Eco-Friendly Energy Independent Island Solution

June, 2017

LG
Life's Good

Agenda

- LG Overview
- Case Study : Microgrid
- Water Energy Food Nexus

Agenda

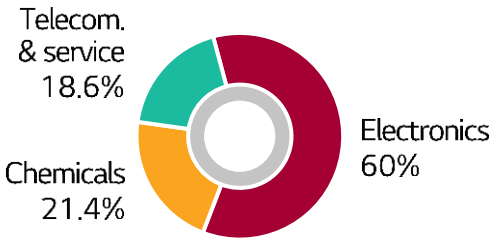
I LG Overview

I Case Study : Microgrid

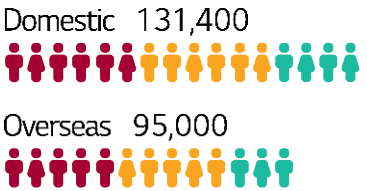
I Water Energy Food Nexus

LG Business Outlook

Founded 1947



Revenues 143B USD



Employee 220,000

Global Subsidiaries 280+

Electronics

Electronic devices and components through innovative technologies

- LG Electronics
- LG Display
- LG Innotek

⋮

16 Companies

Chemicals

Chemical products and materials essential to people's lives

- LG Chem
- LG Hausys
- LG Household & Health Care

⋮

20 Companies

Communication & Service

Smart services anytime anywhere for better life

- LG U+
- LG CNS
- LG International

⋮

30 Companies

Global Top Tier Products and Services

Electronics

- Global No.1
- Mobile Phone
- Global No.2
- Global No.1
- Global No.3

Chemicals

- Global No.1
- Global No.2
- Chemical Materials
- Household Goods
- Cosmetics

Communication & Service

- LTE Service
- IPTV
- IT Service
- Data Center
- EPC

LG Energy Product, Service & Solution

Product

Clean & Highly Efficient Distributed Generation

- PV System
  - Solar Module
  - PCS[2)]

- Solid Oxide Fuel Cell System

- Wind

Safe, Reliable & Efficient T&D[1)]

- ESS
  - Lithium Ion Battery
  - PCS
  - PMS[3)]

- Advanced Metering Infrastructure
  - Smart Meter
  - DCU[4)]

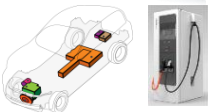
Intelligent Consumption

- EMS[5)]
- BdMS[6)]

- Energy Efficient and Eco-Friendly HVAC[7)]

- LED Lighting

- EV Battery, Components & Charging Infra



Service

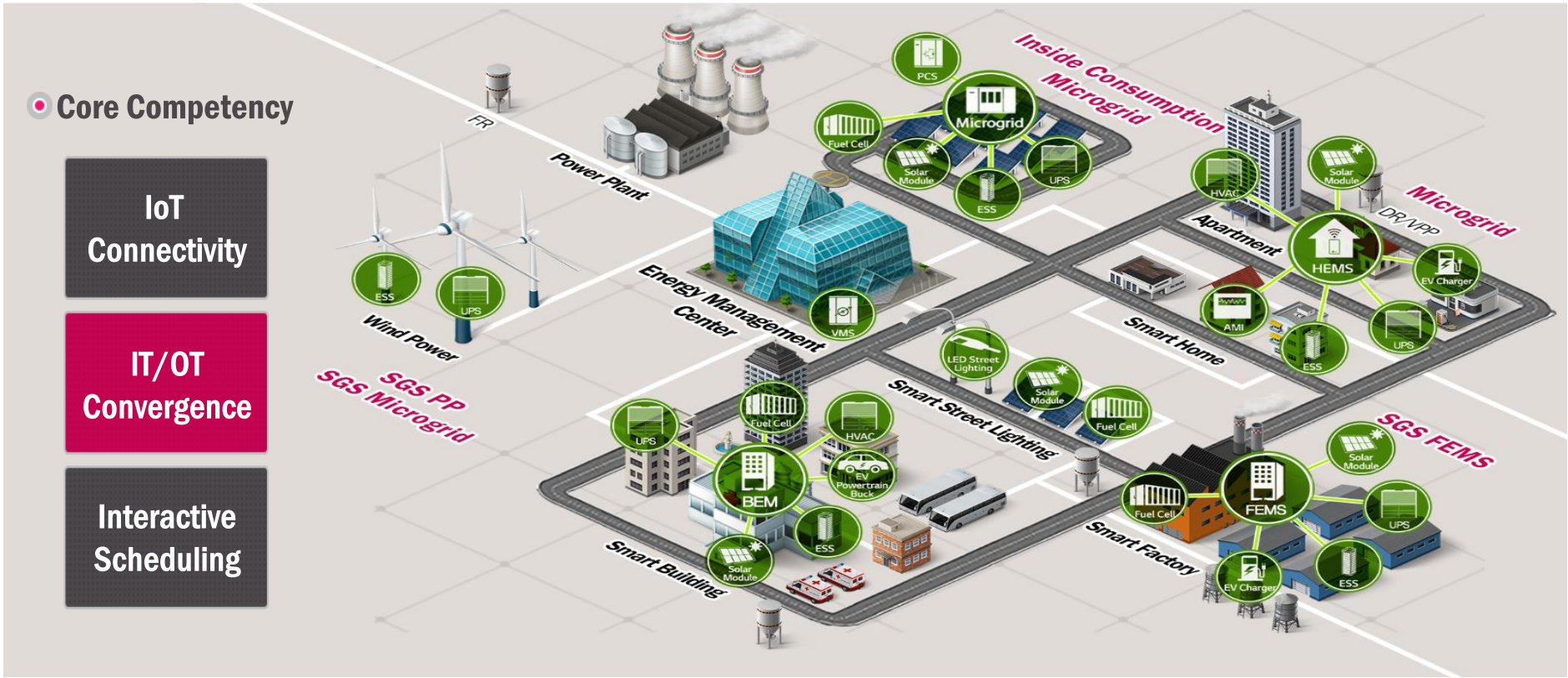
Project Development & Financing	Product & System	EPC[8)]	SI[9)]	O&M[10)]
• LG International • LG CNS	• LG Electronics • LG Chemical • LG U+ • LG Fuel Cell Systems	• LG CNS • ServeOne	• LG CNS	• ServeOne

1) T&D : Transmission & Distribution, 2) PCS : Power Conditioning System, 3) PMS : Power management System 4) DCU : Data Concentrate Unit, 5) EMS : Energy Management System, 6) BdMS : Building Management System, 7) HVAC : Heating, Ventilating and Air Conditioning 8) EPC : Engineering Procurement Construction 9) SI : System Integration 10) O&M : Operation & Maintenance

LG Microgrid Solution

Distributed Generation & Storage + **Power Grid Network & Device** + **Operation Center & EMS**

