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Sustainable Energy Association of Singapore

Marine Renewable Energy in Singapore: Realising the Opportunities

A Position Paper by the

Sustainable Energy Association of Singapore

Marine Renewables Working Group

1 November 2018

Executive Summary

In line with Singapore's drive towards a sustainable future, various efforts that address energy security and economic impact are being explored. Marine Renewable Energy (MRE) and its related sectors are relevant upcoming contributors to Singapore's energy mix.

Marine renewable energy refers to anything in the marine space used to generate renewable energy such as floating solar panels and ocean renewable energy technologies (e.g. tidal range, currents, wave, thermal gradient, salinity gradient). Singapore potentially has substantial MRE resource that can be harnessed for various applications. Some of the MRE-supported applications are as follows:

- Utility-scale electricity
- Off-grid, distributed power generation, island electrification
- Offshore applications, e.g. offshore energy platforms, monitoring stations, navigational systems, fish farms and other aquaculture developments
- Coastal operations and applications, e.g. wave breakers, ports
- Production of alternative fuels e.g. hydrogen
- Desalination and water production
- Green marine and maritime ecosystem development

Being a recognized leader in innovation and research in the region, Singapore has the great opportunity to take the lead in Southeast Asia (SEA) to drive the adoption of MRE and related technologies not only to support sustainable development but also to contribute in enhancing socio-economic growth. The points below summarize some of the opportunities which could be enabled by MRE development:

- Energy and water security nexus
- Addressing climate change by contributing to clean and green alternative energy sources
- Socio-economic growth through job creation, economic resilience, inward investment, public-private partnerships
- Expertise/capability development leading to export potential through creation of regional supply chain and standards, technology, R&D, financial and business models, education and skills development, best practices in utilization of marine space and environment

To realise the opportunities of developing MRE in Singapore, the following next steps are recommended:

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

Contents

1. Introduction

Under the banner of its Urban Sustainability Solutions Initiative, Singapore is pushing for relevant and innovative technologies to address climate change issues in the country and national strategies to achieve a low carbon city. This is an opportunity for the marine renewable energy industry and its related sectors to work closely with different relevant actors and stakeholders in driving forward discussions about the potential of clean and sustainable energy production and its usage in the marine environment within Singapore to start with, but also expanding across Southeast Asia (SEA).

This position paper provides an introduction to the marine renewable energy technologies (MRE), their current status globally and the opportunities for Singapore. It provides an initial analysis on the impacts of marine energy resources on Singapore's energy security and climate change mitigation. Finally, it also outlines the potential impact to Singapore's socio-economic growth, i.e. possible creation of a local and regional supply chain, job creation, education and skills development .

2. Marine and Ocean Renewable Energies

Marine renewable energy (MRE) refers to anything in the marine space used to generate renewable energy, including offshore wind turbines, floating solar panels and ocean renewable energy (ORE) technologies.[1] ORE refers specifically to drawing power from the ocean to generate energy, specifically from tidal currents, tidal range, waves, temperature gradients, and salinity gradients. Due to their likely higher potential for Singapore and the region, the technologies considered further in this position paper are, tidal current energy converters, wave energy converters and floating solar PV.[2] An overview of these technologies is provided in Figure 1.[3]

