Barriers to Ocean Energy Technology Adoption and Role of Policies & Institutional System to Promote in Asia

Dr. Narasimalu Srikanth
* Agenda

- Asia Energy needs
- Asian country’s ocean energy targets & policies
- ASEAN (SEA) ocean renewable focus
- Existing barriers to ocean energy adoption
- Singapore’s ocean energy promotion efforts
- Summary
Asia is in an energy ‘Trilemma’ due to:
- Its population reaching 4.3 billion of 8.7 billion world population by 2035.
- Sustain economic growth
- Energy security
- Control environmental impact

Ocean Renewables can support the region in terms of:
- Job creation
- Lower oil dependence
- Reduced green house gas emissions

Success of Ocean Renewables depends on:
- Improve the efficiency of technologies
- Leverage regional inter-industry competence
- Reduce their costs and develop nature
- Self sustaining industries to manufacture, Install and maintain these systems
China

- **National Plan**

- **National Strategy & Target**
  - The Administrative Center for Marine Renewable Energy (ACMRE, SOA) established in 2010
  - Special fund for marine renewable energy in 5 areas by SOA since 2010
  - National target for renewable energy
    - ≥9.5% renewable energy by 2015
    - ≥20% renewable electricity by 2015
  - National target for marine renewable energy
    - 50MW installed capacity of MRE by 2015
Resource potential

- Wave height of 1.5m (more than 3 months a year) at water depth of 200meters shows up to 19 TWh/yr capacity.
- Tidal current speed 1.5m/sec is observed at 20 to 200m depth 10 TWh/yr.
- OTEC resource shows 20 deg.C for more than 3 months a year can provide 47 TWh/yr.

Targets

- Wave Power Generation: Unit Capacity: < 0.1MW (at present) Plans to achieve 0.5~1.0MW (by 2020) and 2MW (by 2030).
- Full scale tank testing and further from 2013 focuses demonstration of ocean energy research focused power generation system to achieve generation cost of 40 yen/KWh.
- Since 2011, Establish element technologies to achieve power generation cost of 20 yen/KWh & 5~10 yen/kWh (2030).

Policies

- Renewable Portfolio Standards (RPS) introduced since 2003 for different renewables.
- Purchase of residential power started since 2009.
- Feed in tariff for hydropower varies from 25.2 to 35.7 Yen/KWh depending on size for 20 year duration.
- Electric utilities are obliged to allow grid connections and execute contracts as required for the purchase.
- The FIT rate and contract period shall be determined corresponding to the type, form of installation, scale etc. of renewable energy sources.
- Subsidies to reduce initial cost for renewable energy and tax rebates have been introduced for renewables.
India

- India has abundant tidal & wave energy resources.
  - Tidal power potential is estimated to be up to 7GW @ Gulf of Cambay and 1.2 GW @ Gulf of Kachh and 100 MW @ Sundarbans.
  - Wave energy potential off the 6000Km coastal length with capacity of 5 MW to 15 MW/meter is about 40 GW.
  - For example pilot project deployed in Thurvananthalpuram of 150 KW.
- Government Incentives
  - Ministry of New and Renewable Energy (Feb 2011) commits financial incentives of up to 50 percent of the project cost related to tidal power.
  - For example Gujarat supported 4.8 million to develop nation’s first tidal power.
- Good research institutes: IIT-Chennai (Dept. of ocean engg.), National Institute of ocean technology focuses on tidal and wave energy.
- Lack of established industry structure makes OES adoption difficult.
- Similar to wind there are possibilities to uptake in full capacity
- Key challenges exist due to lack of services in finance, resource assessment, environmental surveys, design, manufacture, offshore construction, operation and decommissioning.
- Tidal Barrage is well investigated since 2000
- Tidal range is 11 m and 8 m at Gulf of Cambay and Gulf of Kachh.
Supply by marine renewable energy in 2030: 4.7% of national and renewable target (11% of renewable energy on overall).

Early development of tidal barrage project.

