HYDROGEN FUEL ADOPTION: AN OCEAN RENEWABLE ENERGY APPROACH

PART 3: OCEAN RENEWABLE ENERGY AS A VIABLE ALTERNATIVE

Sameer Guduru and Vice Admiral Pradeep Chauhan

This is the third tranche (Part 3) of an ongoing advocacy of the need for India to secure its future energy-security by effecting a transition away from fossil fuels. The various parts, taken in aggregate, seek to provide Indian policy-makers with a compelling set of arguments, to not only support ocean- based renewable energy as an economically viable and ecologogically sustainable option, but to specifically adopt hydrogen-fuel derived from the oceans as India's best option.

Part 1 of this advocacy brought out the components of India's primary-energy basket and the geopolitical vulnerabilities arising from India's need to import a substantial proportion of these, particularly crude-oil, from West Asia.[1]

Part 2 dwelt upon the principal form of secondary energy, namely, electricity. It sought to demonstrate that current projections by the government were excessively optimistic and that additional sources of energy (apart from solar and wind) would be required if India was to meet its targets for electricity-generation capacity, while simultaneously meeting the commitments it had made at the Paris COP, in 2015. It also addressed the country's transport sector, whose demand for energy by way of petroleum-products drives much of India's oil-based dependence upon imports, and hence makes a significant contribution to the country's geopolitical vulnerability. In an effort to mitigate this dependence (quite apart from the environmental aspects), it introduced India's ongoing drive to switch to Electrically-driven Vehicles (EVs). Since a critical ingredient for the cathodes of batteries used by all electrically-driven vehicles (EVs) is cobalt, the need for cobalt makes new, but equally critical geographic areas the focus of the geostrategies that drive India's geoeconomics and hence shape its geopolitics. Part 2, therefore, sought to set the stage for the recommended thrust towards harnessing Ocean Renewable Energy Resources (ORER) in general, and hydrogen-fuel from the sea, in particular.[2]

This Part progresses the logical flow of the arguments presented in the first two parts.

According to the renewable energy global status report of 2019, 64% of new installations in 2018 were from renewable sources of energy (including solar and wind), marking the fourth consecutive

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[1] Sameer Guduru, "Adoption by India of Hydrogen: An Ocean Renewable Energy Approach Part 1" 2020, https://maritimeindia.org/adoption-by-india-of-hydrogen-an-ocean-renewable-energy-approach-part-1/

[2] Sameer Guduru, "Adoption by India of Hydrogen: An Ocean Renewable Energy Approach Part 2" 2020, https://maritimeindia.org/hydrogen-fuel-adoption-an-ocean-renewable-energy-approach/

year that net additions of renewable power were above 50%.[3] For quite some time now, the MNRE's primary focus has appeared to be restricted solely to solar and wind energy.[4] However, as was shown in Part 2 of this series, the government's projections appear to be significantly optimistic, especially if they are to remain limited principally to these two forms of renewable energy alone. To that somewhat unreasonable optimism, if one were to add unpredictability in weather, temporality, operational and maintenance costs, as well as the predicted demand of an increase in energy requirements by 2040 due to rapid urbanization, it would be clear that the solar-onshore-wind combine will simply not be enough, and, consequently, the exploration of additional sources of clean energy is both necessary and urgent.

India's Ocean Renewable Energy Potential

It is this author's conviction that adding Ocean Renewable Energy Resources (ORER) and hydrogen fuel into the basket of renewable energy reources — alongside solar-, wind- and hydel-energy — offers very substantial potential for the addition of requisite capacity in terms of green-energy installations. Fortunately, there is encouraging evidence of this view being accepted more widely now than has hitherto been the case. Indeed, the website of the Government of India's 'Ministry of New and Renewable Energy' (MNRE), accepts that all forms of renewable energy are necessary for achieving the Paris 2015 targets by 2030. In August of 2019, the MNRE finally decared that ORER were the "*energy resources of the future*", but added the caveat that this was subject to technological evolution and reduction in costs.[5] This cuatious approach notwithstanding, the MNRE has invested in research and development of ORER and is actively collaborating with several premier research institutions of the country such as the Department of Science and Technology (DST), the National Institute of Ocean Technology (NIOT), the Indian Institute of Technology (IIT), etc.[6]

ORER may be categorised into two principal subsets, which are diffeentiated from each other by the methods they employ to covert energy from the intrinsic nature of the ocean. These subsets are 'Ocean Mechanical Energy Conversion' (OMEC), and 'Ocean Thermal Energy Coversion' (OTEC). The former employs methods that convert kinetic energy from the oceans — in the form of waves, tides, and currents (whether tidal currents or ocean currents) — into electricity. The latter, on the other hand, utilises the temperature-differential (thermal-gradient) between warmer surface-water and colder deep-seawater to run a power-cycle and produce electricity.[7]

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[3] REN21. 2019, "Renewables 2019 Global Status Report", https://www.ren21.net/gsr-2019/chapters/chapter_01/chapter_01/

[4] Ministry of New and Renewable Energy, 2019, "2nd Global RE-Invest 2018 a resounding success!, Renewable Energy, *Akshay Urja*", https://mnre.gov.in/img/documents/uploads/58f4da0f67ad455a89b5ab8e4db14174.pdf

[5] Ramya Ranganath, "Government Considers Ocean Energy under Renewable Resources", https://mercomindia.com/government-ocean-energy-renewable-source/ (accessed August 26 2019)

[6] International Energy Agency. 2020. *India 2020 Energy Policy Review*. https://niti.gov.in/sites/default/files/2020-01/IEA-India%202020-In-depth-EnergyPolicy_0.pdf

[7] Vice Admiral Pradeep Chauhan, unpublished manuscript "India's Maritime Strategy — Part 1: India's Maritime Interests", June 2020.

