Taiwan National Energy Program-Phase II

Smart Grid and Meter Main-Axis Specific Project

Development of Smart Community Energy Management System in Taiwan

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成功大學

第二期能源國家型科技計畫

National Energy Program-Phase II

Outline

- Backgrounds of VPP
- VPP System Architecture
- VPP Technologies Developed in Taiwan
- Operational Experiences of VPP in Taiwan
  - System in Shulin TPRI Campus
  - System in Xinglong Public Housing
- Future Work

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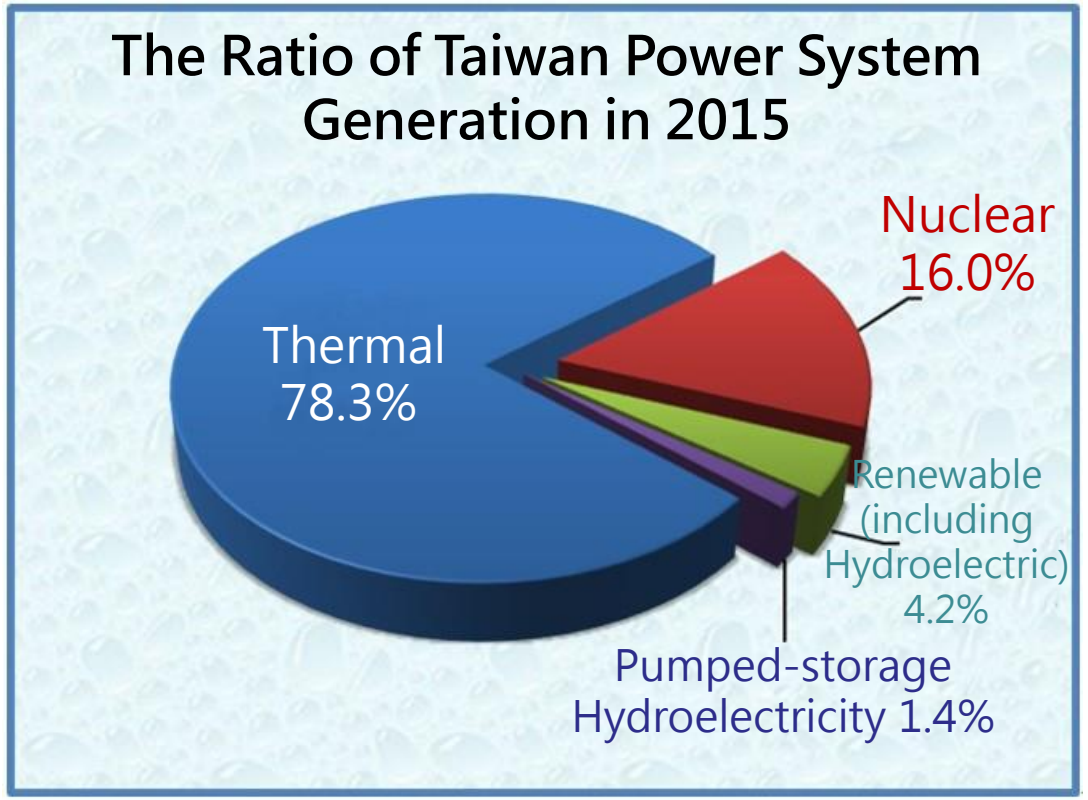
Backgrounds of VPP

- Status of Taiwan power system
  - Nuclear power accounts for 16% of the total electricity generation
  - However, all units will be retired in less than 8 years



Station	Set	Capacity (MW)	Status
1st Jinshan Nuclear Power Plant	1	636	Retire in 2018
	2	636	Retire in 2019
2nd Kuosheng Nuclear Power Plant	1	985	Retire in 2021
	2	985	Retire in 2023
3rd Maanshan Nuclear Power Plant	1	951	Retire in 2024
	2	951	Retire in 2024
4th Lungmen Nuclear Power Plant	1	1350	Safely Mothballed
	2	1350	Suspended

Ref: Taipower Company www.taipower.com.tw

Goal of Renewable Energy Policy in New Government

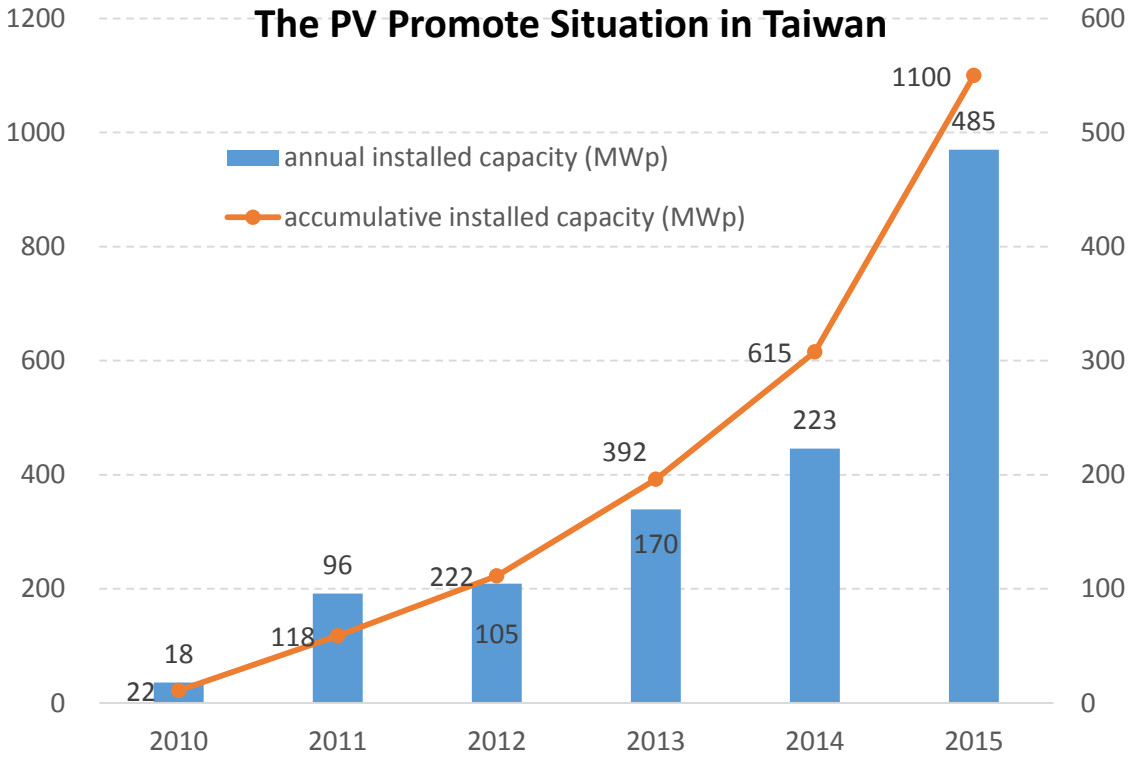
- **Strategic Directions: To achieve nuclear-free homeland and greenhouse gas reduction targets, the new government will expand the solar photovoltaic energy policy, offshore wind power and other renewable energy, also to accelerate provisioning smart grid and meter.**
- **Promoting Objectives: To promote solar PV 20GW (roof 3GW / ground type 17GW), wind power 4.2GW (onshore 1.2GW, offshore 3GW), till 2025 renewable energy will achieve 53.1% of generation capacity, 18.5% of the total generating capacity. And 8 million livelihood users build link to smart grid and smart meters.**

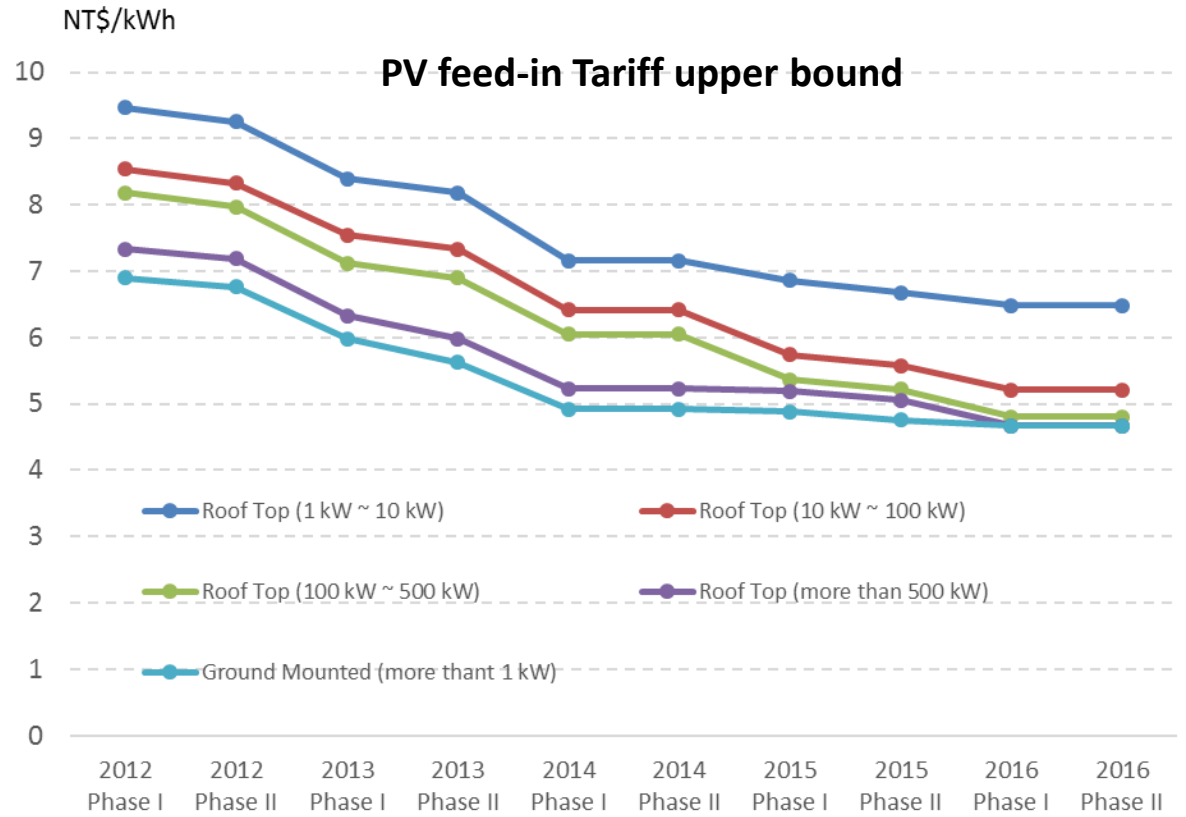
發展時程	實績 2014年		能源局規劃 2030年		民進黨規劃 2025年	
推廣項目	容量(MW)	發電量(億度)	容量(MW)	發電量(億度)	容量(MW)	發電量(億度)
1.水力發電	2,081.4	43.2	2,200	48	2,500	55
2.風力發電	637.2	15.0	5,200	161	4,200	130
陸域	637.2	15.0	1,200	29	1,200	30
離岸	0.0	0.0	4,000	132	3,000	100
3.太陽光電	615.2	5.5	8,700	109	20,000	200
4.地熱發電	0.0	0.0	200	13	600	35
5.生質能發電	740.4	35.0	950	67	1,200	80
合計	4,074.2	98.7	17,250	398	28,500	500
全國系統總量	40,787.0	2,192.2	56,811	2,858	53,691	2,701
再生能源佔系統比率	10.0%	4.5%	30.4%	13.9%	53.1%	18.5%

Data Source:New energy policy, New Frontier Foundation, March 11th 2015.

The PV Promote Situation in Taiwan

Bureau of Energy's PV promotion targets is 20 GWp accumulative capacity in 2030. but how to find out sufficient area for PV installation, the power grid connect capability, and the regulation issues such as the electricity act, renewable energy act will be the challenge of this policy.





資料來源：經濟部能源局

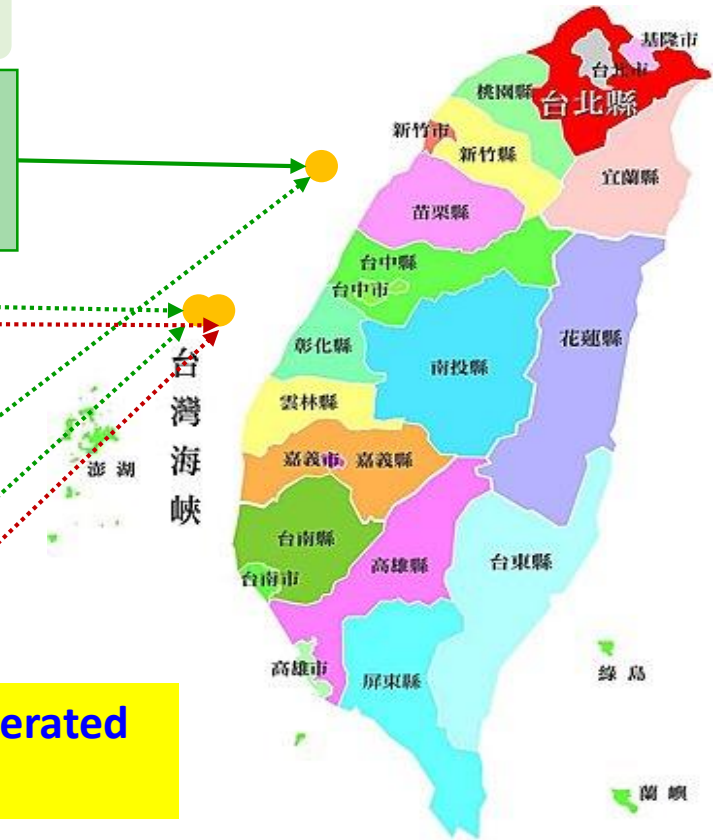
Promotion Goal and Strategy in Taiwan Offshore Wind Power

Strategy: Offshore wind farms are built in from shallow ocean regions under "Offshore Demonstration Incentive Program" to deep sea regions via a district-based development model gradually.

Goal

Offshore Demonstration Incentive Program

	National Project	Private Project	
2016	**Taipower / SENERG** • 5MW * 2 (demo turbines) • Water depth: 15-26 m • Distance to shore: 7-9 km	**TGC** • 4MW * 2 (demo turbines) • Water depth: 20-45 m • Distance to shore: 8-12 km	**Formosa I Wind Power** • 4MW * 2 (demo turbines) • Water depth: 15-35 m • Distance to shore: 2-6 km
2020 0.52GW	**Taipower / SENERG** 108-110 MW (18-30 units) (demonstration wind farm)	**TGC** 4MW * 28 units (demonstration wind farm)	**Formosa I Wind Power** 4MW * 30 units (demonstration wind farm)
2025 3GW			
2030 4GW	**Developing & planning**		



8 MW demonstration turbines will be operated commercially at the end of this year.

Data Source: Taiwan Institute of Economic Research (TIER), Research Division 1.

Progress of Offshore Demonstration Wind Farm Met Mast

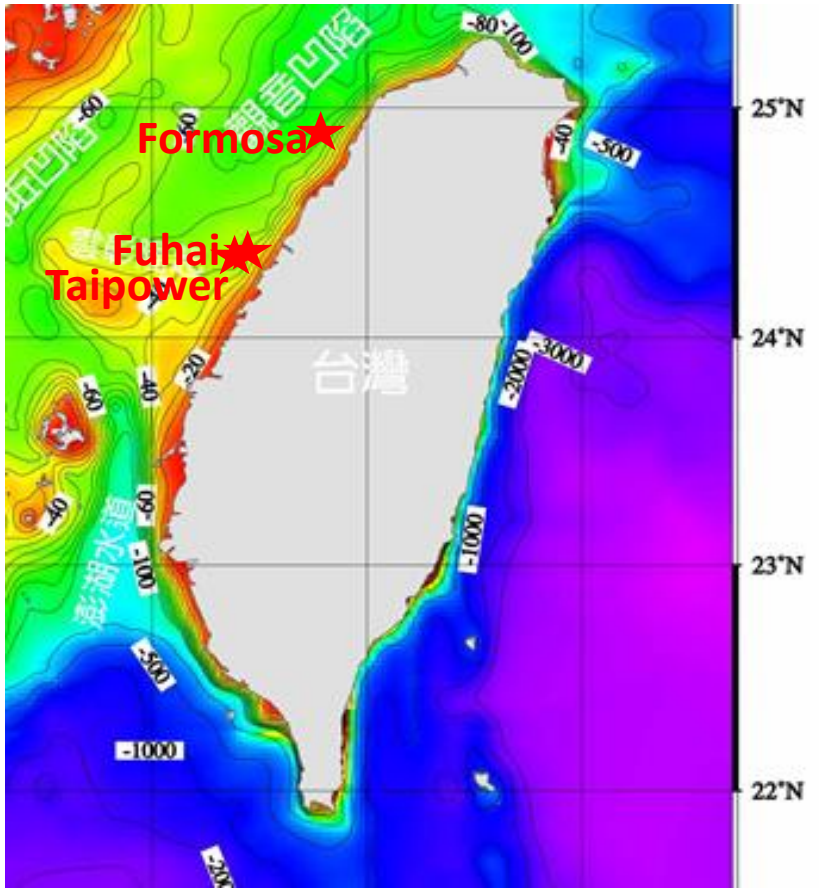
Domestic offshore wind farm developers have completed the Met Mast respectively in 2015, and continue to measure the meteorological data and establish the meteorological database.