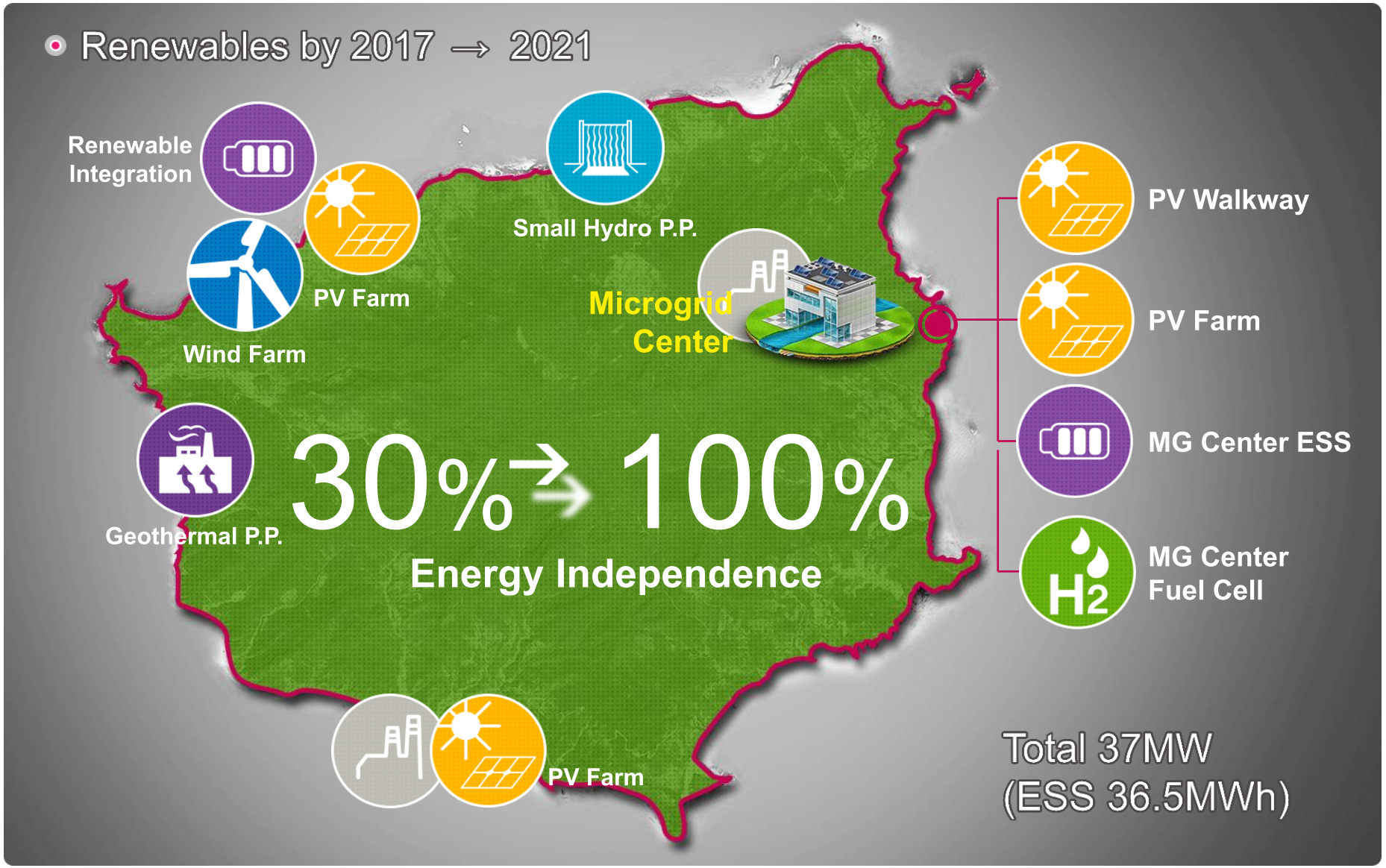
Clean & Renewable Energy Supply	Enhancement of Grid Reliability &Safety	Intelligent Energy Management
PV, Fuel Cell, ESS	Network management, AMI, EV Charger	Real Time Balancing, Big Data Analysis, xEMS



1) OT : Operational Technology

LG Reference : Ulleung-Island Microgrid

1st Commercial Energy Self Reliance Island in Korea



LG Reference : LG Science Park Microgrid

World Largest Eco-Friendly R&D Lab

LG Reference : Solar Power Plant

- Location : Aomori, Japan
- Completion : Dec. 2015
- Installation Capacity : 71 MW
- Expected energy yield : 83 GWh per year

3MW Otae Reservoir

- Location : Gyeongsang Bukdo Province, South Korea
- Completion : Jun. 2015
- Installation Capacity : 3 MW
- Expected energy yield : 3.8 GWh per year

LG Reference : ESS(Energy Storage System)

- Location : Tehachapi, CA, USA
- Completion : Sep. 2014
- Installation Capacity : 8 MW PCS/32MWh Battery
- Turnkey based project
  - Overall project and construction management
  - System engineering and design
  - Battery systems supply

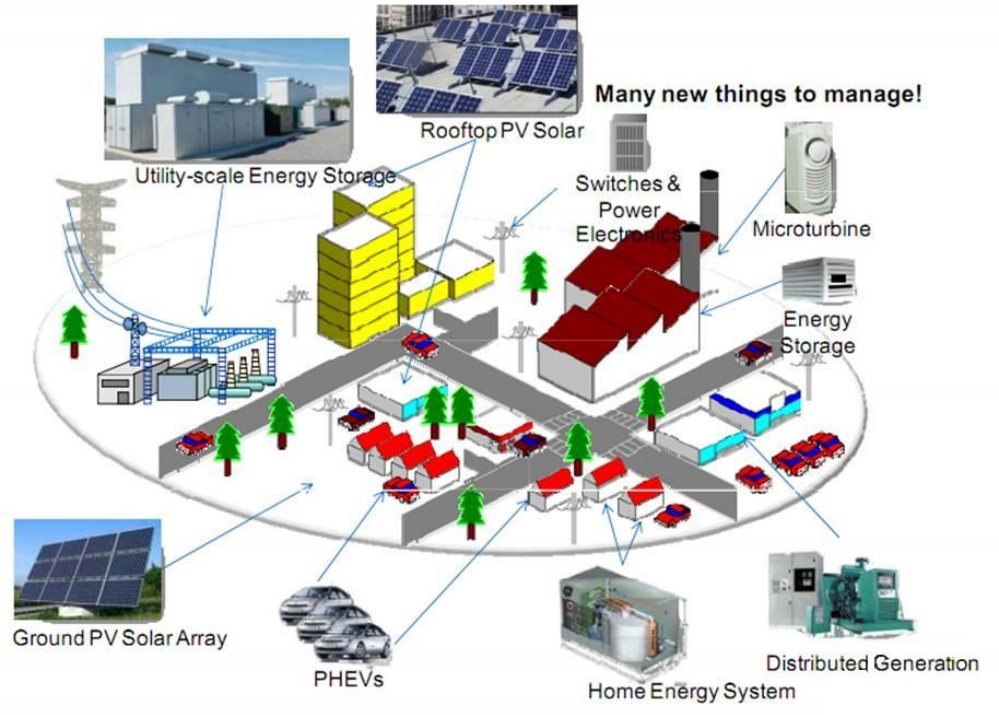
- Location : Gyunggi-do, Korea
- Completion : Dec. 2014
- Installation Capacity : 24 MW PCS/17.66MWh Battery
- Frequency Regulation for KEPCO Main Grid

Agenda

- LG Overview
- **Case Study : Microgrid**
- Water Energy Food Nexus

What is a Microgrid?

What is a Microgrid[1)]



- Interconnected loads and distributed energy resources
- Acts as a single controllable entity
- Connects and disconnects from the grid
  - Grid-connected or "Island" Mode

Microgrid Goals[2)]

Classification	Goals
Economic Value	▪ Control system to dispatch based on rate structure/generation costs - Economic of generation in context of rate structure
Sustainability	▪ Integration of renewable energy and energy efficiency technologies - Primary driver: . Carbon savings . Fuel diversity . Emission goals
Energy Surety	▪ Start with critical loads and expand to other load coverage spheres, diversity of generation and fuel types - Primary driver: . Ensure reliable operation under different operating scenarios

※ Footnote 1) DOE Microgrid Exchange Group
2) NREL, 'Energy Security: Microgrid Planning and Design' 2012.

Why Microgrid especially for Island in Korea?

Electricity Generation Status in Island

Generation (GWh/year)

2010	2011	2012	2013
211	222	233	247

Cost (USD/kWh)

	2010	2011	2012	2013
Island	0.55	0.59	0.62	0.60
Main Land	0.11	0.11	0.15	0.14

Subsidy (MUSD/year)

2010	2011	2012	2013
99	114	124	125

By Accessibility (USD/kWh)

Island	Population (Thousand)	Cost (USD/kWh)
A	2.50	0.76
B	0.03	4.73
Ulleung	10.70	0.45

