"Community Smart Grid: Integrating Renewable Energy with Green Technologies"

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adiCET

**Asian Development College for Community Economy and Technology
Chiang Mai Rajabhat University**

Outline

- Concept of Smart Grid
  - Class Questions
- Examples of Smart Grid Systems
  - Case Study – Jeju Island
- Community Smart Grid – RE & Green Technologies
  - Case Study: Chiang Mai World Green City
  - DC Microgrid
  - Integrating Energy Infrastructure with Green City Components
- Smart Homes
- Conclusion

Class Questions

- What is a grid?

- What is a electrical grid?

- What is a smart grid?

- Why do we need smart grid?
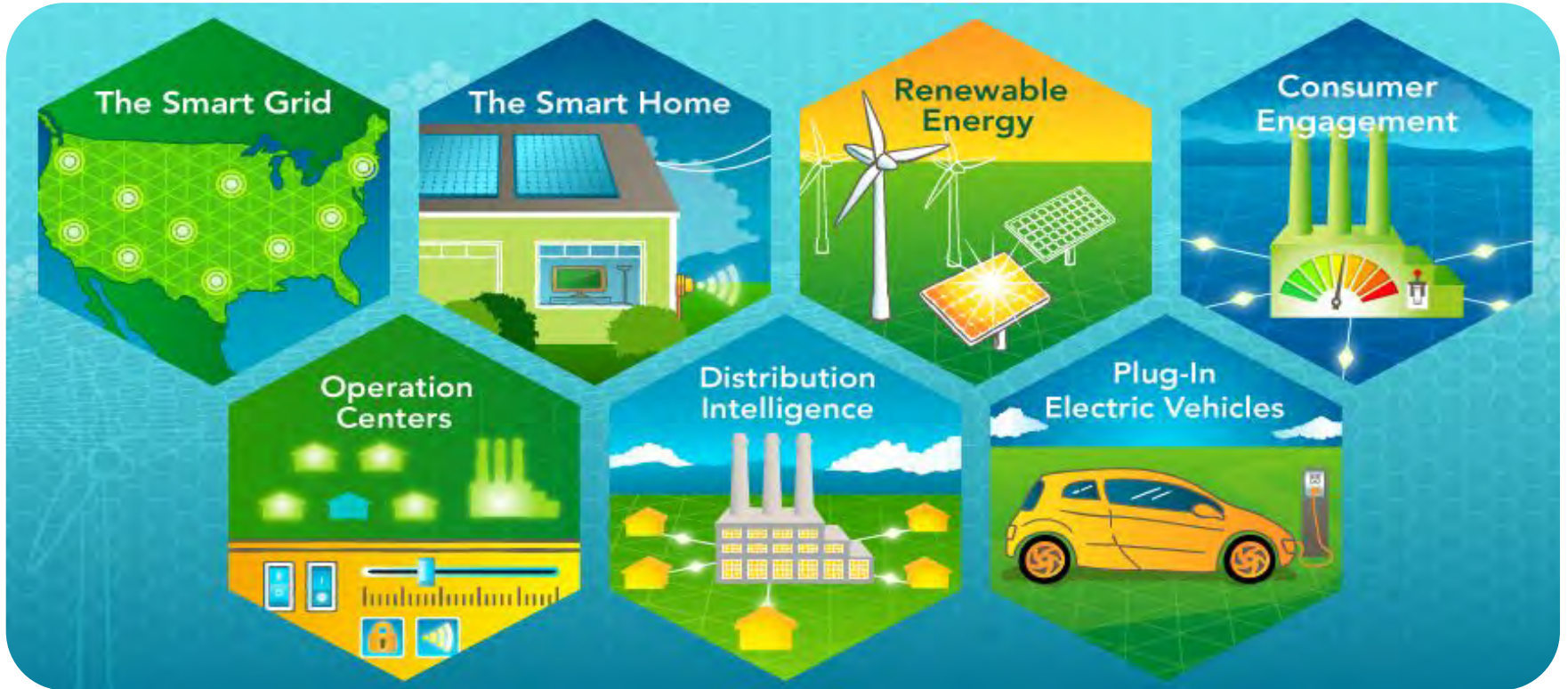
- What are the component of smart grid?

- Distributed Generations
  - What are the generation profiles of renewable energy?
  - What are the load profiles for home, offices, factories, etc?
- What are the role of energy storage and EVs?

Smart Grid Example
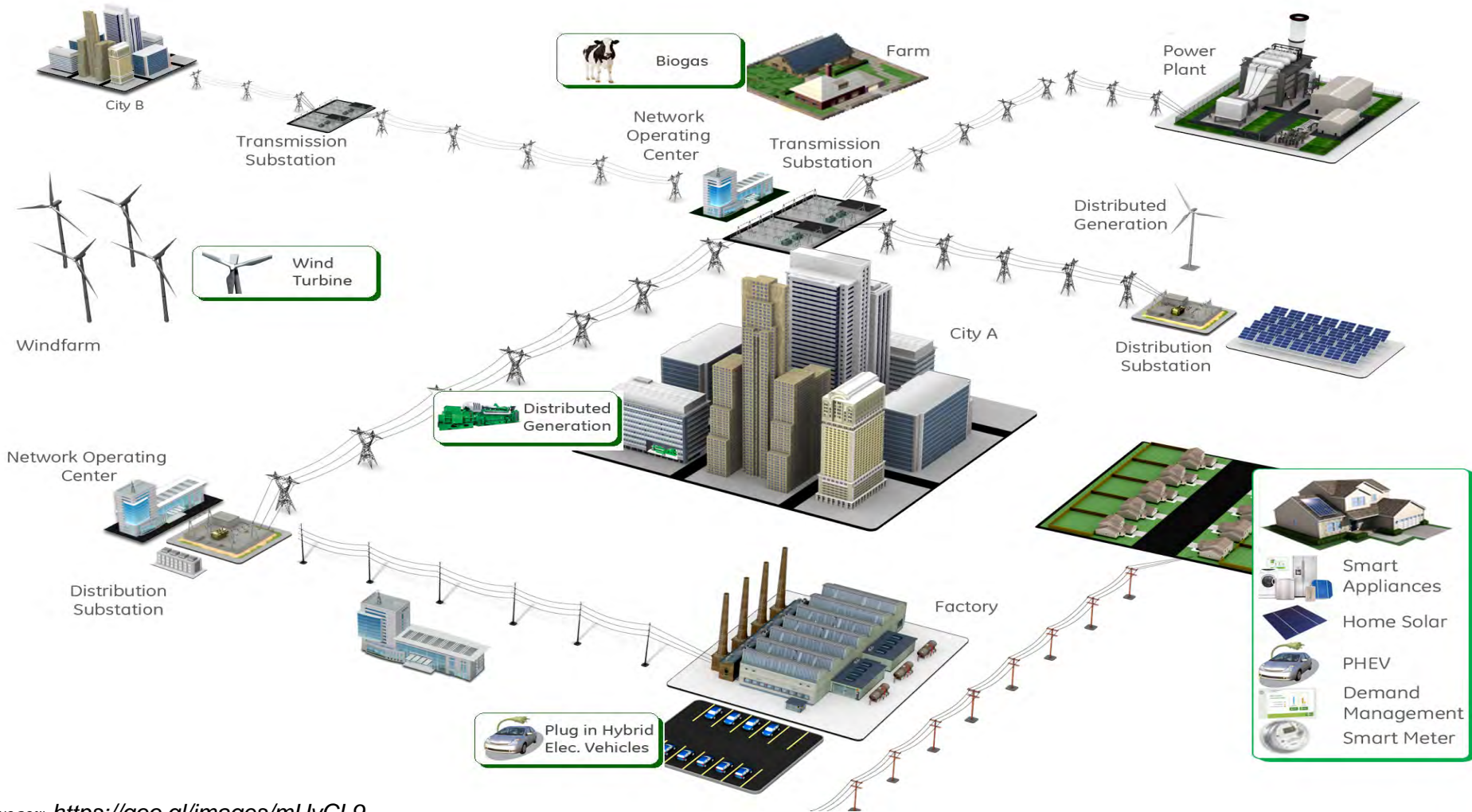
Smart Grid Component

US Department of Energy

EXAMPLES OF SMART GRID SYSTEMS
JEJU ISLAND, KOREA

Jeju Island

Smart Grid Test Bed Infrastructure

Population: 604,670

Area: 1,848 km^2

Gasiri Wind Farm

Dong-Gwang solar village

Gapado – Carbon Free Island

Resources: Wind/Solar

Korea's Vision

Build the world's best nationwide Smart Electricity Grid

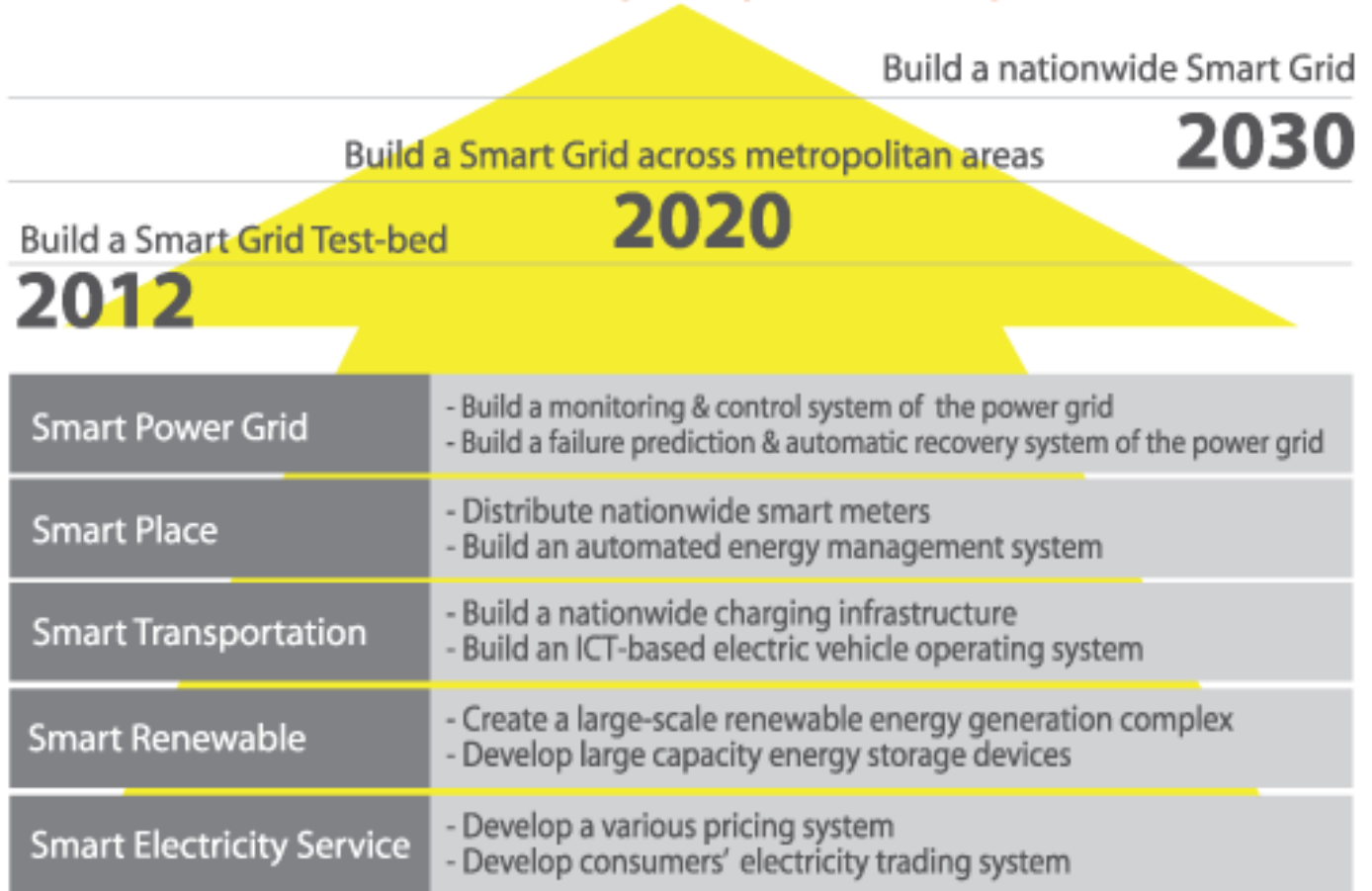→ Realize a low carbon, green growth society

Opportunity Elements

Highly Populated Land

World's Best Broadband Internet Networks

Single Power Transmission & Distribution Company

Vision of Korea's Smart Grid

Vision and Goals of Korea's Smart Grid

Vision

Pave the way for low carbon, green growth through a Smart Grid

Build a nationwide Smart Grid
2030

Build a Smart Grid across metropolitan areas
2020

Goals by phase

Build a Smart Grid Test-bed
2012

Five implementation areas

Smart Power Grid	- Build a monitoring & control system of the power grid - Build a failure prediction & automatic recovery system of the power grid
Smart Place	- Distribute nationwide smart meters - Build an automated energy management system
Smart Transportation	- Build a nationwide charging infrastructure - Build an ICT-based electric vehicle operating system
Smart Renewable	- Create a large-scale renewable energy generation complex - Develop large capacity energy storage devices
Smart Electricity Service	- Develop a various pricing system - Develop consumers' electricity trading system

http://www.smartgrid.or.kr/10eng4-1.php

Alternative Energy No Fossil by 2030

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Renewable Energy

- **100% Electricity usage by RE**
  - Development of 1GW Offshore wind business by 2019 → 15%
  - Development of 2 GW Offshore wind business by 2030 → 100%
    - Onshore 350 MW; Solar PV 100 MW, etc

Electrical Vehicle

- **100% Replacement of Fossil Fuel Cars to Electrical Vehicle by 2030**
  - Public by 2017 → 10% (29,000 vehicles)
  - Public transportation by 2020 →30% (94,000 vehicles)
  - Commercial Vehicles by 2030 → 100% (371,000 vehicles)

Smart Grid

- **Smart Grid City all around Jeju**
  - Smart Grid Pilot Project in 2014
  - Spread Smart Grid Business by 2017
  - Smart Grid City around all Jeju by 2020

Jeju Smart Grid Test-Bed
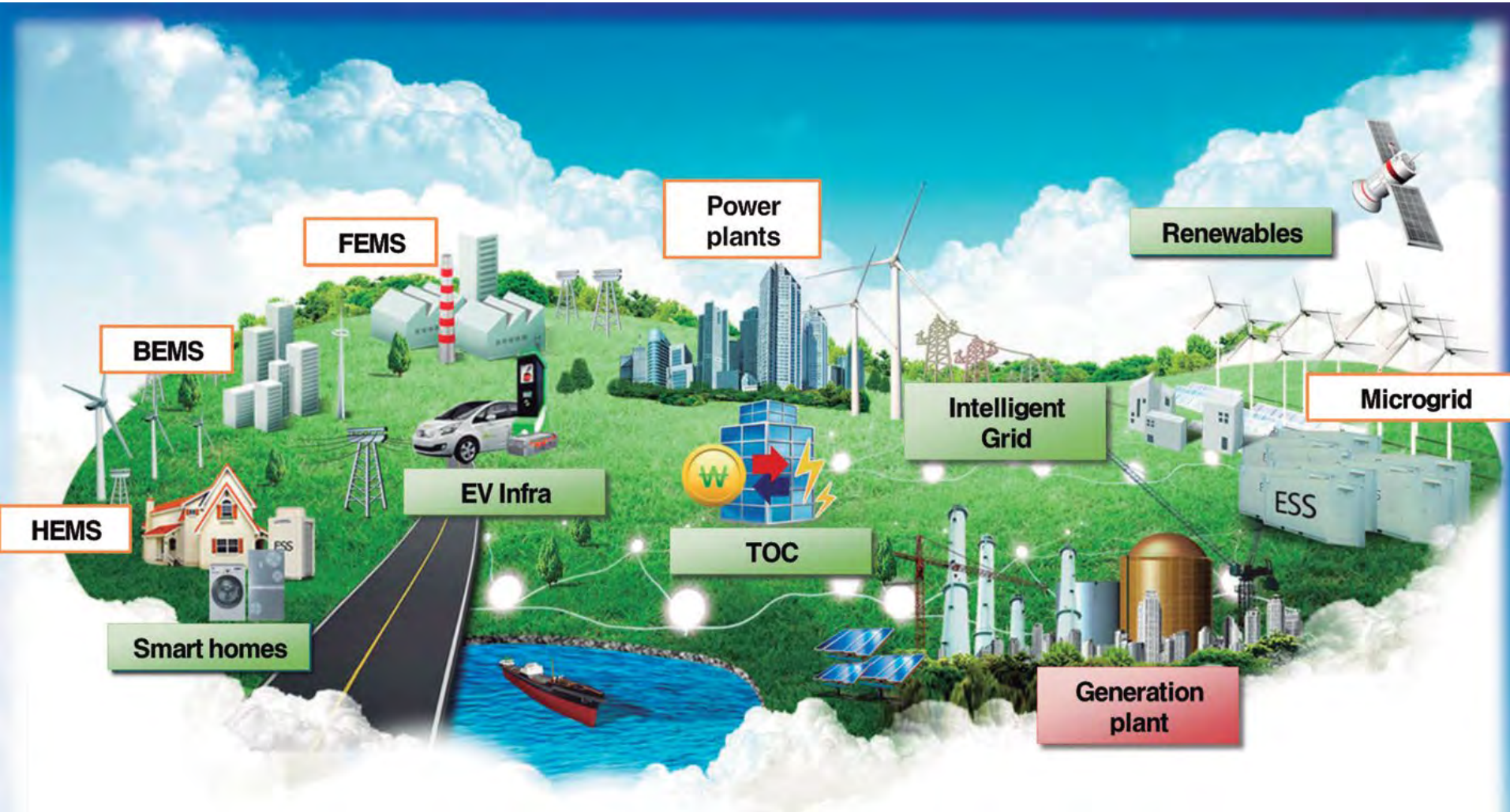
- **1st Stage – Test-bed Infrastructure (Dec 2009– May 2011)**
  - Energy Monitoring Service (200 house/buildings)
  - Energy Efficiency Service (+800 house/buildings)

