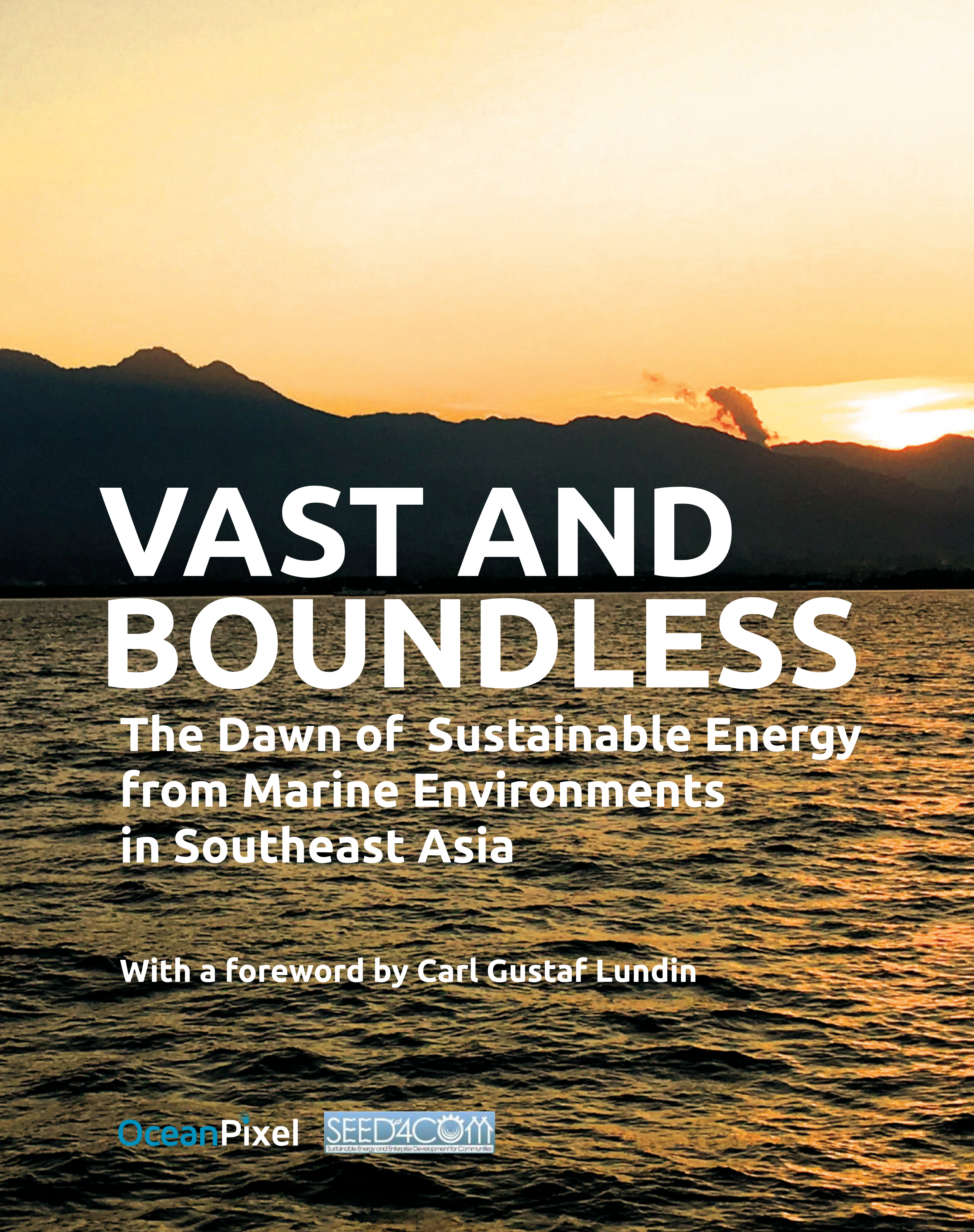

VAST AND BOUNDLESS

The Dawn of Sustainable Energy from Marine Environments in Southeast Asia

With a foreword by Carl Gustaf Lundin

OceanPixel

SEED4COM
Sustainable Energy and Enterprise Development for Communities

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In memoriam

Isabelita Vasquez Abundo

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Foreword

The Promising Dawn of Sustainable Renewable Energy from Marine Environments of Southeast Asia

Among the many and profound changes that are happening on our ocean planet, various efforts have been initiated, supported and consistently improved to enable impactful contribution towards sustainable and equitable use of resources. The International Union for the Conservation of Nature (IUCN) is working to ensure that coastal, marine and polar ecosystems are restored and maintained to the benefit of our and future generations. For me it is refreshing to hear about other endeavours that complement and, potentially, augment global conservation and sustainability and relive pressures on natural ecosystems. With the ever-increasing pressures on the coastal environments due to climate change, we must act fast to find solutions.

The development of sustainable energy production in the marine environments is of significant interest to many stakeholders that are involved with the seas and oceans (covering 71% of the world). We are all dependent on finding new renewable energy sources that can meet our growing needs without destroying our fragile life on this planet. The suitability of marine-inclusive hybridised energy solutions is clearer to me. We need to get our act together and encourage collaboration specifically to promote a holistic and integrated approach for the development of power/energy projects with appropriate technologies. Different types of energy generation will be appropriate in different types of situations, and working with ocean managers to identify needs and opportunities will be important. In our report 'Greening blue energy: identifying and managing the biodiversity risks and opportunities of offshore renewable energy', we addressed the environmental issues facing different types of renewable energy.

This coffee-table book attempts to provide an overview of marine renewable energy and its applicability particularly in the Southeast Asian region and, hopefully, in a more global context. We hope that this compilation helps to address some gaps and challenges to adopting sustainable energy solutions in and for marine environments.

It is with both excitement and humility that we embark on the first steps of harnessing the power of the seas and oceans from which we hope to capture energy and use it in various applications. These endeavours are of utmost relevance to tropical regions such as Southeast Asia and in growth sectors like the following: electricity generation, aquaculture, transportation, clean water production and ice-making, to name a few.

I believe that these innovative approaches can enable sustainability, particularly if they are co-developed with local communities to solve their energy needs. Renewable ocean energy can be even more beneficial if well aligned towards local, national and regional priorities and capacities. I strongly encourage that we not only observe the dawn of marine renewable energy but also actively participate in making it a reality.

Carl Gustaf Lundin

Carl Gustaf Lundin
Director, Global Marine and Polar Programme
International Union for the Conservation of Nature (IUCN)

Preface

A little more than a decade ago, I was exposed to marine science projects that needed engineering solutions for applications like data acquisition, instrumentation, sensors, telemetry, remote monitoring and a range of data collection requirements. Part of the challenge to reach such solutions dealt with the realm of energy – it was just expensive to keep on replacing batteries throughout the data collection period/s. This led to looking at local power generation from resources that were available in the marine environment. Although such technologies were being explored in countries like the UK, USA, Canada, Australia and other parts of Europe, North America and Asia, it seemed not to have reached the Southeast Asian region. Further investigation revealed that there were various groups igniting sparks of interest for progressing the development of the technology and also of potential deployments and installations – even if small-scale – to demonstrate that such marine renewable energy systems can work in the Southeast Asian context (i.e. with the nuances of SEA's local resources, socio-political-economic climate, supply chain and available capability/know-how).

In a similar manner to how on-shore solar and wind energy industries began in not-so-commercially-viable conditions and took a period to reach maturity, the marine renewable energy industry also is treading the development curve (but at a much more significant cadence as compared to its predecessors). A lot of learning has translated to an accelerated development of sustainable energy from marine environments. We are in the advent of the birth of a potential sector that could lead to commercial and industrial growth for nations and regions.

The *ethos* by which we intend to approach the uptake of sustainable energy from marine environments in Southeast Asia is that of *inclusive progressive development* with appropriate interventions (be it in terms of technologies or the wider spectrum of factors that various stakeholders hold relevant). We recognise that for an endeavour to truly be sustainable, there must be significant local content – which is enabled by ensuring local capability development, know-how and knowledge transfer.

It is in the spirit of Beyond's song 'Boundless Sea and Sky' or 'Boundless Oceans, Vast Skies' that this book was undertaken, which reflects the determination and fortitude of the various groups in the world tirelessly working towards global sustainability in their own little way. Even though spatial and temporal boundaries exist for the physical realities such as the oceans, the vastness and boundlessness of the human spirit are what inspire the title of this book. For it is in the active efforts of humans working with nature that we are able to achieve a truly sustainable ecosystem.

I hope that as you immerse yourself in this collation of testimonies and collection of efforts, either the unlit wick in your being may catch a tiny flame or your hidden embers may once again be *enkindled* as you join us in blazing a trail for the future of our society towards a truly sustainable world.

We need all the help we can get. If you are willing to offer your own talents and contribution, be they be in a political, economic, social, technological, environmental, creative, financial, commercial, geographic or any other capacity, there is room for you in building the sustainable future we all long for.

It is with great honour and gratitude that I personally encourage and challenge you – and all other readers of this book – to not just be passive about the contents of the pages you experience, but really care enough to retain the message and actively advocate the available options for sustainable marine energy to your own network. Each of us becoming *a beacon of light for the sea* around us.

Dr Michael Lochinvar Sim Abundo
Managing Director, OceanPixel Pte Ltd

Introduction:
The Blue Solution

We Are Running Low on Power

Human Activity – And the Way We Power It – Takes a Toll on the Environment

The Blue Solution

WE ARE RUNNING LOW ON POWER

Human life, as well as human activity, requires resources. From the most basic needs of food production, preparation and preservation, as well as lighting and heating or cooling in the home, to the equipment used in the offices, factories and other places of work, there is one resource behind it all: power. In particular, electricity.

Depending on where we live – which continent, which country, which state or city – we see electricity differently. For some, it's a fact of everyday life humming in the background, constant and reliable, affordable, taken for granted. For some, it is readily available but a potential financial burden if one is not mindful of usage. For others still, supply is erratic, unreliable.

And that only covers those of us on the electric grid.

In many remote, off-grid areas, people rely on traditional sources of energy like diesel generators. This makes power relatively more expensive and subject to availability of fuel. And then there are those who have no power at all – who rely heavily on daylight to get things done and, after the sun has set, sit by the light of a candle or a fire, or in darkness; who must burn wood, charcoal or waste in order to cook and who preserve their food by means other than refrigeration; who bear uncomfortable, even extreme, weather conditions without the convenience of electric cooling or heating.

Worldwide, there are over a billion people with no access to electricity. About 95% are from sub-Saharan Africa and developing countries in Asia, and the rest from Latin America and the Middle East. More than 80% of those affected are from rural areas.[1]

Let's zoom in to Southeast Asia (SEA). Here, many areas experience expensive or unreliable electricity, while about 15% of the population – some 99 million people – remain without access at all. It is clear that the region needs more electricity.

In addition to this, the continued growth of the economy and the population in SEA has caused energy demand to rise as well. Taking all these into account, the region's energy needs are projected to double by 2025.

Meanwhile, the resources currently being used to produce electricity are running out. About three-fourths of the current supply of electricity in the region comes from the burning of coal, natural gas and oil,[2] all of which are expected to run out within decades – for instance, coal within 33 years and natural gas within 27 years in the Philippines, and oil in only 9 years in Indonesia.

Without another way to produce electricity, SEA could be in total darkness within our lifetime.

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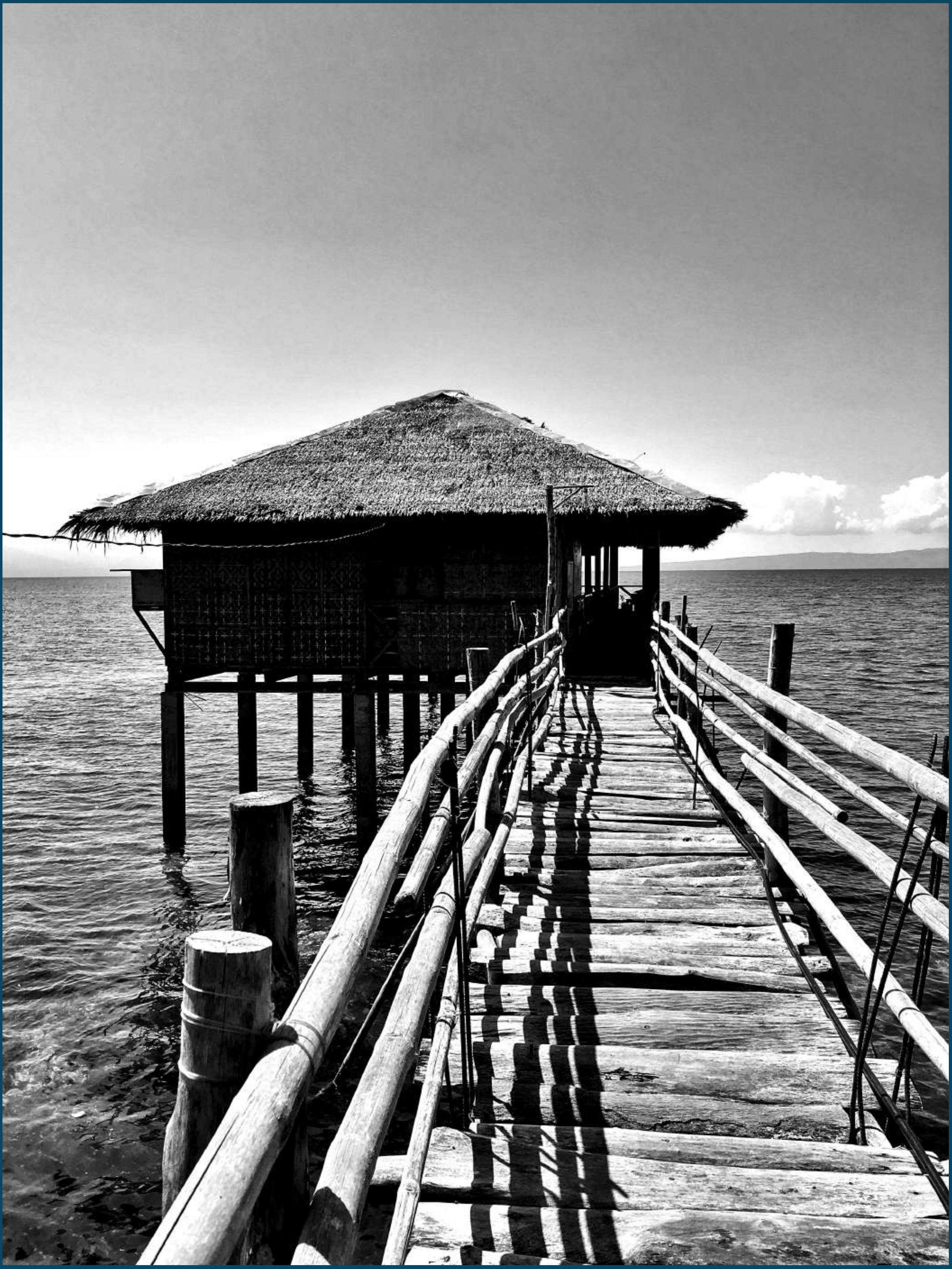
[1] *International Energy Agency, https://www.iea.org/energyaccess/database/, accessed 08 August 2018.*

[2] *International Energy Agency, Southeast Asia Energy Outlook 2017, available at https://www.iea.org/publications/freepublications/publication/WEO2017SpecialReport_SoutheastAsiaEnergyOutlook.pdf.*



HUMAN ACTIVITY – AND THE WAY WE POWER IT – TAKES A TOLL ON THE ENVIRONMENT

When we think about environmentalism, what often comes to mind is garbage, recycling, pollution, mining – all to do with material consumption. Perhaps the fuel we use for transportation will cross our minds. Rarely do we think about electricity having a negative effect on the environment.

