Role of Ocean Energy in the Stand-alone Microgrid System for Green Energy-Independent Island

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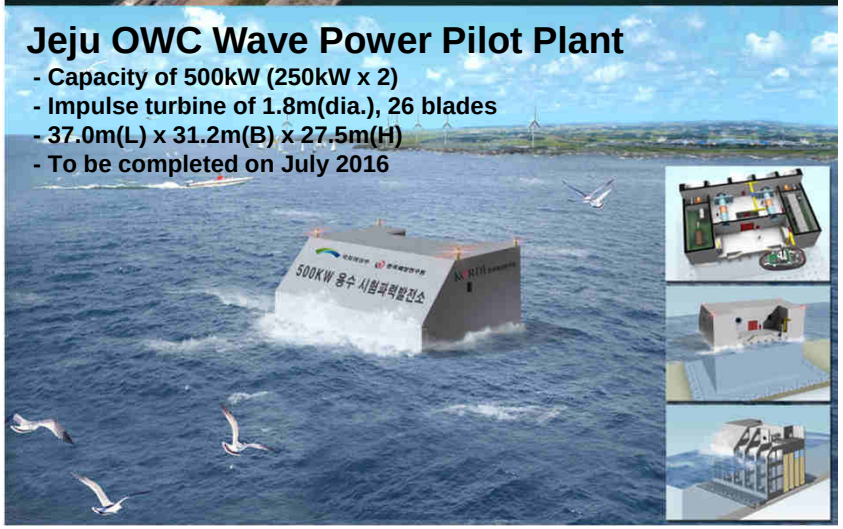
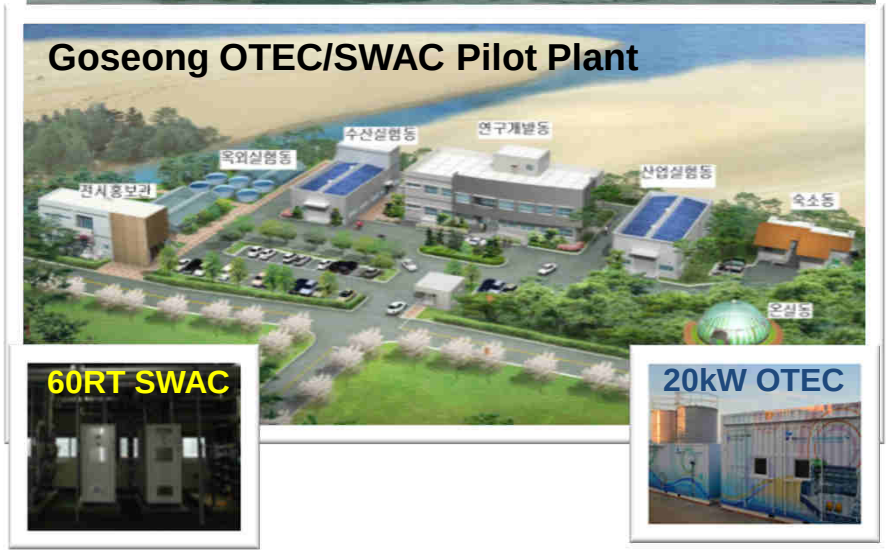
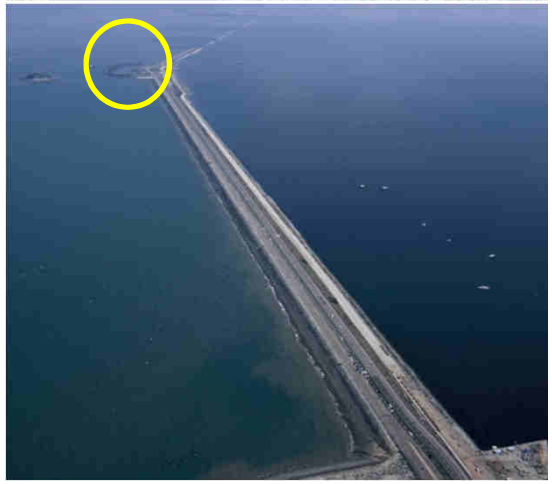
- Ocean Energy Development in Korea
- Microgrid
- Ocean Energy for Microgrid Island
- Discussion

