

Current Status and Future Perspectives of Marine Renewable Energy Development in Korea

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Introduction

● Ocean Energy Promotion in Korea

➤ National Roadmap of Renewable Energy Development

- ✓ National promotion of “Low Carbon Green Growth”
 - Funding for renewable energy R&D: \$320million (2009) → \$380million (2010)
- ✓ 11% of national energy demand supplied by new & renewable energy in 2030

➤ Ocean Energy RD&D Program in Korea

- ✓ MLTM (Ministry of Land, Transport and Maritime Affairs)
 - “Development of Ocean Energy Utilization Technologies”
 - Educational promotion program in ocean energy
- ✓ MKE (Ministry of Knowledge Economy)
 - Ocean energy R&D in “Development of New & Renewable Energy Technologies”
 - Infra structure establishment program

Roadmap of Ocean Energy R&D and Supply

National Master Plan 2030 of New & Renewable Energy RD&D

- National supply of new & renewable energy in 2030 : 11% of national energy demand

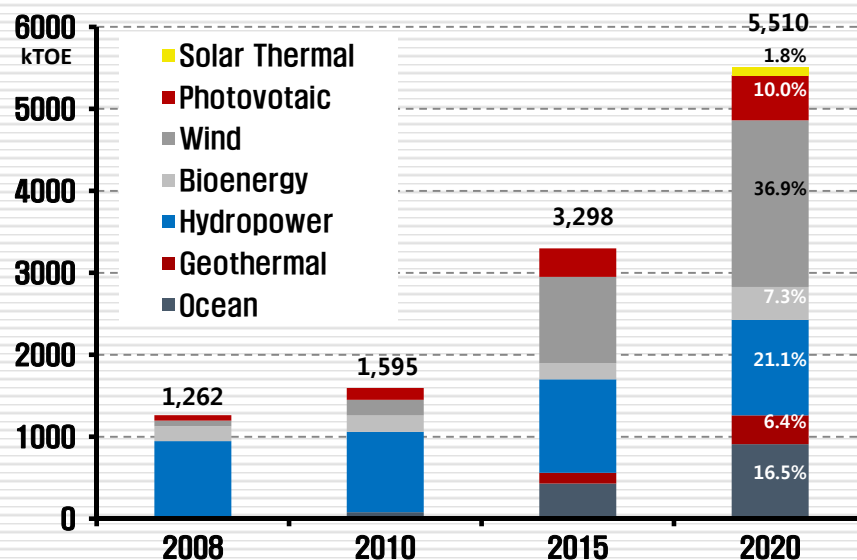
(unit: kTOE, %)

| Resources | 2008 | 2010 | 2015 | 2020 | 2030 | Annual Increase |
|------------------------|----------------|-----------------|------------------|------------------|--------------------|-----------------|
| Solar Thermal | 33 (0.5) | 40 (0.5) | 63 (0.5) | 342 (2.0) | 1,882 (5.7) | 20.2 |
| Photovoltaic | 59 (0.9) | 138 (1.8) | 313 (2.7) | 552 (3.2) | 1,364 (4.1) | 15.3 |
| Wind | 106 (1.7) | 220 (2.9) | 1,084 (9.2) | 2,035 (11.6) | 4,155 (12.6) | 18.1 |
| Bioenergy | 518 (8.1) | 987 (13.0) | 2,210 (18.8) | 4,211 (24.0) | 10,357 (31.4) | 14.6 |
| Hydropower | 946 (14.9) | 972 (12.8) | 1,071 (9.1) | 1,165 (6.6) | 1,447 (4.4) | 1.9 |
| Geothermal | 9 (0.1) | 43 (0.6) | 280 (2.4) | 544 (3.1) | 1,261 (3.8) | 25.5 |
| Ocean | 0 (0.0) | 70 (0.9) | 393 (3.3) | 907 (5.2) | 1,540 (4.7) | 49.6 |
| Waste | 4,688 (73.7) | 5,097 (67.4) | 6,316 (53.8) | 7,764 (44.3) | 11,021 (33.4) | 4.0 |
| Total | 6,360 | 7,566 | 11,731 | 17,520 | 33,027 | 7.8 |
| National Energy (mTOE) | 247 | 253 | 270 | 287 | 300 | 0.9 |
| Ratio | 2.58% | 2.98% | 4.33% | 6.08% | 11.0% | |

