy Research for Carbon Free Island, Jeju

Prof. Yung-Cheol Byun
Jeju National Univ., Jeju, South Korea

제주대학교 JEJU NATIONAL UNIVERSITY

CONTENTS

Research Areas

- **Energy AI**
- ML for **Renewable Energy**
- Data Analytics & Data Balancing using Generative Models
- Vision & Image Processing
- Medical Image Analysis and Diagnosis
- Bigdata & Knowledge Discovery
- Prediction with time series data
- Blockchain and Application
- Recommendation
- Anomaly Detection and O&M

Keywords

Total in Jeju: 700,000 Kw/h

- **Electricity, *'How much electricity energy do you consume (per an hour)?' (1Kw/h)***
- **Balance of Electricity Consumption(Demand) and Supply**
- **Blackout, Curtailment**
- **Power Plant with Coal Fuel (in general)**
- **Carbon, Carbon-Free**
- **Renwable Energy**
- **Energy from Solar, Wind, and others**
- **Solar Pannel and Wind Turbine**
- **Distributed Energy Resource (DER)**
- **Discontinuity / Variability (big issue of RE)**
- **Invisibility (big issue of RE)**
- **Virtual Power Plant(VPP) as an aggregator (middleman)**
- **Microgrid**
- **P2P Energy Trading**

1-1. Infinite Competition for **Carbon Initiative**

Korea's Carbon-Free 2050 Declaration → National Survival Problem

- **Carbon-Free: Minimization of greenhouse gas emmision → Making net emissions zero with natural absorption (Net-Zero)**
- **(Why?) Keeping the temperature rise to less than 1.5℃ by 2100 → Reducing climate change & disasters on Earth (human health and living, economic growth, biodiversity issue, etc)**

Carbon-Fee Plans of Some Countries in the World

- World wide plan for **reduction of carbon emissions**

Country	By 2030 Updated NDC (after carbon-free declearation)	By 2050
EU	At least 55% reduction compared to 1990	△66.7% reduction compared to '30
UK	68% reduction compared to 1990	△66.7% reduction compared to '30
US	50~52% reduction compared to '05	△55.6% reduction compared to '30
Canada	40~45% reduction compared to '05	△55.6% reduction compared to '30
Japan	46% reduction compared to '13	△45.9% reduction compared to '30
China※	N/A	2060 Carbon-Free

※ NDC: Nationally Determined Contribution

Global Warming and Danger

Issues	1.5℃	2℃
Natural Ecosystem	High Danger	Very High Danger
Heat Wave	3℃ UP	4℃ UP
Cold Wave	4.5℃ UP	6℃ UP
Coral Extinction	70~90%	99% more
Poor Population	Hundreds of millions of people expected to grow by 2050	
Lack of Water	50% more (population)	
Risk of extreme weather	medium	medium-high
Biodiversity Change (extinction)	Insect 6% Plant 8% Vertebrate 4%	Insect18% Plant 16% vertebrate 8%
Sea Level Rise	0.26~0.77m	0.3~0.93m

Source=IPCC 6th Report (2021)

1-2. Jeju, Carbon-Free **Experience** and **Infra** (1/3)

Carbon Free Island (CFI) Jeju by 2030

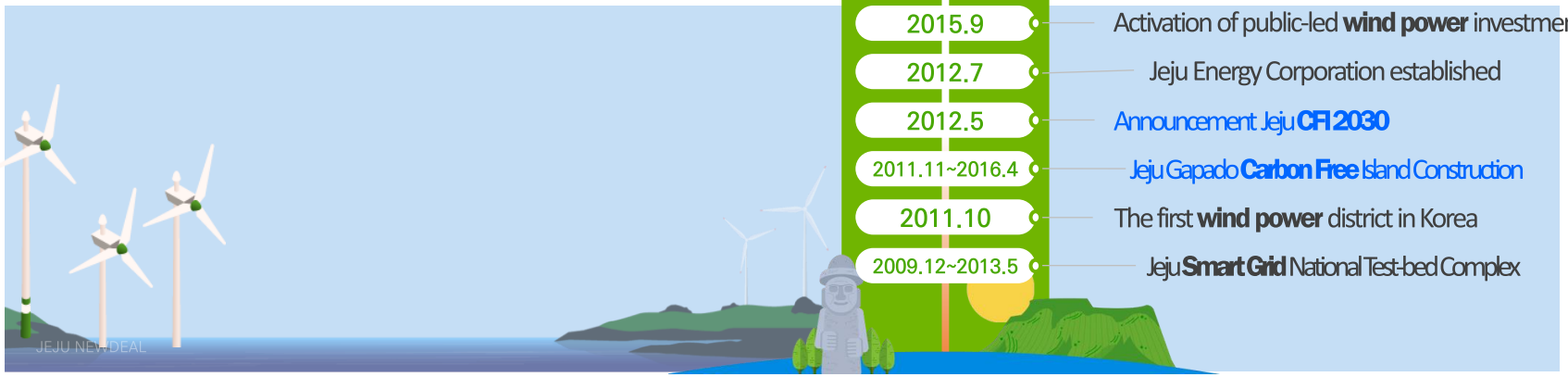
- "In 2012, Jeju already started CFI 2030 using **abundant wind** resources." → 10th anniversary (2022)

Greenhouse Gas Reduction by 2030

- **Renewable Energy** 4,085MW
  100% of electricity demand in Jeju
- **Electric Vehicles**: 75% of all Vehicles (377K)
- Reduce demand through **energy efficiency**(23.4% less)
- Fostering New Energy Convergence Industries

CFI 2030

2021	JEJU won the **grand prize** in the Energy Sector at COP26
2020	Archived **RE 18.2%,** EV 20,000
2019~2023	Designated as a special regulation free zoon for EV charging service
2019.1	Deregulation of **solar power** business
2017~2019	Establishment of EV **waste battery** reuse center
2016.7	**Wind power** profit sharing system (1st)
2015.9	Activation of public-led **wind power** investment
2012.7	Jeju Energy Corporation established
2012.5	Announcement Jeju **CFI 2030**
2011.11~2016.4	Jeju Gapado **Carbon Free** Island Construction
2011.10	The first **wind power** district in Korea
2009.12~2013.5	Jeju **Smart Grid** National Test-bed Complex



1-2. Jeju, Carbon-Free **Experience** and **Infra** (2/3)

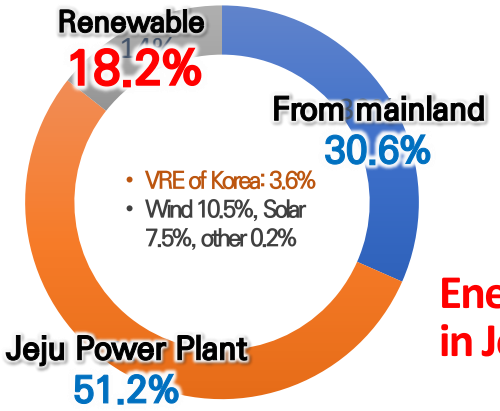
Jeju Power Generation **Facilities** and Electricity **Energy Mix** (Dec. 2021)

3 Facilities in Jeju

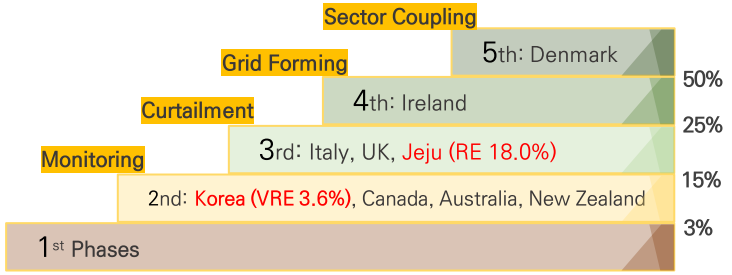
(Unit: kW)

Power Generation Sources			Capacity	Total
Jeju Power Plant	남제주기력 #1,2		20.0	910,000 (41%)
	제주기력 #2,3		15.0	
	제주내연 #1,2		8.0	
	한림복합		10.5	
	제주LNG복합 #1,2		22.9	
	남제주복합		14.6	
Decentralized Power	Renewable	Wind	29.5	903,000 (41%)
		Solar	58.0	
		Other	0.9	
		Total	88.4	
	Etc.		1.9	
From Mainland	#1HVDC		15.0	400,000 (18%)
	#2HVDC		25.0	
합계			221.3	

Power Generation Rate (2020)