But like all things involved in human activity, electricity does leave a footprint.

As mentioned, coal, oil and natural gas provide most of the electricity supply in SEA. Globally, the percentage is lower but still significant at about two-thirds; renewable energy sources such as hydropower make up about 20%, with the rest coming from nuclear sources and biomass.[3] Coal, oil and gas are fossil fuels.

There is some general awareness that the burning of fossil fuels is bad for the environment. Many of us have heard the words being thrown around – global warming, climate change, clean energy, renewables and so forth – but for most people, it is a vague notion. What exactly does all this mean?

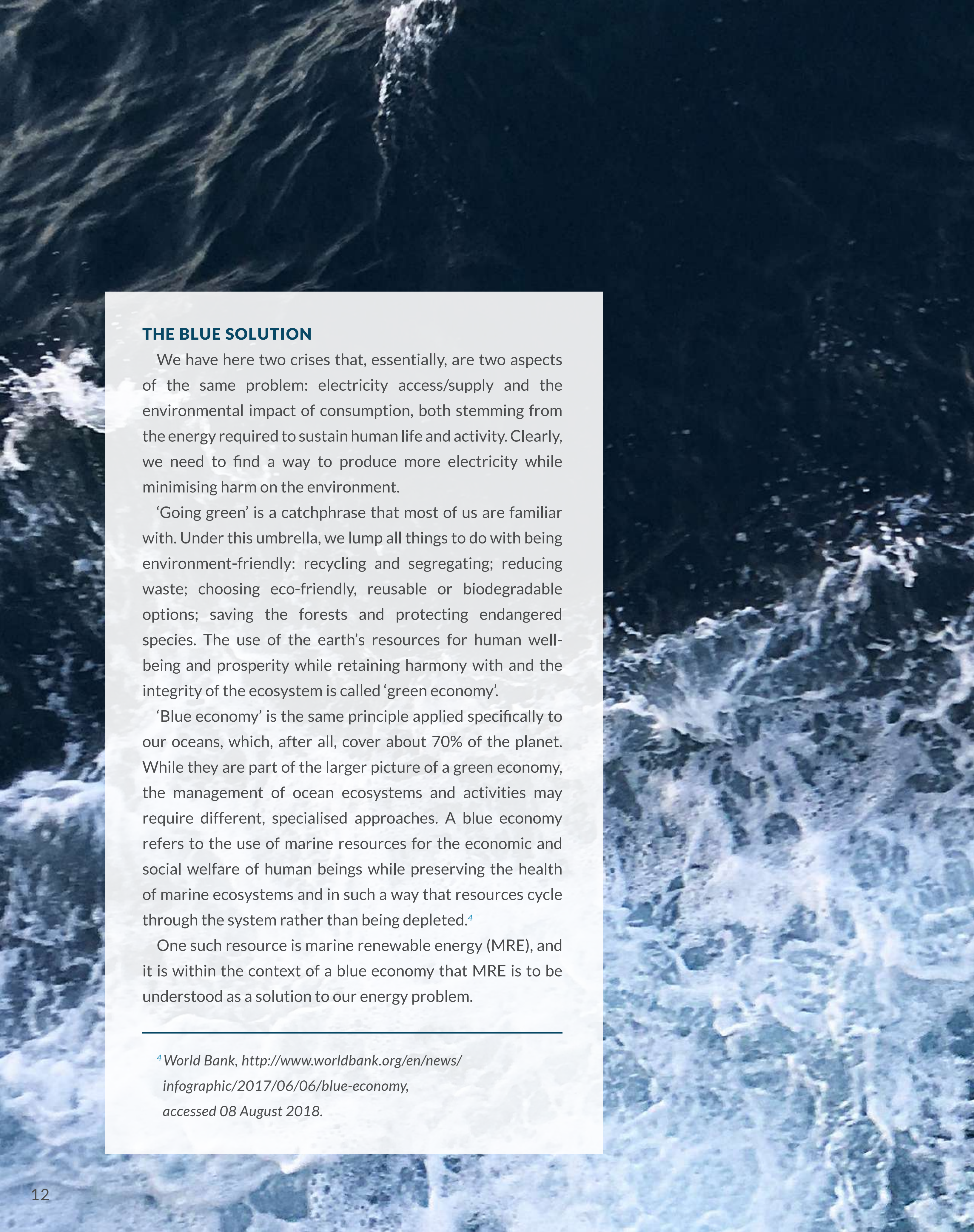
The burning of fossil fuels emits carbon dioxide, a greenhouse gas. While carbon dioxide is a natural

[3] *The Shift Project Data Portal, http://www.tsp-data-portal.org/Breakdown-of-Electricity-Generation-by-Energy-Source#tspQvChart, accessed 08 August 2018.*

component of air and is important to the survival of all species, the burning of fossil fuels causes an overabundance, which has far-reaching negative consequences for the environment. First, it raises the earth's temperature, causing ice caps to melt and sea levels to rise, which thus leads to flooding and the loss of land as it becomes submerged. Second, excess carbon dioxide combines with moisture in the air to produce acid rain, which damages plants and pollutes water and soil. Finally, it lowers the proportion of oxygen in the air, which makes it more difficult to breathe and also means that we take in less oxygen, which could lead to serious health conditions.

Global warming and pollution of the air, water and soil might not alarm us as much as the possibility of life without electricity. It might not be as easy to imagine its impact on our day-to-day existence and subsistence, our needs and convenience, our concrete, present situation. While there is some awareness and action on these environmental concerns, it is slow going, and only a small subset of people are involved.

It is nonetheless an urgent issue, and if not addressed, it can have devastating effects on the health of the earth and on human life.



THE BLUE SOLUTION

We have here two crises that, essentially, are two aspects of the same problem: electricity access/supply and the environmental impact of consumption, both stemming from the energy required to sustain human life and activity. Clearly, we need to find a way to produce more electricity while minimising harm on the environment.

'Going green' is a catchphrase that most of us are familiar with. Under this umbrella, we lump all things to do with being environment-friendly: recycling and segregating; reducing waste; choosing eco-friendly, reusable or biodegradable options; saving the forests and protecting endangered species. The use of the earth's resources for human well-being and prosperity while retaining harmony with and the integrity of the ecosystem is called 'green economy'.

'Blue economy' is the same principle applied specifically to our oceans, which, after all, cover about 70% of the planet. While they are part of the larger picture of a green economy, the management of ocean ecosystems and activities may require different, specialised approaches. A blue economy refers to the use of marine resources for the economic and social welfare of human beings while preserving the health of marine ecosystems and in such a way that resources cycle through the system rather than being depleted.[4]

One such resource is marine renewable energy (MRE), and it is within the context of a blue economy that MRE is to be understood as a solution to our energy problem.

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[4] *World Bank, http://www.worldbank.org/en/news/infographic/2017/06/06/blue-economy, accessed 08 August 2018.*

Marine Renewable Energy:

Vast and Boundless

WHAT IS MARINE RENEWABLE ENERGY?

Our oceans sustain us in more ways than we realise. They provide us with food and a mode of transport, but they are also an abundant source of massive amounts of untapped, clean, renewable energy.

The concept of renewable energy is familiar to most. Ask someone about it, and they likely will nod and mention solar, wind, hydropower, geothermal. But bring up marine renewable energy, and most people will draw a blank. This is not a surprise, because compared to other sources of renewable energy, it is at an earlier stage of commercial development. However, it has been shown to be feasible and reliable, and it is now at a stage where it is ready to be adopted.

Marine renewable energy (MRE) refers to any renewable energy that has to do with the marine environment (e.g. seas, oceans, coasts etc.), whether it uses marine space or marine resources. For instance, floating solar panels and offshore wind turbines, which make use of energy from the sun and the wind, respectively, are considered MRE – while they don't draw their power from the ocean, they are located in it and thus are part of the marine space.

Ocean renewable energy (ORE) is a form of MRE that pertains specifically to energy drawn from the power potentials of the ocean. There are five resources related to ocean waters that can be tapped for energy: currents, tides, waves, temperature gradients and salinity gradients.

CURRENTS

Currents can result from the changing of the tides (tidal current) or from forces on and underneath the surface of the water (ocean current).

Tides are the rise and fall of ocean waters resulting from the gravitational pull of the moon, and to a lesser degree, the sun, on the earth. The rising and falling of the tide causes movement in the water, creating tidal currents. Energy from these currents can be extracted with the use of what are called tidal in-stream devices, which are positioned in areas where water flows quickly. The movement of the water turns the blades of a turbine, which is connected by a shaft to a generator. The generator then converts that energy into electricity. Turbines can be positioned on either a horizontal or a vertical axis, with the latter allowing for large turbine size even in shallow waters.

Tidal in-stream devices are the most developed and widely available ORE technology in Southeast Asia. Examples include the Sentosa floating tidal turbine in Singapore and Universiti Teknologi Malaysia's vertical-axis marine current turbine.

Fig.1: Floating solar facility in Singapore.

Fig.2: Tidal in-stream and wave energy resource assessment project at Tanah Merah Ferry Terminal (2014–2015) by the Wind and Marine Renewables Team at the Energy Research Institute at Nanyang Technological University (ERI@N).

Fig.3: Offshore wind farm in Bac Lieu, Vietnam.

Fig.4: Vertical-axis turbine case study at Institut Teknologi Sepuluh Nopember (ITS), Indonesia.


Fig.1


Fig.2


Fig.3


Fig.4

Fig.5

Fig.6

Fig.7

Ocean currents, on the other hand, are caused by differences in density, temperature and salinity within water. Energy from ocean currents can be harnessed in a similar way to tidal currents. However, ocean currents flow much more slowly and only in one direction, which means lower power potential. The technology for this is at a very early stage and is yet to be developed in Southeast Asia.

TIDAL RANGE

Aside from tidal currents, another way to extract energy from the tides is through tidal range, which makes use of the vertical difference between high and low tides. One way to do this is by using a tidal barrage, which works similarly to a hydroelectric dam. When the tide rises or falls, water flows through a dam. This motion of the water rotates a turbine that is connected to a generator that converts the energy to electricity. For a tidal barrage to capture sufficient power, the difference between high and low tides needs to be at least 5 metres. However, most places in Southeast Asia have a difference of only 2 to 3 metres; thus, this technology is applicable only to limited areas, for example, in Myanmar.

Fig.5: In-stream tidal turbine at Sentosa, Singapore.
Fig.6: Vertical-axis marine current turbine by Universiti Teknologi Malaysia (UTM).
Fig.7: Potential site for tidal barrage in Myanmar.

WAVES

Waves are created by the wind blowing onto the surface of the water as well as by pressure fluctuations below the surface. One type of technology used to harness waves to produce energy is the oscillating water column, which is a partially submerged chamber with a water column inside and a turbine at its opening. Waves cause the water column to move up and down within the chamber, resulting in the movement of air. This airflow moves the turbine, and this energy can, once again, be converted to electricity by a generator.

Fig.8: Conceptual design of a hydraulic buoy to harness wave energy by the University of Engineering and Technology at Vietnam National University in Hanoi.

Fig.9: Pendulum wave energy system in Indonesia.

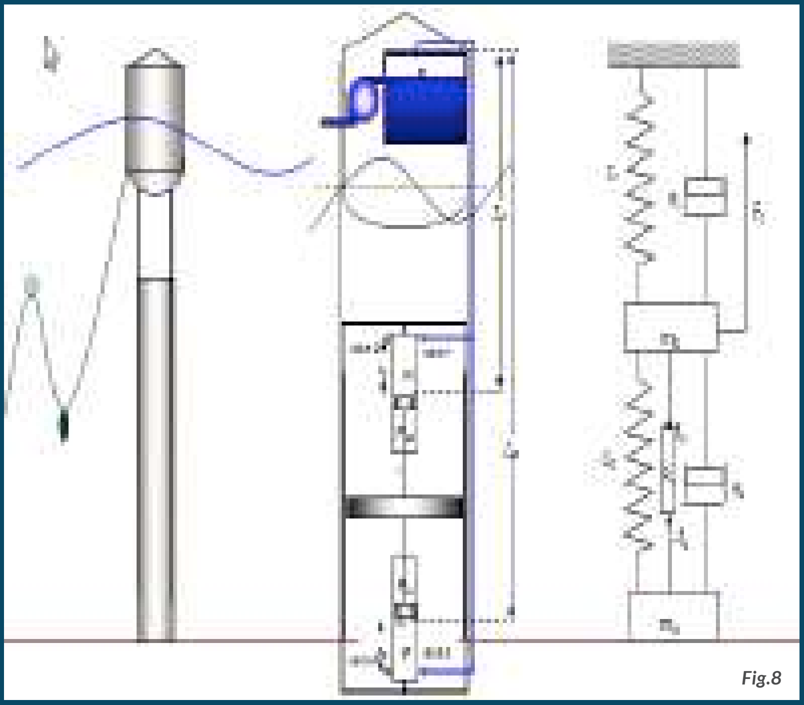


Fig.8


Fig.9

There is vast potential in wave energy in Southeast Asia, as evidenced by the abundance of surfing havens in the region. Some examples of wave energy technology in use are the pendulum wave energy system and the vertical pendulum wave system, both in Indonesia.

While there is great wave energy potential in the region, the development of this technology is not yet as advanced as that for tidal energy. And while many designs have been created, at the moment, most of these are still on a prototype scale and yet to be tested in open tropical water conditions.

Fig.10: Vertical pendulum wave energy system in Indonesia.

Fig.10

OCEAN THERMAL ENERGY CONVERSION

Temperature, specifically, temperature differences between the warmer surface water and the colder deep layers of seawater, can be used to drive a heat engine to produce electricity. This is called ocean thermal energy conversion (OTEC). For this to work, there needs to be at least a 20-degree-Celsius temperature difference between surface and deep seawater, and a massive volume of water is required – billions of gallons daily. Waters with these conditions are widely available in Southeast Asia.

While the technology for this is not at the level of tidal and wave energy, the potential is vast, and studies are currently underway to develop this resource. One example is the OTEC Research Centre in Malaysia, which has pegged Sabah as a potential site for OTEC studies. There is also on-going project development work on OTEC in the Philippines led by the Ocean Thermal Energy Corporation.

Fig.11: Potential sites for ocean thermal energy conversion (OTEC) in the Philippines.

