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HYDROGEN FUEL ADOPTION: AN OCEAN RENEWABLE ENERGY APPROACH

PART 4: HYDROGEN-FUEL FROM 'ORER' — A HYBRID SOLUTION FOR MARITIME ACTIVITY

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This is the fourth and penultimate tranche of the NMF's ongoing effort to provide Indian policy-makers with a compelling set of arguments to not only support ocean renewable energy resources (ORER) as an economically viable and ecologically sustainable option to supplement solar and onshore wind energy, but to specifically adopt hydrogen-fuel derived from the oceans as India's option-of-choice.

Part 1 of this advocacy[1] 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.

Part 2[2] thereafter set the stage for the recommended thrust towards harnessing ORER in general. It dwelt upon the principal form of secondary energy, namely, electricity and sought to demonstrate that current projections by the government were excessively optimistic. Consequently, 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. It emphasised the need for cobalt to support India's ongoing drive to switch to Electrically-driven Vehicles (EVs) and highlighted this new but critical driver of India's geoeconomics, and hence, the country's geopolitics.

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[1] Sameer Guduru, "Adoption by India of Hydrogen: An Ocean Renewable Energy Approach Part 1", 12 May 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" 31 May, 2020, https://maritimeindia.org/hydrogen-fuel-adoption-an-ocean-renewable-energy-approach/

Part 3[3] drew attention to the very substantial potential offered to India by ORER for the addition of requisite capacity in terms of green-energy installations and provided substantive baseline information on the various forms of ORER.

This penultimate segment focuses upon the benefits of utilising ORER techniques such as ocean thermal energy conversion (OTEC) and ocean wave energy conversion (OWEC) to generate hydrogen, and, demonstrates that, far from being a mere theoretical speculation, it is a rapidly maturing option for the maritime sector.

The last (fifth) and final part of this pentad will contextualise the option of hydrogen-fuel, derived from ORER, to India.

Hydrogen Fuel: A Clean Energy Source for the Future

Energy-related CO_2 emissions account for two-thirds of global greenhouse gas emissions and an energy transition is needed now to break the link between economic growth and increased CO_2 emissions. Climate change is the fundamental driver for hydrogen in the energy transition in order to achieve a scenario of containing the average global temperature rise to below 2 degrees Celsius (°C) and requires CO_2 emissions to decline by 25 per cent by 2030 — from 2010 levels — on the way to achieve net zero-emissions by around 2070, according to the Intergovernmental Panel on Climate Change (IPCC) Report of 2018.[4] To stay below 1.5 °C of warming, the net anthropogenic CO_2 emissions should decline by around 45 per cent by 2030, from 2010 levels to achieve net zero by 2050. However, in contrast, it has been observed that over the last few years, emissions have only risen according to a report released in 2018 by the United Nations Environment Programme (UNEP).[5]

The G 20 Karuizawa Innovation Action Plan on Energy Transitions and Global Environment for Sustainable Growth of June 2019 calls upon the International Renewable Energy Agency (IRENA) to identify pathways to a hydrogen-enabled clean energy future.[6] Hydrogen and related synthetic organic fuels offer new prospects for a clean-energy future characterised by decarbonization and carbon neutrality. Even though hydrogen comprises only a small fraction of Earth's atmosphere, it is abundantly available from other sources including fossil fuels and water (after electrolysis). It has the potential of revolutionising long-haul transport, as also industries such as chemicals, iron and

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[3] Sameer Guduru, VAdm Pradeep Chauhan, "Hydrogen-Fuel Adoption: An Ocean Renewable Energy Approach Part 3: Ocean Renewable Energy As A Viable Alternative", 09 July 2020, https://maritimeindia.org/hydrogen-fuel-adoption-an-ocean-renewable-energy-approach-part-3-ocean-renewable-energy-as-a-viable-alternative/

[4] Intergovernmental Panel on Climate Change (IPCC), "Summary for policymakers of IPCC special report on global warming of 1.5^0 Celsius approved by government", https://www.ipcc.ch/2018/10/08/summary-for-policymakers-of-ipcc-special-report-on-global-warming-of-1-5c-approved-by-governments/

[5] United Nations Environment Programme (UNEP). "Emissions Gap Report 2018", https://www.unenvironment.org/resources/emissions-gap-report-2018

[6] G20, "G20 Karuizawa Innovation Action Plan on Energy Transitions and Global Environment for Sustainable Growth", 2019, https://www.mofa.go.jp/policy/economy/g20_summit/osaka19/pdf/documents/en/annex_16.pdf

steel, and, can play a major role in reducing emissions, thereby improving air-quality and enhancing energy-security in a paradigm of an ever-increasing demand for clean energy.[7]

According to a September 2019 joint report prepared by the 2nd Hydrogen Energy Ministerial Meeting and IRENA, renewable green production of hydrogen could be among the cheapest options even as of today.[8] The adoption of hydrogen fuel has several inherent advantages not the least of which is its higher energy output per kilogram of fuel burnt. **Figure 1** compares the calorific value of hydrogen with other 'rival' fuels.