Ocean Energy Development in Korea





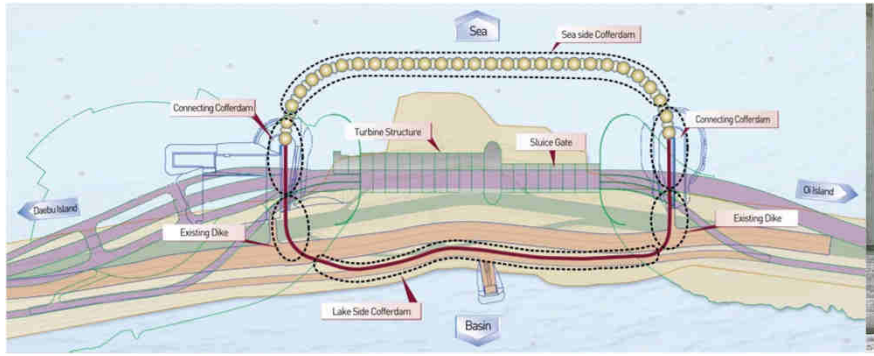
Sihwa Lake Tidal Power Plant



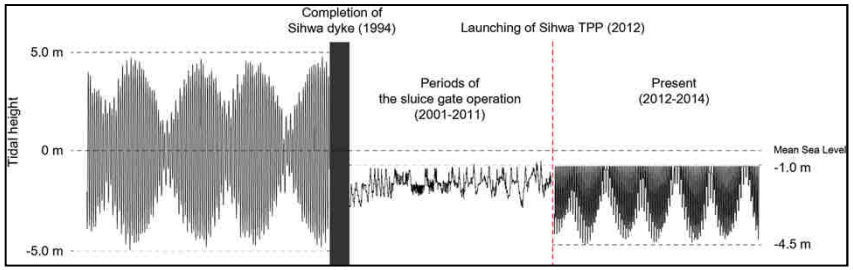
- **History**
  - ✓ Completion of Sea Dyke of 12.7km in 1994
  - ✓ Severe Lake water pollution
  - ✓ Tidal Power Plant was proposed as a counter measure, based on the findings from national R&D
  - ✓ Construction : 2004 ~ 2011
  - ✓ Total Project Cost : USD 355 million
- **Effects of Sihwa Tidal Power Plant**
  - ✓ Improve water quality in Sihwa Lake and environmental recovery
  - ✓ Generate renewable clean energy
  - ✓ Enhancement of regional economy by forming waterfront and tourist attraction
- **Power Output in 2011.8~2014.12**

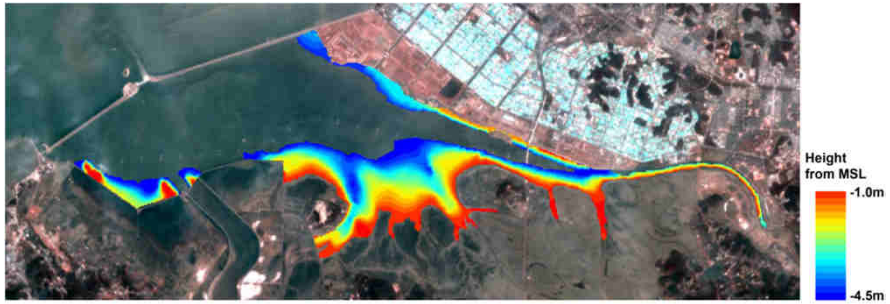
2011.08 ~ 2011.12	52,304 MWh
2012.01 ~ 2012.12	465,924 MWh
2013.01 ~ 2013.12	483,777 MWh
2014.01 ~ 2014.12	492,172 MWh

