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# Review of Recent Advances of Wind Energy

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**Abstract** This paper presents a review of the recent advances of the wind power. The wind power is a very clean and renewable alternative to the burning fossil fuels and has no impact on the environment. The energy scientists are in knowledge of the world needs to increase the clean energy sources. The impact of the classical process for generating the power on the environment has created a need for a strategic planning and development of the clean and sustainable power systems of generation. This paper focuses on the recent aspects of the wind power and the technology including several technical issues.

***Keywords:*** *sustainable, wind, energy, power, turbines, offshore, onshore, solar, photovoltaics (PV), megawatts (MW), gigawatts (GW)*

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## 1. Introduction

The wind is one of the most important natural resources for the world. Several ways and systems are being used to obtain the energy from the wind. The wind quality and strength are mostly effected by the weather changing and the instability warming around the world. The speed and the direction of the wind control the properties of the wind. The speed rise depends on the location like onshore and offshore [1,2]. The wind speed and the power curve of the turbine are very important for the capacity of the wind energy and in air density changes. The size of the blades of the wind energy depends on some parameters. One of the most important parameters is the average air density of the site. Many factors like the air temperature, the air pressure, and the tower's height for the desired location should be studied very carefully. Moreover, it is very important to critically design the correct size of the blades. Also, the atmosphere is very important for the design and the calculation of the expected power generation capacity after installation of the wind power system [3,4]. In 2016, the wind power capacity increased to 486.8 GW around the world. The wind power usages have increased in the past few years in most of countries around the world including Denmark, Portugal, Ireland, Spain, Cyprus, Germany, China, USA and Canada. The rate of increasing between countries varies from 5.5% to 40% [2]. Figure 1 shows the cumulative installed capacity in 2017 up to 539 GW for different countries around the world [3].

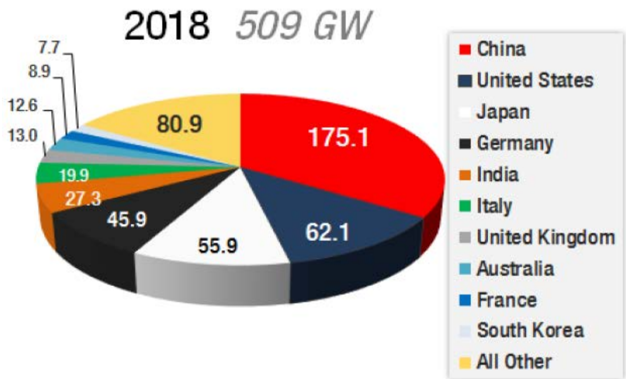


**Figure 1.** Top ten cumulative installed capacity in 2017 [3]

## 2. Wind Turbines

The wind turbines are used to convert the wind energy to mechanical energy, but they need windy areas to working very well. However, the wind turbines have challenges that effect the environment with crowded populations by two parameters: application and operation, which are related to their intense generate noise and highly efficient of the wind, possibility to safety risk, and increase the price, etc. Therefore, there is an urgent need to find suitable solutions for these applications to automatic sensors and observation devices in civilian environments. When the kinetic energy converted into mechanical energy and after that covert the mechanical energy into electrical energy that operation system is called system of the wind turbine. Some component like towers, generator, gearbox, power electronics components, and the propeller are used for the wind power generation [1-6]. Usually, the wind turbines will start to generate the electrical energy as the wind speed increasing. The most important part of the wind energy system is the wind turbines. Figure 2 shows the internal parts of the turbine [6].

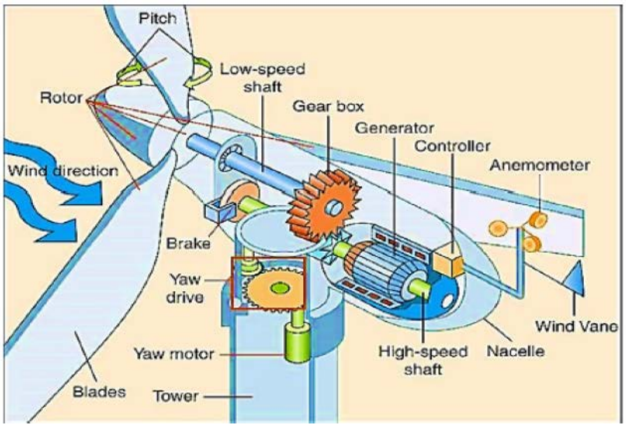


**Figure 2.** Inside wind turbines [6]

## 2.1. Parts of Wind Turbine

The wind turbine system consists of the following parts:

1. **Anemometer:**
   It is used for measuring the wind speed and for transmitting speed data to the controller [6].
2. **Blades:**
   Most of the turbines possess different number of blades. The air flow causes the blades to rotate and generate power [6].
3. **Brake:**
   The brake is used to stop the shaft in case of emergency [6].
4. **Controller:**
   It is used for starting up, and controlling the machine speed in the range of 8-16 mph. Also, it is used to shut off the turbines as the speed exceeds 65 mph. Turbines are not capable of operating 65 mph. This is due to their generators which might overheat [6].
5. **Gear box:**
   The main function of gear is to rise the speed from the high-speed shaft to another shaft. It is connected direct to the generator. For example: the count of speed around (30 to 60) rotations per minute from the first shaft and the second shaft will rotate about (1200 to 1500) rpm that for generate electricity [6].
6. **Generator:**
   It is the most important part of the wind energy system. It is used to produce the A.C. electricity [6].
7. **Shaft:**
   It is used for changing the low speed to high speed by the rotor [6].
8. **Nacelle:**
   The rotor attaches to the nacelle that fixed at the top of the tower. It consists of the gear box, low- and high-speed shafts, generator, brake, and controller. A cover is used to protect it [6].
9. **Pitch:**
   It is used to stop blades or to increase the speed in case of high and low power generation [6].
10. **Rotor:**
    It consists of blades and hub [6].
11. **Tower**:
    The quality of power generation depends on the height of towers. Towers are made of steel. The towers are like tubular tower and there is space inside it that can help the technicians through to up by the elevator for maintenance [6].
12. **Wind Vane:**
    It is a sensor to track the wind's flow and communicate with yaw to change the direction of the blades [6].
13. **Yaw Drive:**
    It is used to track the wind direction [6].

# 3. Types of Wind Turbines

There are two major wind turbine types, the horizontal axis wind turbines (HAWT) and the vertical axis wind turbines (VAWT). ln the HAWT there is a major rotor shaft and electric generator. The gearbox converts the heavy rotation of the blades into a faster rotation, which is convenient for driving to generate electricity [7]. It has the major rotor shaft designed vertically. The main advantage of this system is the high effectivity. Moreover, it can generate power form variable direction of the wind. The winds from different directions can be used by VAWTs. In general, the performance of the horizontal axis turbines in the extraction of the wind power is greater than that of the vertical axis turbines. Therefore, most of the commercial wind turbines are based on the horizontal axis turbines. On the other hand, VAWTs are a wind turbine type that is much less used. However, recent developments have led to important new trends in the use and benefits of VAWT technologies provided by researchers and manufacturers [5]. Figure 3 shows the average rotating power factor (Cp) to the speed ratio variation curve (TSR) in different types of the wind turbines [5,6].

## 3.1. Global Wind Energy Capacity

Among other renewable sources, the wind energy has risen quite rapidly. It can be used to meet the world's electricity needs. It is sustainable, local and renewable. The wind energy has a significant return on the investment comparing with the other renewable energy technologies. At the end of 2017, the total annual growth in the installed global wind power capacity exceeded 539 GW. It has a growth of 52 GW (10.6%) compared to 2016 as shown in Figure 4. China has addition of 19.6 GW in the wind power industry in 2017 from previous years. The capacity of the USA, France, UK and India are 7,017 KW, 6,581 KW, 4,270 GW and 4,148 GW respectively [3].

