

## Wind energy: History, basic principles, implement, environmental and economic impacts

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**Abstract.** Wind power is a conversion shape of sun power, a non-polluting, inexhaustible renewable power. Wind power is especially used to generate electricity, in comparison with conventional power, wind electricity era has no gasoline fee risk, strong electricity era expenses, and does now no longer consist of environmental expenses along with carbon emissions. In positive locations, wind electricity has emerge as much less high-priced than different generators. Wind power is one of the lowest-cost sources of electricity, and wind power facilities are mostly three-d facilities, the use of suitable machines at suitable locations, with low harm to land and ecology. The percentage of wind electricity era has grown twenty-4 instances from 2000 to 2015, and we are able to see the improvement ability of wind power. This paper especially discusses the records of wind power, financial effects, environmental impact, implementation, and concepts of wind turbines. This paper can permit readers understand the simple data and modern-day state of affairs of wind power, and feature a positive knowledge of the concepts of wind turbines.

**Keywords:** non-pollution, lowest-cost sources, three-d facilities.

### 1. Introduction

Wind electricity is a form of electricity to be had to people because of the paintings completed via way of means of air currents, and is a renewable electricity supply (inclusive of water electricity, bioenergy, etc.). The kinetic electricity of airflow is referred to as wind electricity. The better the rate of airflow, the better the kinetic electricity. People can use windmills to transform the kinetic electricity of the wind right into a rotating movement to force a generator to generate energy via way of means of transmitting the rotor (along with air-powered fan blades) to the generator via a force shaft. As of 2008, wind strength generated about 94. 1 megawatts of energy worldwide, imparting greater than 1% of the global's energy usage. Although wind electricity isn't but a chief supply of electricity for maximum nations, it has grown greater than fourfold among 1999 and 2005 [1]. In contemporary-day times, turbine blades are used to transform the mechanical electricity of air currents into electric electricity

and turn out to be generators. In the Middle Ages and historic times, windmills had been used to grind grain and pump water with the mechanical electricity collected. Wind strength is used on large-scale wind farms and in places in which the strength deliver is isolated, making a vast contribution to nearby livelihoods and development. Converting the kinetic electricity of the wind into mechanical kinetic electricity, after which changing mechanical electricity into electric kinetic electricity is referred to as wind strength technology. The precept of wind strength technology is to apply the wind to force the windmill blades to rotate, after which to growth the velocity of rotation via the velocity increaser to result in the generator to generate energy. According to windmill technology, with approximately 3 meters in line with 2nd of breeze speed, then you could begin to generate energy.

Characteristics: Wind electricity is abundant, almost limitless, broadly distributed, easy and moderates the greenhouse effect. It exists inside a positive region of the earth's surface. The common wind electricity density profile derived from long- time period measurements, surveys, and facts is referred to as the premise of electricity usage inside that region and is typically marked on maps via way of means of electricity density lines.

## **2. History of wind energy**

Wind electricity isn't simplest wind strength technology however additionally the conversion of wind electricity into mechanical electricity.

### *2.1. Wind strength for machinery*

The records of human use of wind electricity dates again to B.C. Ancient Egypt, China, and historic Babylon had been many of the first nations withinside the global to harness wind electricity.

*2.1.1. Sailboat.* Wind-powered boats originated as a method of water transportation for historic human beings dwelling withinside the sea and river regions, and withinside the early fifteenth century, Zheng He of the Ming Dynasty led a large fleet of ships on seven voyages to greater than 30 nations in Asia and Africa, all the use of wind-powered crusing ships [2]. Until 1819, whilst the primary steam-powered ships seemed, mankind's fundamental boats had been powered via way of means of the wind [3].

