Integration of Offshore Renewable Energy as the Ocean Health Index’s eleventh goal

**OCEAN HEALTH INDEX (OHI)**

-Index created in 2012 by Halpern et al

-Measure of the healthiness of the ocean – calculated through ten goals:

* Food provision (Fisheries and Mariculture)
* Artisanal fishing opportunity
* Natural products
* Carbon storage
* Coastal protection
* Tourism and recreation
* Coastal livelihoods and economies (Livelihoods and Economies)
* Sense of place (Iconic species and Lasting special places)
* Clean waters
* Biodiversity (Habitats and species)

-The purpose of the index: characterise quantitatively the human-ocean interactions, as most of the scientific research is more directed to the human activities that destroy the ocean environment such as overfishing, pollution

-Thus, OHI takes in consideration the overall condition of coupled human-ocean systems

-challenges: modest number of widely accepted goals, models that measure with reasonable accuracy how well each goal is achieved, robust reference points for each model, incorporate sustainability into index, responsivity of the index to real differences and changes in ocean health, flexibility to adapt to constraints of data availability, quality and quantity

-The ocean health index is calculated for each goal through the next framework:

*Purpose of this project*: integrating offshore renewable energy as the 11th goal of the Ocean Health Index and suggesting possible improvements

**OFFSHORE RENEWABLE ENERGY**

-tried to use the same variables to make the global model and not only the data that has been calculated for particular countries

Goal Description

Offshore renewable energy goal tries to show the potential power that can be extracted on the coastal areas given the variables needed in order to calculate it. A score of 100 means it means that the average taken over the entire country can provide 1MW offshore energy, therefore can provide enough to power approximately 1000 houses. Higher scores would imply a higher potential, thus future research should be taken in consideration in order to exploit these resources.

Model & Data

Model measures the potential amount of power that can be extracted from the three types of energy: wind, wave and tidal. For wind energy, the variables used in order to calculate are: the density of the air passing through the rotor, wind speed, swept area and power coefficient (theoretical limit of power conversion - 0.59). For wave power, the factors that are taken in consideration are wind speed, time water exposure to the wind, open water fetch, water depth and topography of the sea bed. In this case, out of these, it is relatively simpler to calculate the potential amount of energy with the significant wave height and wave period. For tidal power, fluid density, the swept area and the local fluid velocity are the ones which contribute to the calculations. (International Energy Agency Implementing Agreement on Renewable Energy Technology Development, 2012)

Data sources:

- sea surface temperature, wind speed, wave height and wave period: SAIL.MSK.RU (http://www.sail.msk.ru/atlas/)

- density of the air : GPS visualizer and GRC.NASA ([www.gpsvisualizer.com](http://www.gpsvisualizer.com) and <https://www.grc.nasa.gov/www/k-12/airplane/atmos.html>)

- salinity : NODC.NOAA (https://www.nodc.noaa.gov/OC5/WOA05/pr\_woa05.html)

- tidal currents: VOLKOV ATLAS (http://volkov.oce.orst.edu/tides/tpxo8\_atlas.html)

### Reference points

The reference point is the amount of power needed in order to provide energy for 1000 houses which is approximately 1 MW among all assessed regions. The number has been given under the assumption that there are at least 1000 houses that can be provided with this amount of energy - a few countries might have less than this number of houses.

**LAYERS**

*\*Offshore wind energy\* - ore\_wind\_power.csv*

The temperature differences which occur due to the day and night cycle, the amount of solar irradiance and different structures of the Earth is resulting in pressures differences that will set the air masses in motion. Therefore, solar energy is creating this new energy - wind.

Wind energy is a function of four factors: density of the air passing through the rotor(rho), wind speed (v), swept area (A) and power coefficient (cp)

It is illustrated by: power=1/2 \* rho \* A \* v^3 \* cp

(International Energy Agency Implementing Agreement on Renewable Energy Technology Development, 2012)

*\*Offshore wave energy\*- ore\_wave\_power.csv*

Waves are a concentrated form of wind energy, their height being determined by wind speed, time exposure to the wind, open water fetch, bathymetry and topography of sea bed. The energy can be approximated to 1/2 \* H^2 \* T where H is the significant wave height and T is the wave period.

(International Energy Agency Implementing Agreement on Renewable Energy Technology Development, 2012)

*\*Offshore tidal energy\* - ore\_tidal\_power.csv*

Tidal energy is generated due to changes in the gravitational forces that induce cyclic variations of the sea level, resulting in water currents.

