Revolutionizing Our Energy Future

- Joint International Smart Grid Demonstration Projects by NEDO -

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Today's Topics

1. Introduction of NEDO
2. Recent Issues and Challenges in the Energy field.
3. NEDO's Smart Grid Demonstration Projects in the U. S.

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1. Outline of NEDO

New Energy and industrial technology Development Organization

NEDO is Japan's largest public R&D management organization.
Following the two oil crises of the 1970s, the need for energy diversification increased. Against this backdrop, NEDO was established as a governmental organization in 1980 to promote the development and introduction of new energy technologies.

Chairman: Mr. Kazuo Furukawa

Organization: -Incorporated administrative agency under the Ministry of Economy, Trade and Industry (METI) of the Japanese government
- Established in 1980

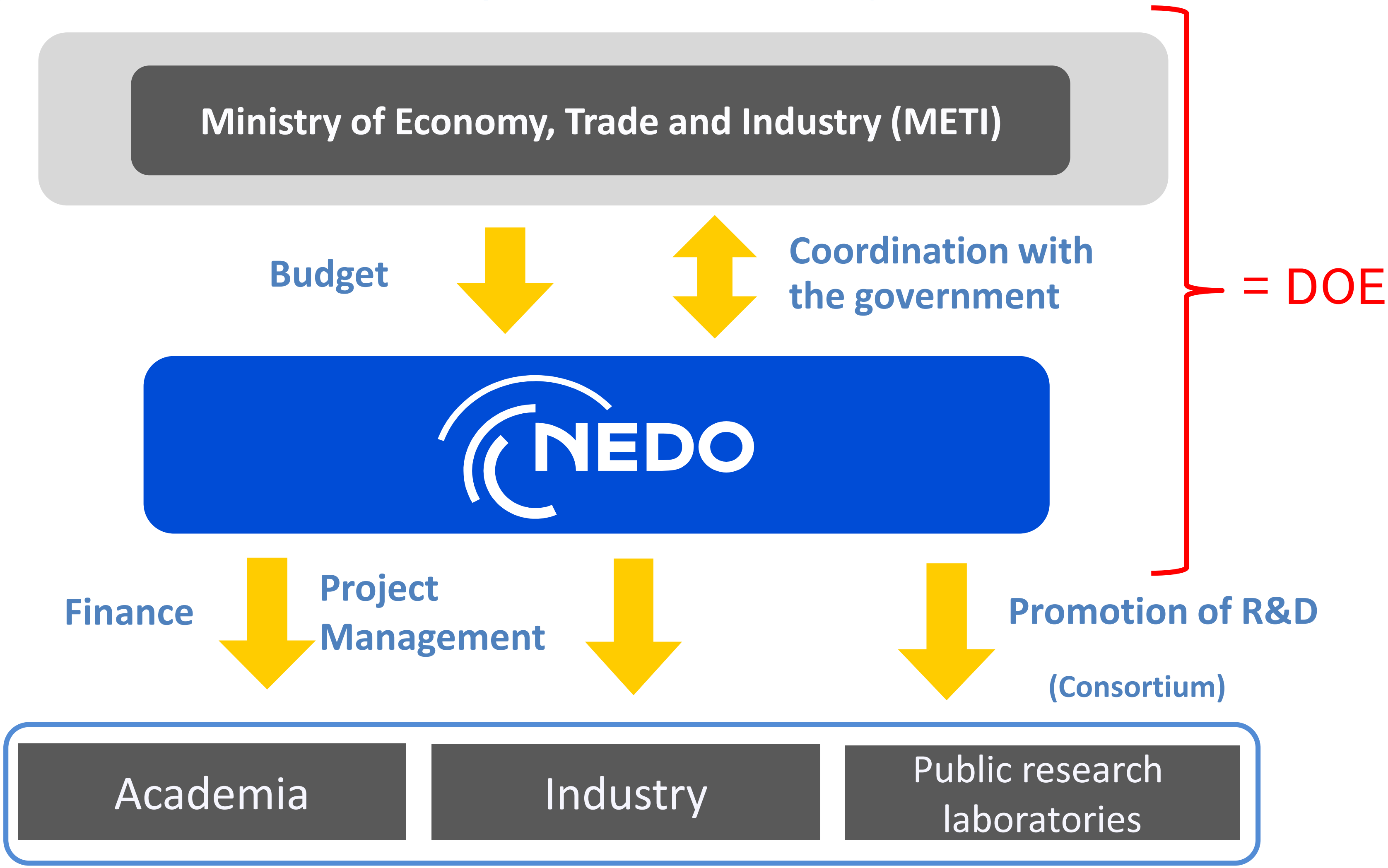
Location: Kawasaki City, Japan

Personnel About 800

Budget Approximately 1319 million USD (2015 fiscal year)

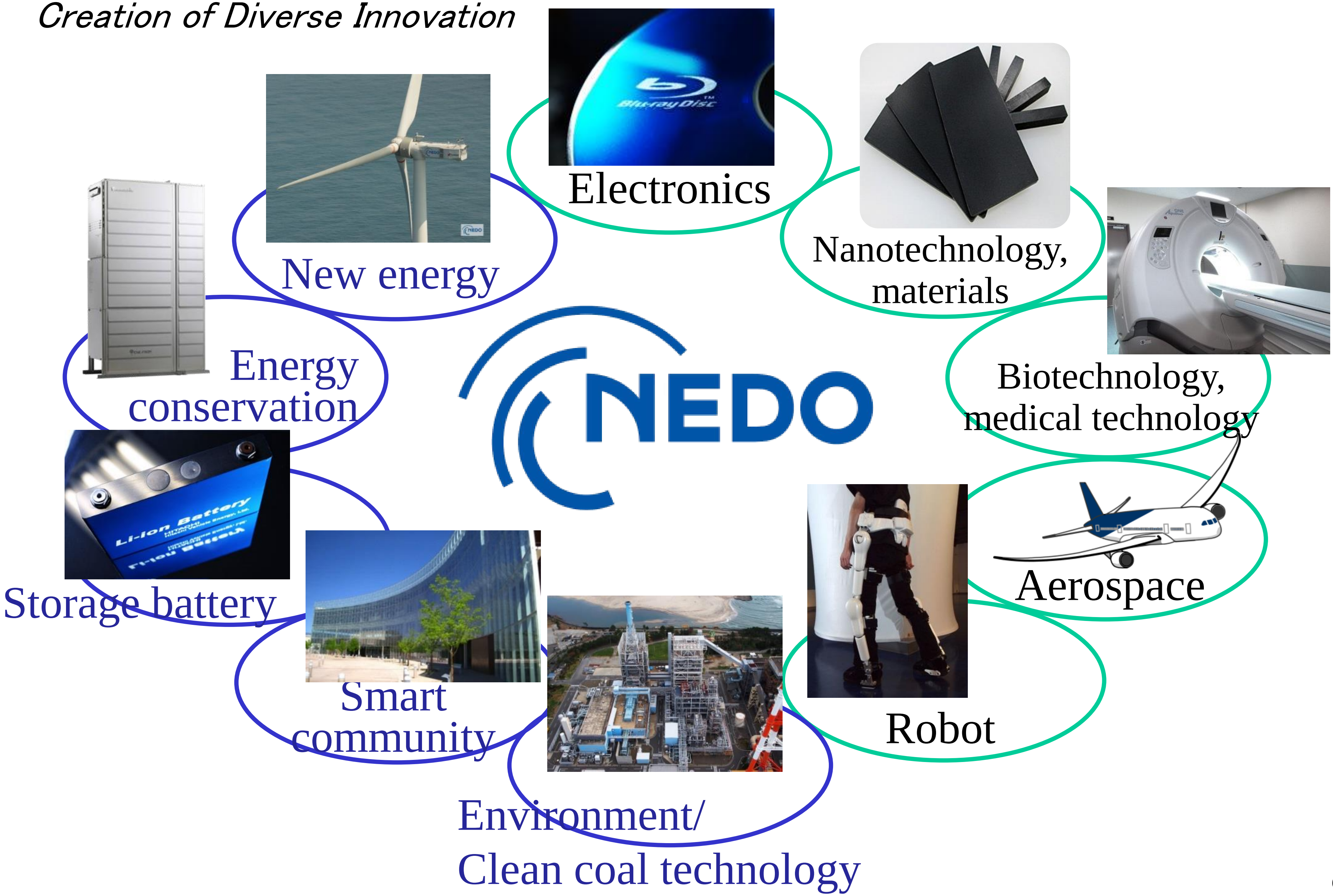
1. Outline of NEDO

Japanese version of Department of Energy (DOE)



1. Outline of NEDO

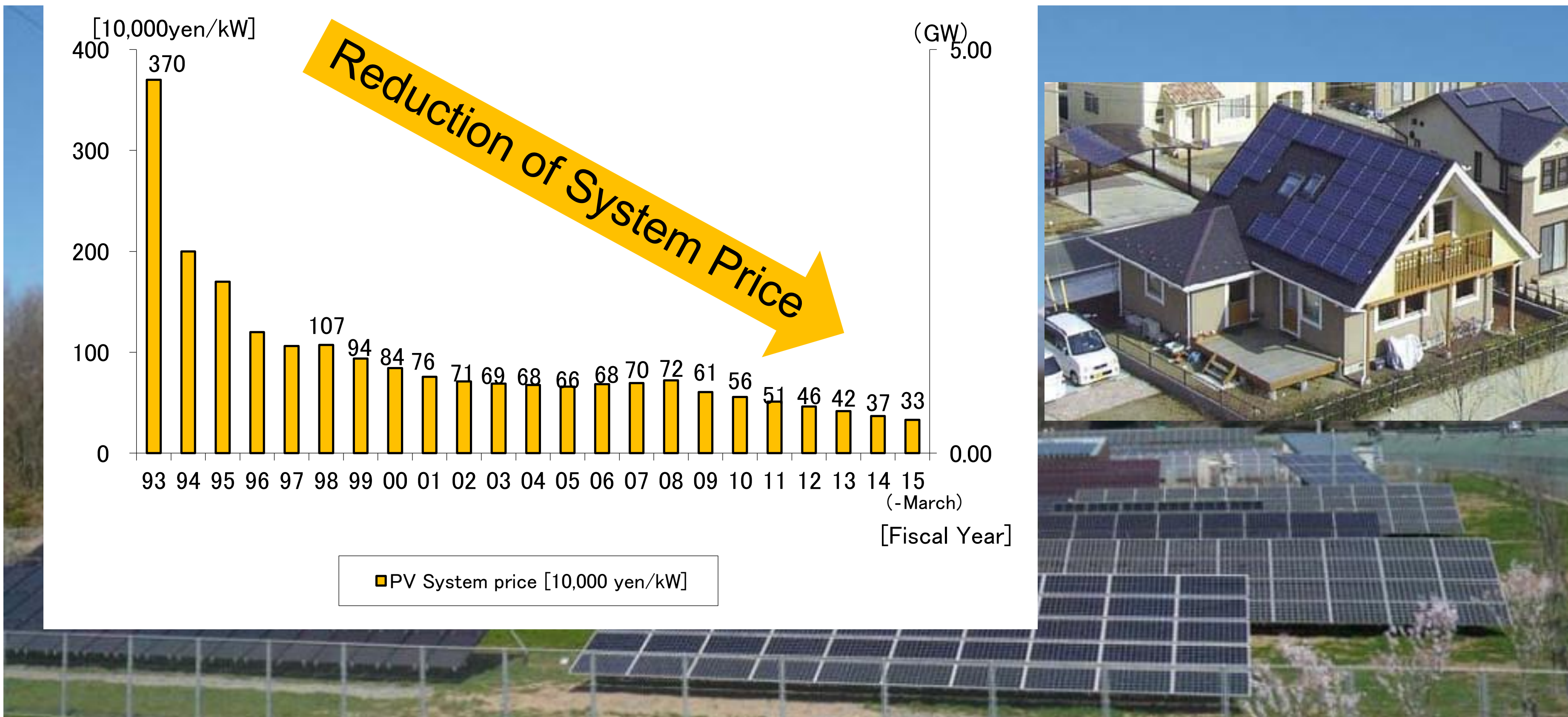
Creation of Diverse Innovation



1. Outline of NEDO

NEDO's R&D led to the creation of the Solar Cell Market

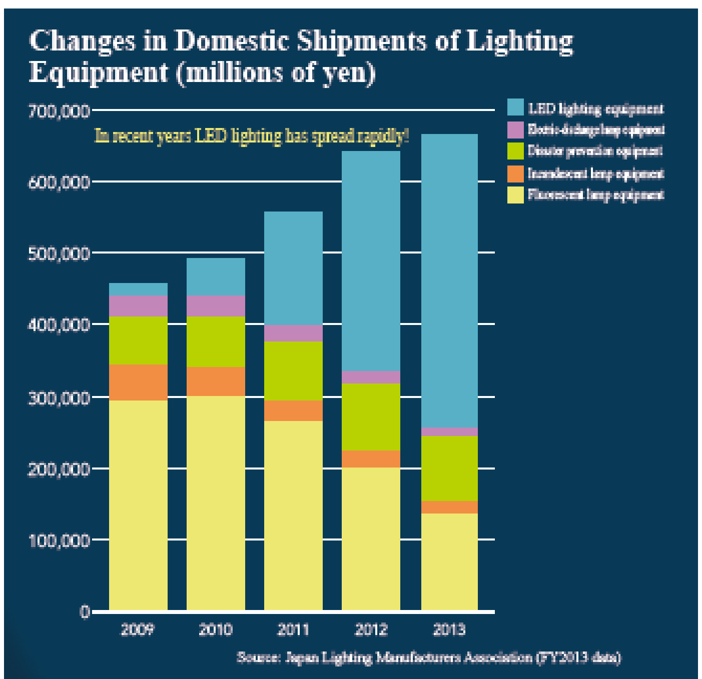
- NEDO carried out 30 years of research to "COMMERCIALIZE" PV technology.
- A system installation price is 10 times Lower Now.



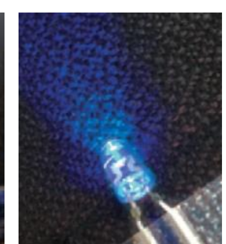
1. Outline of NEDO

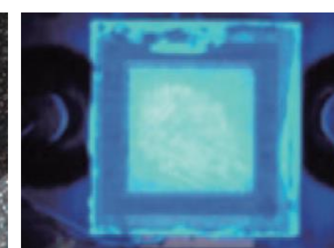
Advanced LED Technology

- The project leader, Professor Hiroshi Amano, was awarded the 2014 Nobel Prize in Physics.



NEDO's Project Leader is
a 2014 Nobel Prize Winner!

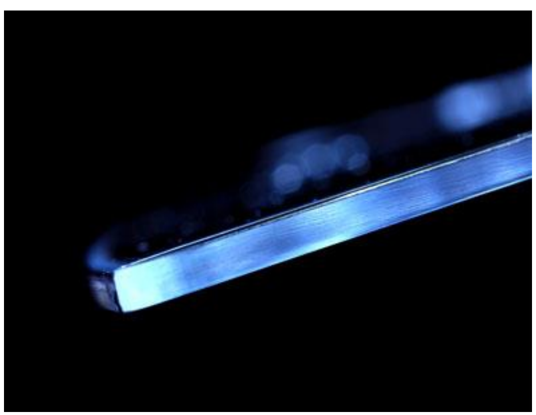




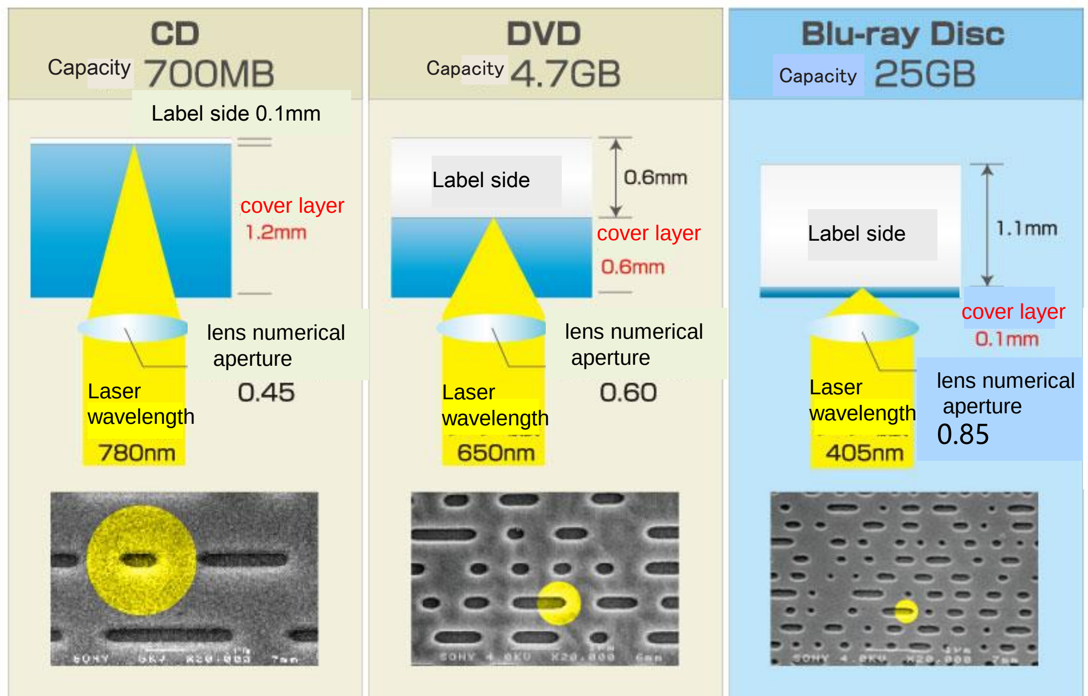
1. Outline of NEDO

Blu-ray Disc

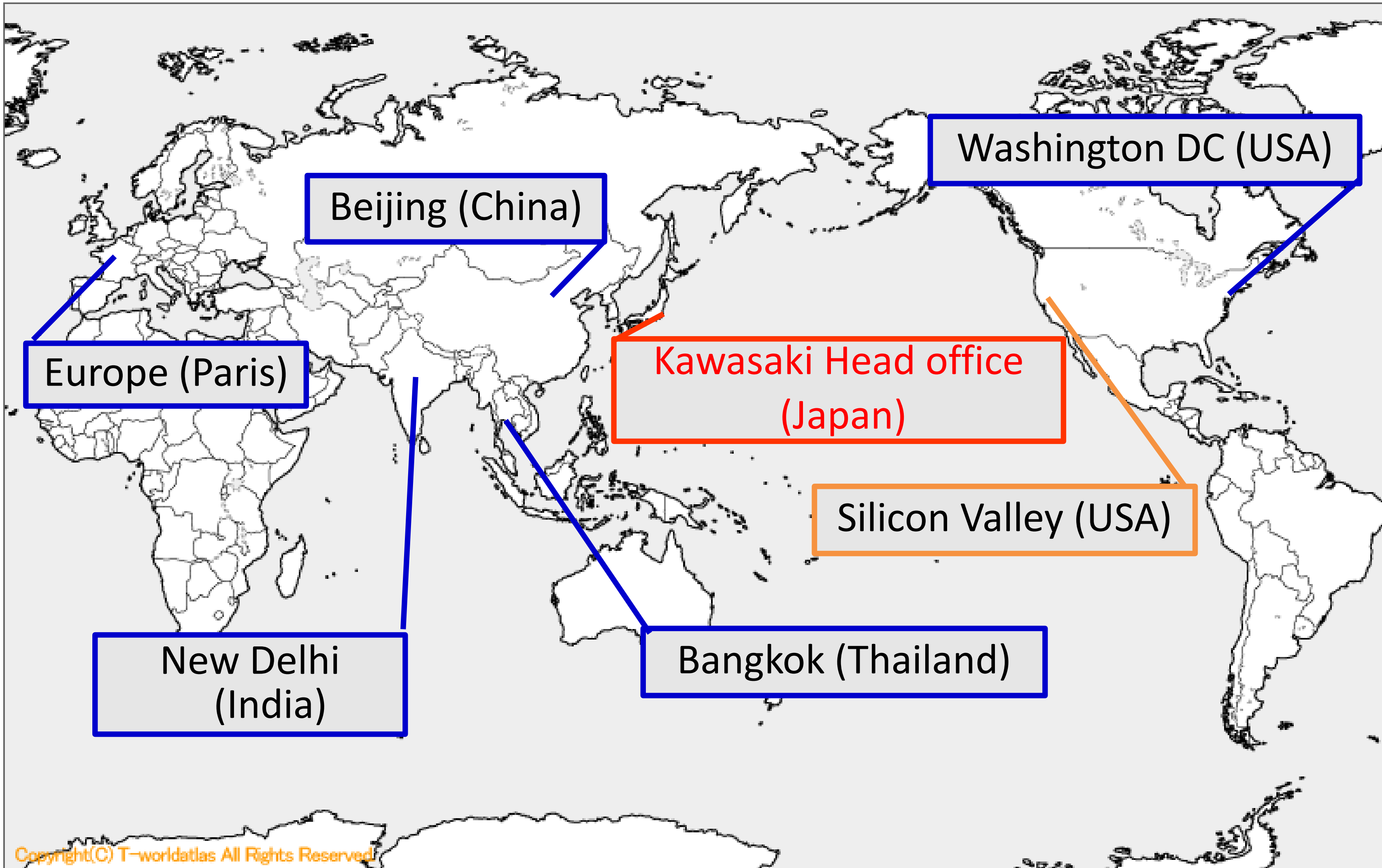
- The development of the Blu-ray Disc technology was derived from a NEDO project.
- The Project succeeded in raising recording density by technology which reads data by detecting the very small pit on a disk with blue laser.



