Ocean Energy in Southeast Asia: A Holistic Approach towards Adoption

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Abstract

This paper examines the opportunities, challenges, and risks of adopting ocean renewable energy (ORE) in Southeast Asia (SEA) beyond its technical aspects. It conducts a critical analysis of the socio-political aspects of ORE development at a regional scale, which has been less studied in the existing literature. Aside from providing a sustainable energy source, the development of the ORE sector could provide socio-economic benefits to SEA countries through employment opportunities, inter-industry learning, inbound investments and improving economic resilience. However, these benefits can only be maximised if the costs of deployment, maintenance and repair are reduced, the impact on the marine environment is taken into consideration, and public acceptance issues are addressed. Beyond a cost-benefit analysis, this study critically assesses the unintended risks and consequences of ORE technologies and activities in the region and recommends different policy strategies to mitigate them. It concludes that for the region to reap the benefits of ORE, a coordinated approach among various stakeholders (technology developers, policymakers, and end-users) is needed to minimise the risks and unintended consequences.

Keywords: ocean renewable energy, Southeast Asia, renewable energy adoption, island communities, energy security

I. Introduction

The Southeast Asia (SEA) region has set a 36 per cent target for the renewable energy share of its regional energy mix by 2030, which will encourage around US$300 billion worth of investment in the renewable energy sector (OceanPixel and Deloitte, 2017). One of the emerging renewable energy sources available in SEA is ocean renewable energy (ORE) (OceanPixel, 2017; Quirapas, Htet, Abundo, Brahim, & Santos, 2015). The region has an abundance of islands with high tidal intensity, making them suitable for ORE development. The SEA region has around 1 terawatt (TW) ORE potential, mostly coming from tidal in-stream. Examples of these are the Sentosa floating tidal turbine (SEAS, 2018) and Universiti Teknologi Malaysia's (UTM's) vertical-axis marine current turbine (Sim, Quirapas, & Abundo, 2018), located in Singapore and Malaysia, respectively. There is also evidence of wave energy potential in SEA (SEAcORE, 2015).

While scholars working on ORE in the SEA region agree that there is potential for it to be fully utilised as a renewable energy source, its development has been slower than other renewables. Some studies point to the technical challenges of turbine deployment unique to the region, e.g., the design of turbines that fit the flow velocity of SEA waters or coating materials to deal with biofouling (SEAcORE, 2015). Only a few studies have looked into the techno-economic aspects of ORE, i.e. the costs and benefits of investing in ORE compared to fossil

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fuels or diesel (Abundo, 2016), while some have produced technical reports, market analysis and position papers to analyse the general trends of ORE in the region (Ocean Energy Systems, 2020). However, the socio-political aspects of ORE development at a regional scale, i.e., in the SEA region, have been less studied in the existing literature.

This paper aims to add to the growing academic literature on ORE in SEA by improving understanding of the opportunities and challenges of ORE development in the region beyond its technical aspects. As scholars argue, energy transitions "are not ordinary shifts in technologies; but they are also strongly glued to the orderings of human societies, economies and polities" (Delina, 2018). With the increasing push to decarbonise using renewables, what are the technical, economic, environmental, and political considerations that might affect the development and utilisation of ORE technologies in SEA? More importantly, what are the risks and intended and unintended consequences? Finally, while there are technical reports and market analyses about ORE in SEA, this paper is one of the few attempts to present the opportunities and challenges, risks, and consequences of ORE development at a regional scale by applying an academic research framework relating to risks and consequences.

This paper makes use of both primary and secondary data analysis. The data are collected from previous and recent studies on ORE by SEA country. The following section explains the theoretical framework used in the study, followed by discussing the opportunities and challenges in adopting ORE technologies in the region. This presents the technical, socio-economic, environmental, and political barriers that need to be considered in developing a regional ORE sector. The Discussion Section provides an in-depth analysis of the implications of ORE using the risks and consequences framework of the study. The final part of the paper concludes with policy recommendations for further developing ORE in the SEA region.

