OCEAN THERMAL ENERGY CONVERSION

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Abstract - *The demand for renewable energy has increased over the past few years to meet our energy needs, but our existing sources are polluting and depleting our environment. There are different renewable energy sources that can be used to overcome these problems, with ocean thermal energy considered to be very efficient. In this system, the temperature differences between ocean surface waters and deep ocean waters are harnessed to provide us with energy. Despite this, it is not commonly used because it is still relatively new. Nonetheless, with some research and development, it can be used, as a viable alternative to meet our energy needs. This review paper discusses the different methods and devices used across the world to extract ocean thermal energy along with their advantages and disadvantages.*

Key Words: Renewable energy, Ocean Thermal Energy, Temperature difference, surface waters, deep ocean waters.

1.INTRODUCTION

Ocean thermal energy conversion (OTEC) harnesses the difference in temperature between ocean surface waters and deep ocean waters to generate energy. Energy from the sun heats the surface of the ocean. Surface water in tropical regions can have a higher temperature than deep water. This temperature difference can be used to produce electricity and to desalinate ocean water. Ocean Thermal Energy Conversion (OTEC) systems use a temperature difference to drive a turbine. An evaporator containing a working fluid pumps warm surface water through a turbine. The vaporized fluid drives a turbine/generator. The vaporized fluid is turned back to a liquid in a condenser cooled by cold ocean water pumped from deep into the ocean.

OTEC is one of the continuously available renewable energy resources that can contribute to base-load power supply among ocean power sources. It is considered that OTEC has a large resource potential compared with other ocean energy forms. It is possible to generate 88,000 TWh of electricity per year without harming the ocean's thermal structure through OTEC. It is possible to have closed-cycle systems or open-cycle systems. Typical closed-cycle OTECs use working fluids like ammonia or R134a as refrigerants. They have low boiling points, making them ideal for powering the generator of the system. Rankine cycles, using a low-pressure turbine, have been a common heat cycle used for OTEC. In open-cycle engines, seawater vapor acts as the working fluid. As a by-product of its operations,

OTEC can also provide cold water in large quantities. This can be used for air conditioning and refrigeration, and deep ocean water that is nutrient-rich can supplement a variety of biological technologies. Distilled seawater is another byproduct.
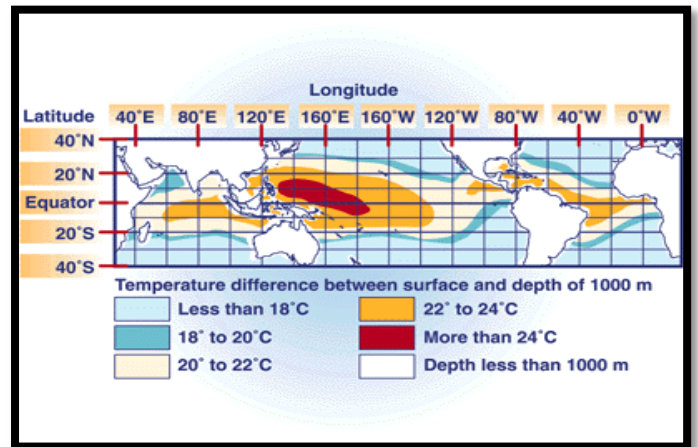

Fig. 1: World map highlighting oceanic regions with high temperature gradients (between surface and 1000m depth)
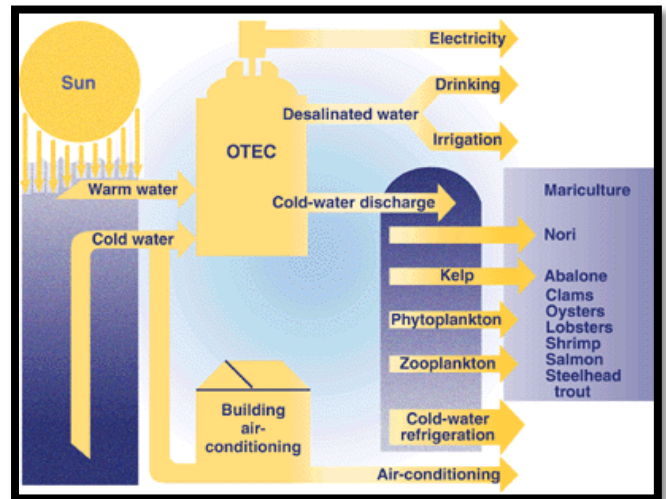