*2.1.2. Windmill.* The windmill itself seemed withinside the seventh century, withinside the region of present-day Iran. The invention quickly unfold throughout Europe, especially in regions in which high winds often blow, such as those of the Atlantic Netherlands, and improvements started to accumulate. Wind and water drove the turbines, which had been basically the primary factories in records. They consisted of buildings, electricity, machines, and employees, from which a product emerged. In those nations, windmills seemed withinside the thirteenth century and unfold rapidly. Later, windmills had been constructed even in regions in which water became abundant, proof of the exhaustive use of rivers and streams. The variety of windmills that existed withinside the early Middle Ages remains an unknown amount due to the fact the few lines studied do now no longer permit us to perceive whether or not they had been hydraulic or wind-powered windmills. For example, we understand that in 1300 there had been among 10,000 and 12,000 turbines in England. Nowadays simplest unbiased windmills, which started to seem withinside the overdue thirteenth century, are to be had. More accurate records did now no longer seem until the 18th and 19th centuries whilst windmill technology became developed [4].

In fact, the windmill may be used now no longer simplest for grinding flour and pounding rice, however additionally for sporting water for irrigation or use withinside the live.

### *2.2. Wind strength generates energy*

*2.2.1. July 1887 James Blyth.* Blyth became then appointed Freeland Professor of Natural Philosophy at Anderson's College in 1880 (now the University of Strathclyde) [5]. In July 1887, James Blyth, a

Scottish electric engineer, constructed the global's first wind turbine in southern Scotland. The wind turbine became constructed withinside the outside of the residence the engineer used for his vacation. It furnished energy for his residence [6]. James Blyth has due to the fact that constructed a bigger wind turbine to be utilized by a hospital. James Blyth became a top notch supporter of renewable electricity and believed that wind strength might be higher than fossil electricity, and he was hoping that wind strength might be reused withinside the future [7].

During the wintry weather of 1887- 1888, Charles F. Brush a few months after James Blyth constructed the primary wind turbine, withinside the wintry weather of 1887, Charles F. Brush constructed the world's first mechanically working wind turbine. It became additionally the primary parallel wind turbine. This wind turbine had a *rotor* diameter of 17 meters (50 feet) and one hundred forty four rotor blades made from cedar wood. Despite the huge length of the turbine, the generator is most effective to be had in a 12 kW model. This is due to the fact the common performance of gradual rotating wind mills of the American Wind Rose kind isn't specially excessive. This turbine ran for two decades and charged the batteries withinside the cellar of his mansion [8].

The Wind Energy Leader - Poul I. a. Cour Poul La Cour, a pioneer of present day aerodynamics, added the concern of wind energy engineering on the nearby excessive college in 1904 after his personal tries to construct wind mills. Meanwhile, because the direction improved and increasingly more human beings have become wind energy engineers, Poul La Cour based the Wind Electricians' Association in 1905, which had 356 individuals in 1906. In addition, Poul La Cour published the world's first journal related to wind energy technology- "Wind Power Magazine" [9-12].

1940- 1950, The F.L. Smidth Turbines during World War II, the Danish corporation F.L. Smidth constructed kinds of wind mills, each of which produced direct present day, and in 1942 the primary wind turbine with 3 blades became constructed at the island of Borg and have become a part of the island's power supply. And by 1951, the asynchronous alternator changed the direct present day generator. On Borg, a 35 kW asynchronous alternator changed the authentic DC generator and have become the island's 2nd wind turbine [13].

*2.2.2. Wind energy improvement & innovation withinside the 1980s.* In 1980, exceptional wind mills commenced to compete. Christian Riisager commenced to layout his personal wind mills round 1980, primarily based totally at the conventional Gedser wind turbine, which protected a vertical axis Darrieus device, a device with energy manipulate the use of flaps or hydraulics for transmission systems, etc. Typical energy technology can attain eleven Kw [14].

