Marine Renewable Energy

Introduction

The rise of temperatures and global climate change has resulted in instances of a rapid decline in biodiversity within complex ecosystems. This leads to questions about the viability of the world's sustainability in the face of imminent changes- both small and large. The industries play a major role in affecting sustainability on a global scale. The transportation and electricity sectors account for more than 50% of total greenhouse gasses (GHG) emissions in the US. The energy industry stands second with 26.9% of 2018 greenhouse gas emissions with approximately 63% coming from burning fossil fuels [1]. The increasing trend in urbanization, electric vehicles, and policies towards GHG emissions has led to the integration of variable energy resources (VER) and energy storage into the power grid.

In the United States, a measure of heat energy called British thermal units (Btu), is commonly used for comparing different types of energy with each other. In 2019, the total US primary energy consumption was approximately equal to 100.2 quadrillion Btu. The US primary energy consumption by a source in 2019 is as shown in Figure 1. The total renewable energy consumption was only 11% accounting for 11.4 quadrillion Btu [2]. To increase the current renewable energy sources, energy departments are looking for alternate sources.

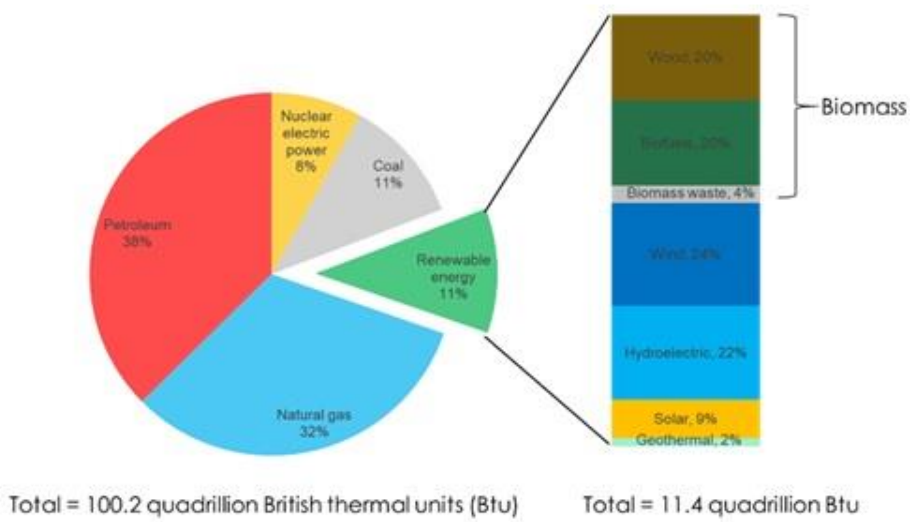

Fig. 1: US Primary energy consumption by source in 2019 [2]

Sourcing energy from fossil fuels is not the solution over the long term. Climate change, future exhaustion of fossil fuels, and major concerns with nuclear power leads to the necessity for renewable resources. Renewable energy sources such as solar, wind, and hydropower are currently considered for economic power generation in the US. One of the best prospects for renewable energy comes from energy in the ocean in the form of Marine renewable energy [3].

Marine renewable energy totes a promising future if the efficiency of such devices increases. Considering that 70% of Earth's surface is covered in the ocean [4], the resource is readily available. Additionally, the ocean already is critical to life on earth as well as to the atmosphere, weather, and climate. The initial cost of these energy capturing devices is high and considering the uncertainty and variabilities in the ocean energy, the cost of production is high. Hence the need for subsidies and incentives are much needed for promoting the MRE.

A NREL study has shown that 50% of the US population lives within 50 miles of the coast and the MHK has the potential of 2300 TWh/year [5] and 1285 TWh/year usable energy. Where 1 TWh/year can power 90000 homes. The energy potential based on resources is as shown in table 1 [6].

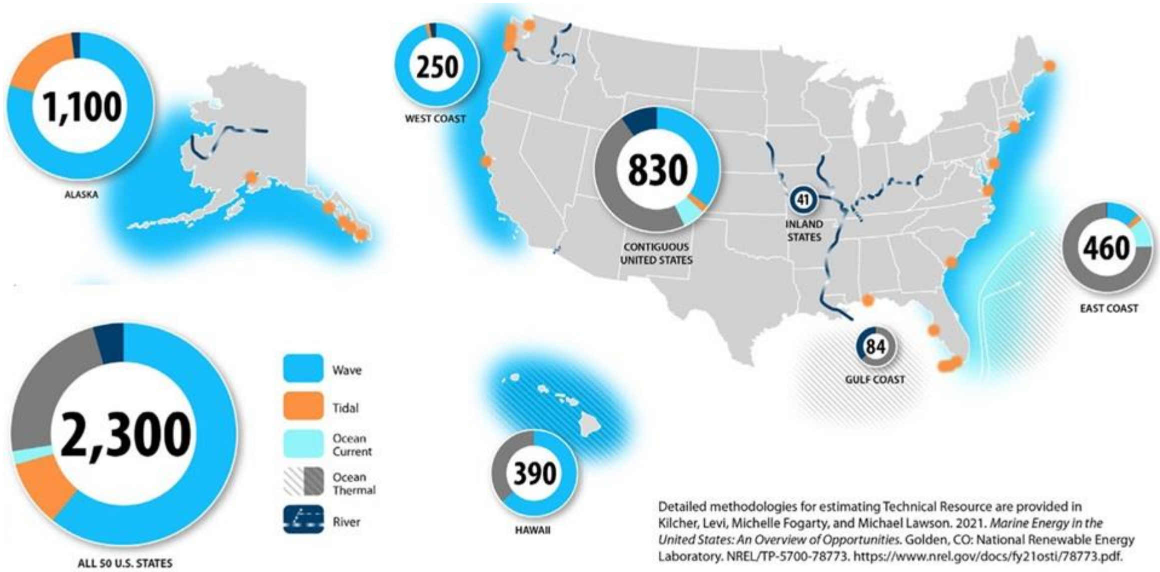

Fig. 2: Technical Power Potential of U.S. Marine Energy Resources [5]

