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Harnessing Wind Energy

By

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Abstract

Renewable energy plays a vital role into the lives of humans for them to thrive and survive. Harnessing them requires a lot of research, permutation and combinations, technological innovations, the right equipment's to convert it to usable source of energy. One such energy is wind energy; it is one source of energy that is available freely and in abundance. The first practical windmills were used in Sistan, Persia in the mid-to-late 7th century. From then to now many new innovations and technological developments / advancements have happened which has led us to harnessing maximum wind and converting it to energy and using it to the optimum. From setting up windmill plants over open land to integrating them in the buildings, we have come a long way. Initially the windmills needed to be installed on the outskirts of any settlements due to factors such as: - noise of the turbine, open lands leading to unobstructed winds. But the negatives of windmill plants were that they occupied too much of land area; and with the increase in population the demand for lands is also increasing. Therefore, the integration of wind turbine in the skin of the structure in the urban context has proven to be beneficial and the parameters such as noise control is taken care of. The following paper will cover the chronology of the wind mills in brief and skyscraper wind turbines in depth which will be supported with case studies. All of the following will be a second hand study but will prove to spread awareness about the "Wind Harnessing Technology", also open doors to new further research and innovations as we all are aware that currently the globe is in need for sustainable solutions.

Index Terms— green technology, skyscraper wind turbines, wind energy.

Introduction

Wind energy is the easiest source of energy to capture as it doesn't seize to exist and is available in abundance. The most common conversion of wind energy is electricity and the wind is captured for it is through wind mills or wind turbines. The most conventionally used are the wind mills, they require vast spans of clear lands for its installation. This makes them expensive at all levels such as the manufacturing, transportation, installation and land cost, even after being available in abundance; it also adds up to the carbon footprint.

But as the industry is technologically advancing and more innovations are taking place, more doors are opening towards affordable and clean technology which is and will prove to be affordable, user friendly as well as eco-friendly.

One such technology is wind turbines on skyscrapers. A few years ago even thinking of such a thing as an idea seemed impossible, but as we are advancing technologically and moving forward every such idea can be brought to life with trials and people who are passionate and have dedication towards betterment of the environment, leading to betterment of the human race.

Wind flow is the main factor for harvesting wind energy. The only complexity face in the urban areas is the wind flow pattern; it is much obstructed due to the heights of the structures, their orientation, all of these factors demand for innovation and strike a balance between technology, wind flow pattern and building design for optimum production and utilization of wind energy.

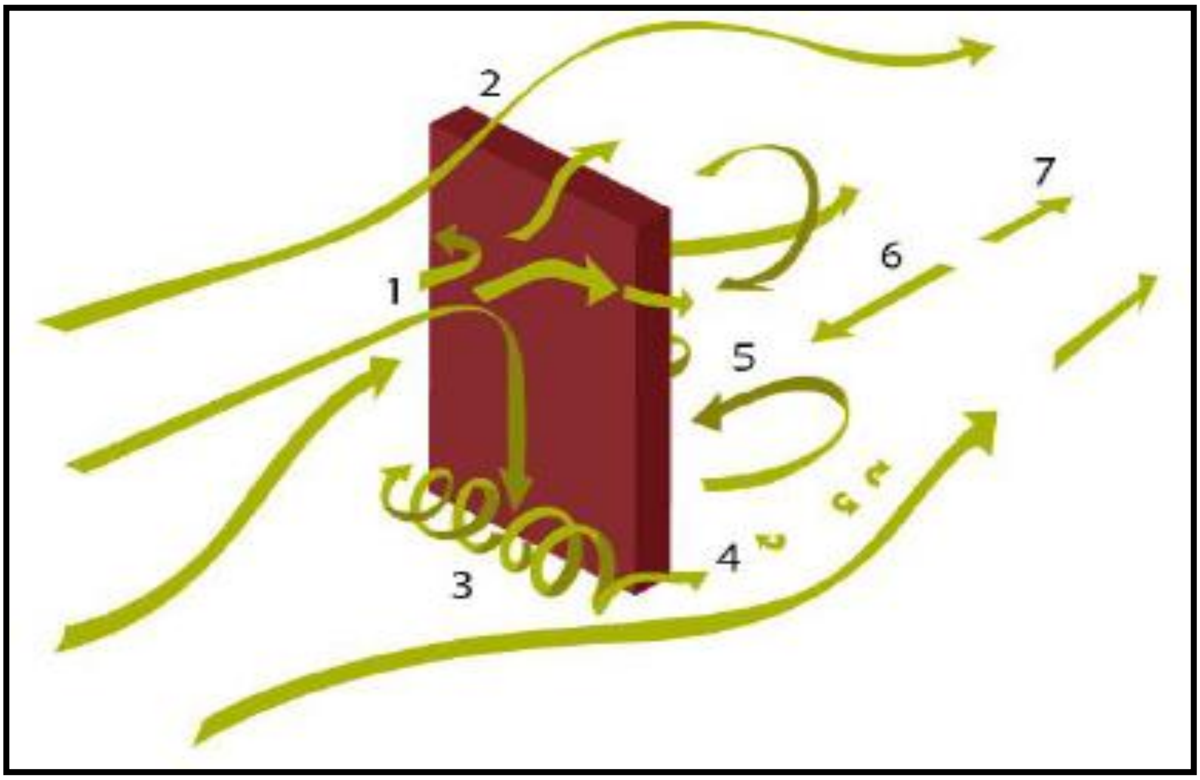


Fig 1. *General Wind Flow Pattern around a Single Stand-Alone Structure.*

The following are the parts of a conventional wind turbine and they have been described through the following figure.