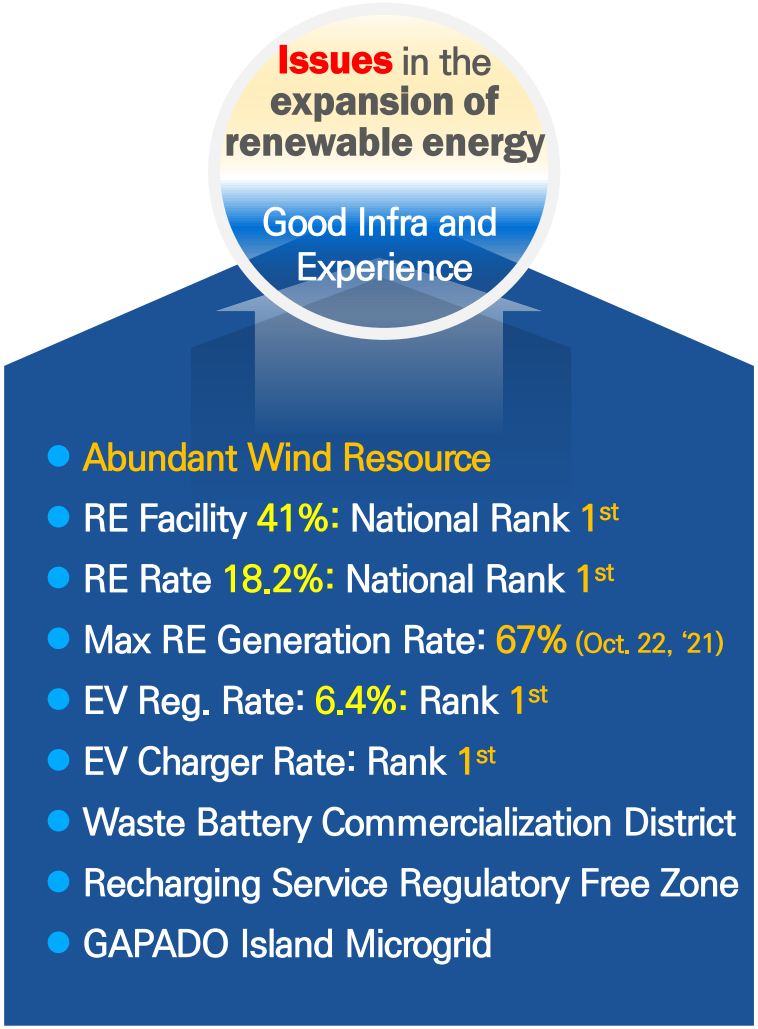
Energy Mix in Jeju



Phases of RE Development (IEA, Int. Energy Agency)

1-2. Jeju, Carbon-Free **Experience** and **Infra** (3/3)

Various RE **Infrastructure** and Carbon-Fee **Experience** in Jeju



Curtailment

- 제주 풍력·태양광 발전, 남아돌아 강제종료 朝鮮日報
- 2034년 제주 신재생에너지 발전 연중 절반은 멈춰선다. 한경 경제
- [단독]신재생에너지 과잉…"제주, 2030년 최대 179일 멈춰야" The JoongAng
- "풍력·태양광 너무 많아요" 제주, 총량제 도입하나 한겨레
- "제주 신재생에너지 2만 MW 만들고도 못 써…실시간 탄력 전기료 필요" MT 머니투데이
- 제주도가 해결해야 할 신재생발전 전력 불균형 朝鮮日報

DR/+DR, ESS, VPP

- 친환경 분산전원 시스템 개발... 전기차 확산 이끈다. YTN
- "신재생에너지 잉여전력+전기차 배터리" 사업모델 발굴 나서 파이낸셜뉴스
- 수요반응(DR)으로 '스마트한 전력 수요관리' 방안 모색 KDI 경제정보센터

Microgrid and DE

- 신재생에너지 천국 "제주 분산에너지 특구로 지정" Industry News
- 제주를 분산에너지 특구로 지정 전력 직거래 허용 이투뉴스
- 전기協, 분산에너지 활성화 실현방안 논의 kharn
- 제주형 분산에너지 규제 자유 특구 국토일보
- 제주도 전국 1호 분산에너지 특구 지정전략 마련 토론회 MT 머니투데이
- 전력설비 건설 갈등 해소 위해 분산에너지 활성화 필요 내외전기통신

Hydrogen and sector coupling

- 수요처 전기화(electrification)을 통한 섹터 커플링, 에너지 '아나바다' 시대 전기저널
- 그린뉴딜 제주, 그린 수소로 한국판 뉴딜 선도한다 (에너지 전환). 연합뉴스
- 제주바람·그린 수소 연계, P2G 실증으로 제주형 뉴딜 본격화 월간수소경제

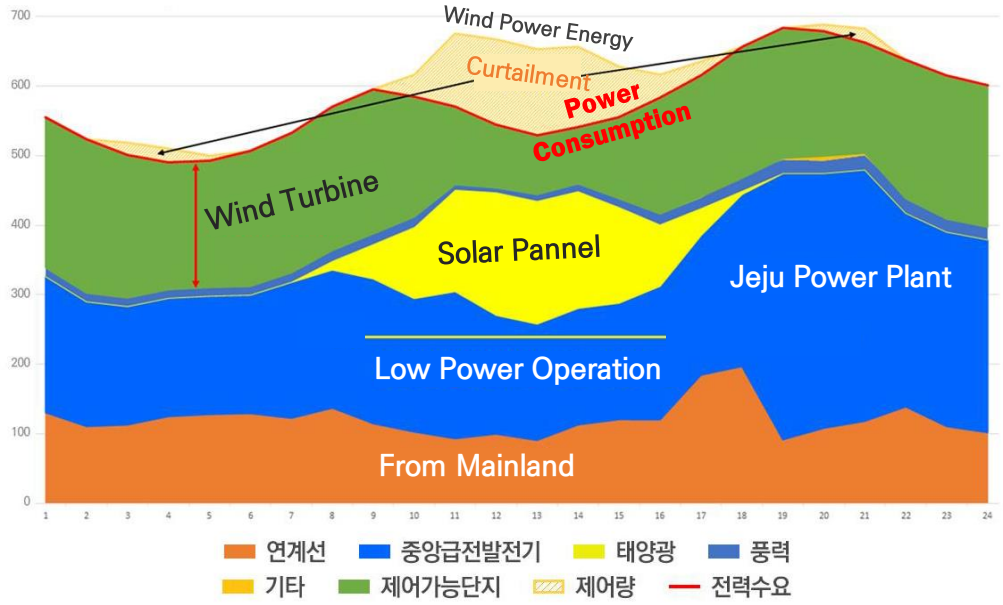
신재생과 원전과의 조화

- 인수위 "원전·신재생에너지 조화… 수요정책 강화" 에너지타임즈

1-3. Renewable Energy **Expansion** and **Issues** – Curtailment

1-3. Renewable Energy **Expansion** and **Issues** – Curtailment

Renewable Energy **Overgeneration** and **Curtailment**



※ Korea Power Exchange Institute (TSO): JEJU

Year	Curtailment	Power Amount Ⓐ (MWh)	Total Power Generation (MWh) Ⓑ	Rate(%) Ⓐ/Ⓑ ×100
'15	3	152	344,678	0.04
'16	6	252	463,613	0.05
'17	14	1,301	535,384	0.24
'18	15	1,366	533,618	0.25
'19	46	9,223	546,846	1.67
'20	77	19,449	574,481	3.39

"

Curtailment occurs when electricity demand is low.
(FYI, 18.2% of RE rate in Jeju)

→ The crossroads of renewable energy expansion and stagnation!

"제주 풍력-태양광 인허가 남발하더니… 이러다 다죽어"

제주의소리 2022년 3월 7일

한전, 태양광 발전 사업자 상대 출력제한 설명회...민간사업자들 "허가 내준 제주도 책임"

Demand Shift (+DR, sector coupling, etc.),
Power Shift (battery, hydrogen, etc.)