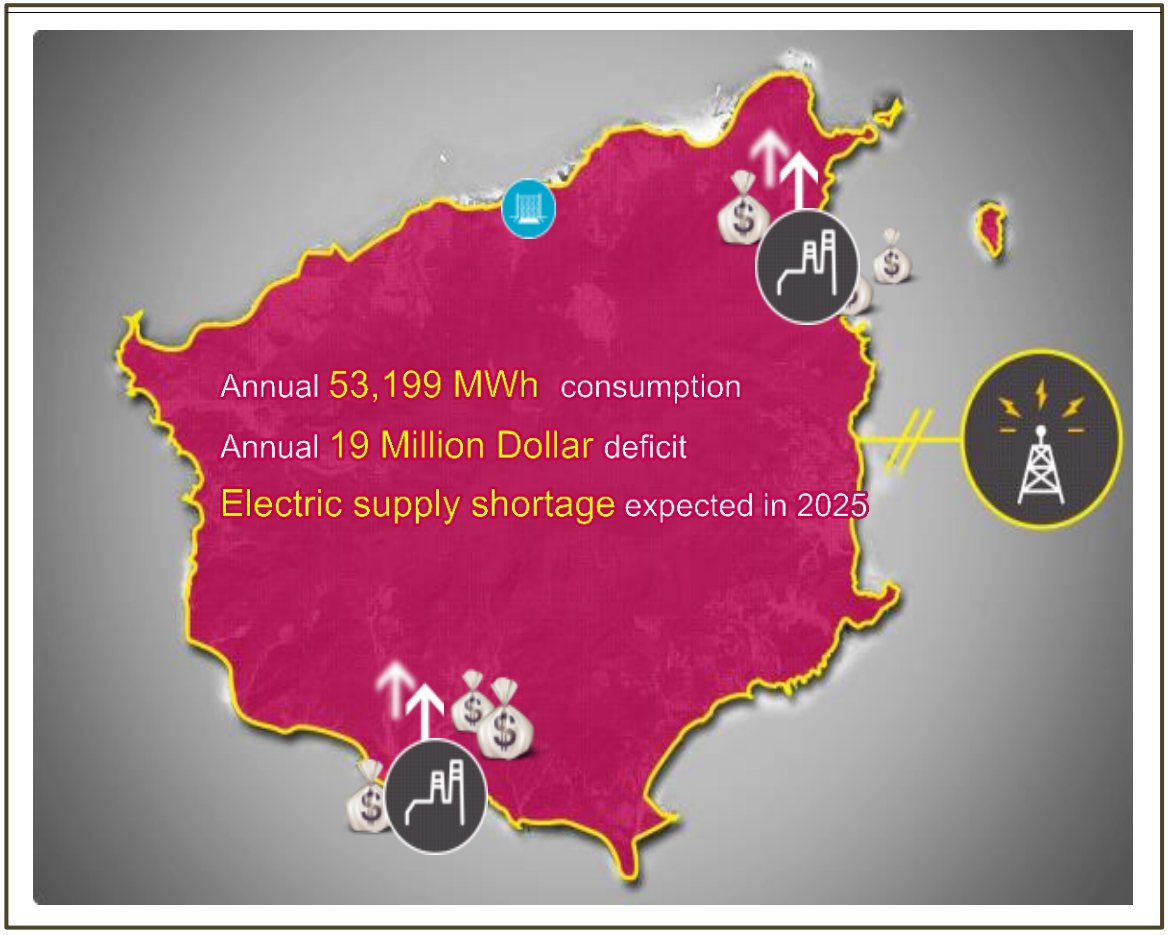
Implications

- The trend increase in electricity demand
- Island Unit cost of Electricity is 5times more expensive than main land
- Therefore Subsidy of electricity for Island is getting worse....
- Unit cost of Electricity generation relies heavily upon not only Oil cost but also transportation cost of Oil

Case Study : As-was Ulleung Island

Annual Subsidy was 19 million USD due to High cost of electricity from Diesel generator

Ulleung-Island (As-was)



※ Power Load Status (2013) : Max 10.9 MW, Average 7.1 MW, Min 4.9 MW

Island Profile

- Location:130km east of peninsula
- Area: 72.9 km^2
- Population: 10,673 (Clients: 7,392)
- Tourists: 415,745 annually

Power Generation

Diesel	Hydro	Solar
(18,500 kW)	(700 kW)	(217 kW)

Key Factors

- High cost of electricity (2014)
  : 45 cents/ kWh (2014)
  - Sales Electricity Price: 13 cent/ kWh
  - **Annual Subsidy: $19 million USD**
- Increased CO_2 Emissions

Why Microgrid with Renewable Energy?

Dramatic Changes in the Global Energy Industry…..

The Uncertainty of Oil Prices

Expanded Efforts to Reduce GHG Emissions

PARIS2015
UN CLIMATE CHANGE CONFERENCE
COP21·CMP11

The Significant Progress of Renewable Energy

Fuel Cell

ESS

The Clean disruption of energy will happen, it's inevitable.
The industrial age of energy and transportation will be over by 2030
…Exponentially improving technologies such as solar,
...will disrupt and sweep away energy as we know it

Tony Seba, Serial Entrepreneur and Lecturer at Stanford University

Question #1 : What kind of Renewable Energy ?

▣ Renewable Energy?

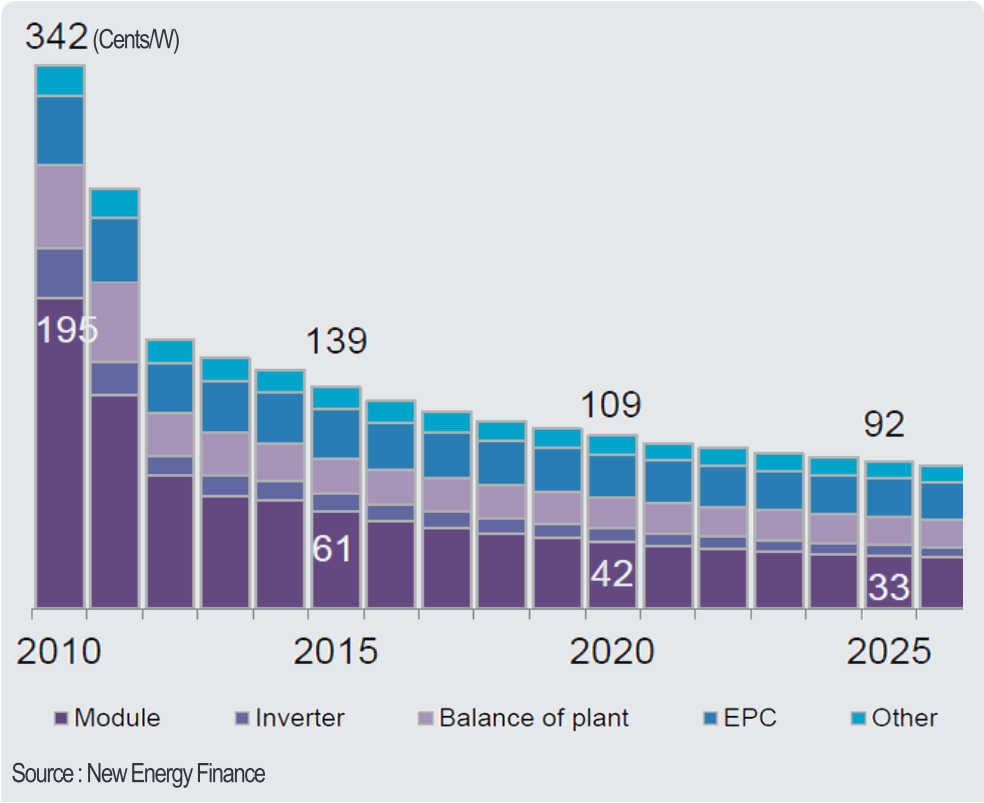
- Photovoltaics, Active Solar Heating, Wind, Hydrogen Fuel Cells, Biomass, Municipal and General Wastes, Geothermal, Hydro Power, Wave ...

▣ Renewable Energy for Island Microgrid in Korea

Source	Photovoltaics	Wind	Geothermal
How it Works	- Solar energy is generally captured via photovoltaic cells for electricity generation	- Wind turbines directly generate electricity - Quite efficient (not a heat engine)	- Power plant : Use earth's heat to power steam turbines
Initial investment (Capacity : 1MW, Korea)	2MUSD	Onshore : 3MUSD (Offshore : 5M)	9MUSD
Efficiency	15%~20%	20%~30%	90%~100%
Advantage	- Most widely available source - Not as limited in location siting as other renewable sources - Largest potential for decentralized power generation	- Very clean source of energy . No pollution (air or water) - Long operating life	- Cost Efficiency(Grid Parity) - 24 Hours operation
Disadvantage	- Cannot contribute to base-load power without energy storage - Imposes great stress on the grid owing to fluctuating nature	- Energy storage issues . An intermittent source of energy; need backup (eg stored energy) for low-wind days - Only practical in areas that are windy enough . Grid Connection Cost Issue - Noise issue	- Not available everywhere Land surveying - H2S pollution - Produces some water pollution (somewhat similar to mining)