<table>
<thead>
<tr>
<th>Resources</th>
<th>2008</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
<th>2030</th>
<th>Annual Increase</th>
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<tbody>
<tr>
<td>Solar Thermal</td>
<td>33 (0.5)</td>
<td>40 (0.5)</td>
<td>63 (0.5)</td>
<td>342 (2.0)</td>
<td>1,882 (6.7)</td>
<td>20.2</td>
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<tr>
<td>Photovoltaic</td>
<td>59 (0.9)</td>
<td>138 (1.8)</td>
<td>313 (2.7)</td>
<td>552 (3.2)</td>
<td>1,364 (4.1)</td>
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<tr>
<td>Wind</td>
<td>106 (1.7)</td>
<td>220 (2.9)</td>
<td>1,084 (9.2)</td>
<td>2,035 (11.6)</td>
<td>4,155 (12.6)</td>
<td>18.1</td>
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<tr>
<td>Bioenergy</td>
<td>518 (8.1)</td>
<td>987 (13.0)</td>
<td>2,210 (18.8)</td>
<td>4,211 (24.0)</td>
<td>10,357 (31.4)</td>
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<tr>
<td>Hydropower</td>
<td>946 (14.9)</td>
<td>972 (12.8)</td>
<td>1,071 (9.1)</td>
<td>1,165 (6.6)</td>
<td>1,447 (4.4)</td>
<td>1.9</td>
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<td>Geothermal</td>
<td>9 (0.1)</td>
<td>43 (0.6)</td>
<td>280 (2.4)</td>
<td>544 (3.1)</td>
<td>1,261 (3.8)</td>
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<tr>
<td>Ocean</td>
<td>0 (0.0)</td>
<td>70 (0.9)</td>
<td>393 (3.3)</td>
<td>907 (5.2)</td>
<td>1,540 (4.7)</td>
<td>49.6</td>
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<tr>
<td>Waste</td>
<td>4,688 (73.7)</td>
<td>5,097 (67.4)</td>
<td>6,316 (53.8)</td>
<td>7,764 (44.3)</td>
<td>11,021 (33.4)</td>
<td>4.0</td>
</tr>
<tr>
<td>Total</td>
<td>6,360</td>
<td>7,566</td>
<td>11,731</td>
<td>17,520</td>
<td>33,027</td>
<td>7.8</td>
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<tr>
<td>National Energy (mTOE)</td>
<td>247</td>
<td>253</td>
<td>270</td>
<td>287</td>
<td>300</td>
<td>0.9</td>
</tr>
</tbody>
</table>
Australia

- Emissions Management: Carbon price introduced $23/Ton to be introduced in July & increase 2.5% p.a for 3 years
- Ocean Energy Industry Australia started since July 2011
- Resources: CSIRO Tidal estimates 8TW.h/yr Kimberley and 0.13 TWh/yr Tasmania banks strait
- CSIRO estimates wave energy of 1300 TWh/Yr along the south coast
- Institutions: Australian Renewable Energy Agency (ARENA)
  - National funding of R&D, deployment & commercialization of renewables.
  - $3 billion investment (2012-2022)
  - Supports pilot scale projects ($89 million up to date)
  - Regulation: develops national framework for ORE.
- Around 10 universities active in ocean renewables.
- There are 19 ocean energy developers in Australia (11 wave and 8 tidal)
  - Wave: Oceanlinx (Energetech): Oscillating water column, Carnegie wave energy
  - Victorian wave partners: Ocen power technologies: Floating buoy, Leighton contractors
  - Tidal: Tenax (450MW Clarence Strait, 350 MW NT), Atlantis resources, Tidal energy Pty Ltd.

Source: Stephanie Thornton, OEIA, www.Seaenergyassociates.com
For developing countries like those in Southeast Asia, the main driver is the electrification target especially for rural areas.

Existing energy mix is predominantly fossil.

Countries like the Philippines, Thailand, Indonesia and Malaysia have set out their long-term renewable energy targets which are reflected in their national energy plans.

Singapore is determined to be a research and development centre for renewable energy in the region.

There are economic and non-economic challenges that each country faces.

Ocean energy could serve as off-grid solutions to rural communities.

Biggest challenge is existing subsidies to fossil fuel (such as diesel power).

Adoption is purely based on cost of energy with high TRL & minimal capital investment.
**Resource Availability of Wave & Tidal Energy**

- There is minimal information of ocean energy resource in Asia (specifically in ASEAN)

- However present satellite information and localized resource mapping shows localized intense energy presence.