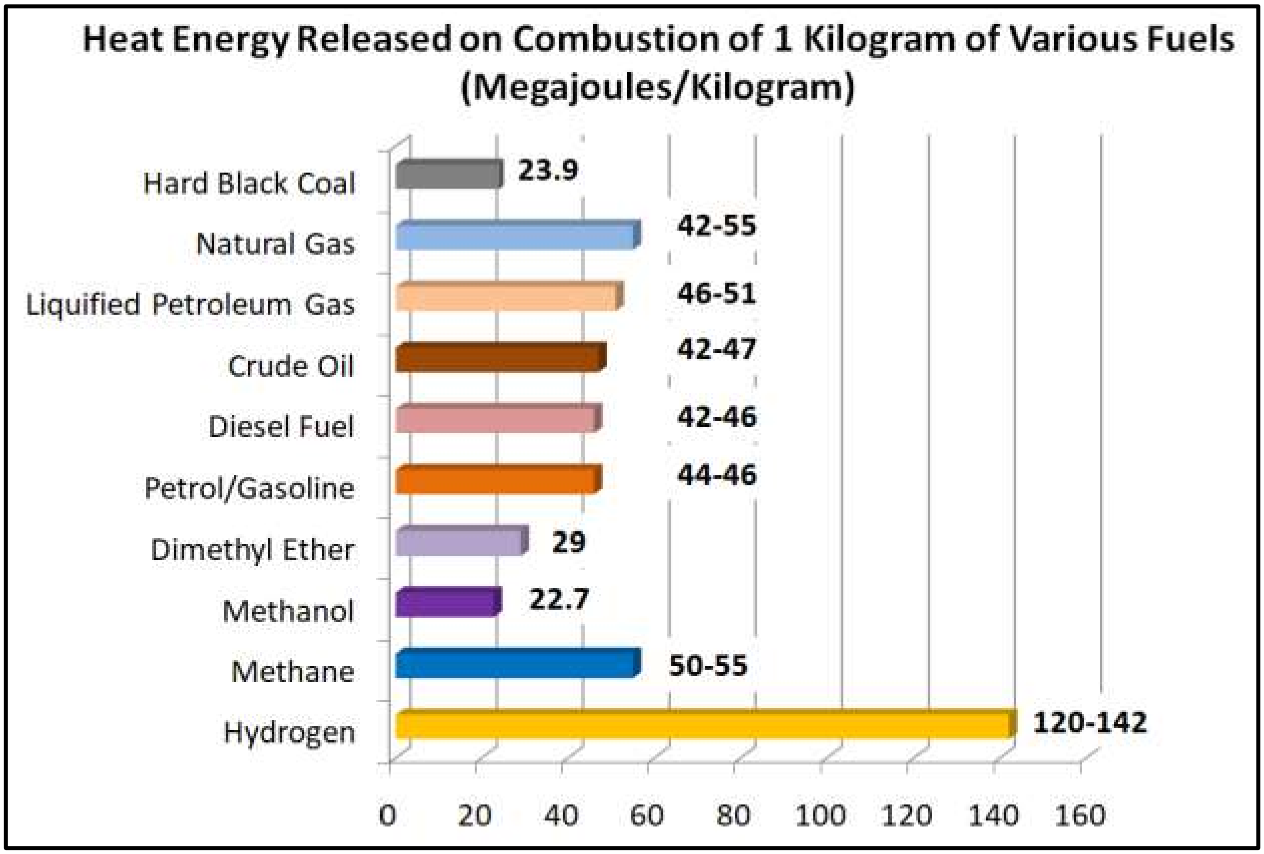

Fig 1: Comparative Heat-energy produced by burning 1 kilogram of various fuels
Source: Created by Dr Sameer Guduru with data from the World Nuclear Association, https://www.world-nuclear.org/information-library/facts-and-figures/heat-values-of-various-fuels.aspx

Added to this advantage of hydrogen are a much greater ease of storage, portability, the elimination of grid-connectivity and related ancillaries, the obviation of bulky batteries, a green-energy output with water as the by-product of combustion, and, a high prospect of achieving net carbon-neutrality. More than 90 per cent of hydrogen produced is from fossil fuels by stripping them of carbon via

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[7] Patrick Molloy, "Hydrogen Fuel Cells Can Decarbonize Heavy Transport", https://energypost.eu/hydrogen-fuel-cell-trucks-can-decarbonise-heavy-transport/

[8] International Renewable Energy Agency (IRENA), *"Hydrogen a Renewable Energy Perspective"*, IRENA Report, 2019, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Hydrogen_2019.pdf

processes like steam reforming, methane oxidation and coal gasification.[9] As such, these processes of producing hydrogen themselves contribute to the net carbon footprint. Hence, a method of producing hydrogen from renewables is the need of the hour. With the cost per unit of energy from renewables such as solar and wind already competing with those of fossil fuels, the former can be exploited for producing hydrogen in a cleaner and carbon free manner via electrolysis.