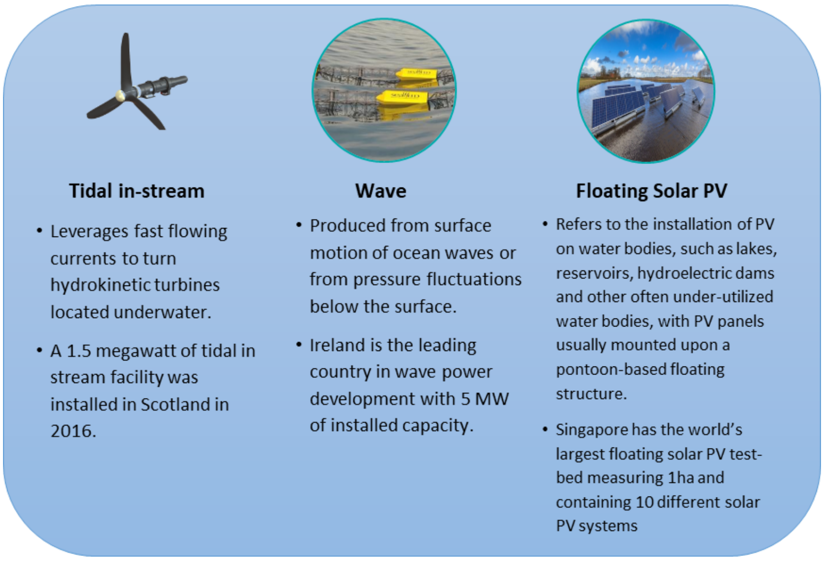

Figure 1 – Selected ocean renewable energy technologies

[1] International Energy Agency-Ocean Energy System (OES). 2017. Annual Report. An Overview of Ocean Energy Activities in 2017. Available at: https://www.ocean-energy-systems.org/publications/annual-reports/document/oes-annual-report-2017/ (last accessed: 28 Sept 2018).

[2] The other types of MRE are ocean thermal conversion (OTEC), and salinity gradient. Offshore wind and tidal range are not considered further in this position paper. Both are established technologies that require a different set of strategic support mechanisms to those of the newer technologies considered here.

[3] find out more check: IEA-ETSAP. (2010) Marine Energy. available at https://iea-etsap.org/E-TechDS/PDF/E08-Ocean_Energy_GSgct_Ana_LCPL_rev30Nov2010.pdf (last accessed : 16 Oct 2018). For floating solar PV: SERIS.http://www.seris.nus.edu.sg/activities/Floating-PV-R&D-and-Testbed.html (last accessed 28Oct2018)

3. Status of marine renewable energy

3.1. Global status of marine energy[4]

Across the globe, wave and tidal energy alone are projected to have an installed capacity of around 300 GW by 2050, creating around 680,000 direct jobs, with a total investment worth 35 USD billion in 2050 and carbon savings of 500 million tonnes of CO_2.

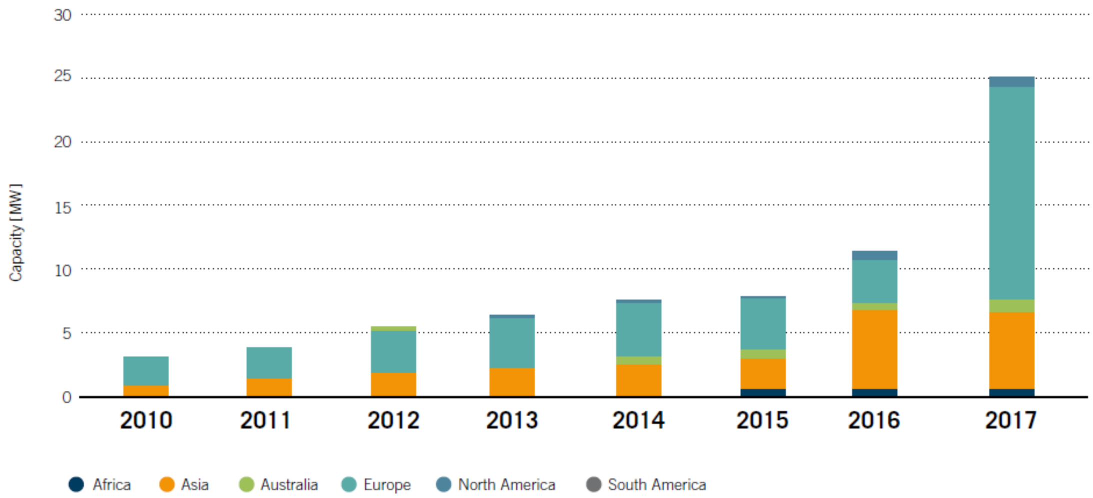

Figure 2 – Cumulated ocean energy capacity from 2010 – 2017[5]

In 2017, the global cumulative capacity of tidal and wave energy doubled compared with the previous year. This is due to successful large-scale deployments across the globe that shows the sector's taking off to more commercial scale. According to the International Energy Association - Ocean Energy Systems (IEA-OES), "The major projects behind this development are MeyGen/Inner Sound Phase 1A in the UK, Paimpol-Bréhat in France and the LHD Tidal Current Energy Demonstration Project in China. Wave energy deployments has also doubled in 2017. The main drivers of this development are the Sotenäs project in Sweden and Wello's Penguin prototype at the European Marine Energy Centre (EMEC)."