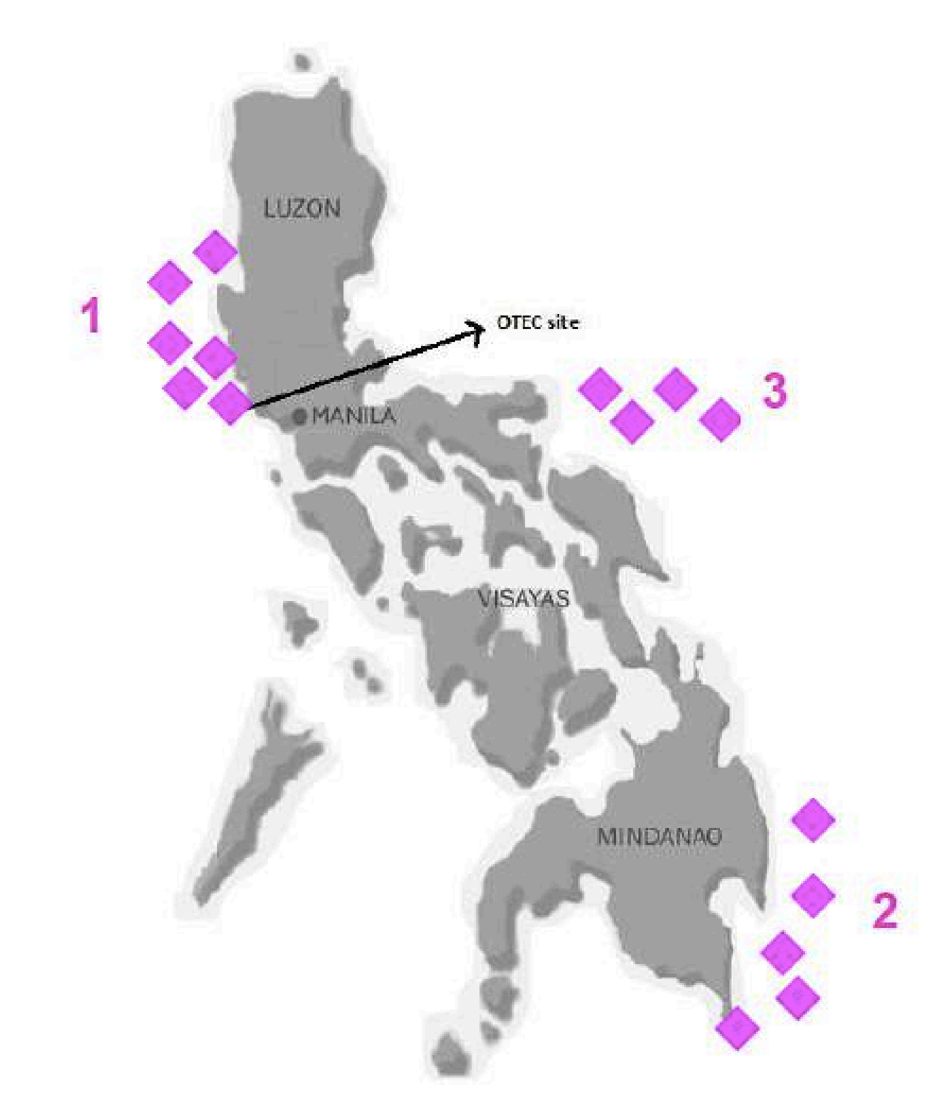
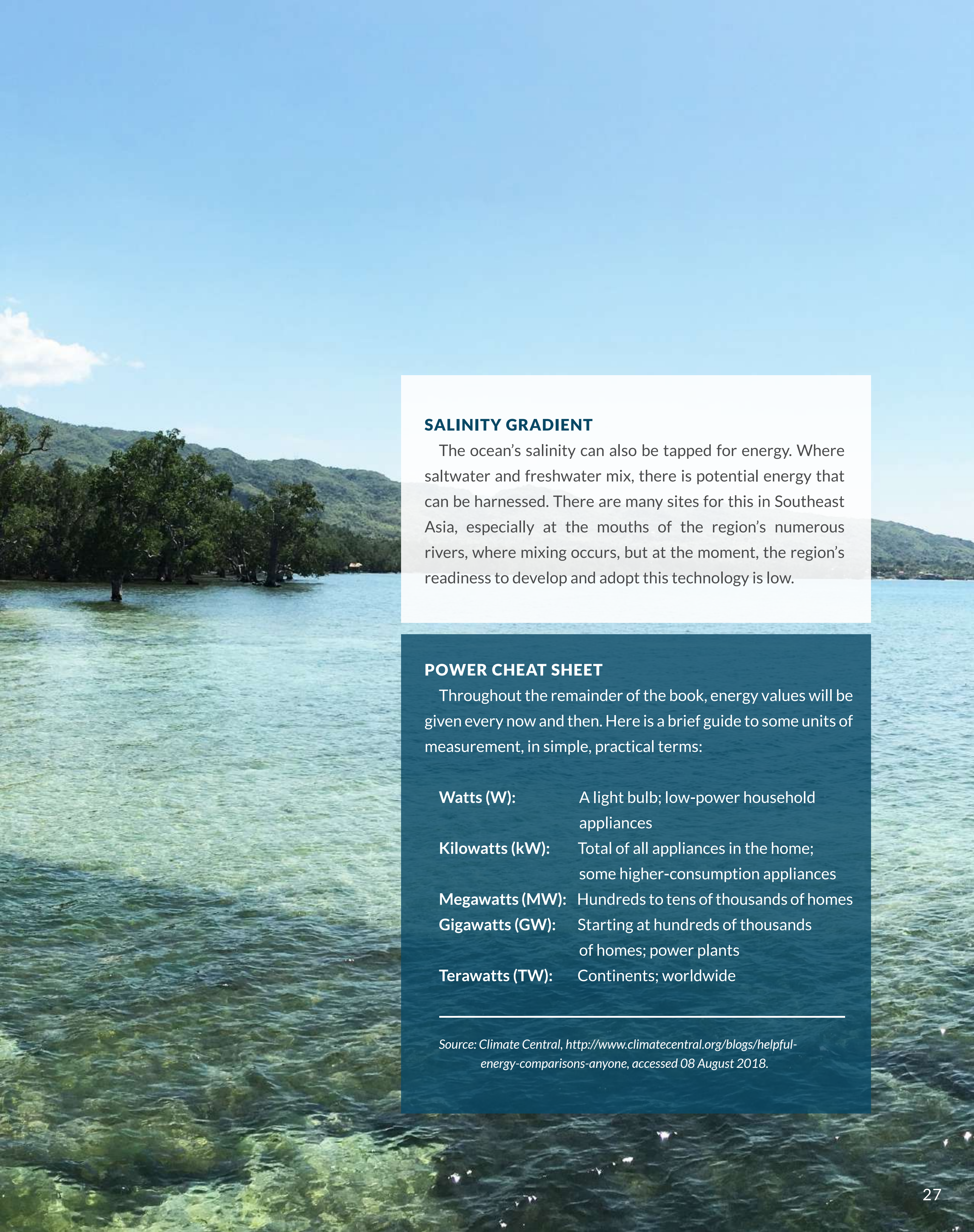


Fig.11



SALINITY GRADIENT

The ocean's salinity can also be tapped for energy. Where saltwater and freshwater mix, there is potential energy that can be harnessed. There are many sites for this in Southeast Asia, especially at the mouths of the region's numerous rivers, where mixing occurs, but at the moment, the region's readiness to develop and adopt this technology is low.

POWER CHEAT SHEET

Throughout the remainder of the book, energy values will be given every now and then. Here is a brief guide to some units of measurement, in simple, practical terms:

Watts (W):	A light bulb; low-power household appliances
Kilowatts (kW):	Total of all appliances in the home; some higher-consumption appliances
Megawatts (MW):	Hundreds to tens of thousands of homes
Gigawatts (GW):	Starting at hundreds of thousands of homes; power plants
Terawatts (TW):	Continents; worldwide

Source: Climate Central, http://www.climatecentral.org/blogs/helpful-energy-comparisons-anyone, accessed 08 August 2018.

Ocean Renewable Energy in Southeast Asia:

Where Need and Opportunity Meet

SOUTHEAST ASIA'S ENERGY SITUATION

In Southeast Asia (SEA), access to electricity varies depending upon location. People in urban areas have access to electricity but may struggle with expensive prices or unstable supply (or both), experiencing frequent power fluctuations and outages. Many rural or remote areas are not connected to the electric grid – affecting 15% of the population, or about 99 million people. Among them, many rely heavily on diesel generators, while others have no access to power at all.

At the same time, the economy and population of the region have continuously developed. SEA has experienced a steady 5% economic growth over the last 15 years, higher than the global rate of about 3.5%. The population has grown at a rate of just above 1%. This might seem like a small number, but with more than 600 million people, 1% translates to an additional 6 million people a year.

Considering the need to ensure that everyone has access to inexpensive, stable electricity together with the increased

energy demand that comes with economic and population growth, the region will need to increase its electricity output. It is projected that by 2025, SEA will need double the electricity of today. This will require about US$400 billion in total energy investments – equivalent to the entire GDP (2016) of Thailand, the region's second-largest economy.

Currently, about 75% of the region's electricity is generated by the burning of fossil fuels (coal, oil, natural gas). But with the dwindling supply of fossil fuels as well as their harmful effects on the environment and human health, we need another energy source, one that is abundant in supply and doesn't run out, and one that poses no harm to the environment and humans.

Thus we turn to renewable energy.

By 2025, SEA looks to increase the percentage of electricity that comes from renewable sources from its current 17% level to 36%. This requires the region to triple its production of renewable energy, adding about 130 gigawatts (GW), which is equivalent to the combined total power generation capacity of Indonesia, Thailand and Malaysia (the region's three largest producers of electricity). This amounts to US$300 billion in investment opportunities – three-fourths of the total energy investment required!

At present, renewable energy in the region is dominated by hydropower, accounting for about 75%, followed by biofuel and geothermal sources, each at about 12%. Solar and wind energy make up the rest.

The 2025 projections see an increase in energy output across the board, with solar energy catching up with biofuel and geothermal sources in terms of power output and a many-fold increase in wind energy output as well. Ocean renewable energy (ORE) will be included in the mix, providing 3 GW of power.

OCEAN RENEWABLE ENERGY IS A GOOD FIT

SEA is an archipelagic region. Its ten countries (Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Vietnam) are made up of more than 25,000 islands. The region accounts for a whopping 30% of the world's coastline, despite its relatively small land area.

The geography of SEA means that there are many remote islands without access to electricity, due to the challenges of building an electric grid across many islands. At the same time, this geography gives the region great access to marine waters – and the untapped energy within them.

In this unique situation, need and opportunity meet.

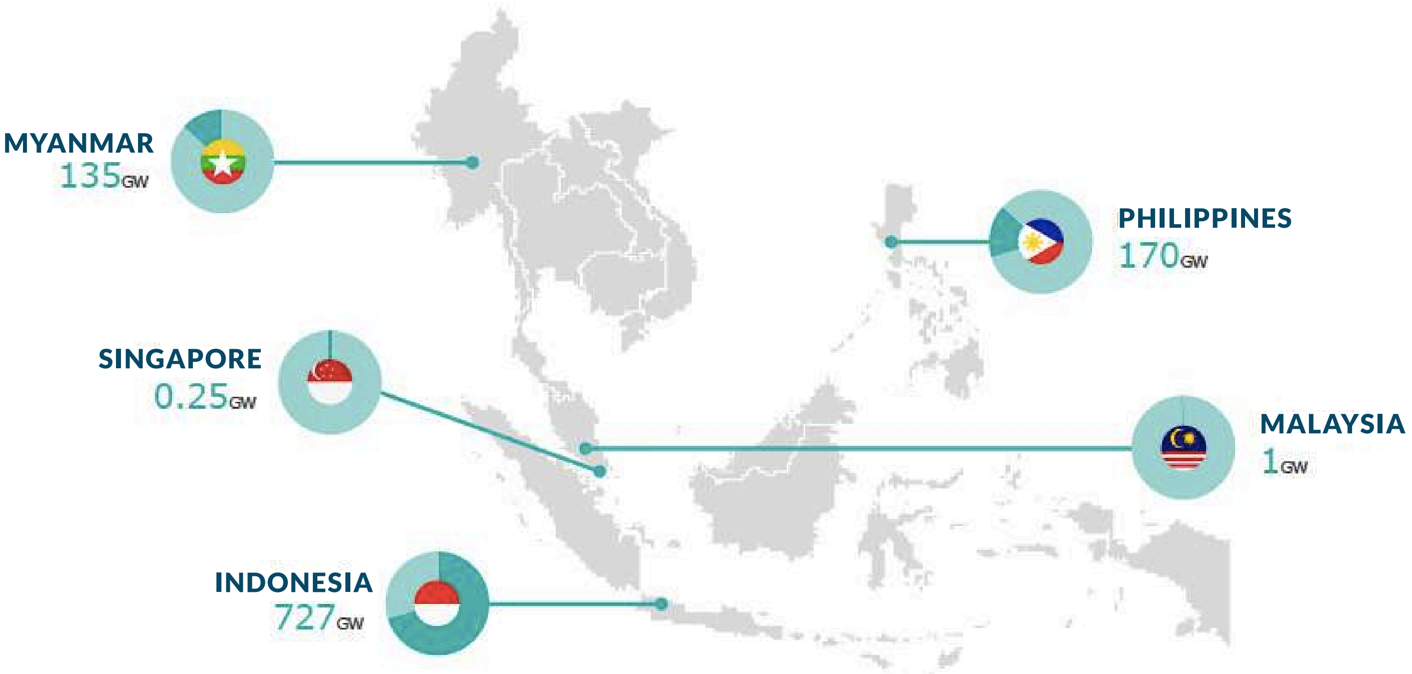
The power potential of ORE in SEA is vast. The 2025 goal of 3 GW of ocean power might seem like a small number, especially compared to other renewable energy sources, but it translates to power for over 500,000 homes for an entire year. Furthermore, the total power potential of ORE in the region is 1 terawatt (TW) – the largest among all renewable energy sources in the region. For perspective, the total energy consumption of the USA in 2008 was 3.3 TW. This means that the ORE potential in SEA alone could power one-third of the entire USA for a whole year!

Another advantage of ORE is that its facilities are easier to build, operate and maintain compared to other forms of renewable energy. The technology is also highly efficient. In addition, minimal specialisation is needed, and most of the work can be done by local suppliers and workers.

Best of all, ORE is a highly stable resource, in terms of both availability and predictability. Water is not consumed in the process of energy generation, which means that it never runs out and can be continuously tapped for energy. Tides, one of the major sources of ocean energy in the region, can be predicted with great accuracy a hundred years into the future, which enables reliable planning and energy output.

Research and development of ORE has been on-going across SEA, and at some sites, the technology is already being deployed.

Fig.12: Potential ocean renewable energy resources in selected countries in Southeast Asia.