Wave Energy

The natural generation of waves in the ocean is usually the result of disturbances caused by wind, although waves can also be generated by an underwater seismic event. Where wind is the source, waves result from the transfer of kinetic energy from the wind to the water. Wind blowing on the surface of the water also creates friction and the difference in pressure created between the upward wind movement and the leeward side of the wave-crest results in a shear-stress upon the water, which, in turn, causes the waves to grow in size.[8] The kinetic energy carried by the waves can be harnessed in a variety of ways. Common techniques (schematically-depicted in **Figure 1**) include the Oscillating Water Column (OWC), the Oscillating Body Converter (OBC), and, the Overtopping Converter (OC), although, of course, these are not the only options.

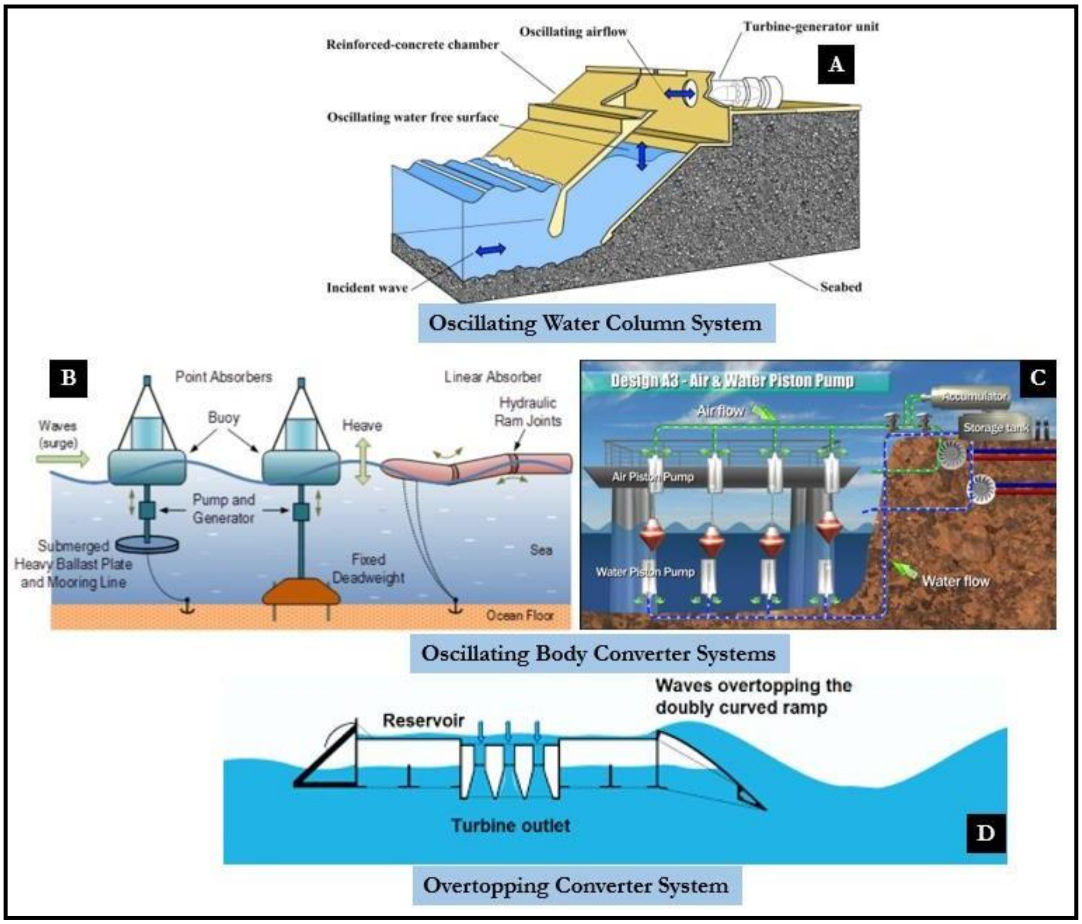

Figure 1: Wave-Energy Conversion Techniques:
(A) Oscillating Water Column; (B) & (C) Oscillating Body Converter Systems;
(D) Overtopping Wave Energy Converter Systems

Sources: 1(A) - Journal of Ocean Engineering, Vol 164
1(B) - Alternative Engineering Tutorials (AET): "Wave Energy Devices"
1(C) – "Blue Energy – Ocean Power", YouTube Video, 4:57, 20 Oct 2012
1(D) – Parmeggiani *et al*, Energies, 2013, doi: 10.3390/en6041961

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[8] MR Hashemi and SP Neill, "Fundamentals of Ocean Renewable Energy: Generating Electricity from the Sea", Cambridge Academic Press, 2018, https://doi.org/10.1016/C2016-0-00230-9

Figure 1A[9] depicts the working principle of the OWC, which has a semi-submerged chamber with space within it for an air-column. The movement of the ocean waves results in the air in the chamber getting pushed out at a high velocity. This air is used to run a turbine to produce electricity. **Figure 1B**[10] and **1C**[11], on the other hand, depict a simplified OBC, comprising either floating or submerged platforms, which exploit more the powerful 'swell-waves' that are generated underwater, in order to produce electricity. These platforms are positioned in the direction of wave propagation and are usually held in place by moorings attached to the sea floor. OBCs employ either hydraulic pumps or piston pumps such that they oscillate vertically (i.e., they bob up and down) when waves pass over. This causes the piston in the pump-assembly to similarly move either up or down, thereby compressing the air or hydraulic-fluid in the cylinder. This motion generates or releases pressure and, in either case, causes a suitable gear to be turned in one direction alone (either clockwise or counter-clockwise). This then drives one or more motors, which in turn run turbines to produce electricity. **Figure 1D**[12] shows that the working principle of an OC is quite similar to that of a hydroelectric dam, wherein water in a reservoir containing potential energy is released to flow rapidly down a slope and runs turbines to produce electricity. The OC achieves this by employing structures that force incoming waves to spill water into a smaller reservoir, which is thereafter released onto the blades of small hydro-turbines to produce electricity.[13]

As has already been mentioned, there are other wave-energy devices that are in contemporary use. Notable amongst these is the 'Pelamis System' ('Pelamis' is the name of a sea-snake). This is depicted in Figure 2.[14] It comprises a series of articulated floating sections, each typically 120-150 metres long and 3.5 metres in diameter, slackly moored to the sea bed such that the device aligns itself perpendicular to the prevailing wave-crests. Here, the waves are 'resisted' by a pair of hydraulic rams located with the articulated-joints and one or the other ram is compressed. The ensuing hydraulic pressure is used to pump high-pressure oil to drive hydraulic motors that in turn, drive electrical-generators.