Fig. 2: OTEC diagram and its applications

2.Types of Ocean Thermal Energy Conversion Systems

2.1 Closed Cycle

The closed cycle Ocean Thermal Energy Conversion system uses a fluid with a low boiling point, such as Ammonia, as the working fluid and powers a turbine to produce electricity. Warm seawater from the surface of the oceans and cold water from deep below the surface are used. In the heat exchanger, warm seawater vaporizes the fluid, causing the turbines to turn. The vaporized fluid is then exposed to cold water to turn it back into a liquid. A closed system recycles the fluid within itself, which is why it is called such.
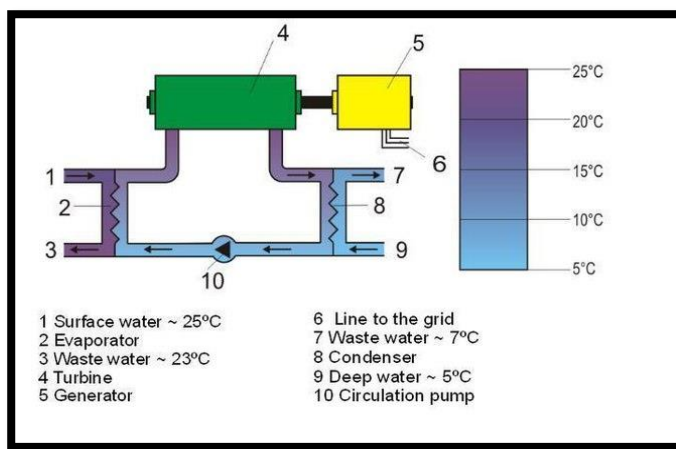
Fig 3: Diagram of a closed cycle OTEC plant

2.2 Open Cycle

The open cycle OTEC produces electricity from warm seawater directly. The warm seawater is pumped into a low-pressure chamber where the pressure drops, resulting in a drop in boiling point. This results in the water boiling. Steam is used to drive the low-pressure turbine, which powers the electrical generator. The advantage of this system over a closed one is that desalinated water is obtained as steam, which is devoid of all impurities. In addition to domestic and industrial uses, this water can also be used for agricultural purposes.
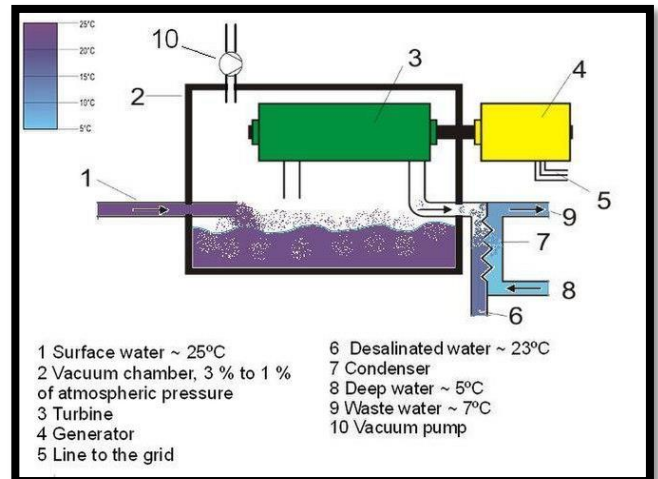
Fig 4: Diagram of an open cycle OTEC plant

2.3 Hybrid System

A hybrid system combines the benefits of open-cycle and closed-cycle systems. Warm seawater is flash-evaporated into steam in a vacuum chamber, similar to the open-cycle evaporation process. The steam vaporizes a low-boiling point fluid (in a closed cycle loop), which drives a turbine to generate electricity.