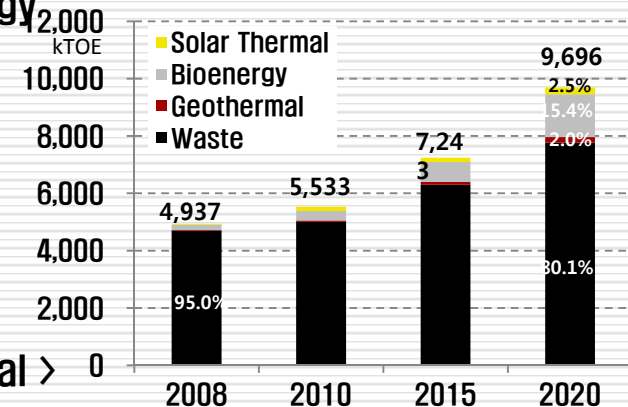
Plan of Ocean Energy Supply in Electricity

- Electricity supply by renewable energy in 2020(2030) : 4.7(7.7)% of national electricity demand
- Major contribution from wind, hydropower & ocean energy

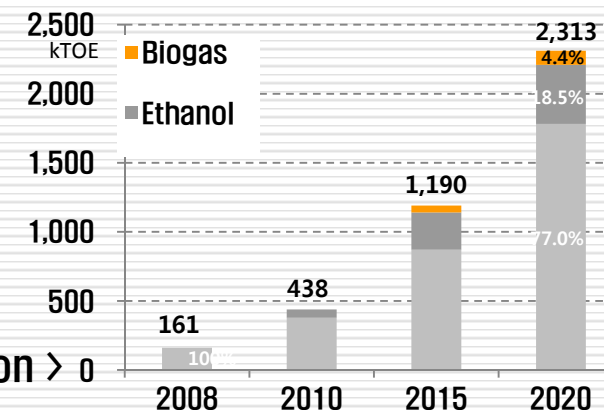
< supply prospect in electricity >



< Thermal >



< Transportation >



Ocean Energy Resources in Korea

Resources and Sites

- Estimated ocean energy resources
: more than 14,000MW

| Tidal Range | Tidal Stream | Wave (Offshore) |
|-------------|--------------|-----------------|
| 6,500MW | 1,000MW | 6,500MW (50GW) |

- Feasible capacity
- ✓ Tidal R. : Approx. 2,400 MW
 - ✓ Tidal S. : Approx. 500 MW
 - ✓ Wave : Approx. 650 MW (Coastal)



Tidal Range Sites in Korea

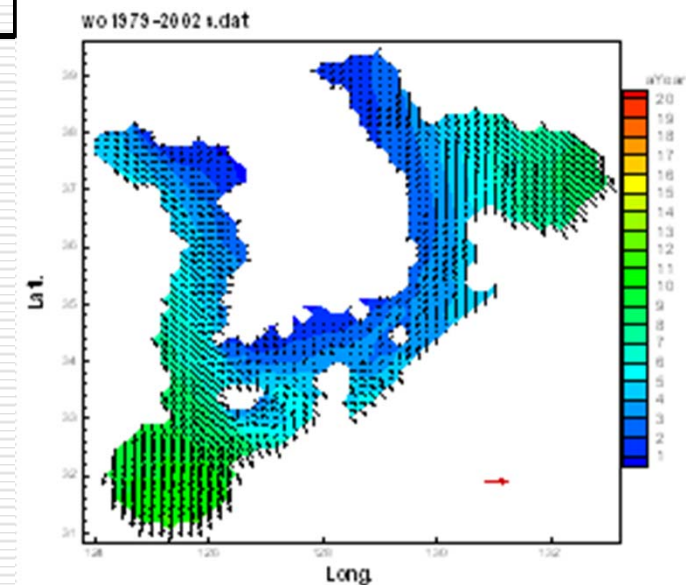
| Site | Installation Capacity (MW) | Annual Output (MWh) | Tonnage of Oil Equivalent (TOE) | CO2 Reduction (ton) | Remark |
|------------|----------------------------|---------------------|---------------------------------|---------------------|--------|
| Sihwa | 254 | 552,700 | 123,525 | 232,245 | 2010 |
| Garolim | 520 | 950,532 | 211,969 | 399,414 | |
| Incheon | 1,440 | 2,271,000 | 506,433 | 954,274 | |
| Ganghwa | 810 | 1,536,000 | 342,528 | 645,427 | |
| Saemangeum | 400 | 687,000 | 153,201 | 288,677 | |
| Cheonsu | 720 | 1,206,000 | 268,938 | 506,761 | |
| Haeju | 2,300 | 2,999,000 | 668,777 | 1,260,180 | |
| Total | 6,444 | 10,202,232 | 2,275,098 | 4,286,978 | |

