Collaborative Efforts towards Regional Ocean Renewables

This annual report summarises both the local and regional efforts of the Southeast Asian Collaboration for Ocean Renewable Energy (SEAcORE) for the year 2015. Among the highlights of this report are: 1) Regional Technological Roadmap; 2) Commercialisation efforts of ocean RE in SEA and 3) Asian Wave and Tidal Energy Conference (AWTEC) 2016. The Annex provides country reports from SEAcORE members.
Table of Contents

Introduction

THE ENERGY RESEARCH INSTITUTE @ NTU (ERI@N) 2
WIND AND MARINE RENEWABLES TEAM 2
ERI@N AND SEACORE 3
WHO IS SEACORE? 4

Regional Roadmap for Ocean Energy

METHODOLOGY 5
CHALLENGES TO OCEAN RE 7
COST REDUCTION 9
THIRD PARTY AND TEST CENTRES 9
POLICIES AND REGULATIONS 9
COLLABORATION, INTER-INDUSTRY AND KNOWLEDGE TRANSFER 10
OCEAN RE AS NEW MARKET 12
CONCLUSION 13

Strengthening Regional Collaboration

ASIA CLEAN ENERGY SUMMIT 2015 14
MOU WITH ACE 14

Future Activities

ASIA WAVE AND TIDAL ENERGY CONFERENCE (AWTEC) 2016 16

Annex: ORE Country Reports

BRUNEI 17
MALAYSIA 19
MYANMAR 31
PHILIPPINES 40
SINGAPORE 43
THAILAND 53
Annual Report 2015

Collaborative Efforts towards Regional Ocean Renewables

INTRODUCTION

The Energy Research Institute @ NTU

The Energy Research Institute @ Nanyang Technological University (ERI@N) focuses on the areas of sustainable energy, energy efficiency infrastructure and socio-economic aspects of energy research. Its mission is to be a centre-of-excellence for conducting advanced research, development and demonstration of innovative solutions which have both regional and global impact.

The Institute and its research centers have considerable expertise and strength in areas of offshore energy which includes wind, wave and tidal energy and complementary technologies such as energy storage, micro grids, and smart energy systems and collectively provide an integrated set of expertise from materials design & synthesis, device fabrication and modelling, and systems integration and optimization.

Wind and Marine Renewables Team

ERI@N’s Wind and Marine research program is aimed at improving the performance, lowering costs and accelerating deployment of offshore renewable technologies specific towards tropics where unique technology challenges exist. It advances the technology maturity through early collaboration with industry. In these efforts it closely works with the government agencies to understand regional needs, and with local and global renewable energy firms to identify technology gaps. Research efforts are principally concerned with bringing technologies developed in the lab to field through real test bedding activities. Thereby the risks are evaluated and technologies are matured.
The key research focus of the team includes tidal, wave and wind energy resource mapping, turbine device development, offshore support structure studies, advanced materials research against environmental impact and grid integration studies. The group has initiated wind, wave and tidal current resource assessments for tropics and an ocean renewable energy project feasibility tool.

One such effort is its flagship programme called Renewable Energy Integration Demonstrator Singapore (REIDS) project which aims to power one of Singapore’s islands called Semakau purely through renewables including ocean energy along with latest smart grid technology advancements. This is the world’s largest micro-grid in the tropics that will integrate multiple renewables and coevolve novel technologies such as power-to-gas technologies and smart hybrid grids.

ERI@N Wind and Marine and SEAcORE

In order to understand the regional energy needs and ocean energy technology challenges specific to tropical conditions, ERI@N Wind and Marine Renewables team sets up the Southeast Asian Collaboration for Ocean Renewable Energy (SEAcORE) with its neighboring countries, such as Brunei, Indonesia, Malaysia, Myanmar, Philippines, Singapore, Thailand and Vietnam.

SEAcORE is envisioned to be a platform for the exchange of ideas, initiatives, & experiences from R&D, policymakers, and industry. It forms a collated and active core network of expertise and technical know-how in Southeast Asia (SEA) to set, assist, augment, or facilitate adoption of Ocean Renewable Energy (ORE) in the region; and also promotes diffusion of renewables’ products and creates new markets for partner industrial firms. Presently cooperation is in the form of joint projects in resource mapping and assessments among the network.

Offshore Renewables

SEAcORE as a platform of different stakeholders in ocean renewable energy also looks at the importance of offshore renewables and its expanding market around the world. The Southeast Asian region is seen to be one of the most promising avenues for cutting-edge research work and technology development in the offshore renewables. The SEAcORE network is open to potential expansion through collaborative projects in this field.
Who is SEAcORE?

The following are the current active participants in the network:

- Brunei – Universiti Brunei Darussalam (UBD)
- Malaysia – Universiti Tunku Abdul Rahman (UTAR); Universiti Teknologi Malaysia (UTM)
- Myanmar – Myanmar Maritime University (MMU); Myanmar Engineering Society (MES), and Myanmar Industries Association
- Philippines – University of the Philippines (UP), UP Marine Science Institute (UPMSI)
- Singapore – Nanyang Technological University (NTU)
- Thailand – King Mongkut’s University of Technology Thonburi (KMUTT)
- Vietnam – Hanoi University of Science and Technology (HUST); Institute of Energy Science (IES)

A Secretariat has also been formed (one representative from each country), which is mainly responsible for the coordination, administration and organization of SEAcORE activities.

The following are the Secretariat from each SEAcORE country representative:

- Brunei – Dr. Chee Ming Lim and Dr. Sathyajith Mathew, UBD
- Malaysia – Prof. Omar Yaakob, UTM and Dr. Lim Yun Seng, UTAR
- Myanmar – Mr. Htun Naing Aung, MIA and Dr. Myat Lwin, MMU
- Singapore – Dr. Srikanth Narasimalu, Dr. Michael Abundo and Ms. Mary Ann Joy Quirapas, Mr. Ly Duy Khiem ERI@N-NTU
- Thailand – Dr. Sirintornthep Towprayoon and Dr. Chaiwat, JGSEE-KMUTT
- Philippines – Dr. Louis Danao, Dr. Laura David and Ms. Marianne Catanyag, UP
- Vietnam – Mr. Nguyen Binh Khanh, IES and Prof. Nguyen The Mich, HUST
REGIONAL ROADMAP FOR OCEAN RENEWABLE ENERGY

By: Ms. Mary Ann Joy Quirapas and Dr. Michael Lochinvar Abundo, ERI@N

ERI@N being the representative of Singapore to the International Energy Agency – Ocean Energy Systems (IEA-OES), has partnered with overseas counterparts to come up with a global technology roadmap for ocean RE. The main objective of this technological roadmap is to see the pathways on how to achieve levelised cost of energy within the ocean energy sector and in the case of Southeast Asia region, to look at the opportunities and challenges to supply chain creation of offshore RE technologies by learning from the experience of other related and mature industries like offshore wind, oil and gas and etc.

Figures 1 and 2 show the demographic details of the interview respondents both their location and which type of sector they are from.

Around 100 companies were approached for the survey and 62 companies were interviewed in the global scale. ERI@N Roadmap team had conducted 26 interviews from different industries both inside and outside Singapore as baselining methodology for the final roadmap report. The team also organized workshop and roundtable discussions as follow-up activities to the interviews. These companies were classified along the supply chain of ocean renewable energy sector covering 3 major category types: 1) Orkney Marine Renewables Supply Chain; 2) OES Roadmap Committee suggested categories; 3) Levelised cost of energy categories (from OES Annual Reports and SI Ocean Report). The database showed that most industries in Singapore and within neighboring countries are
from marine engineering; vessels and charts and finally, monitoring and inspections companies which are all ocean-related industries.

Other mature industries including defense, mining, oil and gas, aerospace, to name few were also taken into consideration to know whether their existing “know-how and processes” could be applicable to ocean renewable energy as potential solutions to the sector’s current challenges.

<table>
<thead>
<tr>
<th>Orkney Supply Chain Categories</th>
<th>OES Roadmap Group Suggested Categories</th>
<th>LCOE Categories (OES Annual Report 2012 and Si-Ocean)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>Decommissioning and Emergency Response</td>
<td></td>
</tr>
<tr>
<td>Construction and Installation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 1: Baselining Methodology for Supply Chain Category Identification

As point of reference, the industries were asked of their perception towards ocean renewable energy in the region. Most of them suggested that sector is very much on its initial stage of development. For example, there are a number of activities happening within the region in terms of R&D on ocean renewables; however there is little commercial activity. The technology is relatively expensive compared to other renewable energy sources and more so from traditional sources like fossil fuels. In terms of policies and regulations, there seems to be lack of awareness from both public and private sectors on ocean renewable energy’s potential cost and benefits to the region and current policy priorities are yet to be realized for ocean renewables. However, there is a consensus from the interviewees that despite the current challenges to ocean renewable energy adoption in the region, it is or can be a sunrise industry – the technology might take some time to mature, but as one interviewee from the aerospace mentioned “the future is bright” for ocean renewables.

Fig 3: Perception towards Level of Development of Ocean RE in Southeast Asia

Fig 4: Is ocean renewable energy a “sunrise industry”?
**Challenges to ocean renewables**

The successful uptake of ocean renewable energy in the region is not without challenges. Few of the major ones are below (these also contribute to increase cost):

1) Installation
2) Maintenance and repair strategies
3) Reliability strategies

“Installability” of ocean renewables takes into consideration the conditions like weather and space. Based from the collated information, ocean-related industries like tidal and current energy converters see that there is lack of best practices where technology developers could learn from. Current installation for ocean energy technologies are seen to be not enough and alternative strategies for installation are yet to be discovered – these two factors would likely reduce installation cost (or estimation of it) which is among the main challenges in ocean renewable installation phase. The ground condition like underwater environment is also crucial to avoid impact to marine life and species.