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[9] I Hashem, HS Abdel Hameed, and MH Mohamed, "An Axial Turbine in an Innovative Oscillating Water Column (OWC) Device for Sea-Wave Energy Conversion", Ocean Engineering, Vol. 164, 536-562

[10] Alternate Energy Tutorials (AET), "Wave Energy Devices", https://www.alternative-energy-tutorials.com/wave-energy/wave-energy-devices.html

[11] Henry Teng Choy Lam, "Blue Energy - Ocean Power (Piston Pump & Racks)", YouTube Video, 4:57, 20 October 2012, https://www.youtube.com/watch?v=fYfs-qYGzvs

[12] Stefano Parmeggiani *et al*, "Experimental Update of the Overtopping Model Used for the Wave Dragon Wave Energy Converter", Energies 2013, 6, 1961-1992; doi:10.3390/en6041961

[13] International Renewable Energy Agency (IRENA), "Wave Energy Technology Brief, Ocean Energy Technology Brief 4 2014", https://www.irena.org/documentdownloads/publications/wave-energy_v4_web.pdf, (accessed June 2014)

[14] P Swati & C Latha, "Wave Power Conversions Systems for Electrical Energy Production"; Shri Krishnadevaraya University (College of Engineering & Technology), Anantapuram, Andhra Pradesh, http://www.slideshare.net/chakri218/pelamis-wave-energy-convertor-ppt

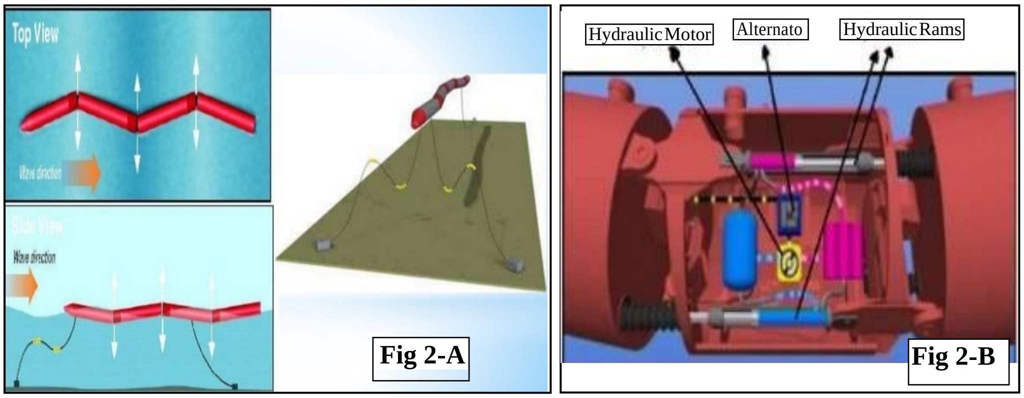

Fig 2: Working-principle of a Pelamis System

Source: P Swati & C Latha, "Wave Power Conversions Systems for Electrical Energy Production", Shri Krishnadevaraya University, Anantapuram, Andhra Pradesh

Coastal sites deemed suitable for the installation of wave-energy devices are depicted in Figure 3.[15] India's annual potential power from wave-energy is currently assessed to be 41 GW.[16]

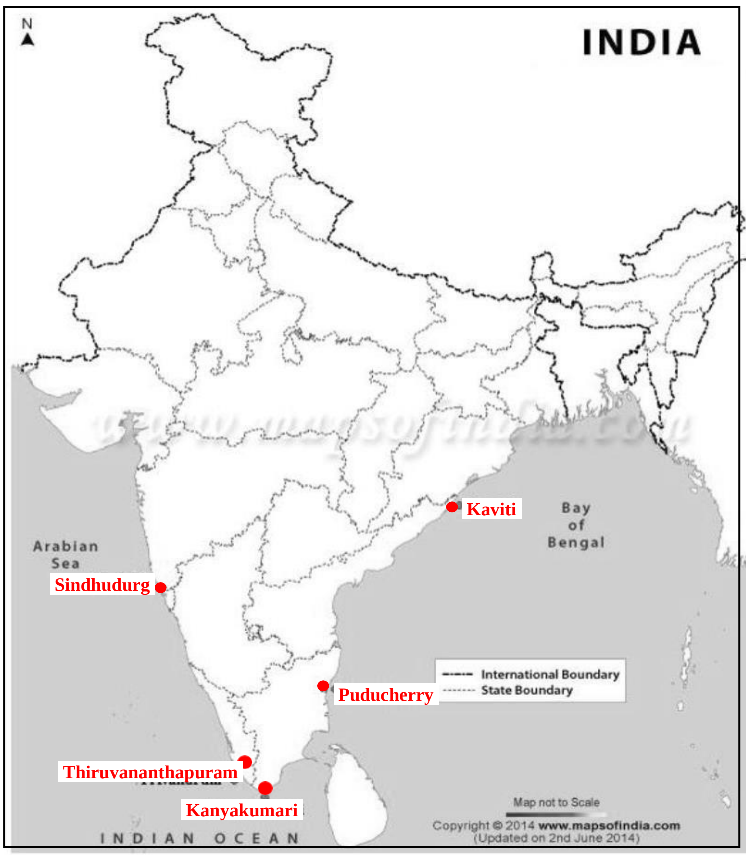

Fig 3: Indian Coastal Sites Suitable for the Installation of Wave-energy Devices

Source: CRISIL & IIT Madras

[15] CRISIL Risk and Infrastructure Solutions Limited in Association with Indian Institute of Technology Madras, "Study on Tidal & Waves Energy in India: Survey on the Potential & Proposition of a Roadmap Final Report", https://www.ireda.in/doc/publications/sarve2.pdf, (accessed December 2014)