II. Theoretical Framework

The paper discusses the technical, economic, environmental, and political challenges that need to be analysed regarding the implications of developing ORE in SEA. To provide a more in-depth understanding, this paper also discusses the various risks and consequences related to developing ORE in the context of the SEA region. Knowing the barriers, risks, and consequences is essential to evaluate the appropriate policy design to support ORE development in the region. The risks and consequences framework advanced by Justen et al. (Justen et al., 2014) is used to analyse the effects of adopting ORE technology in the region. This framework provides a taxonomy of the effects of ORE adoption from the viewpoint of policymakers. This is helpful as it allows for a more systematic approach to analysing the effects of such policy interventions. It organises the effects into two categories: the intended and unintended consequences, along with their possible implications. The implications are further subdivided into first- and second-order effects to provide a layered analysis of the unintended consequences of policy interventions. The knowledge dimension is categorised into the known and unknown realms. The known realm relates to the realised or anticipated effects of ORE development. On the other hand, the unknown realm refers to effects that might be overlooked or unknown from a policymaker's perspective.

Table 1 – Modified risks and consequences framework of Justen et al. (Justen et al., 2014) **used to analyse the impacts of ORE development in SEA**

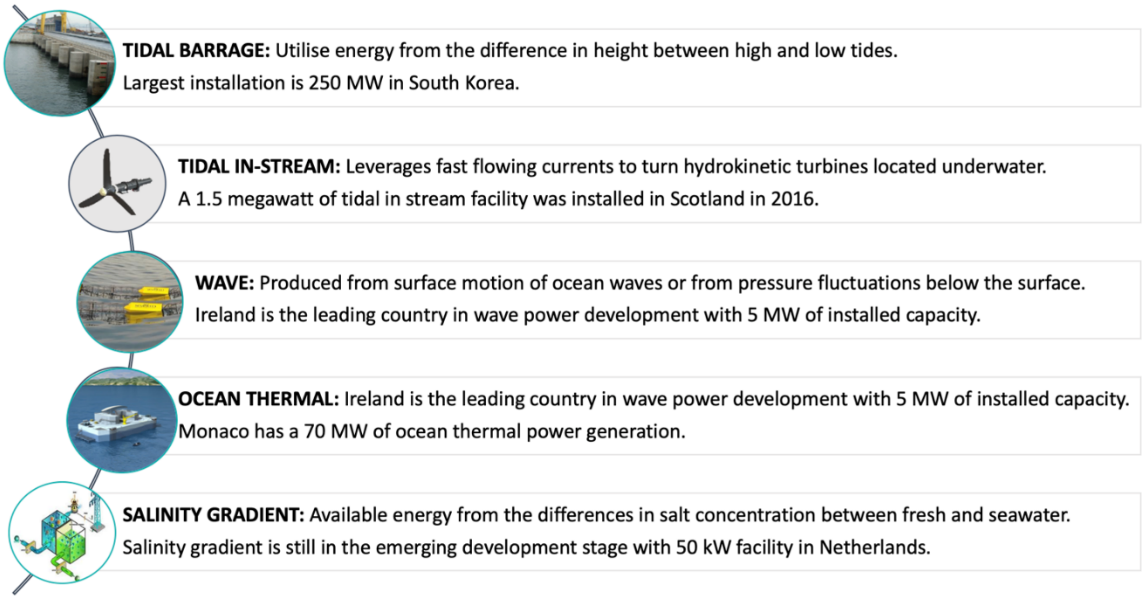
		Consequence dimension		
		Intended consequences	**Unintended consequences**	
Knowledge dimension			Unintended consequences	Implications **(to be categorised into first-order, second-order etc.… implications if need be)**
	Known	The consequences that decision-makers intended to produce through the intervention	Unintended consequences that were anticipated at the time decisions were made	Impact of the unintended consequences that were anticipated at the time decisions was made
	Unknown	Advantageous effects that are not known; serendipitous effects	Unintended consequences that were not known at the time decisions were made	Impact of the unintended consequences that were not anticipated at the time decisions was made