Sihwa Lake Tidal Power Plant

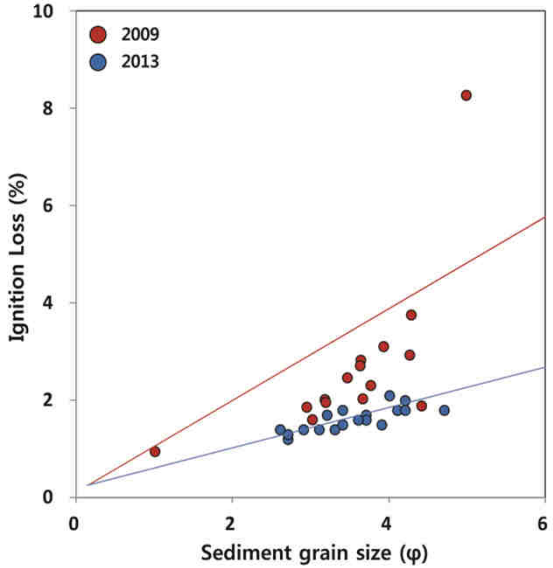


- **Water Level Variations & Restored Tidal Flat**





- **Variation of ignition Loss in tidal flat**



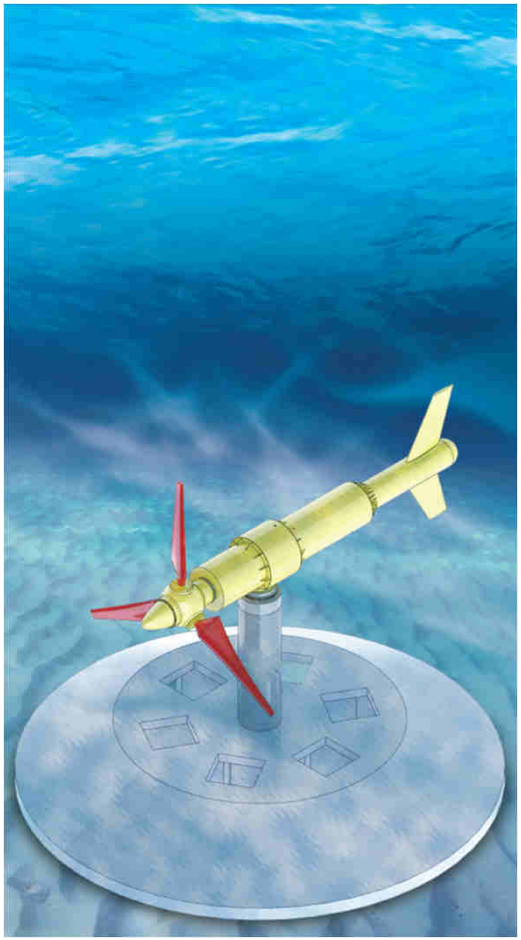
Tidal Current Power Generation System with active-control device

- **Medium Scale Model(1:5) Outdoor Experiment**
  - ✓ 2013~2014 / Uldolmok Test Site
  - ✓ Rotor Dia. : 2.4m
  - ✓ Blade Active Pitch Control
  - ✓ Passive/Active Yawing by Rudder
- **Design of KS200**
  - ✓ 2014~2015
  - ✓ Based on Experimental Results
- **Fabrication of KS200**
  - ✓ 2015~2016
- **Installation**
  - ✓ 2016. 9 ~ 10
  - ✓ Near Uldolmok Test Site
- **Verification Test**
  - ✓ 1st : 2016. 11 ~ 2017. 12.
  - ✓ 2nd : 2018 ~ 2020
  - ✓ Performance Assessment
  - ✓ Environmental Impact Monitoring

KS200 (Korean Shark 200)

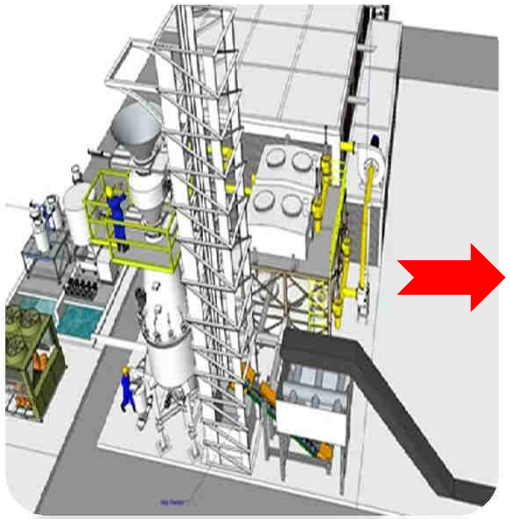
Specification

Rotor	
Diameter	12m
Swept Area	113m²
Rotor speed	16 rpm
Power regulation	Active blade pitch regulation
Yawing system	
Type	Rudder pitch control
Control type	Passive/Active
Transmission system	
Type	Direct drive
Mechanical brake	
Type	Hydraulically released
Generator	
Type	Permanent Magnet Synchronous Generator (PMSG)
Rated power	225kW
Voltage	3Φ 575 V_{LL}
Cooling system	Direct to passing sea water
Monitoring system	
SCADA system	Server-client
Remote control	Full turbine control
Tower & Substructure	
Type of tower	Cylindrical tubular steel
Type of substructure	Gravity type circular caisson
Hub height	11m from seabed
Operational data	
Cut-in current speed	1m/s
Rated current speed	2.3m/s
Weight	
Nacelle & Drive train	Less than 60 tons
Tower & Substructure	Less than 700 tons



Hybrid-OTEC Power Plant (200kW, 2014)

- **Combined operation with wood chip gasification power plant**
- **Using multiple heat sources**



500kW Wood Power Plant (MOTIE)

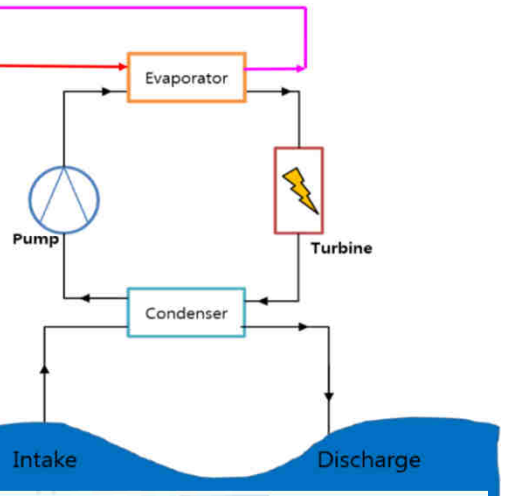
[Solar Energy]

[Wind energy]

[Incineration heat energy]

[Heat storage tank]

200kW H-OTEC Plant (MOF)