[16] *Ibid*

Tidal Energy

'Tides' are actually long-period oceanic waves that are caused by the gravitational pull exerted upon the oceans by the moon and sun. When these long-period waves approach the coastline, they appear to human beings as a regular and periodic rise and fall of the sea surface. When the highest part (the crest) of the wave reaches a particular location, 'high tide' occurs. By corollary, 'low tide' corresponds to the lowest part of the wave (the trough) reaching the same location. The difference in height between the high tide and the low tide is called the 'tidal range'. These natural phenomena can be exploited to generate electricity in several ways.

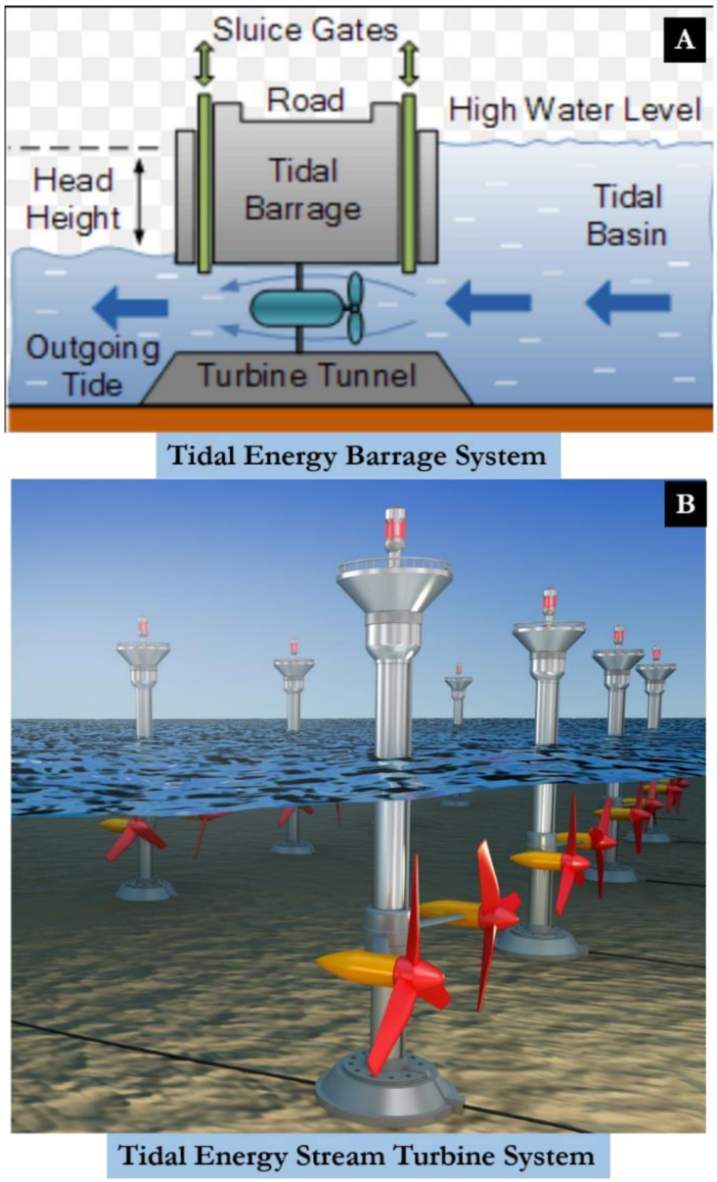

Figure 4: Ocean Tidal Energy Conversion Techniques
(A) Tidal Energy Barrage System; (B) Tidal Energy Stream Turbine System
Sources: 4A – Alternative Energy Tutorials (AET), "Tidal Energy Devices"
4B – Clean Energy Ideas, "What is Tidal Power? Tidal Energy Explained"

The traditional method, depicted in **Figure 4A**,[17] is to utilise a 'tidal barrage' preferably in a narrow pasage connecting the sea to a bay or an estuary. The barrage acts as a dam between the sea on the one side and the bay/estuary (or even an artifically-built reservoir) on the other. Sluice-gates are lowered to prevent water from flowing from the sea into the estuary. As the tide rises, the level of the sea becomes higher than the water in the estuary. This creates a pressure differential. When the sluice-gates are raised, water from the higher level (in this case the sea) rushes into the estuary. This rush of water is used to drive a controllable-pitch propellor. This acts as a rotor and, when spun within the coils fitted in the body in which it is housed (the stator), produces electricity. Once the two water-levels (in the sea and in the estuary) are the same, the propellor stops. The sluice-gates are lowered once more. As the tide recedes, the water level becomes higher in the estuary than it is in the sea. The sluice-gates are raised, the blades of the propelor are reversed and the turbine is made to run again, with the water now rushing from the estuary side into the sea. This working- principle is depicted in **Figure 4A**.