- **2nd Stage – Operation (June 2011 – May 2013)**
  - Real-time Pricing, DR, Power Trading, etc. (+Buildings/Industrial Plants)
  - Business Model Implementation (Smart Grid City)
- Area: 186 km^2 (1/10 of Jeju)
- Population: 15,500 (6,250 Homes)

**Budget 230M US$** (Government 70M US$, Private Sector 160 M US$)
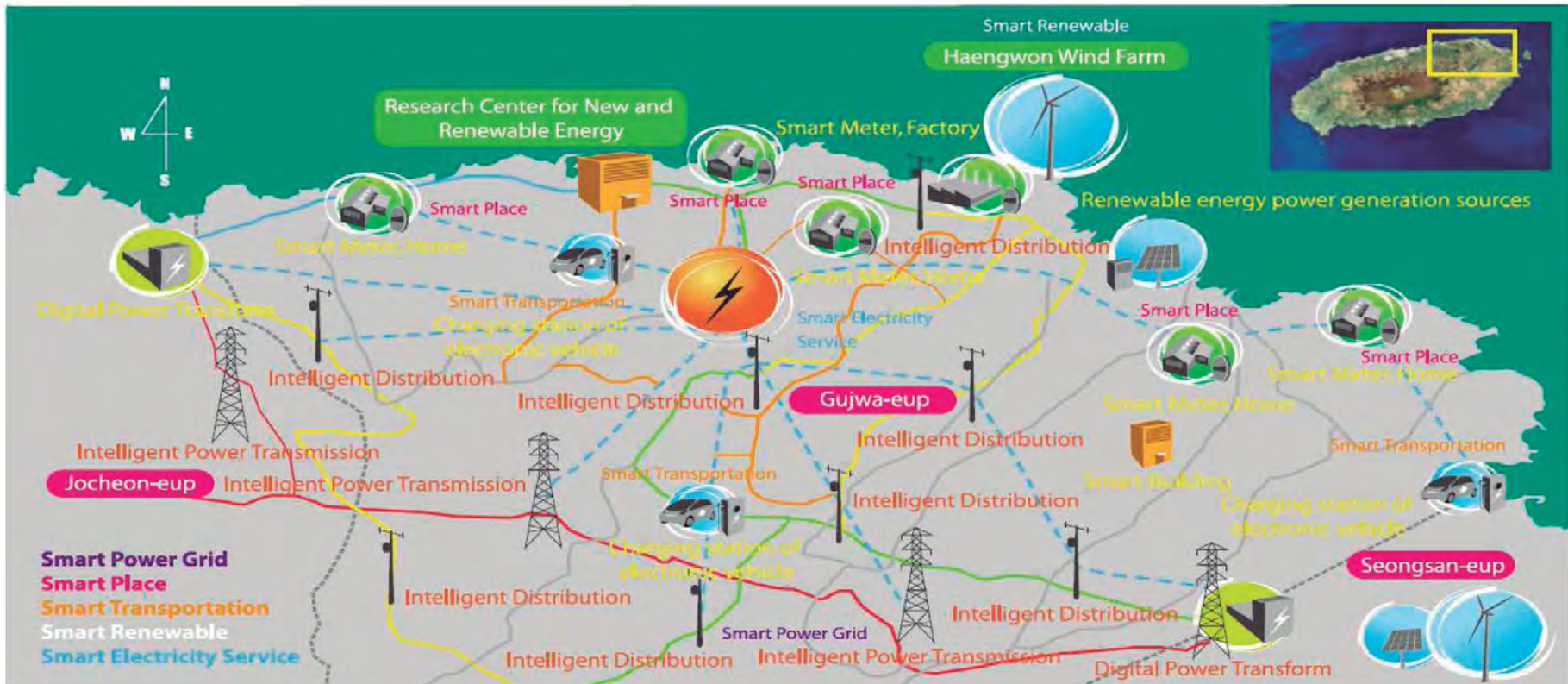
Implementation Directions by Phase	First Stage (2010~2012) 'Construction and operation of the Smart Grid Test-bed' (Technical validation)	Second Stage (2012~2020) 'Expansion into metropolitan areas' (Intelligent consumers)	Third Stage (2021~2030) 'Completion of a nationwide power grid' (Intelligent power grid)
Smart Power Grid	- Real-time power grid monitoring - Digital power transmission - Operate optimal distribution system	- Predict possible failures in power grids - Connect the power system with that of other countries - Connect the power delivery system with distributed generation and power storage devices	- Self-recovery of power grids - Operate an integrated energy Smart Grid
Smart Consumer	- Power management of intelligent homes - Various choices for consumers including rates	- Smart power management of buildings/factories - Encourage consumers' power production	- Zero energy homes/buildings
Smart Transportation	- Build & test electric vehicle charging facilities - Operate electric vehicles as a pilot project	- Expand electric vehicle charging facilities across the nation - Effective maintenance and management of electric vehicles	- Make the presence of charging facilities commonly available - Diversify charging methods - Utilize portable power storage devices
Smart Renewable	- Operate microgrids by connecting distributed generation, power storage devices and electric vehicles - Expanded utilization of power storage devices and distributed generation	- Optimal operation of the power system with microgrids - Expand the application of power storage devices	- Make renewable energy universally available
Smart Electricity Service	- Consumers' choice of electricity rates - Consumers' selling of renewable energy	- Promote transactions of electrical power derivatives - Implement real-time pricing system nationwide - Emergence of voluntary market participants	- Promote various types of electrical power transactions - Promote convergence for the market of electricity-based sectors - Lead the power market in Northeast Asia

http://www.smartgrid.or.kr/10eng4-1.php

Field trial in Jeju Island

Main Grid

Smart Home

Smart Meter

Solar

PCS

Energy Storage

WCDMA/WiBro

Smart Box (G/W)

Smart Appliance

Smart Tag

EV Charger

Operating Center

Power Market

3G

IP Premium

HEMS MDMS App.

REMS DRMS Billing

CEM EMS Asset Mg.

Smart Building/Factory

Smart Meter

Solar

PCS

Wind

E/S

FTTH

BEMS/FEMS

Smart Power Hub

Building/Factory

EV charger

※ REMS(Renewable Energy Management System)
※ DRMS(Demand Response Management System)
※ CEM(Carbon Emission Management System)

Power — **Comm.**

AMI
- Smart Metering
- Measured Data Management

EMS
- Energy Monitoring & Control
- Energy Usage Optimization

EVCI
- Normal Charging & Quick Charging
- Communications

Interconnection
- Renewables (Wind Power, PV etc.)
- Microgrids

ESS
- Renewable Power Output Smoothing
- Peak Shaving & Load Leveling

Intelligent Device
- Electronic Sensors and IED
- Intelligent T&D Devices

DR
- Reliability Based DR
- Market Based DR

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Power services for energy optimization

SK telecom (29 firms) olleh kt (14 firms)

LG Electronics (15 firms) KEPCO (38 firms)

Smart Place

Building EV infrastructure

KEPCO (22 firms)

SK energy (13 firms)

GS Caltex (7 firms)

Smart Transportation

Smart Renewables

Operation of stabilized clean energy

KEPCO (16 firms)

HYUNDAI HEAVY INDUSTRIES CO.,LTD. (6 firms)

posco ict (7 firms)

Construction of integrated grid network

KEPCO (13 firms)

Smart Power Grid

Smart Electricity Service

Diverse power fare algorithms

Power exchange markets

KEPCO

KPX KOREA POWER EXCHANGE (5 firms)

Smart Power Grid

Smart Renewables

Smart Renewables is new technology that
improve the quality of power from renewable energy sources and
it realizes stable interconnection of distributed resources with power grid
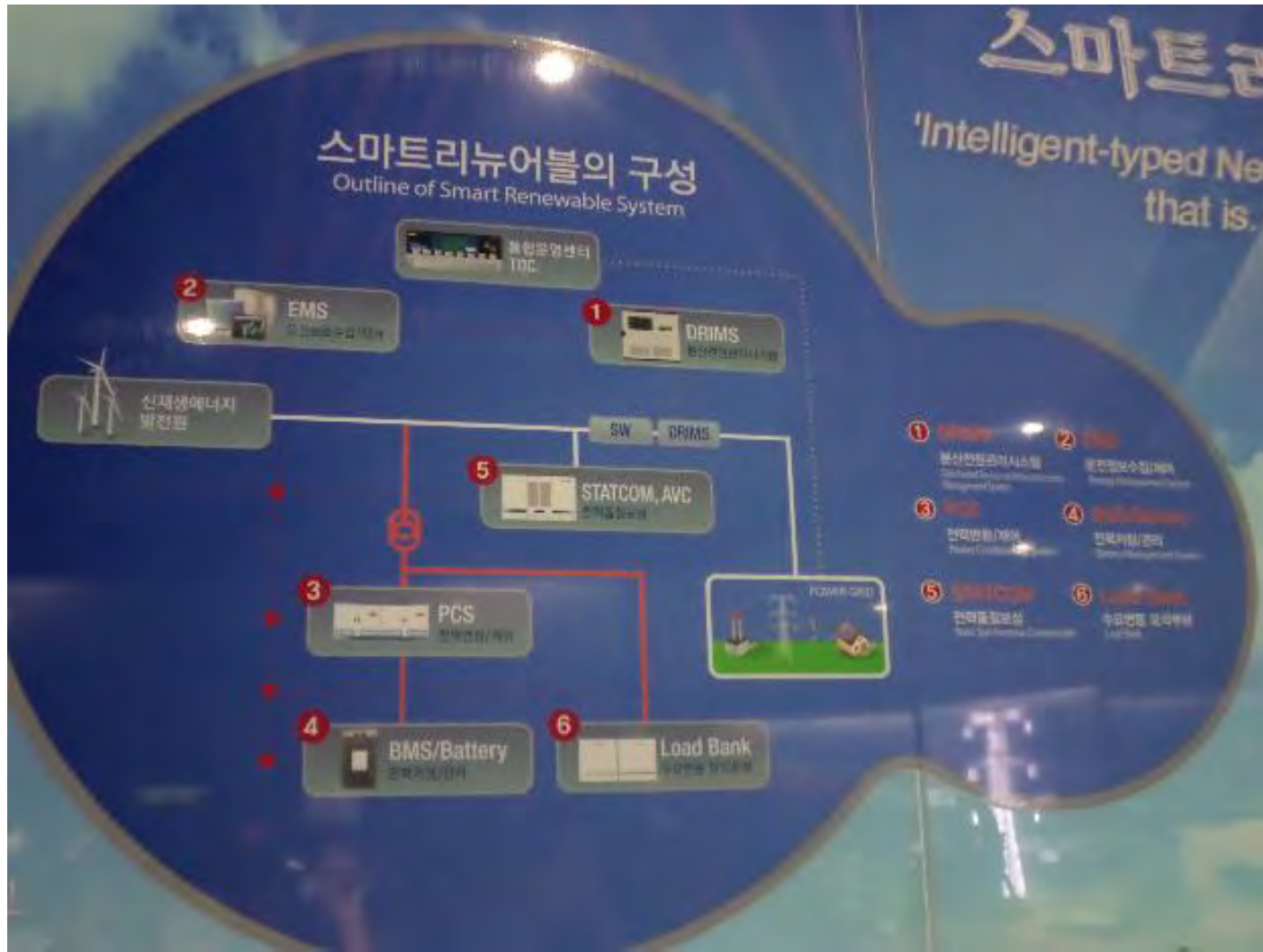
Showcase – New & Renewable Energy

Current Generating Plant in Jeju

Renewables
15%

Synchro
Condenser
13%

Combined
Cycle
13%

Gas Turbine
7%

Diesel
Power
10%

Thermal
Power
42%
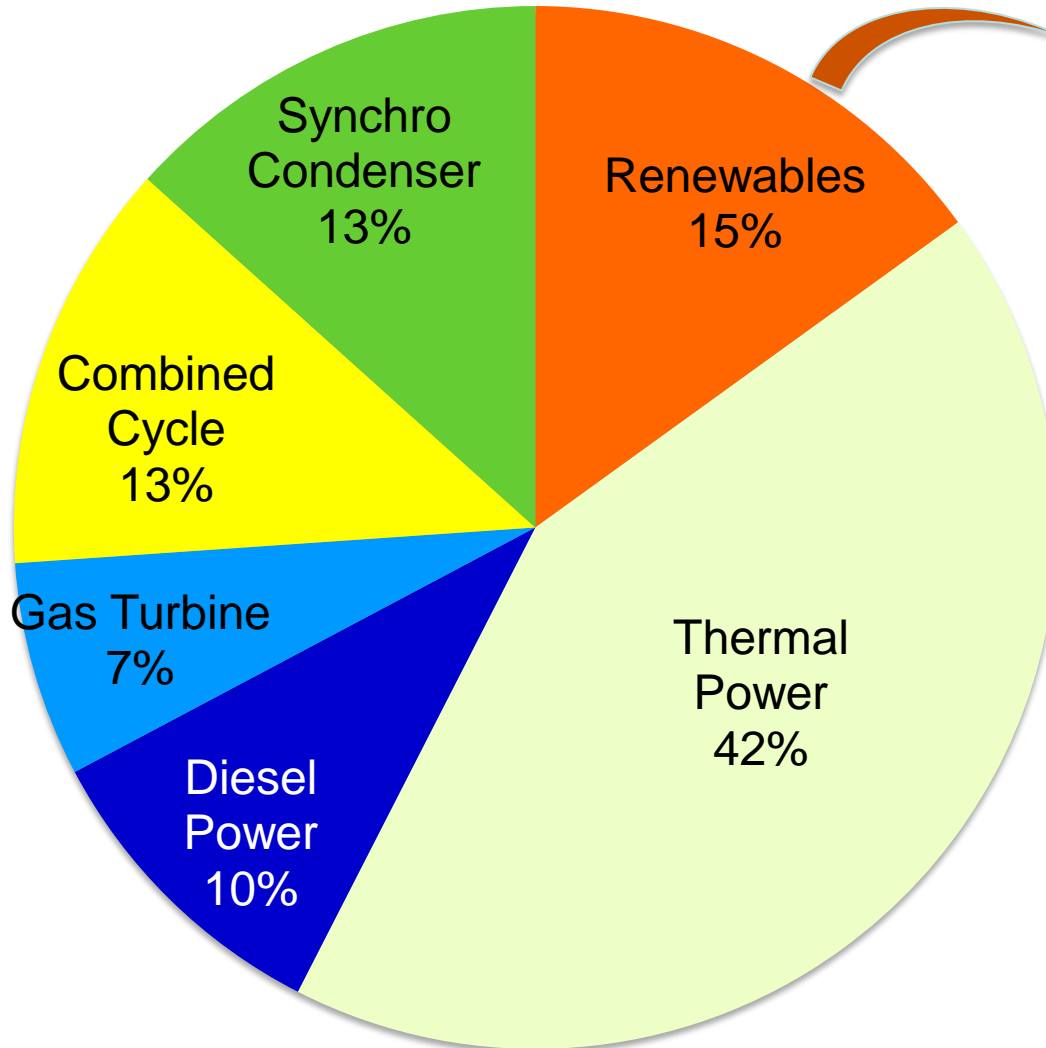
Wind   = 112.2 MW
PV   = 9.6 MW
Small Hydro, LFG, etc
**   = 2.66 MW**
Total   = 124.41 MW

Total Capacity = 822.2 MW

Energy Storage System
Renewables Power Output Smoothing
Peak Shaving & Load Leveling

Smart **T**ransportation

Smart Transportation is to build infrastructure
for electric vehicle which is the next generation transportation

CHARGING STATION

Smart Grid Informatio

kepco

LS

CHARGING STAND

전기자동차충전기
(Electric Vehicle Charger)

규 격 (Specification)	급속충전기 (Quick Charger)	완속충전기 (Normal Charger)
입력전압 (Input Power)	3Ø, 380Vac	1Ø, 22(Vac
출력용량 (Output Capacity)	50kW	7.7kW
출력전압 (Output Voltage)	직류 (DC) 50V~400V	1Ø, 220Vac
충전시간 (Charging Time)	20~30분 (min)	약 5시간 (About 5 hours)

kepco
Smart Transportation Consortium

스마트콘센트(Smart Tag)

전력사용량과 대기전력 관리가 가능한 콘센트

The Smart Tag is abale to manage the amount of
eletric power used and standby power.