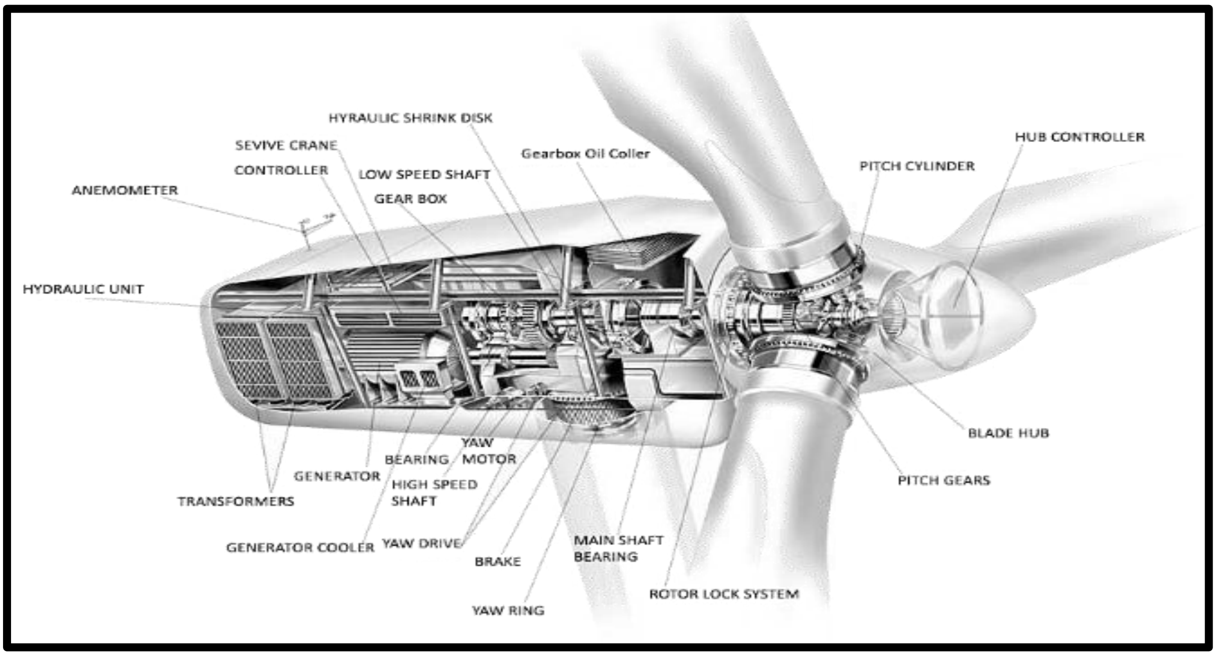


Fig 2. *Wind Turbine Component Diagram*

. The types of Wind Turbines that can be integrated in the structure / buildings in the urban context are as follows: -

- **Stand-Alone** – Turbine that are placed as a free standing tower away from the main building/structure.
- **Building Mounted** – They are installed over / above a building / structure.
- **Building Augmented** – In this case buildings are designed and oriented to direct the wind flow towards the turbines and they are installed over buildings / structures

The two main types of designs that are integrated into a structure are Horizontal Axis Wind Turbines (HAWT) and Vertical Axis Wind Turbines (VAWT). These designs have been thought through from the perspectives to harness the positive as well as the negative wind pressures for optimum production harvestment of wind energy. Therefore, they have been described in detail.

- ***Horizontal Axis Wind Turbines (HAWT).***

They are propeller type rotor mounted on a horizontal axis and need to be positioned in the direction of the prevailing wind by means of a tail or an active motorizes yawing system. As they are depended on the prevailing wind direction they prove to be sensitive to the changes in the wind direction and turbulence. This sensitivity affects the wind energy negatively and therefore; they prove to be more favorable in open areas with few obstacles.

Fig 3. *Horizontal Axis Wind Turbine*

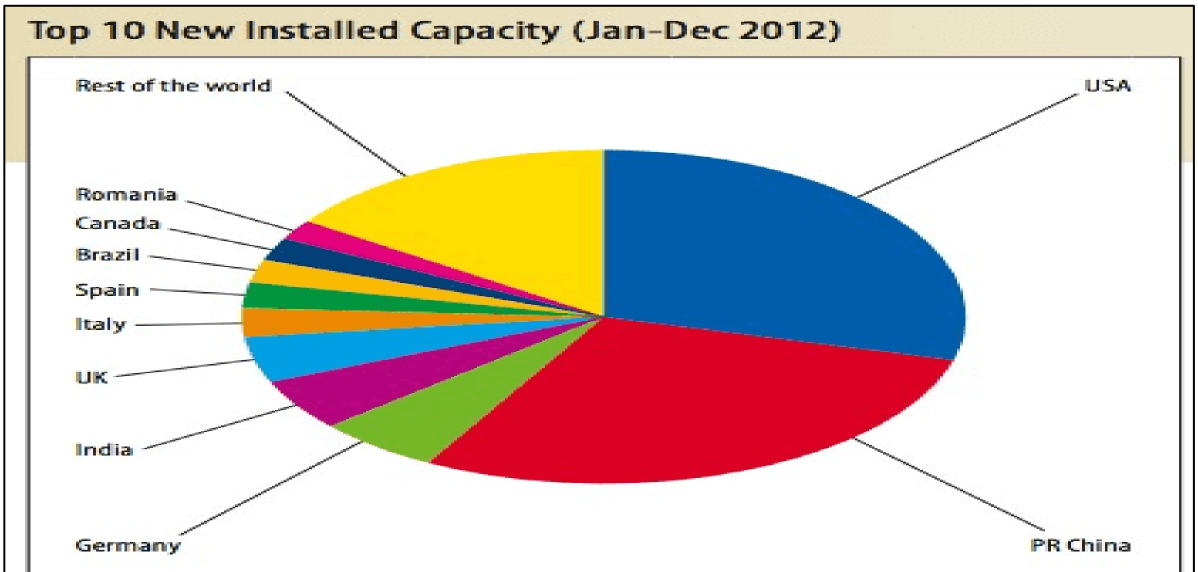
- ***Vertical Axis Wind Turbines (VAWT).***

These types of wind turbines represent a vertical main rotor shaft with vertical blades attached to it. Small VAWTs are suitable for production of wind energy in the urban areas as their performance is not dependent on any sort of wind direction.

Fig 4. *Vertical Axis Wind Turbine.*

history of wind mills / turbines.

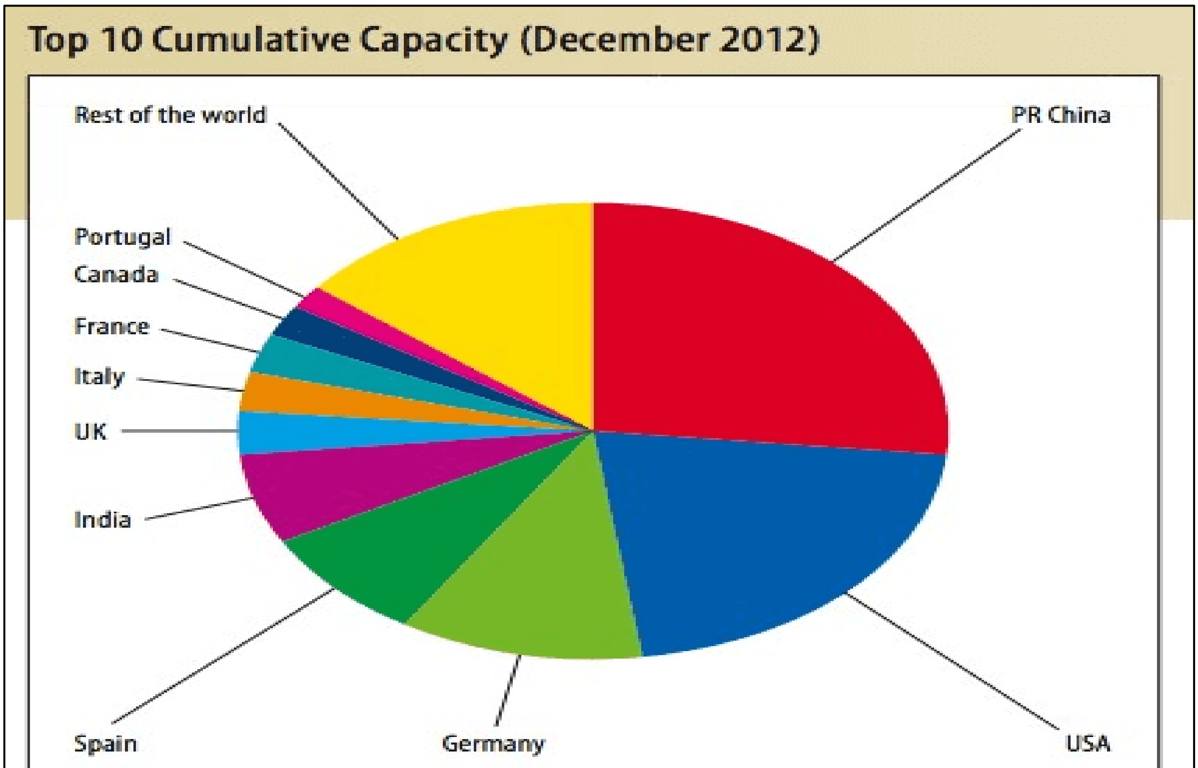
This topic will covers the history of windmill / turbine chronologically.