<table>
<thead>
<tr>
<th>TRL 1-3</th>
<th>TRL 4-6</th>
<th>TRL 7-9</th>
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<tbody>
<tr>
<td>3</td>
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<td>0</td>
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</tbody>
</table>

**Technology Readiness Level (TRL)**

- **TRL 1-3**: Proof of principle / Proof of concept
- **TRL 4-6**: Validation tests in simulated environment
- **TRL 7-9**: Field operational tests / commercial deployment

**Project Status Legend**
- Phase 0 - Undeveloped
- Phase 1 - Siting/Planning
- Phase 2 - Site Development
- Phase 3 - Device Testing/Commissioning - Pilot
- Phase 4 - Deployed - Grid Connected
**SEA resources**

- In terms of tidal energy, Indonesia has of 4.8 GW potential in practice, wave energy is 1.2 GW and OTEC is 43 GW.

- Malaysia is also looking at OTEC as one primary source of ocean renewable energy (Yaakob 2013).

- Philippines, on the other hand, is looking at tidal energy potential of 35 TWh/yr which is around 40 GW to 60 GW power potential (Buhali, et al. 2012)

- In terms of wave energy, the pacific side has 33 kW/m/yr ocean renewable energy potential and from South China Sea side is 35 kW/m/yr (World Bank, Philippine Coastal and Marine Resources: An Introduction n.d.).

- Singapore has a positive indication of ocean renewable energy as well, in theory– around 250 MW extractable tidal energy has been studied and assessed on the Southern islands of the country (Abundo 2012).

- For Vietnam, there is potential for tidal energy around 1,753 GWh/yr (barrage) (Pham 2013).

- Brunei Darussalam has a 335 kW tidal energy potential in theory while 0.66 GW theoretical potential in wave (Malik 2011).

- Cambodia, Myanmar and Thailand’s information on ocean renewable energy are quite minimal and are focusing on viability of ocean renewable energy in their countries (Port of Yangon 2013) (Bird 2010)
Indonesia

- Indonesia is a country of “Thousands of Islands”
- To increase the energy access: Electricity ratio is currently 67%. Remote islands are having limited access to electricity.
- To reduce oil addiction of 15% of national budget for energy subsidies.
- National energy council is advocating the development of ocean energy in Indonesia through the National Energy Policy. More than 15 straits or channels have been identified as potential location for tidal current energy systems;
- Tidal energy flux in Indonesia estimates show 150 KW/m 160GW theoretical potential and ocean wave of 510 GW. Technically they estimate 22.5GW and 2 GW, respectively. Practically they expect 4.8 GW, 1.2 GW depending on technological maturity and market development, including availability of successful project in grid connection.
- INOCEAN estimates ocean energy potential and advocates OE projects and collaborations.
- INOCEAN targets pilot project of ocean energy power plant, connected to grid in 2014, at minimum of: 1MW tidal & wave energy, respectively.

Source: DEWAN ENERGI NASIONAL, Mukhtasor@oe.its.ac.id
* Motivation For Tropics

- **Untapped Energy from Tidal Currents**
  - Tidal In-Stream Energy: Clean & Renewable
  - High predictability (hourly, ~18.6 yrs)
  - Available Extraction Devices (TRL 6-8)

- **Island Electrification**
  - High Cost of Grid Infra: Remote (eg cabling US$1M/km)
  - High Cost of Electricity: Diesel Generators

- **Technology ‘tweaking’ for SEA conditions**
  - Low Flow (Turbine)
  - Biofouling (Materials)
  - Less Harsh Site Conditions (Deployment)
  - Distributed Solutions (Power System)

- **Market: “Equatorial Band” (SEA++) & more**

**Potential TISE Sites/Locations**

- **15MWp (~40GWh/yr)**
- **170MWp (~450GWh/yr)**

[Satellite based Tidal Intensity Map]

[Singapore, Philippines]
Barriers towards adoption & diffusion

- Barriers to technology diffusion:
  - Lack of access to the electric grid at reasonable prices
  - High cost of technology & need to achieve economies of scale.
  - High upfront cost compared to conventional renewables & energy sources
  - Lack of financial credits
  - Failure to internalize all costs and benefits of energy production and use
  - Possible barriers to ocean renewables from fishing, defense, shipping routes & environmental concerns
  - Widespread lack of awareness about the scale of resources available
  - The pace of development & Potential economic advantage of renewable energy
  - Fossil based electric utilities maintain monopoly rights to produce, transmit and distribute electricity.
  - Fossil based electric method provides flexibilities with least intermittency in tune to varying loads in terms of cheaper cost, while renewables in general demands energy storage to assure such quality power.