The study is not without limitations. One of the limitations of the framework used is that the relationships of each column, i.e., the relationship of the intended consequences to their unintended consequences and the relationship of first- to second-order effects, might not always be a one-to-one relationship. One intended effect might cause two unintended effects, and the unintended effects might result in several first- and second-order effects. As Justen et al. describe it, "the consequence framework is like building a web consisting of nodes and linkages between those nodes" (Justen et al., 2014, p. 20). One node can be linked to more than one node, but the linkages might be different. Another limitation is that this web-like framework, like other models for policy assessment, is incapable of providing the complete picture of implications regarding both scope and depth. The framework is likely to depict only a particular portion of the complex web of interactions and impacts of ORE development in the region (Justen et al., 2014).

III. Opportunities and Barriers of ORE in SEA

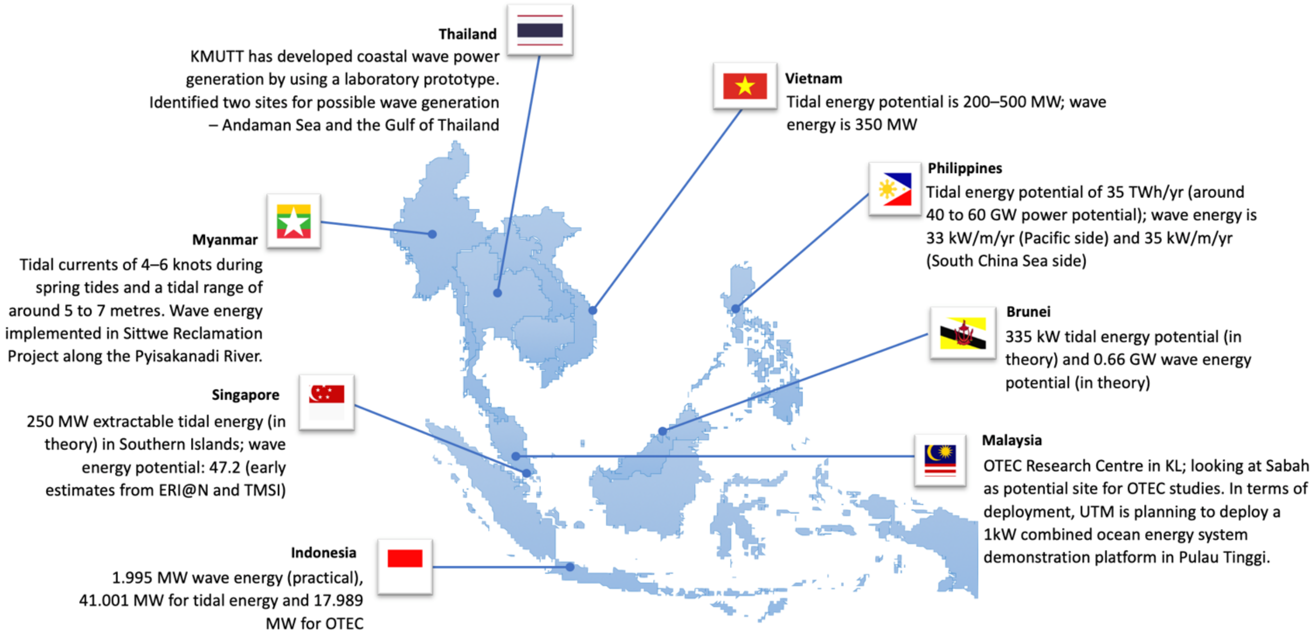
Marine renewable energy (MRE) is a general term that refers to anything in the marine space that is used to generate renewable energy, including offshore wind turbines, floating solar panels and ORE technologies (SEAS, 2018; IEA-ETSAP, 2010). On the other hand, ORE refers specifically to drawing power from the ocean to generate energy, specifically from tidal currents, tidal range, waves, temperature gradients, and salinity gradients (Ocean Energy Systems, 2020). This study focuses on ORE technologies, the potential ORE resources, and the status and activities in this area in SEA. A brief overview of ORE technologies, adapted from an OceanPixel and Deloitte ORE market assessment report, is given below in Figure 1:

Figure 1: Types of ORE and current activities across the globe (OceanPixel and Deloitte, 2017)



The opportunities to deploy and utilise ORE in SEA are driven by technical, environmental, socio-economic, and political factors. When it comes to technical availability, wave, tidal, and ocean thermal energy conversion (OTEC) could all be potentially harnessed in the region (Quirapas & Taeihagh, 2021). The countries for which the most significant number of studies on potential ORE resources have been conducted are Indonesia, Malaysia, the Philippines, Singapore, and Vietnam. For other SEA countries, the activities on ORE mainly relate to studying its theoretical potential and possible sites for resource assessment. The figure below summarises the current known estimates of ocean energy in selected SEA countries.

Figure 2: Summary of current known estimates of ORE potential in SEA (Quirapas & Taeihagh, 2021)



ORE technologies can also be combined with other clean energy systems to help mitigate climate change. An integrated energy system of ORE, e.g., hybrid systems of ORE with small-scale wind turbines, or ORE with solar PV (floating solar PV) or with diesel generators, can provide a more accessible and cleaner energy alternative than depending on diesel fuel alone. ORE generation could also be integrated with coastal protection infrastructure. OceanPixel reports that the combination of MRE with coastal protection infrastructure provides electricity from renewable energy and insurance against inundation and sea-level rises (OceanPixel, 2017).

The development and emergence of an ORE sector in SEA could lead to more job opportunities and employment, especially for related industries like oil and gas, maritime and offshore energy (SEAS, 2018). Knowledge and skills transfer from one sector to another within the region could help build a robust and reliable ORE supply and value chain. Development of the ORE sector could bring in investments and collaborative projects that could cultivate regional capabilities, technical expertise, and knowledge on ORE—multi-stakeholder investment projects (e.g., test-bedding and demonstration sites). Finally, ORE projects that involve proper community-driven approaches could enhance the livelihood of rural communities by providing the energy required to satisfy communities' socio-economic needs.

In terms of policy support, each SEA country applies various policy approaches towards ORE. Most of the SEA countries have supportive policies towards renewable energy development and implementation. Indonesia, Malaysia, and the Philippines have specific policy tools that encourage ORE activities at the national level. For example, ORE is part of the Philippines' national energy plan, while OTEC is also included in the new renewable energy sources under the 11th Malaysian Plan. Indonesia incorporates pilot testing of MRE projects as part of the RE development in the country. For other countries' policies, policy support on MRE is indirect through their national renewable energy plans.

On the other hand, an energy transition to ORE is not without challenges. One difficulty is to make ORE economically competitive concerning fossil fuels in terms of installation, maintenance, and repair. There is a need to have a well-designed and fully integrated ORE system to improve performance and reduce ORE technologies' capital expenditure and operating costs. There can also be social resistance towards ORE projects because of their possible impact on marine life, the environment, and even other users of marine space. Ongoing research work and development projects are studying and assessing the environmental effects of ORE turbines before and after deployment. Aside from the technical and social, and economic barriers, political hurdles like burdensome bureaucratic procedures for deployment and corruption will also impact ORE development in the region.

The table below summarises the opportunities and challenges of ORE development in Southeast Asia:

Table 2: Summary of opportunities and challenges of ORE development in SEA
(Quirapas and Taeihagh, 2021)