Met Mast in Fuhai Offshore wind farm

Met Mast in Formosa Offshore wind farm

Met Mast in Taipower Offshore wind farm

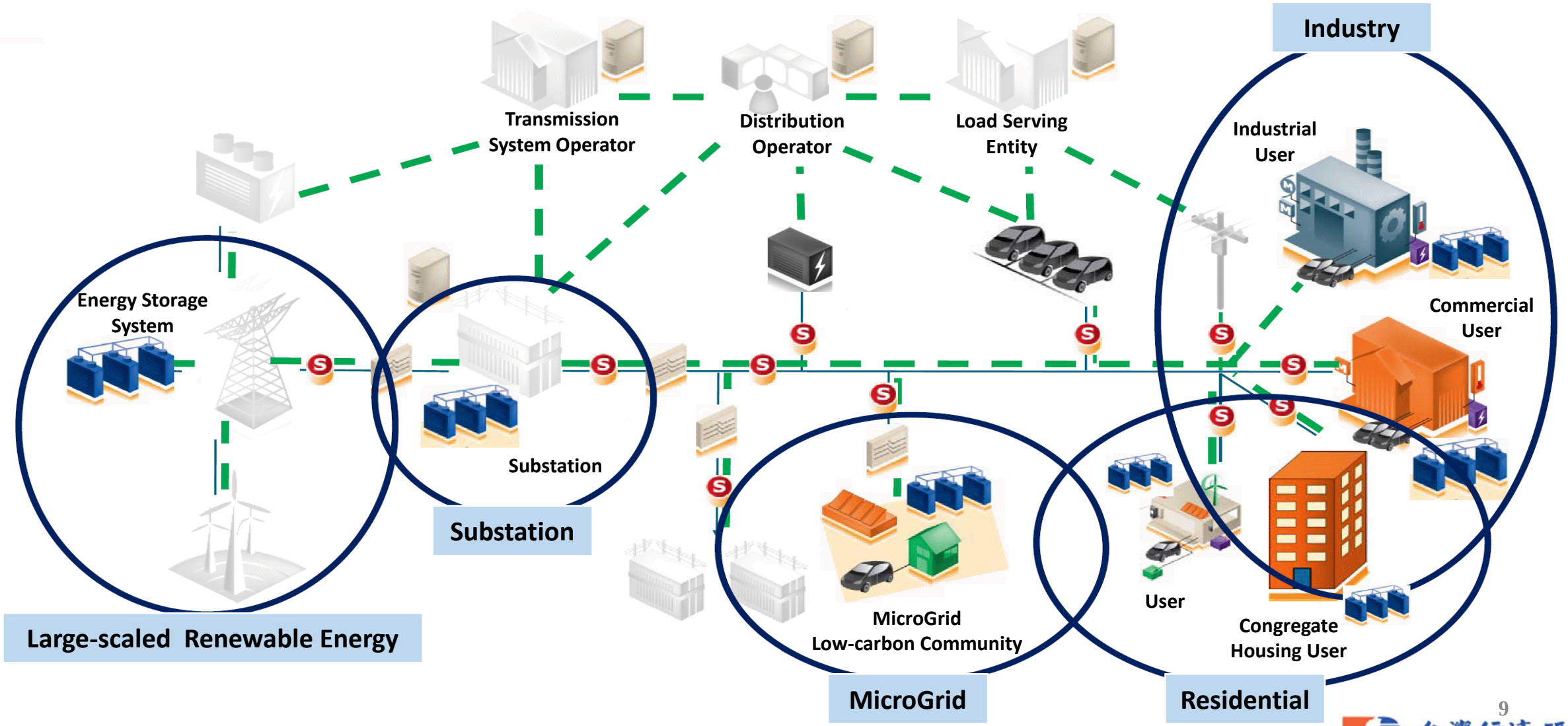
Developer	Location	Distance (km)	Depth (m)	Numbers	Capacity (MW)	Support Vessel	Progress
Fuhai (TGC)	Offshore Fangyuan, Changhua	8~12	20~45	30	120	CSBC Huadian 1001	Met Mast has been completed in Aug 2015.
Formosa (Swancor)	Offshore Chunan, Miaoli	2~6	15~35	32	128	Domestic Platform Barge	Met Mast has been completed in Aug 2015.
Taipower	Offshore Fangyuan, Changhua	5~8	15~ 25	22~36	108	HongYu No.1	Met Mast has been completed in Nov 2015.



Location of Taiwan Offshore Demonstration Wind Farms

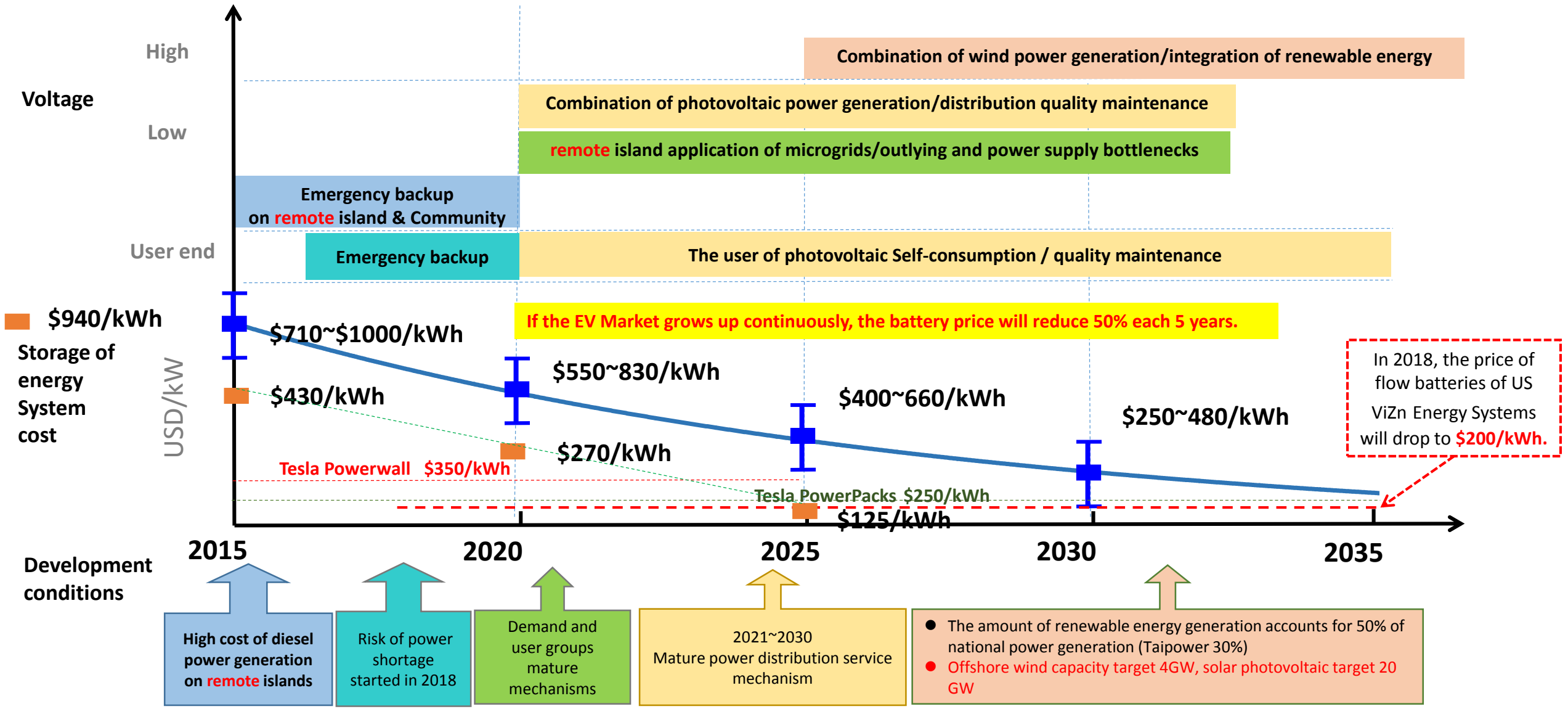
Data Source: National Energy Program-Phase II-Offshore Wind Power and Marine Energy Focus Center

Value Chain of Energy Storage System in Electricity Industry



Source：EPRI Electricity Energy Storage Technology Options, 2011, organized by TIER

Energy Storage System Cost and Domestic Energy Storage Market Trends



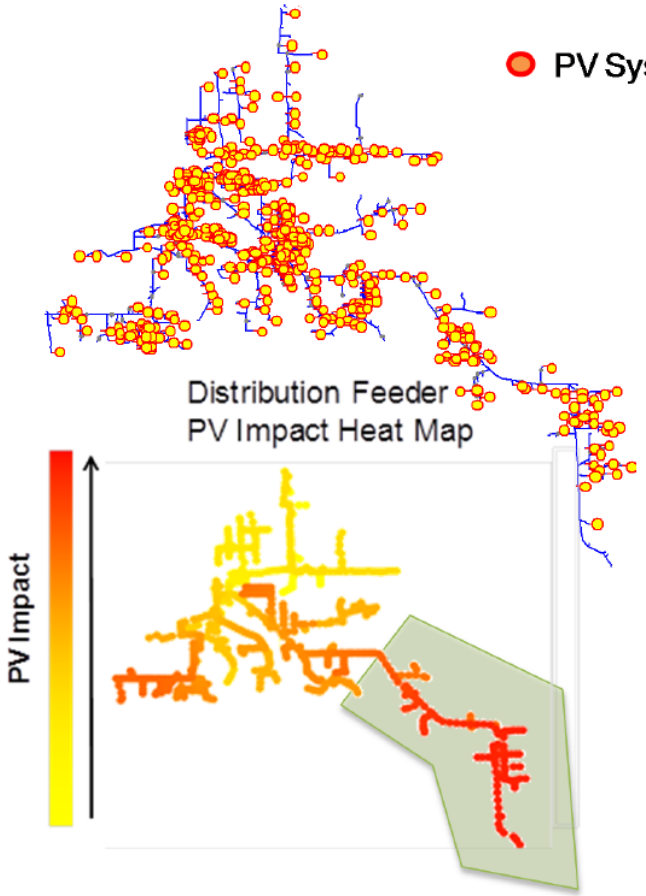
Note:The energy storage system does not include storage systems besides pumped hydro and compressed air

(Source: Marchment Hill Consulting Analysis, 2012; Executive Yuan Bureau of Energy , smart grid master plan,2012/10; Executive Yuan Bureau of Energy, 2014Energy and Industrial Technology White Paper,2015; 2015 Three regeneration policies Taiwan Institute of Economic Research2014)

台灣經濟研究院 Taiwan Institute of Economic Research

Backgrounds of VPP

- Dilemma to be faced
  - Impacts caused by renewable energy (RE)
  - Power congestion in densely populated areas
- Virtual power plant (VPP) in smart grid
  - Demand side management (DSM)
    - Smart home/building energy management system (H/BEMS)
    - Automated demand response (ADR)
  - Distributed energy resource (DER) integration
    - Distributed generators (DG)
    - Energy storage system (ESS)
- Goals
  - Relieve power congestion, increase RE penetration, improve reliability, and postpone investment in power industry



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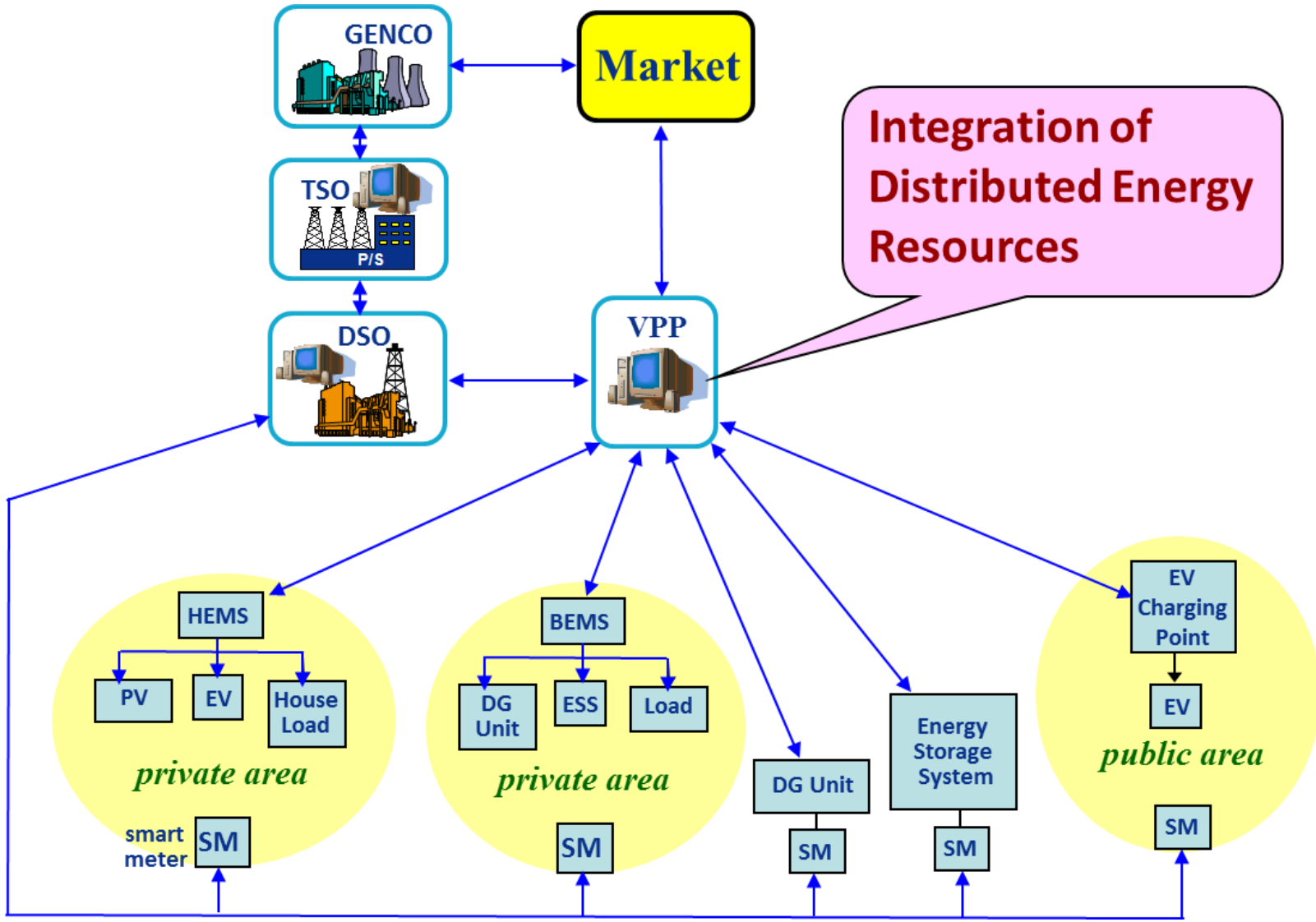
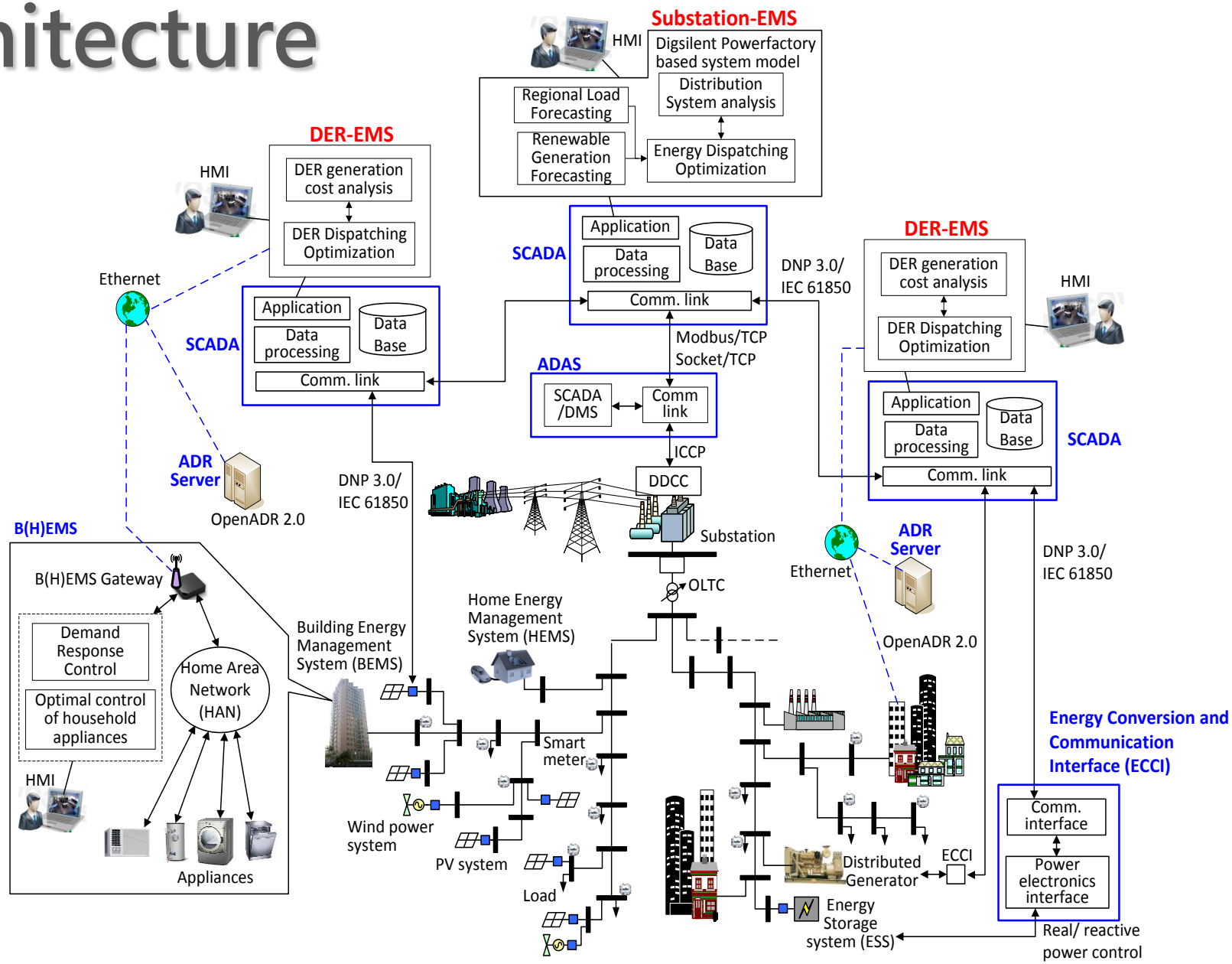
Relationship between VPP and Grid Operators