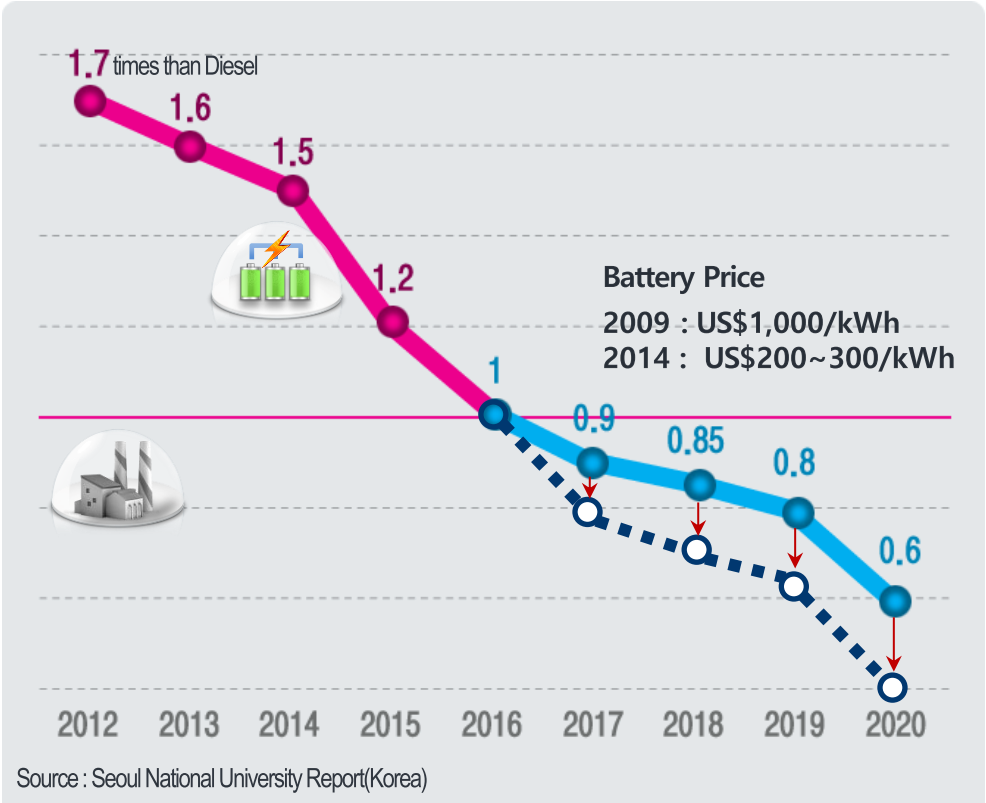
Question #2 : Grid Parity ?

Trend of PV System Cost



Source : New Energy Finance

Cost comparison of ESS vs. Diesel Emergency Generator



Source : Seoul National University Report(Korea)

Diesel

45cents/Wp

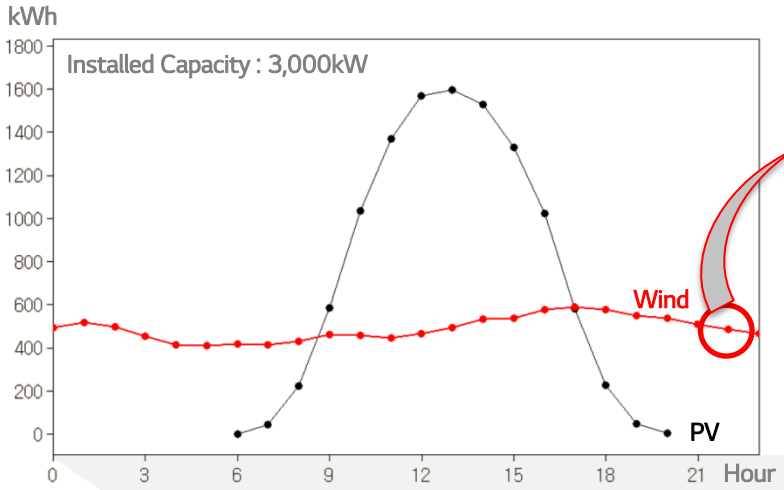
VS.

PV + ESS

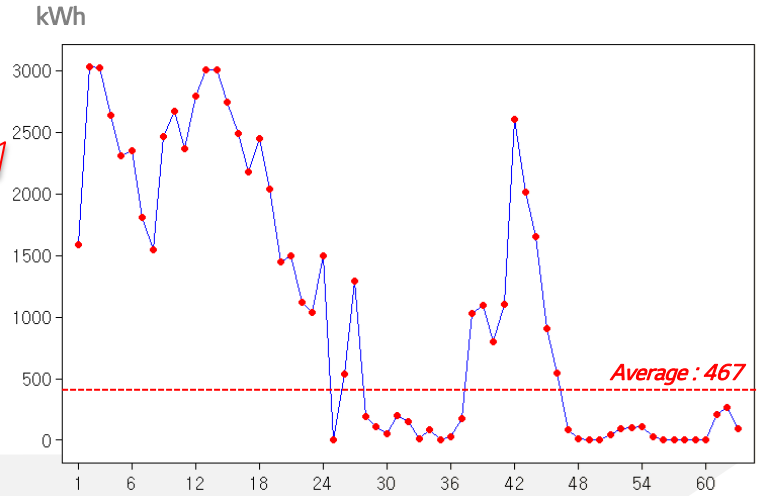
41cents/Wp

Question #3 : Reliability of supply ?

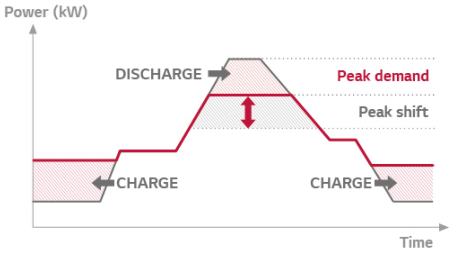
Average Electricity Generation



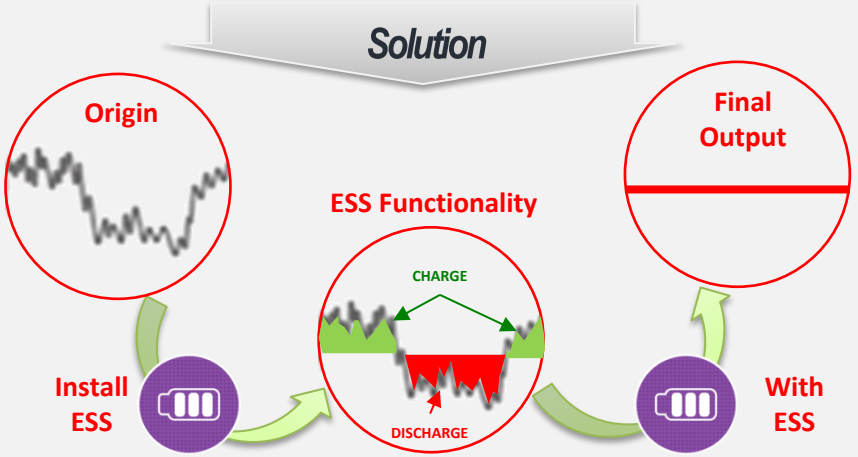
Time series plot of Wind Generation in Detail



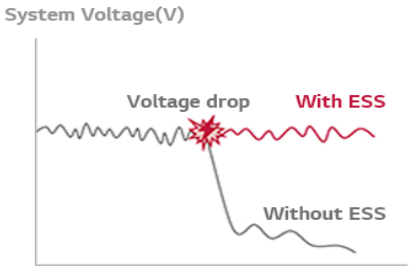
Relies heavily upon the weather for sources of supply: rain, wind, and sunshine



[Peak shifting]