3. Advantages of OTEC System

- OTEC's power is continuous, renewable, and pollution-free.
- In contrast to solar plants that cannot work at night and wind turbines that can only generate power when it is windy, OTEC can produce electricity all day long.
- With a minimum impact on the environment, warm and cold seawater could be drawn and returned close to the thermocline.
- Hydrogen could also be produced by the electric power generated by OTEC.
- It is possible to make tropical and subtropical island sites pollution-free by using conventional fuels for electricity generation.
- Through the OTEC system, nutrients from the unproductive deep waters are transported to the warmer surface waters, thereby enriching fishing grounds.
- Power can be generated by floating OTEC plants even at mid-ocean and can be used for processing manganese nodules off shore

4. Disadvantages of OTEC System

- Presently, electricity produced by OTEC costs more than electricity generated by fossil fuels.
- As this project had only been tested at a small scale, there were no energy companies interested in funding it. Pipes and OTEC plants can damage reefs and near-shore marine ecosystems if they are constructed in coastal waters.
- The construction and operation of OTEC plants might affect commercial and recreational fishing.

- The steam electric power generation plants present other risks associated with the OTEC power system which are: -
  - Electrical hazards
  - Rotating machinery
  - Use of compressed gases
  - Heavy material-handling equipment
  - Shop and maintenance hazards.

5. Applications of OTEC System

5.1 Desalination

Open- or hybrid-cycle plants can produce desalinated water by evaporating seawater-using condensers. Based on a system analysis, a 2-megawatt plant could desalinate 4,300 cubic meters of water per day. Richard Bailey developed a system that regulates deep ocean water flow through surface condensers in relation to fluctuating dew-point temperatures to produce condensate water. This condensation system uses no incremental energy and has no moving parts.
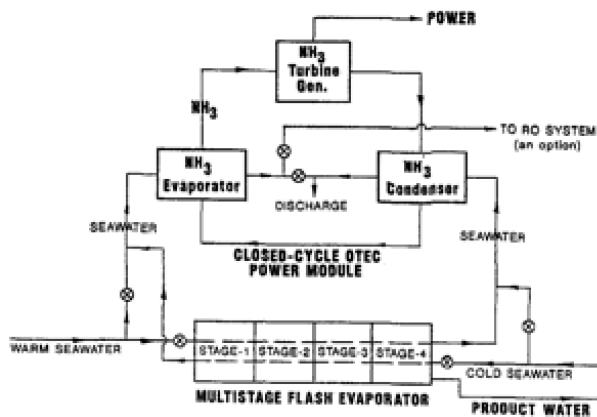

Fig 5: Schematic Flow Diagram of a OTEC Desalination Plant

5.2 Air Conditioning

An OTEC system provides cooling to industries and homes nearby by utilizing the cold seawater, which is 5 °C. Buildings can use chilled-water coils to provide air-conditioning. According to estimates, a pipe 1 foot (0.30 m) in diameter can deliver 4,700 gallons of water per minute. The temperature of water at 6 °C would be enough to provide air conditioning for any large building. Operating for 8,000 hours per year in lieu of electrical conditioning selling for 5-10¢ per kilowatt-hour, it would save $200,000-$400,000 in energy bills annually. A district cooling plant was opened in Copenhagen, Denmark, in 2010. Commercial and industrial buildings receive cold seawater from the plant, which reduces electrical consumption by 80 percent.
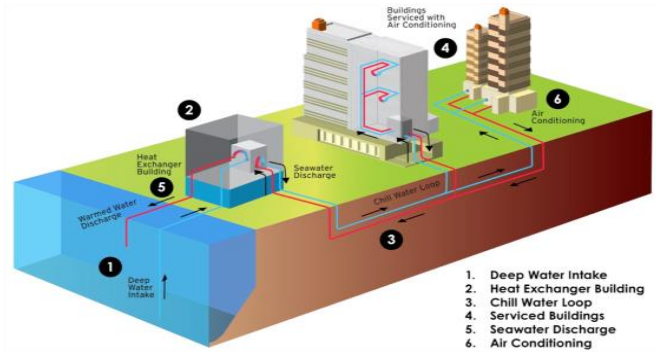

Fig 6: Seawater Air Conditioning

5.3 Aquaculture

One of the best-known products is aquaculture, because it reduces financial and energy costs associated with pumping large amounts of water from deep oceans. Biological consumption in surface waters has drained deep ocean waters of their essential nutrients. This "artificial upwelling" mimics the natural upwellings that are responsible for supporting the world's largest marine ecosystems, as well as the highest density of life on the planet. The cold, deep sea is perfect for cold-water sea animals like salmon and lobster. It is also possible to cultivate microalgae, such as spirulina, which is a health food supplement. It is possible to deliver water at the optimal temperature by combining deep-ocean water with surface water.