MYANMAR
135GW
PHILIPPINES
170GW
SINGAPORE
0.25GW
MALAYSIA
1GW
INDONESIA
727GW
Fig.12

Singapore:

A Regional Hub for Ocean Renewable Energy

Country Background

Projects

Policy


PSA
701

COUNTRY BACKGROUND

Singapore has the smallest land area among all countries in Southeast Asia. At about 720 km^2, it is one-eighth the size of the next-smallest country (Brunei) and dwarfed by all other countries in the region, each with land areas in the hundreds of thousands of square kilometres.

Because it has limited domestic resources to produce electricity, it relies heavily on importation of gas, constituting the vast majority of its energy supply. It also has one of the busiest shipping lines in the world, which is great for the economy but at the same time makes it a challenge to find locations for ocean renewable energy (ORE) facilities.

Despite these limitations, 100% of the population have access to electricity. Furthermore, Singapore positions itself as a regional hub for ORE knowledge and technology. This is possible due to its status as a developed country, as well as an environment that encourages research and innovation, with resources widely available in terms of funding, intelligence and industry capability.

COUNTRY SNAPSHOT (2016)

- Electricity consumption: 52 TWh
- Electrification: 100%
- Population: 5.6 million (2nd lowest in SEA)
- Growth over last decade: economic, 4.7%; population, 2.5%

ENERGY MIX

- Current mix: gas 95%, coal 1%, oil 1%, renewable sources 3% (municipal waste, biomass, solar)
- Additional requirement by 2025: 5 GW

RENEWABLE ENERGY

- Current renewable energy (RE) capacity: 0.3 GW
- Additional RE capacity needed by 2025: 2.7 GW
- Investment opportunity in RE: US$1.1 billion per year
- Total ORE potential: 250 MW (tidal)

Fig.13: Potential sites for tidal in-stream energy in Singapore.

Fig.13

PROJECTS

Singapore aims to be a pioneer in the adoption of ORE in the region. First, it encourages the development and testing of technology, including setting up test beds where devices can be seen at work in natural environment settings. The country's processes for getting licenses and permits to conduct testing are also predictable and easy to navigate, which appeals to potential investors, project developers and suppliers. Second, it facilitates collaboration among the academe and industry, in terms of both knowledge sharing and joint project development.

Development projects include demonstration of a tidal turbine test bed at Sentosa (2013); assessment of energy resources, tidal in-stream and wave energy in particular, at Tanah Merah (2014–2015); and deployment of a floating tidal turbine, also at Sentosa (2017).

Collaborative efforts have mainly stemmed from the Energy Research Institute at Nanyang Technological University (ERI@N). The ERI@N Wind and Marine Renewable Energy team works in partnership with other stakeholders to complete projects from the lab stage to field deployment, including resource assessment and measurement, development of technology appropriate for the region's tropical conditions, environmental impact assessment and government policy. One such endeavour resulted in the floating tidal turbine at Sentosa. Also initiated by ERI@N is the Southeast Asian Collaboration for Ocean Renewable Energy (SEAcORE), with partners from Brunei, Indonesia, Malaysia, Myanmar, the Philippines, Thailand and Vietnam. Member institutions collaborate on resource mapping and assessment projects and share country developments in ORE with the network. The Association of Southeast Asian Nations' (ASEAN's) Centre for Energy (ACE) Renewable Energy Sub-sector Network (RE-SSN) has made SEAcORE its official technical working group for offshore and ocean renewable energy. Start-up company OceanPixel, which specialises in MRE intelligence and undertakes projects in partnership with many stakeholders in the region, also spun off from ERI@N.

Fig.14: Sentosa tidal turbine test-bed demonstration (2013).
Energy specs: 1 kW capacity
Stakeholders: Sentosa, ERI@N

Fig.15: Tanah Merah tidal in-stream and wave energy resource assessment (2014–2015).
Energy specs: 35 MWh/year tidal and 28 MWh/year wave potential
Stakeholders: Energy Research Institute at Nanyang Technological University (ERI@N), Tanah Merah Ferry Terminal

Fig.16: Sentosa floating tidal turbine (2017).
Energy specs: 62 kW Schottel in-stream turbine
Stakeholders: Envirotek, OceanPixel, ERI@AN, Schottel Hydro, Aquatera, LitaOcean, Orcades Marine, DHI, Braemar Offshore, Singapore Salvage Engineers, YJP Surveyors Pte Ltd

Fig.14

Fig.15

Fig.16

Fig.17

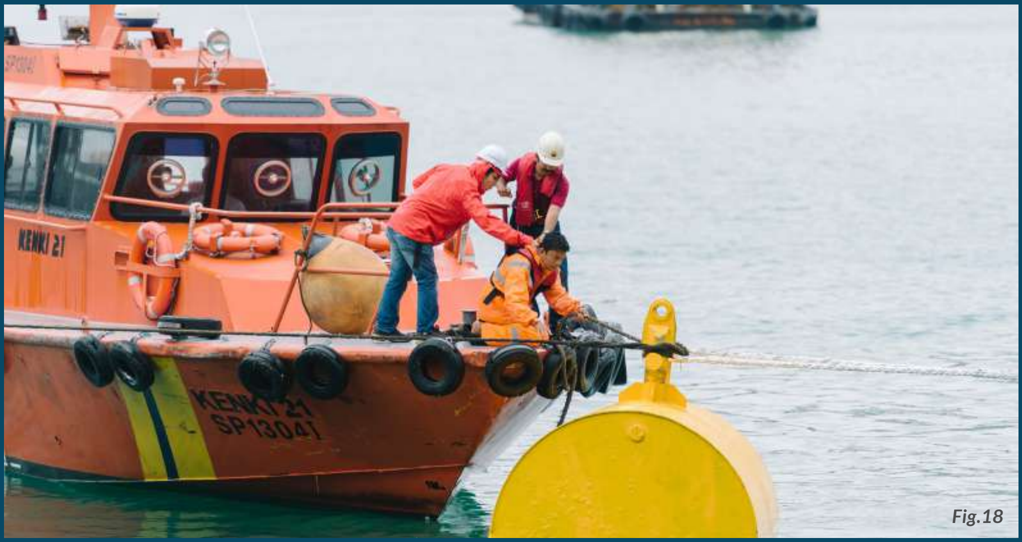


Fig.18

Fig.19

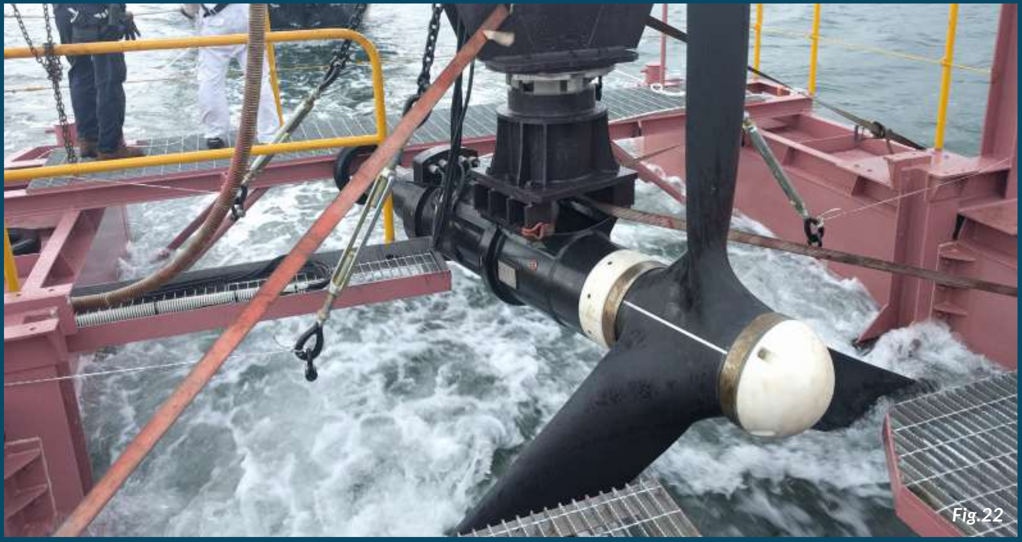


Fig.17–22: Sentosa floating tidal turbine (2017).

POLICY

Singapore does not have a current law specific to ORE, but it does have a general policy framework on energy efficiency, which places high importance on the use of renewable energy. There is also public funding towards energy use, water, green buildings and land scarcity, which are closely connected with ORE. The country aims to reduce energy intensity across the economy and establish energy efficiency measures to attain this. It likewise aims to produce a clear set of rules on the deployment of renewable energy and has provided support mechanisms to attract investments. As Singapore envisions itself as a regional centre for R&D, the government has been supportive of research, development and demonstration of renewable energy technologies.

Fig.23: Energy Research Institute at Nanyang Technological University (ERI@N).
Fig.24: Southeast Asian Collaboration for Ocean Renewable Energy (SEAcORE).

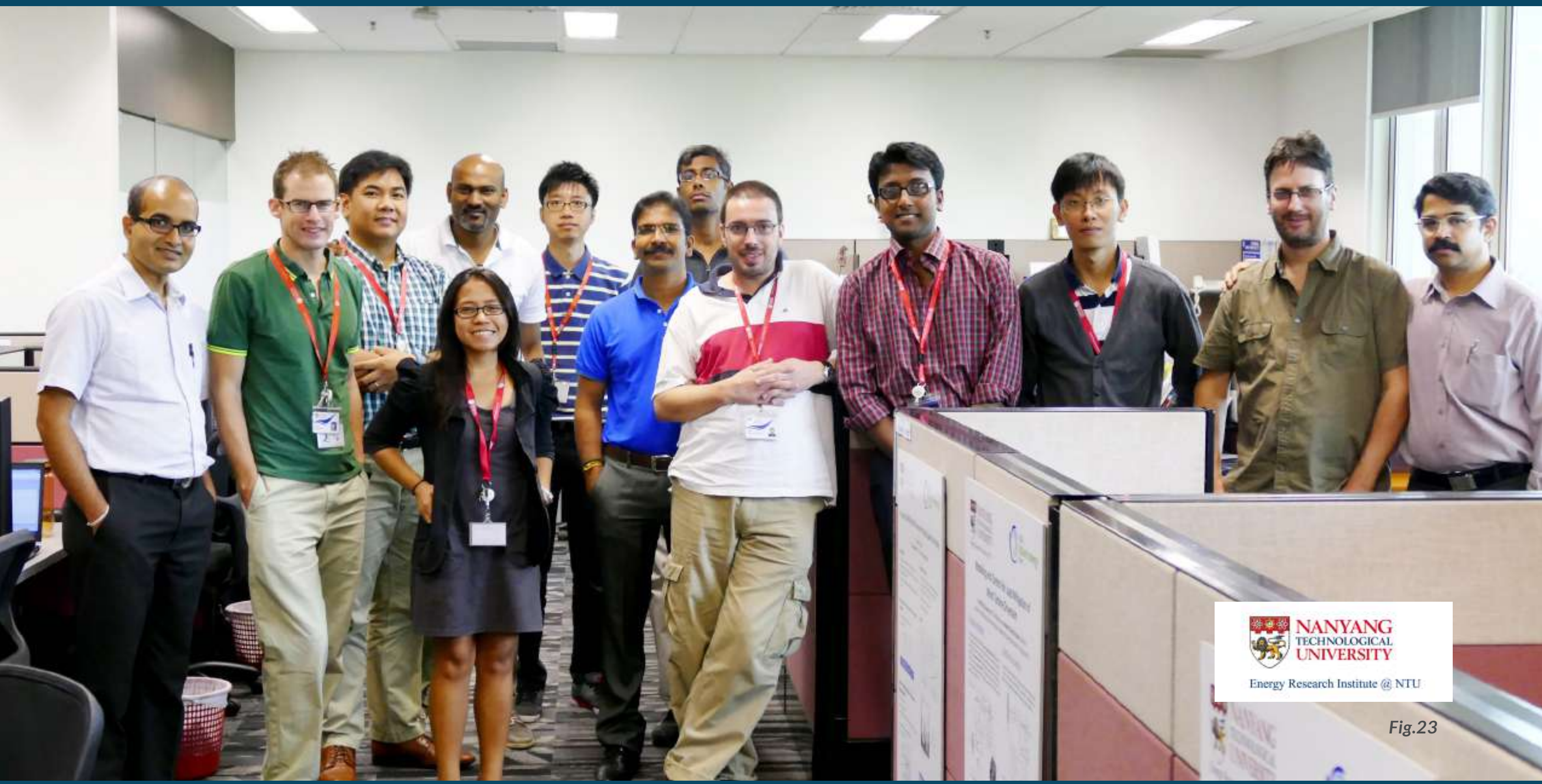

NANYANG
TECHNOLOGICAL
UNIVERSITY
Energy Research Institute @ NTU

Fig.23


British
High Commission
Singapore
UK-South East Asia
seacore
southeast asian collaboration for ocean renewable energy

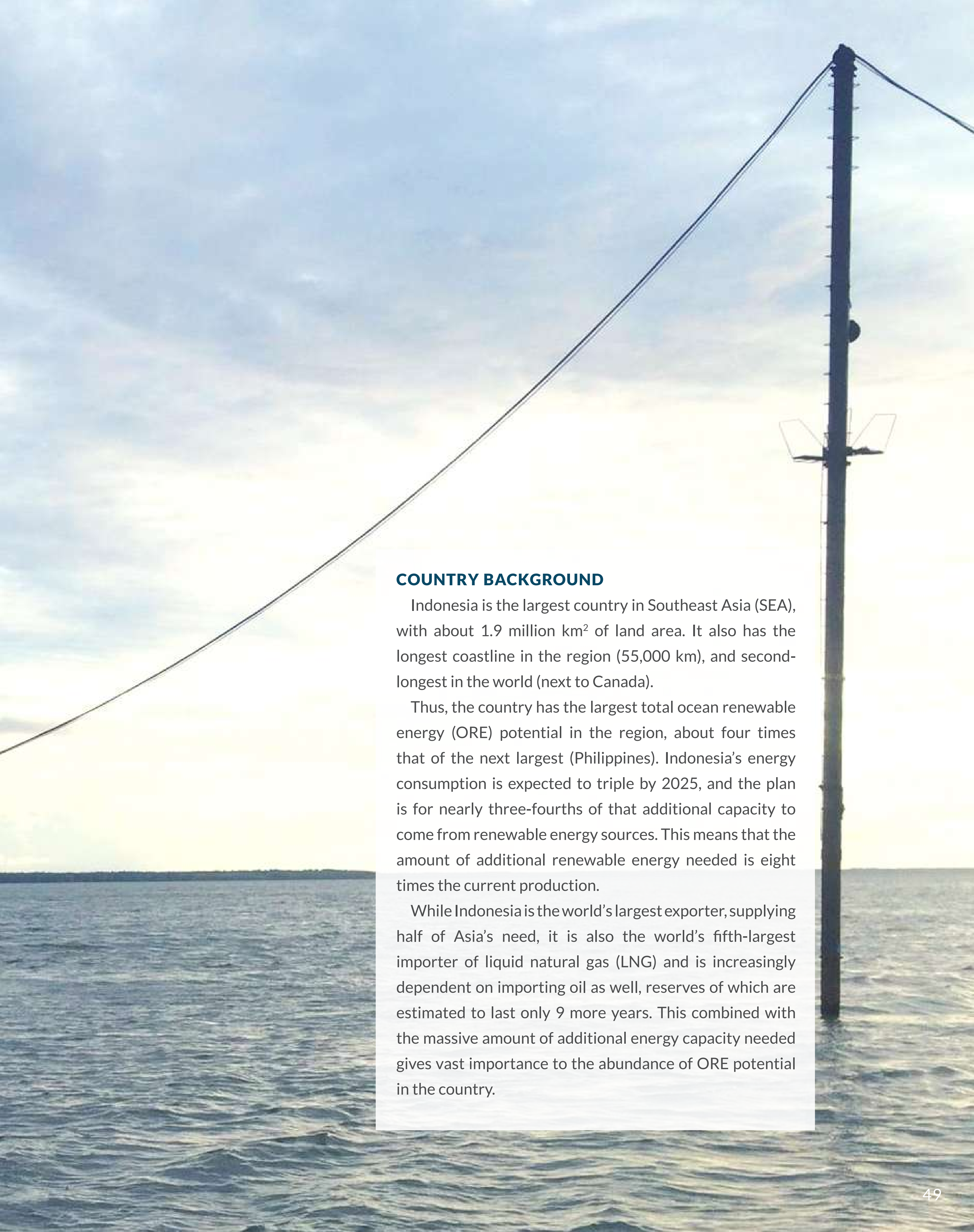
Fig.24

Indonesia:
Massive Ocean Renewable Energy Potential

Country Background

Projects

Policy



COUNTRY BACKGROUND

Indonesia is the largest country in Southeast Asia (SEA), with about 1.9 million km^2 of land area. It also has the longest coastline in the region (55,000 km), and second-longest in the world (next to Canada).

