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Is Current Wind Power Sustainable?

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Abstract

There is an ever-increasing interest in considering renewables as a way to offset our use of carbon based fuels. In most cases it has been as a hedge against possible dwindling supplies, the environmental impact of the continued use of these fossil fuels and also because it seems, at least on the surface, that free energy from the wind is a win-win situation. The number of wind turbines in the United States and in numerous places around the globe has grown as a result of this continued push for clean, renewable energy. The real question becomes then, is wind power in its present form, and operating under our current conditions economically viable. More importantly is the use of wind power even fiscally sound if all of the environmental and societal impact factors are taken into consideration, as viewed from a cradle-to-grave analysis.

Currently, most wind turbines, including those in large aggregate wind farms are unable to meet their theoretical production and lifespan predictions. Even with government subsidies and the implementation of preferential energy purchase agreements, they are typically unable to even break even on their upfront and routine maintenance costs, notwithstanding their true lifetime costs. Add to this the environmental costs and the land usage and public nuisance costs along with the long-term environmental impact to flora and fauna, and the question becomes even more complicated. Is wind energy viable in its current technological state? Can wind power sustain itself and get around all of the impact factors that are growing even more problematic with their proliferation? This paper addresses these issues with a less than favourable immediate outcome but with a call for more advanced and modern wind turbine solutions that will provide the next best set of answers.

Keywords:	Wind power; Wind turbines; Sustainability; Renewable energy; Clean energy

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1. Introduction

Wind is a result of irregularities in the heat provided by the sun, the varying topography of the earth's surface, and earth's rotation around the sun. [1] Wind energy has become a current focus due to the growing demand for the use of our renewable resources. Wind energy does not come with the finite end of energy production that can be found with fossil fuels. The sun will clearly be around for a while. It does not directly produce the same harmful pollutants that are associated with the acquisition and use of fossil fuels. At least that is the apparent understanding of the general public with a less than complete cradle-to-grave environmental impact analysis to support their arguments. With the increasing global demand for total energy, wind energy is needed to help accommodate and offset that growth, hopefully with new designs that can improve their sustainability.

As of March 2016 wind energy accounts for 1.9% of the Total U.S. Energy consumption. [2] Wind energy has been steadily increasing since 1970, however, it is still only a small portion of the U.S. electrical supply. Globally the percentage provided by wind is not much higher at 2.5% [3].

The wind capacity added globally in 2015 was 432.9 GW, a 17% growth rate. This was considered to be unexpectedly high. This was due to various factors, but the one not considered was China. China added 30,753 MW wind power in 2015, keeping it as the largest overall market for wind power since 2009 [4].

One of the major factors promoting the growth of wind energy are government subsidies and tax credits. The total amount of subsidies in the U.S. since 2000 is $176 billion [5]. This includes local, state, and federal subsidies including federal loans and loan guarantees. These subsidies allow companies to breach the market of wind energy. The two major tax credits associated with wind energy are the Renewable Energy Production Tax (PTC) and the Business Energy Investment Tax Credit

(ITC). These tax credits were created in 1992 and have since been renewed several times. The most recent renewal was through the Consolidated Appropriation Act in 2016, this extended the expiration of the credit from 2015 to 2019. Worldwide, several governments have similar programs or control and support the region's supply of energy.

2. Non-financial costs of wind turbines

When considering the utilization of wind energy there are non-monetary ramifications to consider. Some of these additional factors are environmental impact, land usage, public nuisance, and the impact on plants and animals. Some wind turbines have caught on fire producing large amounts of smoke and debris. The lubricating fluids used for wind turbines have the potential to leak polluting the area around the turbines and potentially more if it comes into contact with a water supply [6]. Access roads and electrical service lines are required to reach the sites of the wind turbines taking additional land away from flora and fauna. The bearings used in wind turbines consist of rare earth metals that are often mined in countries with less stringent environmental practices than the United States [6].