There are also intergovernmental organisations formed to create collaborative platforms in the MRE field e.g. the International Energy Agency (IEA) established the Technology Collaboration Programme for Ocean Energy Systems (OES) with 23 Member States. There is also a global network of over 40 established open-sea test sites in around 15 countries. A number of key industry milestones are presented in Figure 3.

Apart from using the ocean as an energy source, there is also the possibility to use the marine space for placing renewable energy generators. In recent years, one new deployment option has taken the global solar photovoltaics (PV) industry by storm: putting solar panels on water bodies, called "Floating Solar" or "Floating PV" (FPV). From a humble 150 MWp in 2016, the total installed FPV capacity in 2018 has surpassed 1 GWp. The vast majority of those installations are on fresh water reservoirs, but there is growing interest in putting floating solar installations in the marine environment. This could be a huge opportunity for countries that have many islands like Indonesia or the Philippines. Moving

[4] International Energy Agency-Ocean Energy System (OES). 2017. Annual Report. An Overview of Ocean Energy Activities in 2017. Available at: https://www.ocean-energy-systems.org/publications/annual-reports/document/oes-annual-report-2017/ (last accessed: 28 Sept 2018)

[5] *Ibid.* Also, this graph excludes tidal barrage and floating solar PV.

from inland reservoirs to the marine space poses certain challenges (more corrosive environment, biofouling, higher waves), but also opens new opportunities by developing multi-purpose structures and hybrid systems, which can solve more than one problem for a specific country. Highly promising multi-dimensional applications of floating solar are combinations together with fish farming (food supply), electrolysis (hydrogen generation for a future hydrogen economy) or desalination (fresh water supply).

Australia

- Completion of Wave Energy Atlas
- A number of successful deployments (14,000 cumulative hours of operation at Carnegie's Perth Project)
- Western Australia funding committed to develop Albany Wave Energy Centre ($19.5m)
- Establishment of Australian Marine Energy Task Force

Canada

- Canadian Marine Renewable Energy Technology Roadmap launched in 2011
- Fundy Ocean Renewable Center for Energy (FORCE) established in 2009
- Nova Scotia:
  - Marine Renewable Energy Strategy – 2012
  - Marine Renewable-energy Act – 2015 (amended 2017)
  - NS Offshore Energy Research Association (OERA)
  - Market support mechanisms in place (Development FIT and COMFIT)
  - 22MW approved for FIT at FORCE to date

Ireland

- Offshore Renewable Energy Development Plan established in 2014
- Centre of excellence at established at MaREI
- Testing facility at Lir National Ocean Test Facility
- Established open-sea test site at Galway Bay (Marine and Renewable Energy Test Site) – Smart Bay

United Kingdom

- Establishment of the European Marine Energy Centre (EMEC) in 2003 – >20 technologies to date
- First commercial scale leasing round in 2010
- 1.2GW leased for development in Scotland
- First phase of two commercial arrays completed – MeyGen (6MW) and Nova Innovation (300kW)
- Strategic R&D programme for wave (Wave Energy Scotland) established - £24.4m invested to date
- Leases for 6 Demonstration Zones issued in 2016

United States

- DOE draft National Strategy for Marine and Hydrokinetics to 2035
- Established network of Marine Renewable Energy Centres (MRECs) and open sea test sites
- Marine Energy Act introduced – May 2017
- Strategic R&D programme established and funded through DOE's WPTO
- DOE partnerships in place with DOE National Labs

Figure 3 – Selected key industry milestones for wave and tidal energy[6]

Due to the nascent stage of the wave and tidal current sectors, the levelized cost of energy (LCOE) of each is currently relatively high compared to fossil fuels and other more established renewables. However, as outlined in a recent report by the Offshore Renewable Energy (ORE) Catapult in the UK, significant progress has been made in the tidal current sector in recent years through economies of volume (producing and deploying multiple devices), time and cost savings through 'learning by doing', process optimisation, engineering validation and improved commercial terms[7].