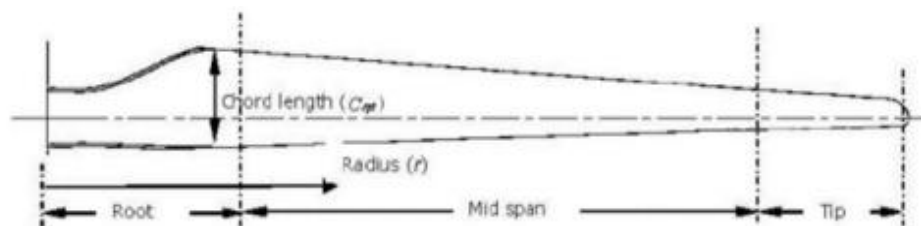
The country of wind energy withinside the twenty first century Today, wind power is the most important present day renewable power supply with mounted ability at the planet, a long way exceeding the variety of different options together with photovoltaic, thermoelectric, tidal and geothermal. After studying the historic tendencies of wind power improvement, it could be inferred that maximum international locations will boost up the improvement of wind power withinside the future, as maximum of them begin to be aware of environmental issues.

### **3. Technology in wind energy**

In general, the procedure of the wind turbine is a procedure to switch the kinetic strength to the electricity. In the government's article, which is aimed to tell the resident about how the wind turbine works (Energy.gov,2022), it stated that the wind turbine that carries a propeller-like blades, that is looks as if the wings in an airplane. When the wind blows, a pocket of low-strain air paperwork on one aspect of the blade. The low-strain air pocket then pulls the blade in the direction of it, inflicting the rotor to turn. Which is referred to as raise withinside the physics. The pressure of that strain is tons better than the pressure of the wind's pressure while towards the blade it's miles the downward pressure, that is referred to as drag. The aggregate of raise and drag reasons the rotor to spin like a propeller. And the kinetic of the pressure distinction among the raise and drag makes the axle withinside the wind turbine rolling, and after the strength switch withinside the wind turbine, it'll sooner or later will become the electricity [15-20].

The blade of the wind turbine is containing all the cutting-edge era withinside the world. In order to most the efficiency, the blade want to lessen the air friction. In perfect situation, it want to apply the Betz's Elementary Momentum Theory (BEM) to calculate the chord length [21].

The Betz's Elementary Momentum Theory (BEM) is a precept that used to calculate the nearby forces on a propeller or wind-turbine blade. According to the Prof. Adaramola, withinside the ee-book Wind Turbine Technology: Principles and design, it indicates that the Betz's Elementary Momentum Theory is used to calculate the nearby forces on a propeller or wind-turbine blade. Blade detail concept is blended with momentum concept to relieve a number of the problems in calculating the triggered velocities on the rotor. By the perfect situation, the blade of the aircraft could have a honest form to lessen the air friction, like Figure 1:



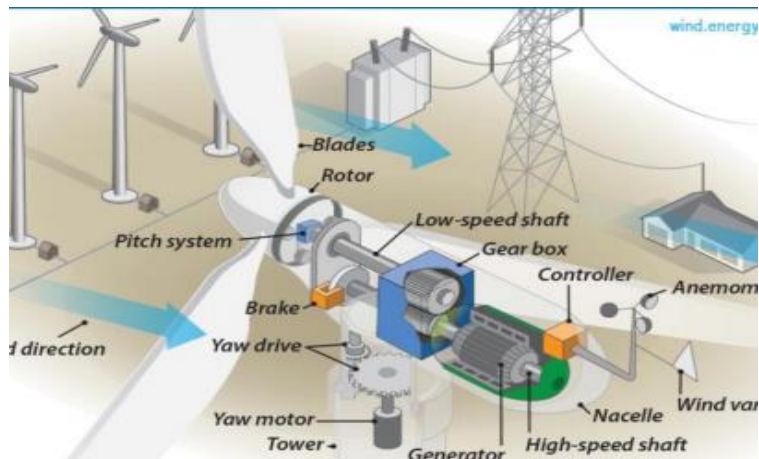
**Figure 1.** A typical blade plan and region classification.