1-3. Renewable Energy **Expansion** and **Issues** – **Invisibility** of DER

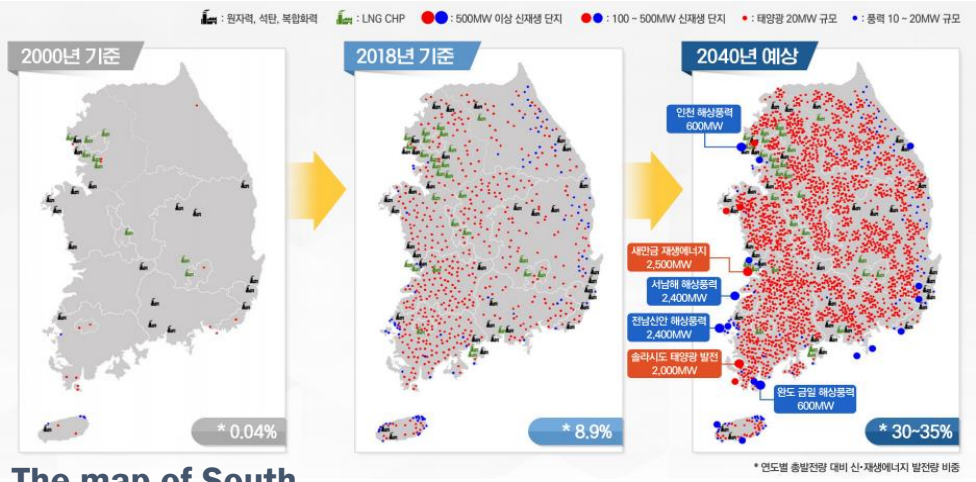
Increase in Distributed Energy Resources (Solar and Wind Power) in Korea

- What is Distributed Energy Resource?

Distinguished from central power plants, local producing, storing, and utilizing near the demanding point so that it is possible to reduce power loss due to long-distance power transmission.

- **Rapid transition** from large central power plants to very small RE distributed power generation

※ Nationally 20,000 sites of DER in 2020 (South Korea)



The map of South Korea

※ 20 wind farms & 1,000 solar sites in Jeju (2021)

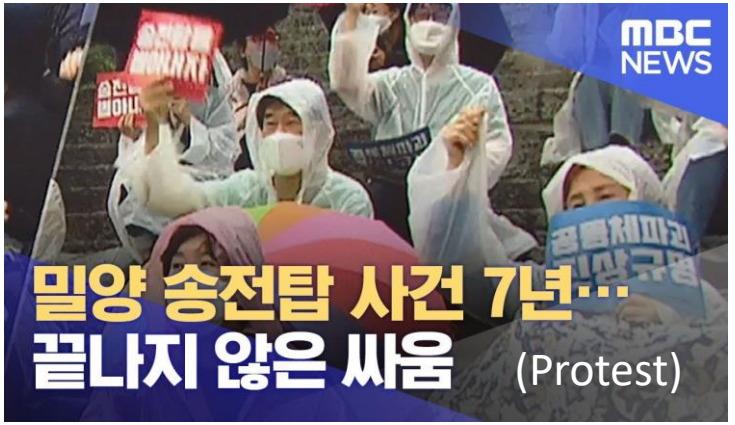
Direct monitoring and controlling by KEPCO and KPX is **impossible - Invisibility**

Need **aggregators (VPP)** and VPP platform technology to solve the visibility of very small resources (DER)

1-3. Renewable Energy **Expansion** and **Issues** – **Limitation** of Legacy Grid

Problems in National (Korea) Grid

- **Social acceptance** issue of power transmission facility (utility pole) construction
- Problems caused by the nationwide flat electricity rate system
- Power loss issue from long-distance power transmission
- Difficulty in **P2P energy transaction**
- Difficulty in supply-demand balance management
- One-way energy transmission → Difficulty in the emergence of prosumers (doing the role of energy producer and consumer)



The Need for **Microgrid**

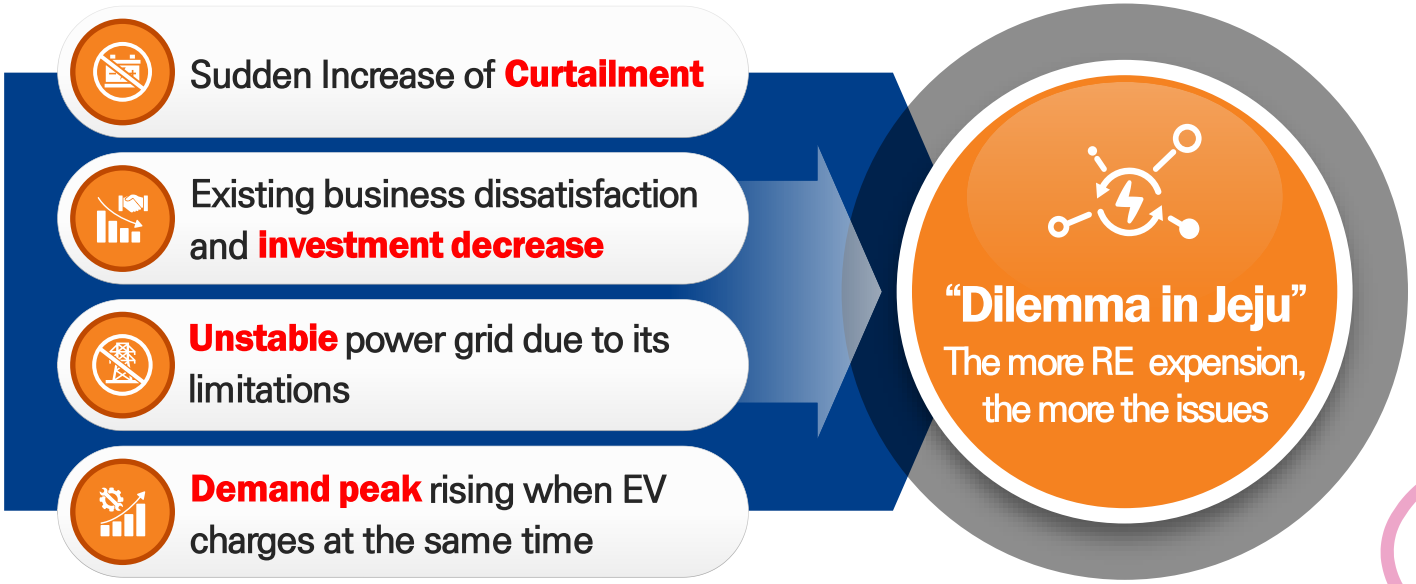
- **Small-scale regional power grids** that produce, supply, and demand locally by connecting local DER (↔ wide-area national power grid)

Microgrid platform technology is required to collect various information in the **microgrid**.

Providing intelligent services such as power price prediction, P2P power transaction, and optimal power (energy) mix management

1-4. **Direction** of the Research (Center)

18.2% Rate of Jeju Renewable Energy, and the Current Issues



→ A problem that will soon appear nationwide in Korea (RE 7.4%)!

Direction of the Center

"We try to **solve this issue** in Jeju first, and apply the solution for Carbon-Free 2050 of Korea.

2-1. Our **Goals** of R&D Projects (1/6)

CFI Distibuted Energy Research Center

비전 Vision

"Jeju Island as a **Sustainable Energy Self-Sufficient Island** with CFI2030, Leading Korea's Carbon-Free 2050"

목표 Goal

Problem-solving technology for RE, Leading innovative growth in the RE industry

연구 Content

Group 1

RE Optimization & Platform
DE Prediction and O&M

Research Topics

- **Prediction** of Wind Energy & Verification
- Energy Consumption Prediction and Optimization
- Distirubted Energy **Platform**
- Stable **Energy Trading** Technology for Participants

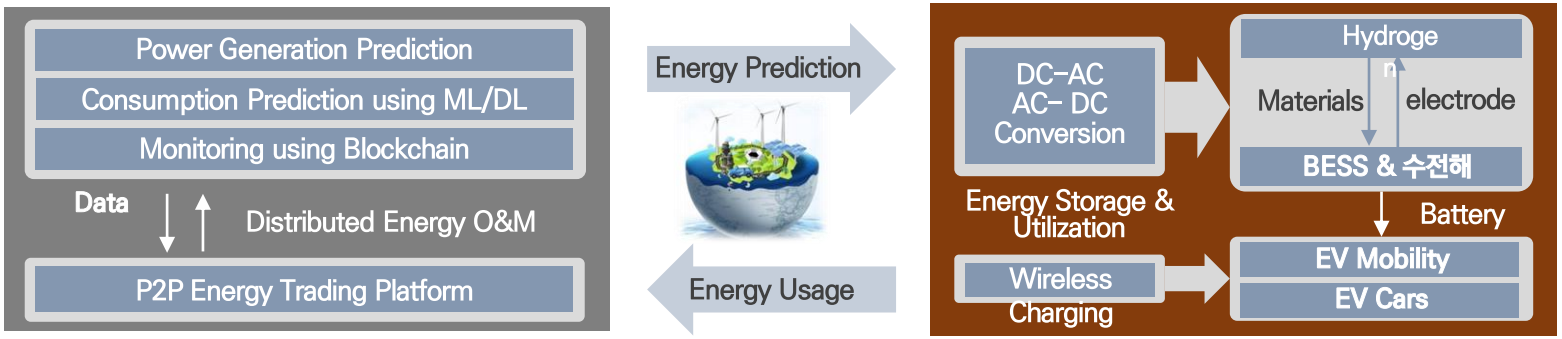
Group 2

RE Utilization
Eco-friendly Energy Utilization and Storage

Research Topics

- Development of Cyan **Hydrogen** Production
- Energy Conversion/**Storage** Materials
- Power **Conversion** for Renewable Energy
- Wireless **Power Transmission** for EV

