Eco-Friendly Energy Independent Island Solution

June, 2017
Agenda

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

LG Overview

Case Study: Microgrid

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
- Solid Oxide Fuel Cell System
- Wind

**Safe, Reliable & Efficient T&D**
- ESS
  - Lithium Ion Battery
  - PCS
  - PMS
- Advanced Metering Infrastructure
  - Smart Meter
  - DCU

**Intelligent Consumption**
- EMS
- BdMS
- Energy Efficient and Eco-Friendly HVAC
- LED Lighting
- EV Battery, Components & Charging Infra

**Service**

**Project Development & Financing**
- LG International
- LG CNS

**Product & System**
- LG Electronics
- LG Chemical
- LG U+
- LG Fuel Cell Systems

**EPC**
- LG CNS
- ServeOne

**SI**
- LG CNS

**O&M**
- ServeOne

---

LG Microgrid Solution

- Distributed Generation & Storage
  - Clean & Renewable Energy Supply
    - PV
    - Fuel Cell
    - ESS

- Power Grid Network & Device
  - Enhancement of Grid Reliability & Safety
    - Network management
    - AMI
    - EV Charger

- Operation Center & EMS
  - Intelligent Energy Management
    - Real Time Balancing
    - Big Data Analysis
    - xEMS

Core Competency
- IoT Connectivity
- IT/OT Convergence
- Interactive Scheduling

1) OT: Operational Technology
LG Reference: Ulleung-Island Microgrid

1st Commercial Energy Self Reliance Island in Korea

Renewables by 2017 → 2021

Energy Independence

30% → 100%

Total 37MW (ESS 36.5MWh)
LG Reference: LG Science Park Microgrid

World Largest Eco-Friendly R&D Lab

PV
- Capacity: 2.7 MW
- Modules: 5,446 EA

ESS
- Capacity: 2 MW (0.5C)
- # of sets: 4 sets

Geo-Thermal
- Capacity: 2.5 MW

BECON manager / microgrid
- Points: 200,000 (Approx.)
- Clients SW: 26 EA

DC Microgrid

Lighting
- LED to support Sensor networks
- LED lamp, luminaries, Plasma etc.

HVAC
- Commercial Air Con. (Heat pump)
- Chillers (Turbo, Absorption)
- AHU (Smart AHU, Under Floor Ventilation)
LG Reference: Solar Power Plant

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

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

LG Reference: ESS (Energy Storage System)
Agenda

- LG Overview
- Case Study: Microgrid
- Water Energy Food Nexus
What is a Microgrid?

- 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

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

※ Footnote 1) DOE Microgrid Exchange Group
Why Microgrid especially for Island in Korea?

Electricity Generation Status in Island

<table>
<thead>
<tr>
<th>Year</th>
<th>Island Generation (GWh/year)</th>
<th>Main Land Generation (GWh/year)</th>
<th>Island Cost (USD/kWh)</th>
<th>Main Land Cost (USD/kWh)</th>
<th>Island Subsidy (MUSD/year)</th>
<th>Main Land Subsidy (MUSD/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>211</td>
<td>99</td>
<td>0.55</td>
<td>0.11</td>
<td>99</td>
<td>0.55</td>
</tr>
<tr>
<td>2011</td>
<td>222</td>
<td>114</td>
<td>0.59</td>
<td>0.11</td>
<td>0.59</td>
<td>0.11</td>
</tr>
<tr>
<td>2012</td>
<td>233</td>
<td>124</td>
<td>0.62</td>
<td>0.15</td>
<td>0.62</td>
<td>0.15</td>
</tr>
<tr>
<td>2013</td>
<td>247</td>
<td>125</td>
<td>0.60</td>
<td>0.14</td>
<td>0.60</td>
<td>0.14</td>
</tr>
</tbody>
</table>

Implications

- The trend increase in electricity demand
- Island Unit cost of Electricity is 5 times 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)

- Annual 53,199 MWh consumption
- Annual 19 Million Dollar deficit
- Electric supply shortage expected in 2025

Island Profile
- Location: 130km east of peninsula
- Area: 72.9 km²
- Population: 10,673 (Clients: 7,392)
- Tourists: 415,745 annually

