Japanese test bed of renewable integration

- Challenges of high penetration of renewable DERs into existing grids -

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- Japan’s policy and electricity supply situations
- Challenges on renewable energy deployment
- Grid code for DERs
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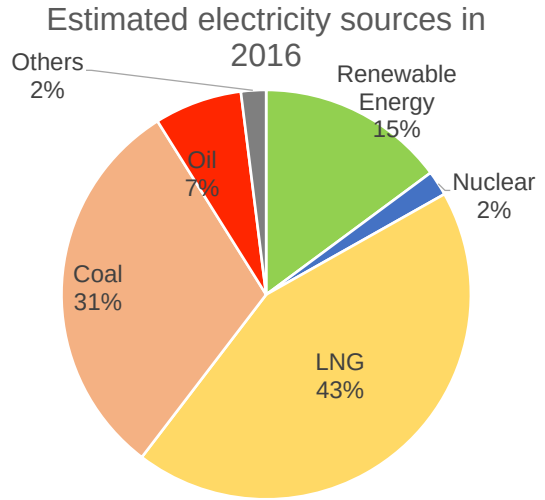
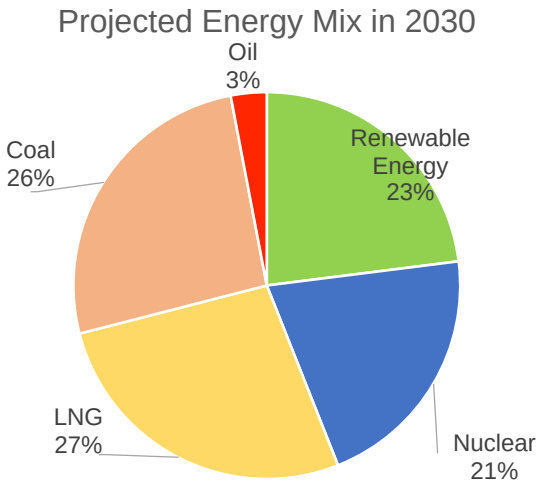
Japan Policy in Electricity Supply

Japan has set long-term targets for self-sufficiency, electricity prices and CO2 emissions for 2030

- Self-Sufficient Rate
  - Raise to 25% with renewable and nuclear energy
- Electricity Cost
  - Utilize nuclear and coal-fired thermal power generation
- CO2 Emissions
  - Utilize renewable and nuclear energy
  - Optimize efficiency of coal-fired thermal power generation





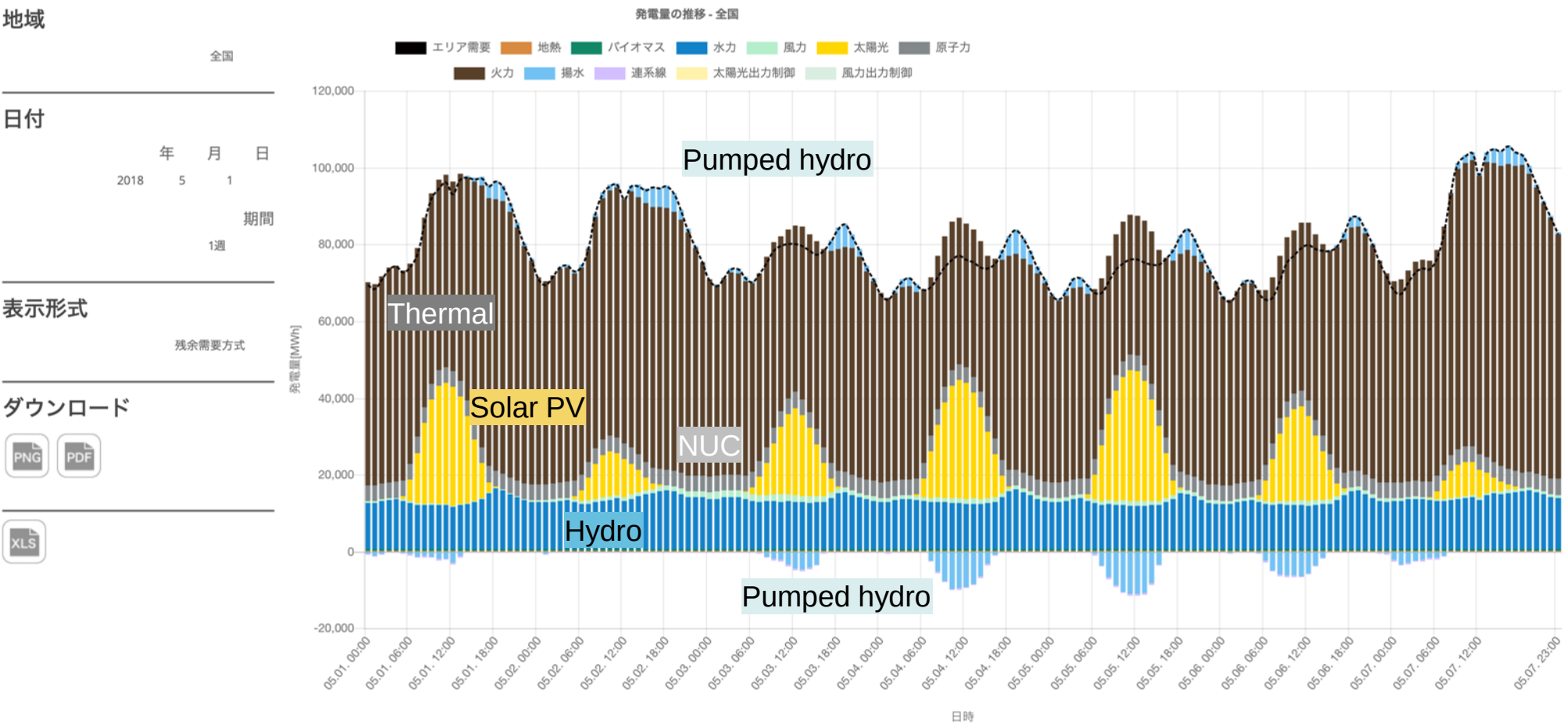
The share of energy sources in total power generation in Japan in 2017