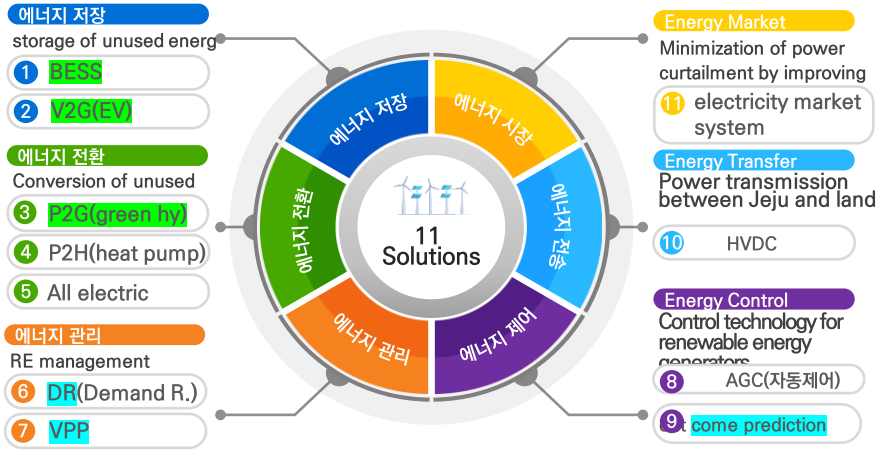
Collaboration-based Researchs



2-1. Our **Goals** of R&D Projects (2/6)

3 Major National Plans for **Renewable Energy** in Jeju

1. Carbon-Free Island CFI2030 (2022~2030)



2. 3rd Jeju Internationalization Plan (2022~2031)

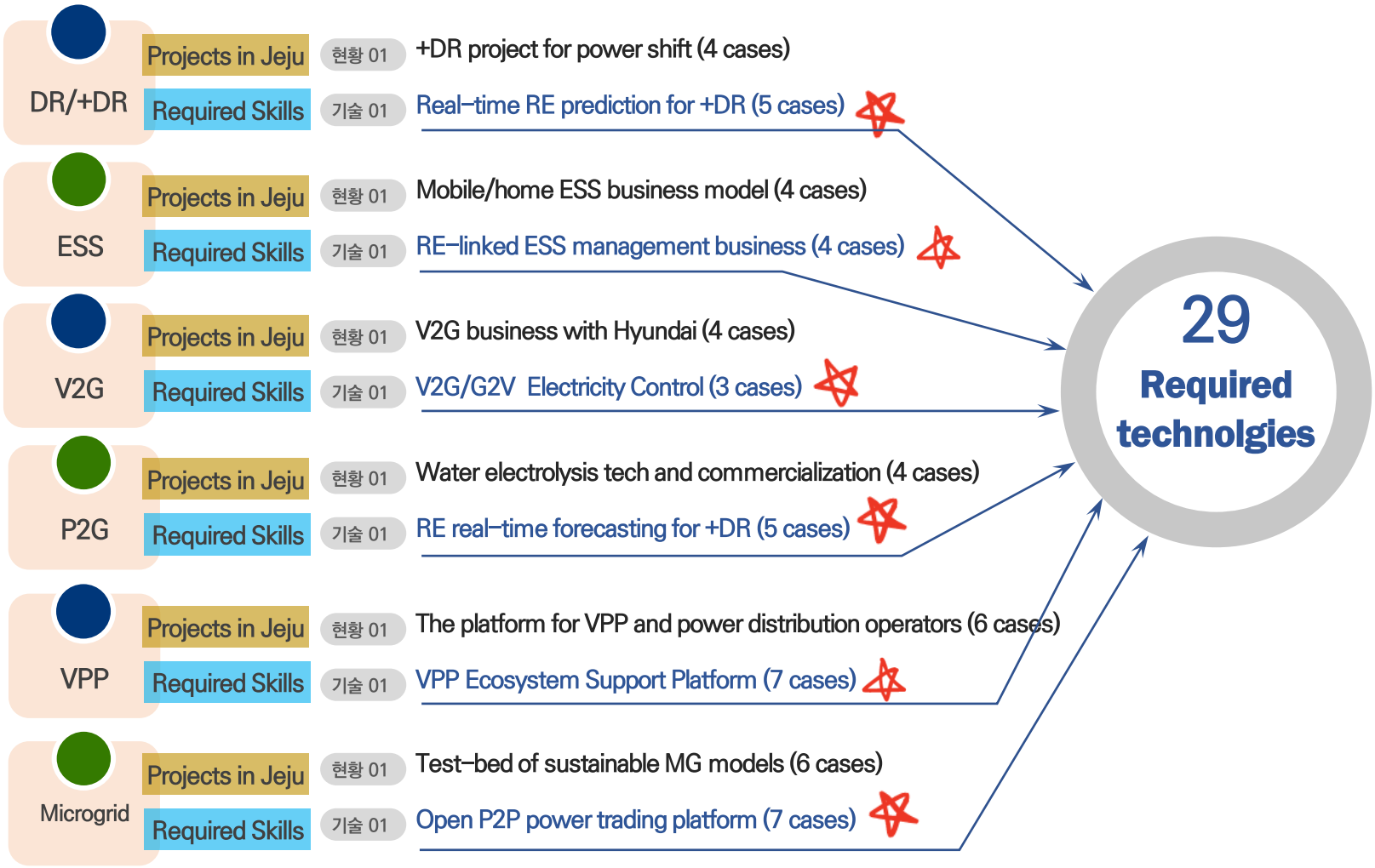
- All electric building and town microgrid construction
- Fossil fuel reduction and excess power demand in agriculture/fisheries
- RE prediction and CFI integrated management system
- Demonstration and diffusion of electricity trading ※2023년 초, 2023년 말
- A win-win strategy in the carbon-free energy environment
- CFI 2030 citizens governance, global leading model
- Fostering the hydrogen and fuel cell industry

3. Distributed Energy Plan in Jeju (2022~2026, 27~)

- Sector coupling business model
  - P2G, P2H demonstration (green hydrogen ecosystem) and expansion (private sector)
  - V2G pilot project and charging/discharging model
- Test of DE special zone model and industry fostering
  - Value compensation system, VPP business expansion
  - +DR spread (transport → housing, agriculture → daily life)
- Sustainable Microgrid Model
  - Testing microgrid for island in island