Dimension	Opportunities	Challenges
Technical /technological	Incorporating inter-industry knowledge and learning from more mature sectors, such as oil and gas and offshore wind, in the ORE sector.	Successful installation of ORE infrastructure requires good weather and sea conditions and technical expertise and knowledge to install and address possible installation problems.
	Creating innovative ORE solutions applicable to the local and regional conditions, e.g., ORE as an off-grid solution for small tropical islands such as the Philippines and Indonesia.	The upfront cost of installing, maintaining, and repairing ORE technologies remains expensive and is not yet competitive compared to fossil fuel at a larger scale.
Socio-economic	Creation of an ORE sector could lead to job creation and security, regional supply chains that could reduce ORE cost and uplift rural communities' livelihoods.	Policy decision-makers and community end-users need to be aware of and onboard on ORE projects to lessen the social resistance to the projects.
Environmental	As a source of cleaner and renewable energy, ORE can help mitigate the impact of climate change.	Addressing the impact on the marine life and environment, and other users of the marine space.
Political	Supportive ORE policies could address the issue of energy access of rural islands, provide an alternative energy source to address increasing energy demand, and reduce dependence on fossil fuels.	There are demographic and geographic conditions that need to be considered—political hurdles like burdensome bureaucratic procedures for deployment, corruption, or social acceptance issues.

IV. Discussion

Aside from the cost and benefit analysis, it is also essential to know the risks and unintended consequences of ORE deployment in the region (Quirapas and Taeihagh, 2021). Using the theoretical framework presented in Table 1, this study demonstrates the findings below in two categories: the known and unknown dimensions. The consequences dimension shows the intended and unintended consequences and their first- and second-order implications.

A. Known intended and unintended consequences of ORE development in SEA and their implications

1. An alternative source of renewable and dependable energy

Like other renewable energy sources, the development of ORE can provide an alternative source of energy. ORE comes from the movements and patterns of easily accessible natural sources like wind and bodies of water, e.g., the ocean and tidal energy. It comes from the gravitational forces of the sun, moon, and Earth. This makes ORE a clean, predictable, and dependable energy source (OceanPixel Pte Ltd, 2017). However, the unintended consequences of ORE are its impacts on marine life and the environment. Turbines are usually deployed underwater and might disrupt marine life, e.g., fisheries and coral reefs. Migration patterns of aquatic animals could be affected when ORE installations are located near the shore. It can also cause unnatural silt build-ups, which could impede the flow of sediments, affecting the marine ecosystem (OceanPixel Pte Ltd, 2017; UNESCAP, 2012). There is a need to develop more hardware and software tools that can assist in data collection and analysis of ORE technologies' environmental impacts in actual sea conditions. This can be complemented by more technical training workshops specifically on ORE to increase the knowledge and skills of renewable energy stakeholders (OES, 2020).

2. Addressing climate change

Aside from energy security, the development of renewable energy like ORE can mitigate the effects of climate change (Hammons, 2009; Zullah, Jae-Ung, & Lee, 2016). ORE technologies can be combined with other MRE technologies, like floating solar PV, and also with energy storage "to maximise energy efficiencies, reliability and cost reduction" (SEAS, 2018, p. 9). On the other hand, the risks of utilising ORE technologies relate to its compatibility with the local conditions of the region. This includes its technological components, such as tidal turbines and the skills needed to deploy, operate, and maintain them. Most of the turbines at the demonstration scale in SEA are manufactured outside the region, e.g., in the UK or Germany. This might be cheaper for testing purposes; however, there is a need to develop the local capabilities and capacity of the ORE sector to suit the SEA conditions and further reduce the costs of installation and maintenance in the long term.

3. Production of utility-scale and off-grid-scale electricity

ORE could be used as a source of electricity at the large utility-scale and at off-grid or distribution scale, depending on the availability of the resource. In islands and off-grid areas, where diesel generators are the primary energy source, ORE can be integrated with other renewable energy solutions to make it a more competitive option than diesel fuel (Abundo, 2016). However, an underlying risk of ORE development, especially in off-grid and remote areas, relates to people's acceptance of the relatively new technology (Quirapas & Srikanth, 2017). As mentioned in the section above, the acceptance of end-users is a crucial aspect of the full adoption of ORE. While electricity is essential, ORE project developers need to consider how the technology can enable communities' livelihood and economic needs (OceanPixel, 2017).