- The share of renewable energy: 15.6%.
  - The share of VRE (solar PV and wind): 6.3%.
  - The share of solar PV: 5.7% (rapidly increased from 4.4% in the previous year (2016)
  - The peak of solar PV reached 30% in whole Japan, 80% in Kyushu island

- The share of thermal power generation (Fossil Fuel): 81.6%

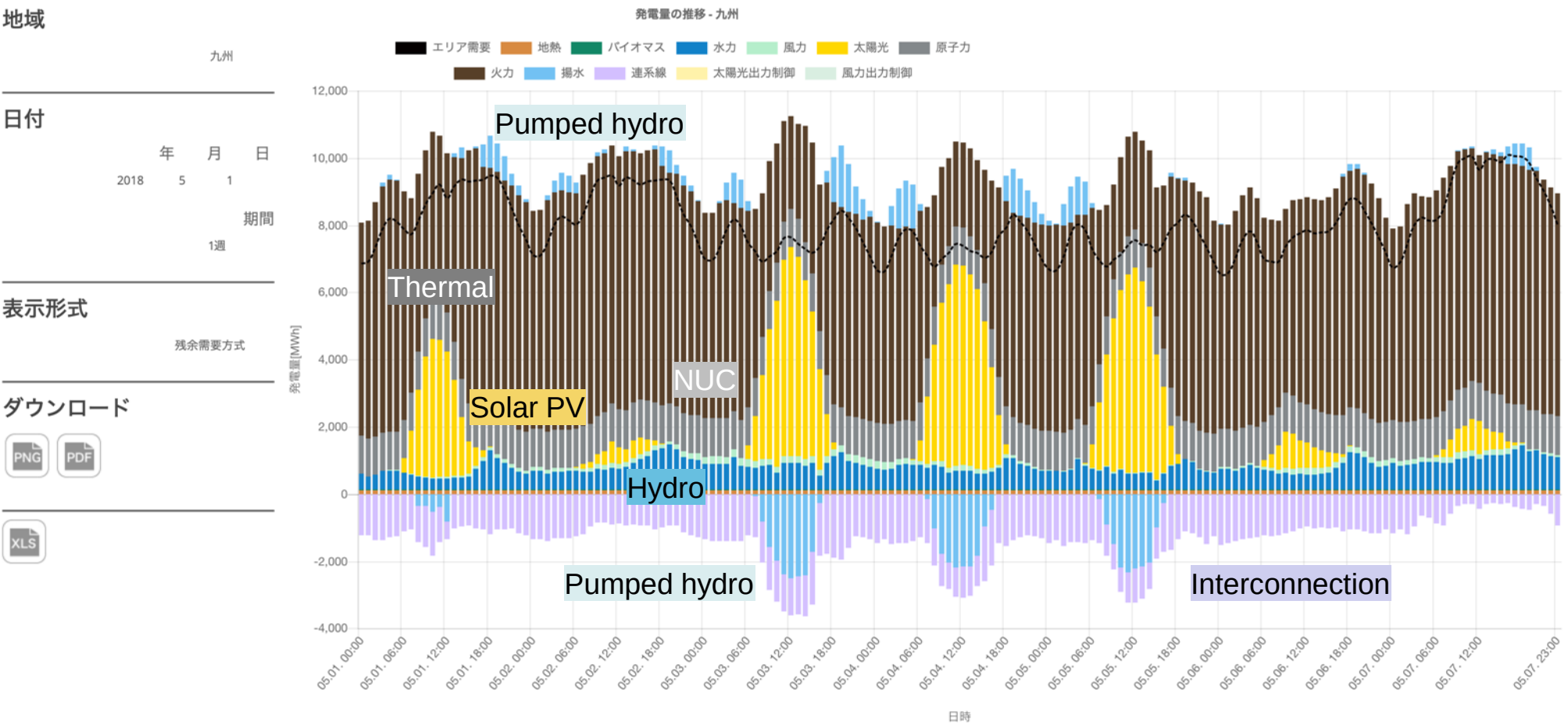
- The share of nuclear power has increased to 2.8% maintaining a low level (approximately half of the solar power).