KEPCO SMART PLACE CONSORTIUM
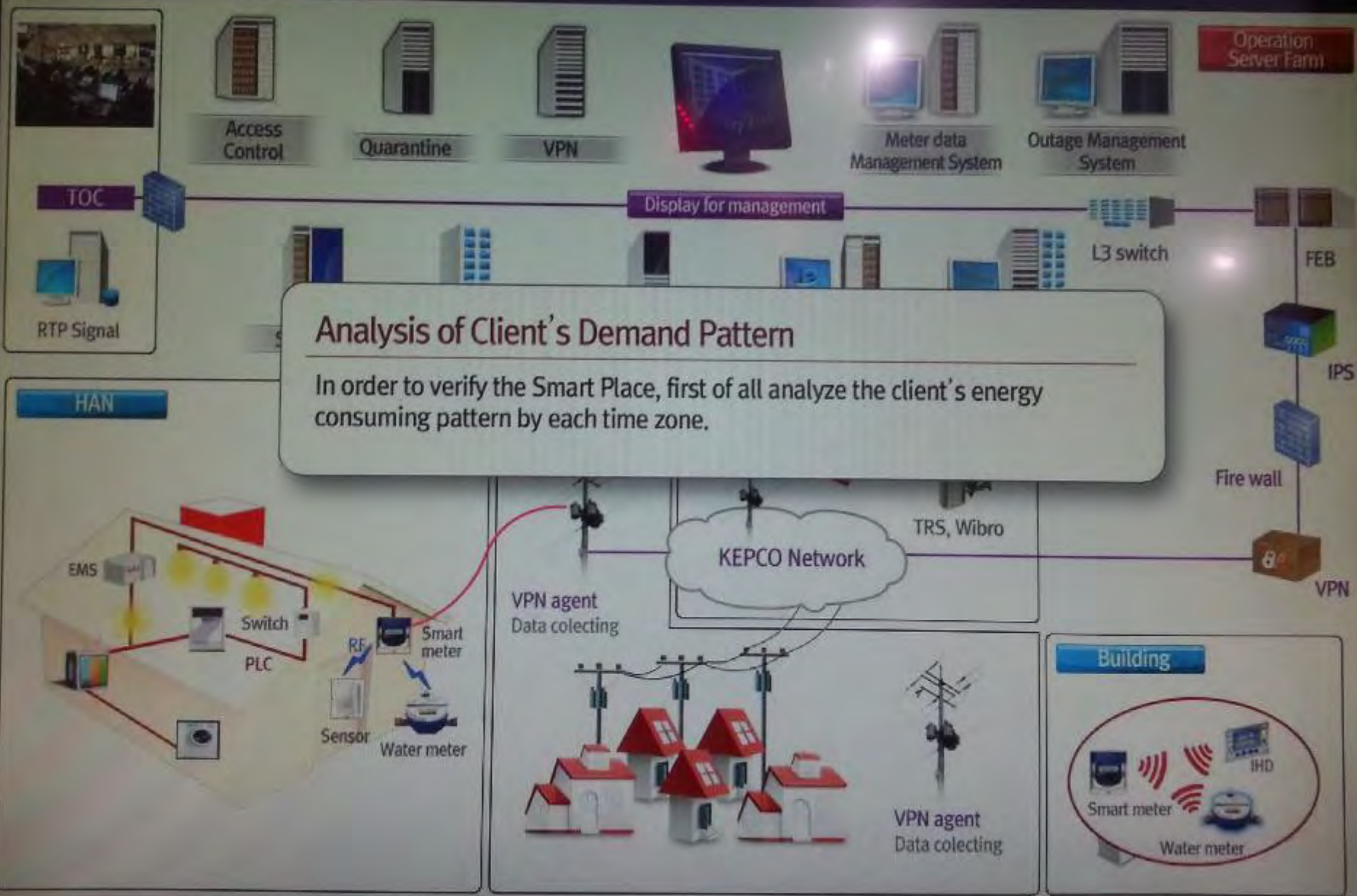
Analysis of Client's Demand Pattern

In order to verify the Smart Place, first of all analyze the client's energy consuming pattern by each time zone.

Business **M**odel **V**erification

9 Business Models developed and verified
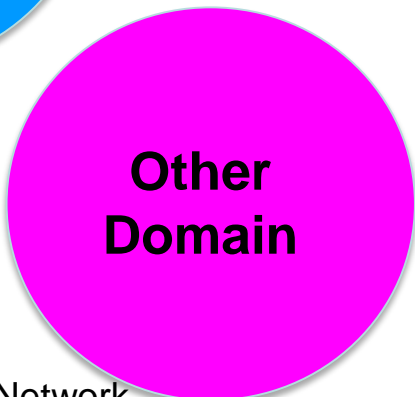
Consumer Domain

- **Electric Retail Service**
- **Demand Response**
- **Retail Market Service**
- **Virtual Power Plant Service**

Transportation Domain

- **EV Charging Service**
- **Mobile Charging Service**
- **EV Rental Service**

Other Domain

- **Energy Usage Consulting Service**
- **Load Leveling & Quality Improvement**

From: International Smart Grid Action Network

Conclusion - Driving Force

- Strong Policy for Smart Grid with Challenging Road Map

- International Smart Grid Action Network (ISGAN)

- Korean Smart Grid Association (KSGA)

- Smart Grid → Business

- 150 Companies
  - Electricity, heavy electric machines, IT, electronics, automobile, energy storage devices
  - Korean Electric Power Corporation
  - Samsung, LG, Hyundai, LS, SK Telecom, Korea Hydro & Nuclear Power, etc.

COMMUNITY SMART GRID

CASE STUDY:

CHIANG MAI WORLD GREEN CITY
CHIANG MAI, THAILAND

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Chiang Mai Rajabhat University, Thailand

Asian Development College for Community Economy and Technology
Maerim Campus, Chiang Mai, Thailand
– 30 km from Chiang Mai City
– 1 hr flight from Bangkok

CHIANG MAI

PHITSANULOK

BANGKOK

PUKET

7,000 rai ~ 2,700 acre ~ 1,120 hectare

500 rai ~
200 acre ~ 80 hectare
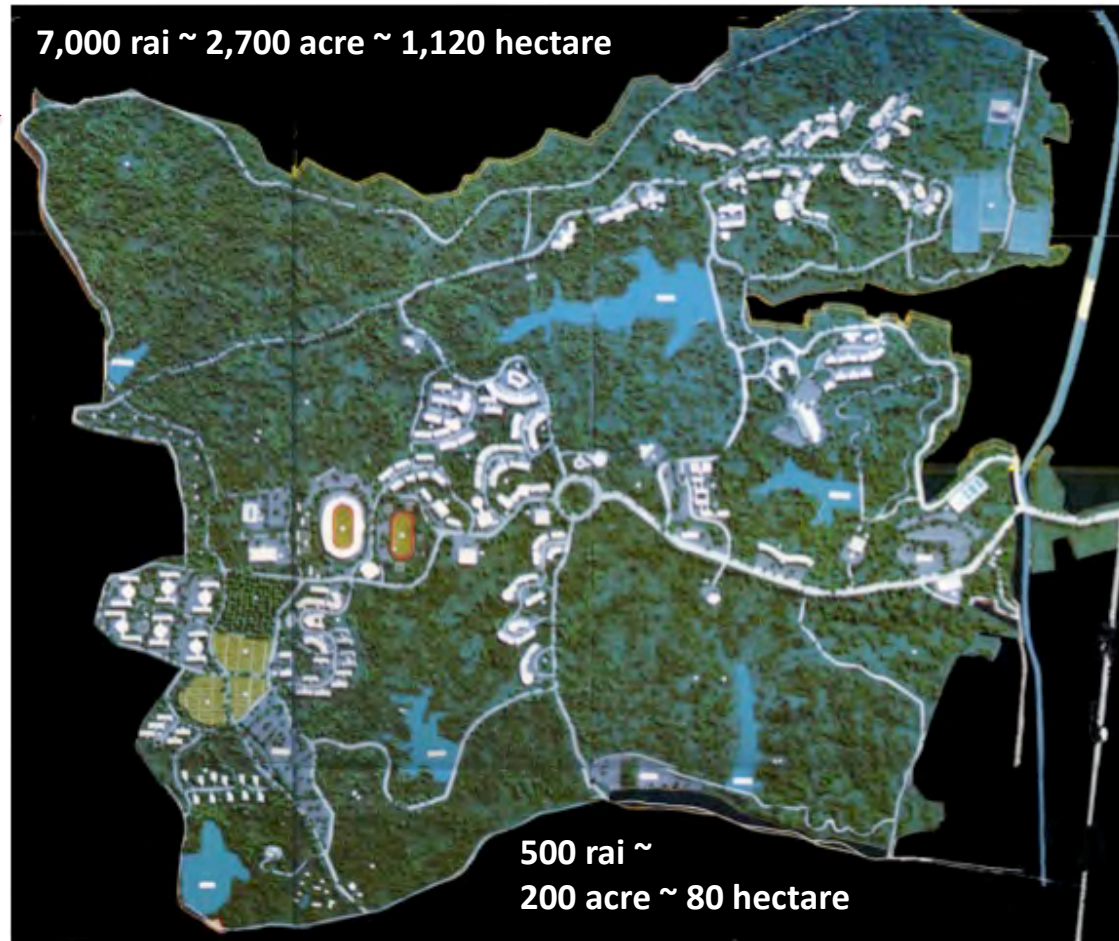
- Academic – R&D – Training institution for the well-being of the community by using green technologies.
- adiCET campus is on Chiang Mai World Green City (CMGC).
- Smart Community – Model Community uses 100% renewable energy.
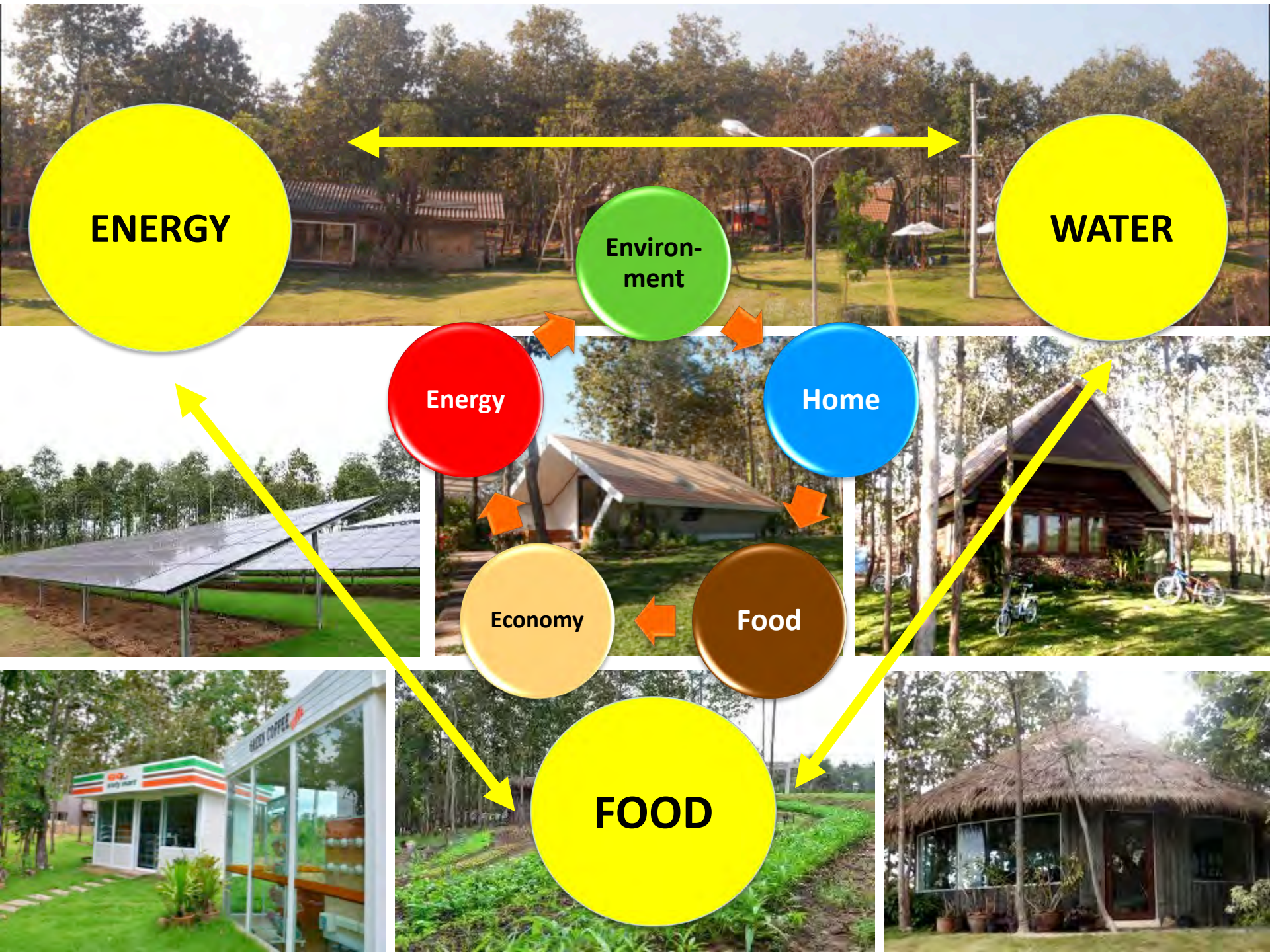
ENERGY

WATER

Environ-ment

Energy

Home

Economy

Food

FOOD

Research Concept:
Sufficiency Economy → Bioenergy Cycle

W. Rakwichian
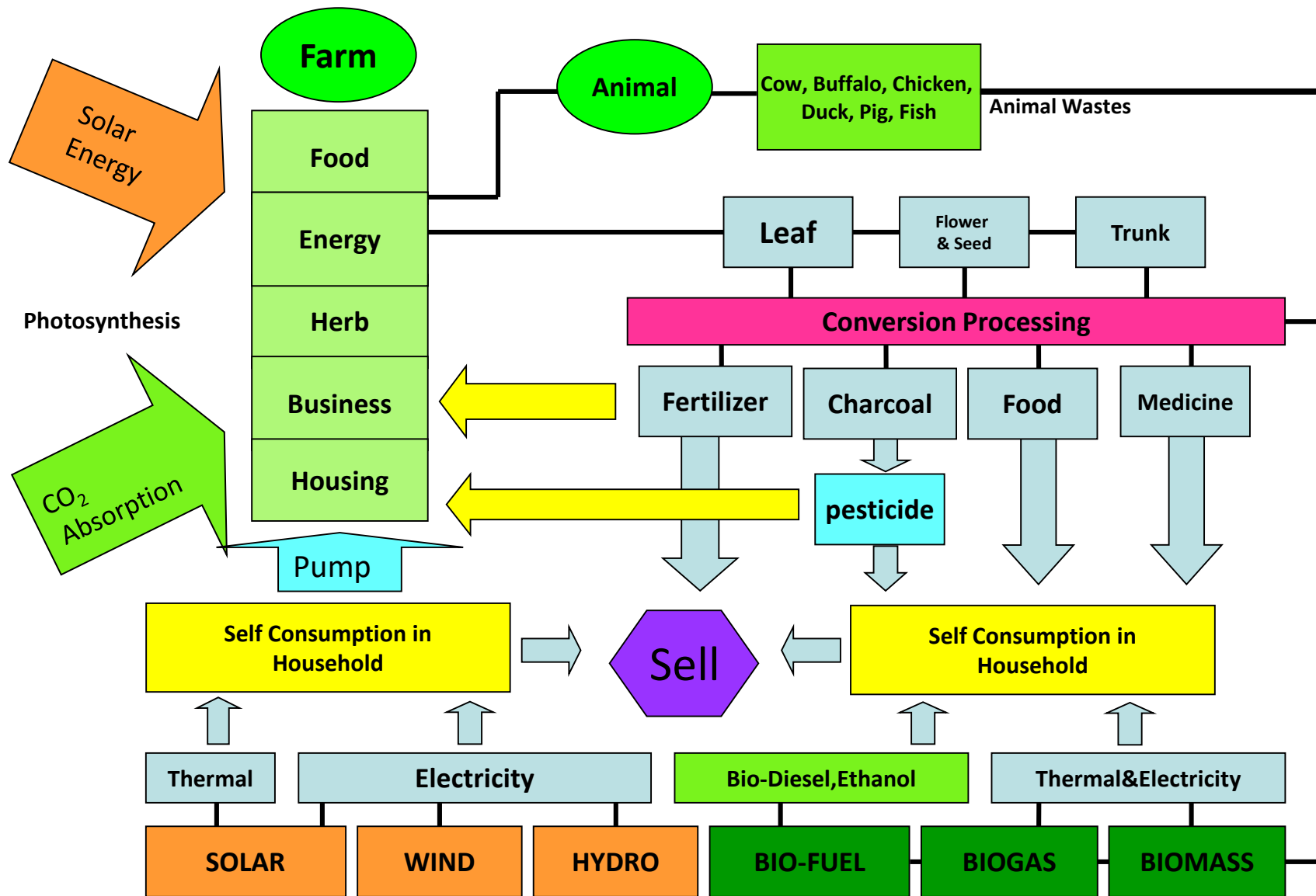
Goal

"Smart Grid Infrastructure for Green City Development"

Peak (Day Time)

1. Wind   6. Biogas
2. Energy Storage 7. Biomass
3. Charge controller 8. Sub-station
4. Inverter   9. Load
5. Solar

Chiang Mai World Green City: Real Living Learning Park

Labels visible in the aerial image:

- Community Product
- DC Home
- Community Business
- Green Resort
- Community Restaurant
- PV Stand Alone
- DC Microgrid
- Recycle Road
- Household Biogas
- Community Power Training Center
- Biodiesel Generator
- Exhibition Center
- Solar Pumping
- Energy Efficient Building
- AC Microgrid
- Biogas
- Low Carbon Agriculture
- Natural Material Building
- PV Grid Connected
- Community Solar Farms
- Smart Water System
- Biomass Gasifier
- Energy Crop
- Hydroponics
- Fertilizer Organic wastes
- Wood chip Wood pellet

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Renewable Energy & Green Technologies

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Energy

1. PV 25.5 kW DC Microgrid
2. PV 25 kW AC Microgrid
3. PV 702 kW Community Solar farm
4. PV Rooftop 3.5 kW
   Grid Connected
5. PV Bus stop 2.64 kW
   Stand Alone & EV & Charging Station
6. PV Pumping 3 kW
   Stand Alone
7. Biodiesel Generation 40 kW
8. Biomass Gasifier 20 kW
9. Charcoal/ Energy Efficient Stove
10. Biogas Fix Dome 16 m^3
    (~1.5 kW)
11. Biogas Fix Dome 1 m^3 x2
12. Biogas Generator 5 kW