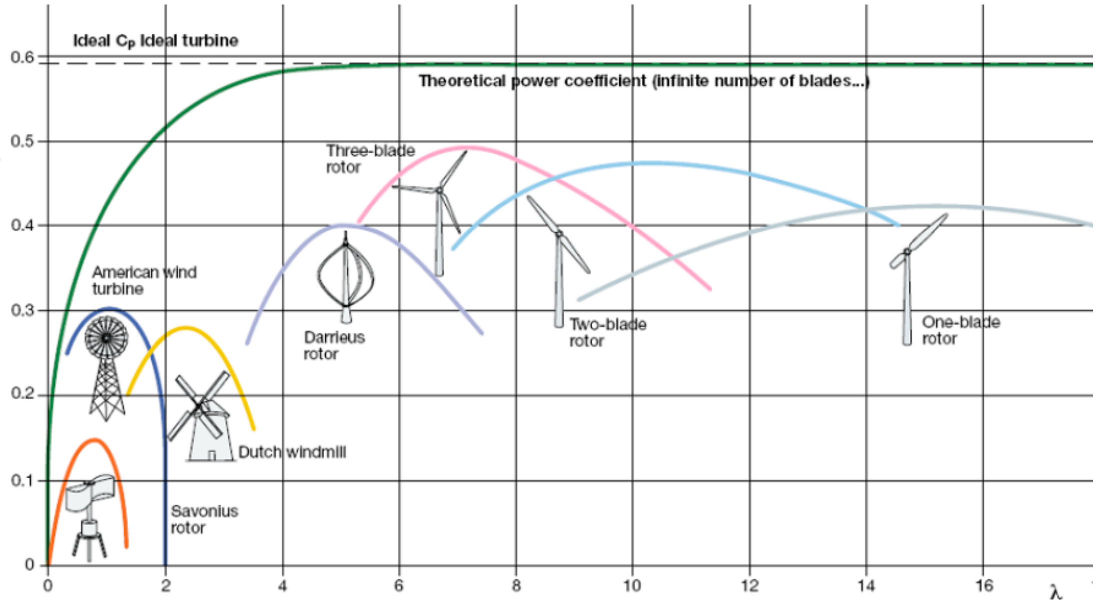


**Figure 3.** Cp to TSR in different types of wind turbines [5]

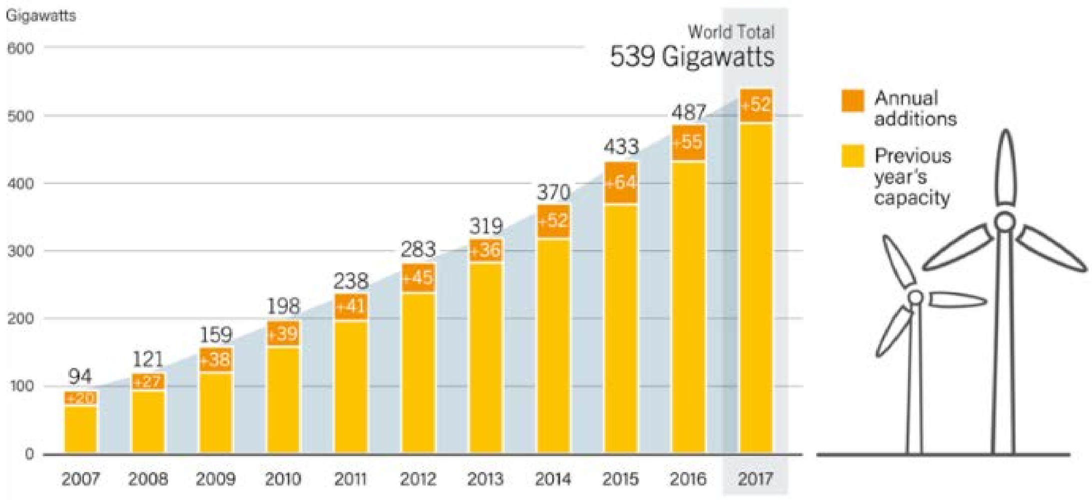


**Figure 4.** Global cumulative installed capacity 2007-2017 [8]

## 3.2. Power Electronics Applications in Wind Energy Conversion

The power electronics are an essential part of the Variable-speed Wind Energy Conversion System (WECS). This enables the incorporation of variable velocity wind systems to achieve high efficiency and performance when connected to the grid. In addition, the power electronics switches, such as thyristors, are used as an easy start to the fixed-speed WECS system, where the system is connected directly to the network. The power electronics transformers are used to align the wind generator characteristics with the network connection specifications such as frequency and voltage, active and reactive power control, harmonics, etc. [9].

# 4. Wind Energy Conversion System Description

The major elements of the wind turbine network are shown in Figure 5. These elements are the wind turbine rotation through the synchronous generator gearbox. The generator is connected by the transmission line and the transmission network of power electronics to electrical network [10]. The different steps are used to generate the electric power. The mechanical energy is produced by the wind that rotates on the wind turbines. The synchronous generator transforms this mechanical energy into electrical energy. Figure 6 shows an embedded block diagram that describes these processes using the Adaptive Model Prediction Control (AMPC) [10]. The wind turbines use the turbine blades to graph the wind power and to convert it into mechanical power. The control and the limitation of converted mechanical power during higher wind speeds is very critical and can be achieved by stalling, stalling or effective pitch [9]. The wind energy conversion system (WECS) can be divided into two groups according to the rotational speed; constant speed and variable speed. For variable speeds, WECS can also be divided into wind generator systems using a full and partial electronic transformer at the rate of the power transformer associated with the generator capacity [9].