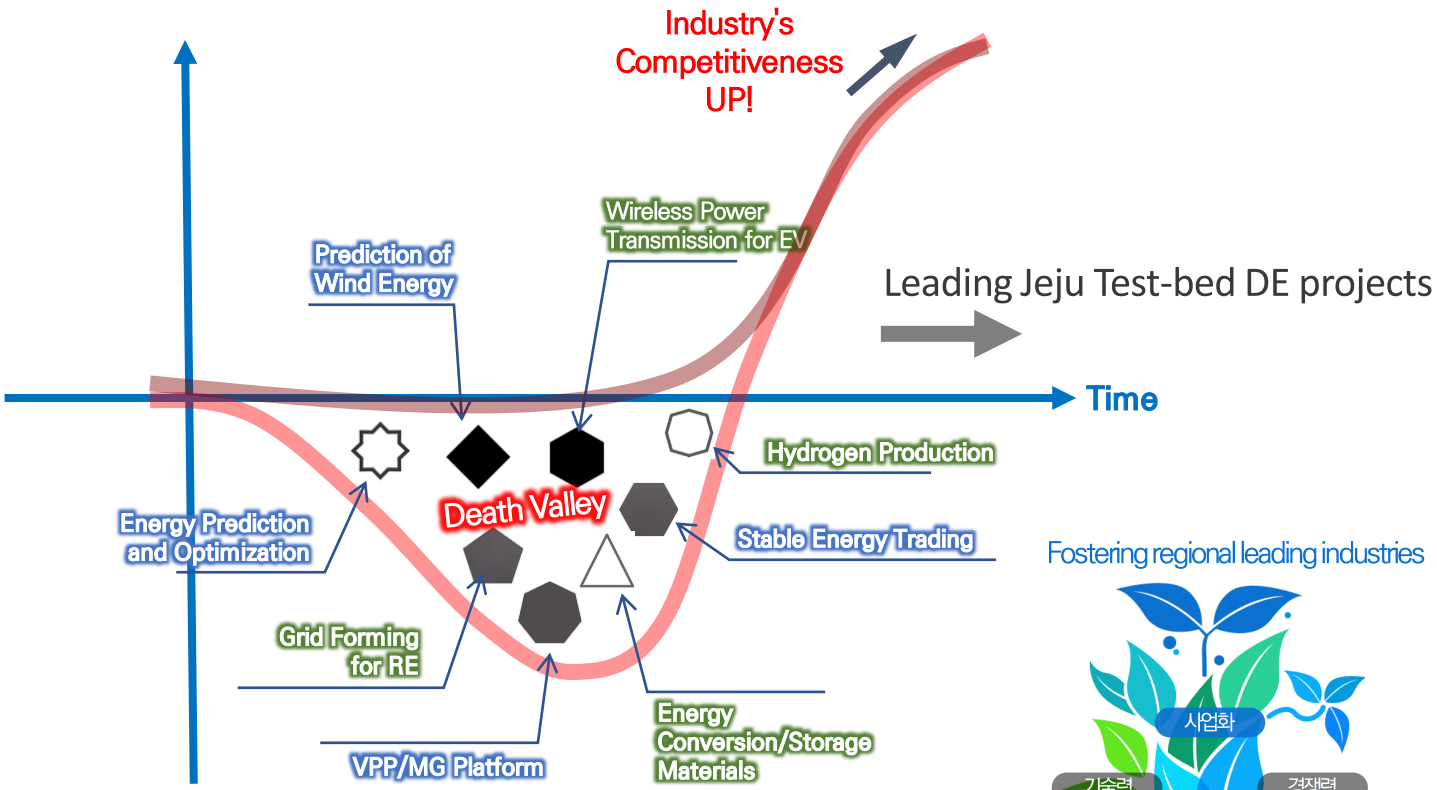
2-1. Our **Goals** of R&D Projects (3/6)

Ongoing Jeju RE Plans Analysis (in 6 Categories) → Definition of Required Tech. for Industry



2-1. Our **Goals** of R&D Projects (4/6)

29 required tech. → 8 categories as **Death Valley Overcomming Technologies**



"DE Prediction and O&M" → 1 Group

"RE Utilization" → 2 Group

2-1. Our **Goals** of R&D Projects (5/6)

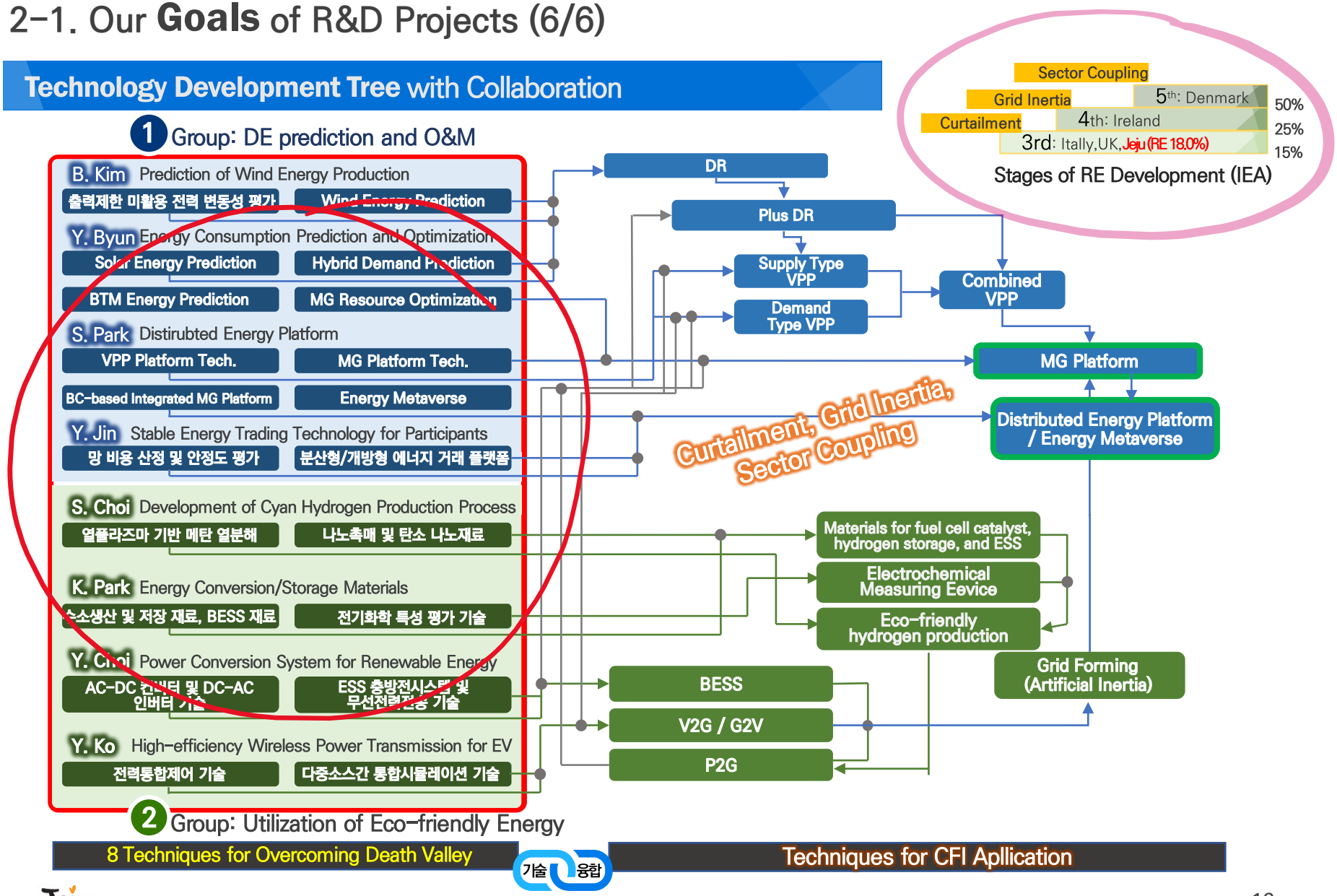
8 Death Valley Overcoming Technologies & 8 Researchers

	Technologies	B. Kim	Y. Byun	S. Park	Y. Jin	S. Choi	K. Park	Y. Choi	Y. Ko
RE Optimization & Platform 1 Group	Prediction of Wind Energy & Verification	●	◐	○	○	○	○	○	○
	Energy Consumption Prediction and Optimization	◐	●	◐	◐	◐	○	○	○
	Distirubted Energy Platform	○	◐	●	◐	○	○	◐	○
	Stable Energy Trading Technology for Participants	◐	○	◐	●	○	○	○	○
RE Utilization 2 Group	Development of Cyan Hydrogen Production Process	○	○	○	○	●	◐	○	○
	Energy Conversion/Storage Materials	○	○	○	○	◐	●	◐	○
	Power Conversion System for Renewable Energy	○	○	○	○	○	◐	●	◐
	Wireless Power Transmission for EV	○	○	○	○	◐	◐	○	●