Construction/Building

1. Road from waste plastic bag
2. Energy efficient house EPS x1
3. Energy efficient conference room x3
4. Energy efficient classroom x2
5. Low cost house x2
6. Coffee Shop
7. Minimart
8. Restaurant
9. Residential housing x 16
10. DC Smart Home

Green Business

1. Green Coffee Shop
2. Restaurant
3. Minimart
4. Bilingual Eco-education Learning

Agriculture

1. Smart Farm
2. Low Carbon Agriculture
3. Smart Watering System
4. Organic fertilizer from biogas system
5. Energy Crop

Environment

1. Green City Carbon Footprint Calculation
2. Biomass waste management
3. Water management
4. Forest Conservation and land management

Smart Community – DC Smart Grid

Biodiesel Generator 40 kW

PV DC Microgrid 25.5 kW

Biomass Gasifier 20 kW

PV AC Microgrid 25 kW

Off-grid: PV DC Microgrid Battery Bank (~100 kWh)
Backup power/ Power Control and Stability

On-grid: PV AC Microgrid Battery Bank (~100 kWh)
Backup power/ Power Control and Stability

Biomass Gasifier

Biomass Gasifier: electricity for base load
Biochar/Charcoal: food, heat, soil conditioner

Energy from waste agriculture products
"Solve open field burning"

D. Kantayos – Intern
W. Photacharoen - Researcher

Diesel Generator 40 kW
Backup Power

DC Smart Plug
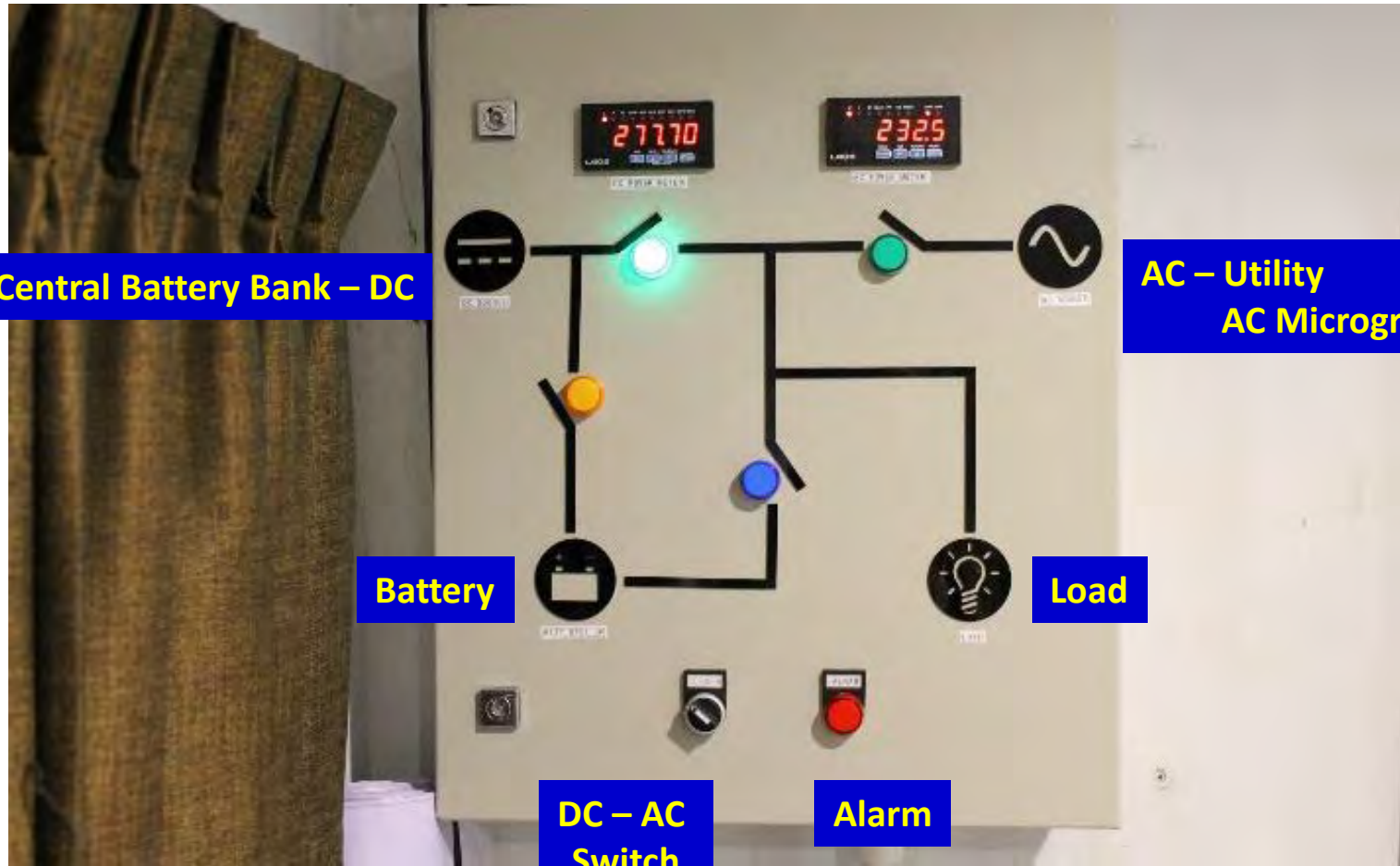
Online Function

Web and Application

- Controls
- Monitors
- Program

Measurement Function

- Power consumption
- Behavior

⚠ Safety

Smart Function

- Smart Connection
- Smart Data Collection
- Energy saving

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Expanded Polystyrene Foam

Reuse material house

Zone C: Green Exhibition

Tissue Culture Lab

Community Biogas

K. Chuamuangpan – Intern
T. Takam – Intern
T. Seethong – Intern
C. Kongudomsap – Researcher

Smart Farm

PV Water Pumping
Moisture Sensor

Smart Farm

Soil Moisture Sensor

Water Sprinkler

Flow Sensor
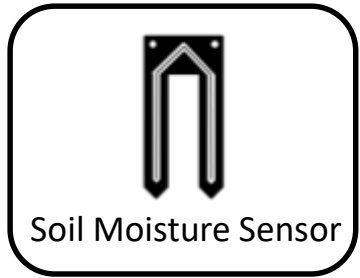
Soil Moisture 40-54%

Solar Cell

Soil Moisture 55-74%

Solenoid Valve

Water Pump

Water Tank

Solar Charger

Solenoid Valve

MCU

Microcontroller

Soil Moisture 75-90%

Solenoid Valve

Battery
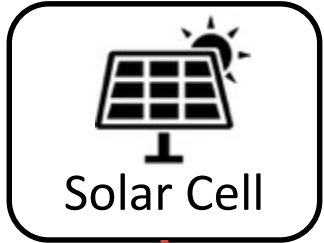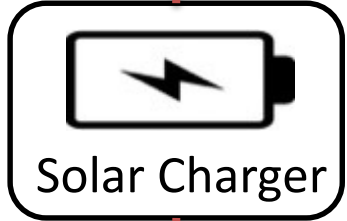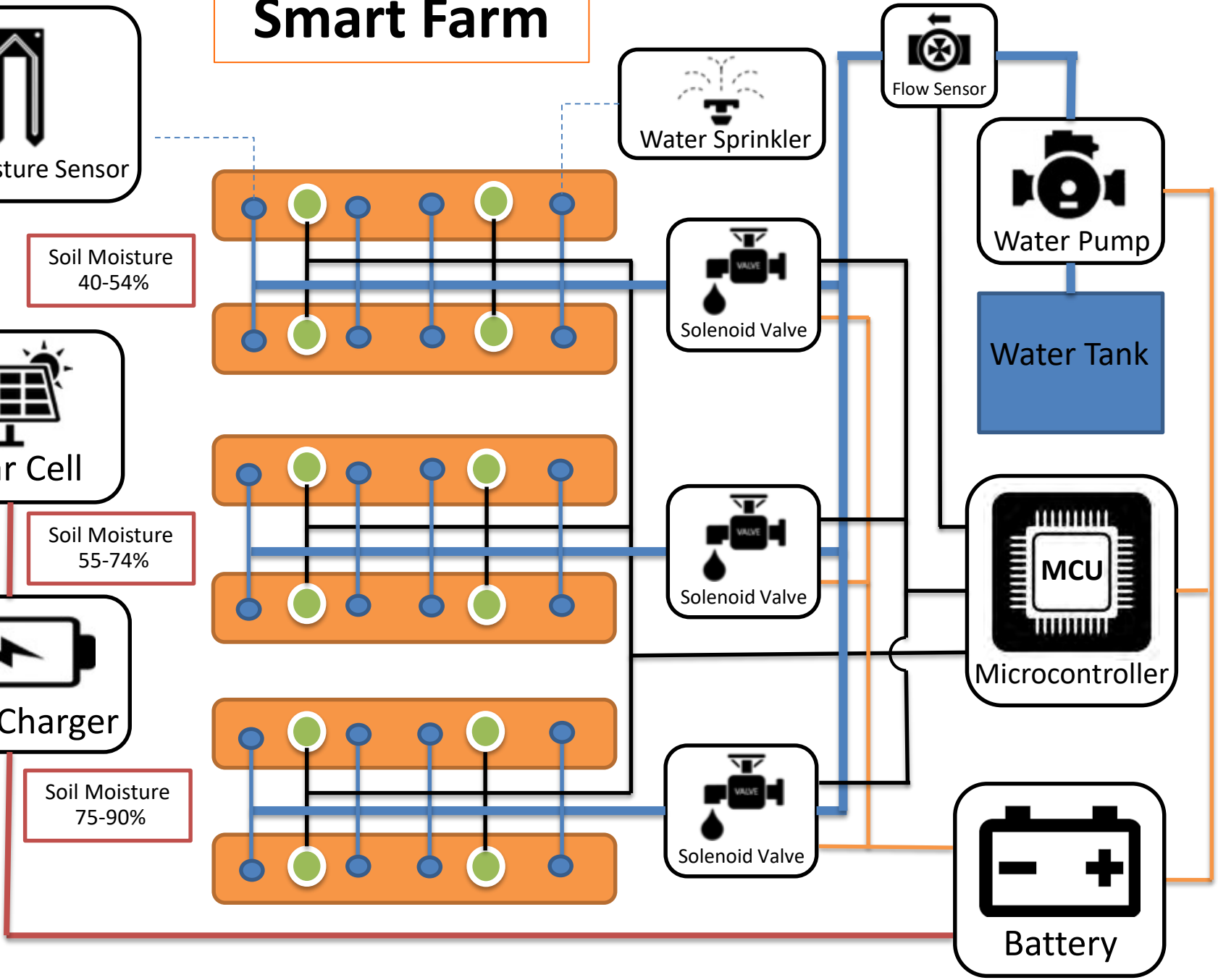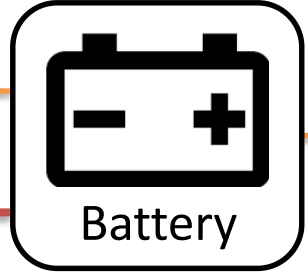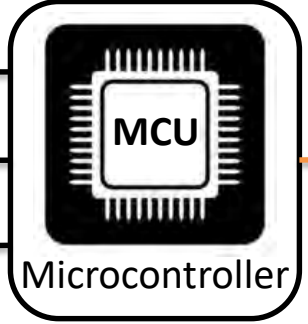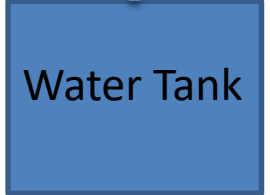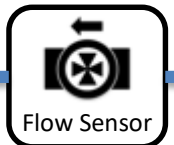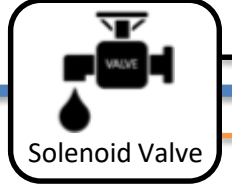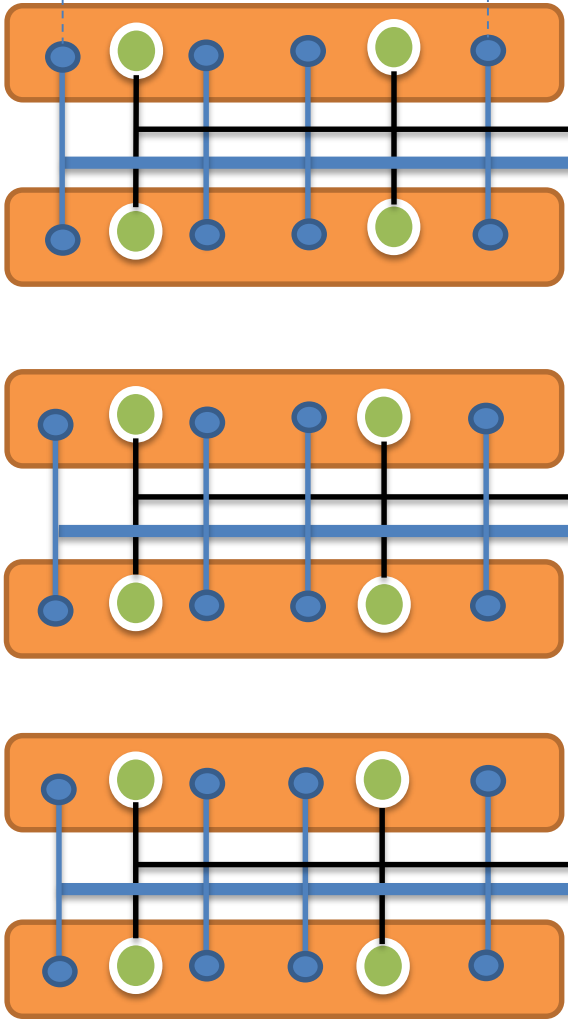
Waste Plastic Road

W. Lakas – PhD

Solar Bus Stop
EV Charging Station

T. Jaorum - Intern
W. Luangpraditkul - Researcher

700 kW Solar Farm
10.00-11.00 น.

รถรางรับ-ส่ง
สามารถเดินได้ 200 เมตร

Community Business
11.20 น.

PV DC Community Grid
11.10 น.

Smart Home
11.30 น.

เดินอ้อมทางร้านอาหาร
ไปฟาร์ม

Smart Farm
11.40 น.

BioEnergy Cycle Center
11.50 น.

Website of Community Smart Grid

Thai/ English/ Chinese

Cr. Beni Sugiarto

Workshops

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Mae-Ta Energy Planning Meeting

Community Biogas System Map

11 Households
60 Cattles

25 Households
120 Cattles

14 Households
70 Cattles

ตัว

จ

School

Temple
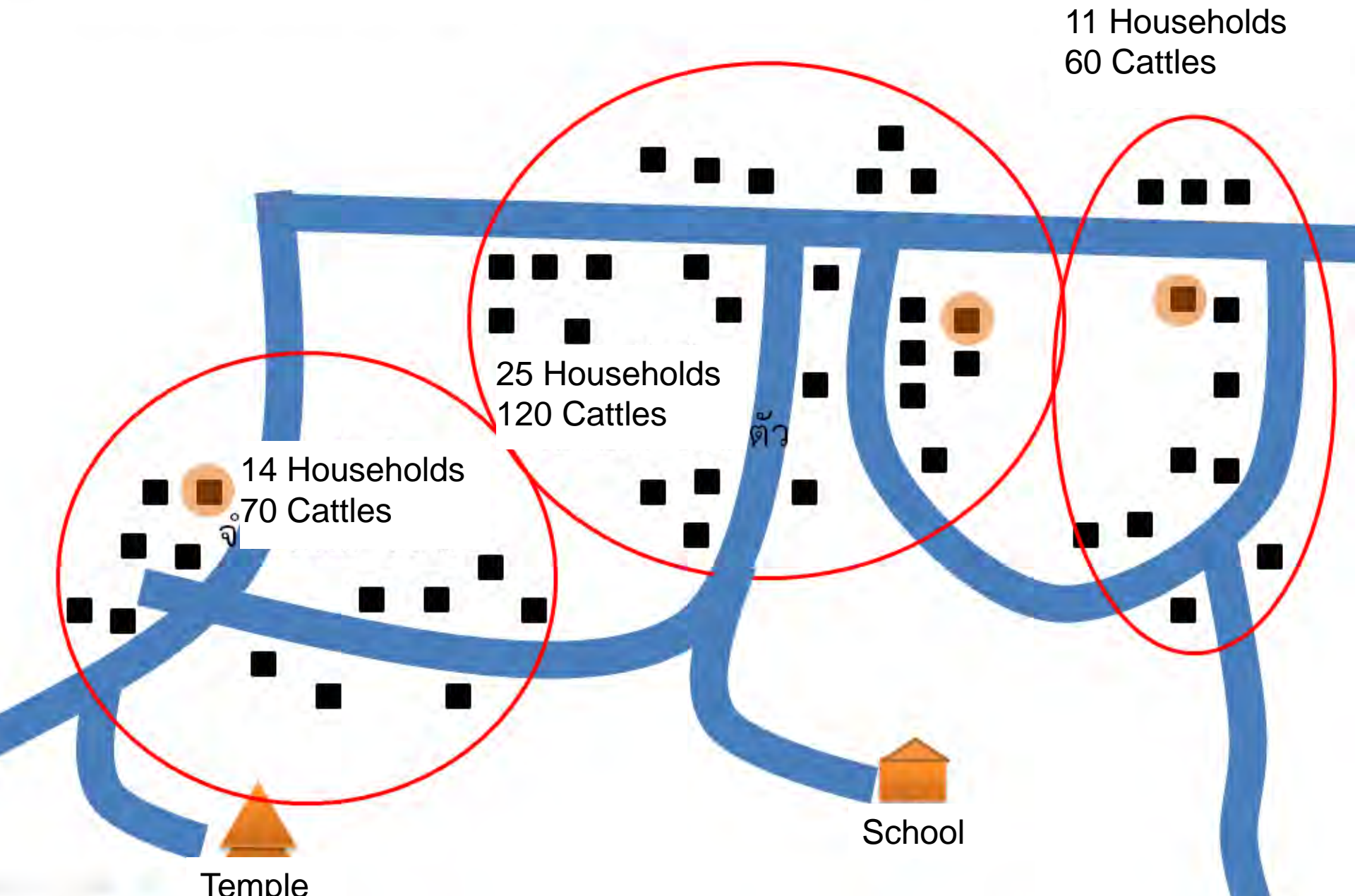
Sharp Asian Solution Installation - 100 kW Rooftop PV

on 14 Public Buildings, 4 Water Pumping Station

Summary – adiCET

- Concept: Renewable Energy and Green Technology for Local Community
  - Integrate with Community Resources - Ways of Living
  - Sufficiency Economy + Green Technologies (RE & EE)
  - Smart Grid as Infrastructure for Green Community Development