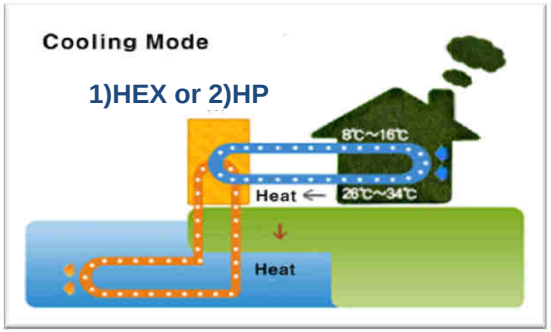
substituted by Geothermal or Solar heat sources for SIDS

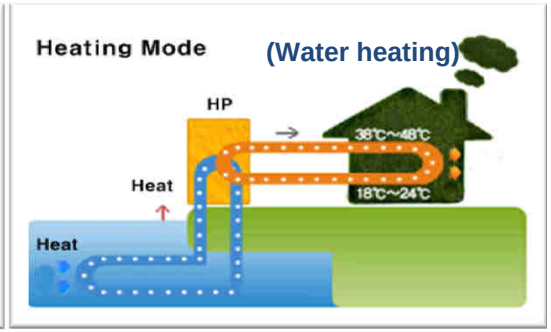
SWAC plant to reduce energy demand

- **Cooling source can be acquired from**

1) **direct heat exchanger by cold deep ocean water**
2) **cold heat of evaporator of heat pump by use of seawater as a condensing heat source**

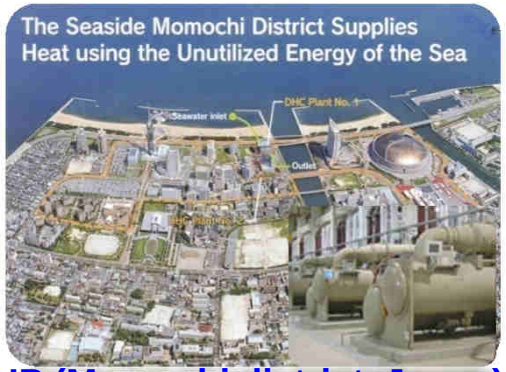
- **Test bed (100RT & 500RT) were established in 2014 and 2015**





HEX & HP (KRISO, KIOST)

HEX (Resort, Bora Bora)



HP (Momochi district, Japan)

Technology Development

● Technology Readiness Levels

Energy Resources	Europe	Korea
Tidal Barrage	TRL 9	TRL 9
Tidal Current	TRL 8	TRL 6-7
Wave	TRL 8-9	TRL 5-6
OTEC/SWAC	TRL 8-9	TRL 5-6

● Technology Topics

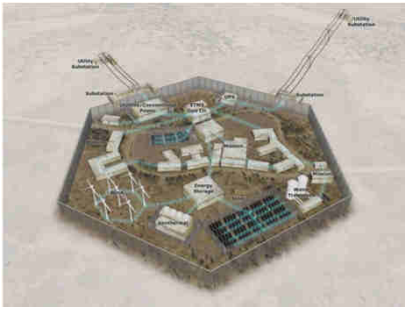
1. Proving reliable operation
2. Device design : cost reduction and development of promising technologies
3. Enabling technologies (cabling and electrical connection)
4. Innovation : novel technologies, new components and subcomponents
5. Knowledge sharing

❖ Wave and Tidal Energy Strategic Technology Agenda. SI Ocean (2014)

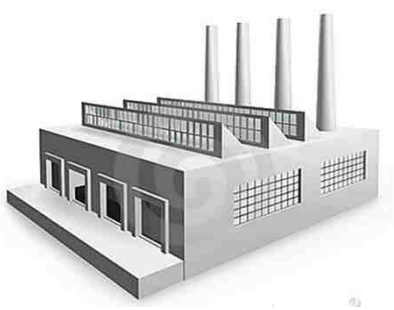
Microgrid

- Microgrid is a local energy system which incorporates three key components; Generation, Storage and Demand all within a bounded and controlled network. It may or may not be connected to the grid.
- Benefits
  - ✓ Economic : Improved efficiency and long term predictable energy cost
  - ✓ Resiliency : Field-proven reliability improvement against natural disasters such as earthquakes, tsunamis and storms
  - ✓ Environmental : Reduction in harmful emissions resulting from optimal use of renewable resources and energy efficiency programs