Country	MW	% SHARE
USA	13,124	29.3
PR China	12,960	28.9
Germany	2,415	5.4
India	2,336	5.2
UK	1,897	4.2
Italy	1,273	2.8
Spain	1,122	2.5
Brazil	1,077	2.4
Canada	935	2.1
Romania	923	2.1
Rest of the world	6,737	15.0
Total TOP 10	38,062	85
World Total	**44,799**	**100.0**

Source: GWEC

Fig 5. *New Installed Capacity.*



Country	MW	% SHARE
PR China	75,324	26.7
USA	60,007	21.2
Germany	31,308	11.1
Spain	22,796	8.1
India	18,421	6.5
UK	8,445	3.0
Italy	8,144	2.9
France	7,564	2.7
Canada	6,200	2.2
Portugal	4,525	1.6
Rest of the world	39,853	14.1
Total TOP 10	242,734	85.9
World Total	**282,587**	**100.0**

Source: GWEC

Fig 6. *Cumulative Capacity.*

Table 1. *Year Wise Development of Wind Mills*

YEAR / TIME	DEVELOPMENT
1st Century AD	For the first time in history, a wind driven wheel is used to power a machine. It was created by a Greek engineer Heron of Alexandria.
By 7th to 9th Century AD	Windwheels were used for practical purposes in the Sistan region in Iran, near Afganistan. The Panemone windmills were used to grind corn, grind flour and pump water.
By 1000 AD	Windmills are used for pumping seawater to make salt in China and Sicily
1180s	Vertical windmills are used in Northwestern Europe for grinding flour.

YEAR / TIME	DEVELOPMENT
1887	The first wind turbine to be used to produce electricity was built in Scotland. It was created by Prof James Blyth of Anderson's College, Glasgow (Now known as Strathclyde University). "Blyth's 10 m high, cloth-sailed wind turbine was installed in the garden of his holiday home/cottage at Marykrik in Kincardineshire and was used to charge accumulators developed by the Frenchman Camille Alphonse Faure, to power the lighting in the cottage, thus making it the first house in the world to have its electricity supplied by wind power.
1888	The first known US wind turbines created for electricity production was built by an inventor Charles Brush to provide electricity for his mansion in Ohio.
1891	A Danish scientist, Poul la Cour, developes an electricity generating wind turbines and later figured out how to supply a steady stream of power from the wind turbine by use of regulator, a Kratostate.
1895	Poul la Cour converted his windmill into a prototype electrical power plant and then used it to provide electricity to light the village of Askov.
By 1900	Approximately 2,500 windmills with a combined peak power capacity of 30 megawatts were being used across Denmark for mechanical purposes, such as grinding of grains and pumping of water.
1903	Poul la Cour started the Society of Wind Electricians. He was also the first few to discover that wind turbines with fewer blades spin faster and more efficiently than the ones with many blades. I In 1904 'The Society of Wind Electricians' holds its first course on wind electricity.
By 1908	Denmark installed 72 electricity generating wind power systems that ranged from 5 kW to 25 kW in size.
1927	Joe Jacobs and Marcellus Jacobs opened a "Jacob Wind" Factory in Minneapolis, Minnesota that manufactured wind turbines for the use of farms as farms had no access to the grid. The wind turbine were generally used for the charging of batteries and to power lights.
1931	A vertical-axis wind turbine (VAWT) design named Darrieus patented by Georges Jean Marie Darrieus, a French aeronautical engineer. This type of wind turbine is still used today, but for niche applications such as boats; not nearly a widely as horizontal-axis wind turbines. A horizontal axis wind turbine (HAWT) similar to the one used today in Yalta. This wind turbine has the 100 kW of capacity, 32 mt high tower and a 32% load factor; similar to the one that we get today.
1941	The first megawatt-size wind turbine was connected to the local electrical grid. The 1.25 MW Smith-Putnam wind turbine was erected on Castletown, Vermont. Its blades are 75 feet in length. During WW II – Small wind turbines were used on German U-boats to recharge submarine batteries and save fuel.

YEAR / TIME	DEVELOPMENT
1957	Jacods Wind produced and sold approximately 30,000 wind turbines; including countries like Africa and Antarctica. Johannes Juul, a former student of Poul la Cour built a horizontal axis wind turbine with a diameter and 3 blades very similar in design to wind turbines used today. The wind turbine has a capacity of 200 kW and if employs a new invention, emergency aerodynamic tip breaks, which is still used in wind turbines.
1975	NASA started a wind turbine program to develop utility-scale wind turbines. This research and development program pioneered many of the multi-megawatt turbine technologies in use today, including: steel tube towers, variable-speed generators, composite blade materials, partial-span pitch control, as well as aerodynamic, structural, and acoustic engineering design capabilities. The large wind turbines developed under this effort set several world records for diameter and power output. The first US wind farm is put online, producing enough power for up to 4,149 homes.
1978	The world's first multi-megawatt wind turbine is produced by Tvind school teachers and students. The 2 megawatt wind turbine pioneered many technologies used in modern wind turbines and allowed Vestas, Siemens and others to get the parts they needed. The most important thing was that the novel wing construction used help from the German aeronautics specialist. Danish wind turbine manufacturer Vestas produced its first wind turbine. The Public Utility Regulatory Policies Act (PURPA P.L. 95-617) was enacted in the US. PURPA required the utilities to interconnect renewable energy projects to the grid.
1980	Wind developer Zond was founded (eventually becomes GE Wind Energy). Wind turbine manufacturer Danregn Vindkraft was founded, spinning off from Danish manufacturer of irrigation systems; later coming Bonus Energy and then Siemens Wind Power. Levelized cos t of wind power to $0.38/kWh in the United States. World's first wind farm including 20 wind turbines was put online. Offshore siting of wind turbines was started in Denmark. Enertech began building 1.8kW wind turbine that could be connected to the grid. Commercial wind turbine rotor got up to a diameter of 17 meters and a capacity of 75 kilowatts.
1981	Second wind farm was set up in the US, which led to installation of total wind power capacity of approximately 10 megawatts; enough to power approximately 8,575 homes. California implemented tax credits on wind turbines.
1982	Four wind farms were set up in the US, double the number from the previous year producing enough energy to power up 13,500 homes.

