Prospects and Risks of Marine Renewable Energy: Empowering Our Generation from Oceans Away from Climate Change, Regenerating Our Sustainable, Climate Resilient, Blue Economy Future From A Post COVID19 and Non-Fossil Powered Age.

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Glossary/List of Abbreviations and Acronyms:

ADB:	Asian Development Bank
AFDB:	African Development Bank
AIMS:	African Union Integrated Maritime Strategy
CARIFORUM:	Caribbean Regional Forum
CMEP:	Commonwealth Marine Energy Programme.
CSIRO:	Commonwealth Scientific and Industrial Research Organisation
EMEC:	European Marine Energy Centre
FAO:	Food and Agricultural Organisation
GW:	Gigawatt.
GWEC:	Global Wind Energy Council.
IPCC:	Intergovernmental Panel on Climate Change
IRENA:	International Renewable Energy Agency
KWh:	Kilowatt Hours
MW:	Megawatts.
NRDC:	Natural Resources Defence Council
OEE:	Ocean Energy Europe
OES:	Ocean Energy Systems
OTEC:	Ocean Thermal Energy Conversion
SOPAC:	South Pacific Applied Geosciences Commission
UN:	United Nations
UNDP:	United Nations Development Programme
UNECA:	United Nations Economic Commission for Africa
WB:	World Bank
WWF:	World Wildlife Fund

Executive Summary/Abstract

As global climate change, current society, livelihoods and economies jeopardise not only business as usual but our, our ecosystem and planet's very existence; more and more stakeholders are becoming more proactive and conscious from policymakers at the 2015 Paris Climate Change Agreement to private sector commercial and investor initiatives such as Climate Action 100+ and the Global Investors Group Coalition on Climate Change to activists such as Greta Thunberg, communities, SIDS's and those far less conspicuous but also committed to change. Still others are committed to the concept of the blue economy and harnessing the oceans to provide more sustainable radical solutions towards preserving our cultural, ecological, socioeconomic and general heritage. This research's conceptual contribution is to consider how each of these two approaches can be reconciled via the concept of marine renewable energy and investigating the extent to which it can be utilised to empower the blue economy, whilst simultaneously moving from fossil fuels and a current carbon dominated and powered world. It aims to assist those concerned about the green, blue, climate and circular economy transitions; to understand the possible extent and role that the emerging sector of marine renewable (MRE) and ocean energy may potentially play. It provides an impartial, non-affiliated, external approach by a professional blue economist to evaluate many of the risks, prospects and consequences of this under-investigated, under-appreciated sector.

The International Renewable Energy Authority (IRENA) and United Nations Economic Commission for Africa estimate up to 400% of present global energy demand could be satiated by ocean energy transmission and distribution with over 120 GW at present. It offers potential to generate up to 2000 to 4000 TWh per year. Yet this source is among the first to synthesise over 150 leading sources in Literature Review chapters to identify the core successes, failures and components necessary towards implementation. It recognises that to implement MRE effectively, participants need to develop a supply chain and interconnecting economy, fathom stakeholder requirements, establish site specific criteria, effective, policies, legislations and incentives to undertake these. This research differs from other previous scholarship in providing these, to simplify and accelerate the market process. It identifies the not only past MRE developments but insight into contemporary market demand, supply, the industry stakeholders and trends and stages of technological progress necessary to consider participating and investing. The existing and potential sites, institutions and stakeholders are involved. This seeks to overcome the time, research, labour, scarce skills and education along with other constraints typically required to accelerate any emerging blue or general economy sector.

In 2019 one market survey estimated a minimum of 180 ocean energy test and market activities exist globally with 109 tidal energy, 58 wave, 12 OTEC, 1 salinity and a number of offshore wind/0 marine bioenergy. In 2013 OES estimated world tidal market revenue exceeding 200 billion pounds, wave energy exceeding 750 billion pounds and annual servicing/maintenance income of 14.25 billion. Ocean Energy Systems (OES) aim to facilitate MRE development to reach up to 337 GW, create and sustain over 1,200,000 jobs and avert over 1 billion tonnes of CO_2 emissions. OES forecasted a current 2020 market worth 26000 direct jobs, 13,000 indirect and gross value activity. It aims to have over 300 GW in installed capacity and 680,000 jobs by 2050. One subobjective is to achieve over 100/300 GW potential in total tidal and wave capacity. Market prices or levelized offshore wind tariffs in developed nations such as Europe to supply grids have decreased as technology improvise from $150 in 2000 to over $200 per MWh in 2010 to around $50 in 2025, ensuring it is increasingly more cost effective for national grids, policymakers and consumers to consider

2019 global total renewable energy (land and marine); was 2,537 GW off installed capacity, estimated 72% of the global total capacity with only 28% of new capacity as fossil fuelled. This reflects a significant historic increase since 1,227 GW in 2010. This is aided by significant adverse publicity and calls for the financial sector to divest from coal, oil and natural gas powered sources. Wave, wind, tidal, current, ocean thermal energy conversion (OTEC), floating solar voltaic, salinity gradient and bioenergy offer unprecedented advantages and potential disadvantages. These include myriad economic/fiscal, social, environmental, educational and training, technical, legal, strategic, geopolitical, security and others. However, this report highlights these as conditional upon managing and responding to certain risks including climate change, market information, socioeconomic and markets, legal and regulatory uncertainty, marketing or popular acceptance; psychological and reacting with people; technological, competitor; IP and patents', commercialisation and general inexperience; access to finance and general constraints of developing nations/small island developing states or remote communities.

It concludes by emphasising multiple opportunities that exist from capitalising on markets and providing reliable energy, resource security, import substation and other benefits to various blue economy sectors. These include ports, shipping and navigation; navies, security, defence and warfare; drones, AI, oceans governance, the 4th Industrial Revolution and risk management including climate change, poaching, piracy, climate-oceans, oil spills, accidents and marine pollution reduction. Others include aquaculture and fisheries, marine spatial planning, communications and Big Data/4th IR, technology, coastal, marine, nautical and eco-tourism. It offers potential for small islands and remote communities, water security and desalination; energy and water security, underwater culture, maritime research, education and training; seabed and seawater mining, offshore oil and gas along with shipbuilding, conversion and repairs. Others include empowering COVID 9, pandemics and humanitarian logistics, creating ecosystem restoration and reserves, artificial reefs and other activities, artificial habitats/cities and undersea/ocean Exploration. MRE can tap into many significant markets. AUV's are envisioned to reach US$ 1,206,000,000 by 2020 (from $309,000,000 in 2016 or 23.19% of market share) with few specifically devoted to the maritime sector. Global aquaculture is projected to reach $274.8 billion by 2025 according to the FAO, providing multiple microgrid opportunities. Global fisheries are conversely forecast to reach $438.5 billion. Marine biotechnology is predicted to grow from US$ 3.5 Billion in 2017 to US$ 6.5 Billion in 2022 Priorities need to move beyond pilot scale to commercialisation. Successful implementation will remain conditional upon allocation of sufficient resources, following stakeholder requirements, conducting ocean resource assessments, markets and ecological surveys, ensuring sufficient mass individual, community and investor awareness. It also requires sufficient priorities in research, training and augmented institutional capacity that reward the blue economy and MRE, whilst penalising fossil fuel sector-based activities, sources and stakeholders.

CHAPTER I: INTRODUCTION AND BACKGROUND

1.1: Overview to Climate Change Risks, Marine Renewable Energy and the Blue Economy

Commitment to a fossil fuelled economy, society and lifestyle is no longer practical. Electricity generated by oil, coal, gas and to a lesser extent nuclear, has systematically accelerated climate change to an all too real threat jeopardising the future of many African and global nations. Increasing emission temperatures, sea level rises, species migration, biodiversity loss and extinction, ocean acidification for coral reefs and a combined actual or projected increase in the duration, frequency and intensity of climate-related natural disasters mean that we can no longer afford to dismiss the problems and react as business as usual. Petroleum, oil and diesel transport create too many ecological hazards including spill and emissions risks. The unusual scientific community and credible peer reviewed evidence of institutions such as the Intergovernmental Panel on Climate Change, have led to many global nation pledges initially under Kyoto in 1992, and even more under the 2015 Paris Agreement. Global financial institutions, individuals, corporations, communities and nations are pledging to divest away from fossil fuel linked investments, commit to initiatives such as the 2018 UNEP Sustainable Blue Economy Finance Principles and take committed action.

Globally, increasing attention has been towards more inclusive impacts, preserving society, ecosystems/environment and cultural heritage, beyond the economy; as manifested in commitments to sustainability, waste minimisation, economy and efficiency, under the blue, green and circular economies. Humanity has increasingly prioritised the ocean or blue economy to exploit or utilise on its $1.5-3 trillion minimal estimate value of blue natural capital. Ocean energy has received minimal initial attention in European Union's (EU's) Horizon 2020 and FAO Blue Growth Vision to the Atlantic Strategy; INTERREG, Asian Development Bank's Blue Oceans Action Plan, World Bank's PROBLUE, the Commonwealth Blue Charter, Commonwealth Marine Economies Programme (CMEP) and others. It has also appeared in the African Package for Climate Resilient Ocean Economies, African Union Integrated Maritime Strategy (AIMS), the Mauritius Ocean Economy National Development Plan and Seychelles Blue Economy Roadmap and UNECA 2016 report on Africa but unusually not in South Africa's Operation Phakisa including ship repair, maritime education, aquaculture, marine tourism, oil and offshore gas or many other approaches. Ocean or Marine Renewable Energy could assist the African Development Bank in its aims to "*Light up and Power Africa, "Feed Africa, "Industrialise Africa", "Integrate Africa"* and "*Improve the Quality of Life for Africa."*

Ocean renewable and thermal energy has been considered promising yet underfunded and supported since 1981. The International Renewable Energy Authority (IRENA) and United Nations Economic Commission for Africa (UNECA) estimate up to 400% of present global energy demand could be satiated by ocean energy transmission and distribution with over 120 GW at present. Geographically, marine renewable energy projects are yet to be commercially pursued across Africa, with most in Europe, the USA and Asia. IRENA estimate offshore wind energy could rapidly accelerate from around 22.8 MW inn 2019 to 228 MW by 2030. Installed land wind power was worth over $1.8 billion per year in 2013 alone. Global tidal energy has been estimated as potentially adding more than a TW to current capacity by IRENA. A 2019 report by the World Bank estimated Morocco alone could supply 178 GW from offshore wind energy and South Africa 589 GW.

Therefore, this research's conceptual contribution is to address existing asymmetrical information and uncertainty, experienced by many stakeholders in harnessing ocean energy for sustainable developments and climate resilient ocean, blue or circular economies. This includes: "H*ow to implement it? Which technologies to select and why? Where should resources be channelled and which are needed?" What is the current status and what future opportunities should receive initial focus, given finite time, budget, research, staff, opportunity costs and other resource constraints?"* Superficially at present, current African projects exist in North Africa, Nigerian experimental tidal power, South African wave/offshore wind and current energy efforts and Ghana wave/wind interest or Kenya desalination and tidal energy off Mombasa. Ghana has a 0.4 MW wave energy plant off Ada Foah since 2015. Tapping into Nigeria's coastal basins was estimated by one source to reduce costs from $7,900 per KWh to $2,500. Mauritius are investigating the feasibility of a 10 -20 MW offshore farm. South Africa has undertaken several research initiatives with promise including the Agulhas Ocean Current via Minesto Deep Green turbines; wave energy converters off East London, the Southwest coast and elsewhere. Its Department of Environmental Affairs has already published 2015 guidelines for ocean wind, waves and waste energy, even though few projects exist. In 2003 it estimated over 56,000 MW could be generated. Other theoretical work relates to thermal energy and salinity gradient differentials including a very brief guide for local South African governments. In 2013 stakeholders proposed the formation of an Ocean Energy Network but it failed to gain political and popular support or attention.

If we are to continue our economies, societies and existence during and after COVID-19, it becomes more and more crucial to focus on how we can sustainably secure reliable, continuous, cost-effective and ecologically considerate means of electrical energy generation. Although fossil fuels may be initially perceived as cheap; the example of Eskom which crippled the South African economy for 12 years against renewable alternatives due to vested interests along with the global preoccupation and myriad conflicts in petroleum based nations from the Middle East to Libya, Nigeria, Venezuela and Angola reveal more accurate costs. Dutch disease remains a peril. However, this research envisions it on a practical level to radically regenerate our future more sustainably. It can especially empower many coastal areas/cities, ocean based activities and shipping fleets. A future vision for ocean energy includes supporting smart blue ports, small harbour, marinas and associated activities. It includes empowering drones and navies for greater ocean governance, safety and security. It protects aquaculture and fisheries via additional food security and risk mitigation from uncertain land power connections. It could apply to deep sea exploration and data information; undersea communication cable repairs and desalination. It could support eco, cruise, marine and nautical tourism; artificial floating cities and reef habitat regeneration. It could aid in species biodiversity recording and reserve established. It could even aid considering if seabed mining or offshore oil and gas are really necessary or ecologically viable.

It especially can benefit small island developing states and territories such as the Comoros, Cape Verde, Sao Tome and Principe, Mauritius, St Helena, Zanzibar and further. Others include the Cook Islands, Nauru, Niue, Palau, Samoa Tonga, Tuvalu, Maldives, Montserrat, Anguilla, the Virgin Islands, Antigua and Barbuda, ABC Islands, Bahamas, Barbados, Cayman Islands, Turks and Caicos and others where physical space, elevation and sea level rise encroach as a premium cost to any shore based development of wind, solar or fossil fuel. It reduces the need for import and reduces nuclear waste risks as for the Marshall Islands. If we do not, then the consequences of failing to prioritise action may be unpredictably catastrophic in exceeding Earth's ecological capacity to absorb carbon and continuing to plunder increasingly scarce and finite resources unsustainably. There will also remain a certain economic imperative demand for shipping, ports and aquaculture, among other activities in the absence of many nations attaining self-sufficiency, creating a certain market for ocean energy; the challenge remains to harness it. As global pressure exists for more technological innovation and the 4th Industrial Revolution, including the move to work remotely from the COVID-19 pandemic, electricity is needed to progress and it has to be sustainable. It could even apply to empowering yachts and other vessels fleeing from the projected chaos of any global event, each time in port or moored offshore. The aim should be to strive towards climateproofing and prospering from marine renewable energy sustainably, regardless of how the world progresses.

Comparatively few global reviews provide an independent professional evaluation as to how marine renewable energy can be implemented towards a sustainable, climate resilient, blue economy future. This research aspires to consider moving beyond fossil fuels to effectively climateproof against disruption where possible. It seeks to elucidate emerging risks, technologies, investments, markets, frontiers and opportunities. This proposal/conceptual piece of scholarship specifically concentrates on how marine renewable or ocean energy can be harnessed for sustainable development, as among the pioneering African-centred approaches by a local, to assist the African Development Bank, World Bank, governments, businesses, NGO's, academia and other stakeholders. It recognises a current research gap exists as many of the above international and African specific initiatives may refer to ocean or marine renewable energy broadly but without attention to practical means of implementation. Therefore, subsequent sections specifically concentrate on a Literature Review of initial and existing policies, related initiatives, institutions, stakeholders, research and markets (Section 2). This will assist in determining potential markets, demand and supply (Section 3), along with current options, challenges and opportunities for ocean renewable energy. This extends to various types including the feasibility, institutional capacity, resources needed and potential prospects of Wave, Wind, tidal, current, thermal, LNG-shipping, salinity gradient, bioenergy -biotechnology and circular economy along with other sources. It will specifically highlight future emerging opportunities for the blue economy and discoveries/funding. Section 4 will outline conclusions, study limitations, implementation recommendations and directions for future research

Chapter 2: Literature Review

2.0: Introduction

Chapter 2 provides a structured, thematic and issues centred, Literature Review as a basis to identify existing sources related to marine renewable energy as an emerging blue economy sector. This includes establishing and defining the significance of the blue/oceans/marine economy (Section 2.1.1) prior to specifically concentrating on the definitions and characteristics of specific marine renewable energy (MRE) types. Examples include offshore wind, wave, tidal, current, thermal, salinity gradient, floating solar voltaic and bioenergy -biotechnology/algal biofuel and others relating to LNG-shipping, desalination or unconventional electrical energy generation. Section 2.1.2 considers specific characteristics/concepts of MRE versus traditional renewable energy. Section 2.2 then identifies actual stakeholder requirements and priorities, types across a potential supply chain and resources/site specific criteria necessary to establish potential energy types and networks.

Section 2.3 then highlights existing and potential policies, legislations and guidelines that could be utilised to provide greater legal/regulatory certainty for policymakers, businesses and other interconnected stakeholders. Section 2.4 then considers the features and lessons learnt from existing case studies successes and experiments, whilst Section 2.5 highlights existing failures and issues. Section 2.6 emphasises existing research gaps, theoretical motivations and directions forward to justify the subsequent methodology and theoretical/actual significance of this research. These all aim to subsequently assist in creating a sustainable blue economy future via a comprehensive synthesis of existing related, MRE research. It aims to minimise finite, scarce resources and associated opportunity costs to determine whether this sector should be prioritised in direct response to climate change and the quest for less emissions intensive means of energy empowering ocean/coastal sectors and communities. Existing experience improves the effectiveness of implementation or avoiding it related to ocean/marine energy for investors, researchers, value chain stakeholders, individuals, governments, nongovernmental organisations, communities/civil society and all other participants directly or indirectly affected.

2.1.1: The Blue/Marine/Ocean Economy

Previous Research by this research and available on the www.blueeconomyfuture.org.za website has extensively reviewed blue economy characteristics as a more ecologically, socially, economically and technically long term sustainable, recent variation of the ocean or marine economy. This is often geographically defined in relation to the coast/seas/oceans or maritime sector. It is projected to increase from US $1.5 trillion in economic activity and 31,000,000 direct jobs to over $3 trillion and 45,000,000 jobs between 2010-2030. In response it has attracted increasing global attention and priority via myriad initiatives as detailed in Chapter 1. This includes those not only related to fisheries, ports, tourism, offshore oil and gas, seabed mining, biotechnology and maritime technology/education but marine renewable energy (MRE) as envisioned by this research. This scholarship aims to focus on MRE specifically as an emerging blue economy opportunity in direct response to climate change risks, the need for mitigation and adaptation simultaneously and the subsequent ascendency of sustainable ocean finance, technology and other current trends and developments.

Although various experiments have been conducted over the past few decades, few have proven commercially viable when scaled up or received significant interest until climate change and the blue economy have dawned as comparatively recent areas of global focus. Past research by this source has focused on various blue economy areas as above but not specifically for marine renewable energy.

Subsequent priorities will consider ocean governance, marine spatial planning/protected areas and seabed/sea mineral mining. This research considers MRE to offer under-investigated options and horizons as a core research gap, especially when related to the blue economy as its conceptual contribution. Previous studies have also neglected the characteristics, advantages, disadvantages, risks and opportunities of specific marine renewable energy types, definitions and characteristics as in following times.

2.1.2: Marine Renewable Energy Types Definitions and Characteristics

Although no formal definition of Marine Renewable Energy exists, this section defines it as *"electrical energy or power generated and utilised continuously from ecologically sustainable, non-fossil fuel powered ocean, river, lake, marine, offshore or coastal related sources,"*

Examples recognised by the International Renewable Energy Agency (IRENA) detailed in this research extend to offshore wind, wave, tidal, current, thermal, salinity gradient, floating solar voltaic and bioenergy - biotechnology/algal biofuel. IRENA have published detailed overviews on the status and development of most of these sources with the exceptions of floating solar voltaic. The Intergovernmental Panel on Climate Change recognises the potential of wave, tidal range, tidal currents, ocean current, salinity gradient and ocean thermal energy (Lewis and Estefen 2013). Few nations have global potential for all these energy sources such as Australia, the US, Brazil and others yet to be fully determined but all coastal regions should have some potential in conducting an ocean/marine renewable energy analysis and applying it to the blue economy (CSIRO 2012).

2.1.2.1: Offshore Wind Energy

Offshore Wind Energy is powered via wind turbine-based propulsion (IRENA 2016), similar to onshore based but with windmill-based technology moored out at sea. It is well established not just at a test or pilot research stage but commercially with over 12 GW globally. Depths reach up to 50 metres and distances from shores connect up to 80 kilometres at present. Although only at a pilot phase in the US and present in China, Europe has over 54 wind farms present across the United Kingdom, Denmark, Netherlands, Sweden, Belgium and Germany.

2.1.2.2: Wave Energy

Wave Energy directly harnesses ocean, sea or other waves via various air and hydraulic turbine propulsion-based systems and technologies Wave energy generation technology types include submerged pressure differential devices, attenuators, point absorbers, bulge wave devices, terminators, parabolic reflectors, rotating mass converters, oscillating wave energy converter, (oscillating water columns, oscillating body converters and overtopping converters (US Department of Energy 2009; IRENA 2014(c); Muzathik 2017). It is the second most established marine energy source with multiple commercial and pilot applications globally, after offshore wind. Costs are currently estimated at an average of 330-630 euros per MWh but projected to decrease to 113-226 euros as technology improves. Global wave energy appears one of the most abundant potential sources at over 500 GW. Wave energy is often most potent around latitudes 30-60 degrees with a global potential up to 29,500 TWh per year. These are divided into shore, near shore and offshore devices. Characteristics of global wave energy rely on a control, power take-off, connector and transmission system (currently the most expensive component for many), the prime mover/structure harnessing the electricity and the foundational structure linked to the seabed or platform. A wave energy park may need the anchors and floats, mooring cables, tendons and catenary lines. Equipment can benefit from observational drones, buoys and satellites. Wave energy converters can employ air, seawater and pressure oil as fluids

Wave energy examples include Aquamarine Power, Wave Star, Pelamis Wave Power, Wave Dragon, Wave Cat, Oyster, Wave Roller, Aqua-Buoy, Mighty Whale, TAPCHAN, Penguin, Oceanus, the Archimedes Wave Swing, McCabe Wave Pump and others (Global Energy Network Institute 2009, US Department of Energy 2009; IRENA 2014(c); Muzathik 2017). In 2013 an extensive detailed analysis of various wave energy converters currently on the market was provided by one source (Joubert et al. 2013). Examples are Companies include Eco Wave Power, Carnegie Wave Energy, Oceanlinx and Ocean Power Technologies. Others are Anaconda, MRC 1000, Seabased AB, Wave Rider, Wave Energy Buoy, Aegir dynamo, Wave Plane, Wave berg, CETO II, C Wave, PS Frog, Ocean Star, Poseidon, Surf Power, Synch Wave Power Resonator, Oceanstar, Centrepod, Triton, Motor Wave, Eel Grass, Pontoon Power Converter, Tetron and Hydro Air. Successful locations include Wales and the USA. Fixed wave energy technology can have an average depth range of 5-50 metres, 2.8-60 KW/m power range and output of 5-2000 kW (Felix et al 2013). In contrast floating wave energy technology can have a depth range of 2-2500 metres, 4-100 KW/m mean wave power range and 4-2250 W power output. An alternative energy source arises indirectly from the hydrogen potentially derived from wave energy, although this has yet to be pursued beyond the experimental/theoretical stages (Blanco-Fernandez and Arribas 2017). Production could potentially occur via electrolysis, biomass fermentation, biolysis, oxidation or gasification. Onn average around 76% of hydrogen production costs is electricity, 17% capital, 6% operation and maintenance and 1% for average variable costs. Global wave energy sources are geographically situated in Figure 2.1.

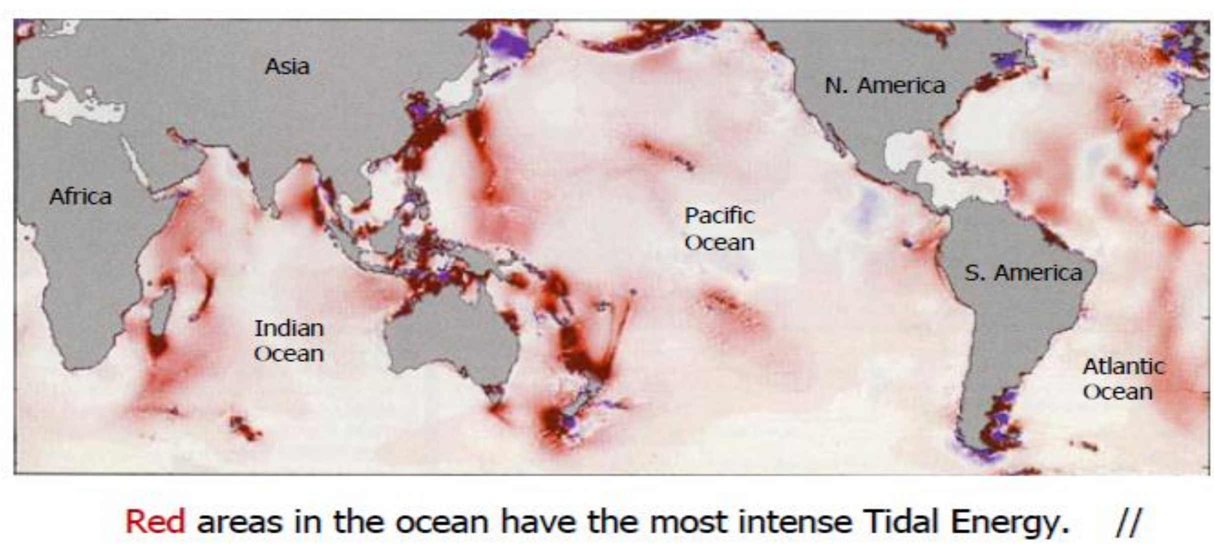
Figure 2.1: Global Wave Energy Generation Source in kW per Metre of Ridge.

Source: Muzathik 2017.

2.1.2.3: Tidal Energy

Tidal energy is well recognised and established relating to Earth's tides and gravity force connections to the Sun and Moon utilising turbines via either streams, artificial reefs, fences, lagoon, currents or dams (tidal range). Tidal barrage or dam infrastructure include the barrage itself, sluice gates, slip locks, connecting transmission grid, turbines, generator and energy storage relying on the tides for propulsion (Chandran, Arsha and Johny 2015). Tidal fences have similar basic infrastructure but deploy vertical axis turbines instead and are more open with a caisson structure and rotations from tidal currents. Tidal basins can obtain energy via pumping, ebb/outflow, flood or a two way combination of both the ebb and flood generation. Another variant employs the Venturi effect. For tidal energy the blade speed and length, pressure differential, reservoirs, collectors and turbine speed influence the extent of electricity produced (MER 2010). To minimise potential ecological effects best practise recommends deterring species via sound, light and colour. Tidal range developments and prototypes exist in India, Korea, Russia, the UK and the Philippines but 5 commercially operated from 1960 to 2012 in Canada, China, France and Russia. Global energy potential capacity is at least a TW. Effective tidal energy requires a 1.5 metre per second and dependent on the flow of 6-12 hours per day. Production costs range between $0.07-0.47 per KWh. The most potentially effective sources have been geographically identified in previous research as in Figure 2.2 (Anderson 2007). Examples of tidal energy pilot projects and companies include Hyundai, Kawasaki and Voith Hydro (IRENA 2014(b) Corlon Hafran near Bristol England and Swansea Bay Tidal Lagoon in Wales, the Netherlands and a tidal fence in the Philippines, Andritz Hydro, ABB, Astrom, GDF Suez and DCNS are a few examples of commercialising pioneers. Infrastructure includes a transmission/shore connection grid, the turbines, array formation, generator and foundational support linked to the seabed. Levelized costs of energy production range from $0.25-0.47 on average.

Figure 2.2: Tidal Energy Sources.

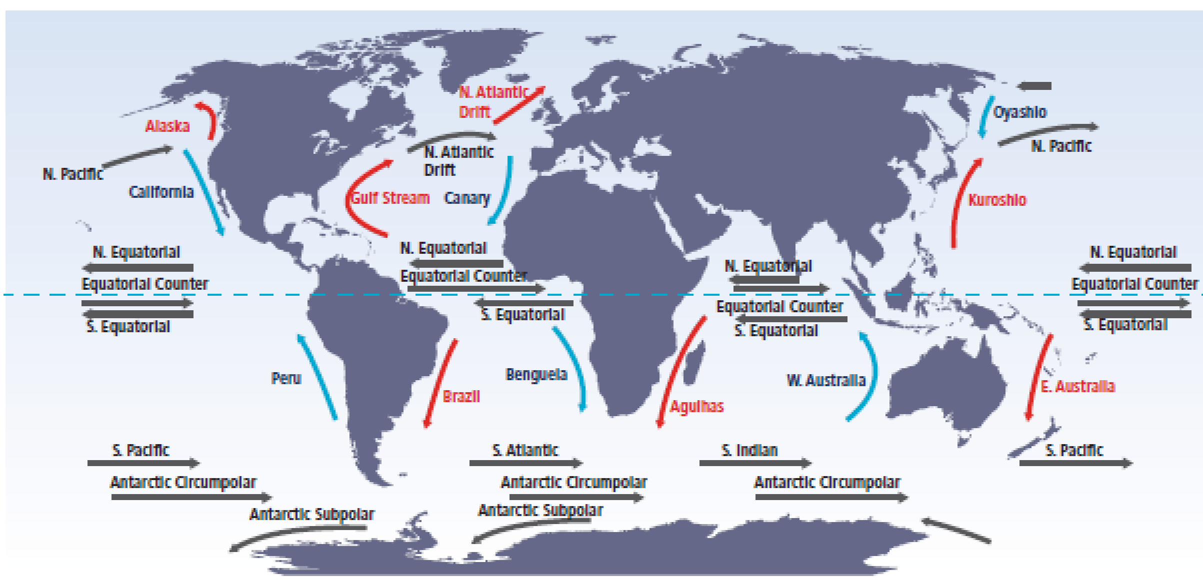


Source: Anderson 2007.

2.1.2.4: Current Energy

Ocean current energy is powered via thermohaline ocean circulation and winds (IRENA 2017b). It offers only pilot scale projects at present and is restricted to geographical areas near currents as in Figure 2.1. One variant utilises hydrokinetic energy, turbines and hydrogen storage schemes (Tsakyridas et al. 2017). Conventional current energy converters include horizontal, ducted horizontal and vertical axis turbines along with oscillating hydrofoils (wing based) (US Department of Energy, 2009). Marine current energy will also need conversion arrays, turbines and initial current flow or measurement surveys (Bahaj 2013). One study focusing on the USA and ocean current potential from the Gulf Stream (Georgia Tech Research Corporation 2013) recommended the need for a current velocity, power density, flow and effect database to be established prior to construction. It estimated potential up to 45 TWh per year. Industry stakeholder examples include Blue Energy, Open Hydro and Tidal Generation.

Figure 2.3: Global Ocean Currents as Potential Energy Sources.