In order to produce wind turbines, energy is required which was potentially produced using fossil fuels. Most larger wind turbines need to be cycled during no-wind conditions to save wear and tear on the bearings. Additionally, wind turbines can be considered a public nuisance if located close to towns and cities. Commercial-sized power systems and wind farms are large and require vast areas of land for power production [7]. These can also have a visual impact on the landscape and some people complain of the sound that is produced by the blades.

There is also the problem of the death of birds and bats caused by wind turbines. Modern wind turbines turn at lower rpm's than older turbines, however, these turbines have longer blades and are moving at 150 to 200 mph at the tips [8]. A few studies have been done on this subject over a 5-month summer period where 2,000 to 4,000 birds and bats were killed by the 120 wind turbines in the study [9].

3. Cost analysis

3.1. Upfront cost

There are many pre-planning factors that lead to the construction of wind turbines. Wind farms take up large areas of land. The land must be evaluated, leased, and permitted prior to the construction of wind turbines. The process of evaluating the land consists of a soil boring, and site specific foundation design. These processes cost between $25,000 and $45,000 [10]. The land lease and planning are required to ensure the proper spacing of the turbines; improper placement can diminish the overall output.

These land leases for megawatt scale turbines range from $3000-$12,000 per turbine per year depending on the size of the turbine and the amount of area required for it [10]. In addition to this a building permit is required to build the turbines in most regions. In order to obtain the permit archeologically and environmental studies are normally conducted. These studies and the cost of the consultants range from $5,000 to $50,000 per turbine [10]. These are the costs prior to the production of the wind turbines.

The cost of the turbine hardware makes up 70% of the cost associated with onshore wind turbine projects [11]. Utility scale turbines range from $1.3 million to $2.2 million per megawatt. The most common size installed currently is 2 MW wind turbines. These cost between $3 and $4 million [12]. In addition to the cost of the turbine, access roads and power supply lines must be provided in order for the large trucks to access the building area and to then send the generated power to the consumer. These gravel roads can cost up to $35,000 per quarter mile and the power lines can run into the millions of dollars depending on their needed capacity [10].

With the roads laid the trucks can now access the site to start the foundations for the turbines. The cost of these foundations are dependent on the height and weight of the turbines being installed. Most foundations average 14 truckloads of concrete per turbine, this cost comes to $175,000. In order to erect the turbines a 300-foot crane is needed with a 400-ton lifting capacity. The crane rental ranges from $100,000 to $150,000 per megawatt of installed turbine.

These costs are still relatively low when compared to the cost of putting a gas or coal fired power plant on line. The normal power plant has some economy of scale advantages and years of experience in their construction. A coal-fired power plant can exceed their life expectancy by decades with good maintenance and modernization. Wind turbine farms are rated for twenty years but few will ever reach that age without a complete system overhaul.

3.2. Operation and maintenance cost

The operation and maintenance costs also add to the cost during the lifetime of wind turbines. According the U.S. Department of Energy in a report on wind turbines, the operational costs vary depending on the current age of the wind turbine. Assuming a new turbine installed after 2010, the operating and maintenance cost is $9 per megawatt hour [13]. According to U.S. Energy Information Administration the average capacity factor of turbines in the United States in 2015 was 32.2% [14]. To put that in perspective a 2 MW turbine is producing 5641 megawatt hour per year. Based on the operating and maintenance cost from the DOE there's an additional cost of $50,772 per year for an individual turbine. These operating and maintenance costs do not include turbine failures and normal maintenance.

One of the seldom mentioned expenses of wind power, particularly where the wind power is designed to supplement more traditional power generating systems, is the cost associated with the lack of consistency and strength of the wind. Most modern power plants with their associated power grids must maintain consistent power levels to meet the needs of their consumers. Since wind can be so unpredictable, additional generating capacity must be maintained and spooled up to handle the wind conditions. The overall costs of these back-up capabilities are often ignored in pricing wind turbine farms, but for many situations these singular costs can outweigh any of the benefits of the wind turbine provided in the first place, at least as they are designed at this point.