The potential power is a influenced by the fluid density (rho), swept area (A) and the local fluid velocity (U) according to the formula:

P=1/2 \* rho \* A \* U^3

(International Energy Agency Implementing Agreement on Renewable Energy Technology Development, 2012)

*\*Offshore renewable energy trend\* - ore\_trend.csv*

Global trend in renewable energy - study by Frankfurt School of Finance and Management gGmbH 2017

**TEXT PROCESSING FOR OFFSHORE RENEWABLE ENERGY AS 11TH GOAL OHI –all in Python**

*DATA: SST, WIND SPEED, WAVE HEIGHT, WAVE PERIOD*

/uki/python scripts/data originates from http://sail.msk.ru/wow/

-directory http://sail.msk.ru/wow/data/CENTENNIAL/OBS/ 2010/01 to 2015/12

-information taken in consideration (units): Latitude(degrees), Longitude(degrees), Air temperature(Celsius degrees), SST (sea surface temperature) (Celsius degrees), Wind speed (m/s), Significant wave height (m), Dominant wave period (s)

\*\* changed all wind speeds of weird values (example 27.01138.2) to 6

\*\* noticed after processing all data that it is a matter of combining 2 columns in CENTENNIAL/OBS/ data

-concatenating all .txt files found in /data + sorting > total.txt

-python script used total.py in order to calculate the average of the variables across all similar Latitudes and Longitudes

**IMPORTANT PYTHON SCRIPT** - can be improved - oncountries.py

-associating countries to latitudes and longitudes (beforehand! Selected 4 grid points for each country North West, North East, South West and South East that includes the entire country – not only the coastal areas or the EEZ)

oncountries.py > file.txt

-averaging on countries: countryaverage.py > fileout.txt

-sorting awk 'NR==1; NR>1 {print $0 | "sort -n"}' < fileout.txt > wavewinddata.txt

*DATA: AIR DENSITY*

-created matrix - matrix.py

-found elevation points with GPS visualizer http://www.gpsvisualizer.com/

> elevations.txt

https://www.grc.nasa.gov/www/k-12/airplane/atmos.html

-calculated density - density.py

*DATA: SALINITY*

-data from https://www.nodc.noaa.gov/General/salinity.html

-averaged for 0-60 m depth for all data points > salinity.txt

-salinity per country - attributing data point to countries with saloncountry.py >salinitycountry.txt

-averaging for each country - with salinity.py > salinityfinal.txt

-sorted, deleted extra columns that are not used in this case

>airdensity.txt

>data.txt

>salinitydata.txt

*FLUID DENSITY*

According to the state equation from https://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0ahUKEwim08P2z-3VAhWnJ8AKHXiqABQQFggpMAA&url=https%3A%2F%2Fwww.niot.res.in%2FCOAT%2Fcoat\_pdf%2FCHAP%2520III%2520-%2520Equation%2520of%2520State.pdf&usg=AFQjCNHXfwWKYLbkZAg2QjWiatmO26AzPg

-using SST and Salinity > fluiddensity.py > fluiddensity.txt

*DATA: TIDAL CURRENTS*

Data for tidal velocities taken from http://volkov.oce.orst.edu/tides/tpxo8\_atlas.html.

Downloading the transports in the netcdf format (M2, S2, N2, K2, K1, O1, P1, Q1, M4) and the bathymetry in netcdf format.

Using currents.py in order to calculate the tidal speed (multiplying each transport by the bathymetry -in the right direction- and turning the vector into a speed).

All data > tidalcurrents.txt.

Adding the column to the corresponding latitudes and longitudes > currents.txt

Taking the average per country with tidal.py > countrytidal.txt

**PRESSURES – REFERENCES for the pressure matrix**

*POLLUTION*

* Chemicals

Epoxies are generally selected for underwater applications because, of all the resin systems, they are the most resistant to progressive moisture absorption and hydrolytic attack, so development has concentrated on suitable modification of the epoxy polymer for improved fatigue performance. AEL and its partners are working on purpose-developed epoxy resins that will deliver the required combination of properties and ensure the most efficient use of materials.

<https://link.springer.com/article/10.1007/s10443-010-9143-1>

http://www.materialstoday.com/composite-applications/features/tidal-energy-an-emerging-market-for-composites/

http://www.renewableenergyfocus.com/view/1710/wave-and-tidal-power-an-emerging-new-market-for-composites/

http://www.sciencedirect.com/science/article/pii/S0010938X10004841

http://www.sciencedirect.com/science/article/pii/S0266353896001704

* Human pathogens – a human virus won’t affect offshore feasibility
* Eutrophycation and hypoxia

http://www.sciencedirect.com/science/article/pii/S0166445X14002483

Hypoxia occurs naturally in marine systems and is associated with areas where mixing of the water column is limited \*due to the formation of thermoclines and areas of upwelling where, due to the influx of nutrients supporting the food chain, the oxygen consumption by aerobic organisms exceeds oxygen production by photosynthetic organisms and diffusion from the atmosphere. As a result, large areas of marine environment are characterized by low oxygen concentration

<https://books.google.co.uk/books?id=eYYSDAAAQBAJ&pg=PA86&lpg=PA86&dq=hypoxia+environment+on+metals&source=bl&ots=DkrR4k2wF9&sig=aMB6ezsn742uU0j_h7guZGiM27U&hl=ro&sa=X&ved=0ahUKEwifuvqyu-jVAhUCCsAKHWwwDecQ6AEILjAA#v=onepage&q=hypoxia%20environment%20on%20metals&f=false>