![Technology Readiness Level (TRL) Chart]

- TRL 1-3: Proof of principle / Proof of concept
- TRL 4-6: Validation tests in simulated environment
- TRL 7-9: Field operational tests / commercial deployment
Technology Issues & Remedies

Challenges:
- Too few incentives to highlight scale effect.
- SEA lacks detailed resource & siting studies.
- Too high capital cost & upfront investment.
- Less promising due to intermittency compared to fossil based energy.
- Technology barriers: grid integration of RE
- Based on IRENA’s review, globally TRL of Ocean energy is not upto wind and solar. Hence demands more research and development.

Possible solutions:
- Require disruptive concepts that evolve into site-specific single turbine & modular design to form massive arrays of devices.
- Need rapid demonstration to exhibit reliability
- Should possess resilience towards weak grid & minimal interruption through energy storage
- Develop design standards specific to the region.
- Co-evolve regional market, supply chain & integrate with local skills.
- Demonstrate minimal environmental impact and better life cycle analysis.
- South east asia demands more disruptive innovation to reduce cost of energy towards $2000/KW and a COE of $0.20/KWh.
**Policy Challenges**

- Around the globe, the policy tools that have been used in driving ocean renewables are regulation and standard policies, quantity instruments (specifically RPS and RECs) and price instruments (mainly fiscal incentives, public financing and feed-in-tariff).

- Fossil fuel based subsidies amount to $51 billion in 2012. Despite recent reforms in Malaysia and Indonesia they distort the energy market (WEO special report).

- The policy should meet the economic growth, enhance energy per capita & make energy available to remote island population’s basic needs and minimize emissions.

- In the case of Southeast Asia, the Philippines, Thailand and Indonesia have made ocean renewable energy either part of their energy mix or renewable energy roadmap.

- Thailand, on the other hand, has a 2 MW target from wave and tidal energy.

- Ocean renewable energy has been part of Indonesia’s energy mix through an amendment made on their National Energy Policy (i.e. Act No. 30 of 2007, Amendment of Presidential Decree No. 5). This paved way to the creation of Indonesian Ocean Energy Association (INOCEAN) which will be responsible in coordinating the tripartite efforts of the government, academia and industry in driving ocean renewables in Indonesia.

- Malaysia, like Indonesia, had set-up the National Oceanography Directorate (NOD)

- Brunei, Cambodia, Myanmar Vietnam and Lao PDR have yet to formulate specific policy tools for the uptake of ocean renewable energy in their countries.

*(source: Ren21)*
Philippines

- Increase RE Capacity by 100% by 2020 with ocean energy up to 120 MW
- Targets: The Department of Energy (DoE) expects the Philippines’ first ocean energy facility to start commercial operations by 2018.
- Deep Ocean Power was looking to develop between 10MW and 300MW of capacity on each site, adding that sites may be used for a number of technologies if suitable.
- The first project to go into operation will be the 10-MW Cabangan ocean energy thermal conversion (Otec) project in Zambales.
- Private firms granted service contracts:
  - Fourteen of the sites have already been identified as specifically suitable for ocean thermal energy conversion (OTEC) technologies, eight for tidal energy projects and the others for offshore wind farms.
- RE Support Policies
  - Renewable energy act of 2008
  - Legal and policy framework of RE (ocean, hydro)
  - National Renewable Energy Board (NREB) and Renewable Energy Management Bureau (REMB) as technical secretariat to implement policies & plans in DOE.
  - Both FIT, Renewable portfolio standard (RPS) and Renewable energy certificates (REC) are implemented & harmonized.
  - By 2030, Increase RE resources to represent 50% of energy mix and achieve 60% self sufficiency (PEP, 2009-2030)
  - Clean technology fund (CTF) $250 million allocation
  - Banks to support investment towards renewables & electricity cooperatives.
  - Pilot Net metering and Grid code amendment in progress.