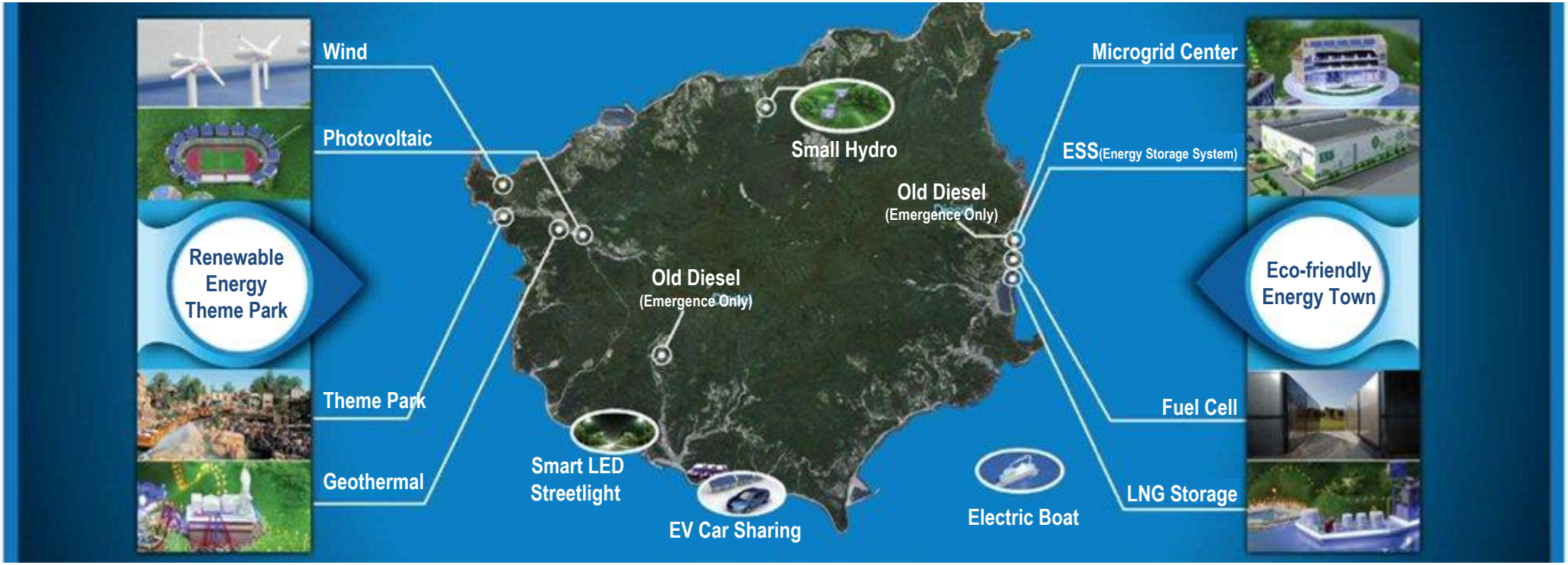
[Renewable Integration]



[Black Start]

Present& Future: Ulleung Island

Ulleung-Island will transform into a zero-diesel and eco-friendly energy independent island



As-was (Fossil fuel 96%)	Phase 1 by 2017 (Renewal Energy 30%)	Phase 2 by 2020 (Renewal Energy 100%)
Diesel (18.5MW)	Diesel (15.2MW)	Hydro (0.7MW)
Hydro (0.7MW)	Hydro (0.7MW)	PV (1MW)
	PV (1MW)	WIND (8MW)
	WIND (8MW)	Fuel Cell (23MW)
	ESS (21MWh)	Geothermal (4MW)
		ESS (37MWh)
		Emergency Only

Expansion of Energy Independence Island in Korea

3rd Expansion of Energy Independence Island

Population	House	Electricity	
1,947	1,345	2.9MW	Deokjek
435	370	0.9MW	Sabshi
2,351	2,280	2.0MW	Jo
1,922	1,452	4.5MW	Geomoon
2,311	1,455	5.5MW	Chuja

1st Ulleung

Population : 10,673
House : 7,392
Electricity : 19.4MW

2nd Jeju

Population : 617,038
House : 216,000
Electricity : 1,086MW

Type of Microgrid

▣ Renewable Energy Independence Island

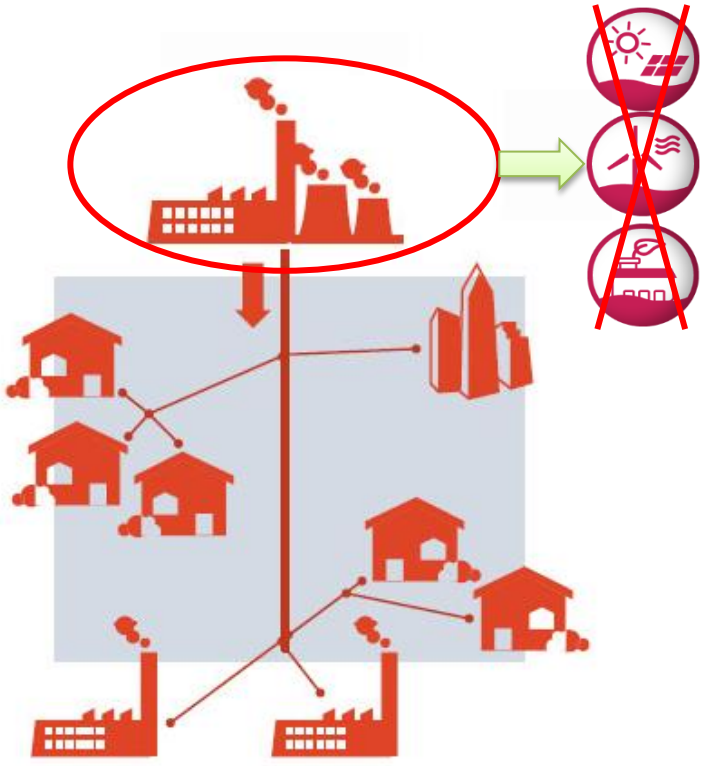
Island	Population	Generation (MWh/Year)	Electricity (Capacity : MW)				Investment (MUSD)
			As-was		To-be		
Ulleung	10,673	63,043	Diesel Hydro	18.5 0.7	PV Wind Geothermal Hydro Fuel Cell	1.0 8.0 4.0 0.7 23	354
Deokjek	1,669	9,462	Diesel	2.9	PV Wind	0.5 1.5	22
Sabshi	435	2,045	Diesel	0.9	PV	1.6	22
Jo	2,351	8,378	Diesel	2.0	PV Wind	0.3 1.5	46
Geomoon	1,922	10,578	Diesel	4.5	PV Wind	1.2 1.5	59
Chuja	2,311	14,073	Diesel	5.5	PV Wind	1.3 3.2	46

▣ Convergence Case

Island	Population	Combination of Electricity Sources
Jindo Hyeoldo	18	PV 60kW, Wind 6kW, ESS 960kWh, Diesel 160kW
Sammado	250	PV 120kW, Wind 30kW, ESS 1.2MWh, Diesel 2,400kW
Baegyado	51	PV 250kW, Wind 40kW, ESS 1.1MWh, Diesel 225kW

Why Smartgrid?