Cross-section and optical system differences in the CD, DVD and BD



Overseas Offices



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2. Recent Issues and Challenges in the Energy field

1) Climate Change

2) Penetration of Renewable Energy

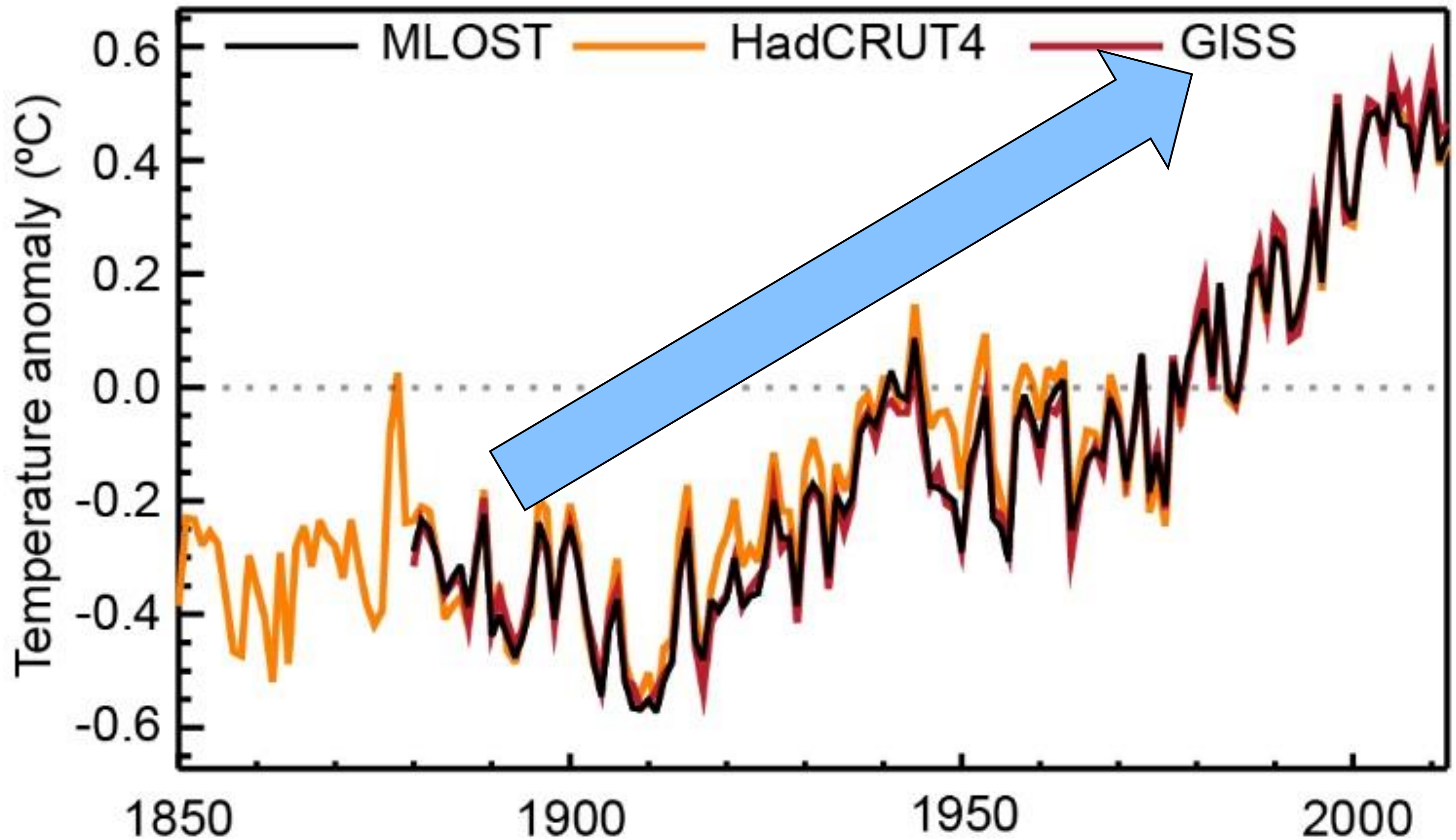
3) Introduction of Distributed Generation

4) Needs for Resilient System

5) Challenges for a Mass Introduction of Renewable Energy
   i. Frequency regulation
   ii. Duck Curve Problem
   iii. Voltage rise

- Global mean Surface temperature has increased since late 19th century.

A warming of 0.85 ° C (1880–2012)



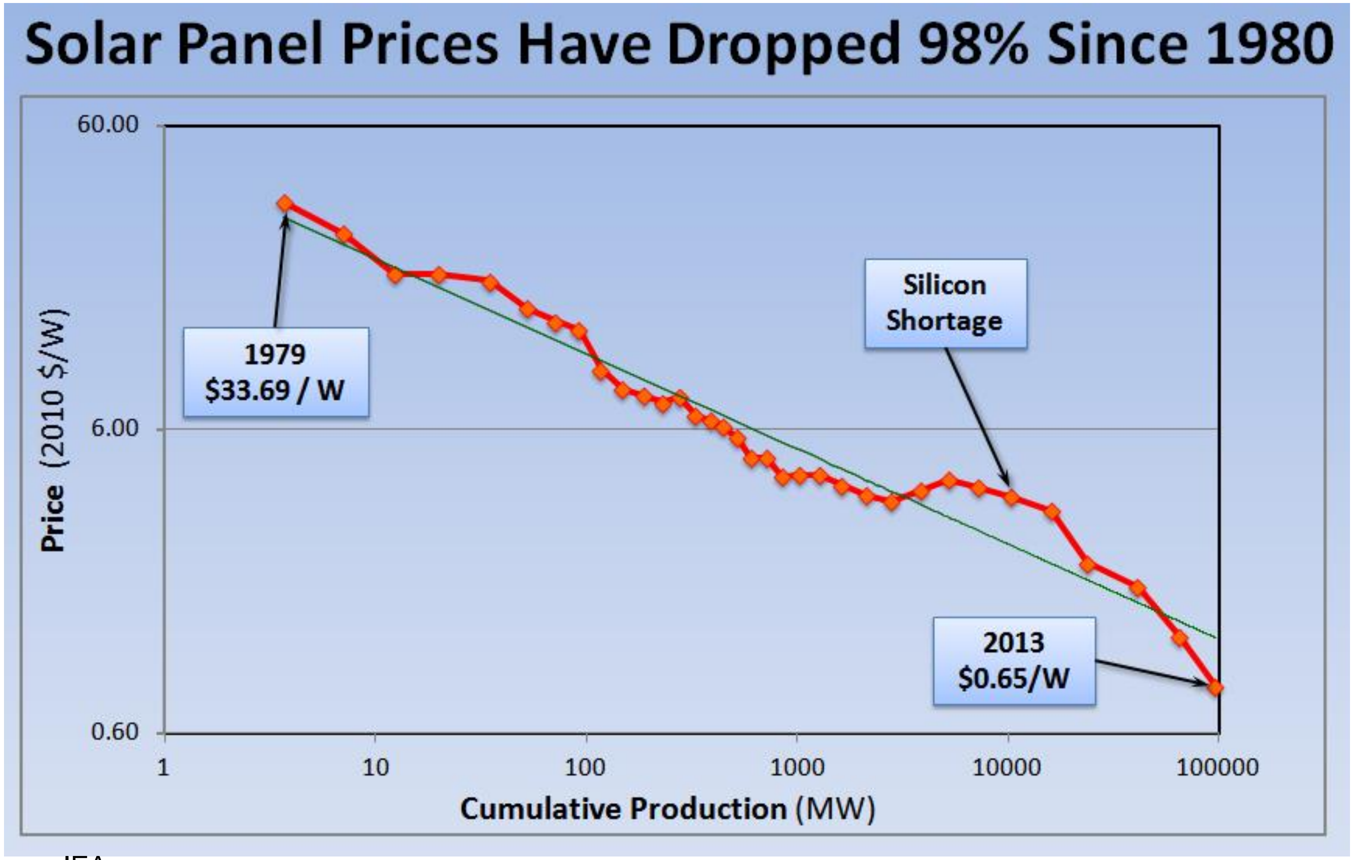
Source：.IPPC Climate Change2013: The Physical Science Basis

2. 1) Climate Change

source：NOAA

Solar Panel Price is going down in the World

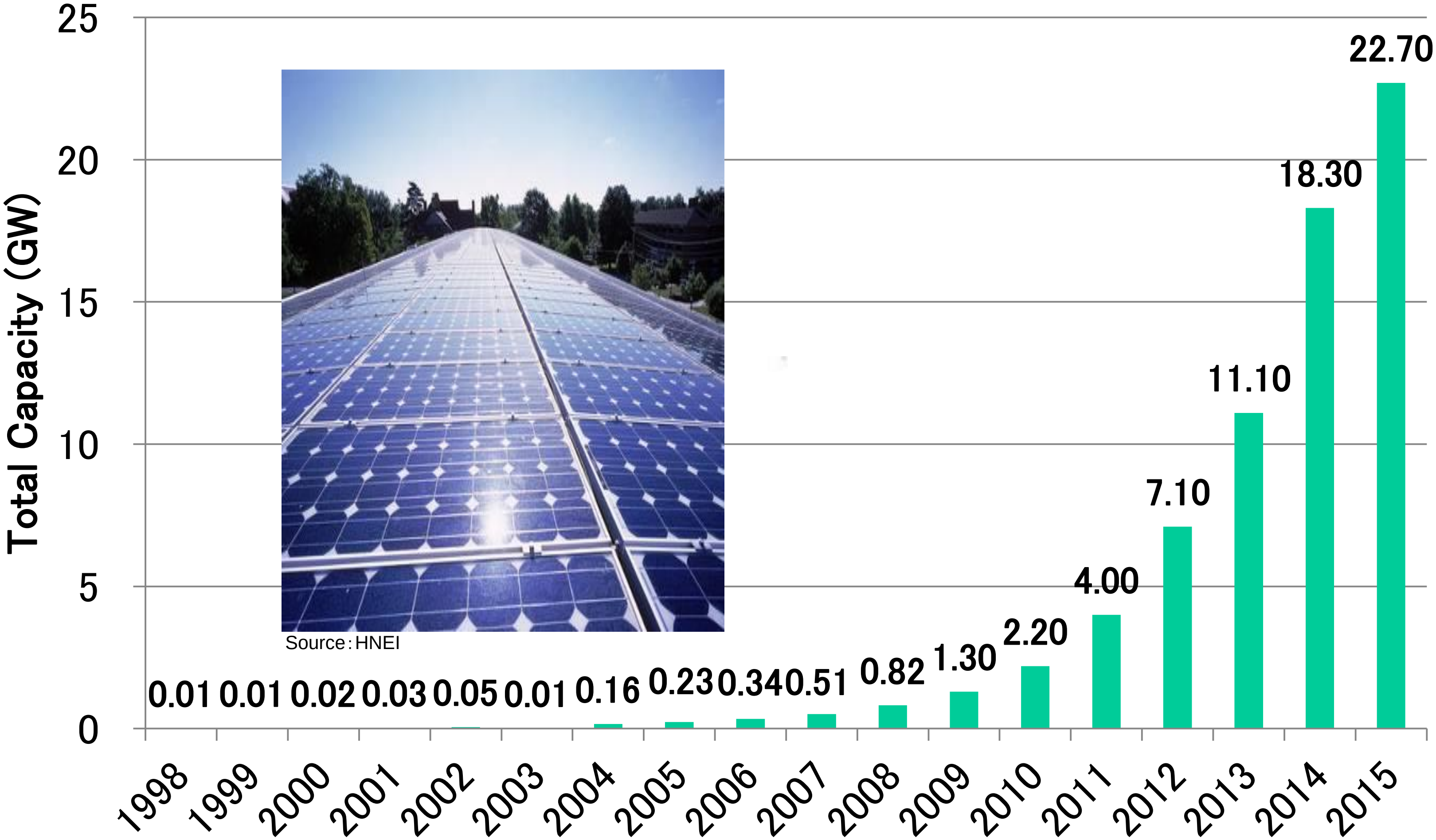
- Price of PV is going down. Recent data from US shows the price of PV is now under \$0.65/W (1979; \$33.69/W) .
- The cost of the energy from PV is lower than the electricity price from utilities in many places.



Source：IEA

2. 2) Penetration of Renewable Energy

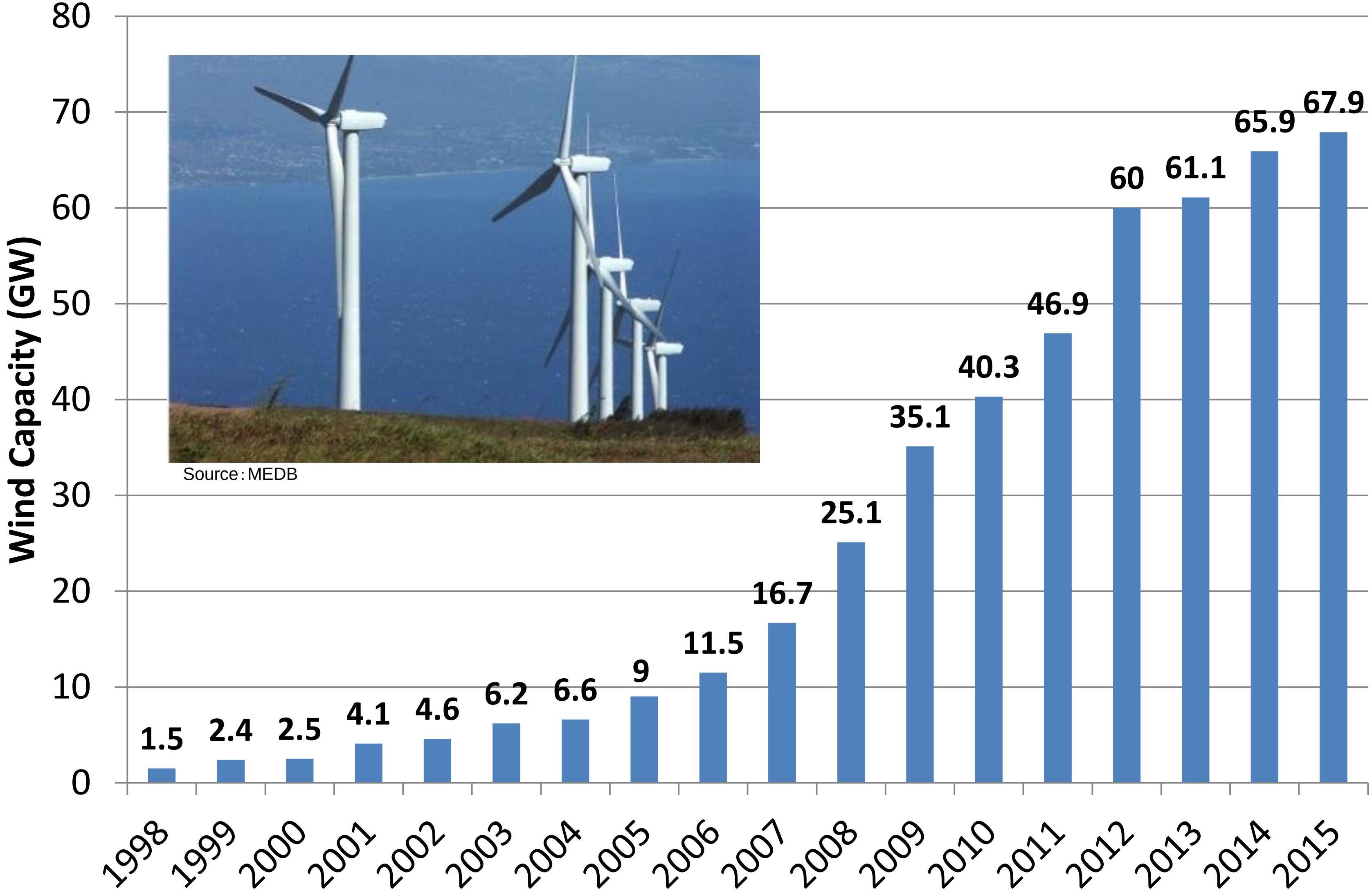
Total Installed Solar PV Capacity in the U.S.



Source: U.S. Department of Energy
https://emp.lbl.gov/publications/tracking-sun-vii-historical-summary-installed-price-photovoltaics-united-states-1998-20

2. 2) Penetration of Renewable Energy

Total Installed Solar Wind Capacity in the U.S.