Energy Surety ← → **Sustainability** ← → **Economic Value**



Military

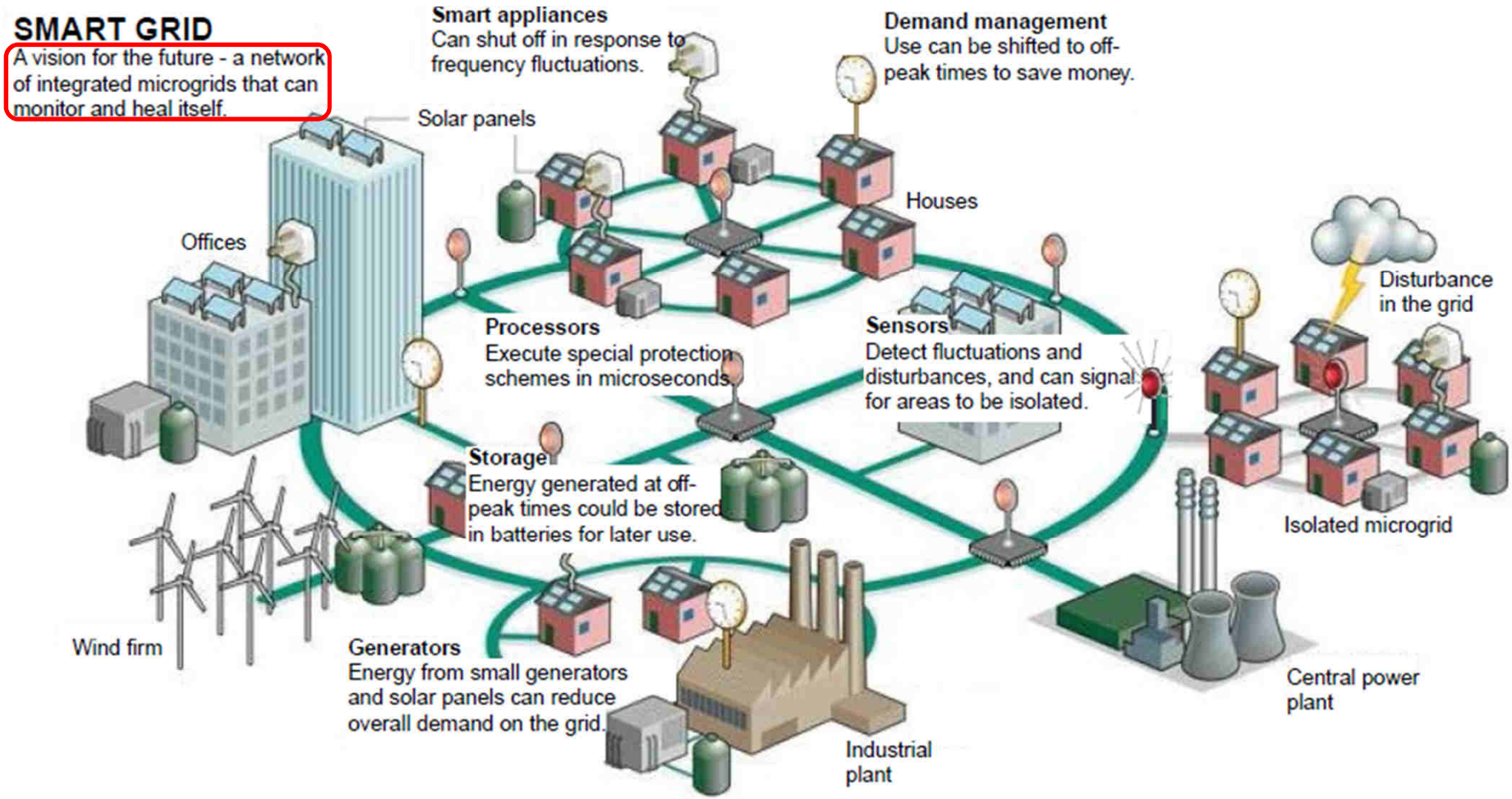


Industrial

Island

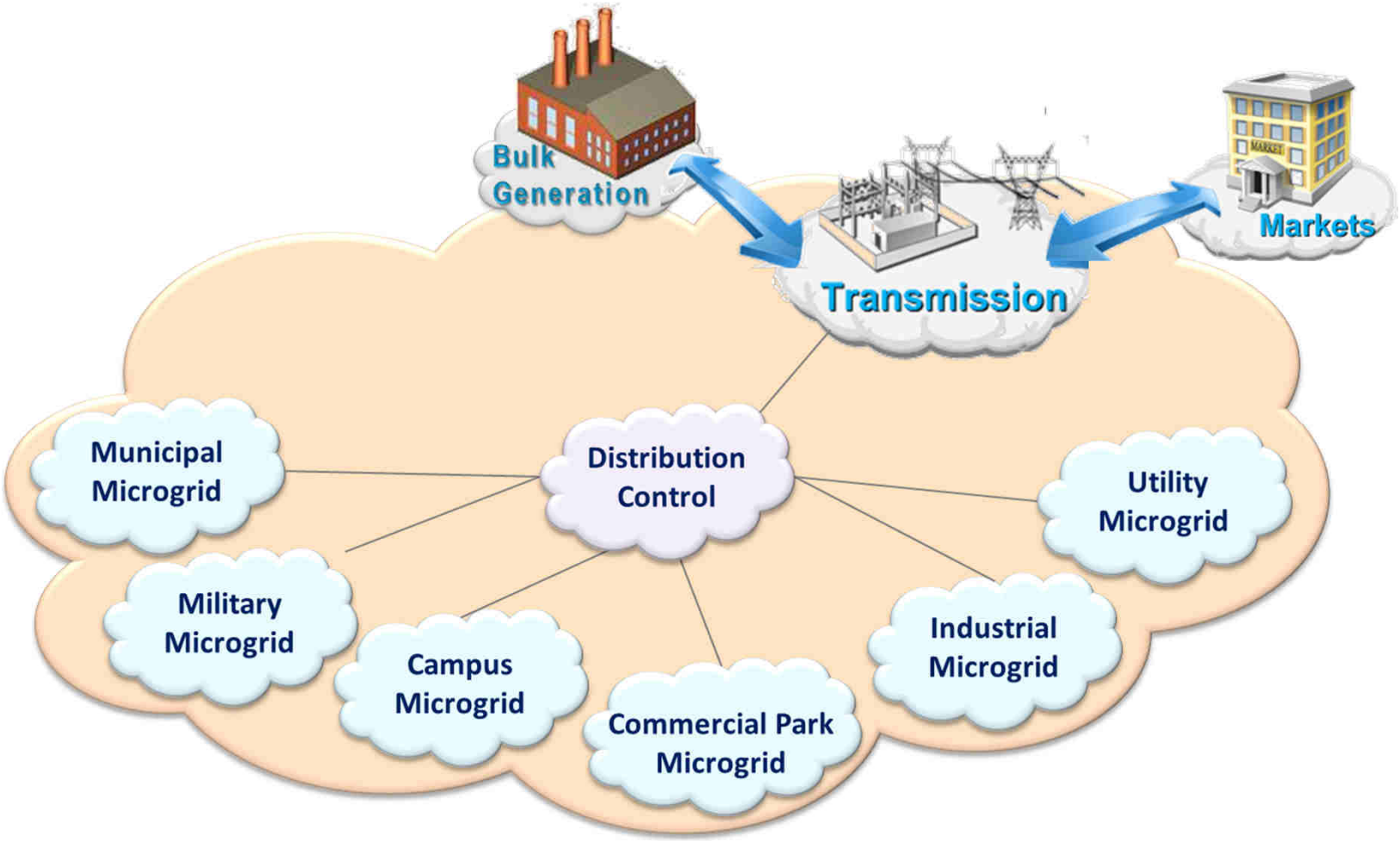