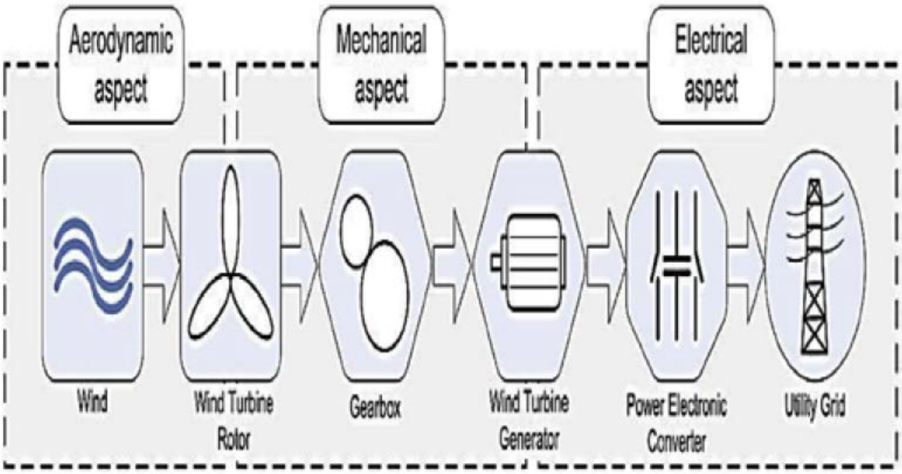


**Figure 5.** Main elements of wind energy conversion system [10]

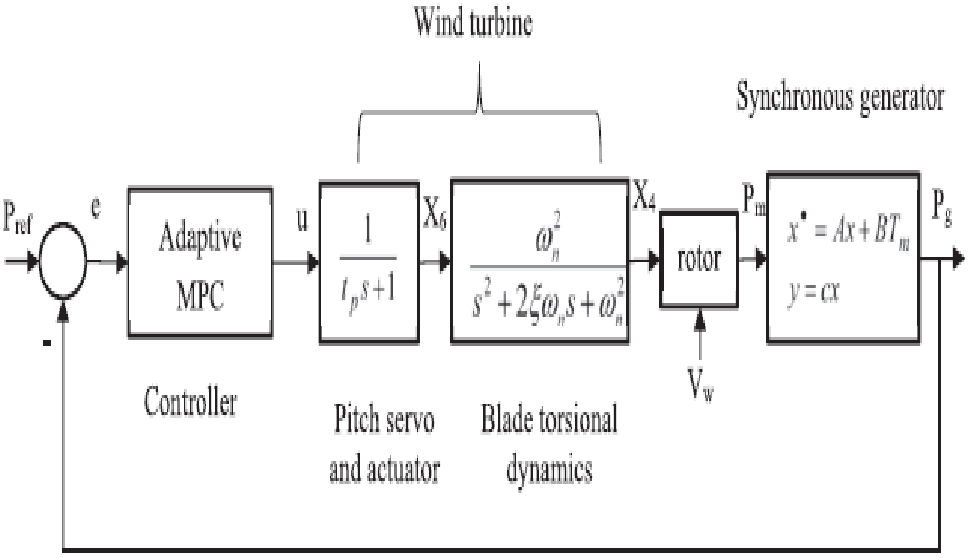


**Figure 6.** Block diagram of the WT with BPC [10]

## 4.1. Offshore Wind Outlook till 2019

The offshore wind is a rapidly growing and spreading source of renewable energy technology. Despite just providing 0.3% of global electricity supply in 2018, its prospects look promising [11]. The physical size of each offshore wind turbines has been enlarging and rated power capacity, leading to increase performance gains for offshore wind installations [11]. Further technology improvements are promising steep cost reductions in the near term [11]. The offshore wind power explores the key uncertainties for the outlook, looking at both the potential for faster growth and the main challenges that could slow development [11].

