CAN OFFSHORE WIND ENERGY BE AN ENERGY ECONOMIC SOLUTION TO ELECTRICITY GENERATION?

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INTRODUCTION

- Offshore Wind Energy (OWE) is a developing solution and option in clean energy generation.

- Primary infuencing factors driving increase utilisation:
  - Decarbization of the energy sector.
  - Search for diversifed renewable energy portfolio.
  - Climate change mitigation & Sustainability (Poudineh et al. 2017).

- … But is OWE economically viable?

State of the Industry

HOW DOES WIND ENERGY LOOK ON THE GLOBAL MARKET.

STATE OF THE INDUSTRY

GLOBAL ENERGY MARKETS.

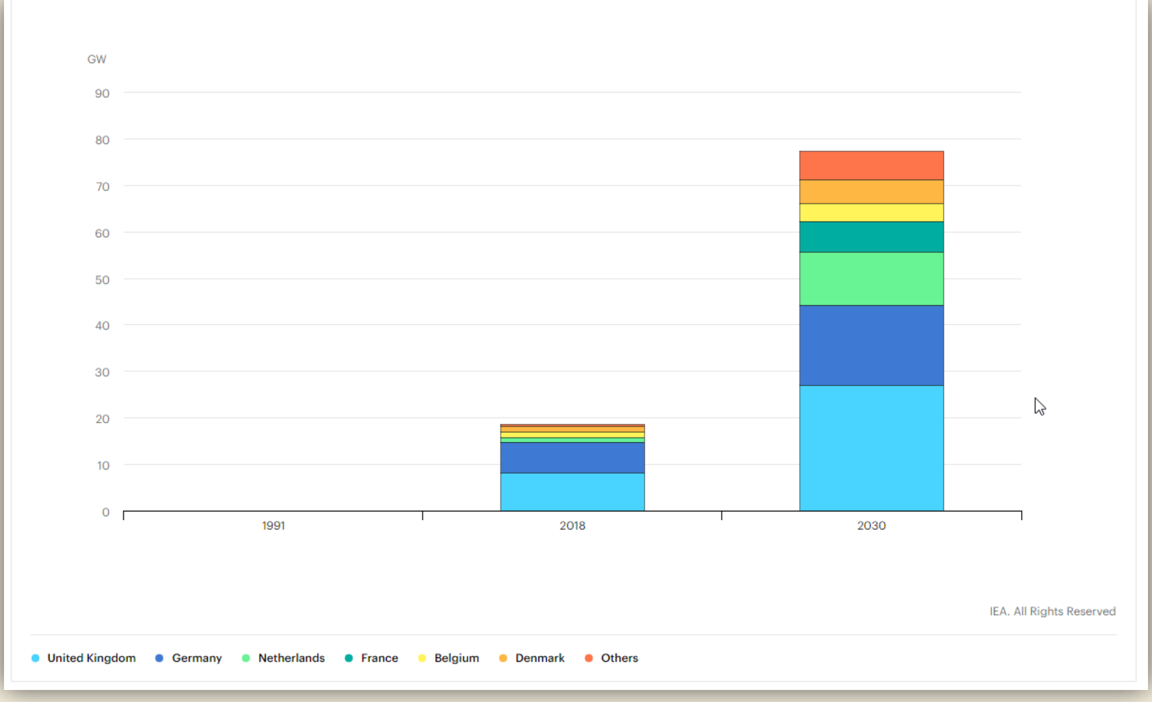


Fig. 1 – IEA, Offshore wind capacity by country, 1991-2030, IEA, Paris (2020) https://www.iea.org/data-and-statistics/charts/offshore-wind-capacity-by-country-1991-2030

