Smart Home Energy Management System with Renewable and Storage Energy

Speaker : Hong-Tzer Yang

（楊宏澤教授，國立成功大學電機系）

Professor & Deputy Director

Center for Energy Technology and Strategy Research

Department of Electrical Engineering

National Cheng-Kung University, Taiwan

成功大學 National Cheng Kung University

Outline

- Master Plan of Smart Grid in Taiwan
- Smart Grid Implementation Plan in Taiwan
- Smart Home/Building Energy Management System
- Future Prospects

Master Plan of Smart Grid in Taiwan

Worldwide Smart Grid Status

USA

- Reliability enhancement by information network and technology to shorten outage duration time. That is supported by DOE from EISA 2007.

EU

- 20/20/20: CO_2 reduction by 20% by 2020 compared with that of 1990. (AMI/AMR & EV)

Japan

- Smart Community alliance had made up by governor and manufacture, to demonstration the smart grid in Yokohama, Toyota, Kyoto, and Kitakyushu City.

China

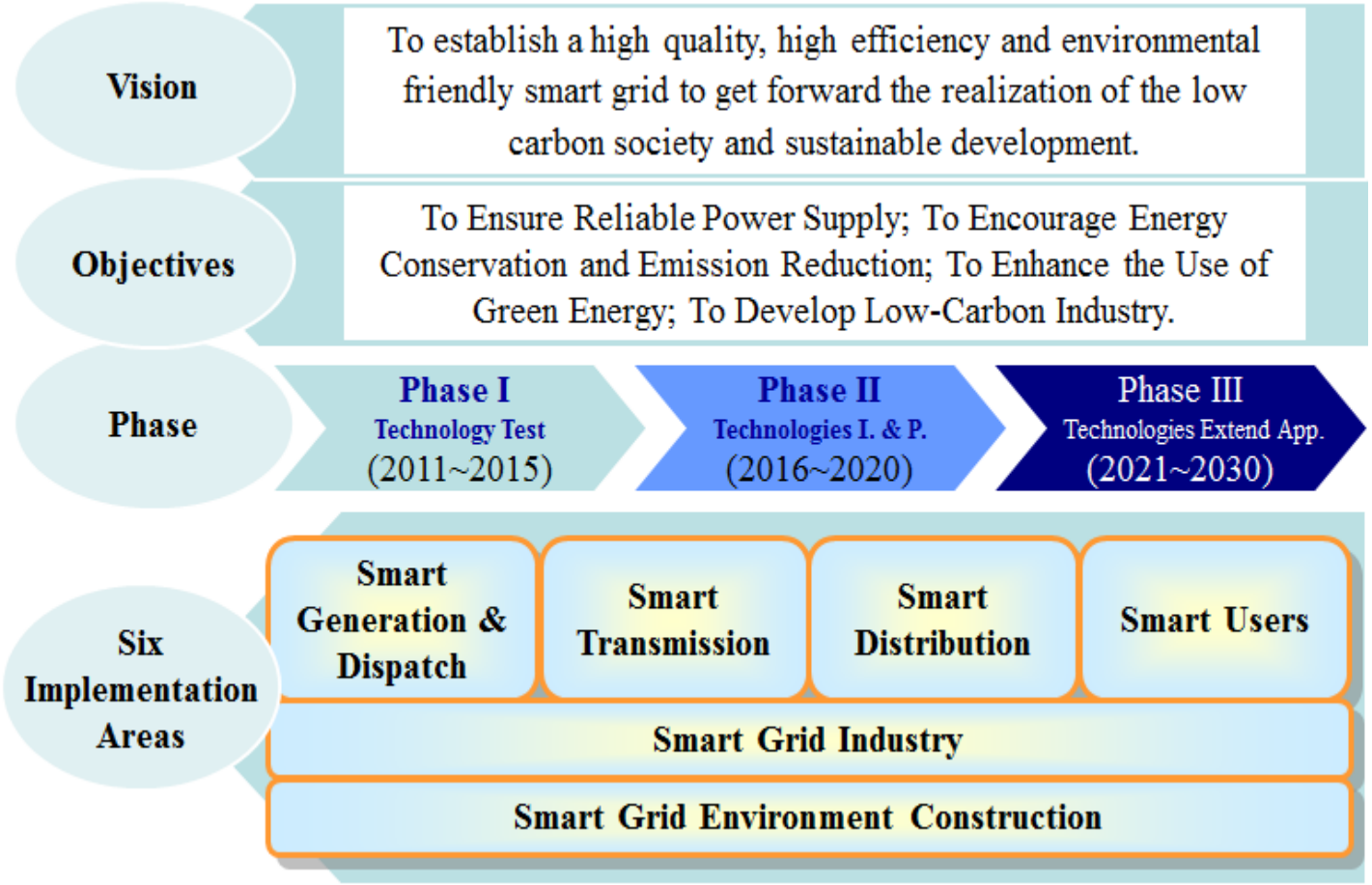
- China announced the 12th 5-year plan, and will invest $250 billion (USD) in 7 areas (include generation, transmission, substation, distribution, dispatch, customer, and communication) for a strong and smart power grid.

Korea

- There are three phases to 5 implementation areas from power grid to service, which are integrated at Jeju Island as a smart grid test-bed.

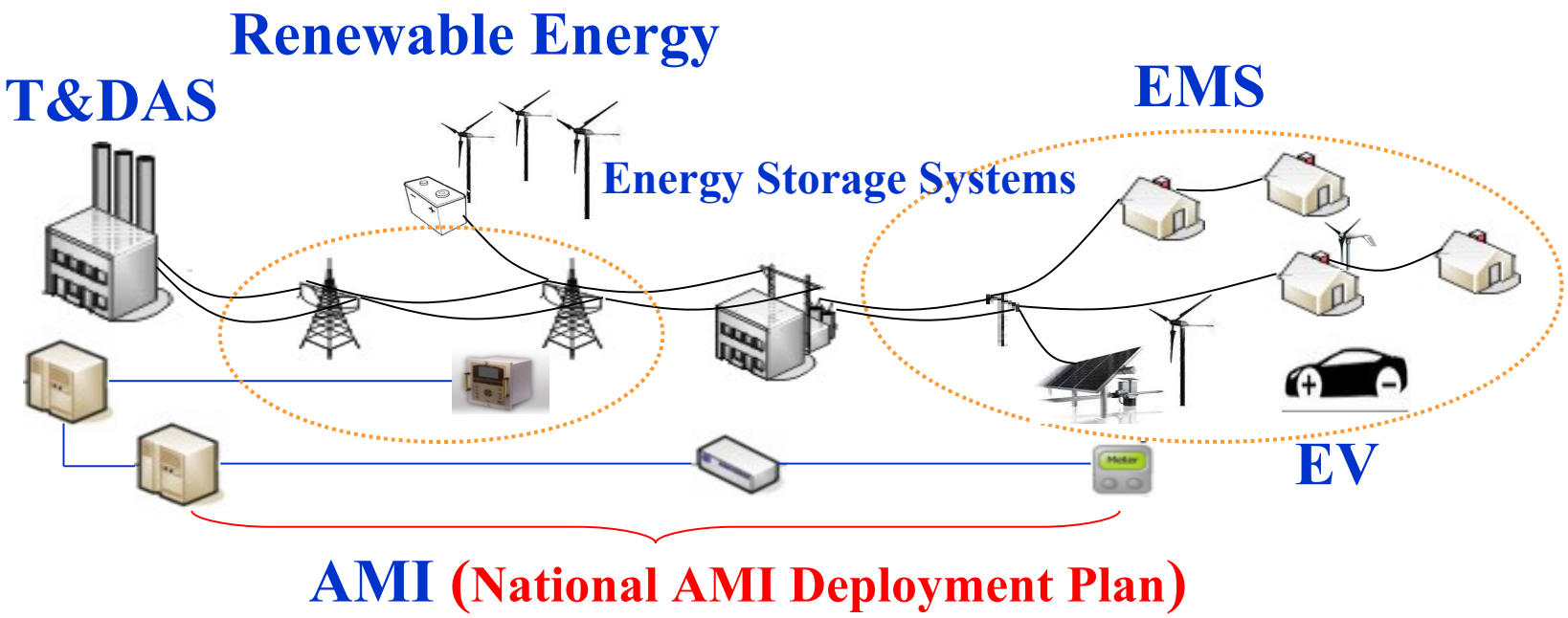
Smart Grid Master Plan in Taiwan

- Smart Grid Master Plan is formally announced on 3 Sept. 2012.
- We will invest about USD $4 billion in six implementation areas to construct smart grid infrastructure during 2011-2030.



Vision

- To establish a **high quality, high efficiency and environmental friendly smart grid** to get forward the realization of the low carbon society and sustainable development.



Renewable Energy: Onshore/Offshore Wind Farms/Solar Power/Energy Storage Systems

Objectives

(1)To Ensure Reliable Power Supply:

- The SAIDI (System Average Interruption Duration Index) should be maintained on the top five of the world in 2030. (2030:15.5min./year)
- Reducing the power transmission loss from 4.8% to 4.4% in 2030.

(2) To Encourage Energy Conservation and Emission Reduction:

- Reducing 100 million ton CO_2 emission per year in 2030.

(3) To Enhance the Use of Green Energy:

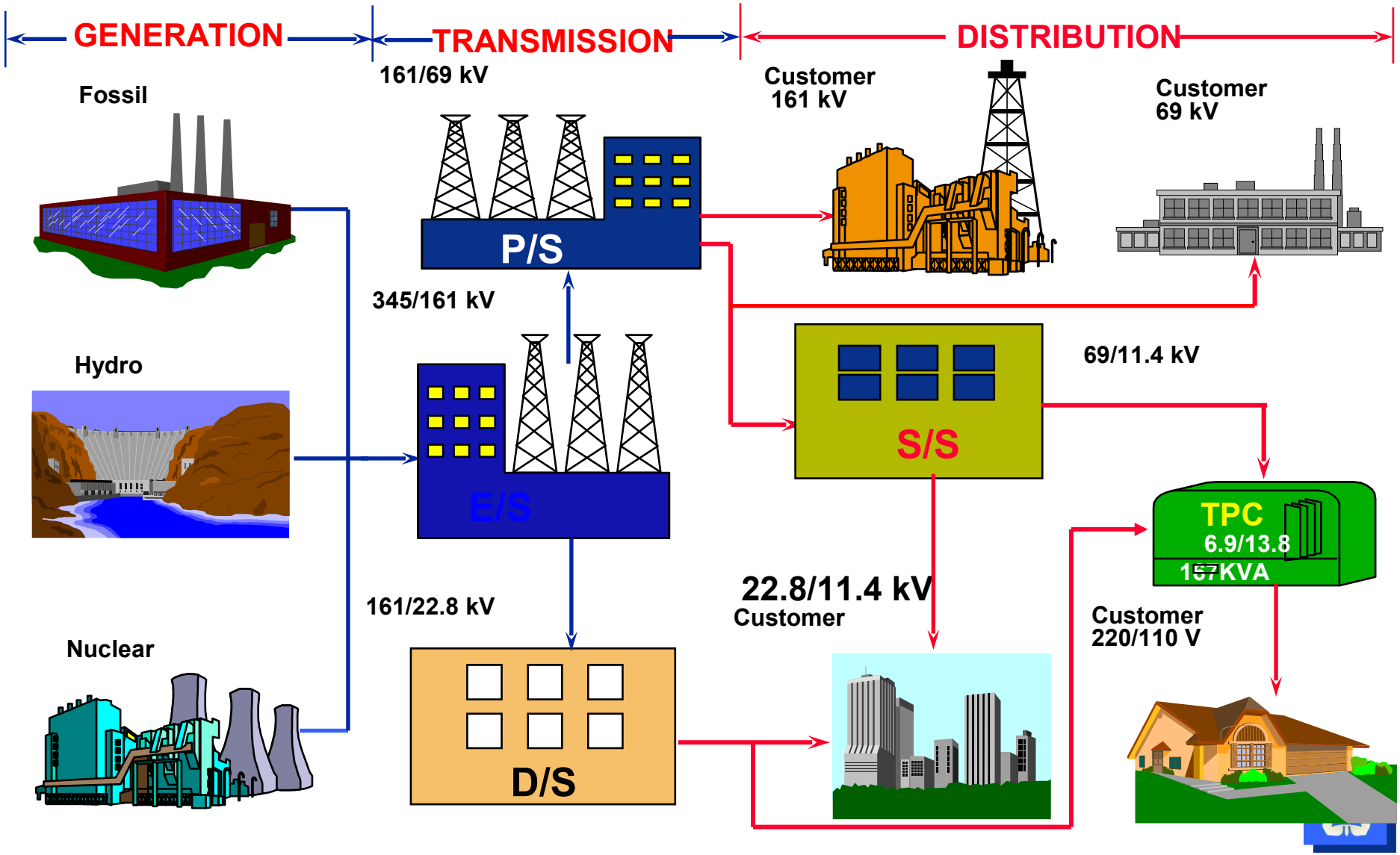
- Improving the renewable power interconnection capability to 30% in 2030.

(4) To Develop Low-carbon Industry:

- Driving smart grid industry to create NTD 700 billion value in 2030.