Other mature industries experience in installation is similar to ocean renewables. For example, an oil and gas company mentioned that weather is also important to them especially to installation of offshore equipment; space is also limited on offshore platforms, thus there is a need to modularize. For utility companies, “installability” may be more of a site selection issue than a technology issue. However, they also see the need for cost of deployment and maintaining the equipment, i.e. turbine to be made more efficient in the pursuit to reduce cost.

In terms of maintenance and repair, ocean-related industries are faced with challenge on having subsystems that can withstand conditions underwater over a long period of time. Prognostics, health monitoring and management are increasingly seen to be important assets to a less costly repair and acts like a preventive maintenance to damage for ocean renewable energy technologies. This could be done by having effective sensor system underwater that could monitor that health and condition of the subsystem. The coatings industry especially for offshore structures also faces similar challenges like that of ocean renewables – there is a struggle to have more than 5-year maintenance interval, making the subsystem (and its coatings and sealing) more robust in underwater conditions. As one of the coatings experts advised the ocean energy sector in the region, the sector could make use of two types of protective coatings: 1) anti-corrosive coating which is more on protection and 2) anti-fouling which improves performance, efficiency and health monitoring.
Reliability and survivability in the conditions under water are also crucial factors to ocean renewable energy. Building redundancies into the system design and emphasis on best practice approach is seen to be among the biggest challenge to a reliable ocean energy system. For other mature industries, they make use of different strategies to ensure reliability. For example, utility companies make use of Equipment Performance Centre (EPC) and Smart Signal while shipping and operations industries rely on monitoring process and manpower management. The oil and gas sector makes use of other sources of energy, like wind, solar and tidal to power unmanned oil and gas platforms – this could last for a year without any intervention or maintenance. Classification societies suggested that ocean renewables could make use of condition base monitoring systems to help with reliability. There is also a need to do inspection at regular intervals, operating monitoring as well as Root Cause Analysis.

Inter-industry learning is highly encouraged from ocean-related industries to other mature industries, like oil and gas, offshore companies, etc. to lessen the technological barriers mentioned above. For example, oil and gas sector which also faces maintenance and repair challenges makes use of inspection regime for offshore mooring system that could be tested for an offshore structure in ocean renewables system. Reliability issues can be dealt with the use of “off-the-shelf solutions and existing equipment and know-how from other mature industries.
Cost reduction challenges

Aside from the technological challenges mentioned above, the cost for ocean renewable energy sector is high for its deployment and O&M. Sixty (60) percent of its system is underwater thus making it more challenging to install, repair and maintain. It also makes use a lot of materials and weight. As there is an insufficient large-scale deployment history for ocean renewables, accurate cost and risk estimation is tough.

Third Party Certification and Test Centre Facilities

Eighty (80) percent of the interview respondents (including the ocean-related and other mature industries) in the region mentioned that they use third party certification and verification and its impact to their products ranges from important to very important. For example, a tidal energy company agreed that third party verification has a very high impact towards their productions especially on propulsions. A manufacturing company added that having to verify and certify their products is “expensive to secure but essential to reduce insurance cost.” A local Singapore shipping and logistics company shared that some of their international clients require certification and standards before engaging them to a transaction. On other hand, an oil and gas representative shared his thoughts the third parties are good to have but internal verification is also needed.

Regulation and Policies

Legislation and regulation can act to accelerate or slow down technological developments depending on different contexts (e.g. region or country-specific), however most of the correspondents agreed that the most important aspect of policies and regulations is its clarity and consistency.

In Southeast Asia, there is a general feedback from the interviews that awareness and expertise on ocean renewable energy are yet to be further developed in the region. Along with other renewable energy sources, there is a need for these alternative sources to be among the priority in terms of inclusion in the energy mix of each country. The socio-political stability of the country is also one factor in creating an environment which is encouraging to ocean renewables. One example given during the interview is from a shipping and logistics company wherein the importation and exportation taxes and regulations are crucial if bulky equipment like tidal turbines and wave converters are to be transported from one country to another. Although, these regulations are country-specific, the predictability of tariffs and quotas (e.g. policies remain the same even with change
of leadership) are helpful for those logistics companies to assess if ocean energy sector is worth risking into as their new market.

**Collaboration, new opportunities and knowledge transfer**

The industry stakeholders were also asked whether there is possibility for their company to contribute to ocean renewable energy supply chain in the region.

![Fig 6: Responses in percentage to the possibility of contribution of other mature industries to ocean renewable energy supply chain in Southeast Asia](chart)

Most of them are positive that their industry could contribute to ocean renewable energy’s supply chain and vice-versa. For example, ocean renewable energy sector could learn from other renewable energy’s optimization of procurement process and execution methodology; while inventory management, supplier selection and monitoring, planning software could be gained from the transportation and logistics industry. There is also a possibility for adaption of oil and gas regulations for mooring and foundation to ocean energy sector. In other parts of the supply chain, other mature industries could be part of the ocean energy sector by supplying mechanical gearboxes, special coatings, anti-corrosion treatments, marine foundations and composite blades.

A specific example of knowledge transfer is through the subsystem devices and processes. A consulting company to other renewable energy mentioned that with regard to subsystems, “the ocean energy sector can learn from offshore wind... in terms of cabling, usage of vessels, and maintenance scheduling which are relevant to wave and tidal.” From the data collected, there high transferability in the areas of power electronics, power take-off, bearing and hydraulic systems.
Another example of transferability is on array devices and processes. A third-party verification company commented that among the most relevant knowledge transfer is on relation to marine propellers, while other mature industries mentioned that with regard to arrays, there is transferability from offshore wind industry to ocean sector from the use of vessels, transfer of personnel to device, etc.

On the other hand, there were also concerns about looking too early at supply chain for ocean renewables in the region as the sector itself is composed of “unconsolidated” technologies. Even more is trying to look at supply chain innovation to reduce ocean energy technology costs when supply chain for this sector is not yet well established.
Ocean renewable energy sector as a new market?

Most of industries along the supply chain of ocean energy sector have seen it as possible new market for them to take advantage of and which they could contribute their capabilities and expertise on.

For example, a global leader in the marine power and automation sees the importance of ocean energy and how their company could provide their expertise in safety and performance of turbine installation vessels. The mooring industry could also be seen as among the positive players in ocean energy sector. Few of the capabilities that the moorings and foundation industry that could be incorporated to the ocean energy supply chain are the following: 1) design, fabrication and supply of offshore foundations for floating system; 2) design and supply of mooring lines for floating systems and 3) installation of the foundations or mooring lines offshore.

Subsea contractors, which are well knowledgeable on installation and maintenance of underwater equipment, sees ocean energy sector as possible customer for them, “as long as it can be built and generate energy cheaply enough.” In addition, a coatings company mentions that ocean energy is something they closely look at as their experience and expertise in lubrication and anti-fouling coatings could be applicable to ocean energy. Classification society shares a similar sentiment of being able to impart their capabilities to ocean energy in terms of “certification of vessels and experience in ensuring safety of life and safe usage of equipment's at sea...” These capabilities of other mature industries are useful in developing the supply chain of ocean energy sector and at the same time a positive opportunity for industries to explore ocean energy as a new market.

Fig 9: Respondents were asked on how they find ocean renewable energy sector as a new market for them

![Pie chart showing responses: 58% Very Important, 11% Important, 21% Less Important, 5% Not Important, 5% Others]
Conclusion

The baselining activity (i.e. interviews) for a global technological roadmap shows that ocean renewable energy in the region still faces a number of challenges before it could be fully utilized as an alternative source of energy. Among the issues and concerns are 1) costs – harnessing energy from ocean is still expensive compared to fossil fuels like oil and gas; 2) technical (installability, reliability and maintenance issues) and non-technical barriers (cost reduction challenges and policy and regulations).

Collaboration, inter-industry learning and knowledge transferability are few of the solutions that the region could take advantage of in order to address the above challenges. There is a highlight on the importance of engaging the local community, resources and market in order for costs (both OPEX and CAPEX) to be reduced. Local demonstrations are needed to realize the true cost of deployment in the region. These demonstrations could happen along the remote coastal areas and islands (with high potential of ocean renewable resource) and will also serve as potential market for ocean renewables. At the same time, regional needs to electrify rural coastal areas and islands are also addressed. Most of these islands are still not connected to the grid or probably highly dependent on diesel generators for electricity.

In terms of non-technical barriers, local engagement and demonstrations create awareness, experience and added-value to crucial stakeholders like the energy producers (project and technology developers), consumers (energy-users) and policy-makers. As these stakeholders are made aware and knowledgeable of ocean energy through the “localization” of its technology, effective policies and regulations are expected, local experts are created and end-users become local stewards of ocean renewable energy.
Strengthening Regional Collaboration

Asia Clean Energy Summit 2015

The annual Asia Clean Energy Summit (ACES) within the Singapore International Energy Week (SIEW) organised by the Energy Market Authority of Singapore (EMA) happened last October 27 to 28, 2015 with ERI@N Wind and Marine group taking part as the technical team for the offshore renewable energy (RE) track. This is the third year ERI@N has successfully organized the offshore RE plenary and technical sessions with partner organisations like Sustainable Energy Association of Singapore (SEAS) and Economic Development Board (EDB).

This year’s offshore track has relatively grown in its size with number of speakers almost doubled compared to the past two years. There were 2 plenary sessions, 7 technical sessions and a number of poster presentations dedicated to offshore and ocean renewables.

Technological and technical aspects of offshore RE were discussed alongside with the growing interest to include the field’s techno-economics, policies and more regional-based research.