Figure 2 depicts major factors that affect the final price of hydrogen. It indicates that the most

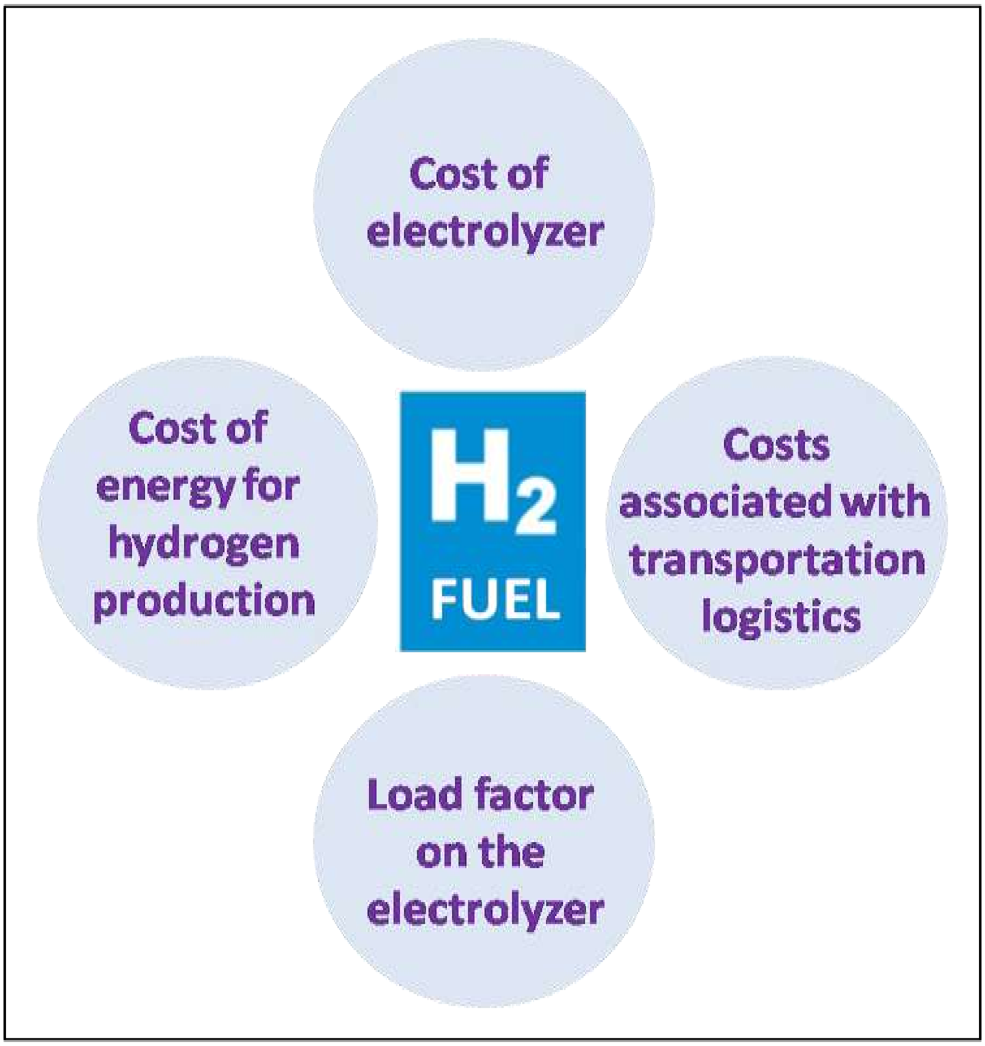

Fig 2: Determinants of the Final Price of Hydrogen
Source: Created by Dr Sameer Guduru, with data drawn from International Renewable Energy Agency (IRENA): *"Hydrogen a Renewable Energy Perspective,"* 2019, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Hydrogen_2019.pdf

important variable for hydrogen production today is that of the cost of electrolyser that forms the heart of the electrolysis process used to break molecules of water down to their constituent elements, i.e., hydrogen and oxygen. Two other variables of importance are: the load-factor of the electrolyser, which ideally should be more than 50 per cent so as to achieve the lowest cost of production per kilogram of hydrogen, and, the cost of the logistics.