Today's Electricity



Tomorrow's Choices

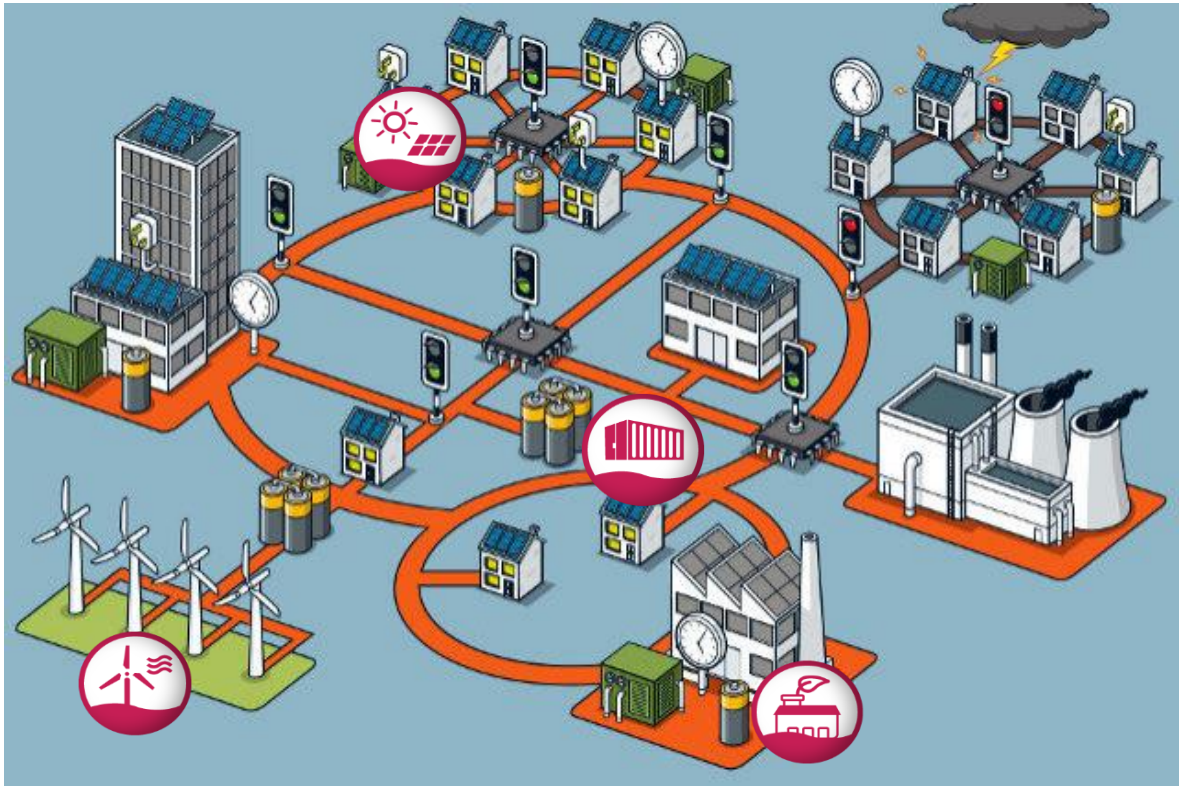


Image Source: http://eandt.theiet.org/magazine/2012/12/grid-gets-the-smarts.cfm

▣ Smartgrid ?

- Uses information technologies to improve how electricity travels from power plants to consumers
- Allows consumers to interact with the grid (Demand Response, E-Prosumer)
- Integrates new and improved technologies into the operation of the grid

Agenda

I LG Overview

I Case Study : Microgrid

I **Water Energy Food Nexus**

Strategic Direction of Water/Energy/Food Nexus

Energy

around 40% of Total Generation Cost of Water

Key factor of Economical efficiency

Water

Food

Microgrid

"Changing People's Lives for the better"

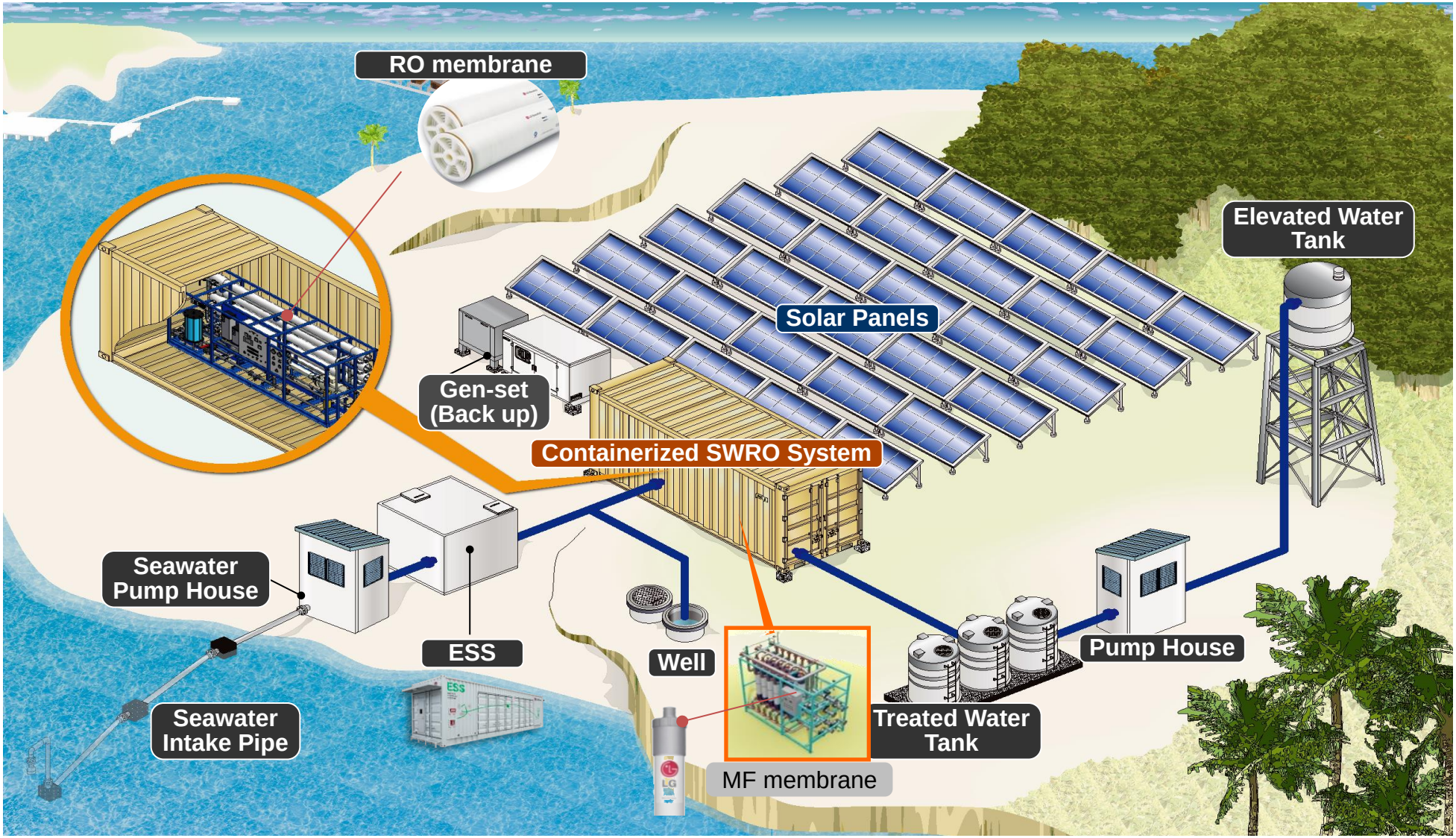
Water Treatment

Smart Farm

Essential element of plant growing

Water Solution : SWRO with Microgrid

Portable water supply solution with SWRO+Solar+ESS without commercial power resource