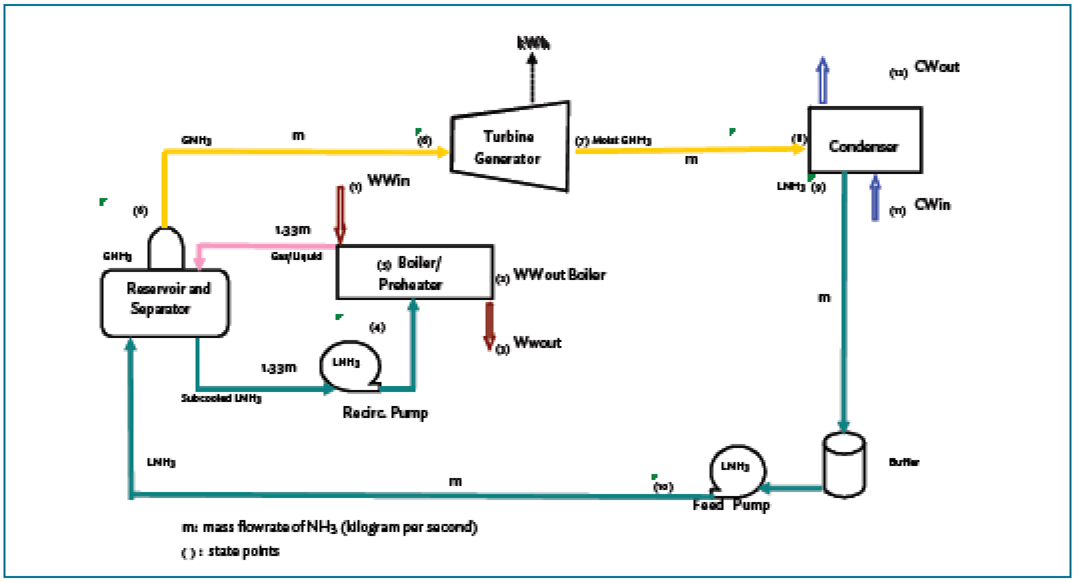


Source: Bahaj 2013.

2.1.2.5: Thermal Energy

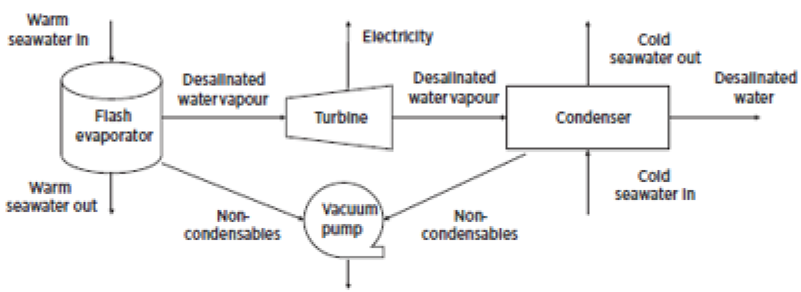
Ocean thermal energy conversion (OTEC) exploits divergences in warmer and cooler ocean temperatures. It is often divided into closed cycle systems exploiting ammonia for refrigerant turbine energy propulsion and open cycle systems which utilise seawater directly or marine hydrokinetic energy from ocean currents (Bane et al. 2017). A third variant employs a hybrid system using water and ammonia or the Kalina cycle (IRENA 2014a). An example of a closed cycle system is highlighted in Figure 2.4 and open cycle process in Figure 2.5. OTEC are most effective with around a 20 degree Celsius temperature differential but can operate 24/7 rather than being constrained by solar energy, tides or winds. (Etemadi et al. 2011; Dugger et al. 2015). Open Cycle power plants first undertake warm seawater flash evaporation then subsequent steam vapour is turbine rotated to transfer thermal energy via the cold seawater and condenser, compressing the desalinated water and releasing the electrical energy. Ocean Thermal Energy Infrastructure also needs access to salt water/divergent temperatures, a surface condenser, water tank, ammonia, turbogenerator, fluid pump, turbines, evaporator, transmission grid and seabed cable/foundation, pre-desecrator and liquefaction system. OTEC facilities need a transmission and connection grid system, turbines, water ducts/cold water pipes, flash evaporator, heat exchangers, a vacuum pump and a moored/land/floating platform (IRENA 2014 (a)). One research has even proposed how OTEC facilities can be adapted to more sustainable fisheries via methanol, ammonia, CO_2 dissolution, hydrogen liquefaction, water electrolysis and desalination production (Golmen, Masutani and Ouchi 2005). Electricity costs can reach $0.25-0.75 per KWh. With economies of scale it is estimated to become more economical at $0.07-$0.19 per KWh. Pilot scale projects exist up to 1 MW globally including the US such as the New England Marine Energy System and Canada. Ocean thermal energy is most powerful within Equatorial regions but benefits from extreme temperature differences such as the Caribbean, Pacific and Africa. Industry stakeholders incorporate OTEC International, SBM Offshore, Lockheed Martin, Offshore Infrastructure Associates, Energy Island Ltd and Ocean Thermal Energy Corporation.

Figure 2.4: Ocean Thermal Energy Closed Cycle Conversion System



Source: Global Energy Network Institute 2009

Figure 2.5: Ocean Thermal Energy Open Cycle System

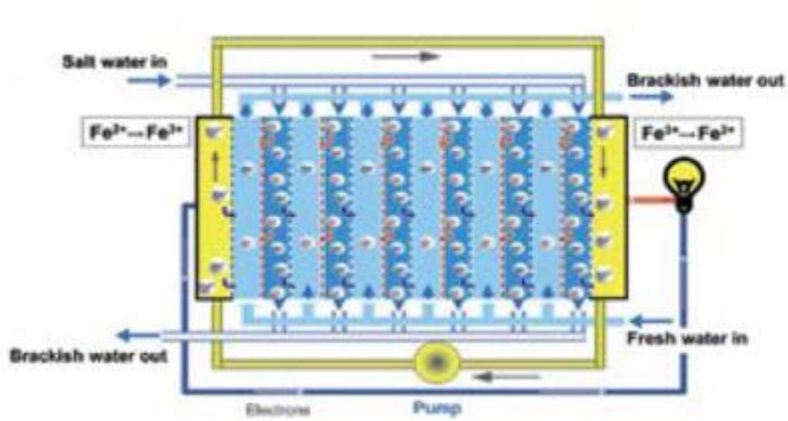


Source: IRENA 2014(a).

2.1.2.6: Salinity Gradient Energy

Salinity gradient energy operates similarly to ocean thermal energy but exploits salt concentration differences between fresh and coastal/ocean water and is therefore confined to limited rivers/streams/coastlines unless extracted from energy recovery processes and brine. It offers mostly pilot scale projects globally via 2 different turbine and pressure exchanger technologies based on permeable membranes or Pressure Retarded Osmosis or semi-permeable membranes via chemicals and electrodialysis (Figure 2.6) (I Post 2009; IRENA 2015(a); IRENA 2017; Soukissian et al. 2017). It also requires biofouling prevention processes of the sensitive membranes when constructing and maintaining. Salinity gradient energy has been estimated as a theoretical potential of 3158 GW, mostly in Asia and South America. It offers a global estimated generating capacity of 647 GW. Pilot companies include Porifera, Pentair X Flow, Fuma-Tech, Osmo-Blue, Oasys Water, Statkraft and others. Experiments have been conducted in the US, Canada and Norway among others. It is proving to be extremely economic at present with estimates ranging from $0.09 to $0.28 KWh.

Figure 2.6: Reversed Electrodialysis, Salinity Gradient Energy Generator



Source: IRENA 2015(a).

2.1.2.7: Floating Solar Voltaic Energy

Floating Photovoltaic involves solar panels on a floating pontoon operating similar to conventional solar electricity on land. Certain examples have even linked to the circular economy in being completely recyclable. Certain estimates have indicated even greater thermal energy conversion efficiency factors than their land centred counterparts from the ocean. A government example pilot exists in New Zealand.

2.1.2.8: Bioenergy

Bioenergy refers to organic derived, electrical energy being produced such as algae (macro and micro), cyanobacteria and regular bacteria, seaweed, biomass, bacteria and other compounds. Production processes involve harvesting, extraction, pyrolysis, gasification, liquification, processing and anaerobic digestion. Examples have been restricted to experimental pilot project form including algal biofuels and cross-sectoral interlinkages with marine biotechnology (US Department of Energy 2010). One marine bioenergy application is for shipping biofuels to ensure greener, less emissions intensive transport (Hsieh and Felby 2017). This could be extracted, converted and refined from not only marine bioenergy sources but bioethanol, thermochemical, oleochemical, fermentation, emulsion and blending. This sector is projected to accelerate in value from the mandatory 2020 IMO Sulphur Cap fuel emissions regulations and a 50% reduction aim of total global emissions by 2050. Advanced biofuels have yet to fully commercialise beyond the experimental/ piloting phase especially in relation to marine renewable energy (IRENA 2019). The global biofuel market for transport in general hovers only around 1% of the total given stakeholder uncertainty over potential rates of return on investment, consumer and regulator responses. One South Korea experiment case study recognised the possibilities in microalgae but costs exceed $10 per kg of inputs to produce (Lee 2015). It identified the opportunities offered by permeable membrane technology and seawater nutrients.

2.1.2: Renewable Versus Marine Renewable Energy

Other forms of renewable energy extend to solar and wind (replicable to an extent offshore), hydropower from direct water sources, geothermal (from geysers), hydrogen, biotechnology and biomass such as from wood and vegetation. These specifically vary from more emission's intensive, fossil fuel based oil, coal and natural gas hydrocarbons or nuclear energy with its risks of radiation leaks and contamination They differ primarily in being from land-based sources with solar and wind power being the most popular. Marine Renewable Energy as specified above consists of offshore wind, wave, tidal, current, thermal, salinity gradient, floating voltaic and bioenergy. These research specifically does not focus on renewable energy as it is far more invested in, researched, popularly conscious among society, businesses and individuals and lobbied for, although it offers many of the similar markets, advantages and opportunities as for MRE. Both energy main types seek to reduce all greenhouse gas emissions, and encourage more responsible reductions of resources utilised and recycled towards a more climate resilient, circular economy through mitigation of the associated externality and impact costs.

2.2: Stakeholder Requirements, Concerns, Marine Renewable Energy Stakeholders and Economy/Supply Chain.

In order to effectively achieve a sustainable blue economy future, empowered by marine renewable energy, this section advices the need to consult with stakeholders to determine their priorities and requirements/concerns. It is essential to consider all phases of a supply chain and creation process along all participants that need to be involved throughout implementation. This research extends this to identifying resources, projected costs, risks, stakeholders, impacts, processes and ideas necessary to prevail. The challenge remains also how to connect existing stakeholders, transmission grids, regulatory infrastructure, markets, economy activities and others to covert away from fossil fuels and to marine renewable energy. It is especially essential to consider the supply chain in section 2.2.1 and site specific criteria in section 2.2.2. Social, research and economic/tax/legal incentives still need to be formulated to convince change for many entities. Stakeholders have identified various requirements and concerns in Table 2.1.

Table 2.1: Aggregated Stakeholder Requirements for Marine Renewable Energy

Expectations of an Industry Producer	**Commercial/Community Expectations**
Provide and consistently update sufficient information	Availability; Customer service and feedback
Ease of operation and maintenance	Promptness/swiftness of services/infrastructure
Security and Risk management	Allocative/Productive Efficiency
Cost Competitive	Functions are modernized as much as possible
Productive/Efficient – swift and accurate processing	Direct service/transport connections exist
Reliable/frequent functions of sufficient quality	Productive, trained labour responsive to needs
Satisfying unusual requests – altering schedules/ flexible to changing circumstances	Sufficient Capacity exists Efficient – utilises capacity/economies of scale
Sufficient quantity of functions exists.	Commercially profitable
It satisfies marginal caller requirements	Equitable in satisfying the user pays principle
It avoids delays/strikes etc	Minimises negative externality/congestion costs
Reliability -components, endurability of structure	Comparable market electricity prices
Access to laboratories, technology updates and research	Sustainability -ecologically
Utilisation of highly skilled and qualified staff	Circular economy -reduce, recycle, renew

Source: This Study.

Stakeholders aim essentially to replicate the benefits of conventional electricity without many of the associated ecological, emissions, technical, aesthetics, sound, aroma, resource depletion, reputational, legal, marketing and other associated costs of fossil fuels. Few are especially bothered whether it is specifically from land or marine based renewable energy sources provided it enables them to resume business and lives as usual, preferably with far less pollution but with reliable energy security. With Marine Renewable Energy many stakeholders will no longer have to depend upon fluctuating oil prices, uncertain electricity transmissions, a significant proportion of the emissions producing global climate change and geopolitics often dominated by conflict over oil, coal and other resources. It will free up significant other resources to be more ecologically protected whilst capable of supporting both existing and future supply chains. The most essential criteria for blue, green, circular and conventional economy activities include long term cost effectiveness via economies of scale, reliability of components and energy supply and durability aside from technical feasibility. This aims to further assist potential state policymakers and other supply chain stakeholders to potentially establish a prospective industry that thrives from resource security but as inputs, focus on climate change resilience, proactive risk management and pollution minimisation. Citizens need to consider preserving ecosystem resources and ensuring Earth can regenerate from existing aeons of decay when pursuing MRE and linked powered activities.

2.2.1: The Supply Chain. Stakeholders and a Vision for a Marine Renewable Energy Economy.

Proposed MRE Implementation Stages can be summarised as the following:

Stage I: Initial Site/Energy Type Selection, Inspection, Resource Investigation and Assessment.
Stage II: MRE Component and Technology Industry Fabrication and manufacturing Pre-Installation.
Stage III: Installation of Various MRE and associated activities
Stage IV: Stakeholder Consultation, Marketing, Market Feasibility and Grid Integration.
Stage V: Operation, Servicing, Empowering Supply Chains and Maintenance/Risk Management.
Stage VI: Decommissioning, Monitoring and Evaluation, Recycling and the Circular Economy.

In devising an optimal supply chain and economy for MRE, this research's conceptual contribution is to consider all stages of the process, associated inputs, outputs, resources, labour, capital, land and marine environment, associated ecosystems, cultural heritage, economic livelihoods and societies. This needs to apply through several processes from the renewable natural resource inputs for the energy types defined in Section 2.1 (Figure 2.7), to conserving marine ecosystems (Figure 2.8). This incorporates reducing impacts as much as practically possible, to supporting conventional maritime/other supply chain activities (Figure 2.9) to extending transmission and empowering blue economy activities such as in Table 2.3. MRE supply chain stages can be divided into initial site selection, inspection, evaluation and testing as Stage I. This incorporates preinstallation planning and resource assessment/stakeholder analysis, environmental impacts and other investigations as in Section 2.2.2. Others include project architecture, design and development. Stage II considers actual MRE industry component fabrication and manufacturing. This extends to supply chain manufacturing, assembling, testing, researching the components, marketing; electrical generation; design, engineering, power take off, and generator; electrical and automation, bearings and all other components related to the various technologies and provision of supplied energy types in report section 2.1.

This research's recommended Stage III refers to actual installation of the proposed components. It involves specialist vessels, consultancy services, skills, training and education (Dalton 2014, IRENA 2016). It also includes any related professional services such as surveying, environmental, legal, insurance, financial, IT and Internet access, geotechnical, environmental and accountancy. Components and structure compiling include the foundations; subsea cables and substations; steel and electrical grid transmission systems, sensors and technology. Stage IV includes all additional stakeholder consultation, marketing, market feasibility and other studies needed to minimise objections and ensure a profitable, sustainable market supply of reliable electricity combined with actual grid creation and integration for blue and regular economy activities. Stage V: Operation, servicing, actual empowering of activities and supply chains along with any related servicing, Maintenance and continuous risk assessment and management. Stage VI includes decommissioning, monitoring and evaluation, then recycling and the Circular Economy to minimise associated pollution, waste and emissions. These stages extend to coatings, diagnostics, divers, drones, associated logistics, ports, storage, distribution and sales, salvage and further parts upgrading or installation/replacement. A feasibility study for ocean energy in Indonesia advises supply chains need to consider provision and processing of sufficient climate and oceanographic/marine environmental data, aside from resource mapping of the latent energy available (Kusuma 2018). It advises reliability and survivability. To be cost effective, the localised cost of energy is comprised of capital, operational and annual fixed costs. An effective support network, marketing and customer service base also benefits sales and revenue as with most businesses, supported by research and development.

Figure 2.7: Natural MRE Resources

Natural resources are highlighted above but include wind, wave, solar, salinity, divergent water temperatures, currents and marine vegetation/hydrogen.

An example of a potential maritime supply chain with various stakeholders is presented in Figure 2.8 and marine industry process in Figure 2.9. Stakeholders extend to industry, producers, consumers, governments, NGOs, international organisations, academia, labour unions, professional associations, civic communities, religions and individuals. When synthesising wave and other MRE forms, supply chains need to consider not only the environment and climate but the distances involved both in deployment of each device and in relation to the more remote islands or coastal locations to which the technology and related components need to be provided including maintenance and other servicing (Manasseh et al. 2017). Other criteria include mitigation of the various risks and externality costs including those in Chapter 3, along with manoeuvrability, the environment and maintenance (Joubert et al. 2013).

Figure 2.8: Maritime Ecosystem/Blue Economy Resources

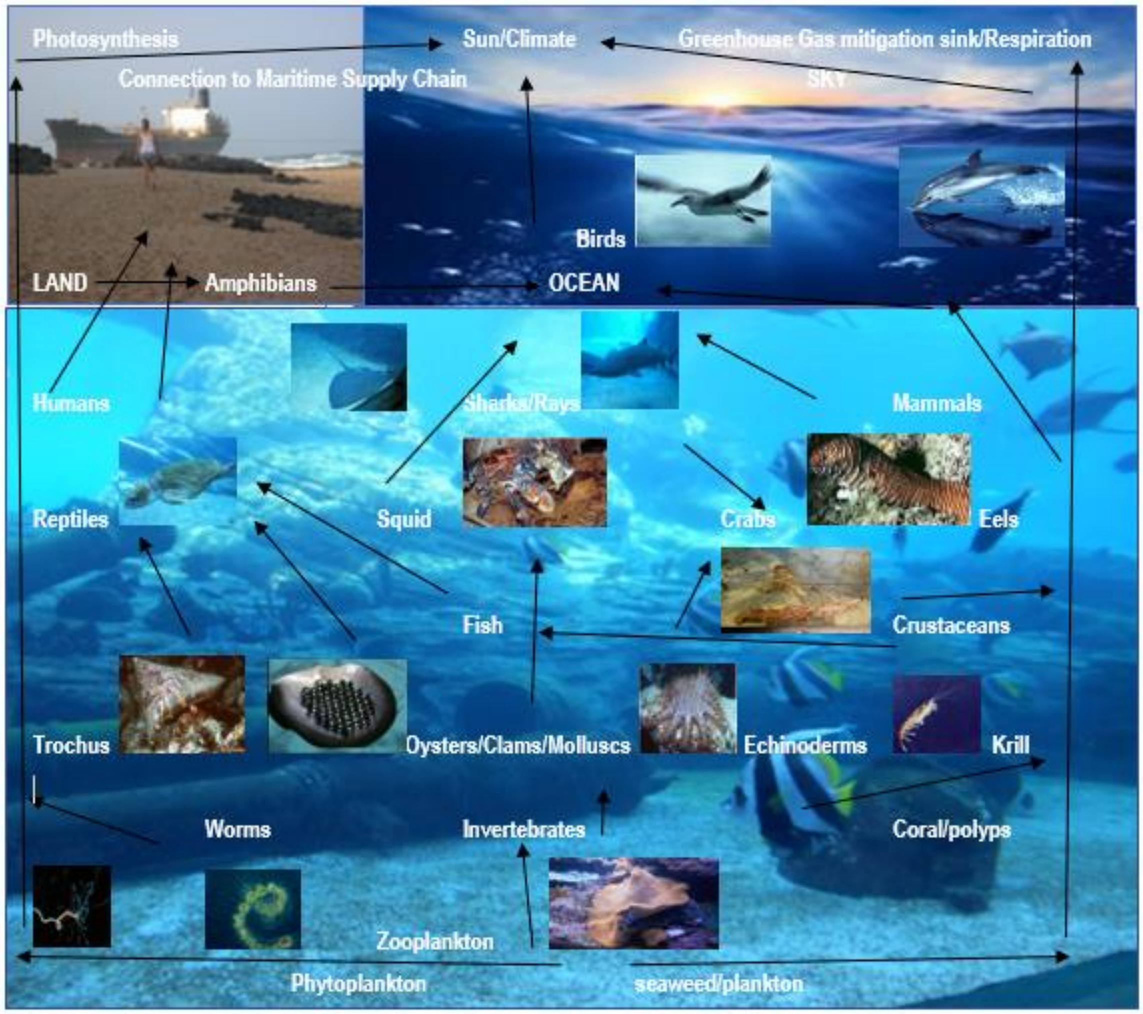
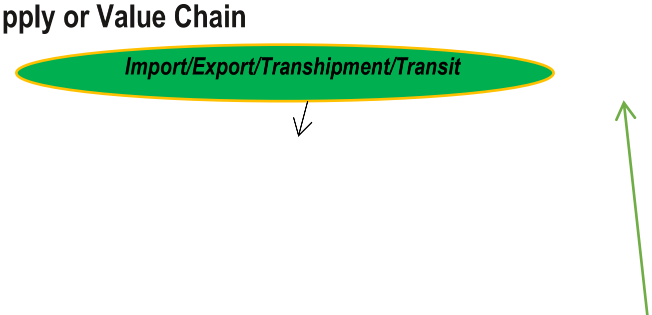


Table 2.2: Ocean and Blue Economy Activities

Ocean Economy Activities	Emerging Blue Economy Opportunities
Fisheries, Aquaculture	Cabotage
Shipping; Transport and Ports	Marine finance and insurance; Dry Ports
Marine and Cargo Services	Undersea mining/Bioprospecting
Navies - Ocean and Coastal Governance	Drones, Robotics/Marine Protection
Offshore oil and gas	Marine Renewable Energy; Desalination
Marine, Cruise Tourism and Recreation	Marine Biotechnology; Blue Carbon
Education and Training	Maritime research and development, Technology e.g. sensors
Ship Repair Vessel automation and conversion;	4^{th} Industrial Revolution -maritime education and training.

Source: This Study

Figure 2.9: A Global Marine Industry Supply or Value Chain



Source: Author.

To establish a potential global MRE and blue economy sector, this review mentions the need for active stakeholder engagement along with regular maintenance and risk monitoring along with evaluation. This extends across the above supply chains and activities from producer to consumer. To avoid under or over-utilisation costs, transmission connections need to exist to the extent demanded by these stakeholders with minimal risk exposure and externality costs to justify the conversion from regular sources. It is therefore essential for any solutions or initiatives to provide sufficient qualities and quantities of labour, equipment, management, capital, technology, infrastructure and services to satisfy market demand with supply to adequately provide a consistent, adequate, profitable and productive service capable of allowing for fluctuations in growth, existing capacity and future projected growth. It needs to be commercially viable at sufficient economies of scale, able to recover fixed and variable costs without external funding. Potential projects also need to satisfy security concerns against hypothetical environmental, public health and other risks identified in Chapter 3. Stakeholders also need to ensure appropriate environments, water supply, land use/property rights and climate, market and transport access along with crime and perceptions by neighbours. This aims to reduce potential complaints and associated costs including the possible suspension/loss of business, fines and other expensive measures that impede business. Table 2. 3 provides a partial list of core stakeholders for MRE. This aims to simplify efforts at collaboration, coordination and obtaining information, to accelerate progress towards implementation given the urgency of global climate change.

Table 2.3: List of Marine Renewable Energy Influential Stakeholders

Agencies	**Companies**
IRENA	ABB
Ocean Energy Europe	Aegir Dynamo
Ocean Energy Systems	Anaconda,
International Windship Association	Andritz Hydro
Companies	Archimedes Wave Swing,
Aqua-Buoy	Astrom, Atlantis Marine Resources
Aquamarine Power	Blue Energy,
Carnegie Wave Energy	CETO II
Centrepod,	DCNS
C Wave	Eco Wave Power,
GDF Suez	Eel Grass
Hydro Air	Energy Island Ltd; Fuma-Tech,
Kawasaki	Hyundai
Lockheed Martin, Marine Current Turbines	McCabe Wave Pump
Mighty Whale, Minesto	Motor Wave; MRC 1000
Nautricity Ltd, Oceanus,	Osmo-Blue, Oasys Water,
Oceanlinx; Ocean Power Technologies,	Ocean Star, Ocean Thermal Energy Corporation
Open Hydro, Offshore Infrastructure Associates,	OTEC International, Oyster
Penguin, Pelamis Wave Power	Pentair X Flow, Porifera,
PS Frog, Poseidon	Pontoon Power Converter, SBM Offshore,
Seabased AB, Statkraft;	Surf Power, Synch Wave Power Resonator,
TAPCHAN, Tetron	Tidal Generation; Triton
Verdant Power	Voith Hydro
Wave berg, Wave Cat	Wave Dragon, Wave Energy Buoy,
Wave Roller, Wave Rider,	Wave Plane, Wave Star,

Source: This Study,

2.2.2: Site Selection Criteria

Marine Renewable energy and hydrokinetic site selection criteria is recommended to consider a variety of factors including economic, environmental, IT connectivity, physical land or geophysical, oceanographic, climate, climate change. It also includes resource or power availability, reliability and density; shipping and logistics cost, water depth, energy price, transmission distance, market size; data availability, experience and research, other costs, past, present and future climate risk events along with stakeholder's psychological reactions and experiences conditioning them to these sites. It is essential to consider existing market types, demand and supply from other competitors in fossil fuel, land renewable and other marine renewable energy possibilities. Other influential factors that may influence the choice and overall long-term commercial, technical and ecological viability include financial incentives, technology types, geology, geography, legislation, planning, and marine spatial planning; the availability of insurance and potential legal or liability risks. Offshore facilities are counselled to consider a life cycle assessment, component reliability analysis, environmental impact and economic feasibility study for wind and other MRE sources ((Kilcher and Thresher 2016; Yihdego, Salem and Pudza 2017).

The Secretariat of the Pacific Community (SPC) consider Pacific wave energy needs to consider the pre-installation, component assembling, fabrication and transport, installation, operation and decommissioning phases for site selection including local markets, resources supplied, constraints and opportunities (Bosserelle, Reddy and Kruger 2015). It advises identifying the stakeholders involved for consultation and approval, publicity, taxation, and marketing. Site selection criteria needs to investigate any existing land use and possible conflicts; bathymetry, sediment and seabed morphology, infrastructure and grid connections across its entire transmission network. It needs to consider the interlinking supply chain and economy. Significant capital is also required for investment as with other energy production plants. For example, a Pelamis wave energy converter in 2015 was estimated at US $4.7-6.300,000 (3-4,000,000 for the device, $300-400,000 mooring, $1,200,000-1,600,000 for installation (Bosserelle, Reddy and Kruger 2015). It might need several vessels including recovery and maintenance cost, ROV and drones, supply vessels and derrick barges frequently to operate. It also needs access to spare components for device failures. To operate Pelamis, it costs an average of US $49,000-272,000 in annual operation and maintenance costs, 490,000-680,000 for a once off maintenance after 13 years and $1000,000 in decommissioning. Average lifespan is around 25 years.

2.3: Global, Regional and Local Policies and Legislation

Africa, South America, the Caribbean, South Pacific and Middle East are all identical in regions offering significant potential for marine renewable energy but offering no specific legal mandate or guidelines to enable them to do so. Few exist in Asia, Europe and America with the notable conspicuous examples of a few such as Norway, France, the UK, China, South Korea, Canada's Nova Scotia and the US State of Maine. Whilst few nations have specifically focused on marine renewable energy under policy guidelines and legislation, an increasing number have pledged to renewable energy targets to reduce various greenhouse gas emissions under the 1992 Rio Agreement, 2012 UNFCC and the 2015 Paris Agreement on Climate Change. For example, Tuvalu, the Cook Islands and Dominica are well on track towards reaching 100% renewable energy by the end of 2020, whilst Cape Verde aimed to decrease fossil fuel imports by 20%. South Korea are aiming for 4.7% of total energy supply to be from marine locations. New Zealand inaugurated a Marine Energy Deployment Fund in 2007. Spain aim for 20-25 MW of MRE each year from 2016-2020. In order to implement an effective MRE powered Age for the blue economy, this scholarship considers it pivotal to identify existing policies, frameworks and legislation best practises and research recommendations including those related to more conventional energy sources, as a prelude to determining a more effective legal framework for MRE. This aims to provide greater investor, public, consumer, business and policymaker uncertainty as another basis towards more effective governance, aiming to mitigate anticipated risks, avert regulatory capture and market failure as much as possible.

The Caribbean follow African, the South Pacific, Mediterranean islands (Greece, Balearics, Malta, Sardinia, Sicily, Corsica and Cyprus along with other more remote islands such as St Helena, Tristan Da Cunha, the Azores, Falklands, St Pierre and Miquelon, Ascension and Tristan da Cunha or the polar regions in lacking the regulatory/legal and other enabling policies sufficient to empower remote communities with limited land space and other resource constraints far from conventional fossil fuel/oil power sources. The Caribbean region has renewable energy policies for Antigua and Barbuda, the Bahamas, Barbados, Grenada, St Kitts and Nevis, St Lucia, St Vincent and the Grenadines, Suriname and Trinidad and Tobago (Williams 2012). These could be revised to incorporate MRE as could many others. Several research studies have emphasised the increasing attractiveness of investing in Caribbean renewable energy from investment ease, lack of chronic excess regulation, a technically skilled and diligent labour source, good logistics and market connections, excellent sources of energy, improved demand, upgraded infrastructure, economic and political stability (Caribbean Export Development Agency 2016; CARIFORUM 2017). It forecasts a 58% increase in renewable energy demand from 2013 to 2027. In 2014 only 12% out of a total of 8.8 GW (1.14) was from renewable, none from marine sources, despite proximity to thermal, salinity gradient, current, wind, wave, tidal and solar capacity. The source advices the need for feed in tariffs, public loans/Grants, tax credits, tax reductions, net metering/billing and interconnection standards. Although not maritime, USAID have a Caribbean Clean Energy Programme. A GIZ funded Technical Assistance Programme and Inter-American Bank sponsored Technical Assistance on the Caribbean Sustainable Energy Strategy has been introduced to enhance institutional capacity including training, risk awareness and management, communication, monitoring and evaluation (CARIFORUM 2017).