YEAR / TIME	DEVELOPMENT
1983	Danregn Vindkraft changed its name to Bonus Energy for better appealing purposes in the US market. Eight wind farms were put online in the US, doubling the number from the previous year, producing enough energy to power 109,000 homes and over a dozen more than two years prior.
1984	Fifteen wind farms went online in the US, doubling from the previous year; producing enough power for up to 146,000 homes. Enercon was founded and it eventually became Germany's largest wind turbine manufacturer, and it still is.
1986	The tax credits on wind turbines in California expired. Vestas, which previously focused on other machines back in the year 1898 now decided to focus 100% on wind turbine market; it formed Vestas Wind Systems A/S and sold off its other business arms.
1987	A 3.2 megawatt wind turbine was developed by NASA under the wind turbine program. It was the first large-scale variable speed drive train and a sectioned, two-blade rotor which allowed easy transport.
1990	The Solar, Wind, Waste and Geothermal Power Production Incentives Act of 1990 was enacted to amend PURPA and remove size limitations on renewable energy power plants qualifying fpr PURPA benefits. The durability and performances of the wind turbines became more important at the user end which led to the use of tubular steel and reinforced concrete tower underneath wind turbines. Vestas sold its 1,000th wind turbine.
1991	The first offshore wind farm in the world was constructed in southern Denmark. It included 11 wind turbines manufactured by Bonus Energy, Each with capacity of 450 kW. UK's first onshore wind farm was constructed in Cornwall. The wind farm includes 10 wind farm that cumulatively produces enough electricity for approximately 2,700 homes.
1992	The United States implemented the Production Tax Credit (PTC) for wind power. PTC incentives electricity production rather than simply incentivizing installation, which resulted in performance and reliability. In the initial years, wind power producers got paid 1.5 ₵ per kWh for the electricity they produced for the first 10 years of operations. The PTC was a key incentive, probably the most important incentive, driving wind power growth across the US. Though, Congress let it expire before reinstating it several times, leading to a boom-bust cycle and limiting its overall effect.
1994	Vestas rolls out OptiSlip with a new wind turbine. OptiSlip allows the wind turbine to supply a constant current of electricity to the electric grid. Gamesa Eólica, a subsidiary of Spanish-based Gamesa Corporación Tecnológica (which was formed in 1976 to develop new technologies and apply them to emerging activities), was formed in order to manufacture wind turbines. The next year, they also started developing wind power projects.

YEAR / TIME	DEVELOPMENT
1995	Vestas produced their first offshore wind turbines. Suzlon Energy was founded in India to manufacture, install and operate wind turbines.
1995 - 2000	Commercial wind turbines rotor were made with a dia up to 50 meters and up to a capacity of 750 kilowatts, which proved to be 10 times more than approximately 10 years ago.
1996	Global wind power capacity reached 6,100 megawatts.
1997	Eron acquired Zond and German wind turbine manufacturer Tackle. Global wind power capacity reached 10,200 megawatts.
1998	China-based Goldwind was formed to manufacture wind turbines. Vestas went public, putting out an initial public offering (IPO) on the Copenhagen Stock Exchange.
1999	Vestas launched a wind turbine with “OptiSpeed”, which made it suitable for low-wind sites.
2000	97 wind farms were put online in the US, providing enough power for up to 592,000 homes. US installed wind power capacity is up to 2,554 megawatts. An order for 1,800 Vestas wind turbines, the largest wind turbine order in the world, was made by Spain’s Gamesa. Gamesa went public with an initial public offering (IPO) on the Bolsa de Madrid. Global wind power capacity reached 17,400 megawatts.
2002	GE acquired Enron Wind during Enron’s bankruptcy proceedings. (GE Wind Energy eventually became #1 wind turbine manufacturer in the world in 2012). 149 wind farms were put online in the US, providing enough power for up to 1.1 million homes. Global wind power capacity reached 31,100 megawatts.
2003	UK’s first offshore wind farm opened in Wales. It Included 30 wind turbines, each with a power capacity of 2 megawatts.
2004	Vestas and NEG Micron merge. Afterwards, Vestas commanded 34% of the wind turbine market, far more than any other country. Siemens acquired Bonus Energy (originally called Danregn Vindkraft). (“Between 2004 and 2011, Siemens grew wind power from 0.5% to 5% of the combined Siemens turnover, with employees growing from 800 to 7,800.”)
2005	226 wind farms were put online in the US, providing enough power for up to 2.2 million homes. Global wind power capacity reached 59,091 megawatts.
2007	The UK announced plans to install thousands of offshore wind turbines, enough to provide electricity for every home in Britain by 2020. Global wind power capacity reached 93,820 megawatts.
2008	416 wind farms were put online in the US, providing enough power for up to 6.5 million homes. Nearly 2000 wind farms were in operation across the UK, producing enough electricity for over 1.5 million British homes. Global wind power capacity reached 120,291 megawatts.

YEAR / TIME	DEVELOPMENT
2009	The first large-capacity floating wind turbine in the world began operating off the coast of Norway. It used a Siemens wind turbine and was developed by Statoil. The Roscoe Wind Farm in Texas became the largest wind farm in the world. It had powered capacity of 781.5 megawatts and includes 634 wind turbines. An investment tax credit was implemented for manufacturers of wind power products. The 30% tax credit was part of the American Recovery and Reinvestment Act of 2009. Under the American Recovery and Reinvestment Act of 2009, $93 million was dedicated to wind power research and development. "$45 million go towards wind turbine drivetrain R&D and testing, $14 million for technology and development, $24 million for wind power research and development, and $10 million for the National Renewable Energy Laboratory (NREL) will receive more than $100 million from ARRA". New wind power projects in the US were eligible for a 30% grant from the US Treasury Department to help cover the cost of the projects and simulate economic activity. The grant program was a part of the American Recovery and Reinvestment Act of 2009, and was only available for projects placed in service by the end of 2010. New wind power projects in the US were eligible for a 30% Investment Tax Credit (ITC) in the place of PTC if they prefer. The grant program is part of the American Recovery and Reinvestment Act of 2009, and is only available for projects placed in the service by the end of 2013. 581 wind farms were put online in the US, providing enough power for up to 10 million homes.
2010	The median levelized cost of wind power was $0.08/kWh in the United States, approximately 21% what it was in the 1980s. (The minimum was $0.06/kWh). The US department of the Interior signed the first lease for an offshore wind energy project, Cape Wind. China passed US to become the country with the most cumulative installed wind power capacity in the world. Global wind power capacity reached 197,039 megawatts. The Siemens Wind Power Division was formed.
2011	The median levelized cost of wind power was $0.07/kWh in the United States. (The minimum was $0.05/kWh). Commercial wind turbine rotors got up to a diameter of 126 meters and their capacity got up to 7500 kilowatts, approximately 100 times more than in the 1980s. Japan plans on a multiple-unit floating wind farm (6 wind turbines, each with a capacity of 2 megawatts). By 2020, Japan intends to have up to 80 floating wind turbines off its coast near Fukushima.