Power Generation
- Diesel (18,500 kW)
- Hydro (700 kW)
- Solar (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 CO₂ Emissions

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

<table>
<thead>
<tr>
<th>Source</th>
<th>Photovoltaics</th>
<th>Wind</th>
<th>Geothermal</th>
</tr>
</thead>
</table>
| **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

- 342 (Cents/W) in 2010
- 195 (Cents/W) in 2015
- 139 (Cents/W) in 2020
- 92 (Cents/W) in 2025

Cost comparison of ESS vs. Diesel Emergency Generator

- Current Battery Price: 0.6 USD/kWh
- Diesel: 1.7 times than Diesel
- Solar + Battery: 1.5 times than Diesel

Diesel: 45 cents/Wp
PV + ESS: 41 cents/Wp

Source: New Energy Finance
Source: Seoul National University Report (Korea)
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

Solution

[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)  Hydro (0.7MW)  Diesel (15.2MW)  Hydro (0.7MW)  PV (1MW)  WIND (8MW)  ESS (21MWh)  Hydro (0.7MW)  PV (1MW)  WIND (8MW)  Fuel Cell (23MW)  Geothermal (4MW)  ESS (37MWh)

Ulleung Island will transform into a zero-diesel and eco-friendly energy independent island.
Expansion of Energy Independence Island in Korea

3rd Expansion of Energy Independence Island

<table>
<thead>
<tr>
<th>Island</th>
<th>Population</th>
<th>House</th>
<th>Electricity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deokjek</td>
<td>1,947</td>
<td>1,345</td>
<td>2.9MW</td>
</tr>
<tr>
<td>Sabshi</td>
<td>435</td>
<td>370</td>
<td>0.9MW</td>
</tr>
<tr>
<td>Jo</td>
<td>2,351</td>
<td>2,280</td>
<td>2.0MW</td>
</tr>
<tr>
<td>Geomoon</td>
<td>1,922</td>
<td>1,452</td>
<td>4.5MW</td>
</tr>
<tr>
<td>Chuja</td>
<td>2,311</td>
<td>1,455</td>
<td>5.5MW</td>
</tr>
</tbody>
</table>

South Korea

1st Ulleung
- Population: 10,673
- House: 7,392
- Electricity: 19.4MW

2nd Jeju
- Population: 617,038
- House: 216,000
- Electricity: 1,086MW

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

Ulleung
- Population: 10,673
- House: 7,392
- Electricity: 19.4MW
## Type of Microgrid

### Renewable Energy Independence Island

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

### Convergence Case

<table>
<thead>
<tr>
<th>Island</th>
<th>Population</th>
<th>Combination of Electricity Sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Jindo Hyeoldo</td>
<td>18</td>
<td>PV 60kW, Wind 6kW, ESS 960kWh, Diesel 160kW</td>
</tr>
<tr>
<td>Sammado</td>
<td>250</td>
<td>PV 120kW, Wind 30kW, ESS 1.2MWh, Diesel 2,400kW</td>
</tr>
<tr>
<td>Baegyado</td>
<td>51</td>
<td>PV 250kW, Wind 40kW, ESS 1.1MWh, Diesel 225kW</td>
</tr>
</tbody>
</table>
Why Smartgrid?

Today’s Electricity

明日’s Choices

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

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

- LG Overview
- Case Study: Microgrid
- Water Energy Food Nexus
Strategic Direction of Water/Energy/Food Nexus

“Changing People’s Lives for the better”

- Water
- Energy
- Food

- Key factor of Economical efficiency
- around 40% of Total Generation Cost of Water
- Essential element of plant growing
Portable water supply solution with SWRO+Solar+ESS without commercial power resource
**Water Solution: Is it Possible?**

**Fiscal Year (2015) Total Cost Statement of Power Generation**
(65 island managed by KEPCO, Source: KEPCO Web Site)

- **Scatterplot of Selling Costs (USD) vs Power Generation (MWh)**

- **Pareto Chart of Cost Range**

- **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

Flexible Height Management

Water Recycling Rate: more than 90%
Thank You

For more information about LG Energy Solutions,

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