Canada and its Nova Scotia province reflects one of the few with a specialised Marine Renewable Energy Act (Nova Scotia Government 2019). This strategy details the priorities for marine energy, licensing and site selection process, delegated powers and authorisation needed, feed in and other tariffs or pricing, power purchasing agreements, the need for security, insurance, license renewal, maintenance, site rehabilitation after decommissioning and a responsible decommissioning process. It links to associated environmental impact and other assessments combined with penalties for violations, the need for responsible data confidentiality and connections towards other departments and regulations or laws. It even details the specific sites and energy types initially allocated, approved and deliminated such as an in stream tidal generator in the Force MRE, Grand and Petit Passage and Digby Guts areas. The US State of Maine in 2009 established a Governor's Ocean Task Force and Energy Act. This act required the need to consider economics; reliability; environment; public health and safety; scenic, historic and recreational values, state renewable energy targets, proximity of transmission line to inhabited dwellings or vessels, energy transmission, conservation and load management. It considered the need for specific incentives, authorisation and competitive bidding contract processes to enable equitable market entry and participation, the research, finance, testing and construction of facilities (Maine State Government 2009). It considers the need for a reasonable cost or tariff structure to be established in parallel, to consult with stakeholders and consider existing marine/land uses to avert conflicts.

Norway's Offshore Energy Act of 2008 specifically applies to ocean renewable energy (Norwegian Government 2009). It focuses on the need to actually enable it as a possibility in research, development and commercialisation with similar legal considerations as conventional and renewable energy sources. This extends to finance, transmission, generation, licensing and operation. The MERIFIC Project or Marine Energy in Far Peripheral and Island Communities Project focused on UK and France legislation in 2012. Rather than focusing on specifically penalising the nascent blue economy sector, the UK embraced the market and research approach, with a contract in difference approach and small reliance on feed in tariffs. France focused on state provision of electricity, price setting and tariffs, with a few experiments in tidal and other energy.

Ireland's Renewable Energy and Ocean Energy Strategy aims to achieve 500 MW of ocean energy potential by 2020 and 4.3 billion euros worth of linked economic activity. Scotland requires significant marine environment and ecology assessments as an authorising requirement (Benjamin et al 2014) but has no specific policies as with many global and European nations. This focuses on establishing a local market and industry value chain, along with enabling facilities to be positioned, installed, tested and operated. From 2004-2010 it received a devoted marine energy budget allocation. China's 2010 Renewable Energy Law was broadened to marine renewable energy in the 12th 5 Year Plan as they envision up to 2,750 GW of potential resources (Abtey 2012). South Korea's 2017 New Energy and Renewable Energy Development, Use and Spread Promotion Law also specifically entails marine renewable energy; including a revised feed in tariff, energy technical standards, capacity and testing criteria and other financial, legal, market and research/development incentives (Ko et al. 2019).

Individual nations vary in the extent of their legal requirements for renewable energy projects and investments, although more land specific. Many require environmental and integrated coastal management related act compliance along with water usage, electricity and other related legislation. For example, in Australia this applied with the 1999 Environmental and Biodiversity Conservation Act and the 1995 Coastal Management Act. Belgium have specifically focused on special regulations applying to MRE in the North Sea. Installations require four permits for offshore energy parks: domain concession, environmental permit, Authorization for the construction and operation, offshore cable building permit. Aside from the Novia Scotia MRE policy and Canadian Environmental Assessment Act 2012 (CEAA 2012); developments need to comply. Canadian Environmental Protection Act 1999; Fisheries Act; Migratory Birds Convention Act; Navigable Waters Protection Act and Species at Risk Act. China requires compliance with the 2009 Renewable Energy Law, the 2013 National Marine Zoning regulations and the 13th Ocean Energy Development 5 Year Plans.

Denmark requires compliance with the 2018 Energy Agreement and the Promotion of Renewable Energy Act including a license to carry out preliminary investigations, license to establish the offshore project (only given if preliminary investigations show that the project is compatible with the relevant interests at sea) and a license to exploit the energy source for a given number of years, and an approval of electricity production (given if conditions in license to establish project are kept). It also requires an Environmental Impact Assessment. Others situated within the European Union area include the 2001 Strategic Environmental Assessment Directive, 2009 Renewable Energy Initiative, the Birds and Habitats Directives, the 2014 Maritime Spatial Planning Directive and Environmental Impact Assessment Directive. France requires an EIA, a sea space occupation permit and license to occupy the maritime public domain. Projects larger than 50 MW require a special Ministry of Energy permit. The overall process was simplified in 2018. In Germany projects have to comply with the 2018 Coalition Agreement, the Renewable Energy Sources Act, the Offshore Regional Energy Plan, the Maritime Spatial Plans for the Baltic and North Sea, an EIA, the Federal Waterways and Shipping Administration (WSV) and the Federal Agency for Nature Conservation (BfN).

India requires Coastal Regulatory Zone clearing processes. Ireland needs compliance with its 2014 Offshore Renewable Energy Compliance Plan and Guidance on the EIA and NIS preparation of Offshore Renewable Energy Projects, the Foreshore Licence and Lease Agreements and 1999 Electricity Regulation Act. Italy has the 2010 National Action Plan for Renewable Energy. Japan has the 2018, Third Basic Plan on Ocean Policy and the 2019 Ministry of Economy, Trade and Industry Act of Promoting Utilization of Sea Areas in Development of Power Generation Facilities Using Maritime Renewable Energy Resources. Mexican projects entail the Law for the Sustainable Use of Energy (LASE), Law for Energetic Transition and General Law of Ecological Equilibrium and Protection of the Environment (LGEEPA). Norway presents the Ocean Energy Act. In Portugal affairs are more complex requiring a concession, license or authorisation for the private use of maritime space; licensing of the energy production activity; licensing projects and ancillary facilities on land and an Environmental Impact Assessment. DGEG is the licensing entity for projects with a power capacity of up to 10 MW. Above 10 MW authorisation is needed from the Ministry of Energy. Requirements differ for regular and feed in tariffs.

South Korean projects necessitate the Marine Fisheries Science and Technology Promotion Act (Act 14515) in 2017, the 2018 Ministry of Fisheries Basic Plan for the Marine Fisheries, Science and Technology Promotion Public Waters Management and Reclamation Act (Act 15607). Others include the 2017 Marine

Environmental Impact Assessment Act (Act 15662), the Promotion of the Development, Use and Diffusion of New and Renewable Energy Act (Act 14670), the Energy Act (Act15344), Framework Act on Low Carbon Green Growth (Act 16133) and Energy Use Rationalization Act (Act 15574). Spain expect the 2013 Environmental Impact Assessment Law, the 1988 and 2013 Coastal Laws along with the 2007 Royal Decree specifically relating to licensing offshore renewable energy projects. Sweden require the 1998 Environmental Act, the 2008 National Maritime Policy Bill 2008, the 1987 Planning and Building Act (1987), the 1994 Act on Technical Requirements for Construction Works, the 1992 Swedish Economic Zone Act and the 1982 Fishery Act. Netherlands MRE related requirements are the Sea Water Pollution Law, the Environmental Administration Law, Spatial Arrangement Law, Environmental Protection Law, Water Act, Wreckage Law, Monuments Law, Excavation Works Law, North Sea Installations Law and (Sea) Bottom Protection Law.

The UK require the Marine Management Organisation, the 2009 Marine and Coastal Access Act; the 2004 Energy Act, the 1989 Electricity Act. Projects greater than 100 MW need a Development Consent Order as Nationally Significant Infrastructure Projects (NSIPs). Scotland have Marine Scotland Guidance for Marine Licence Applicants and the Welsh Marine Renewable Energy Framework/Plan. The US require the approval of the Federal Energy Supply Commission and the Bureau of Ocean Energy Management, which currently offers three types of leases: Either a limited lease (usually 5 years) authorizes site assessment and technology testing, but it cannot be converted into a commercial lease. Or a commercial lease gives rights for production, sale, and delivery energy as well as easements required for cables and support facilities. These are generally 30-year term leases, with 5-year site assessment term and 25-year construction and operations term. Thirdly, a research lease is only for government agencies or state universities for testing and research not commercialisation aside from the US Army Corps of Engineers and the US Coast Guard.

Although not formally added with separate policies and regulation guidelines; MRE appears in the 2007 European Commission Blue Growth Strategy and 2014 Strategic Initiative for Ocean Energy (Dalton 2014). These advise the need to consider financial, technology, experiment and testing, maintenance, operating, regulatory and grid connection elements. Financial incentives include a feed in tariff via a regular long-term contract, grants, investment equity and other sources. In 2016 Denmark set a maximum tariff of 0.0.8 Euros per KWh for MRE and renewable energy sources. France and the Netherlands set 0.15 euros per KWh Germany 0.035-0.125, Italy 0.30 if under 5 MW projects and 0.194 if over 5 MW and Ireland at 260 euros per MWh 0r 0.260 per KWh. An effective policy framework is also recommended to consider existing policies and regulatory frameworks combined with means of implementation to ensure it is compatible with incentives discouraging use of fossil fuel powered alternatives (Oxford Institute for Energy Studies 2015). Although South Africa has yet to offer any actual commercial projects, its Department of Environmental Affairs in 2015 has already extended its guidelines for renewable and conventional energy projects to mandate an environmental impact assessment for any potential related ocean energy project ahead of other government entities. It focuses on offshore wind, solar, wave and bioenergy at present. However, it provides an example of high onerous regulatory requirements penalising subsequent investors, specifying a minimum of 25 significant pieces of legislation, many of which are not even relevant, to comply with. Examples include the Civil Avian Act, Astronomy Geographic Advantage Act Subdivision of Agricultural Land Act, National Road Act, Spatial Planning and Land Use Act, Municipal Systems Act and others. Developers also need to consider water use, air quality, environment, minerals and petroleum, natural heritage, electricity, agriculture, natural heritage and other excessive acts. This penalises even basic research, despite promising initiatives under wave, wind, floating solar voltaic and the Agulhas Current (over 2000 MW in potential), despite crippling electricity blackouts and erratic supply for 12 years from the state monopoly Eskom (one of the highest polluting companies in the world.

The Africa 2030: Roadmap for a Renewable Energy Future, is among the several renewable energy frameworks that completely ignore marine sources but could benefit from being revised (IRENA 2015(b), whilst offering several energy policy guidelines including considering fiscal, training and mass awareness incentives. It aims to extend renewable energy by 50% by 2030 and over 200 GW of installed operating capacity needing $70 billion. In a specific IPCC report on ocean energy incentives they advise policy frameworks to market incentives of feed in tariffs, tradeable certificates, research and development/deployment capital grants and site regulations (IPCC 2014). For Indian Ocean Islands such as the Comoros, Madagascar, Mauritius, and Seychelles a previous study emphasised the need to ensure electricity access, pricing and regulatory frameworks that were equity based, cost effective, regular, reliable and sustainable (Hadush and Bhagwat 2019). It needs to encourage energy efficiency and private market participation along with a sound regulatory system.

Additionally, although international laws and technical standards/guidelines have yet to be established for MRE types and be internationally accepted; this source notes comparable standards exist for ports, the offshore oil and gas, fisheries and other sectors, which could be modified. These include ISO, Bureau Veritas, the American Bureau of Standards and Det Norske Veritas. One source on offshore wind energy planning in Greece emphasises the need for regulations to contemplate marine spatial planning, existing and potential, other blue economy activities/stakeholders (Stefanakou and Nikitakos 2019). It identified the need for social acceptance as crucial to ensure success. It also links these to international conventions such as CORLEG, SOLAS and MARPOL for safety and marine pollution along with various Regional and local fisheries management incentives such as the UN Fish Stock Agreement or the UN High Seas Treaty/DOALOS on ocean governance and territorial boundaries under Exclusive Economic Zones. Others include the Barcelona Convention on integrated coastal zone management and the Convention on Biological Diversity.

2.3.3: Proposed Characteristics of an MRE Act:

In conclusion to this section, this source notes that very few nations, regions or municipalities have any regulations specifically related to marine or ocean energy. It remains a conspicuous absence from international law and agencies, lacking its own convention, recommended guidelines and technical standard's. This research's further conceptual contribution is to provide recommended criteria for policies/laws or guidelines including an Act, site specific criteria, investor criteria, operating and technical standard guidelines. Proposed characteristics of a MRE Act or operating framework should consider the following:

- 6 Stages of Development Above
- Designated powers and responsibilities, capacity to make, amend or repeal regulations
- Site selection criteria
- Authorisation process
- Management, operation and maintenance
- Marine spatial planning and existing area uses
- Decommissioning, recycling, waste minimisation and the circular economy.
- Risk management and links to other legislation including safety, security, environment, water, Admiralty Jurisdiction, cargo, fisheries, tourism, etc.
- Freedom of financing, lease security and concession, ability to set port/marina user fees; fines for infringement and incentives
- Freedom over selling/procuring assets and properties/pay supply chain on time without the rigorous onus of centralised government procurement policies inhibiting development.
- Incentives and transfer from fossil fuel and land renewable energy sources -Financial; technology transfer, IP, licensing and authorisation, pilot projects, import substitution, customs
- Transmission connections
- Financial structure, electricity prices and market incentives

- Links to fisheries, aquaculture and other blue economy areas
- Ocean sovereignty and governance; creation of marine protected areas and private reserves.
- Marine spatial planning and functional zoning/integrated coastal zone management
- Links to blue carbon expansion and preserving
- Preserving of marine biodiversity and ecosystems; Regulated introduction and exploitation of rare and exotic species sustainably.
- Need to establish marine reserves and protected areas.
- Education, research and training.
- Specific ring-fenced budgetary resources provided for long and short term maintenance, potential expansions/construction and 15-20% for contingencies.
- Environmental, water/ocean impact assessments for certain activities with a maximum specified time period.
- Research, information; marketing, commercialisation and all value chain issues.
- Trade regulation, exports and provision of financial, investment, research and other incentives.
- Resolving market barriers to entry -competition; infrastructure and standards;
- Issues over marine resources,
- A suitable enforcement, regulatory and independent oversight/appeals authority
- The extent of public participation and consultation in the process
- Avoiding of marine threats -issues of Polluter Pays Principle, carbon footprint offsetting, and company liability. Risk management. Need to ensure recycling, reduction of bycatch and related waste and the principle of ensuring the circular economy wherever possible.
- Issues over resources as climate change develops
- Links to other policies and supporting legislation
- Specific prescribed legal and other penalties for violations
- The resolution of disputes and appeals process

2.3.4: Marine Renewable Energy Installations Design/Operational Plans and Technical Standards Guidelines

- Construction Plan/Site Specific Selection Criteria as in Section 2.1/2.2 for technology type
- Engineering/Technical Design Standards
- Business/Operational, Financing, Marketing and HR Policies/Plans -education and training
- Environmental Management Plan, Climate Change Risk, Impact and Adaptation Approach;
- -Sound, Light, Air and Water Quality, Pollution etc.
- Safety, Security, Oil Spill, Pollution and Other Risk Management Approaches
- Circular Economy -Recycling-Waste Management, Water Security and Renewable Energy Plans
- Maintenance Policy
- Ocean Governance and Marine Conservation -Enforcement
- Community Engagement/Social Responsibility
- Specific Fisheries, Marine/Leisure/Cruise Tourism and other blue economy requirements
- Cybersecurity, Data Gathering/Statistics and Management Protocol.

For a well-functioning MRE operation to operate, this maritime economist recommends the following at a minimum.

- Sufficient funding/reserves to ensure a 15-20% contingency reserve along with operations
- Minimal, well trained, experienced and qualified staff professionals
- An effective, cyber-secure IT and Port Community System and external site backup
- Sufficient and well-maintained assets, infrastructure and equipment to address stakeholder needs
- A suitably climateproofed and sheltered physical office
- Provision of Internet services.
- Provision of bunkerage -including cleaner fuels, renewable energy, water minimising facilities
- Marketing budget
- Hosting events etc to stimulate sufficient community and investor interests.
- Considering a competitor analysis on what competitor counterparts are undertaking and responding accordingly.

2.3.5: Investor Guidelines/Criteria

These are not extensive but include:

- Site specific characteristics and marketing -i.e. location; availability of attractions/services
- Commercial indicators (See section 3.4) such as profit, Rate of return on investment
- Fiscal Incentives, fines and penalties
- Extent of regulations -are they practical or excessively bureaucratic and onerous as a detriment
- Security of leisure/property rights and tenure
- Local development of area and surrounding economy -does it provide growth potential
- Competitors -considering an opportunity cost on the rate of return on potential investment?
- Social, environment, heritage and other factors.
- Extent of management, maintenance and receptiveness to client/stakeholder requirements- i.e. reputation and experience.
- Environment/Climate Change Hazards
- Possibilities of reducing commercial congestion from larger ports.
- Integration into Smart Ports/4th IR and efficiency
- Greater eco-chances and sustainability of marine environments -for creating blue carbon finance, marine reserves, blue economy activities and other opportunities as in Section 3.6.
- An independent regulator with clear accountability, independent roles, responsibilities, accounting, reasonable pricing tariff determinations given stakeholder interests and regulation.

2.4: Evaluating Case Study Methods, Lessons and Approaches Successes/Progress

To ensure an effective transition towards ocean or marine renewable energy for the blue economy, this source considers it essential to identify the best practices, experiences and factors influencing past successes that stakeholders across the supply chain, economy and community can learn and be enriched from. This section therefore focuses on existing case study progress chronicled in research. For example, wave energy has proven itself to be among the cleaner, purified and continuous sources of electricity (Global Energy Network Institute 2009). Axial turbine centred generation plants have operated successfully in regions as diverse as Kvalsund Norway, Devon England, New York and Northern Island, whilst vertical turbines in Canada, Maine, San Francisco, Wales, South Korea and New Zealand.

A 2012 study confirmed wave energy could supply at least 6.5% of the total 2004 national demand with 300 TWh/year off Hawaii, 1,250 TWh off Alaska, 110 TWh off New England and the Mid Atlantic (Electric Power Research Institute 2012) and West America 440 TWh. It estimated localised production costs could range from 11.1 to 39.1 cents per KWh with sufficient economies of scale. It advises learning from existing successes such as the 700 kW Archimedes Wave Swing in the UK and Portugal, 500 kW Energetech in Australia, the 750 kW Pelamis in Scotland and 40 kW Power Buoy in Hawaii. It recommends the value of establishing a localised weather station with continuous observations if one is not presently available nearby. It therefore argues that technology can progress with sufficient legal and policymaker support.

2.4.1: The USA, Canada, the Caribbean

A recent MRE market analysis noted the increasing interest among developers in the USA with successful prototypes attracting investment and stakeholder attention such as Makah Bay and Admiralty Inlet Offshore Wave Park in Washington state and Wind Float Pacific in Oregon (Industrial Economics Incorporated 2019). Another existed off Oregon's Newport. The same source estimated the economic impact analysis of a North Atlantic 500 MW wave energy plant in 2018 could create 3,490 job years during construction and 284 in operation, attracting $652,000,000 in expenditure investment under construction and $50,000,000 under operation. This is offset against a cost of $27,200,000. It estimated 149,698 jobs could be sustained directly/indirectly during construction and 9,021 across a supply chain under operation each year. The source calculated only 190 full time jobs and $21-159,000,000 of investments existed in 2013 with 33 projects. Other attempted project examples include Cape Wind Massachusetts, Galveston Texas, Block Island Rhode Island, Mustang Island Tennessee, New York's Roosevelt Island and Lake Erie Ohio.

A 2012 Hawaii experiment at Kaneohe Bay by Makai Ocean Engineering proved Ocean Thermal Energy Conversion could work economically at 23-25 cents per KWh with feed in energy tariffs and policy set renewable energy targets as inducements to participate (Cramer et al. 2019). It estimated a 100 MW plant could reduce costs to 0.07-0.19 per KWh with 12 plants necessary for 100% of Hawaii's total energy needs. Although it consulted with society and the Humpback Whale Sanctuary it conceded the need for more substantial socioecological and economic impact assessments to evaluate even greater value. Hawaii are targeting 800 MW of offshore wind capacity costing $1.9 billion by 2045. Canada has also proven capable of marine renewable energy being successful with over 20 GWh per year from a 1984 tidal barrage energy generating plant at Annapolis Royal in the Bay of Fundy (CSIRO 2012) with the Fundy Tidal Institute. Canada could benefit from up to 255 TWh per year from tides and 1600 TWh from waves. It estimates 167 divergent projects and individual companies/consortiums were researching and testing MRE projects around 2012 alone from Blue Energy and Clean Current to Nova Scotia Power and Wavemill Energy Corporation.

From 2008 the state of Maine specifically passed an Act (Section 2.3) and 3 test sites aiming to pursue ocean energy as an option for greater electricity security. Another expression of interest includes the 350-700 MW wind farm off Long Island by the Long Island-New York Offshore Wind Alliance. The USA has become a later entrant into the market than Europe and Asia over initial scepticism over the ecological, economic, real estate values, tourism and marine spatial planning concerns along with technical feasibility (Environmental and Energy Study Institute 2010). However, many of these have been affirmed to have no or minimal negative associated externality costs such as property prices, in contrast to land based renewable energy options. The source cites advantages for military and civilian telecommunication possible usages as well. The study cites economic benefits, with over 85,000 people employed in land situated, wind industry supply chains alone. Ecologically, the US Department of Energy emphasises the climate change mitigation advantages of each GW produced can reduce over 1.3 billion gallons of water, 1,800,000,000 tons of emissions and 1,200,000,000 tons of coal.

An economic and technical feasibility study into offshore wind energy in Oregon calculated up to 62 GW as capable of being harnessed sustainably (Musial et al. 2019). In it the National Renewable Energy Laboratory conducted semi-structured interviews, model and cost simulations and field research observations of data. It identified lower finance and floating platform unit costs, reduced operating time and production costs from

$197 per MWh (0.197 per KWh) for the pilot/experiment phase to $63 per MWh (0.063 per KWh). It considers aesthetics need to be minimised and therefore purposely located possible sites further than 10 miles from shore. For a 24 MW plant it estimated CAPEX costs of $8,870,000 versus $2,924,000 for a 600 MW plant and $172,000 and $52000 for operational costs respectively. A wave energy conversion system in Hawaii demonstrates another global area capable of managing the transition towards a blue economy future (Hana and Na'auao 2009). It focused on oscillating water columns, wave surge or focusing devices and floats or pitching devices. Project examples include the Power Buoy with 20-50 KW per buoy at a 1-4 metre below surface depth. Advantages included more economical, reduced maintenance, and an easily assembled modular design that could be simply transported along with a significant availability of supply and sustainability. Eco advantages of no visual and noise pollution, minimal aesthetics, avoiding coral, promotes biodiversity growth, avoids oil spill and waste, emissions, radiation and particulate matter. However, currently Hawaii has significant existing tourism and other marine space usages, presenting possible safety, navigation and congestion risks, coastal erosion risks and high installation and development costs exist for the present state of technological progress.

Another US study conducted an offshore wind energy cost-benefit analysis to empirically confirm the benefits of MRE for test projects between 2000 and 2008 (Snyder and Kaiser 2008). It is more cost effective with reduced socioeconomic, emissions and environmental impact costs than rivals. It is known not to have any major navigational safety implications for shipping and lower fuel volatility along with other advantages as pinpointed in Section 3.3. Offshore projects do not impair from a sound or visual appearance for coastal and land purposes and are simpler to transport via shipping then via road or rail ashore. It provides a range of past European offshore wind farms from 1991 to 2008, 2 to 300 MW and a cost from $4.8 to 1,250 million.
To assert evidence of a minimal ecological impact cost, it cites the example of a Cape Wind offshore wind park with limited disturbance to local fisheries, endangered and other marine wildlife from a distance, birds and local climates, waves, sediment, currents and temperature.

One Trinidad and Tobago case study identified the technical feasibility of ocean energy from field research, stakeholder interviews and oceanographic surveys (Henry et al. 2018). It established wave power could reach 5-10 cents per KWh basic production costs, ocean thermal energy 5-25 cents and offshore wind 5-16 cents with economies of scale compare to 5-40 cents for oil and natural gas powered production. Existing hydrocarbon reserves are only forecast to last 50 years from 2020 and remain incompatible with climate change emissions reduction target obligations. It cites the advantages of ocean sourced energy as avoiding the physical scarce land constraints of alternatives. However, the Caribbean experiences challenges for skilled labour, access to capital, technology, research and other constraints. It remains close to the USA however, which offers many situational advantages. It contends the especial values for OTEC based energy in provided desalinated water simultaneously, further improving water security prospects. Caribbean and other future OTEC linked projects could learn from other global examples including Martinique, French Polynesia and Reunion (Abtey 2012). Tidal energy power has been reliably generated since 1977 or 500 GWh per year from France's Rance Tidal Dam with a 2009 Lake Sihwa project in South Korea. Norway and Reunion provide salinity gradient power test sites.

2.4.2: Europe

Since 2010 the European Union and various entities have pursued MRE; recognising the myriad benefits (European Marine Board 2010). Although it lacks a formal governance framework and regulations, various European agencies and individual governments or stakeholders have provided evidence of implicit belief, budget, research, entrepreneurial, innovation, training and other support towards marine renewable energy. This includes various market based incentives and a grid. It estimates 563 TWh per year for offshore wind and 142 TWh for wave energy as possible within Europe, with over 200 project examples to ruminate as potential evidence as Denmark's Wave Dragon. Several are summarised above in Table 2.3, others in India and Scotland. Bristol's Severn Estuary Tidal Barrage could contribute another 17.1 TWh per year. Tidal and ocean currents can add 36 TWh and salinity gradients 28 TW annually. This excludes millions of marine algae and seaweed related species that could be investigated.

The European Marine Energy Centre in Scotland's Orkney Islands prove to be one of the most convincing case studies of the reality and practicality of various marine renewable energy types (EMEC 2016). The European Marine Energy Centre with 13 test beds and 250+ jobs include projects such as Aquaterra, Minesto, Morlais, ITP Energised and Wavehub (EMEC 2019) and consultancy expertise across 249 million. Scotland has reached 897 MW and the rest of the UK exceeds 340 MW directly supporting 1700 jobs. With over 450 million pounds across the supply chain The UK envision MRE sector potential up to 22,600 direct jobs by 2040, along with improving skills and education, reducing imports and providing more diverse livelihoods. Orbital Marine Power produces 130 MWh and Mey-Gen 8 GW. Scotland alone exceeds 197 MW of offshore wind energy production; which Mauritius are seeking to replicate certain of the conditions which ensured their viability (Cramer et al. 2019). Existing examples range from 30 MW at 152,000,000 pounds for Hywind Scotland Pilot Project to 784 MW at Inch Cape at 3 billion pounds for offshore wind from 40 MW (APL Lewis) to 200 MW (Costa Head) for wave power. It extends from 0.5 MW (Argyll Tidal Demonstrator project) to 398 MW (Mey-Gen) for tidal. Wales also has proven to have a significant economic impact from wave and tidal energy with one source estimating various scenarios of 60 MW, 300 MW and 1 GW capacity at pilot areas (Fanning 2013). It estimated economic GVA impact for 800,000 to 1,200,000 pounds. Total Wales potential could be 1.5-6 GW of combined energy. Project examples include a 1.2 MW of Tidal Energy Ltd, 8 MW of EON, 7 MW at Wave Dragon and 10 MW in Marine Energy. It estimated 165 pounds per KW to tidal and 175 pounds for wave energy along with 50-440 jobs, provided sufficient investment incentives and opportunities exist.

Ireland has focused on successful trials of marine current energy devices (Bedard et al. 2010) via cost-benefit analysis. These need to consider grid integration, technical feasibility and resource presence. It was installed and operated in Strangford Lough since 2008. The location has a theoretical potential of up to 130 GWh per year. It confirmed long term costs could be reduced to 94-105 pounds per MWh over 15 years. Investment would assist to overcome a 91% of total fuel energy demands being imported. Others include 273 GWh off the northeast Coast, 125 off Ram-Race Copeland islands, 111 off Shannon Estuary and 177 GWh by Tuskar Rock and Camsore Point. Denmark has benefitted from three decades off offshore wind farm experiments and testing since 1991. For example, one study estimates the 399.6 MW Anholt and 40 MW Middelgrunden wind farms (Cramer et al. 2019) to cost $1.5 billion and $50 million respectively. Yet these and 11 other wind farms directly support over 500 other companies and 28,000 jobs across their supply chains. It cites the community co-ownership model with 8700 citizens involved for Middelgrunden. Denmark also exports to Norway and provides feed in tariffs and other financial incentives.

Scholarship on Mediterranean marine renewable energy advised the need for geotechnical/engineering, market, social and climate survey assessments to be conducted (Soukissian et al. 2017). Although marine spatial planning presents challenges, it argues advantages from the lack of an extensive regulatory environment framework, consistent energy supplies and in promoting employment/value chain and market activities. It identifies other areas have benefitted beyond the Mediterranean with 9.099 GW for offshore wind the North Sea, 2.689 GW for the Irish and 1.457 GW in the Baltic and 5 MW for the Atlantic Ocean. Europe has significant experience in research, development, commercialisation, test facilities and marine data. Other gains may include improved technology plus marine biodiversity and structures to support aquaculture, conservation, tourism and biotechnology. It argues sites can become more popular through social education and marketing awareness campaigns. One tidal current and range energy case study in Italy's Straits of Messina utilised an environmental impact assessment to affirm the energy type's overall sustainability and other benefits (El-Geziry, Bryden and Couch 2009). It provides far less ecological costs to aquatic biodiversity and generates reduced marine pollution, although still at risk to biofouling. It advises the need to consider existing seabed configuration and dredging areas, navigation and other existing marine area uses. It proposes assessing impacts over the tidal farm project's lifecycle and all related stages such as assembling, transportation, installation, operation and decommissioning. It advised the need to minimise noise throughout to reduce ecosystem disturbance including whales. It is considered technologically feasible with an accessible market and various incentives including proactive risk management.