3.3. Failure costs

When dealing with operation and maintenance costs the life span of these turbines comes into question. Typically reported lifespans range from 20-25 years, however, actually use and studies point more towards only 12 years. The reason these turbines are not reaching their projected lifespans is due to failures. These failures are the result of damaged rotor blades or faulty gearboxes. The blades can be damaged by extreme weather such as high winds or lightning, and snow and ice in the extreme northern and southern regions of the globe.

As of 2015 worldwide blades are failing at around 3,800 a year. That equates to .54% of the 700,000 in operation worldwide [15]. This is not a major issue for onshore turbines, but it does need to be considered as a possible cost. The problems with the gearbox typically stem from failures with the bearings. These failures are associated with contamination of the lubricants with sharp particles such as dust, sand, and rust. These debris cause wear on the bearings which can lead to pitting of the bearing rollers and then failure. The estimated lifespan of these gear boxes is 7-13 years. This doesn't meet the expected lifespan of the wind turbine. These bearings are made of costly materials such as composites or rare earth metals.

3.4. Breakeven point for wind turbine

The major tax incentives for Wind Energy in the United States are the Federal Renewable Electricity Production Tax Credit (PTC) and Investment Tax Credit (ITC). The PTC is granted to owners of utility scale wind energy producing facilities based on the per kilowatt-hour electricity production by the facility over a 10-year period. The amount per kilowatt-hour is currently 2.3 cents. This rate was set to decrease by 20% at the end of 2016 and decrease again by the end of 2017, before the final phase-out in 2019. In order to receive the credit, the facility must start construction before the end of 2019. The ITC provides tax credit of 30% worth of the value of the wind turbine facility. This credit can be received by any size wind facility. The owner of the facility may only choose to receive one of these two credits.

In order for a wind facility to breakeven the National Renewable Energy Laboratories (NREL) has produced a formula for calculating the profitability of the wind turbine facility:

$$\left(\frac{(FCR*ICC)}{AEP}+\left(\frac{LRC+O\&M+LLC}{AEP}\right)\right) \tag{1}$$

Where FCR is the fixed charge rate, ICC is the initial capital cost, LRC is the levelled replacement cost, O&M is the operations and maintenance cost, LLC is the land lease cost, and AEP is the net annual energy production in kWh.

According to the EIA as of November 2016 the cost per kWh in the United States is 10.10 cents, this will be used as the FCR. The ICC for a 2 MW wind turbine is $3 million. The LRC if the yearly fund for replacements:

$$LRC=\frac{ICC}{Lifespan\ of\ Wind\ Turbine} \tag{2}$$

Assuming the predicted lifespan of 20 years the LRC for a 2 MW turbine is $150,000 per year. The O&M cost from earlier for a 2 MW turbine was $50,772 per year. Going back to the previous numbers at 32.2% capacity factor the 2 MW wind turbine is producing 5,641,000 kWh per year, the AEP. According to the AWEA the LLC is 5% of the annual revenue at $28,4875. The cost of wind power for a 2 MW wind turbine is 13.98 cents per kilowatt hour.

In order to get the total annual expense:

$$Cost\ of\ Wind\ Power\ in\ kWh*AEP \tag{3}$$

The total annual expenses are $788,611. The gross annual income is $569,741. The amount made in a year is -$218,870. At these costs the only way to turn a profit is with government subsidies and tax incentives. If a facility chooses the PTC they would receive an annual tax credit of $129,743, bringing their profit for the year to -$89,127. If they choose the ITC based on the initial investment of $3 million for the 2 MW wind turbine they would receive a credit of $900,000. Meaning the facility could run for a little more than 4 years before running a deficit. The expected lifespan of these wind turbines is 20 years, which is seldom achieved.