Tidal Stream Sites in Korea

| Site | Installation Capacity (MW) | Annual Output (MWh) | Tonnage of Oil Equivalent (TOE) | CO2 Reduction (ton) | Remark |
|----------|----------------------------|---------------------|---------------------------------|---------------------|--------|
| Uldolmok | 50 | 122,640 | 27,349 | 51,533 | 2009 |
| Jangjuk | 150 | 367,920 | 82,046 | 154,600 | |
| Maenggol | 250 | 613,200 | 136,744 | 257,667 | |
| Others | 550 | 1,349,040 | 300,836 | 566,867 | |
| Total | 1,000 | 2,452,800 | 546,974 | 1,030,667 | |

● Wave Sites in Korea

| Region | Feasible Capacity (MW) | Annual Output (MWh) | Tonnage of Oil Equivalent (TOE) | CO2 Reduction (ton) |
|----------|------------------------|---------------------|---------------------------------|---------------------|
| Coastal | 650 | 1,138,800 | 253,952 | 478,522 |
| Offshore | 5,000 | 13,140,000 | 2,930,220 | 5,521,414 |



Korean Status of Tidal Energy Development

Tidal Energy Plant and RD&D in Korea

| Project (Charged by, Funded by) | Type of Converter | Structure | Power Capacity | Project Period | Remarks |
|---|--------------------------|-------------------------|--------------------------|-------------------|-------------------------------------|
| Shihwa Power Plant (KORDI, K water) | Horizontal Axial Bulb | Concrete Dam | 10X 25.4MW | 2004- 2010 | Operation in 2011 |
| Uldolmok Pilot Plant (KORDI, MLTM) | Helical Turbine (VAT) | Jacket | 2X500kW | 2001- 2010 | Completed In 2009 |
| OS Tidal Stream Device (OceanSpace, MKE) | 2 Blades Propeller | Floating | 100kW | 2006- 2009 | Sea Test in 2009 |
| Tidal Stream Energy RC (KMU, MKE) | (Turbine Design) | (Underwater Design) | (Resource Assessment) | 2009- 2014 | Joint Research Center |
| Standard Turbine Design S/W (KMU, MKE) | (HAT/VAT) | (Performance Charts) | (GUI System) | 2009- 2012 | Based on CFD |
| VIVEED (MOERI, MKE) | VIV Cylinder | Pile | ? | 2009- 2012 | VIVACE by Michigan Univ. |
| In-stream Hydro System (Ecocean Ltd., MKE) | Helical Turbine (HAT) | Jacket | 50kW | 2010- 2012 | Discharge Channel of Power Plant |
| MW Class Tidal Stream Device (HHI, MKE) | Pitch Control | ? | >500kW | 2010- 2015 | Sea Test in 2014 |

● Sihwa Tidal Barrage Power Plant

➤ Site Conditions

- ✓ Mean tidal range : 5.6m
- ✓ Basin area : 43km²(MSL)
- ✓ Capacity : 254MW
- ✓ Estimated annual output : 553GWh
- ✓ One-way flood generation



➤ Construction History

- ✓ Sea dike of 12.7km completed in 1994
- ✓ Proposed as a counter measure to lake water pollution in 1997
- ✓ Feasibility study in 2002
- ✓ Plant construction 2004 to 2010



● Uldolmok Tidal Current Pilot Plant

➤ 1MW Pilot Plant

- ✓ Max. current speed : 5.5m/s
- ✓ Helical turbine (2x500kW)
- ✓ Completion : 2009. 5.