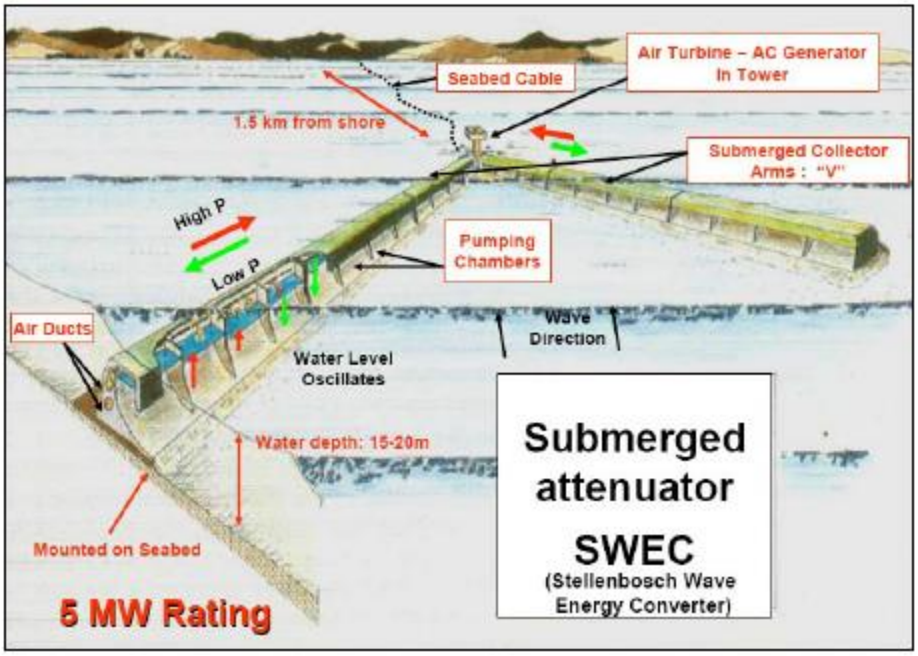
2.4.3: Africa:

An extensive research on the Agulhas current's electricity opportunity (Meyer 2009) emphasised how South Africa could with sufficient focus and resources resolve its chronic 12 years of electricity generation catastrophe. It proposed the use of Natal pulses, sensors and Minesto Deep Green 12, turbine technology up to 2000 MW, conditional upon reaching stable depths exceeding 250 metres as technologically ready. It does not affect existing marine conservation and fisheries activities in the areas proposed. A further South African study estimated 21-27 GW as latent Agulhas ocean current energy, yet to be harvested and feasibility off the Kei River Mouth and East London, along with OTEC off the south KZN coast and wave energy off Port Nolloth, Cape Point and Slangkop (Sustainable Energy Africa 2017). It estimated MRE costs are currently R5 per KWh but need to be reduced to R0.60 to be competitive with solar photo PV and wind. It is technically possible but needs infrastructure and financial/policy support to be capable. A 2013 state assessment of ocean renewable energy sources confirmed this (Schumann 2013). OTEC plants can share decommissioned oil exploration sites and function with structures around 100 metres deep. However, a fully comprehensive ecological survey and oceanographic modelling has yet to be conducted with a need for marine spatial planning.

An additional assessment by Ocean Energy Network confirmed South African prospects to utilise the Agulhas Current (Ocean Energy Network 2013). It established a possible site off Cape Morgan with current speeds up to 1.5 m/s, capable of interlinking possibly to the state electricity transmission grid but advises the need to consider implementation, stakeholder coordination and cooperation. South African wave energy also appears promising with electrical energy potential from 25-50 MW per kilometre with a buoy network, piston pumps and oscillating column technology, with an average of 18-23 KW/metre for most of the coast, except for the southwest at 40 KW/metre (Fourie and Johnson 2017). Additional benefits include reverse osmosis generated desalination plants for water security. An investigation into South African wave energy has proven viable scientifically via am initial resource evaluation, numerical wave model and wave converter experiments (Lavidas and Venugopal 2018). Wave energy has potential up to 6-7 metres with stable current supply prospects and produce up to 10 jobs per MW of energy produced.

An earlier study affirmed this chance for wave energy to reduce existing supply instability off the southwest coast (Joubert 2008). It too proposes wave energy converters from Cape Point to Eland's Bay via a sensitivity analysis and potential wave energy power up to 40 KW/metre and theoretical up to 50. This ranks among the highest globally that are easily accessible along with equivalent latitudes in South America, Australia, New Zealand and the South Pacific and Northern Europe, Canada/the USA. It also conducted spectral, climate and meteorological data analysis and energy density of waves. Pilot wave energy converter projects date back to the 1980's at Stellenbosch University with the 1989 version possessing potential of 5 MW and revised several times including 2007 (Figure 2.10). In contrast the globally popular Pelamis offered only a maximum of 750 KWh and Aqua Buoy 250 KW, indicating significant export opportunity for South Africa. The UK Archimedes Wave Swing offers 4 MW per unit but a $4-6 million installation cost. An alternative case study confirms wave energy conversion as not only technically feasible and sustainable but also cost effective (Biyela and Cronje 2016). A Wave Star project would cost $13,210,000 in capital and 1056.83 K$ per year with a Localised Cost of Energy of $3,049 per MWh over 20 years average lifespan. A Pelamis project would cost $ 31,920,0000 in capital and 2,553.60 K $ per year with a minimum $5136 per MWH over 20 years. Joubert estimates a R3.4 billion wave plant could produce 770 MW with 154 converter units at an initial price of 60 to 75 cents per KWh. It offers fewer transmission costs than offshore wind, salinity gradient and OTEC being closer to shore. It is subsequently therefore easier to operate and maintain.

Figure 2.10: Stellenbosch Wave Energy Converter South Africa.



Source: Joubert 2008.

In Africa a pilot study in Nigeria has estimated how hydrokinetic energy via the Benue/Niger rivers could reduce installation costs of electricity from $7,900 per installed KW to $2500 (Eme et al. 2019) with savings on imported fuel and logistics as co-benefits. Mauritius also has a chance to be empowered with 250 MW of offshore wind energy potential with previous proposals such as Hexicon stalled from a lack of investor funding rather than environmental, climate and technical impracticality (Cramer et al. 2019). 3.6-7.2 GW wave energy has been estimated with a 20-42 KW/m power density. A combined floating solar voltaic and wave energy 5 MW pilot project was attempted in 2016 with further benefits of desalinated water. Mauritius is also projected to be suitable for OTEC energy and floating solar voltaic. It advises a need for financial and regulation incentives, integrated grid connections, ecological and ocean surveys along with marine spatial planning.

2.4.4: Asia

China is also starting to investigate marine renewable energy, especially the offshore wind industry sector (Carbon Trust 2014). Aside from its Renewable Energy Law, technical standards and feed in tariffs, it is undertaking various research and tests, although not commercially active yet. Chinese offshore wind farms were estimated to cost 1,300,000 to 1,400,00 pounds per 1 MW, contrasting with a similar 1,200,000 to 1,500,000 pound price for the UK. China still faces market uncertainty over the reliability of components, assembly costs and divergences in soil/climate/skills and risks of typhoons. From 2001 to 2012 China's onshore wind power capacity increased from 381 MW in total to 75,324 MW. Offshore wind capacity increased from 1.5 MW to 389.6 MW from 2007 to 2012. Yet this remains substantially below a total estimated potential of up to 200 GW. From 2013 to 2020 China projects a dramatic increase from 471 MW to 31,527 MW. Guangdong province alone aims for 10.71 GW by 2030. Most remain in the concept or early planning stage

China has been experimenting with marine renewable energy especially, tidal and wave since 1958 with 11 MW of capacity in 2012 (CSIRO 2012). Examples include Jiangxia, Haishan and Baishakou tidal barrage along with wave power for Wangxiang, Daguan Island and Guangzhou. However, projects remain state and academic driven rather than commercial at present. China has offered various policy and financial incentives under its 2006 Renewable Energy Law. In India 2007 estimates included potential up to 175 TWh/year wave energy, 88 TWh/year for tidal and a dramatic 440 TWh for OTEC. Wave energy experiments are occurring in Kerala state and tidal energy for the Gulf of Kutch, Khambat and Sunderbans Delta. Ocean current energy has proven feasible with axial flow water turbines in Wallacea near East Timor for Indonesia (Nugraha and Rijanto 2012). It is considered highly reliable and stable and accessible with logistics. Another study has determined the potential for 216 GW of MRE in East Nusa Tenggara Province, Indonesia from current, tidal and wave energy production (Kusama 2018). It affirms the need for effective resource mapping, design innovation and need for sound technology and effective grid connections. It cites possible social and economic benefits from increased employment, energy security and climate change mitigation. A significant market is forecast with a targeted 80% increase in energy demand from 2000 to 2030.

2.4.5: Australia/South Pacific

South Pacific research of the past 3 decades has emphasised the technical potential and certain benefit of various marine renewable energy, even though this has yet to be accompanied by a subsequent surge in pilot and commercial projects. For example, ocean wave energy was considered practical in a 1996 study from a long-term SOPAC study of Waverider buoy oceanographic data survey across Fiji, Samoa, Tonga and Vanuatu and 3 European satellites (Barstow 1996). However, designs need to consider certain technical standards given high vulnerability, to climate related natural disasters on cyclones, tsunamis, rogue waves and storms. A more recent article affirmed the cost effectiveness of specifically deploying the Pelamis wave energy converter in Oceania with definite benefits to overcoming high fuel import costs (Bosserelle, Reddy and Kruger 2015). It estimates a Pelamis device could utilise over 20 KW per metre of wave producing 1200 MWh and costing $0.004-0.090 per KWh in operation and maintenance, $0.02-0.18 in installation and a capital cost of $ 6,318,000-14,104,000 per device. It notices significant wave energy potential for the Cook Islands, French Polynesia, New Caledonia and Tonga but not the Solomon Islands, Samoa, Marshall Islands, Federated States of Micronesia and Papua New Guinea. However, the South Pacific lacks commercial project examples to validate this, offers few specialised skills and institutional capacity at present and high logistics costs. Yet more potential sustainable ocean finance is being developed. The small scale nature of many of these technology's energy capacity would still suffice to empower many more remote island communities, where shore based renewable and fossil fuel powered substitutes would be less economical.

Australia has also extensive institutional capacity including resources, training, pilot projects and research expertise such as CSIRO, the University of Tasmania's IMAS, Universities of Sydney, Wollongong, ANCORS and others to ensure victorious ocean renewable energy (CSIRO 2012). Wind, wave, OTEC and solar voltaic energy remained competitive and practical to 2050 but not tidal and current energy. It has extensive oceanographic data and survey access capacity. Examples of viable companies include Tenax Energy with proposals for a 200 MW tidal energy plant by Darwin and an 80.6 TW facility from 45 turbines in Port Phillip Bay. From 2006-2012 the Atlantis Resources Corporation also fixated on 200-500 MW of tidal energy at San Remo Victoria, via the Venturi effect. In 2010 Cetus Energy developed a successful ocean/tidal current based energy system at Rubicon Valley Mountain Stream, Victoria.

2.4.6: General

A review on ocean energy estimated its value can be confirmed through its technical, environmental and economic feasibility globally, as confirmed by myriad pilot projects; provided it can be scaled up sufficiently and implemented correctly (Uihlein and Magagna 2016). It advises the need for a life cycle assessment of the various proposed technology and components combined with an overall project cost benefit analysis. It contends global wave technology has proven itself via initial modelling across Cornwall, the Orkney Islands, Black Sea, Azores, Mediterranean, Pacific, Caribbean and India. Tidal current energy assessments have been conducted across Fiji, Iran, Taiwan, Canada, Norway and China. The examples of Ireland's Open Hydro and Sea Gen tidal in-stream turbine units confirm over 12 years of proven examples to gain experience from when design micro-scale and test units up to 10 MW (Bedard 2008). Osmotic or salinity gradient energy has had one successful exemplar in Norway since 1997 under Statkraft.

Existing sources continue to cite examples of pilot stage project successes to emphasise how practical various ocean and marine energy projects can be with 39 wind energy farms as early as 2010 in Europe with 2,396 MW of total installed capacity and a further 100 GW under consideration (Environmental and Energy Study Institute 2010). Certain nations such as Denmark benefit from not only access to well developed technologies, supply chains, fiscal and policy incentives but increasing society acceptance and preference for marine solutions as being far less aesthetically and practically intruding than shore based equivalents. The UK reached 13 offshore wind farms by 2010 and 1,341 MW actual with 3,772 MW proposed for total installed capacity. This contrasted with 246.8 MW in the Netherlands, 163.65 for Sweden, 2.3 in Norway, 24 in Finland, 102 MW in China, 11 in Japan and 0 in the US. Offshore energy can benefit even more via marine spatial planning, LIDAR, radar, sonar, satellites, surface heat flux and other climate-oceanographic-atmospheric simulation models or data.

Various technology types are becoming more economical over time. Tidal energy projects have also been proven globally; although on a reduced scale in comparison to wind and wave energy (Mendi, Rao and Seelam 2016). One example includes the 2017 installed 4.5 MW Korea Tidal Current Energy Centre in Jindo South Korea and another in India with benefits of being predictable, constant and sustainable. Indian examples include 100 MW in Sunderbans, 1200 MW in the Gulf of Kutch and 7000 MW in the Gulf of Khambhat. Other pilot examples include Russia's White and Okhotsk Sea, Puerto Rio Gallegos Argentina, Ganville and La Rance France, Canada's 500 KW Blue Energy, Norway's Blue Concept and the UK's Seagen Marine Current Turbine. Ocean current energy examples are Gulf Stream Turbines in the USA and the Agucadoura Wave Farm in Portugal. Other possibilities include the East Australian Current, Brazil Current and Japan's Kurushio Current. In conclusion, these case studies can confirm that marine renewable energy can be made to work under certain circumstances with multiple project examples as partially summarised in Table 2.4 below.

Table 2.4: Summary of Marine Renewable Energy Global Project Examples and Case Studies

Energy Type	Project	Location	Power Capacity	Source
OTEC	Kanede Bay	Hawaii, USA		Cramer et. al 2019
Wave Energy	Power Buoy	Hawaii	40 KW	Hana and Nauo 2009
Tidal Barrage	Annapolis Royal	Bay of Fundy Canada		CSIRO 2012
Wind	New York-Long Island Offshore Wind Alliance	New York-Long Island USA	350-700 MW	Environmental and Energy Study Institute 2010
Various		Trinidad and Tobago		Henry et al. 2018
Tidal Barrage	Rance Tidal Dam	France		Abtey 2012
Various Wave	European Marine Energy Centre Pelamis Archimedes Wave Swing	Orkneys, UK	Various -13 test beds 750 KW 4 MW	EMEC 2016 Ocean Energy Network 2013
Tidal Barrage	Severn Estuary	Bristol, UK	Potential 17.1 TWh per year	
Wind Wave Tidal	Hy-Wind, Inch Cape etc APL Lewis, Costa Head Argyll Tidal Demonstrator, Mey-Gen	Scotland, UK	30 MW at Hy-Wind to 784 MW at Inch Cape; 40 MW APL Lewis to 200 MW Costa Head 0.5 MW Argyll 398 MW Mey-Gen	Fanning 2013
Marine Current	Strangford Lough	Ireland	Potential 130 TW/year	Bedard et al. 2010
Wind	Anholt, Middelgrunden	Denmark	399.6 MW Anholt and 40 MW Middelgrunden	Cramer et al. 2019
Current OTEC Wave Energy	Potential Potential Trial Phase	South Africa	2000 MW initial Potential 21-27 GW Not estimated 5 MW test phase	Joubert 2008; Schumann 2013; Ocean Energy Network 2013; Sustainable Energy Africa 2017
Offshore Wind	Hexicon- Lack of funding	Mauritius	250 MW	Cramer et al. 2019
Tidal	Lake Sihwa Korea Tidal Current Energy Centre	South Korea Jindao	 4.5 MW	Abtey 2012
Salinity Gradient	Statkraft	Norway		Bedard et al. 2010
Tidal	Jiangxia, Haishan and Baishakou	China	11 MW	CSIRO 2012
Wave Tidal	Kerala Gulf of Kutch, Khambat and Sunderbans Delta	India	100 MW Sunderbans, 1200 MW Kutch, 7000 MW Khambhat.	CSIRO 2012
Current	Wallacea	Indonesia		Nugraha and Rijanto 2012
Wave	Potential	South Pacific	1200 MWh	Bosserelle, Reddy and Kruger 2015
Tidal Current	Tenax Energy Atlantis Resources Ceto Energy	Australia	200 MW and 80.6 TW proposed 200-500 MW	CSIRO 2012

Source: This Study.

2.5: Evaluating Case Study Methods, Lessons and Approaches: Failures/Issues.

Avoiding mistakes, errors, failures and other lessons learnt from the experience and effort of others such as the case studies and sources in this section; can be as beneficial for marine renewable or ocean based energy as it can be for other sectors. General issues include the secrecy over the extent of commercialised prospects from the myriad experiments along with a minimal or non-existent regulatory framework or sources of funding (Borthwick 2016). Comparatively few research studies recognise the merits of focusing on weaknesses and failures rather than successful projects. Sources and stakeholders testify to the unpredictability of energy supply inputs from climate related events and implementation challenges of scaling up to commercialisation beyond the experimental phases. It lacks the same extent of successful marketing, investor and stakeholder consumer interest as other areas of energy production and the blue economy. Risks also potentially exist over conflicting marine space use as well as others more specifically detailed in sections 3.4 and 3.5.

Many underpublicized examples exist of many companies that went bankrupt, faced liquidation or cashflow constraints, unable to accelerate various envisioned ideas (Dalton 2014). These include Pelamis Wave Power liquidated and restructured in November 2014. Aquamarine Power was liquidated in November 2015 followed by Wave Star, Oceanlinx and Wave Gen. Stakeholders often remain uncertain psychologically as to how this experimental market will progress and uncertainty over technology, regulatory development and commercialisation. Despite several decades of experiments, comparatively few large global players and related research studies exist and institutional capacity including few marine spatial planning experts, hinders development of the sector (Economist Intelligence Unit 2015).

Even where it has theoretically proven to work it may be considered as more expensive to develop then alternatives given finite constraints and this restricted capacity as for OTEC technology and the South Pacific (SOPAC 2001). This case study considers few successful case studies exist and it has yet to convincingly prove itself in the short and long term as more economical for the Pacific ($0.149 per KWh at 1990 prices than current fossil fuel substitutes or even wave power at $0.062-0.072. However, this study was 19 years. It expressed concerns as to the uncertain ecological implications from installation and a 3 kilometre cold water outflow pipe as pressurising already climate sensitive marine ecology. It cites technical, financial and institutional barriers as constraints. Whilst salinity gradient energy offers many potential prospects for nations as one Australian case study confirms via immense salt pans and other sources, desalination benefits and research incentives, these retain uncertain ecological implications (Heifer et. al 2014). It argued extensive canals and processes would not be feasible for certain sources and that membrane based technology was insufficiently advanced at present with high capital costs and few commercial examples to emulate. Other issues included salinity and other biofouling implications for membranes, technological and legal uncertainty and scaling up challenges from pilot/experimental phases.

Perhaps the most conspicuous examples are where marine renewable energy sites and research are not currently emerging from including Latin America, the Middle East and Caribbean, remaining conspicuously absent from renewable energy market research and funding such as the Inter-American Development Bank (Flavin et. al 2014). It lacks public and private funds, a market structure, research and financial incentives in these areas with very marginal considerations of integration into national transmission grids. Other risks include uncertain markets, poor transmission risks, lack of local capacity, training and expertise, socioeconomic, currency and political instability along with virtually no accessible case studies. Virtually no Latin American and Caribbean nations offer accelerated depreciation, customs import, tax relief, rebates or other incentives favouring general or marine renewable energy. These issues were confirmed by a second study in which stakeholders perceived renewable energy as requiring costly subsidies and capable of not providing significant electricity contributions to demand requirements (Vergara, Alatorre and Alves 2013). Although studies estimate at a minimum 10-15% of total continent demand, no commercial ocean projects and very few pilot projects have been attempted apart from Chile for wave and tidal.

Caribbean marine renewable energy challenges include issues of affordability, accessibility, high tariffs, fragmented small markets, institutional capacity and limited peak demand (Williams 2011; Williams 2012). It extends to a lack of public awareness and popular support, few researchers and engineers, restricted investment capital from ignorant banks and financiers, inexperience and challenges to transmission connections. In the USA Cape Wind an offshore wind farm by Cape Cod Massachusetts, received significant protests and legal challenges from local residents over higher electricity costs and environment/marine species being possibly adversely impacted. Yet it eventually received authorisation following an environmental impact assessment.

In the Mediterranean, marine renewable energy issues have included issues of technological uncertainty, grid constraints, lack of access to finance, high market entry barriers, administrative, ecological and legal concerns (Soukissian et al. 2017). It highlights the problems caused by climate related events and other disruptions to supply by solar voltaic, wind, wave, tidal and other energy processes. For example, in the Cote de Azur in 2011, residents successfully prevented an offshore wind energy development out of proclaimed concerns for nature and tourism, based on aesthetics and noise. Pelamis Wave Power operated from 2008 to 2010 in Portugal ceased to operate, losing solvency after climate and ocean equipment damage. High biofouling and corrosion risks exist for many equipment. In China offshore wind energy has experienced significant bureaucratic implementation issues including a lack of consultation, coordination and agreements over various marine spatial area usages (Carbon Trust 2014). Concerns were voiced over creating a sufficient feed in tariff that encourages conversion and consumption for users whilst remaining a profitable rate of return on investment.

2.6: Research Gaps, Moving Forward and Findings/Conclusions

In conclusion existing research has focused on identifying various project developments, successes and the theoretical potential to implement marine renewable energy. This source's conceptual contribution has been to not only analyse existing sources moving forward to identify various research gaps to assist the transition and determine how feasible MRE sources can initially be. It includes identifying stakeholders, the supply chains and existing legal/other research gaps to propose new site specific criteria, regulatory structures, research case studies and other factors indispensable towards reducing the need for fossil or other fuel as a basis before further detailing its conceptual contribution in chapter 3. Few sources have concentrated on failures, issues and lessons learnt, yet these remain essential to avoid associated inaction, maladaptation and opportunity costs for stakeholders.

Chapter 3:

3.0: Introduction

Marine renewable energy prospects may have been increasing over the past three decades but has yet to make an impressively substantial contribution to the electrical transmission grids of Earth or venture beyond the pilot/initial testing phase for many energy types. To empower our generation towards a climate resilient, emissions reductive blue and circular economy in a Post-COVID 19 era, away from the fossil fuel overdependency enslaving so many, this Chapter's conceptual contribution is to move beyond synthesising existing sources and research gaps towards accruing part of the information necessary to move forward. This aims to assist various actual and intended participants from individuals, businesses, communities and NGO's to policymakers and investors, beyond a few academics to facilitate the transition towards implementation. Chapter 3 therefore identifies a brief history of marine renewable and ocean energy progress in Section 3.1. It outlines the current and potential markets, technology locations, stakeholders and developments in Section 3.2, along with demand and supply options. It highlights advantages (Section 3.3), disadvantages, (3.4), risks, issues or challenges (3.5), any existing and prospective opportunities (3.6) for Wave, Wind, tidal, current, thermal, LNG-shipping, salinity gradient, bioenergy -biotechnology and circular economy.

3.1: A History of Marine and Other Renewable Energy Reduction

Humanity's first efforts at harnessing energy production can be traced back to fire with our distant forbears and wood cultivated for biomass. Coal and peat mines can be traced to the Ancient Romans and Greeks, with legends of complaints of the first recorded air pollution near the mines of Hispania in the Second and First centuries before the Common Area. However, wind power's legends can be traced to Daedalus creating artificial wings to escape King Minos with his son Icarus, although Icarus plummeted. Yet humanity first turned their attention to wave, current and tidal power with water and tidal mills using dams and waterwheels for mills and agriculture under the Romans as evidenced in Britannia or modern England. This was later retained under the "Dark" and "Middle" Ages across Europe with similar evidence existing across China, Korea and Japan. In the Renaissance Leonardo Da Vinci pioneered helicopters, aerial craft powered by wind and submarines. However, it was only with Jules' Verne's fictional 20,000 Leagues Under the Sea and Captain Nemo's thermal gradient powered, mammoth Nautilus submarine that presaged the 20th century efforts towards oceans and marine energy, although land based sources received first preference as more familiar, accessible and economical.

In 1929, the French scientist George Claude managed to achieve a 22 KW Ocean Thermal Energy Conversion (OTEC) demonstration project off Cuba's Bay of Matanzas. Curiously pilot MRE projects have been proposed as far back as 1956 for Africa (UNECA 1981) and wind, wave, thermal and tidal recommended by the United Nations Economic Commission for Africa since 1981. The initial 1956 project in Abidjan Ivory Coast aimed to harness the Trou sans Ford area for OTEC generation, with origins under the Swiss Mr Wimmer following the Cuban experiments in 1929. It was soon discarded, although efforts were reattempted in the 1960's and 1980's. More recent technological improvements and access to funding globally may make it even more feasible. The US National Science Foundation and RANN entities funded a prototype OTEC plant in 1974 undertaken by companies Lockheed and TRW, receiving 84 submission bids and 20 shortlisted projects. OTEC energy pilot projects extend to the 18 KW pilot project in the US followed by 1 MW in 1981 (Sasikumar, Sundaresan and Nagaraja 2018). Nauru in the South Pacific received a Japanese OTEC prototype up to 123 KW from 1982-1983. In 1983 Keahole Point in Hawaii reached a 50 KW prototype experiment after receiving the Natural Energy Laboratory created in 1974. From 1993-1998 Hawaii undertook a pilot project reaching 255 KW in output for OTEC. Lockheed Martin then tested a 10 MW option off Hawaii in 2013 and another 10 MW in China but these failed to receive ongoing fiscal support. India received technical problems with its cold water pipe and desalination with a similar effort in 2000 for OTEC. Japan tested an 18 KW pilot in 2006. Its Saga University created a 30 KW prototype in 2006, while Xenesys Incorporated managed to supply an integrated aquaculture facility for 50 KW off Okinawa Island in 2013. DCNS France investigated OTEC technology off Martinique from 2013-2016.

Tidal commercial technology started with the 240 MW La Rance in France in 1967 with others in Canada, China and Russia (IRENA 2014). La Rance offers 24 10 MW bulb turbines weighing 470 tons, a 750 long, 13 metre high dam (Clark, Klossner and Kologe 2003). It has not recorded any major ecological or flooding impacts in 50 years of operation, powers over 300,000 homes and attracts tourists for additional revenue. Russia started with a 0.4 MW pilot Kislaya project in 1968 on the White Sea. Canada operates a 20 MW Annapolis Royale power plant at the Bay of Fundy for decades. South Korea opened Lake Sihwa in 2012 as a 254 MW tidal barrage scheme. From 2012-2016 the Severn Barrage Scheme was estimated to require 216 turbines with potential to generate up to 17 TWh per year but has not yet reached optimal performance and installation energy potential. Jiangxia Power Station in China achieves 3.2 MW of output and up to 6.4 GWh per year.

Japan's Yoshio Masuda experimented with wave energy as early as 1947. The UK invented the initial Duck WEC technology in 1973, with the Department of energy using incentives to add 2000 MW of capacity to the grid from 1976-1982 during the global OPEC energy crisis. Denmark initiated more technology based wave energy interest in the early 1980's, whilst other European nations started researching in the 1990's. Sweden conducted a 30 KW proto type around 1985. China researched wave energy since the 1980's with a pioneer 3 KW, Oscillating Water Column device off Dawanshan in 1991 (Barstow 1996). From 1985-1991, the Indian Institute of Technology experimented with a 150 KW wave energy converter, deployed off the coast of Madras. Wave energy pilot examples included Lunar Energy in 2001, SMD Hydrovision and TGL in 2005 along with Pulse in 2007 but several received fiscal constraints. Pelamis reached 750 KW with Portugal tests in 2008. From 2006-2010 Wales undertook several projects (Mer 2010) including Lunar Energy (St David's), Skerries Tidal Stream Array and South Stack Tidal Stream Array (Anglesey Island), Swan Turbines (Swansea and Milford Haven), Tidal Hydraulic Generators/Wave Dragon (Pembrokeshire) and Tidal Energy Limited (Ramsey Sound). South Africa investigated current based energy between 2007-2013 but with no working prototypes. Salinity gradient energy received its first successful pilot project in 2009 with Statkraft in Norway, powering a 5 KW electric kettle, although scaling up and improving membrane technology since then and subsequently stalled due to repeated global biofouling issues for membranes and turbines. However other pilots are being undertaken in Norway and the Netherlands.

3.2: Current Developments and Initiatives for Marine Renewable Energy and the Blue Economy.

3.2.1: Global Supply and Demand for Marine Renewable Energy.

This section's objective is to provide a current overview of the present and possible market conditions, type, structure, news, developments and initiatives related to marine renewable or ocean based energy and the blue economy. This potential has been estimated as at least 2000-4000 TWh each year (Parker 2015). This may be aided by projects such as Russia's Penzhina Bay with planned ultimate capacity of 87 GW and the 8.1 GW output from the UK Severn Estuary for tidal power. Existing global facilities supplying MRE are summarised in Table 3.1. The global capacity of oceans and marine resources has yet to be fully examined but initial estimates based on existing research at a minimum are estimated in Table 3.2. However, this excludes sites that may have to be rejected for ecological, economic or marine spatial planning and existing conflicted uses. Table 3.3 provides an indication of those sources and institutions leading in research, in combination with the stakeholders identified in Section 2.2 as among the innovators in this emerging blue economy sector. Table 3.4 provides 2020 other MRE test site locations. Table 3.5 highlights possible options for future supply, conditional upon sufficient market demand, resources and surveys being conducted. In 2016 the largest offshore wind turbine was the USA made 10 MW Sea Titan, 190 metre rotor diameter and 125 metre hub height. In 2019 the MHI Vestas Turbine was the largest turbine

Table 3.1: Existing Global Facilities/Supply for Marine Renewable and Ocean Energy.

Energy Type	Date	Project	Location	Potential Output Capacity
Tidal barrage	1967	La Rance	France	240 MW
Tidal	1984	Annapolis Royal	Canada	20 MW, Potential 11,700 GWh
Tidal	1968	Kislaya	White Sea, Russia	0.4 MW
Tidal	2012	Lake Sihwa	South Korea	250 MW
Tidal	2016	Severn Estuary	Bristol, UK	Potential 12,900 GWh
Salinity gradient	2009	Pilot	Norway/Netherlands	Unknown
Marine Current	2008	Marine Current Turbine	Ireland	
Offshore wind	2017	Hy-Wind	Ireland	30 MW
Offshore wind	2017	Wind Float Atlantic	Portugal	25 MW
Offshore wind	2017	Kincaidine Offshore Floating Wind Farm	Scotland	50 MW
Offshore wind	2017	Various	France	96 MW -4 x 24 MW
Wave	1999	Pico Wave Power Plant	Portugal	400 KW
Wave	1999	Wave Pendulum	Daguan Island China	30 KW
Wave	2000	Isle of Islay	Scotland	500 KW
Wave	2007	Energetech	Rhode Island, USA	500 KW
Wave	2008	Acadoura Wave Park	Portugal	2.25 MW
Wave	2011	Mutriku Wave Energy Plant	Spain	300 KW
Wave	2014	Garden Island	Australia	720 KW
Wave Point absorber	2015	Ada Foah	Ghana	400 KW
Wave	2016	Sotenus Project	Sweden	1.05 MW
Wave	Pending	Zhaitang Island	China	500 KW,
Wave	Pending	Wanshan Island	China	500 KW
Tidal	2004	Andritz-Hydro	Norway	300 KW
Tidal stream	2005	Kobold I	Straits of Messina, Italy	1 MW
Tidal stream	2008	Sea Gen	Portaferry North Ireland	1.2 MW
Tidal stream	2011	Uldomok Tidal Power Station	South Korea	500 KW
Tidal stream	2011	Scot Renewables	Scotland	250 KW
Tidal stream	2012	Cobscook Bay Maine	USA	150 KW
Tidal stream	2015	Sabella D10	Brittany France	50 KW
Tidal stream	2015	Inner Sound 1A	Caithness Scotland	6 MW
Tidal stream	2019	Cape Sharp	Nova Scotia Canada	4 MW
Tidal stream	2019	Shetland Tidal Array	UK	500 KW
Tidal range	1972	Haishan Tidal	China	250 KW
Tidal range	1978	Baishakou Tidal Power	China	950 KW

Tidal range	1980	Jiangxia Tidal Power	China	250 KW
Tidal range	2017	Incheon Tidal Power Plant	South Korea	1.320 MW
Tidal range	2019	Saemangeun Reclamation Project	South Korea	400 KW
Salinity Gradient	Planned	DCNS	Reunion	15 KW
Salinity Gradient	Planned	Makai Ocean Engineering	Hawaii	105 KW
Salinity Gradient	Planned	Xenesys	Japan	30 KW
Salinity Gradient	Planned	Xenesys	Japan	100 KW
Salinity Gradient	Planned	Kriso	South Korea	20 KW
Salinity Gradient	Planned	DCNS	Martinique	10 MW
Salinity Gradient	Planned	Kriso	Kiribati	1 MW
Salinity Gradient	Planned	Blue-rise	Curacao	500 KW
Salinity Gradient	Planned	Xenesys	Japan	1 MW
Salinity Gradient	Planned	Bell Pirie Power Corp	Philippines	10 MW

Source: This Study, adapted from myriad sources including IRENA 2014-2020; Bosserelle, Reddy and Kruger 2015, Asian Development Bank 2015.