YEAR / TIME	DEVELOPMENT
2012	The Alta Wind Energy Center in California became the largest wind farm in the world. It had the capacity of 1,320 megawatts, with plans to increase that to 3,000 megawatts. It included 440 wind turbines at the end of 2012. 815 wind farms were put in operation in the US, with a total power capacity of 60 gigawatts, enough to power up to 15 million US homes. Wind power became #1 source of new power capacity in the US. 45,100 wind turbines were installed in the US that year, accounting for 42% of all new US power capacity. The US again became the world's largest wind power market. Installed wind power capacity in China reached 75 gigawatts, the most in the world for a single country. The UK had over 3 gigawatts of offshore wind power capacity installed, the most in the world and over three times more than Denmark, which came in second. Global wind power capacity reached 282,587 megawatts. Wind power now produced over 30% of Denmark's electricity needs. Vestas produced its 50,000th wind turbine, and its wind turbines installed around the world reached 50,000 megawatts of power capacity. The median levelized cost of wind power was \$0.06/kWh in the United States, approximately 15% what it was in the 1980s. At \$0.06/kWh, the price of electricity.
2013	The world's first hybrid wind/current-powered turbine was installed off the coast of Japan. The London Array wind farm was completed in the UK. The Londan Array became the largest offshore wind farm in the world. It includes 175 wind turbines for a total capacity of 630 megawatts of power capacity, enough to cover the annual electricity consumption of 480,000 British homes. GE produced wind turbines that incorporated energy storage. 54% of Spain's electricity came from renewable energy, mostly wind energy, in one month (April). China again passed the US and became the world's largest wind power market. Wind power became China's third-largest source of power, passing nuclear power. Wind power produced more electricity than any other source in Spain for three consecutive months and provided country with approximately 25% of its electricity. The first offshore wind turbine was launched in the US.

Following table represents the wind direction and wind speed of Gaungzhou, China.

Table 2. *Wind Direction & Wind Speed, Guanghou, China.*

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wind Direction (In Degree)	0	0	0	140	160	160	160	0	40	0	20	20
Wind Speed (In m/s)	2	1	2	1	1	1	2	2	2	1	2	2

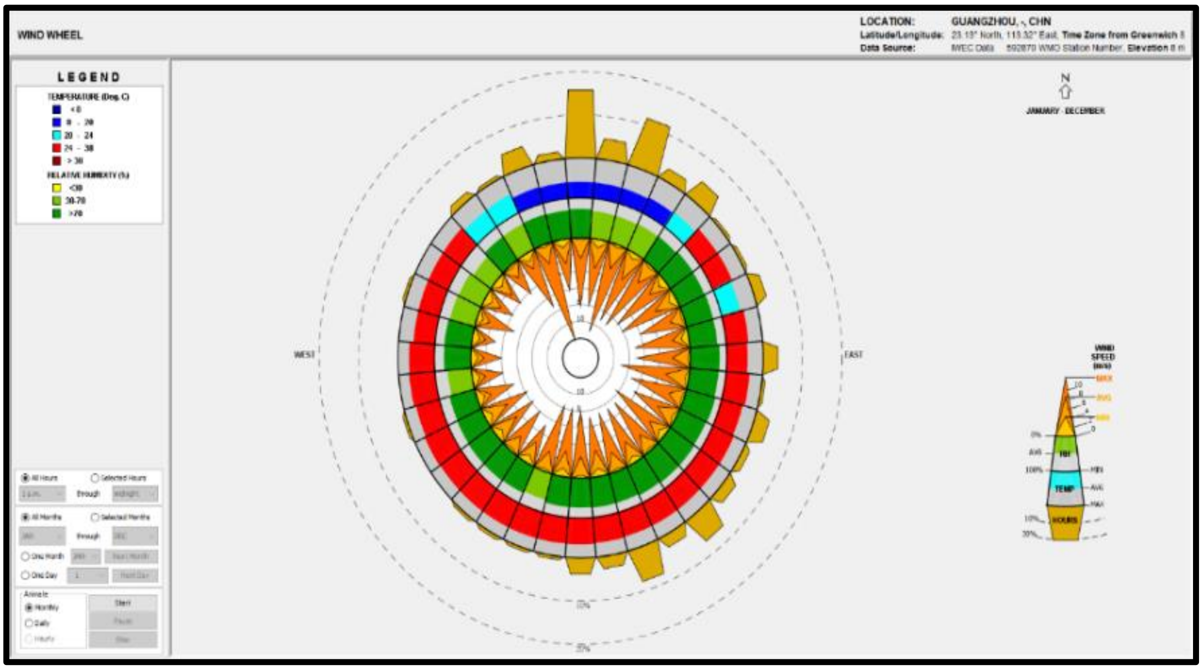


Fig 9. *Wind Wheel, Gaungzhou, China.*

Wind speeds have been cogitated according to the height of the tower and at various levels; the average wind speeds in Gaungzhou is 4.3 m/s at 50 meters' height and 5.3 m/s at 300 meters' height. The curvilinear design of the façade enhances the performance by funneling the air through the turbine inlets and accelerates the wind velocity factor by 2.5, resulting in 8 times more power generation compared to the power generated by wind turbine in an open space.