## 4.2. Current Status of Wind Energy

The offshore wind became one of the most dynamic technologies in the energy system. In 2010, the offshore wind global the capacity additions surpassed 1 GW. In 2018, a total of 4.3 GW of new offshore wind capacity was completed as shown in Figure 7 [11], from 3 GW of the offshore wind in operation in 2010, installed capacity expanded to 23 GW in 2018. The annual deployment has increased by nearly 30% per year, higher than any other source of electricity except solar PV [11]. By mid-2019, there were over 5500 offshore turbines connected to a grid in 17 countries [11]. The regulation and policy support have been fundamental to this expansion, including; Through technology-specific capacity tenders, progress on including offshore wind in marine planning and financial support and regulatory efforts to support grid development. Due to the geographical location of European countries bordering the North Seas, the growth of the offshore the wind industry was fostered where high quality wind and relatively shallow water offered exceptionally good conditions for the development and marketing of the offshore wind technologies [11]. The wind energy has a flexible and stable policies supported nearly 17 GW of the offshore wind capacity additions in Europe between 2010 and 2018 [11]. The United Kingdom, Germany, Belgium, Netherlands and Denmark together added 2.7 GW of capacity in 2018 [11]. Recently, China has taken steps in the direction of the offshore wind and is now one of the market leaders. China installed about 1.6 GW of the offshore wind power in 2018 [11]. This rapid growth has been driven by the government's 13th Five-Year Plan, which called for 5 GW of the offshore wind capacity to be completed by 2020 [11].

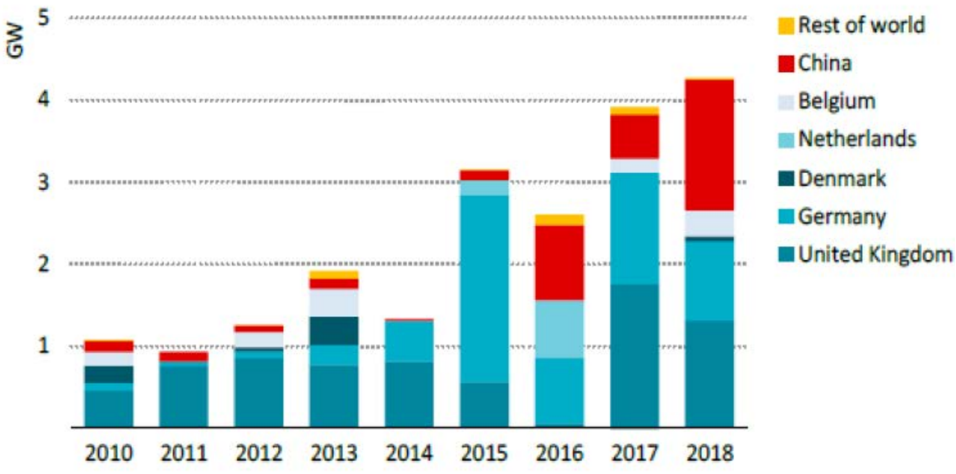


**Figure 7.** Annual offshore wind capacity additions by region, 2010-2018 [11]

**Table 1. Leading market players in the offshore wind industry, 2018 [11]**

| Rank | Company | Offshore wind market share, 2018 | Offshore wind market share, 1995-2018 | Offshore wind capacity sold, 1995-2018 (MW) |
|---|---|---|---|---|
| 1 | Siemens Gamesa | 41% | 63% | 13 881 |
| 2 | MHI Vestas | 30% | 18% | 3 882 |
| 3 | Envision | 15% | 4% | 804 |
| 4 | Goldwind | 8% | 3% | 574 |
| 5 | Ming Yang | 2% | 1% | 113 |
| 6 | Sewind | 2% | 1% | 306 |
| 7 | GE Renewable Energy | 0.4% | 1% | 177 |
| 8 | Taiyuan | 0.2% | 0% | 10 |
| 9 | Senvion | - | 6% | 1 253 |
| 10 | Bard | - | 2% | 405 |