A somewhat newer approach is to do away with the tidal barrage and, instead, to install , a propellor-blade turbine underwater, in the path of the tidal stream. When the tide is rising, the tidal flow is from the sea to the shore and the turbine blades turn, driving the generator and producing electricity. When the tide is ebbing, the pitch of the propellor is reversed and electricity is once again generated. This is depicted in **Figure 4B**.[18]

Whatever the approach, in order to generate a sufficient pressure differential, a tidal range of at least five metres (and preferably seven metres or more) is needed if the operation is to be economically viable. power and for economical operation. There are very few locations on earth with tidal ranges that are this high. Amongst these, however, are the Gulf of Khambat (Cambay) — which experiences a maximum tidal range of 11 metres and an average one of 6.77 metres — and the Gulf of Kachchh (Kutch) — where the maximum tidal range is 8 metres and the average is 5.23 metres.[19] Both these gulfs are located in Gujarat, on the west coast of India and have a combined potential of some 8,200 MW (7,000 MW for the Gulf of Khambat and 1,200 MW for the Gulf of Kachchh).[20] Likewise, the Ganges Delta in West Bengal's *Sunderbans* area is suitable for small-scale tidal power generation and has a potential of 100 MW.[21] A 2014 joint report by CRISIL and IIT (Madras) indicated that technological advancements had led to the achievable tidal potential being revised upwards to 12,445 MW.[22]

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[17] AET, "Tidal Energy Devices", https://www.alternative-energy-tutorials.com/wave-energy/wave-energy-devices.html
[18] Clean Energy Ideas, "What is Tidal Power? Tidal Energy Explained", https://www.clean-energy- ideas.com/hydro/tidal-power/what-is-tidal-power-tidal-energy-explained/ (accessed July 23, 2019)
[19] The Energy Research Institute (TERI), "Energy Supply: Tidal Energy", TERI Energy and Environment Data Diary and Yearbook (TEDDY) 2016/17 (TERI Press, New Delhi, India, 2018), Chapter 5, 80
[20] TEDDY 2016/17
[21] TEDDY 2016/17
[22] CRISIL Risk and Infrastructure Solutions Ltd in association with Indian Institute of Technology, Madras; "Final Report of a Study on Tidal & Wave Energy in India" (Clients: Agence Française de Dévelopment [AFD] and Indian Renewable Energy Development Agency Ltd [IREDA]); 31 December 2014, 61-68
http://www.ireda.gov.in/writereaddata/AFD_Tidal.pdf

Regrettably, however, current inputs (2019) are that the high capital cost of establishing tidal-power stations have led India to abandon this option, even though *"globally, many countries, mostly in Europe, have continued to invest in tidal and ocean energy projects. This has resulted in energy generation from these projects increase from 5 gigawatt-hours in 2009 to 45 gigawatt-hours in 2019".*[23]

Current Energy

The emergence of ocean currents can be attributed to a variety of natural factors that impact the oceans, such as the temperature gradient, the density differential, the salinity differential, etc., at different horizontal and vertical locations of seawater. **Figure 5**[24] shows the global distribution of ocean currents, where the colour-scale denotes tidal range differences, which essentially reflect the strength of tidal streams.

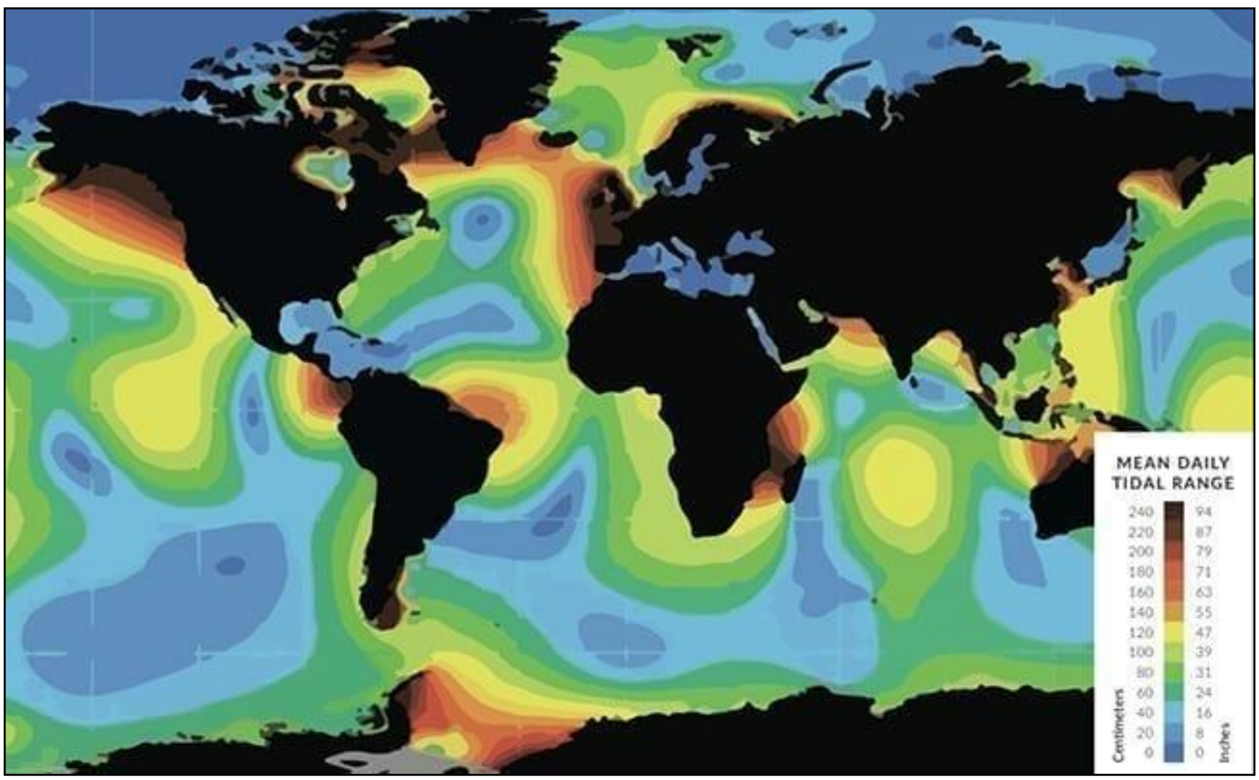

Fig 5: Global Distribution of Ocean Currents
Source: Power Magazine, Courtesy: Minesto AB, Sweden

The movement of seawater in the form of ocean currents can be exploited to produce energy by placing enery-conversion devices such as underwater horizontal-axis turbines.[25] These turbines,

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[23] Saurabh, "India Gives Up On Tidal Power", https://cleantechnica.com/2020/03/30/india-gives-up-on-tidal-power/

[24] Sonal Patel, "Subsea Kite Technology Makes a Big Splash for Marine Power", Power Magazine, 31 April 2020, https://www.powermag.com/subsea-kite-technology-makes-a-big-splash-for-marine-power/

[25] Bobby Zarubin, "Ocean Current Energy: Underwater Turbines", http://large.stanford.edu/courses/2014/ph240/zarubin2/, (accessed January 24, 2015)

depicted in **Figure 6**,[26] sit on the seabed and typically require currents folowing at velocities of 2.5 m/s (about 5 knots) or higher, in order to produce electricity cost-effectively. Such fast flowing currents are relatively uncommon in most close-coast areas of the world. Moreover, the capital cost involved in installing the turbines and their support-structures is fairly high. Consequently, their adoption for electricity-generation has been fairly low.