Electricity production in Japan from 1 to 7 May 2018



Source: isep-energychart.com

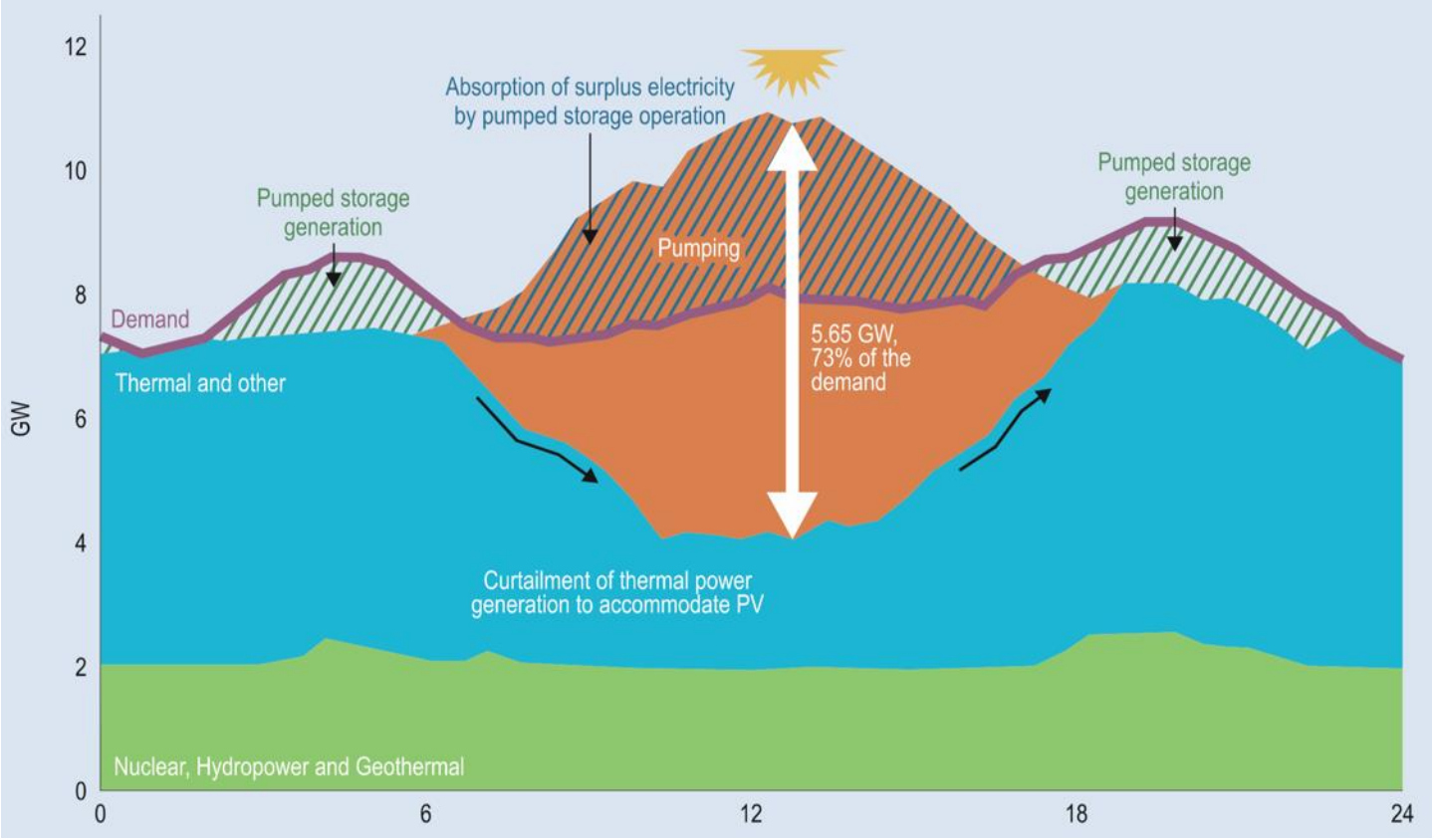
Electricity production in Kyushu from 1 to 7 May 2018