Thus, the country has the largest total ocean renewable energy (ORE) potential in the region, about four times that of the next largest (Philippines). Indonesia's energy consumption is expected to triple by 2025, and the plan is for nearly three-fourths of that additional capacity to come from renewable energy sources. This means that the amount of additional renewable energy needed is eight times the current production.

While Indonesia is the world's largest exporter, supplying half of Asia's need, it is also the world's fifth-largest importer of liquid natural gas (LNG) and is increasingly dependent on importing oil as well, reserves of which are estimated to last only 9 more years. This combined with the massive amount of additional energy capacity needed gives vast importance to the abundance of ORE potential in the country.

COUNTRY SNAPSHOT (2016)

- Electricity consumption: 249 TWh (2016)
- Electrification: >20 million people with no access to electricity
- Population: 261 million
- Growth over last decade: economic, 5.6%; population, 1.3%

ENERGY MIX

- Current mix: coal 58%, gas 27%, oil 3%, renewable sources 11% (hydropower, geothermal)
- Additional requirement by 2025: 92 GW

RENEWABLE ENERGY

- Additional RE capacity needed by 2025: 66 GW
- Investment opportunity in RE: US$10 billion per year
- Total MRE potential: 727 GW (tidal, OTEC and wave)
- MRE potential is the largest among all RE sources in the country

Fig.25: Potential tidal, wave and OTEC sites in Indonesia.

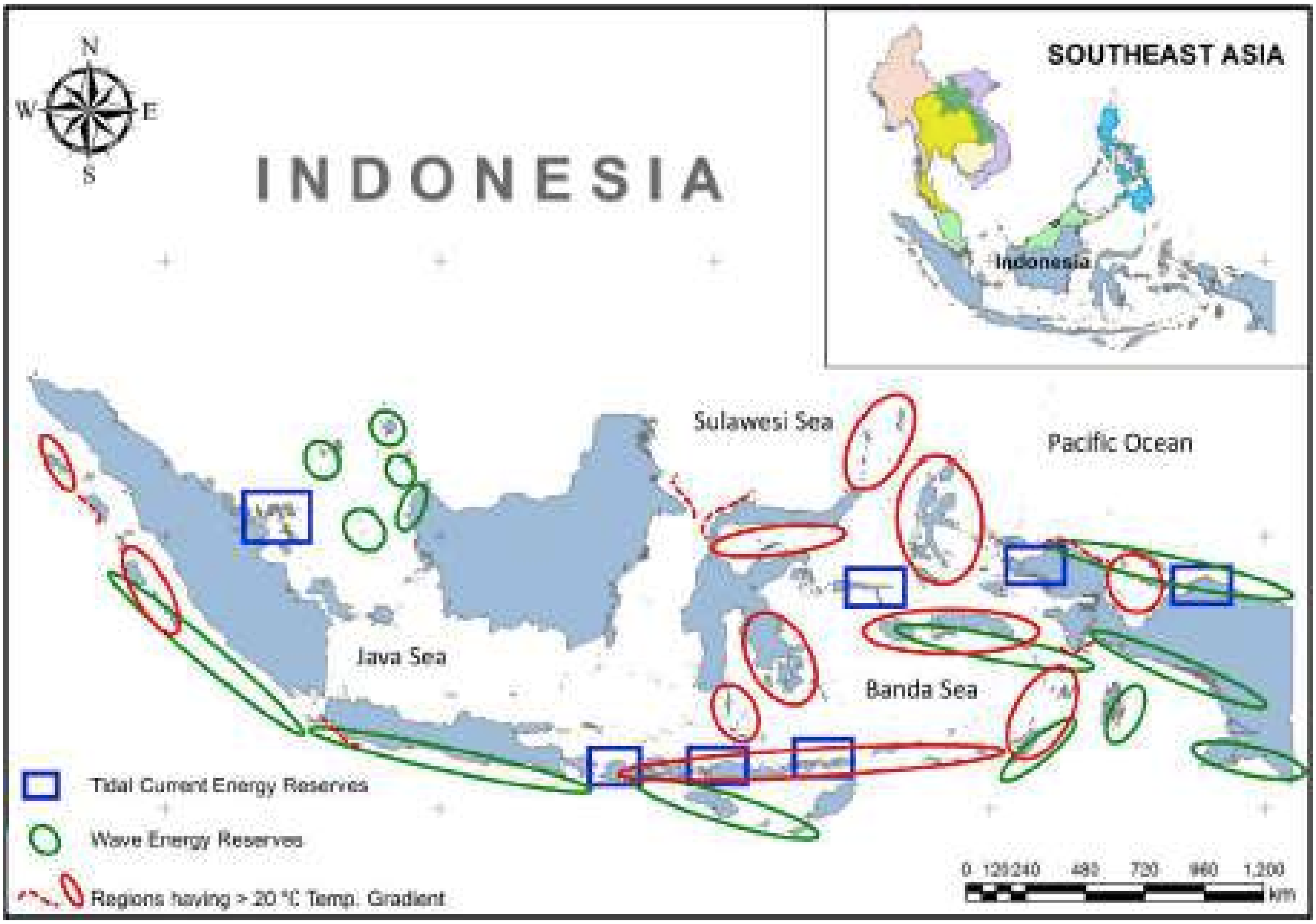

N
W
E
S
INDONESIA
SOUTHEAST ASIA
Indonesia
Sulawesi Sea
Pacific Ocean
Java Sea
Banda Sea
Tidal Current Energy Reserves
Wave Energy Reserves
Regions having > 20 °C Temp. Gradient
0 120 240 480 720 960 1,200
km

Fig.25

PROJECTS

A pioneering endeavour for ORE in Indonesia is the development of a tidal in-stream renewable energy generation facility at the PT Bintuni Utama Murni Wood Industries (BUMWI) concession area on Amutu Besar Island, West Papua, Indonesia. The 50-kW-capacity project, which started development in 2014 and was commissioned in 2016, was brought to fruition through collaboration among academe and industry partners.

This case proved valuable, as it revealed the challenges that come with the development of local ORE facilities, namely, the difficulty of selecting the right site (in terms of both what is theoretically ideal as well as what is practically feasible); the logistics of deployment at a remote location; the language barrier between industry people and the local community; and limited availability of local technical experts as support.

It nevertheless showed that tidal in-stream energy generation is viable in the area and that many of the key components of the facility can be sourced and developed locally. Furthermore, it showed that location is essential in order to determine a facility's energy output.

In addition to the BUMWI project, Indonesia has been testing other devices for both tidal energy and wave energy. One such device is the turbine technology called Kobold, developed by Italian company Ponte di Archimede S.p.A. (PDA) and the University of Naples (UNINA), which has been installed in Lombok. ORE development is also being undertaken by PT T-Files, a company formed by students and alumnae from Institut Teknologi Bandung (ITB), which partially owns the company as well.

Aside from the development of technology, studies have also identified other potential sites for tidal and wave energy. Many of these places usually rely on diesel for power or have no electricity access at all. Areas include the Riau Islands, Nusa Tenggara Barat, Nusa Tenggara Timur, Maluku Utara, Papua Barat and Papua. Local experts are also focusing on building the country's capacity to adopt ORE technology through workshops and training, aiming to have pilot projects and to push for supportive policies.

Fig.26: PT T-Files project.
Fig.27: Kobold project in Lombok.
Fig.28: PT Bintuni Utama Murni Wood Industries (BUMWI) tidal in-stream facility (2014, currently operational).
Energy specs: 50 kW tidal in-stream
Stakeholders: Greenforest Pte Ltd, Energy Research Institute at Nanyang Technological University (ERI@N), Aquatera, Orcades Marines, Schottel Hydro, OceanPixel Pte Ltd

Fig.26

Fig.27

Fig.28

POLICY

Indonesia has a general framework for renewable energy. For instance, Law 17 of 2007 put into effect the National Long-Term Development Plan, which moves to strengthen funding for alternative energy. Governmental Regulation No. 79 of 2014, the National Energy Policy, includes provisions for reducing the use of fossil fuels and increasing renewable energy sources, improving the national electricity supply and improving access in remote areas. The government's definition of renewable energy includes marine renewable energy (MRE), and its goals include the development of MRE pilots to prepare for commercialisation. Furthermore, the National Energy Council is reviewing energy policy to include ORE in the country's energy mix.

Fig.29: Wave energy pendulum system.

Fig.30: ORE device in Maluku, Utara, Indonesia.

Fig.31: Energy Research Institute at Nanyang Technological University (ERI@N), Singapore, visit to Dewan Energi Nasional, Indonesia.

Fig.29


Fig.30


Fig.31

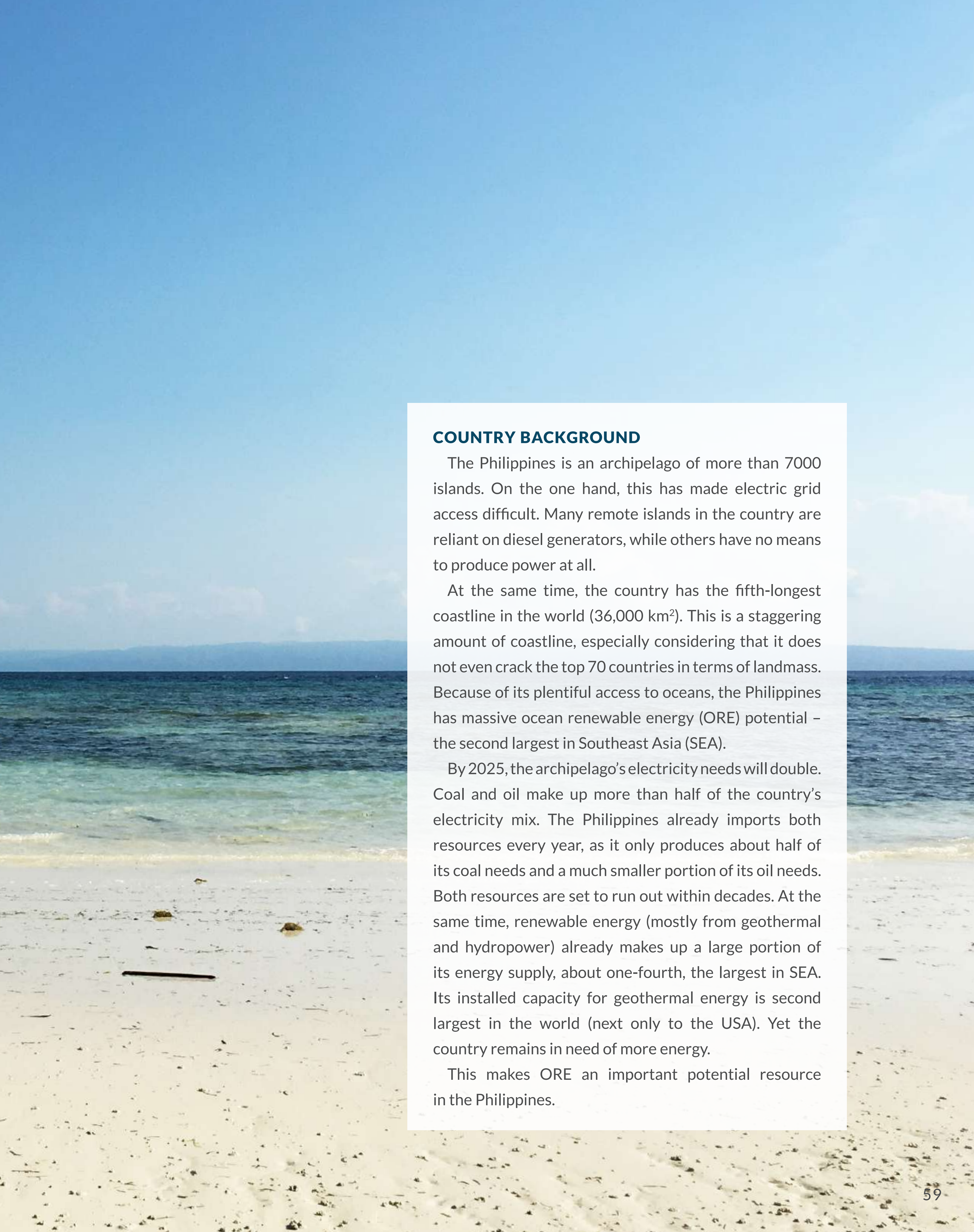
The Philippines:

Abundant Access to Ocean Renewable Energy Sources

Country Background

Projects

Policy



COUNTRY BACKGROUND

The Philippines is an archipelago of more than 7000 islands. On the one hand, this has made electric grid access difficult. Many remote islands in the country are reliant on diesel generators, while others have no means to produce power at all.

At the same time, the country has the fifth-longest coastline in the world (36,000 km^2). This is a staggering amount of coastline, especially considering that it does not even crack the top 70 countries in terms of landmass. Because of its plentiful access to oceans, the Philippines has massive ocean renewable energy (ORE) potential – the second largest in Southeast Asia (SEA).

By 2025, the archipelago's electricity needs will double. Coal and oil make up more than half of the country's electricity mix. The Philippines already imports both resources every year, as it only produces about half of its coal needs and a much smaller portion of its oil needs. Both resources are set to run out within decades. At the same time, renewable energy (mostly from geothermal and hydropower) already makes up a large portion of its energy supply, about one-fourth, the largest in SEA. Its installed capacity for geothermal energy is second largest in the world (next only to the USA). Yet the country remains in need of more energy.