The ORE Catapult report also states that as the sector moves towards commercialisation, further significant cost reductions are expected in the near term through economies of scale, economies of

[6] International Energy Agency-Ocean Energy System (OES). 2017. Annual Report. An Overview of Ocean Energy Activities in 2017. Available at: https://www.ocean-energy-systems.org/publications/annual-reports/document/oes-annual-report-2017/ (last accessed: 28 Sept 2018)

[7] Catapult Offshore Renewable Energy. 2018. Available at: https://s3-eu-west-1.amazonaws.com/media.newore.catapult/app/uploads/2018/05/04120736/Tidal-Stream-and-Wave-Energy-Cost-Reduction-and-Ind-Benefit-FINAL-v03.02.pdf (last accessed 28 October 2018)

volume, accelerated learning and innovation[8]. As the sector progresses, savings are also expected in terms of 'cost of capital' as projects gain access to a wider range of finance options

MRE has unique benefits and many applications which will be further discussed in the next sections. It is important to note that MRE technologies have different price points to other sources of energy and can already compete with the price of some traditional sources of energy, such as diesel generators.

3.2. Singapore's marine renewable energy potential

A macro-level study completed by the Energy Research Institute at Nanyang Technological University (ERI@N) in collaboration with the Tropical Marine Science Institute (TMSI) reveals that Singapore holds at least 250 megawatts of tidal in-stream energy (TISE) installed capacity potential.[9] Figure 4 below shows the potential sites where marine renewable energy can be extracted from Singapore.

In addition to that, the Solar Energy Research Institute of Singapore (SERIS) at the National University of Singapore (NUS) has carried out as an initial assessment of areas suitable for near-shore floating solar and concluded that the potential could surpass more than 1 GWp, provided that certain areas, which are currently used for anchorage for the Singapore ports, could be freed up and re-assigned for the use of floating solar, be with or without combinations with other users.

No	Peak Power
1	105 megawatt
2	65 megawatt
3	15 megawatt
4	20 megawatt
5	3 megawatt
6	12 megawatt
7	5 megawatt
8	15 megawatt
9	5 megawatt
10	2 megawatt
11	3 megawatt

Figure 4: Summary of Ocean Renewable Energy Data in Singapore

4. Applications of marine renewable energy

One of the main advantages of MRE is that it can be used to generate energy from a variety of natural resources and provide essential products and services to a wide range of end users and off-takers, thereby creating a diverse range of possible applications and market opportunities. An overview of these is provided in Figure 5.

[8] *Ibid.*

[9] Quirapas, et.al (2015). Ocean renewable energy in Southeast Asia: A review. *Renewable and Sustainable Energy Reviews.* pp. 799-817. http://dx.doi.org/10.1016/j.rser.2014.08.016

Utility scale electricity

MRE can be used to generate utility scale power and supply to the main grid as part of the main energy mix. At the utility-scale level, the marine energy sector has made significant progress with the completion of the first phase of two commercial arrays in UK, i.e. MeyGen (6 MW) and Bluemull Sound in Shetland (currently being extended to 600kW)

Off-grid / distribution scale electricity / islands

The generation of electricity in most remote islands is through diesel generators. The cost of transportation and consumption of the oil makes the electricity cost per kW very high in those islands. An integrated renewable energy-based solution can provide a viable and more competitive solution to these islands. Hybrid energy systems, such as those being developed in Singapore Renewable Energy Integration Demonstration (REIDS) project will be crucial in the uptake of renewable energy in both mainland and island conditions.

Offshore Applications

MRE is ideally suited to providing energy to offshore installations e.g. oil platforms, navigational systems, weather and climate monitoring stations, fish farms and other aquaculture developments. A number wave, tidal current and marine floating solar technology companies are currently developing and testing solutions for such applications around the world.