Institutional

Microgrid/Smart Grid : WEC Perspective



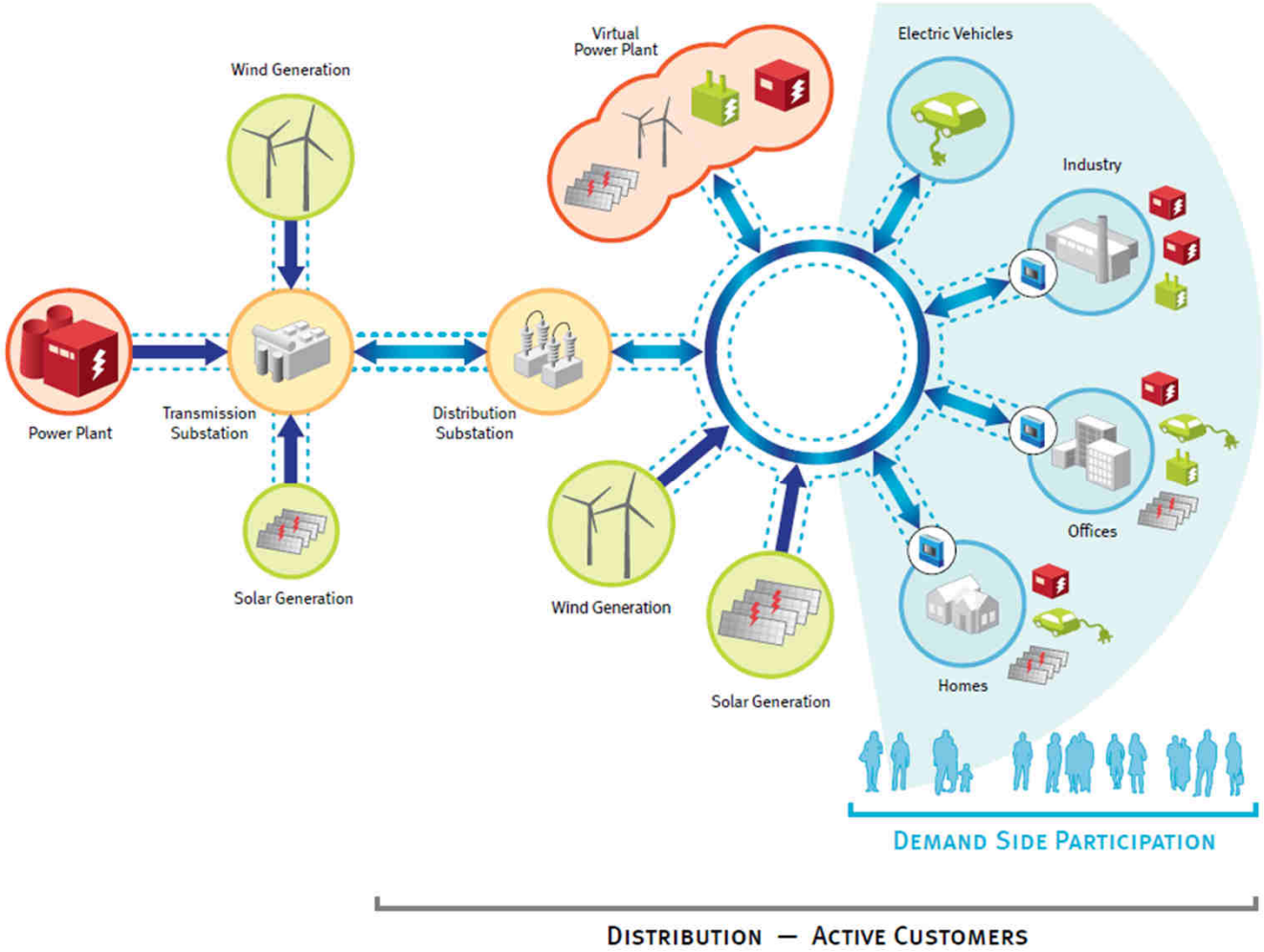
From: "Smart grids: best practice fundamentals for a modern energy system", WEC, 2012