Smart Grid Implementation Plan in Taiwan

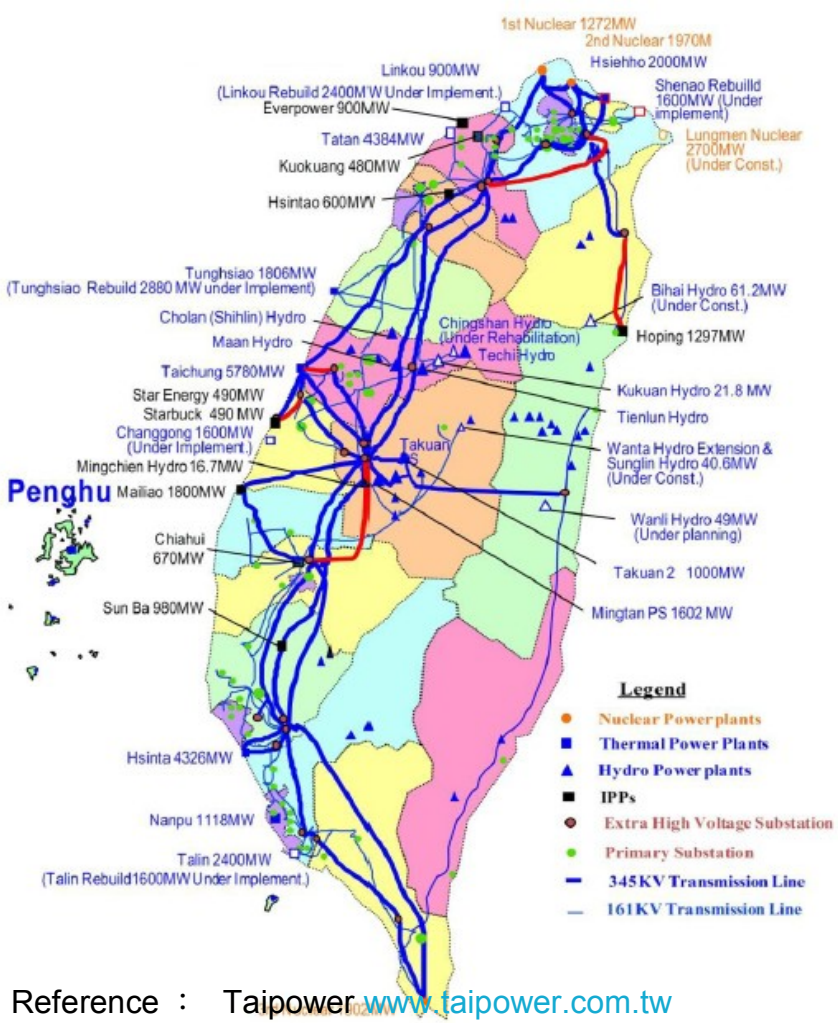
Overview of Taiwan Power System



Overview of Taiwan Power Company

- Taiwan Power Company (Taipower) is a state-owned electric power utility providing electric power to Taiwan and off-shore islands

Installed Capacity in Year 2011: 41,400 MW



	Installed Capacity	MW	%
Taipower	**Nuclear**	**5,144.00**	12.6
	Thermal	**22,717.60**	54.90
	Oil	3,324.6	8.00
	Coal	8,800.0	21.30
	LNG	10,593.0	25.60
	Hydro	**4,353.60**	10.5
	Convential Hydro	1,751.6	4.20
	Pumped storage Hydro	2,602.0	6.30
	Wind	**286.76**	0.70
	PV	**6.10**	0.01
Subtotal of Taipower		**32,508.06**	78.50
IPP	Thermal	**7,707.10**	18.60
	Coal	3,097.1	7.50
	LNG	4,610.0	11.10
	Hydro	**289.10**	0.70
	Wind	**236.10**	0.50
	PV	**38.30**	0.01
	CoGeneration	**622.00**	1.50
Subtotal of IPP		**8,892.60**	21.5
Total Installed Capacity		**41,400.7**	100

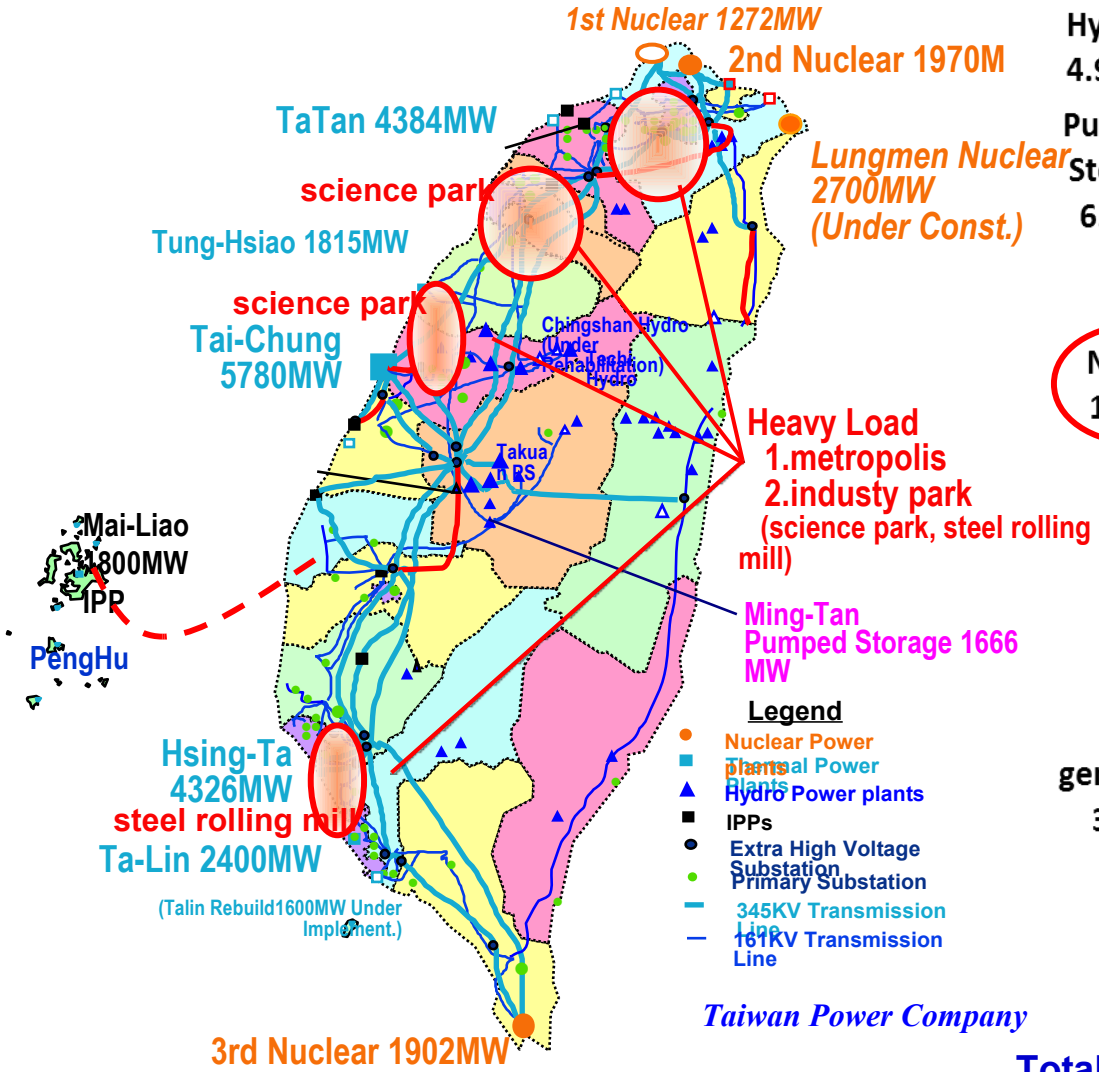
Substation	No.	MVA
EHV	28	56000
Primary	261	68450
Secondary	295	20728

	ckt-km
Transmission Lines	16,898
Distribution Lines	339,057

Reference ： Taipower www.taipower.com.tw

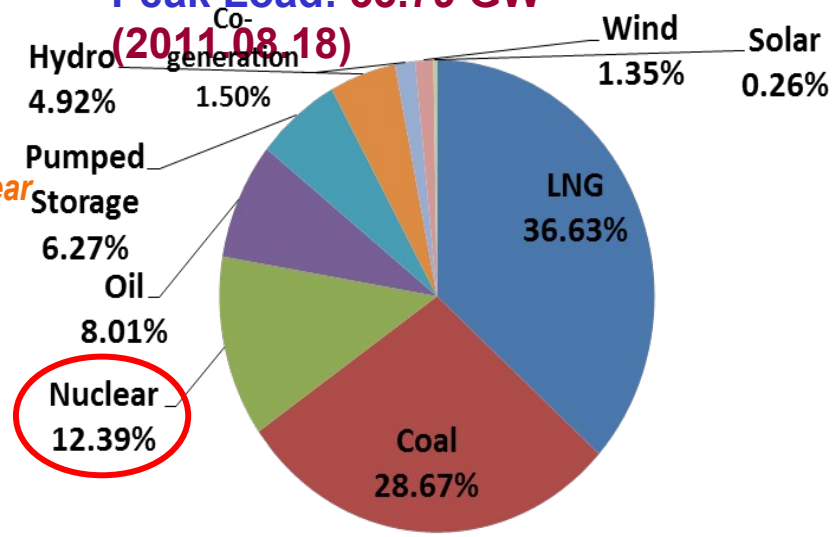
Overview of Taiwan Power System

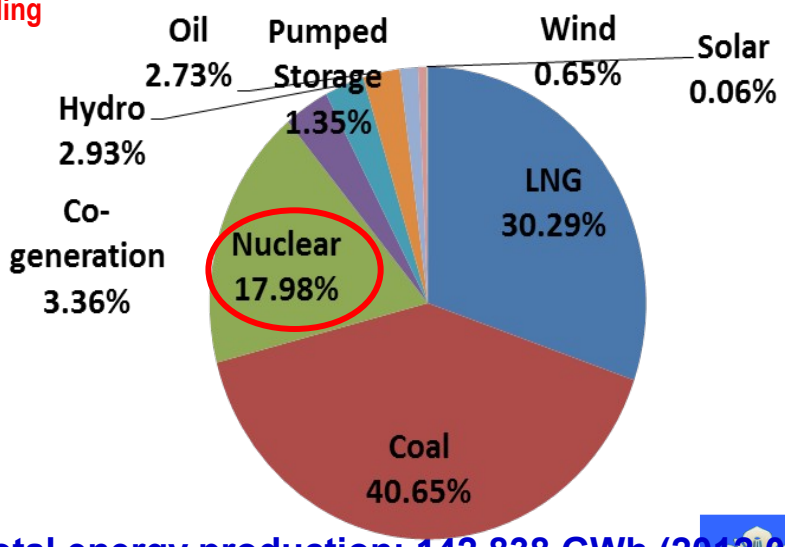
Installed Capacity : 41,501MW (2012.08)



Taiwan Power Company

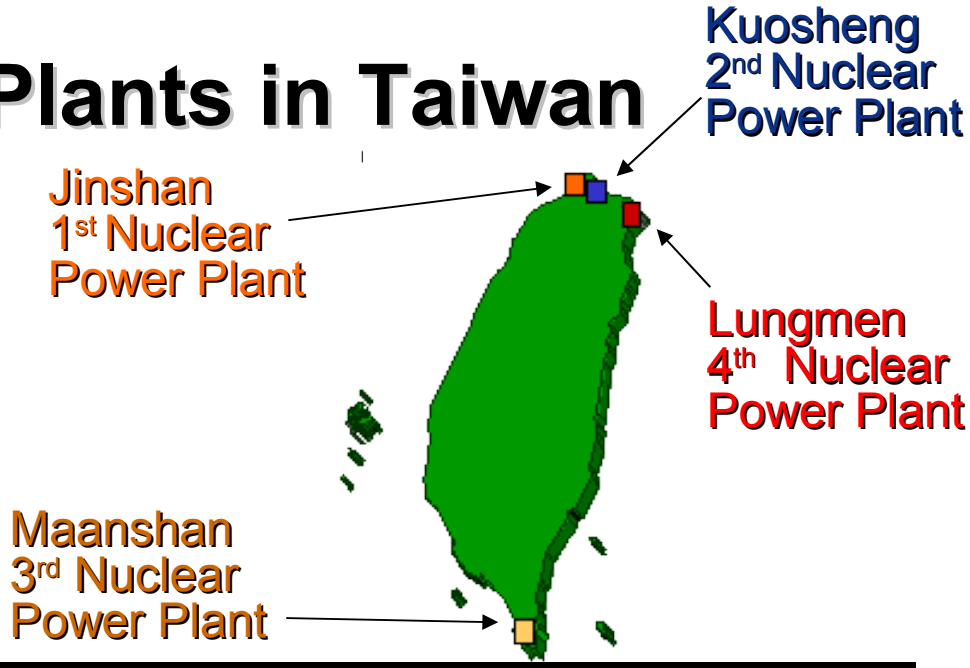
Peak Load: 33.79 GW (2011.08.18)





Total energy production: 142,838 GWh (2012.08)

Nuclear Power Plants in Taiwan



Reference ： Taipower www.taipower.com.tw

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	Operate in 2014
	2	1350	Operate in 2016

Overview of Taiwan Power System

- **Energy Policy of Taiwan**

a. Steadily Reducing Nuclear Dependency

a) No extension to life spans of existing plants, and the decommissioning plan should be launched as planned.

b) The security of the 4th Nuclear Power Plant must be ensured prior its commercial operation.

b. Replacing Nuclear with LNG for Base Load

LNG total installation capacity is expected to reach 26,532 MW (accounting for 40% of total capacity of power installations) by 2030.

c. Promoting Renewable Energy Extensively

Under the campaign of "one thousand wind mills" and "one million sunshine roofs", the installed capacity of renewable energy is expected to reach 12,502 MW (accounting for 16% of total power installations) by 2030.

Smart Grid Implementation Plan in Taiwan

(1) Strategies

a. Smart Generation & Dispatching

a) Upgrade traditional thermal power generation efficiency

b) Integrate large scale renewable energies

b. Smart Transmission

a) Increase transmission grid efficiency and reliability using new technologies

b) Enhance capability of asset management

c. Smart Distribution

a) Improve the reliability of distribution network

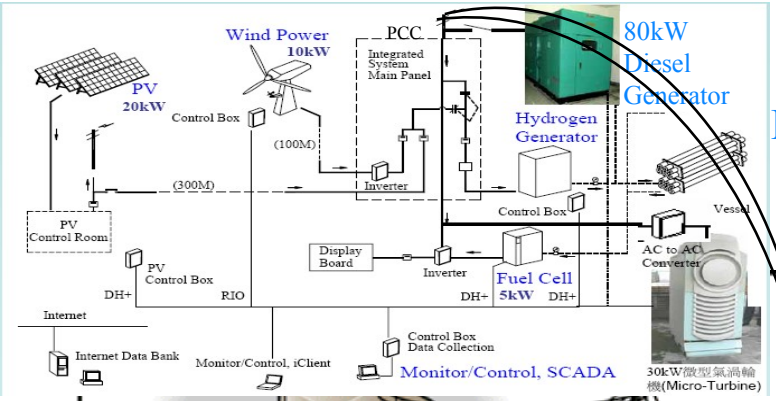
b) Increase the penetration of distributed renewable energy