※ **Research Relevance** : Strong(●), Normal(◐), Week○

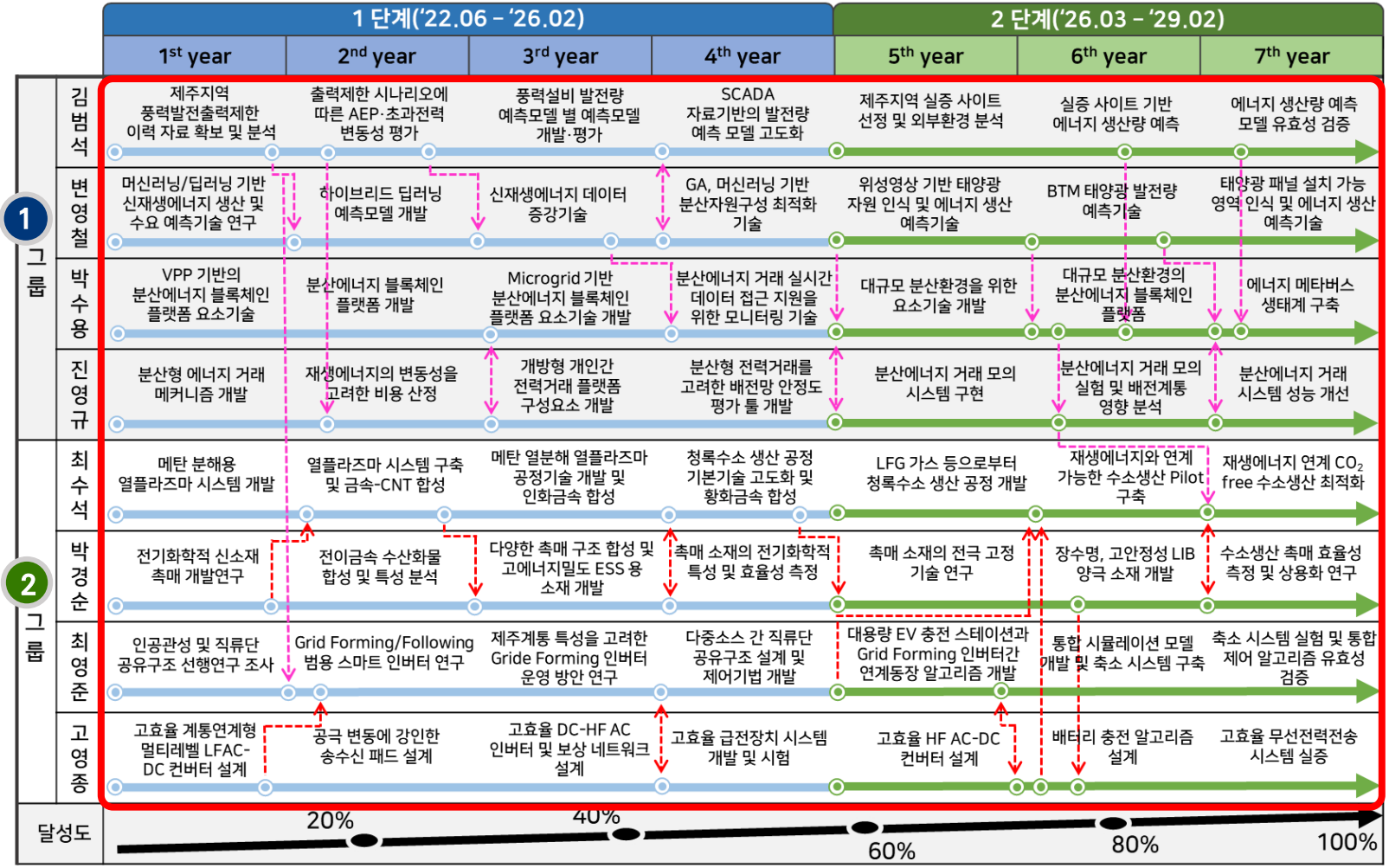
2-1. Our **Goals** of R&D Projects (6/6)

Technology Development Tree with Collaboration



2-2. Yearly R&D Plan with Collaboration

Yearly Plan for R&D (56 Core Techniques)



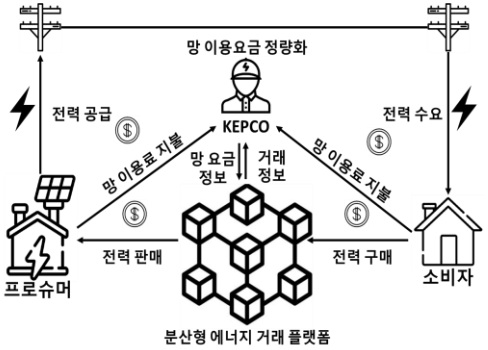
2-3. **Examples** of Collaboration-based R&D

R&D Result 1 — Group 1

Distributed Energy Platform for Intelligent Power Service

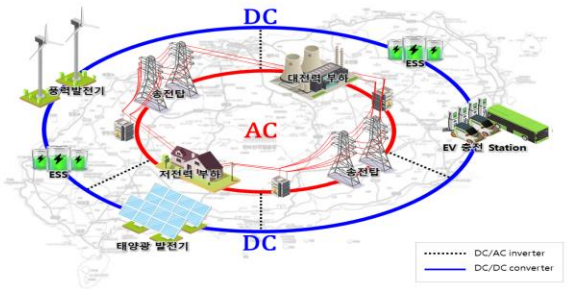
R&D Result 2 — Group 1

Regional-Driven Distributed Energy System



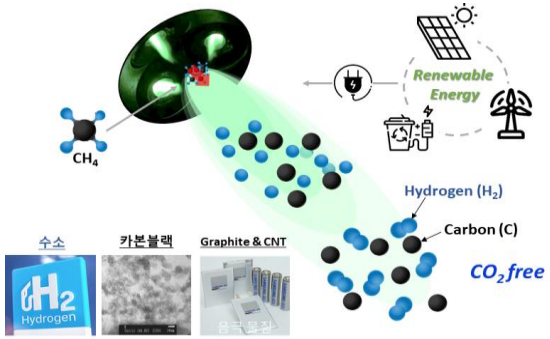
R&D Result 3 — Group 2

Artificial Inertial Power Conversion Network for Renewable Energy



R&D Result 4 — Group 2

Eco-friendly hydrogen production pilot system



3-1. Collaborative R&D (1/4)

5 Companies → Commercialization

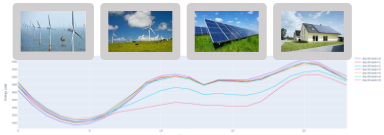
Tilon Soft · UPP LAB · NANCOMENERGY · ㈜진우소프트이노베이션 · 이브이렉스

1

R&D Result 1 "Distributed Energy Platform for Intelligent Power Service"

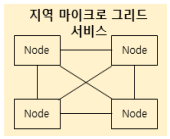
RE Predictive technology

- **Analysis of factors** affecting wind and solar power generation
- **Data-based prediction** technology



Distributed Energy Platform

- **Design of microgrid platform** components in individual units (for regions)
- **Extensible MG Platform** for Grid-of-Grid

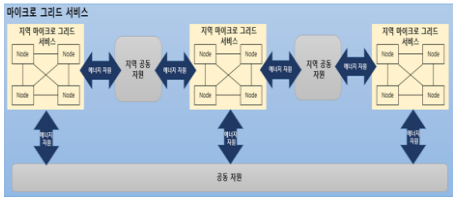


Advancement of predictive technology

- **BTM prediction technology** (Wind & Solar)
- **Grid resource configuration optimization** (for region/environment/ power facility)

Distributed Energy Platform

- **Large volumn of data magement** in microgrids
- **Grid-of-Grid platform** for integrated management of multiple microgrids



Jeju-style distributed energy platform

- **High-performance RE generation prediction** and resource management.
- **Leading technology** for DR/+DR, VPP, microgrid platform based on data.
- **Development and testing of a platform** that integrates microgrids
- **DE resource composition optimization** tech. in microgrid (Electricity rate, renewable energy utilization rate, etc.)

3-1. Collaborative R&D (2/4)

4 Companies → Commercialization

CityLabs INUC UPP LAb NANOOMENERGY

1

R&D Result 2 "Regional-Driven Distributed Energy System"

Energy Trading Mechanism

- **Design of transaction consensus algorithm** among participants
- **Development of incentive system** for market participation

Network Costing and Distribution

- Network **cost estimation** tech.
- Network **cost distribution** method considering transaction transparency

P2P power trading platform

- **Distributed ledger technology** development and settlement mechanism
- Transaction Validation and Consistency Verification

Grid Stability Assessment Tool

- Development of **Distributed Power Transaction Simulator** of Actor-Based Model
- Derivation of requirements for **distributed electricity trading** system

Decentralized Energy Trading Simulation

- **Interface design** for distributed energy trading
- **Simulation scenario** of electricity transaction based on a real grid
- **Verification of the effect** of distributed energy trading

3-1. Collaborative R&D (3/4)

3 Companies → Commercialization

(주)대경엔지니어링 CityLabs WINDETECT

2

R&D Result 3 "Artificial Inertial Power Conversion Network for Renewable Energy"

Grid Forming / Following General-Purpose Smart Inverter

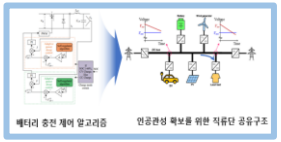
- Frequency and reactive **power compensation**, Inverter design and high-speed control method for grid forming
- **High-speed switching between grid following and grid forming** modes when connecting multiple sources
- Grid forming inverter for large capacity recycled battery and EV station, **Backup Control Algorithm** for Renewable Energy Sources