Microgrid/Smart Grid : DOE Perspective



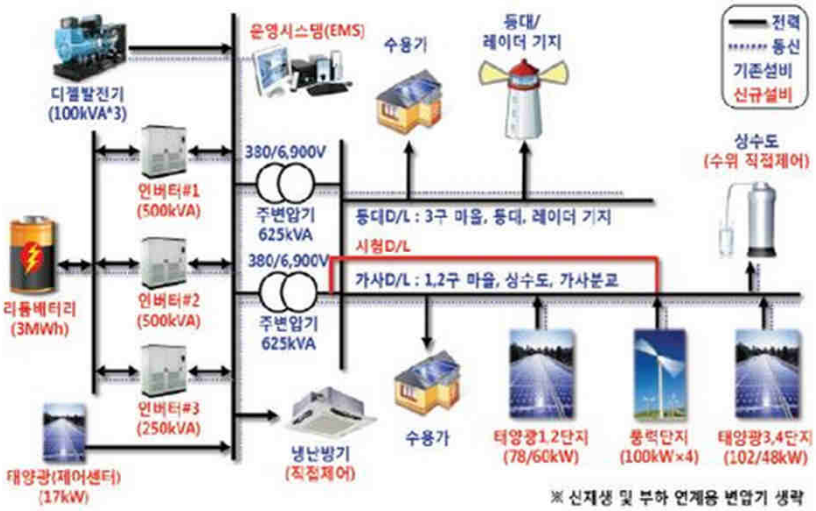
From: "DOE Microgrid Demonstration Project", NETL, 2013

Microgrid/Smart Grid : EU Perspective



http://www.eurelectric.org/media/26140/broch.10steps_lr-2011-030-0304-01-e.pdf

Gasa-Island Energy-Independent (KEPCO, 2014)



● Project General

- ✓ 168 Households (286 Inhabitants)
- ✓ Average Load : 95 kW
- ✓ Average Wind Speed : 5.8 m/s
- ✓ Average Solar Radiation : 3.88 kWh/m^2
- ✓ Total Project Cost : 8 Mil. US$
- ✓ Fuel Cost Saving : 0,28 Mil US$/year