Source: isep-energychart.com

Priority order of output curtailment

Dispatchable thermal power plant → Pumped hydro → Inter-connection → Renewables → Nuclear and inflexible power sources



Kyushu Electric Restricts Renewable Energy Supplies For First Time

- Kyushu Electric had restricted third-party solar power supplies for two days, 13 and 14 Oct. in the last weekend.
- This was the first time, a Japanese utility has curbed the use of renewable energy in a main island.
- The curtailment is made without having to pay compensation after first curbing hydro and fossil fuel power output or transferring excess supplies to other regions.
- 430 MW solar PV was planned to be disconnected to the grid, while possible power supply was estimated at 13 GW, and demand was estimated at 8.3 GW at noon.

Japan Challenges toward RE Expansion

- Curtailment of output from PV and wind
- Energy storage demonstrations and tests
- New R&D platform at FREA
- Liberalization of the Japanese electricity market


FREA Visit, 31 May 2015

Sinzo Abe, Prime minister Japan


FREA-G Visit, 20 Feb 2016

Motoo Hayashi, Former Minister of METI

Energy Storage System Challenges

Tohoku Electric Power, Minami-Soma 40MW Demonstration System

nite, NLAB (National LABoratory for advanced energy storage technologies)

FREA: Fukushima Renewable Energy Institute, AIST

Missions

- International R&D base for renewable energy
- New industry promotion in damaged area

Location

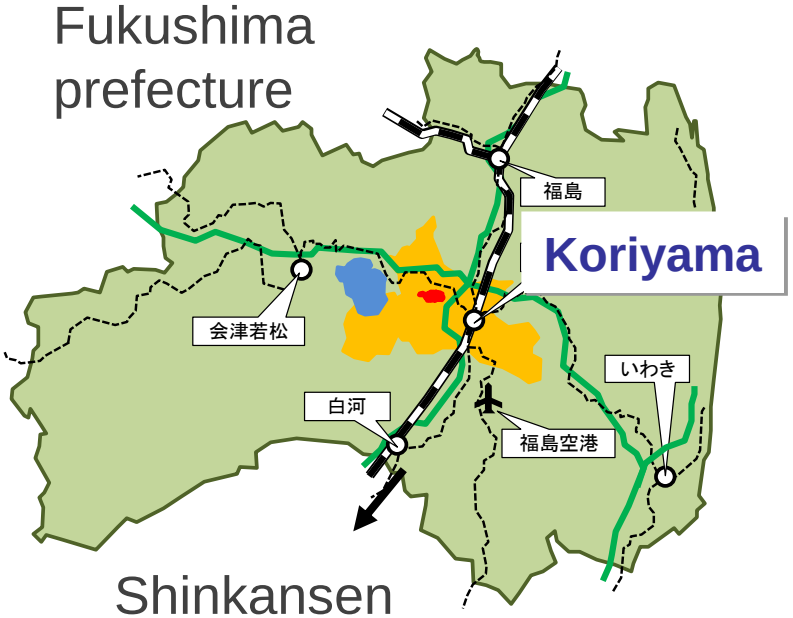
Koriyama, Fukushima

Schedule

‘13,Oct. organization founded
’14, Apr. open in Koriyama

Budget

10 billion yen for start up
(land, buildings, equipment)
3 billion yen/y, 400 people and more