d. Smart Customer

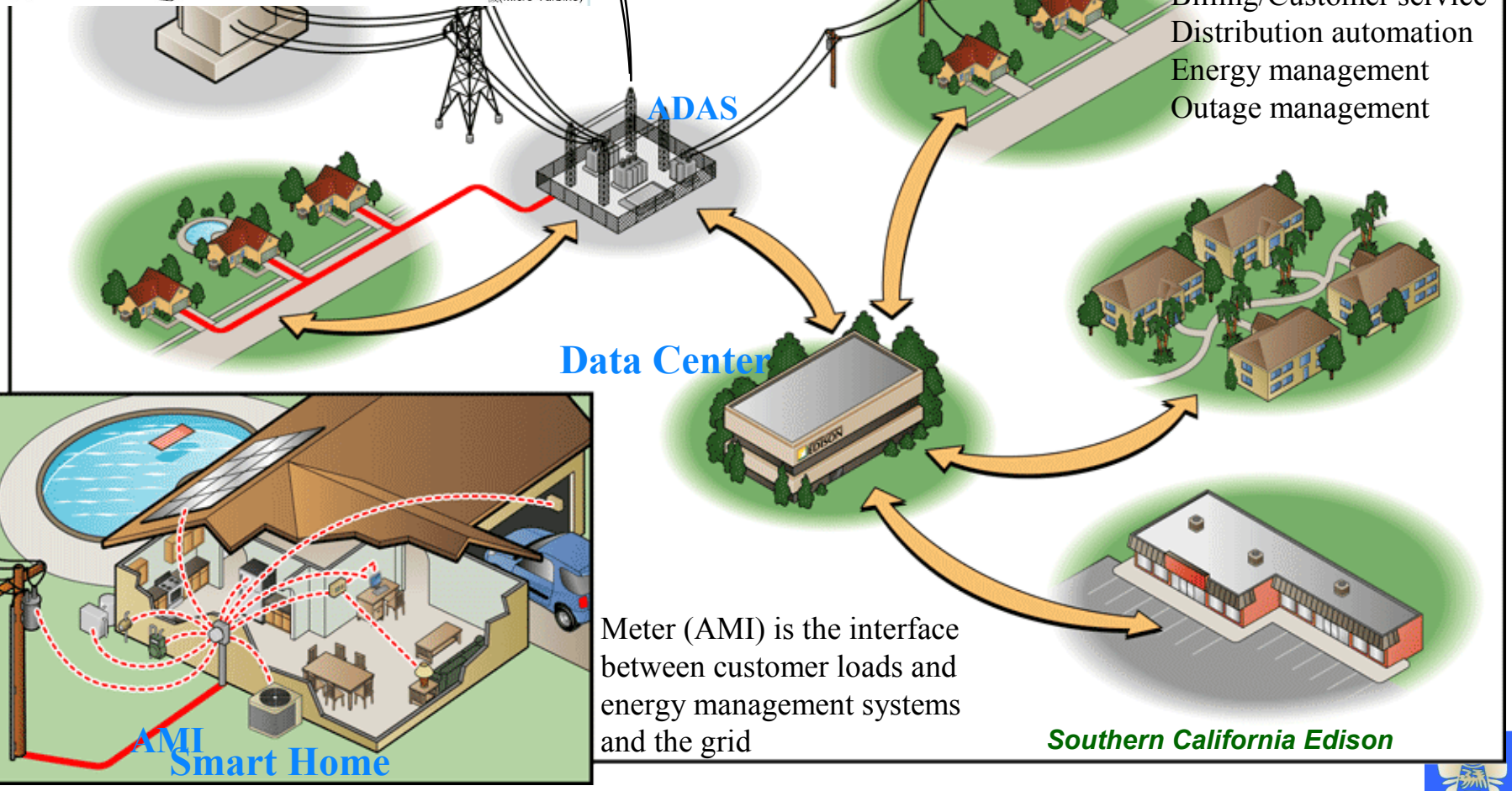
a) Improve energy usage efficiency through customer participation

b) Reduce peak load by way of demand response

Strategic Initiatives of Smart Grid in Taiwan



Microgrid System



(cont.)

In Data Center:
Billing/Customer service
Distribution automation
Energy management
Outage management

Meter (AMI) is the interface between customer loads and energy management systems and the grid

Southern California Edison

Objectives of Taiwan's Smart-Grid Action Plan

Objectives	Phases	2011	Phase I 2012-2015	Phase II 2016-2020	Phase III 2021-2030
Ensured Reliable Power Supply	SAIDI (min/customer · year)	21	17.5	16	15.5
	Reduced transmission loss (%)	4.72	4.64	4.54	4.42
	Improve power supply bottleneck	64 items	solve 20%	solve 40%	solve 80%
	Smart Substation	-	25 stations	303stations	583 stations
	DAS	70%	80%	88%	100%
	AMI (meters)	HV 1,200	HV 23,000 LV 1M	LV 6M	National Wide Deployment

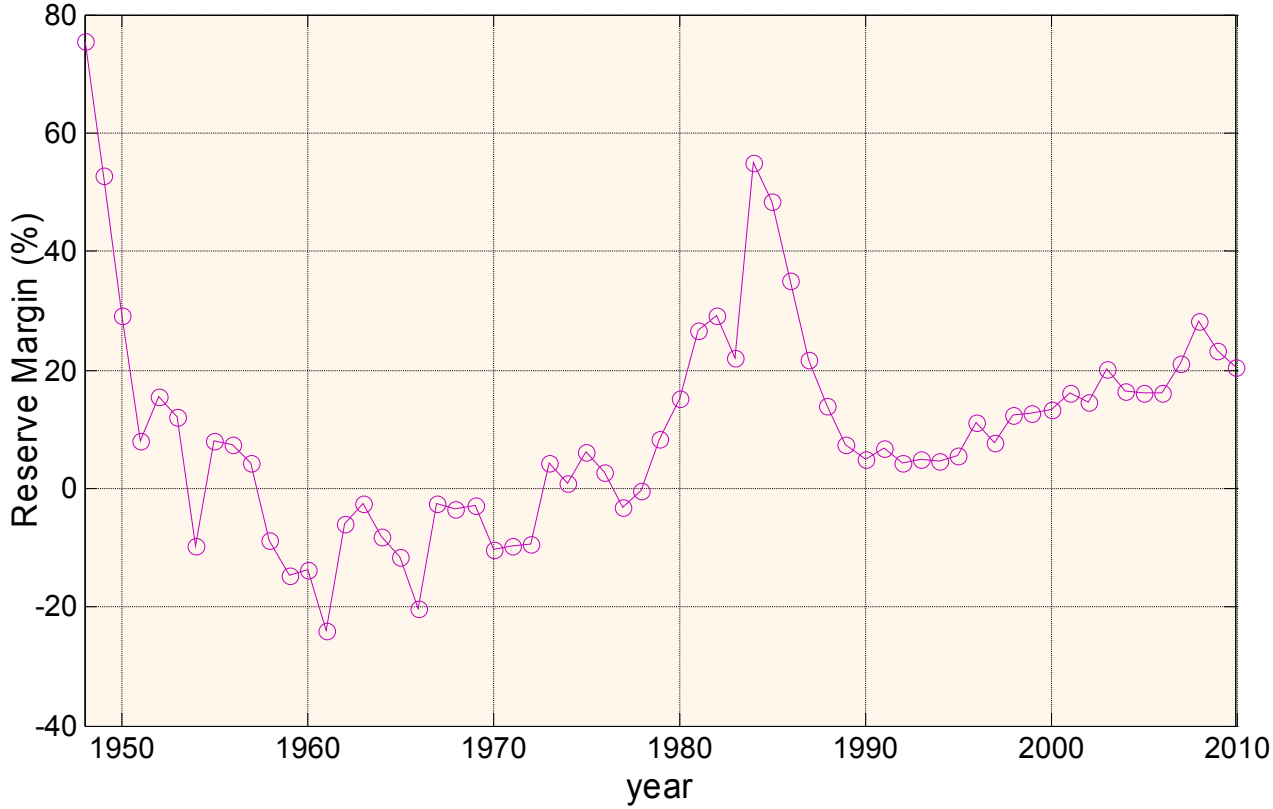
Objectives of Taiwan's Smart-Grid Action Plan

Objectives	Phases	Currently 2011	Phase I 2012-2015	Phase II 2016-2020	Phase III 2021-2030
Energy Conservation and Emission-Reduction	Emission-Reduction (million Ton./year)	-	11.78	35.99	114.71
Enhance the Use of Green Energy	Improving renewable power interconnection capacity (penetration)	10% under	15%	20%	30%
Develop Low-carbon Industry	Smart Grid Revenues (NTD)	25 billion	100 billion	300 billion	700 billion

Reserve Margin (%) in Taiwan

Reserve capacity (MW) = Net Peaking Capability - Peak Load

$$\text{Reserve margin (\%)} = \frac{\text{Reserve Capacity}}{\text{Peak Load}} \times 100\%$$



Reference ： Taipower www.taipower.com.tw

Status of DR Program in Taiwan

- Qualifications
  - Usual Capacity Contract **>500kW**
- Demand Reduction Hours
  - When demand reduction is required, users will be notified 15 min, 30 min or 1 hour ahead.
  - The demand reduction period can last for 2 or 4 hours based on user's choice
- Frequency of DR Operation
  - Maximum reduction time is once a day
  - At least once per month during Summer
  - At least twice during non-Summer
- DR Capacity Contract
  - Contract is agreed by both sides, but not less than the minimum DR contracted capacity
  - Minimum DR contracted capacity is calculated as follows:
    - If usual contracted capacity is less than 5000kW, DR reduction rate should be no less than 20%
    - If usual contracted capacity is more than 5001kW, DR reduction rate should be no less than 10%

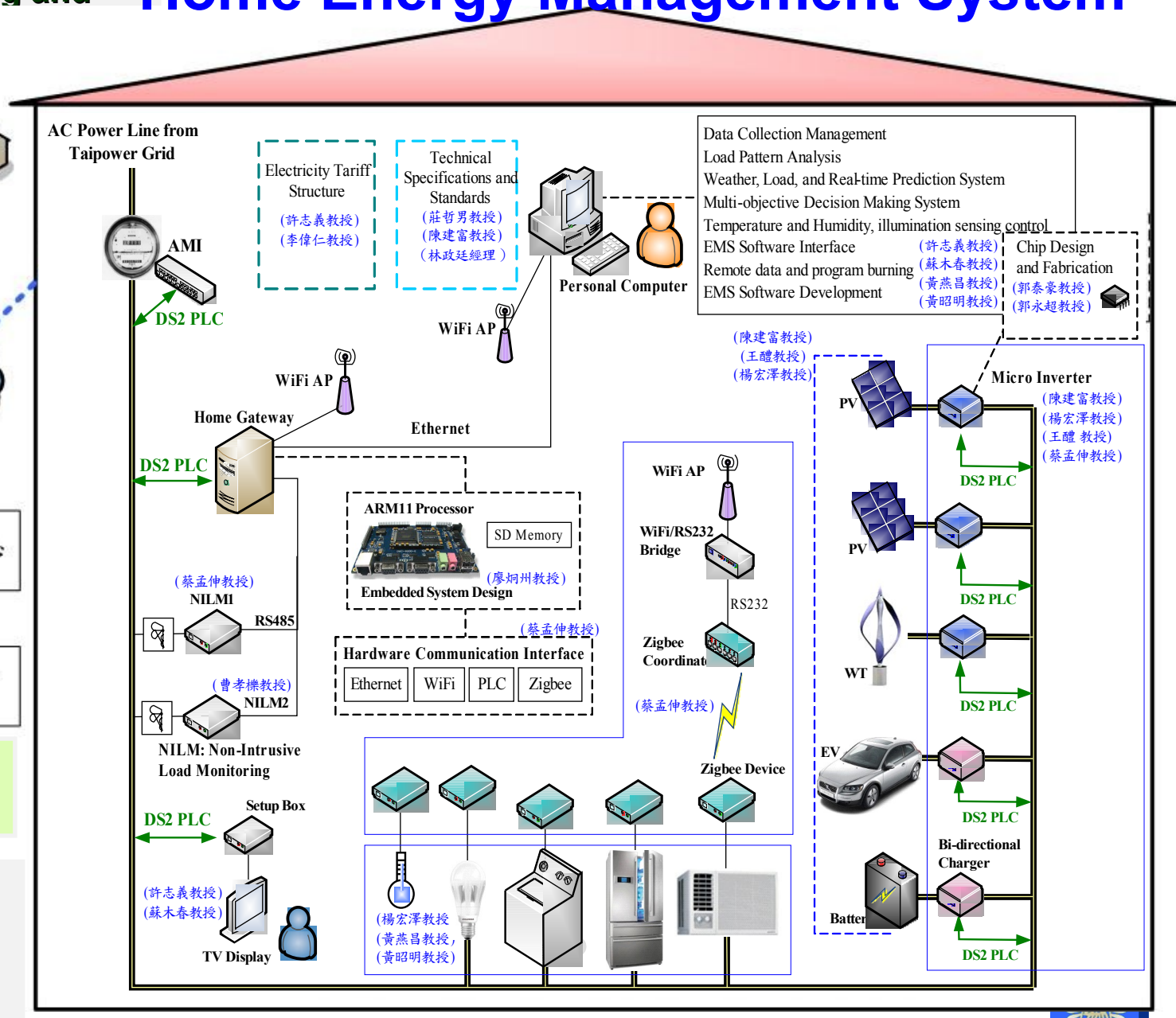
Status of DR Program in Taiwan (cont.)