4. Other applications of ORE

Many ORE systems are installed offshore. As such, these systems could be used to provide energy to offshore installations, e.g., oil platforms, navigational systems, weather and climate monitoring stations, fish farms, and other aquaculture developments (OceanPixel, 2017; SEAS, 2018). These applications require a certain level of expertise regarding integrating offshore and coastal infrastructure with ORE technologies. A potential risk is that the physical damage to infrastructure might worsen when the installations and operations of an integrated system are not executed well. As ORE installation is already costly on its own, the financial damage could be more expensive when an integrated system fails. There is a need to ensure that this infrastructure is secured and located away from physical threats (especially for coastal areas, where natural disasters, piracy and terrorist attacks could be possible).

B. Unknown intended and unintended consequences of ORE development in SEA and its implications

1. Usage of ocean space

Although ocean space is vast, ORE developers do not only need to compete for a resource; they must also compete for space. As more turbines are put into the water, rights and ownership must be determined. Resource management within a regulatory framework must be in place. It is also necessary to have marine space governance that ensures environmental impact assessments and marine spatial planning of ORE technologies (Wright, 2016). In most SEA countries, establishing marine governance and regulatory framework that includes ORE technologies at the commercial level has yet to occur. (Quirapas, Abundo, Htet Lin, Brahim, & Santos, 2015).

2. Contribution to socio-economic growth and development

As the ORE sector matures in the region, it will create opportunities for job creation, inward investments, and private-public partnerships (SEAS, 2018). Current expertise and the labour skillset required in the offshore and marine engineering industry could be applied and transferred to an emerging ORE sector. This presents job opportunities for locals who already have the needed capabilities and only require minimal re-training and orientation. As some industry experts argue, "this market growth would likely also translate to job growth…" (SEAS, 2018, p. 9). As the ORE sector emerges in SEA, initial inward investments are also expected to rise due to the support of ORE technology leaders in the trade, e.g., EU member countries, the US and Canada. Over the past few years, a few companies from Canada, France, the UK, Germany, and the Netherlands have been expanding into the commercialisation of their ORE technologies in SEA (SEAS, 2018; Cameron, Leybourne, Abundo, & Quirapas, 2018). Collaboration through joint RD&D work among the academic, private, and public sectors should be further encouraged to build demonstration ORE projects. Del Rio and Burguillo argue that the socio-economic benefits from RETs also depend on the relationships among the different stakeholders and the involvement of the local community (del Rio & Burguillo, 2009).

3. Creation of a regional supply chain, industry standards and business financial models

As ORE develops in the region, an unknown intended consequence would be developing and creating a regional and local supply chain, standards and best practices, and various business financial models that cater specifically to the ORE sector. The existing marine-related and offshore sector (even the oil and gas sector) could help build up an ORE ecosystem through knowledge and technology transfer. In interviews with actors in marine-related industries, the respondents mentioned that the ORE sector is a potential new market and avenue they could take advantage of and contribute to their capabilities and expertise (Quirapas, 2016). Along with developing a regional and local supply chain, creating standards and various business models specifically catering to SEA ORE conditions could also occur.

On the other hand, the development of the ORE sector in the SEA assumes a ready and stable infrastructure, policy and regulatory framework, and even appropriate social conditions. As mentioned in the previous sections, there is a need to consider the different technological, economic, environmental, and political conditions needed to create the ORE sector in the region. Some SEA countries still face "infrastructure, grid-related problems and regulatory and administrative hurdles" (Olz & Beerepoot, 2010, p. 11) that would need to be overcome to create a new sector like ORE.

4. Development of technology, RD&D and innovation suitable to SEA conditions

Apart from the sector itself, the emergence of an ORE sector in the region could lead to developing new and innovative ORE technologies and solutions suitable to SEA. The existing

ORE turbines and systems need to be "localised" to fit (and last in) the tropical conditions of the ocean and seawater in the region. Experts encourage a modular, smaller scale that could be integrated with the existing energy system for insular areas – as has been suggested. This could address the lack of energy sources in off-grid remote coastal communities (Abundo, Singapore Tidal Energy Demonstration Project, 2016; Quirapas & Srikanth, 2017; Yaakob, 2017). However, energy transitions are not only technological. They are also political and social. The transition to ORE technologies also means creating a political environment that enables and encourages innovative thinking and solutions. The government could also provide more in-depth knowledge and skills development training to policymakers to furnish them with expertise on ORE technologies, deployment, and business model strategies to encourage investments. In addition, social acceptance is also an essential factor in transitioning to clean technologies like ORE. These technologies transform the use of technology and how people live and cope with change (Delina, 2018). Fishing communities are most likely to be the end-users of ORE, especially in off-grid island communities. As such, their knowledge about the benefits, risks, and consequences of ORE technologies is crucial to long-term adoption.