Table 3.2: Potential Global Ocean Resources Supply for Marine Renewable and Ocean Energy.

Energy Type	Location	Potential Output Capacity	Potential Annual Generation
Marine Current	Global	0.6 TW	600, TWh
Salinity Gradient	Global	30 TW	2,000 TWh
Ocean Thermal Energy	Global	40 TW	44,000 TWh
Tidal	Global	3 TW	30,000 TWh
Wave	Global	3 TW	30,000 TWh
Solar voltaic	Global	Unknown	Unknown
Wind	Global	Unknown	Unknown
Bioenergy	Global	Unknown	Unknown
Wave energy	Australia	Unknown	1,300 TWh/year
Marine current	Australia	Unknown	44 TWH/year
Wave Energy	West-North Europe	Unknown	2,800
Wave Energy	Mediterranean Sea and Atlantic Archipelagos	Unknown	1,300
Wave Energy	North America, Greenland	Unknown	4,000 (2,640 in US)
Wave Energy	Central America	Unknown	1,500
Wave Energy	South America	Unknown	4,600
Wave Energy	Africa	Unknown	3,500
Wave Energy	Asia	Unknown	6,200
Wave Energy	Oceania/South Pacific	Unknown	5,600
Salinity Gradient	Europe	23 GW	200
Offshore Wind	Europe	4000 GW	Unknown
Offshore Wind	USA	2450	Unknown
Offshore Wind	Japan	500	Unknown
Offshore Wind	Taiwan	90	Unknown
Offshore Wind	Brazil	748 GW Floating, 480 GW fixed	Unknown
Offshore Wind	India	83 GW floating, 112 Fixed	Unknown
Offshore Wind	Morocco	178 GW floating, 22 GW fixed	Unknown
Offshore Wind	Philippines	160 GW floating, 18 GW fixed	Unknown
Offshore Wind	South Africa	589 GW floating, 57 GW fixed	Unknown

Offshore Wind	Sri Lanka	37 GW floating, 55 GW fixed	Unknown
Offshore Wind	Turkey	57 GW floating, 12 GW fixed	Unknown
Offshore Wind	Vietnam	214 GW floating, 261 GW fixed	Unknown
Wave	West and North Europe	Unknown	2,800 TWh/year
Wave	Mediterranean Sea and Atlantic Archipelagos	Unknown	1,300 TWh/year
Wave	North America and Greenland	Unknown	4000, TWh/year
Wave	Central America	Unknown	1,500 TWh/year
Wave	South America	Unknown	4,600 TWh/year
Wave	Africa	Wave	3,500 TWh/year
Wave	Asia	Wave	6,200 TWh/year
Wave	Australia, New Zealand, Pacific Islands	Wave	5,600 TWh/year
Varies	China	22 GW tidal energy, thermal energy 1300 GW, 450 GW wind Total Capacity 2,750 GW,	Unknown

Source: This Study Adapted from myriad sources including Post 2009; Electric Power Research Institute, 2012, IRENA 2014-2020; Parker 2015; World Energy Council 2016; World Bank 2019.

Table 3.3 Specialist MRE Research Institutions and Test Sites

Institution	Location	Institution	Location
European Marine Energy Centre	Orkney Isles Scotland	Wave Hub	SW England,
Super Gen Marine Research Consortium	UK	PRIMARE	SW England
Plymouth University, Queen's University Belfast	UK	Exeter University	UK
Hydraulics Maritime Research Centre	Ireland	Wave Energy Centre	Portugal
Northwest National Marine Renewable Energy Centre	Oregon/Washington	NAREC	NE England
National Marine Renewable Energy Centre	Hawaii	Marine Institute	Ireland
New England Marine Renewable Energy Centre National Renewable Energy Laboratory	USA	URI	Rhode Island
Ocean Renewable Energy Coalition	USA	EPRI	USA
Fundy Ocean Research Centre for Energy	Canada	Ocean Frontier Institute	Canada
Florida Atlantic University Centre for Ocean Technology	Florida	Offshore Energy Network	Denmark
University College Cork, University of Limerick, Sustainable Energy Ireland, Electricity Research Centre;	Ireland	MAREI	Ireland
Stellenbosch University	South Africa	NMMU	South Africa
University of Reunion	Reunion	SAGA University	Japan
National University of Columbia	Columbia	University of Curacao	Curacao
Delft University of Technology	Netherlands	Otago University	New Zealand
National Marine Energy Centre	New Zealand	Uppsala University	Sweden
University of Naples Federico II	Naples	UTM	Malaysia
Global Ocean Resources and Energy Association	Japan	Runde Environment Centre	Norway
MARINET - Marine Renewable Infrastructure Network for Emerging Energy Infrastructure, Offshore Energy Research Association	EU	Danish Wave Energy Centre	Denmark

Biscay Marine Energy Platform and PLOCAN - Oceanic Platform of the Canary Islands	Spain	NTNU, SINTEF-MARITEK	Norway
National Engineering Research Centre of Offshore Wind Power, State Key Lab of Wind Power Equipment,	China	National Energy Offshore Wind Power Technical Equipment R+D Centre	China

Source: This Study Adapted from myriad sources including Mueller et al. 2010; OECD 2019; World Energy Council 2016

Table 3.4: Other Global Test Site Facilities 2020.

Test Site Name	**Location**
Oosterschelde Tidal Test Centre Den Oever; Blue Tec Floating Platform Dexel Island; Red Stack Afsltdjk	Netherlands
European Marine Energy Centre Orkneys Scotland, Wave Hub Cornwall England FAB Test -Falmouth Bay, Marine Energy Test Haven, Milford Haven UK; Morias Tidal Demonstration Zone, Anglesey UK;	UK
Canadian Hydrokinetic Turbine Test Centre, Winnipeg River, Manitoba; Fundy Ocean Research Centre for Energy, Naval Scotia, Wave Energy Research Centre Lord's Cove,	Canada
Jeanette's Pier Wave Energy Test Facility, North Carolina Pacific Marine Energy Centre Seattle Washington, Pacific Marine Energy Centre Pac-Wave North and South Sites, Newport Oregon; Centre for Ocean Renewable Energy, Durham New Hampshire, US Navy Wave Energy Test Site Kaneohe Bay Hawaii, University of Maine Offshore Intermediate Scale Test Site Coastline, Maine, University of Maine Deepwater Offshore Renewable Energy Test Site, OTEC Test Site Keahole Point Hawaii, MRECO Tidal Test Site, Bourne Massachusetts,	USA
AMETS Mayo Ireland, Galway Bay Marine and Renewable Energy Tidal Site,	Ireland
Agucadoura Test site Portugal, Viana do Castelo Pilot Zone	Portugal
Mutriku Wave Power Plant; PLOCAN -Canary Islands;	Spain
Port El Sauzal Baja California, Station Puerto Morales, Quintana Roo,	Mexico
Lyseil wave Energy Test Site, Soderfers Research Site;	Sweden
Dan WEC Hantsholm; Dan WEC NB, Nissum Bredning	Denmark
Runde Environmental Centre	Norway
Ostend Wave Energy Test Site	Belgium
SEM-REV Wave and Floating Onshore Wind Test Site Le Croisic; SENEOH Estuarine and Tidal Site Bordeaux; Paimpol-Brehat Tidal Site	France
China National Small Scale Test Site Weihai; Zhoushan Tidal Energy Test Site; Wanshan Wave Energy Test Site;	China
Sentosa Tidal Test Site	Singapore
KRISO Wave Energy Test Site, Korea Tidal Current Energy Centre	South Korea
Kaipara Harbour Tidal Energy Site, Moa Point Test Site -wave energy, Chatham Islands -wave energy; Tamaki Drive Road bridge -tidal energy; Steward Island -wave energy	New Zealand

Source This Study: Adapted from OES 2019; Cramer et. al 2019.

The above research facilities have a range of current technological priorities, facilities and achievements but remain mostly on the testing phase of development. Whilst an extensive analysis of each is not feasible for this research, websites, social media and publications can confirm their achievements and the extent to which each can contribute towards MRE development. For example, the Supergen Network Marine Research Consortium across the UK is composed over several universities, commercial developers, test facilities and associated supply chains investigating multiple aspects. These include reliability, moorings and control, climate, ecological, economic and ocean effects, various component parts including power take off systems, among others with design and validation model formation, sea trials experiments, demonstration and commercialisation (Mueller et al. 2010). It aims to magnify resilience, reliability and sustainability, endurance, predictability, affordability, installability and operability. Northeast England's NAREC offers a wave tank and 2 other drydocks, ROV vehicles, testing electrical engineering laboratories, power take off test rigs, design and consultancy services. Ireland's Marine Institute offers a 37 hectare site with 24 metre water depth access with Wave Buoy and Ocean Energy buoys since 2006. The US Florida Atlantic University Centre for Ocean Technology offers access to the South Florida Testing facility.

These sources have access to innovation networks, marine biology labs and aquariums, AUV's, ROV', sensors, satellites, surveys, divers, engineering workshops, wave tanks and other laboratories (OECD 2019). The UK and Ireland have at least 167 projects at present supporting their supply chains. Examples include TETRON, Irish Tube Compressor, McCabe Wave Pump, Wave-bob, Ocean Energy OWC Buoy, Cyan Wave, TFI Wave Protector, Salter Duck, Sperboy, Manchester Bobber, Limpet, Triton, Linear Generator, Ocean Treader, Wave Master and OWEL Energy Converter. Other projects being tested include DEXA WEC, Electric Generating Wave Pipe, Horizon Platform, Gyro-Wave-Gen, Wave Surfer, Wave Catcher, SEADOG and Resolute WEC. Other global sites summarised in Table 3.5 have yet to be investigated at all, yet have significant ocean resource energy prospects for these and other institutions to investigate as a more immediate priority as well as concentrating on accelerating existing project's commercial prospects.

Table 3.5: Possible Future Supply Options for Marine Renewable Energy Sources

Energy Type	Date	Project Area	Location	Potential Output Capacity GWh/year
Tidal	Unknown	Rio Gallegos	Argentina	Unknown
Tidal	Unknown	Walcott Inlet	Australia	Unknown
Tidal	Unknown	Cobequid	Canada	14,0000
Tidal	Unknown	Penzhinsk	Russia	190,000
Tidal	Unknown	Turnagain Arm	USA	16,600
Tidal	Unknown	Khambhat Gulf	India	15,000
Tidal	Unknown	Garolin	South Korea	17,000
Tidal	Unknown	Mersey	UK	700 MW (Unknown Potential)
Tidal	Unknown	San Jose	Argentina	7000 MW (Unknown Potential)
Tidal	Unknown	Mezen	Russia	15,000 MW (Unknown potential)

Source: This Study, Adapted from various sources.

There has been an increase in the number of certain markets, supply chains, research consortia networks, related industries and innovation clusters in specific regions such as those in Table 3.3 and others such as Denmark's offshore wind industry. For OTEC technology several innovation clusters have been observed such as around Naval Energies and Akuo Energy in France; Delft University of Technology and Blue-Rise in the Netherlands; Saga University and Xenesys in Japan; OTE Corporation/Makai Ocean Engineering and the University of Hawaii Natural Energy Research Laboratory in the USA plus the University of Technology in Malaysia (Salz 2018) These clusters can have multiple development benefits including economies of scale and spillover externality benefits from pooling resources, access to research and specialised facilities and past experience or expertise, events, experts, patents, technology and institutions such as Oceans Energy Europe. Access to private sector entrepreneurs, markets, legal and fiscal incentives as well as other conditions in sections 2.1-2.3 can enable feasible market conditions towards Europe, the USA, Australia, Japan and China. These regions experience proportionally far lower entry barrier costs. This assists to clarify less apparent market support structures to incentivise demand, supply and an ocean/marine energy economy sector for Africa, South America, other parts of Asia, the Middle East, Caribbean and South Pacific, even where latent supply exists.

In the absence of many established marine renewable energy markets; this source considers estimated projected demand can be determined from 2 sources: the demand for conventional energy sources or total electricity supply; and the demand or interest in shore based renewable energy. These both provide targets for MRE to penetrate. A third market exists for those who would like to pursue various economy projects but have been frustrated and thwarted for years or even decades in the absence of a reliable, cost effective, sustainable and clean source of electricity generation, especially in emerging or developing nations such as South Africa, Zimbabwe and others. Developed nation markets are increasingly bound by commitments to cleaner, greener, renewable energy but for historic and other reasons are constrained by a lack of suitable locations for shore based sources, even if more economical initially than MRE. Africa has limited experience specifically with developing marine specific renewable energy markets. However, it is familiar with shore based renewable energy potential, especially with solar and wind since projects in Egypt in the 1980's, to which similar principles could apply (Mukasa et. al 2013). For example, wind energy received $1.8 billion in conditional finance to install 1.1 GW of onshore wind in Africa, mostly through development funding. Projects have mostly emerged recently after 2000, showing a more modern trend. The market for renewable energy is dominated mostly by Egypt, Morocco, Tunisia, Mauritius, Namibia and South Africa although other nations are rapidly becoming more interested. Emerging markets in Africa, Asia, the Middle East, Caribbean and Latin America are therefore advised to apply similar principles in motivating for finance, ensuring popular and political support, establishing markets and considering similar climate, technical and business/economic factors.

3.2.2: Other MRE Market Developments and Initiatives

In 2019 one market survey estimated a minimum of 180 ocean energy test and market activities exist globally with 109 tidal energy, 58 wave, 12 OTEC, 1 salinity and a number of offshore wind/0 marine bioenergy. (Felix et al. 2019). Very limited research has concentrated and quantified the significant market potential of this area (Alam 2008) but even 6% of the 2008 US electricity market yielded over $16 billion in potential value. In 2013 OES estimated world tidal market revenue exceeding 200 billion pounds, wave energy exceeding 750 billion pounds and annual servicing/maintenance income of 14.25 billion. Given this latent market potential and existing success, several nations are gradually becoming more interested and involved. Mexico recently established a Wave, a Salinity Gradient and a Tidal and Current Group at CEMIE Oceano with 3D wave tanks, modelling, equipment and testing laboratory facilities. The Netherlands have had a delayed opening to the Tidal Technology Centre at Grevelingendam, expected to be 2020 or longer, unaided by the COVID19 pandemic and other delays. It has envisioned pilot projects from Tocardo Phase II at 2 MW, the Browers Barrier tidal range plant and RED Stack demonstration plant. Singapore recently completed Mako Tidal Turbines Energy Plant as a floating solar-voltaic and tidal energy hybrid. South Korea's Institute of Ocean Science and Technology is undertaking an 18 MW test bed facility for tidal energy, constructed from 2017-2022.

In 2013 Ocean Energy Systems formed annual reports on related progress by core nations expressing a potential interest such as Portugal, Denmark, the UK, Ireland, Belgium, Germany, Norway, Spain, Italy, Monaco, Canada, Mexico, the USA, Nigeria, South Africa, China, South Africa, Australia and New Zealand (Ocean Energy Systems 2013). The organisation aims to facilitate MRE development to reach up to 337 GW, create and sustain over 1,200,000 jobs and avert over 1 billion tonnes of CO_2 emissions. Globally the MARE market has been slower to commercialise then other sectors for various regions with high entry barrier/market, research and development costs and dominated by public-private partnerships, rather than purely public or private, with commercial operators often dependent on incentives such as public funding, military or academic research laboratories and test facilities. The European Union has established the 9 million euro funded, MARINET (Marine Renewable Infrastructure Network for Emerging Energy Infrastructure) with 42 participant testing facilities in 12 nations and 28 institutions. This aims to simplify access to specialised infrastructure facilities. More sectors are realising the need for increasing coordination and cooperation for the UK marine wave energy parks in Pentland Firth/Orkney Waters and the Southwest. From 2015 the Solent Ocean Energy Centre is being constructed in addition to those above and the testing site in Falmouth Harbour England. Few large organisations conduct their own specific research and development and MRE lacks the extent of related events, funding grants and other opportunities to share knowledge and transfer technology. DCNS France however, claim to devote 8-10% of their research and development budget. Markets however can benefit from multiple examples of MRE pilot projects to learn from.

From 2013-2017 the Ocean Net Training Network received 3.4 million euros to promote MRE training, education and skills development. Recent market developments include Spanish UHINDAR consortium cooperated over a wave energy converter project. Scottish Power Renewables are focusing on over 1000 MW of tidal and 600 MW for wave in projects. Belgium created a 1 MW project off Ostend harbour. Portugal is seeking to accelerate its Ocean Plug Portuguese Pilot Project MRE zone and single source, accelerated Environmental Impact Assessment report under the REN-ENONDAS initiative to establish 250 MW of initial capacity. Spain's state operated testing facilities with Biscay Marine Energy Platform with 20 MW and PLOCAN -Oceanic Platform of the Canary Islands with 15 MW in 2014. In Italy the Kobold Turbine University of Naples Federico II is being conducted with 100 KW prototype and the GEMS Ocean's Energy Kite. Norway passed a 2010 Ocean Energy Bill and NTNU/SINTEF-MARINTEK, Straum and Havkraft AS research cluster are prioritising this sector with the Hydra Tidal, Wind Sea Jacket and OWC Power. Others include Flumil, Deep River, Ocean Energy AS and Tidal Sails. Sweden's market developments focused on Lyseil wave power and Soderfors marine current site operated at Uppsala University. Sweden was revising marine spatial planning policies to incorporate ocean renewable energy in 2014.

The UK have established the Offshore Renewable Energy Catapult Initiative and the Marine Farm Accelerator since 2013 to support start-ups, entrepreneurs, venture capital and other potential innovation related to the private sector via traditional accelerator mentoring and support. Japan aimed to construct the world's largest offshore wind farm since 2015 near Fukushima. Marine Renewables Canada -received $85 million for state fiscal incentives such as feed in tariff. Canada aim for 2 GW by 2030 and 250 MW by 2020. In 2013 the US Department of Energy established 5 grants of $150,000 each towards pilot MRE projects along with over $16,000,000 in budgets (OES 2013). The US are investing $40 million in a new marine energy research centre. The New Zealand Marine Energy Centre and Otago University along with the 2008-2011 Marine Energy Deployment Fund provided basic incentives. No state research test facilities currrently exist in Australia. However, the private sector has aimed to overcome the current Federal deficit through various trials prior to commercialisation although several have benefitted from state grants such as Ocean Power Technologies Australia, Carnegie Perth Wave Energy, Port Fairy Bio Wave and Port Macdonnell.

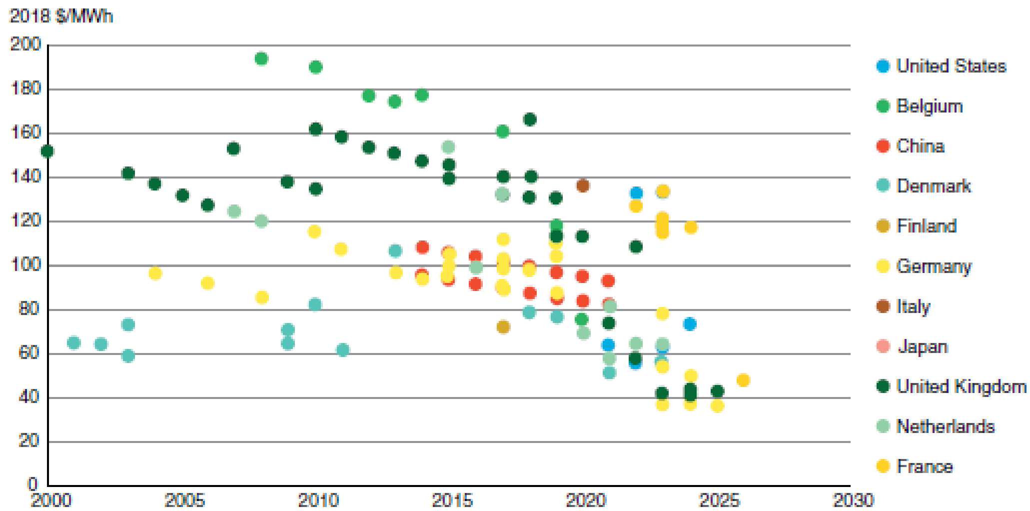
In 2014 the MRE supply chains, facilities and patent companies were dominated by Europe with 167 patent companies in the UK followed by 57 in France and Germany, 55 in Norway and only 10 across East Europe (Dalton 2014). Ocean Energy Systems forecasted a current 2020 market worth 26000 direct jobs, 13,000 indirect and gross value activity. It aims to have over 300 GW in installed capacity and 680,000 jobs by 2050. One subobjective is to achieve over 100/300 GW potential in total tidal and wave capacity (Magagna and Uihlein 2015). It identifies existing EU challenges towards full implementation include: technology development in reliability, endurance and design standards, grid availability, environmental and administrative issues and finance and markets. The source cited European investment in 2011 reach 142 million euros, with 58% committed to waves. The UK, France, Ireland, Spain, Portugal, Denmark and Germany have a variety of contracts for difference, prizes, specific funds and feed in tariffs as market incentives. Over 170 wave energy companies existed in 2014. Of 46 tidal energy manufacturers, 51% are within the EU dominated by the UK, Netherlands, Spain and Germany 49% externally and the USA, Norway, China and Australia in particular. 29% of companies in 2014 focused on supplying mechanical components, 18% on installation, 14% structure and foundation, 10% electronics, 10% electronic engineering and 9% research and development. The wave energy sector supply chain was dominated 40% on the point absorber, 23% on attenuator, 19% oscillating wave surge and 7% oscillating water column. However, it would benefit the development of this sector for a full market analysis to be conducted for other global regions and energy types. Most technology that has been commercially successful merely focuses as variants of existing technology rather than prompting significant innovation although modern approaches exist.

The World Bank estimated 25 GW of global offshore wind capacity in 2019 and $26 billion of investment from 1.3 GW in 2008. China also aims to achieve 30 GW by the end of 2020 (Carbon Trust 2014). The most significant wind turbine suppliers include GE Wind in the US, Denmark's Vestas, Germany's Siemens and Enercon, India's Suizon Group, China's Goldwind, Sinovel and United Power In 2019 European offshore wind statistics reached 18.499 GW of cumulative installed capacity, dominated by the UK (44%), Germany (34%) and Denmark (7%) (Wind Europe 2019). 11 European nations have 105 wind farms at sea with 39 in the UK, 25 in Germany, 14 Denmark, 7 Belgium, 6 Netherlands, 4 Sweden, 2 Spain, 2 France and 1 each in Norway and Ireland. Offshore wind energy investments increased from 8.4 billion euros in 2010 and 2.649 additional GW to a peak of 4 GW and $18.2 billion in 2016 down to 10.3 billion and 4 GW in 2018. 93% of the wind turbine market was fabricated by Siemens Gamesa Renewable Energy and MHI Vestas Offshore Wind. Senvion follow with about 5%. Each average turbine increased from 0.5 MW in 1991 up to 6.8 MW, affirming improved technological progress. In 2008 the largest global turbine was 54 metres high and 1.6 MW output and rotor diameter with 69 metres with projections of up to 125 metres high, 190 metre rotor diameter and 11.8 MW in output by 2030. Average wind farm increased from 79.6 MW in 2007 to 561 MW in 2018. In 2018 the largest European wind farm or Hornsea I started construction with 174 turbines and 1.2 GW envisioned.

Aside from Europe and China (section 2.4), other global nations expressing interest in the offshore wind energy sector include Brazil, India, Morocco, Philippines, South Africa, Sri Lanka, Turkey and Vietnam, yet these have yet to follow up with pilot and commercialisation stages but offer investor promise (World Bank 2019). In 2018 India established a 5 GW offshore wind energy target by 2022 and 30 GW by 2030 but the others have yet to incorporate these policies for MRE specifically. Foreign investors were deterred from the high local manufacturing component required for its first offshore energy pilot project proposal in 2018. The World Bank estimates 7-11 GW at a minimum could be added from 2019 to 2024. Market prices or levelized offshore wind tariffs in developed nations such as Europe to supply grids have decreased as technology improvise from $150 in 2000 to over $200 per MWh in 2010 to around $50 in 2025 as in Figure 3.1 (World Bank 2019), ensuring it is becoming increasingly more cost effective for national grids, policymakers and consumers to consider. Offshore wind has proven to be more expensive at present than ashore projects with average development costs of $10-50,000,000 capital investment needed versus $1000,0000 to $2,000,000. Both Germany and the Netherlands have however, phased out market distorting subsidies to ensure competitiveness, unlike many fossil fuel producers with artificially low prices and other support. (Global Wind

Energy Council 2017). Japan has revised its Ports and Harbours Act to accommodate specific MRE test sites for research.

Figure 3.1: Global Nations Average Levelized Offshore Wind Market Prices/Tariffs 2000-2030 $MWh



Source: World Bank 2019.

From 2014 to 2024, one market forecast anticipates wave and tidal energy market value to intensify from $487,700,000 to $11,365,000,000 ((Konrad Adenaur Stiftung 2019). The global offshore wind energy market can assist other marine/ocean and land renewable energy sources to achieve over 90% of global carbon emissions from energy needed under the 2015 Paris Agreement on Climate Change and the preceding IPCC Reports (IRENA 2019 (b)). It projects the need for onshore wind to accelerate up to 1737 GW by 2030 and 5,044 by 2050 and offshore up to 228 GW. It predicts onshore wind installation costs falls to $800-1,350 per KW by 2030 and $650-1000 by 2050 along with offshore wind to US$ 1700 to 3,200 per KW by 2030 to $1400-2,800 by 2050. IRENA aims to reduce fossil fuel demand by 64%. It estimates the need for grid integration and related technology investments to accelerate from US$297 billion in 2018 to 374 billion by 2030.

Ocean Energy System's most recent report on the MRE industry indicated wave and tidal energy global power increased from 5 GW combined in 2009 to 45 GW by 2019 with potential to offer 746 GW, up to 40 billion pounds in revenue and over 160,000 jobs per year by 2050. (Ocean Energy Systems 2019). The US and EU are specifically investing into MRE research and development via targeted funding and it has received an expression of interest as a book chapter consultancy position advertised by the African Development Bank in April 2020. The European Union devoted over 165,000,000 euros from 2014 to 2019 directly. Australia created the Ocean Energy Group as a recent consortium alliance of concerned stakeholders. Spain is aiming for 25 MW by 2025 and 50 MW by 2050. Scotland created the Saltire Tidal Energy Fund up to 10,000,000 pounds. Cost reduction goals have been strengthened to overcome one of the more significant deterrents to full scale commercialisation, implementation and grid provision, striving to reduce localised production costs to 10 euro cents per KWh for tidal and 15 for wave energy respectively. Ocean Energy Systems has also created various events, statistics and research, awareness campaigns, an advised GIS database of ocean energy and technical standards/guidelines to facilitate MRE.

Recent developments include the Mako, Wave Swell and Carnegie Clean Energy pilot projects in Australia (OES 2019), Belgium's formation of the WECA-NET and Laminaria project along with Sustainable Marine Energy, Jupiter Hydro, Nova Innovation, Yourbrook Energy Systems, Oneka Technologies and others in Canada. China is forming the Zhoushan and Wanshan tidal current energy project; Zhejiang University Tidal Current Energy Platform and revised feed in tariffs. Denmark are pursuing options under Crest-wing, Floating Power Plant, Wave-Piston and the Ocean Energy Scale Up Alliance. French pilot projects include SBM Offshore, Hydroquest Ocean, WEMEC and the Guinard Energy turbine along with OTEC technology via Naval Energies. Germany is undertaking NEMOS and SINN Power. India are undertaking an OTEC pilot project off the Lakshadweep Islands. It has developed initial research for offshore wind farms off the Tamil Nadu and Gujarat coasts with floating wave prototypes at ESSO-NIOT (Konrad Adenaur Stiftung 2019). Taiwan aims for 1 GW floating offshore wind by 2030 and Japan 18 GW by 2050.

Ireland supported OPIN and OCEANSET initiatives and Italy have the REWEC3 and ISWEC projects. The Netherlands focused on tidal energy (Sea Querrent), offshore wind and salinity gradient (Redstack). Sweden's COR Power are testing pilots in Portugal. Portugal have pilot projects via AW Energy's Wave Roller and IST-ISMEC. The US have Aqua Harmonics, Cal Wave, C Power, Ocean Energy, Ocean Power Technologies, Oscilla Power Ocean Renewable Energy Power Company and Verdant INTEEREG are funding a 11 million euro blue energy grid integration scheme in Europe. Belgium's Maritime Cluster seeks offshore floating solar voltaic and hybrid aquaculture project. The USA has also formed the Marine and Hydrokinetic Graduate Student Research Programme and the Marine Energy Collegiate Competition. China have generated an experiment Penghu, wave powered floating aquaculture farm from 2019 and added 1.5 GW to its tidal current energy demonstration project. In Brazil one case study affirmed how limited certain areas have been in considering marine renewable energy and how this needs to radically be revised if it is to contribute towards total global ocean energy installation and research requirements (Shadman et al. 2019). The source estimated that Europe still dominates 60.66% of current total MRE projects, North America 17.10%, Asia 13.35%, Oceania 5.62% but only 1.62% for Africa, 0.94% for Central America and the Caribbean and 0.7% for South America. Morocco are also looking at 52% of total capacity as renewable including the ocean sector with tidal power feasible (Alaoui 2019).