Korean Status of Wave Energy Development

Wave Energy RD&D in Korea

| Project (Charged by, Funded by) | Type of Converter | Structure | Power Capacity | Project Period | Remarks |
|---|------------------------------|-------------------------------|---------------------------|--------------------------------|---|
| Jujeon-A (MOERI, KEPRI/MKE) | OWC | Floating | 60kW | 1993-2001 | Pilot Plant in 2001 |
| Water Reservoir WEC (MOERI, KEPRI/MKE) | Wave Overtopping | Caisson | 250kW | 2003-2005 | Basic Research |
| Yongsoo 500kW OWC (MOERI, MLTM) | BBDB OWC | Floating Caisson | 150W 500kW | 2003-2007 2003-2012 | Sea Test in 2006 Pilot Plant in 2011 |
| Reef with Vanes (MOERI, MKE) | Wave Overtopping | Monopile or Jacket | 250kW | 2007-2010 | Optimal Design for Pilot Plant |
| Variable Liquid Column Oscillator (KEPRI, MKE) | Attenuator | Floating | 300kW | 2010-2011 | Prototype Test in 2011 |
| Hydraulic Pumping WEC (Taekyung Ind., MKE) | Point Absorber | Floating | 200kW | 2010-2011 | Prototype Test in 2011 |
| Pendulum WEC (MOERI, MLTM) | Oscillating Surge | Floating | 300kW | 2010-2015 | International Collaboration |

● Floating BBDB(Backward Bent Duct Buoy)

■ MOERI/KORDI (2003~2007)

- ☐ 150W navigational floating lighthouse
- ☐ Installed at Chaguido in Jeju
- ☐ Sea test for 2006.6~2007.5
- ☐ L : 5.5m, B : 2.75m, D : 2.5m



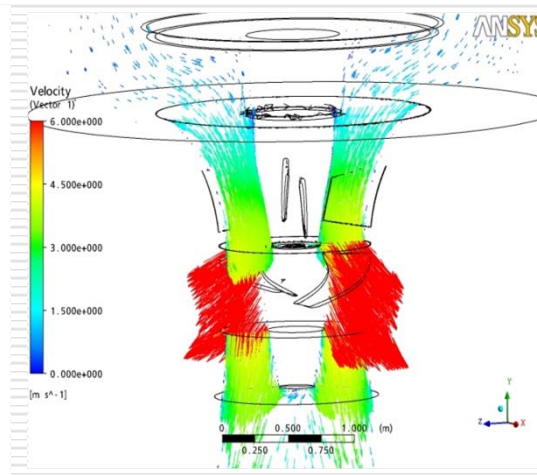
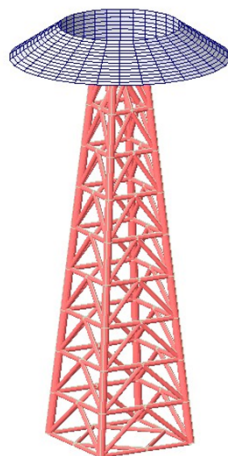
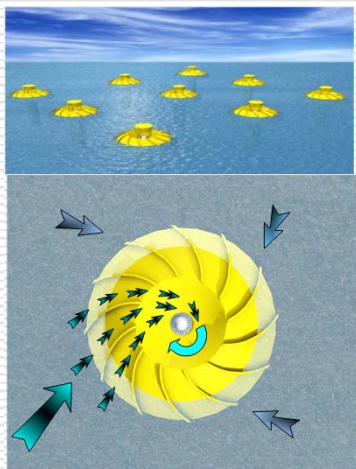
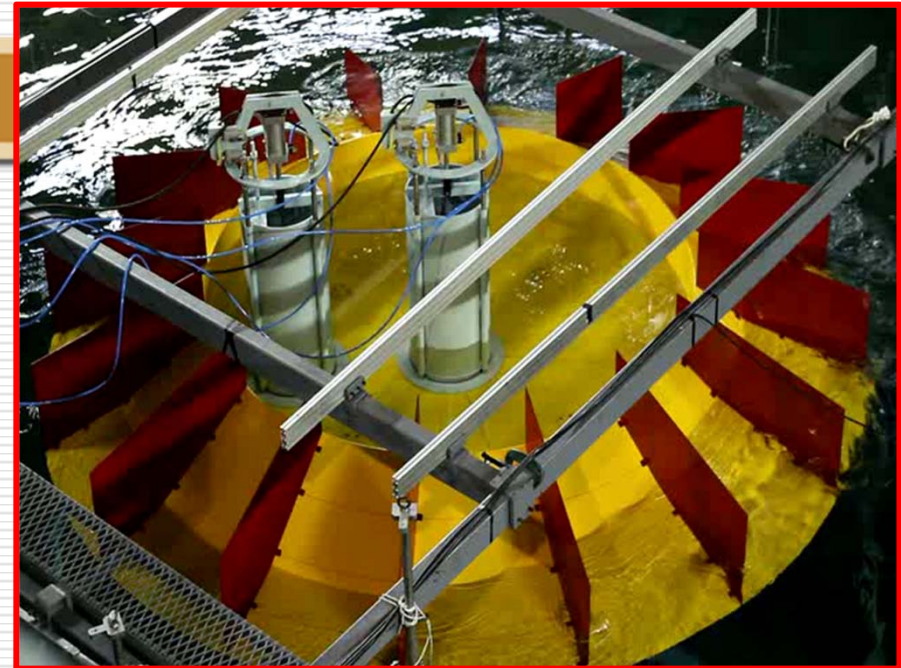
● Wave Overtopping Reef