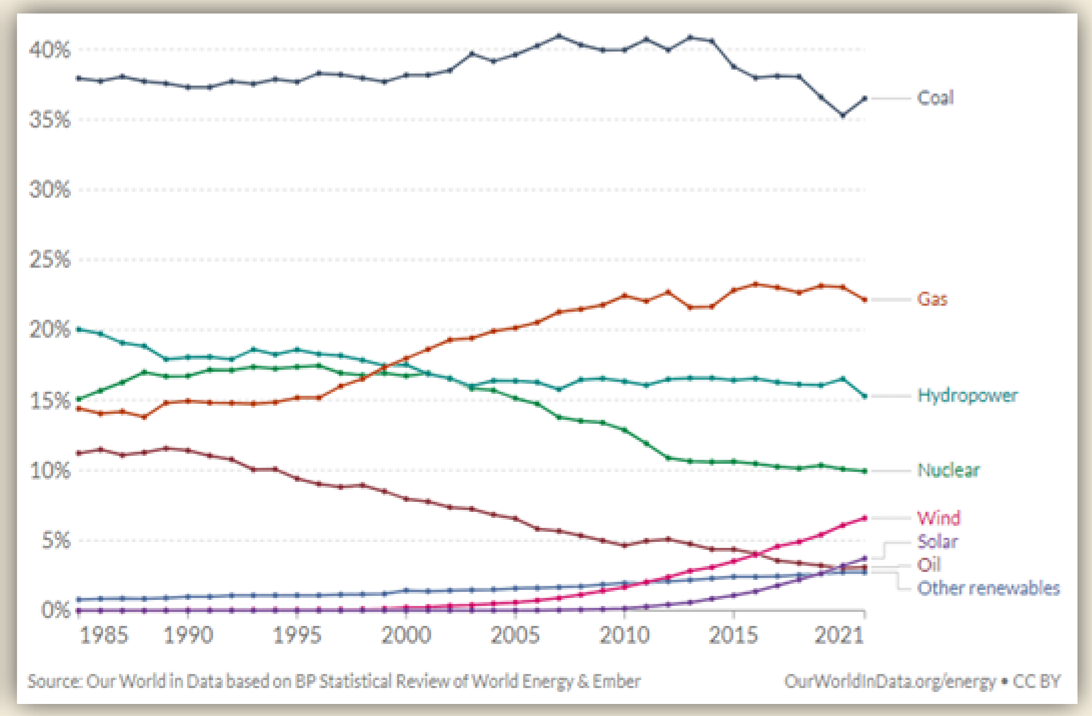


Fig. 2 – Share of Global Energy Production by Source from 1985- 2021 (Ritchie et al., 2022).

State of the Industry

When it comes to electricity production, wind energy comprised a total share of 6.59% of the entire globe (Ritchie et al., 2022) in 2021. In 2019, the total share of OWE is reported to be just 0.3% of the global production (IEA, 2019). While this represents a small share, it must be considered that OWE is a relatively new technology in comparison to traditional sources used to generate electricity as well as some renewable sources.

Looking forward, it appears OW will continue to play a greater role as decarbonisation and sustainability efforts increase (IEA, 2019).

State of the technology

HOW DO WIND TURBINES FUNCTION?

WIND TURBINE FUNDAMENTALS

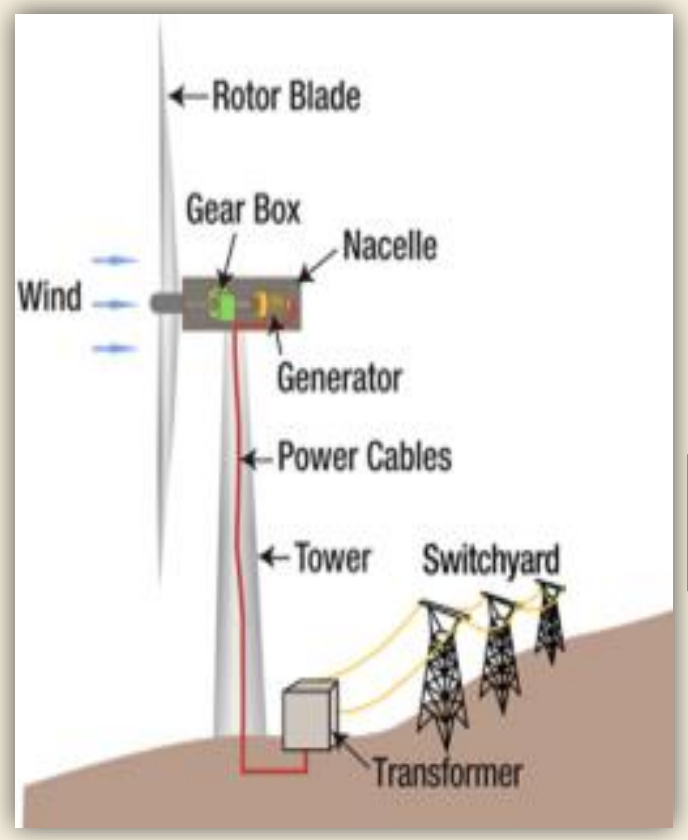


Fig. 3 – Components of a Wind Turbine (Kaylani et al. 2021)

Kinetic energy from the wind.

↓

Rotational movements of rotor blade.

↓

Rotation of the turbine through the gear box.

↓

Electrical energy produced in the generator.

↓

Electrical energy carried through power cables to transformer.

↓

Frequency and current type matched and exported to grid.

PHYSICS OF WIND ENERGY

$$\text{Power [W]} = 0.5 \times \rho \times A \times Cp \times V^3 \times Ng \times Nb$$

where,

ρ = Air density in kg/m^3 ,

A = Rotor swept area (m^2)

Cp = Coefficient of performance

V = wind velocity (m/s)

Ng = generator efficiency

Nb = gear box bearing efficiency

Equation 1.0 – Power Generation of a Wind Turbine (Sarkar & Behera, 2012).