This makes ORE an important potential resource in the Philippines.

COUNTRY SNAPSHOT (2016)

- Electricity consumption: 91 TWh
- Electrification: >10 million people with no access to electricity
- Population: 103 million
- Growth over last decade: economic, 5.6%; population, 1.6%

ENERGY MIX

- Current mix: coal 48%, gas 22%, oil 6%, renewable sources 24% (geothermal, hydropower, solar, wind)
- Additional energy needed by 2025: 15 GW

RENEWABLE ENERGY

- Current renewable energy (RE) capacity: 5.9 GW
- Additional RE capacity needed by 2025: 7 GW
- Investment opportunity in RE: US$1.3 billion per year
- Total ORE potential: 170 GW (tidal, OTEC and wave)
- ORE potential about the same as solar, with each being four times larger than the potential from all other renewable energy sources combined

Fig.32: Potential sites of ocean renewable energy in the Philippines.

TIDAL CURRENT **OCEAN THERMAL** **WAVE**

Fig.32

PROJECTS

At the moment, the Philippines' ORE projects are at the stage of site assessment and obtaining permits. One such project is at the San Bernardino Strait, for which the government has funded a tool for assessing tidal current energy and spatial planning. Three sites are being studied, one in Matnog, Sorsogon (Luzon), and two in San Antonio, Northern Samar (Visayas), each with a potential of 5 MW. The goal is to put up ocean power facilities, to be built by renewable energy developer H&WB Asia Pacific Corporation.

Other projects currently undergoing studies include Cabangan Ocean Thermal Energy Conversion (OTEC) in Zambales (Luzon) with 5 MW potential (Bell Pirie Power Corporation); Gaboc Channel Ocean Energy in Surigao (Mindanao) with 6 MW potential (Adnama Power Resources, Inc.); and the tidal in-stream energy conversion (TISEC) project in Northern Samar (Visayas; Poseidon Renewable Energy Corporation).

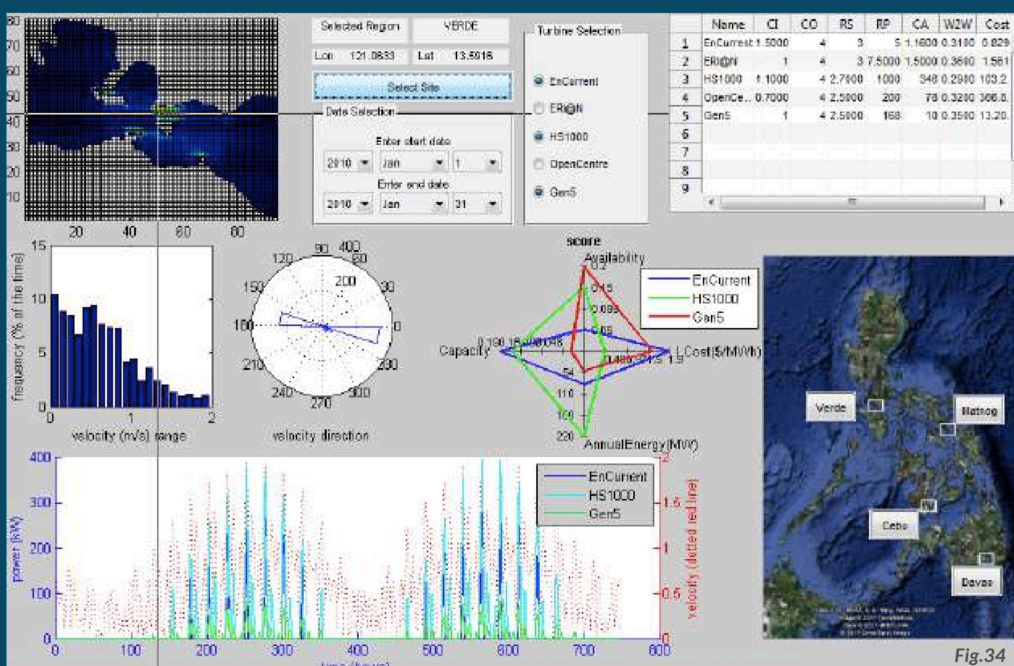
Government and academic institutions, such as the Department of Science and Technology, the National Power Corporation, Mindanao State University, University of the Philippines and University of San Carlos, have also studied the country's ORE potential and possible sites. The Department of Energy, together with industry partner Fugro OCEANOR, have released maps for tidal, wave and OTEC.

Fig.33: San Bernardino Strait assessment (on-going).
Energy specs: 10 MW potential
Stakeholders: H&WB Asia Pacific Corporation
Fig.34: Example of an ORE assessment tool: OceanPixel's Tidal Resource Investigation, Device, and Energy Tool (TRIDEnT).

POLICY

ORE is included in the country's energy development plan. The Philippine Council for Industry and Energy Research and Development (PCIERD) released an ORE roadmap containing a plan for the first ORE facility by 2030. The plan includes resource assessment, demonstration of technology (mainly on ocean currents) and a framework for international collaboration in research, with the goals of creating a map of ocean current resources, building an ocean current demonstration power plant and performing an ocean energy technology demonstration.

Fig.33



Selected Region
VERDE
Lon 121.0833
Lat 13.5018
Select Site
Date Selection
Enter start date
2010 Jan 1
Enter end date
2010 Jan 31
Turbine Selection
EnCurrent
ERI@N
HS1000
OpenCentre
Gen5
Name CI CO RS RP CA W2W Cost
1 EnCurrent 1.5000 4 3 5 1.1600 0.3100 0.829
2 ERI@N 1 4 3 7.5000 1.5000 0.3600 1.561
3 HS1000 1.1000 4 2.7000 1000 348 0.2900 103.2
4 OpenCe... 0.7000 4 2.5000 200 78 0.3200 306.8
5 Gen5 1 4 2.5000 168 10 0.3500 13.20
frequency (% of the time)
velocity (m/s) range
velocity direction
score
Availability
Capacity
LCost($/MWh)
AnnualEnergy(MW)
EnCurrent
HS1000
Gen5
power (kW)
velocity (dotted red line)
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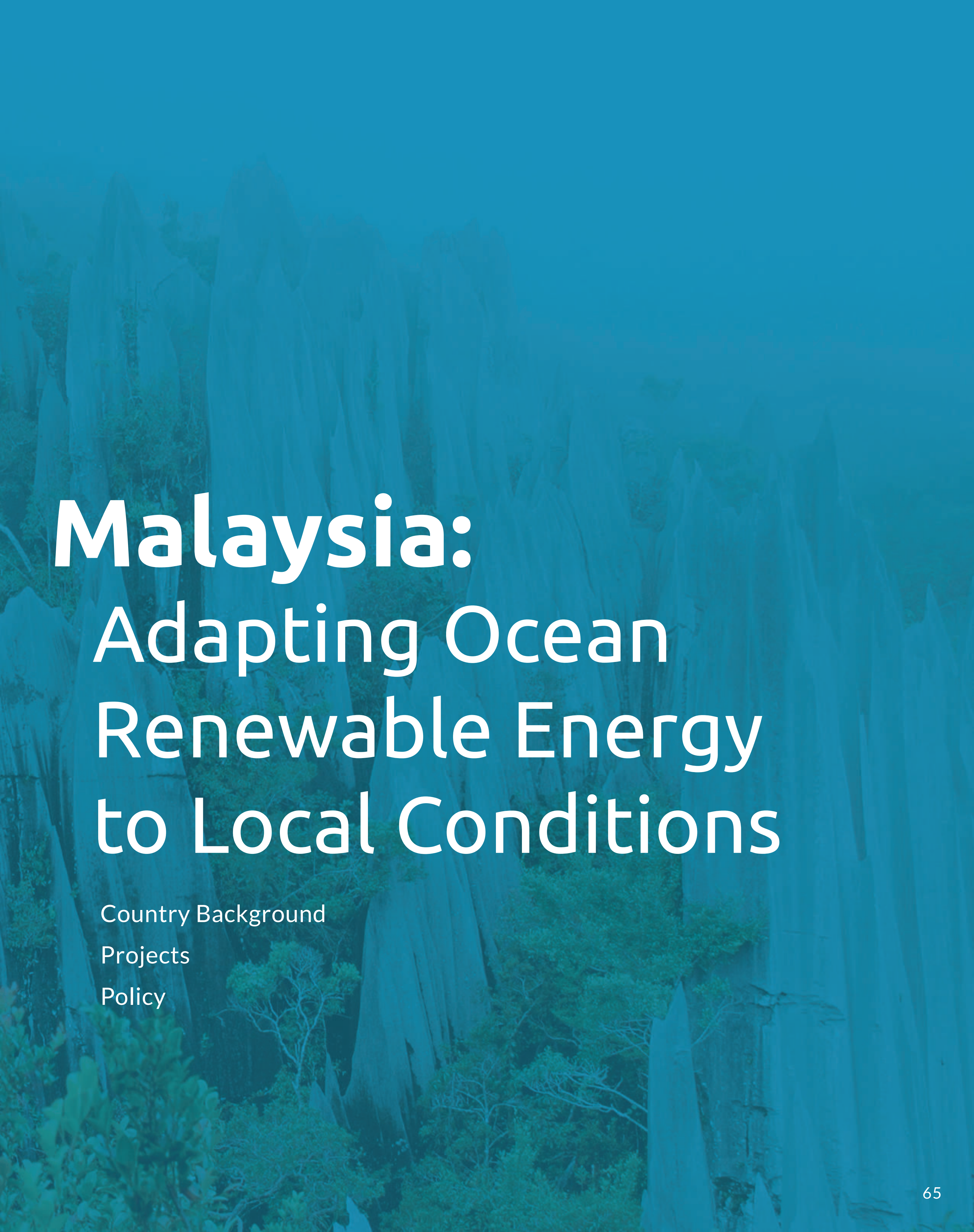
Verde
Matnog
Cebu
Davao

Fig.34



Malaysia:
Adapting Ocean Renewable Energy to Local Conditions

COUNTRY BACKGROUND

Malaysia's oceans are characterised by slow currents, low wave heights and shallow waters, which translate into smaller energy potential. Many of the areas with tidal potential are located far from connections to the national electric grid, while for areas with wave potential, finding compatible devices is a challenge, as existing wave energy devices are built for areas of high energy intensity.

These factors have steered the development of ocean renewable energy (ORE) in a particular direction. It has been determined that ORE is best used for local grids on small islands and coastal areas, which typically are dependent on diesel, a resource both expensive and difficult to transport, particularly during monsoon season. A focus is placed on the design and prototyping of devices that are compatible with local conditions. Activities have been more geared towards resource assessment, simulation and laboratory- and small-scale prototyping.

While resources and opportunity may be smaller compared to some of the country's Southeast Asian (SEA) neighbours, Malaysia remains active in developing ORE suited to its unique conditions. In addition to tidal and wave energy, they are looking into ocean thermal energy conversion (OTEC) as well.

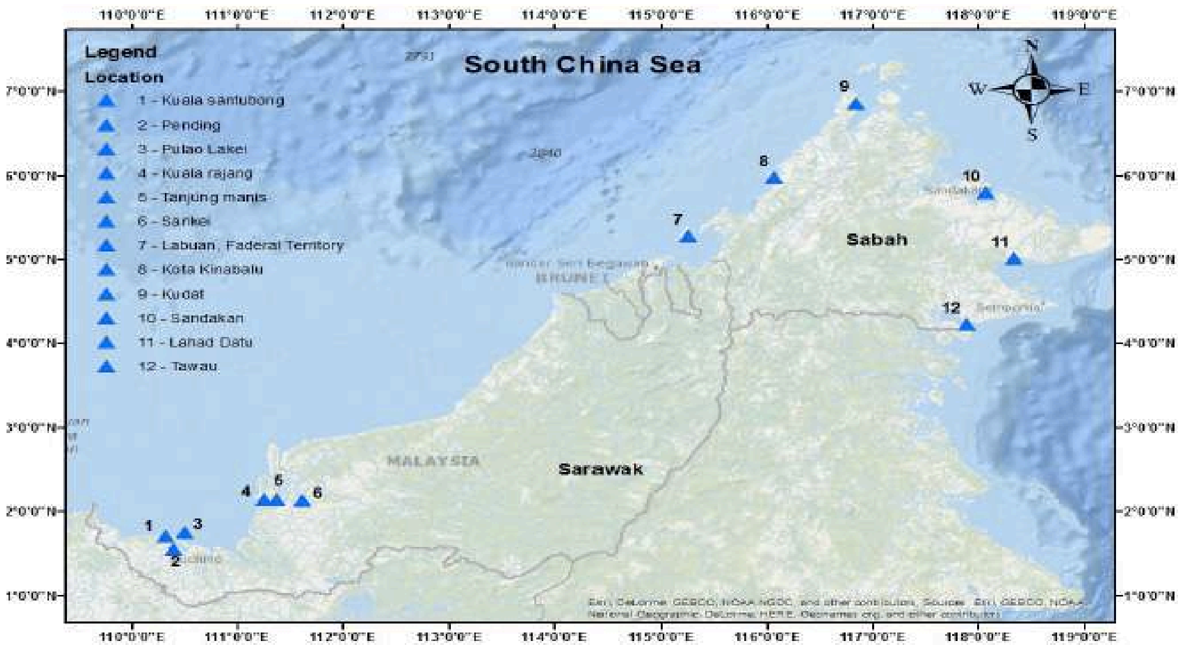
COUNTRY SNAPSHOT (2015)

- Electricity consumption: 141 TWh
- Population: 30 million

ENERGY HIGHLIGHTS

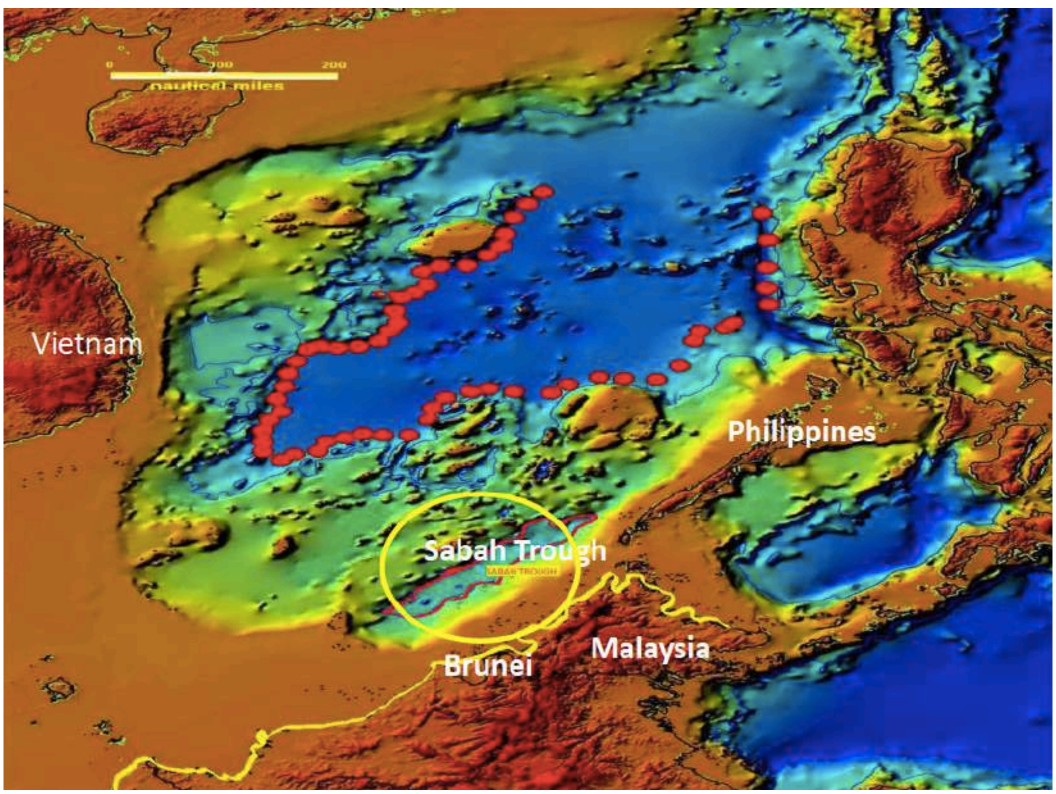
- Current mix: natural gas + coal 89%, oil + biofuels 2%, renewable sources 9% (hydropower, solar)
- Modest goals with regard to renewable energy generation
- Smaller ORE potential compared to Indonesia, the Philippines and Singapore

Fig.35: Sites with potential tidal energy in Malaysia.
Fig.36: Ocean thermal energy conversion potential at Sabah Trough.