Ref: Deliverable D1.3, "Identifying EV smart control approaches under a VPP management", EU project on MERGE, http://www.evmerge.eu/images/stories/uploads/MERGE_WP1_D1.3_Final.pdf, Access on 22 Mar. 2011.

VPP System Architecture

- Mitigate dilemma in distribution system
  - High penetration of RE
    - Overvoltage, voltage/freq. fluctuation
  - Regional power congestion
    - Overload, under voltage, & power shortage
- Enhance system reliability
- Increase RE penetration
- Improve energy efficiency
- Shave peak load



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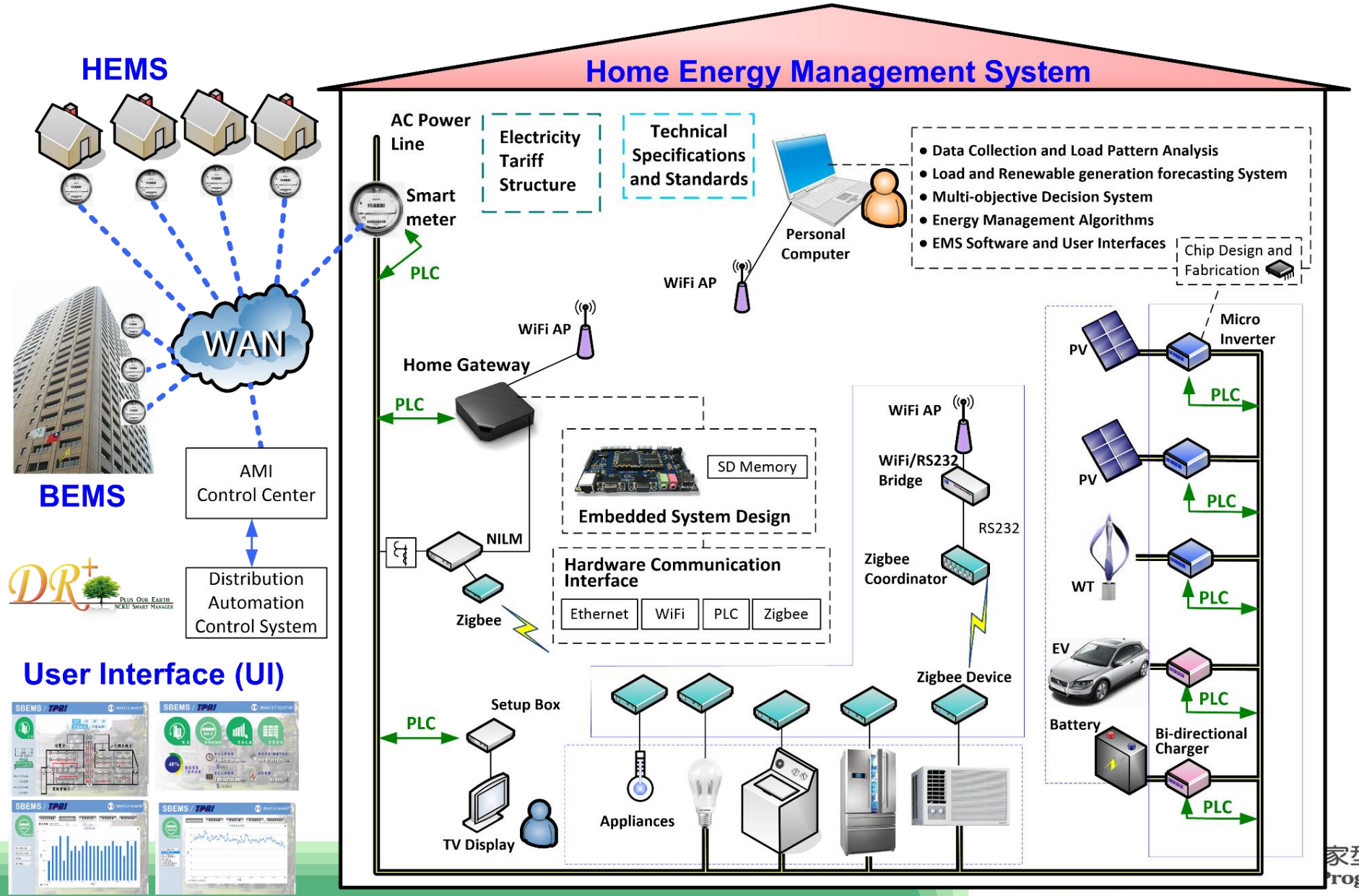
Smart Home/Building Energy Management System



Certification of Open Automated Demand Response (OpenADR 2.0)

- H/BEMS systems receive control signal from ADR management center for load management
  - Integrating DR programs of end-users
  - Promoting energy saving via management
  - Via third-party certification of OpenADR
    - To develop the energy-service industries
    - To increase the opportunity for product exporting


openADR 2.0a CERTIFIED

Certificate of System Conformance Awarded to

National Cheng Kung University

DR Plus
(Firmware V1.0)

Certified October 26, 2014 to OpenADR 2.0a Test Plan 1.05

Rolf Bienert
Technical Director

Barry Haaser
Managing Director


openADR 2.0b CERTIFIED

Certificate of System Conformance Awarded to

National Cheng Kung University

DR Plus b
(Firmware v. 1.0)

Certified August 27, 2015 to OpenADR 2.0b Test Plan 1.0.6

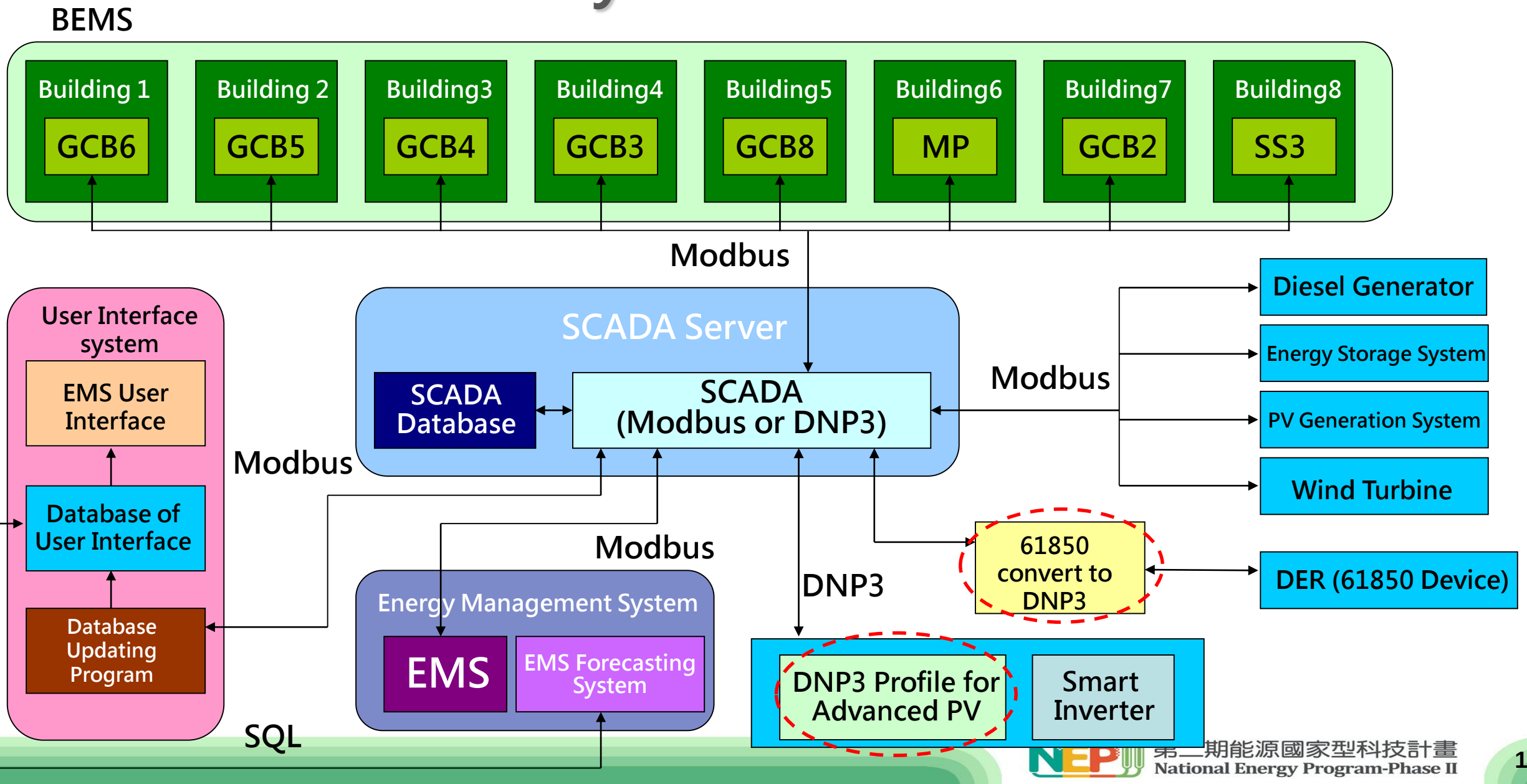
Rolf Bienert
Technical Director

Barry Haaser
Managing Director

DR+ PLUS OUR EARTH NCKU SMART MANAGER

(The OpenADR 2.0 is the standard for energy demand response regulated by the USA)

SCADA System Architecture

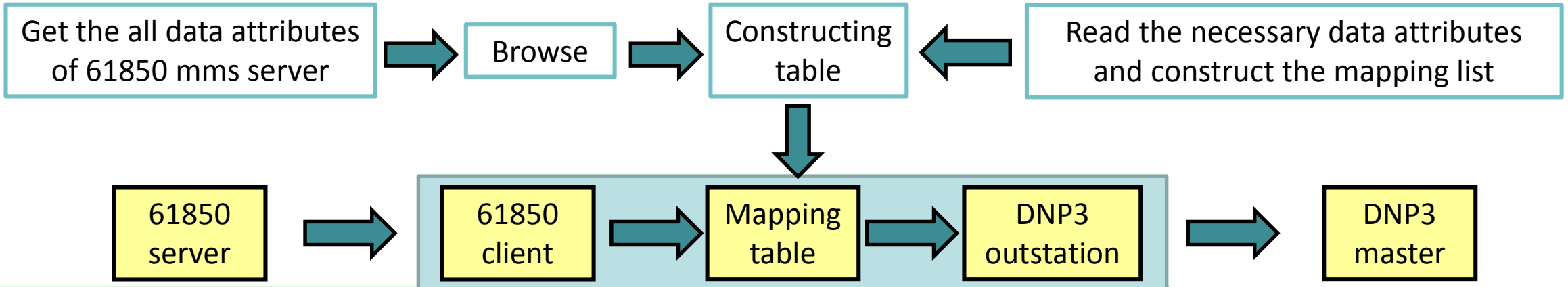


International Standard IEC61850/DNP3 Data Transformation Gateway

- IEC61850 data ⟷ DNP3 data
  - Through data mapping table
- **Technology first** established in Taiwan

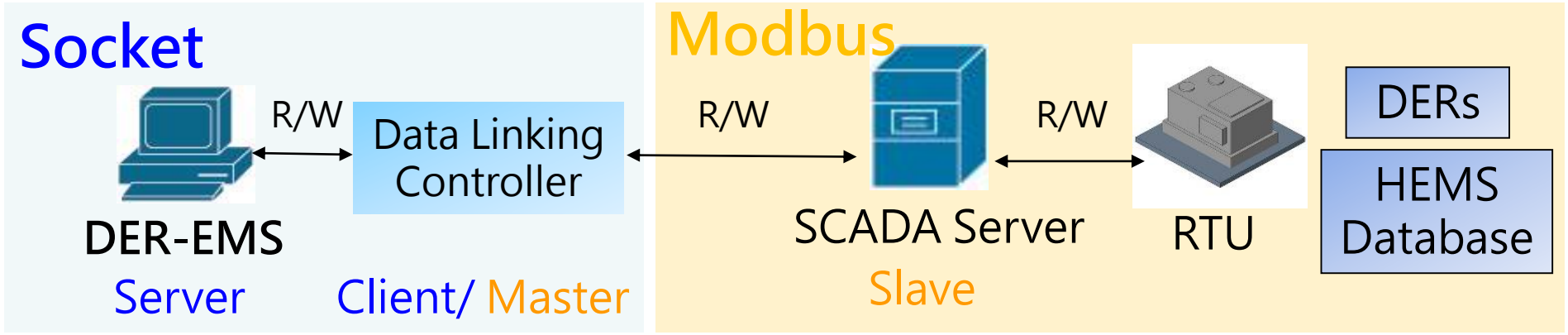
IEC61850/DNP3
Data Transformation Gateway