Offshore foundations

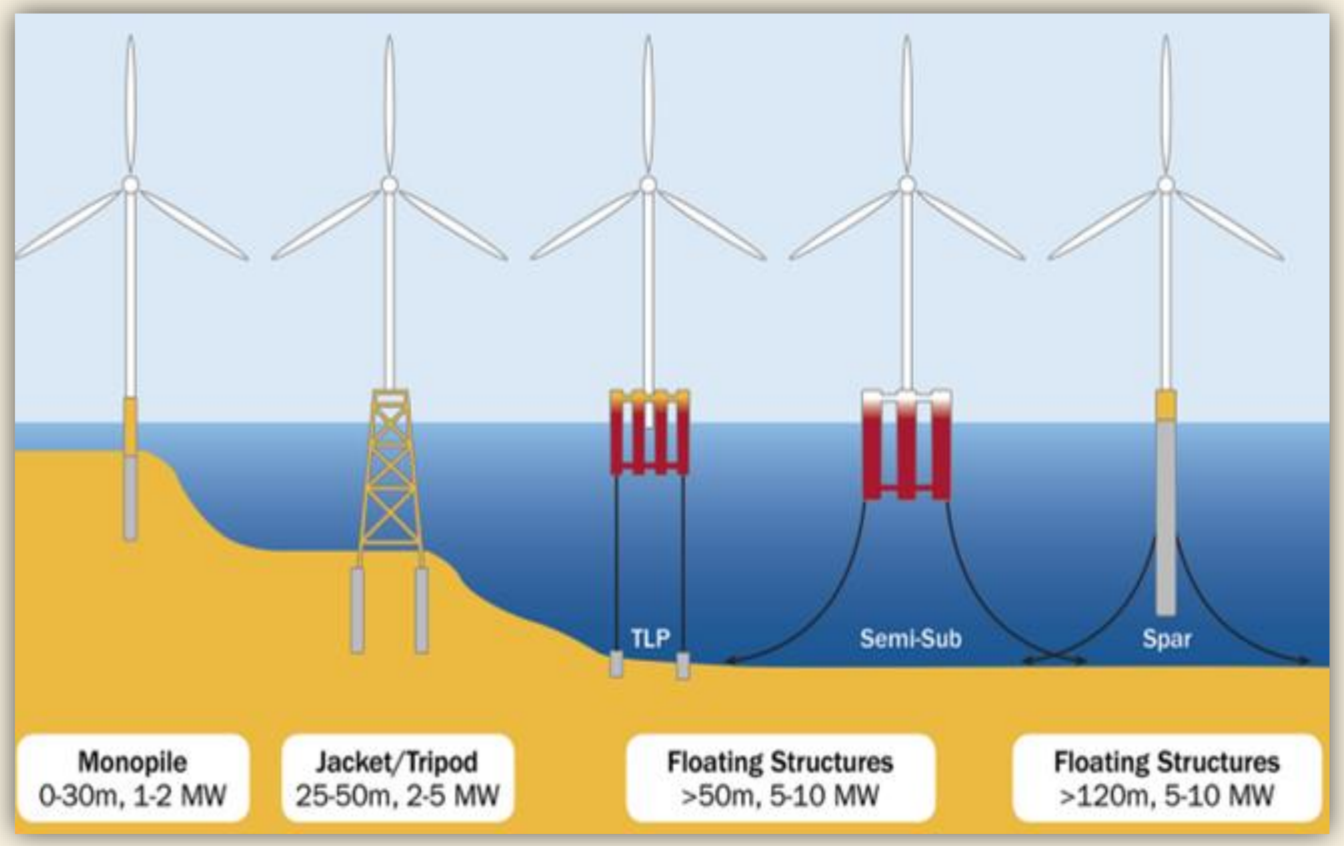


Fig. 4 – Foundation Types of OWT (Bailey et al., 2014).

Selection varies depending on:

- Distance to shore.
- Seafloor conditions and compostion.
- Turbine capacity and therefore its size.
- Budget.

BARRIERS AND ENABLERS OF OFFSHORE WIND ENERGY

WHAT ARE THE DRIVING & CHALLENGING FACTORS FOR OFFSHORE WIND?

ENABLERS AND BARRIERS OF OFFSHORE WIND ENERGY

Figures 1 & 2 show:
-Wind energy utilization increase
-More specifically, OWE increase and predicted utilization inceases.

but what exactly drives this development? What are the enabling factors and barriers?

ENABLERS

Offshore wind farms utilize less land than almost all other energy options (Poudineh et al., 2017).

- greater potential to avoid NIMBY sentiments compared to on land wind turbines.
- more land left available for other use purposes.
- less impact on land based ecological services.

Reduced wind turbulence at sea compared to inland (IEA, 2020).

- increased capacity factors compared to landbased turbines.
- More reliable weather patterns.
- Higher wind speeds.

ENABLERS

Since OWF ultimately occupy space in the water, sufficient attention needs to be placed so that marine environments are not destroyed in the build, use and decommissioning phases of wind turbines (Poudineh et al., 2017).

Interestingly however, OW has the potential to extend and modify benthic ecosystems during their operation phase leading to biodiversity change. This in itself raises some important issues, which obscure the cost-effect to ecosystem services of OWTs, and is a characteristic so far unique to OWFs (Causon and Gill, 2018).

Variability of effects on Ecosytem Processes.