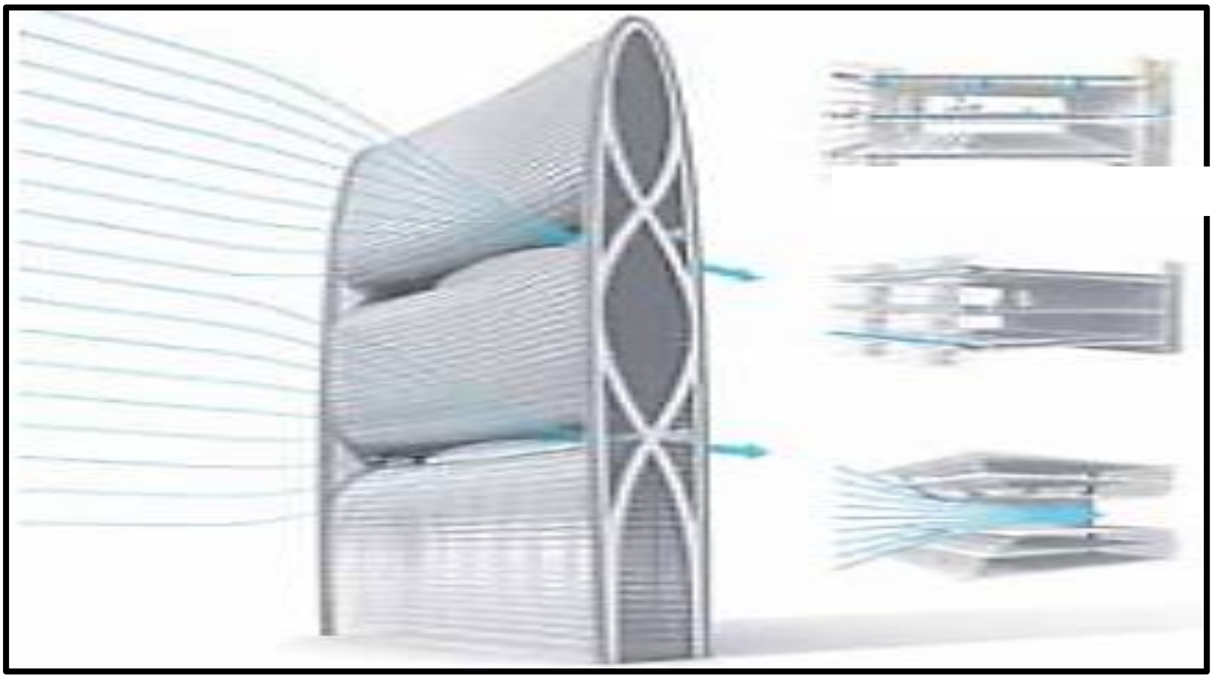


Fig 10. *Wind flow Pattern through the Structure.*

4 large openings of the size 3X4 m wide are designed at the heights of 50 meters and 300 meters each from ground level; these openings will fit Vertical Axis Wind Turbines (VAWT). The façade is deigned to decrease the drag force and increase the wind velocity; the

openings made for the turbines also act as pressure reliever, this strategy increases the wind power translating it to increase power potential. This proves that VAWT has harnessed both passive and prevailing wind directions.

On-site plant generates power with an efficiency of 80%. Each turbine is approximately the size of an oversized domestic kitchen refrigerator and has the capacity of generating power of approximately 65 KW. They can be connected to each other in a series to achieve and deliver the desired capacity to the structure.

A. Strata Tower, London.

It was the 1st skyscraper to integrate wind turbine into its building fabric, contributing to 8% of the estimated total energy. As it is a residential building the energy consumption in greater than a commercial building; therefore, opting for such technology has proved to be useful in the case of this specific structure.

The design brief of Strata Tower was designed to be a residential complex that would be 43 story high (148 m i.e. 485 ft) accommodating 408 apartments (1, 2 and 3 BHK) with over 1000 residents. The estimated project cost was 113.5 million pounds.

Fig 11.*Strata Tower, London.*

Following table specifies the wind direction and the wind speed; also the wind wheel gives the graphical representation of the same.

Table 3. *Wind Direction & Wind Speed, London*

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wind Direction (In Degree)	200	80	280	70	210	20	200	210	10	70	180	220
Wind Speed (In m/s)	3	2	4	3	3	3	2	2	3	2	2	3