Aside from the main conference, there were also side conference events organized by the ERI@N Team: 1) IEA- OES Offshore RE Roadmap Workshop and 2) SEAcORE Meeting and 3) technical tours with conference attendees. (Please see SEAcORE Nov 2015 Bulletin for more information)

SEAcORE as Technical Working Group of ASEAN Centre for Energy

The ASEAN Centre for Energy (ACE) also recognizes the efforts done by the network and thus officially made it as the technical working group for ocean RE in SEA. During the ACES week, ERI@N signed a memorandum of understanding (MoU) with the ACE to signify the continuous dedicated effort of both organizations to increase the uptake of offshore/ocean RE in the region. Among the areas of
cooperation under this MoU: 1) research on offshore RE and its technological solutions, techno-economics and policy aspects towards Southeast Asian regional energy security and 2) human resources and capacity building activities on offshore RE.

There are also on-going discussions on research collaboration agreements (RCAs) among the SEAcORE members which mainly focus on resource assessment of ocean energy resource, technology matching and few prototype developments suited for the chosen location in the partner country.

To further raise awareness on ocean renewables, the SEAcORE website has been updated with current news and information about offshore/ocean renewable activities in the region. For more information: https://blogs.ntu.edu.sg/seacore/.

Fig 11: Dr. Sanjayan Velautham, Executive Director of ACE and Dr. Srikanth signing the MoU during ACES

Fig 12: ERI@N-SEAcORE Team with Dr. Sanjayan of ACE
FUTURE ACTIVITIES

Asia Wave and Tidal Energy Conference (AWTEC) 2016

Singapore has been chosen to host the next location for the Asian Wave and Tidal Energy Conference (AWTEC) in 2016 (AWTEC, 2014). AWTEC is to be held during October 24th to 28th 2016 in conjunction with the popular Singapore International Energy Week (SIEW 2016) at the Marina Bay Sands of Singapore.

AWTEC provides a platform and opportunity for researchers, engineers, policy makers and stakeholders to exchange knowledge through profound discussions and recent research presentations, and promotes international and multi-disciplinary collaboration.

Aside from the technical sessions, there will also be pre-conference events, i.e. workshops and technical training about ocean energy field and technical tours after the conference. Showcases of marine renewable energy technologies from all over the world will also be present during AWTEC. Participants could also take advantage of joining SIEW-related events like “Roundtable Discussions” hosted by Economic Development Board of Singapore (EDB) and Singapore Energy Market Authority (EMA).

ERI@N heads the Local Organising Committee and along with experts from Japan, Korea, UK and Australia, the team will run the conference, providing opportunity to showcase ocean technology development efforts and innovative solutions with greater regional impact and broader reach. Recently, the Call of Papers has been released, with all submissions expected to be received by February 1, 2016.

For more information about the Asian Wave and Tidal Energy Conference (AWTEC) 2016, please visit: www.awtec.asia/conferences/awtec-2016/

---

ANNEX: COUNTRY REPORTS

Brunei Country Report

By: Dr. Sathyajith Matthew and Dr. Chee Ming Lim, Universiti of Brunei Darussalam (UDB)

There are currently different favoring conditions for Brunei Darussalam to drive more ocean renewable energy uptake in the country. At the national level, as stated in the Energy White Paper (2014), Brunei targets to increase the share of renewable energy in the total power generation mix by 10 percent (or 954,000 MWh based on projection in 2010) by 2035. This is an opportunity for further work on ocean/offshore renewables especially in the case of land availability where other alternative sources of energy, like solar energy, will need more. University Brunei Darussalam (UBD) team led by Dr Lim and Dr Mathew are focusing on research on offshore wind energy which includes “three dimensional layout optimization for offshore wind farms.” This project aims a 5-10% increase in energy yield with same amount of investment, increase the life time of the turbines by minimizing the stress on load. The system is integrated with Google Earth for easy usage and patented by US Patent and Trademark Office (PTO).

Fig 13: Screen Image of the optimization tool for offshore wind renewable energy by UBD

2 This part presents the latest updates on ocean renewables per country from 2014 – 2015. Other country reports which might contain updates on certain topics like policy updates, etc. for the past two years are available at blogs.ntu.edu.sg/seacore/.
Another research work that team is currently doing is the “short term energy forecast for offshore wind farms” which they make use of machine learning approach and validates the report using the data from Horns Rev offshore wind farm, Denmark.

**Fig 14:** Short-term energy forecast for offshore wind farms

**Fig 15:** UBD also does studies on low wind speed turbine technology, i.e. UBD Flyer.
Malaysia has a long coastline and associated coastal zone of about 4,800km. In view that Malaysia is a country mostly surrounded by water, it may have several potential locations for marine renewable energy, particularly in wave energy. Several potential locations have been identified throughout researches and surveys.

**OCEAN ENERGY POLICY**

**Strategy and National Targets**

Malaysia has added renewable energy (RE) as the fifth source in the diversification energy policy and mainly focused on biomass, solar, hydrogen fuel cells, landfill gas and municipal solid waste and nuclear incineration. Malaysia aims to achieve 5% of renewable energy contribution for the nation’s electricity. In the Eleventh Malaysia Plan (2016-2020), “Ocean energy” has for the first time been included as a potential source.

“...17.65 Utilisation of RE sources including biomass, biogas, solar PV and mini hydro will be continued as alternative fuel sources for electricity generation. In addition, the potential of geothermal, wind and ocean energy will also be explored. RE capacity is expected to reach 2,080 MW by 2020, contributing to 7.8% of total installed capacity in Peninsular Malaysia and Sabah.…” (Eleventh Malaysia Plan Strategy Paper 17: Sustainable Usage of Energy to Support Growth, pp. 17-30)

**Main Public Funding Mechanisms**

The Government through the Ministry of Science, Technology and Innovation (MOSTI) has provided several research grants to support the research development of science and technology in Malaysia.

1. *Science Fund:* It is a grant provided by the government to carry out Research and development (R&D) projects that can contribute to the discovery of new ideas and the advancement of knowledge in applied science, focusing on high impact and innovative research. The quantum of funding for each project is up
to RM 500,000.00. Most researches carried out in Malaysia funded under this grant.

2. **Techno Fund**: TechnoFund provided a grant scheme which aims to stimulate the growth and successful innovation of Malaysian Enterprises by increasing the level of R&D and its commercialization. The scheme provides quantum of funding between RM 1,500,000.00 to RM 3,000,000.00 for technology development, up to pre-commercialization stage depending on the merit proposal.

In addition, the Ministry of Higher Education (MOHE) also has allocated RM 200 Million under the Fundamental Research Grant Scheme (FRGS) to fund the fundamental research projects in Public of Higher Education Institutions.

**Relevant Legislation and Regulation**

Malaysia is set to record over 2000 megawatts (MW) of energy from the renewable energy sources by 2020. Several Renewable Energy Policies which aims to lead a strategic development of new energy sources including renewable energy have been introduced:

1. **National Renewable Energy Policy and Action Plan (2009)**: The policy is aiming to enhance the utilization of indigenous renewable energy (RE) resources to contribute towards national electricity supply security and sustainable socioeconomic development.

2. **Ocean Renewable Energy Roadmap 2010-2020**: The National Oceanography Directorate (NOD) as the national focal point for all oceanographic and marine science activities has been tasked to spearhead the preparation of National Roadmap in Renewable Energy (RE) in accordance with National RE Policy prepared by Ministry of Energy, Green Technology and Water (KeTTHA). The roadmap lasts for 10 years and aims to set the direction of Research and Development (R&D) and Technology Development of Renewable Energy in Malaysia.

3. **Renewable Energy Act 2011**. An act to provide for the establishment and implementation of a special tariff system to catalyst the generation of renewable energy and to provide for related matters.

4. **Sustainable Energy Development Authority (SEDA) Act 2011**: SEDA Act 2011 is an act to provide for the establishment of the Sustainable Energy Development Authority (SEDA) of Malaysia and to provide for its functions.
and powers and for related matters. The main role of this body is to administer and manage the implementation of the feed-in tariff mechanism which is mandated under the Renewable Energy Act 2011 [Act 725]. It defines the rules for: the eligibility criteria for feed in tariffs, conditions for renewable energy power purchase agreements, technical and operational requirements as well as payment, duration and regression of the tariffs, etc.

RESEARCH & DEVELOPMENT

Resource Assessment

Resource assessment is an important step throughout a wave energy project development, from initial site selection to farm operation. At its most basic level, it aims to identify the level of wave energy resource available for the extraction of energy. A number of ocean energy resource assessment studies have been published for Malaysian sea region.

Wave Energy

Table below presents summary of several wave energy resource assessments conducted in Malaysia by researchers from various institutions. The studies were funded by the Government under several fund schemes such as Ministry of Higher Education (MOHE) grant, MOSTI Science fund, Ministry of Energy, Green Technology and Water (KeTTHA) and institutional.