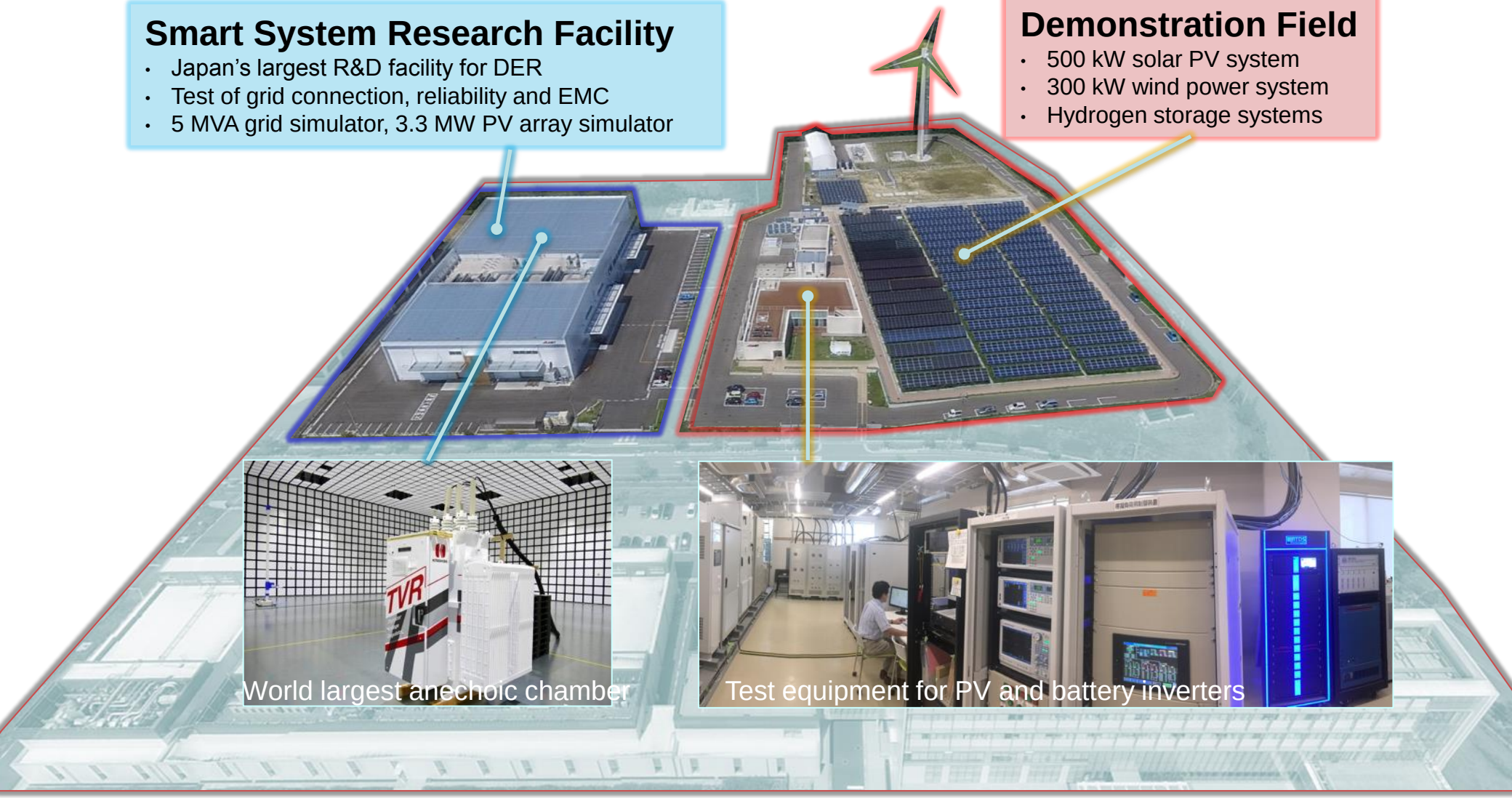
Aerial View of FREA

Smart System Research Facility

- Japan's largest R&D facility for DER
- Test of grid connection, reliability and EMC
- 5 MVA grid simulator, 3.3 MW PV array simulator