Fig 6: Underwater Horizontal-Axis Turbines Operated by Ocean Currents
Source: US Department of the Interior, Bureau of Ocean Energy Management (BOEM)

However, this limitation has now (since 2018) been overcome to a significant degree — specifically by a private company based in Sweden, Minesto AB, which was hived out of the well known Swedish aircraft company, Saab. Minesto Company's 'Deep Green' subsea kite converts the kinetic energy present in marine currents into power via a turbine mounted beneath a wing that is anchored to the seabed (or a surface platform) by a tether. The wing is subjected to the lifting force of the underwater current, which propels the system through the water. The power plant moves on a figure-eight trajectory, using a control system and rudder. As it moves across the current, the surrounding water flows through the turbine at a speed several times that of the actual current velocity. This unique technology is presently the only one that can cost-effectively exploit low-flow marine streams (with velocities of around 1.2 m/s (about 2¼ knots), which are encountered much more frequently across the globe.

[26] US Department of the Interior, Bureau of Ocean Energy Management (BOEM), "Ocean Current Energy", https://www.boem.gov/renewable-energy/renewable-energy-program-overview

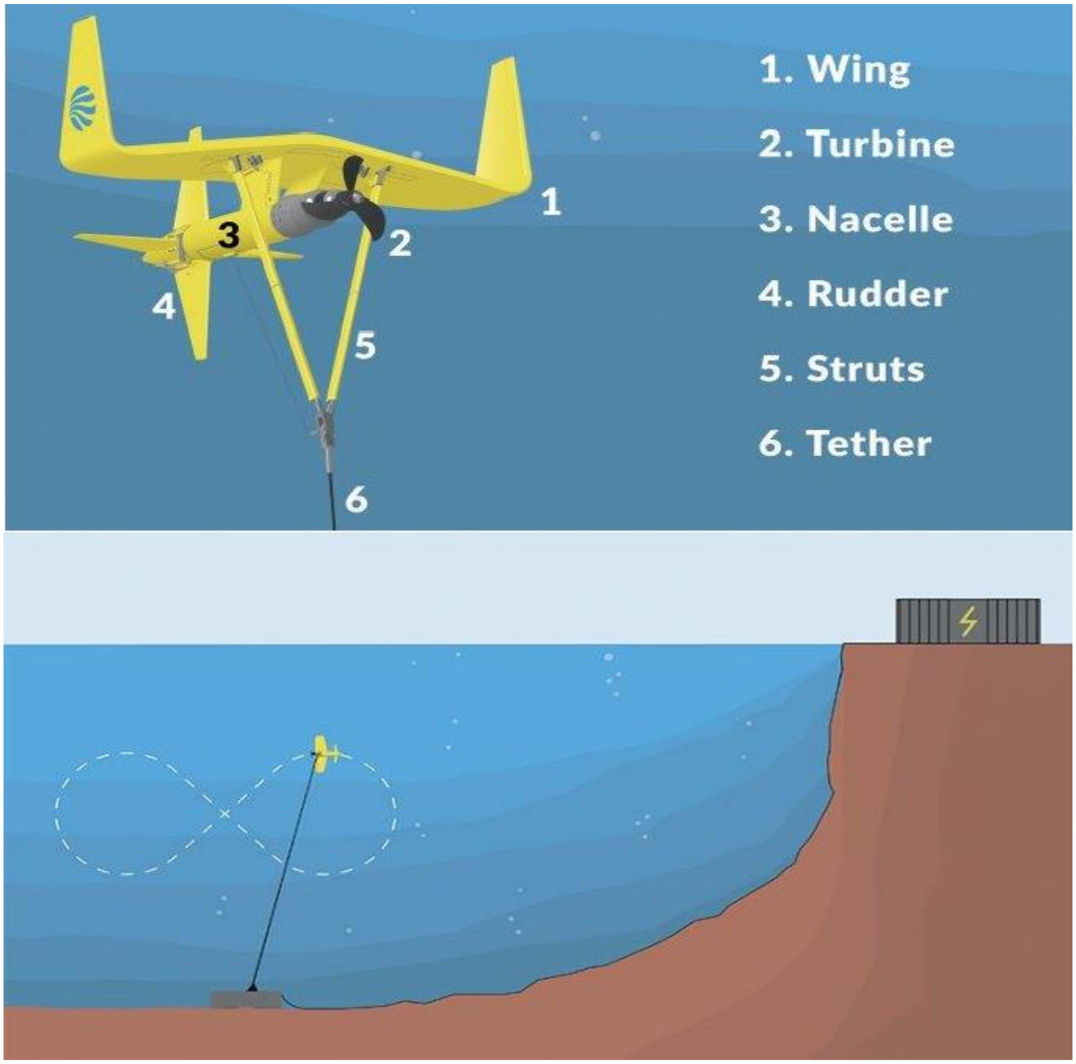

Fig 7: Ocean Current Energy using a Sub-sea Kite
Source: Minesto AB, "The Future of Renewable Energy"

Figure 7[27] depicts the working principle. The underwater current creates a hydrodynamic lift force on the wing and pushes the kite forward and, ultimately, steers it automatically in a 'figure-of-eight' pattern. As the kite 'flies' across the ocean current, it pushes the turbine through the water "at a speed several times faster than the actual flow rate, essentially multiplying the stream flow through the turbine and enables efficient energy conversion in low-velocity marine currents. Power produced in the onboard generator is then transmitted to shore via a cable in the tether that is attached to the wing.[28] Unfortunately, current-velocities off the Indian coast are assessed to be too low even for sub-sea kites. It must, however, be added that Indian scientific measurements have been extremely scanty.