■ 1st Phase (2007~2010)

- ☐ Wave overtopping type WEC
- ☐ Simple bottom-fixed supporting structure
- ☐ 250kW capacity

■ 2nd Phase (2011~)

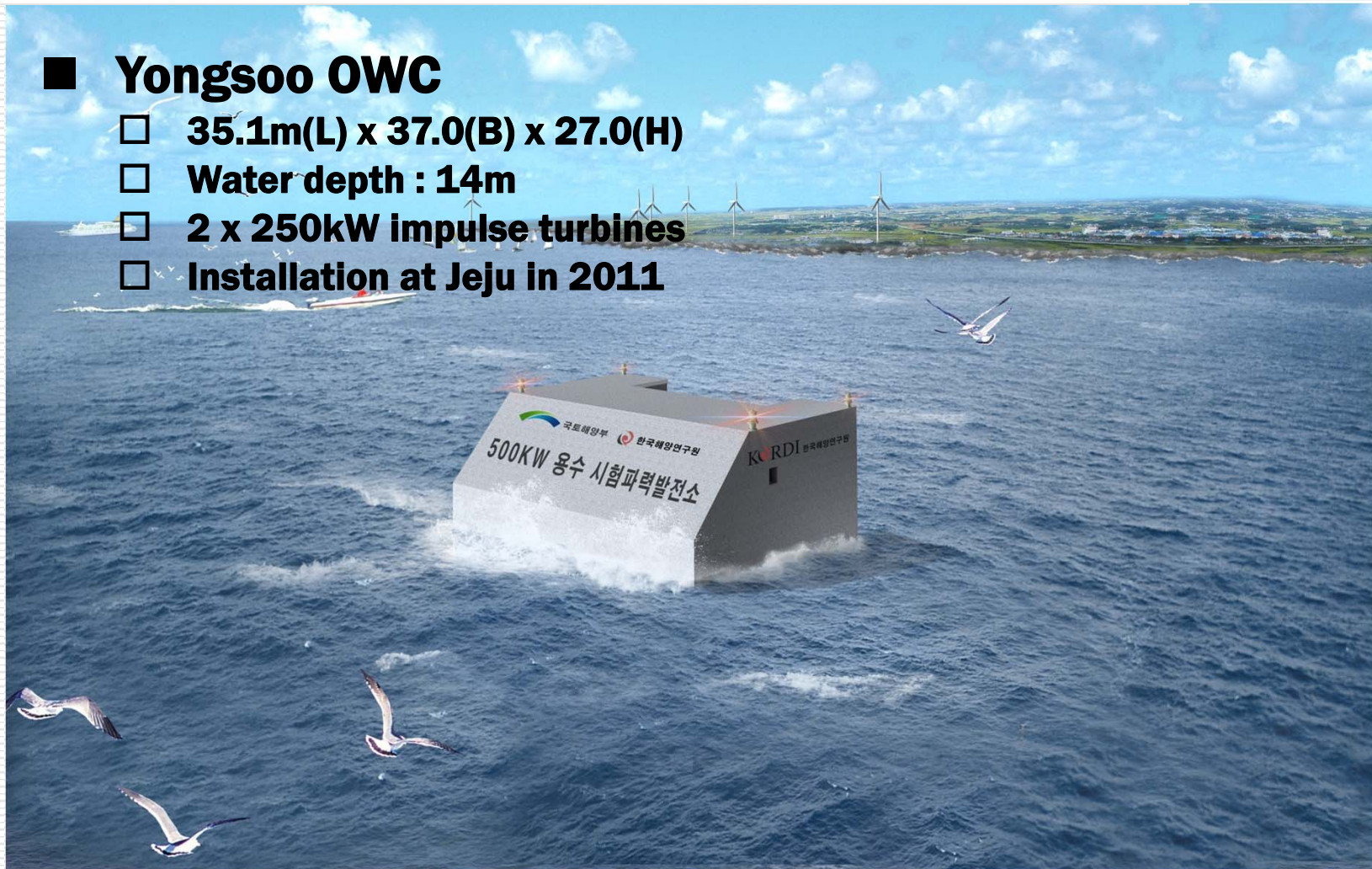
- ☐ Sea test of prototype



● Yongsoo 500kW OWC Pilot Plant

■ Yongsoo OWC

- 35.1m(L) x 37.0(B) x 27.0(H)
- Water depth : 14m
- 2 x 250kW impulse turbines
- Installation at Jeju in 2011



● Wave Activated Floating Pendulum