5.4 Mineral Extraction

57 trace elements are dissolved in the ocean in the form of salts and other forms.

A majority of economic analyses found that mining oceans for trace elements was unprofitable, particularly since pumping the water was energy-intensive.

The mining industry generally targets high-concentration minerals that can be easily extracted, such as magnesium. OTEC plants supply water, so the only cost is for extraction. Japanese scientists researched the possibility of extracting uranium and found that developments in other technologies (especially materials sciences) were improving the prospects.

Table 1: Review of research papers on otec

	Author	Title	Parameters	Result
1	Ilse María Hernandez-Romero, Fabricio Napoles-Rivera, Antonio Flores-Tlacuahuac, Luis Fabian ´Fuentes-Cort´es (2020)	Optimal design of the ocean thermal energy conversion systems involving weather and energy demand variations	Turbine efficiency η^{Tr} - 0.9 Generator efficiency η^G - 0.87 Motor efficiency η^M - 0.8 Working fluid pump efficiency η^{wf} - 0.75 Cold Seawater inlet temperature $T^{cw,in}$ - 4.5 ◦C Cold Seawater outlet temperature $T^{cw,o}$ - 8 ◦C Optical efficiency η^o - 0.8 Warm and cold seawater pipelines diameter D^{ws}, D^{cw} - 0.5m Warm seawater pipeline length L^{ws} - 50 m Cold seawater pipeline length L^{cw} - 950 m	The results of the study show that increasing the seawater temperature before it enters the evaporator with the help of a solar collector increases the cycle's efficiency by considerable amounts.
2	Abhishek kishore AmeenUddin Ahmad (2017)	How to Minimise the Cost of Ocean Thermal Energy Conversion (OTEC)	Ocean covered 70% of earth's surface, which is abundant form of solar collector and solar storage capacity. Ocean has an abundant form of renewable source of energy, which has a potential to fulfil billions of watts of electricity. Nowadays OTEC is required to generate electricity due to sky rocketing price of oil, natural gas and coal. The objective was how to minimise the cost of Ocean Thermal Energy Conversion Plant.	In order to maximize OTEC's economics, sea water must be utilized effectively and the temperature difference must be maintained without high heat exchange costs. Due to the OTEC's location near the shore, fewer cables are necessary. Limiting the number of cable on ship. There should be a shorter distance between interconnected and the shore. Replaced old material with modern material to reduce weight.
3	Zahid Ayub Samuel Sami, (2013)	Prospects of ammonia based ocean thermal energy conversion (OTEC) system	Cycle components (kW) <u>R134a</u> Evaporator- 34,979 Condenser - 33,678 Regenerator - 5,473 Pump – 14 Turbine – 402 ORC Efficiency – 1.2 Price, $/kWe - 3.300 <u>Ammonia</u> Evaporator - 42,898 Condenser – 42,190 Regenerator – 2,566 Pump - 8 Turbine - 557 ORC Efficiency – 1.32 Price, $/kWe – 2,500	A variety of working fluids are currently available, including hydrocarbons and natural refrigerants. They each have their pros and cons. Hydrocarbons are flammable, halocarbons are environmentally harmful, and ammonia is toxic. Of these fluids, ammonia stands out. • Has better transport and cycle performance • Has the least flow rate per unit energy • Natural with no impact on the environment with global warming potential (GWP) of zero • Least expensive and readily available
4	D. Vera, A. Baccioli, F. Jurado, U. Desideri (2020)	Modeling and optimization of an ocean thermal energy conversion system for remote islands electrification	<u>Deep water pipe</u> Material Fiber glass -reinforced plastic Seawater density (kg/m3)- 1030 Mass flow (kg/s) - 450 Length (m) - From 600 m to 1000 m Diameter (m) - 0.72 Velocity (m/s) - 1.063 Roughness (mm) - 0.0053 <u>Surface water pipe</u>	The ORC subsystem has been evaluated with 11 suitable working fluids. A number of performance parameters were calculated in order to determine the optimal working fluid, including net electric power (Pe), pumping losses (horc), and net electric efficiency (he). R1234yf has exhibited the maximum horc (3.60%) and he (2.57%) for 30 C surface water and 5 C deep water. In contrast, ammonia has reached the highest net electric power (99.3