Inside the wind turbine is the generator component, it aimed to transfer the kinetic power into the electricity. It may be divided into numerous components: Rotor/pitch force/nacelle/brake/low-pace shaft/ equipment field/excessive Speed shaft/generator/hear exchanger/controller/anemometer/wind vane/yaw force/tower [22].

The tower is crafted from the tubular metallic, concrete or metallic lattice, it's miles participate in helping the shape of the turbine. As the peak boom, the wind pace will boom, either. And the taller the tower is, the greater power it may assist to capture.

The generator could be capable of produces 60-cycle AC electricity, and it also includes an off-the shelf induction generator. And the shaft will assist to drives the generator. The nacelle is a sits to forestall the tower and it include maximum of the components of the turbine, generally it's miles massive as it have to include sufficient spaces.

The wind vane is aimed to get the route of the wind and ship them to the yaw force to orient the turbine because the route of the wind. And the equipment field is the maximum vital component withinside the wind turbine, it connects the low-pace shaft(30-60rpm) and boom the rotational speeds from the low pace to about 1000- 1800 rpm, it's miles the heaviest component withinside the wind turbine. The pitch goes to turns the blades out the wind that allows you to manage the rotor pace, and it additionally participate in keep away from the rotor is simply too excessive or too low in produce electricity. The yaw force orients upwind generators to maintain the dealing with the wind whilst the route changes [23-25]. In general, the shape of the wind turbine is proven withinside the Figure 2:



**Figure 2.** the structure of the wind turbine.

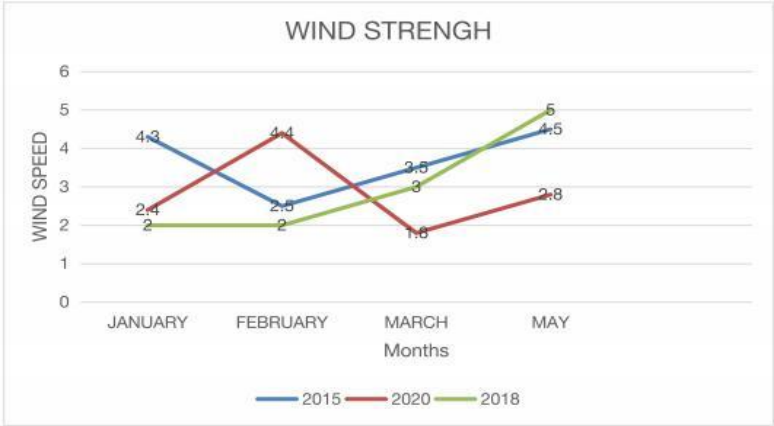
According to Preetan, the efficiency of the wind energy can be up to 59%, even if the efficiency is not as much as other renewable sources, but the unique feature of the wind power—such as the cost and the location of wind turbine—makes the wind turbine a good choice of widely use.

**4. Implementation of wind energy worldwide**

One of the most significant scientific breakthroughs in history has been the discovery of electrical energy. There are numerous types of energy, including sound, light, energy stored, change in momentum, thermal energy, electricity, and heat. Electricity is the most significant type of energy among these. Shahan claimed that it is possible to compare the position of power in various energy forms to that of money in various asset forms. Electricity can be spent with the same degrees of convenience as currency at any point and with the exact ease as other types of assets. Electricity is the cornerstone of modern society.

The average wind speed across the globe increased from 6.5 mph to 7.3 mph in less than ten years. That amounts to a 16% increase in wind energy potential for the typical wind turbine. Detroit argued that it might account for approximately half of the rise in wind generating capacity in the United States since 2010. The study might assist resolve a scientific controversy that has baffled scientists for a long time [26].