[9] Planete-Energies, "Hydrogen Production." https://www.planete-energies.com/en/medias/close/hydrogen-production

Hydrogen is typically transported in one of three ways: (a) in its gaseous form, (b) by liquefying it, (c) by storing it in the form of either toluene (commonly encountered as a solvent that is used in making paints, paint thinners, fingernail polish, lacquers, adhesives, and rubber) or ammonia. Each of these processes, such as the liquefaction of hydrogen (which occurs at very low temperatures of the order of Minus 250° C) or the reconversion of toluene and/or ammonia into hydrogen, expend energy, of the order of 45 per cent, 30 per cent and 13 per cent respectively. Obviously, this influences the end-price of hydrogen and need to be factored when making a comparison with other renewable sources of energy. This comparison is done through the concept of 'Levelized Cost of Energy' (LCOE). *LCOE measures lifetime-costs divided by energy-production. It calculates the present value of the total cost of building and operating a power plant over an assumed lifetime. It thus allows the comparison of different technologies (e.g., wind, solar, natural gas) of unequal life spans, project size, different capital cost, risk, return, and capacities. As such, it is critical to making an informed decision to proceed with development of a facility, community or commercial-scale project.*[10] According to IRENA[11], in order to compete with other energy sources such as fossil fuels, the levelized cost of hydrogen production from renewables should be under US$ 2.5 per kilogram. The IRENA report of 2019 analysed two different scenarios of power tariffs relevant to wind-energy. The first was a *"relatively low cost"* scenario, with the power-tariff being US$ 40/MWh, and the second, a *"very low cost"* scenario at US$ 20/MWh. The study also factored the current and the projected future-price of electrolysers at US$ 840/kW and US$ 200/kW, respectively. It concluded that the production of hydrogen from renewables in these scenarios could not compete with traditional methods of production of hydrogen from natural gas (US$ 5 per gigajoule, i.e., 1.8 US cents/kW[12]). But, renewable production of hydrogen can compete with natural-gas prices for non-household large-scale application, where the costs are in the range of (USD 10/16 per gigajoule). IRENA also predicts that between 2020 and 2050, with the expected improvements in electrolyser efficiency and their consequent price-reduction, the cost of producing hydrogen will be will be brought down further. Further, taxation on carbon and the application of carbon credits will compel a faster transition towards hydrogen. The report concludes that the price of green renewable hydrogen will start competing with other fossil fuel-based production of hydrogen by the year 2035 and, in the most idealistic scenario in some parts of the world, this might even happen within the next five to six years.

Hydrogen-generation from ORER: A 'Hybrid' Approach

In India, as had been emphasised in Part 3 of this series, the potential of electricity-generation from ORER remains largely untapped despite the fact that ORER is an abundant and constant source of energy. Hence, integrating hydrogen-production using ORER, could well provide economically viable alternative solutions for India in terms of both, mitigating the impacts of climate change as

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[10] US Department of Energy, Office of Indian Energy, Slide-presentation, August 2015, https://www.energy.gov/sites/prod/files/2015/08/f25/LCOE.pdf

[11] IRENA Report, 2019, *Supra* 8

[12] One Gigajoule of energy = 1 GJ = 277.77 kWh

well as transitioning to clean energy for the transport sector. Given the impressive length of India's coastline (7,516 kilometres), there is an enormous potential for installing ocean-energy power-plants combined with electrolysis for hydrogen-production. However, ocean renewable energy resources have not yet attained maturity, and therefore, capacity augmentation and grid integration are not straightforward. Transporting power from an offshore location to the land requires the use of submarine cables, a solution that is likely to be expensive, thereby contributing to the LCOE.[13] In addition, the fluctuation in output, and, ancillary issues such as energy storage in batteries, compound the problem further.[14] These challenges notwithstanding, 'combined' approaches, which seek to produce hydrogen from ocean renewables sources of energy, are already being explored in Germany, Japan, Italy, Iran, etc.[15]

Figure 3 schematically depicts the utilisation of the electricity generated by various forms of ORER to power seawater-electrolysis, which, in turn, produces hydrogen.

Producing hydrogen via the process of electrolysis is a 'clean' process in that, unlike traditional methods that employ fossil fuels, it does not contribute to carbon emissions. For example, it would be recalled from Part 3 of this series that one of the forms of ORER is Ocean Thermal-Energy Conversion (OTEC) and that an associated technology of OTEC is 'Low Temperature Thermal Desalination' (LTTD), which produces pure drinking water using the principle of distillation. Interestingly, India's 'National Institute of Ocean Technology' (NIOT), an organisation affiliated to the Ministry of Earth Sciences (MoES), is credited with being the global pioneer of LTTD technology. The water generated from LTTD, and the power from OTEC — and other forms of ORER — can be synergised to produce clean hydrogen-fuel, which can then be used to power various sectors of the economy.[16] However, this is not the only option available. Indeed, several interesting approaches of harnessing ORER for the production of 'green' hydrogen have been proposed and a few of them have even been demonstrated.