Coastal Operations and Applications

Coastal protection infrastructure could be integrated with marine renewable energy generation. The combination of marine renewable energy with coastal protection infrastructure provides electricity from renewable energy and insurance against damage from inundation and sea level rising. At the regional level, Southeast Asia also has numerous coastal operations and applications that require electricity, for example, ship-building and port operations, wood processing, aquaculture and processing.

Green Marine and Maritime Ecosystems

The initiative of the "Green Ship and Green Port" Program by Maritime and Port Authority (MPA) encourages ocean-going ships to reduce carbon dioxide, sulphur oxides emission and emission of pollutions at the port. Renewable power applications for "green ships and ports" can be achieved using an integrated marine renewable energy power generation system to remove the greenhouse gas emission and other pollutant gases.

Figure 5: Overview of marine renewable energy applications

5. The opportunities for Singapore

With the country's energy demand projected to grow at a compound annual growth rate (GAGR) of between 1.3% to 1.9% up to 2028, Singapore will likely need to explore diversifying its energy mix to secure reliable and resilient energy supply. The country being a recognized leader in innovation and research in the region, Singapore has the great opportunity to take the lead in SEA to drive the adoption and development of MRE and related technologies, services and innovation.

5.1. Energy and Water Security Nexus

Electricity is not the only application of MRE technologies. One of the key benefits of MRE is its ability to supply a wide range of essential services e.g. electricity and drinking water In the case of Singapore, this presents a significant opportunity for integrated developments for providing multiple infrastructure needs. In addition, it opens great export potential for island communities and near-shore cities in Southeast Asia.

5.2. Addressing Climate Change

Singapore has pledged to reduce its greenhouse gas (GHG) emission intensity by 36% from 2005 levels by 2030.[10] The power sector, being responsible for 43% of Singapore's GHG has much to contribute to this commitment. With 250 MW of potential capacity for tidal in-stream energy (TISE) and beyond 1 GWp of floating solar within the territory of Singapore, MRE has a great potential to significantly contribute to Singapore carbon emission reduction targets. There are also further potential benefits and savings to be realised from combining MRE systems with each other and/or with energy storage, to maximise system efficiencies, reliability and reduce costs – ultimately contributing to cleaner and greener sources of energy, e.g. hybrid systems of ORE and floating solar PV and integrating ORE with existing generation systems to boost capacity and availability.

5.3. Socio-economic growth

5.3.1.Job creation

With the country's marine and offshore equipment (M&OE) industry accounting for S$3.6billion to Singapore's Gross Domestic Product (GDP) and employing 23,00 workers in 2016[11] despite the effects of the oil price fluctuations, the sector remains an important contributor in the country's economy. The M&OE Industry Transformation Map (ITM) currently takes the offshore wind market into consideration, which is expected to surge past US$130 billion by 2023. Notably, the ITM did not take into consideration the emerging market of MRE, which reportedly presents a global market potential of US$11.3 billion by 2024.[12]

The influx and emergence of the MRE sector will inevitably allow for the growth of the labour market within Singapore. The labour skillset required could be refined from the existing skillset utilised in the offshore and marine engineering industry. With the offshore and marine engineering industry contributing to about 1.3% of Singapore's economy in 2015,[13] it is one of the largest oil trading and refinery centres in the world.

The emerging MRE sector, which lacks existing specialized supply in the region, presents an opportunity for Singapore to position itself in gaining first-mover advantages and secure market shares via its advanced M&OE and maritime industry. Much of the required capabilities already exist in Singapore, and will likely only require relatively minimal re-training or transformation. This market growth would likely also translate to job growth for Singapore.

5.3.2.Economic resilience

Comparative to the conventional energy market which is extremely vulnerable to fluctuations in fuel prices, MRE market is foreseen to be much more resilient. With the almost perpetually available natural resources (with the exception of the variable generation from Floating PV), and relative resistance to direct short-term foreign manipulation, MRE can help to build up Singapore's economic resilience.

MRE power plants, when established, requires long-term operation and maintenance (O&M) supply. Companies contracted to provide such services or established as Original Equipment Manufacturer

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[10] National Climate Change Secretariat of Singapore (2016). Take Action Today for a Carbon Efficient Singapore.