Demonstration Field

- 500 kW solar PV system
- 300 kW wind power system
- Hydrogen storage systems

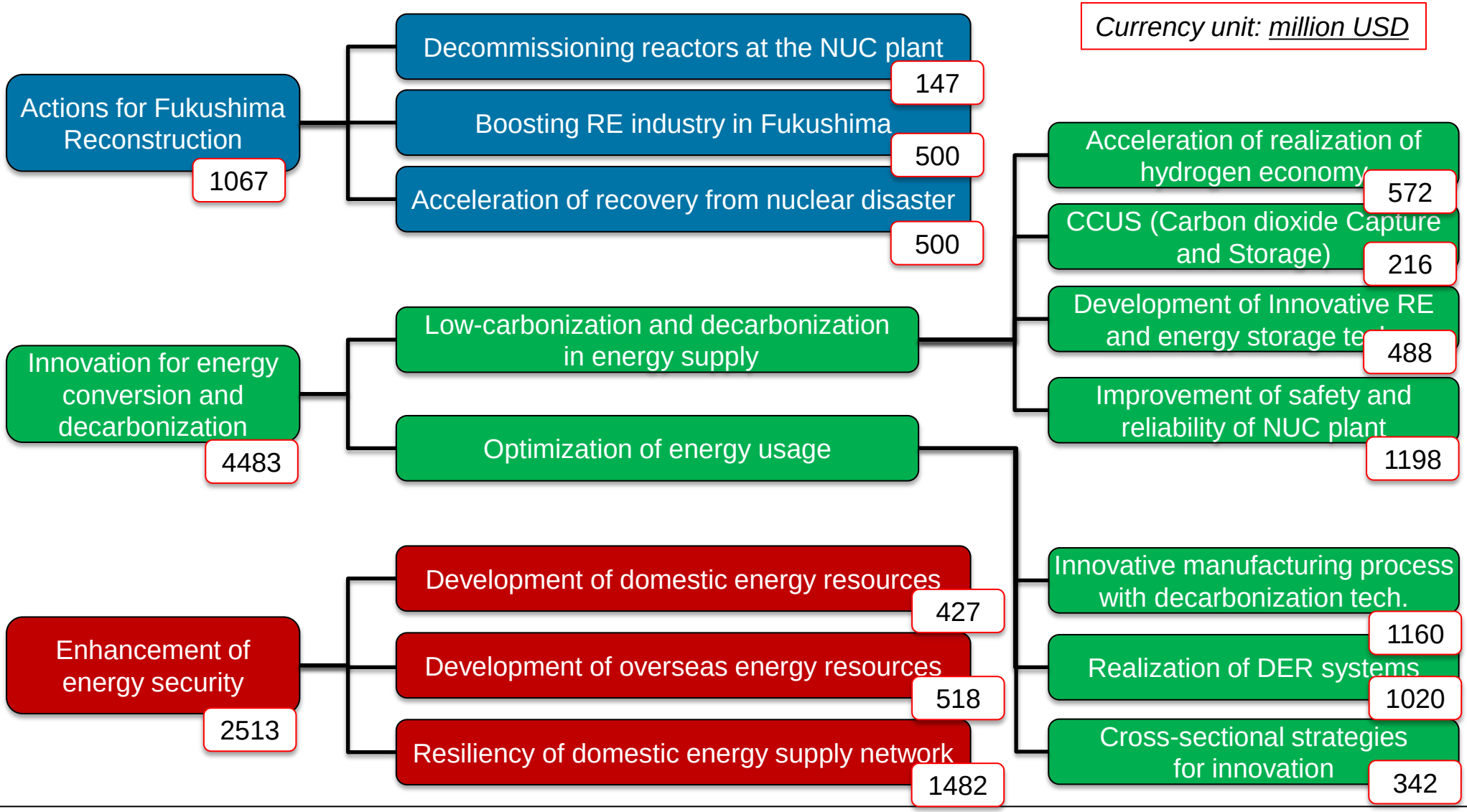


World largest anechoic chamber

Test equipment for PV and battery inverters

Overview of budget request for FY 2019 in resource and energy field

Currency unit: million USD



Grid support function requirements (LV)

Country	Germany	Italy	Austria	France	Spain	Europe (≦16A)	Europe (>16A)	U.S.	Japan
Function	2011	2012	2013	2013	2011/ 2014	2013	2014	(2018)	2016
Q control	X	X	X		N/A	X	X	X	N/A
PF control		X	P		N/A	X	X	X	N/A
Frequency control	X	X	X	X	N/A	X	X	X	N/A
Remote output control	X	X	X		N/A		X	X	P
LVRT		X			N/A		X	X	X
HVRT		X			N/A		X	X	N/A
Ref.	FGW TR3/VDE ARN4105	CEI 0-21	TOR D4	ERDF-NOI -RES_13E	RD1699/UN E206007-1	EN 50438	CLC/TS 50549-1	EEE1547 Full revision	JEAC 9701

X: available, P: partial available

Source: J.Hashimoto et al, Smart Inverter Functionality Testing for Battery Energy Storage Systems, Smart Grid and Renewable Energy, 2017

History of Grid Code in Japan

Updating Year by Year

Government
The Agency for Natural Resource and Energy, METI

Aug. 1986
Establishing “Grid connection Technical Requirement Guideline

Oct. 2004
Update to “Grid connection Technical Requirement related to Power quality Guideline”

National Standard
The Japan Electric Association (JEA: Non governmental)

2001
Establishing “Technical guidance of interconnection for distributed power supply ” JEAC9701

2006
Establishing “Grid-interconnection Code” JEAC 9701-2006

Utilities

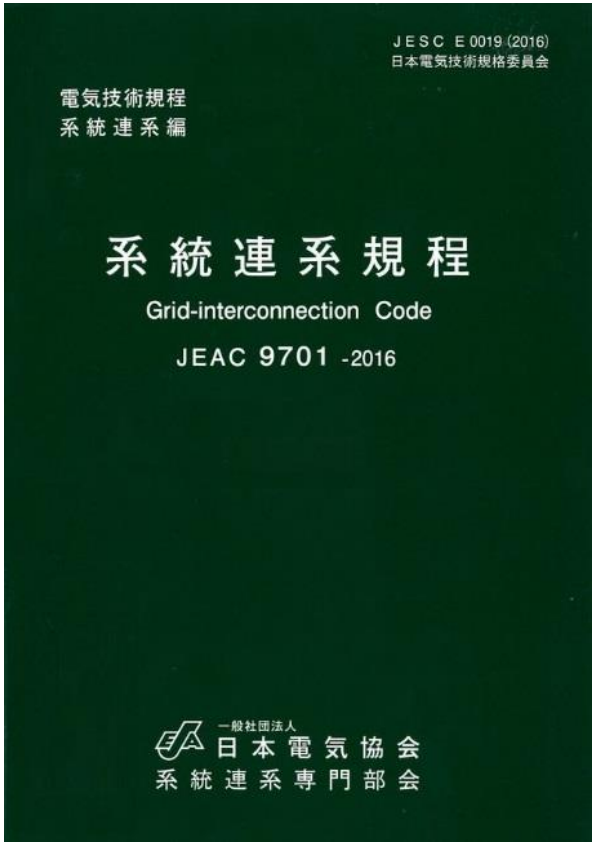
Each utility prepares its own “ Grid Code” (according to the codes)