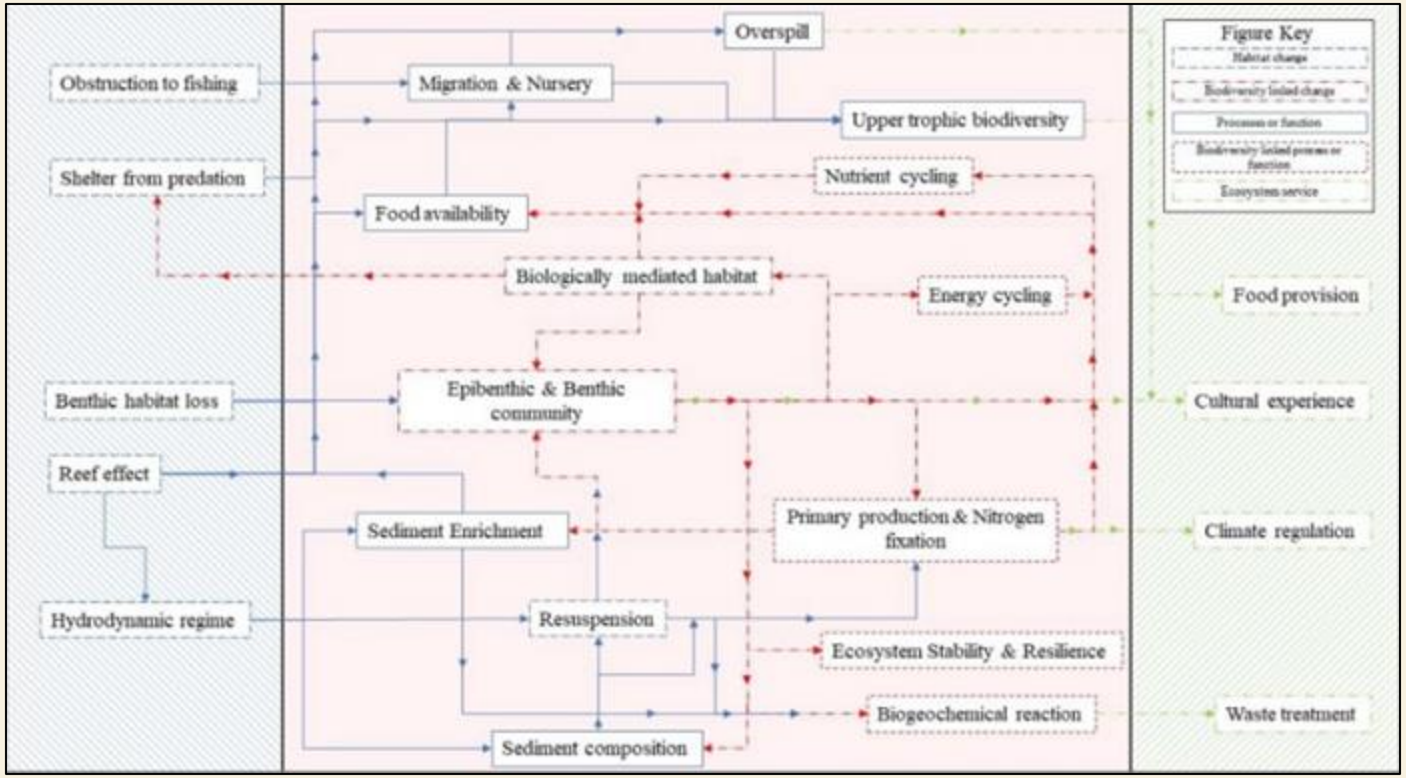


Fig. 5 - Biodiversity mediated linkages between habitat modification, ecosystem processes and functions, and the provision of ecosystem services in relation to offshore wind farm structures. Zones represent direct changes (blue hatching – left), secondary changes effecting processes and functions (red – centre), and linked ecosystem services (green hatching – right). Taken from (Causon and Gill, 2018).

Positive Environmental Considerations

The potential to utilize OWT foundation structions to influence marine biodiversity can forder interesting research projects, which have the potential to increase biodiversity and coral reef coverage in coastal waters (Causon and Gill, 2018).

OWFs might help:

- commercially exploited species recover,
- safeguard migratory populations and juveniles,
- promote higher trophic biodiversity, and even
- This would support human food provision as well as cultural events such as fishing and wildlife enjoyment as seen in Figure 5 (Causon and Gill, 2018).

ENABLERS

Lastly;

- OW is in a category of its own as the only variable baseload power generation technology. Due to
- High capacity factors, ranging from 40-50%, rivaling that of efficient gas-fired power plants and coal plants in some regions.
- Although wind output varies with wind speed, its hourly variability fluctuates minimally compared to other renewable energy sources. For example, 20% from hour to hour, while solar can fluctuate 40% between hours during the day and even up to 100% variability between night and day (IEA. 2020).

BARRIERS OF OFFSHORE WIND ENERGY

According to Poudineh et al. (2017), OW has been historically more expensive than its onshore counterparts have. This is due primarily to the increased risks with building, operating and conducting maintenance in marine environments, which are generally harsher than inland environments.