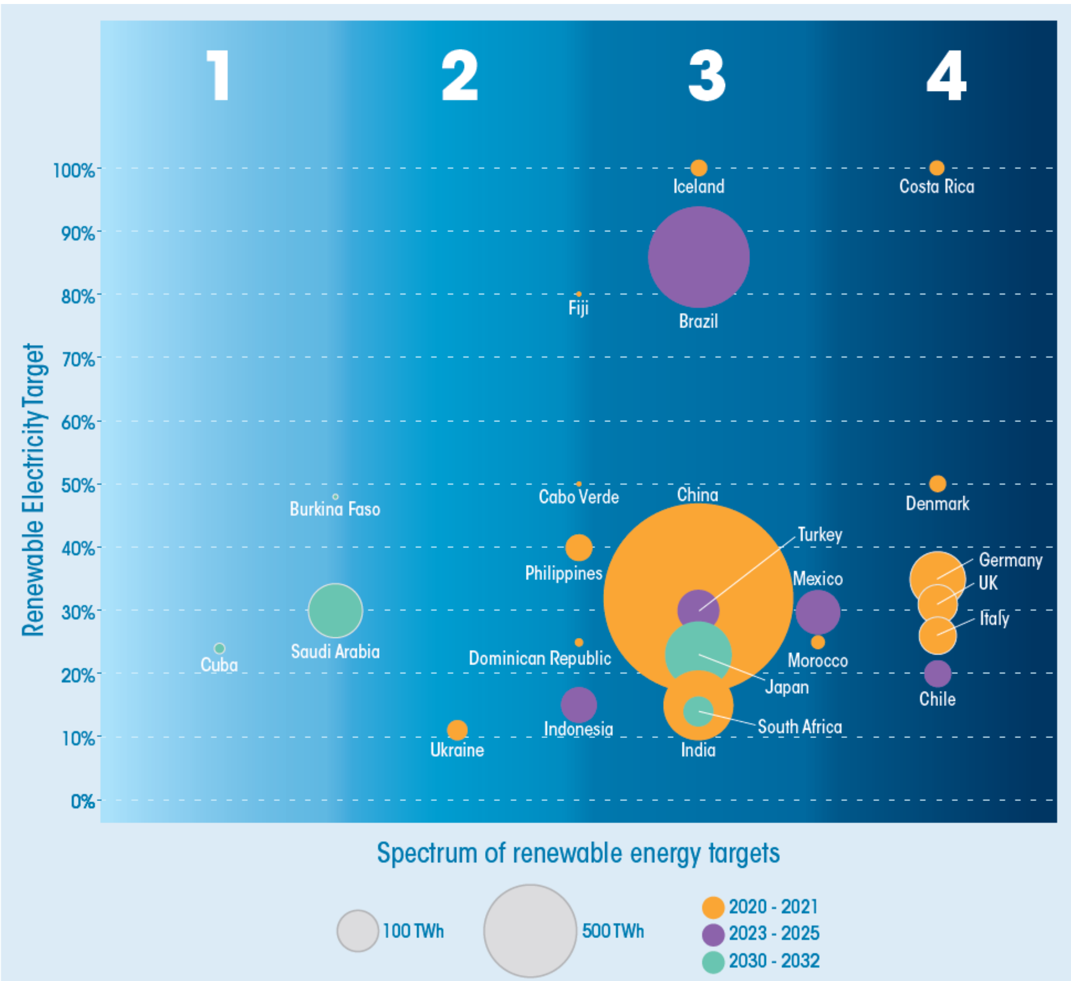
Source: U.S. Department of Energy
https://emp.lbl.gov/publications/2014-wind-technologies-ma

2. 2) Penetration of Renewable Energy

Renewable Energy Targets of the world

- Many countries already set ambitious targets for renewable energy.

Renewable Energy Targets



Spectrum of Renewable Energy Targets

Source：.IRENA "Renewable Energy Target setting"

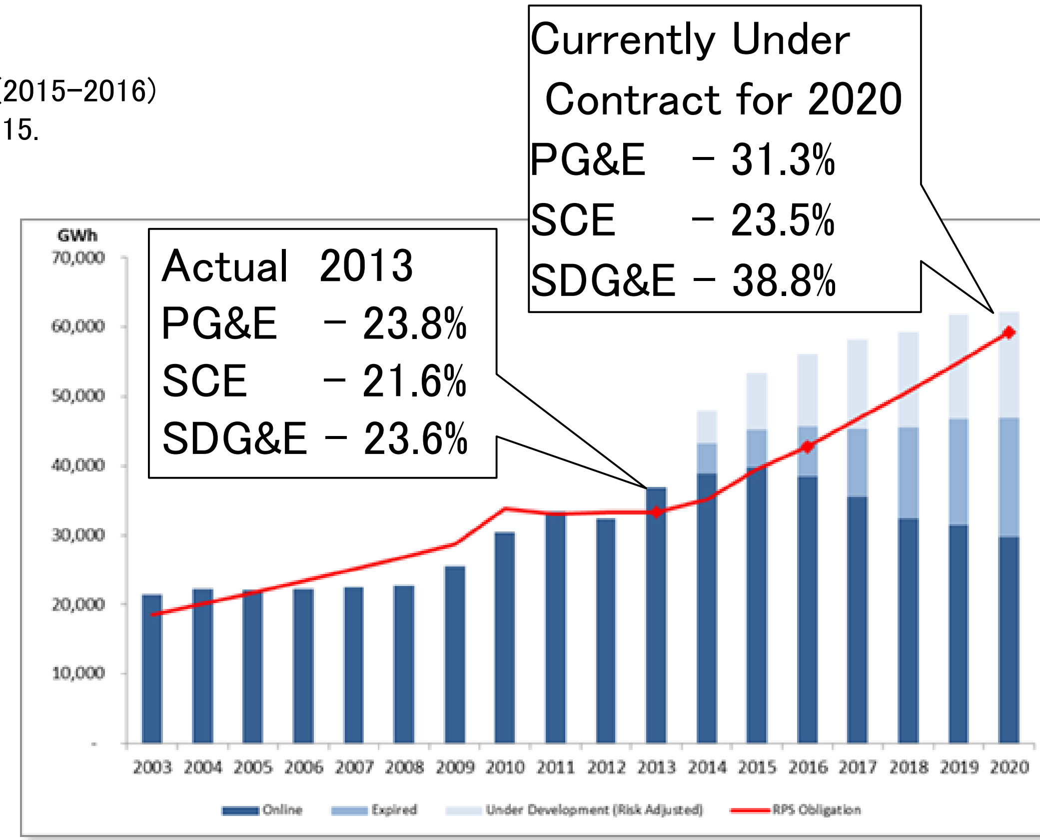
2. 2) Penetration of Renewable Energy

California Renewable Energy Target

- The California State must achieve RPS target of 33% by 2020.
- Governor Brow has just signed new ambitious RPS target of 50% by 2030 on October 7th.

SB-350 Clean Energy and Pollution Reduction Act of 2015.(2015-2016)
Senate Bill No. 350 Approved by Governor October 07, 2015.

Source：Go-biz

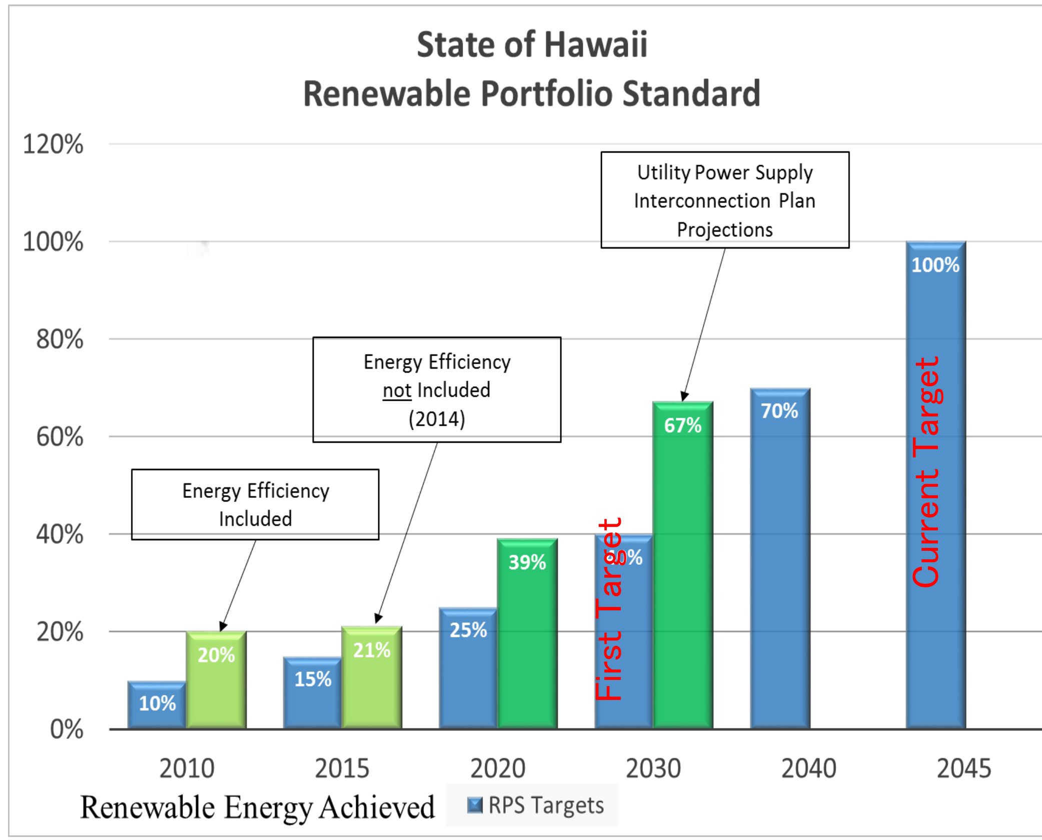


Source：CPUC “Renewables Portfolio Standard Quarterly Report Q1 2015”

Hawaii Renewable Energy Target

The State of Hawaii set a RPS target of 100% by 2045 on July 1st. 2015.(HB623)

Source: Governor.hawaii.gov



Source: HNEI

2. 3) Introduction of Distributed Generation

- Roof-top solar is penetrating to the customer side.

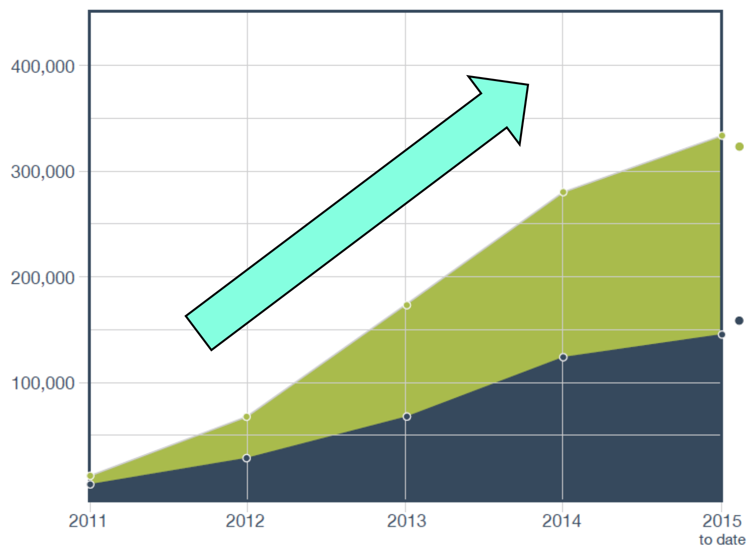
Residential solar PV capacity 0.8GW(2011) → 4.4GW(2014)
Source: EIA data

2. 3) Introduction of Distributed Generation

- The spread of EV will cause a higher peak of demand.
- EV can be used as a battery.

Source：MEDB

EV Sales

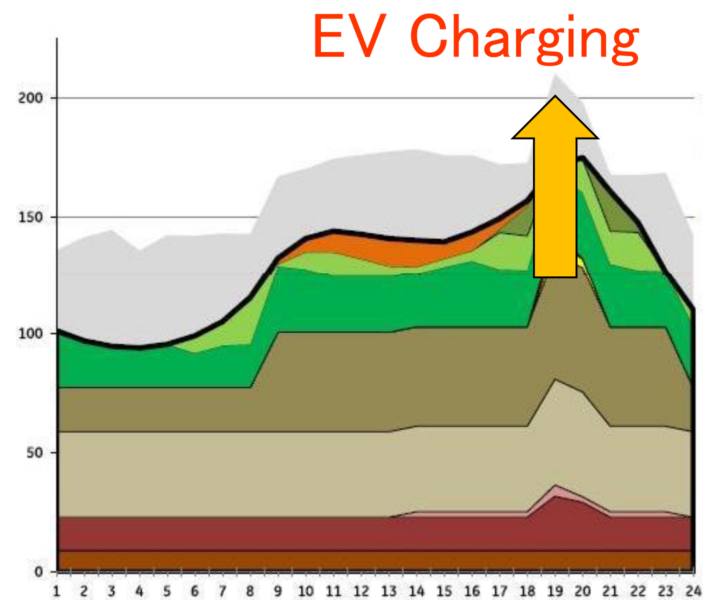


Source：California Plug-In Electric Vehicle Collaborative

Cumulative 2011–present: 339,529 (National)

Cumulative 2011–present: 142,069 (CA)

An image of power demand



The figure is for illustrative purposes only.
source：Hawaii University

Other tools for Distributed Generation

Storage batteries

Gas engine generator

Source：DOE, PG&E

Demand Response

Hydrogen Fuel Cell

2. 4) Needs for Resilient System

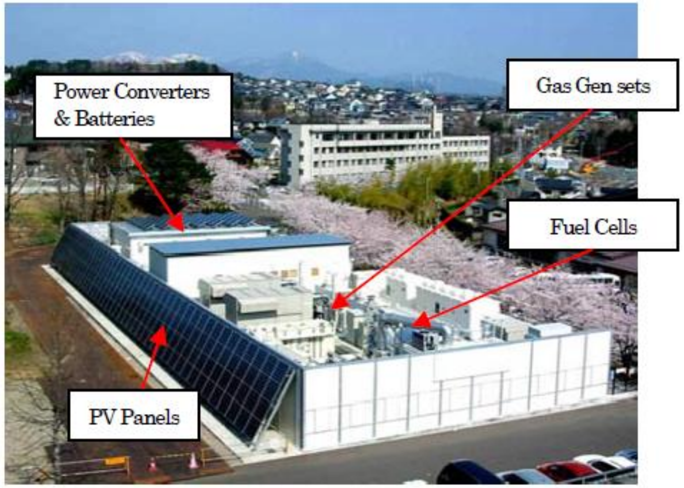
- Hurricane Sandy alone caused more than 8.5 million power outage across 21States.
- Centralized grids are inherently vulnerable to single points of failure.

Source：DOC/NOAA web

Operational Experience of Sendai Micro Grid

- Sendai Micro Grid survived the huge earthquake and supplied electricity to the hospital.

Great East Japan Earthquake(2:46 pm on March 11, 2011)



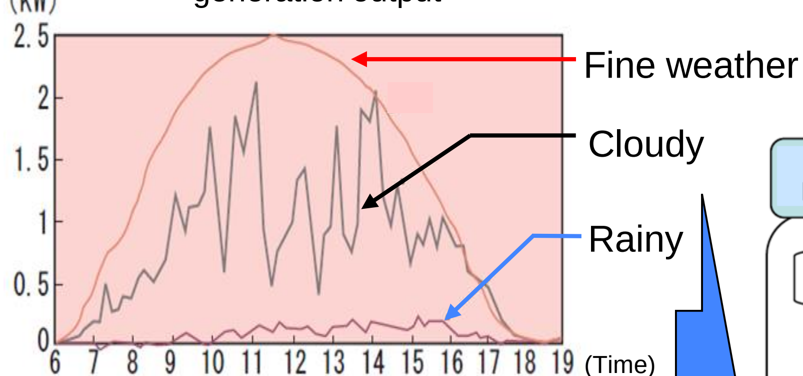
Demonstration Project on Power Supply System by Service Level

2. 5) Challenges for a Mass Introduction of Renewable Energy

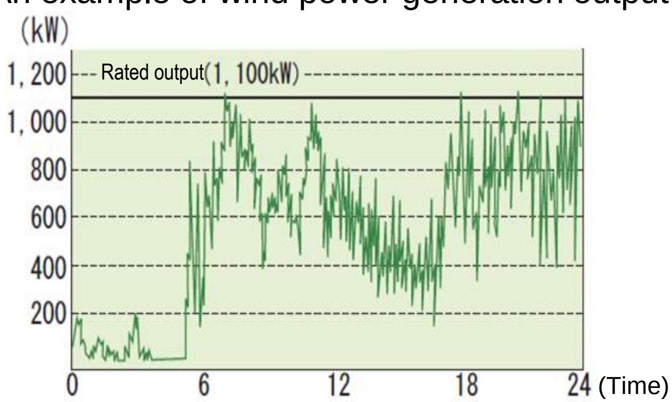
ⅰ. Frequency regulation

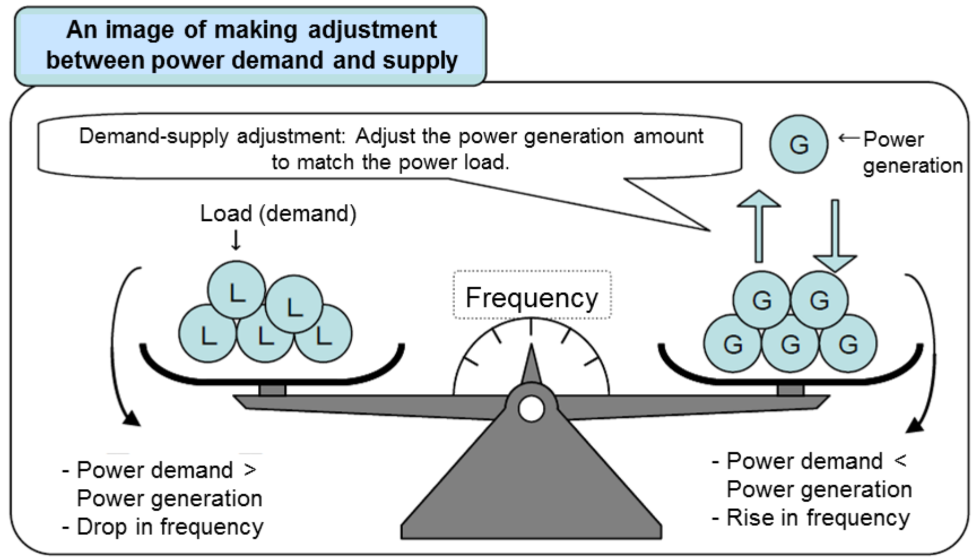
- As renewable energy sources are variable in nature, they could cause difficulty in the stable supply of electricity when introduced on a large scale.
- Power demand and supply always need to be matched, and frequency is maintained constant by matching demand and supply.