DC link control algorithm between multiple sources

- **DC link sharing** structure design and control technique among renewable energy, recycled batteries, and EV stations
- V2G/G2V **power utilization control algorithm** of large-capacity EV station considering the power grid situation
- **Linked operation of multi-source inverter and EV station** reflecting the prediction of power generation, grid forming role sharing algorithms

High-efficiency, high-reliability power conversion network

- High-efficiency **DC/DC converter design** for ESS charging /discharging
- **Inverter control algorithm** considering sudden supply power fluctuation
- **Battery charging control** in case of sudden supply power fluctuations
- Establishment of high-efficiency and high-reliability **system that increases the acceptability of renewable energy and secures artificial inertia**



3-1. Collaborative R&D (4/4)

3 Companies → Commercialization

(주)대경엔지니어링 NATURE MOBILITY 2 WINDETECT

R&D Result ϟ "Eco-friendly hydrogen production pilot system"

Thermal plasma-based cyan hydrogen production system

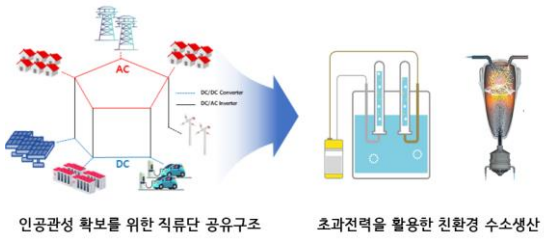
- Development of thermal plasma-based pyrolysis process system for hydrogen production from waste-derived methane
- Development of a 30kW pilot system linked to RE
- Secondary battery technology using by-product carbon material
- Economic feasibility analysis of developed process technology

Development of high-efficiency green hydrogen

- Alkaline water electrolysis stack and measuring device configuration for water electrolysis environment
- Materials for low-risk, high-efficiency hydrogen storage devices
- Optimization of mass production process of cathode material for BESS
- Optimization of commercialization technology for catalysts for green hydrogen

Renewable Energy-based Grid system

- Grid forming inverter operation tech. considering Jeju grid
- DC link sharing structure design and control tech. among RE, BESS, and EV stations
- Eco-friendly hydrogen production pilot system linked with renewable energy



인공관성 확보를 위한 직류단 공유구조 초과전력을 활용한 친환경 수소생산

Colavorative Research 1 + 2 + 3 + 4

→ Jeju Style Eco-Friendly Distributed Energy System

3-1. R&D - Inovation & Originality

Inovation Aspect

Energy Mix Optimization

BC-based **Energy Trading** Platform

Artificial Inertia (Grid Forming)

Energy Mix Optimization for MG	● **Optimal DE mix** of fossil fuel energy, nuclear energy, RE considering energy cost and stability in MG ● Energy mix optimization ccording to environment and region (Jeju type, Seoul type, and etc.)
Blokchain-based P2P Energy Trading Platform	● Developing **MG-based smart contract technology**, building a reliable energy trading, and supporting the energy trading ecosystem ● Converting real contracts to smart contracts and developing smart contract language
Artificial Inertia for VRE	● Power conversion-based **artificial inertia technology (Grid Forming) considering power mix** ● Power converter topology, modeling and voltage control, frequency control system

Originality

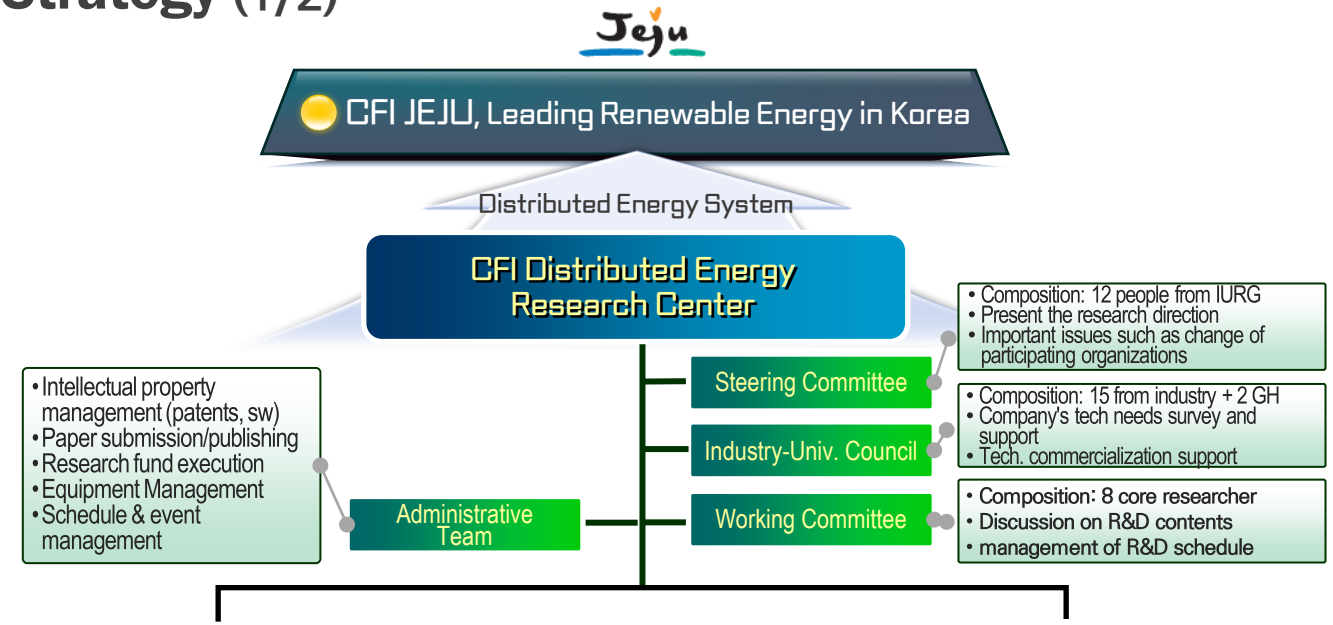
Clean Hydrogen Production

Energy Metaverse

Wireless Charging in RE Environment

Clean Hydrogen Production	● Hydrogen production **using waste hydrocarbons** from livestock ● Synthesis of high-quality carbon with high utility value using by-products
Energy Metaverse	● **Implementation of DE environment in virtual world**, establishment of renewable energy digital twin for O&M ● Metaverse platform technology and P2P asset transaction using blockchain technology
Wireless Charging	● **Wireless charging system using waste batteries of EVs** ● Development of control technology for sudden fluctuations in supply power, inverter control algorithm