<table>
<thead>
<tr>
<th>Author</th>
<th>Institution</th>
<th>Study Area</th>
<th>Wave energy potential</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Muzathik et al., 2010)</td>
<td>Universiti Malaysia Terengganu</td>
<td>Coast of Terengganu</td>
<td>• Total mean wave energy is 1.8 x 10^7 Wh/m</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Average wave power less than 6500 W/m</td>
</tr>
<tr>
<td>(Samrat et al., 2014b)</td>
<td>University of Malaya and Universiti Malaysia Pahang</td>
<td>5 different locations in Peninsular Malaysia and Borneo;</td>
<td>Average power output for each locations, respectively:</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1. Sarawak</td>
<td>1. 5 kW/m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2. Kota Kinabalu</td>
<td>2. 6.5 kW/m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3. Mabul Island</td>
<td>3. 7.91 kW/m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>4. Mentagor Island</td>
<td>4. 7.00 kW/m</td>
</tr>
<tr>
<td></td>
<td></td>
<td>5. Perhentian Island</td>
<td>5. 15.9 kW/m</td>
</tr>
<tr>
<td>(Mirzaei et al., 2014)</td>
<td>Universiti Kebangsaan Malaysia</td>
<td>9 different sites along the East coast of Peninsular Malaysia</td>
<td>Annual average wave power for sites in the northern (southern) section of the coast ranges from 2.6 to 4.6 kW/m (0.5 to 1.5 kW/m)</td>
</tr>
</tbody>
</table>


Each study used different wave data resources including buoy, Malaysian Meteorological Department (MMD), numerical wave model and satellite altimeter. Figure 16 shows an example of annual mean spatial distribution of wave energy developed by Mirzaei et al. (2014). Yaakob et al. (2016) on the other hand, used satellite altimetry wave data to assess wave energy resource in fifteen zones in Malaysia. Figure 17 illustrates the fifteen selected zones along the east coast of Peninsular Malaysia and Borneo and their respective average wave energy density as described in Figure 18.

Figure 16 Annual mean spatial distribution of wave energy during 31-year using WAVEWATCH-III model (Mirzaei et al., 2014)

Figure 17 Selected areas along the East coast of Peninsular Malaysia and Borneo (Yaakob et al., 2016)
Even though different wave measurement methods were used, it can be concluded that Malaysia could provide low wave power resources. Thus, developments of efficient and reliable Wave Energy Converters (WECs) suitable for low sea state conditions as in Malaysia are required to enable maximum energy being harvested.

**Tidal Energy**

Lee et al. (2009) provides simulation studies to identify the potential of tidal energy using tidal current turbines. The study used the Computational Fluid Dynamic technique, Fluent to simulate the fluid flow, heat and mass transfer, and a host of related phenomena involving turbulence, reactions and multiphase flow. It is indicated that a single tidal turbine installed in Sejingat for example, is 14790 kWh and able to provide energy to about 75 household for a month, assuming that the monthly power consumption of an average household is 220 kWh.

Figure 19 shows the energy density profile of tidal current across Malaysia (Lim et al., 2010). The study indicated that Kapar, Pontian, Alor Star, Tanjung karang, Semporna, Kota Belud, Kuching and Sibu are the locations with great potential for tidal energy extraction. The study concluded that the total amount of electricity that can be generated by marine current turbines on those locations is about 14.5 GWh/year.
Sakmani et al. (2013) investigated the tidal stream resources and the topology of the Straits of Malacca using Acoustic Doppler Current Profiler (ADCP) in order to propose Pangkor Island as potential site for exploitation of the tidal stream energy.

In 2014, a Memorandum of Understanding (MoU) was signed by Green Power Solutions, based in Malaysian state of Sabah with Current2Current International. The aim of the project is to develop a 10MW tidal energy project. However, the potential of the resources in Malaysia need to examined thoroughly. The proposed tidal energy project could be installed in the Straits of Malacca, between Labuan and Kuala Penyu off the coast of Sabah or offshore Banggi Island in Kudat (http://www.offshorewind.biz/2014/10/23/ocean-renewable-project-planned-for-malaysia/).

**Ocean Thermal Energy Conversion**

A study of OTEC is being conducted mainly by UTM Ocean Thermal Energy Centre (UTM-OTEC) which acts as the centre of excellence. In the 3rd International OTEC Symposium (September 2015) held at UTM-OTEC, the UTM OTEC Director, Prof Dr Md Nor Musa said that UTM plans to set up the country’s pilot OTEC power plant but still considering suitable sites. He said a development fund of RM35 million had been applied for the project under the 11th Malaysia Plan. The power plant would be able to create commercial opportunities and transform the socio-economic well-being of the country tremendously. (Source: http://otec.utm.my/)
**Device Development**

Most of the studies were focusing on research, simulation and conceptual design of the wave energy converters (WECs) and marine current turbine.

**Wave Energy**

Amir et al. (2014) carried out simulation of heave buoy response to wave in Malaysian water using MathCAD software. The results show that the heave buoy give a good heave response with regards of the wave phase. In this particular area, it is estimated that the wave force can produce as much as $4 \times 10^5$ kW/m. Samrat et al. (2014a) proposed a standalone hybrid photovoltaic (PV) – wave energy conversion system with energy storage. Based on the simulation results obtained from Matlab/Simulink, it has been found that the overall hybrid framework is capable of working under the variable weather and local conditions of Malaysia. Figure 20 illustrated the block diagram of the proposed standalone PV-wave hybrid system.

Ahmed et al. (2014) presented a simulation of Wells turbine for wave energy conversion for Malaysian ocean. The study concluded that a design of Wells turbine that able to generate energy from Malaysian ocean effectively is establish with profile blade of NACA0020 and turbine solidity of 0.64 with range of turbine efficiency of 30% to 64% throughout flow coefficient using Computational Fluid Dynamics (CFD) code AnsysCFX. The study also recommended suitable locations for installation of shore mounted and floating Oscillating Water Column (OWC) in the state of Kelantan and Terengganu.

![Figure 20 Block diagram of the proposed standalone PV-wave hybrid system (Samrat et al., 2014a)](image-url)
Hamim et al. (2015) proposed three linear permanent magnet generator designs for wave energy conversion in Peninsular Malaysia with different types of permanent magnet layout. The study showed that the permanent magnet used can provide better flux density compared to other topologies. Figure 22 shows 2D design for the first proposed generator.

**Figure 21 Surface mesh for the Well turbine (Ahmed et al., 2014)**

**Figure 22 2D design for the 1st proposed generator (Hamim et al., 2015)**

**Tidal Current**

The tidal current projects are being conducted mainly by Universiti Teknologi Malaysia, Universiti Malaya, Universiti Malaysia Terengganu. Behrouzi et al. (2014) presented the new innovative concept for optimal design of UTM Vertical Axis Current Turbines (VACT) applicable in low current speed. The new concept is able to decrease hydrodynamic resistance and drag force with increasing performance and efficiency. Meanwhile, a new type of Savonius turbine was proposed by another UTM researcher. Designated ReT, the turbine (Figure 24) is expected to have a peak efficiency of 35%, a marked improvement from conventional Savonius turbine (Figure 25).
Figure 23 Left: Innovative concept of vertical axis current turbine for low current speed; Right: Self-rotating vertical axis current turbine test in water canal of civil laboratory in UTM (Behrouzi et al., 2014)

Figure 24 Reza Turbine (designated ReT) (Abbasabadi, 2015)
Ocean Thermal Energy Conversion (OTEC)

Chik et al. (2015) presented a simulation of the OTEC plant, Low Thermal Temperature Desalination (LTTD) plant and the Integrated OTEC (I-OTEC) plant using FORTRAN software. The simulation was based on temperature and topographic characteristics information in Malaysia. They indicated that Malaysia has a potential to build an integrated OTEC-LTTD plant in Sabah Trough which having more than 20°C temperature gradient and strategic location near to populated island. Universiti Teknologi Malaysia OTEC Centre has carried out a number of research projects on OTEC and some of them were presented at the 3rd International OTEC Symposium 2015 (IOSKL, 2015) which was held in Kuala Lumpur, Malaysia on 1-2 September 2015. The proceedings of the symposium can be downloaded here http://otec2015.utm.my/2015/11/30/proceedings-of-ioskl-2015/

Figure 25 Comparison and validation of coefficient of power between simulation results and experimental results for ReT and conventional Savonius turbines (Abbasabadi, 2015)
TECHNOLOGY DEMONSTRATION

New Developments

The present developments in Malaysia are mainly focused on resource assessment, simulation and development of laboratory and small scale proto-types of the various devices. The tidal and ocean current speeds, tidal range and wave heights in Malaysia are relatively low compared to those in Europe and North-East Asia (Japan, Korea and China). Theoretically, the Ocean Thermal Energy Conversion (OTEC) has a bigger potential resources but the technology is still at small scale prototype stages. Thus, there is a need for local indigenous development of devices for wave and tidal energy.

Figure 26 Schematic diagram of OTEC-LTTD plant (Chik et al., 2015)
### 1.1 Installed Capacity & Consented Projects

<table>
<thead>
<tr>
<th>Capacity [kW]</th>
<th>Installed</th>
<th>Consented projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wave Power</td>
<td>5kW</td>
<td>5kW combined wave and tidal current project by Universiti Teknologi Malaysia</td>
</tr>
<tr>
<td>Tidal and ocean currents</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Tidal Power</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>OTEC</td>
<td>NA</td>
<td></td>
</tr>
<tr>
<td>Salinity Gradient</td>
<td>NA</td>
<td></td>
</tr>
</tbody>
</table>
Myanmar Country Report

By: Dr. Myat Lwin, Myanmar Maritime University and Mr. Htun Naing Aung, Myanmar Industries Association

Myanmar is one of the member countries of ASEAN, geographically located between two giant countries of China & India with 676,577Km2 with approximate population of 52 millions. It has 1930Km coaster line along Bay of Bengal and Andaman Sea.

With the political changes of the country, Myanmar has become a shining star for the business development and so called last frontier in ASEAN. The main sources of energy are biomass, oil & gas and hydro power with the energy share of 70%, 20% and 10% respectively.

As the country changed its political system to be democratic country, the government revised all existing laws and also enacted new laws to be in line with other democratic countries. At the same time, private enterprises are being encouraged to be at the leading role of country’s main economic reform.

Myanmar has not only changed peacefully from military regime to people elected government but it has successfully held a free and fair election in 2015 for the new government to lead the country from 2016.