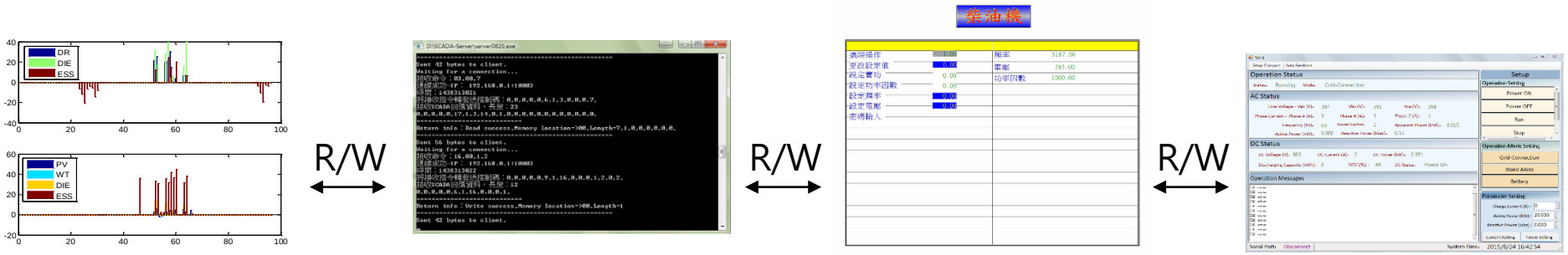
- Procedure of Data Convert



Integrated EMS, SCADA and DER Remote Control Interface

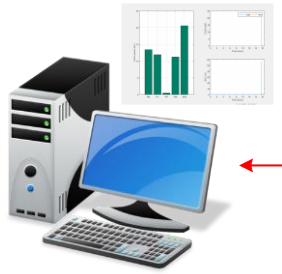
- System conversion structure: EMS ⇔ SCADA ⇔ DER remote control interface





Smart Inverter of Wind Turbine

- With the functions
  - Power factor adjustment
  - Remote control



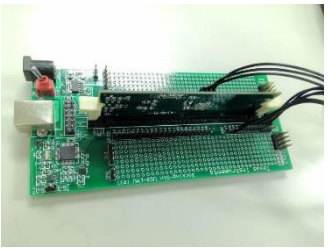
EMS

IP: 140.116.163.1

Data Connecter

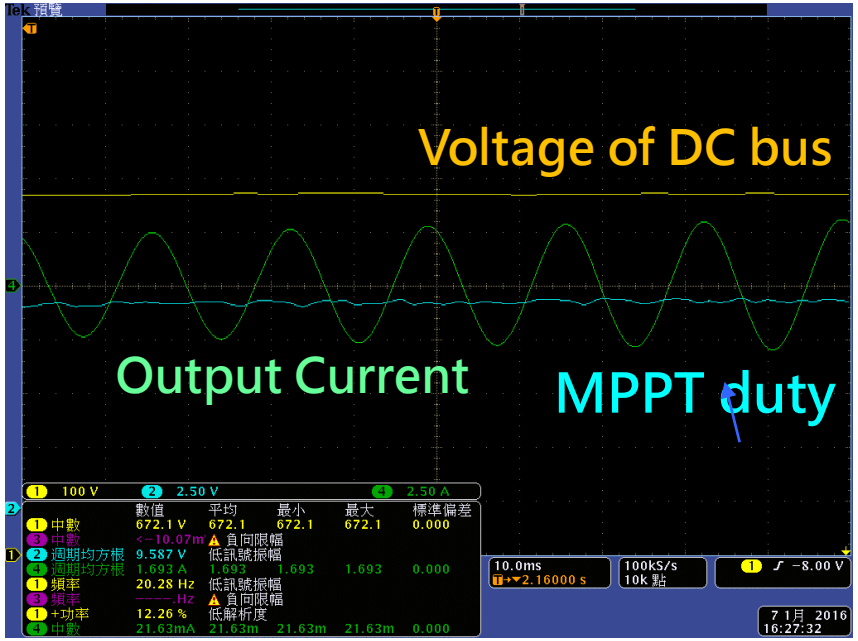
NCKU SCADA Server

IP: 140.116.163.18

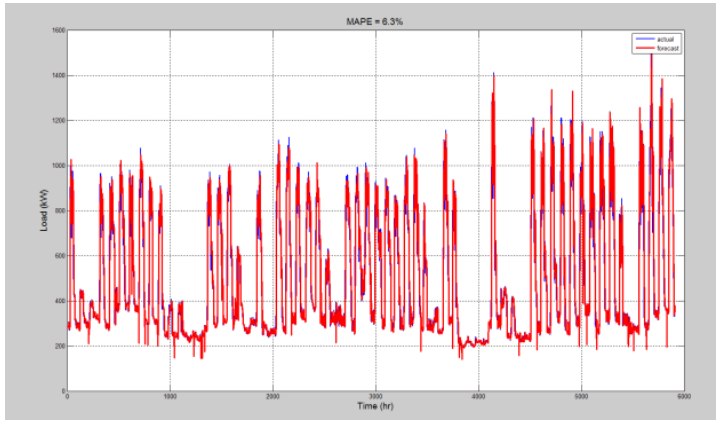
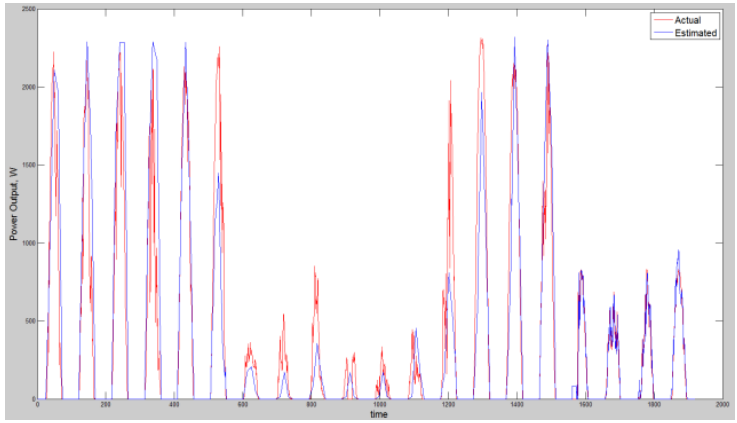
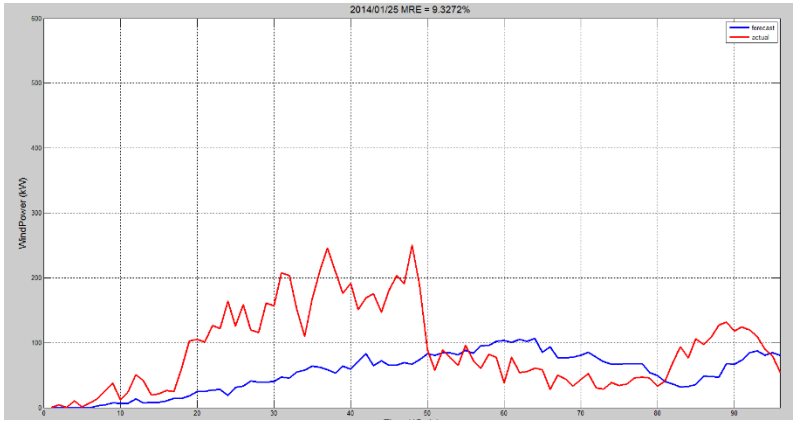
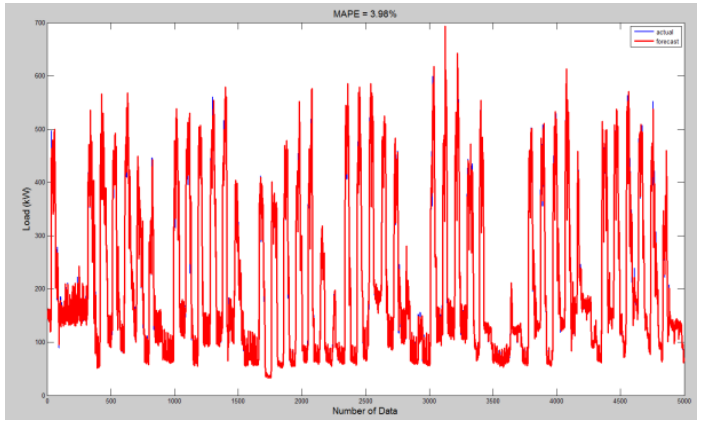
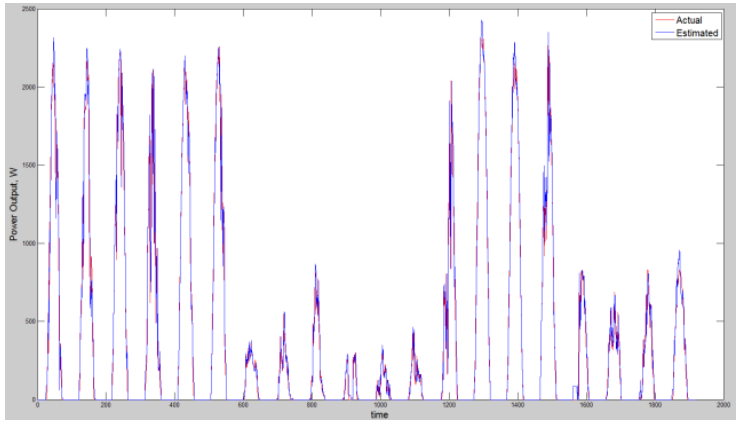
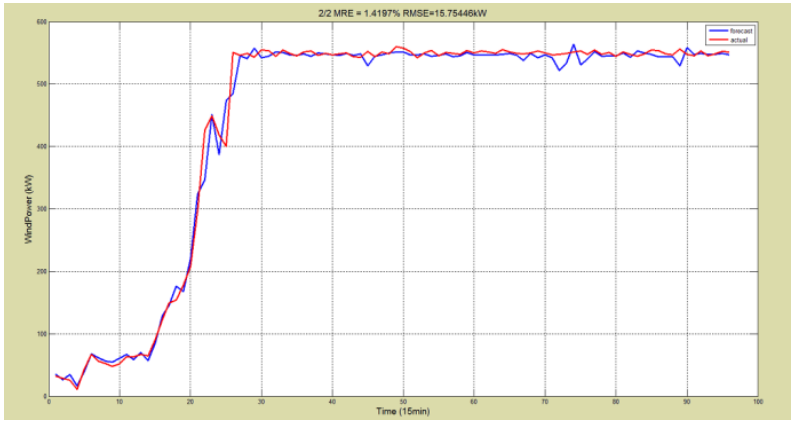


Controller of Wind Turbine's Inverter

IP: 192.168.0.10

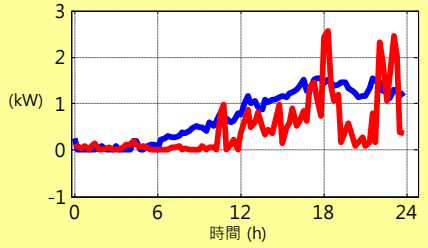


Forecasting Systems

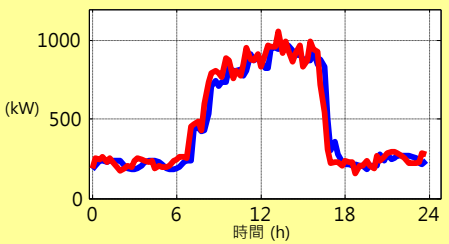
	Load Forecasting	PV Generation Forecasting	WT Generation Forecasting
Day-ahead			
	Error 5.8%	Error 4.35%	Error 12.2%
Real-Time			
	Error 3.98%	Error 1.33%	Error 3.77%

Hierarchical Structure DER-EMS

RE Power Forecasting



Load Forecasting



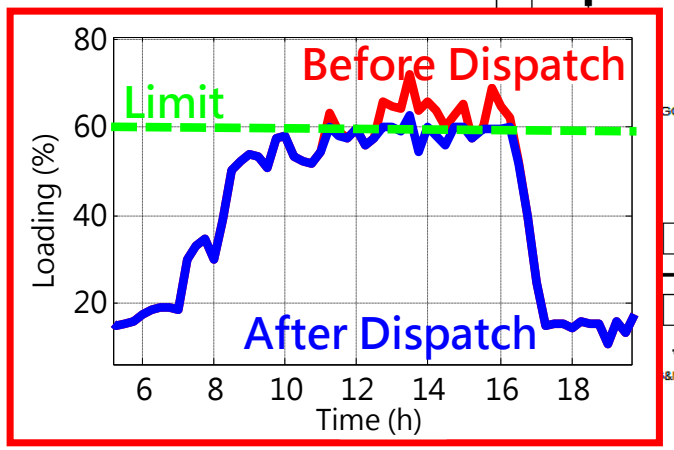
Forecasting Error Analysis and Power Shortage Risk Assessment

Substation-EMS

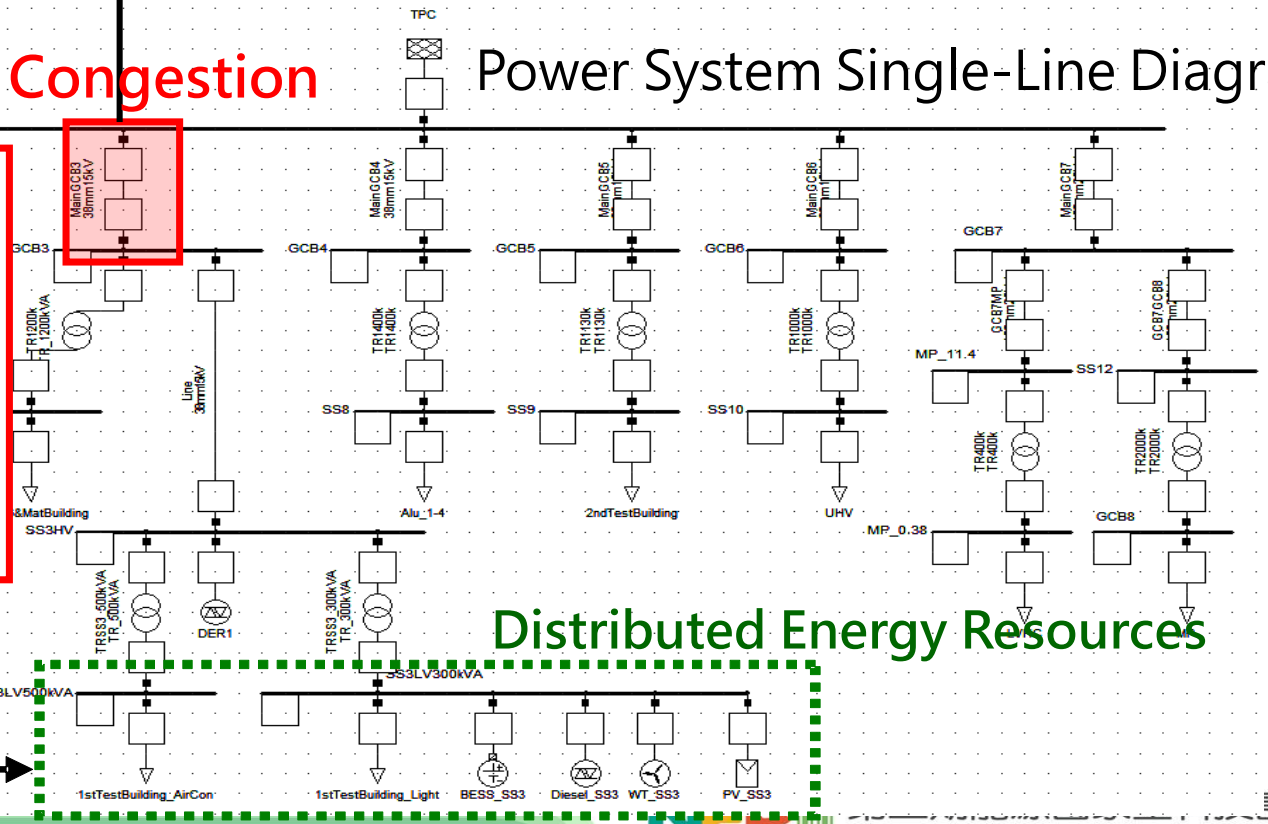
Distribution Level Energy Management System