[11] Ministry of Trade & Industry Singapore (2018). Speech by Minister Iswaran at the Launch of the Marine and Offshore Engineering ITM; (https://www.mti.gov.sg/NewsRoom/Pages/Speech-by-Minister-Iswaran-at-the-Launch-of-the-Marine-and-Offshore-Engineering-ITM-.aspx)

[12] Marine Renewable Canada, 2018. 2018 State of The Sector Report.

[13] Straits Times (25th October 2017) Offshore and Marine Sector Remains Key to Economy

(OEM), are also more likely to survive economy downturns, as energy is a constant if not ever-growing demand.

5.3.3. Inward investment

Initial inward investments can be expected as the emerging MRE sector arises within Southeast Asia, supported by technology leaders in the trade, i.e. EU member countries, looking at expanding into commercialization of their technology in the Southeast Asia. Singapore having political and economic stability allows for test bedding of technologies ("living laboratory"), while taking advantage of the reduced CAPEX in mass production of their technology.

5.3.4. Public-private partnerships

As maintaining and further strengthening energy and water security have been a national endeavour, a move towards MRE will allow for public-private partnerships through the conglomeration of Singapore's government bodies and private sectors, supported by international expertise, eventually paving the way for sustained socio-economic growth.

5.4. Export Potential of Marine Renewable Energy to Southeast Asia Region

In line with rising environmental awareness, Southeast Asia (SEA) has set an ambitious target for renewable energy to contribute 36% of its energy needs by year 2030, greater than 3 times the current production. This target opens almost US$300 billion of investment opportunities in the renewable energy industry[14]. Among all renewable energy sources, MRE, is an emerging "disruptor" in the region with initial projects being developed. MRE is well suited for the SEA region, and coupled with strong demand growth for power, it represents an attractive investment opportunity. Figure 6 shows the summary of potential ORE per SEA country.

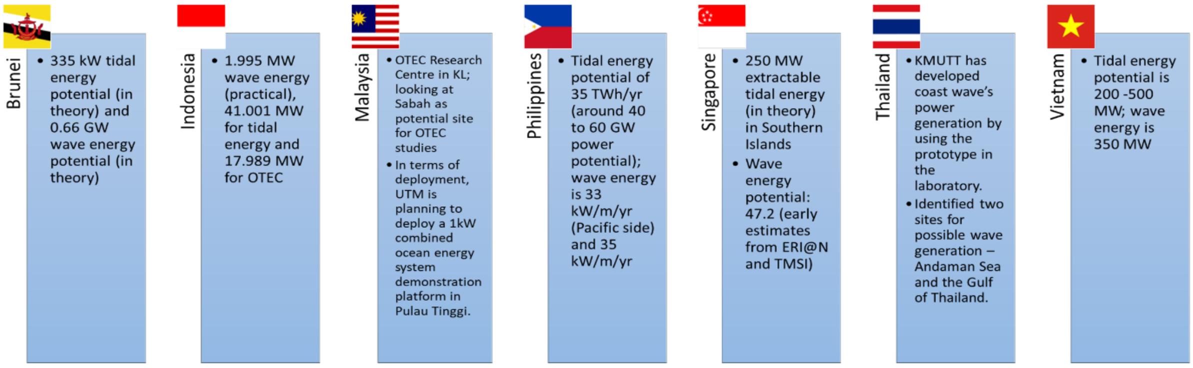

Figure 6: Summary of Current Known Estimates of Ocean Renewable Potential Estimates in Southeast Asia[15]

Aside from the rich fisheries and traditional sources of energy, there are also on-going research works on potential MRE which could be harnessed in the South China Sea (SCS). Theoretical studies have indicated that in the SCS, the wave mean annual energy density can potentially reach up to 65 kW/m.[16] Given the right regional political climate, Singapore could potentially utilise renewable energy

[14] Deloitte Consulting and OceanPixel (2017). Marine Renewable Energy: Unlocking the Hidden Potential, Southeast Asia Market Assessment. Singapore: OceanPixel. Available at: https://app.oceanpixel.org/reports (last accessed: 16 Oct 2018)

[15] OceanPixel Pte Ltd. (2017). Ocean Renewable Energy in Southeast Asia: Overview of Status and Developments. Singapore: OceanPixel.