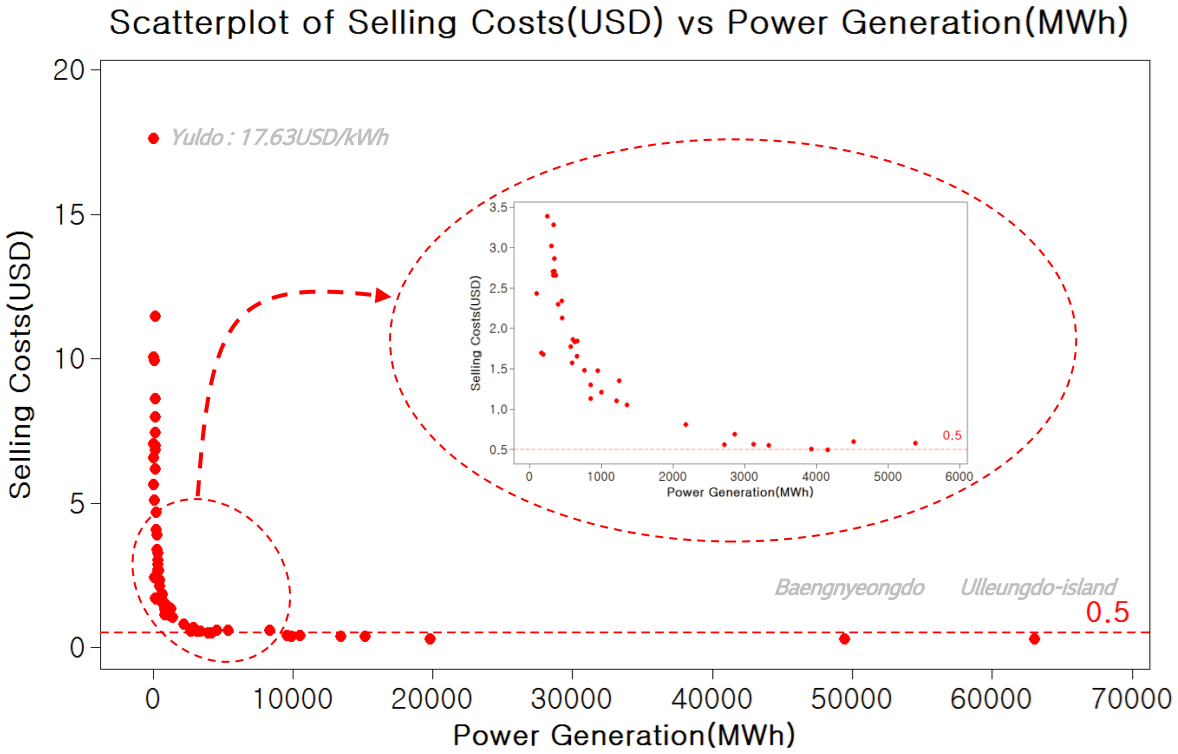


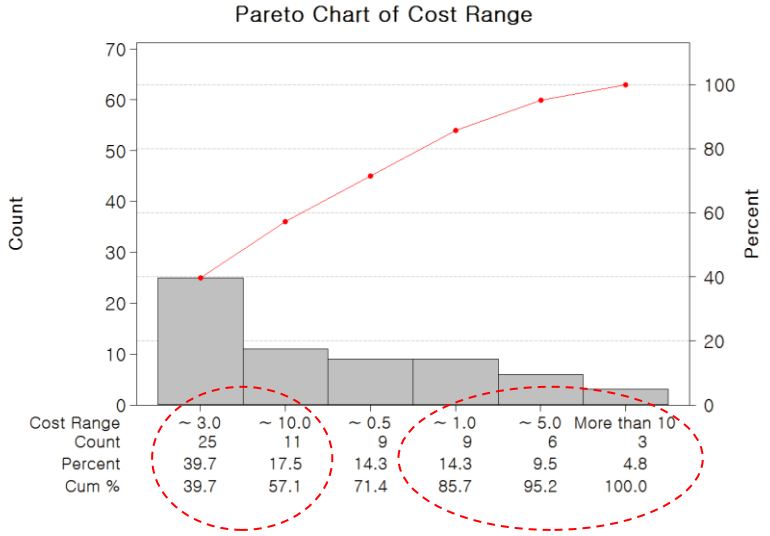
SWRO(SeaWater Reverse Osmosis)

Water Solution : Is it Possible?

Fiscal Year(2015) Total Cost Statement of Power Generation

(65 island managed by KEPCO, Source : KEPCO Web Site)

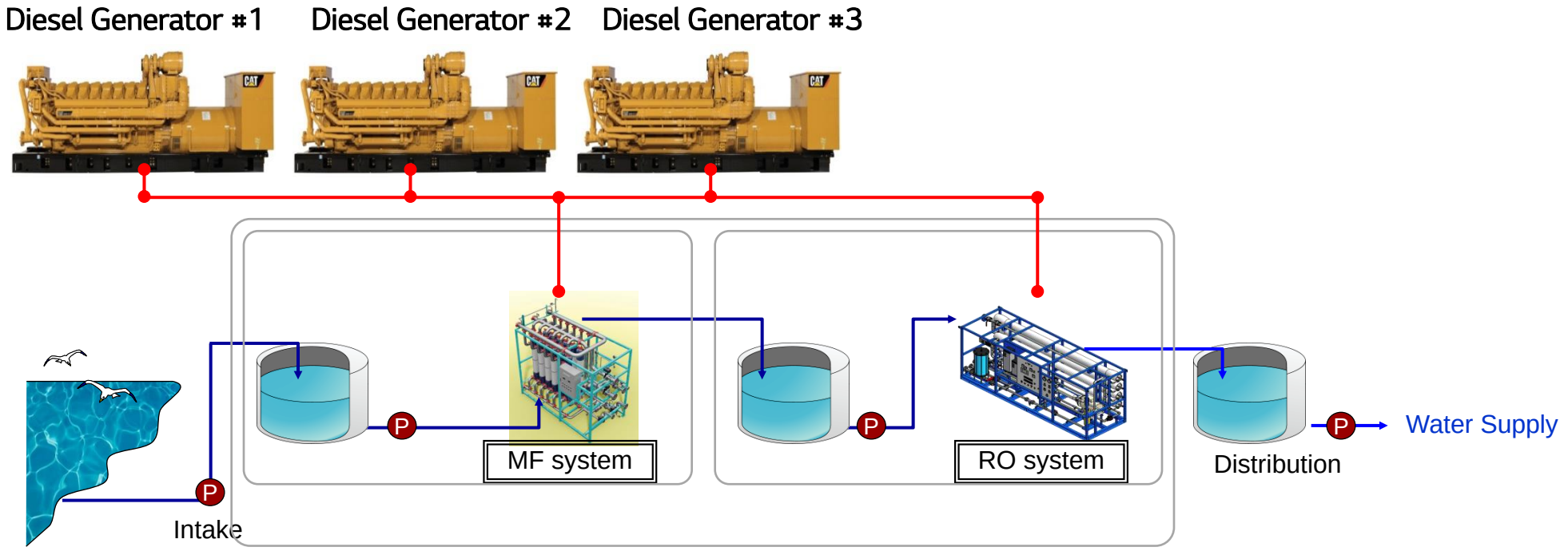


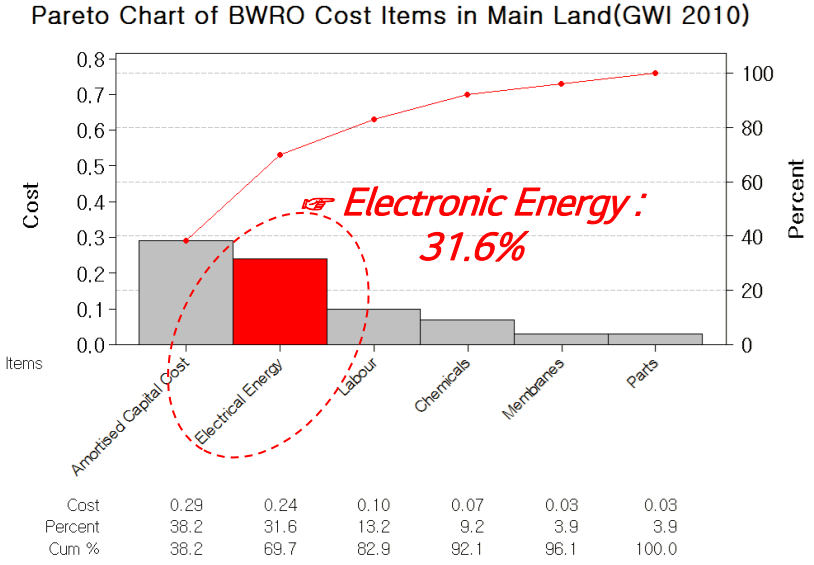


☞ *Target Cost of power generation using PV + ESS ➔ 0.5 USD/kWh*

- Most of power generation cost in KEPCO managed island *-85.7%-* is higher than Target cost of power generation using PV+ESS

Water Solution : As-is Island SWRO System





☞ But in case of Island in Korea

- Required Electrical energy(kWh/ton) : BWRO 2.4kWh ~ SWRO 4.0kWh
- Electricity production unit cost : 0.31USD/kWh ~ 18.51USD/kWh