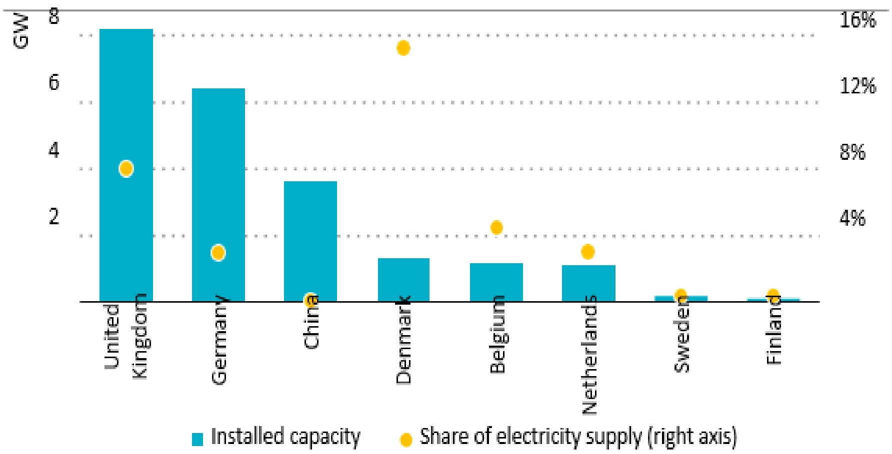


**Figure 8.** Offshore wind installed capacity and share of electricity supply by country in 2018 [11]

The offshore wind is set to gain a trend renewable energy in new markets in the next five years. The current pipeline includes about 150 new offshore wind projects spread across 19 countries [11]. Over 100 projects are scheduled to be completed by 2021, pointing to further acceleration in the rate of annual capacity additions [11]. In the United States, there are 25 GW of the offshore wind projects in the longer-term pipeline (US DOE, 2019) [11]. In addition, there are also large-scale projects in India, Japan Chinese Taipei, Australia, Korea, New Zealand, Turkey and Viet Nam [11]. In Europe 2018, more than 80% of the global installed offshore wind capacity was located on it. Around 8 GW, one-third of the total, was in the United Kingdom and 6.5 GW in Germany, with Denmark, Netherlands and Belgium providing a further 3.6 GW between them [11]. Even as a relative newcomer, China already has 3.6 GW of offshore wind capacity as shown Figure 8 [11].

### 4.3. Market Size and Key Player

Today, the offshore wind is a great business, with developed supply chains in leading markets that span development, project construction and installation, operation and maintenance, and decommissioning activities [11,12,13,14].

The offshore wind industry attracted a growing share of investment in wind and renewable energy in recent years, nearing $20 billion in 2018, up from less than $8 billion in 2010. The investment in the offshore wind in 2018 accounted for nearly one-quarter of global investment in the wind sector and 6% of all investment in renewable energy [11,12,13,14]. Accounted for just 0.3% of global electricity supply in 2018 but played a larger role in the leading countries [11,12,13,14]. It provided 15% of electricity generation in Denmark in 2018, where the onshore and the offshore wind together accounted for almost 50% of electricity generation [11,12,13,14]. The offshore wind provided 8% of electricity generation in the United Kingdom, more than twice as much as from solar PV generation, and for 3-5% of electricity generation in Belgium, Netherlands and Germany [11,12,13,14]. Despite the recent growth, output from China's offshore wind fleet in 2018 represented just 0.1% of its overall power output [11,12,13,14]. Investment was particularly pronounced in the European Union, where offshore wind accounted for about half of total investment in wind power in 2018 and one-quarter of total investment in renewable energy (IEA, 2019a).Investment in offshore wind projects is mainly by large utilities and investment funds because the projects have relatively high upfront capital costs: a 250- MW project costs around $1 billion. The solar PV and onshore wind by contrast have lower upfront costs and present fewer barriers to entry for smaller players [11,12,13,14]. Table 1 and Table 2 show the leading market players and the leading manufacturing in the offshore wind industry, 2018 [11,12,13,14].

**Table 2. Leading manufacturers of offshore wind turbines, 2018 [11]**

| Rank | Company | Offshore wind market share, 2018 | Offshore wind market share, 1995-2018 | Offshore wind capacity sold, 1995-2018 (MW) |
|---|---|---|---|---|
| 1 | Siemens Gamesa | 41% | 63% | 13 881 |
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| 10 | Bard | - | 2% | 405 |

### 4.4. Offshore Wind Technology and Performance

The offshore wind technology has made impressive advances since the first turbines were installed near the shore in Denmark in 1991 [11,12,13,14]. Since then, equipment suppliers have focused research and development spending on developing bigger and better performing offshore wind turbines. The technology has grown dramatically in physical size and rated power output [11]. Technology innovation has led to an increase in the turbine size in terms of tip height and swept area, and this has raised their maximum output. In 2016, the turbines capacity is rise from 3 MW to 8 MW, and its growth from 100 meters to 200 meters [11]. The larger swept area allows for more wind to be captured per turbine. It is estimated that a 12 MW turbine currently under development will exceed 260 meters or 80% of the Eiffel Tower's height as shown in Figure 9 [11]. The industry is targeting even larger 15-20 MW turbines for 2030 [11]. This increases in the turbine size and rating has put upward pressure on capital costs as larger turbines pose construction challenges and require larger foundations, but it has also reduced the operation and maintenance costs, ultimately leading to lower levelized costs of electricity [11,12,13,14].