These numbers offer a bleak realization of the sustainability of wind energy, at least for the United States. It should be noted that there are numerous regions around the world where these costs could be considered economical as compared to the current alternative in those areas. Without an alternate choice, these costs for modernization would be regarded as inexpensive, at least until an alternative can be brought on line or future improvements can be made to extend the usefulness of the current wind turbine technology.

4. Onshore versus offshore

A topic not covered in depth is offshore wind energy, as it is a fledgling idea in the United States, versus a major factor in Europe. Offshore wind energy provides many benefits as well as many additional difficulties compared to onshore wind.

Offshore wind speeds tend to be higher and more consistent than onshore wind speeds [16]. Thus, offshore turbines will be able to operate at higher efficiencies compare to onshore turbines. Wind speed also tends to increase in the afternoon during peak demand for energy. The non-finical public nuisance cost of wind turbines is solved by moving turbines offshore. Additionally, large cities which would be the main consumers of the energy are often located near the coast [16]. This would help lower the transportation cost of the energy.

Offshore wind turbines are more expensive to build, operate, and maintain than their onshore counterparts. Various sources state that offshore turbines are 1.5 times to 3 times more to build and maintain than onshore wind turbines [16], [17], [18], [19], [20] (Figures 1, 2 and 3).

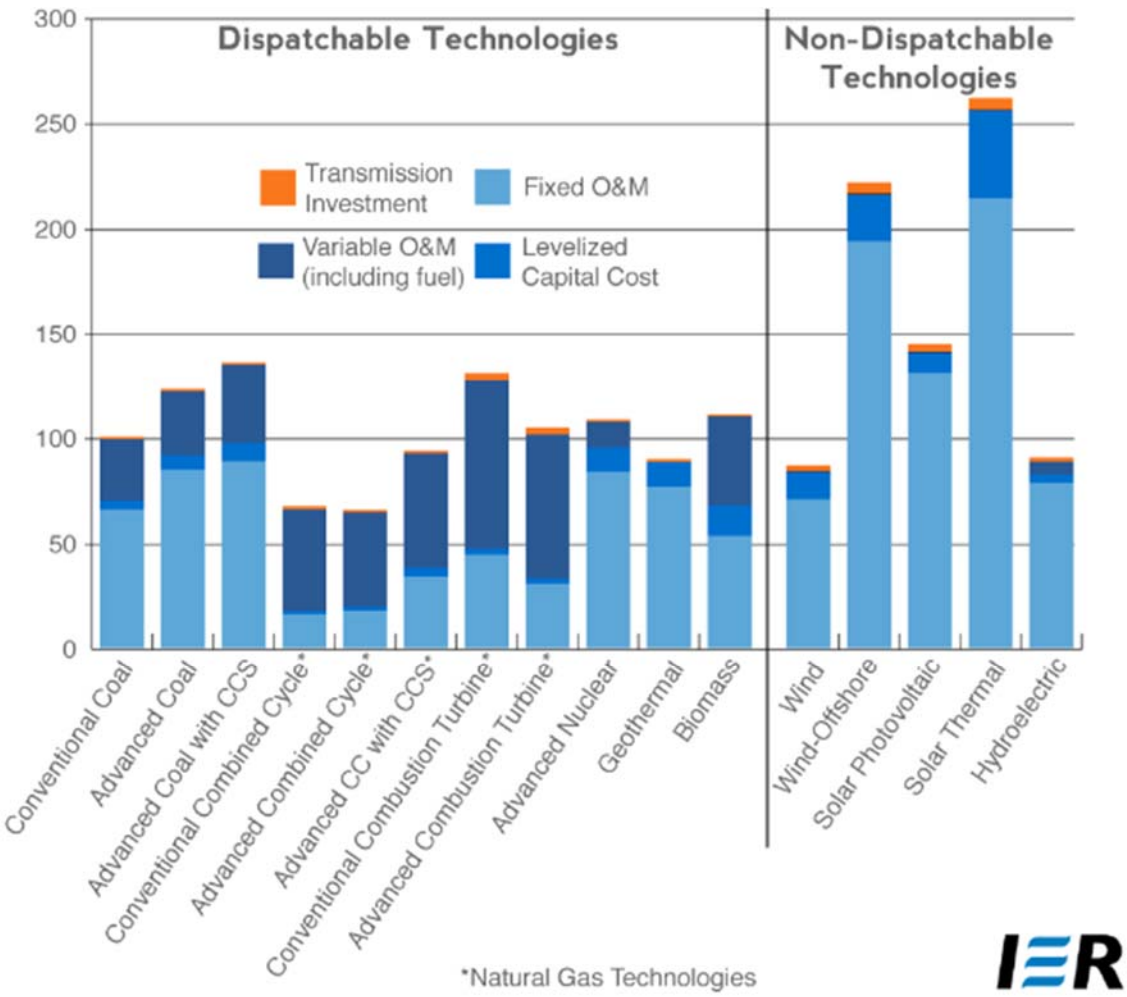

Figure 1. Estimated Levelized Cost of new electrical generating technologies in 2018 (2011 $/megawatthour) according to the Intitule for Energy Research [17]

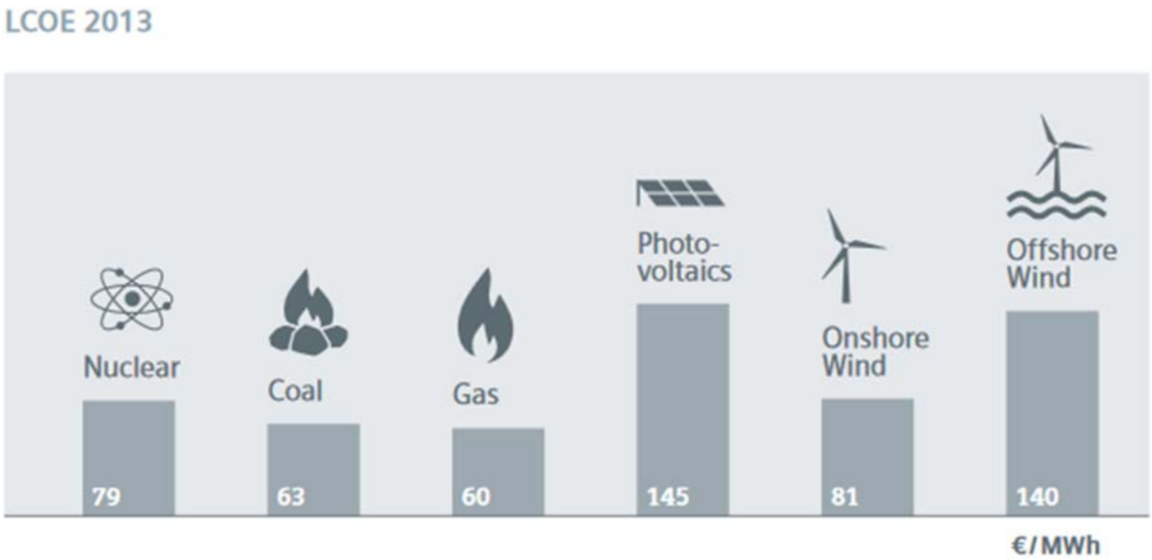

Figure 2.System costs Levelized Cost of Energy (LCOE) for all primary energy sources in UK for 2013 [20]