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[13] Eva Segura et al. "Cost Assessment Methodology and Economic Viability of Tidal Energy Projects" *Energies* 10 (2017): 1806; doi:10.3390/en10111806

[14] 2nd Hydrogen Energy Ministerial Meeting, "Hydrogen: A Renewable Energy Perspective", 2019, https://www.irena.org/-/media/Files/IRENA/Agency/Publication/2019/Sep/IRENA_Hydrogen_2019.pdf

[15] "Renewable Hydrogen Production in Hamburg", YouTube Video, 5:18, posted by Toyota Motor Corporation, 16 November 2015, https://www.youtube.com/watch?v=xOMBJ2H7bSA

See Also:

(a) United Nations Climate Change Conference 24 (COP 24). "Floating offshore wind turbines and hydrogen system open-up the new era of the decarbonization." http://copjapan.env.go.jp/cop/cop24/en/pavilion/02/

(b) Vincenzo Franzitta, et al, "Hydrogen Production from Sea Wave for Alternative Energy Vehicles for Public Transport in Trapani (Italy)" *Energies* 9 (2016): 850; https://doi.org/10.3390/en9100850

(c) A Khosravi et al, "Thermodynamic and Economic Analysis of a Hybrid Ocean Thermal Energy Conversion/Photovoltaic System with Hydrogen-based Energy Storage System" *Energy* 172 (2019): 304-319; https://doi.org/10.1016/j.energy.2019.01.100

[16] Marine Energy, "New Opportunities for OTEC in India", Offshore-energy.biz., https://www.offshore-energy.biz/new-opportunities-for-otec-in-india/

See also: National Institute of Ocean Technology (NIOT). "Energy and Fresh Water — OTEC", https://www.niot.res.in/niot1/efw_intro.php

