Marine Renewable Energy: Enabling Green Marine and Maritime Ecosystems Towards a Sustainable Blue Economy

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OceanPixel
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OceanPixel is a Singapore start-up company that spun off from the Nanyang Technological University’s (NTU) Energy Research Institute. OP is currently engaged in ocean energy projects in Singapore, Indonesia, and the Philippines.

**Resource assessment**
Collects preliminary data via independent surveys, or oversee Licensed Surveyors to collect data for marine energy resource assessment.

**Project Intelligence**
In-house team of hydrodynamists to carry out quality checks, simulation, processing and analysis of data.

**Project management**
Provides project management services for project developers, from pre-feasibility studies to resource assessments, techno-economic studies, planning and execution of deployment or installation operations.

**Research and Development**
Manages performance assessment campaigns or plan and execute tests for technology developers. These tests may be long-term tests at a specific site, or in other forms like tow tests.

**Report Product**
Produces report products, which informs project developers regarding feasibility of project development in numerous sites of interest.
Around 70.8% of Earth’s surface -> 361,254,000 km².

Produces more than 70% of the oxygen on Earth.

40% of the world’s population live within 100km of an oceanic coast.

10% of the world’s population depend on fishing for livelihood.
Makings of Sustainable Marine Ecosystems

- Minimal greenhouse gas footprint of various activities in the marine space
- Efficient and sustainable use of marine space and resources through improved planning, engineering and operations
- Strive for minimal impact on marine environment by human activities
- Continued monitoring and regulating of interactions between human activities and the environment
Through What Means?

- Decrease reliance on fossil fuel
- Green energy production
- Resource and waste management
- Forward thinking infrastructures and technologies
- Regulations of marine activities
- Conservation and wildlife protection areas
- Protection against invasive species
- Education and increase awareness
Electrification: More than just electricity supply

- Electrification of Transportation
- Electrification of Vessels
- Electrification of Ports
- Automation of Processes
- Energy Storage Systems
- Aquaculture Applications
- Water Production (e.g. Desalination)
- Ice Making
- Others?
Sustainable Integrated Development for Islands & Coasts

Aquaculture & Fisheries

Green Transport – Sea and Land

Green Maritime Ecosystem – Ports, Vessels, Aquaculture, Desalination, Water, Ice/Cooling ++

Renewable Energy + Green Transport + Aquaculture + Water Production + Freezing/Cooling + Local Content + Other Sustainable Initiatives
Marine Renewable Energy

“Renewable energy production which makes use of marine resources or marine space.”*

*European Science Foundation

Ocean Renewable Energy

- Offshore Wind
- Floating Solar
- Marine biomass (micro- and macro-algae)
- Currents (Ocean Current, Tidal Currents/In-Stream)
- Tides (Tidal Range)
- Waves
- Salinity / Osmotic Gradient
- Thermal Gradient
Ocean Renewable Energy

5 Ocean Renewable Energy Resources*

• **Ocean Current / Tidal In-Stream** energy is harvested by Current/Hydrokinetic turbines placed underwater where fast-flowing currents turn the generator blades similar to what wind does with wind turbines.

• **Tides (Tidal Range)** Tidal Barrages utilize the potential energy from the difference in height between high and low tides.

• **Wave** energy is produced from the surface motion of ocean waves or from pressure fluctuations below the surface.

• **Ocean Thermal** energy conversion (OTEC) uses the temperature difference between the surface seawaters (warm) and the deep seawaters (cool) to drive a heat engine to produce electricity.

• **Salinity Gradient** power is the available energy (or chemical potential) from the differences in salt concentration between the fresh water and seawater.

*IEA-OES
Marine Renewable Energy: Technology Readiness

- **Marine Floating Solar**
  - Deep Ocean Current
    - Very few active concepts being developed; laboratory-scale tank testing has occurred
  - Wave Energy Converters
    - Full-scale prototypes being tested. Many leading WEC designs have remained at this stage for some time
  - Tidal Stream
    - Leading developers testing individual prototypes in locations representative of potential commercial sites, generating grid-connected electricity. Demonstration in arrays still lacking
  - Tidal Range
    - Most mature of the ocean energy technologies, with a proven track record stretching back to the 1960s but limited deployment to date

- **Offshore Wind**
  - Salinity Gradient
    - A handful of university-based research projects have been conducted, as well as small-scale system operation
  - OTEC
    - A few test facilities (mostly pilot-scale) trialed, but no long-term operation

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**Source:** IRENA
Global Initiatives

>1,000 Sites
200MW each

>1,000 Sites
200MW each
Total = > 5,000 MW deliverable capacity

107% of electrical demand in Orkney met by renewables in 2014

Orkney Islands, North Scotland, UK
Developing Countries’ Initiatives

Simulation Studies
- Myanmar Tidal Barrage
- Indonesia Tidal Current Test
- Philippines Tidal Barrage

Myanmar Tidal Barrage
- Tow Tanks (eg UTM, MMU, NTU)

Indonesia Tidal Current Test
- Malaysia OWC Test

Vietnam Tidal Turbine Drive Train
- Singapore Tidal Turbine Testing

Europe, N. America, Australia

Brunei Offshore Wind

Tow Tanks (eg UTM, MMU, NTU)

Philippines Tidal Barrage

Source: SEAcORE 2013
The BUMWI facility is located on the southern side of Bintuni Bay, West Papua, Indonesia.