			Material Fiber glass - Stainless Steal Seawater density (kg/m3) -1030 Mass flow (kg/s) - 900 Length (m) - 50 Diameter (m) - 0.80 Velocity (m/s) -1.738 Roughness (mm) - 0.0030	kW) and, therefore, the lowest power pumping losses (20.6% of the gross electric power).
5	Sajjad Zereshkian, Dariush Mansoury (2020)	A study on the feasibility of using solar radiation energy and ocean thermal energy conversion to supply electricity for offshore oil and gas fields in the Caspian Sea	• In this study, the SSRD (Surface Solar Radiation Downward) parameter with a spatial resolution of 0.125 and a time step of 3 h was used for the period from 2005 to 2014 for solar radiation. • ECMWF site surface temperature parameter with a spatial resolution of 0.125 and a time step of 6 h was used for the period from 2005 to 2014 to study water temperature variations in various months a year.	The monthly averages indicate that only parts of the southern basin are observed for optimum ocean thermal energy conversion during the warm months of the year in July, August and September. Based on daily analysis of the temperature change in the eastern part of the southern Caspian basin for June, July, August and September, ocean thermal energy conversion can be used optimally 64 days a year.
6	Guohui Wang, Yanan Yang, Shuxin Wang, Hongwei Zhang, Yanhui Wang (2019)	Efficiency analysis and experimental validation of the ocean thermal energy conversion with phase change material for underwater vehicle	PCM C_{sd}/C_{ld} 1.64/2.09 kJ·kg^{-1}·K^{-1} m_{pcm} 2 kg ΔH_m 236 J·kg^{-1} T_0 18 °C Hydraulic pipe L 1000 mm d 3 mm Throttle A 28.27 mm^2 C_d 0.7 Hydraulic motor D_H 0.25 ml r^{-1} ω_{max} 6000 rpm k_{TP} 1.8 × 10^{-8} Hydraulic motor τ_0 0.02 Nm P_{Nom} 18 MPa η_{HVNom} 92% Gearbox i_G 5.8 η_G 80% Generator k_E 0.0044 V·rpm^{-1} k_T 0.0359 A·(N·m)$^{-1}$ R_s 1.26 Ω L_s 0.000312H R_{Fe} 200 Ω Rectifier filter R_{diode} 0.5 Ω L_{diode} 0.000721H C_{filter} 100 µF	When meeting the power generation time constraint, a large displacement hydraulic motor is more conducive to increasing the system's efficiency; the use of low viscosity hydraulic oil is an effective way to improve OTEC-PCM efficiency; As a result of the sea trials, OTEC-PCM has demonstrated an average efficiency of 0.396% and a maximum energy output of 6696 J, which meets the energy requirements of underwater vehicles. By improving ocean thermal energy utilization in underwater vehicles, and miniaturizing ocean thermal energy collection and transformation, this study provides a solution for improving ocean thermal energy utilization.
7	Chengyu Lia, Lisheng Panb, Yongzhen Wang (2020)	Thermodynamic optimization of Rankine cycle using CO2-based binary zeotropic	Heat input of OTEC, Qin (MW) 1 Warm seawater inlet temperature, Tws, in (°C) 26–30 Deep cold seawater inlet temperature, Tcs, in (°C) 5	According to the thermodynamic results, the Rankine cycle with binary CO2-based mixture is a promising alternative solution for OTEC systems.