Legend
Location
1 - Kuala santubong
2 - Pending
3 - Pulao Lakei
4 - Kuala rajang
5 - Tanjung manis
6 - Sarikei
7 - Labuan, Federal Territory
8 - Kota Kinabalu
9 - Kudat
10 - Sandakan
11 - Lahad Datu
12 - Tawau
South China Sea
Sabah
Sarawak
MALAYSIA
BRUNEI

Fig.35



nautical miles
Vietnam
Philippines
Sabah Trough
Brunei
Malaysia

Fig.36

PROJECTS

Universiti Teknologi Malaysia (UTM) is among the leading institutions focusing on research, development and demonstration (RD&D) on ORE in the country. One of its projects is aimed at deploying a 1-kW Combined Ocean Renewable Energy System (CORES) demonstration platform in Pulau Tinggi using both tidal and wave energy. It consists of an oscillating water column, a wave point absorber and a Savonius underwater turbine, to be attached to floating jetty.

UTM also launched the Ocean Thermal Energy Centre in Kuala Lumpur to spearhead OTEC studies, among which is a study of its potential of OTEC in the Sabah peninsula and off Sipadan Island (within the National Marine Research Park).

Another academic institution in Malaysia studying ORE is Universiti Malaysia Sarawak (UNIMAS), which is conducting tidal energy mapping in Sabah and Sarawak. One potential site for tidal barrage energy is the Kuching Barrage in Sarawak, which has been assessed for environmental impact and has been shown not to obstruct any shipping lines; future studies need to be conducted to determine its potential power output and to choose a well-suited energy harvester. The tidal stream energy potential of Sarawak has been assessed as well, in terms of energy potential and space availability; long-term data gathering is recommended to reliably predict energy sources.

Fig.37: UTM hosts representatives from the Energy Research Institute at Nanyang Technological University (ERI@N), Singapore, in 2013.

Fig.38: UTM Marine Technology Centre.

Fig.39: Sea test at Pulau Tinggi, 2013: oscillating water column (part of a small-scale prototype of the UTM wave energy device).

Fig.40: Model of UTM's Combined Ocean Renewable Energy System.

Fig.37

Fig.38

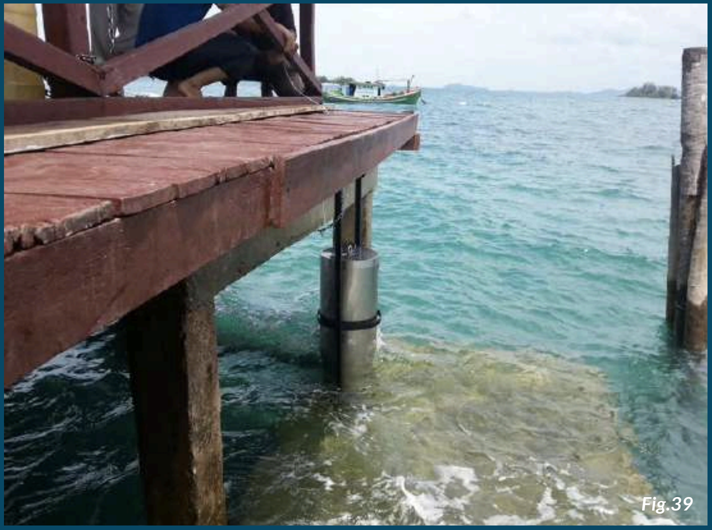


Fig.39

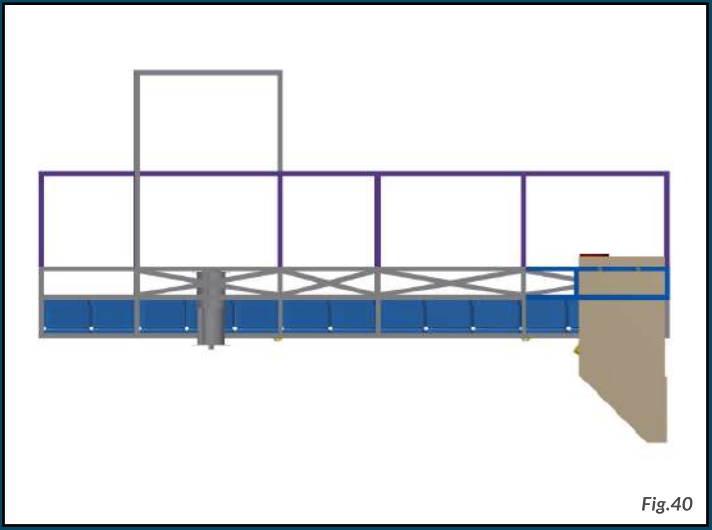


Fig.40

POLICY

Malaysia has a general framework for renewable energy, with the government setting modest goals. Other ORE stakeholders continuously work with the government to come up with a technological roadmap that specifically caters to the adoption of ORE in Malaysia, such as UTM's Ocean Thermal Energy Centre.

There is also government support through policy and funding. For instance, the National Oceanography Directorate (NOD) is a hub for all oceanographic and marine science research and activities. This organisation leads the preparation of the National Roadmap in Renewable Energy under the Ministry of Energy, Green Technology and Water (KeTTHA), which sets the direction for renewable energy in the country. Another example is the Sustainable Energy Development Authority (SEDA), created to establish and implement a special tariff system for renewable energy.

Funding opportunities in renewable energy are available through the Ministry of Science Technology and Innovation (MOSTI), including ScienceFund (for high-impact, innovative applied science) and TechnoFund (which drives innovation from Malaysian enterprises through research and development activities and commercialisation).

Fig.41: Towing carriage at the Marine Technology Centre, UTM.
Maximum speed, 5.0 m/s; maximum acceleration, 1.0 m/s

Fig.42: Towing tank at the Marine Technology Centre, UTM.
Length,120 m; width, 4 m; depth, 2.5 m

Fig.43–44: Testing at sea of the Universiti Malaysia Teranggu/Universiti Malaya oscillating water column.

Fig.45: Sipadan Island, a potential OTEC site in the National Marine Research Park, Sabah.

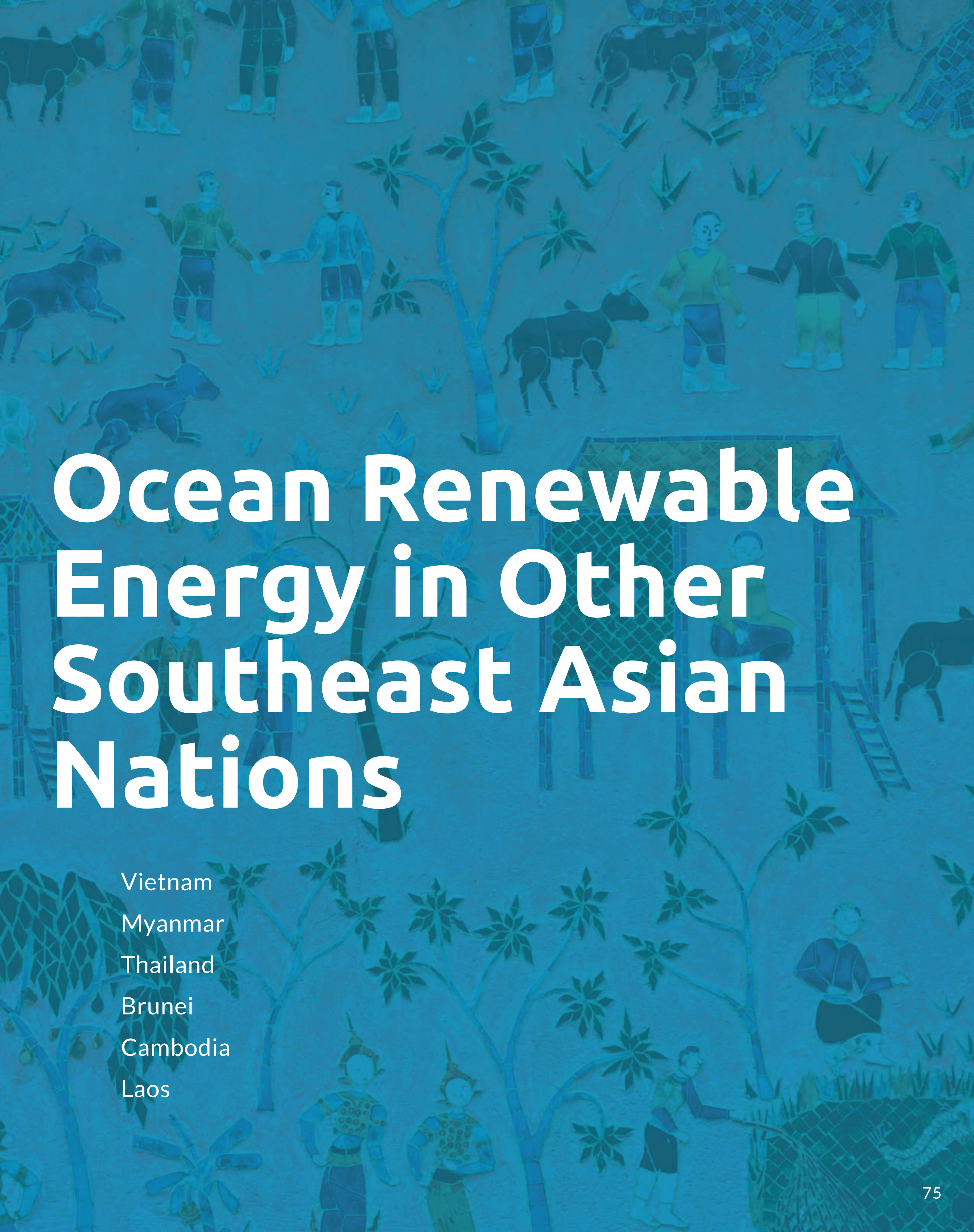
Fig.41

Fig.42

Fig.43

Fig.44

Fig.45



Ocean Renewable Energy in Other Southeast Asian Nations

- Vietnam
- Myanmar
- Thailand
- Brunei
- Cambodia
- Laos

In the rest of Southeast Asia, while there is some development in ocean renewable energy (ORE), there is not yet as much activity in this sector as the countries previously discussed. Current projects include resource assessment, simulations, site selection and working on complementary technologies that can be applied to ORE. Vietnam, Myanmar and Thailand have begun studies on the practical application of ORE, whereas Brunei is just starting to look into the theoretical potential. Cambodia and Laos, on the other hand, have renewable energy initiatives, but these have yet to include ORE.

VIETNAM

Vietnam has significant ocean energy resource potential. Because it has a long coast and many gulfs and estuaries, it has high tidal potential of 200–500 MW, mostly concentrated in the northeastern part of the country. Wave potential is high as well, at 350 MW.

Studies in the early 2000s, such as those by the Institute of Transport Science and Technology and the Graduate University of Science and Technology Study, focused on assessing energy potential. However, in the last decade, institutions have begun building and testing their own models and devices.

The Institute of Energy Science at the Vietnam Academy of Science and Technology (IES VAST) has conducted a number of projects, one of which is the prototyping of overtopping devices to capture wave energy. Another is a laboratory-scale model of a 30-W device that generates energy from the pressure of incoming waves against a seawall. They have also done on-site testing at the port of Nghi Son Island, Thanh Hoa. In addition to device development, VAST has also created the Wave Power Station Economic Analysis Software (WPSEA) to study the economic aspects of an ORE project, such as investment, prices and support mechanisms.

Other projects in the country include the study and design of a 10-kW buoy-type wave generator by the National Research Institute of Mechanical Engineering (2010) and a 5-kW vertical-axis current turbine by the Institute for Hydropower and Renewable Energy (2013).

In terms of policy, Vietnam has a general framework for energy efficiency, which includes renewable energy. For instance, Master Plan VI looks to increase the percentage of renewable energy in the country's energy mix, with goals set for 2030 and 2050; it also aims to provide electricity to 600,000 households through renewable energy sources.

Fig.46: Visitors from the Energy Research Institute at Nanyang Technological University (ERI@N), Singapore, at the Institute of Energy Science at the Vietnam Academy of Science and Technology (IES VAST), Vietnam.

Fig.47: Field test of a wave energy device in Vietnam.

Fig.48: A 10-kW wave generator in Vietnam.

Fig.46

Fig.47

Fig.48

MYANMAR

Myanmar has begun looking into some ORE projects, in terms of scouting for potential sites, assessment of potential resources and deployment of technology. One area being considered is the Sittwe Reclamation Project on the bank of Pyisakandi River, which is being studied for wave energy availability. There have also been efforts to develop a 20-kW, plug-and-play ocean energy device. Due to local conditions and facilities available, tidal barrage is also being considered.

The country has a general policy framework for energy efficiency and renewables but nothing specific to ORE. For example, the National Commission for Environmental Affairs' (NCEA's) Agenda 21 looks towards the integration of environment and sustainable development. Myanmar is implementing support initiatives, such as free permits for importing renewable energy devices, as incentives to invest in renewable energy.

Fig.49: Site of Sittwe Reclamation Project in Myanmar.

Fig.50: A 20-kW, plug-and-play ocean energy device in Myanmar.

Fig.51–53: Tidal barrage in Myanmar.

Fig.54: Representatives from the Energy Research Institute at Nanyang Technological University (ERI@N), Singapore, visit Myanmar Maritime University.