Table 3 Summary of risks and consequences of ORE development in the SEA region

	Consequences dimension				
	Intended consequences	**Unintended consequences**			**SEA country where applicable**
		Unintended consequences	**First-order implications**	**Second-order implications**	
Known	ORE as an alternative source of renewable and dependable energy	Impact on marine life and environment	Migration patterns of aquatic life may be disturbed; silt build-ups could impede the flow of sediment, affecting the marine ecosystem	A need for developing framework, tools, and software to understand the actual environmental impacts of ORE technologies and how to mitigate them	Indonesia, Malaysia, Philippines
	ORE development to address climate change	A risk in utilising ORE technologies is its compatibility with the local conditions of the region	Import of technology and expertise from outside the region might be costly in the long-term	Development of local capabilities and capacity to make the ORE sector more sustainable in the region	Indonesia, Malaysia, Philippines, Singapore
	Production of utility-scale and off-grid-scale electricity	There might be resistance from communities who are not familiar with ORE technologies	Local communities and businesses (e.g., diesel generator owners) should be aware of and knowledgeable about how ORE	Local communities' acceptance of the relatively new technology and the possibility of creating an integrated energy system, e.g., diesel	

			works, and as such, should be assured that it would not impact them detrimentally	with ORE and solar PV	
	Other applications of ORE to offshore installations and coastal infrastructure	Physical damage to infrastructure might be worse when installations and operations of an integrated system are not executed well	Financial damage could be more expensive when an integrated system fails	Ensuring that this infrastructure is secured and located away from the physical threat	
Unknown	Usage of ocean space	ORE developers need to compete not only for a resource but also for space	Possible conflict with other ocean users; lack of a regulatory framework	Establishment of marine governance and regulatory framework that includes ORE technologies at the commercial level	Indonesia, Malaysia, Philippines, Singapore
	Contribution to socio-economic growth and development	ORE sector creates opportunities for job creation, inward investments, and private-public partnerships	Inter-sector and inter-regional learning through collaboration	More demonstration ORE projects and scaling up of the devices	
	Creation of regional supply chain, industry standards and business financial models	ORE development in the region assumes ready and stable infrastructure, a policy and regulatory framework, and even social conditions	SEA countries still face infrastructure and grid-related problems and regulatory and administrative hurdles	Unsuccessful implementation of ORE projects when such non-economic and political barriers are not addressed	

	Development of technology, RD&D and innovation suitable to SEA conditions	Existing ORE turbines and systems need to be "localised" to fit (and last in) the tropical conditions of the ocean and seawater in the region	Need for local participation from communities and end-users	Unsuccessful local participation could lead to short-term ORE adoption only	Indonesia, Malaysia, Myanmar, Philippines, Singapore, Thailand, Vietnam

V. Conclusion

As indicated in the discussion above, there is agreement among experts and scholars that potential energy can technically be harnessed from the oceans of SEA. When utilised, this potential can help address the push for the region to achieve sustainable development through renewables and possibly act as an alternative energy source in insular areas of the region. However, utilising this potential is a question of the availability of the resources and requires a combination of suitable technical, economic, environmental, and political conditions in the SEA region. The unintended risks and consequences are essential when developing a supportive policy framework to establish the ORE sector in the region.