Global wind speeds have been declining since they began to increase again in 2010. The "universal stilling," as it became known, was the subject of numerous scientific theories. One of the more widely accepted theories proposed that rising urbanization and other changes in land use have changed the Earth's surface, making it more unstable [27]. As shown below in figure 3:



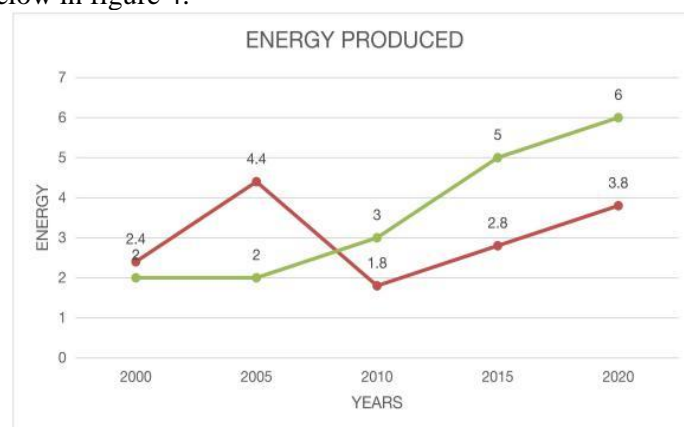
**Figure 3.** The table of wind strength.

Since there are no harmful emissions, it does not contribute to global warming, it represents one of the most accessible forms of renewable energy, and it is potentially a limitless source of energy, renewable energy is one of the most environmentally friendly ways to produce electricity. According to Whale many people, governments, and businesses find wind turbines to be among the most cost-effective ways to produce electricity in suitably windy places. As a result, it is the source of electricity that is expanding the quickest globally, with an increase of 15% in annual additions added in 2013 compared to 2012. Bolt states the cost of using wind power limits the amount of energy that could be capture. According to Savonius the size of something like the turbine blades determines a wind energy turbine's rating. Although a 11 m wind turbine has a voltage level of about 25 kW, a 70 m thrust reverser has a value of over 1600 kW. Itziar Martí' nez de Alegry states that chain of huge turbines produces electricity either for a specific industry or that will be sold to something like a utility provider, while a single small power station can serve a single dwelling, a mid-sized turbine can serve. As a result, wind energy turbines are very scalable and can power both a small resident building and a sizable industrial installation. In conclusion, wind energy is a distinctive source of energy.

Modern wind turbines have grown in size as their power ratings have increased. At the same time, this has produced economic benefits and made the technology more and more reliable. Blakeway, D., & White, C.B. claimed that starting in 1999, average turbine capacity began to rise. Turbines installed in 2016 had an average capacity of 2.15 megawatts. In the United States, there are many different types of flora, aquatic bodies, and geographical variations that affect the wind streamlines and speeds. Humans utilize this wind speed, or moving at a constant speed, for a variety of activities, including sailing, kite flying, and even electricity generation.

Wind turbine's main rotor is similar to an airplane wing or a helicopter rotor blade. It works by using aerodynamics to convert wind energy into electricity. The cabin pressure on one blade's other side falls as wind passes across it. According Cinti all the lift and drag is due to the different pressure on each side of the blade. The rotor spins because the force of something like the lift is greater than the forces of the drag. If the generator is directly driving the turbine, the rotor can be directly connected to it. In addition, if a gearbox is used to accelerate the rotation, this could allow people to use smaller and lighter generators.

Even if it's just approximately 1. 1 percent overall and 3 percent at the best wind speeds, the boost in energy generation from a particular installation may not seem like much. However, as there are more wind farms being built all the time to achieve accelerated climate objectives, the method may be used to any wind farm. According to Ryan, if that 1. 1 percent power generation increase were decided to apply to all the current wind farms in the world, this would be the comparable of installing upwards of 3,600 new wind farms, or enough to energy about 2.5 million homes, withtotal gain to energy companies of close to a billion dollars annually. And virtually nothing out of pocket. The onshore and the offshore wind energy are compared and we get their differences in energy produced as seen in the graph as illustrated below in figure 4:



**Figure 4.** The data of energy production.

## 5. Environmental impact of wind energy

With the increasing development of society, people have begun to pay more and more attention to the future global energy demand and social environment. Therefore, in order to reduce concerns and ensure the future development of human beings, the global communities are looking for good alternative energy sources or developing more efficient and environmentally friendly technology. In this regard, the development of wind energy will become one of the important concerns of the future of mankind. This is due to the fact that wind energy is considered as a source of green energy. Also, wind energy is a renewable energy source, so when we use it, we are not reducing the wind energy. Consequently, wind power has many environmental benefits.