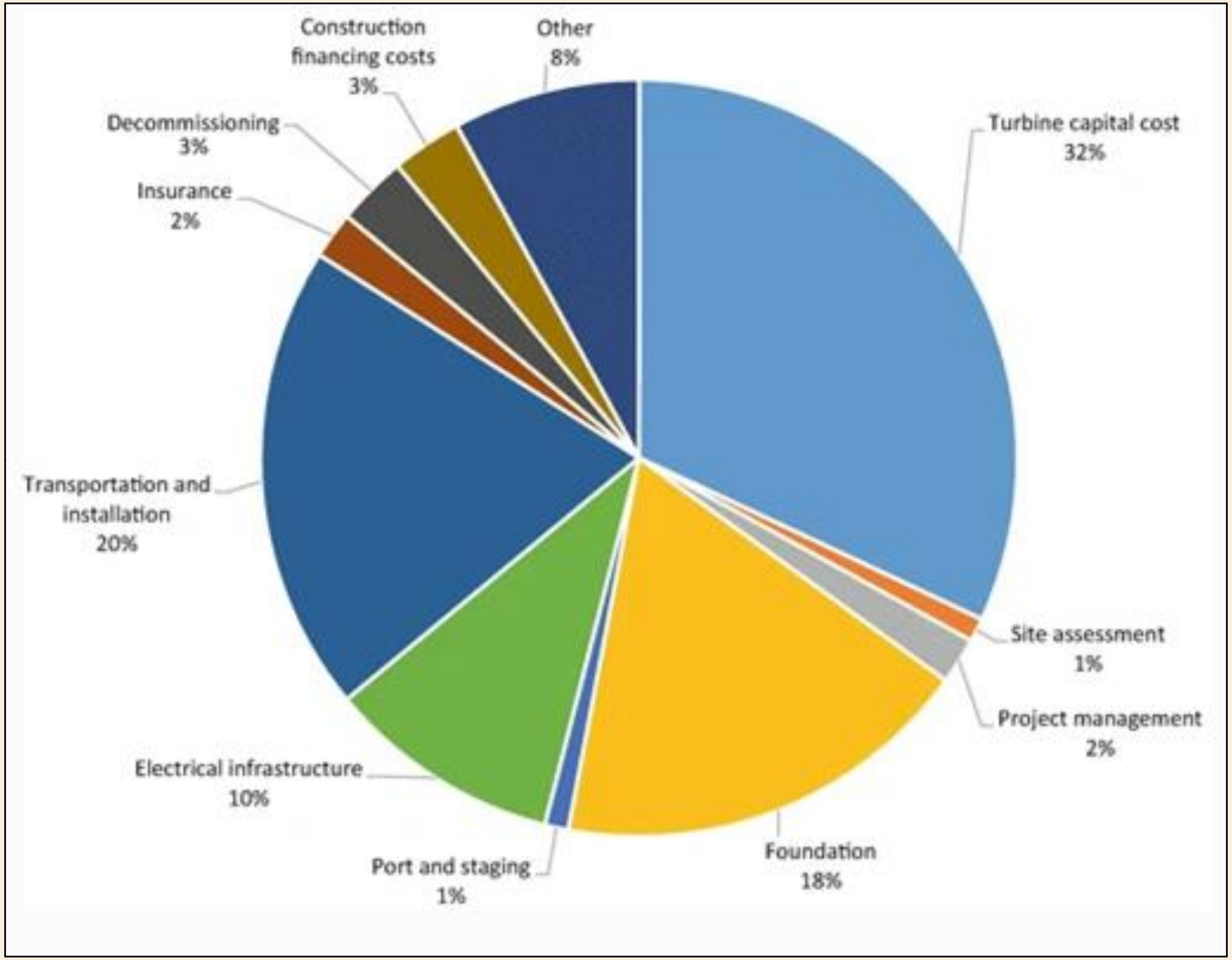


Fig. 6 – Cost breakdown During the Life Cycle of an Offshore Wind Farm (Poudineh, 2017).

COSTS COMPONENTS FOR CONSIDERATION.

- Turbine capital costs account for the largest costs during turbine life cycle.

- Transportation and installation of the turbine. this is a highly specialized task, often requiring specialized ships, equipment and assembling apparatus. weather conditions affect time frame and costs.

- Construction of the underwater foundation.

BARRIERS OF OFFSHORE WIND ENERGY

Also important in foundation design is the distance away from the shore and the depth of water for the installation. Greater distances and depths tend to increase planning complexities and consequently, costs (Poudineh et al., 2017).

- the length of subsea cable requires the positioning of the transformer at sea or on the shore, and dictates the ease of accessibility for maintenance operations.

Other barriers and limitations to OW include:

- intermittency of wind in general (more relevant for onshore wind plants),
- grid connection cost and responsibility management,
- the ecological impact of the turbines of marine ecosystems and coastal birds. Reported ecological impacts in 2008 include bird and bat collisions; temporary or permanent habitat loss of fish and other marine animals; fragmentation of breeding, feeding, and migratory routes; disturbance of behaviour and stress; and alteration in the plant and animal community composition (OSPAR, 2008).