- Electricity Bill Reduction
  - Customer's electricity bill will be deducted by how long ahead they choose to be notified for DR operation

US$:NT$ = 1:30

Notification Time	Base Charge Reduction (NT$/kW/month)	Energy charge Reduction (NT$/kWh)
15 min ahead	20	8
30 min ahead	20	6
1 hour ahead	20	4

2011:System Planning and Home Energy Management System



2012:Smart Building EMS Demonstration

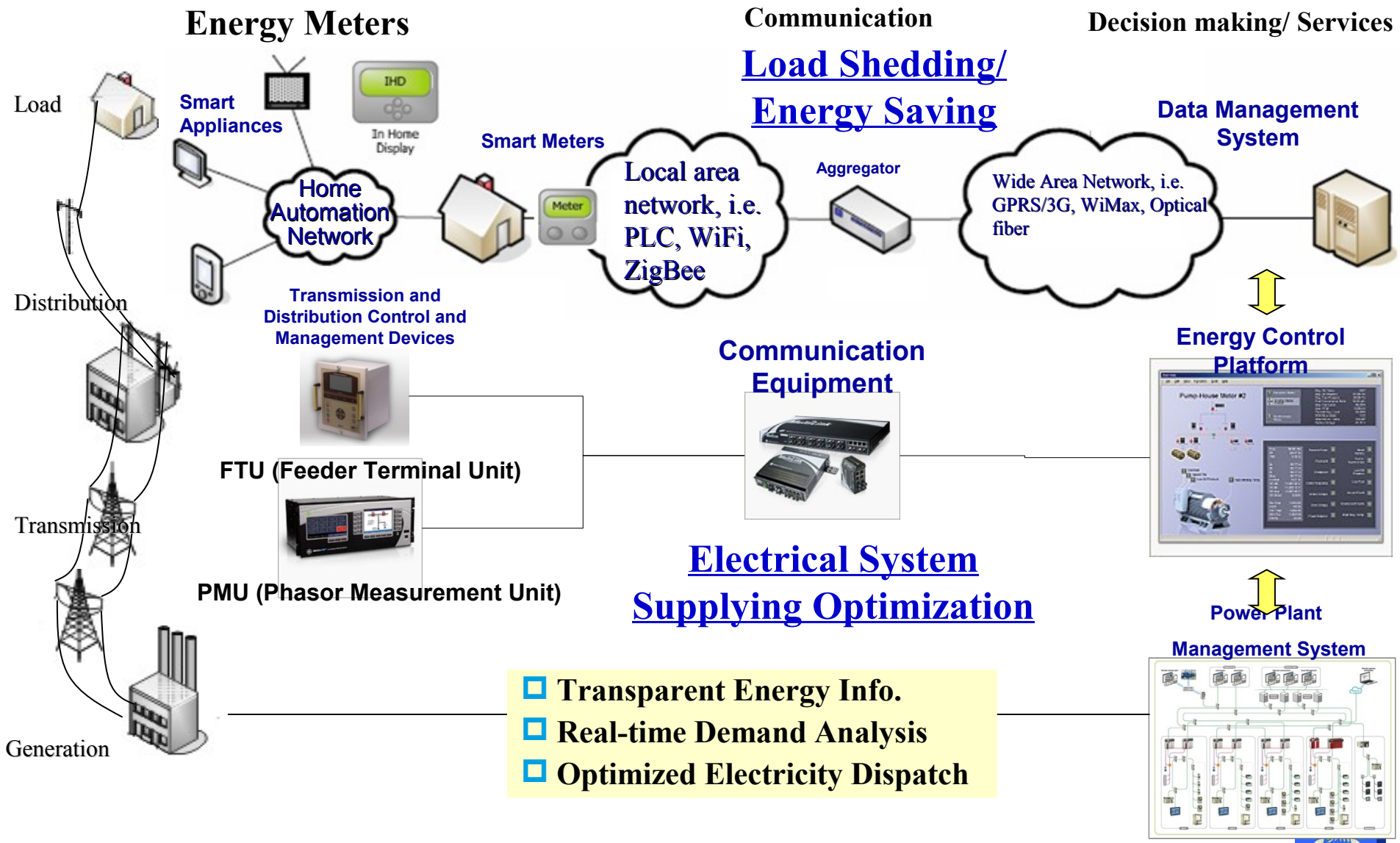
2013:All System Integration and Cost Effectiveness Analysis

Low Voltage AMI Timeline

	Year	Meter NO. to be installed	Working Items
1'st Stage (**Tech.test**)	2009	50	●Communication Technology Testing
	2010	300~500	●Define Function and standard ●Test platform Plan
2'nd Stage (**Preliminary Installation**)	2011 2012	10,000	●MIDMS Meter Function Test ●Meter Function Std. ID. ●Construct Test Platform ●Construct New TOU FEEs
		Technology Confirm & C/B Ass.	
3'rd Stage (**Fundamental Installation**)	2013 2014 2015	1,000,000	●Meters Installation ●New TOU Fee Execution ●Load Management and Demand Response Study
		Cost/Benefit Assessment	
4'th Stage (**Extended Installation**	2016 ->	5,000,000	●Construct Distribution Automation ●Apply Load Management and Demand Response

Reference ： Taipower www.taipower.com.tw

Advanced Metering Infrastructure

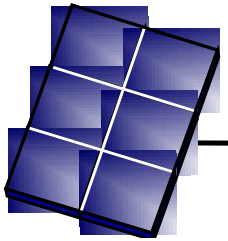


Residential Renewable Energy Systems

Module Inverter
(Increase the efficiency and lower the partial shading effects)

IC Design
(Lower the Cost)

Home Gateway (Energy management optimization)

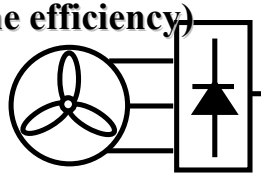


PV generation System

$v_{o1}=V_1\angle\varphi_1$

i_{o1}

Power Factor Correction
(Increase the efficiency)



Wind Power System

$v_{o2}=V_2\angle\varphi_2$

i_{o2}

Wired/Wireless Communication
Zigbee, PLC (Protocols, Standards …)

$v_g=V_g\angle\varphi_g$

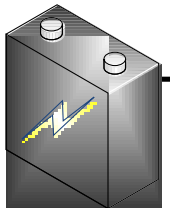
STS

Utility Grid

P_g

110V$_{ac}$, 60Hz

PCC



$V_{o3}=V_3\angle\varphi_3$

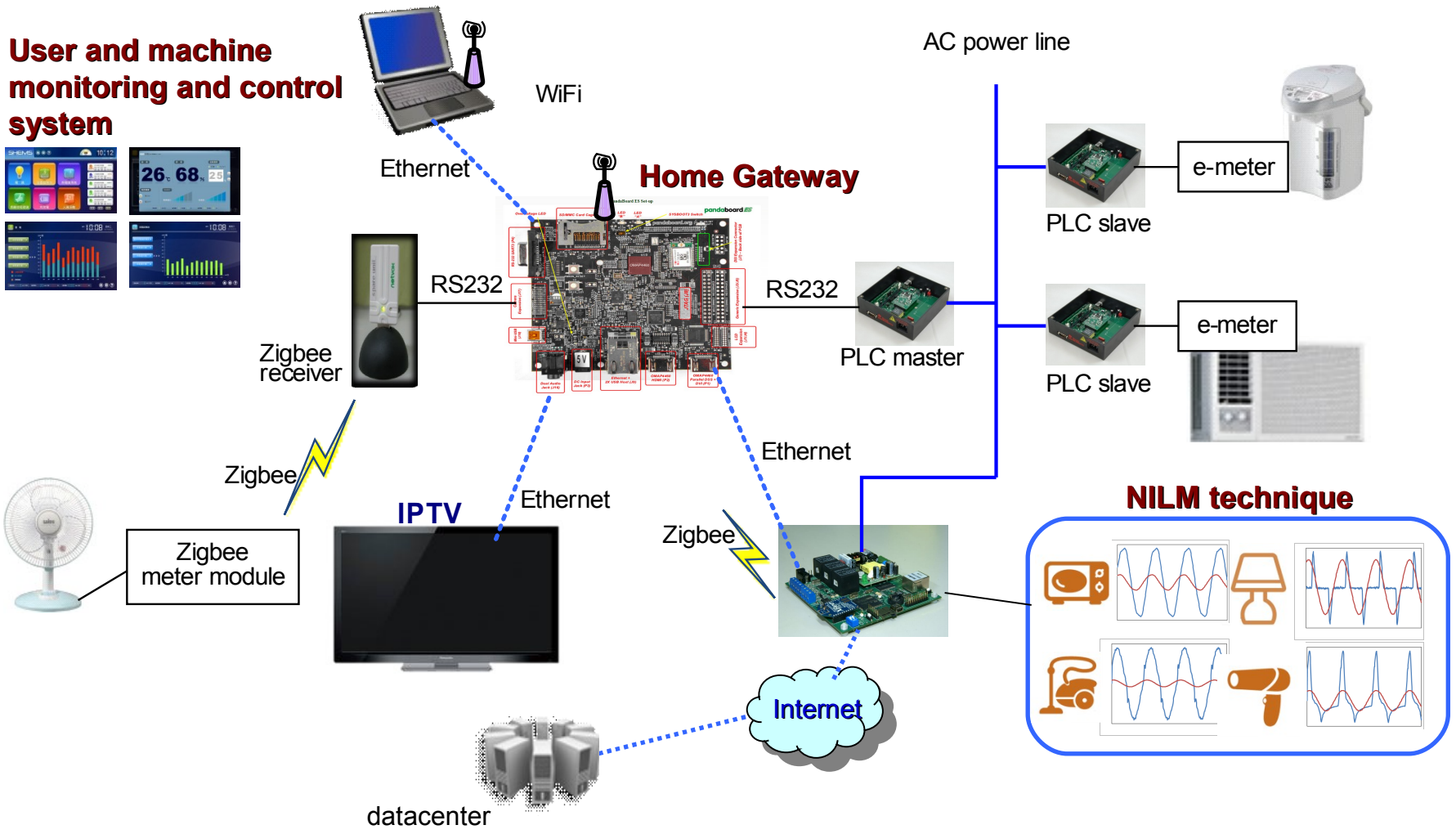
i_{o2}

Islanding Detection
Insures system stability by fast detection with minimized NDZ

Residential Load

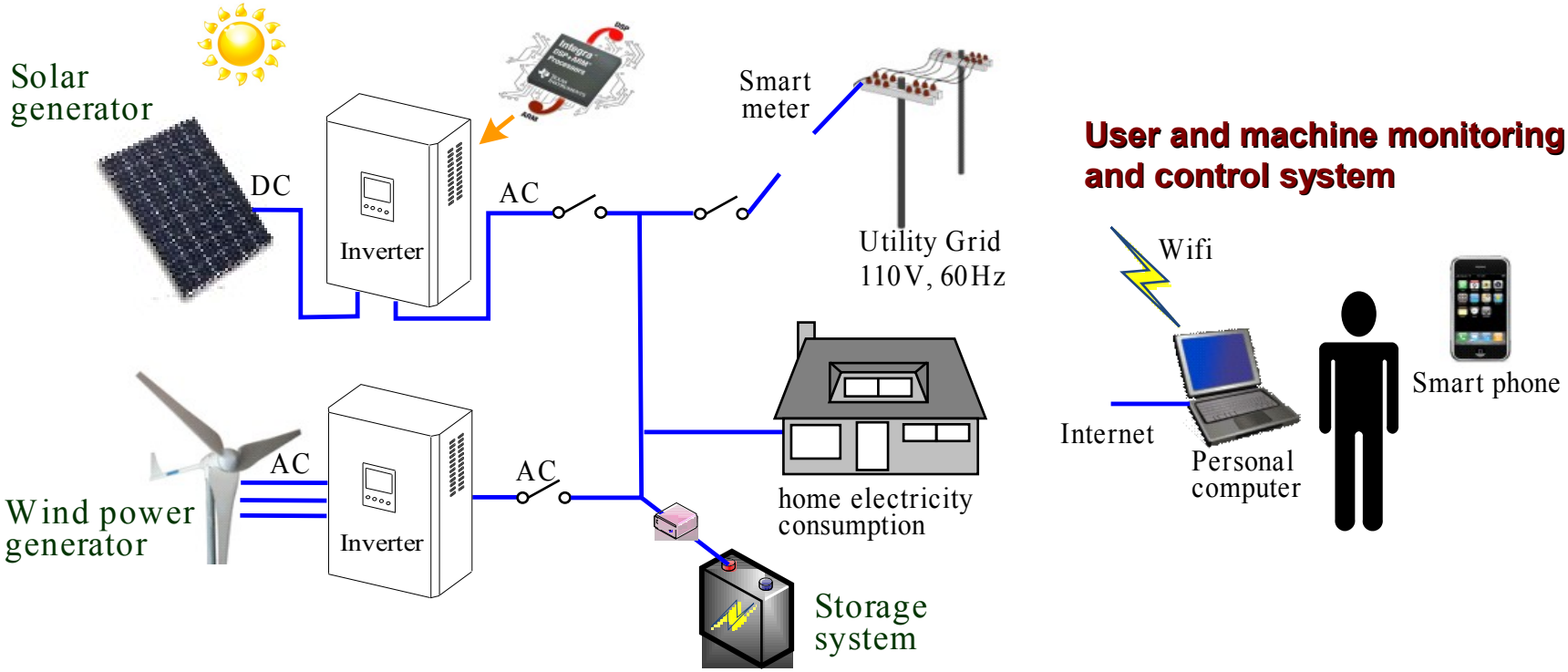
Energy Storage System or EV
Increase the electricity supply reliability and coordinate with energy management optimization

Home Area Network



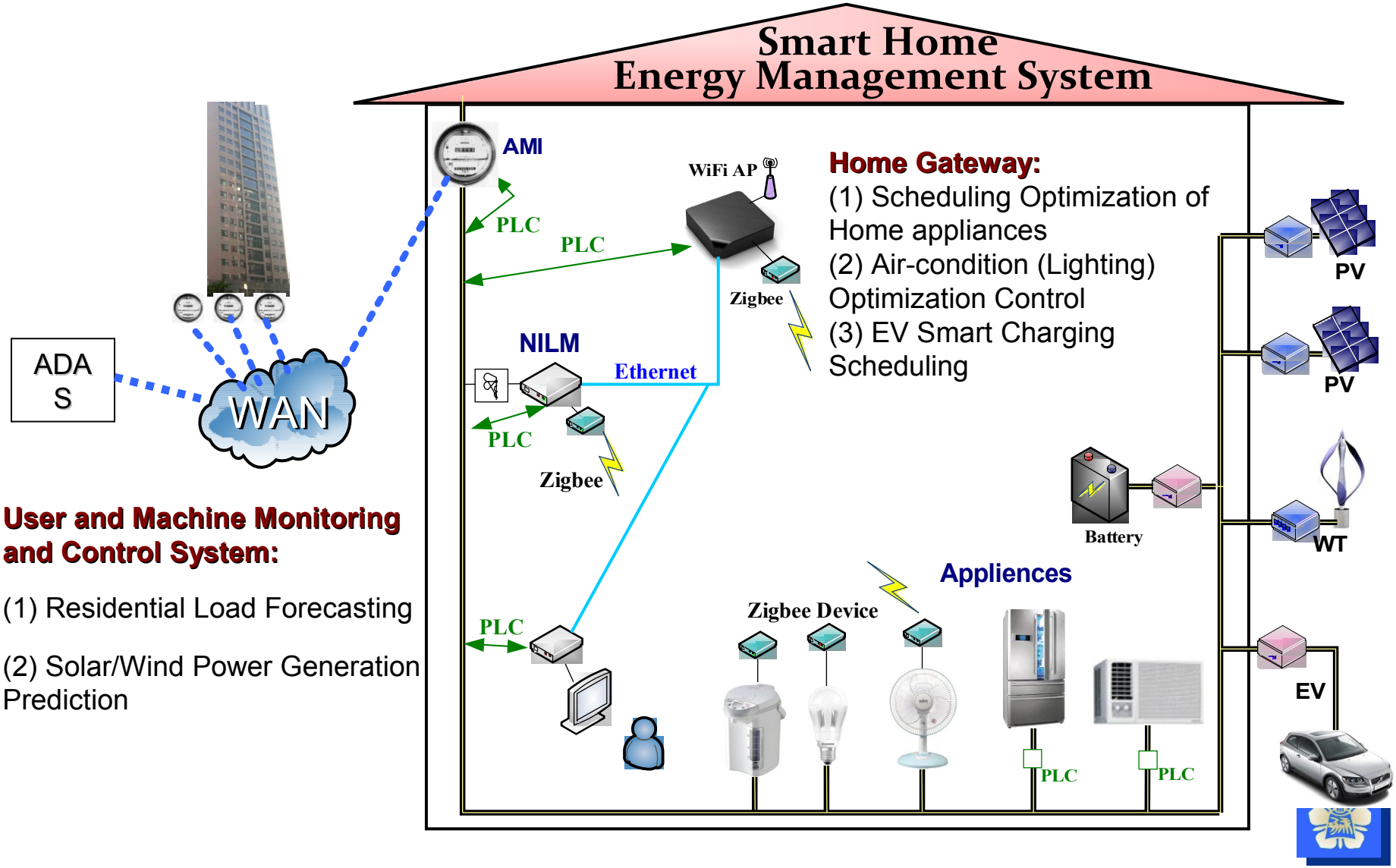
Renewable Energies in a Smart Home

Digital Signal Processor (DSP) programing design:
MPPT control, Power factor correction (PFC) control (Wind-turbine), charging/discharging control, grid-connected control, power flow control, islanding detection…