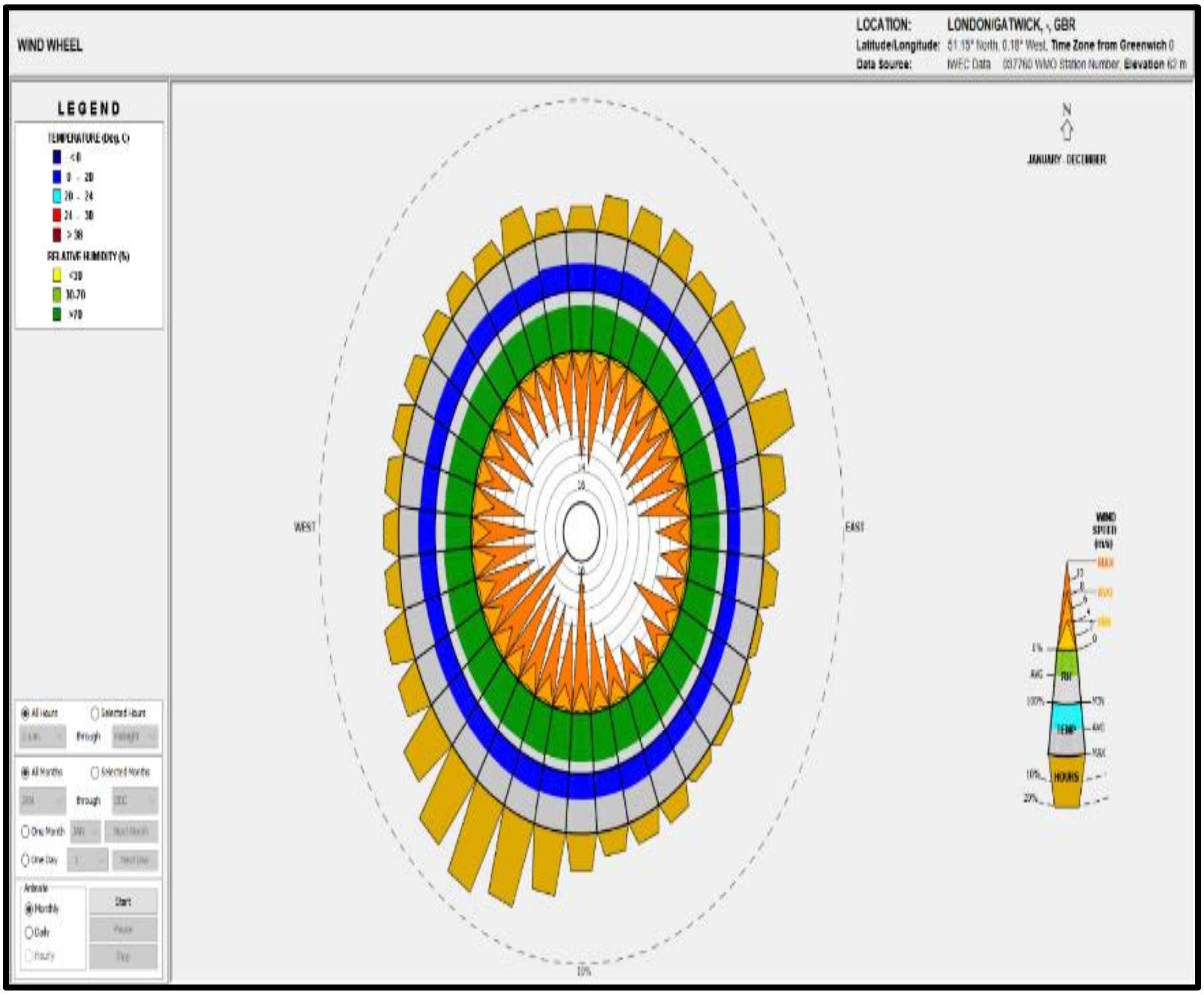


Fig 12.*Wind Wheel, London.*

About the Turbines: -

Three turbines rated 19 kW with blade size 3X5 each produce 50 MW/h of electricity annually. Venturi tubes of 9 m dia are also a part of the façade design. The energy produced is enough to meet the annual demand of 30 X 2 BHK (206 building regulation) and 20 X 2 BHK (2001 building regulation). Wind turbines optimum operating range depend on the regions wind speed and its prevailing wind direction; in the following case study it'll be 8 – 16 /s from south. The turbines will run 24 hours using the negative wind pressure for optimum production of electricity. It is anticipated that there won't be any acoustic impact. The only drawback of the specific case it that when it was built they were not to sell the excess produced energy to the grid.

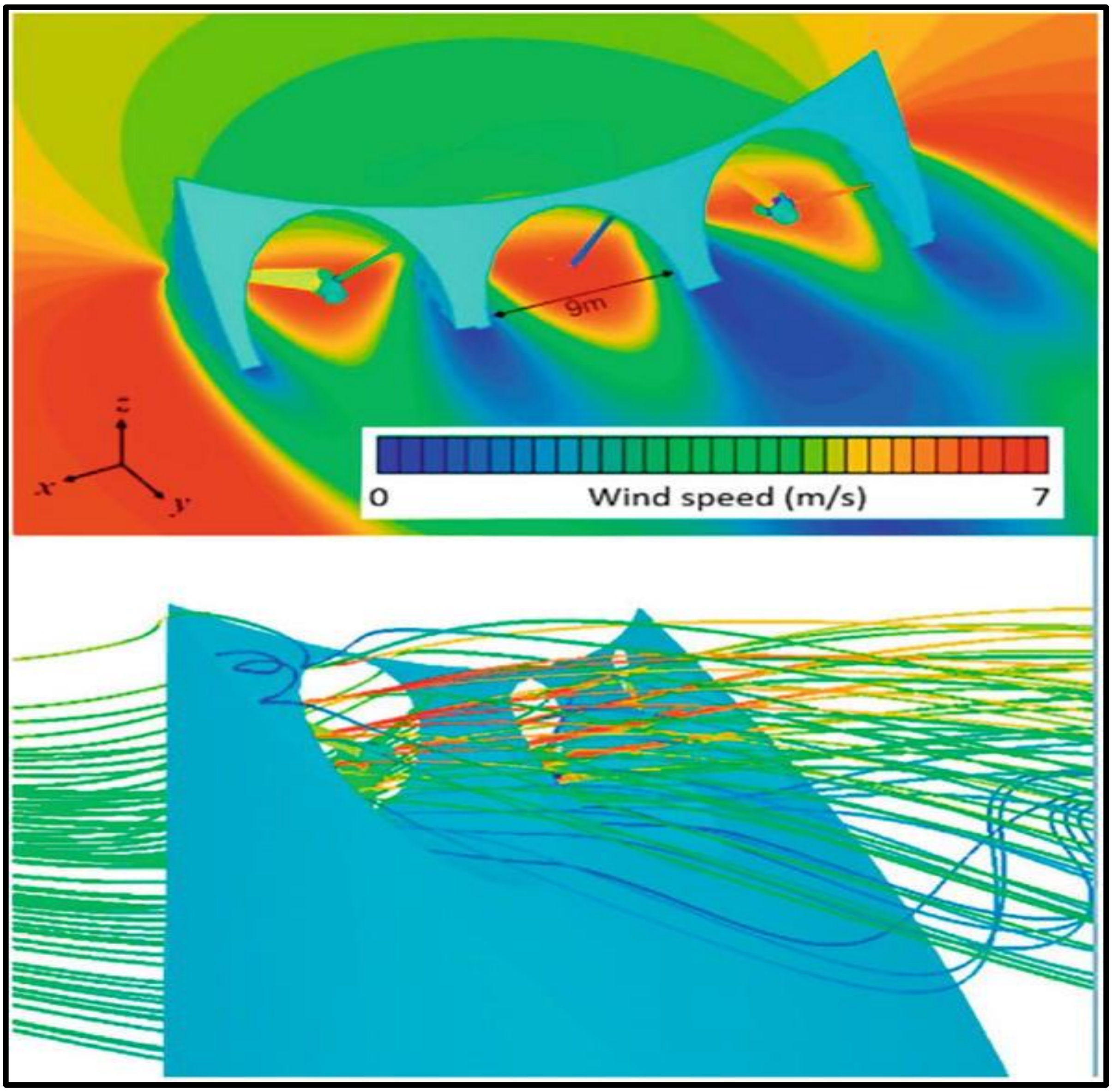


Fig 13. *Simulation to Study Wind Flow through the Turbine.*

Table 4. *Wind Turbine Details.*

Hub HeightBladesRotor DiameterRated RPMPower RegulationRated PowerPredicted Annual PowerYAW MechanismTower TypeDesign	135 m58.5 m1000Air Brakes / Pitch-able Blades18 kW45 – 100 MWh / annumNone / Fixed12.5 DEG tilted Custom MastNorwin, custom design

B. Bahrain World Trade Center

Design brief of Bahrain World Trade Center has (Al-Kodmany, 2018)incorporated 3 wind turbines to harvest wind energy for generating electricity. Two 50 storey sail shaped office towers tapering to a height of 240 meters, supporting three 29 m dia horizontal axis wind turbines (HAWT). To sculpt the airflow, a balance is struck between shape and spatial relationship creating an “S”, the center of the wind stream remains nearly perpendicular to the turbine within a 45° wind azimuth, either side of the central axis. The project cost of the two towers is $150 million.

Fig 14.*Bahrain World Trade Center.*

Following tables specifies the wind direction and wind flow. For consideration sake the nearest two cities (Abu Dhabi and Riyadh) wind direction and wind flow have been studied.