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[27] Minesto AB, "The Future of Renewable Energy", https://minesto.com/our-technology
[28] Sonal Patel, "Subsea Kite Technology Makes a Big Splash for Marine Power", https://www.powermag.com/subsea-kite-technology-makes-a-big-splash-for-marine-power/ (accessed March 31, 2020)

Ocean Thermal Energy Conversion (OTEC)

OTEC systems exploit the temperature-difference between the seawater at the surface and that in the deep sea to run a thermodynamic heat-engine, in a process called the 'Rankine Cycle', to generate electricity. The working principle is depicted in **Figure 8**.[29]

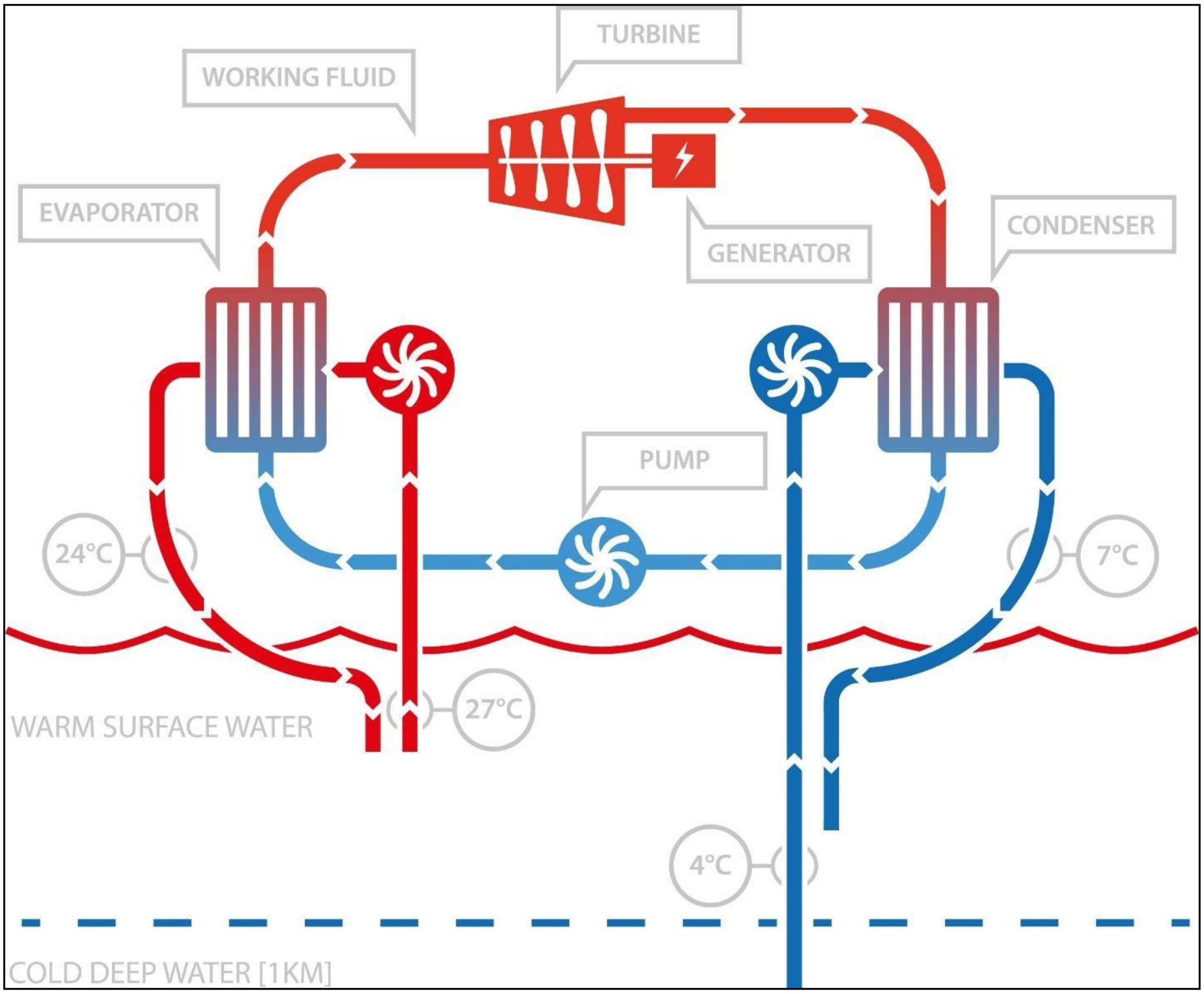

Figure 8: Working Principle of a Closed-cycle OTEC System
Source: Delft Technical University

The cycle may either be 'open' or 'closed'. In the former, the working fluid is warm surface water itself, while in the latter fluids with low boiling-points, such as ammonia, for instance, are used. The process requires a temperature difference of at least 20° C if is to operate with any degree of efficency. The working fluid is used to drive turbines to produce electricity. Tropical areas are ideal for locating OTEC plants, because in such areas, the temperature difference can be as great as 40°
C. Even so, in order to produce power within such a low temperature-range, the working fluids