An example of solar photovoltaic power generation output



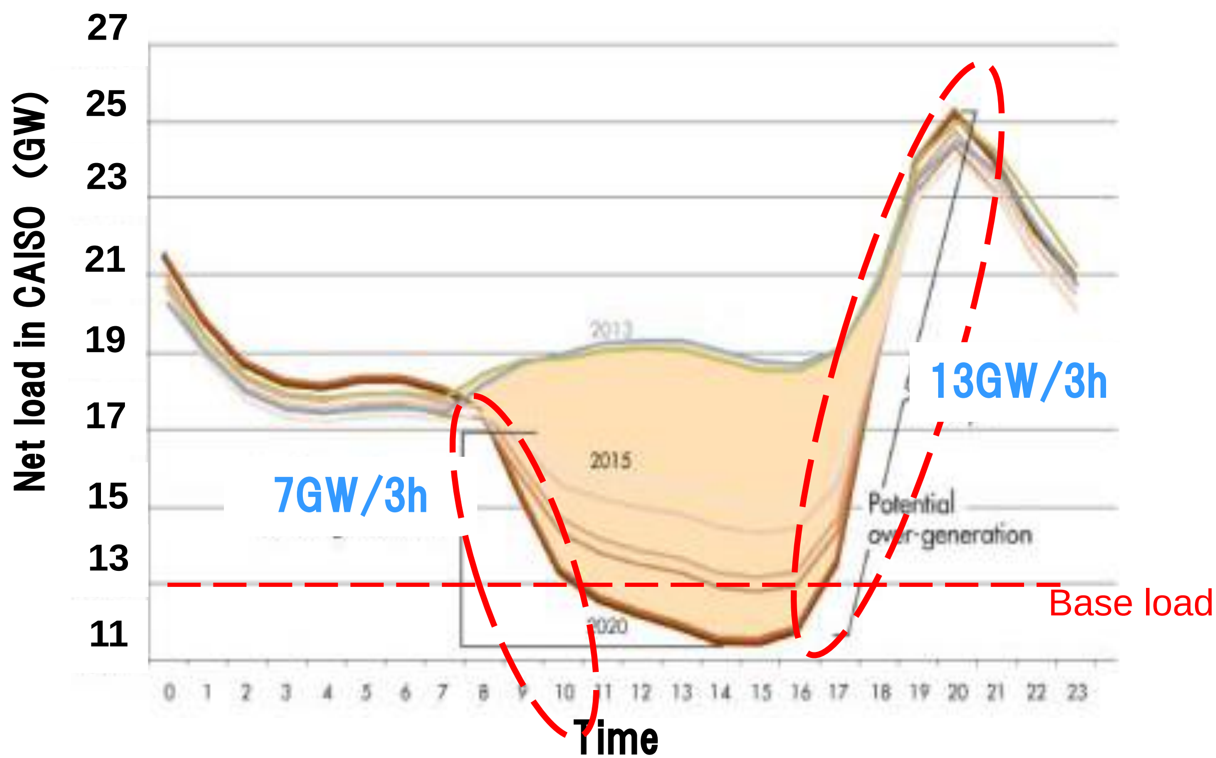
An example of wind power generation output





ⅱ. Duck Curve Problem

- Due to increase of rooftop PV, big demand drop appears in noon time and big ramp appears in the morning and evening.



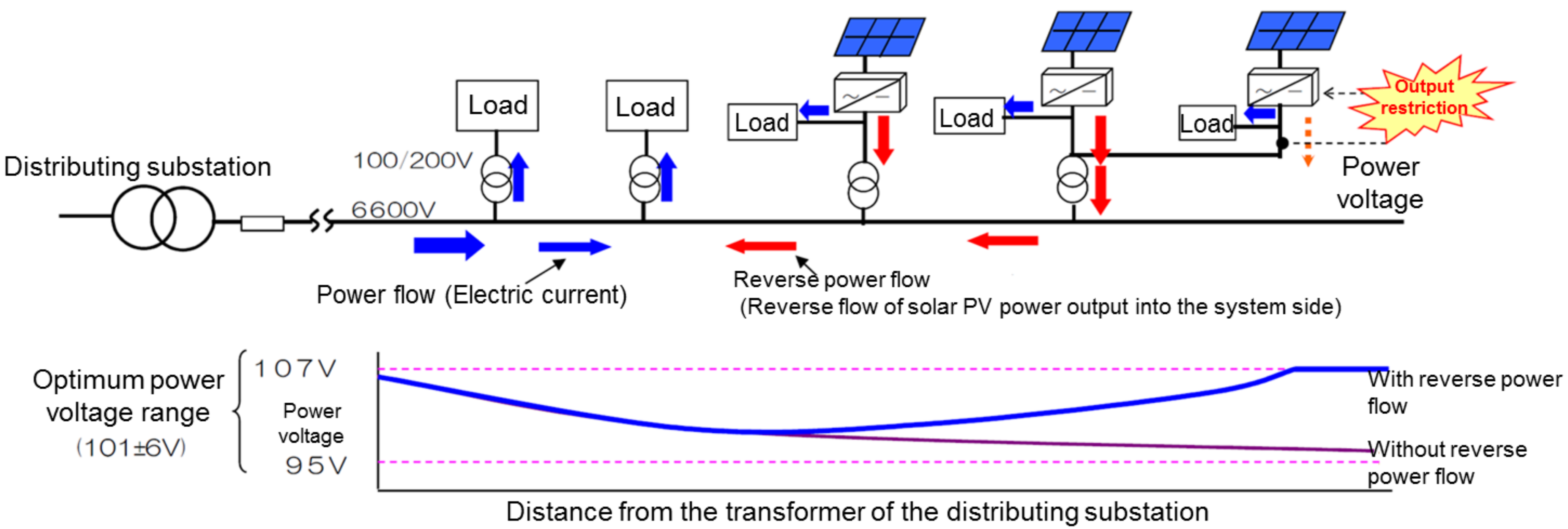
- ✓ Big ramp of 3 hours
- ✓ Large sub-hourly fluctuation at the big ramp caused by
  - ➢Fluctuation of PV
  - ➢Gas fired peaker
- ✓ Surplus of Renewable Generation

Source : CAISO

2. 5) Challenges for a Mass Introduction of Renewable Energy

iii. Voltage rise

- If the we have a large number of PVs in a feeder, the voltage rise problem occurs.
- The voltage rise may result in a fire of a transformer.



Source: Material for the Secretariat of the 1st Next Generation Power Transmission/Distribution Network Research Meeting, Agency for Natural Resources and Energy

An image of the voltage rise problem in the power distribution system

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1) Project in New Mexico,

i. Albuquerque

ii. Los Alamos

2) JUMPSmartmaui project in Hawaii

*** Coming California projects ***

i . DC Fast Charging Project

ii . Energy Storage Project

3. 1） ｉ. Albuquerque

Micro Grid Plant in Albuquerque

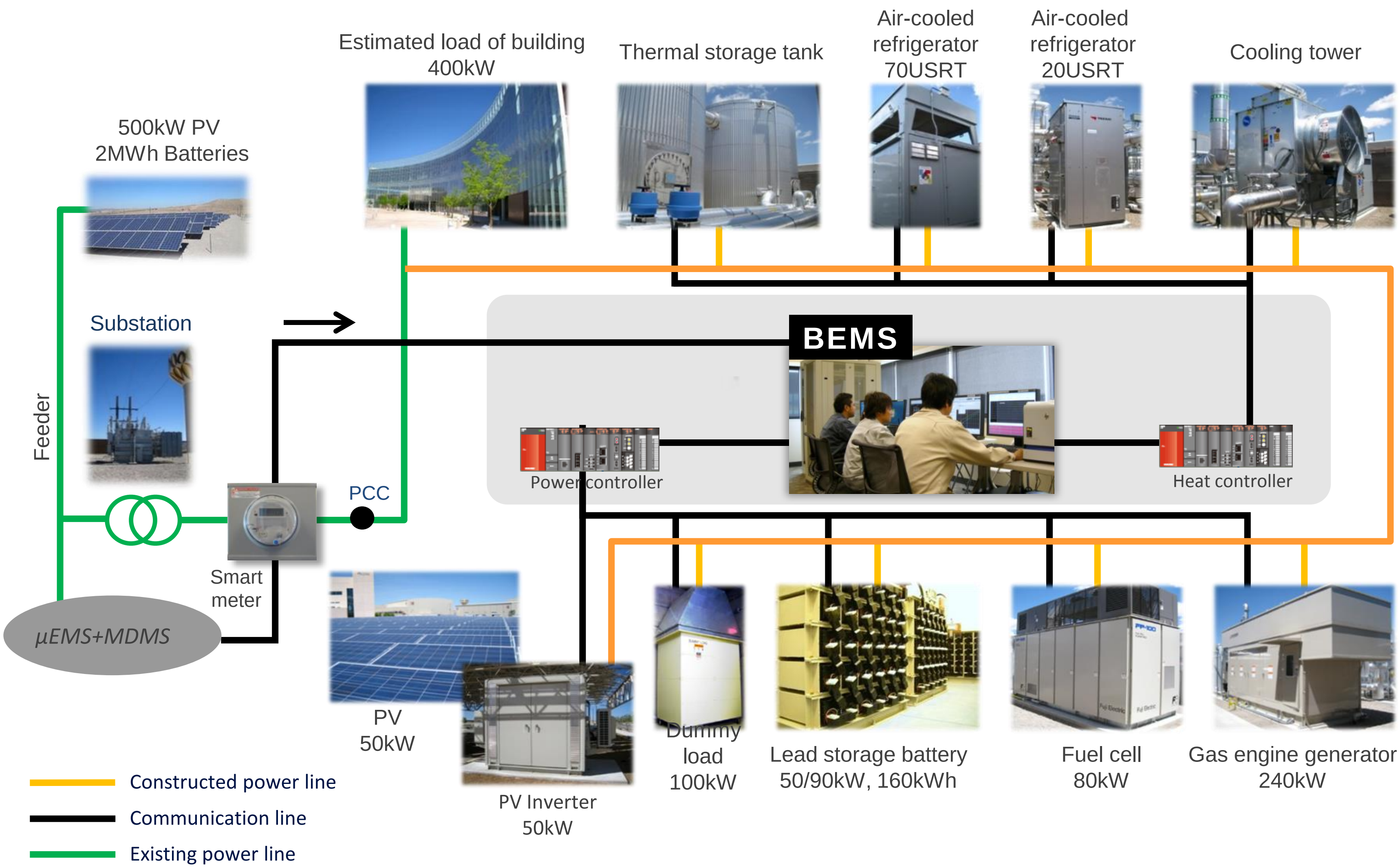
Mesa del Sol Aperture Center

Micro Grid Plant

Sandia National Laboratories
University of New Mexico
Public Service of New Mexico
Mesa Del Sol

3. 1) ⅰ. Albuquerque

BEMS configuration

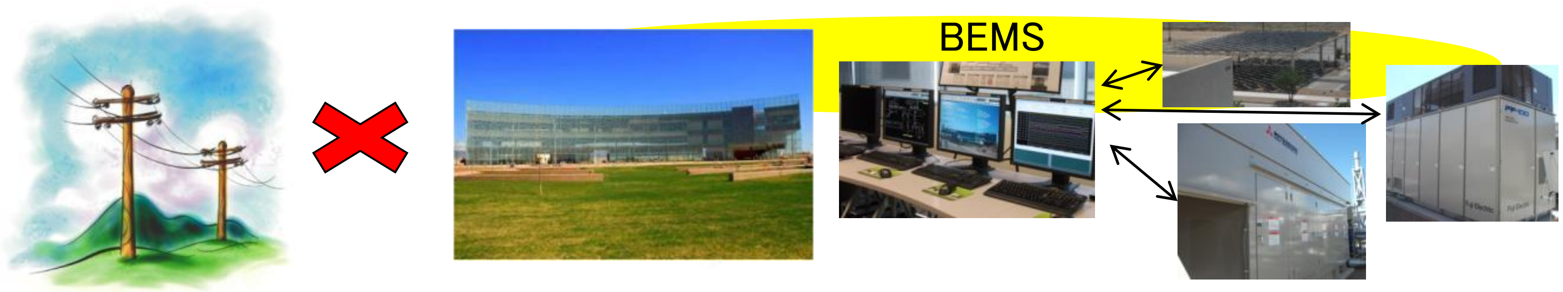


PCC: Point of common coupling

3. 1) ⅰ. Albuquerque

Main Demonstration Contents

a) Independent operation of microgrid



b) Virtual power plant

3. 1) ⅰ. a) Independent operation of microgrid

BEMS system

μ-EMS

Function of supply demand management by BEMS

BEMS

Day-ahead supply-demand plan

OR

Load (demand) forecast

PV generation forecast

operation plan (supply power and heat plan)

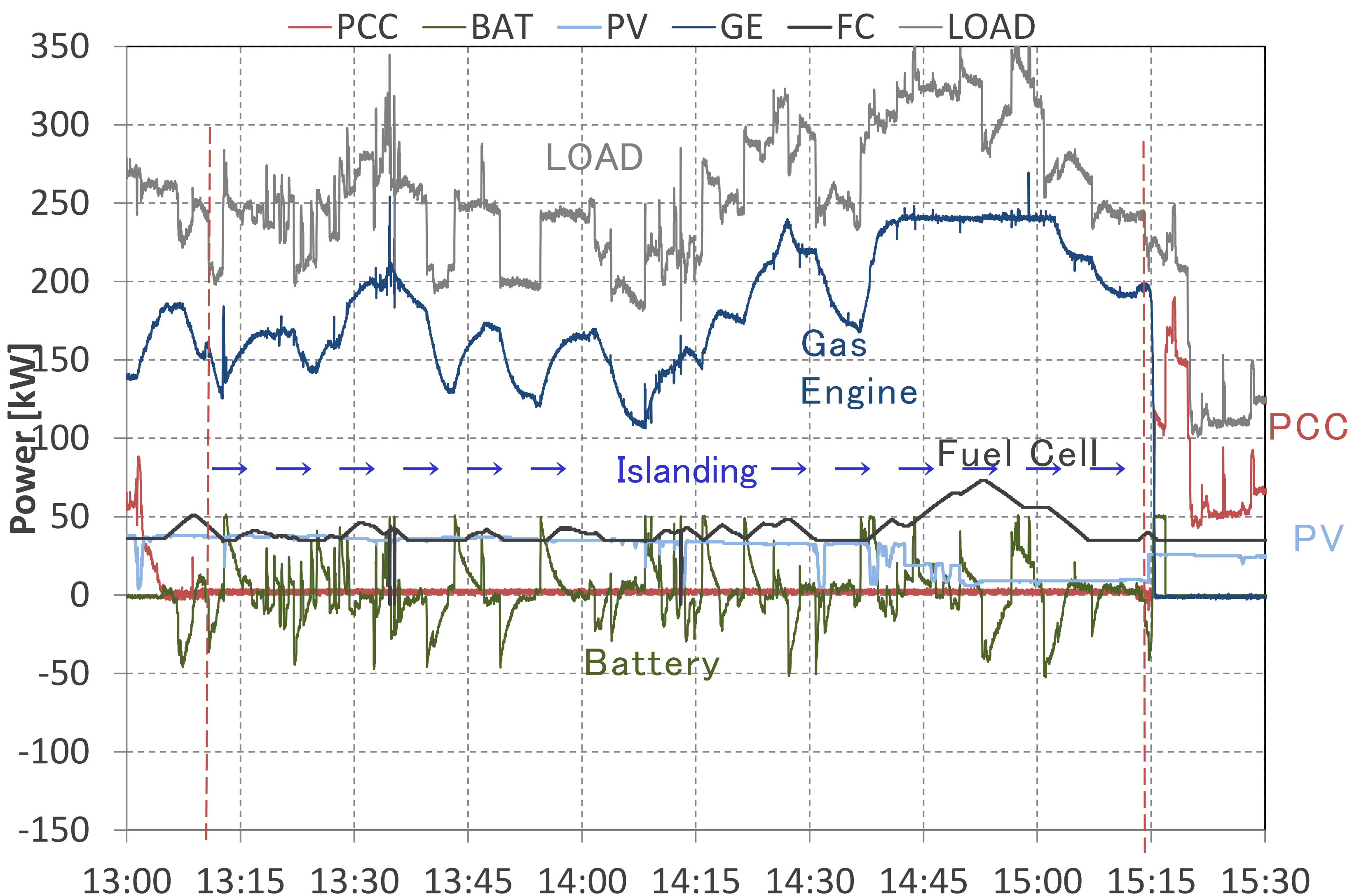
Supply-demand control (electric power and thermal energy control)

real-time active control gas-engine, fuel cells, battery, Cooling tower, Thermal storage

Battery Energy Storage System
for reactive power control

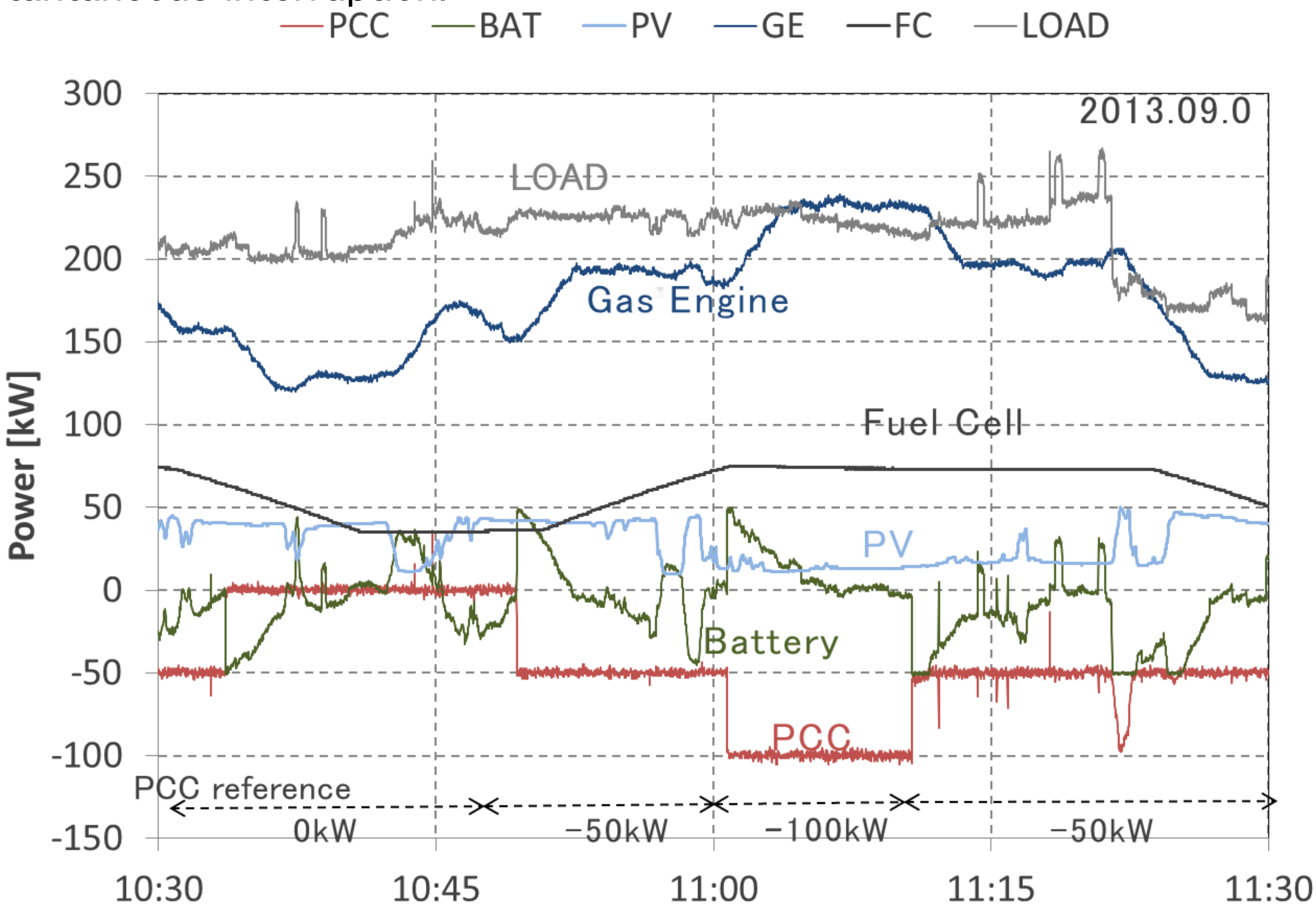
Performance results in BEMS islanding mode

- BEMS perfectly controlled the balance between demand and supply of electricity.