Power conversion circuit design and implementation:
DC-DC Converter, Inverter, soft-switching technology, high step-up technology, bi-direction charging circuit…

Computing Intelligence Applications in Smart Home EMS



Home Gateway:

(1) Scheduling Optimization of Home appliances

(2) Air-condition (Lighting) Optimization Control

(3) EV Smart Charging Scheduling

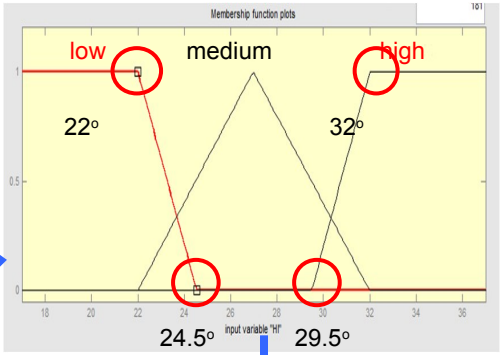
User and Machine Monitoring and Control System:

(1) Residential Load Forecasting

(2) Solar/Wind Power Generation Prediction

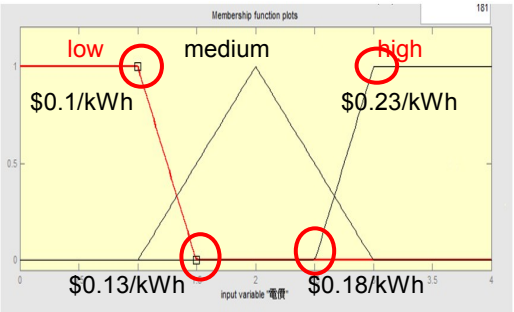
Fuzzy Logic Control Algorithm for Air-conditioners

Temperature and humidity → Calculate Humidity Index



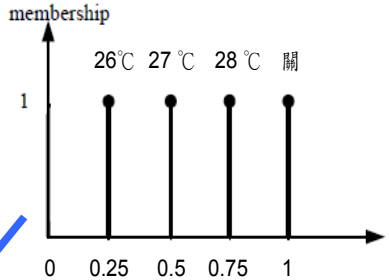
Adjustable

Electricity Tariff →



Fuzzy Rule

	low	medium	high
low	28	27	26
medium	OFF	28	27
high	OFF	28	28



IR

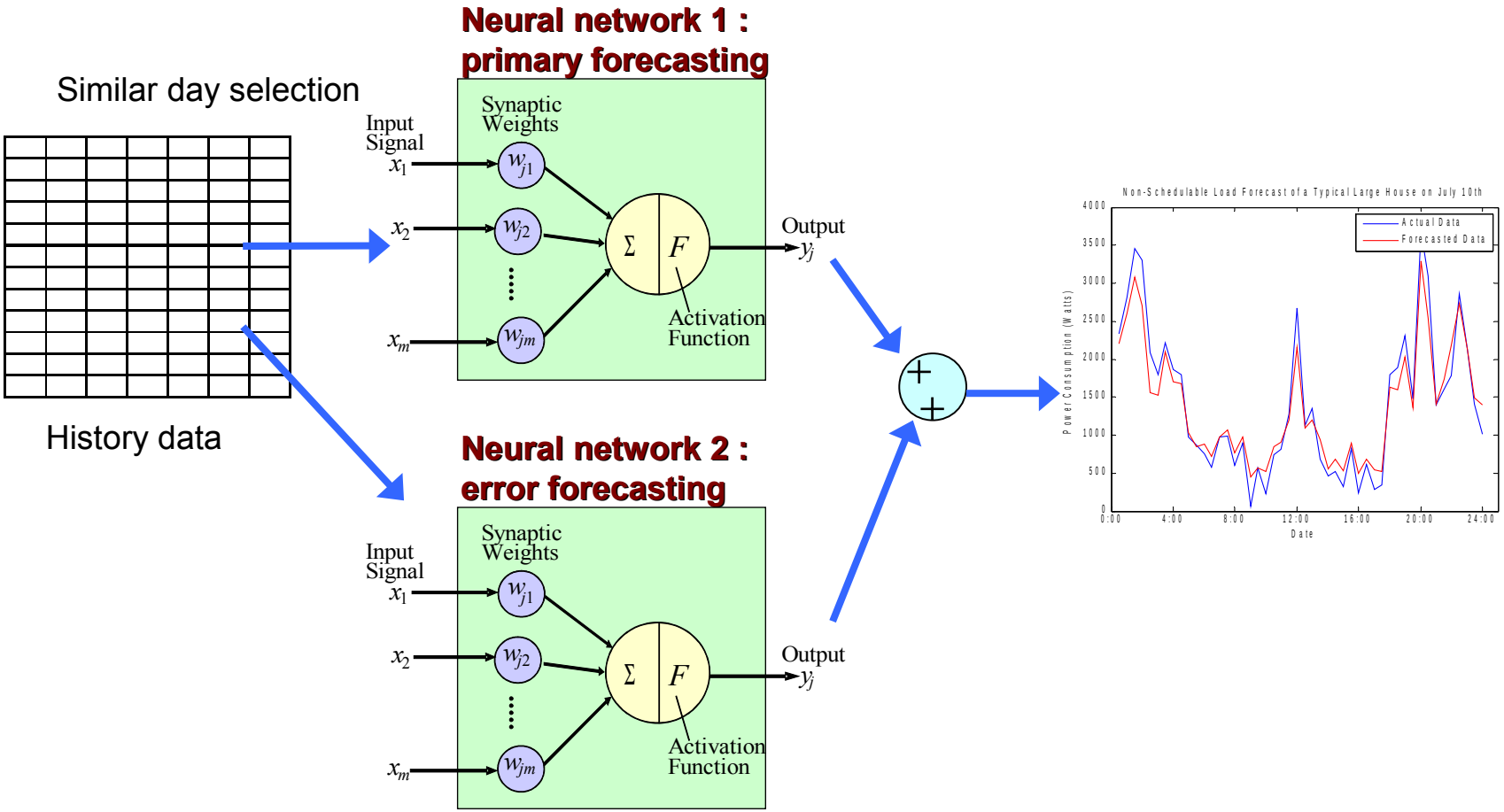
Zigbee module

Zigbee

behavior learning

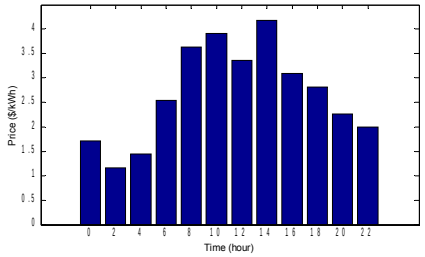
Home Gateway

Residential Load Forecasting

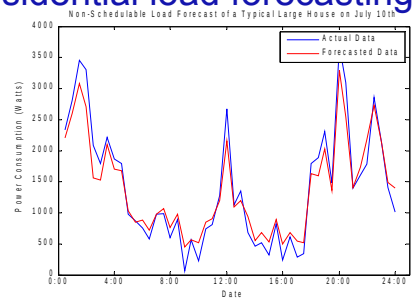


Scheduling Optimization of Home Appliances

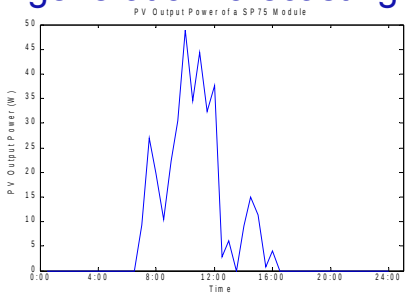
Time-of-use



Residential load forecasting result



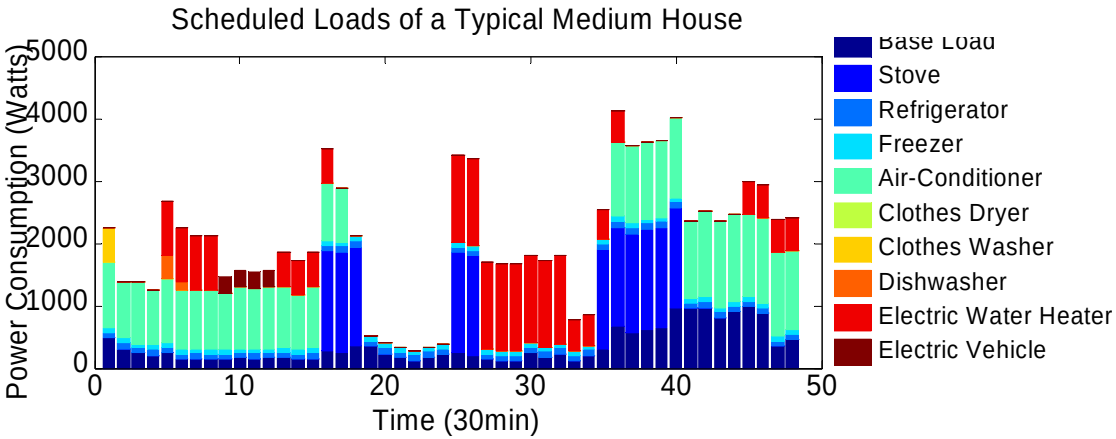
Renewable energy generation forecasting



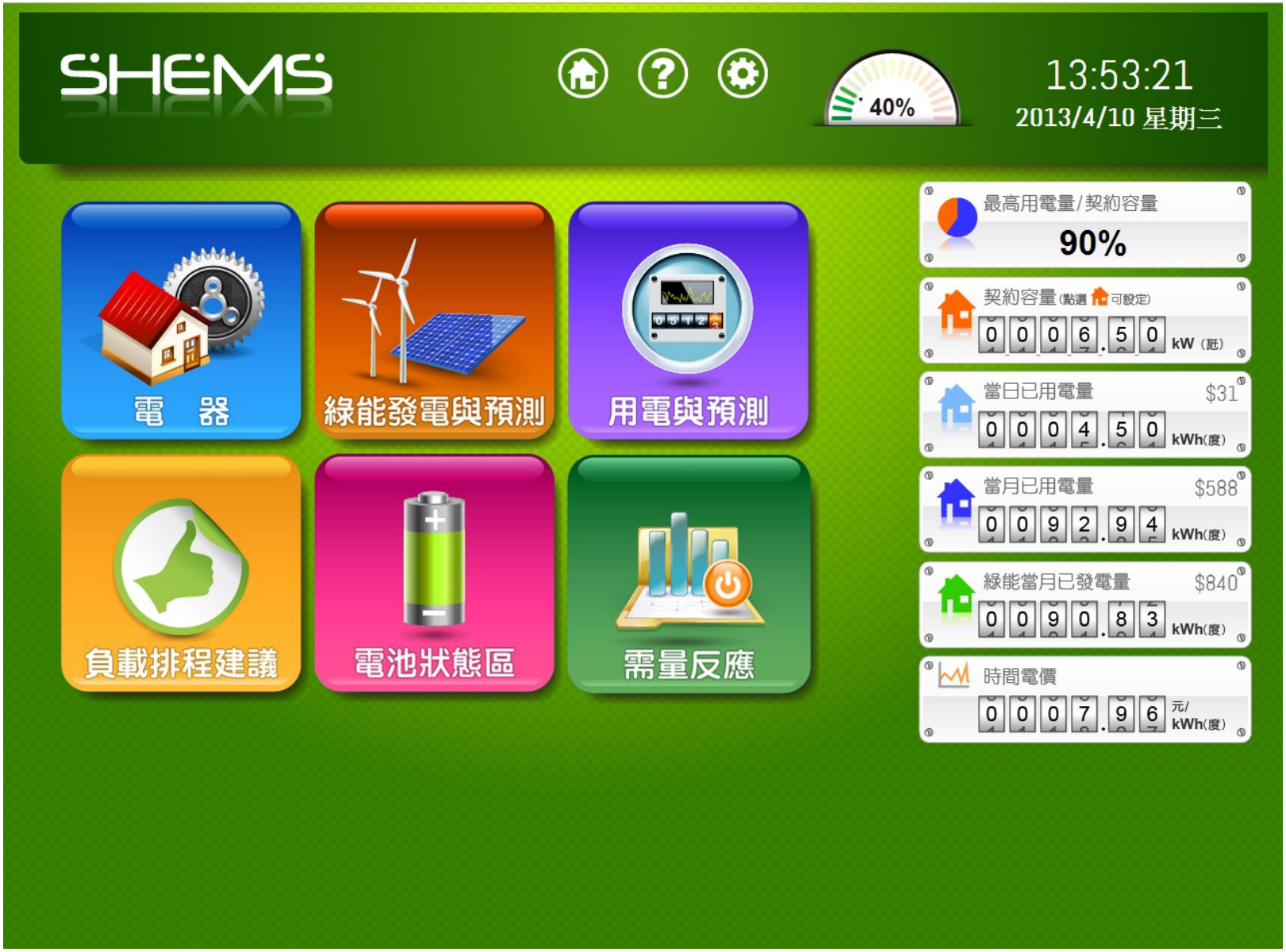
Optimization objective

Min (Cost)
Subject to :
- Comfort level
- Convenience

Optimization solving methods:
Particle Swarm Optimization (PSO)
Simulated Annealing (SA)
Genetic Algorithms (GA)