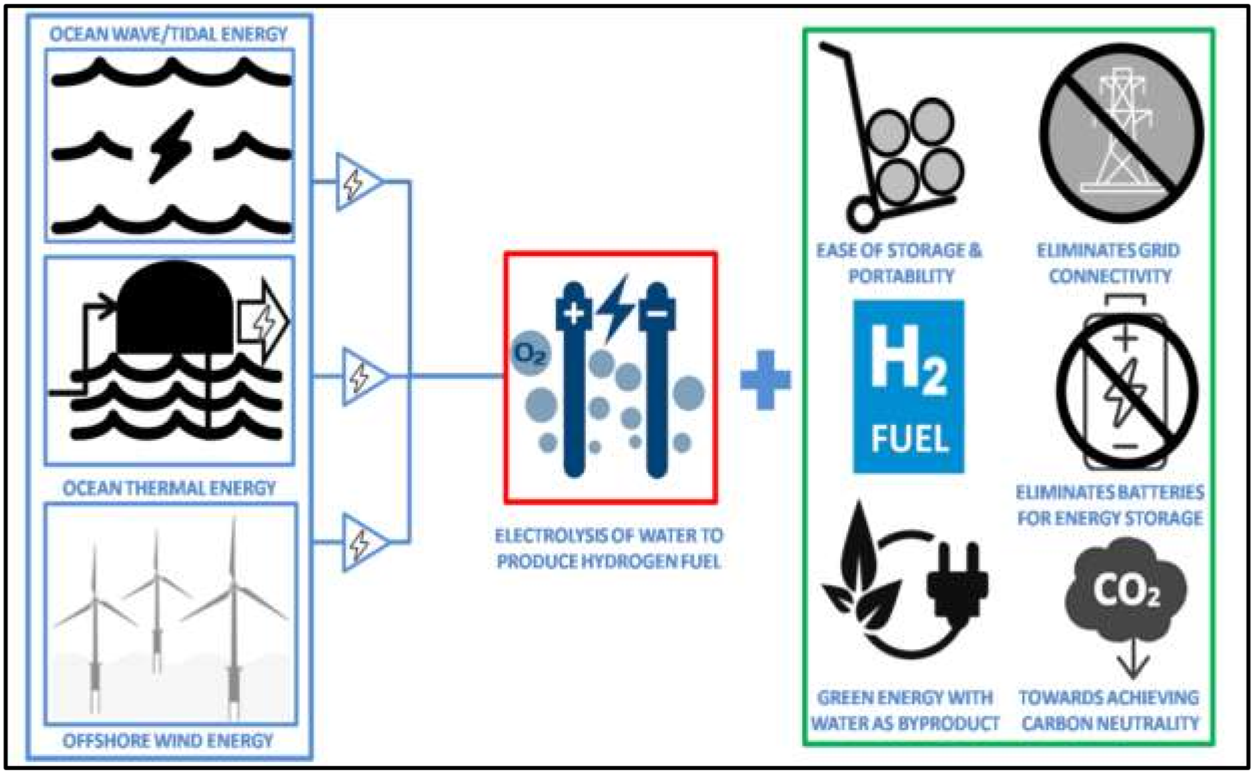

Fig 3: Utilisation of Power from ORER for Hydrogen-production by Electrolysis of Water.
Source: Created by Dr Sameer Guduru

An increasing volume of serious literature indicates that the widely held contemporary belief that transport sector will have to be driven by fossil fuels may well need to be abandoned as an urban myth. For a country like India, this is a truly momentous opportunity and one that needs some significant advocacy amongst both, government bureaucracies and the lay public.

For instance, Khosravi *et al*, have discussed a hybrid approach of utilising solar photovoltaic cells to power the pumping processes associated with an OTEC system and the electrolyser for hydrogen-production.[17] This particular study was conducted in the remote Iranian island of Lavan in the Persian Gulf and sought to evaluate the setting-up of such a hybrid power-system with hydrogen-storage capability. The study concluded that for such a system, the final cost of the power produced was US$ 0.1688 and the payback time was eight years.

In more practical terms, the city of Hamburg, Germany, has already demonstrated the use of offshore-wind energy to produce hydrogen, and to thus power intra-city public transport, as also private cars running on hydrogen fuel-cell technologies.[18] As a part of its 'green energy' initiative,

[17] Khosravi, "Thermodynamic and Economic Analysis," 304-319, *Supra* 15(c)
[18] "Renewable Hydrogen Production in Hamburg," YouTube Video, https://www.youtube.com/watch?v=xOMBJ2H7bSA

and, with concerted efforts involving local government agencies and industry, the city has set itself the ambitious target of installing a 700 MW offshore-wind plant exclusively for the production of hydrogen to power the public transport entirely, as well as play a role in the aviation sector.[19]

Going a step further, Oldenbroek *et al* propose a novel model for a 100 per cent clean-energy-based 'smart city' by integrating vehicular fuel cells to the city's grid system for energy purposes. The authors discuss a scenario of using hydrogen to power the cities of Hamburg in Germany and Murcia in Spain, in their entirety. The study concludes that by the middle of the current century, the adoption of hydrogen would bring down the costs of household energy consumption by 65 per cent, when compared to the existing cost of energy produced through the use of fossil fuels. They forecast an expenditure of US$ 577-854 per annum on energy using green hydrogen. The study also concludes that the LCOE by mid-century will be between US$ 79 and US$ 115, per MWh of electricity, with the cost of hydrogen being US$ 2.8-3.3 per kilogram.[20]

Likewise, Franzitta *et al* discuss the utilisation of both Ocean Wave-Energy Conversion (OWEC) and offshore-wind energy-systems for hydrogen-production in a combined manner in the Italian islands of Sicily and Pantelleria, and conclude that this approach can significantly reduce carbon emissions.[21] Similar studies on the potential of applying OWEC are currently being carried out in North Carolina, USA.[22] However, since such approaches of using OWEC for hydrogen production are still in their nascent stages, no significant economic analysis is currently available.

Hydrogen-Fuel Applications in the Maritime Domain

The maritime-transportation sector (shipping) has, thus far, been stubbornly resistant to efforts to ensure a financially profitable transformation from fossil-fuel derivatives for propulsive power to one or another form of clean renewable energy. Yet, here, too, hybrid ORER-hydrogen-fuel offers extremely promising prospects for India. As things presently stand, mercantile shipping is a major contributor to carbon-based pollution. This is not to demean, in any way, the entirely laudable mitigation-efforts of the IMO-approved Energy Efficiency Design Index (EEDI), which is the first globally-binding climate-change standard and entered into force on 1 January 2013. The EEDI requires new ships to become more energy efficient, by adhering to standards that will be made increasingly more stringent over time. A target of a 10% improvement overall in terms of energy

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[19] Alicia Moore, "700-megawatt Green Hydrogen Plant to Provide Carbon Neutral Aviation Fuel", http://www.hydrogenfuelnews.com/700-megawatt-green-hydrogen-plant-to-provide-carbon-neutral-aviation-fuel/8538866/

[20] Vincent Oldenbroek et al, "Fuel Cell Electric Vehicle as a Power Plant: Techno-Economic Scenario Analysis of a Renewable Integrated Transportation and Energy System for Smart Cities in Two Climates", *Applied Sciences* 10 (2020): 143; doi:10.3390/app10010143