Performance results in Grid-connected mode

- The system has the ability to change the target value at connected point to the Grid.
- The system can shift from the grid-connected mode to the islanding mode without any instantaneous interruption.



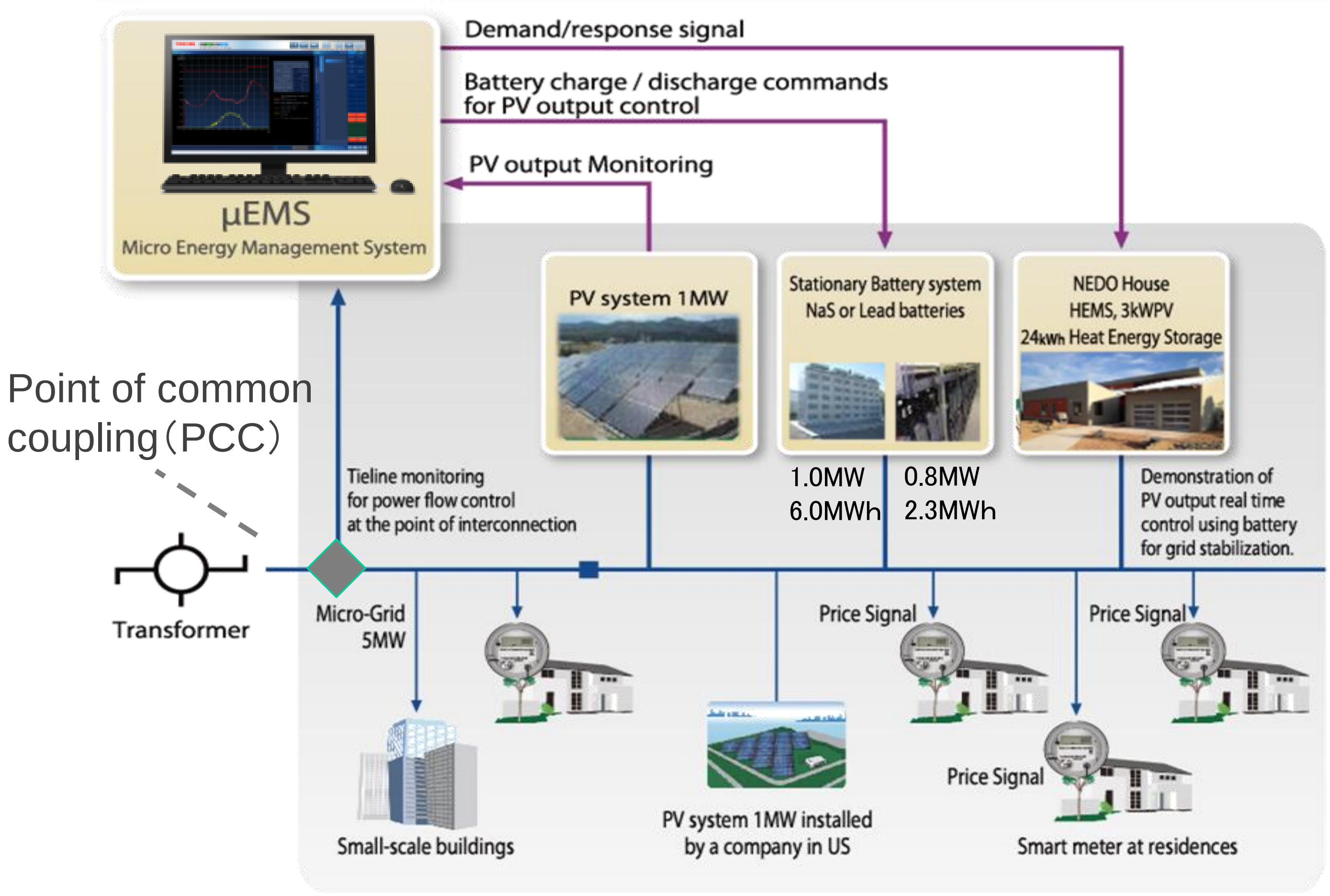
3. 1) ⅱ. Los Alamos

Los Alamos National Laboratory
Los Alamos County

Source：Los Alamos Department of Public Utilities

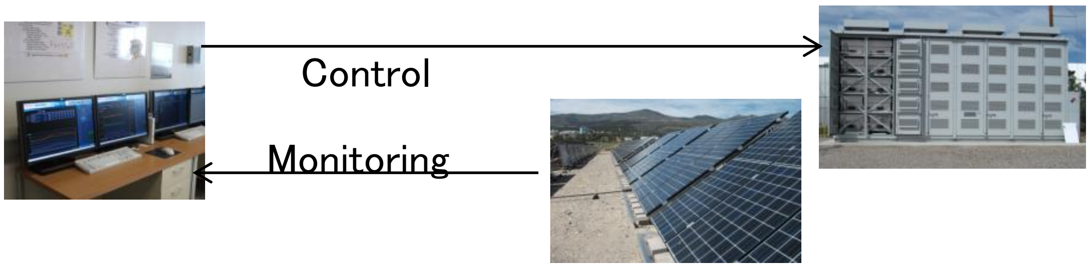
3. 1） ⅱ. Los Alamos

System configuration in Los Alamos site

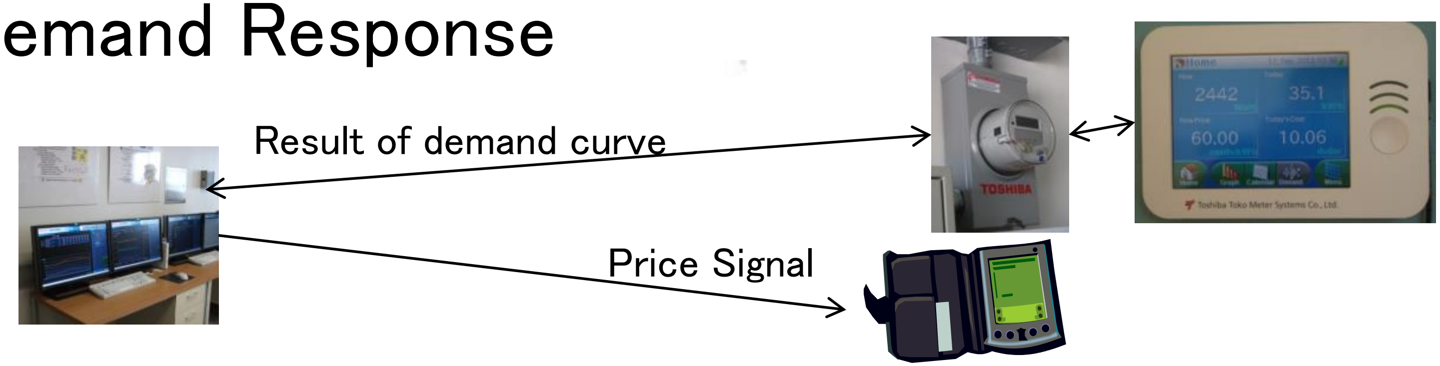


Main Demonstration Contents

a) Integrated energy management system (μ EMS)



b) Demand Response



c) Smart house

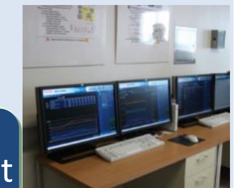
Demonstration of
Smart House System

3. 1) ⅱ. a) Integrated energy management system (μ EMS)

Function of supply demand management by μEMS

- Prediction (demand, PV output)
- Supply-demand scheduling
- Supply-demand balancing
- Optimum control of hybrid batteries
- Coordination with upper level system
- Demand response

Day-ahead supply-demand plan



Load (demand) forecast → NAS battery operation plan (charge/discharge plan)

PV generation forecast → NAS battery operation plan (charge/discharge plan)

↓

Supply-demand control (hybrid battery control)

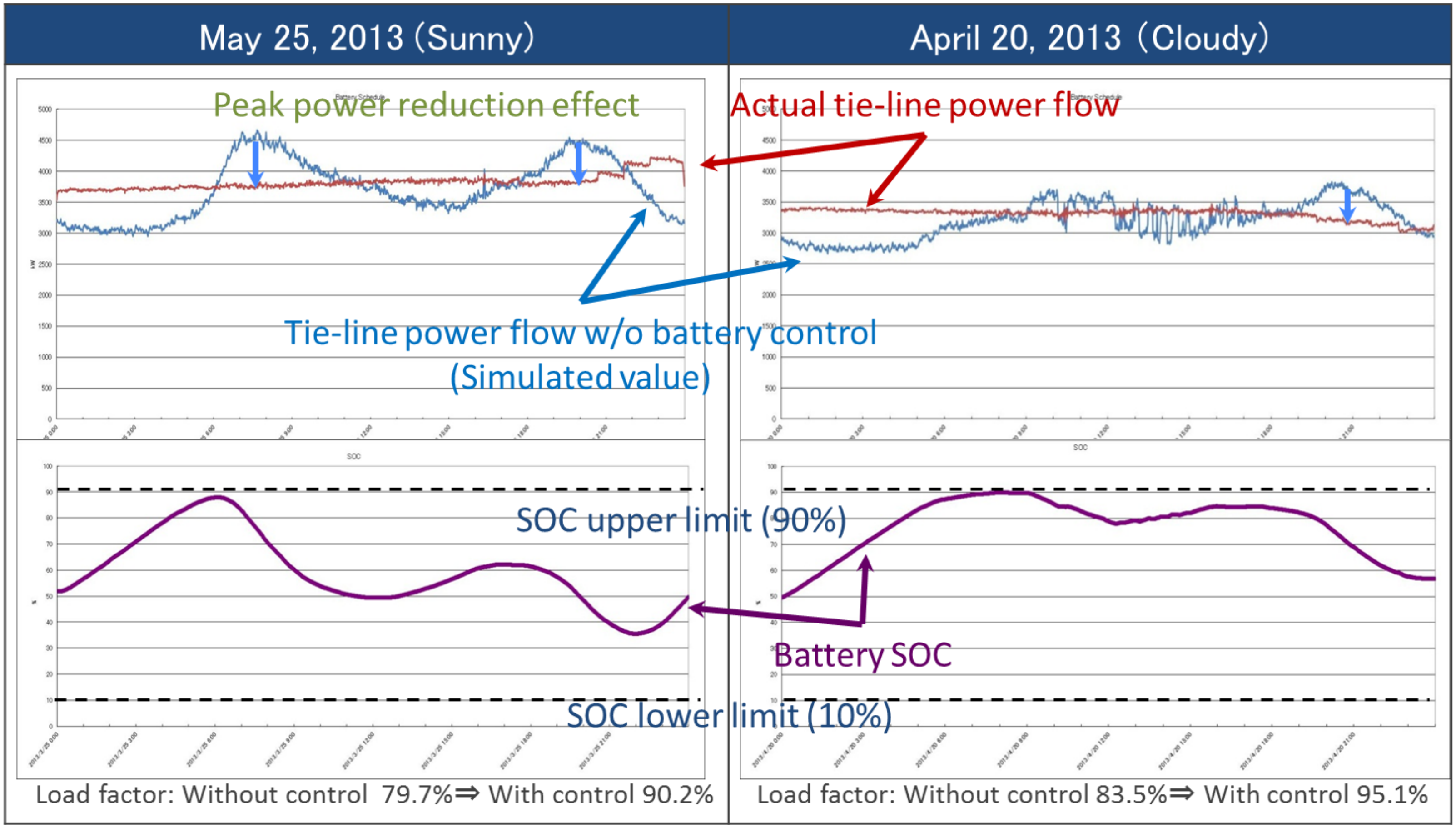
Control NaS battery
in low frequency range

Control Lead-Acid battery
in high frequency range

3. 1) ⅱ. a) Integrated energy management system (μ EMS)

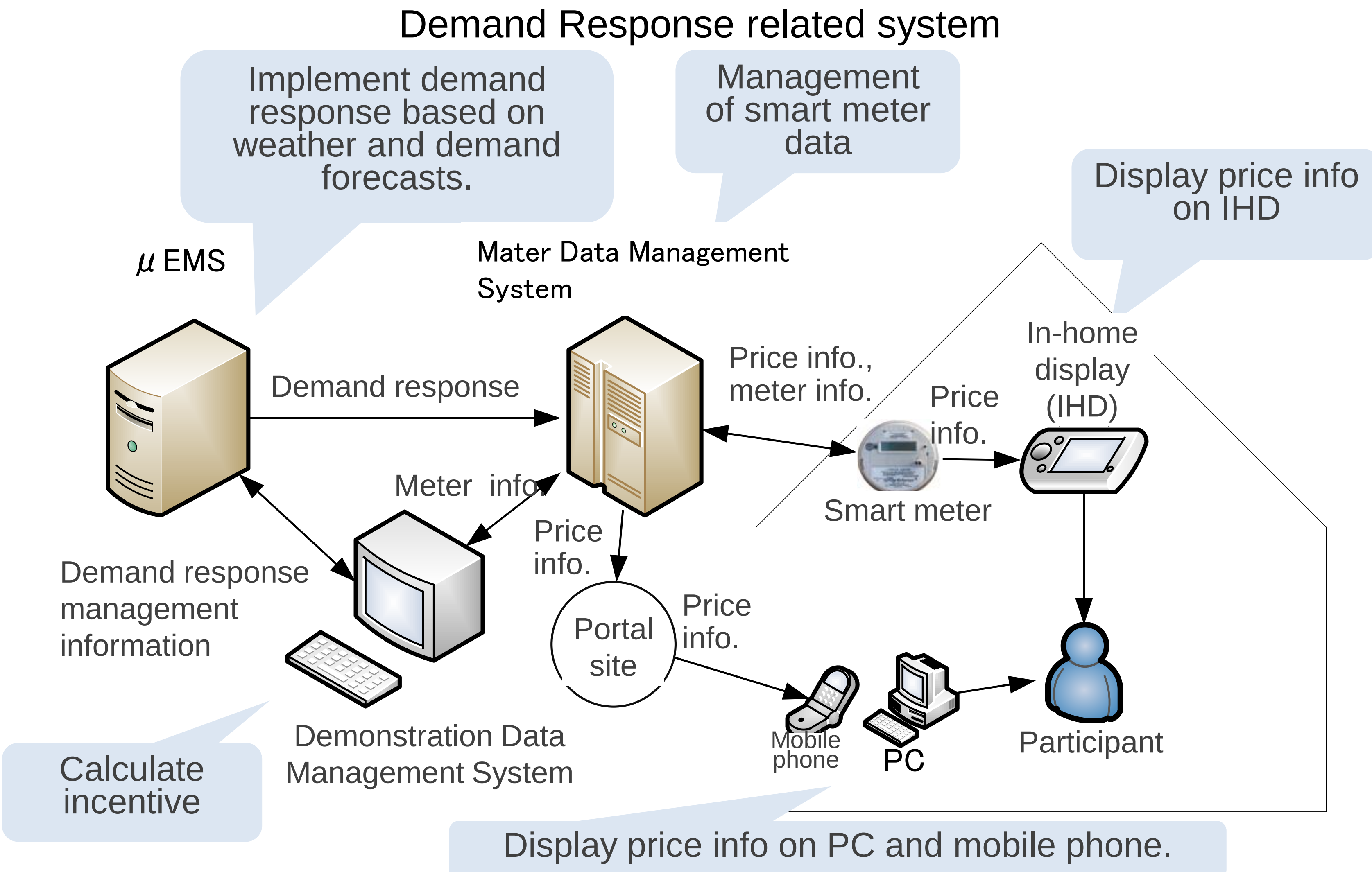
- μ EMS keeps the power flow flat with 50% Renewables under light load condition on distribution line level.
- μ EMS can contribute to the issue of high renewable energy penetration.

μEMS demonstration results



3. 1) ⅱ. b) Demand Response

- In Los Alamos site, 900 households with installed smart meters volunteered to participate in the demand response demonstration.



3. 1) ⅱ. b) Demand Response

Demand response menu applied in the experiment

Group	Initial	Opt-in	Opt-out
Opt-in CPP	Flat	CPP	-
Opt-out CPP	CPP	-	Flat
Opt-out PTR	PTR	-	Flat
Control	Flat	-	-

CPP（Critical Peak Pricing）: Very high price during peak period and discounted price during off-peak period
[Price] Peak: 75¢/KWh, LAC flat rate: 9.52¢/KWh, Off-Peak: 7.77¢/KWh
PTR（Peak Time Rebate）: customers with peak-time consumption less than baseline will receive rebate
[Rebate] 75¢/KWh x kWh saved
The combinations of two pricing scenarios with default options (Opt-in and Opt-out)

3. 1) ii . b) Demand Response

- The best result was obtained with Opt-in CPP in summer time where TOT was 10.49%, showing very high peak reduction effect.