Demand Dispatch

Congestion



Power System Single-Line Diagram



Distributed Energy Resources

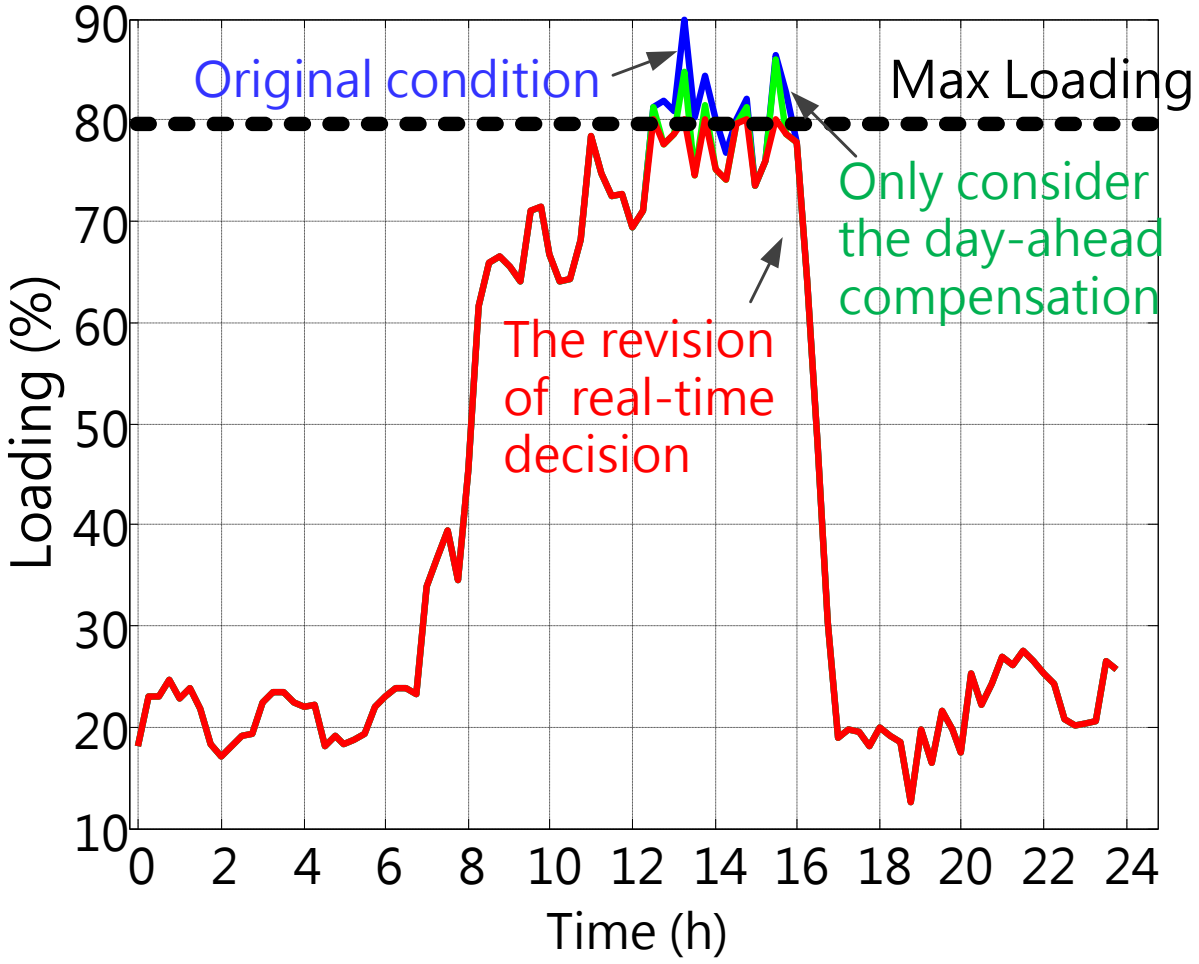
DER-EMS

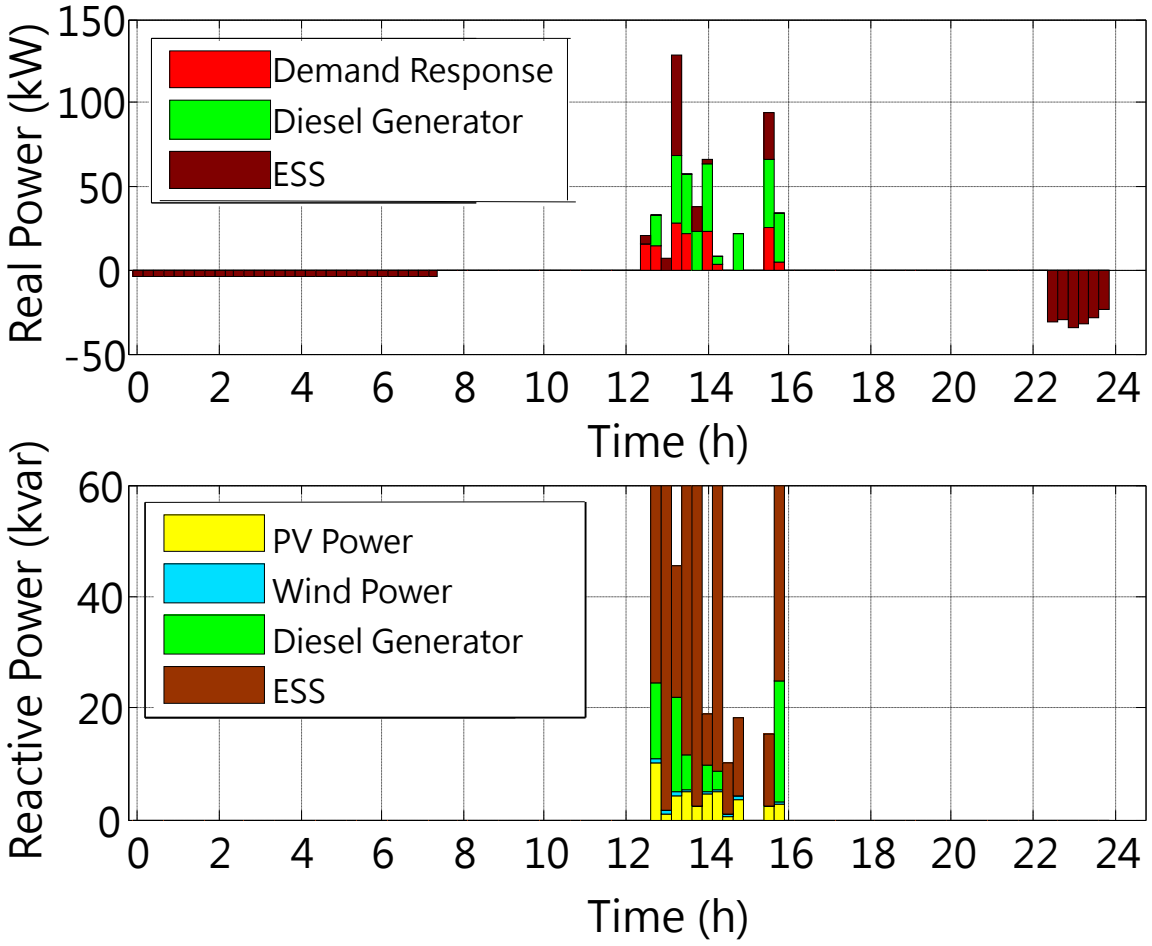
Distributed Energy Resource Energy Management System

Optimal Control

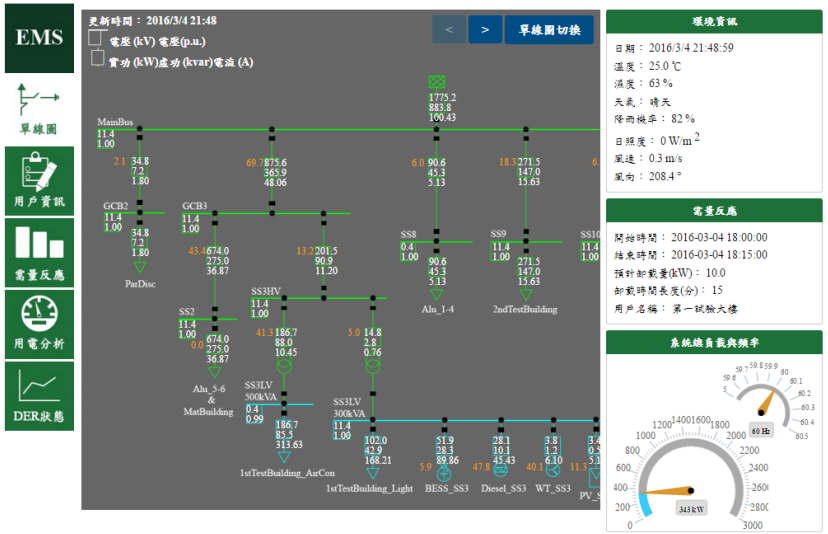
Case Study in Shulin TPRI Campus

- Feeder loading management
- Dispatching allocation for DERs

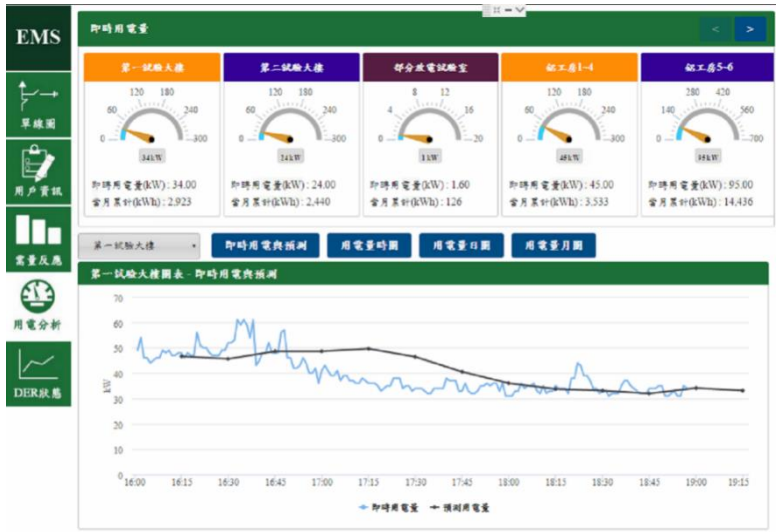




User Interface of Distribution-level EMS



Single-Line Diagram



Load Consumption Information

Demand Response

DER Status Information

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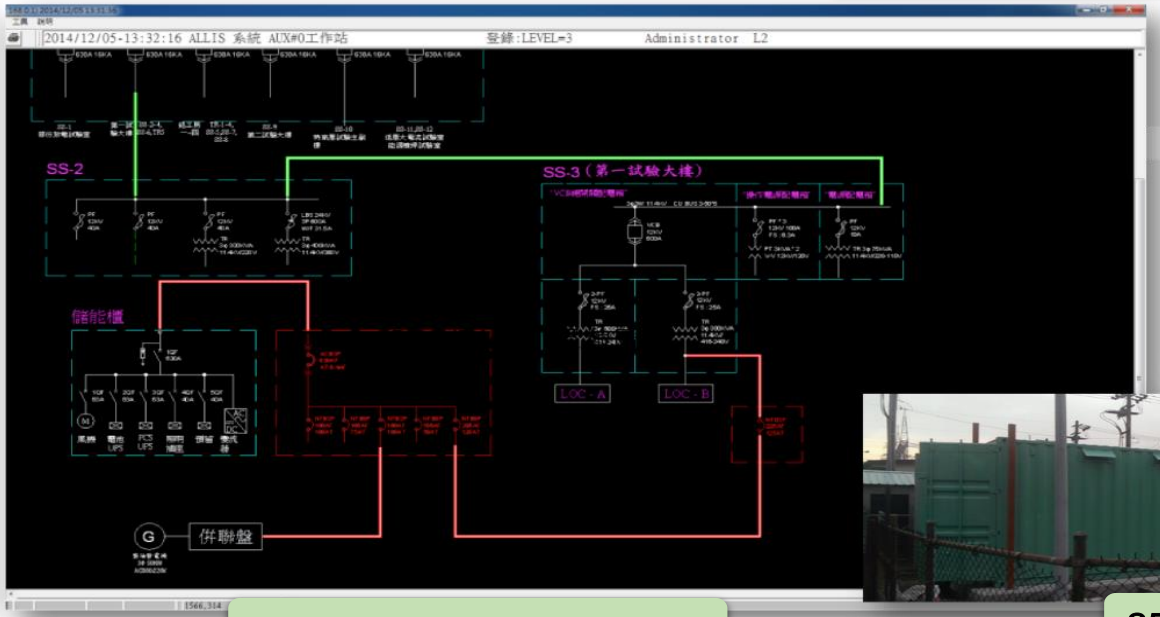
System in Shulin TPRI Campus

SCADA System Development

SCADA Server



System Single Line Diagram

Microgrid Testbed DER Construction

PV Smart Inverter

250kW ESS

Sockets Meter

High-Voltage Meter

BEMS and High Voltage Meter Construction

10kW Wind Turbine

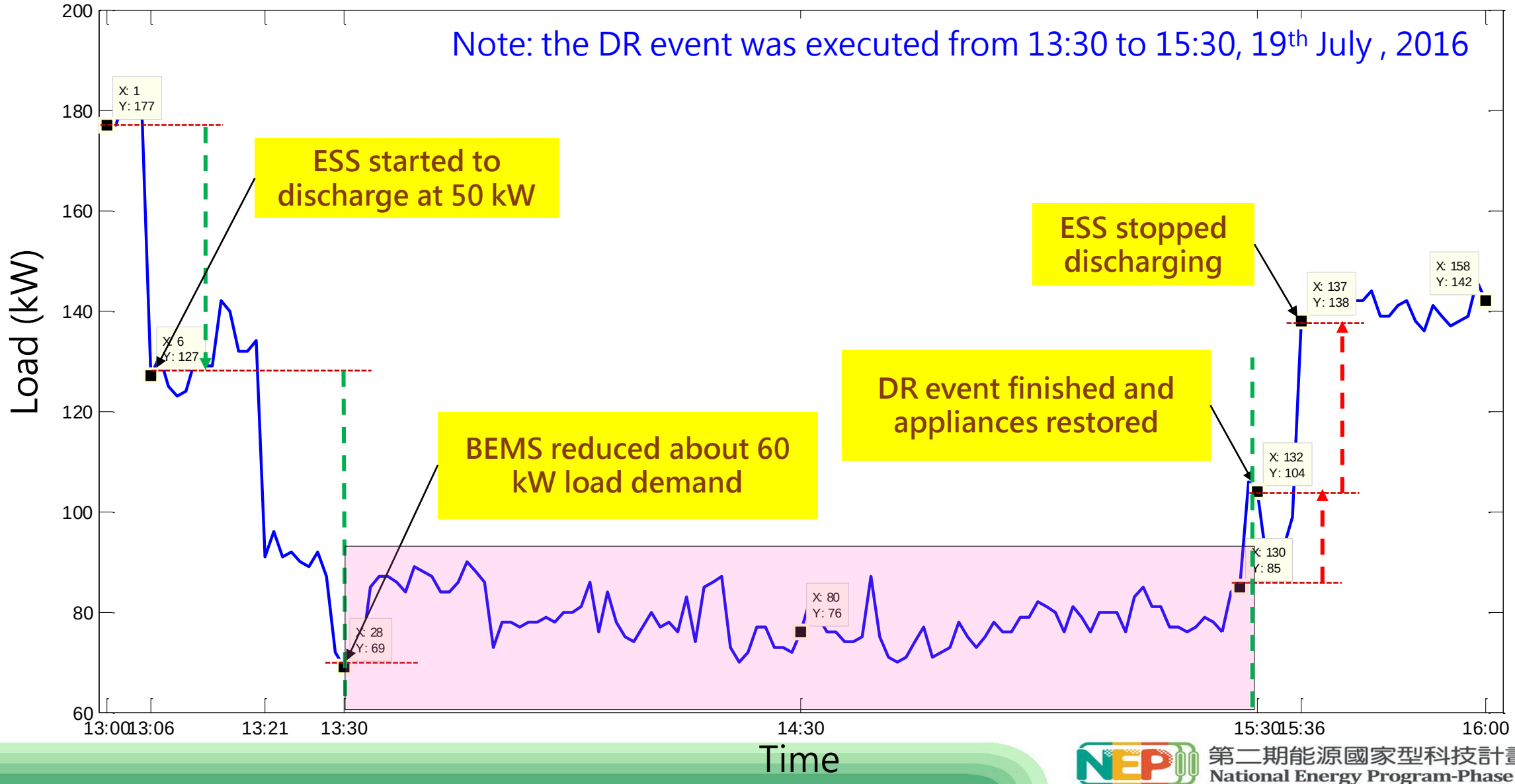
50kW Diesel Generator

System Integration of 1st Testing Building BEMS and ESS

- Integrating ESS in the demo site with BEMS system
  - Increasing equivalent load shedding for DR event
- ESS control page functions
  - Showing real-time operating status
  - Automatic/manual charging/ discharging setting
  - User emergency setting