Public perception and attitude can have a tremendous influence as well:

- visual impact eg. Residents prerogative as to how thier coastlines should appear.
- the possibility of it affecting their health and well-being. In the past, including public opinion has often extended the time taken for a project to be approved, and is a considerable factor to bear in mind while planning OWF as well (Poudineh et al., 2017).

THE POSSIBILITY OF OFFSHORE WIND IN BARBADOS

Source: Chabad of Barbados
https://chabadbarbados.com/

Barbados at a glance...

- Barbados is an independent island nation in the Caribbean Sea.

- Population size of 287,973

- yearly consumption of 24,537 kWh (Ritchie et al., 2020).

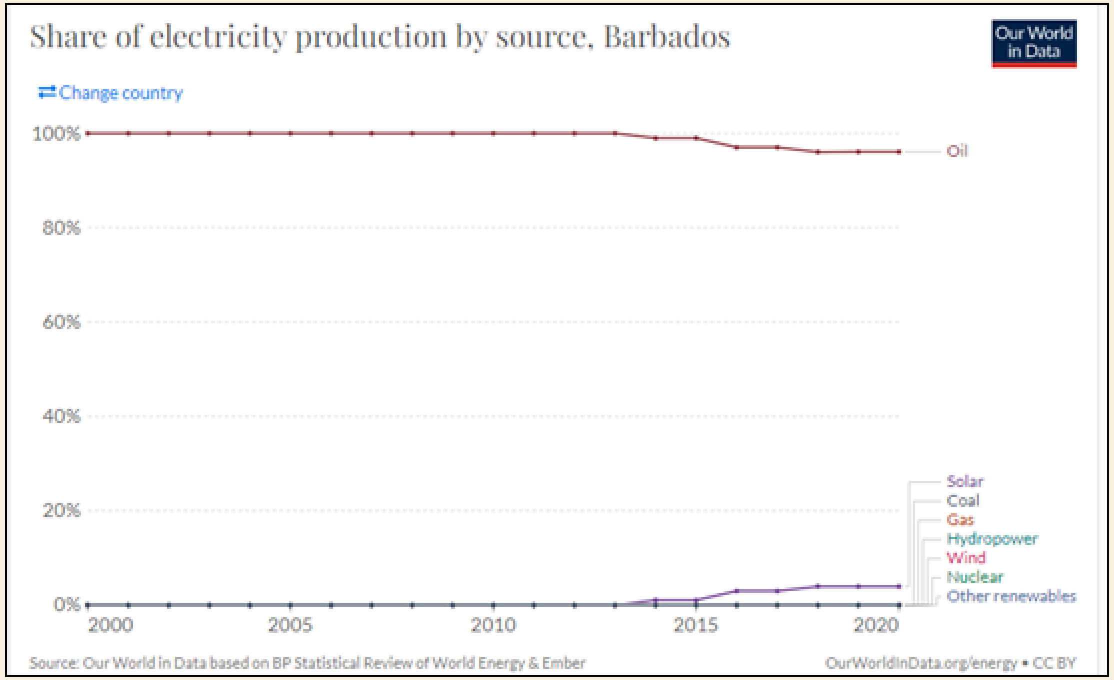
- The total consumption is 990million kWh.

- Total energy production is 102% the consumption needed; 1 billion kWh.

Currently, the price of electricity in Barbados is USD $0.289/kWh (ETI, 2015).
By global standards this is high; fitting in 4th position in a catalogue from Statista (2021) on household electricity prices worldwide.

… But how is this electricity produced?

Electricity Production Share: Barbados.