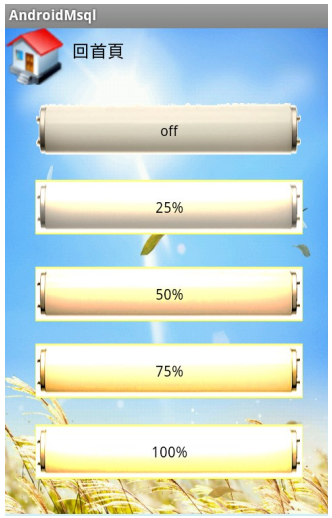


SHEMS User Interface Design – Web Based



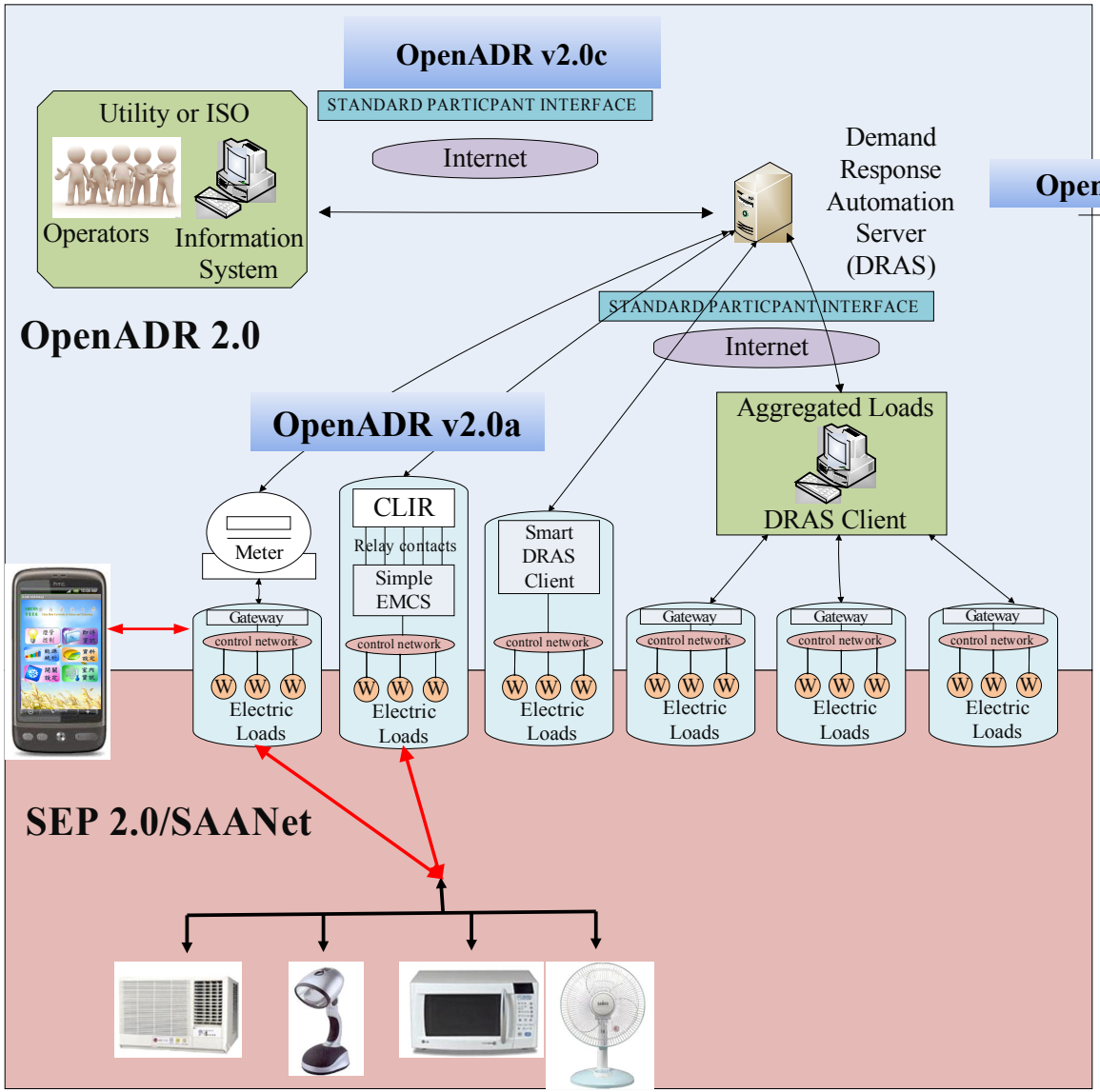
SHEMS User Interface Design – APP Based

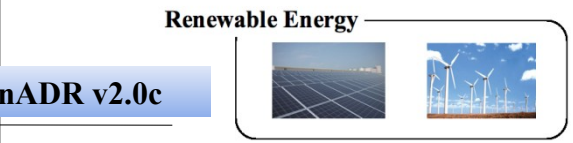
- **Android based APP Design**



Standard and Specification - OpenADR

Web-base Transport Infrastructure





OpenADR Alliance for OpenADR v2.0 with a、b、c versions:

- ✓ **OpenADR v2.0a**
  - ➢ **DRAS ↔ Simple DARS Client**
- ✓ **OpenADR v2.0b**
  - ➢ **DRAS ↔ All DRAS Client**
- ✓ **OpenADR v.2.0c**
  - ➢ **Utility & Renewable ↔ Client**

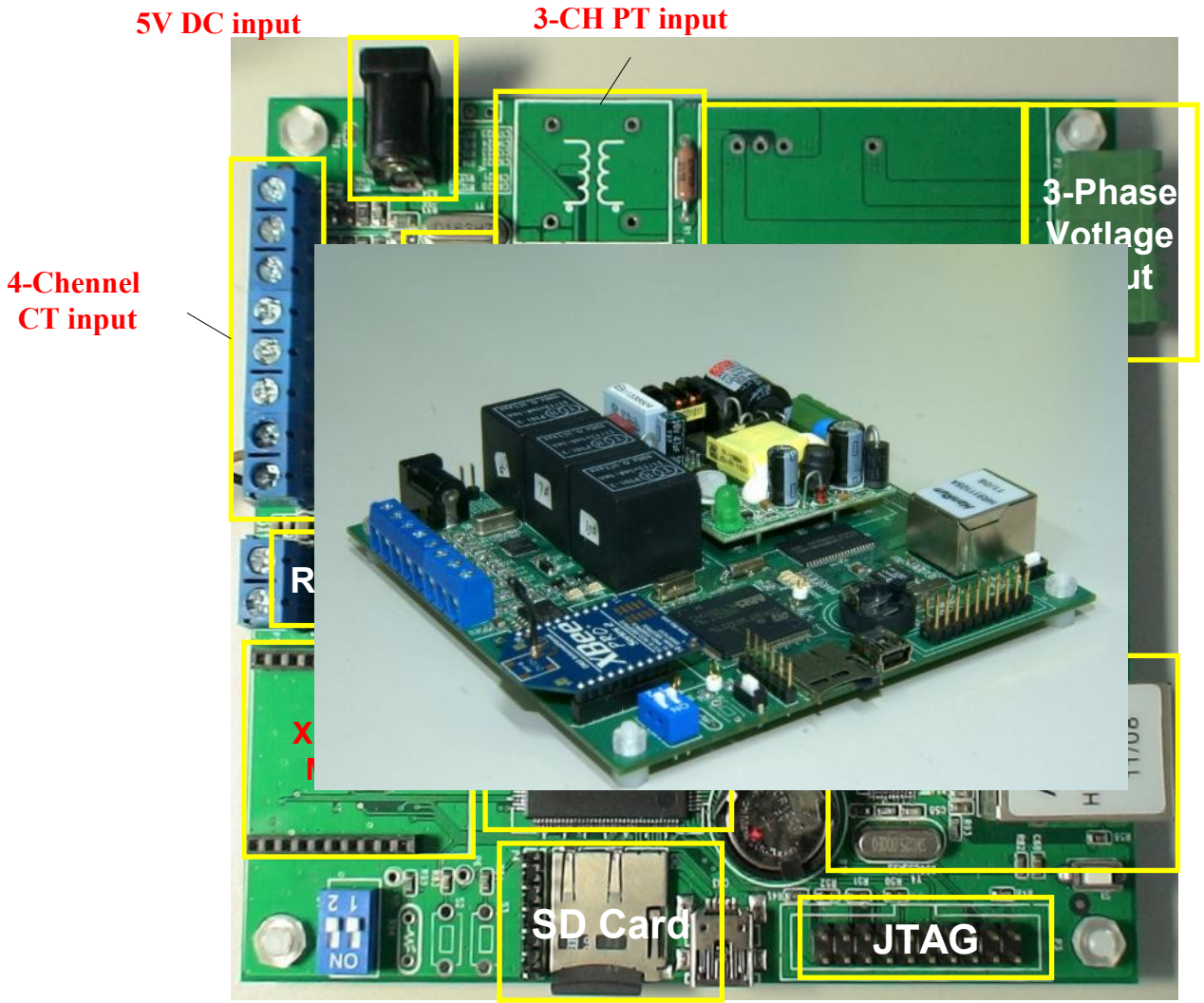
DR transmission mode

--Pull mode--

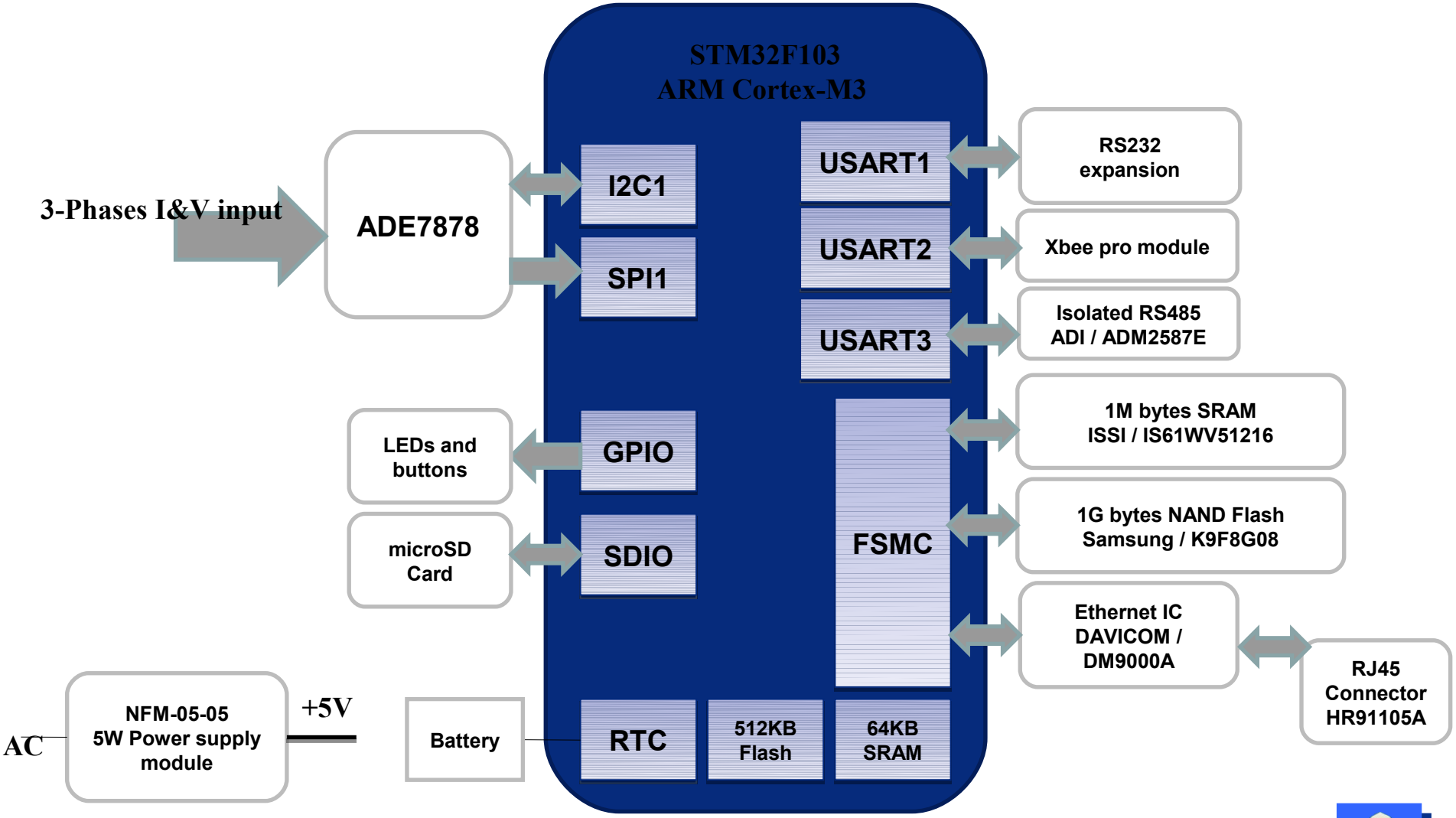
--Push mode--

Nonintrusive Load Monitoring (NILM)