- Smart Community
  - Living/ learning/training center for student, researchers, and general public
  - Projects focus on appropriate technology and methods to solve real green city problems
  - Train problem solving skills relating to RE & Green Technology for local issues

DC MICROGRID

CASE STUDY:

SMART COMMUNITY, CWGC

CHIANG MAI, THAILAND
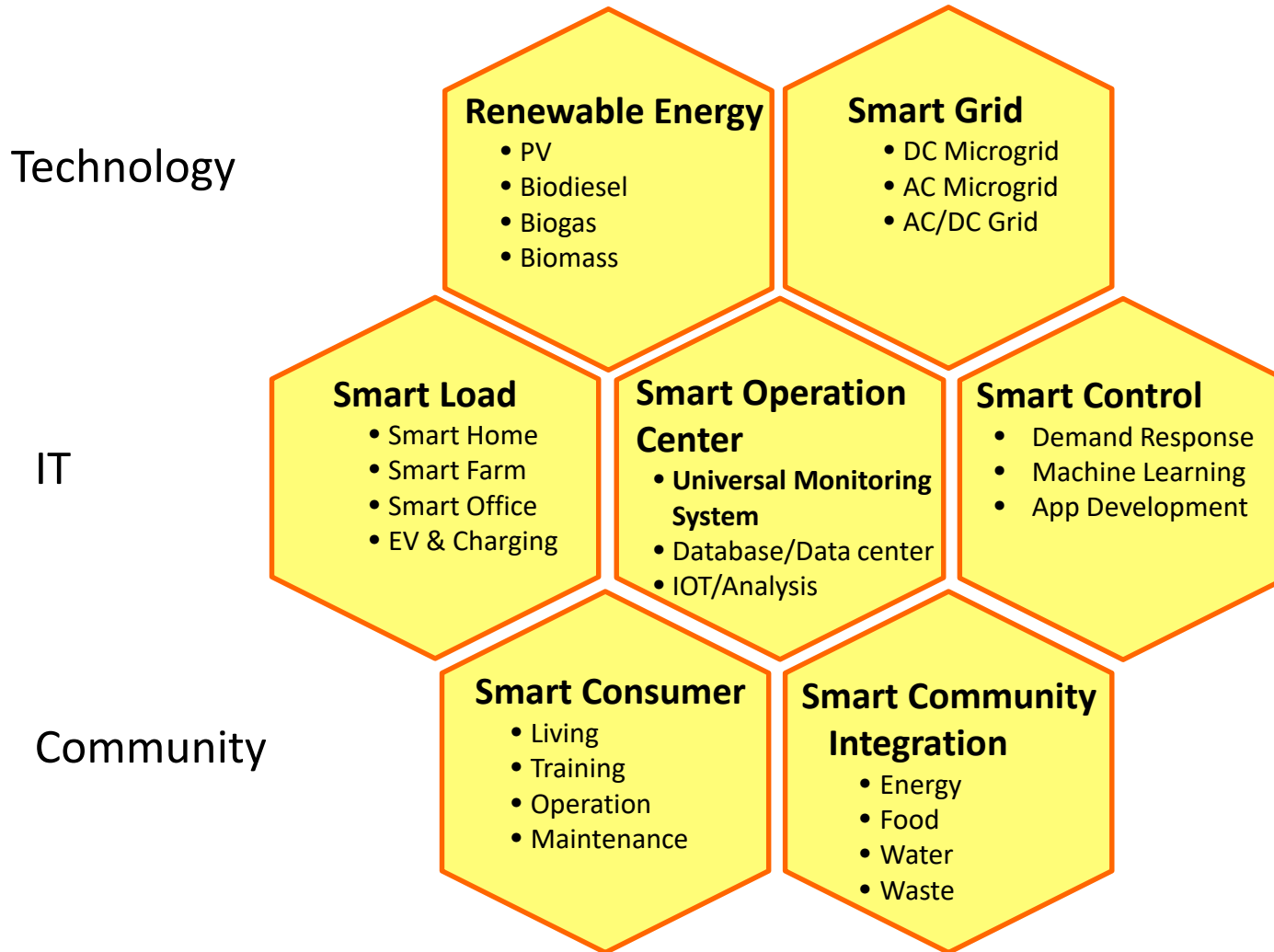
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adiCET Smart Grid Component

Technology

Renewable Energy
- PV
- Biodiesel
- Biogas
- Biomass

Smart Grid
- DC Microgrid
- AC Microgrid
- AC/DC Grid

IT

Smart Load
- Smart Home
- Smart Farm
- Smart Office
- EV & Charging

Smart Operation Center
- **Universal Monitoring System**
- Database/Data center
- IOT/Analysis

Smart Control
- Demand Response
- Machine Learning
- App Development

Community

Smart Consumer
- Living
- Training
- Operation
- Maintenance

Smart Community Integration
- Energy
- Food
- Water
- Waste

Scope of DC Community

- Living Laboratory for community transition from
  AC → AC/DC → DC Community

- Evaluate Low Cost - Low Voltage DC Community Power System at the Smart Community
  - Phase 1: Lightings 24 VDC/ 1 House 240 VDC
  - Phase 2: Household Appliances 260-297 VDC

- Modify/Testing Household Appliances for DC & AC usage
  - Lighting, Refrigerator, Air Conditioner, Water Heater, Television, Computer, Rice Cooker, Microwave, Washing Machine

- Evaluate appliances during operation, stability and safety
  - Full DC
  - Full AC
  - Mixed DC & AC

2nd Phase DC Microgrid

Mode	Central Battery Voltage Stage	Usage
Full	297 – 260 VDC	DC use directly from Central Battery bank
Battery Boosting	260 – 250 VDC	DC from Battery bank (260 VDC) & Booster (54 VDC)
Biodiesel Generator Start	250 – 242 VDC	Generator - Charge Battery Bank - Charge Booster Batteries If ran out of fuel, AC from Utility will convert to DC
Battery dead	Below 242 VDC	Automatically switch to AC

Note: Voltage range depends on Charger Specification, battery voltage range and electrical load device requirements.
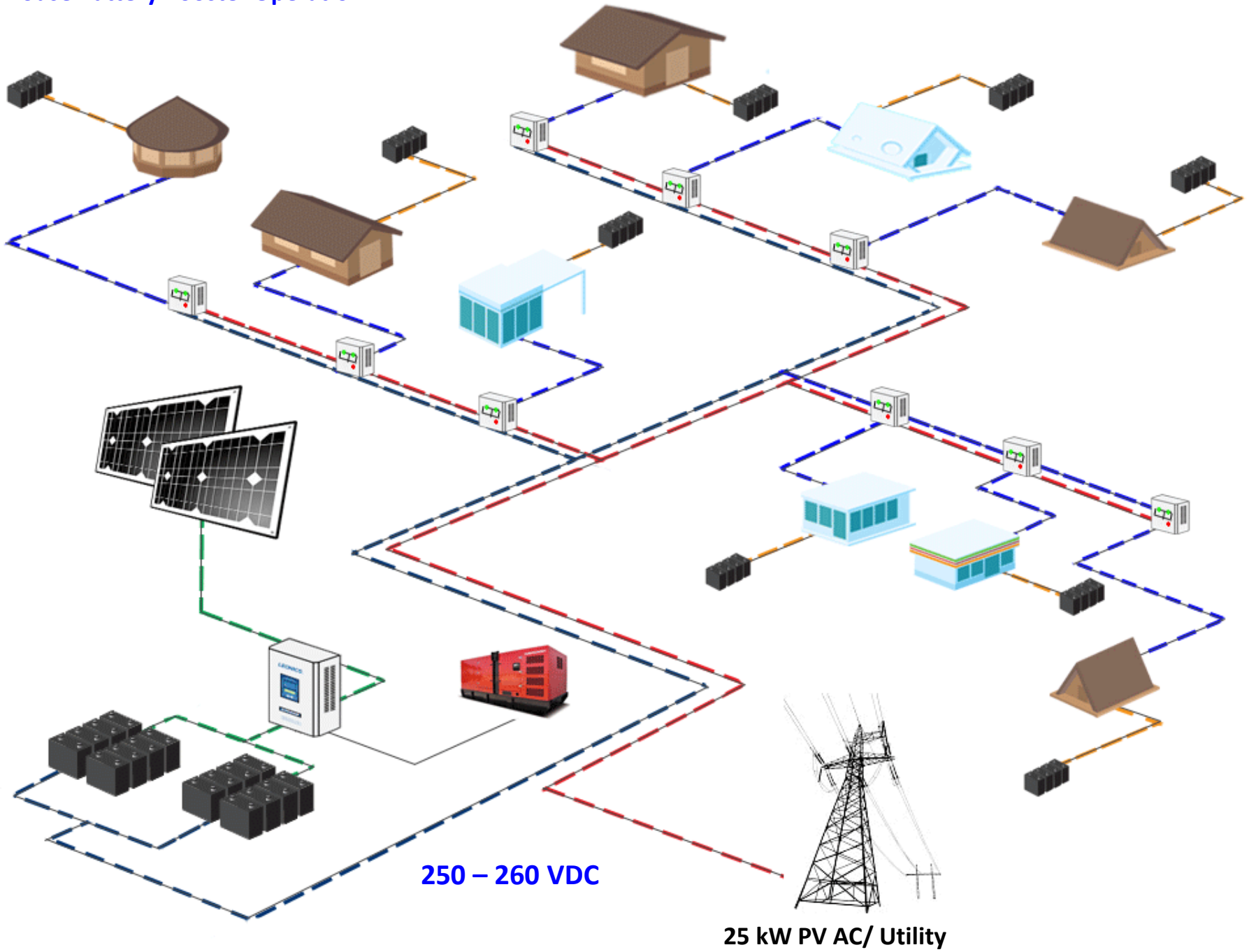
Phase 2:
Building Power Consumption

Daytime DC & AC Operation
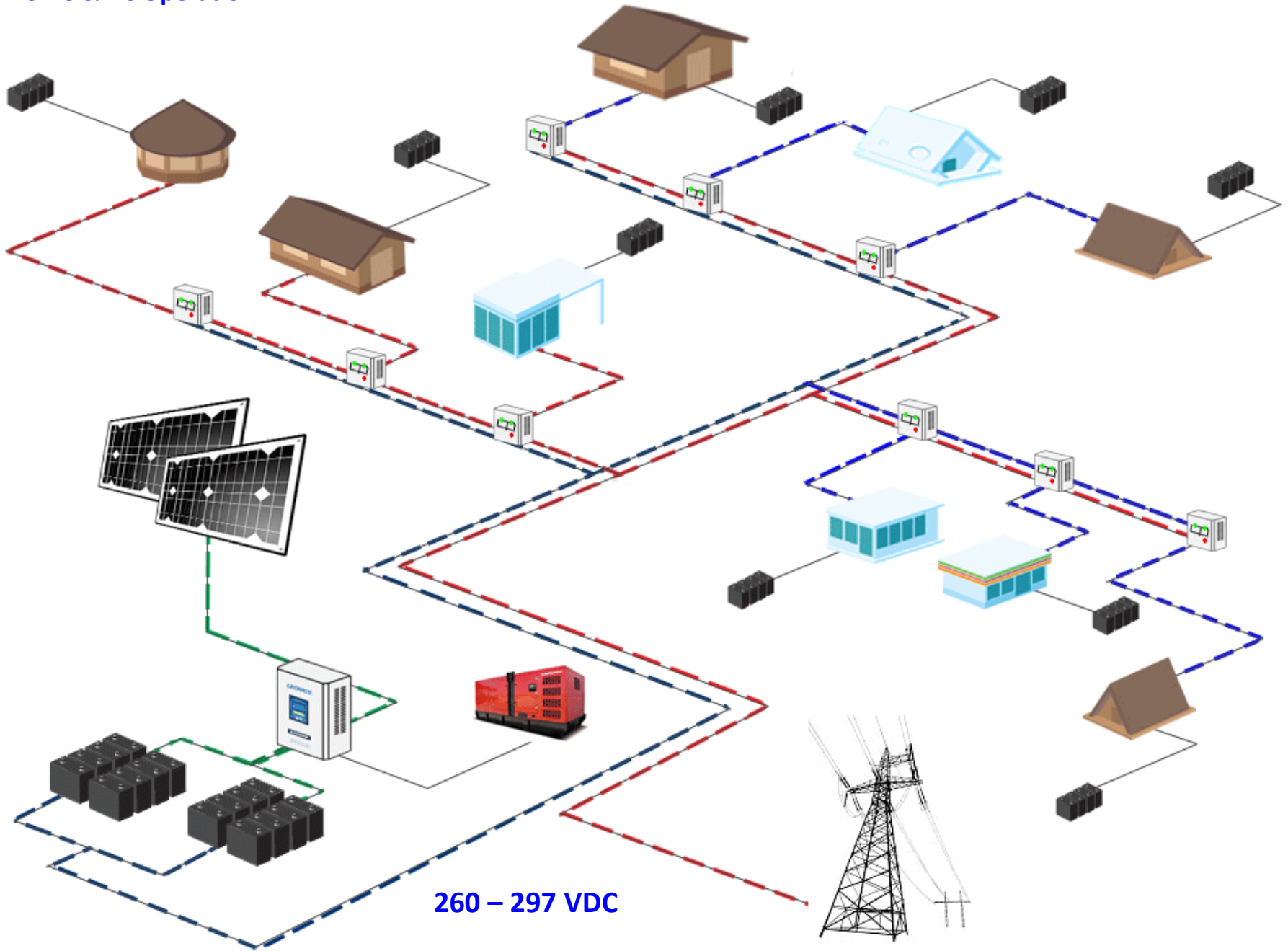
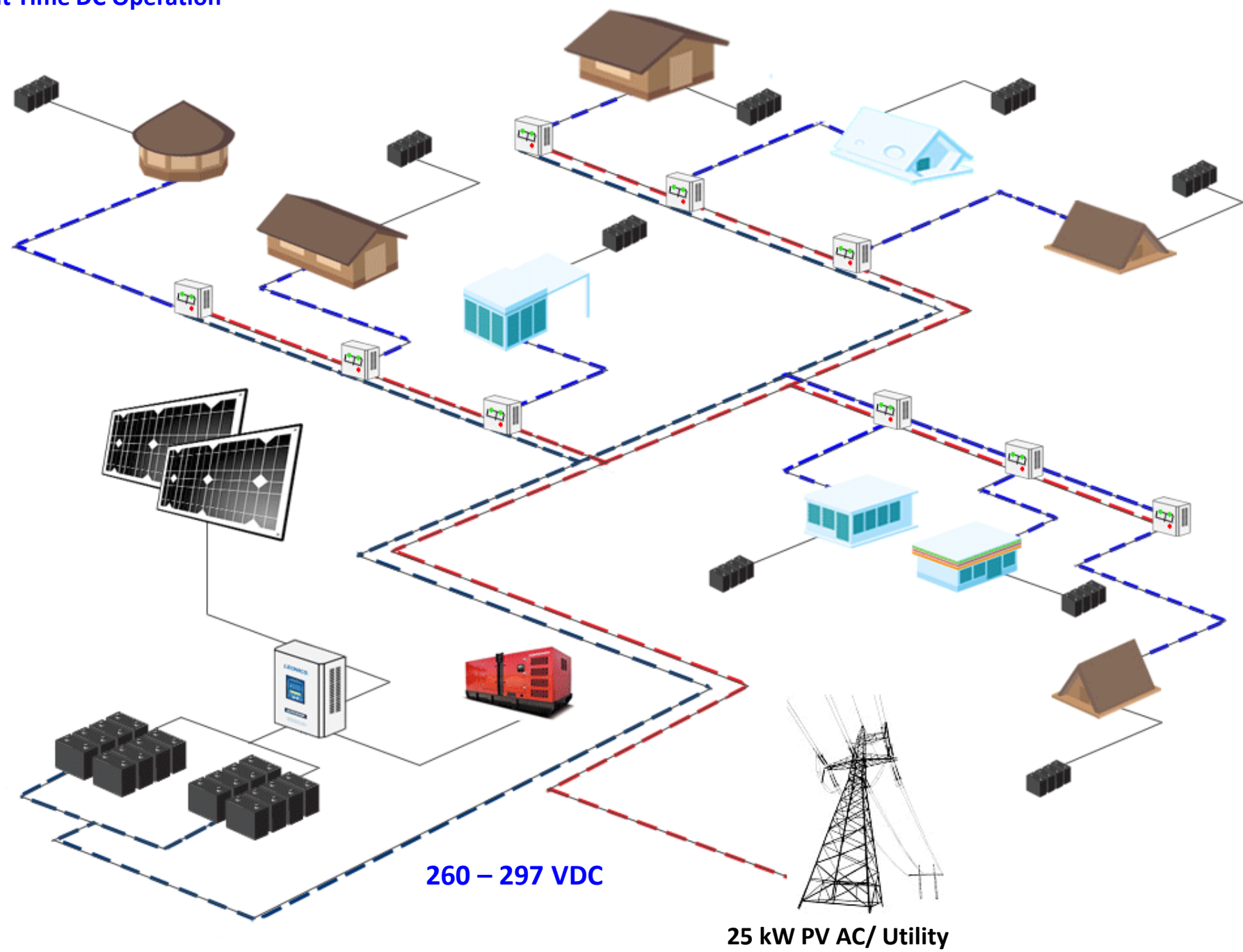**260 – 297 VDC**