The ESS Control Page

Performance Analysis of DR in Shulin TPRI Campus



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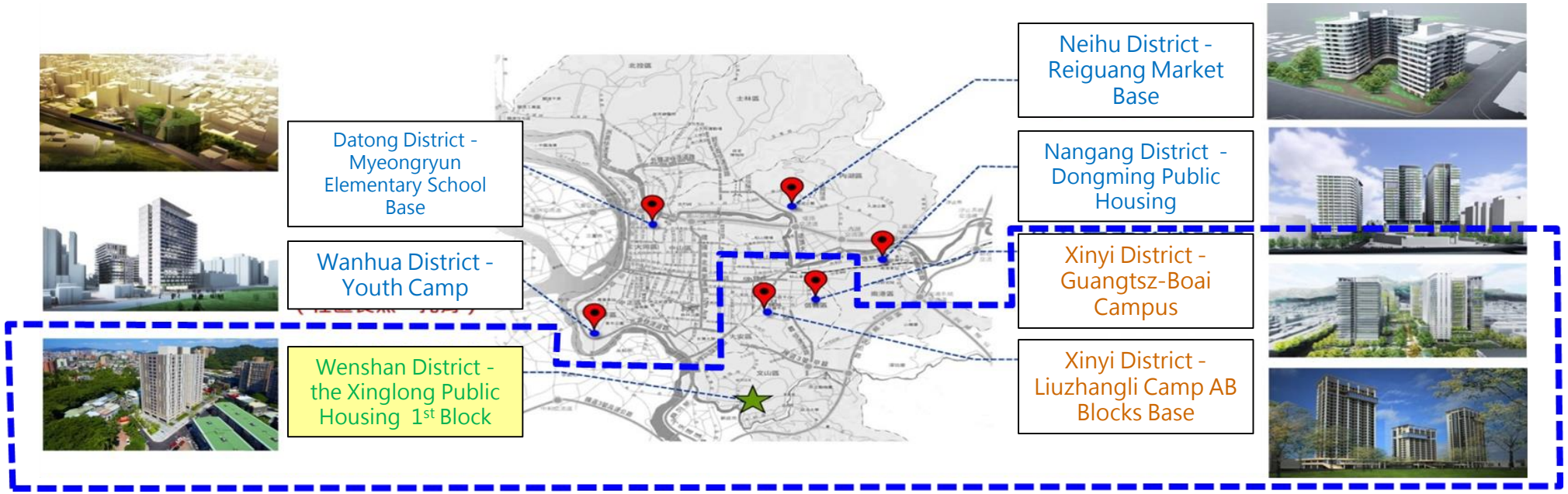
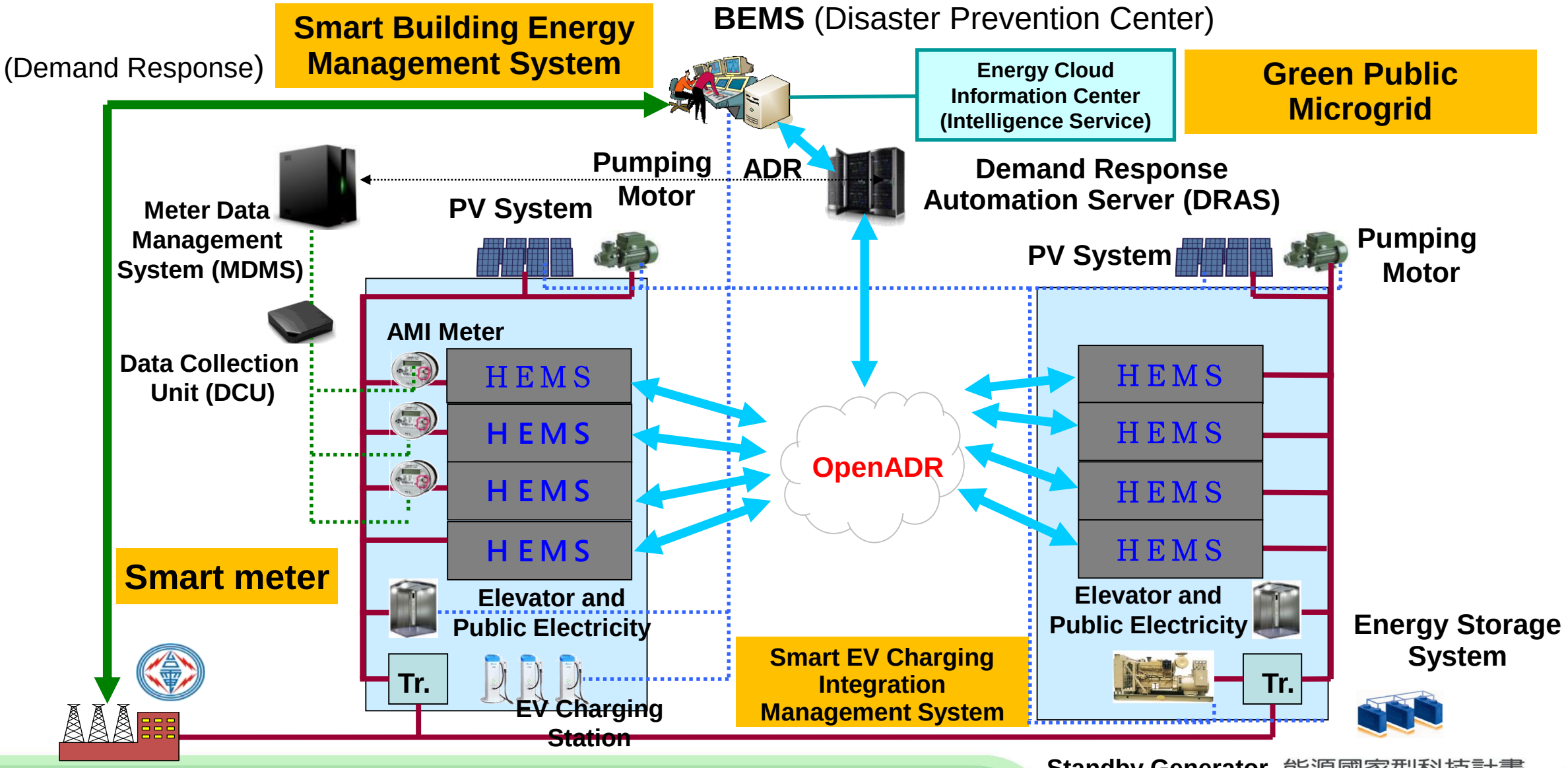
Six Smart-City Demo Sites (over 6,000 Households)



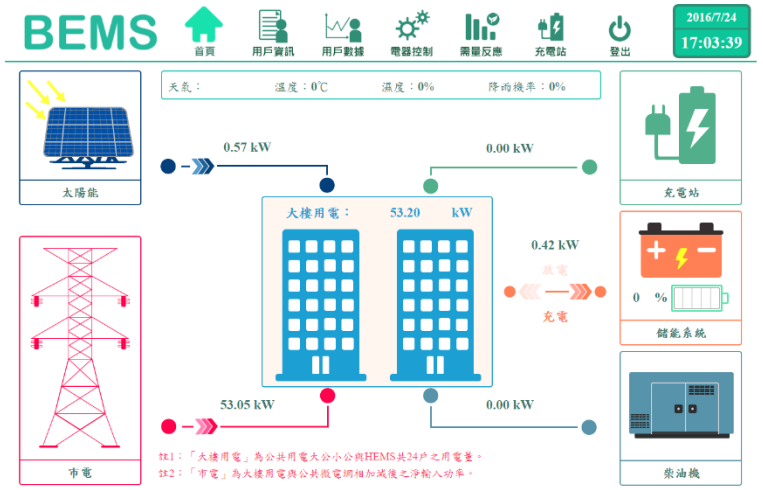
Agency	Cooperative Contents
臺北市政府都市發展局 Department of Urban Development, Taipei City Government	Offering Xinglong Public Housing 1st Block, Xinyi District Guangtsz-Boai Campus and Liuzhangli Camp AB Blocks as the smart grid demonstation fields
第二期能源國家型科技計畫 National Energy Program-Phase II	● The experimental period for the 24 smart grid householders is from Mar. 2016 to Feb. 2017. ● AMI planning and construction ● Implementing the EMS, microgrid, smart EV charging integration management system, etc. ● Researching the most suitable TOU of smart grid to increase the energy efficiency
Taiwan power company	Assisting the AMI and DR mechanism related matters

Xinglong Smart Collective Housing EMS

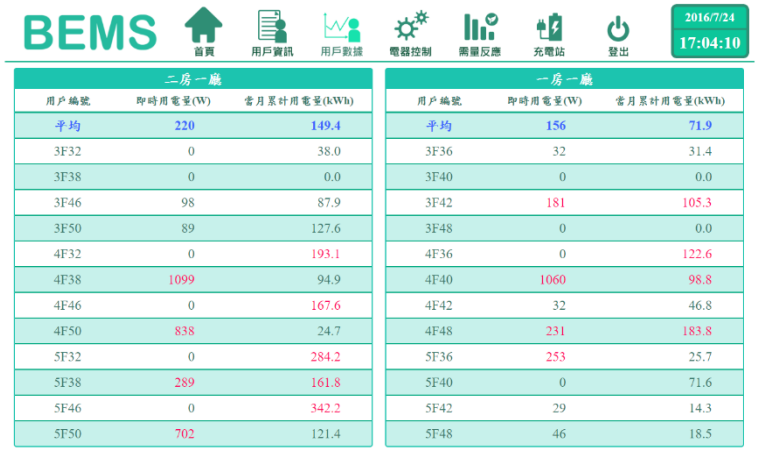


Building Energy Management System (BEMS)

- Energy monitoring and control
  - Enhanced facility management efficiency
  - Flexible demand control
- Data management
  - Data collection, statistics, analysis, visualization
- Energy management
  - Optimal scheduling via PV and ESS coordination
  - Shaving peak load demand
  - Supplying power during outage



Instant Power flow Status



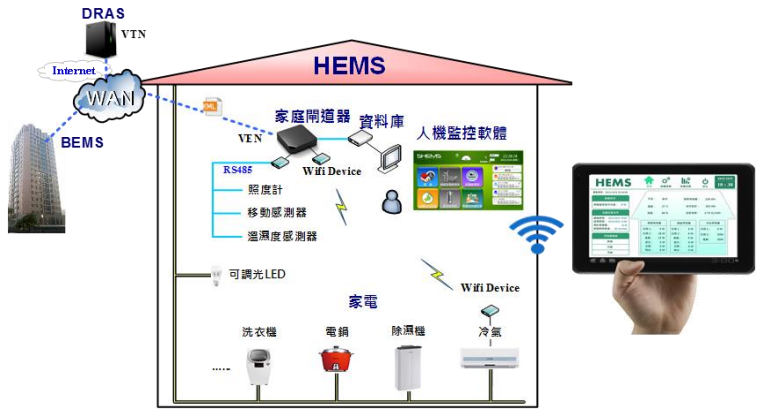
Users Consumption Information

DR Event Information and Reducible Load Setting

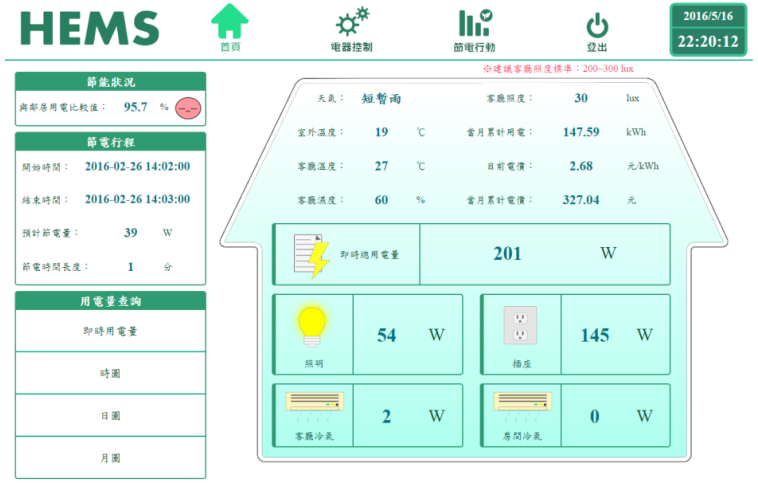
EV Charging Station Status and Management

Home Energy Management System (HEMS)

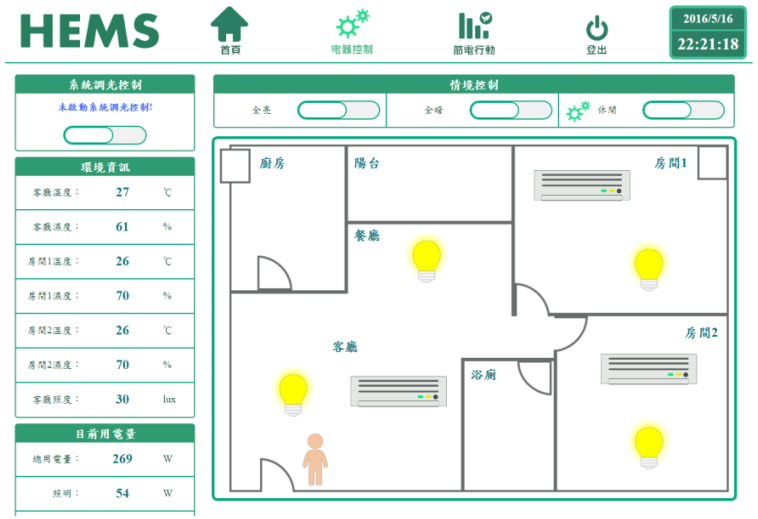
- Power visualization
- Optimized scheduling
  - Cost minimization
  - Comfort
- Scenario control
  - In/Out scenario
  - Lighting scenario
  - Air conditioner scenario
- Demand Response
  - Air Conditioner
  - Lighting



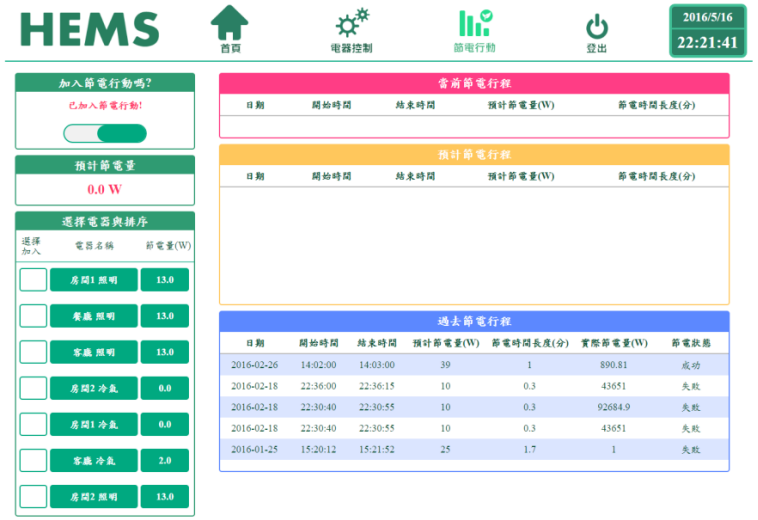
System Operating Diagram



Power Consumption Information



Appliances Instant Status



Energy Saving Operation Information

Green Public Electricity Microgrid

PV Generation System on Roofs

Energy storage systems in The Basement

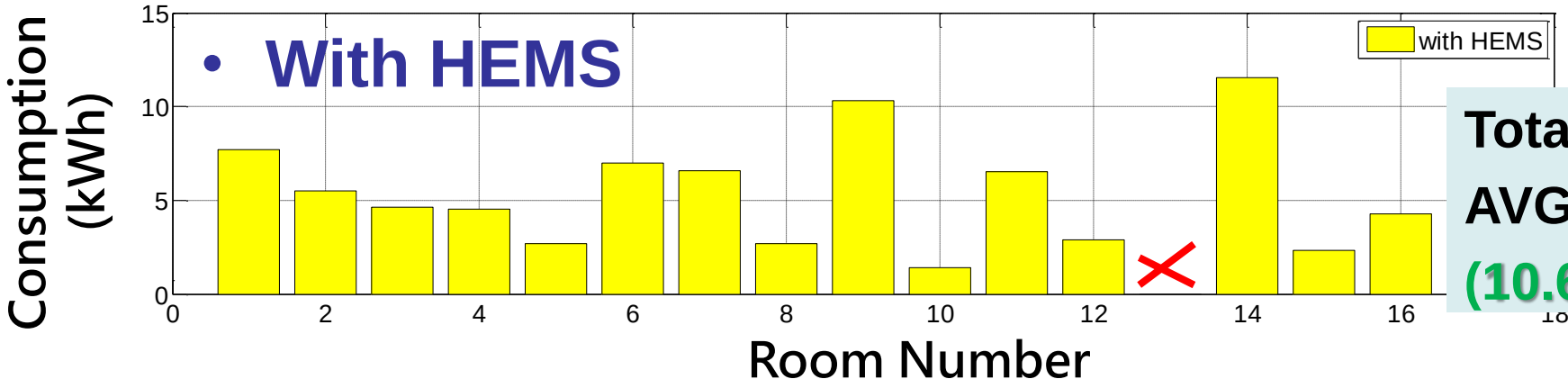
EV Charging Station

AMI- Smart Grid Infrastructure

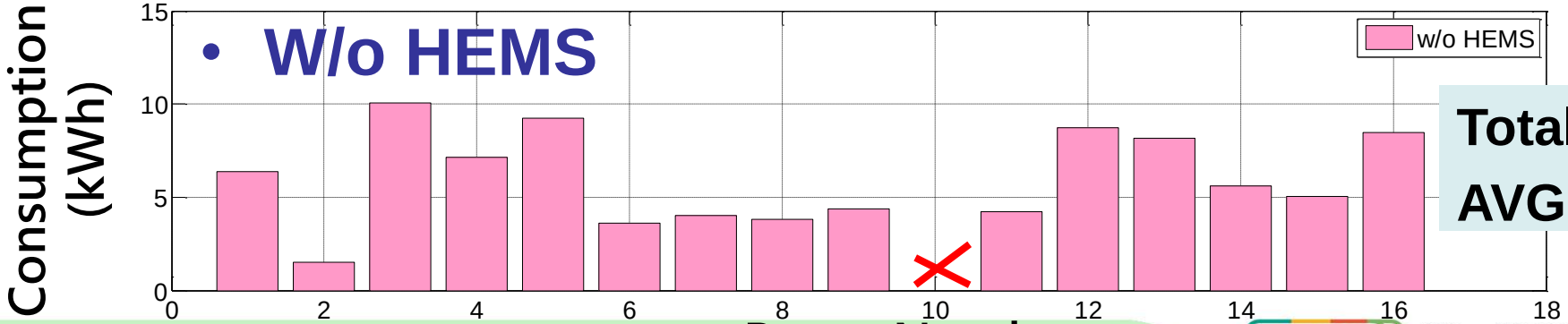
Xinglong Public Housing Smart Grid Project
Energy-Saving Analysis