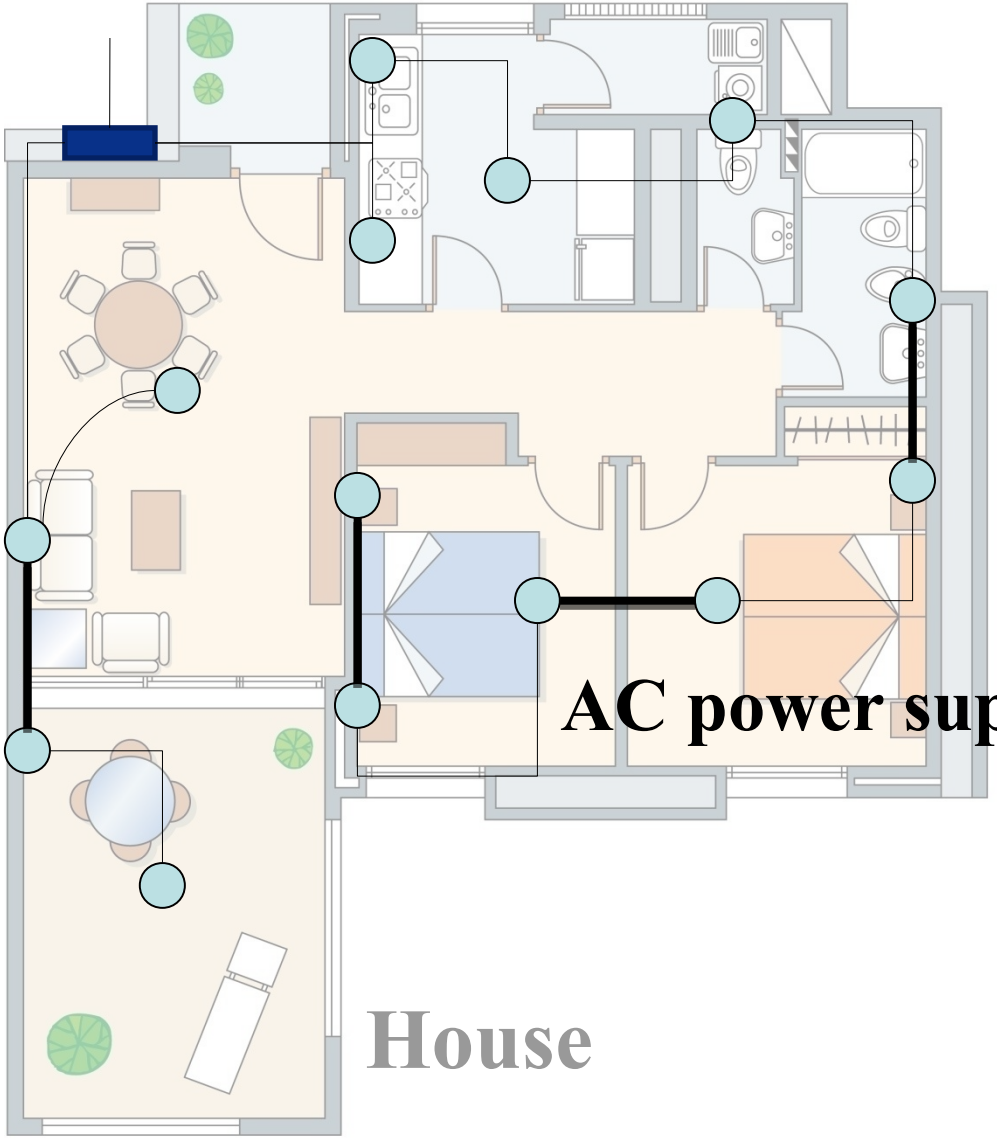
Smarter Meter developed for NILM



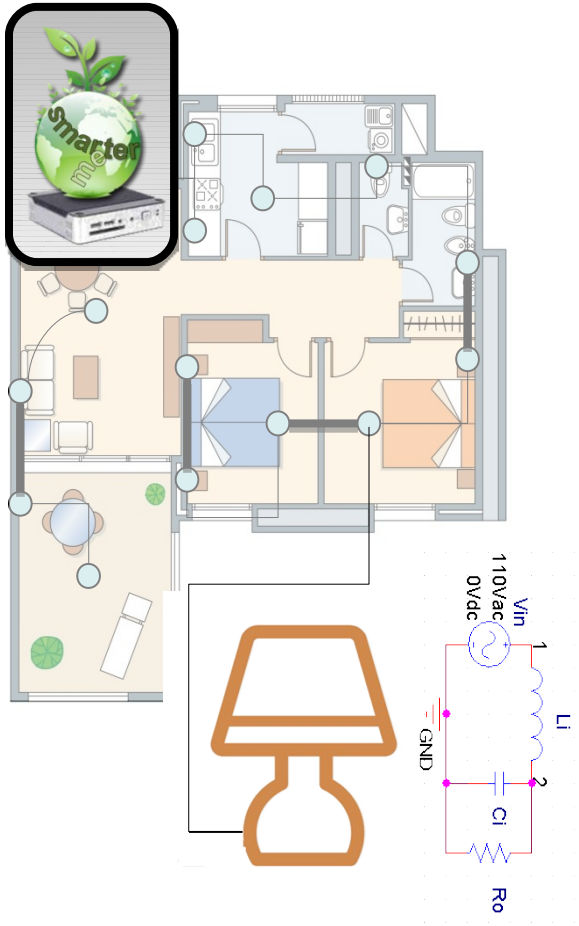
Structure of Hardware

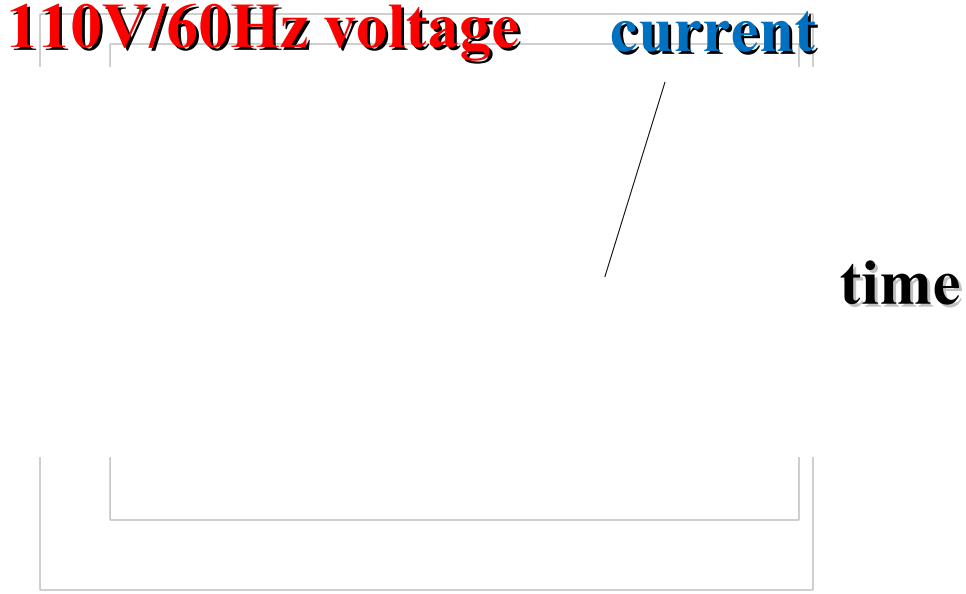


Applications of the Smarter Meter for NILM



Applications (Cont.)

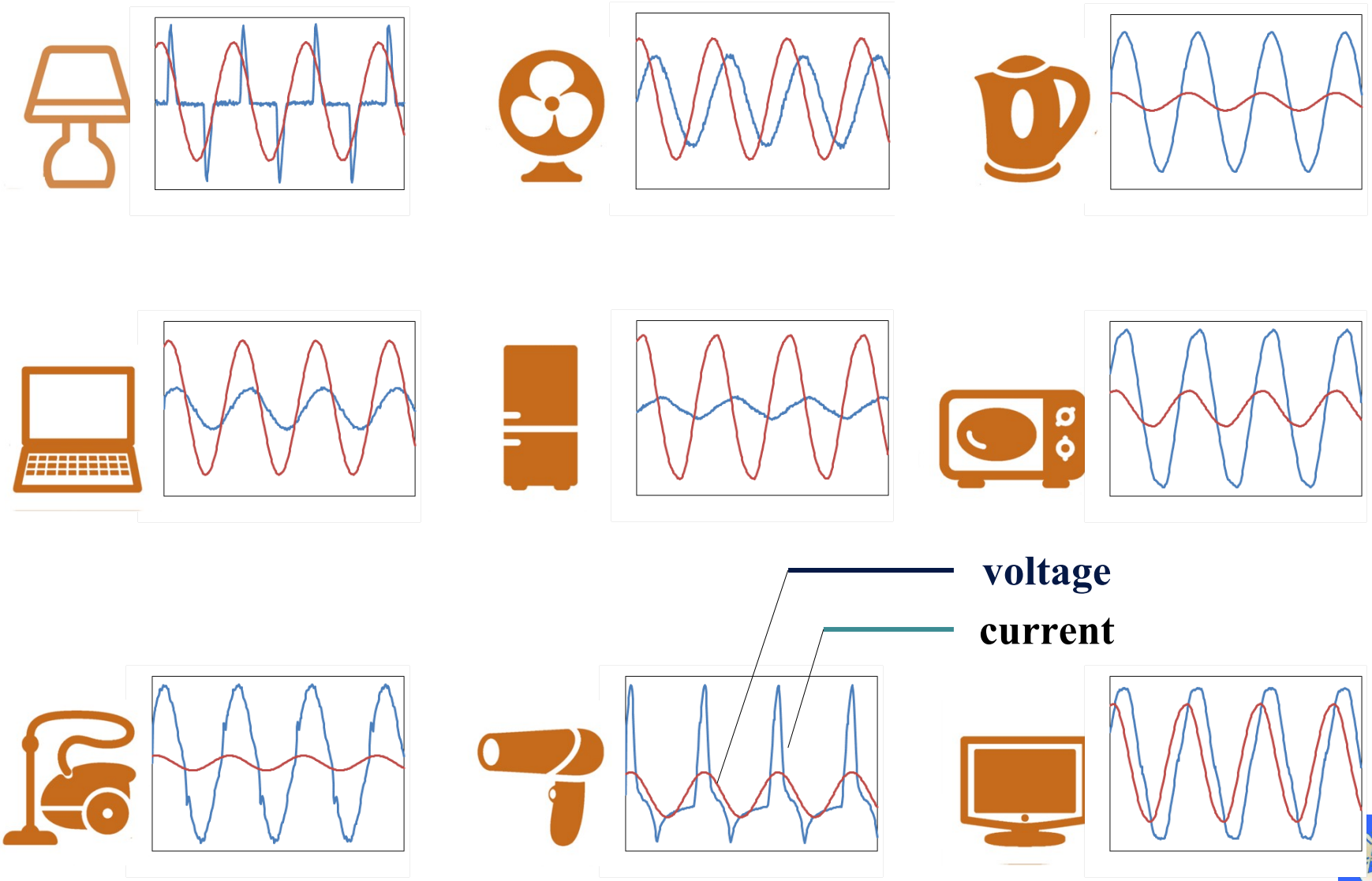




Signature

of an appliance and its state

Application (Cont.)



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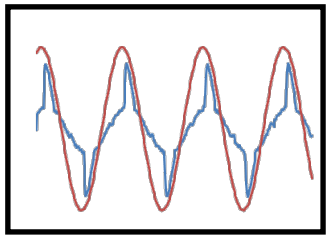
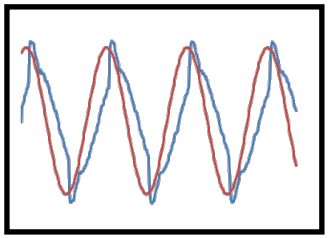
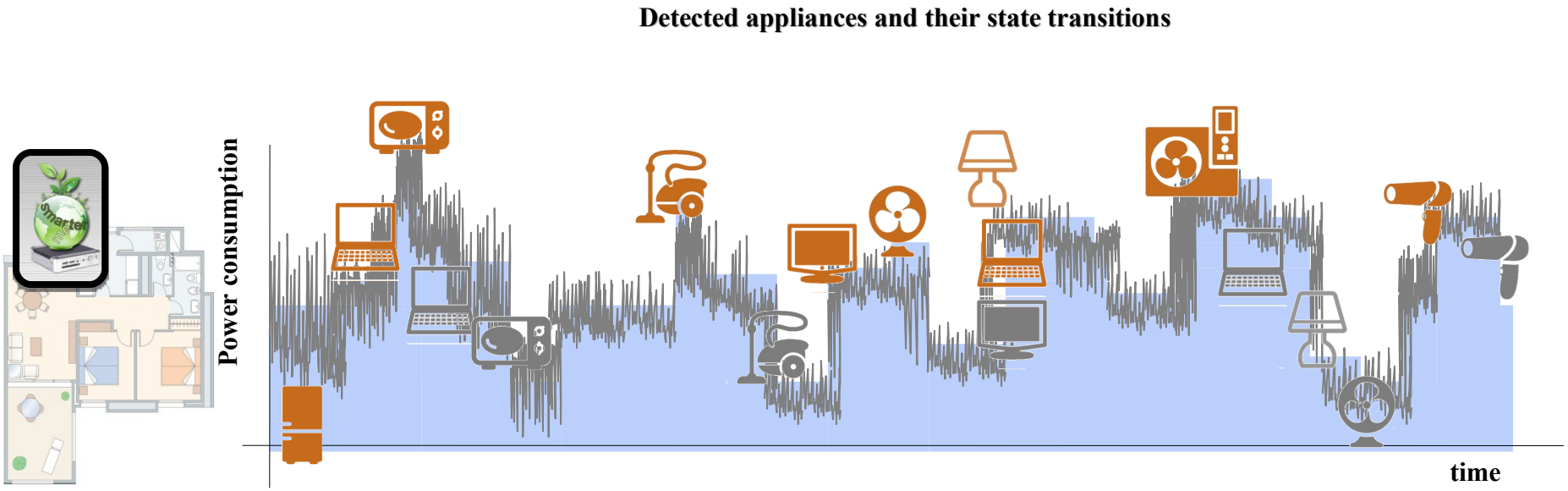
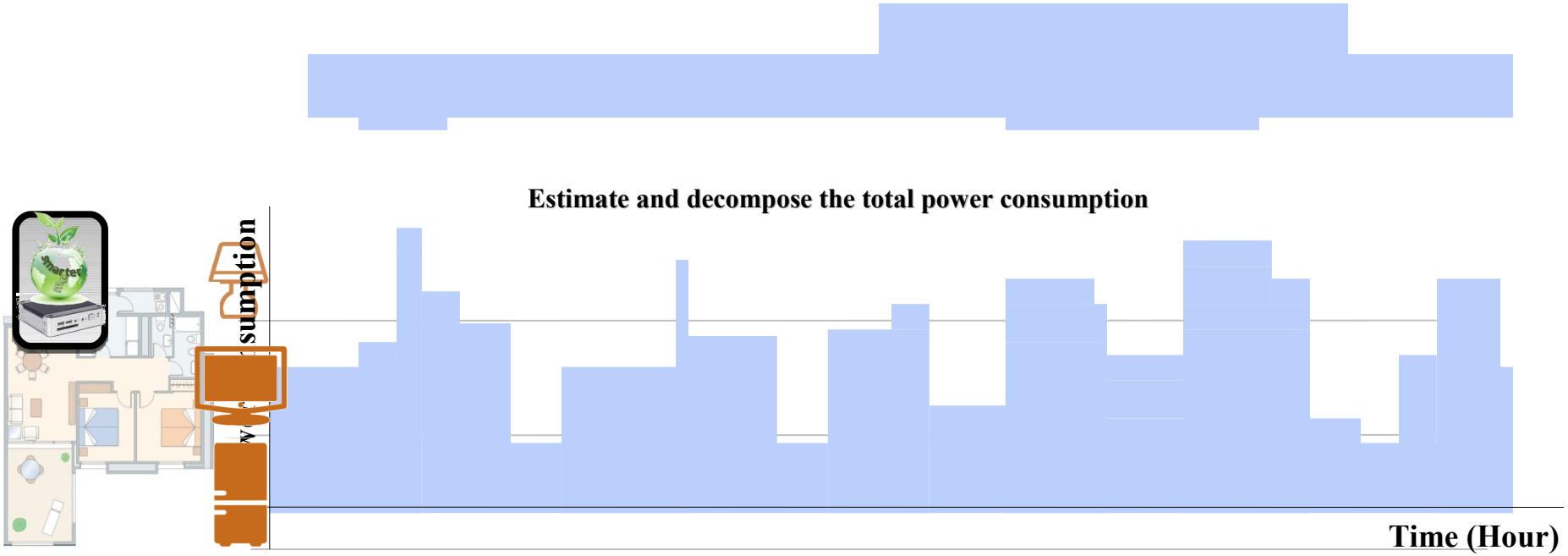