Result of DR experiment in 2013

	Group	TOT effect	Choice probability	ITT effect
Summer	Opt-in CPP	-10.49%	64%	-6.90%
	Opt-out CPP	-4.71%	98%	-4.59%
	Opt-out PTR	-4.17%	97%	-4.06%
Winter	Opt-in CPP	-7.12%	64%	-4.78%
	Opt-out CPP	-4.41%	98%	-4.27%
	Opt-out PTR	-3.37%	97%	-3.26%

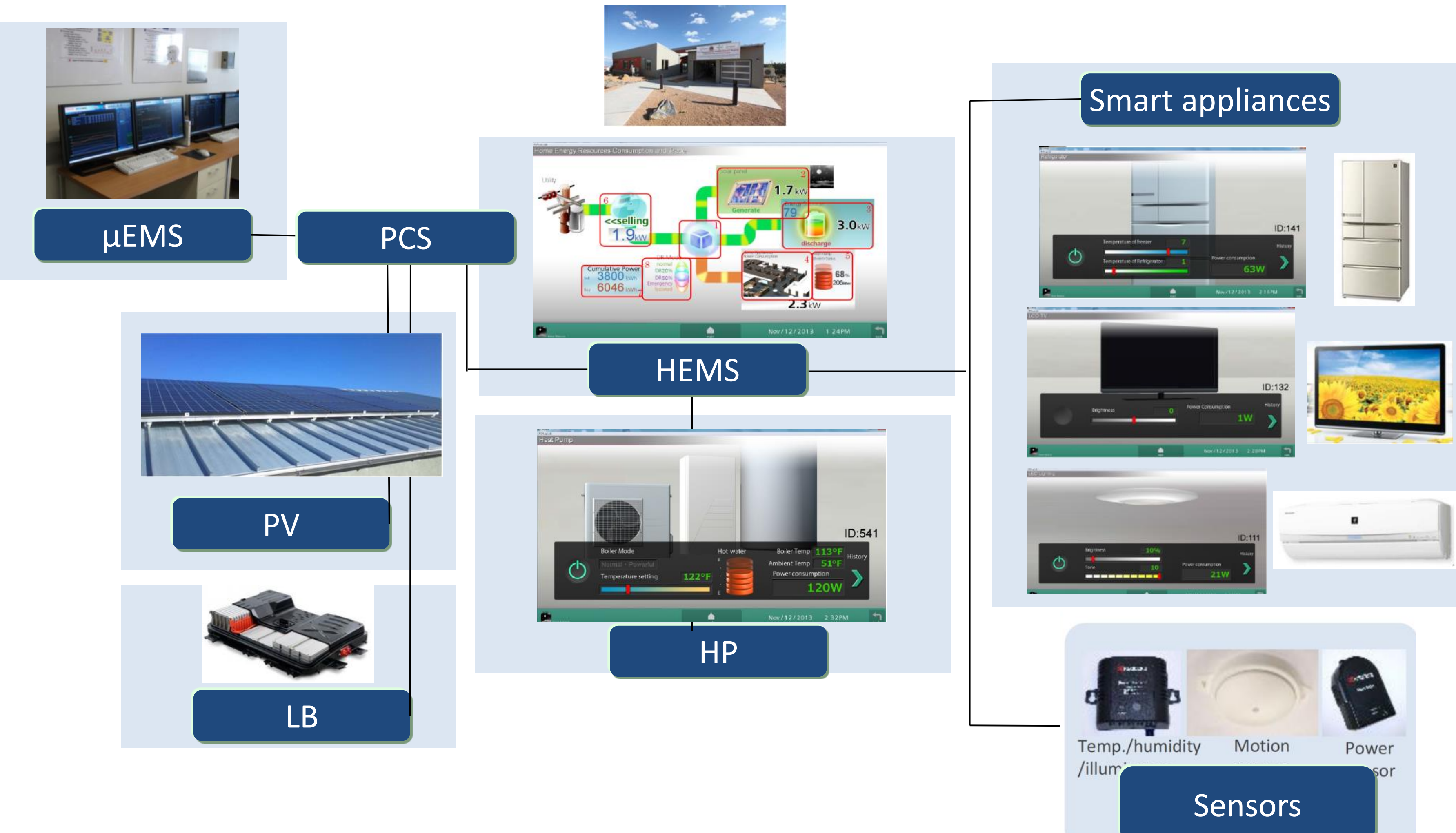
* TOT effect : Treatment on the Treated. Net peak cut effect when a treatment was given.
- ITT effect : Intention to Treat. Choice probability x TOT effect.

* The majority of people do not own air conditioners.

3. 1) ii . c) Smart house

- The HEMS (Home Energy Management System) completely controls all household Smart appliances and devices.

Energy system of Smart House



3. 1) ii . c) Smart house

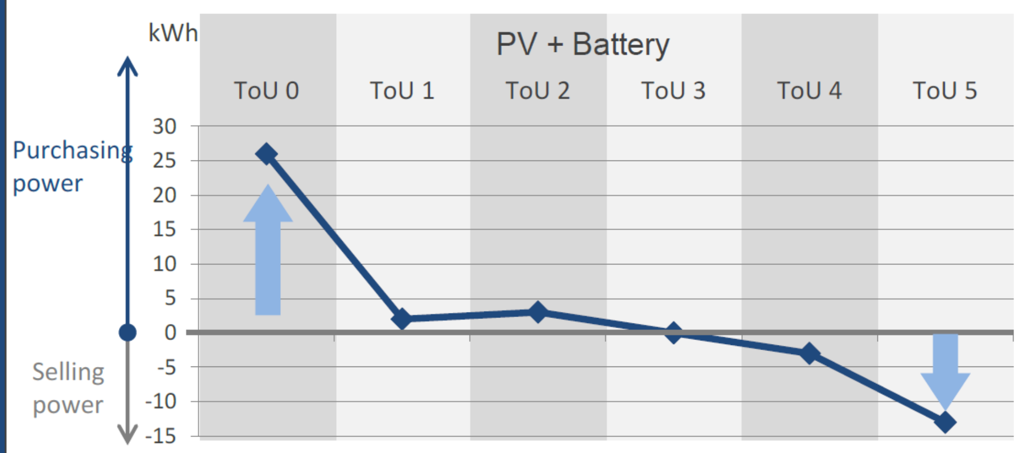
Optimizing energy consumption in association with TOU

- HEMS minimizes energy costs of the home in association with TOU and does not disturb the resident’s comfort.
- The result of the demonstration is a maximum profit is $20/day.

Result of demonstration of TOU control

Virtual ToU rates	Rate category	ToU0	ToU1	ToU2	ToU3	ToU4	ToU5
	Selling price(cent/kWh)	15	25	45	65	85	99
	Purchasing price (cent/kWh)	10	20	40	60	80	90

Performance in power trading for a smart house (Sept. 25, 2013)



Findings

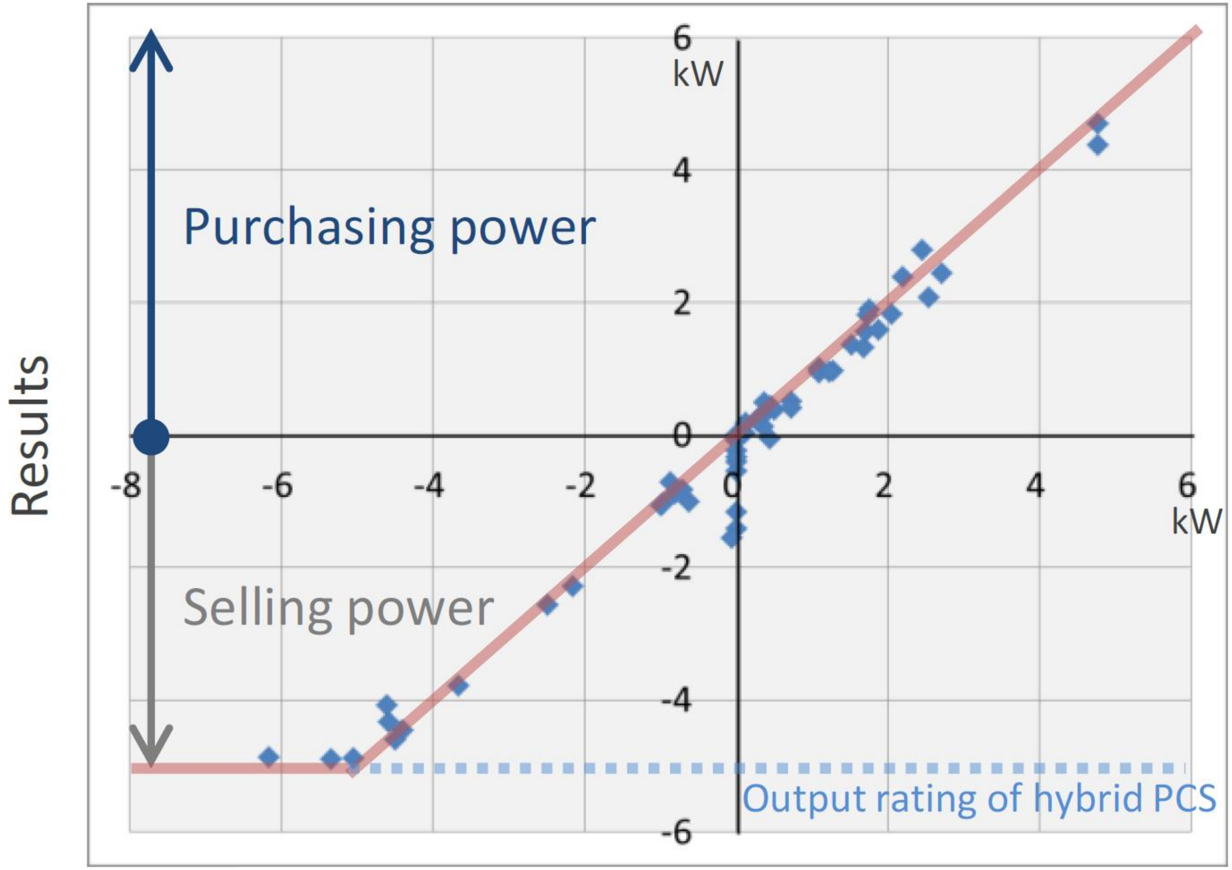
- An introduction of PV and battery produces $11.5 of income per day.
- $20.5 of profit can be made compared with the case when PV and battery are not introduced resulting in $9 of spending per day.
- Impact on grid can be reduced and customer can expect great economic value.

3. 1) ii . c) Smart house

Optimizing energy use in response to the request from μEMS

- HEMS Perfectly controls the power output to the grid based on the request from μEMS.

Result of control in response to μEMS' request



Target Value of Power at connected point

3. 2) JUMPSmartmaui Project

NEDO

NEDO

HNEI
Hawai'i Natural Energy Institute
University of Hawai'i at Mānoa

maui economic DEVELOPMENT BOARD

Hawaiian Electric

Maui Electric

3. 2) JUMPSmartmaui Project

Maui of Hawaii Today

- High cost of energy is driven by variable oil prices.

  Hawaii ranks #1 in electric energy costs:
  45.85 cents/kWh Lanai, 47.06 cents/kWh Molokai, 41.89 cents/kWh Hawaii,
  37.83 cents/kWh Maui, 35.48 cents/kWh Oahu (Avg. Residential rates in 2014)
  11 – 12 cents/kWh U.S. avg.

- Hawaii has relied on fossil fuels for 90% of its energy consumption.

- Island is experiencing rapid growth of intermittent renewable generation negatively impacting grid operations and reliability.

  -RE ratio in Hawaii 21%(2014) Target; 100% (2045)

These circumstances are ideal to demonstrate advanced smart grid technologies.

3. 2) JUMPSmartmaui Project

<u>Partners;</u>

The State of Hawaii, Hawaiian Electric Company, Maui Electric Company, Hawaii Natural Energy Institute, The County of Maui, The Maui Economic Development Board etc.,

<u>Entrusted parties;</u>

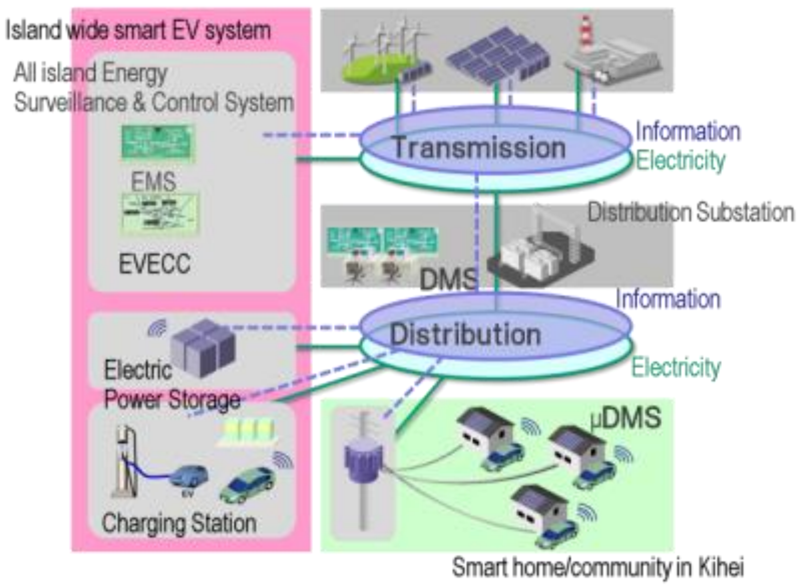
Hitachi, Mizuho Corporate Bank, Cyber Defense

Maui Island

Peak load : 190MW

Off Peak : 90MW

Outline of the system

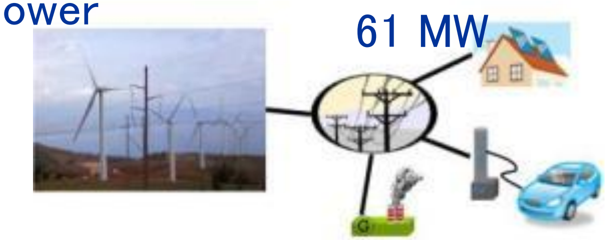


Wind Power

72 MW

Solar Power

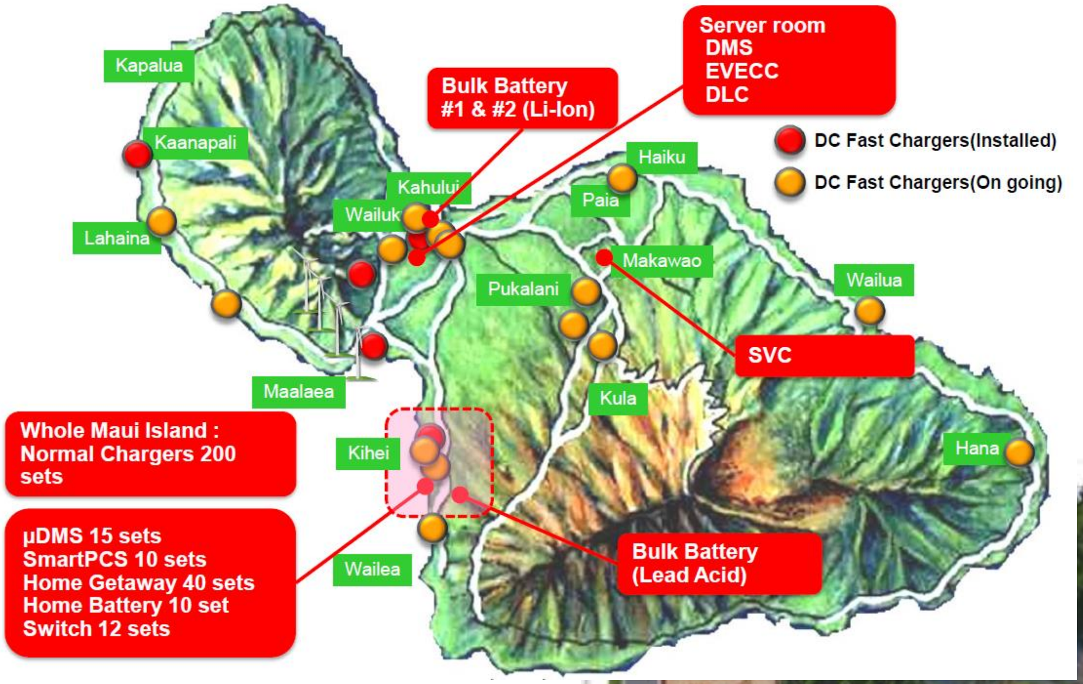
61 MW



- Manage EV charge
    - ➢Shift to midnight
    - ➢Stop charging when unexpected Wind down ramp occurs etc.,
- 20 Quick Charging Stations

3. 2) JUMPSmartmaui Project

Geographical Locations of Devices in Maui



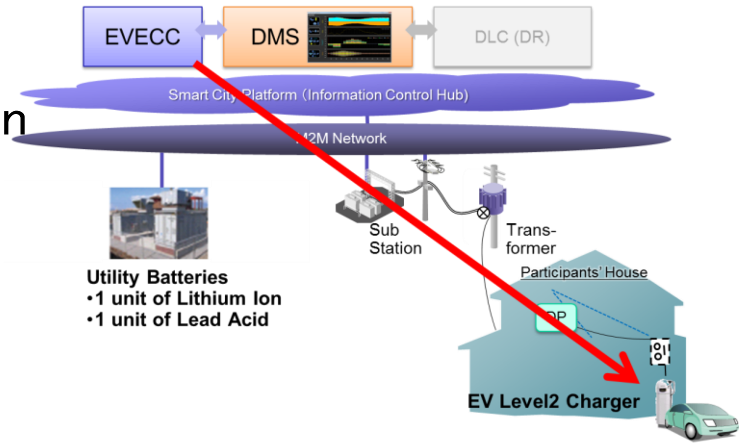
Participation of EV volunteers

250 (Currently)
↓
400 (March 2016)

Demonstration Contents of Phase 1

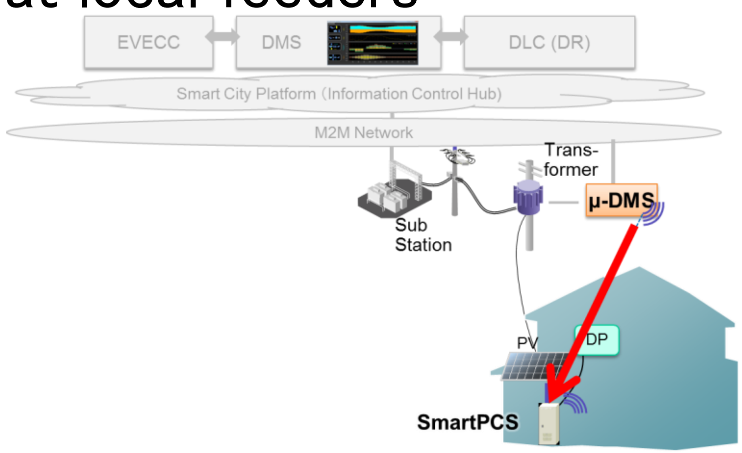
ⅰ. Shift of EV charging load

Direct control technology demonstration using EV/PHEV



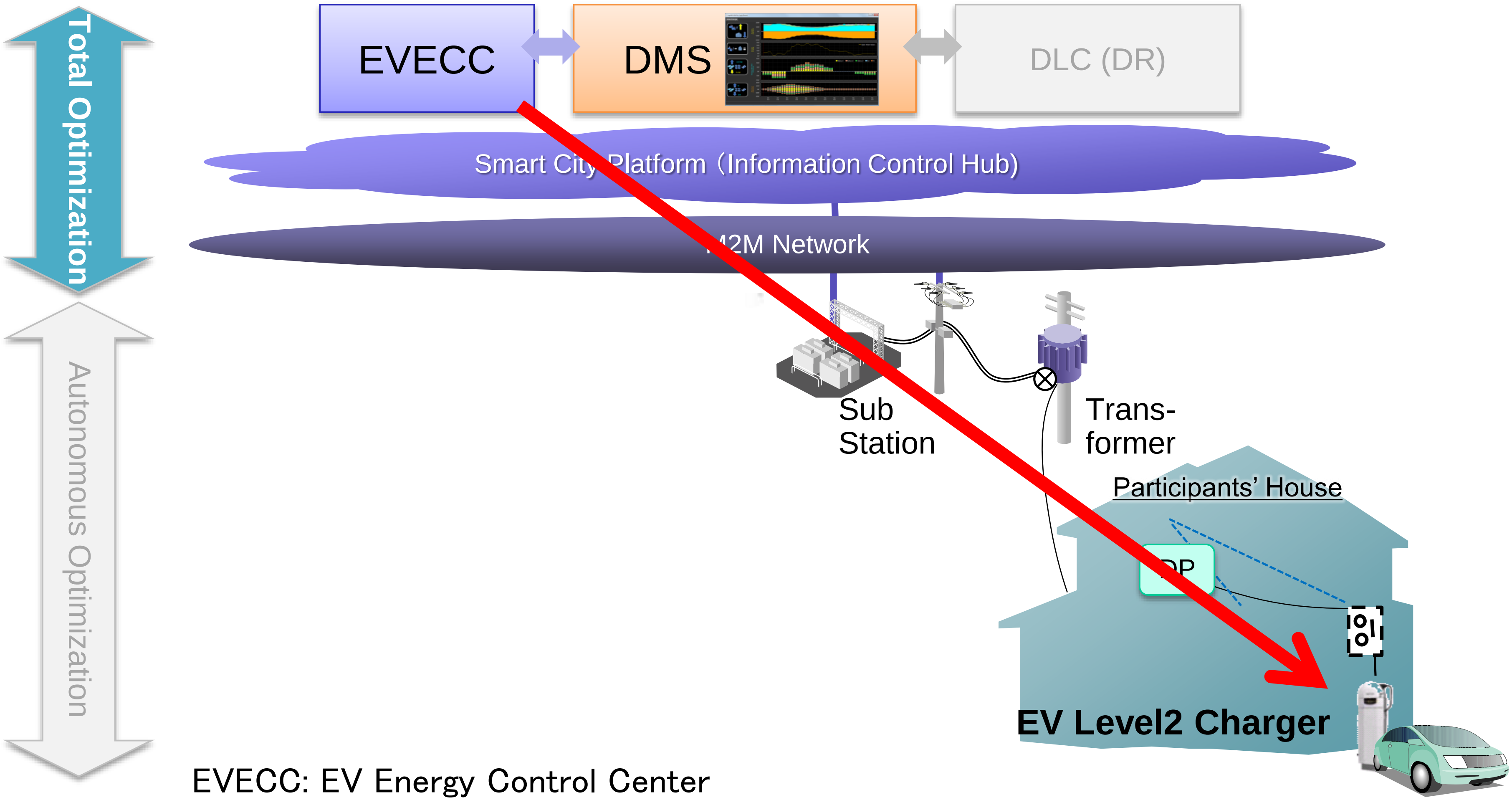
ⅱ. Mitigation of over-voltage issue at local feeders