The carbon footprint of the plant is now set to be reduced by harnessing power from nearby tidal currents.

Initiated by: BUMWI

Supported by: OceanPixel, aquatera, Energy Research Institute @ NTU
The project approach combines appropriate technology with local content and know-how.

The tidal turbine is suspended below a floating barge in a simple and robust arrangement which allows for straightforward inspection and maintenance and can be easily replicated.

The project has proven the capability of a multi-company team to develop, implement and successfully deploy a tidal turbine in one of the most remote and areas of Indonesia.

The installation of Schottel Hydro’s 50kW turbine in West Papua is a significant step on the journey to use marine renewables to de-carbonise energy supplies across the region.
Case Study: Hybrid System for an Island Micro-Grids

Power System Config.

<table>
<thead>
<tr>
<th>Configuration</th>
<th>RE Fraction</th>
<th>Excess Electricity</th>
<th>LCOE (USD/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diesel GenSets (910, 100 kVA) + Batt (576kWh) + Solar (300kWp) + Tidal (200kWp)</td>
<td>31.6%</td>
<td>12.6%</td>
<td>0.368</td>
</tr>
<tr>
<td>Diesel GenSets (910kVA, 100 kVA) + Batt (720kWh) + Solar (600kWp)</td>
<td>38.6%</td>
<td>20.1%</td>
<td>0.386</td>
</tr>
<tr>
<td>Diesel GenSets (910kVA, 100 kVA) + Batt (1440kWh)</td>
<td>0.0%</td>
<td>2.47%</td>
<td>0.456</td>
</tr>
<tr>
<td>Diesel GenSets (2 x 910, 500, 100 kVA)</td>
<td>0.0%</td>
<td>14.5%</td>
<td>0.50</td>
</tr>
</tbody>
</table>

DIESEL Generators Only
Ocean Energy - Configuration Options
(Tidal In-Stream Energy Device example)

• Jetty-based / fixed structure (e.g. bridges)
• Floating
• Submerged (neutrally-buoyant)
• Seabed-mounted
• Others? – Vessel-mounted?
Hybridized Marine RE Pathway

Off-Grid and Co-App Market → Grid-Connected Project Dev’t (Progressive Dev’t) → Large Scale Commercial Grid-Tied Projects

Scoping
Strategic Planning
Scouting [1-3 years]
Small Scale Pilot (Off-Grid and Micro-grid) → Increase Pilot Capacity (Progressive Dev’t) [3-5 years] → Large Scale Grid-Connected and Other Islands’ Micro-Grid Projects

Capability Development
Support Mechanisms (Financial, Policy, etc)

Outer Islands’ Projects

Deployments/Installations

OceanPixel
Building the Sustainable Future Blue Economy

Long-Term Sustainability
Global Competitiveness
New Products & Services

Inward Investment
Coordination
Capability Dev't
Enriched Regional Ecosystem

Marine & Maritime Sustainability Hub Stage

>$150M in the next 5 years

Various Efforts
- Agencies
- R&D
- Network
- SMEs
- Industries

Offshore Marine Maritime Logistics Clean Tech Energy Intelligence

Synergy
Alignment
Potential Pilot Projects

Ocean/Marine Renewable Energy, Floating Solar

Energy Systems Integration

Transportation

Ice

Energy Storage

Testbedding
Other Innovations Technologies
Business Models “Learn by Doing”

Ports/Marinas/Bays

Water Production

OceanPixel
Key Take Away Points

- Marine Renewable Energy is coming up.
  - *Tidal/wave energy are potential options, typically hybrid with solar energy, storage and diesel are the way to go*

- Having Market Supports (e.g. Feed-in-Tariff) can accelerate the progress of Marine RE
  - *Pilot, Demos, First movers are needed.*

- Clean Electricity (from the Ocean) is just one aspect, there are also jobs, industries, and other benefits
Summary / Conclusions / Recommendations

- **Marine Renewable Energy Options Exist**
  - Floating Solar, Offshore Wind (can be feasible)
  - Waves and Currents, maybe OTEC and Salinity Gradient
  - Need for a Resource Inventory Review and Suitability Studies for Pilot Projects

- **Green Marine and Maritime Ecosystem**
  - Lower Hanging Fruits - Green Vessels, Green Ports
  - Electrification of a Suite of Applications - Transport, Aquaculture, Food, Water
  - Detailed planning of a Sustainable Integrated Development for Islands and Coasts

- **Progressive Development Approach Towards a Blue Economy**
  - Leverage the Marine/Maritime Ecosystem of the Country/Region(s)
  - Capability Development - Local Supply Chain (especially Services)
  - Demonstration and Pilot Projects can accelerate the uptake
  - Hybrid Systems and Co-Application will be key to success
Realising Marine Renewable Energy Opportunities in the Region

- Strategic Marine Renewable Energy Resource Assessment
- Marine Spatial Planning
- Pilot Projects and Demonstrations
- Industry Development Roadmap
- Survey of Current Human and Resource Capabilities
- Outreach and Awareness Program
Thank You! ☺

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