[29] Technical University of Delft, "Thermal Gradient (OTEC)", https://www.tudelft.nl/ocean-energy/research/thermal-gradient-otec/

used to drive the turbines must have very low boiling-points. Ammonia and R-134a have been found to be suitable for this purpose.[30] OTEC plants are operational in Japan, the USA, South Korea, France, etc.[31] Insofar as India is concerned, the theorotical estimate of the potential of OTEC is 180 GW, according to a study jointly carried out by the National Institute of Ocean Technology (NIOT) and IIT Madras.[32] A prototype OTEC plant, called *Sagar Shakti*, with a power generation capacity of One MW, was tested in Inda as long ago as the year 2002. However, it was dogged by poor engineering and has since been decommissioned.[33]

This premature abandonment of the Indian endeavour nowithstanding, a very important spinoff from OTEC plants is the productoin of fresh water, through an associated technology known as 'Low Temperature Thermal Desalination' (LTTD).[34] LTTD plants have a staggering potential to alleviate water-stress in volcanic islands that are surrounded by deep water on at least the windward side. A little-known, but hugely celebratory fact is that India has pioneered and matured its ability to manufacture and install LTTD-generated fresh water plants. On the 26th of December, 2018, Dr Harsh Vardhan, Minister, Ministry of Science and Technology and Earth Sciences, formally informed the Indian Parliament three LTTD plants, each with a capacity to generate 100,000 litres of drinking water per day, were functional in the Lakshadweep islands of Minicoy, Agatti, Lakshadweep and Kavaratti, and, that six additional plants had been approved to be installed on the islands of Amini, Androth, Chetlat, Kadamat, Kalpeni and Kiltan, within the Lakshadweep chain.[35] One such plant, installed on the island of Agatti, is depicted in **Figure 9**.[36]

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30 M.A. Atmanand, "Ocean Technology Capacity Building in India." *J Geol Soc India* 94, 447–452 (2019). https://doi.org/10.1007/s12594-019-1340-4

31 IRENA, "Ocean Thermal Energy Conversion Technology Brief, Ocean Energy Technology Brief 1, 2014", https://www.irena.org/documentdownloads/publications/ocean_thermal_energy_v4_web.pdf (accessed June 2014)

32 M. Ravindran, "The Indian 1 MW Floating OTEC Plant An Overview", DOSSIER OCÉAN ET ÉNERGIE - ÉNERGIE THERMIQUE DES MERS Sommaire IOA News Letters, http://www.clubdesargonautes.org/otec/vol/vol11-2-1.htm#:~:text=INTRODUCTION,the%20OTEC%20potential%20is%20concerned.&text=Apart%20from%20this%2C%20attractive%20OTEC,gross%20power%20for%20parasitic%20losses.

33 Vijay Sakhuja & Kapil Narula. *Perspectives on the Blue Economy*. New Delhi: Vij Books India Pvt Ltd, 2017

34 M.A. Atmanand, "NIOT's Progressive Trends in Thermal Desalination." *J Geol Soc India 95*, 5–8 (2020). https://doi.org/10.1007/s12594-020-1380-9

35 Government of India, Lok Sabha Unstarred Question No 2313, answered by the Hon'ble Minister, Ministry of Earth Sciences, 26 December 2018, https://moes.gov.in/writereaddata/files/LS_US_26122018_2313_ust.pdf

36 National Institute of Ocean Technology (NIOT), Chennai, (Ministry of Earth Sciences, Government of India), "Technical Report on Design and Execution of Desalination Plants in Minicoy and Agatti, UT Lakshadweep", https://www.niot.res.in/img/Island_Desalination_Technical_Report.pdf

Fig 9: LTTD Plant at Agatti Is., Lakshadweep
Source: NIOT

As such, India is extremely well-positioned to use LTTD as an invaluable tool of foreign-policy, by assisting volcanic island-States such as the Maldives and the Seychelles to generate very-nearly 'free' fresh water to alleviate their water-stress. That this possibility has not yet received attention — let alone policy-incentives — from India's Ministry of External Affairs, is astonishing, to say the least. In December of 2014, responding with its usual alacrity to an urgent request from the Government, the Indian Navy despatched two of its warships of, INS *Sukanya* and INS *Deepak*, to rush to the aid of Male, the beleagured capital of the Maldives, which was facing a crippling water-crisis after its main water treatment plant was badly damaged in a fire. The two Indian Naval warships, ably assisted by an aircraft of the Indian Ar Force, transported some 2,000 tonnes of fresh water to Male, once again demostrating a very tangible manifestation India's avowed ability to be a net provider of security in the region. The Indian reaction was praiseworthy, as was the instantaneous response from the Navy and the Air Force. Yet, how much better — and how much more in keeping with India's effort to provide requisite leadership-by-example in the regional transition from a 'Brown' economy to a 'Blue' one — would it have been, had this emergency humanitarian-aid been vigorously followed-through with an offer to install an LTTD plant in Male? It would certainly have cut the ground from under the Chinese feet that were, at that point in time, stomping all over the Maldives much to Indian discomfiture, after President Xi Jin Ping's September-visit to the Madives! Five-and-a-half years down the line, there is still little clarity that the mandarins of South Block or Jawaharlal Nehru Bhawan have fully grapsed the enormous potential that India has in this regard.

The next segment of this series will address Offshore Wind as the penultimate option within the ORER 'basket' before turning to the final and recommended solution — the adoption of hydrogen-fuel, which itself is capable of being drawn from the oceans — to bridge the gap between India's wholly justified ambition vis-à-vis renewable energy and the realisation of that ambition.

To be continued in Part 4…

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About the Authors

* *Dr Sameer Guduru, PhD, is an Associate Fellow at the National Maritime Foundation. His research focusses upon technical issues relevant to India's maritime domain. Parts 1 and 2 of this ongoing advocacy of his were published on the NMF Website on 12 May 2020 and 31 May, respectively. Part 1 is available to readers, at* https://maritimeindia.org/adoption-by-india-of-hydrogen-an-ocean-renewable-energy-approach-part-1/. *Part 2 may be read at* https://maritimeindia.org/hydrogen-fuel-adoption-an-ocean-renewable-energy-approach/.
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