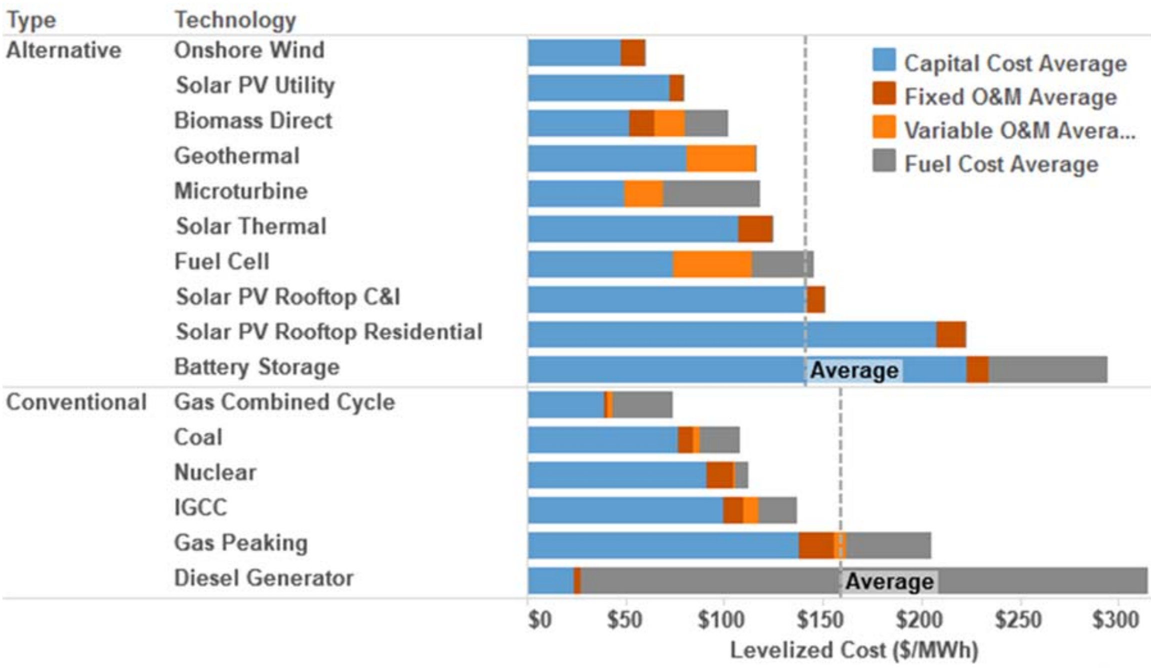

Figure 3.Components Levelized Cost of Energy [21]

Another disadvantage for offshore turbines includes the need to withstand the higher wind speeds and additional wear presented by seawater. On top of the higher wind speeds associated with offshore, there are the increased concerns for storms, that are not as much a factor in Europe as in the United States. Wind turbines must be able to weather hurricane force storms. The additional corrosive impact of seawater, adds to the operation and maintenance cost of offshore turbines. All the additional maintenance costs of offshore rigs are amplified by the fact that they require the use of helicopters and/or a jackup rigs to access and repair [16].

Offshore turbines have the ability to produce more energy than onshore turbines, but at a higher initial cost and O&M cost. As with onshore turbines, offshore turbines will become more cost effective as technology continues to improve. Wind energy is still a developing technology; it is expensive and is inefficient. It will be a factor in moving away from fossil fuels and towards renewable energies; though, it may not ever be a cost effective means of energy.

5. Conclusions and recommendations

What would it take to get wind to a sustainable point? In the current state wind energy is not a sustainable way to produce energy. Until the capacity factor, cost, and efficiency can be improved wind energy will continue to take a backseat to other more reliable sources of energy. More research and innovation needs to occur before large scale adoption of wind energy should be attempted. Current models of wind turbines do not make their projected lifespans and thus without subsidies and tax credits there is little to no return on investment for wind facility owners and investors. More importantly, it is the consumer and taxpayer that fronts these actual costs, often without a choice.

While this short study would indicate a strong argument against the wholesale use of wind power, the reality is that in the future we will need all of the power we can economically and environmentally capture. For wind turbines to take their place in this effort will require a major investment in innovative designs that overcome their current drawbacks. Some of this work is currently underway but to have a greater impact the current policies of continuing to do the same things and expecting a different outcome must stop. With the correct designs and the right approach to their use, wind power can have a positive impact on our power needs in the future. What we cannot continue to do is to provide a feel good solution that in fact is more detrimental than the existing systems.

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