Source (world bank, 2014)
Singapore’s Ocean Energy Support

- Singapore determined to be R&D Hub for clean energy
  - Competitive research grant for scientific research (CRP fund scheme).
  - Sponsor Doctoral students to support research and Firm’s R&E manpower needs.
  - Clean energy research grant for maturing technology with industrial firm (EIRP fund)
  - Proof of concept & Proof of value studies (Spring Singapore & NRF)
  - Co-funding research institute and infrastructure for technology test bedding.
  - Target to uptake 5% clean energy from renewables.
  - Purchase renewable based power for government consumption.
  - Promote foreign subsidiaries to setup R&D within Singapore (EDB) & promote homegrown enterprises.
  - Promote local SMEs and MNC subsidiaries towards global market (IE Singapore)
Policies Methods Suggested

More common Policies

Policies → Subsidies for increased installations → Reduced Cost of energy

"Demand Side Policies"

Policies → Promote New Innovations Adoption towards regional needs

Supply chain creation/ Promote learning & automation

Subsidies to technology suppliers & device manufacturers → Reduced Cost of energy

"Technology Supply Side Policies are Promoted"
Policy Recommendations to promote Ocean energy uptake

- Both Technology push and Market Pull specific to gaps is required.
- Disruptive technologies that aid to provide cost-effective technologies meeting the regional skill set is required.
- Policy support:
  - Promote technology creating firms to evolve useful technology stock.
  - Capital support for pilot projects
  - Support in terms of price per MWh
  - Involve domestic know-how and enhance Job creation and local content
  - Assess barriers due to grid and supply chain early.
  - Accelerate cost and risk reduction through pilot instalment through open innovation.
  - Based on technology gaps promote Industry-Academia-Government interaction to promote test bedding and commercialization co-evolve supply chain creation.
Asean Energy Cooperation

- Asean countries collaborate towards a common grid.
SeaCore: Regional Offshore Energy Research Collaboration

Objectives:

- Collaborative Research in Low flow tropical marine energy.
- To support SEA countries’ Regional Energy Security.
- Knowledge sharing of offshore renewables: Technology, Innovation, Industry and policies.

Activities:

- Tropical Marine Energy Centers
- Marine Spatial Planning
- Environmental Impact Assessment
- Training Programs/R&D Collaborations
- Standards and Certification
We need to Investigate Sites of Interest

- **Current Uncertainties without proper Resource and Site Assessment**
  - How much resource?
  - Locations of the resource?
  - Any restrictions and constraints?
  - Challenges at different depths?

- **How to Reduce Uncertainty**
  - use proper devices, techniques, and methods
Resource Mapping
OceanPixel Project

Web-based Integrated Assessment Tool For Ocean Renewable Energy Planning

- Energy Density
- Project Dev’t Planning
- Environmental Scores
- Technology Library
- Distance-to-Shore
- Resource Analysis
- Cost Ranging
- Resource Data
- Decision Support Maps
- Navigation & Shipping Considerations
- Device-in-the-Water Performance
- Site-Device Suitability Score
Singapore Tidal In-Stream Energy

**Total Resource**\(^1\) ~3 TWh/year

<table>
<thead>
<tr>
<th></th>
<th>Technically(^2) Extractable Energy Resource</th>
<th>Practically(^3) Extractable Energy Resource</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>~900 – 1,200 GWh/yr</td>
<td>~300-600 GWh/yr</td>
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</table>

<table>
<thead>
<tr>
<th>SITE</th>
<th>Peak Power (MW)</th>
<th>Annual Energy Yield (GWh / yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>105</td>
<td>115.96 – 276</td>
</tr>
<tr>
<td>B</td>
<td>65</td>
<td>71.78 – 170</td>
</tr>
<tr>
<td>C</td>
<td>15</td>
<td>16.57 – 39.4</td>
</tr>
<tr>
<td>D</td>
<td>20</td>
<td>22.09 – 52.56</td>
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<tr>
<td>E</td>
<td>3</td>
<td>3.31 – 7.88</td>
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<td>F</td>
<td>12</td>
<td>13.25 – 31.53</td>
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<td>G</td>
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<td>5.52 – 13.14</td>
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<td>I</td>
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<td>5.52 – 13.14</td>
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<td>J</td>
<td>2</td>
<td>2.21 – 5.25</td>
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<td>K</td>
<td>3</td>
<td>3.31 - 7.88</td>
</tr>
</tbody>
</table>