The institutions are working to development the turbines so in this time turbines are expected to reach 260 meters, or 80% of the height of the Eiffel Tower. The industry is targeting even larger 15-20 MW turbines for 2030. This increase sin turbine size and rating has put upward pressure on capital costs as larger turbines pose construction challenges and require larger foundations, but it has also reduced the operation and the maintenance costs, ultimately leading to lower levelized costs of electricity [11,12,13,14].

The average turbine size used in offshore wind farms increased from 3 MW in 2010 to 5.5 MW for projects completed in 2018 (IRENA, 2019). In the same period, annual capacity factors for new projects increased from 38% to 43%. New turbines of 10-12 MW promise to achieve capacity factors well over 50% (before wake losses) [11,12,13,14].

Compared to smaller units, a bigger turbine can achieve a capacity factor improvement of two to seven percentage points given the same site conditions. However, not all projects will necessarily see a significant increase in performance as a result of using larger turbines [11,12,13,14]. The capacity factors remain dependent on the quality of the wind speeds of individual sites, which may not be suitable for larger turbines.

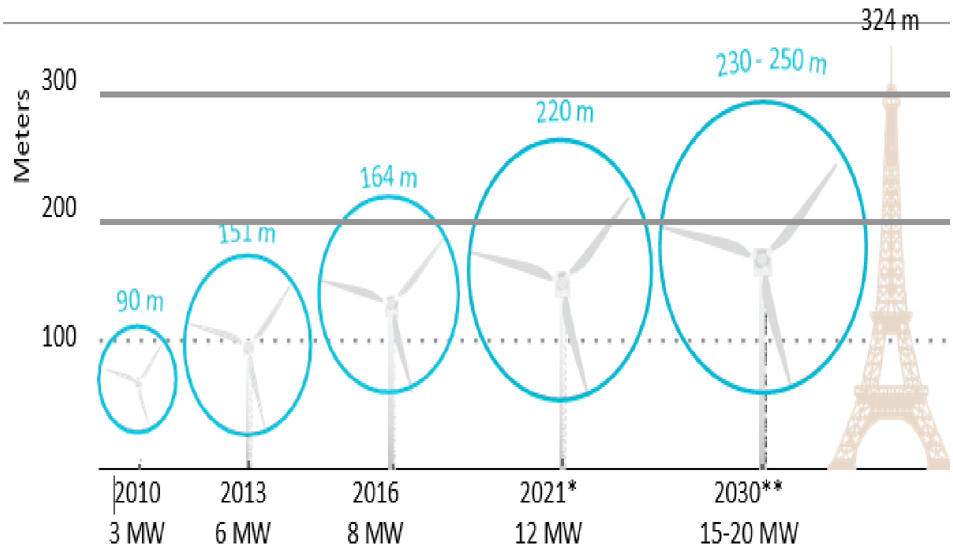


**Figure 9.** Size of wind fans [11]

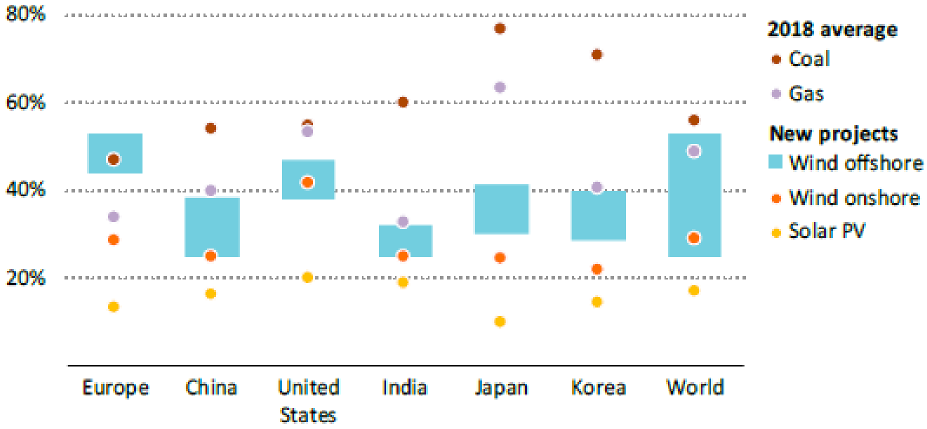


**Figure 10**. Indicative annual capacity factors by technology and region [11]

There may also be a trade-off for developers between incremental performance gains and higher costs of larger turbines [11,12,13,14]. The united offshore wind provides higher capacity factors than other variable renewables. In 2018, the average global capacity factor for the offshore wind turbines was 33% compared with 25% for the onshore wind turbines and 14% for solar PV [11]. Further, the new offshore wind projects are expected to have capacity factors of over 40% in moderate wind conditions and over 50% in areas with high quality wind resources. Other variable renewable energy technologies are also likely to see improvements, but not to match the expected capacity factors of new offshore wind projects [11,12,13,14]. For example, technology improvements are raising expected capacity factors for the onshore wind to between 30% and 40% in most regions as shown in Figure 10 [11]. The capacity factor describes the average output over the year relative to the maximum rated power capacity. The wake loss refers to the effect on the space behind a turbine that is marked by decreased wind speed on a downstream wind turbine since the turbine itself used the energy in turning the blades.