		mixture for ocean thermal energy conversion	Pinch point temperature difference, Tpp (°C) 2 Turbine efficiency, ηt 85% Working fluid pump efficiency, ηp 80% Seawater pump efficiency, ηp, ws(cs) 80% Roughness of seawater pipeline, K (μm) 4 Seawater velocity in pipeline, v (m/s) 1 Length of warm seawater pipeline, (m) 200 Length of cold seawater pipeline, (m) 1000	
8	Shoaib Khanmohammadi, Mohammad Mehdi Baseri, Pouria Ahmadi, Abdullah A.A.A. Al-Rashed, Masoud Afrand (2019)	Proposal of a novel integrated ocean thermal energy conversion system with flat plate solar collectors and thermoelectric generators: Energy, exergy and environmental analyses	Inlet temperature to solar collector ^{0}C 23 Temperature of cold water inlet to the condenser ^{0}C 4 Temperature of cold water inlet to the TEG ^{0}C 4 Solar radiation intensity (W m2) 500-800 Environment temperature K 293 Environment pressure kPa 100 Inlet pressure to solar collector kPa 200 Pressure of cold water inlet to the condenser kPa 110 Pressure of cold water inlet to the TEG kPa 110	According to the calculation, the S-OTEC and S-OTEC/TEG systems have an exergy efficiency of 48.69% and 54.96 percent, respectively. The results show that the gross output power of the TEG modules in the S-OTC/TEG is 12.64 kW, while the TEG pump input power is 4.96 kW. With 103.3 kW output, the ORC system using methanol as a working fluid has the highest turbine power, while the ORC system using ethylbenzene has the lowest value, about 101.2 kW
9	A. Hasan, I. Dincer (2020)	An ocean thermal energy conversion based system for district cooling, ammonia and power production	Warm water temperature 26 (^{0}C) Flow rate 50,000 (kg/s) Cold water temperature 4.5 (^{0}C) Flow rate 28,450 (kg/s) Working fluid - NH3 Maximum cycle pressure 8.96 bar Minimum cycle pressure 6.47 bar Efficiencies Water pumps 0.72 Working fluid pumps 0.72 Power turbine 0.75 Generator 0.94	In case 1 and 2, the highest energy efficiency was found to be 1.37% and 1.83%, respectively. The highest energy efficiency in both cases was found at a coldwater flow rate of 23,862 kg/s and a working fluid flow rate of 573 kg/s
10	A. Khosravi, Sanna Syri, M.E.H. Assad, M. Malekan (2019)	Thermodynamic and economic analysis of a hybrid ocean thermal energy conversion/photo voltaic system with hydrogen-based energy storage system	Turbine efficiency 0.82% Generator efficiency 0.95% Warm seawater pumping efficiency 0.85% Cold seawater pumping efficiency 0.85% Cold deep seawater inlet temperature (T_{cs};inlet) 5 ^{0}C Warm sweater inlet temperature (T_{ws};inlet) 27 ^{0}C Pipe length of the cold seawater (Lcs) 1000 m Pipe length of the warm seawater (Lws) 100 m Velocity of the warm seawater	Based on the results, the monthly optimum azimuth angle for solar collectors was found to be 0 0C. This is in line with Liu and Jordan's assumption. In addition, the optimum slope angles for solar collectors were determined as 52, 43, 28, 11, 4, 11, 8, 5, 23, 41, 51 and 55 for each month, respectively. In the case study region, EE efficiency for the photovoltaic panels averaged 12.86% and 15.97%, respectively. We also obtained an approximate payback period of 8 years for the hybrid system