The International Renewable National Agency (IRENA 2020 (a)) estimates 4 Scenarios, the "Planned Energy Scenario," "Transforming Energy Scenario," "Baseline Energy Scenario" and the "Deep Decarbonisation Scenario." It estimates the need to invest $110 trillion in renewable energy by 2050 for a sustainable, climate resilient future with an estimated global energy demand over 556 EJ versus 571 EJ in 2015, producing 25 GT versus 32 GT in 2015. The source estimated in 2019, global total renewable energy (land and marine); was 2,537 GW off installed capacity (IRENA 2020b), estimated 72% of the global total capacity with only 28% of new capacity as fossil fuelled. This reflects a significant historic increase since 1,227 GW in 2010. This is aided by significant adverse publicity and calls for the financial sector to divest from coal, oil and natural gas powered sources. Africa's renewable energy capacity increased from 27,329 GW to 48,443. Central America and the Caribbean increased from 7,674 MW to 15,572 in 2019. Eurasia increased capacity from 69,570 to 105,800 GW. Global marine energy increased from an estimated 250 GW in 2010 to 531 in 2019, of which Europe increased from 222 to 249 GW and Asia rapidly from 5 to 180 GW. Renewable energy market auctions reflect another evolving development focusing on project, quantity, adjustment, price, product and blended strategies (IRENA (2019 c). These attracted 55 nations in 2017/2018 but have yet to occur for marine renewable energy types aside from offshore wind with 9.7 GW, especially in Germany and the UK. Stakeholders auctioning are advised to consider various risks such as reputational, marketing, socio-economic, climate, environment, inflation and currency exchange, market and oil price risks and contract duration.

Renewables Now estimated the renewable energy industry directly supported the employment and livelihoods of over 11,000,000 jobs by 2018 primarily in China (over 3,600,000), Brazil (876,000), the US (777,000,000), 385,000 in India, 310,000 in Japan and 1,200,000 in the EU. The solar photovoltaic industry supported the most of any energy types with over 3,100,000 jobs (IRENA 2017 (a)). Future market developments need to consider efficiency, cost reduction, policy changes, investment flows, dawning risks, sustainability and the circular economy to reduce waste over a life cycle approach (Renewables Now 2019). Certain projects such as Naval Energies' Open Hydro have been postponed or ultimately cancelled due to fluctuating market uncertainty. In 2018 the European Commission estimated the need for $1.2 billion euros investment in Europe up to 2030. Even greater potential exists to make islands and many coastal economy/remote communities' sectors entirely self-sufficient and generating from marine sources such as Port Victoria wind farm plus OTEC in Reunion and Martinique (IRENA 2016). This could stabilise electricity supply, reduce fuel logistics and import costs, provide energy security and avoid as high volumes of diesel and oil required along with reducing emissions. A European Technology and Innovation Platform for Ocean Energy aims to improve collaboration on technology performance, validating devices in marine and climate conditions, technical standards and grid connections (PEMSEA, GEF and UNDP 2018).

3.2.3: MRE Prospects and Current Research or Market Developments from Individual Participants

Carnegie Wave Energy are refining their CETO energy after surviving liquidation, rescue and restructuring in 2019. In 2018 Aquanet Power developed a zero emissions, offshore wind turbine and breakwater (Figure 3.2) in the United Kingdom and a test facility in Taiwan with access to global ocean and climate data. Ocean Power Technology's Power Buoy Figure I), wave energy generator in the US is eyeing markets in offshore oil and gas exploration, security and communications. On the 27th April 2020, Atlantis SIMEC are working with China to establish a 8.2 GW tidal energy plant in Wuhan under the COVID pandemic. A second project from 2001 will work in partnership with the Development Agency for Normandy. Other developments include Principle Power's 5-10 MW Wind float, Resolute Energy's OTEC and Wave2OTM desalination project aiming to deploy a 500 m3/day then 4,000 m3/day and initiatives by the International Windship Association to develop renewable powered vessels since 2015. Peace Ship's Eco Ship may reflect the future of sustainable cruise vessels. The vessel has biofuel powered engines, ten retractable wind generators, ten retractable photovoltaic sails, kinetic floors and a 6,000m² solar farm on its top deck. It incorporates a self-sustained garden that uses recycled garbage and wastewater recirculation systems. Future vessels ay use marine algae as biofuels and other marine energy sources, especially around ports. It aims to curtail electricity usage by 50% and 20% propulsion energy.

Figure 3.2: Ocean Power Technology's Power Buoy.

Source: Ocean Power Technologies

Figure 3.3: An Example of Aquanet's Patented Breakwater Application

Source: Aquanet Power.

Figure 3.4: Peace Ship's Eco Ships

Source: This Study.

One recent development in April 2020 includes a €46.8 million ($52 million) project or the Tidal Stream Industry Energiser Project in partnership between the UK and France with up to 8 MW of tidal current energy with 19 organisations. It claims a long-term aim to reduce generating costs of tidal stream energy from the existing €300MW/h to €150MW/h by 2025 and upscale commercialisation. This connects to the EU target to reach €100/MWh by 2030. The EU Horizon 2020 Wave Boost project achieved a net carbon footprint of 31.4 gCO2e/kWh based on the first prototype WEC generation design SIMEC Atlantis focused recently on achieving the world's largest single-rotor, tidal turbine. EMEC and Orbital Power in the Orkney Islands are aiming to test and launch a 2 MW floating tidal farm to power 1,700 homes. The UK's Triton Knoll, 857 MW offshore wind park is receiving special measures to deter marine seals, whales and other species from Seiche Environmental. In April 2020 the US Department of Energy specifically committed $22,000,000 to wave energy research and commercialisation support initiatives aside from a new Atlantic Marine Renewable Energy Centre. The US National Renewable Energy laboratory not only launched a specific report on identifying blue economy commercial markets for MRE but 11 prize winners of the DISCOVER competition seeking related innovative solutions, with Seatrec and OTEC technology as the grand winner. Canada and China have revised tidal energy feed-in tariffs to offer greater market incentives recently. However, cautionary risks need to be considered -Falmouth Massachusetts faced over $5 million, lengthy court cases and other issues both ecological and sound exceeding 110 decibels per turbine.

3.3: Potential Advantages of Investing and Supporting Marine Renewable Energy Strategies

Marine Renewable Energy can offer myriad economic/fiscal, social, environmental, educational and training, technical, legal, strategic, geopolitical, security and other advantages or prospects beyond the long-term benefits of reducing climate change emissions and ensuring our long term economic, physical and ecological survival towards a decarbonised, climate resilient, blue economy future. Those investing and supporting MRE can be reassured that the sector will have significantly more sustainable and viable current and future, additional jobs, tax revenue, production, consumption, customs duties, savings, investment and value added expenditure or beneficiation across the supply chain as economic benefits. If import substitution is prioritised it will further reduce the balance of payments, import costs, scarce foreign exchange reserves and dependency on diesel, fuel, oil and coal prices or imports. This also has significant implications to improve energy security along with reducing associated logistics and supply chain costs. This leads significantly to other geopolitical and strategic implications allowing greater foreign policy flexibility and liberty to determine sovereignty rather than being so dominated by the need to conduct excellent relationships with a handful of top fossil fuel suppliers.

This research recommends not only the economic benefits but the research, technology, training, skills development and education benefits from contemplating initial resource feasibility assessments, pilot projects, incentives and considerations for full implementation of MRE where resources are feasible. This may extend to dedicated research institutes, with spillover externality benefits from innovation and discoveries. The project would work with various stakeholders to provide a marine renewable energy research institute and power station testing facilities involving wind, wave, currents, solar, tides, ocean thermal energy and other prototype onshore and offshore facilities. It would consider experimental shore-based connections and various applications including potential testing and a free trade incentive/export processing zone for various opportunities. It would extend to specific careers guidance via the Maritime Cluster and targeted support to aid entrepreneurs to contribute towards initiatives such as the Independent Power Producers Programme.

For this research's contribution to the blue economy in particular, there are also possible tourism and other advantages both directly from the facility itself and indirectly from freeing up valuable coastal/inshore real estate from land based facilities, relocated out at sea with aesthetic and sound reducing factors if not directly in line of site. Guided tours and direct observation of the marine energy research centre and various installations could provide a minor benefit for various cruise, marine and coastal tourists including attracting other African and international researchers. Providing these facilities could directly benefit the provision of electricity to power marine biotechnology, aquaculture sites and ferry services. Connections could aid vessels in port or outside anchorage, awaiting entry into ports. The assemblage, maintenance and development of technology, devices and physical infrastructure could further stimulate marine manufacturing and local industry. It should further stimulate related maritime and marine related employment for graduates of education/training/research centres. Offshore ocean governance prospects for maritime drones will provide further opportunities and linkages to support the progress of the blue economy. Offshore grid connections can especially benefit remote and rural island communities, coastal and offshore activities such as shipping

As with the other value proposition opportunities, various myriad employment and economic opportunities exist, as summarised in Table 3.6. It would further assist nations facing severe unreliable electricity such as South Africa in its efforts to ensure an environmentally sustainable and energy secure source of generating electricity, given a11 year old fluctuating unreliability and instability of Eskom since 2008. It aids social service delivery of essential services. It would provide significant social, environmental and health benefits, given the high pollution levels of many areas powered by fossil fuels, gaining the endorsement of community support. This also has significant unquantifiable public health advantages for communities facing air pollution, respiratory diseases, water pollution and emissions from conventional power sources. MRE remain far more ecologically sustainable. Improved electricity access and security would improve reputational, marketing and adverse psychological risks that has consistently hindered foreign direct investments, the expansion of industry, shipping, logistics supply chains and economic activity. OTEC technology can even assist with water security via desalination.

Table 3.6: Offshore/Marine Renewable Energy Job Opportunities

Drilling/energy/mining engineer; geologists, geochemist	Vessel repair and maintenance, tugs and barges
Construction of tidal, wave, wind, solar, current, thermal energy conversion and other energy types infrastructure, vessels, offshore platforms, tidal stream devices	Equipment -pipes, drilling, tools, lubrication, paint, spools, wind tensioning cables, turbines, various sensors, installations, operations and maintenance
Hydrographic surveyor; geoscientist; Electronics	Intermodal transport and storage, ports,
HR and Recruitment, Procurement, Administration	Medical, Health and Safety
Marketing, Distribution and Logistics,	Seafarers, Officers, Shipping, Training, Testing
IT, Software/Simulations, Environmental Monitoring	Deployment, Recovery and Monitoring, Array Design
Security, Legal, Environmental, Insurance,	Technology, Technicians, Research and Development
Drones, diving, inspections, ports, shipping	Catering, entertainment, bunkerage services

Subsea and pipeline engineers, Electricians,	Refineries, petrol stations, pipelines, processing, retail
Banking, Insurance and finance	Desalination plants; Salinity gradient technology;
Hydrodynamicists, Sales managers,	Oceanographers, Riggers, pipe fitters and wielders
Tourism	Consultants,
Decommissioning	circular economy

Source: This Study:

There are also legal and fiscal/ PR and marketing benefits to sectors that are increasingly attracting political and investor support and more market friendly investor incentives as in sections 2.3 and 3.2. It far reduces the comparable marketing needed for customers, investors and regulators to approve and endorse or utilise given the perception and reality of “clean green or Blue energy.” It proves one of the most practical measures to honour nation’s commitments to the 2015 Paris Agreement on Climate Change and related investor pledges from a reputational risk and legal liability perspective. The technology has been proven as feasible across myriad case study examples at pilot stage, it just needs to be upscaled, implemented and accelerated more commercially and to more regions. Improved economic prospects can offer significant rates of return on investment, despite being capital cost intensive. Electricity costs have shown capacity to be competitive with fossil fuel and shore based renewables, with sufficient economies of scale.

Significant social benefits are also projected to increase from marine renewable energy and greater economic potential, especially if industry is situated in areas offering poverty or fewer employment alternatives including reduced crime, gender or other violence, drugs, gambling, alcohol, prostitution and other issues. It can open up significant career prospects as published under the European Union Blue Generation Project aiming to target youth aged 15-29 with a career guide and 2 international conferences along with other outreach and engagement processes (Blue Generation Project 2019). It seeks to target 39,000 people and ensure employment for at least 2000. It cites opportunities in entry level mechanical work, marine engineering, supply, logistics, construction, research and science, boating and transport along with project development, operations and maintenance. It identified around 320 existing ocean energy companies exist. Others include service boat crew, mechanics and maintenance workers, health and safety, IT, energy information and career advisors, renewable energy project managers designers, electricians and technicians

The European Marine Energy Centre in Scotland’s Orkney Islands provides significantly convincing evidence as to how those local economies and supply chains can be transformed; especially in more remote isolated communities with suitable ocean and climate conditions. It estimated the presence of the Centre, Scarpa

Flow and Shapinsay Sound test site directly support 300 jobs, with 20 staff, and contribute a minimum of 1 million pounds per prototype device in the local blue economy and supply chain (EMEC 2016). Founded in 2003 it has received over 300 million pounds of investment. It offers marine wildlife observation points, 6 wave test beds, an 8 berth tidal test site and 2 others or the Fall of Wariness and Billia Croo test sites along with undersea cables and national grid connections. It offers incubator support for start-up entrepreneurs and trial projects with specialised laboratory facilities, demonstration and feasibility study assessment advice. Aside from wave and tidal energy, a recent development included the formulation of an integrated hydrogen system in a hydrogen cell – "Surf and Turf" tidal and wind power hybrid to power local island ferries and provide backup. The facility is currently undertaking 27 devices from 17 companies and has tested over 100 research and development projects via 120 tidal and 260 wave companies, generating over 15 TB of data experience. Since 2014 the Orkney Islands have received 104% of their total electricity supply from renewable energy sources, aided by the close proximity of multiple sources from the Centre along with plenty of redundancy and perpetual motion capacity, with access to the latest in innovation.

More global market interest has been based on seawater desalination than upscaling commercial grid applications for electricity transmission grid supply. Multiple OTE benefits have been confirmed. Japan achieved practical OTEC applications through the Okinawa Deep Seawater Research institute to empower oyster, prawn, sea grape and other forms of aquaculture as early as 2000. It is converting its 100 KW pilot plant to 1 MW and higher (Salz 2018). Japan has also formed the Global Ocean Resource and Energy Association with over 50 member institutions. Blue-rise in the Netherlands have applied OTEC technology for agriculture, aquaculture and Curacao airport air conditioning in the Caribbean. Bardot Ocean installed an OTEC plant for a Maldives Resort in 2016. In 2017 Bell Pirie Corporation applied a Philippines project. OTE Corporation in the USA has pilot project examples for OTEC including water and electricity for Eco Village in the US Virgin Islands, various US military bases from Guam to Diego Garcia; the Baha Mer resort in the Bahamas, and portable water across Ghana, Tanzania, Zanzibar, the Philippines, Cayman Islands and American Samoa. In France DCNS or Naval Energies support over 13,000 jobs in the OTEC industry and Akuo a further 200-500. The University of Technology in Malaysia is similarly seeking to interest others in creating a viable MRE cluster since 2013.

Environmentally, MRE is projected to have no effect on land ecosystems and certain sound, light, waste, pollution and aesthetic effects can be minimised with sufficient specified precautions, guidelines and contractual obligations. It has even been speculated that certain species may benefit an increase in biodiversity and fish aggregation to assist in ecological rehabilitation as habitats are considered as artificial reefs and habitats for certain species. More evidence exists for wave energy converters than other devices (Inger et. al 2009). It definitely contributes to a reduced carbon footprint and far lower lifecycle environmental then conventional land wind energy or fossil fuel/nuclear counterparts.

Ocean or marine energy sources have both similar advantages and those conditional upon the type. The hazards of fossil fuels have been extensively chronicled in public health, scientific, economic, social and other research, education and media awareness (Global Energy Network Institute 2009; IRENA 2020). MRE avoids all of these problems and issues without enslavement or hyper-dependency on a few highly polluting, resource intensive, climate change accelerating, life decreasing, superfluous commodities for many. Costs can be far more reliable, perpetual, secure and cost effective with virtually no pollution or gas emissions, creating desalination and other benefits. Individual MRE sources have specific advantages. For example, tidal energy can improve coastal protection, operates continuously throughout the year irrespective of the climate or ocean conditions and 24/7, virtually free. Tidal power exceeds 80% energy efficiency in contrast to oil and coal at 30%. Tidal turbine technology is more efficient in generating electricity, predictable and cost effective in cheaper materials utilised such as steel with reduced maintenance than offshore wind turbine technology (Randhawa 2015). Tidal energy avoids greenhouse gas emissions being emitted with low maintenance costs and a high energy density (Tousif and Taslim 2010).

Offshore wind energy can benefit from the extensive experience, expertise, established supply chains and technology of the onshore wind energy sector, in contrast to other sectors. Solar photovoltaic when floating offers similar advantages to more well established industries then MRE counterparts. Wave energy is also regular with very few adverse ecological costs, reduced land use and favours certain latitudes with stronger power density. Wind energy saves up to 2000 litres of water per MW. Marine current energy is reliably predictable, perpetual motion, offers a high power density necessitating fewer generators and does not require high barrage, dam or structure costs as with tidal power, wind turbines and shore based alternatives. Aesthetically the impact is minimal with substations and related infrastructure compared to other energy sources. It is modular and scalable. Marine bioenergy offers even more advantages in aiding biodiversity, reducing eutrophication and algal bloom potential, offers a perpetually renewable resource with few costs, high per acre productivity, food and biotechnology possible benefits, CO_2 sequestration, biofuel prospects and can be derived from multiple water sources. It requires substantially less refining and associated externality costs. However, it presently offers problems of scaling up from pilot phase. OTEC technology offshore have how energy availability and desalination benefits. It offers a 90-95% capacity factor and 80% energy efficiency. OTEC technology would not influence global ocean temperature and has 70-80% energy efficiency. It offers desalinated water potential via open cycle plants. 2.28 million litres of water can be produced per MW of power. Salinity gradient energy offers similar advantages in its initial phases.

Marine Renewable Energy for the blue and general global economy has potential to revive the shipbuilding/repair industry sectors given a global excess of shipping capacity at present as dockyards and engineering workshops could be easily and rapidly modified. Indirectly other benefits may accrue from increased cooperation, social, environmental, fiscal and economic, research and development, marketing and technology (European Thematic Network on Wave Energy 2003). It has also received increasing attention for the future of ocean exploration, research and discovery via the International Council for the Exploration of the Sea (International Council for the Exploration of the Sea 2016). It has investigated existing development states on each technology, decision support and management planning tools, events, relationships and cross-sectoral issues related to MRE and certain aspects of ocean economies as recommendations for future practise. Therefore, any detailed appraisal of MRE should consider these advantages as summarised in Table 3.7.

Table 3.7: Potential Advantages of Marine Renewable Energy

Economic including tourism	Environmental
Climate Change -reducing Emissions	Market
Educational and training, research and skills	social, technical, legal, strategic,
Technical	Legal
Energy/electricity Security	Geostrategic or political/foreign affairs autonomy
Desalination and water security	Links to the circular and bioeconomy -biofuels/food security etc
Benefit from Renewable Energy Experience	Aesthetic
Frees up land space/real estate	

Source: This Study

3.4: Potential Disadvantages of Investing and Supporting Marine Renewable Energy Solutions

Although a number of economic, financial, technological, environmental, research, legal/reputational, market and other potential disadvantages exist to investing and supporting marine renewable energy solutions as a solution towards futureproofing climate resilient, blue economies against climate change and other risks; as detailed in this section; many of these professed disadvantages will be rectified with greater scaling up of pilot projects; commercialisation, familiarity, awareness, simple modifications and guidelines. These extend to many of the best practise examples and standards elaborate in detail throughout this scholarship. Perhaps the most significant disadvantage is the fact that comparatively few commercialisation projects have matured, been supported and researched in the long term. This would subsequently provide more case studies to assess the long term ecological, economic, social, technical, climate change, legal, research and other possible implications of each MRE type to assess whether many of the potential disadvantages enumerated and cautioned here may actually become a reality.

Few commercial prospect case studies bring significantly uncertain legal and other reputational/or market disadvantages in having less chance to prove themselves as offering quantifiable benefits to policymakers, investors seeking a rate of return on investment, those eco-conscious, consumers, businesses and societies. This contrasts with more popularly aware renewable and fossil fuel energy sources. MRE markets have yet to establish themselves, often experiencing scaling up or other technical challenges towards full implementation and have to fight or contest with a heavily subsidised fossil fuel lobby with market distorting subsidies and other barriers to entry. Comparatively few nations and institutions offer financial access and other incentives. Although cheaper than a coal, oil, gas or nuclear power station only a comparatively few market players enter due to still high initial sunk capital costs.

Certain MRE technology has specific disadvantages, conditional upon its type. Marine bioenergy sources remain comparatively underprioritised with far more attention and competing attention being devoted to marine biotechnology non-electricity purposes (Inger et. al 2009). Its alternative uses and prospects have been detailed in previous research by this author on the www.blueeconomyfuture.org.za website. Salinity gradient energy only has about 1 full scale commercial development at present. Waves can fluctuate in size, duration and intensity and are disturbed during storms, tsunamis, cyclones, superstorms and rogue waves (Global Energy Network Institute, 2009). Floating solar voltaic remains highly exposed to sensitive ocean and climate conditions and is less recommended outside sheltered bays/anchorages/coast areas at present. It remains subject to the testing phase and is solar dependent. Tidal, wind, wave, salinity gradient and OTEC are often area, climate or ocean specific in their deployment and can be vulnerable to such hazards. Until economies of scale are developed these may lack cost-effectiveness with higher installation and electricity market costs i.e. $5000 to $15,000 per KW for OTEC, however, sections 3.2-3.3 have affirmed how costs reduce over time. Onshore grid connections can remain challenging including battery storage, power maintained and controlled.

MRE depends on the presence of marine, rivers, lakes, dams or other waterway sources, restricting options for landlocked nations. These technology costs may be especially susceptible to biofouling, invasive species and other potential damages to risks. They have possible disadvantages for seabed scouring/morphology and sediment disturbance, habitat loss and other ecological costs if environmental impact assessments are not conducted from undersea cables, turbines and other components. Certain probable ecological disadvantages may extend to effects on water circulation patterns and quality, benthic habitats, species collision and avoidance behaviour changes (European Marine Board 2010). Pollution output may leak out throughout all project lifecycle stages, although projected to be minimal compared to land sources of electricity generation. Other possible disadvantages include avian and marine species collision, feeding, migration or entanglement risks, noise, aesthetics, sound and light along with possible electromagnetic field radiation; although these effects can be minimised. I.e. wave energy converters are far less visually intrusive, quieter and less implications for species then offshore wind turbines and tidal barrages. It remains uncertain how underwater noise may imperil species' communication, risk awareness and other usages of sound on a prolonged basis.

OTEC desalination and salinity gradient technology may affect the sensitivity of ocean conditions via saline level modification. If not sufficiently prepared for with marine spatial planning and sufficient consultation/notification and awareness it may cause unexpected challenges or cost consequences for fishing, marine recreation and watersports or other activities. Tidal power offers few sites with high flow and range energy. Tidal fences and barrages in particular may especially disturb natural processes such as shoreline sand accretion, energy transfers and other processes from a freely flowing marine source. They can affect the liberty of species and vessels to move and operate. They can have significant maintenance costs to reduce ocean acidification, salinity and coastal erosion pressures or component fatigue/pressure.

OTEC technology could lead to leakages of chemicals and other pollutants (Boehlert and Gill 2010). The impact of 4-20 metre wide, cold water pipes could influence local water processes and initiate an algal bloom risk Tidal energy has high turbine creation operation and maintenance costs along with unknown resilience. The random nature of offshore wind and wave energy has been noted as a significant disadvantage over other sources and higher commercialisation costs (Thorpe 1999).

Very few nongovernmental funding sources have been established (IRENA 2019). Other technology related disadvantages include the lack of industry professional technical standards, a related specific global MRE ocean and climate condition database) (Abtey 2012), energy storage, ensuring long term reliability of components and materials utilised, the need for more specialised skills, training, education and research and mooring system stability. However certain sectors in land renewable energy, offshore oil and gas, ports sector, marine engineering, seabed mining and communications, salvaging, drones and naval architecture are expected to overcome many of these stated disadvantages via comparable and adaptable systems, experience, curricula and processes. More monitoring and evaluation of project long term implications, successes and failures would overcome many cited issues or problems, provided more people, funding sources and institutions can be persuaded to investigate. Certain MRE technologies will therefore experience disadvantages from a lack of stakeholder familiarity and social acceptance initally until given a chance to prove itself, including developing associated supply chain experience.

A few existing research sources have confirmed certain adverse ecological cost implications that may dawn from MRE devices. For example, wave and wind power may highly disturb avian and marine species via collision, suffocation, entanglement, disturbance, noise, senses, spatio-temporal perception, navigation, flight, displacement and redirection throughout its existence (Grecian et al 2010). This could lead to permanent or temporary injury or death. Limited evidence has existed of how specific species have suffered, in contrast to other energy sources although one report estimated an extra 500 metre detour was needed by around 200,000 Eider ducks during their migration from Denmark's wind farms. One North Sea study on offshore wind energy generation by the World Wildlife Fund identified the imperative to avoid disturbing species' migration routes, consider integrated coastal zone management and marine spatial planning to avoid permanent habitat loss (World Wildlife Fund 2014). It cites the example of Nysted offshore wind farm in Denmark in which the porpoise population only eventually recovered to 30% of pre-operation levels, after 10 years of operation. Scotland's Robin Rigg offshore wind farm received a 50% displacement of northern gannet within the first year of operation. It may affect ocean and climate functions with ratifications for food security. Few EIA assessments are publicly available. Offshore wave and wind are less consistent than other energy types, reducing potential security as an electricity resource (Uihlein and Magagna 2016).

One NOAA report on Pacific Northwest wave energy experiments set up actual working groups to evaluate possible adverse physical environment, pelagic and benthic habitat, species, energy absorbing structures, chemical, lighting, acoustics, electromagnetic, over system and cumulative effects (Boehlert, McMurray and Tortorici 2007). It counselled the need of directly connecting projects with consequences via environmental surveys and recording or monitoring mechanisms. Certain devices may improve biodiversity and habitats for certain species but this in turn may result in extra predators or temptations for aquaculture and fisheries sectors to congregate placing additional pressure on marine ecosystems. This is confirmed by one European wave energy study in Europe with risks of coastal erosion, impacts on species, possible mooring or technology damage repercussions, noise and other effects (European Thematic Network on Wave Energy 2003). Tidal energy experiences current issues of high speeds which have in certain areas slaughtered up to 15% of fish within the area but this can be adjusted to a reduced velocity. Mooring line entanglement may create issues for ghost and discarded fishing. Certain paints utilised may create issues. Cleaning and maintenance, installation, operation and decommissioning all need to reduce toxic and other effects, mitigating risks to avoid disadvantages.

Another study situated in Scotland affirmed these issues as risks of unknown encounter effects on species, invasive species, aside from latent deoxygenation, nutrient loss, circulation and flushing pattern consequences. It argues limited longitudinal research has being conducted on species including diversion and distraction, stress and other unquantifiable species (Schlappy 2016). Few species collisions have been publicised as evidence. The greater impact is often via the construction and decommissioning phases rather than the operation based on the limited evidence available. Electromagnetic and sound fields may distort natural behaviour including reproduction, nutrition and other habits. Strangford Lough in Northern Ireland caused moderate ecological damage but EMEC in Orkneys experienced no effects so far as of 16 years. The MERIFIC project in Europe argued that disadvantages were conditional on the sensitivity of the environment, regulatory framework involved and sites selected including water depth, topography, surface flow and velocity, species affected etc (Sotta 2012). The toxicity of paints and chemicals/oil spills can be managed, air or water quality and other factors. The greater the project size, the greater the associated collision, entrapment and other risks.

A Wales report on Marine Renewable energy installations and implications for species risks identified these risks were influenced by possible collision damage, close range evasion, extent and type of exposure, species and ecosystem resilience or long-range avoidance due to sound, light and other effects (MER 2010). Even when experiments have been tested for individual technology types and projects, these have yet to be scaled up to a cumulative effect of myriad devices. It recommends specific precautions to mitigate against these possible sources of maiming or death include more lab and field tests, sound, lighting, colour, aesthetics and design improvements along with risk monitoring. A Scottish natural heritage report specifically affirms how larger species can become entangled or enmeshed with various aspects and uses of ocean energy generation (Benjamin et al. 2014) It estimated up to 12.9% of marine mammals get embroiled with fishing gear and other human hazards. More specifically it could cause greater accumulation and risks of ghost gear fishing along with marine plastic/other pollution. It argues that whilst large species are generally expected not to be ravished, it is imperative for developments to adhere to their legal protected status. Many pilot projects are often being stalled in gaining full authorisation to operate and commercialise due to the uncertainty of ecological consequences and a lower lobbying industry pressure for MRE than fossil fuels.

MRE face market disadvantages of few commercialisation, marketing and scientific monitoring, long-term successes as stated (Baring-Gould et al. 2015). Limited array configuration, cost and power quality, control and widespread grid integration or market experience information has been publicised. High grid costs penalise ocean/marine and land renewable energy sources in many nations. Few stakeholders currently share research experience and findings. High research and development costs therefore can discourage the sector. Even where information exists, stakeholders often do not know here to access it and thus providing another justification for this specific impartial review on MRE prospects in relation to the blue economy. Additional predator avian species could emerge to disrupt food webs and ecosystems from additional roosting perches for fish species tempted to accumulate or paused due to confusion over the rotating blades or presence of unfamiliar structures. Specialised monitoring and recording equipment that can be deployed on or near devices to observe species interactions need to be developed or refined (Alam 2008). More species are sensitive to direct than alternating current. Other unknown factors include coastal erosion, the ocean energy balance, tide disturbances and chemical/other morphology geological long-term formation (Pacific

Northwest National Laboratory 2016). It extends to the hydrodynamic environment vertical mixing, tidal propagation and residual drift of oceanographic features (Thorpe 1999).

Long-time survival of components still needs to be certified to acquire greater market confidence. A multibeam sonar and 12 hydrophones were commissioned to protected grey seals and porpoises in the UK's Ramsey sound as a deterrent. Strangford Lough in Northern Ireland uprooted resident porpoises under the construction phase but became more accustomed to its sound under operation. 13 species of New York's East River were also tested with no signs of wounds for the Roosevelt Island Tidal Energy Project. However, there remains a need for more project lifecycle assessments and cost-benefit or impact cost analysis. From a recreational, fisheries, watersports and tourism boating perspective, the British Royal Yachting Association echoes others in the need for comprehensive cost-benefit analysis and to consider grid integration, implications on navigation and communication equipment, existing area uses, need for technical standards, safety risks and for turbines in particular specifying a minimum height of 22 metre high minimum rotor tip draft tip. (Royal Yachting Association 2019). Greater priority needs to consider any disadvantages that may occur for multiple competitor uses or marine/blue economy activities that may be affected by an MRE installation or serve as a potential competitor for the area involved. From a research perspective, sources are biased towards Europe, the USA, Australia, Canada and a comparatively few areas, with many significant data gaps that would enable a fairer, more accurate appraisal. Limited legal expertise related to MRE challengers any aspirant developers for any subsequent problems that may emerge.