The utilisation of ORE potential is highly related to a decrease in the cost of initial installation and deployment of ORE technologies in the water. This is further dependent on the local and regional stakeholders' level of knowledge and expertise, as mentioned in the sections above. To build technological expertise, human and resource capability should also be developed. "Knowing who does what and where" is vital in the creation of inter-sector learning, sharing of knowledge and technical know-how, e.g., collaboration among academics, government agencies, marine and offshore-related industries, and potential investors and project developers (SEAS, 2018). This could pave the way for creating a local supply chain that could eventually bring down the cost of installation, operation and maintenance, and repairs.

There is a need to have more pre-commercial- and commercial-scale projects in SEA. According to OES, the current costs of ORE technologies are estimated based on laboratory and prototype scales and not commercial-scale deployment. Naturally, these projections are higher than the costs incurred in actual ORE projects. This is important because the cost of ORE technologies goes down significantly after a specific volume of production has been achieved (Smart & Noonan, 2018). The Offshore Renewable Energy Catapult Report in the UK also mentions that there has been a significant cost reduction in ORE development and deployment due to the progress of the sector towards more commercial-scale deployment. The report refers to an "increase in the economies of volume, i.e., production and deployment of multiple tidal energy devices, time and cost savings through 'learning by doing, process optimisation, engineering validation and improved commercial terms" (Smart & Noonan, 2018, p. 7). In addition, cost estimations from commercial projects are also more helpful for continuous progress in ORE RD&D and policy formulation to support future deployments.

One significant risk of ORE technologies is the expensive ORE power plant's initial construction and production costs. This could be addressed by investing and deploying more hybrid energy systems, e.g., solar plus tidal turbine systems, even at a small scale (Abundo, 2016). This could be a viable cheaper alternative to the traditional diesel generators often used by off-grid and island communities. According to experts, the expensive upfront cost of ORE deployment could be balanced out by its total lifespan and the decreased cost for maintenance and repair compared to fossil fuel power plants. For example, a tidal power plant's life span is estimated to be 100 years for the barrage structure and 40 years for the equipment (OceanPixel, 2017), while a coal power plant only lasts from 30 to 50 years (US Energy Information Administration, 2011)

Once the technological and human resource expertise is built, ORE resource assessment can be done more effectively and accurately. Aside from saving cost, time and effort, effective resource assessment is a key to obtaining more accurate information about the type of ORE available, the kind of technology to use in harnessing it, and the potential energy capacity it can produce. From a public policy perspective, this could encourage policymakers to look into this sector and provide support mechanisms. For example, the Philippine Department of Energy has approved the commencement of predevelopment of utility-scale tidal energy in the San Bernardino region of the Philippines. This collaboration is with Oceantera, a regional ORE project developer, showcasing successful deployments of two ORE projects in Singapore and Indonesia (Oceantera, 2018). Similar partnerships have also happened in Malaysia, Singapore, and Indonesia (SEACORE, 2015), where an initial successful ORE deployment had a domino effect on creating more ORE projects in the sea. Pilot projects are essential to test the suitability of devices in the water, the bankability of projects, and local technology developers and suppliers (SEAS, 2018).

To maintain a sustainable ORE sector in the region, marine governance should also be a priority. As discussed above, many potential issues can arise due to marine and ocean space management and the possible impact of ORE technologies on marine life, the environment, and current users and stakeholders. Marine spatial planning (MSP) and environmental impact assessment (EIA) tools are available to help policymakers utilise ORE technologies without harming the marine ecosystem. An industry report explains that MSP "is used to map out priority areas for development while considering other existing and planned used of the sea" (SEAS, 2018, p. 13). MSP and EIAs also bring together different stakeholders in inclusive planning, minimising conflict. The creation of multi-stakeholder roadmaps, e.g., technology and industry roadmaps, will also be helpful in the identification of goals and actions to drive more coordinated ORE activities in the region.

Finally, efforts to develop ORE technologies and an ORE sector entail the buy-in not only of the technology and project developers, policymakers, and investors, but, more importantly, the local communities who will be the ultimate adopters of such technology. Acceptance is a critical element of any energy transition (Vivoda, 2012), and as such, their involvement in the planning, deployment and implementation of any ORE projects can help ensure its long-term adoption at the community level.

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