Wind energy plants produce no direct air pollutants and greenhouse gases. Thus, compared with the most basic and traditional resources such as natural gas and coal to generate electricity, wind power can effectively reduce the problems of global warming and air pollution. This is because, according to statistics, one megawatt-hour of wind energy reduces carbon dioxide emissions by an average of 0.75 tons (1,500 pounds). A conventional 2-megawatt wind turbine can avoid about 4000-4500 tons of carbon emissions per year, which is equivalent to the annual carbon emissions of about more than 700 cars [26]. Moreover, the potential of wind power in preventing global warming was fully demonstrated in the 2013 Wind Energy Survey of the United States. The data shows that the 167.7 million megawatts hours of wind energy produced in the United States that year reduced nearly 126.8 million tons of carbon dioxide emissions, equivalent to reducing the emissions of the power industry by more than 5% [26]. Therefore, with the emphasis on wind power generation year by year, we can infer that wind energy will play a greater role in future emission reductions.

Water is one of the essential prerequisites for human survival. Therefore, in order to ensure the quality and quantity of water resources, human beings apply a lot of wind energy to generate electricity. This is because typical power generation modes such as natural gas, coal-fired power plants, etc. will consume large amounts of water in the condensing part of the thermodynamic cycle. For instance, the statistics show that the water consumption of natural gas power plants is estimated to be around 0.7 cubic meters per megawatt hour, and the water consumption of coal power plants is estimated to be between 1.7 and 2 cubic meters per megawatt hour [27]. However, non-thermal technologies such as wind or PV use considerably less water per unit of electricity generation and life cycle, since wind turbines consume water for only a small amount of cooling and occasional blade cleaning. Moreover, sometimes the blades of turbines can be washed away by natural rainwater, so if humans use wind energy in large quantities, the problem of depletion of water resources will be greatly alleviated.

At the same time, wind power also has several significant adverse impacts, such as accidental injury to a large number of wild animals, noise and visual damage to the environment, and so on. For the impact of the destruction of wildlife habitat and the death of wildlife, the construction of wind farms is a contributing factor to habitat loss, because wind turbines and related equipment on wind farms influence bird habitat selection. [28] As it turned out, bird population densities were significantly higher in grassy areas with no wind turbines or more than 80 m from wind turbines than in wind farm areas. Furthermore, large wind farms have hundreds of wind turbines, and collisions with wind turbines are the direct cause of bird death. This is because the rotating height range of the fan blades is generally 40 meters to 120 meters, which is also the most common flying altitude for birds. Therefore, there is a high risk of impact if birds fail to change course in a time when encountering wind turbines during flight. As the results of a four-year study by Dr. Sean Smallwood in 2004 showed, Wind farms in Altamonte Pass, California, kill an average of 116 golden eagles per year. These deaths pose a major threat to the balance of ecosystems and biodiversity [29].

Finally, with the rapid development of wind energy, a huge drawback (noise from the wind power) has also come to light. The working principle of the wind turbine is to drive the gears to rotate mechanically through the rotation of the turbine blades, thereby generating electricity. However, when the gears are engaged with each other, huge vibrations will be generated, and the resulting huge noises are almost unavoidable. In addition to this, there is another type of noise that wind turbines can

produce, aerodynamic noise. This type of noise is produced by the wide-band swish generated by the rotation of the blades. These noises will have a huge and irreversible impact on the species living around them, and even endanger biodiversity.