A specific US Congress Report warned of the need for a detailed Environmental Impact Assessment to consider potential disadvantages of conflicting human resources, avoiding cultural, environmental, noise, navigational, transport, aesthetics and socioeconomic disadvantages to be eradicated as much as possible (US Department of Energy 2009). It identifies the challenges of determining which of the pilot projects are most suitable for wide space commercialisation, authorisation and support, contrasting with far fewer and more conventional fossil fuel alternatives with far more predictable ecological devastation results. The source emphasises hazard mitigation, reduction, avoidance and ecological rehabilitation or extension as much as possible. Certain measures include sparing species during spawning and reproduction season and technological alterations to deter species along with imposing standards, regulations, penalties and enforcement. The Department of Energy does maintain a Marine and Hydrokinetic Energy Technology

Database, which other nations could replicate as far more projects become available to overcome existing uncertainty for many actual and intended participants.

Table 3.8: Potential Disadvantages of Marine Renewable Energy

Economic -opportunity costs	Environmental
Limited research	Market -Few commercialized examples
Educational and training -few specialised at present	Social
Technical specific	Legal -few expertise
Potential conflict over uses	Reputational
High lobbying power	Need for long term monitoring and evaluation

Source: This Study

3.5: Risks

Although in its pilot phases for several decades, marine renewable energy has clearly stalled in many areas from being an active contributor to global electricity supply, reducing emissions and pollutions and full-scale commercialisation, although many sites and technology types have proven themselves to be technically capable with considerable possible benefits so far. This section therefore concentrates on the emerging risks associated with deployment and support of marine renewable energy and how these may be mitigated against for the blue economy if it is to empower our future. Various dawning risks that need to be successfully managed include socioeconomic and markets, legal and regulatory uncertainty, marketing or popular acceptance; psychological and reacting with people; technological, competitor; IP and patents', commercialisation and general inexperience; access to finance and general constraints of developing nations/small island developing states or remote communities.

Socioeconomic and market risks include the lack of certainty associated with economic and trade cycle fluctuations including the possibilities of recession, supply and demand fluctuations and extent of market size or access. Challenges exist for MRE with initially high sunk costs and barriers to entry, as with other market supply chains. These markets including grid integration and mass marketing can only be achieved through social and mass popular acceptance via marketing, awareness, education, training, finance, innovation and other incentives as enabling factors. More results need to be published with long term studies to remind people of the benefits whilst demonstrating the disadvantages can be managed. Although it offers myriad opportunities and chances for local economies as in Sections 3.3 and 3.6, it presents opportunity cost risks for those currently invested in working and supporting the fossil fuel sector. Their displacement may lead to unemployment, crime, welfare and other social pressures if insufficiently retrained. Uncertain risks exist as to the extent to which a skilled labour force will be willing and able to be established along with an innovative research and development sector. Markets also appear uncertain given current risks of a lack of local or global technical standards, best practises, full scale commercialisation advantages and other factors influencing an uncertain regulatory framework. The lack of legal certainty, research available and commercialised examples deters investors, entrepreneurs, business supply chains and even communities to embrace marine renewable energy.

Other uncertain risks especially include the psychological reaction. As previously highlighted, the fundamental concern with marine renewable energy is the gap between pilot phases and commercialisation. To some extent these can be addressed via more commercial examples, marketing and access to finance but the real issue to implement something is to persuade various people to actually act to support such a transition via permanent, sustainable behaviour change, overcoming asymmetrical information and uncertainty, converting to renewable energy and diverting vociferously against fossil fuel sectors and their lobbyists. It remains highly risky to project how people themselves will react and how to manage their adaptive expectations, although game theory and psychology can react. Other risks include Black Swan Events as low probability, high impact events such as COVID19 and climate change related disaster events projected to increase in duration, frequency and intensity. Several sources confirm similar challenges of improving the technology, socioeconomic, ecological and other performance, survival and climate or ocean resilience for wave and other marine renewable energy types (WWF 2014; Felix et. al 2019; Industrial Economics Incorporated 2019; IRENA 2019). Tropical regions present additional biofouling and fatigue or corrosion risks. The MRE sector also needs to consider market factors, infrastructure availability, regulatory uncertainty, conflicts with other uses and uncertain biodiversity impacts (Industrial Economics Incorporated 2019).

3.1.1: Climate Change

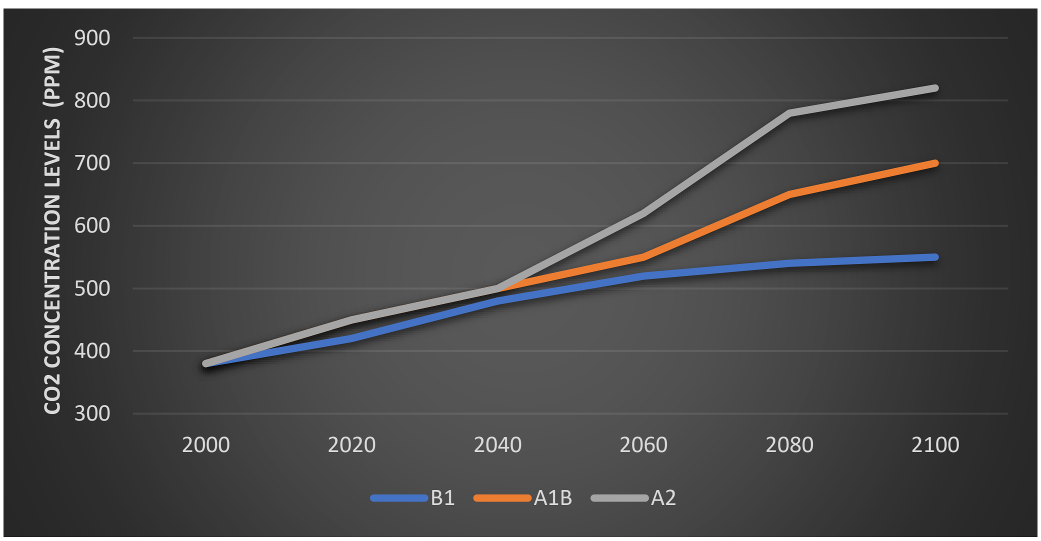
Although for many sectors climate change presents significant risks infringing upon damage to property, species, lives and livelihoods; it may create unprecedented pressures and opportunities as increasing emissions and growth rates substantially motivates the need for radical conversion towards marine renewable energy. However, it creates uncertainty as to the actual extent of market demand. One overwhelming advantages of MRE is its lack of contribution towards this imperilling crisis. Wind, waves, tidal, current, thermal, LNG-shipping, salinity gradient, bioenergy -biotechnology and circular economy are all perpetual resources that can be supplied. Global climate change projections may require other unexpected changes including means of doing business, revised climateproofing technical standards and other minor additions. The Intergovernmental Panel on Climate Change in their 2015 report forecast significant gradual climate change disruption risks for business as usual operations, which will accelerate existing related risks. Such risks include increases in global sea level rise, air, land and sea surface temperature and change in precipitation, wind velocity, wind direction, currents, humidity, wave energy, sedimentation and currents. Forecasting is complicated by risks and uncertainty affecting the qualities, distributions, quantities, types and habitats of aquatic ecosystem plant, coral and animal species anticipated to be present under various time horizons and climate scenarios. This affects the successful undertaking of many ocean and blue economy activities change. It is therefore essential to develop sources away from fossil fuel, whether land or marine.

The IPCC (2015), South African Weather Service and other meteorology agencies conventionally utilise baseline historic data. This provides a mechanism to help determine future, climate change scenarios. This section outlines three scenarios (B1, A1B and A2) that will be utilised to identify potential future risks for marine bioeconomies on a global scale, over 3 time horizons. B1 is used by the IPCC (2015) and international, climate change policy makers refer to a low emission, growth scenario. This occurs if humanity were to become substantially more environmentally sustainable; to convert from an industrial to a services-based economy which is less resource and emissions intensive and restrict population growth to reduce emissions. A1B refers to a medium, emissions growth scenario or “business as usual” if population and economic activity were to continue at current growth levels. A2 refers to a projected, high emissions growth scenario. This occurs if developing countries do not stabilise population, dramatically reduce emissions and pursue the globalisation or industrialisation, economic activity levels of developed nations. The three projected time horizons (2030, 2055 and 2090) are defined as short, medium and long-term periods for marine pollution reduction and blue economy stakeholders to adapt.

3.1.1. Projected CO_2 Emissions Growth

Global CO_2 emissions are projected to increase from an actual baseline of 380 parts per million (ppm) in 2000 to 550 ppm under a B1, 700 ppm for an A1B and over 800 ppm for an A2 high emissions scenario. This is based on IPCC (2015) data estimates and illustrated in Figure 3.5. The implications of increased emissions possess significant, disruption risks and direct and indirect impacts with adaptation costs for marine pollution reduction and circular economies. Increased ocean acidification and changes in salinity/pH balance from emissions; project further disruption costs to natural resources and coastal protection roles of coral reefs and other tropical ecosystems. These projections illustrate how vital it is for interdependent stakeholders globally from producer to governments, ports and intermodal transport to consumers; to prioritise not just mitigation but adaptation.

Figure 3.5: Global Projected CO_2 Emissions Scenario Growth

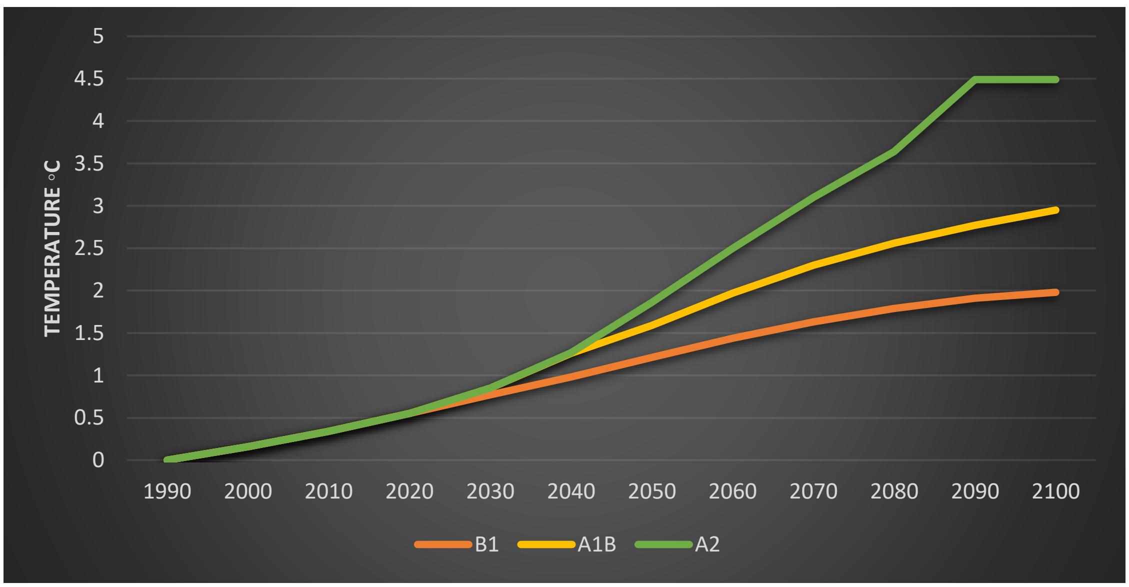


Source: This Study

3.1.1.2. Historic and Projected, Global Mean Temperature Rise

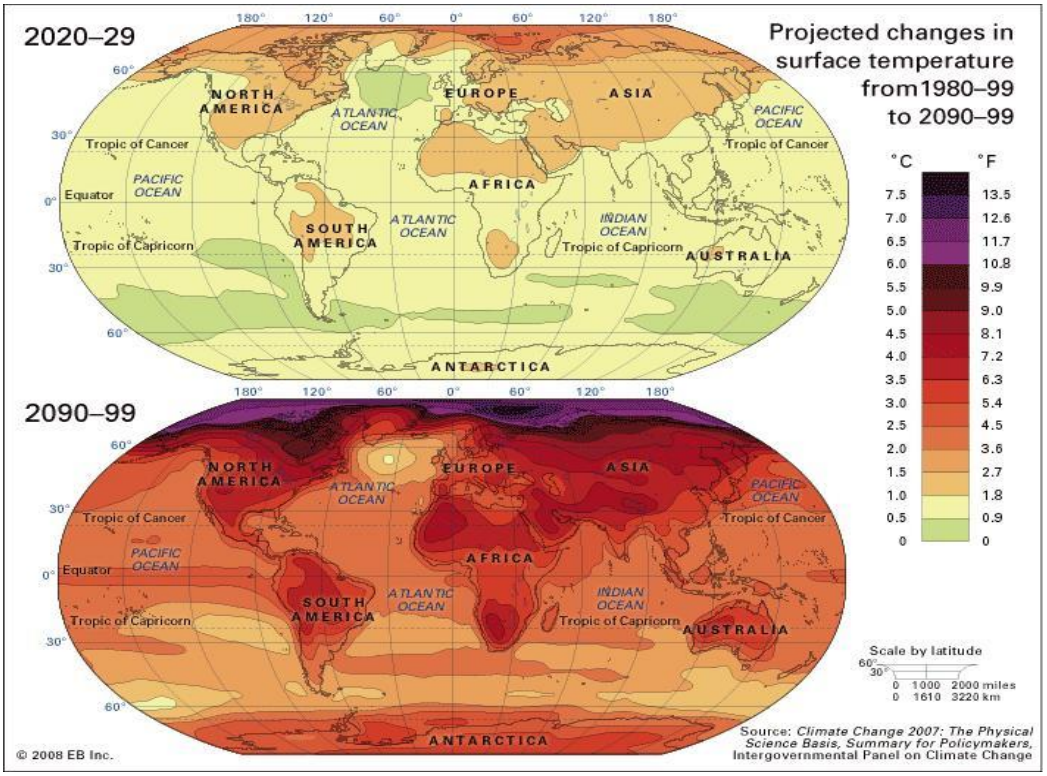
Based on IPCC (2015) data estimates and Figure 3.6, global, mean surface temperature rises are projected to increase from an actual baseline of 0º C in 2000 to 0.85 ºC by 2030 under all 3 scenarios. By 2055, emissions are projected to diverge, around 1.2º C under a B1, 1.59⁰ C for an A1B and 1.86º C for an A2 scenario. This increases to an average of 2, 3 and 4.5 ºC respectively by a 2100, long term projection. Figure 3.4 (IPCC 2015) provides an alternative visual representation of how specific world regions will be affected and vulnerable under an A2 scenario. Increased global mean temperature implications for blue bioeconomies are indicated throughout this research possessing significant disruption risks, direct and indirect impact and adaptation costs. These projections illustrate how vital it is for these stakeholders globally to adapt, enhancing resilience to higher temperatures and increased salinity. Higher temperatures contribute towards an increased frequency of droughts, greater temperature extremes; reduced water; higher evaporation and evapotranspiration rates. This affects future climates, natural resources and productivity. According to these sources climate change projections may include slower ocean currents/thermohaline circulation, complicating species migration.

Figure 3.6: Global Mean Surface Temperature Change



Source: This Study.

Figure 3.7: Projected Climate Change, Surface Temperature Changes 1999-2090.

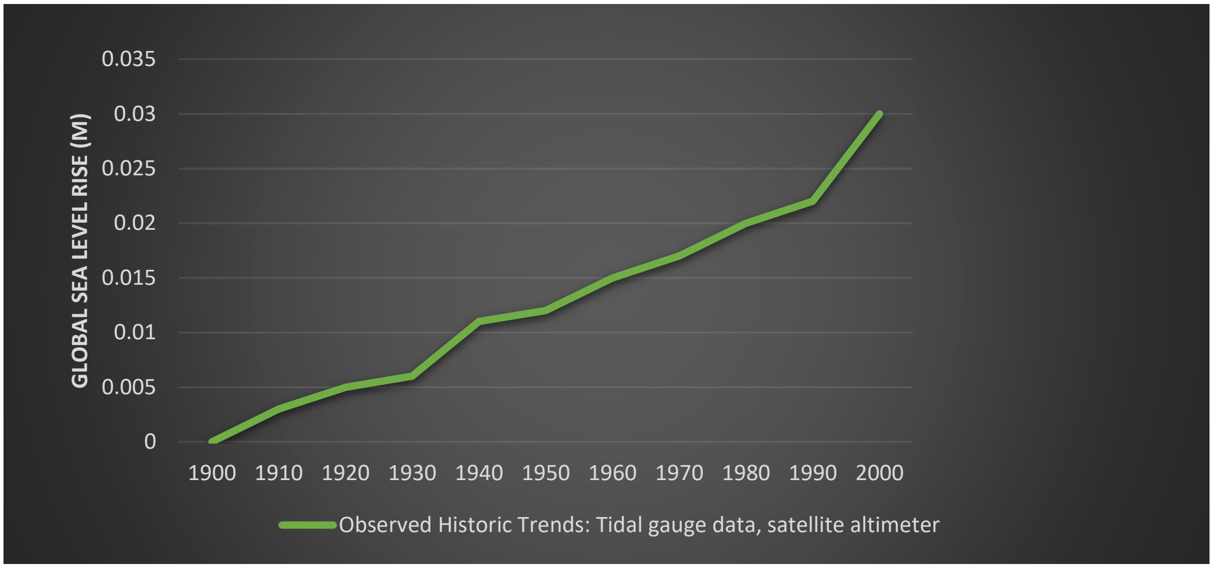


Source: Encyclopaedia Britannica 2008, page 72.

3.1.1.3. Historic and Projected Sea Level Rise

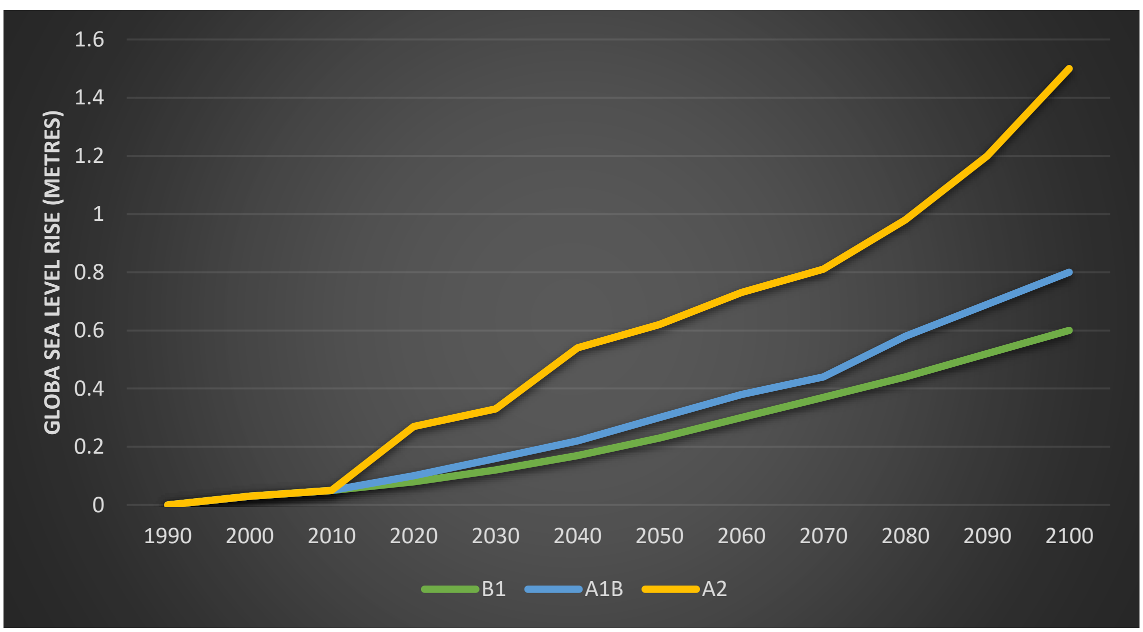
IPCC (2015) data from tidal gauge data and satellite altimeters; illustrated in Figure 3.8, estimate global average, SLR rose historically from a 0m baseline in 1900 to 0.03 m by 2000. The rate of increase has substantially accelerated from several, global, climate change related factors. These include accelerated polar melting of sheets, glaciers and ice caps, land-based water discharges and thermal ocean expansion from increased mean temperatures. These have expanded from an average of 1-1.5 mm (1900-1980) to 3-3.5 mm per year (1980-2014) (IPCC 2019). It's projected to reach 8-10 mm per year by 2100, if global climate change trends are not stabilised. From IPCC (2015) data and Figure 3.9, global, mean SLR is projected to increase from a 0 baseline in 2000 under all 3 scenarios. However, by 2030, scenarios are projected to diverge around 0.12 metres under a B1, 0.16 m for an A1B and 0.33 m for an A2 scenario. This increases to an average of 0.23, 0.3 and 0.62 m respectively for a 2055, medium time horizon. By 2100 marine bioeconomy stakeholders are anticipated to experience a mean, SLR of 0.6 (B1), 0.8 (A1B) and 1.5 metres.

Figure 3.8: Historic Average Global Sea Level Rise (SLR) 1900-2000.



Source: This Study

Figure 3.9: Global SLR, Climate Change Risk Projections



Source: This Study.

3.5.1.3 Implications of Global Climate Change for Marine Renewable Energy Stakeholders

The implications of increased global SLR, temperatures and other long-term risks for African and other marine/blue biotechnology participants vary significant but all are vulnerable under projected time horizons, various risk types and scenarios. Stakeholders may have to adapt to a world where low altitude countries, ports, populations, infrastructure, resources and coastlines experience substantial disruption risks such as climate related natural disasters, El Nino/La Nina events and algal blooms. Fisheries are projected to decrease by 2.8-5.3 % in catch yield in 2050 if emissions ceased instantly but 7.8-12.5 % at a minimum, even 30-65 % by 2050 under worst case scenarios according to the FAO and IPCC (Barange et al. 2018). As the peer reviewed Intergovernmental Panel Reports on Climate and Oceans/Cryosphere in a Changing Climate, the UNEP Blue Economy Finance Principles, the 2016 Report by the International Investors on Climate Change Group, 2015 Paris Agreement and empirical evidence, sufficient consensus exists about the actual effects and process of climate change and the blue economy. This justifies stakeholders adapting from the Precautionary Principle; even where various climate change models provide a range of confidence intervals, risks, impact costs and solutions, not the actual occurrence. This research includes projections to identify risks, assist adaptation strategies and climateproofing opportunities and in response to the following stakeholder concerns expressed as existing literature weaknesses or possible directions for future research.

More localised projections are subsequently in need of investigation and support. Accurate projections might incentivise private sector funding for enhanced supply chain resilience and other adaptation solutions. Externally financed, situational awareness and accurate information especially aids many African nations with limited government funding and attention towards climate change and the oceans/coasts. Moral hazard, asymmetrical information and other factors provide a reluctance to invest in supply chain adaptation without more certain information. Accurate detailed projections can further aid impact damage cost estimates and various Indian/Atlantic Ocean/island ecosystem replacement values This improves impact cost analysis of climate change for bioeconomy supply chains. Further benefits of using local level data and examples exist. Previous natural disasters and gradual risks can demonstrate current vulnerabilities and disruption risks to minimise opportunity, delay, externality and maladaptation costs for anticipated events.

It is an emerging legal requirement for key infrastructure and systems of more countries, such as ports and, to consider projected climate change and to disclose emissions and risks. This has not yet been extended to the plastics industry to disclose marine waste and emissions contributions. More financiers are favouring portfolio decarbonisation. It also aims to aid companies especially those listed on the Australian, US, UK and other stock exchanges, (whose supply chains may stretch as far as Africa.) These must identify and disclose physical risks/impact of climate change for individual businesses. Awareness may reduce legal, reputational, litigation and other noncompliance risks, including stakeholder pressures. This section aims to minimise legal compliance costs for marine pollution and blue economy stakeholders provides specific global, regional and local projections to determine relationships between key risk variables and supply chain stages. However, a significant constraint to implementing adaptation solutions, is most supply chain, business planning horizons are short term: 1, 5 or even 10 years, yet current reviews envision 100 years for projected climate change (IPCC 2015).

Circular economy supply chain stakeholders require a tool such as Pacific Climate Change Futures, or literature proposed models Stakeholders need projections considering a range of scenarios and time horizons to aid effective decision making when planning to adapt businesses. This tool approach is flexible enough to aid adaptation solutions. Examples include revising technical design standards, climateproofing existing infrastructure, equipment, transport and processes to determine the degree of resilience. It includes the stress and asset lifespan to determine adaptation and post-event, recovery and replacement cost; disaster reduction and risk management responses. This is necessary as risk may be significantly underestimated by stakeholders relying on guidelines. Therefore, this research guide considers accurate projections contain advantages for stakeholders to assess how risks originate and subsequently develop. It determines how impacts can differ across various economic sectors, stages, stakeholders, countries and even between short, medium and long-term time horizons. This section and its projections aim to contribute towards stakeholder awareness of risks. This must mainstream climate change information including data availability, the cost effectiveness of proposed responses and the urgency of risks an markets for MRE through projections, Scenarios can further aid risk identification, assessment severity and prioritisation. They ascertain direct and indirect impact costs, timing and type of adaptation response. Comparatively accurate climate projections and short-term, meteorological data are essential to ensure business continuity, future profits and rates of return on investment for stakeholders.

Identifying possible global, regional and local climate change impacts upon blue economies further emphasises the need to incorporate scenarios and assumptions into any subsequent methodology. High resolution impact data has already aided Caribbean and Pacific coastal supply chains that are similarly climate risk exposed. For example, stakeholders could use Google maps and satellite imagery to identify impacts of SLR, temperature and other risks. This research provides specific projections and a theoretical screening framework for these stakeholders to access to data and scenario simulations independently. This reduces the need to rely on research of external consultants and conflicting research studies. Accurate, localised, updated projections enable stakeholders to evaluate each adaptation strategy's costs and benefits and individual solutions to minimise impact costs. A significant constraint remaining is the limited availability of shared information and cooperation across different stakeholders; even when mutually advantageous in lowering costs. Accurate information also assists in identifying an event's timing, threats and opportunities presented. These further indicate the need for a joint risk, cooperation approach in information, communication and adaptation across entire African or global blue economies, integrating stakeholders. This aims to minimise disruption costs to international trade and economic activity, throughout an event.

The following consequences exist:

- The current ocean has acted as a carbon sink for over 90% of atmospheric emissions, doubling the rate of warming since 1993 with accelerating frequency, duration and intensity of marine heatwaves since 1982 (IPCC 2019). 84-90% of heatwaves are estimated to be from increased emissions.
- Marine ecosystems have also experienced higher ocean acidification and decreased oxygen concentrations (0.5-3.3% at a minimum but could range to 3-8% loss). Rate of ocean warming has increased from 3.22 +/- 1.61 ZJ year (0-700 metre depth) and 0.97 +/- 0.61 between 1969-1993 to 6.28 +/- 48 ZJ per year (0-700 metres) and 3.86 +/- 2.09 ZJ per year (700-2000 metres) (IPCC 2019).
- The Southern Ocean including Antarctica experienced most of the global ocean warming (45-62%) from 2005-2017, a phenomenal increase from 35% as recently as 1970).
- Ocean density mean stratification has increased rapidly by 2.3 +/- 0.1% from the 1971-1990 average influencing the flow of marine ecosystem nutrients, carbon and oxygen levels.
- Upper ocean oxygen levels are predicted to decrease by 3-4%; upper ocean nitrate content by 4-11%; net primary species production by 4-11% and carbon export by 9-16%.

- Ocean acidification is projected to increase by 0.3 pH by 2080-2100.
- Coral reefs have a high probability of decreasing by 70% by 2050 and 100% by 2100 along with associated marine biodiversity.
- Seal Level Rise is accelerating from the rapid melting of the Antarctic and Greenland Ice Sheets.
- An increase of 1.5-2º Celsius in global average surface, atmosphere and sea level temperature levels based on historic inventory levels; even if emissions were to cease (IPCC 2015).
- An increase of 2.5-4ºC if emissions are stabilised at the current, medium growth rate by 2100.
- Increases of 4-7ºC if emissions are not reduced.
- A 0.5 metre global, average sea level rise (SLR) is projected for a low risk, current growth scenario, where emissions are highly reduced. A 1.0m rise exists for a medium risk (if emissions are stabilised). Up to 2 m exists for a high risk, continued emissions increase scenario by 2100 if current, global GDP growth rates of 3-5% annually remain.
- Greenhouse CO_2 emissions would have to stabilise around 430-450 parts per million (ppm) at present. It could reach no higher than 550 ppm (530–580) by 2100 to ensure survival conditions.
- A projected increase in the frequency, duration and intensity of climate-change related natural disasters, including storms, flooding, tsunamis, hurricanes, typhoons, heatwaves and landslides.
- El Nino and La Nina, mass coral bleaching and algal bloom events will also rapidly accelerate in the frequency, duration and intensity along with species extinction, migration and biodiversity loss.

3.5.2: Economic, Commercial, Legal and Other Risks

Other risks include access to the finance necessary to support MRE empowering the blue and general economies. Although more investors are committing towards investment in the blue, green economy and finance sectors as recent April and May 2020 publications on this author's www.blueeconomyfuture.org.za website testify to; ocean energy has yet to receive the same attention. This research hopes to provide an initial stepping stone towards achieving that. Significantly more capital is needed to support the transition and this can only occur with full economies of scale and any existing general and specific technical constraints needed to overcome this inexperience and reticence to convert electricity generation sources. Increased legal and liability risks may arise, needing access to insurance that has yet to be developed. It remains critical to secure uncertainty over intellectual property, data management and ownership, other research and developments, to encourage information sharing and cooperation, whilst rewarding ingenuity and effort. A core risk also remains the rate of technological progress for each energy type i.e. wind, OTEC, salinity gradient and bioenergy and how each will develop.

Small countries, remote communities and state territories along with remote experience scarce education, economies of scale, technology, repair skills, finance and institutional capacity for MRE; as general constraints. (Commonwealth Secretariat 2016). One study on wave energy prospects for tropical countries include in development, deployment, operation, cumulative, monitoring and evaluation or ocean governance and law enforcement (Felix et al. 2019). For example, the Cook Islands has the world's second largest marine sanctuary and good wave conditions but a total patrol force of 13 and one boat. One Indonesian case study also observed core barriers to implement include technology challenges, economic and market, environmental and social, infrastructure practicalities (Kusama 2018). Further general challenges that can be noted include uncertainty over marine spatial planning, and existing inclinations of bureaucrats to hinder development rather then search for constructive means and their inclinations towards the need to regulate. It can be challenging for MRE developers who are often penalised as being as polluting and problematic as fossil fuel based sources of electrical energy.