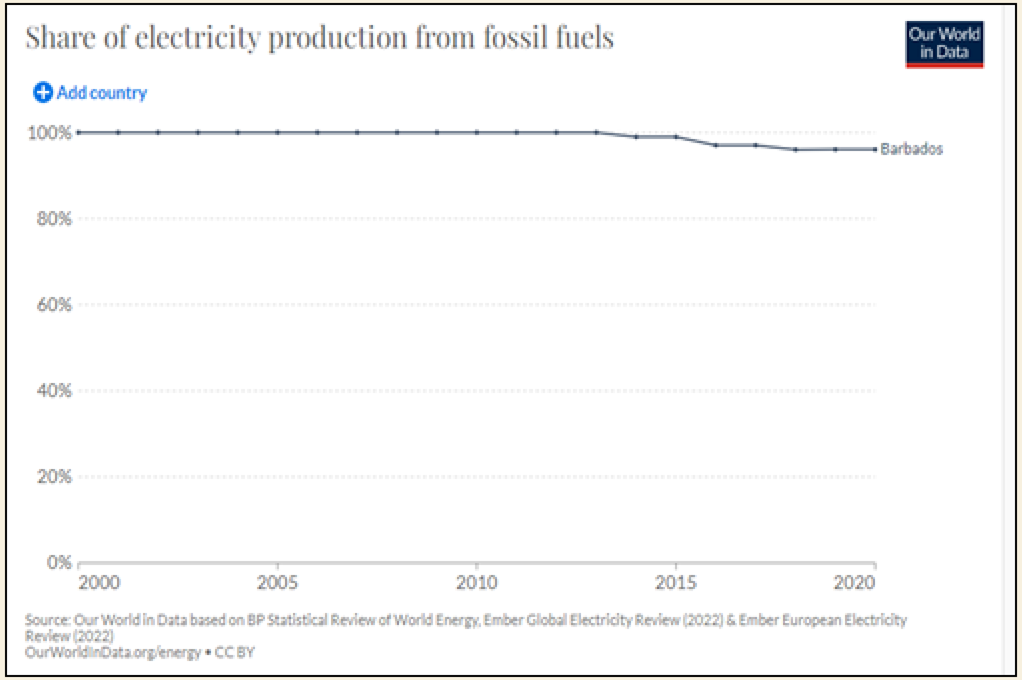


Fig. 7 – Share of electricity production by source, Barbados (Ritchie et al., 2020).

Fig. 8 - Share of electricity production from fossil fuel, Barbados (Ritchie et al., 2020).

Wind Quality & Consistency: Barbados

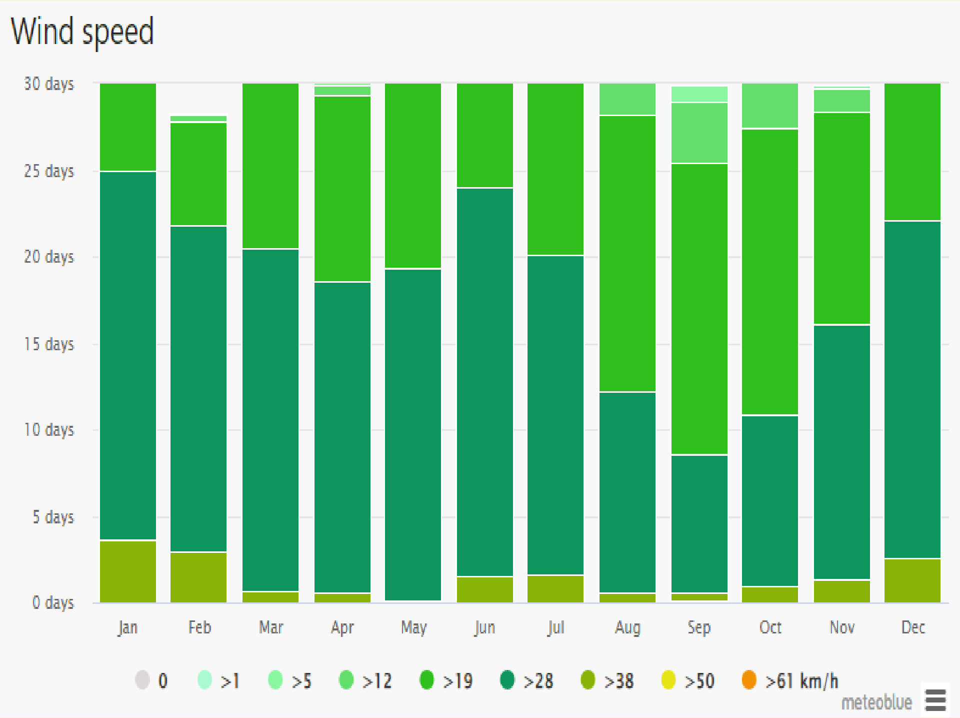


Fig. 9 - Aggregated wind speed/hr data over the last 30 years. Barbados (Meteoblue, 2022).

Fig. 10 – Direction of Wind origin, aggregated over last 30 years, Barbados (Meteoblue, 2022).