[16] In fact, offshore wind and wave mean annual energy density can potentially reach up to 1100 W/m2 and 65 kW/m respectively. For more information: Wang, Z, et.al. 2018. Long-term wind and wave energy resource assessment in South China Sea on 30-year hindcast data. *Ocean Engineering.* 58-75.
(available at: https://doi.org/10.1016/j.oceaneng.2018.05.070)

from MRE deployment in the SCS to support her international climate commitments and action plans. Singapore can strengthen its position as the regional knowledge and technological hub in SEA by leading the following activities that can drive MRE not only at the national level but at the regional scale.

5.4.1. Creation of regional supply chain and standards

The development of marine-related support industries contributes to the build-up of a marine renewable energy ecosystem. From ports development, ship-building, to marine services outlined above, the economic benefits from the uptake of the MRE industry will significantly improve the lives of populations in municipalities where MRE projects are executed. Most of the industries along the MRE supply chain based in Singapore have seen it as a possible new market for them to take advantage of and which they could contribute their capabilities and expertise to.[17]

Singapore has started to build on this opportunity by leading the standardisation of TC-114 specifically for MRE technologies in tropical conditions. This is through the establishment of the National Mirror Committee under SPRING Singapore led by ERI@N. Local and regional collaborations have also been spearheaded by different marine and related industries through Sustainable Energy Association of Singapore (SEAS) Working Group. The Southeast Asian Collaboration for Ocean Energy (SEAcORE) is also established here in Singapore which is currently the regional technical working group recognised by the ASEAN Centre for Energy (ACE).

5.4.2. Technology, R&D and innovation

Singapore, being the leading SEA country in research & development (R&D) field, is well-positioned to establish itself as a centre of excellence in developing new technological solutions specifically for the tropics. Singapore MRE technologies have already reached into the European and Asia markets[18]. For the case of solar PV, Singapore operates the largest floating solar testbed in the world, located at Tengeh reservoir. This has put Singapore at the forefront of global research in FPV and also led to Singapore running the only conference series globally that purely focuses on floating solar: The International Floating Solar Symposium (IFSS), which is integral part of the annual Asia Clean Energy Summit (ACES).The ability to conceptualize and execute open sea test bedding opportunities for MRE technologies will allow Singapore to be the green hub and a leader in the region.

5.4.3. Financial and business models

With the possibility of an MRE hub and regional supply chain situated in Singapore, this opens up the opportunity for the creation of new financial and business models that specifically caters for MRE and are unique to the region. This is a short-term opportunity for Singapore as it is known for its stable and efficient financial services and regulatory system that could easily attract investments even in emerging sectors like MRE.

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[17] Quirapas, M. (2016). Ocean Renewable Energy: A Pathway to Secure Energy in Southeast Asia. In S. Narasimalu (Ed.), Ocean Renewable Energy in Southeast Asia: Landscape, Opportunities and Challenges (pp. 66-85). Singapore, Singapore: Research Publishing. Reference for the wave energy potential in Singapore can be found at Ly,et al (2014). Wave energy resource assessment for Southeast Asia. Available at https://www.researchgate.net/publication/282439591_Wave_energy_resource_assessment_for_Southeast_Asia (last accessed 16 Oct 2018)

[18] Cheam, J. (2010). Singapore firm makes waves in tidal energy. *Eco-Business.* Available at: https://www.eco-business.com/news/spore-firm-makes-waves-tidal-energy/ (last accessed 16 Oct 2018) and Marine Energy Biz. (2016). Drakoo wave device generates first power in China. Available at: https://marineenergy.biz/2016/12/29/drakoo-wave-device-generates-first-power-china/ (last accessed: 16 Oct 2018)

5.4.4. Education and skills development

MRE-related education programs for schools and universities can be delivered as inter-disciplinary courses that cater for new innovative technical and engineering knowledge, region specific environmental and social impact assessment methods for MRE energy systems, as well opportunities to experiment on different policy and policy measure designs to encourage the uptake of the sector. Skills development could also be harnessed from current employees with transferable skills, e.g. oil and gas or offshore energy through the establishment of the MRE sector. Testing centres, test sites and demonstrations build awareness, education and skills enhancement through all levels of society.