*CLIMATE*

* Ocean acidification

http://tos.org/oceanography/article/effect-of-ocean-acidification-on-the-speciation-of-metals-in-seawater

* Sea level rise

https://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0ahUKEwiI3N\_Br-rVAhWKJsAKHc7VCBUQFggwMAE&url=http%3A%2F%2Fwww.parliament.uk%2Fdocuments%2Fpost%2Fpostpn315.pdf&usg=AFQjCNHJl3-gXSELhpmNhMApu9bnnEvk5w

* Sea surface temperature

https://link.springer.com/article/10.1007/s10443-010-9143-1

* UV radiation

<http://journals.sagepub.com/doi/abs/10.1177/0021998307075441>

http://scholar.google.co.uk/scholar\_url?url=https://www.researchgate.net/profile/Abdullah\_Kafi/publication/258157216\_Study\_on\_the\_Mechanical\_Properties\_of\_JuteGlass\_Fiber-reinforced\_Unsaturated\_Polyester\_Hybrid\_Composites\_Effect\_of\_Surface\_Modification\_by\_Ultraviolet\_Radiation/links/560a242708ae1396914ba172.pdf&hl=ro&sa=X&scisig=AAGBfm0OQf0ZOVeoY0bQTH5qj3FV7SepmQ&nossl=1&oi=scholarr&ved=0ahUKEwjclZvRtOrVAhWJI8AKHV8MDcMQgAMIJigAMAA

journals.sagepub.com/doi/abs/10.1177/002199802761675511

* Bottom

<http://offshorewind.net/offshore-wind-turbine-foundations-current-future-prototypes/>

<https://ore.catapult.org.uk/our-services/innovation-challenges/offshore-wind-innovation-challenges/foundations-substructures/>

<https://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwit092PuurVAhVlCcAKHeI5BUcQFggnMAA&url=https%3A%2F%2Fwww.carbontrust.com%2Fmedia%2F170419%2Ffoundations-and-moorings-tidal-systems.pdf&usg=AFQjCNFR-zBtpRhRcWaLl_uIn3NWwzxdbw>

<https://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=2&cad=rja&uact=8&ved=0ahUKEwit092PuurVAhVlCcAKHeI5BUcQFggwMAE&url=https%3A%2F%2Fwww.oceanologyinternational.com%2F__novadocuments%2F231062%3Fv%3D635954439741700000&usg=AFQjCNGCSAwbv-PYkVJ9BcKyL6D8aB3m6Q>

https://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&cad=rja&uact=8&ved=0ahUKEwjck\_aHuurVAhXlCcAKHZ2hD14QFgg3MAI&url=https%3A%2F%2Fformationemr16.sciencesconf.org%2Ffile%2F266745&usg=AFQjCNGGRBpLuFRVMmLaUKZ85GES0xmKHQ

<http://www.emec.org.uk/marine-energy/wave-devices/>

*SOCIAL*

https://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwiQzpC9vurVAhWrL8AKHYc0AVoQFggsMAA&url=http%3A%2F%2Fwww.climatexchange.org.uk%2Ffiles%2F7314%2F2226%2F8751%2FFull\_Report\_-\_Community\_Benefits\_from\_Offshore\_Renewables\_-\_Good\_Practice\_Review.pdf&usg=AFQjCNGdf6bJw7rltXMfFK2YyidU0qDTKg

https://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwjDg\_u0v-rVAhVqKcAKHQvsDJcQFggsMAA&url=https%3A%2F%2Facademic.oup.com%2Fyel%2Farticle-pdf%2F35%2F1%2F621%2F8579417%2Fyew022.pdf&usg=AFQjCNHKDqnEVj33jKqTtOlYKyzlpTuWHw

**Resiliencies taken: only WGI**

*TREND*

<https://www.google.co.uk/url?sa=t&rct=j&q=&esrc=s&source=web&cd=3&cad=rja&uact=8&ved=0ahUKEwjX9MK0muvVAhXMDMAKHfT1BH8QFgg6MAI&url=http%3A%2F%2Ffs-unep-centre.org%2Fsites%2Fdefault%2Ffiles%2Fpublications%2Fglobaltrendsinrenewableenergyinvestment2017.pdf&usg=AFQjCNGaBosWk4d0ZSe7ZFM0A7helgl24g>

**POSSIBLE IMPROVEMENTS**

**-**plot

**-**change reference point with the amount of potential energy that is considered sustainable for each type of energy (wind/tidal/wave)

-change trend for each country and take in consideration only offshore renewable energy, not the whole trend for renewable energy

-as fishing, include this goal as a pressure and resilience too and how it will influence all the other goals – it has to be different for all the goals as offshore renewable energy will influence all the goals in different way (this would be a different method from the other pressures and resiliencies as OHI code takes in only one value for influencing all the goals) also, it can be weighted differently to the other goals

-change the location of data points – take in consideration only EEZ

**INCLUDING ORE CODE IN OHI SCHEME**

-can be seen here: <https://github.com/OHI-Science/uki>