## 4.5. Potential Offshore Wind Performance

The quality of the wind resources for energy production is best represented by the average capacity factor for the new wind projects, which translates the wind speeds in a given area into the average performance over the course of a year [11,12,13,14]. The last report from IRENA 2019 figure out that the speed of wind it will be increase around the world. Based on the global assessment performed for this analysis, wind resources are generally of higher quality for energy production near to the poles as shown in Figure 11. In Europe, the North Sea, Baltic Sea, Bay of Biscay, Irish Sea and Norwegian Sea, the offshore wind has average annual capacity factors of around 45-65%, which is higher than the comparable figures for the United States (40-55%), China (35-45%), and Japan (35-45%) [11]. The capacity factor is also high in regions off the coast of South America and New Zealand (50-65%). The moderate wind speeds resources in India translate to a 30-40% average capacity factor [11,12,13,14]. The average capacity factor in general is relatively low in regions nearer to the equator for example in Southeast Asia and parts of western Africa [11,12,13,14]. The detailed geospatial analysis captures varying conditions within regions, bringing out for example capacity factors in the Palk Strait between India and Sri Lanka that are well above average for the region and comparable to those found in Europe [11,12,13,14].

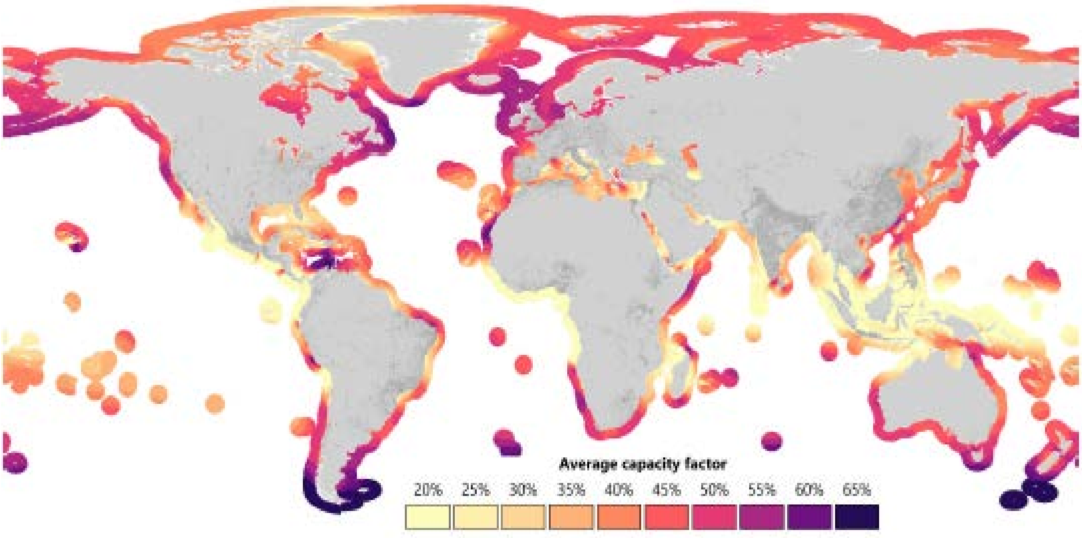


**Figure 11.** Energy production near to the poles [11]

## 5. Conclusion

In conclusion, a review of the recent advances of the wind power has been presented. It was found that it is very important to reduce the global energy-related $CO_2$ emissions. So, the wind energy the one of the best solutions for $CO_2$ emissions. On the other hand, the global offshore wind market is growing very rapidly. This rapid growth is due to the technological developments. The use of offshore wind farms can provide more than the maximum amount of electricity generated today worldwide. The offshore wind can help drive energy transitions by decarbonising electricity and by producing low-carbon fuels. The offshore wind can provide 50 % of global electricity supply in the next 20 years. The wind energy will play an important role in the world energy system. It could solve the problem of the global warming and save the planet for next generation.

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