By establishing cost-effectiveness on the execution of an MRE pilot project, Singapore can strive to assist her neighbours in alleviating basic energy consumption needs in rural or off-grid islands.

5.4.5. Best practices in the utilisation of marine space and environment

Utilizing previously untapped spaces and at times presenting a higher energy density per square meter of footprint as compared to solar and wind, it is this sector's belief that MRE should be seriously considered as part of any marine spatial development plans. By being the pioneer of MRE technologies including FPV in the region and providing test bedding opportunities for our neighbours, Singapore has the opportunity to lead the region into a greener and more sustainable future. This may present a significant improvement in space use efficiency, as some of the technologies allow space utilization in all three dimensions; not just horizontal footprint, but downwards underwater too. It is hoped that a holistic planning process, through well-thought-out studies, can aid the authorities in achieving this.

6. Realising Marine Renewable Energy Opportunities in Singapore and Beyond

Below are some recommended next steps to realise the opportunities of utilising marine renewable energy in Singapore and its possible positive ripple effect towards the region.

- **Strategic Marine Renewable Energy Resource Assessment**

A robust strategic resource assessment, which considers all available MRE resources, will provide the information necessary for Singapore and other countries in the region to better understand the potential capacity that the sector could add to the current and future energy generation portfolio as well as the location of key energy resources in relation to existing and likely future demand.

- **Marine Spatial Planning**

Marine Spatial Planning (MSP) is a process used help inform key decisions around the sustainable use of the marine environment. It can be used to map out priority areas for development whilst considering other existing and planned used of the sea. By applying this coordinated process that brings together all users of the marine environment at an early stage, a robust and inclusive planning process can be established, maximising opportunities and minimising conflict.

- **Pilot Projects and Demonstrations**

Pilot projects play an important role in demonstrating the reliability and efficiency of the whole energy system i.e. generating technology, connection to shore, integration with the power off-taker etc. This in turn helps build confidence in the technology and its bankability, attracting project developers and investors to the sector and the region.

- **Industry Development Roadmap**

An industry development roadmap aims to identify actions that need to be implemented in order to achieve established development goals. A roadmap will provide a single coordinated working document that sets out priority actions which are assigned to key stakeholders, which can be used to inform key decisions, strategies and investments at a regional, national and local level.

- **Survey of Current Human and Resource Capabilities**

Aside from the technical and technological capabilities, knowing "who does what and where?" is crucial in establishing the local supply and value chain of marine renewable energy sector here in Singapore, and possibly at the regional level as well. The possibility of inter-sector and industry learning and knowledge sharing is an opportunity that must be taken advantage by the marine energy sector here in Singapore.

- **Outreach and Awareness Program**

There is a need to drive more awareness and education especially to policy makers and the end-users of what are the benefits and challenges of deploying marine renewable energy. More than the technological expertise, engagement to these groups is crucial in order for such new technology to accept it as a viable alternative energy source. They should be involved in planning and implementation of any projects so that non-technical barriers could be overcome even on the onset of project development.

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Acknowledgements

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SEAS Marine Renewable Energy Working Group

The Sustainable Energy Association of Singapore has setup a “Marine Energy Working Group" (MEWG) in April 2018. The scope of the MEWG includes clean and sustainable energy production and usage, energy efficiency, and energy sustainability in various marine environments – e.g. coastal, offshore, seas, oceans, etc. This can include ocean renewable energy, e.g. tidal range, currents, wave, OTEC, salinity gradient; floating hybrid systems - e.g. floating solar; electrification of vessels and ports, solar boats; sustainable energy for various marine applications – e.g. aquaculture, water production, ice making, etc.; and other marine-environment sustainable energy markets – e.g. offshore platforms, buoys, etc.

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