In conclusion, compared with other energy sources, wind energy is a more practical and clean option, so wind energy has a bright future in development. Nonetheless, the energy produced by a wind turbine is not free from adverse effects. Thus, for the better future of mankind, we should make good use of wind energy and further modify equipment such as wind turbines in order to minimize these negative effects.

## 6. Economic effect of wind energy

A prerequisite for planning any energy development project is estimating and understanding project costs and benefits. The extraction and use of energy itself are unreliable if the actual economic effects are not taken into account when researching energy. Because of the non-renewable nature of fossil fuels and their damage to the environment, wind energy as clean renewable energy has received extensive attention from scientists, so the economic consumption and benefits brought by wind energy are also very important. In this part of the article, I will describe the economics of wind energy based on three sections.

Costs and revenues:

In this section, I will talk about the costs and benefits of wind energy acquisition, and discuss the economic viability of wind energy in general.

According to the latest data for 2022, each average size commercial wind turbine is \$2.6-4 million, with a typical cost of \$1.3 million per megawatt (MW) of electricity generated, most commercial wind turbines have a capacity of 2-3 MW, but offshore turbines can be up to 12 MW [30, 31]. In addition to the high cost of turbines, there are a number of operating and maintenance costs, including:

1. Insurance
2. Land rent
3. Service, repair parts
4. Power (it does need some electricity to run)
5. Administrative tasks

German data shows that these components add up to an average of 1-2 euro cents per kilowatt-hour (kWh) produced.

Besides, from the American data, this number is 1-2 cents per kilowatt-hour produced, in another word, \$42,000 – \$48,000 per year [30].

These costs may seem really high in the energy industry, but since this is a long-term investment, there is a high probability that it will pay off and even continue to be profitable after many years.

**Table 1.** Project costs overview for the rush creek wind farm.

Input	Cost	Source	Note
Balance of Plant	\$364/kW	2016 Cost of Wind Energy Review	Typical for a 600- MW wind farm in the interior region of the US
Turbine Equipment	\$800/kW	2017 Wind Technologies Market Report	Turbine costs ranged between \$750-\$950/kW



**Table 1.** (continued).

Installed Project	\$1164/kW			Installed costs do not include financial costs
Annual O&M	\$4360/kW	2016 of Wind Energy Review	Cost	Excludes lease account for JEDI breakdown
				land to

As can be seen in Table 1, a form shows the detailed data of costs in Rush Creek Wind Farm which is the largest wind power project in Colorado in 2018 [31].

Since we have covered the cost part, next I'm going to talk about the revenue and power we actually get from those wind turbines.

The size of wind turbines is in megawatts (MW<sup>①</sup>), which refers to their power generation capacity. The larger wind turbines are, the more expensive they are, but they generate more electricity through larger nacelles and turbine blades.

① : 1 MW = 1000000 watts of power.

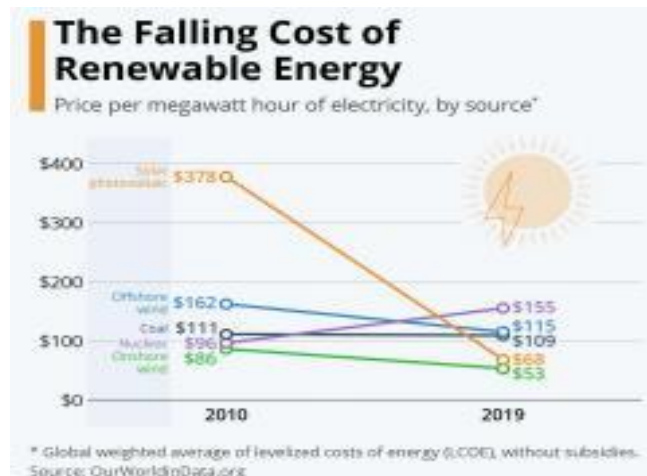
One megawatt can power about 1000 households for one month, but in practice, wind turbines cannot reach their rated capacity due to changes in wind speed.