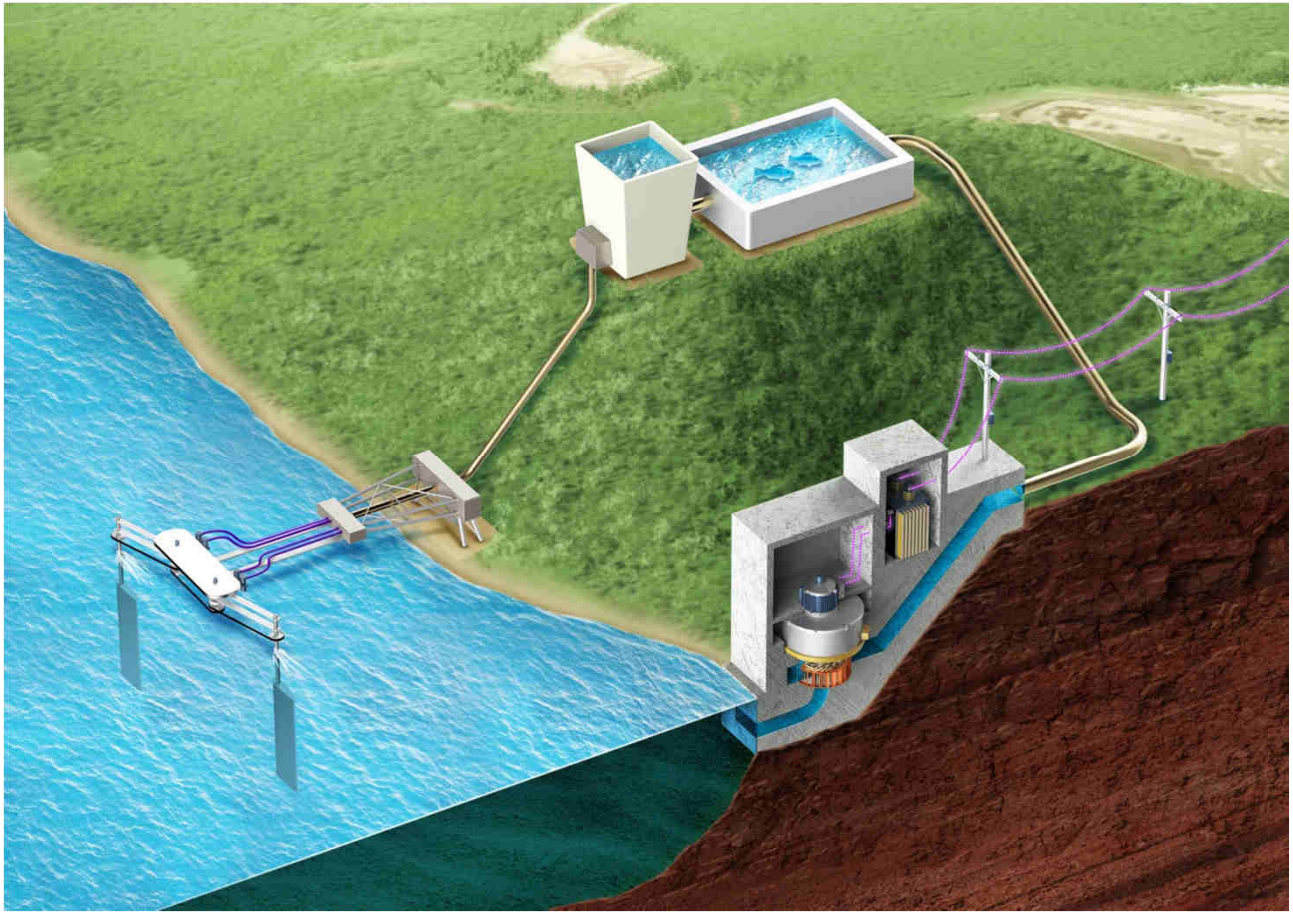
● Installed Facilities

- ✓ Operation : SCADA+EMS (Automatic Source Control)
- ✓ Inverter : 2 x 500 kVA, 1 x 250kVA
- ✓ Lithium Battery : 3MWh
- ✓ Wind Generator : 4 x 100kW (PMSG)
- ✓ Solar Generation : 314 kW (8 Places)
- ✓ Demand Management : Water Supply Tank & Air Conditioner
- ✓ Diesel Generator : 3 x 100kW (existing)

Uldolmok Experimental Station for Hybrid System

- **Modification of Existing Plant**
  - ✓ Wind Energy
  - ✓ Solar Energy
  - ✓ Tidal Energy
  - ✓ Energy Storage System (Micro-CAES ; Compressed Air Energy Storage)
- **Installation**
  - ✓ 2016 ~ 2017
- **R&D Purpose**
  - ✓ Developing Technologies
  - ✓ Performance Assessment
  - ✓ Environmental Impact Monitoring

Seawater Pumped Hydropower Storage (PHS)



- **Pumping**
  - ✓ Wind
  - ✓ Wave (combine with Breakwater)
  - ✓ Tide (Current)
- **Pumped Seawater**
  - ✓ Aquaculture
  - ✓ Cultivation of Ulva pertusa ➔ Biofuel / Fertilizer
  - ✓ Heated by Solar Energy ➔ Air Conditioning
- **Micro-Hydropower**
  - ✓ Energy Storage for Microgrid
  - ✓ Easy Control of Power -in / -off
  - ✓ Saving O&M Cost (??)

Summary and Discussions

- Technologies for ocean energy development have been improved rapidly, and several machines for wave and tidal energy is at the pre-commercial stage.
- Ocean energy could play an important role as energy supplier and storage in the microgrid for energy-independent island.
- In order to support to green energy-independent island project of Korea including ESS (Energy Storage System), CAES (Compressed Air Energy Storage) combined with breakwater and seawater pumped hydropower storage (PHS) using wind, wave and tide energy are proposed.
- Ocean energy resources, environmental and economic conditions are different from country to country and site to site. For the cost-effective and environmentally sound development of an isolated microgrid of an island, the energy scheme and system should be carefully studied at the design stage.

Thank You