Source：NEDO

“Grid-interconnection Code” JEAC 9701

Grid-Interconnection Code “JEAC 9701-2016”
“JESC E0019(2016) ”

- ✓ it has been revised every year based on requirements from power utilities and etc.
- ✓ Its amendments have been published as needed.
- ✓ Authorized by those two committees in the Japan Electric Associates
  - ✓ “Specialized sectional committee regarding Grid Interconnection” and
  - ✓ “Japan electric standard and code committee”



Source：NEDO

Essence of “Grid-interconnection Code” JEAC 9701

Low voltage distribution line (100/200V)

- ✓ Single or three phase power sources can be connected.
- ✓ Principally, only inverter based power sources can be connected.
- ✓ Anti-islanding is required.

Medium voltage distribution network (6.6kV-33kV)

- ✓ Principally, three phase rotating machine or inverter based generators can be connected.
- ✓ Anti-islanding is required.

High Voltage (Sub transmission)

- ✓ Anti-islanding is not required, with frequency relay or transfer-interrupting systems.

Spot Network*

- ✓ Principally, reverse power flow is not allowed.

* 22kV or 33kV, Three phase parallel underground cable system, where customer connected to secondary side of transformer.

Source：NEDO

History for Grid-Interconnection requirements for DER

1990s	Establishment of Grid connection guideline
2000s	Deployment of Renewables Update to Grid connection Guideline
2002～2010	Development of new Anti-islanding method by NEDO R&D projects including Ota-Project
2011～2012	Standardization of testing method of Anti-islanding system. Discussion about FRT requirement for
2012	Reflected to Grid-interconnection Code in Japan of Anti-islanding and FRT system for PV
2017	**Voltage flicker in Kyushu region triggered by Anti-islanding system**
2019	**Review of Anti-islanding system for medium voltage（plan）**

Source：NEDO

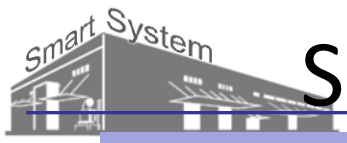
Amendment of JEAC9701-2016 in 2018 : Anti-Islanding

Voltage Flicker triggered by PV inverters

- "voltage flicker" occurred in Kyushu in 2017.
- Caused by large amount of reactive power from PV inverters with new anti-islanding system.
- Kyushu Power Electric has changed the setting of reactive power injection for PV inverters (10 kW and more).
- Anti-islanding system for medium voltage（6600 V）will be reviewed after 2019.

Amendment of JEAC 9701-2016

- Grid Code JEAC 9701 was amended in 2018 by adding rule for new anti-islanding system to avoid voltage flicker.

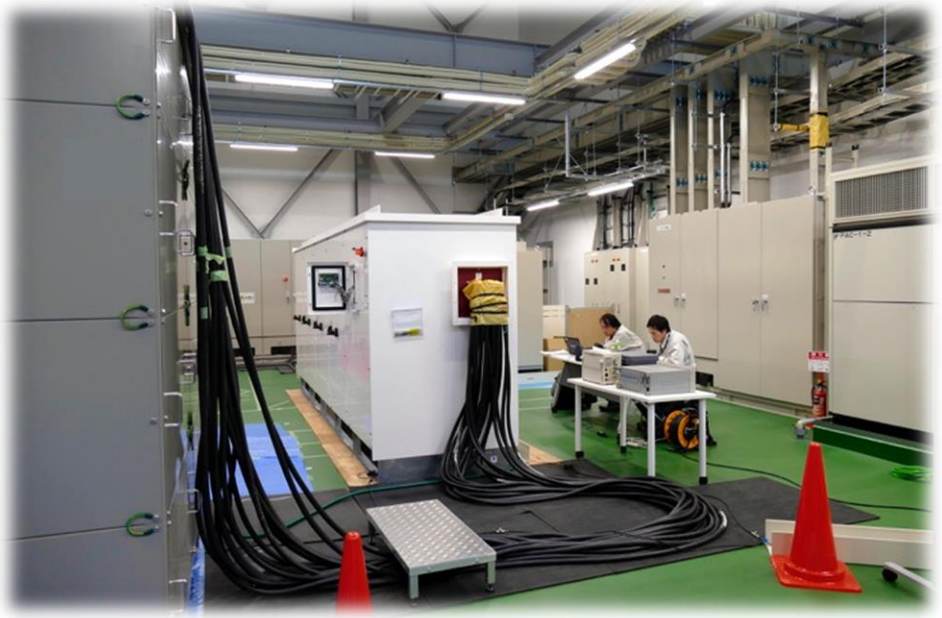


Smart System R&D Test Platform (FREA-G)