□ MOERI/KORDI (2010~2015)

- Collaboration with Prof. T. Watabe
- Pendulum motion in standing waves
- Rotary vane pump, pitching motion damper
- 300kW capacity

740kW Offshore Wind/Wave Power Plant

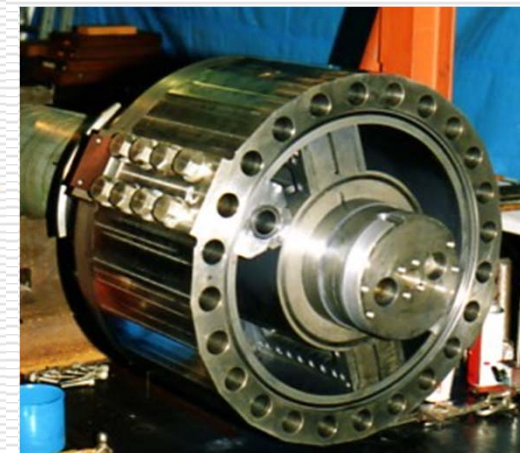
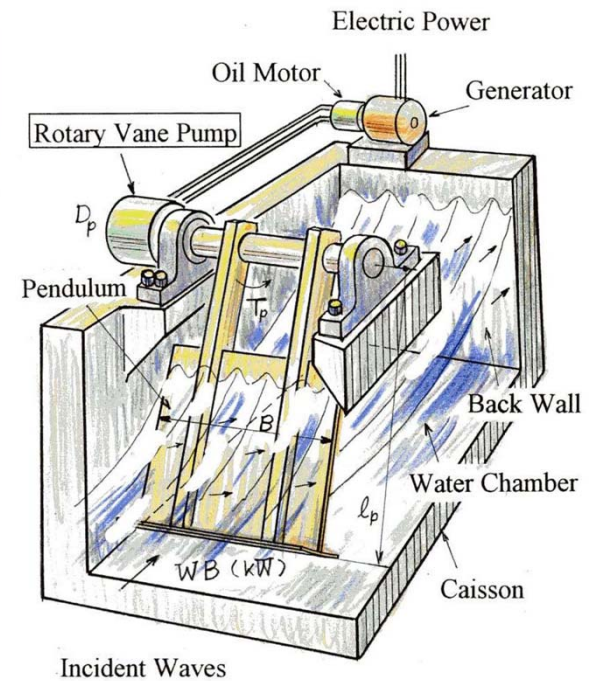
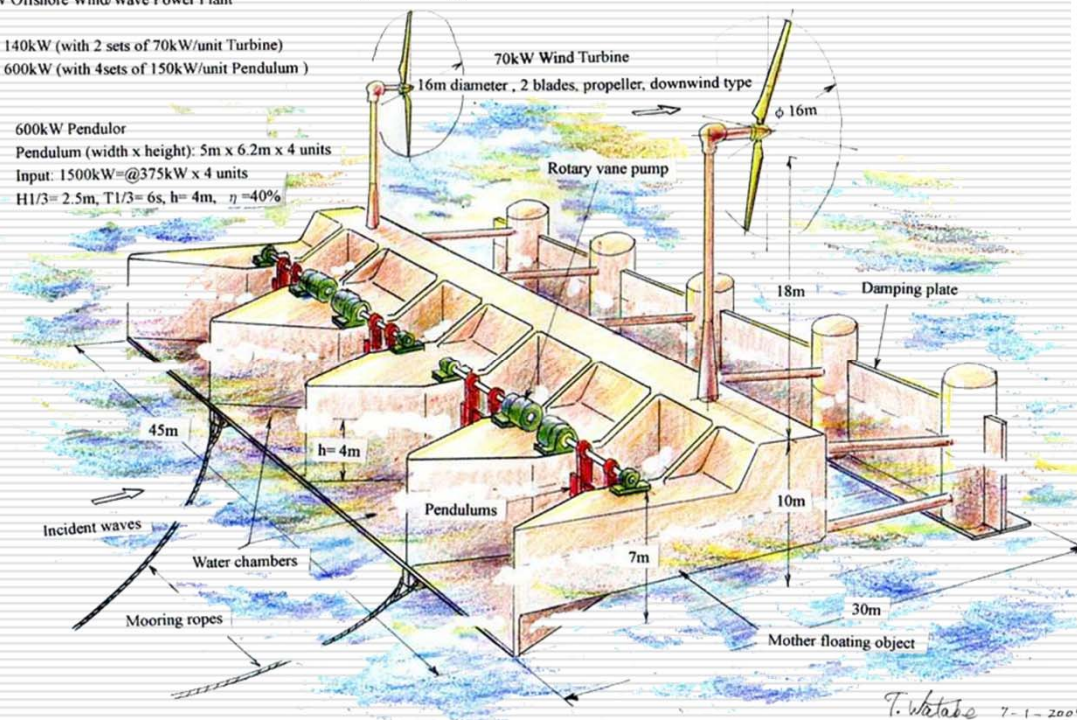
Wind: 140kW (with 2 sets of 70kW/unit Turbine)
Wave: 600kW (with 4 sets of 150kW/unit Pendulum)