D-EMS demonstration by controlling demand and PVs under substation



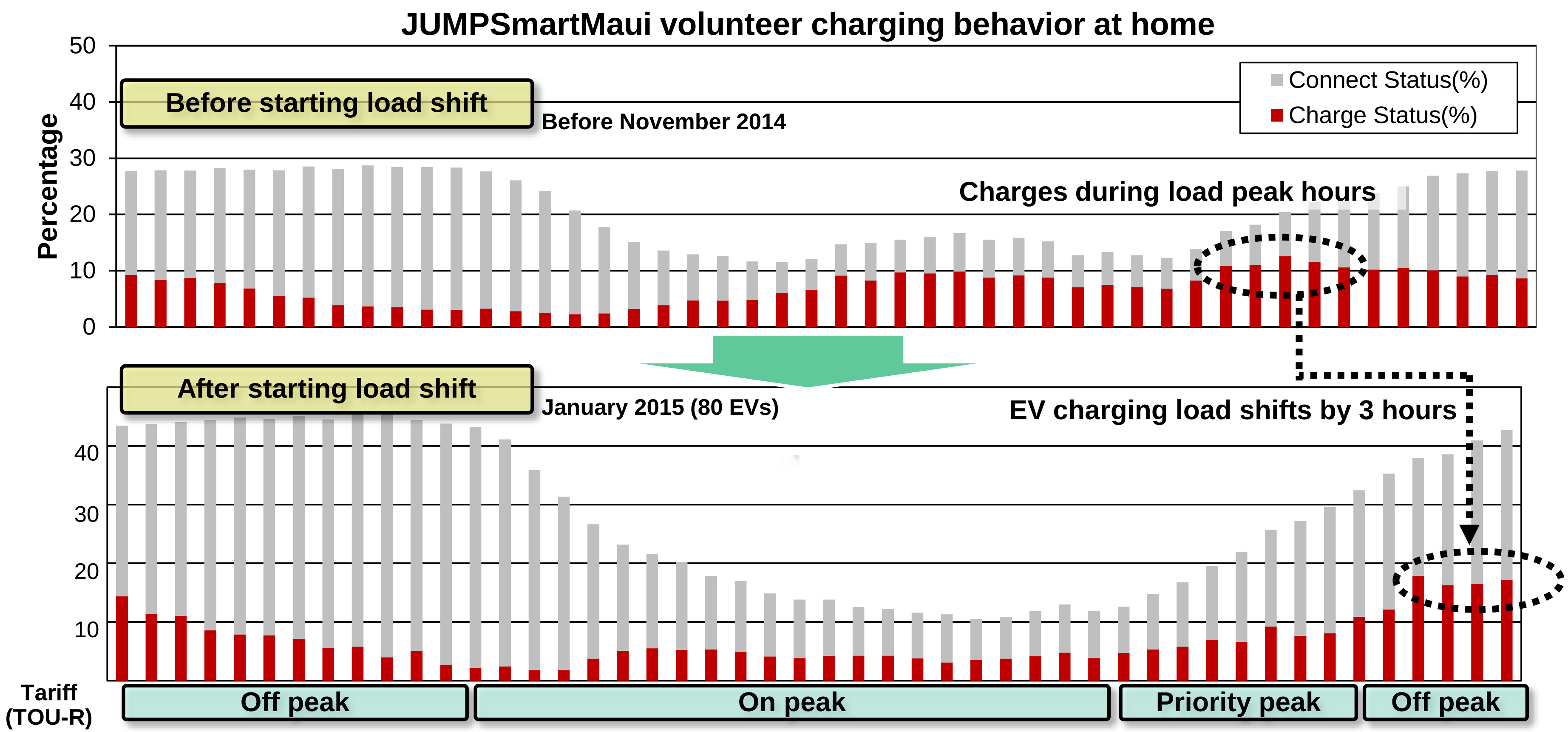
3. 2) ｉ. Shift of EV charging load

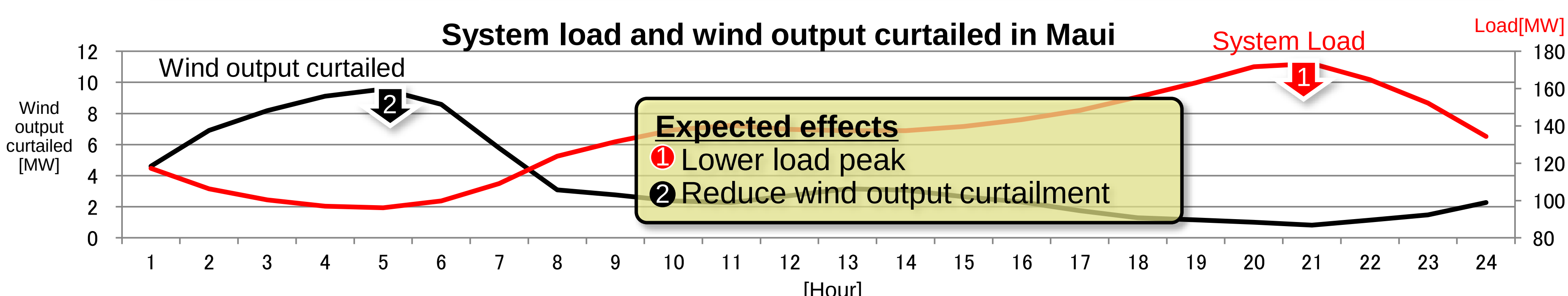
- **EVECC controls EV charging period** based on **DMS forecast** to **best utilize renewables** (to reduce curtailment of renewables)



EVECC: EV Energy Control Center

3. 2) ⅰ. Shift of EV charging load

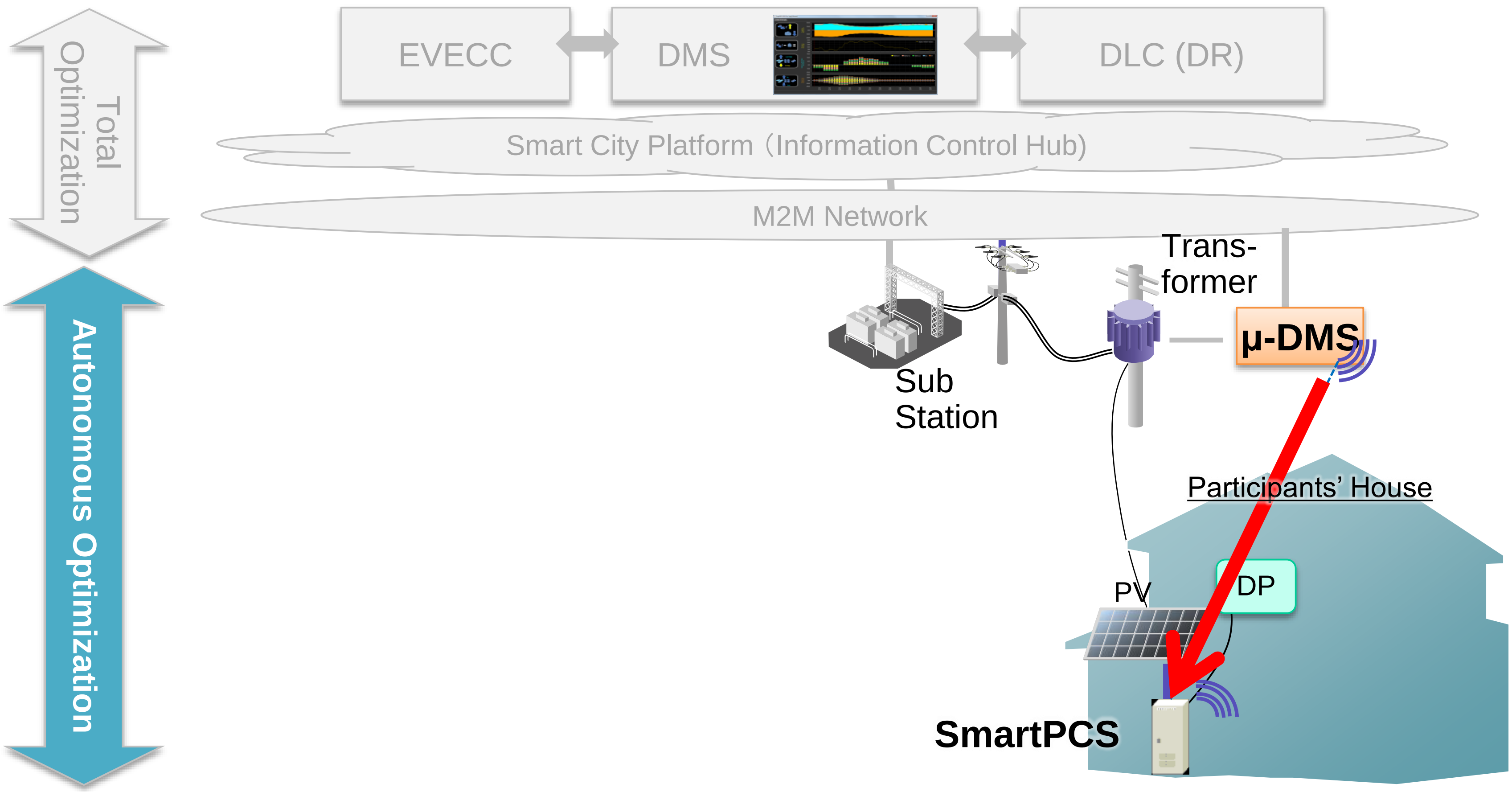




Data source：HITACHI

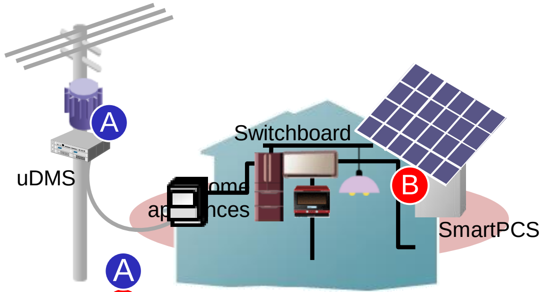
3. 2) ii . Mitigation of over-voltage issue at local feeders

- **μ-DMS** monitors the grid status at transformer level and **controls Smart PCS** to **mitigate possible over-voltage** at transformers with PV densely installed.

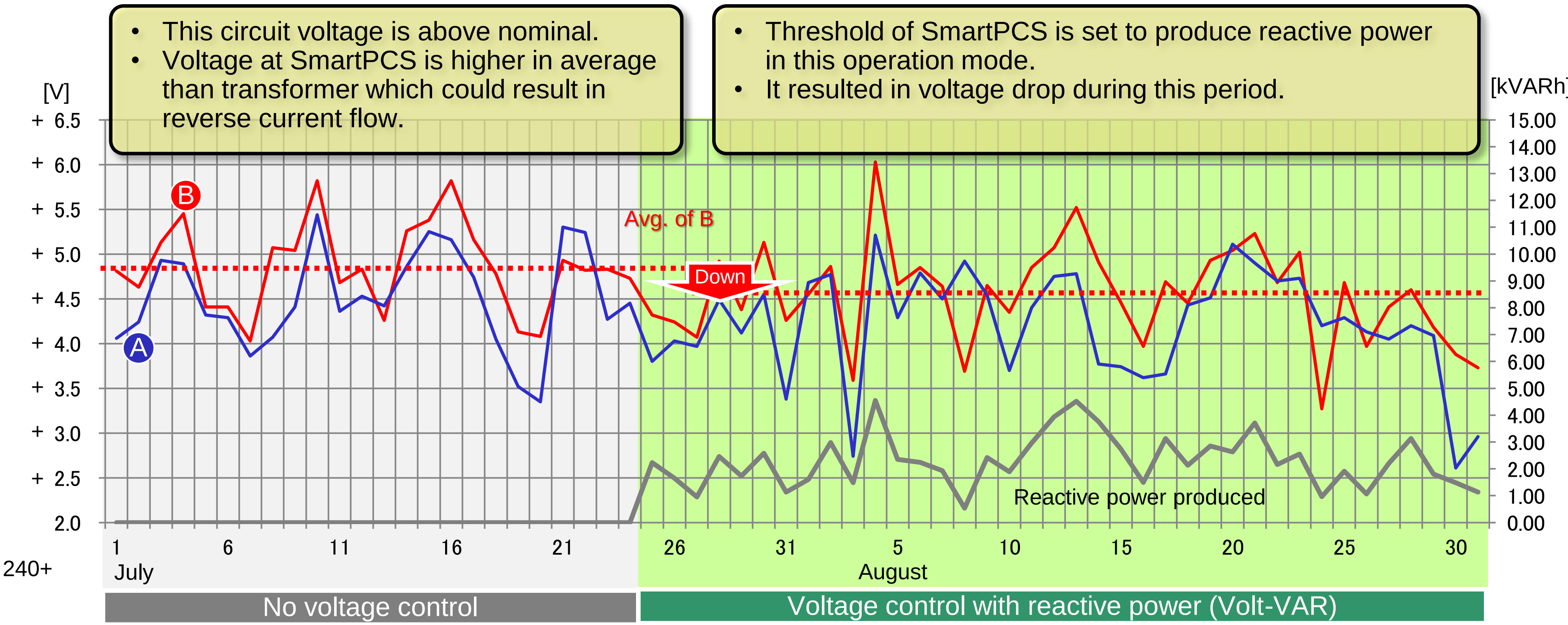


3. 2) ii . Mitigation of over-voltage issue at local feeders

- Micro DMS and Smart PCS can contribute to mitigate power quality issues in distribution grid with PV densely installed.



A
B : on secondary of the transformer
: at SmartPCS grid connection point



Data source：HITACHI

3. 2) JUMPSmartmaui Project

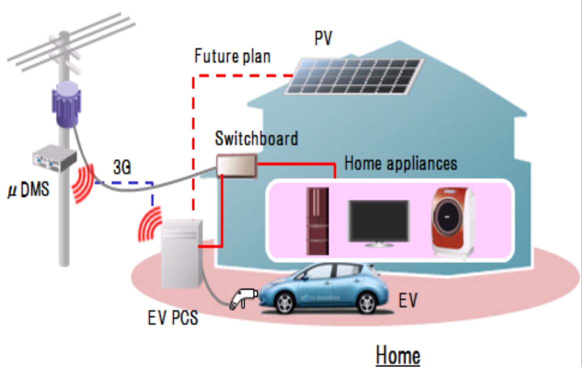
Overview of Phase 2

Phase2: Demonstration with “Dis-charging” function

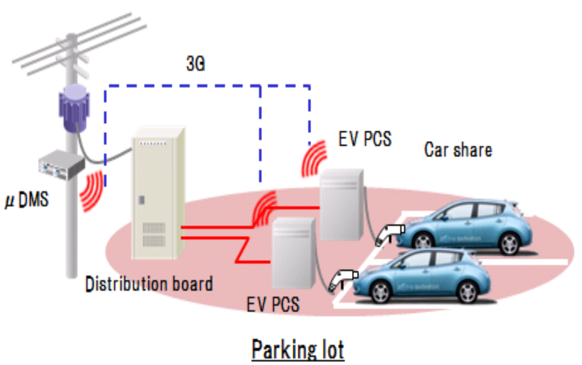
Demonstration in highly RE penetrated area like Maui:

Phase2 will evaluate using integrated, controlled EV battery discharge and management of distributed loads including V2X, as a “Virtual Power Plant (VPP) ”

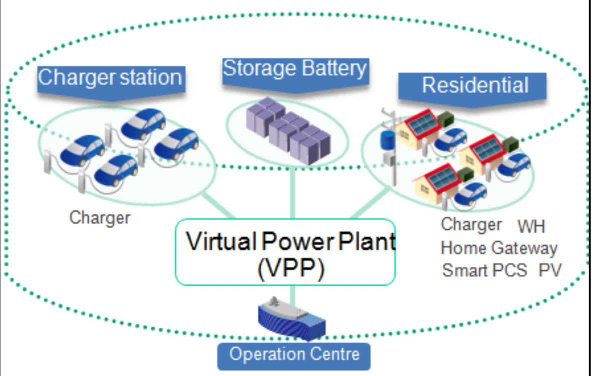
V2H (Vehicle to Home)



V2G (Vehicle to Grid)



VPP (Virtual Power Plant)



Virtual Power Plant (VPP):
"Aggregating and optimizing available distributed energy resources (including EVs, storage, and demand response) to replicate the functions of a traditional power plant

Coming California Projects

ⅰ. DC Fast Charging Project

ⅱ. Energy Storage Project

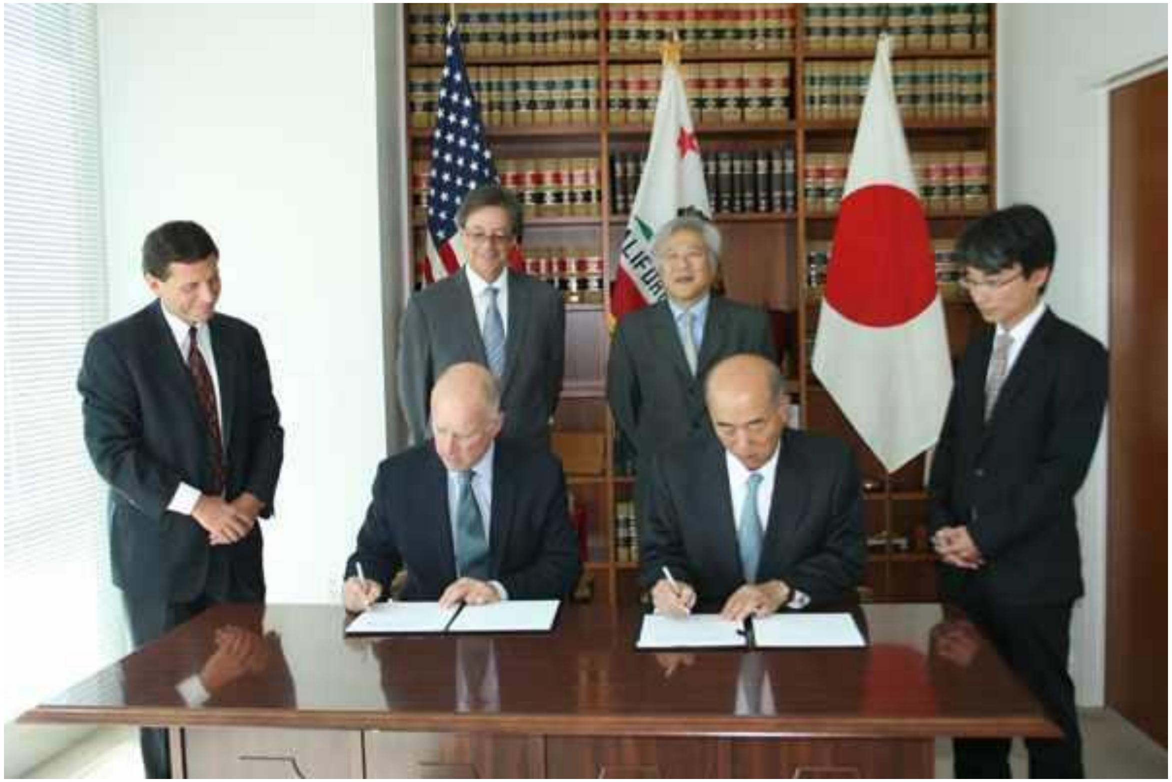
Source：Nissan

Source：Sumitomo Electric Industries

Coming California projects

MOC of JAPAN and California

- Governor Brown and Japanese Ambassador to the U.S. signed a Memorandum of Cooperation (MOC) in September 2014 for climate change and renewable energy.