25 kW PV AC/ Utility

PV & House Battery Booster Operation

250 – 260 VDC
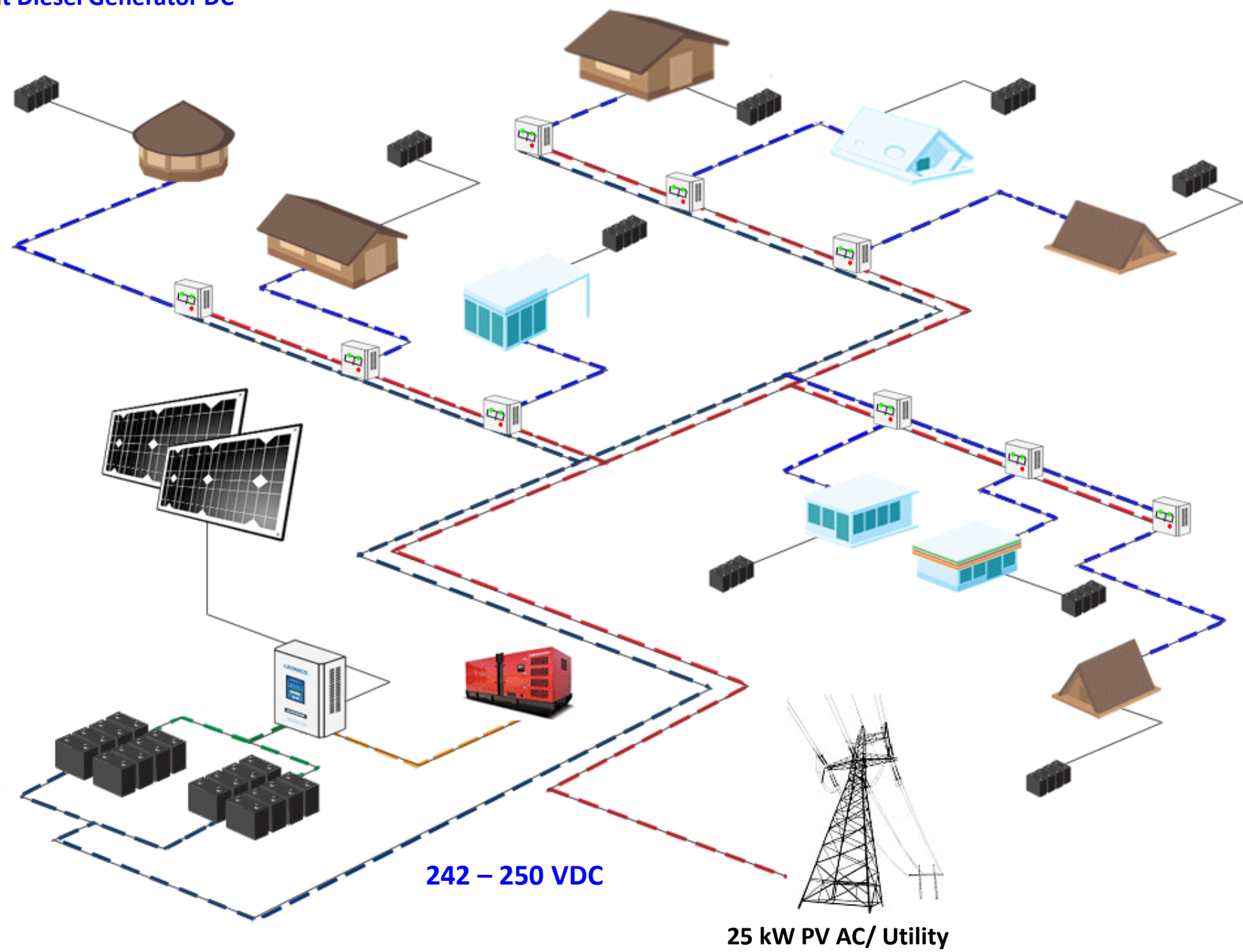
25 kW PV AC/ Utility

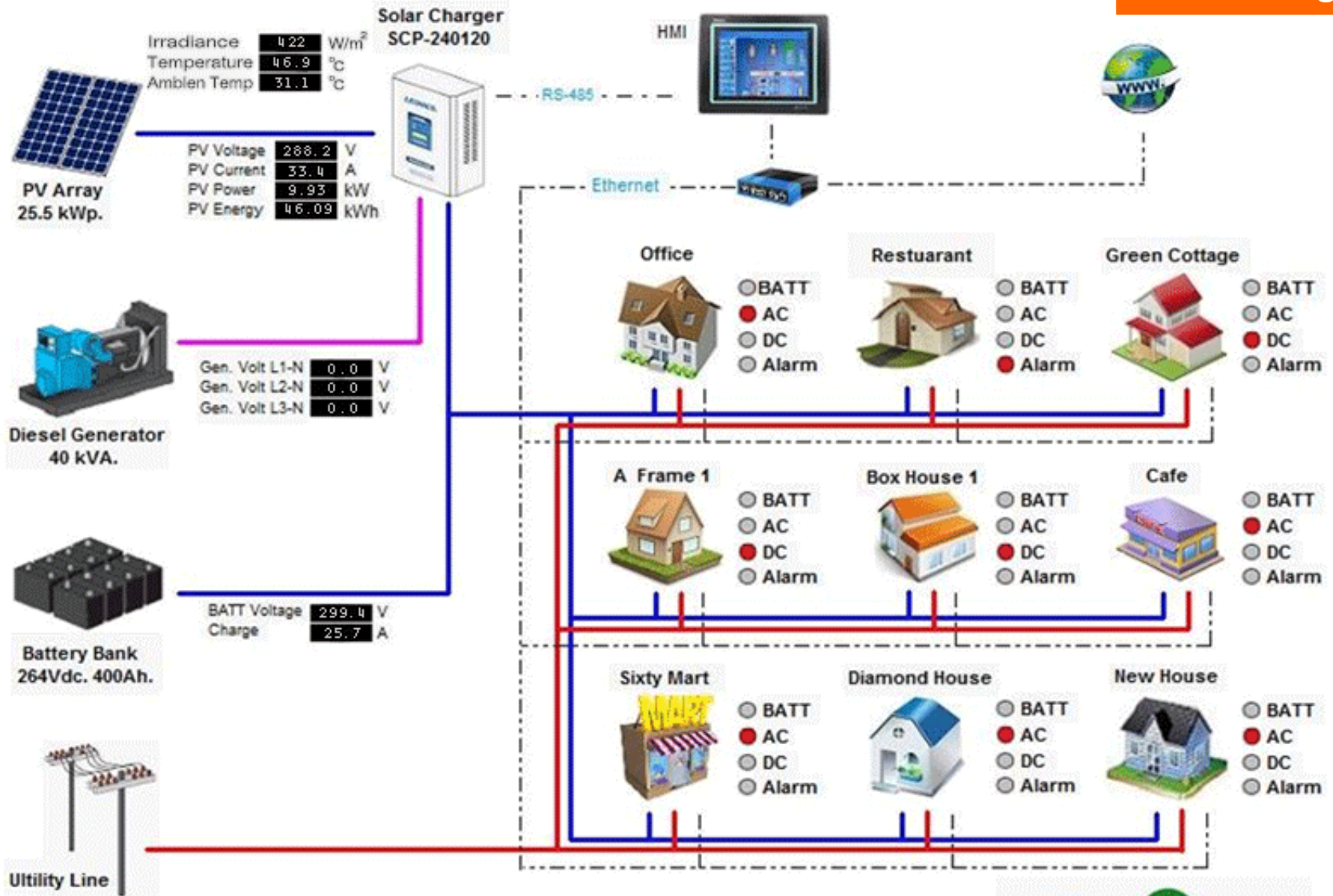**Night Time DC Operation**

260 – 297 VDC

25 kW PV AC/ Utility

Night Diesel Generator DC
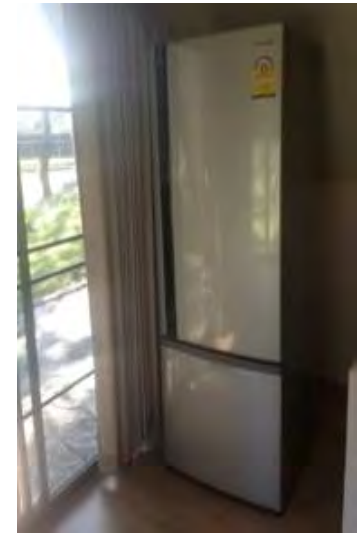
242 – 250 VDC

25 kW PV AC/ Utility

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- **LED lightings**

- **Refrigerator**

- **Water Heater**

- **Television**

- **Air Conditioner 9,000 btu**

- **Air Conditioner 13,000 btu**

- **Air Conditioner 18,000 btu**

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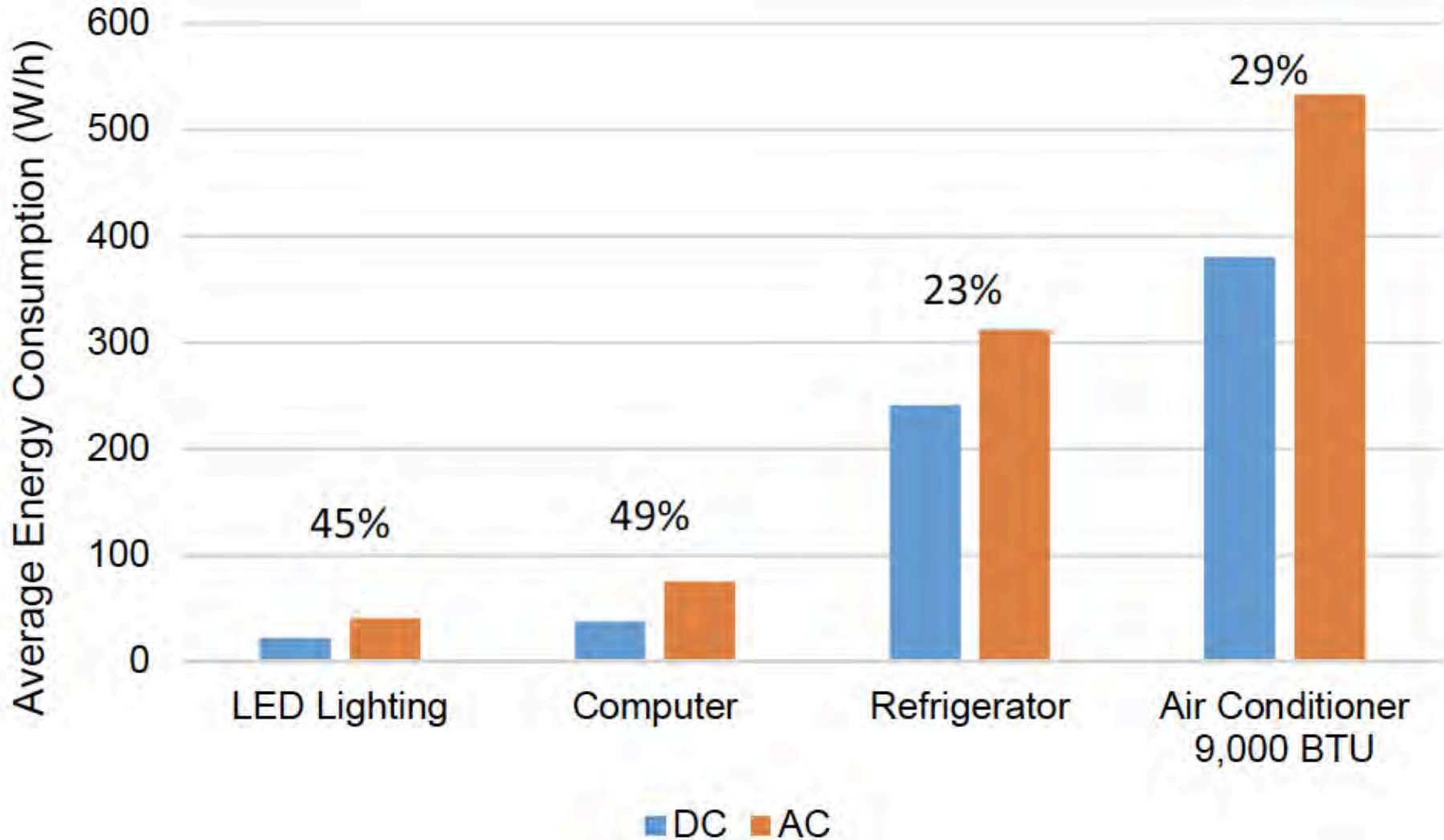
- **System Issues**

  - Stability/Durability of components of the power supply when switching between DC and AC (capacitor, PLC)

  - The online connectivity with university network

  - Integrating Distributed Generations (voltage range - Diesel Generator)

- **Nature Issues**

  - During the rain, the voltage fluctuates from the utility line which cause the Hybrid Microgrid system to be disrupted.

  - Animals

- **Human Issues**

Goal

Demo-Site for

Energy Hybrid Systems
Community Smart Grid
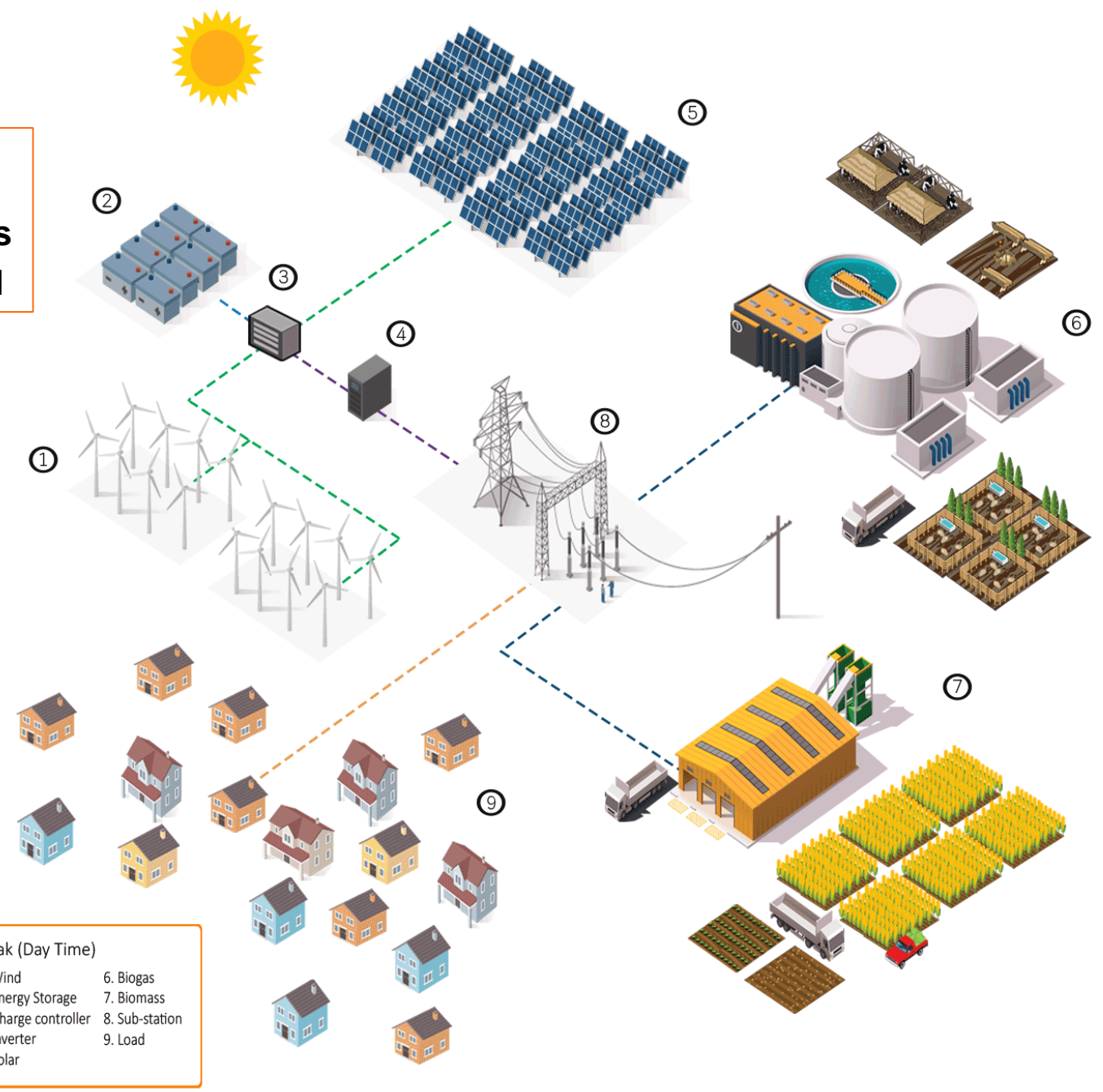
② ③ ④ ⑤ ⑥ ⑦ ⑧ ⑨ ①

Peak (Day Time)