With this reform process, the business investments from both local and overseas dramatically increase and power demand is higher than ever. This makes renewable energy and energy conservation important aspects in policy-making.

The study shows that there are many promising potential of renewable energies such as biomass, biogas, hydro power, solar energy and tidal etc.

OCEAN ENERGY POLICY

Strategy and National Targets

Myanmar has formulated and adapted Myanmar Agenda 21 published by the National Commission for Environmental Affairs (NCEA) with general aim of facilitating the integration of environmental and sustainable development. It also formed National Energy Management Committee (NEMC) and Energy Development Committee (EDC).
To maintain the status of energy dependence, the main policy is to promote the usage of new and renewable energy as alternative fuel used in the households and to achieve energy efficiency conservation.

There are three key issues in the renewable energy in Myanmar such as (1) to have adequate renewable energy sources of different types, (2) to encourage more inter-ministerial and interdepartmental cooperation, (3) to promote private sector participation in the development of energy programme.

In terms of ocean energy, even though the country has a long coaster line of 1,930km, there is no specific policy yet on ocean renewable energy; however is highly encouraged to be among the country’s renewable energy resource. Among the activities on ocean renewables was the construction of the 2kW tidal power plant at Kanbalar village, Ayeyarwaddy Division. It won the 1st runner up place during the ASEAN Energy Awards in 2008.

This small scale projects make use of more than 1930Km of coastline of the country through numerous small creeks for harnessing tidal energy (1m-6m difference). With the application of appropriate technology, tidal energy would be capable in the electrification of rural remote villages.

**Support Initiatives and Market Stimulation Incentives**

The import tax and free permit to import renewable energy related machines and equipment are the major initiatives and incentives to stimulate the market.

**Main Public Funding Mechanisms**

To formulate funding mechanism for implementing achievable energy efficiency and conservation activities is one of the proposed policies to the government by Ministry of Industry to the National Energy Management Committee.

**Relevant Legislation and Regulation**


Renewable energy was mentioned in one of the nine key points stated in the Myanmar National Energy Policy, i.e. “To implement programmes on a wider scale, utilizing renewable energy resources such as wind, solar, hydro, geo-thermal and bio-energy for the sustainable energy development in Myanmar.”
With the help of United Nations Industrial Development Organisation (UNIDO) and Asian Development Bank, PROMEEC (Promotion of Energy Efficiency and Conservation) Myanmar is on its way to promote the energy efficiency and conservation master plan. It could successfully implement the training program collaboration among PROMEEC, MOI (Ministry of Information), MOE (Ministry of Energy) and MES (Myanmar Engineering Society) with the outcome of 50 energy managers throughout the country.

RESEARCH & DEVELOPMENT

Myanmar Science & Technology Research & Development (MSTRD) is the focal point of R&D in Myanmar organized by the Ministry of Science & Technology.

The R&D on the development of “tar free biomass gasifier” is underway with the cooperation among MSTRD, Myanmar Industries Association (MIA), Kaung Kyaw Say Engineering (KKS).

Participation in Collaborative International Projects

Myanmar joined Bangladesh India Myanmar Sri Lanka Thailand Economic Cooperation (BIMST-EC) in 1997. Myanmar signed an agreement on the established of the ASEAN Centre for Energy in 198 together with eight other ASEAN countries. PROMEEC (Promotion of Energy Efficiency and Conservation) is a programme coordinated by ASEAN to facilitate capacity building and exchange of information between the ASEAN countries.

Greater Mekong Sub-region (GMS) Economic Cooperation with six member countries was launched with the assistance of the Asian Development Bank in 1992. Its economic cooperation in energy sector includes: regional power interconnection & power trade agreements; sub-regional strategy for the utilization of natural gas; and sub-regional strategy for cooperation in renewable energy. The inter-governmental agreement on regional power trade in the GMS was signed in 2002 and the Regional Power Trade Coordination Committee (RPTCC) was created in 2002 to coordinate, promote and implement regional power trade development.

In 2005 Myanmar and Thailand signed and MOU on cooperation in renewable energy and energy saving sectors.

The Energy Efficiency and Conservation (EE&C) goals submitted to the 5th East Asia Summit Energy Ministerial Meeting held on 20 September 2011 in Brunei Darussalam, state that the country uses TPES as the EE Indicator and aims at 5%
reduction by 2020 from 2005 level and 10% reduction by 2030 from 2005 level. However the action plans submitted were from 2009 and not concrete.


TECHNOLOGY DEMONSTRATION

Operational Ocean Energy Projects

The tidal power project using the height of water level different is one of the proven technology demonstrations in Myanmar led by the members of Myanmar Engineering Society. It is 2kW power production plant constructed at “Kanbalar Village” in Ayeyarwaddy Division. The small (earth filled) dam was constructed across the creek to create the water reservoir at the upstream side, similar to dam run on river design. The water is stored when the up tide and closed the gate to trap in the reservoir.

With the water level different on both sides due to the down tide water level and stored water level, the micro hydro turbine started to produce the electricity at the minimum height different of 2 meter.

The dam with 3m-height and 10m-length with a wooden gate (0.35m height x 0.35m width x 8m length) was connected to the turbine casing through outlet gate. The draft tube has been installed at the outlet of turbine. As there are 2 tide cycles in a day and with the size of the dam and reservoir, 2kW micro hydro turbine consumes only 1/12 of stored water in 12 hours operation time in one tide cycle. It is found micro hydro turbines could be made available at this plant. The cost estimate of turbine is US$500 and the construction of dam and power plant is carried by the villagers in volunteer basic.

One on-going project is the pre-feasibility on the tidal current power project at Kyaikhamee in Mon State which was started since 2008. It has potential tide current which is about 1to 1.5 m/s and needed specific study. It is about 7m tidal height at that area it is learnt.
NEW DEVELOPMENTS

A tentative organization is formed among Myanmar Industries Association (MIA), Myanmar Maritime University (MMU) and Myanmar Engineering Society (MES) to jointly study on ocean renewable energy in Myanmar.

Myanmar Maritime University successfully held annual competition and the following is the latest event held in this early year.

Myanmar ROV & AUV Competition

(Remotely Operated Vehicles (ROV) & Autonomous Underwater Vehicles (AUV) Competition)

Introduction

1. Myanmar Maritime University started to map the guidelines for this ROV & AUV competition in (2010-2011) academic year for the following purposes
   (a) to construct and study the control system of research underwater vehicles in accordance with the developing technologies
   (b) to promote the students' creativity and knowledge
   (c) to help conduct the national underwater researches
2. In (2010-2011) academic year, a group of student submitted a study on ROV & AUV as their final year project and got some accomplishments. In 2012-2013 academic year, the study of underwater vehicles come alive again when two groups of students study and construct ROV and AUV separately as their final project. These two projects tried to rectify the previous work by their predecessor and made some improvements.
3. These works by students intrigue me to lay out the plan for competition on underwater technology, especially ROV & AUV, which would allow students to work in group regardless of their field of studies, for students who have passion for inventions and technology. These competitions will surely benefits in allowing students to uncover their potentials and creativity and exploration of new technologies.
4. 1st Myanmar ROV Competition had been successfully held on 9th January 2015 at Myanmar Maritime University’s swimming pool. This competition awarded 5 prizes. 2nd Myanmar ROV Competition also had been successfully held on 8th January 2016 supported USD 5000 by Weathernews Inc.(Japan).

Aim
5. To enhance the creativity of students from Myanmar Maritime University and to develop underwater robotics and research vehicles which can be used in national underwater researches.

Benefits of this competition

6. We can get the following benefits from the ROV & AUV Competition,
   (a) Participation of students from various majors
   (b) Collaboration and mutual understanding of students from different principles of study
   (c) Enhancement of creativity and productivity of students
   (d) Acquiring help and guidance from international underwater technology research firms and organizations
   (e) Helping national underwater researches

Conclusion

7. By doing this competition, underwater technology in Myanmar will be improved and operational AUV & ROV with leading-edge technology will be developed from university level to national level, which can give a great advantage to national underwater researches. This will help to realize the motto, "To construct a modern developed nation with education", and attain development of marine science and technology.

Ocean Related Activity by Private Sector

The following wave measurement for reclamation project was done in 2014-2015.

Wave Measurement for Reclamation Project in Sittwe

Sittwe, the capital city of Rakhine State is located on the sea shore of Bay of Bangol and at the mouth of Kaladan River, northwest of Yangon.
With the guidance of Rakhine State Regional Government, the project developer is now planning the urban development project including the reclamation at the bank of Kaladan River.

The wave and the water depth measurement are the most important aspects to the reclamation project and it is also to get information on FS to the wave energy at this area that result of 7m height.

This should be one of the pilot projects to Myanmar offshore area getting developed ocean renewable energy.

The investigation and analysis were done during FS state from the month of November 2014 to March 2015.

Design Wave (1) Wave Height (2) Wave Period (3) Wave Direction are also recorded. We could also record the Design Water Level (1) Highest High water Level (2) Mean Sea Level (3) Lowest Low Water Level.
The measurement or study area is 30 km from the seashore as we do not enough facility and support.

However, the wave direction from SSW is the highest wave recorded as (0.53m ~ 1.55m) with period of 13.77 sec.

During the south wave direction, it is recorded the wave period as 17.54 sec which is longest idle period followed by 6.27 sec at SW and 9.5 at WSW wave direction.

Based on this study, it is expected to extract wave energy to transform into electricity and could be one of the solutions to the nearby area where electrification is badly needed.