- Past 8 months (3/1~10/31) household AMI power consumption data
- The smart grid demonstration households (with HEMS) saved about **10.63%** power consumption than the others (w/o HEMS) for comparison

The Daily Average Power Consumption for Each Household



Total: 80.68 kWh
AVG: 5.38 kWh
(10.63% Saved)

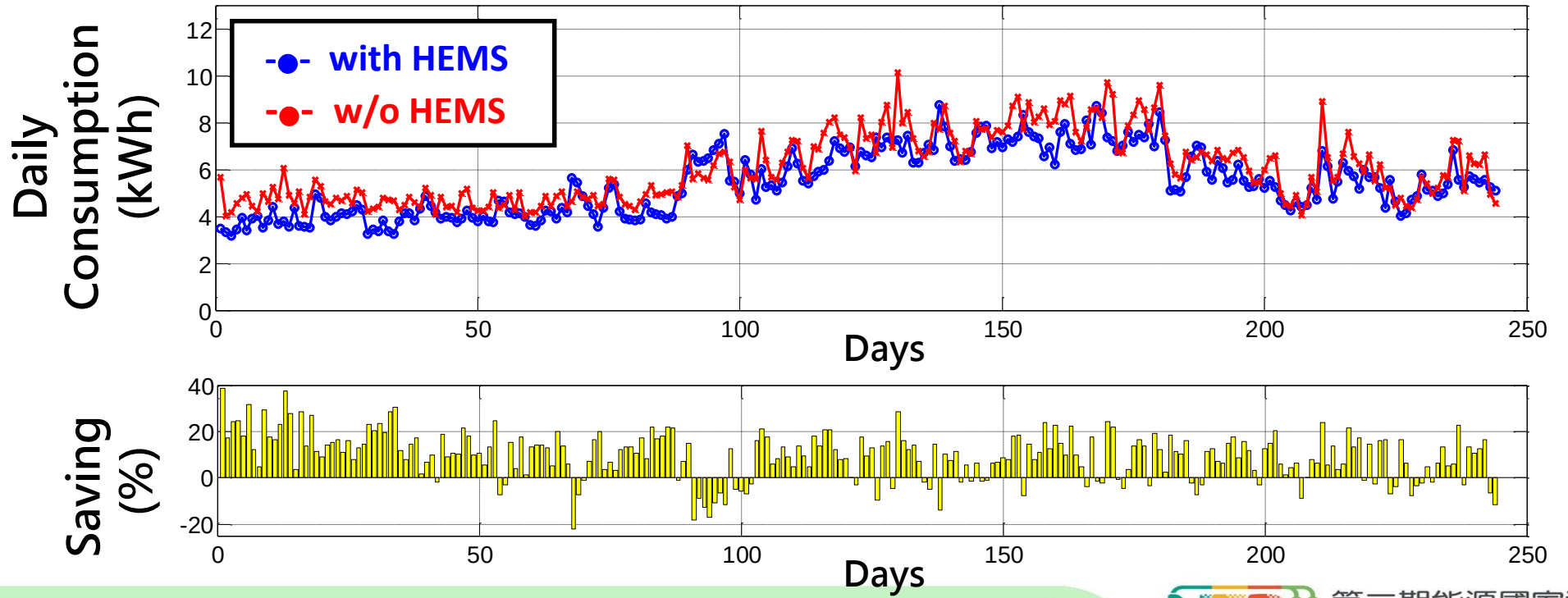


Total: 90.33 kWh
AVG: 6.02 kWh

Xinglong Public Housing Smart Grid Project
Energy-Saving Analysis

- Low-voltage users not been provided with DSM programs, such as TOU and DR, yet
  - Only through HEMS, providing power visualization and energy-saving control autonomously
- According to foreign experiences, expected to further increase energy-saving efficiency through TOU and DR programs

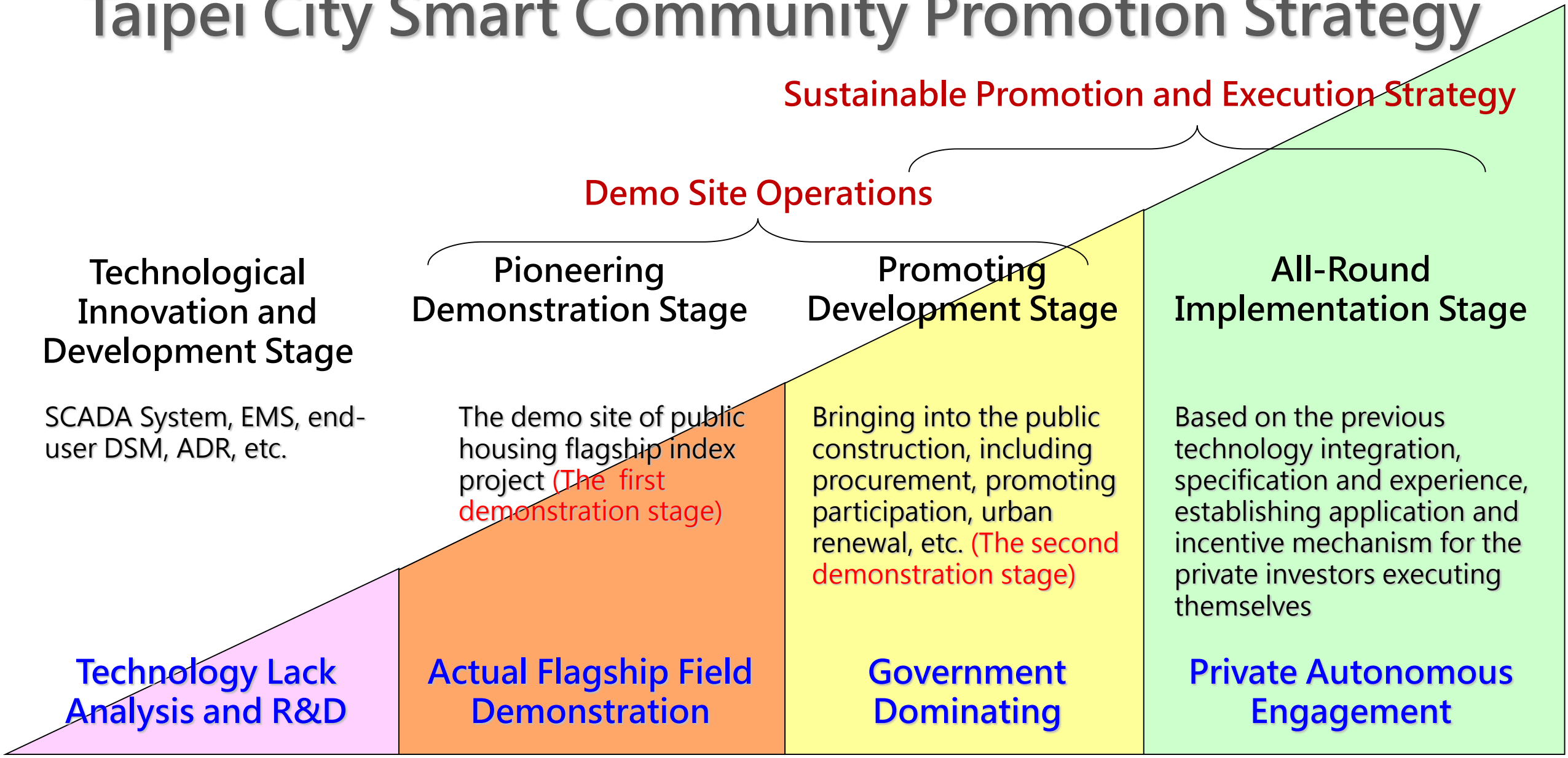
Comparison of Daily Average Power Consumption



Outline

- Backgrounds of VPP
- VPP System Architecture
- VPP Technologies Developed in Taiwan
- Operational Experiences of VPP in Taiwan
  - System in Shulin TPRI Campus
  - System in Xinglong Public Housing
- Future Work

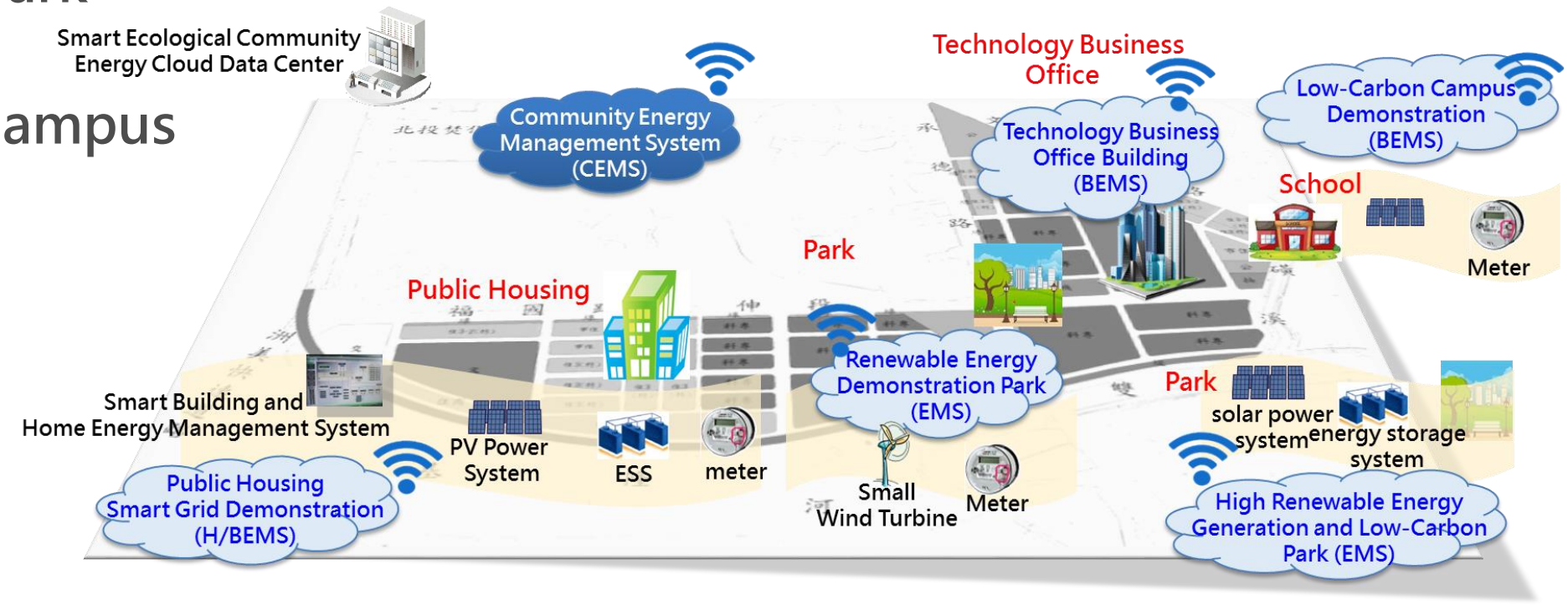
Taipei City Smart Community Promotion Strategy



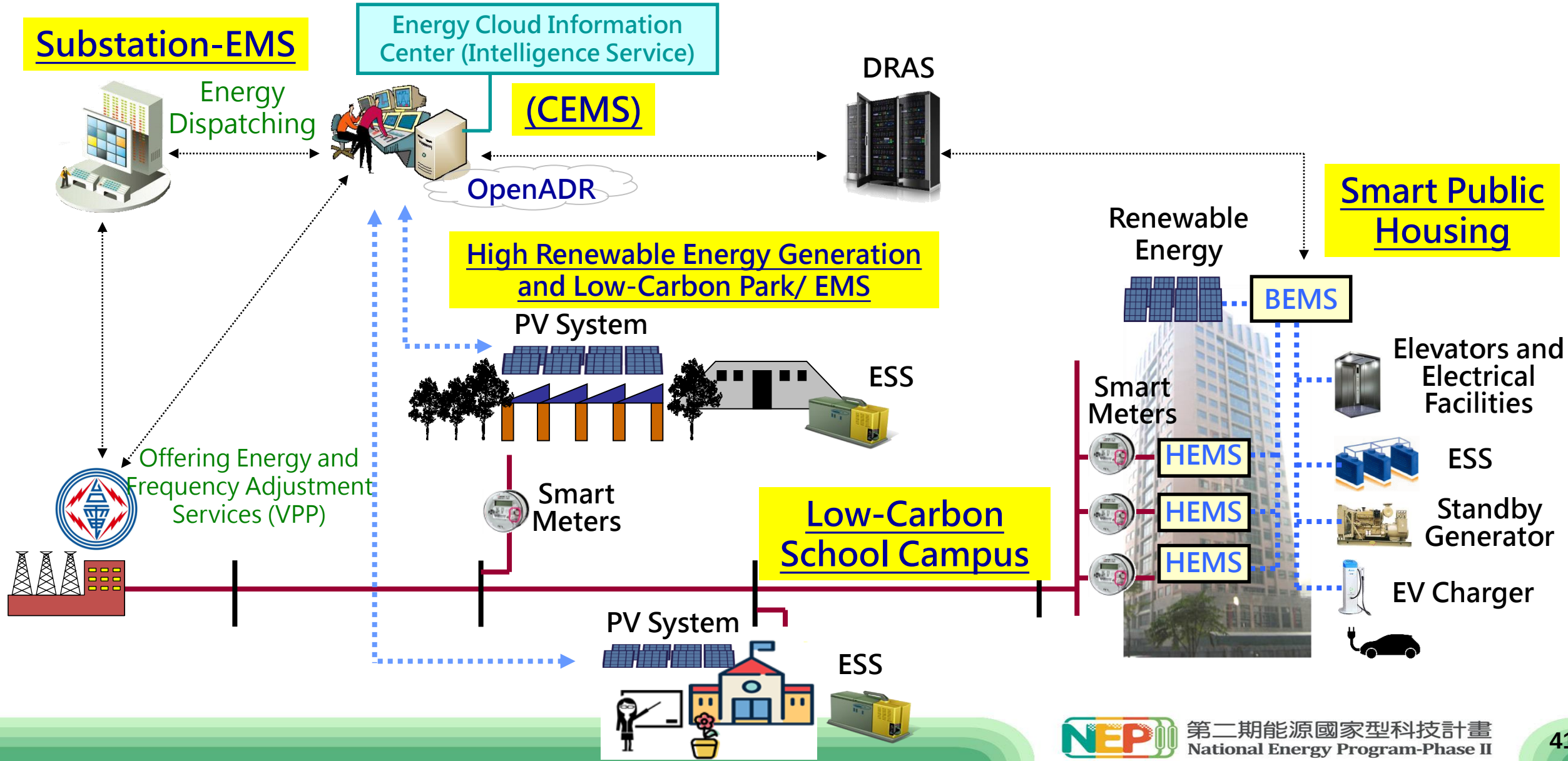
Beitou-Shilin Technology Campus (BSTC)