1. Wind   6. Biogas
2. Energy Storage   7. Biomass
3. Charge controller 8. Sub-station
4. Inverter   9. Load
5. Solar

Goal: Realtime - Smart Community Monitoring

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Legend:
- Electricity
- Heat
- Water
- Biomass/Vegetables
- Compost/Charcoal/Biochar
- Biomass Waste
- Household Wastes
- Money

2017 Approved Project for Energy Conservation Fund, Ministry of Energy, Thailand

Smart Community Database

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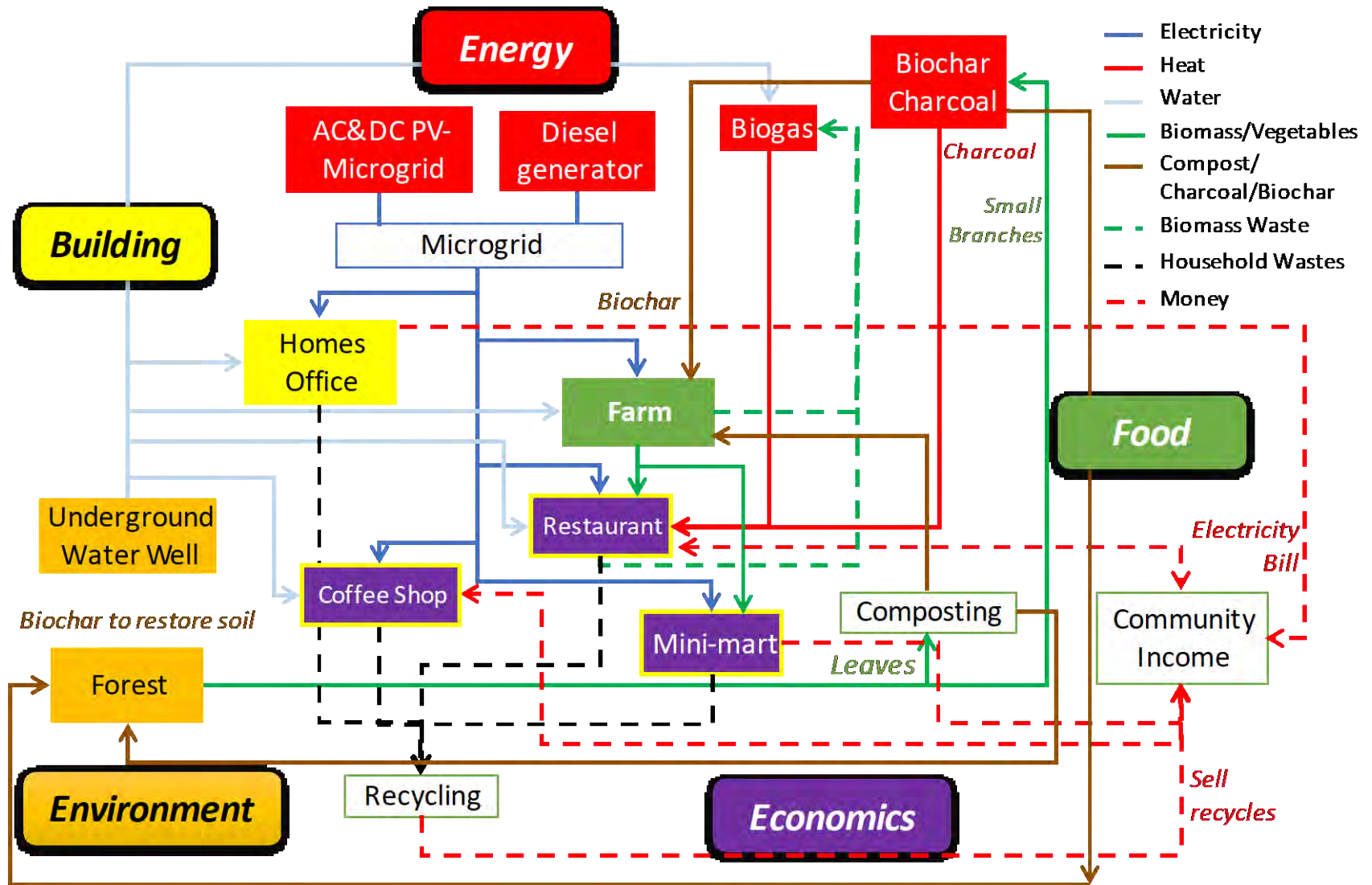
Environmental

Recycle waste (kg)
Organic waste (kg)
Hazardous waste (kg)
The frequency of dumping waste (time)
Date/time

Food

Vegetable production (Kg)
Using fertilizer (Kg)
Another material in cultivation (Kg)
Consumption and sale of vegetable (Kg)
Date/Time

Energy

Production (kwh)
Consumption (kw)
Raw material of biogas and charcoal production (kg)
Biogas and charcoal yield/consumption (kg)
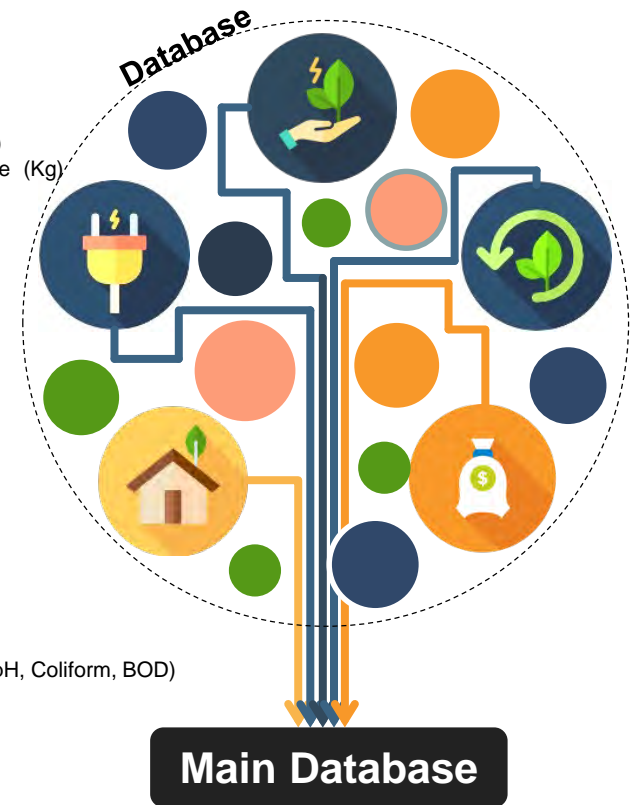Fuel consumption in transportation (L)
Date/time

Economic
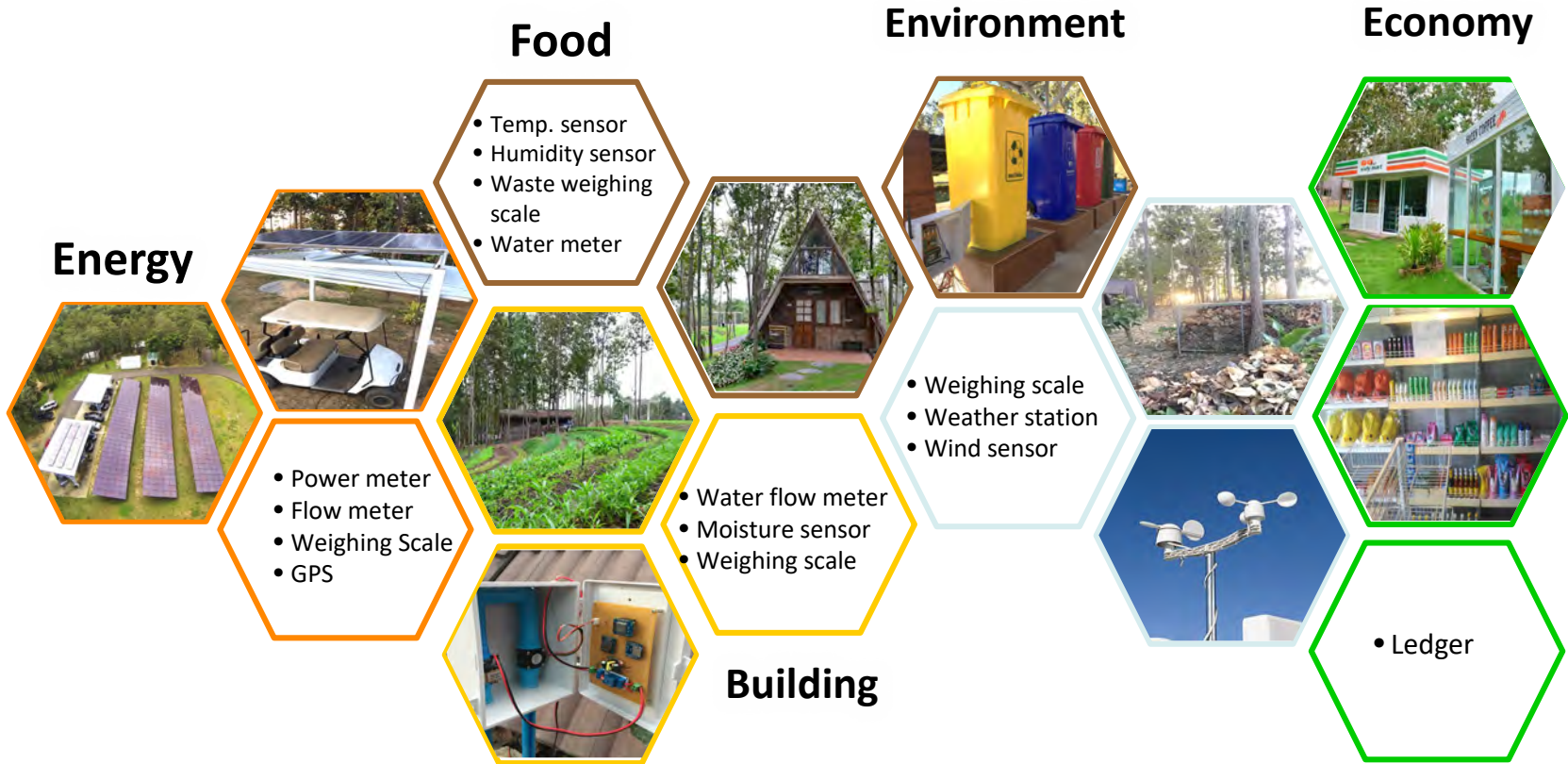
Expenses (Baht)
Income (Baht)
Date/Time

Building

Indoor/Outdoor temperature (°C) and humidity (%)
Outdoor solar intensity (W/m2) and wind velocity (m/s)
Water consumption (L) / Water flow rate average (L/min) and quality (Nephelometric Turbidity Units, pH, Coliform, BOD)
Particulate in the air (PM)
The frequency of using water (Time)
Date/Time

Database

Main Database

Instruments for Data Collection

Food

- Temp. sensor
- Humidity sensor
- Waste weighing scale
- Water meter

Environment

Economy

Energy

- Power meter
- Flow meter
- Weighing Scale
- GPS

- Water flow meter
- Moisture sensor
- Weighing scale

- Weighing scale
- Weather station
- Wind sensor

- Ledger

Building

THE START OF SMART GRID…..

START WITH SMART HOME

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- What is a smart home?
- What functions do you want your smart home to have?

- What are the groups of the functions?
- How can smart home support smart grid?

Group 1

1. Control for irrigation the land by app and sensors
2. Control the light time outside automatically
3. Charging the Electric car and motorcycles
4. Safe house by alarm System + Camera
5. Wifi Communication for manage household appliances like TV, air conditioner, plug, heating water, cleaning, machine, playing music
6. Make smart light flash when the package is on the way
7. Smart Parking of the car, washing cloths,
8. Preparing coffee by boiler, video, phone, computer printer, telephone
9. Audio and video application, internet
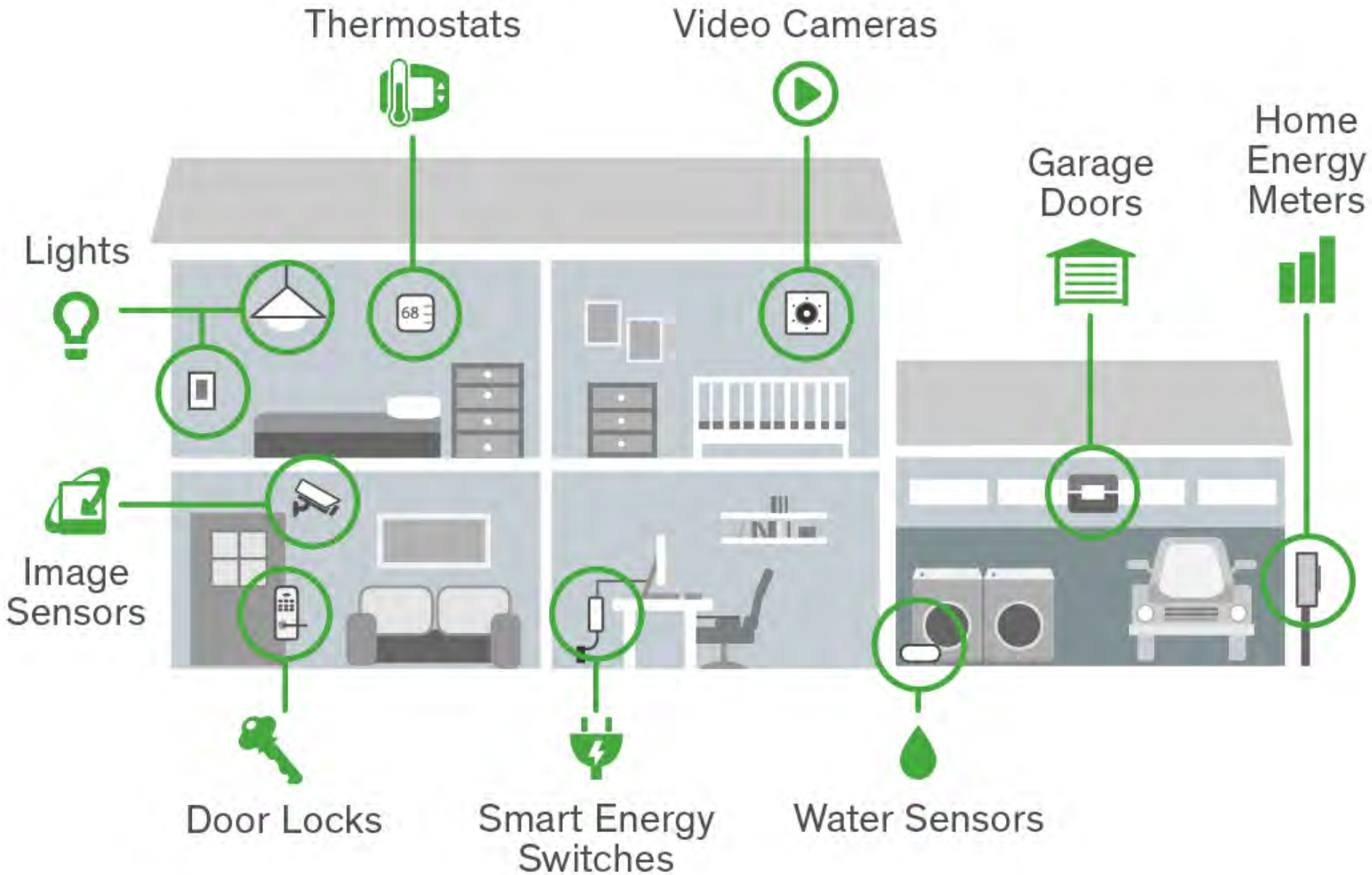10. Fire detector/ Car lock

Group 2

- Light turn on/off
- Appliances turn on/off in home
- Cooking food by facial expression
- Security System (Alarm go out locked)
- Energy Management
- Energy/other appliances- communication
- Waste collection/ Holidays, kids programs, etc.
- Communicate Scheduled programs
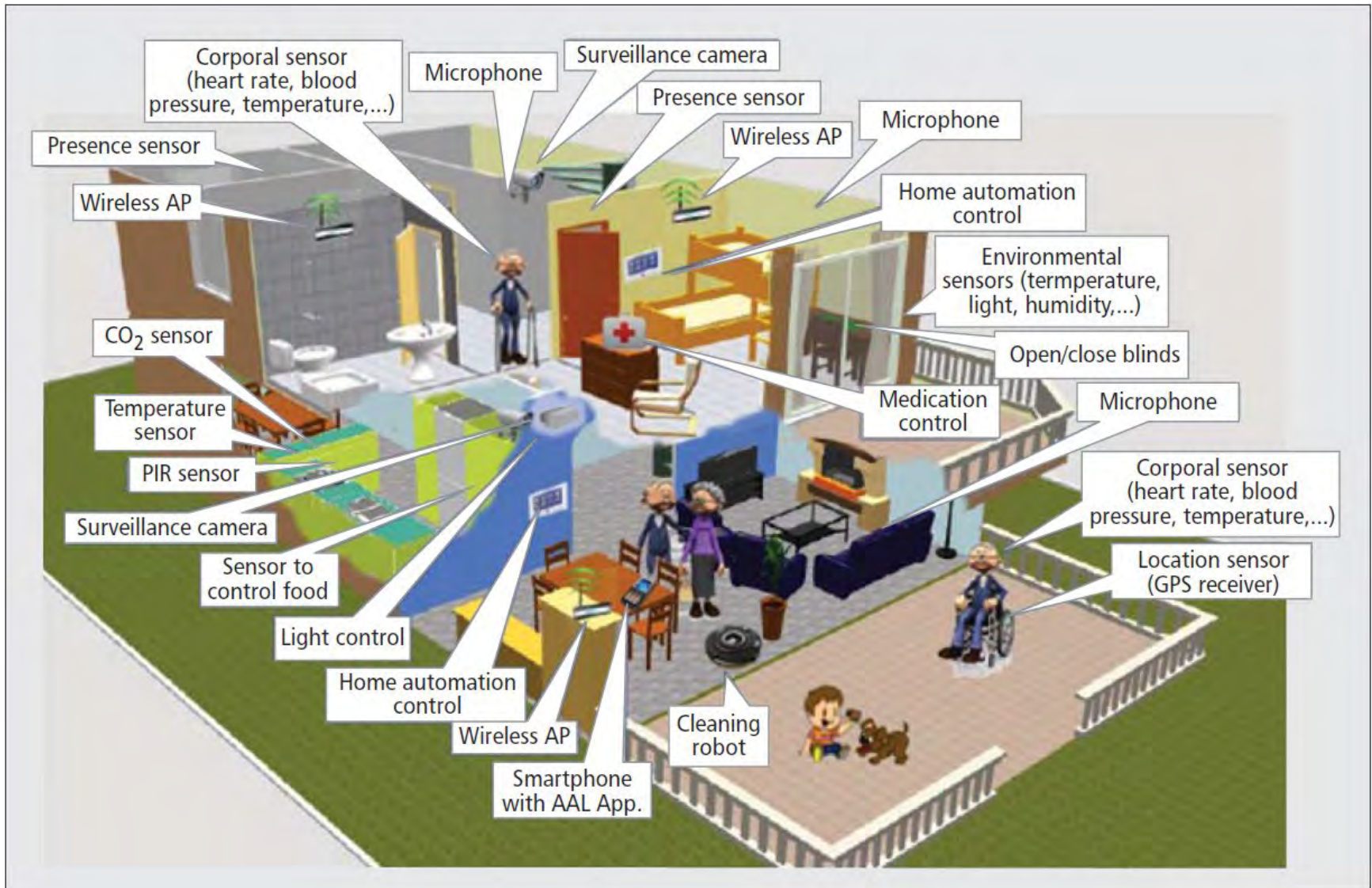- Waste bin signals to collector