Fig.55: Marine Hydrodynamics Centre of Myanmar Maritime University.

Fig.49

Fig.50

Fig.51

Fig.52

Fig.53

Fig.54

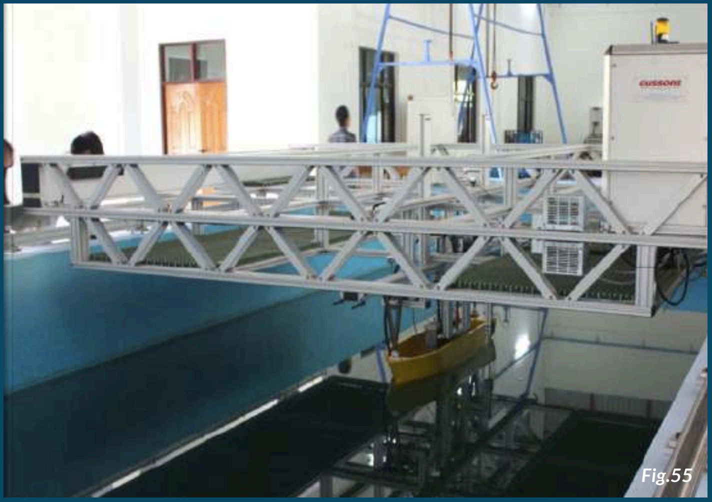


Fig.55

THAILAND

Thailand's work on ORE began with identifying sites with high energy potential. The Joint Graduate School of Energy and Environment (JGSEE) of King Mongkut University of Technology Thonburi (KMUTT) conducted modelling using SWAN (Simulating Waves Nearshore) technology in the Andaman Sea and the Gulf of Thailand. By evaluating the potential wave energy in those areas, they created a season wave energy map identifying areas with high potential for wave energy. They have also developed a lab prototype of a coast wave power generation device as well as installed a model at Sirindhorn International Environmental Park, Phetchaburi, and Ao Manao, Narathiwat. Currently, KMUTT is working with government agencies to seek funding in order to assess more sites and to move forward with device matching and development.

The Alternative Energy Development Plan (AEDP) 2015–2036 targets a renewable energy share of 20% by 2036. The main goal of the energy plan is to reduce the country's energy demand. Although ORE is not currently included in policy, there is on-going research, development and demonstration (RD&D) in the academic sector.

Fig.56: Visitors from the Energy Research Institute at Nanyang Technological University (ERI@N), Singapore, visit King Mongkut University of Technology Thonburi, Thailand.
Fig.57: Gulf of Thailand.
Fig.58: Andaman Sea.


Fig.56


Fig.57


Fig.58

BRUNEI

Brunei has large potential in wave energy (0.66 GW), some in tidal energy (335 kW) and some in ocean thermal energy conversion (OTEC) as well. However, as of now, work on ORE is limited to looking into its feasibility. In terms of the general marine environment, Universiti Brunei Darussalam (UBD) with the UBD IBM Centre has been conducting studies on offshore wind farms, but there are no practical studies on ocean energy in particular.

Although Brunei's energy policy is relatively more focused on the oil and gas sectors, there is a push for renewable energy adoption. With the aims of energy efficiency and a 10% renewable energy share in the country's energy mix by 2035, the government has created organisations such as the Brunei Energy Association (BENA), Energy Efficiency Conservation Committee (EECC), and Brunei National Energy Research Institute (BENRI) to conduct research and development on the country's renewable energy potential. Energy subsidies would go a long way towards pushing investment in renewable energy.

CAMBODIA

Cambodia is currently focused on developing cost-effective and reliable electricity sources powered by renewable energy and to increase rural access to electricity. The government aims to increase the percentage of households with access to the electric grid from the current rate of about 50% to 70%.

LAOS

Laos has likewise been working on the improvement of access to electricity, with the government setting a goal of 30% renewable energy. As the country is land-locked, ORE may not be a viable energy source.


Regional Collaborations and Other Activities on Ocean Renewable Energy in Southeast Asia

Much of the development of ocean renewable energy (ORE) in Southeast Asia (SEA) has been borne of collaboration, and this must continue to be the case for it to further develop and flourish. Among the few pioneering regional collaborations on ORE in the region is the Southeast Asian Collaboration for Ocean Renewable Energy (SEAcORE), initiated by the Energy Research Institute at Nanyang Technological University (ERI@N) in 2013. With member institutions from Brunei, Indonesia, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Vietnam, SEAcORE is envisioned to be a platform for the exchange of ideas, initiatives and experiences from research and development (R&D), policymakers and industry. It forms a collated and active core network of expertise and technical know-how in SEA to set, assist, augment or facilitate the adoption of ORE in the region.

The Association of Southeast Asian Nations (ASEAN) Centre for Energy (ACE) has recognised the efforts of SEAcORE and officially made it the technical working group for ORE in the region. SEAcORE, together with ACE, will drive projects, activities and events that lead to increasing awareness and the uptake of ocean renewables in SEA. Member institutions have undertaken joint projects in resource mapping and assessment, as well as sharing knowledge and resources through country visits, workshops and conferences.

Aside from SEAcORE, there are also other crucial ORE-related collaborations driving its adoption in the region. The Southeast Asian Marine Energy Centre (SEAMEC), an academic, business, community and government (ABCG) regional platform, aims to provide international support and expertise in ORE. The Intergovernmental Oceanographic Commission (IOC) of the United Nations also convened in 2012 to establish a working group on ORE to further advance R&D in the Western Pacific.

Conferences hosted by the region include the Asian Wave and Tidal Energy Conference (AWTEC) 2016, organised by the Sustainable Energy Association of Singapore (SEAS) and ERI@N, and the Asia Clean Energy Summit (ACES) from 2014 to 2018, all held in Singapore.

Fig.59: Meeting between representatives of the Energy Research Institute at Nanyang Technological University (ERI@N), Singapore, and Myanmar Maritime University.

Fig.60: ACE SEAcORE meeting in Kuala Lumpur, Malaysia.

Fig.61–62: Workshop on Ocean Renewable Energy in Islandic Conditions, 2017, at Nanyang Technological University, Singapore.

Fig.63–65: Asian Wave and Tidal Energy Conference (AWTEC) 2016 in Singapore.


Fig.59


Fig.60


Fig.61


Fig.62

Fig.63


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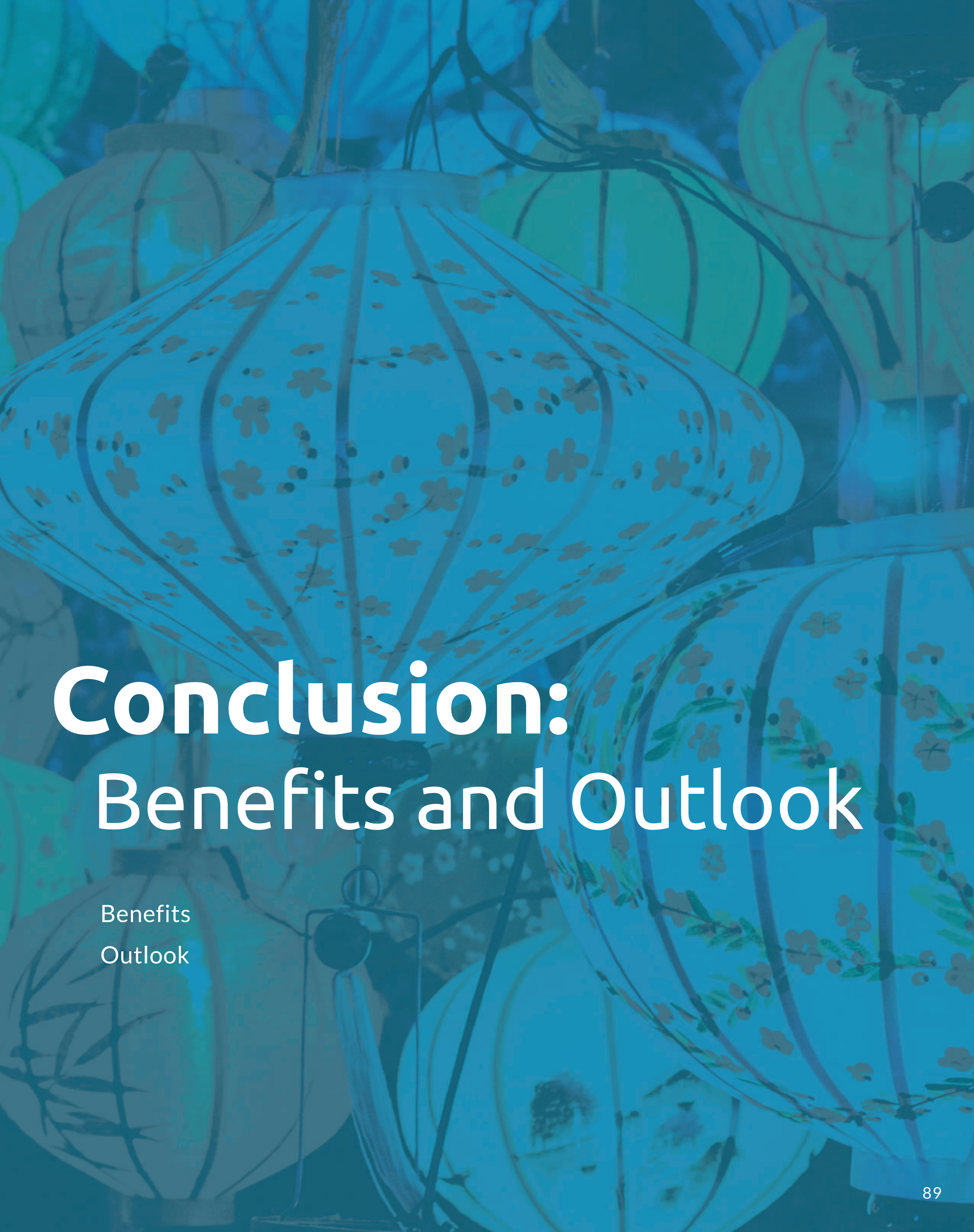
Fig.65



Conclusion:
Benefits and Outlook

BENEFITS

With its vast potential and sustainable nature, ocean renewable energy (ORE) can play a big role in improving access to electricity and in addressing the growing energy needs that come with a growing economy and population, with minimised impact on the environment. This benefit goes beyond the electrification of homes and industry. The power generated from the ocean can be used for many other purposes as well, for instance, treatment of water for drinking, or desalination for irrigation.

On top of a reliable energy supply and environmental benefits, the adoption of ORE has potential far-reaching economic benefits as well: resource abundance due to decreased need and use of finite resources, a burgeoning industry due to power availability and efficiency and increased employment from jobs in ORE. Awareness and adoption of ORE can also lead to community awareness and engagement in being responsible consumers and living sustainably.

ORE technology need not be used in isolation. While devices can be used on their own, they are also resources that can be combined with other resources and used according to what people and areas need. For instance, it has been shown that hybrid systems composed of ORE, solar and diesel components could supply lower-cost, cleaner energy to remote islands, which are numerous in the region.

And then there is the wider picture of a blue economy, where ORE, and marine renewable energy (MRE) in general, works alongside sustainable fishing, maritime transport, tourism and other activities. Collectively, all of these can help us realise the vision of human prosperity in harmony with the thriving of the marine environment and all within it.

OUTLOOK

In comparison to other energy technologies available in Southeast Asia, ORE, although with great potential, is still in its infancy. The region must deal with a few challenges in order for ORE to blossom locally.

The first is price. While ORE facilities are comparatively inexpensive to run and maintain, the initial costs for building are expensive. The second is device suitability. There is a need to adapt available technology developed outside the region to local conditions. The third is a knowledge gap. The region needs more qualified local industry and personnel, as well as training on ORE.

Funding from government as well as the private sector could go a long way towards conquering these challenges. The funding of initial construction costs will pay off in lower operation and maintenance costs; furthermore, ORE facilities have a long life, further reducing costs. Funding can also be made available for the adaptation of technology to suit local conditions as well as education on ORE.

Consistent and stable government policies and policy framework are also essential, as they could significantly lower the barriers to the adoption of ORE. Supportive policies could come in several forms, including lowering restrictions on importing ORE technology and feed-in tariffs, which pay energy users, from households to businesses, for any renewable energy they generate. Such support mechanisms make ORE a more attractive endeavour for industry as well.

Finally, collaboration and knowledge sharing allow different organisations across different countries to combine knowledge and expertise, allowing faster and wider adoption of ORE.

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About OceanPixel

OceanPixel is a Singapore start-up incorporated in 2014, having spun off from the Energy Research Institute at Nanyang Technological University (ERI@N). The company provides intelligence to the marine supply chain.

The core team has combined expertise in sustainable energy research, development, demonstration and project development, and experience in the relevant industry ecosystem, business, finance, policy and education.

Offering data catalogues, report products and technical services, OceanPixel has various global involvements and currently handles projects in Singapore, Indonesia, the Philippines and the wider Southeast Asian region, with potential projects in other parts of Asia and beyond (e.g. Maldives, Mauritius).

Projects include survey supervision and execution; data processing and simulations; project management and execution (deployment, operations etc.); R&D (design, testing, data acquisition); and report products.

For more information about the contents of this book or to learn more about marine renewable energy endeavours, please contact info@oceanpixel.org.

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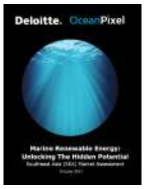
Capul–San Bernardino Tidal Power Preliminary Assessment



OP–Deloitte Southeast Asian (SEA) Market Assessment Report on Marine Renewable Energy

San Bernardino Environmental Risk Map

San Bernardino Environmental Risk Report

San Bernardino MetOcean Conditions

Status of Ocean Renewable Energy in Southeast Asia Report

About SEED4COM

Sustainable Energy and Enterprise Development for Communities

SEED4Com is a non-profit organisation with a focus on providing renewable energy solutions to last-mile communities, promoting sustainable development, fostering social enterprise and saving the environment. The organisation is committed to helping disaster-hit, poverty-stricken rural communities in the Philippines and improving human conditions by empowering them to attain economic and social development and environmental sustainability.

To fulfil its mission, the organisation aims to introduce renewable and clean energy initially as emergency response and eventually provide long-term alternative and sustainable energy solutions; to provide skills training programs for livelihood, including the installation and maintenance of clean energy solutions, and facilitate establishment of community-based social enterprises to make the communities become self-sustaining; and to organise local communities develop their sense of awareness of environmentally friendly and clean energy solutions and inculcate individual responsibility to own, lead and manage community-based initiatives.

For more information about SEED4Com, please visit http://www.seed4com.org or contact diezdt@yahoo.com.

"Tidal in-stream is one of the most proven among marine renewable energy technologies for Southeast Asia. This is a renewable energy solution to reduce electricity price and fuel subsidy in small remote islands currently relying solely on diesel power generation."

–Engr. Roger Chua

LUS Energy System Solutions

"Our demonstration project in Bintuni Bay [Indonesia] proves that tidal stream renewable energy is quite simple to develop and operate."

–Muljadi Tantra

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