- Substantially expand the aforementioned FREA facility to build the world's most advanced test facility.

A. Grid Connection Test Bed

- Conduct required tests to secure power quality for the grid connection of distributed generations.
- Conduct various PCS tests (anti-islanding test, FRT test, etc.)
- Maximum capacity of AC simulator: 5MVA.
- Maximum capacity of EUT: 3MW.

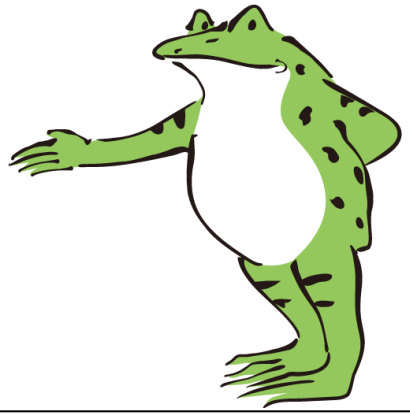


B. Safety Test Bed

- Conduct high-temperature acceleration and heat cycle tests with PCS where real environment is simulated to evaluate long-term reliability, and also safety-related tests including surge voltage test.

C. EMC Test Bed

- Conduct tests to measure electromagnetic radiation from PCS and to check if PCS's functions and behavior would be inhibited by external electromagnetic wave.



D. System Performance Test Bed

- Evaluate different capabilities (e.g. automatic control function to maximize output depending on the weather) of distributed generations (PV, batteries, etc.) and PCS as one single system.

Smart System R&D Test Platform

Manufacturers Integrators

Tests / Certifications

Test Labs

Test Methods
Test Platform

AIST - FREA

Requirement Analysis

Verification Feedback to R&D

Acceptance Test

High Level Design

System Test

Detailed Design

Integration Test

Unit Design

Unit Test

Field Database
Site Acceptance Test

Integration of System Test and Simulation

Control Protocols

DER Unit Test

Smart System R&D Test Platform

Scoping | Design | Development | Buy / Build Implementation | Verification

Contributions to Expansions of Smarter DER Systems

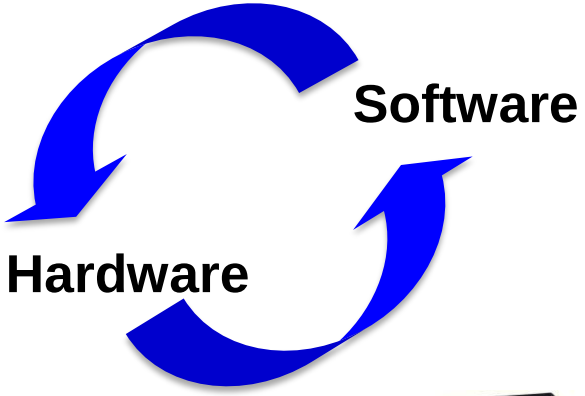
①Hardware Testing ②Interoperability Testing ③System Proofing

FREA-G Test bed

・Single EUT testing

FREA-G with HILs

・EUT test with HILs

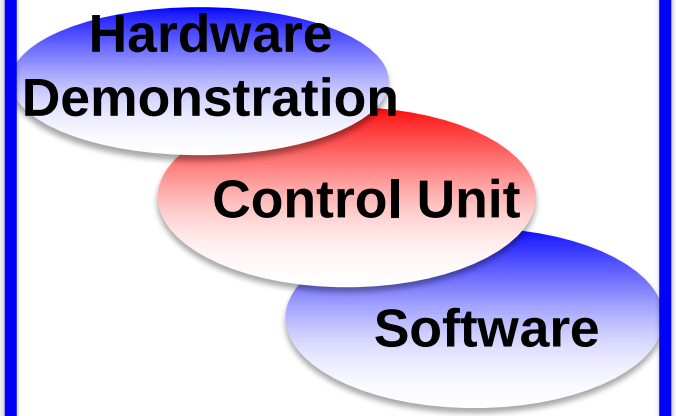


Flexibility

Real Time Digital Simulator

System Validation Field

・DER testing platform



Thank you!