**RE with Ocean Current**

Even though there is potential to extract renewable energy from ocean current, it is still pending due to the lack of financing farm and budget.
ADDITIONAL INFORMATION

Installed capacity & consented projects

<table>
<thead>
<tr>
<th>Capacity [kW]</th>
<th>Installed</th>
<th>Consented projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wave Power</td>
<td>Nil</td>
<td>Nil</td>
</tr>
<tr>
<td>Tidal and ocean currents</td>
<td>Nil</td>
<td>Nil</td>
</tr>
<tr>
<td>Tidal Power</td>
<td>2KW</td>
<td>1</td>
</tr>
<tr>
<td>OTEC</td>
<td>Nil</td>
<td>Nil</td>
</tr>
<tr>
<td>Salinity Gradient</td>
<td>Nil</td>
<td>Nil</td>
</tr>
</tbody>
</table>

Electrical Utilities Involved in R&D and Demo

<table>
<thead>
<tr>
<th>Name of utility</th>
<th>Type of involvement (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floating Hydro Turbine (Planned) (Made in Germany)</td>
<td>Project development <em>(Still pending or no progress due to insufficient budget)</em></td>
</tr>
</tbody>
</table>

(1) R&D, technology demonstration or project development

Open-sea testing facilities existing or in planning phase (see example for bimep)

<table>
<thead>
<tr>
<th>Test Name</th>
<th>Test site promoter/manager</th>
<th>Location</th>
<th>Grid connection (1)</th>
<th>Status (2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tidal Current Test</td>
<td>MIA, MMU, MES/KKS</td>
<td>Kyeikhamee, Mon State</td>
<td>No</td>
<td>2015</td>
</tr>
</tbody>
</table>

(1) Yes or No. In case of Yes, indicate the nominal power.

(2) Existing or planned (in case of planned, indicate the expected year for operation starting)
Philippines Country Report

By: Dr. Louis Danao, University of the Philippines
Presented by: Mr. Marvin Quitoras, University of the Philippines

PhilSHore is a project worth US $ 445,000 which aims to do a resource assessment and create a spatial planning tool for tidal current energy in the country. Few important updates are: 1) hydrodynamic simulations are almost complete and 2) web-based GIS tool, device selection and matching module is already in place. The project started last April 2014 and expected to complete by March 2016.

Concurrently, there are also post-doctoral and PhD studies done on the topics of tidal currents. Dr. Danao visited University of Sheffield, UK to conduct blade design and analysis of tidal current turbine (US$13.3k). The 5 week study included BEM simulations (QBlade) and composite modelling (Ansys Composite PrePost). The results of this study are 1) collaborative work with PhD student to build CFD model of tidal current rotor; 2) one pre-print manuscript for submission to conference. Below are some results of the study:

Fig 16: Model performance validation against University of Southampton blade with NACA63-8xx profiles

Fig 17: Comparable rotor performance using NACA44xx profiles but flatter peak performance curve
The maximum principal stress at 2m/s and 5m/s shows positive result within the material strength while tip deflection is quite excessive for wall thickness at 2% of root chord. Reasonable tip deflection is recorded at 8% thickness as shown at the figures below:

As result of this post-doctoral visit, a PhD research work at the University of Sheffield, Mr. Binoe Abuan of the University of the Philippines, has been started which mainly focuses on the hydrodynamics of a tidal current turbine in unsteady (time-dependent) flow conditions. The initial work involved the development of a CFD model using the blade from Dr. Danao’s study. The project is expected to finish on August 2017. A preliminary CFD model construction contains a stationary outer domain (containing the rotor). Mesh was also created in Ansys ICEM-CFD with a rotor size of 5m diameter.
Dr. Danao and team recently submitted a project proposal entitled “Philippine Tidal In-stream Demonstration and Energy Systems” (PhilTIDES) with a budget of US$2.22M to Department of Science and Technology (DOST) - Philippine Council for Industry, Energy and Emerging Technology Research and Development (PCIEERD). The project’s main objective is to develop and deploy two units of 50kW tidal current turbines at an identified site. If approved, project will be around 3 years commencing on 2016.

**Commercial/ Industry Activities**

Below are few of the commercial and industry activities on ocean renewable energy in the country for 2015:

- French tidal energy developer Sabella has partnered up with H&WB Asia Pacific to develop tidal power plant in the Philippines.

- The two companies have signed a MoU on October 15, 2015, for the development of a tidal power plant in San Bernardino Strait.

- The first stage of the project development will comprise an installation of a 5 MW tidal energy farm in one H&WB’s three lease areas – the Matnog lease area.

- H&WB will be in charge of the resource assessment, site permitting and characterization, while Sabella will provide the technology and the technical expertise for the project.

- The tidal turbines planned to be used are Sabella’s D15 tidal turbines. The turbines are 15 m in diameter and have the maximum power output of 2 MW.

### Awarded Ocean Energy Projects as of June 30, 2015

<table>
<thead>
<tr>
<th>ISLAND</th>
<th>REGION</th>
<th>PROVINCE</th>
<th>CITY/MUNICIPALITY</th>
<th>PROJECT NAME</th>
<th>COMPANY NAME</th>
<th>STATUS</th>
<th>POTENTIAL CAPACITY (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Luzon</td>
<td>III</td>
<td>Cagayan</td>
<td>Sta. Ana and Adjoining Towns in Cagayan Valley (2 sites) - Area 3</td>
<td>H &amp; WB Corporation</td>
<td>On-going study and permitting</td>
<td>5.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Sta. Ana and Adjoining Towns in Cagayan Valley (2 sites) - Area 4</td>
<td>H &amp; WB Corporation</td>
<td>On-going study and permitting</td>
<td>5.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>IV</td>
<td>Zambales</td>
<td>Cagayan</td>
<td>Cagayan Ocean Thermal Energy Conversion (OTEC)</td>
<td>Bell Prite Power Corporation</td>
<td>On-going study and permitting</td>
<td>5.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>San Bernardino Strait between Bicol Peninsula and Samar Leyte Corridor (2 sites) - Area 2</td>
<td>H &amp; WB Corporation</td>
<td>On-going study and permitting</td>
<td>5.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>San Bernardino Strait between Bicol Peninsula and Samar Leyte Corridor (2 sites) - Area 3</td>
<td>H &amp; WB Corporation</td>
<td>On-going study and permitting</td>
<td>5.00</td>
<td></td>
</tr>
<tr>
<td>Luzon</td>
<td>Sum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25.00</td>
</tr>
<tr>
<td>Visayas</td>
<td>VII</td>
<td>Samar</td>
<td>Tlsgc Project Site (Areas 4&amp;5)</td>
<td>Pneoldeo Renewable Energy Corporation</td>
<td>On-going study and permitting</td>
<td>6.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Capul Pass, Bolgo Island, San Antonio, Northern Samar</td>
<td>Tlsgc Project Site (Area 6)</td>
<td>Pneoldeo Renewable Energy Corporation</td>
<td>On-going study and permitting</td>
<td>6.00</td>
</tr>
<tr>
<td>Visayas</td>
<td>Sum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12.00</td>
</tr>
<tr>
<td>Mindanao</td>
<td>Cabaga</td>
<td>Surogo del Norte</td>
<td>Surogo City</td>
<td>Gaboc Channel Ocean Energy</td>
<td>Adama Power Resources, Inc.</td>
<td>On-going study and permitting</td>
<td>6.00</td>
</tr>
<tr>
<td>Mindanao</td>
<td>Sum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6.00</td>
</tr>
</tbody>
</table>

**Table 2: Awarded ocean energy projects in the Philippines as of June 2015**
Singapore Country Report

Dr. Srikanth Narasimalu, Ms. Mary Ann Joy Quirapas, Mr. Ly Duy Khiem and Dr. Michael Abundo, Energy Research Institute at Nanyang Technological University (ERI@N)

The city-state is well known as a clean and green city which strives for environmentally sustainable development, with a continuously growing economy (Tay, 2015). For the past few years, it has shown significant interest in renewable energy research, development and demonstration (RD&D), including in ocean renewable energy (ORE). Singapore has provided a conducive environment for ORE to be further developed, through support from the government in establishing various marine renewable energy test-beds, encouraging collaborative projects among academic research organisations, industries and government agencies, and providing funding and resources for highly innovative ORE technologies.

The Renewable Energy Integration Demonstrator-Singapore (REIDS) project, aims to test and demonstrate, in a large-scale microgrid setting on Pulau Semakau island, the integration of a broad range of onshore and offshore renewable energy production, energy storage and energy management technologies. The REIDS project, led by the Nanyang Technological University (NTU) and supported by the Singapore Economic Development Board (EDB) and National Environment Agency (NEA), was officially launched in October 2014 with ten industry partners and 2015 marked the start of key onshore and offshore projects. A test site for tropical tidal turbines will contribute to the offshore component of REIDS.

In terms of regional collaboration, the Southeast Asian Collaboration for Ocean Renewable Energy (SEAcORE) is a platform initiated by the Energy Research Institute @ NTU (ERI@N) with partners from Southeast Asia to promote ocean renewables and create new markets for partner industrial firms (ERI@N Report, 2012-2014). This year, SEAcORE has been officially recognised by the ASEAN Centre for Energy (ACE) as its technical working group for offshore renewables – spearheading technology assessment and resource mapping methodology guidelines in projects involving marine resource assessment and turbine systems identification suitable for tropical conditions.

In addition, there are efforts to drive the commercialisation of ORE. OceanPixel is a Singapore start-up company that spun off from NTU, through ERI@N’s Wind and Marine team. It has positioned itself as the pioneer company dedicated to ORE in the Southeast Asian region. Several resource assessment and techno-economic feasibility projects between Singapore and other Southeast Asian countries

---

including Indonesia and the Philippines are currently on-going through OceanPixel.

2015 marked the successful completion of different marine-related projects and a stronger commitment towards more innovative and effective means of fully utilising ocean energy sources and technology in Singapore.