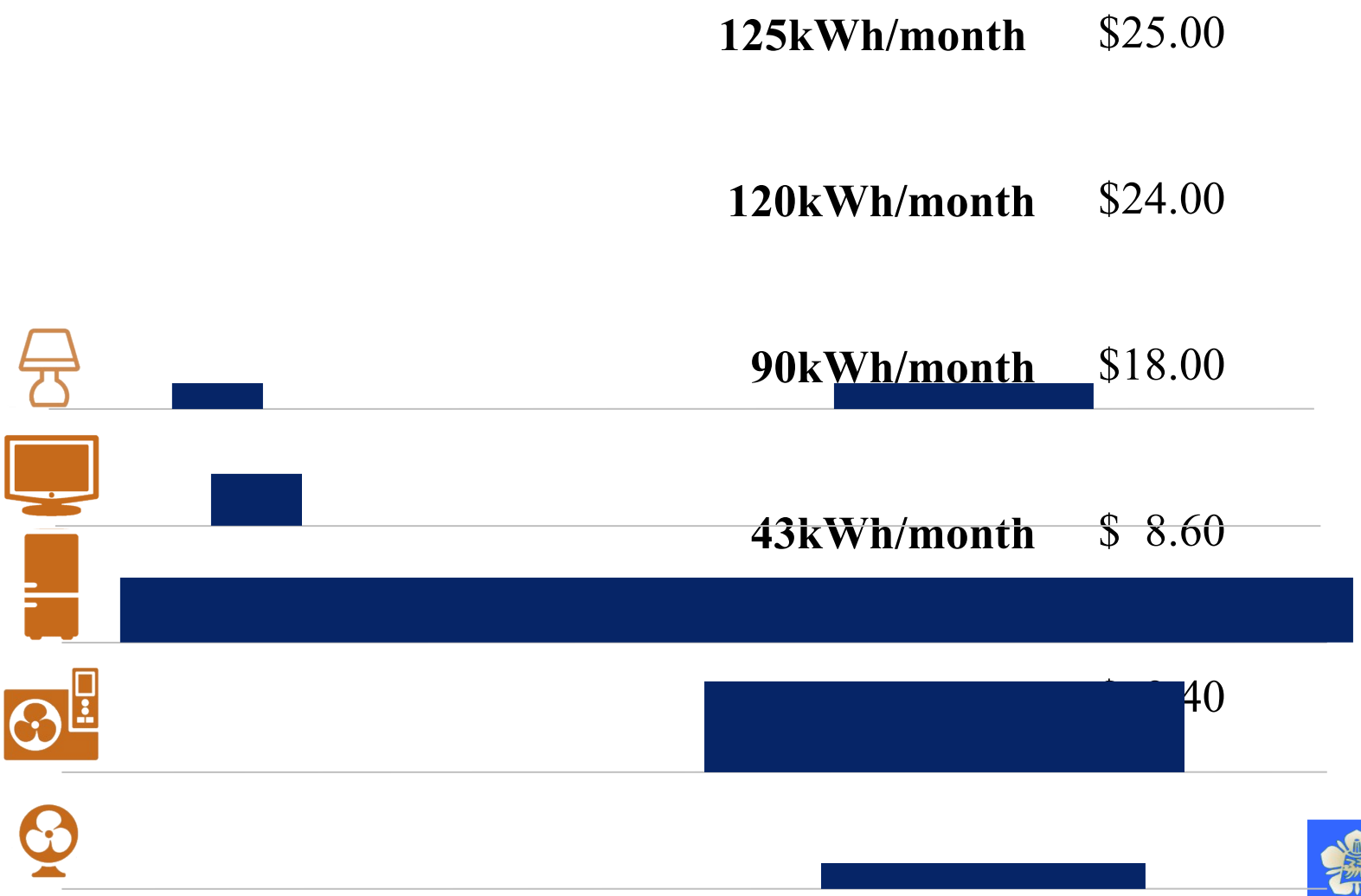
Application (Cont.)



Application (Cont.)



Application (Cont.)



Smart Building Energy Management System (SBEMS) Demonstration

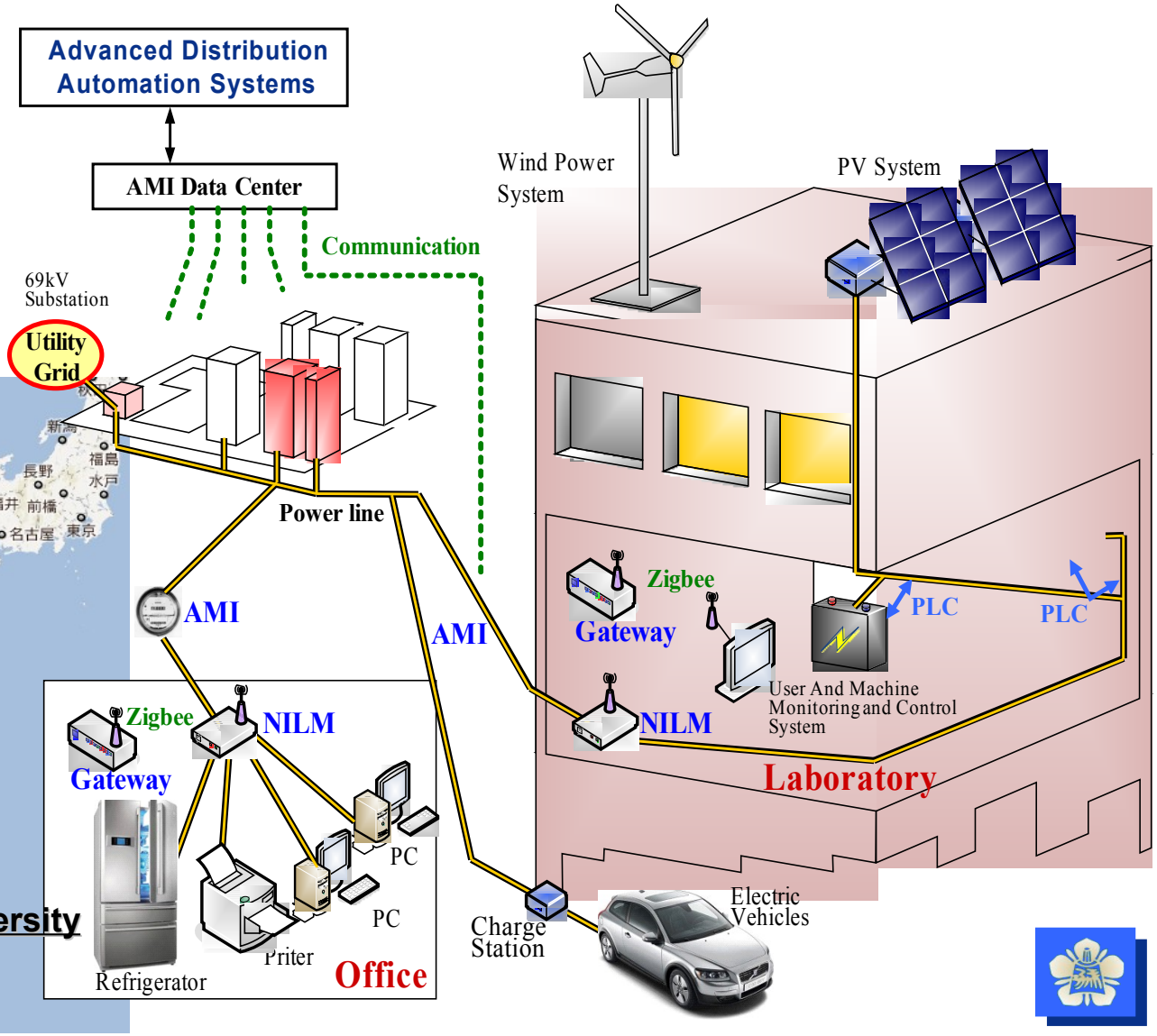
(1)Propose Electricity Tariff Structure

(2)Intergrate systems of all the sub-projects

(3)Define the control structure and strategy of DR

(4) Demonstrate the SBEMS

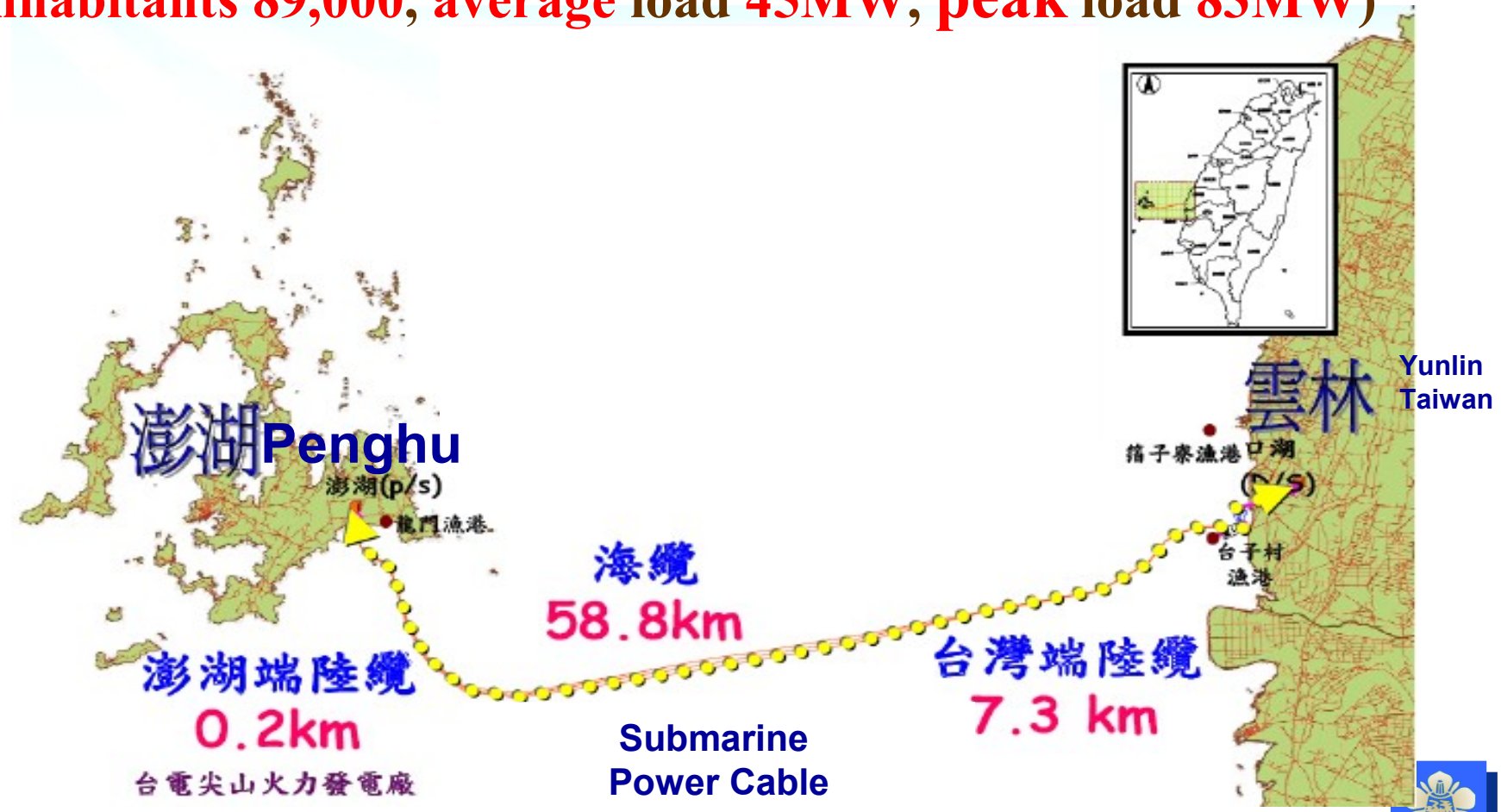
(5) Analyze costs/benefits



Future Prospects

Low-Carbon Island Project in Penghu

- Low Carbon Island Project in Penghu (59km from Taiwan, inhabitants 89,000, average load 45MW, peak load 83MW)



Low-Carbon Island Project in Penghu

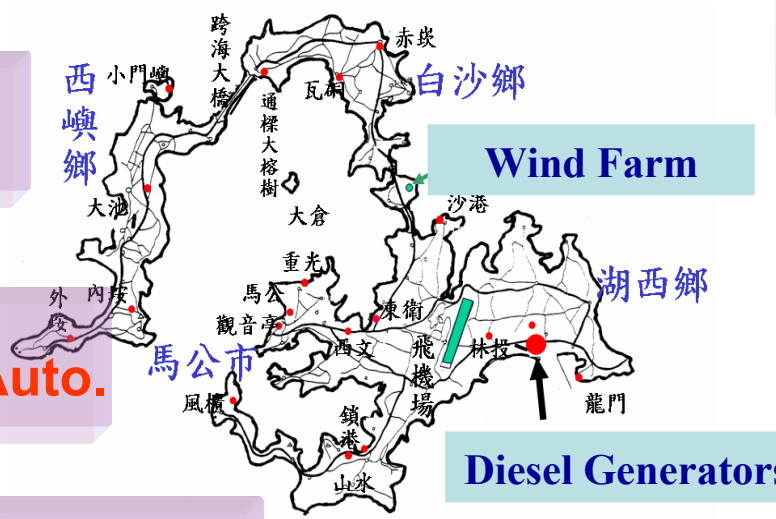
- To verify and demonstrate the key technologies and related business models

AMI (Startup 500 Meters/ total user 30,000)

Solar thermal

Solar PV (2MW)

Micro-grid



Wind Farm

Large-scale Wind Farm (96MW)

Smart Substation Auto.

Diesel Generators

Small-scale Wind Farm (220kW)

EMS/DSM, ToU & DR Model over 200 Customer Side Service/ Management

Electrical Vehicle (include E. Motorcycle and Charging Stations)

Low-Carbon Island Project in Penghu

- A field demonstration of low-carbon green living, low-carbon services, and carbon-reduction technologies
- Combining with tourism service to have negative demand growth in low-carbon homes

- **In 2015, the target of having a decrease of 50% of carbon emissions compared to 2005 to be reached**
- **In 2015, 50% of renewable energy penetration level**
- **Electricity consumption growth rate to be dropped by 7%, and per capita carbon emission to be reduced to 2.1 tons per year.**
- **Establishing investment model of Taiwan's first large-scale wind turbine in prefectural stock (the benefit of the island to be 1.6 times more)**

National Cheng Kung University

Thank You for Your Attention!