			(Vws) 0.9 (m/s) Velocity of the cold seawater (Vcs) 1 (m/s)	
1 1	Ristiyanto Adiputra, Tomoaki Utsunomiya (2019)	Stability based approach to design cold-water pipe (CWP) for ocean thermal energy conversion (OTEC)	Material Steel Aluminum FRP Inner diameter (m) 12 12 12 Thickness (cm) 6 10 16 Section area (m2) 2.27 3.78 6.03 Length (m) 1000 1000 1000 Young`s modulus (MPa) 205,000 72,000 13,776 Yield stress (MPa) 350 240 550 Dry weight (N/m) 173,247 100,116 71,854 Wet weight (N/m) 150,481 62,109 9407 Total weight (N) 150.5×10^6 62×10^6 9.41×10^6 Hysteretic damping loss factor 1.5×10^{-3} 1×10^{-4} 1.6×10^{-2}	FRP has the highest yield stress and low density among the materials examined in this study, so it will be most suitable for OTEC use.
1 2	Do-Yeop Kim, You-Taek Kim (2017)	Preliminary design and performance analysis of a radial inflow turbine for ocean thermal energy conversion	P01 [kPa] 545.89 P5 [kPa] 372.71 T01 [°C] 26 W [kW] 200 Positions 01 Temperature [°C] 26 Pressure [kPa] 545.89 Density [kg/m3] 16.56 Entropy [kJ/kg-K] 2.11 Positions 5 Temperature [°C] 10 Pressure [kPa] 372.71 Density [kg/m3] 11.65 Entropy [kJ/kg-K] 2.1	The proposed approach was verified by designing a 200kW radial inflow turbine using R152a for OTEC, and measuring its performance using mean line analysis and three-dimensional CFD. Using the proposed approach, the researchers were able to perform a preliminary design that met the objectives of the turbine design conditions. The results of the mean line analysis and three-dimensional CFD were similar.
1 3	Yoshitaka Matsuda, Satoru Goto, Takenao Sug, Takafumi Morisaki, Takeshi Yasunaga, Yasuyuki Ikegam (2017)	Control of OTEC Plant Using Double-stage Rankine Cycle Considering Warm Seawater Temperature Variation	Mass flow rate of working fluid in Unit A mwfA [kg/s] 0.344 Mass flow rate of working fluid in Unit B mwfB [kg/s] 0.342 Mass flow rate of warm seawater m∗ws [kg/s] 39.72 Mass flow rate of cold seawater m∗cs [kg/s] 36.94 Cold seawater inlet temperature TcsiB [°C] 9.0 Overall heat transfer coefficient [kW/(m2·K)] 2.0 Specific heat of seawater cw [J/(s·°C)] 4179 Turbine efficiencies ηtA and ηtB 0.85 Target power output Wref [kW] 24.0	Using the heat exchange between evaporator and condenser, two control strategies to manipulate the mass flow rate of warm and cold seawater, respectively were proposed. Control strategies were implemented following PI laws. In order to verify the effectiveness of the proposed control systems, numerical simulations were conducted. Simulation results revealed that, despite the simple control laws adopted in this research, the control could be done successfully.
14	Ling Cai (2016)	Performance evaluation and parametric optimum design of an updated ocean thermal energy conversion system	$\eta_e = \eta_c = 0.95$, $\eta_r = 0.85$, $U_h = U_c = U_r$, $r_p = 2$, $T_h = 398$ K, $T_c = 278$ K, $T_0 = 298$ K	In addition to efficiency and power output, the cold seawater and additional regenerative processes are found to effectively enhance the system's efficiency and efficiency. The optimum value of key parameters at maximum output is determined under various conditions. The results obtained here are applicable to OTEC systems operating at a variety of temperature spans.

15	D.e. Lennard (1995)	The viability and best locations for ocean thermal energy conversion systems around the world	Components %of total Site-specific data 1.7 Heat exchangers 20.2 CWP 6.1 Moorings 4.9 Electrical transmission (seabed and riser) 8.3 Pumps, turbines, generators and control 12.9 Hull, including warm-water circuit 18.0 Installation and maintenance 4.1 Start-up and test 8.0 Miscellaneous 1.9 Unknowns 13.9	The long gestation period for OTEC - and now the DOWA variant of OTEC - has resulted in costs that are approaching economic attractiveness with oil at present prices, particularly where potable water or refrigeration/air conditioning is also involved. Island sites are the most lucrative potential sites, as noted.
16	Hamza Semmari, Driss Stitou, Sylvain Mauran. (2012)	A novel Carnot-based cycle for ocean thermal energy conversion	Evaporator Inlet temperature $T_{i,evap}$ 26 ^{0}C Seawater temperature difference ΔT_{WS} 3.28 K Condenser Inlet temperature $T_{i, cond}$ 6 ^{0}C Seawater temperature difference ΔT_{CS} 3 K Valve Flow coefficient K_v 2.3 m3 /h Cylinder Volume V_{cyl} 7 m3 Pumps Efficiency of warm seawater pump η_{WSP} 0.85 % Efficiency of cold seawater pump η_{CSP} 0.85 % Efficiency of working-fluid pump η_{WFP} 0.85 % Efficiency η_{coup} 0.85 % Generator Efficiency η_{gen} 0.96 % Internal resistance of generator R_i 14 Ω Load Load resistance Rl_{oad} 800 Ω Turbine Isentropic efficiency h_{turb} 0.9 % Specific rotational speed N_s 40 rpm	There is still a significant amount of electrical power produced per cycle (Wel,m = 6.6 kW) at this CAPILI OTEC plant. The global net efficiencies are about 1.2%. Similar values were obtained for ORC OTEC cycles operating in the same temperature range. The main advantage of this CAPILI engine is its hydraulic turbine, which is less expensive and requires less maintenance than a steam turbine.
17	D. E. Cavrot (1993)	Economics of ocean thermal energy Conversion (OTEC)	<u>Capital cost</u>- over $10,000/kW <u>Operation and maintenance costs</u>- Oil-fired plants 3% of capital cost OTEC plants 5% of capital cost <u>Fuel cost</u>- Oil-fired plants - the price of oil is expected to increase at a rate of about 3% per annum. OTEC plants- OTEC fuel (i.e. sun and water) is free.	OTEC is currently only competitive in a few remote island locations, according to economic studies of OTEC, and that its competitiveness should improve in the near future with further cost reductions and/or better economic circumstances.
18	DONALD S. SASSCER AND	OCEAN THERMAL ENERGY	Consider a tabular iceberg 5 kilometers long, 2 kilometers wide,	The projected costs of Ocean Thermal Energy Conversion (OTEC) power plants are lower