OCEAN ENERGY POLICY

Strategy and National Targets

Singapore is determined to reach its national targets to become greener economically and provide environmental and sustainable development for the whole city-state. Singapore has recently announced that “it intends to reduce its emissions intensity by 36% from 2005 levels by 2030, and stabilise its emissions with the aim of peaking around 2030” (UNFCCC, 2015).

This makes the country more determined to establish different energy efficiency measures and to harness alternative sources of energy. The government sees renewable energy as an emerging field which needs to be closely studied and developed in tune to regional needs (SMI, 2014).

More than S$800 million public funding has been set aside by the Singapore government for research in energy, water, green buildings and addressing land scarcity of which S$140 million is allocated for research into clean energy technologies under the banner of the Energy Innovation Programme Office (EIPO) (EDB, 2015). Ocean renewable energy has been identified by ERI@N as a strategic research area.

Singapore, being a small city-state, develops its own solutions to address constraints in land and water resources by building partnerships between public agencies and industries towards the country’s sustainability agenda. An example of this is Singapore positioning itself as a “Living Laboratory” – “making its national urban infrastructure available to local and international companies who find it useful to develop, test, prove and showcase their solutions in a real-life urban environment that is also representative of many Asian cities” (EDB, 2015). This enables Singapore to harness the best technologies and industrial solutions from its partners.

RESEARCH & DEVELOPMENT

ERI@N, supported mainly by the EDB, focuses on the areas of sustainable energy, energy efficiency infrastructure and socio-economic aspects of energy research. Its mission is to be a centre-of-excellence for conducting advanced research,
development and demonstration of innovative solutions which have both regional and global impact.

The Institute and its research centres have considerable expertise and strength in areas of offshore energy which includes wind, wave and tidal energy and complementary technologies such as energy storage, micro grids, and smart energy systems and collectively provide an integrated set of expertise from materials design & synthesis, device fabrication and modelling, and systems integration and optimization.

ERI@N's Wind and Marine (W&M) research programme is aimed at improving the performance, lowering costs and accelerating deployment of offshore renewable technologies specific to the tropics, where unique technology challenges exist. It advances the technology development and commercialisation through early collaboration with industry. It works closely with government agencies to understand regional needs, and with local and global renewable energy firms to identify technology gaps.

The key research focus of the team includes tidal, wave and wind energy resource mapping, turbine device development, offshore support structure studies, advanced materials research against environmental impact and grid integration studies. The group has initiated wind, wave and tidal current resource assessments for tropics and an ocean renewable energy project feasibility tool.

The W&M key research, development, and demonstration efforts of the team include the following: 1) Resource assessment for tidal and wave energy in Singapore and South East Asia, 2) Test-bedding activities for marine renewables (e.g. Sentosa Tidal Test Site and Tanah Merah Wave Energy Test Site), 3) Renewable Energy Integration Demonstrator-Singapore (REIDS) – Offshore, 4) Advanced materials and coatings development, and 5) Regional and international collaborative projects related to resource mapping and test-bedding of ocean energy systems.

1.2 GOVERNMENT FUNDED R&D

Flexible Distributed Generation using tidal in-stream energy system for remote island applications

Among the government funded projects is the “DG-TISE: Flexible Distributed Generation using tidal in-stream energy system for remote island applications”. This research grant aims to develop energy generation and micro-grid systems for research work in the country (EDB, 2014). DG-TISE aims to develop “a novel sensing and signal analysis system which will provide a tidal energy resource measurement method to account for the geographical sea bed conditions and tidal current measurements”, and to evaluate and test-bed commercially ready turbine in Singapore waters.
Sentosa-ERI@N Tidal Test Site

The Sentosa Tidal Test Site is a joint collaboration between Sentosa Development Corporation (SDC) and ERI@N, funded by the Ministry of Trade and Industry’s Core Innovation Fund. This project aims to showcase tidal energy extraction as a feasible and sustainable energy generating technology in Singapore and to provide opportunities to develop local technologies to harness the energy available in the narrow channel between Singapore and Sentosa. In November 2013, ERI@N and SDC officially launched the Sentosa Tidal Test Site (NTU, 2013).

Recent developments on the project include the deployment of scaled tidal turbines supported from the floating barges. Also, novel concepts such as vortex induced vibrating devices are being evaluated for field performance along with anti-biofouling coatings. The power developed is used for electric lighting on the boardwalk.

Figure 1. Floating hinged turbine support frame to house tidal turbines and vortex induced vibration devices. (Left) & Scaled (1:3) tidal turbine in tow tank (Right)

Marine Renewable Energy at Tanah Merah Ferry Terminal

The “Tidal-In Stream and Wave Energy Resource Assessment” project has successfully concluded this year. This project was funded under the Maritime Clean Energy Research Programme (MCERP) driven by the Maritime Port Authority (MPA) and NTU. The project aimed to undertake a feasibility study, device development and prototype installation at Tanah Merah Ferry Terminal (TMFT) in Singapore.

The marine renewable energy resources (tidal: range and currents - tidal in-stream, and wave energy) were assessed, characterized, and analysed to determine the extraction potential at TMFT. A range of suitable energy-harnessing devices can be used but the prototype developed in this project seemed to be the suitable choice taking into account the low wave height-type resource available, the
location, the operations, and leveraging existing mechanisms. Specifically, a wave energy conversion module making use of the floating pontoon, which has an area-averaging feature for wave energy capture, has been developed, installed, and tested/characterized at one of the TMFT jetty berths.

**Renewable Energy Integration Demonstrator-Singapore (REIDS)**

REIDS aims to power Pulau Semakau, an island south of mainland Singapore which serves as a landfill, purely through renewables, including ocean energy. First-of-its-kind in the region, the hybrid microgrid will facilitate the development and commercialisation of energy technologies suited for tropical conditions that will help address the growing demand for renewable energy technologies in Asia. REIDS will integrate multiple renewables and novel technologies such as power-to-gas technologies and smart hybrid grids, and enable the development of solutions suited for small islands, isolated villages, and emergency power supplies.

**REIDS Onshore**
The REIDS onshore project aims to solve engineering, economic, environmental and societal energy transition challenges for off-grid communities. It customizes grid science towards remote islandic needs and integrates various renewables. Technologies deployed at the test-bed include solar photovoltaics, wind, tidal, energy storage, bioenergy, innovative water desalination, hydrogen production, etc.

**REIDS Offshore: Tropical Marine Energy Centre (TMEC)**
Marine renewable energy has been growing at an accelerating pace. In terms of tidal in-stream energy, the industry has reached pre-commercial stages and will consequently be deployed in commercial scales. Testing sites play a crucial role in fostering the development of the industry. While several high energy potential locations, associated with strong tidal currents, in Europe, North America and North Asia have long been identified and harnessed, the tropical markets for lower-tidal-velocity distributed generation, for instance in South East Asia, are yet to be explored. As there is no full scale or even scale test site yet in the region, it is challenging to test and develop tidal turbines, especially tidal turbines that can be used optimally in the tropical conditions.

As a result, the TMEC project initiated by ERI@N and supported by ClassNK seeks to pave the way for establishing the world’s first scaled marine renewable energy testing facility for tropical needs. In March 2015, the feasibility study for the test sites was officially launched and is expected to be completed by mid-2016. This study involves an investment of more than S$2 million.

Presently, an environmental impact assessment (EIA) for the test sites is being carried out. The EIA includes investigating the baseline conditions, possible
effects of the test sites on the surroundings, and other associated research. Geotechnical and geophysical surveys are also being planned.

**Standards Formation Participation for Ocean Renewable Energy**

ERI@N has initiated participation in the International Electrotechnical Commission’s “Marine energy – Wave, tidal and other water current converters” standards technical committee IEC-TC114 through SPRING Singapore, the official body responsible for standards within Singapore. SPRING, with ERI@N’s help, is currently in the process of forming the National Mirror Committee (NMC) for Singapore. Currently, the key members of this NMC are academic institutions such as NTU, NUS, etc, government agencies such as the Maritime and Port Authority of Singapore (MPA), Energy Market Authority (EMA), etc, industries involving local and global firms such as Schottel, DNV-GL, DHI, Mooreast Asia and professional bodies like Institution of Engineers Singapore (IES), TUV SUD PSB, and Association of Singapore Marine Industries (ASMI).

The NMC seeks to review, adapt, and propose guidelines for Marine Energy in Singapore and serves as a stepping stone for possible adoption towards international standards specific for tropical regions such as South East Asia.

### 1.3 Participation in Collaborative International Projects

**ClassNK – Global Research and Innovation Center in Singapore**

ClassNK, a Japanese ship classification and certification society, and the Maritime Port Authority of Singapore (MPA) have signed a Memorandum of Understanding (MOU) in 13 February 2015 “to promote research and development and innovation in the maritime industry” (MPA, 2015). The signing also marked the opening of the Global Research and Innovation Center (GRIC) in Singapore, which will focus on two main sectors – 1) Maritime technologies and 2) Marine renewable energy. For marine renewables, the GRIC aims to “establish a marine energy test site for the tropics to support R&D in energy storage systems, biofouling materials, energy converters, prototype design testing, and creating possibilities to provide energy for maritime industry usage in ports and harbours” (offshoreWind.biz, 2015).

**Joint PhD - Industry Programme (JIP)**

ERI@N has been actively engaging, partnering and collaborating with industry through its JIP projects. The JIP involves local and global academic partners, research agencies of Singapore and multi-national firms who are engaged in cutting-edge research into various aspects of Offshore Renewable Energy, technology development and commercialisation. The technology advancement is
achieved through doctoral projects that are directly involving sponsoring firms’ participation to address real-life technology challenges.

