# Comparison of Solar, Wind & Wave Renewable Energy Power Plants 2019

Charles Haynes, 2019 available from: https://www.neptunewave.ca/downloads

| *Consideration* | *Solar* | *Wind* | *Wave* |
|---|---|---|---|
| Total **Global TWh** produced in 2018 [1] | **600 TWh** | **1,900 TWh** | **0 TWh** (10,000 TWh potential) |
| **Type** of Electricity Produced [2] | **Intermittent** non-dispatchable | **Intermittent** non-dispatchable | **Continuous** dispatchable "Firm" power |
| Operational **Hours** per Day (average) [3] | **5 to 6 h** | **11 h** | **24 h** |
| Operational **Hours** per Year (8,766 hours) [3] | **2,000 h** | **3,500 h** | **8,500 h** |
| **Area [km$^2$]** to Produce 1 TWh in a Year [4] | **9.5 km$^2$** | **68 km$^2$** | **.5 km$^2$** |
| **USD Cost** / MWh to Build Power Plant [5] | **$ 505. / MWh** | **$ 967. / MWh** | **$454. / MWh** |

## *REFERENCES*


***1. Global TWh Produced 2018***

***Solar:*** BP Statistical Review of World Energy 2019, https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html

***Wind:*** same as for Solar above

***Wave: Gunnar Mork, et al, "***ASSESSING THE GLOBAL WAVE ENERGY POTENTIAL" OMAE2010 – 20473 Proceedings of OMAE2010 29th International Conference on Ocean, Offshore Mechanics and Arctic Engineering June 6-11, 2010, Shanghai, China
This paper reports: 21,000 TWh per year hence at 48% conversion efficiency of potential wave energy into electricity then **10,000 TWh per year**

***2. Type of Power*** **Intermittent non-dispatchable or Continuous**

***Solar***: https://energyeducation.ca/encyclopedia/Intermittent_electricity

***Wind:*** http://www.lse.ac.uk/GranthamInstitute/faqs/what-are-the-pros-and-cons-of-onshore-wind-energy/ and https://en.wikipedia.org/wiki/Wind_power

***Wave:*** *Neptune Wave Engine* from Vancouver Wave Energy Testing Station data: https://www.neptunewave.ca/downloads

***3. Operational Hours per Day and per Year***

***Solar:*** average 5 to 6 hours per day hence 5.5 * 365 = 2,008 hours / year in USA https://www.solar-electric.com/learning-center/solar-insolation-maps.html/ in India 1,400 to 1,800 peak rated hours per year over 300 days hence 1,600 hors / 300 = 5.3 hours per day for 300 days https://en.wikipedia.org/wiki/Solar_power_in_India

***Wind:*** **3,000 hours per year average** from Fig 2 in Matthias Huber, et al, Integration of wind and solar power in Europe: Assessment of flexibility requirements, 2014 http://dx.doi.org/10.1016/j.energy.2014.02.109 0360-5442/ 2014, Published by Elsevier Ltd. AND up to **4,000 hours** per year for offshore wind: https://www.sciencedirect.com/topics/engineering/full-load-hour
"in Denmark .. less than 1% of average demand on 54 days during the year 2002": https://en.wikipedia.org/wiki/Wind_power
Hence we consider a wind energy year to have 3,500 hours /315 days = **11 hours peak load wind per day**

***Wave:*** *Neptune Wave Engine* from Vancouver Wave Energy Testing Station data: https://www.neptunewave.ca/downloads

***4.*** **Area in km2 to Produce 1 TWh of Electricity**

***Solar:*** *Kamuthi* 2500 acres = 10.12 km$^2$ and 1.35 TWh / yr hence **7.5 km$^2$ per TWh / yr;** *Kurnool* 24 km$^2$ and 2,104 GWh / yr hence **11.41 km$^2$ / TWh / yr**; so average = **9.45 km$^2$ / TWh per yr**.
https://en.wikipedia.org/wiki/Kamuthi_Solar_Power_Project and https://en.wikipedia.org/wiki/Kurnool_Ultra_Mega_Solar_Park

***Wind:*** *Anholt Offshore:* Area = 88 to 144 km$^2$– *hence we are using average = 116 km$^2$* https://www.power-technology.com/projects/anholt-offshore-wind-farm/ Capacity factor = .487 and Name Plate Capacity = 400 MW hence: 1,706,448 MWh / yr so: 116/1.7 = ***68 km$^2$ to produce 1 TWh per year*** https://en.wikipedia.org/wiki/Anholt_Offshore_Wind_Farm

***Wave:*** *Neptune Wave Engine* from Haynes, C., "Comparisons of Electricity Generation Plants", 2019: https://www.neptunewave.ca/downloads

***5.*** **Cost in USD per MWh To Build Power Plant** [simply the total Cost to build divided by total Power (MWh) produced per 1 year]

***Solar: Kamuthi*** $710,000,000 for 1,350,000 MWh / yr = $ 526.00 / MWh; ***Kurnool*** $1,020,000,000 for 2,102,400 MWh / yr = $ 485.00 / MWh average (526 + .485) / 2 = **USD 505.00 / MWh / yr.** https://en.wikipedia.org/wiki/Kamuthi_Solar_Power_Project

***Wind: Anholt Offshore:*** Construction cost 10 Billion Danish Kroner, 1.35 Bn Euro, USD = 1.65 bn; Cost per MWh = $1,650,000,000 / 1,706,448 MWh / year = ***USD 967.00 / MWh to build*** https://en.wikipedia.org/wiki/Anholt_Offshore_Wind_Farm

***Wave:*** *Neptune Wave Engine* $5,000,000 to build plant that produces 11,000 MWh / yr (in English Channel) = ***USD 454.00 /MWh to build***
"Feasibility Report to www.otary.be: Adding Wave Energy to Wind Turbine Mono-piles", 2019: https://www.neptunewave.ca/downloads