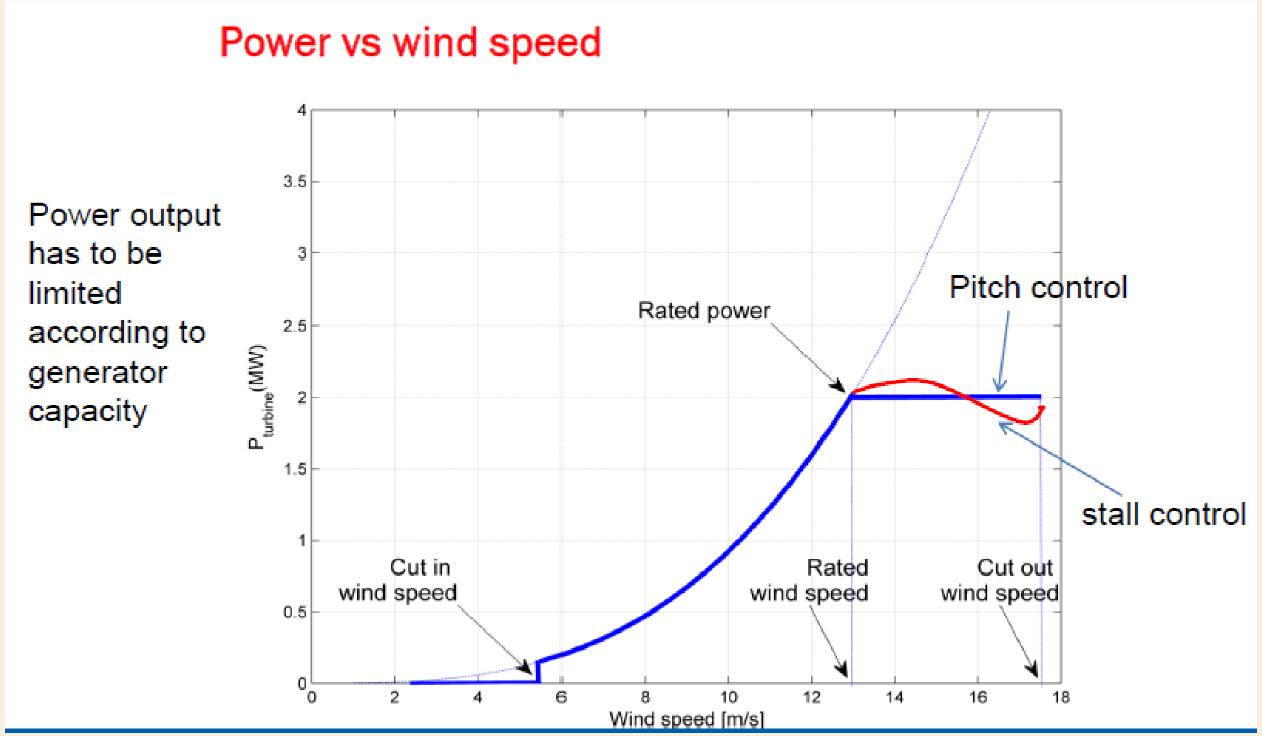


Fig. 11 - Optimal Wind Speed (Sajeer, 2019).

Wind Quality & Consistency: Barbados

From 2014-2022 The mean annual wind speed over the years has been 6.84m/s (Weather Spark, 2022). Wind speeds on and around the island are for most of the year favorable; although a slightly higher wind speed may be optimal, the nature in consistency and direction would have strong potential for a wind farm on the eastern side of the island.

Sajeer (2019) explains optimal mean wind speeds are relevant to the turbine generator capacity. Generally above 5.5m/s is a good cut in windspeed. Barbados shines here, having an mean windspeed of 6.84 m/s!

Comparing Energy Economic solutions with a LCOE

Table 1 – Unsubsubsidized Levelized Cost of Energy Comparison, adapted from Lazard (2014).

Technology	Price Range ($/MWh)
Offshore Wind	~ 162
Diesel Generator	297 - 332
Coal	66 – 151
Nuclear	92 – 132
Gas Combined Cycle	61 - 127

*LCOEs consider capital costs, fixed costs, variable costs and fuel costs. Averages from these areas are collected from many companies around the world and put together in order to compare different electricity generation technologies (EIPT, 2015).

- The diesel generator was the most expensive alternative per MWh of all generation techniques.

- By choosing this method, Barbados leaves a great deal of potential open for reducing electricity costs.

- Barbadian residential electricity cost equal $0.289/kWh (or $289/MWh); the lower end of the estimate in Table 1.

- offshore wind energy could cut cost to $162/MWh (or $0.162/kWh), that is almost half the current price!

Further Considerations

Pros	Cons
Great wind profile	…
the sea to land ratio of the island	…
the levelized cost analysis; cheaper energy	
OWE is environmentally cleaner than the current generators	
Possibly good environmental projects can be coupled to OWT to help marine life.	

Further Considerations: Cons

These technical factors and limitations stretch a long list including,

- integrating OWE into the existing grid,
- managing the responsibility and managing the running efficiency of the base load demand of electricity for the generators.

Before an OWF can be planned, more research needs to be done

- to choose the depth for the wind turbines,
- avoiding coral reefs,
- receiving public acceptance from the surfing associations, sailing associations and residents utilizing and living on this coast of the island.

More research needs to be carried out on the appropriate foundation type and the aerodynamic and hydrodynamic feasibility of it all in the changing wave and wind environment present on the eastern side of the island.

Finally, the logistics and maintenance methods would also need to be outlined. These factors unfortunately lay outside the scope of this report and are imperative to the question of the economic feasibility of OWE in Barbados.

More Research needed to better determine economic practicability of OWE in Barbados!

CONCLUSION

Based on the findings put forward; OWE can be an energy economic solution to electricity generation! But its success depends:

- Available water surface at the coast of a country that can be utilized.
- The depth of the water.
- The distance from the shore.
- The distance of the demand away from the offshore windpark; ost related to investment in grid infrastructure and grid planning logistics.
- The cost of alternative energy sources.

At the moment, investment into the technology is heavily reliant on state subsidies to stay afloat (Poudineh et al., 2017). This is also an important factor influencing initial investment into OWE projects, and offering a stable electricity price against natural gas and coal electricity prices.

However, LCOEs, define costs narrowly; economic externalities are not considered (eg. air pollution or climate change impacts) (EIPT, 2015). With an all encompassing “definition” of costs, renewable/low carbon technologies would perform even better than fossil fuels.

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