[21] Franzitta et al, "Hydrogen Production from Sea Wave," 850; *Supra* 15(b)

[22] Gagee Raut, "Technical Analysis of Hydrogen Production from Wave Energy: A Case Study for North Carolina", Master's Dissertation, The University of North Carolina, 2018, https://repository.uncc.edu/islandora/object/etd%3A257/datastream/PDF/download/citation.pdf

efficiency is already applicable to ships built between 2015 and 2019. Ships built between 2020 and 2024 will have to improve their energy-efficiency by 15 to 20%, depending on the ship type; and ships delivered after 2024 will have to be 30% more efficient.[23] These efforts notwithstanding, the carbon footprint of global shipping is high. In fact, a telling comment is that "If shipping was a country, it would be the sixth-largest polluter in the world".[24] The International Maritime Organization (IMO), which is the principal United Nations regulatory agency for global shipping, has, set a goal of reducing emissions by 50 per cent (from 2008 levels) by 2050.[25] The 2019 edition of the annual "Review of Maritime Transport" by the United Nations Conference on Trade and Development (UNCTAD), published in January 2020, goes a step further and tabulates efficiency-improvement measures to achieve zero-emission shipping by 2050.[26] Hydrogen fuel-cells, and, the adoption of hydrogen as a fuel for internal combustion engines, both figure prominently as options-of-choice.

In addition, ports enabled with clean hydrogen fuel technologies can reduce carbon emissions of berthed vessels by providing them auxiliary power. This is called 'cold ironing' and is being adopted globally to reduce emissions of vessels berthed at ports.[27] At present, berthed ships are forced to expend fuel to keep their engines running in order to facilitate energy-intensive activities such as cargo-operations, safety-lighting, powering routine activities on board, and so forth. It is estimated that the aggregate of carbon emissions from berthed ships is greater than that from the port's own activities.[28] Hence, cold ironing is one way forward. It will also contribute to reducing the level of Sulphur Oxide (SOx) emissions, in accordance with the MARPOL Annex VI of the International Convention for the Prevention of Pollution from Ships, 1973, which requires ships to use less than 0.5 per cent of sulphur-fuel, with effect from 01 January 2020.[29]

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[23] International Maritime Organization (IMO), "Energy Efficiency Measures", http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/Technical-and-Operational-Measures.aspx

[24] Rebecca Hersher, "The Dawn of Low Carbon Shipping", *quoting Nerijus Poskus of the shipping-technology company, Flexport*, https://www.npr.org/2019/07/16/716693006/the-dawn-of-low-carbon-shipping

See Also:

Zoe Schlanger, "If Shipping were a Country, it would be the World's Sixth Biggest Greenhouse Gas Emitter." Weforum.org, https://www.weforum.org/agenda/2018/04/if-shipping-were-a-country-it-would-be-the-world-s-sixth-biggest-greenhouse-gas-emitter

[25] International Maritime Organization (IMO). "Greenhouse Gas Emissions", http://www.imo.org/en/OurWork/Environment/PollutionPrevention/AirPollution/Pages/GHG-Emissions.aspx (accessed 2018)

[26] United Nations Conference on Trade and Development (UNCTAD) "Review of Maritime Transport 2019", 34 (Table 2.4), 31 January, 2020, https://unctad.org/en/PublicationsLibrary/rmt2019_en.pdf

[27] European Union Parliamentary Questions, "Sustainable Maritime Transport: Introduction of Cold Ironing", https://www.europarl.europa.eu/doceo/document/E-9-2019-002668_EN.html

[28] International Maritime Organization (IMO), "UN Body Adopts Climate Change Strategy for Shipping", http://www.imo.org/en/MediaCentre/PressBriefings/Pages/06GHGinitialstrat egy.aspx

[29] International Maritime Organization (IMO). "Sulphur 2020 – Cutting Sulphur Oxide Emissions", http://www.imo.org/en/MediaCentre/HotTopics/Pages/Sulphur-2020.aspx

Efforts towards using clean energy resources for shipping, through the adoption of hydrogen-fuel, have fructified in Norway, United States, Switzerland and France. Most notably, NORLED, a Norwegian transportation company, is currently collaborating with vessel-manufacturer WESTCON in realising the world's first hydrogen-fuelled car-ferry, which is due for delivery later this year. Similar efforts in ferrying commuters, using ferries propelled by hydrogen-fuel for the first time ever, are currently underway in the San Francisco Bay Area of the United States, by a New York based investment firm named SW/TCH (pronounced Switch). To this extent, the Swiss firm, ABB, and the French authority *Hydrogène de France*, have recently established a Memorandum of Understanding (MoU) for manufacturing megawatt-scale hydrogen fuel-cell systems that are capable of powering ocean-going vessels.[30]