Presently, more than 20 doctoral projects are in progress, spanning resource forecasting, sub-structure studies, power generation, transmission, grid, installation, and maintenance. As part of the technology advancement efforts, NTU is teaming up with Technical University of Munich (TUM) to setup an International Center for Energy Research (ICER) where research topics focus towards tropical regional needs in ocean energy system studies, offshore materials and simulation, energy forecasting and grid simulation studies. The intellectual property developed is commercialised through sponsoring firms as well as through technology spin-off firms.

**Southeast Asian Collaboration for Ocean Renewable Energy (SEAcoRE)**

This year, SEAcoRE has been officially named as the technical working group for offshore renewables under the Renewable Energy Sub-sector Network (RE-SSN) of the Association of Southeast Asian Nations (ASEAN) Centre for Energy (ACE). As a technical working group, the SEAcoRE network will work with ACE on providing quality research on offshore renewable energy and its technological solutions, techno-economic and policy aspects towards Southeast Asian regional energy security needs. In addition, there is a focus on human resources and capacity building activities on offshore renewables.

SEAcoRE involves collaboration between neighbouring countries, including Brunei, Indonesia, Malaysia, Myanmar, Philippines, Thailand and Vietnam. This provides a platform for the exchange of ideas, initiatives, and experiences from R&D, policymakers, and industry on offshore/ocean-related field. It aims to facilitate and drive the adoption of ORE in the region; and also promotes the diffusion of renewable energy technologies and creates new markets for partner industrial firms.

**Outreach Programmes**

In line with Singapore’s interest to promote sustainable energy solutions for the tropical region, ERI@N is involved in developing and test-bedding tidal in-stream energy systems for island micro-grids. One current project is the deployment of a floating tidal turbine system in a remote industrial island in West Papua. The collaboration involves Green Forest Product and Technology Pte Ltd (a sustainable mangrove harvesting firm), Schottel Hydro GmbH (a tidal turbine technology

![Figure 2: Dr. Sanjayan Velautham, Executive Director of ACE and Dr. Srikanth signing the MoU during the ACES.](image)
provider), OceanPixel Pte Ltd, and ERI@N. The island micro-grid is currently using diesel generators to power its operations. A hybrid renewable energy solution, including tidal energy, will improve the operations of the island in terms of having a cleaner and relatively cheaper energy source.

Also as part of the outreach, ERI@N participated in the International Renewable Energy Agency’s (IRENA) marine energy workshop for SIDS (Small Island Developing States) towards promoting ocean renewables for islandic energy needs.

ERI@N also took part in the Indian Ocean Regional Association (IORA) to discuss Blue Economy initiatives, which involve nations’ efforts towards exploiting ocean resources such as energy, minerals, food, medicine, etc. Countries such as India, Russia, Indonesia, France and other IORA members also participated. ERI@N highlighted how marine renewables can enable energy security, generate job creation, and provide technology alternatives, economic growth and environmental protection.

**Regional Network and International Conferences towards increasing ORE Uptake in SEA**

**Regional Technological Roadmap on Ocean Renewable Energy**

ERI@N, as Singapore’s representative to the International Energy Agency – Ocean Energy Systems (IEA-OES) Implementing Agreement, has partnered with University of Edinburgh (UK), Cardinal Engineering (US) and Power Projects Ltd (Australasia) to come up with a global technology roadmap for ORE. The main objective of this technological roadmap is to understand barriers towards ocean energy technology adoption and explore pathways and strategies to overcome barriers and support cost reduction of ocean renewable energy technologies in order to achieve competitive levelised cost of energy in comparison with other sources of energy. The report is designed to influence OES members, mainly the public and private technology funders to give them advice regarding R&D prioritization.

In the case of Southeast Asia region, aside from cost reduction strategies, the team specifically looks at the opportunities and challenges to creating the required supply chain for offshore RE technologies by learning from the experience of other related and mature industries like offshore wind, oil and gas and etc. The ERI@N Roadmap team conducted 26 interviews from different industries in the region and they also organised workshop and roundtable discussions. In total, more than 100 Asia-based companies were approached for the survey and 62 companies were interviewed from all the research partners for this activity.
Asia Clean Energy Summit (ACES) 2015

The annual Asia Clean Energy Summit (ACES), an event during the Singapore International Energy Week (SIEW) organised by the Energy Market Authority of Singapore (EMA), was held in October 2015. The ERI@N Wind and Marine team was involved as the technical team for the offshore renewable energy (RE) track. This is the third year ERI@N has successfully organised the offshore RE plenary and technical sessions with partner organisations like Sustainable Energy Association of Singapore (SEAS) and EDB.

This year’s offshore track has significantly grown in its size, with the number of speakers almost doubling from the past two years. Technological and technical aspects of offshore RE were discussed alongside the field’s techno-economics, policies and more regional-based research, which have been growing in interest.

Asian Wave and Tidal Energy Conference (AWTEC) 2016

Singapore has been chosen to host the next Asian Wave and Tidal Energy Conference (AWTEC) in 2016 (AWTEC, 2014). AWTEC is to be held during October 24th to 28th 2016 in conjunction with the popular SIEW 2016 at the Marina Bay Sands, Singapore.

AWTEC provides a platform and opportunity for researchers, engineers, policy makers and stakeholders to exchange knowledge through detailed discussions and recent research presentations, and promotes international and multi-disciplinary collaboration.

Besides the technical sessions, there will also be pre-conference events, i.e. workshops and technical training about ocean energy field and technical tours after the conference. Showcases of marine renewable energy technologies from all over the world will also be present during AWTEC. Participants could also take advantage of joining SIEW-related events like “Roundtable Discussions” hosted by EDB and EMA.
ERI@N heads the Local Organising Committee and along with experts from Japan, Korea, UK and Australia, the team will run the conference, providing opportunity to showcase ocean technology development efforts and innovative solutions with greater regional impact and broader reach. The Call for Papers has recently been released, with all submissions expected to be received by February 1, 2016.

For more information about the Asian Wave and Tidal Energy Conference (AWTEC) 2016, please visit: www.awtec.asia/conferences/awtec-2016/

TECHNOLOGY DEMONSTRATION

ERI@N has designed, prototyped, and installed a Wave Energy Converter (WEC) for harnessing the jetty berth’s pontoon movement due to waves and converting the mechanical power into electrical power. The WEC is presently coupled with its own roller as a system which is separated from existing pontoon rollers to ensure the safety of pontoon operations. Eventually the whole system will substitute the existing support rollers to function as both pontoon movement guides and energy extraction devices.

The technology developed in this project can be further matured from the initial proof-of-concept to the proof-of-value stage through collaboration with an industry partner, who can commercialise the product. A funding support scheme could then help to take this forward. The application of such technology is not limited to shore-based installations - it can be further extended to use in ships and other marine vessels and installations (e.g. offshore rigs, aquaculture platforms, etc.).

![Figure 4. Existing roller, pontoon, and jetty berth at Tanah Merah Ferry Terminal](image-url)
Thailand Country Report

By: Dr Chaiwat Ekkawatpanit and Dr. Duangrudee Kositgittiwong, King Mongkut University of Technology Thonburi

Thailand has been looking at Gulf of Thailand as a study area for ocean renewables with the following research topics: 1) simulation of wave generator (CFD); 2) simulation of ocean wave and 3) evaluation of wave energy by using the observed data (from SWAN and WAM).

From the previous study in 2014, the research on the wave energy potential for power generation in the Gulf of Thailand found out the following information:

- Station 11 has the highest significant wave height in 2.6 m.
- The highest significant wave height can be found during September
- Potential locations for wave energy are stations S7-214.

Fig 19: Gulf of Thailand - Study area for ocean renewable energy

Fig 20(a): average significant wave height (m); (b) different wave potential areas in the Gulf of Thailand
The team verified the model simulation with extreme data set gathered from Typhoon Linda (1997). From this the following were the results:

- The highest significant wave height is 2.71 m at S16.
- The results show a good agreement with the previous study that stations S7-S14 are the stations with high potential.
- The results of stations S11, S13, S14 seem to show the highest potential of power generation amongst all stations.
A SWAN model is used in the present study to evaluate the ocean wave energy and significant wave height in 2010. The results performed show that the highest wave energy of 1.4m is in September and January and the highest natural wave every power of 3.85 kW/m. The team considers the evaluation of ocean wave using numerical model at the Adaman Sea as next step from this current study.

*Simulation of Power Generator from Ocean Wave Energy by Computational Fluid Dynamics (CFD)*

From the previous research work, the team found out that the highest wave height in the Gulf of Thailand can be found in September with the height of 2.6m while the average height is 0.9m. However, there is still no ocean wave energy generator in Thailand. The team aims to simulate the wave generator for power generation wherein they make used of the Drakoo power generator as basis of their study.

![Fig 24: Simulation of Drakoo in CFD program](image)

For the simulation of Drakoo wave generator, the boundary conditions were set as follows:

- The inlet.1 is mass-flow-inlet.
- The outlet.1 is outlet-pressure.
- The fan is exhaust-fan.
- The air vent is outlet-vent.
- All of body is wall.
- Minimum mesh size was 50 mm.
- Drakoo is appropriate with Thailand in term of wave height range 0.4 m and the operation period of wave ranges from 2-10 seconds.
For Brunei Country Report:


For Malaysia Country Report:


For Singapore Country Report:


ERI@N. (2012-2014). ERI@N Annual Report 2012-2014. Singapore: ERI@N.


UNFCCC. (2015). *Singapore INDC.* Retrieved January 6, 2016, from UNFCCC: http://www4.unfccc.int/submissions/INDC/Published%20Documents/Singapore/1/Singapore%20INDC.pdf