TOTAL 250 MW ~300 to 600 GWh/yr

**Notes:**
- \(^1\)Energy Density of ~1MWh/m²/month  
  *5km length (channel width) *50m ave. depth *12 months
- \(^2\)Water-to-Wire Efficiency: 0.3 to 0.4
- \(^3\)Without detrimental environmental effects, Significant Impact Factor (SIF): 0.1 to 0.2
- Velocity Data from PORL, TMSI, NUS

~0.65% to 1.3% of Singapore’s Electricity Demand
Renewable Energy Integration Demonstrator Singapore (REIDS)

1. Project targeted to start mid 2014
2. A total of 9 consortium projects expected with project quantum of S$20 m.
3. Will tie in with the effort to start Offshore test sites.

Power Consumption
Daytime Peak Load: 400kW
Nighttime Peak Load: 200kW
More loads are expected up to MW scale
<table>
<thead>
<tr>
<th>Country</th>
<th>Institution</th>
<th>Potential Projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brunei</td>
<td>Universiti of Brunei Darussalam</td>
<td>Wind Map for Borneo</td>
</tr>
<tr>
<td>Indonesia</td>
<td>Indonesian Ocean Energy Association (INOCEAN) / Indonesian Counterpart for</td>
<td>Enhancing the ORE capacity in SEA; Pilot projects on OTEC, wave and tidal energy</td>
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<td>Energy and Environmental Solutions (ICEES)</td>
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<tr>
<td>Malaysia</td>
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<td>Wave Energy Resource Assessment; Device &amp; Deployment Tech &amp; Methods Dev’t</td>
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<td>Universiti Tunk Abdul Rahman</td>
<td>Energy Systems in Southeast Asia</td>
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<td>Myanmar</td>
<td>Myanmar Maritime University</td>
<td>Resource Assessment of ORE; Characterization via Tow Tank Testing of Devices</td>
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<td>Philippines</td>
<td>University of the Philippines</td>
<td>Resource Assessment of ORE (Ocean Pixel), Pilot Deployments of Small-Scale Devices</td>
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<td>Environmental Impacts Assessment (EIA)</td>
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<td>Thailand</td>
<td>King Mongkut of Technology Thonburi</td>
<td>Resource Assessment in Thailand Gulf</td>
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<td>Vietnam</td>
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<td>Resource Assessment; Small-scale tidal turbine</td>
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<tr>
<td>Singapore</td>
<td>Energy Research Insitute @ NTU; TMSI, NUS</td>
<td>Tidal Turbine R&amp;D; Marine RE Integration; Distributed Generation; Tools and Methods Dev’t; EIA</td>
</tr>
</tbody>
</table>
• Asian countries are keen in adopting Ocean renewables into its energy mix.

• Disruptive technologies that aid to provide cost-effective technologies meeting the regional skill set is required.

• Regional test bedding to prove technology in the tropics is essential to show techno-economics is at par with PV & Biomass.

• Both Technology push and Market Pull specific to gaps is required.

• Government Policy support is key:
  ✓ Test bedding new technology
  ✓ FIT and Renewable portfolio standards
  ✓ Involve domestic know-how and enhance Job creation and local content
  ✓ Assess barriers due to grid and supply chain early.
  ✓ Promote Industry-Academia-Government interaction to promote test bedding and commercialization co-evolve supply chain creation.

• Promote collaboration and knowledge exchange network with technology developed institutions.

http://www.ntu.edu.sg/erian/
Thank You

http://erian.ntu.edu.sg
Potential agenda:

At end of our panel it might be good to know we have covered:

Government Leadership:

1. Policy – how long has policy been in place and any significant changes?

2. Market design – FITs – ROCs and current value in local currency – total converted to residential and then relative to residential.

Renewable Obligation Certificates (ROCs) and the Feed in Tariff (FiT).