September 5, 2014
in San Francisco

Source：Ministry of Foreign Affairs of Japan

Coming California projects

- NEDO and the State of California Governor's Office of Business and Economic Development (GO-Biz) have signed two memorandums of understanding (MOU) in order to implement the following smart community demonstration projects in California.

September 10, 2015
in Sacramento

ｉ. DC Fast Charging project

1. PURPOSE

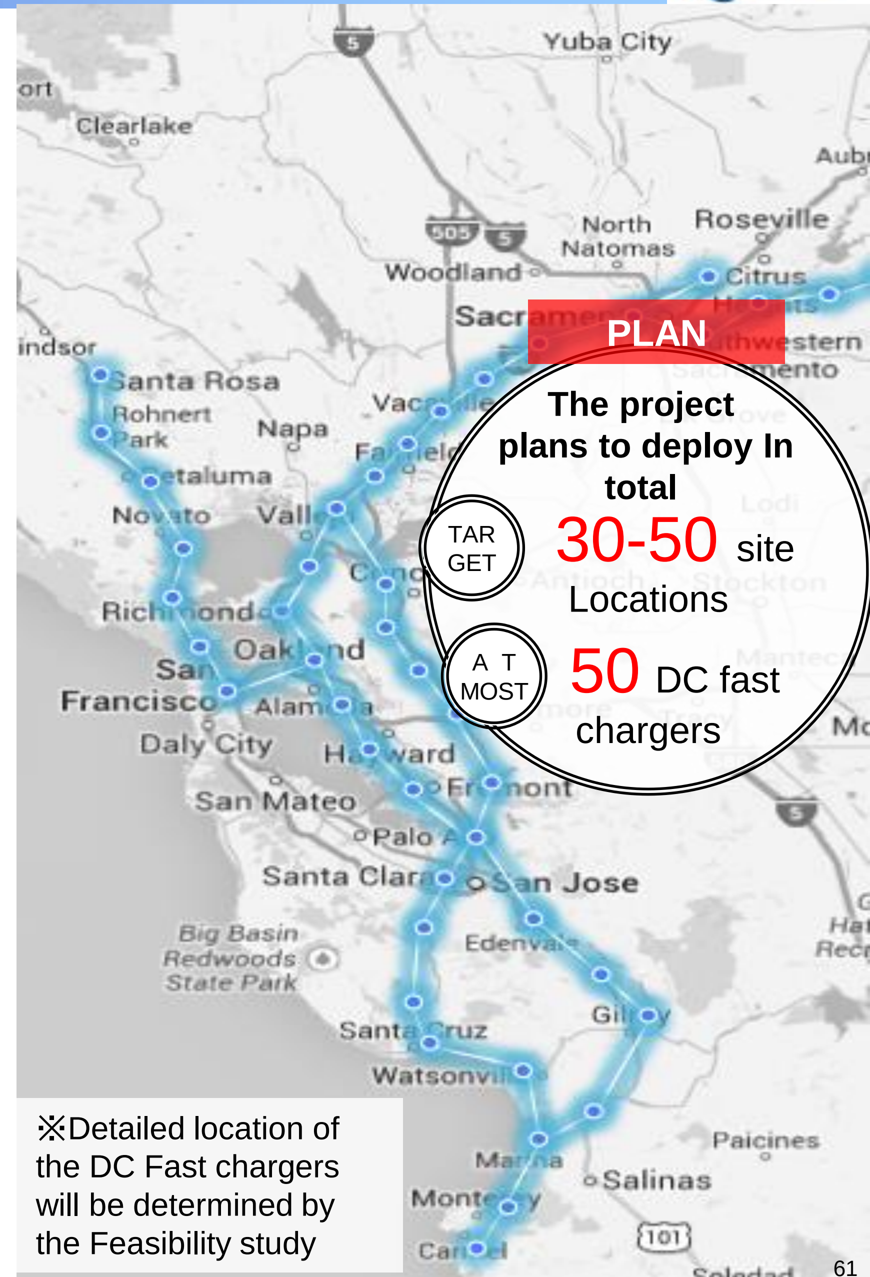
- Project will lengthen EV trips, influence EV drivers’ behavior.
- Reduce greenhouse gas emissions, criteria pollutants, and fossil fuel use by EVs deployment.

2. ISSUE

- EV driving range is shorter than that of conventional vehicle.
- EV charging infrastructure has been mostly deployed in urban area than inter-city area.

3. ACTION

- Installing DC Fast chargers along highways and monitor their use.
- Analyzing EV traffic data and analyzing the correlation between the deployment of DC fast chargers and EV driving behavior.



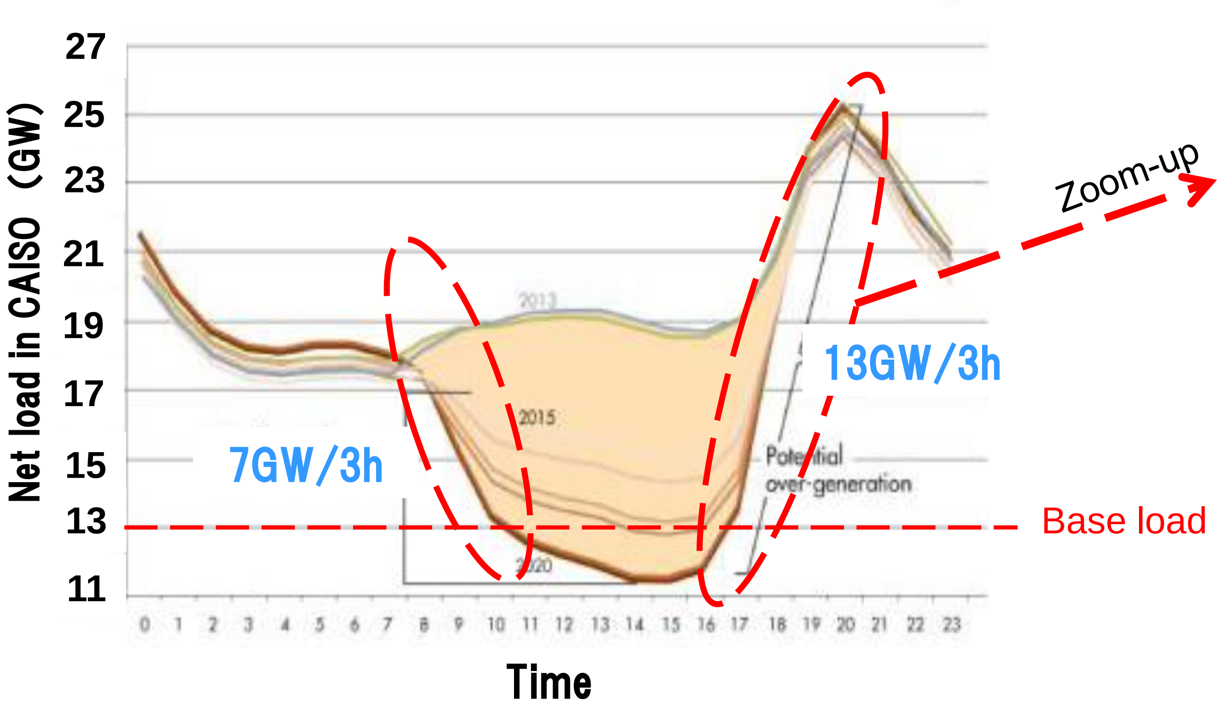
※Detailed location of the DC Fast chargers will be determined by the Feasibility study

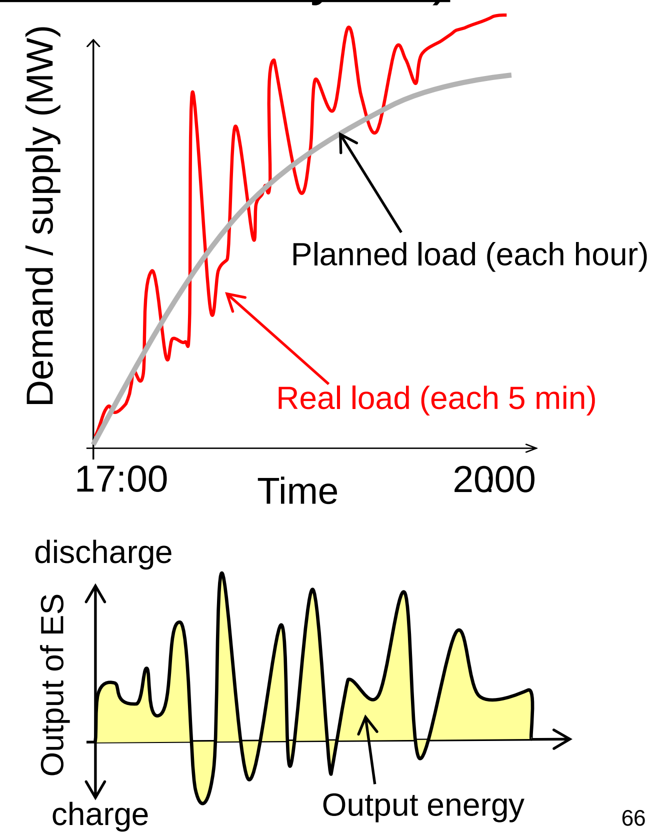
Challenges of CA grid in future

- ✓ Big ramp of 3 hours
- ✓ Large sub-hourly fluctuation
  at the big ramp caused by
  - ➢Fluctuation of PV
  - ➢Gas fired peaker
- ✓ Surplus of Renewable Generation

Requirements for Energy Storage

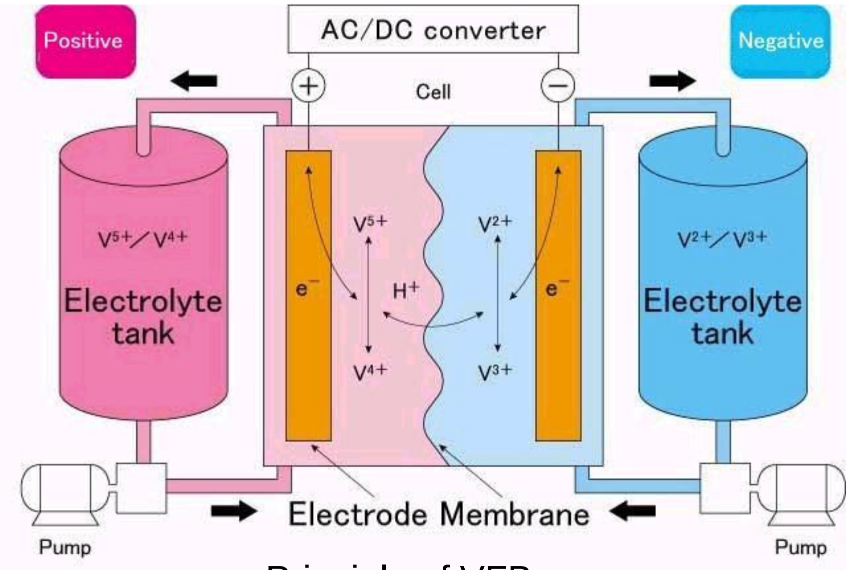
Hybrid system for both
Energy (long duration) and
Frequency Regulation
(large number of cycles)



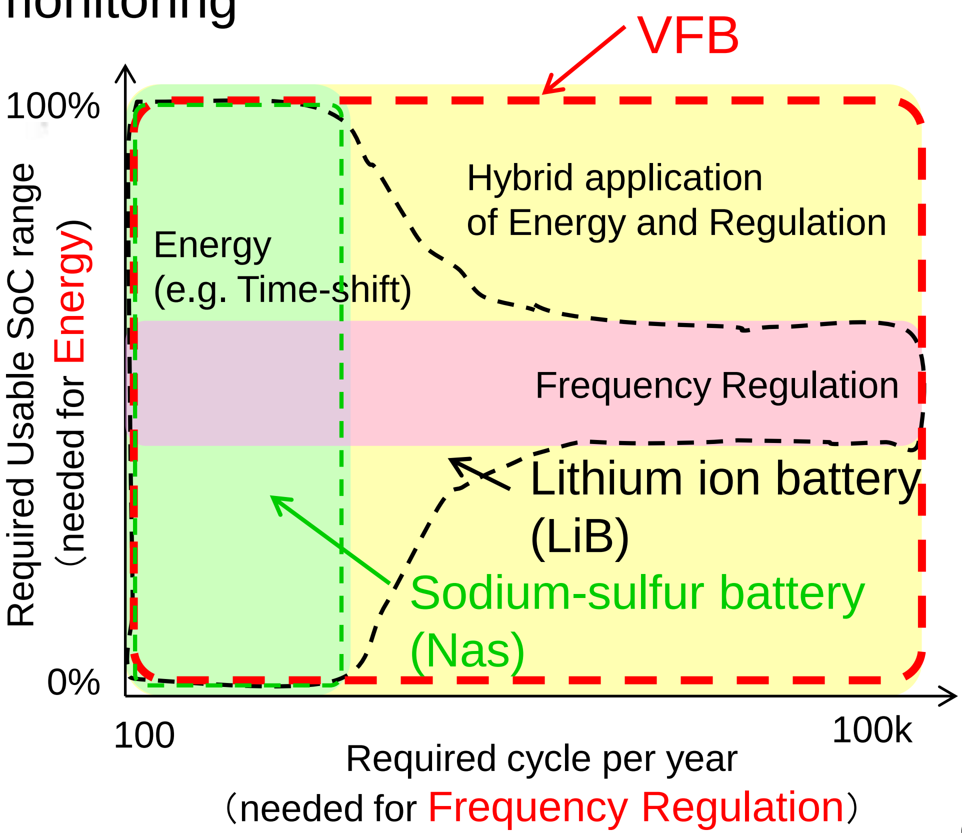


Advantages of VFB as large power storage applications

1. No limit of cycles @full charge/discharge
2. Long lifetime (20+ years)
3. Easy to increase the capacity battery system by adding an electrolyte tank
4. Fast response
5. Accurate State of Charge(SoC) monitoring
6. Non-combustibility



Principle of VFB



1. PURPOSE

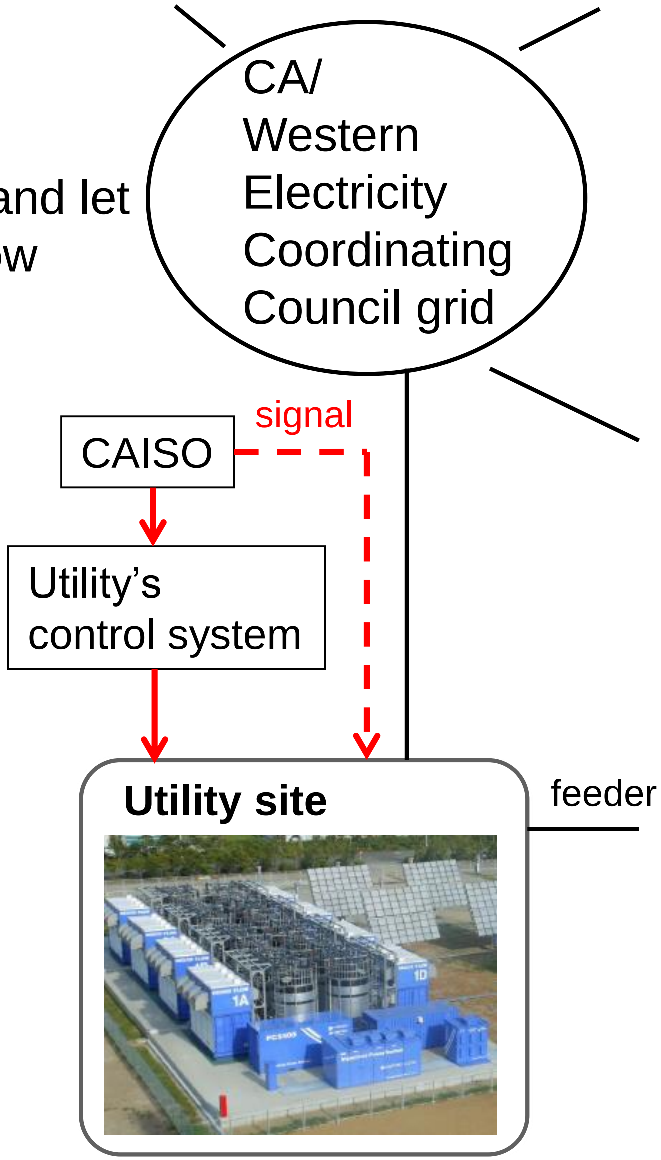
- Provide practical solution toward 2020.
- Work together with Investor owned utility in California and let many Utilities know about the potential of vanadium flow battery.

2. ISSUE

- Little practical experience of operating energy storage system for hybrid application of both energy and regulation
- Little validation of economic value for utility owned energy storage for multiple applications.

3. ACTION

- Install 2MW 4hour VFB at a utility's site in CA
- Demonstrate the energy storage system for both energy and regulation with utility and CAISO.



Thank You for your Attention!

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takizawago@nedo.go.jp