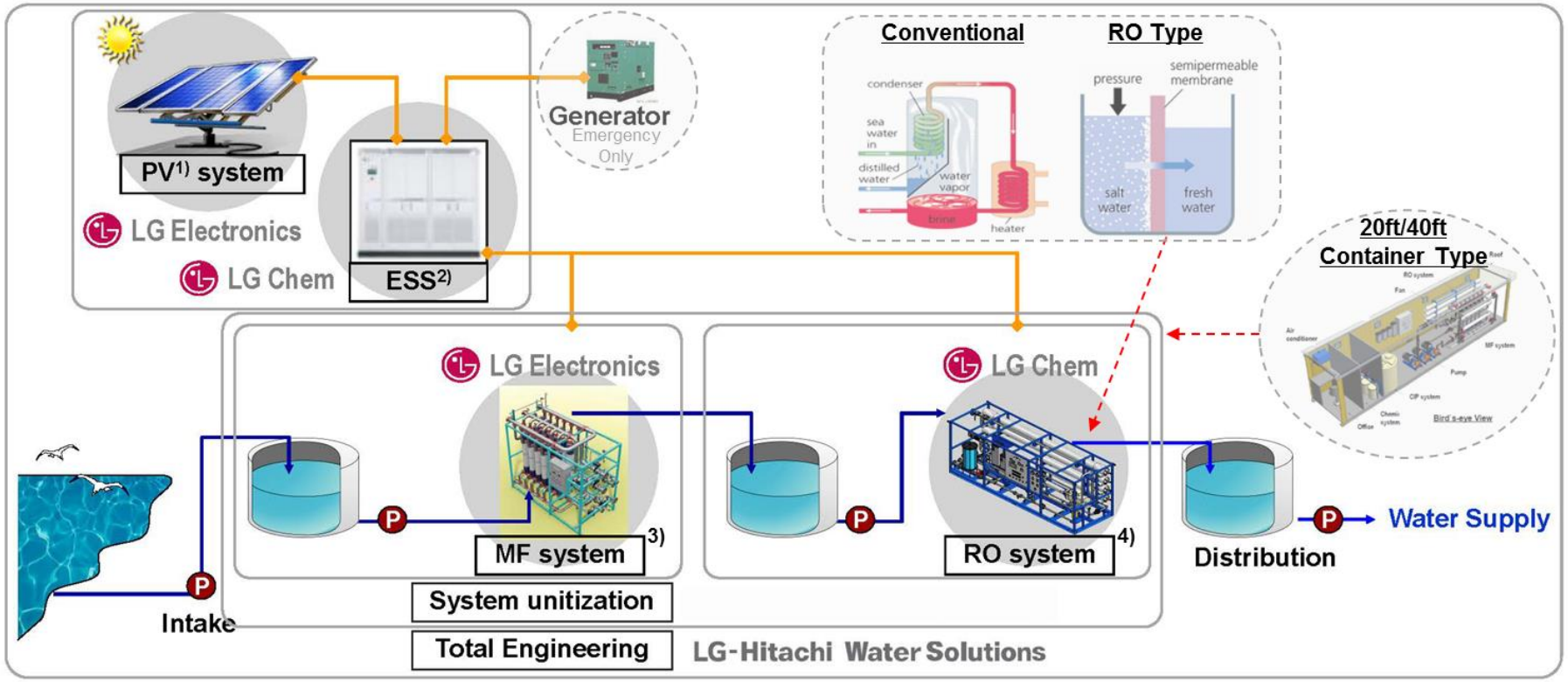
Therefore

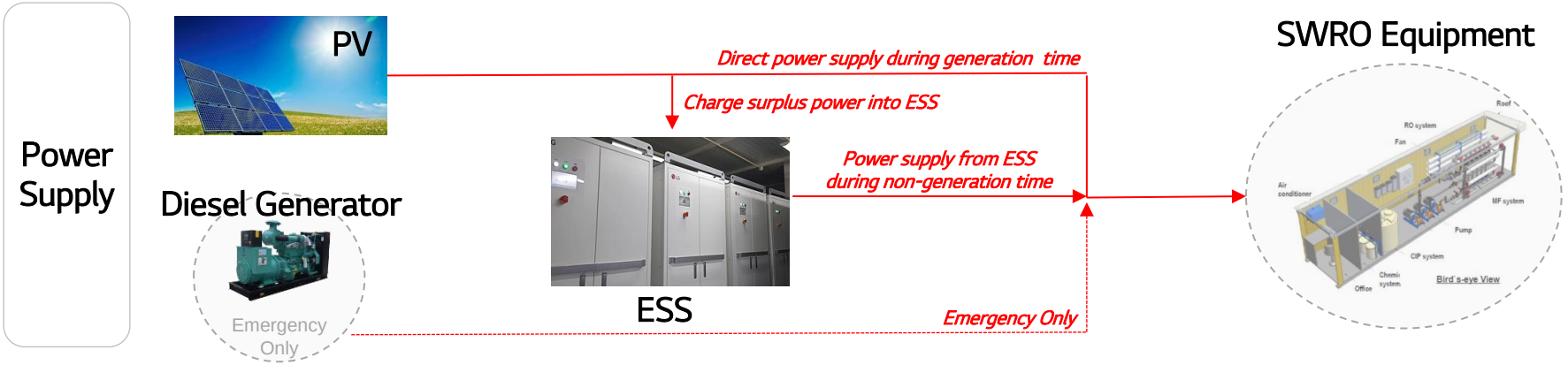
Water production unit cost is between 1.44 USD/ton and 74.66 USD/ton

→ Normally 6.4 USD/ton (Electricity Cost : 1.85/kWh)

Water Solution : How to work?

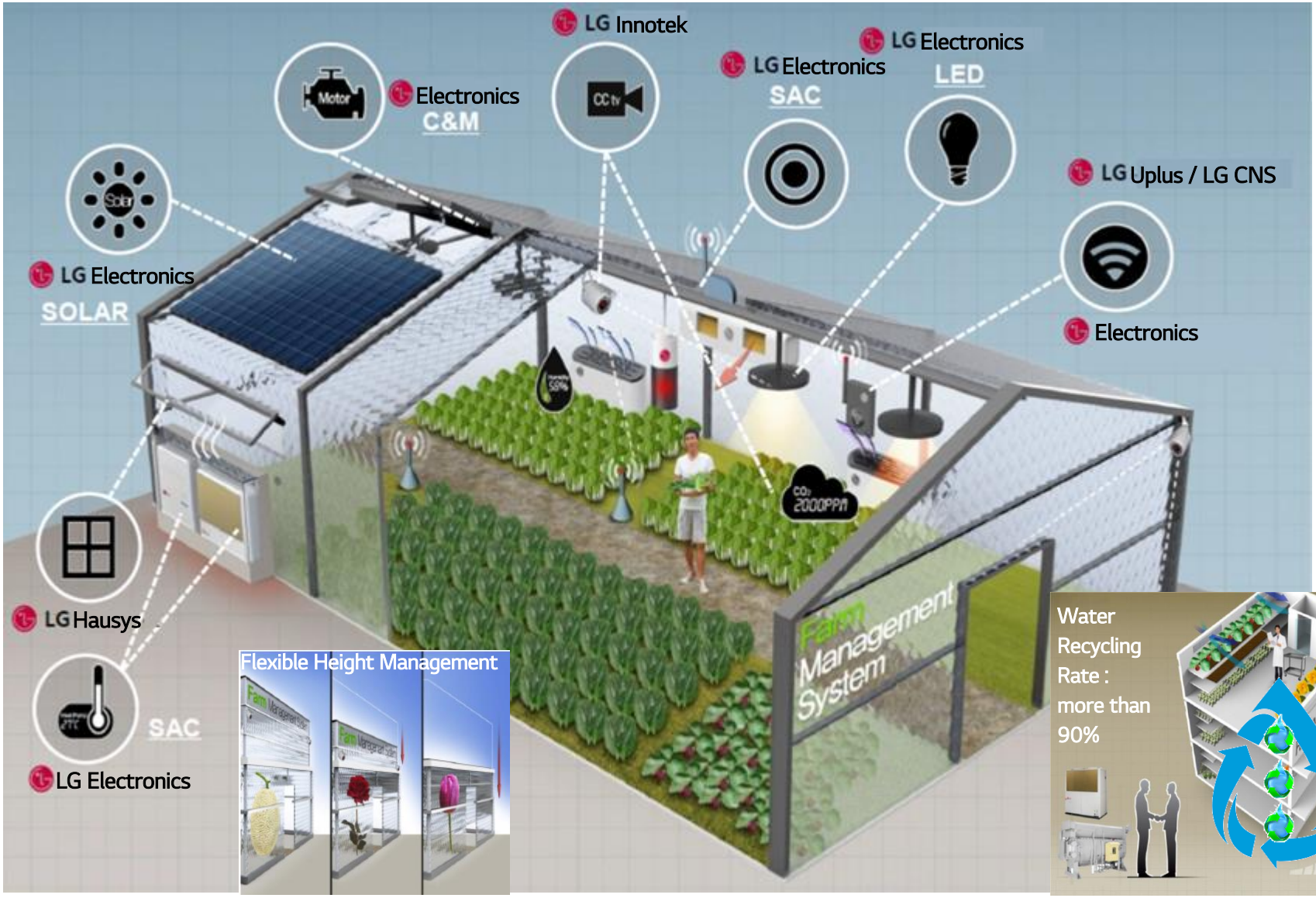
[Total Process Flow]





1) PV : Photovoltaic, 2) ESS : energy Storage System 3) MF : pretreatment(Microfiltration/Ultrafiltration) by Dual Media Filter 4) RO : Reverse Osmosis

Food Solution : Smart Farm integrated with Water and Energy



Grow with LG

Thank You

For more information about LG Energy Solutions,

See http://www.lgenergy.com
Contact us at lgenergy@lge.com

LG Life's Good