3. Regulatory Regime

4. R&D Support
<table>
<thead>
<tr>
<th>Country</th>
<th>Tidal Energy</th>
<th>Wave</th>
<th>OTEC</th>
<th>Salinity Gradient</th>
<th>Other Data</th>
</tr>
</thead>
</table>
| Brunei Darussalam | **Tidal Energy:** 335 kW (theoretical)  
2.08 W/m² potential tidal current energy  
Tidal Barrage: 0.14 to 0.26W/m² | 0.66 GW (theoretical)  
Not possible because the temperature gradient between the top and bottom layers of the ocean is too small (1 to 6.5 degrees C.) to be utilized. | No Data Available  
No Data Available  
Not Data Available | No Data Available | Potential ocean energy of 10 to 35 MW per kilometer |
| Cambodia      | tidal range < 1.5m  
No Data Available  
No Data Available  
No Data Available | No Data Available  
No Data Available  
No Data Available | No Data Available  
No Data Available  
No Data Available | No Data Available |                                                                   |
| Indonesia     | **Tidal Current:** 160 GW (potential in theory); 22.5 GW (technical potential); 4.8 GW (in practice)  
Alas Strait having tidal current energy potential of 641.622 GWh per year (with peak flow: 2 m/s)  
Extractable: 329.299 GWh per year | 810 GW (potential in theory); 2 GW (technical potential); 1.2 GW (in practice)  
ΔT at: 600m - 23.18°C, 800m - 24.73°C, 1000m - 25.46°C | 57GW (potential in theory); 52 GW (technical potential); 43 GW (in practice)  
Sabah: 1200m depth is found within 125 km distance from the shore and the bottom temperature is about 4 degree Celsius at 1200m water depth | No Data Available | Potential ocean energy of 10 to 35 MW per kilometer |
| Lao PDR       | Not Applicable | No Applicable | Not Applicable | Not Applicable |                                                                   |
| Malaysia      | Tidal Range: 2.7 – 5.3m  
Tidal Current: 14,502 kWh per year  
The Straits of Melacca with average 2 m/s (4 knots) | 1m average wave height, 15 kW per meter of wave front  
2.6 to 4.6 kW/m at the northern sections of the east coast of peninsular Malaysia  
0.5 to 1.5 kW/m at the southern sections of the east coast of peninsular Malaysia | Sabah: 1200m depth is found within 125 km distance from the shore and the bottom temperature is about 4 degree Celsius at 1200m water depth | No Data Available |                                                                   |

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<table>
<thead>
<tr>
<th>Country</th>
<th>Tidal Current:</th>
<th>Tidal Barrage:</th>
<th>Western Coast of Myanmar is near to deep waters with depth greater than 1 km</th>
<th>Potential:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Myanmar</td>
<td>Yangon River has tidal currents of 4 - 6 knots during spring tides</td>
<td>5 – 7 m Tidal Range Available</td>
<td>11.5 – 23 GW from 2,300km shoreline</td>
<td>35.1 – 41.58 GW from Irrawaddy River; 17.42 – 18.05 GW from Than Lwin (Salween) River</td>
</tr>
<tr>
<td>Philippines</td>
<td>Tidal in-stream: 1,743 TWh/yr (~200 GW of Power) Theoretical. 350 TWh/yr (~40GW to 60GW of Power) Practical.</td>
<td>Tidal Range is between 3m-4m</td>
<td>Pacific side: 33 kW/m/yr South China Sea side: 35 kW/m/yr</td>
<td>No Data Available</td>
</tr>
<tr>
<td>Singapore</td>
<td>Tidal current: 0-3m/s, 3TWh/yr Extractable: 250 MW Peak</td>
<td>Low waves less than 1 meter (average)</td>
<td>oceanic temperature difference &lt; 20°C and water depth of Singapore waters is &lt; 1 km</td>
<td>100 GWh/yr</td>
</tr>
<tr>
<td>Thailand</td>
<td>0.001 ktoe</td>
<td>0.50 ktoe</td>
<td>No Potential</td>
<td>No Data Available</td>
</tr>
<tr>
<td>Vietnam</td>
<td>Tidal Energy (Barrage) 1,753 GWh/yr (tidal energy)</td>
<td>40-411 kW/m (wave energy flux, offshore)</td>
<td>No Data Available</td>
<td>No Data Available</td>
</tr>
</tbody>
</table>

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