MRE in North Carolina, USA

Moving seawater is a potential renewable energy source for electricity generation. The Gulf Stream is a warm water ocean current that flows in the north-east direction from the south towards the north. It begins in the Caribbean Ocean and ends in the North Atlantic and reaches a max speed of approximately 2 m/s near Cape Hatteras (NC) and transports 90 million cubic meters of ocean water per second at a distance of 15-20 nautical miles [7]. The variability in the Gulf Stream position decides the resource availability. Shallow coast and high current velocities make this an optimal location to quantify the MHK energy resource for NC. [8]. It is to be noted that due to water density, ocean current speed of 1m/s is equivalent to 9.3 m/s of wind speed [4]. Figure 3 shows the potential temperatures (ºC)in the Gulf stream. Figure 4 shows the average current velocities at 75 m from Cape Hatteras in the Gulf stream measured in 2014.

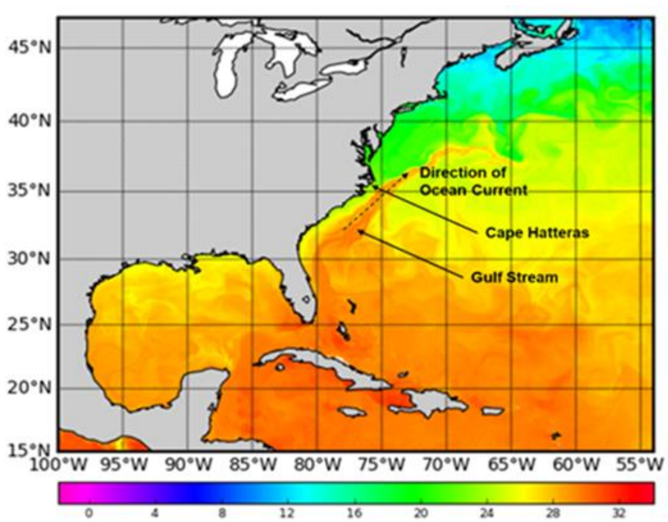

Fig. 3: Gulf Stream Potential Temperature at surface [9]

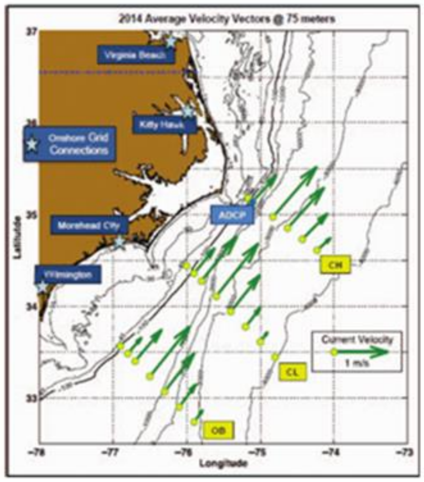

Fig. 4: Average Current Velocities in NC coast [7]

Ocean renewable energy classification

The ocean renewable energy sources can be classified as [10]

1. Marine and Hydrokinetic Energy (MHK)
    a. Waves
    b. Ocean currents
    c. Ocean thermal gradients
    d. Tidal streams
2. Offshore energy sources
    a. Offshore winds
    b. Offshore Solar Plants
    c. Biomass
    d. Compressed Air Energy Storage
    e. Osmotic or salinity gradient

References:

1. "Sources of Greenhouse Gas Emissions." EPA, Environmental Protection Agency, 2019, www.epa.gov/ghgemissions/sources-greenhouse-gas-emissions
2. "U.S. Energy Information Administration - EIA - Independent Statistics and Analysis." U.S. Energy Facts Explained - Consumption and Production - U.S. Energy Information Administration (EIA), www.eia.gov/energyexplained/us-energy-facts/
3. Borthwick, Alistair GL. "Marine renewable energy seascape." Engineering 2, no. 1 (2016): 69-78
4. Dhanak, Manhar R., and Nikolaos I. Xiros, eds. Springer handbook of ocean engineering. Springer, 2016.
5. Kilcher, Levi, Michelle Fogarty, and Michael Lawson. 2021. Marine Energy in the United States: An Overview of Opportunities. Golden, CO: National Renewable Energy Laboratory. NREL/TP-5700-78773. https://www.nrel.gov/docs/fy21osti/78773.pdf.
6. "Marine and Hydrokinetic Resource Assessment and Characterization." Energy.gov, https://www.energy.gov/eere/water/marine-energy-resource-assessment-and-characterization
7. He, Ruoying, John Bane, Mike Muglia, Sara Haines, Caroline Lowcher, Yanlin Gong, and Patterson Taylor. "Gulf stream marine hydrokinetic energy resource characterization off Cape Hatteras, North Carolina USA." In OCEANS 2016-Shanghai, pp. 1-4. IEEE, 2016

8. R. He et al., "Gulf stream marine hydrokinetic energy resource characterization off Cape Hatteras, North Carolina USA," OCEANS 2016 - Shanghai, Shanghai, 2016, pp. 1-4, doi: 10.1109/OCEANSAP.2016.7485538.
9. https://polar.ncep.noaa.gov/global/nc/?-gulfstream-temperature-000-small-
10. Borthwick, Alistair GL. "Marine renewable energy seascape." Engineering 2, no. 1 (2016): 69-78