One US survey into current energy identified specific technological challenges remain for many technologies prior to ensuring sustainable and cost-effective full-scale commercialisation, especially for current, salinity gradient, floating solar voltaic and bioenergy (Minerals Management Service 2006). More surveys, monitoring and evaluation in the long term needs to be financed and implemented for many areas. For example, offshore wind energy offers 70% higher potential from ocean wind speeds then land (Dinh and McKeogh 2019). Yet often these compete for priority with other sectors of renewable and fossil fuel energy. Uncertain risks occur for competitiveness as to how competitors will react from other sources of renewable energy or fossil fuel production and supply chains as to whether this will help or hinder regular access to grid connections and infrastructure as cooperation is often necessary. Offshore installations are often more challenging to construct and maintain over climate and ocean conditions. Economies of scale is often perceived as impractical in requiring significant finance; yet has been proven to be among the only guaranteed ways to ensure practical cost-effectiveness (Snyder and Kaiser 2008; Borthwick 2016). As indicated, stakeholders may still react uncertainly leading to possible unknown conflicts or integration into existing marine spatial planning use requirements, unless suitable guidelines and precautions are taken by all stakeholders likely to be affected including the energy developers themselves. There also remains an uncertain risk of the unknown factor of international cooperation and support beyond IRENA for cross-sectoral issues.

The uncertainty of repositioning MRE with other activities was investigated under the EU MARIBE project to form a risk assessment approach (Williams et al. 2017). It identified operation, economic, political, financial, environmental, socio-economic and health or safety. In China current recorded challenges included lack of localised components of sound quality including fatigue and corrosion risks, insufficiently detailed wind information, inexperience in installation, operation and decommissioning, insufficient coordination and planning or provision of sustainable finance initiatives and incentives for people to sufficiently convert. Other unknown risks include the labour force, legal, logistics, climate, compliance with aviation and radar issues, ensuring emergency access and addressing with component and system reliability. Offshore wind deployment and implementation challenges include low interest rates and a high existing market concentration dominating supply chains/exports (Charles River Associates 2018). To avoid aesthetics and other issues raises transportation/operation and other costs as a challenge (OECD 2019). Additional economic risks across all MRE technologies include commodity prices, currency fluctuations and inflation along with ensuring trust and cooperation from supply chains. Given current tends towards zero waste, sustainability and the green/blue economy, uncertainty needs to be overcome over recycling, sustainability and connections with the circular economy. To conclude, these constraints and challenges towards full scale implementation and commercialisation for marine renewable and oceean energy for the blue econnomy are therefore summarised in Table 3.9.

Table 3.9: Constraints and Challenges towards Implementing Marine Renewable Energy.

IP and patents	Markets and reputational risks
Bureaucratic/Administrative	Site Specific Criteria
Climate, Climate Change	Environmental and ocean
Population growth and competing pressure for marine space Ocean governance, monitoring and evaluation/enforcement	Implementation -overcoming gap of commercialisation and inexperience
Legal and regulatory uncertainty, liability risk	Marketing or popular acceptance
Psychological and reacting with people	Access to finance
Socioeconomic -opportunity costs, labour,	Specific technological challenges including infrastructure and grid integration, battery storage and rate of progress
Competitors, Reactions of Renewable Energy and Fossil Fuel markets, industries, supporters/lobbyists	Constraints of developing nations/small island developing states or remote communities.

Source This Study.

3.6: Opportunities

Significant opportunities exist for those who seek to diversify from fossil fuel, highly polluting and emissions intensive, current means of electricity production towards marine renewable energy. A recent detailed study by the US Department of Energy is rare in alluding to and identifying possible blue economy opportunities (US Department of Energy 2019). It identified 2,640 TWh per year, for ocean wave energy, 445 TWh for tidal current and 200 TWh for ocean current. Examples included possibilities for coastal resilience and disaster recovery; isolated power systems and community microgrids; powering electric boats, aircraft, ocean pollution clean-up, offshore data centres and marine communications. It recommended the need for additional support specialised research facilities and market analysis for future research. Commercial prospects include various benefits including MRE for coastal disaster including climate change, shipwrecks, oil spills and grounding accidents, salvaging, emergency search and rescue, information, communication, aircraft and vessel navigation, telemedicine, fires, ecological rehabilitation. The source argued potential to power marine pollution reduction initiatives such as the Seabin Project, Ocean Cleanup Project and Trash Bin. It estimated over $70 million in costs or 36% of the US desalination market's costs were based on shore based energy consumption, which could be substantially curtailed if marine based. -opportunities of OTEC and salinity gradient

Alternatively, it argues the particular values for community microgrids typically only requiring 200 KW-5 MW with examples from military and naval bases to remote villages, fishing communities and ecotourism resorts. It estimated the US offered a market potential exceeding $350,000,000 with up to 300 communities and Indonesia has over 13,000 communities. The gains towards aiding remote local communities are confirmed in a second source affirm the additional logistics costs, ecological, navigational, safety and other risks of transferring fuel for generators or providing land based energy transmissions (Office of Energy Efficiency and Renewable Energy 2019). If we are to embrace ocean exploration, this will benefit from marine energy sources and recharging station networks for vessels, given over 80% of Earth's Oceans has yet to be truly detailed. Increasing global pressure for marine conservation and blue economy resources, ocean governance and protection also could benefit from renewable sources, given existing battery and fuel range limitations. The global AUV and UUV market was estimated by the US Department of Energy to be around $5.2 billion by 2020. Inspection lights, navigation, LIDAR, sonar, communication and observation systems -

fisheries, climate, ocean, shipping and other purposes all need to have reliable power sources, which can be mostly supplied by MRE.

Marine renewable energy has undoubted potential as this scholarship uniquely identifies in Table 3.10 as Blue Economy Future's mandate is to help facilitate and implement this future via any means necessary. This chapter and research's conceptual contribution is to specifically link to the blue economy and associated activities including Ports/Shipping and Navigation; Drones, AI, Ocean Governance, Navy and Marine Spatial Planning, Aquaculture and Fisheries, Seawater and Seabed Mining, Desalination; Research and Education; Coastal, Marine, Nautical and Eco Tourism, Remote Communities, Underwater Heritage, Maritime Education and Training . It argues the significant prospects of ocean energy to provide a perpetual, reliable and eco-sensitive source to empower each of these sectors, which other research has yet to truly imagine these possibilities. For ports and shipping, potential exists to also aid international decarbonisation and sustainability shipping requirements with the 2020 International Maritime Organisation IMO sulphur cap limit through providing power near coastal areas, ports or alternative forms of shipping via marine energy such as offshore wind, wave, solar power, hydrogen and bioenergy. Many ports and Emission Control Areas in the US, Baltic and Europe have specific slow steaming requirements to avoid emissions. MRE would enable speed and power, facilitating trade through reduced delays, increased speed, fewer emissions and improved quality of port/coast life if converted to MRE sources if in the area. Individual port activities could be empowered via MRE including the significant data systems needed to operate the port, the tugs, pilots, controls and port operations, dredgers, logistics equipment and warehouse storage, customs and other processes

Table 3.10: Marine Renewable Energy and the Blue Economy Prospects and Opportunities

Ports, Shipping and Navigation	Navies, Security, Defence and Warfare -Early Warning
Drones, AI, Oceans Governance Great Sea Wall-Poaching, Piracy	Risk Management -Climate Change, Climate-Oceans, Oil Spills, Accidents, Marine Pollution Reduction
Aquaculture and Fisheries	Marine Spatial Planning
Communications and Big Data/4th IR, Technology	Coastal, Marine, Nautical and Eco Tourism
Small Islands and Remote Communities	Energy Security -supplement main grids and coastal
Underwater Culture	Maritime Research, Education and Training
Seabed and Seawater Mining, Offshore oil and gas	Shipbuilding, conversion and repair
Water security and desalination	4th Industrial Revolution
COVID 19, Pandemics and Humanitarian Logistics	Artificial Reefs -Ecosystem Restoration and Reserves
Artificial Habitats/Cities	Undersea/Ocean Exploration

Source This Study.

It would minimise the need for diesel generators and electricity needed from more polluting other land sources. Utilising ocean energy would be especially beneficial for national defence and security, supplementing the range and other capacity of navies, coastguards and various patrol boats. For example these could power bases, early warning, communication and navigation systems, automated and planned defences such as mine fields and electromagnetic pulses and provide sustainable refuelling stations more long range to complement traditional vessel fuel and other limitations, along with enhancing access to energy and water security (via desalination), minimising the need for fossil fuel imports strategically during conflicts, civic unrest, states of emergency and natural disasters/other strife. Being marine based, they are far less vulnerable to crime, protestors, fires and other land-based incursion risks, enabling more areas to operate strategically and tactically in the future of warfare. Domestically, MRE offers unprecedented potential to augment ocean governance for Exclusive Economic Zones by empowering satellites, buoys, early warning and communication systems along with vessels and means of enforcement, especially AUV's, UUV's, drones and submarines, many of which are limited via electric battery and diesel limitations.

As previously highlighted, empowering drones offers many advantages -ensuring cost effective, coastal defences against poaching from illegal unregulated fishing and piracy. Drones create pressure as a visible deterrent to illicit activities, where existing traditional sources simply cannot reciprocate. AUV's are envisioned to reach US$ 1,206,000,000 (from $309,000,000 in 2016 or 23.19% of market share) with few specifically devoted to the maritime sector. Yet drones can act as substitutes for limited manpower navies, even being armed to respond more rapidly to paralyse, monitor, identify and respond to threats for nations with significant ocean territory. The Chinese have even created a Great Sea Wall of sensors, equipment, drones, research stations, telecommunications and risk monitoring in the ultimate maritime security configuration for situational risk awareness, which can be far more securely powered from ocean energy than land based or generator substitutes. Installing ocean energy capacity can assist in marine and coastal asset maintenance, inspection, protection and extension along with related operations. It even has potential to complement humanitarian logistics pandemics in providing power for cargo operations, human evacuations, emergency search and rescue or debris removal, reconstruction and restoration.

Empowering drones and vessels can also assist with other applications for those with limited enforcement and incident responses. This research identifies significant MRE opportunities for safety and incident risk management. Examples include providing the energy needed to facilitate awareness of and respond to climate, climate change and ocean risks or hazards via sensors, satellites, vessels, assets and infrastructure. MRE can reduce congestion, vessel blockages and facilitate salvaging or biological remediation from oil, chemical and other pollution spills. It can also respond to marine pollution problems such as plastic debris and threats presented to marine species/existing activities and operations by empowering solutions such as Ocean Clean Up, the Trash Wheel and other marine pollution reduction initiatives, as highlighted inn previous research under the www.blueeconomyfuture.org.za website.

Virtually any traditional coastal or ocean situated activity can receive more ecologically sustainable, minimal emissions and waste linked water or electricity. Although the world aims to be encouraging sustainable aquaculture far more than fisheries in principle, both vessels and inshore/more open water aquaculture ranches can gain from non-fossil fuel and diesel-based resources, given these costs represent significant expenses involved in normal operations. There are myriad benefits of ensuring responsible aquaculture with extended producer responsibility traced across maritime supply chains; including for biotechnology, food, textiles, pharmaceuticals, biofuel, construction, tourism and ecosystem restoration. Electricity is needed for various equipment and operations including harvesting, processing, value adding, ballast control, drying, refrigeration and ice, AUV and inspections/enforcement power, lighting and staff/office/security and communication requirements. Global aquaculture is projected to reach $274.8 billion by 2025 according to the FAO, providing multiple microgrid opportunities. Global fisheries are conversely forecast to reach $438.5 billion. Aquaculture has multiple food security, health and other projected benefits. Marine biotechnology also can be another market opportunity for marine renewable energy. Its market is predicted to grow from US$ 3.5 Billion in 2017 to US$ 6.5 Billion in 2024. A competitive opportunity exists for microalgae and macroalgae, full scale biofuel and other farms to provide the security of resource inputs for this sector. The sector not only improves aquaculture and fisheries but offers opportunities for pharmaceuticals, cosmetics, tourism, construction, biomaterials, biofuel and environmental bioremediation such as from oil spills.

Marine renewable energy can also empower the activities needed to ensure optimum utilisation and conservation of coastal and ocean areas via marine spatial planning via integrated coastal zone management, ecological and oceanographic surveys. This complements other roles such as resolving possible disputes or conflicts of resources, enabling greater monitoring, awareness, evaluation and responding whether for fisheries disputes, marine pollution, safety, crime, security and other issues that may arise, via support to the assets, vessels and processes involved. It can also support maintenance, inspections, installation and decommissioning of seabed telecommunication and other cables. It also has implications relating to providing the power and other technical support necessary to advance “Big Data: increasing vessel and process automation and digitisation and; more protected data repositories under the Fourth Industrial Revolution. As more smart ports, vessels, sensors and information systems require emissions and energy intensive processes including blockchain, the Internet of Things, telemedicine, AI, Augmented and Virtual Reality, cryptocurrency; datamining and other areas. This subsequent empowerment via marine related sources, ensuring data provision via sensors, data storage and transmission along with telecommunications and other electricity supplied is far simpler, more cost effective, continuous and environmentally or climate conscious for many coastal/marine related tasks than sourcing directly from land/fossil fuel sources, conventional engines, batteries and generators. This in turn subsequently benefits maritime research, education and training. This can extend to shore based simulators and other facilities.

Other opportunities that this chapter envisions as the destiny for Ocean Energy include specific opportunities to support coastal, Marine, Nautical and Eco Tourism. For example, many resorts are situated either on islands or away from main towns from New Zealand’s Milford Sound to Fiji, the Seychelles and the Caribbean and would benefit from microgrids or aim to market themselves as more eco-friendly such as ecotourism. Cruise vessels could become far more sustainable as via the example of Peace Boat’s Eco Ship (Section 3.2.3). Both cruise ships and yachting or nautical tourism could have MRE empowered small harbours and marinas along with visits to larger ports rather than engines. Additionally, ocean energy could support many areas of small islands and remote communities in providing greater electricity energy security and water security via desalination (OTEC and salinity gradient technology). Examples include scientific research stations in Antarctica, military bases from Ascension to Diego Garcia, lighthouses and navigational aids; along with other remoter islands from St Pierre and Miquelon to St Helena, Tristan de Cunha, Easter Island, Pitcairn Island, Wallis and Fortuna and others. Further security however could be used to initially supplement and ultimately substitute and convert for areas experiencing fossil fuel powered sources, to supplement main grids if sufficiently integrated along with water supplies.

Additional options including supporting the preservation of underwater cultural heritage such as shipwrecks and dive tourism; the creation of underwater sculpture parks and associated museums or reserves -i.e. the wrecks of the Titanic, Lusitania, Britannic, Empress of Ireland and other core legacies. This indirectly supports tourism. MRE will enable more sites to be considered and at further distance, freeing up land real estate and more valuable shore beaches. Other areas that marine energy could help augment and develop including providing electricity for more controversial activities including offshore oil and gas exploration, seabed and seawater mining for certain marine biotechnology and other components including lithium considered imperative for the green and digital economy and hydrogen -possibly for making airships a reality, as another source on airships forecasts under the www.blueeconomyfuture.org.za website. MRE can also empower ship and boatbuilding repairs, testing, construction, conversion or upgrading to decarbonised, shipping and demolition activities. Finally; its offers unprecedented opportunities for future areas of scholarship to undertake for the blue economy including providing electricity for subsequent dreams including ultimate ocean exploration and governance. It can ensure the creation and support to a network of marine protected sanctuaries and areas including ultimate artificial reefs and ecological restoration, against climate change and other threats. Ultimately it can provide refuges and new havens via self-sustaining autarchic vessels, artificial habitats and cities, whether floating, aerial or undersea.

3.7: Conclusion

To conclude this chapter has highlighted where a marine renewable energy market is situated at present, highlighting that whilst it may have few historic examples of long-term commercialisation and environmental success, significant progress has been made in providing dozens of more recent examples in the past 2 decades. With sufficient resources, popular, finance and institutional support, the various energy types including wave, wind, tidal, current, OTEC, floating solar PV, salinity gradient, bioenergy -biotechnology and circular economy can more effectively empower the transition away from the extractive, polluting, emissions intensive ocean economy to more climate resilient communities, businesses and livelihoods. With sufficient ingenuity, each technology type can radically alter our world and many pressing perils or problems. Marine renewable energy remains among the only pragmatic means forward, given the accelerating rate of climate change, high coastal population pressures, surging marine plastic pollution, transboundary ocean governance, illegal fishing pressures and decelerated support for financing and supporting fossil fuel based activities. More concern is increasingly focused not just on which energy is cultivated but the ecological and other implications across an entire ecosystem and biodiversity and how to readdress the inequity of the consequences for more vulnerable communities including those poorer and more fragile such as small island developing states or the conditions of the work force involved.

Chapter 4: Conclusions and Recommendations

In conclusion this research's core focus was to establish the core prospects and risks of marine renewable energy (MRE) as an emerging source of attention and interest away from global climate change risks. It specifically aimed to focus on decarbonisation of economies and the need to regenerate our existence towards a climate resilient, blue economy sector. This aims to accelerate the existing fissure between theoretical research and pilot projects and other implementation gaps towards full scale commercialization. As in Chapter 2's Literature Review many significant research gaps exist to explain the gulf between the many pilot projects pursued or attempted and the gap towards actual realisation and implementation. This study therefore recommends that for a MRE future to emerge for the blue economy and ultimately connect to national grids for all sectors; stakeholders need to consider previous experiences and lessons learnt from case study successes and failures such as Chapter 2. Stakeholders are advised to understand the specific characteristics of each sector and MRE technology type including wave, wind, tidal, current, ocean thermal energy conversion (OTEC), floating solar voltaic, salinity gradient and bioenergy; along with other requirements prior to formulating and participating in a supply chain. These requirements include cost effectiveness, emissions reducing, externality cost minimising, risk mitigating, technically feasible, ecologically sustainable, reliable, predictable, simple to maintain and operate. It argues the need to consider existing and potential local, regional, national and global, legal, financial and other regulatory frameworks, laws, policies and incentives. Chapter 2 identified the significant gap of few examples of MRE specific legal and experience examples with far more focusing on renewable and fossil fuel sources.

Chapter 3 focused on providing the history and current market status on the existing conditions for MRE. This includes the various stakeholders, existing and potential market prospects, tends, institutions and factors influencing prospective demand and supply. This report strongly counsels the need to consider exploiting myriad economic/fiscal, social, environmental, educational and training, technical, legal, strategic, geopolitical, security and other advantages, whilst avoiding any associated disadvantages or adverse inaction, maladaptation, externality and opportunity. It recommends conducting risk analysis including climate change, market information, socioeconomic and markets, legal and regulatory uncertainty, marketing or popular acceptance; psychological and reacting with people; technological, competitor; IP and patents', commercialisation and general inexperience; access to finance and general constraints of developing nations/small island developing states or remote communities, converting these into opportunities and mitigating, adapting or offsetting wherever possible. Both Chapters 2 and 3 highlight the need for a proposed implementation plan to overcome all impediments to ensuring ocean and marine renewable energy can deliver an effective transition towards a climate resilient, sustainable blue economy and ocean livelihood as identified in Section 4.1.

4.1: Proposed Implementation Plan for Governments/other Stakeholders

To actually implement MRE the following processes will be necessary as outlined below and developed in detail for Chapters 2 and 3. Successful implementation will remain conditional upon allocation of sufficient resources, following stakeholder requirements, conducting ocean resource assessments, markets and ecological surveys, ensuring sufficient mass individual, community and investor awareness. It also requires sufficient priorities in research, training and augmented institutional capacity that reward the blue economy and MRE, whilst penalising fossil fuel sector-based activities, sources and stakeholders. It remains essential to protect marine ecosystem resources as much as possible, restoring and extending where possible. This extends to the repeated Characteristics of an MRE Act, Technical Standards, Operational Plan and Investor Criteria.

Characteristics of an MRE Act.

- 6 Stages of Development Below
- Designated powers and responsibilities, capacity to make, amend or repeal regulations
- Site selection criteria
- Authorisation process
- Management, operation and maintenance
- Marine spatial planning and existing area uses
- Decommissioning, recycling, waste minimisation and the circular economy.
- Risk management and links to other legislation including safety, security, environment, water, Admiralty Jurisdiction, cargo, fisheries, tourism, etc.
- Freedom of financing, lease security and concession, ability to set port/marina user fees; fines for infringement and incentives
- Freedom over selling/procuring assets and properties/pay supply chain on time without the rigorous onus of centralised government procurement policies inhibiting development.
- Incentives and transfer from fossil fuel and land renewable energy sources -Financial; technology transfer, IP, licensing and authorisation, pilot projects, import substitution, customs
- Transmission connections
- Financial structure, electricity prices and market incentives

- Links to fisheries, aquaculture and other blue economy areas
- Ocean sovereignty and governance; creation of marine protected areas and private reserves.
- Marine spatial planning and functional zoning/integrated coastal zone management
- Links to blue carbon expansion and preserving
- Preserving of marine biodiversity and ecosystems; Regulated introduction and exploitation of rare and exotic species sustainably.
- Need to establish marine reserves and protected areas.
- Education, research and training.
- Specific ring-fenced budgetary resources provided for long and short term maintenance, potential expansions/construction and 15-20% for contingencies.
- Environmental, water/ocean impact assessments for certain activities with a maximum specified time period.
- Research, information; marketing, commercialisation and all value chain issues.
- Trade regulation, exports and provision of financial, investment, research and other incentives.
- Resolving market barriers to entry -competition; infrastructure and standards;
- Issues over marine resources,
- A suitable enforcement, regulatory and independent oversight/appeals authority
- The extent of public participation and consultation in the process
- Avoiding of marine threats -issues of Polluter Pays Principle, carbon footprint offsetting, and company liability. Risk management. Need to ensure recycling, reduction of bycatch and related waste and the principle of ensuring the circular economy wherever possible.
- Issues over resources as climate change develops
- Links to other policies and supporting legislation
- Specific prescribed legal and other penalties for violations
- The resolution of disputes and appeals process

Marine Renewable Energy Installations Design/Operational Plans and Technical Standards Guidelines

- Construction Plan/Site Specific Selection Criteria as in Section 2.1/2.2 for technology type
- Engineering/Technical Design Standards
- Business/Operational, Financing, Marketing and HR Policies/Plans -education and training
- Environmental Management Plan, Climate Change Risk, Impact and Adaptation Approach;
- -Sound, Light, Air and Water Quality, Pollution etc.
- Safety, Security, Oil Spill, Pollution and Other Risk Management Approaches
- Circular Economy -Recycling-Waste Management, Water Security and Renewable Energy Plans
- Maintenance Policy
- Ocean Governance and Marine Conservation -Enforcement
- Community Engagement/Social Responsibility
- Specific Fisheries, Marine/Leisure/Cruise Tourism and other blue economy requirements
- Cybersecurity, Data Gathering/Statistics and Management Protocol.

For a well-functioning MRE operation to operate, this maritime economist recommends the following at a minimum.

- Sufficient funding/reserves to ensure a 15-20% contingency reserve along with operations
- Minimal, well trained, experienced and qualified staff professionals
- An effective, cyber-secure IT and Port Community System and external site backup
- Sufficient and well-maintained assets, infrastructure and equipment to address stakeholder needs
- A suitably climateproofed and sheltered physical office
- Provision of Internet services.
- Provision of bunkerage -including cleaner fuels, renewable energy, water minimising facilities
- Marketing budget
- Hosting events etc to stimulate sufficient community and investor interests.
- Considering a competitor analysis on what competitor counterparts are undertaking and responding accordingly.

: Investor Guidelines/Criteria

These are not extensive but include:

- Site specific characteristics and marketing -i.e. location; availability of attractions/services
- Commercial indicators (See section 3.4) such as profit, Rate of return on investment
- Fiscal Incentives, fines and penalties
- Extent of regulations -are they practical or excessively bureaucratic and onerous as a detriment
- Security of leisure/property rights and tenure
- Local development of area and surrounding economy -does it provide growth potential
- Competitors -considering an opportunity cost on the rate of return on potential investment?
- Social, environment, heritage and other factors.
- Extent of management, maintenance and receptiveness to client/stakeholder requirements- i.e. reputation and experience.
- Environment/Climate Change Hazards
- Possibilities of reducing commercial congestion from larger ports.
- Integration into Smart Ports/4th IR and efficiency
- Greater eco-chances and sustainability of marine environments -for creating blue carbon finance, marine reserves, blue economy activities and other opportunities as in Section 3.6.
- An independent regulator with clear accountability, independent roles, responsibilities, accounting, reasonable pricing tariff determinations given stakeholder interests and regulation.

Implementation Plan

- **Stage 0. Formulation of a Regulatory Framework (Section 2.3: Characteristics of an MRE Act), Development of Technical Standards, Financial Incentives. Mobilising of Resources Necessary.** This includes a coordinating group or Establishment of a Technical Secretariat. This is needed to provide a professional source of knowledge/information providing technical recommendations and support, inputs and suggestions for reports, policy documents, media releases, tenders and consultancy offering through regular meetings. The establishment and selection of Working Groups with designated responsibilities and progress. It includes researchers, businesses, investors, policy government makers, innovators, legal, environmental, climate change, energy and other stakeholders to spearhead the initiative. A sufficient budget with ring-fenced resources including support staff, venue, training, IT, website, social media, and awareness/marketing campaigns as needed. Political support needs canvassing via lobbyists.
- **Stage I: Initial Site/Energy Type Selection, Inspection, Resource Investigation and Assessment. This includes research and marketing, considering site specific criteria etc.**
- **(Consider Site Specific Criteria as in Chapter 2)**
- The drafting, agreeing and implementation of a Future Vision for Marine Renewable Energy, a proposed Implementation Plan (such as the one above) and Action Plans for each group and involved stakeholders with clearly designated roles, responsibilities, timeframes, actions, resources required and identifying of risks/concerns -how to overcome them along with potential opportunities.
- A Literature Review and establishment of other MRE and related blue economy/environment initiatives, policies, activities etc globally to establish best practise methods, approaches, standards and implementation/identify similar risks and opportunities.
- A Review of all legislative policies/frameworks etc hindering potential development and implementation and subsequently leading to the Establishment of a Marine Renewable Energy Conversion Policy, Research Plan, Act, Code of Conduct, Stakeholders Socio-Environmental-Climate Change Compact and Guidelines to facilitate the above.
- A Pre-Feasibility Study of the Proposed Pilot Project and Various MRE Sites to Focus on the Specific issues, advantages, opportunities, infrastructure, climate, environment, stakeholders etc of each harbour. -Joint research in teams etc.
- Significant marketing efforts via conventional and social media to maximise awareness including hosting events etc.
- Creation of Museums of discoveries.

- Subsequent Monitoring and Evaluation; extension of activities and scaling up to other sites.

- **Stage II: MRE Component and Technology Industry Fabrication and manufacturing Pre-Installation, Developing of Supply Chains, Stakeholder Requirements and Ecological protection.**
- **Stage III: Installation of Various MRE and associated activities**
- **Stage IV: Stakeholder Consultation, Marketing, Market Feasibility and Grid Integration. Identification of markets, competitors, a cost-benefit analysis, impact cost-analysis, advantages, disadvantages, risks and opportunities (Chapter 3)**
- The Formation of Viable Market/Business Proposals and subsequent Investor/Financial Lobbying Support.
- Subsequent creation of pilot sites and implementation via EIA's/Zoning etc but creating an online and physical base connecting all stages so stakeholders can apply for them simultaneously as suggested to accelerate development.
- Public community and other stakeholder consultation.
- Creation of online and learning exchanges; entrepreneurship and innovation hubs -linkages to existing training institutions etc.
- Publicising of opportunities for specific jobs and industries.
- Connecting to other government agencies/private sector -coordination to maximise various socio-financial incentives etc.
- **Stage V: Operation, Servicing, Empowering Supply Chains and Maintenance/Risk Management.**
- **Stage VI: Decommissioning, Monitoring and Evaluation, Recycling and the Circular Economy.**

4.2: Research Motivation, Study Limitations and Directions for Future Research

This highlights the information necessary for those with limited time, finance, attention and other scarce resources to contemplate investing, supporting and prioritising marine renewable energy as an initial step. This research aims to provide an independent evaluation as to the conditions necessary to fabricate an enabling environment for a blue economy sector that has mostly stalled and stagnated, with many projects facing bankruptcy and liquidation, despite being promising technologically, environmentally and economically. It seeks to radically accelerate progress beyond the pilot stage for those who wish to comprehend MRE but seek some guidance as to where to actually begin. Its aim remains to ensure theoretical research matters in reality, by focusing on what and how the past and present, can guide the future whilst cogniscent of existing study limitations from scarcity of existing research including failures and the need for more detailed and specific field research to support the proposed Implementation Plan and various recommendations/opportunities highlighted for stakeholders throughout. This author and Blue Economy Future, www.blueeconnomyfuture.org.za and LinkedIn Blue Economy Future SA remains willing, prepared and able to commit and facilitate to anyone and any initiative willing to progress forward; as with other blue economy sectors

Therefore, marine renewable energy can reflect the future of providing electricity to general economies but also blue economies if the following multiple opportunities that exist from capitalising on markets and providing reliable energy, resource security, import substation and other benefits are investigated and exploited. These include ports, shipping and navigation; navies, security, defence and warfare; drones, AI, oceans governance, the 4th Industrial Revolution and risk management including climate change, poaching, piracy, climate-oceans, oil spills, accidents and marine pollution reduction. Others include aquaculture and fisheries, marine spatial planning, communications and Big Data/4th IR, technology, coastal, marine, nautical and eco-tourism. It offers potential for small islands and remote communities, water security and desalination; energy and water security, underwater culture, maritime research, education and training; seabed and seawater mining, offshore oil and gas along with shipbuilding, conversion and repairs. Others include empowering COVID199, pandemics and humanitarian logistics, creating ecosystem restoration and reserves, artificial reefs and other activities, artificial habitats/cities and undersea/ocean exploration.

Ultimately all sources require energy and global supply from waves, winds, tides, currents and other sources has been estimated to exceed 4 times the current global demand for conventional sources. Existing fossil fuels will only forespell our obliteration, being no longer business as usual; unless we as stakeholders continue to charter, explore, imagine and radically upscale new solutions and innovations. The capacity to harness the oceans may be mired in initial uncertainty and controversy, given few projects have made it to long term commercialisation success and the ecological and other implications have yet to be challenged. Yet more support engulfing the transition from dozens of prototypes, to more actual examples and investigations such as those recommended in the above Implementation Plan will truly help resolve whether

Marine Renewable and Ocean Energy reflects the future, or simply an idle and foolish whim being speculated for the blue economy. As we face unprecedented risks emerging from the fact that virtually no one has even mentioned, yet alone actively striving curbing human population and consumption growth dramatically; MRE may offer a way out of the fossil fuel quagmire for many areas, with many of the advantages but virtually none of the land space, noise, aesthetics, community opposition and ecological deterrents of marine areas; for those with the gumption to seize and be inspired by it.. Few other ways, other than hastening space colonisation or relocating underground and letting our planet ecologically recover for decades; can serve to reverse centuries and years of accelerating human neglect of their planet and climate change.

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