Smart Ecological Community Base

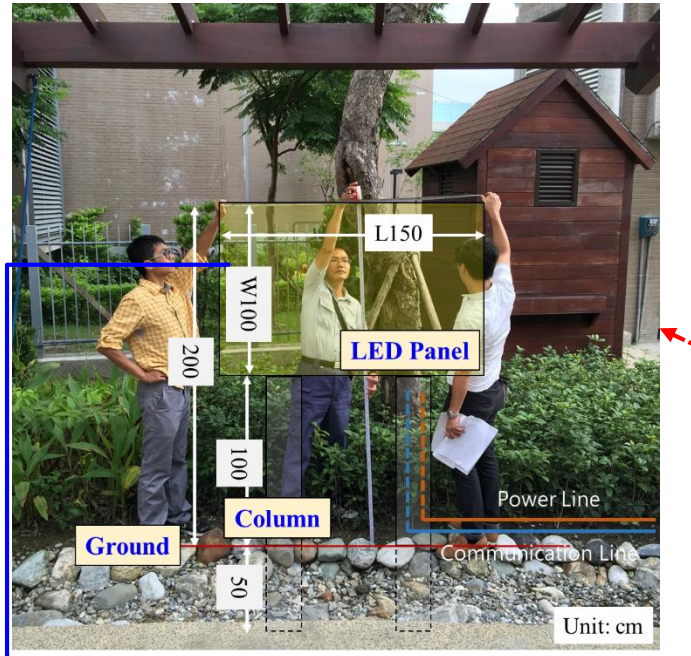
- Community Energy Management System (CEMS)
- Smart public housing
  - Implementing RE and ESS, H/BEMS system, EV (U-car rental station), etc.
- Low-carbon Park
  - RE and ESS
- Low-carbon campus

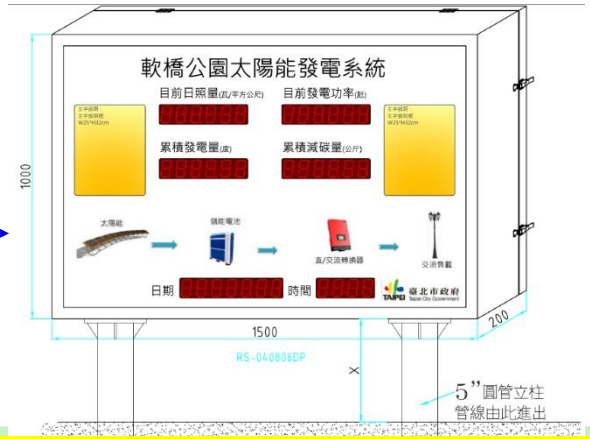


Architecture of CEMS in BSTC



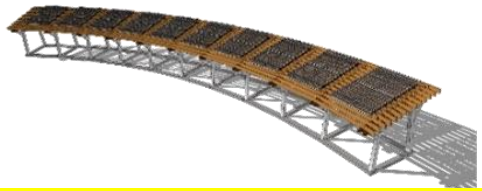
High Renewable Energy Generation and Low-Carbon Park (Public Park no. 2)



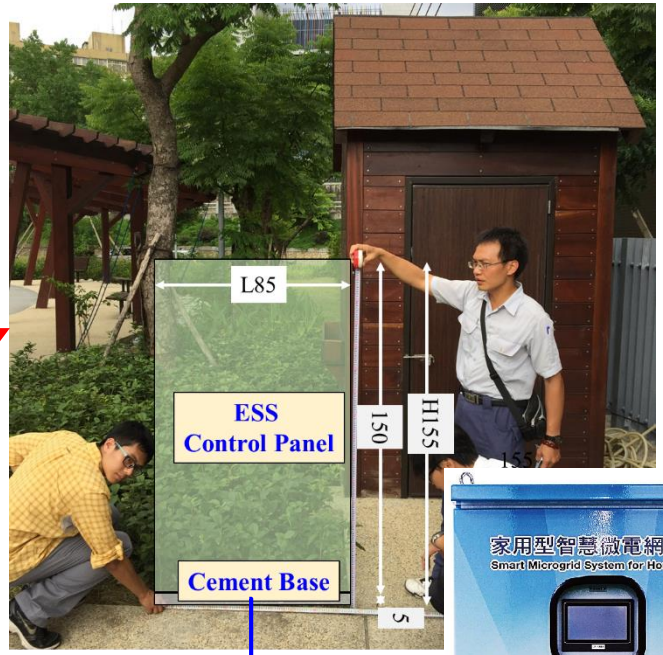


PV Generation Display LED Panel

Public Park no. 2 Plan



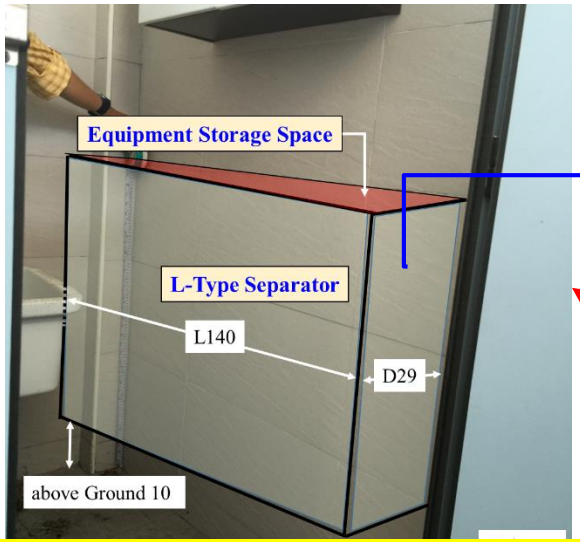
Wooden Gallery with PV Panels



Equipment Items:

ESS Control Panel

Renewable Energy Demonstration Park (Public Park no. 5)

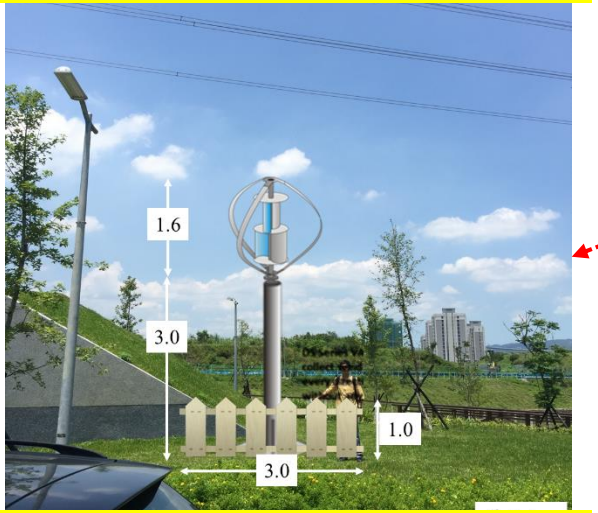


Equipment in Public Toilet

Public Park no. 5 Plan

Meter Box Location

AMI



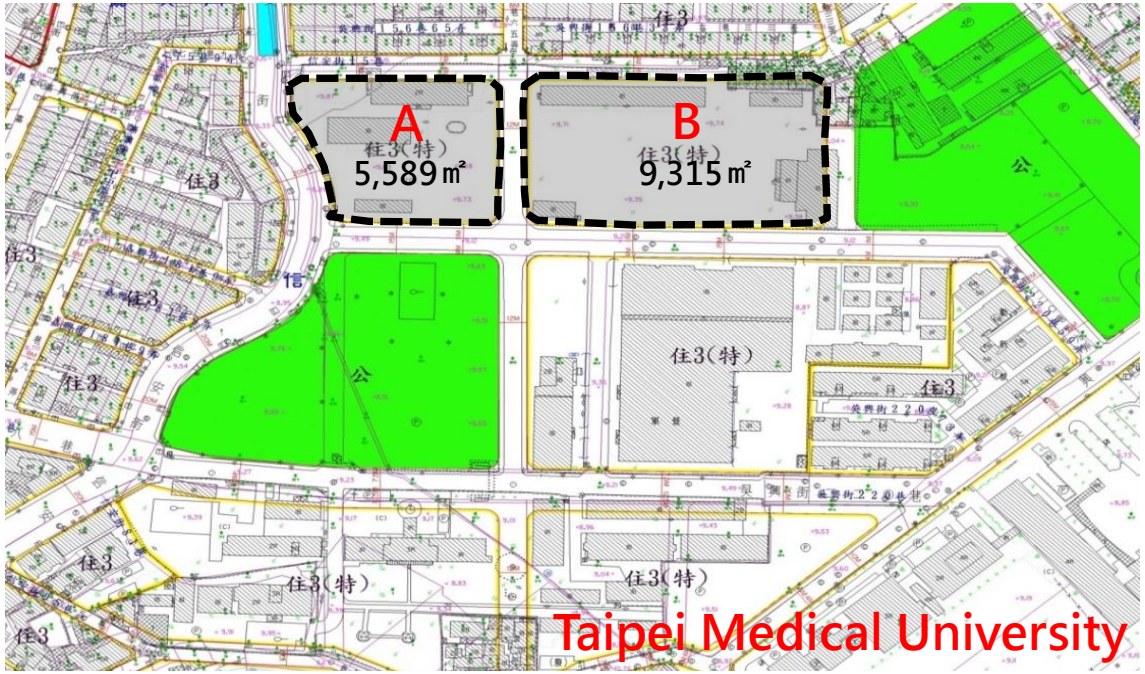
Wind Turbine Location

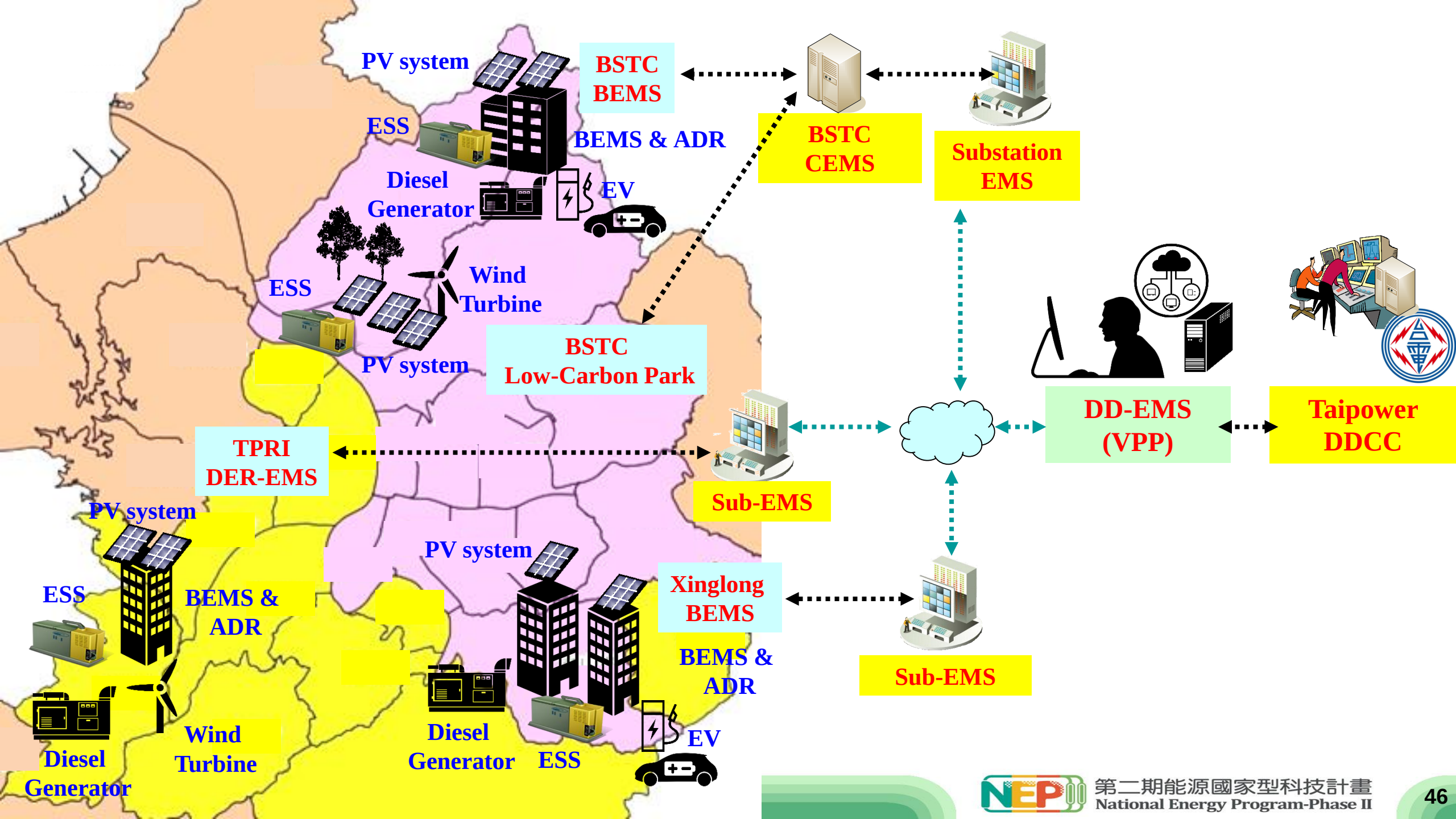
Smart Grid Project Phase 1-
Guangtsz-Boai Campus Base

Area of Base	**64,832.52㎡(19,612 footage)**
Coverage Ratio/Floor Area Ratio	**35%/350%**
Green Area	**42,141.14㎡(at least 65%)**
Public Household Count	**2,800 (About 840(30%) are low-income subsidized by Social Affairs Bureau)**
Estimated Total Floor Area	**381,614m² (115,438.24 footage)**
Participation Service Space	● Xinyi Administrative Center ● Social welfare facilities (for the elderly, the disabled, public nanny, parenting Hall) ● Relay of rehabilitation and care facilities ● Branch library ● Commercial space
Total Funding for Construction of Zone	**Initially estimated 600 million US$**
Tendering Time	• Entrust project management services procurement (Feb. 2016) • Design including supervision procurement (Sep. 2016) • Engineering procurement (Apr. 2017)

Smart Grid Project Phase 1-
Liuzhangli Camp AB Blocks

Area of Base	**14,904㎡(4,508 footage)**
Using Partition	**Specific Third Residential**
Coverage Ratio	**50%**
Floor Area Ratio	**350%**
Estimated Household Count	**972**
Estimated Scope	**16F-25F / B1-B4**
Affiliated Space(1-2F)	• Public nanny • Social welfare facilities (multi-functional care center) • Remote care link to field experiments • Commercial space • EPA's office
Tender and the Estimated Amount	• Entrust project management (including supervision) Procurement Services (3 million US$) • Turnkey engineering procurement (1.3 billion US$)
Tendering Time	• Entrust project management (including supervision) procurement services (Oct. 2015) • Turnkey engineering procurement (Apr. 2016)




PV system
BSTC
BEMS
ESS
BEMS & ADR
Diesel
Generator
EV
ESS
Wind
Turbine
PV system
BSTC
Low-Carbon Park
BSTC
CEMS
Substation
EMS
DD-EMS
(VPP)
Taipower
DDCC
TPRI
DER-EMS
Sub-EMS
PV system
ESS
BEMS &
ADR
Wind
Turbine
Diesel
Generator
PV system
Xinglong
BEMS
BEMS &
ADR
Diesel
Generator
ESS
EV
Sub-EMS

Conclusion

Objectives	• Establishing the first VPP system in Taipei City • To relieve the dilemma to be faced in distribution system • Regional power congestion and high-penetration RE impacts on grid
Key Technologies	• DSM: H/BEMS system and ADR • DER integration: SCADA system, DER remote control interface, Substation-EMS, DER-EMS optimal dispatching algorithm, etc.
Demonstra-tion Sites	• Shulin TPRI campus • Xinglong public housing • Other fields specified by Taipower Company
Vision	• Developing DD-EMS and promoting system to smart ecological CEMS • To achieve energy sustainability in a smart city

Thanks for your attention!