Below, I've listed the four most common commercial wind turbine sizes in megawatts [30]:

1. 1.5 MW (onshore)
2. 2.5 MW (onshore)
3. 4 MW (onshore)
4. 6-8 MW (offshore)

In general, considering both costs and revenues, the general cost of the electricity which comes from wind power is \$1,300,000 USD per megawatt [30].

And in 2019, the average price of wind power purchase agreements across America fell below 2 cents per kilowatt hour which meant - including federal incentives such as production tax credits - that new wind energy facilities provided some of the cheapest new forms of power generation available at the time [32]. Therefore, the wider use of wind power seems practical and believable in the future. In order to make the conclusion more reliable, I will compare the costs of the wind power with other renewable powers.



**Figure 5.** The falling cost of renewable energy.

Figure 5 shows the trends of costs of different renewable energies. From the graph, we can clearly find out that from 2010 to 2019, the costs of the onshore wind are always the lowest which means that even comparing to the whole industry of renewable energy, the use of the wind energy is pretty reliable [33].

#### Financial Incentives:

As mentioned above, financial incentives are an important part of the economic impact of wind energy due to the high cost of turbine development and operation. In order to promote the development of the wind energy industry, the government will take various measures to incentivize local wind energy plants. E.g:

1. Direct funding to energy producers
2. Reduce tax burdens related to energy production, transport, and use
3. Develop and initiate R&D activities to increase national energy production

#### Community effect:

Besides the effect on governments and the industry, wind energy can also bring some economic influences to the local community in several ways:

**Direct employment:** Wind energy projects have brought employment opportunities in manufacturing, transportation and project construction to rural communities. By the end of 2020, the number of employment in the wind energy industry in USA had reached a new high, with more than 116800 full-time workers [34]. The employment situation in this sector will fluctuate according to the level of deployment, the status of federal incentives, trade and the value of the United States dollar.

**Use of the local land:** Because of the small footprint and relatively large spacing of wind turbines, power plants generate a lot of flat, treated and suitable land for farming or grazing. This not only indirectly improved the local agricultural level, but also increased the income of local farmers from the rent brought by the huge amount of land leased. In 2019, in United States, wind power projects on private land provided \$706 million [34] in land rent to rural landowners.

**Local GDP (gross domestic product):** GDP which represents the total amount of economic activity that occurs within the region is also increased due to the wind power industry. As the value of the production of the electricity is much higher than that of farming.

**Table 2.** Summary Economic Impact Estimate from the Rush Creek Wind Farm [35].

Period	Economic Impacts
During construction	©Supported 2970 FTEjobs
	©Supported \$280 million in GDP
	©Supports approximately 180 jobs in Colorado annually
	©Supports \$20 million in GDP
During operations	©Supports approximately \$2.5 million in annual property taxes and approximately \$1.8 million in annual income for landowners who lease their land for Rush Creek wind turbines

## 7. Conclusions

Wind energy is nearly limitless, widely distributed, clean and capable of mitigating the greenhouse effect. Today, wind energy is the largest installed renewable energy source on the planet, and the government is also incentivizing the wind energy industry such as reducing the tax burden associated with energy production and transportation. Moreover, wind power plants do not produce direct air pollution and greenhouse gases, which can effectively reduce problems such as global warming and air pollution. Although large wind farms also have the effect of destroying animal habitats and making noise, compared with other energy sources, wind energy remains a more practical and cleaner option. With the development of wind energy in various countries today, I think the cost of wind energy and its adverse impact on the environment will be further reduced, while its benefits and the efficiency of

wind energy generation will become higher and higher. Through the analysis of wind energy history, economy, environmental impact, implementation and principles of wind turbines in this paper, we can find that under the pressure of energy shortage and global ecological environment deterioration in today's society, wind energy as a pollution-free, renewable new energy will make a great contribution to the society.

### Acknowledgement

All the authors contributed equally to this work and should be considered as co-first author.

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