600kW Pendulum

Pendulum (width x height): 5m x 6.2m x 4 units

Input: 1500kW = @375kW x 4 units

H1/3 = 2.5m, T1/3 = 6s, h = 4m, $\eta = 40\%$



National Strategy for Ocean Energy Development

Development Strategy in Phases

- Classifying ocean energy technologies into tidal(barrage), tidal current, wave, ocean thermal energy conversion(OTEC) and hybrid system
- Promotion based on 3 stages (short/mid/long term) of development

Phase 1 (2008~2012)

Building a Technologically Independent basis

- ✓ Supply Goal: 120kTOE/yr
- ✓ Develop core technologies
- ✓ Development of coastal area
- ✓ Government leading

Phase 2 (2013~2020)

Verification / Technology Advancement

- ✓ Supply goal: 900kTOE/yr
- ✓ Utilization of technologies
- ✓ Development of open sea
- ✓ Participation of Industry

Phase 3 (2021~2030)

High Value-Added Industrialization

- ✓ Supply goal: 1,500kTOE/yr
- ✓ Commercial use
- ✓ Develop Hybrid system
- ✓ Industry leading

Concluding Remarks

● Ocean Energy Development in Korea

➤ **Ocean energy resources of wave, tidal stream and tidal range are richer in the east and Jeju, south, and west coast of Korea, respectively.**

➤ **Current status of ocean energy development in Korea is in RD&D phase except the Sihwa tidal barrage power plant which is expected to start commercial operation in 2010:**

- Tidal stream : sea test of a vertical axis turbine prototype in 2009
- Wave : sea test of a OWC prototype in 2011
- Thermal difference : initiation of R&D in 2010

➤ **Renewable ocean energy RD&D strategy in Korea**

- Promotion based on 3 stages of development
 - Phase 1 (2012) : government leading, development of core technologies
 - Phase 2 (2020) : participation of industry, sea application of technologies
 - Phase 3 (2030) : industry leading, commercial use of technologies
- Supply goal of 907kTOE in 2020 which contributes 5.2% of national renewable energy demand* and 16.5% of national electricity demand provided by renewable energy in 2020 (*6.08% of national energy demand in 2020)

Thank you !