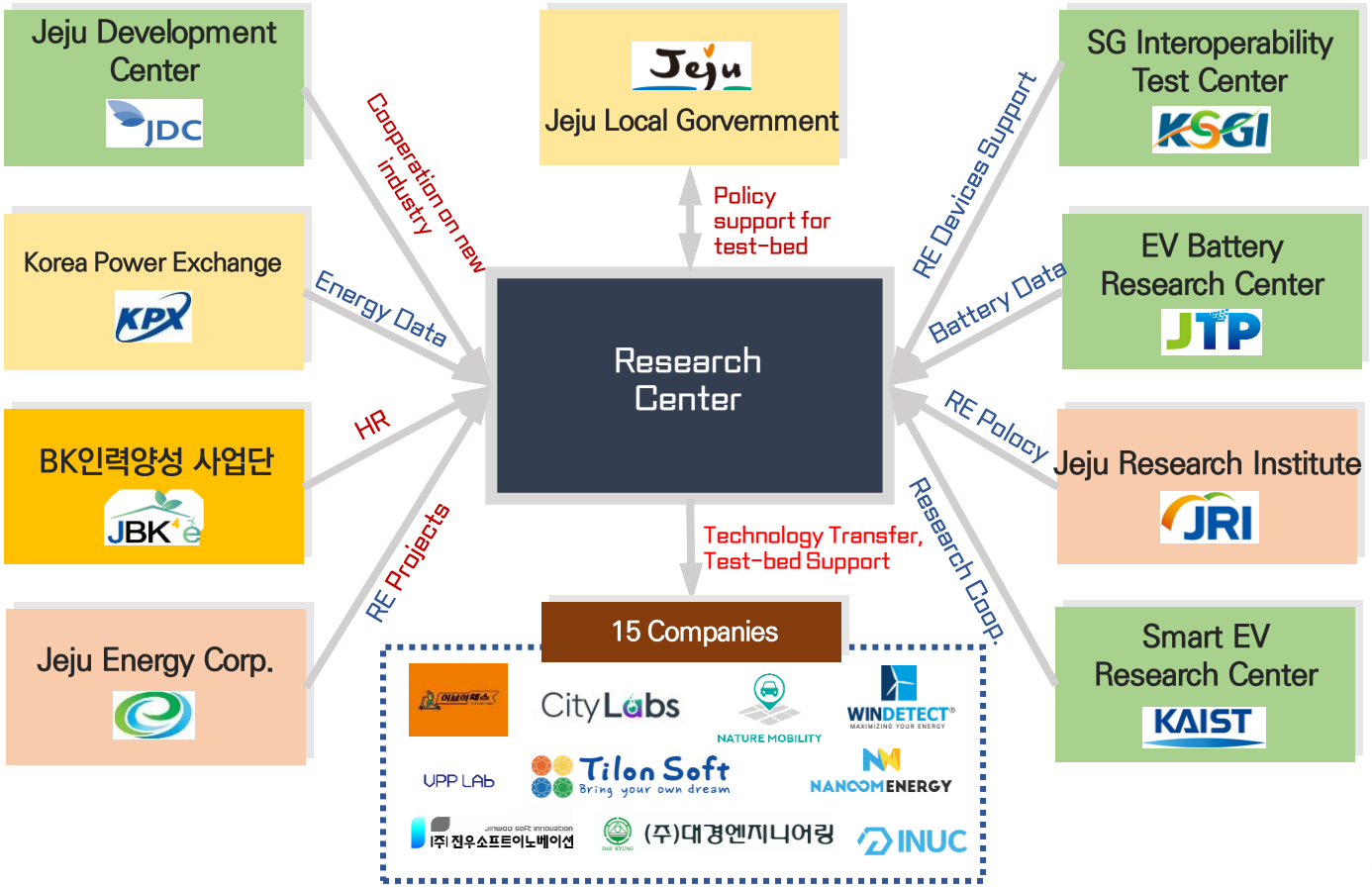
3-2. **R&D Strategy** (1/2)



Categories		Participating organizations
Organizations (29)	University (3)	Juju National Univ., Sogang Univ., Bukyong Univ.
	Companes (15)	ENLIGHTEN, JINWOO, NATUREMOBILITY, INUC, DAEKYUNG E. CITY Labs. NANOOM E., EVPASS, WINDYTEC, TILON, VPPLAB JINI, NEOINTERNET, ARTPQ, JEUS
	Research Institute (9)	BK인력양성사업단, 스마트그리드 상호운용성시험센터, ETRI JDC, 제주테크노파크, JTP전기차배터리산업화센터, 제주연구원 KAIST친환경스마트자동차연구센터, 제주혁신성장센터
	Gorvenmental Organization (2)	Jeju Local Gorvenment, Korea Power Exchange

3-2. **R&D Strategy** (2/2)

Cooperation Plan to Create New Energy Industry **Ecosystem**



5-1. **Applications** of the R&D Results

- Renewable energy prediction technology → Real-time electricity price prediction technology
- Solar BTM prediction technology → Core and CFI application technology
- Utilized as a core tech. for real-time electricity trading price determination

- Lithium-ion battery and electrode material technology → Renewable energy generation and storage
- Production of Green Hydrogen (P2G) using surplus power → Provide hydrogen energy to hydrogen cars

- VPP power bidding and output adjustment technology → Utilized as a source technology for stable system operation
- Wireless battery charging technology → Utilized to electrify various mobility including ships

Core Technologies for **Overcoming Death Valley**

2022 2023 2024 2025 2026 2027 ~

5-2. Expections

From CFI 2030 Jeju Project
over the past 10 years

Infrastructure & Experience

Development of Core Technologies for Carbon-Free

Human Resource Nurturing of Energy AI

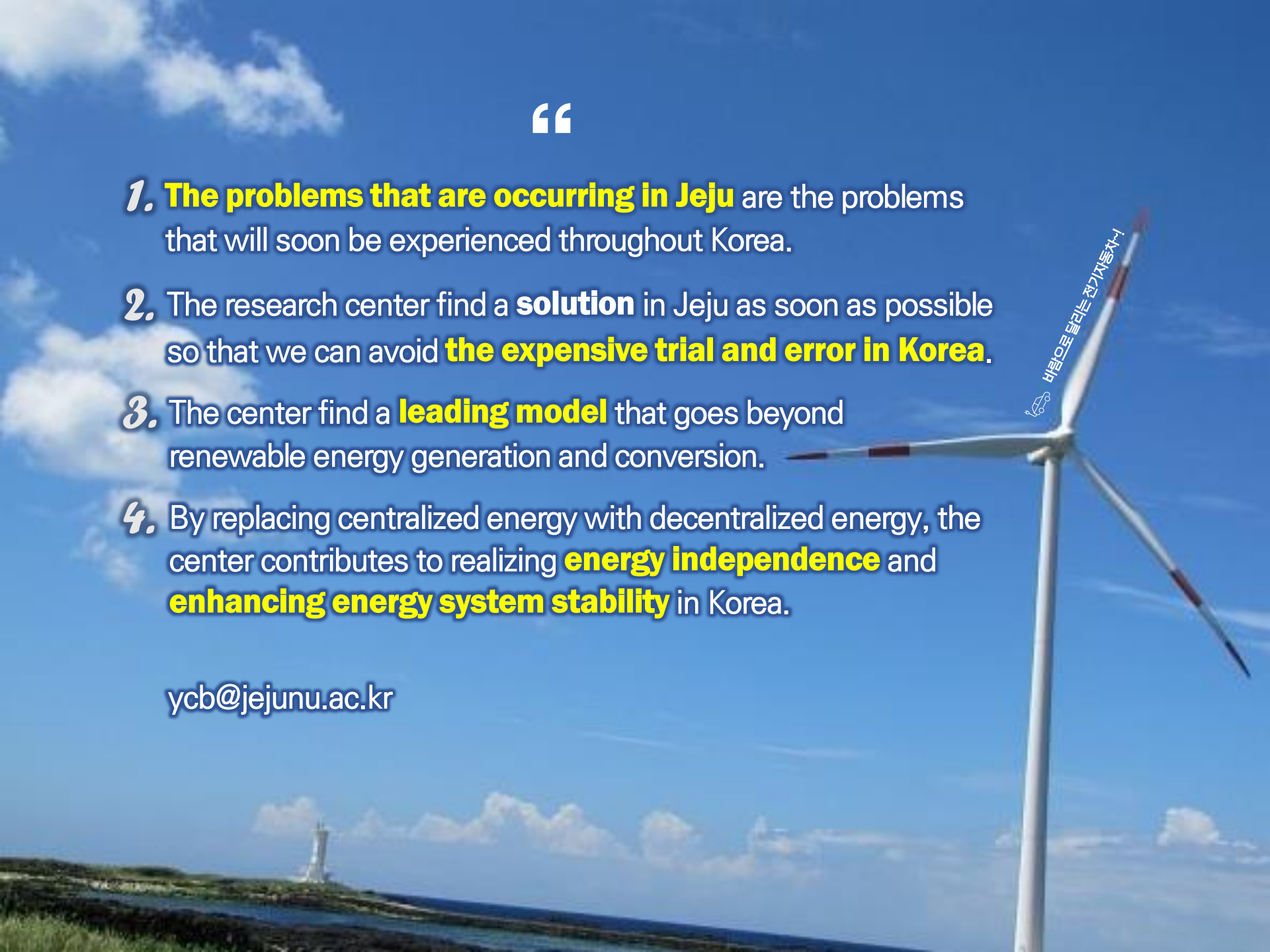
Transfer of Technology to Companies

Enhancing Competitiveness in Energy Industry in Jeju

제주도의 탄소중립 시행착오 경험으로 LOW COST

Realization of Energy Independence in Jeju and Carbon-Fee Model of Korea

Finally, leading Net-Zero 2050 of Korea



“

1. **The problems that are occurring in Jeju** are the problems that will soon be experienced throughout Korea.
2. The research center find a **solution** in Jeju as soon as possible so that we can avoid **the expensive trial and error in Korea**.
3. The center find a **leading model** that goes beyond renewable energy generation and conversion.
4. By replacing centralized energy with decentralized energy, the center contributes to realizing **energy independence** and **enhancing energy system stability** in Korea.

ycb@jejunu.ac.kr