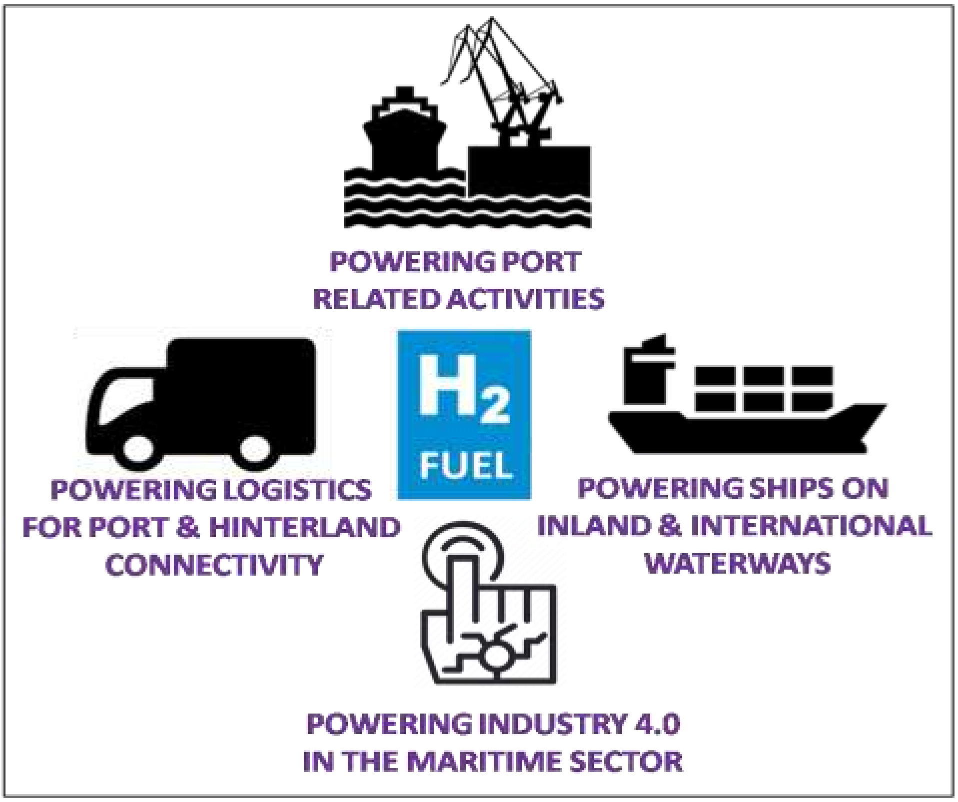

Fig 4: Utilisation of Hydrogen in Fuel-Cells and Port related Activities within Industry 4.0 in the Shipping Sector
Source: Created by Dr Sameer Guduru

[30] Rebecca Moore, "Norway's first Hydrogen-powered Car Ferries Take Shape", https://www.rivieramm.com/news-content-hub/news-content-hub/norwayrsquos-first-hydrogen-powered-car-ferries-take-shape-55559
See also:
(a) Erin Baldassari, "Nations First Hydrogen Fuel Cell Ferry to Transport Commuters Across San Francisco Bay Area", https://phys.org/news/2019-06-nation-hydrogen-fuel-cell-ferry.html
(b) ABB Group Release, "ABB bring Fuel Cell Technology a Step Closer to Powering Large Ships", https://new.abb.com/news/detail/60096/abb-brings-fuel-cell-technology-a-step-closer-to-powering-large-ships
(c) John Snyder, "Hydrogen Fuel Cells Gain Momentum in Maritime Sector", https://www.rivieramm.com/news-content-hub/news-content-hub/hydrogen-fuel-cells-gain-momentum-in-maritime-sector-56087#:~:text=Within%20five%20years%2C%20vessels%20using,Hyon%20managing%20director%20Tomas%20Tronstad

Figure 4 offers a generic depiction of the various applications of hydrogen fuel in the maritime doman.

With hydrogen-fuel finding increasing favour as the option of choice for mercantile shipping and port-activities, and, with the hydrogen itself being capable of being sourced from ocean renewable energy-resources such as OTEC and OWEC, two questions that now arise are: (a) What is the 'state of the art' where it comes to hydrogen-fuel being used to power ***warships***, i.e., both, surface combatants and subsurface ones? (b) How might this hybrid-option (of producing hydrogen from ORER and then using it to power the transport sector, thereby removing or reducing the sector's current reliance upon fossil-fuels), be adopted by India? These twin questions will be addressed in the concluding segment of this pentad

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