	UGUR ORTABASI (1979)	CONVERSION (OTEC) TUGBOATS FOR ICEBERG TOWING IN TROPICAL WATERS	and 250 meters deep. A thrust of 30,000 KN would be needed to tow this 2.5 (10^9) tonne iceberg at a speed of 1 knot. If 5.5 MW are delivered to each of the 25m diameter propellers, then the power density would be 1 .1 x 10^4 W/m^2. At a velocity of 1 knot (0.5m/s), the power to thrust ratio would be 3 W/N . Thus the 30,000 KN thrust could be produced by a 90 MW OTEC tugboat.	than the costs of stationary oil fired steam power plants. Aside from their lower costs, OTEC power plants are more efficient due to their large size and low power density, which allows them to extract large bollard pulls.
19	H. Ishaq, I. Dincer (2019)	A comparative evaluation of OTEC, solar and wind energy based systems for clean hydrogen production	The wind and OTEC sources employ PEM electrolyser to utilize electrical power for hydrogen production while solar source utilizes the CuCl cycle for producing hydrogen. WIND Average Ontario wind speed- 4.17m/s Wind turbine efficiency- 59.3% Area- 1600 m^2 OTEC Working fluid- Ammonia Cold and warm water temperatures- 5 ^{0}C and 28 ^{0}C. Entry Pressure- 950 kPa Exit Pressure- 565kPa SOLAR Working fluid- Molten salt Direct normal irradiance (DNI)- 0.85 kW/m^2.	Energy and efficiency requirements for producing hydrogen using wind energy are 33.51% and 32.7%, for ocean thermal energy conversion based systems are 5.61% and 13.6% respectively, and for solar energy based thermochemical methods they are 32.7% and 33.2%.

6. Conclusions

Since the Industrial Revolution, most countries' energy mix has become dominated by fossil fuels. Fossil fuel combustion results in around three-quarters of the global greenhouse gas emissions. This has significant implications for the global climate as well as for human health. The fossil fuel industry contributes to air pollution, which leads to at least 5 million premature deaths a year. Recent developments in technology and bitcoin mining activities have led to an exponential increase in energy consumption.

The world needs to rapidly shift to low-carbon energy sources, such as nuclear and renewable technologies, to reduce CO2 emissions and air pollution. A safe answer to an ever-decreasing energy demand had to be renewable sources. Renewable energy will playa vital role in the decarbonization of our energy systems.

Ocean thermal energy conversion is a potential source of renewable energy that creates no emissions it is fuel free. It has a low environmental impact, can supply pure water for both drinking and agriculture purposes. It can also supply refrigeration and cooling and can provide a coastal community with reliable energy. It is predicted that in the year 2040, the world will consume 820 quadrillion Btu of energy. Amount of solar energy absorbed by oceans is 4000 times the amount presently consumed by humans. We would need less than 1% of that renewable energy to satisfy our desires.

There are various devices and techniques used for the extraction of power from the ocean and new devices and techniques are being developed. Some of the techniques have even proved to be successful, but still, further research and development have to be done to enhance these techniques. They have to overcome the drawbacks like it should be more efficient; the maintenance costs should be low and should be eco-friendly, it should not harm the marine species.

The electricity demand is always going to increase and OTEC has the potential to meet our needs. It can soon become one of the most prominent renewable energy sources but some research in the field has to be done. Currently, Ocean Energy is not used to its full potential. Though it cannot be a complete solution to our problem in the future it can make a significant contribution to our energy needs.

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