Group 3

a) A home equipped with lighting, heating, and other systems and can be controlled by smart phones and computers to provide inhabitants with monitoring and control over the building functions
b) Monitoring and controlling triggered events
   i) Lighting, ii) Blinds, Doors
   iii) HVAC/Air Conditioning
   iv) Security
   v) Feeding pets & watering plants
   vi) Home Energy Meters
   vii) Entertainment
   viii) Preparing foods

Group 4

1. Notice alarm for organizing our daily schedule
2. Setting condition for our mood booster
3. Spray different smell of perfumes
4. Draining system for collecting rainfall
5. Automatically feed pets
6. Scanning health with medical report
7. Checking our daily needs storage
8. Controls shelter to make the temperature
9. Safety thief system (Sent the stranger picture when we are not in home/ automatically locking the doors and windows)
10. Leaving message for guests when we are not at home
11. Giving the news today
12. Automatically turn on vacuum machine when the smart home detects dirty and cutting grass machines
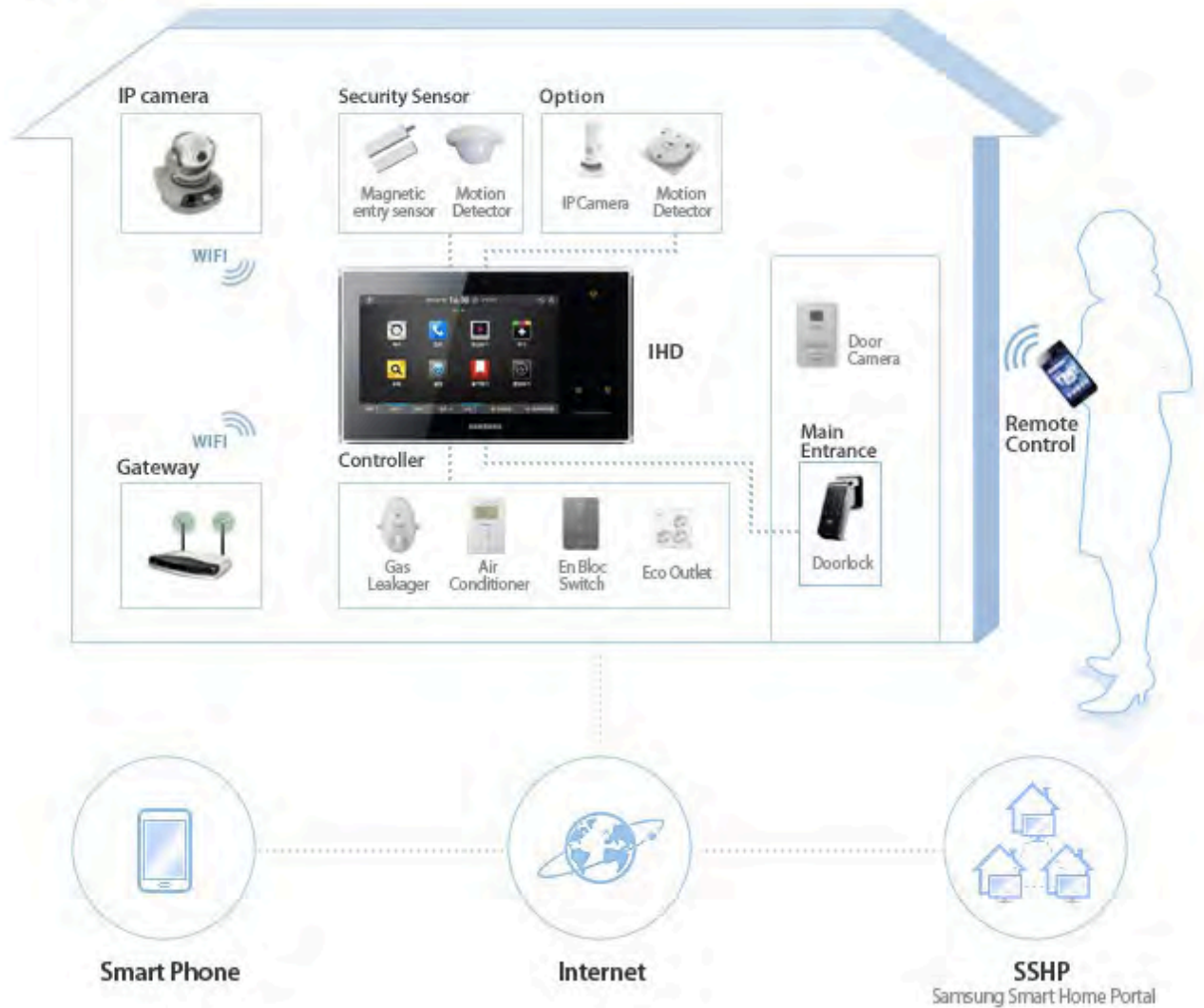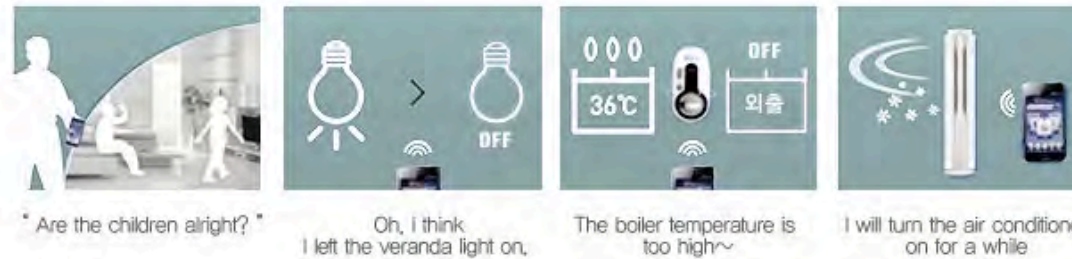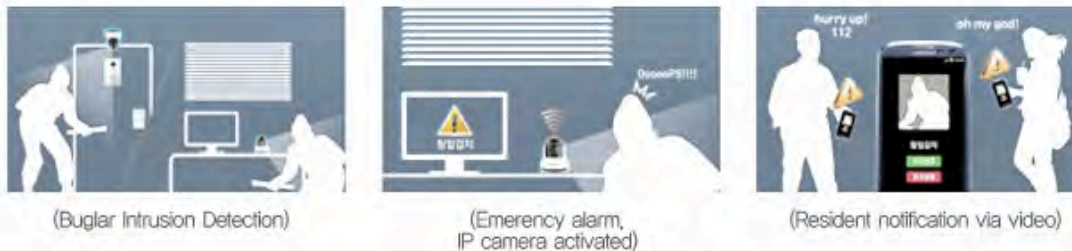13. Turning on the electricity breaker when fire alarm on.

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Smart Home Examples

Grouping Smart Home Functions
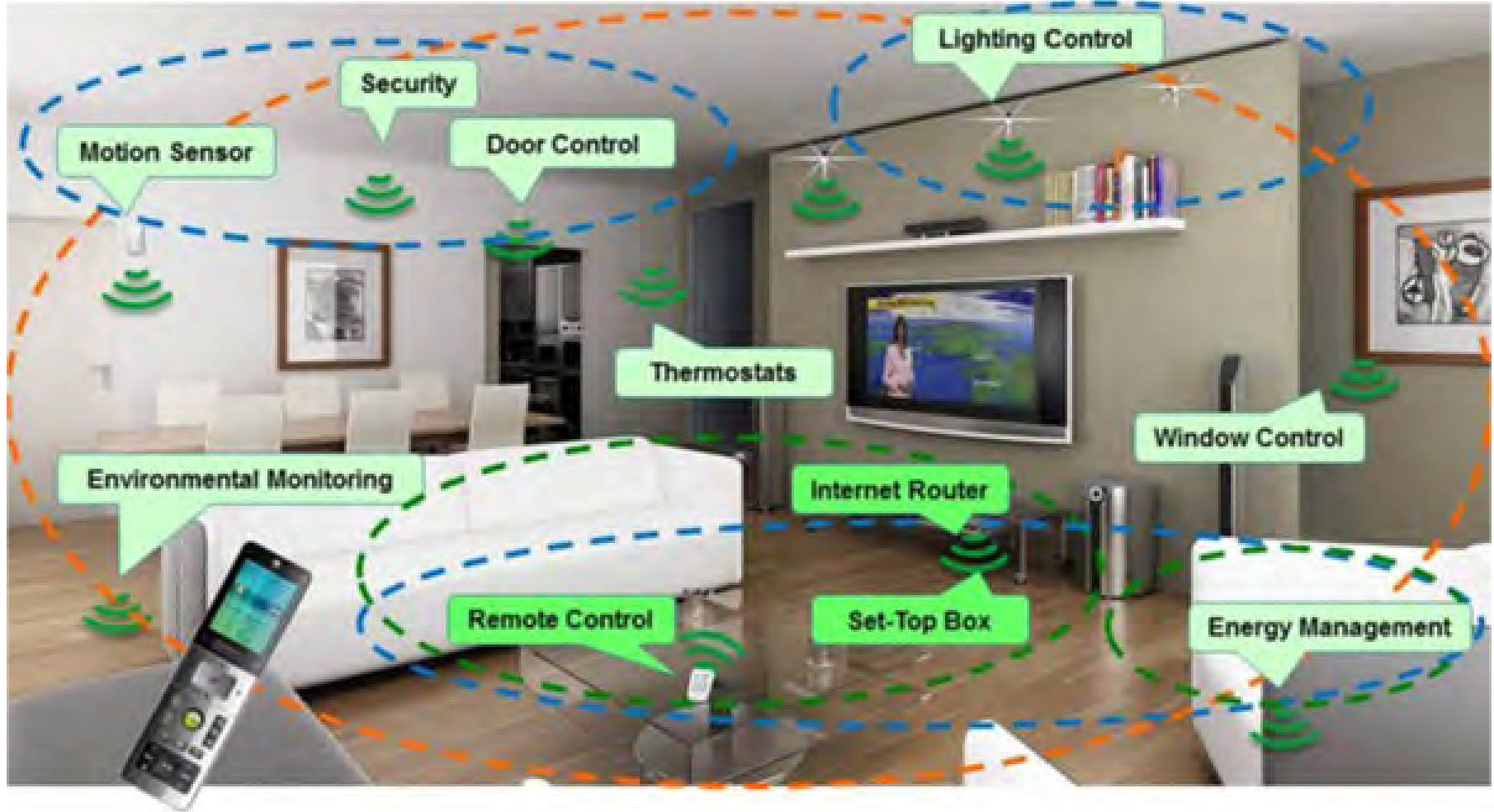
MOST APPEALING SMART HOME SERVICES AND SOLUTIONS ACCORDING TO CONSUMERS

GfK

Security and control
55%

Energy and lighting
53%

Entertainment and connectivity
48%

Health
43%

Appliances
43%
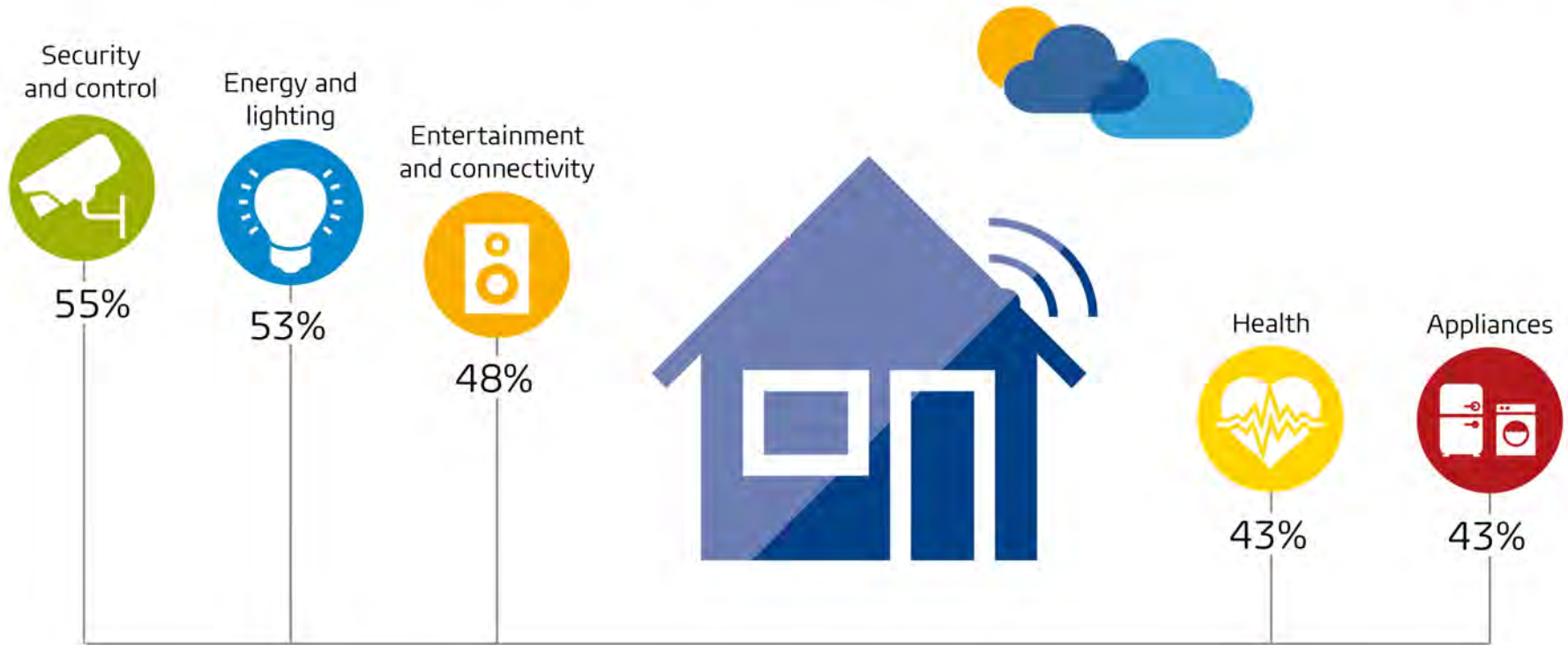
Source: GfK smart home study 2015, +7000 consumers surveyed in September and October 2015 in Brazil, China, Germany, Japan, South Korea, UK and US (China and Japan data not included in this graphic)

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https://blog.gfk.com/2015/11/unlocking-the-smart-home-opportunity/

What we have discussed…

- Concept of Smart Grid

- Learn from Examples of Smart Grid Systems
  - Case Study – Jeju Island
  - Business oriented

- Learn from Demonstration Sites
  - Case Study: Chiang Mai World Green City
  - Community Smart Grid (DC&AC) – RE & Green Technologies
  - Integrating Energy Infrastructure with Green City Components

- Smart Home Functions

- Smart Grid: - Efficient use of power by IT communications
    - Balance: Supply – Demand
    - Monitor – Control – Optimize

- Jeju Island
    - Strong Policy
    - Collaboration with Private Sectors
    - Business Oriented

- Smart Community
    - Living/ learning/training center for student, researchers, and general public
    - Appropriate technology and methods to solve real green city problems
    - Train problem solving skills - RE & Green Technology for local issues
    - Integrate with Community Resources - Ways of Living
    - Sufficiency Economy + Green Technologies (RE & EE)
    - Smart Grid as Infrastructure for Green Community Development

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- Obstacles ???
    - Renewable Energy Deployment (Investment, Market, Policy)
    - Poor grid infrastructure/ Lack Feeder (Utility, Policy)
    - Lack policy/ Lack understanding – Integrated way forward
    - Market driven?

- Do you think smart grid is possible?

- Moving Forward
    - Appropriate Technology; Monitoring/Optimization
    - Integration with Social Development and Green Economic Development
    - Create awareness/ Share best practices/ Demonstrations Sites/ Community Implementation
    - Training General Public; Private Sectors; Policy Maker

Acknowledgments

- Ministry of Energy, Thailand

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- Uttaradit Rajabhat University

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