Table 5. *Wind Direction & Wind Speed, Abu Dhabi*

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wind Direction(In Degree)	320	290	320	330	320	300	320	320	160	80	310	310
Wind Speed(In m/s)	3	3	3	3	4	4	3	3	3	3	2	3

Table 6. *Wind Direction & Wind Speed, Riyadh.*

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Wind Direction(In Degree)	120	0	150	20	160	0	330	30	0	0	150	150
Wind Speed (In m/s)	2	3	3	3	3	3	4	3	2	2	1	2

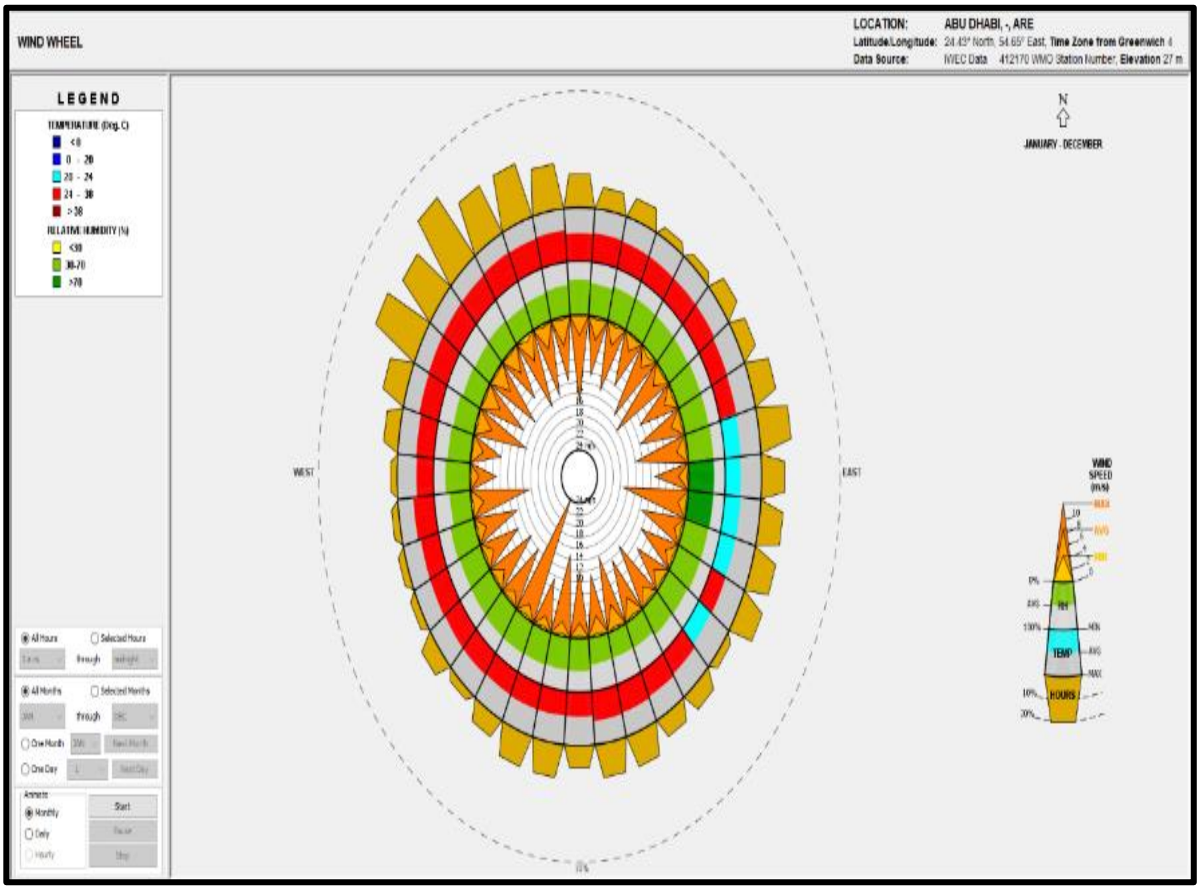


Fig 15.*Wind Wheel Abu Dhabi.*

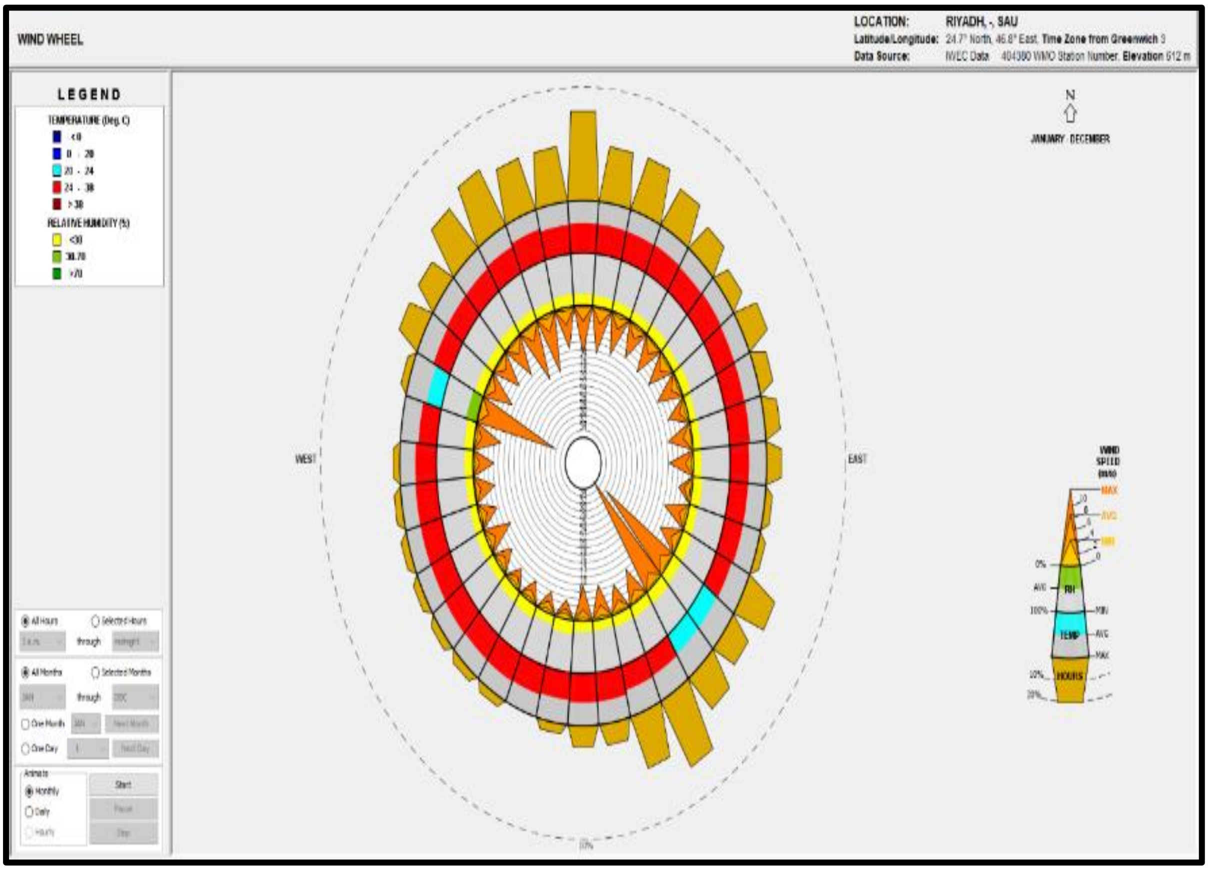


Fig 16.*Wind Wheel Riyadh.*

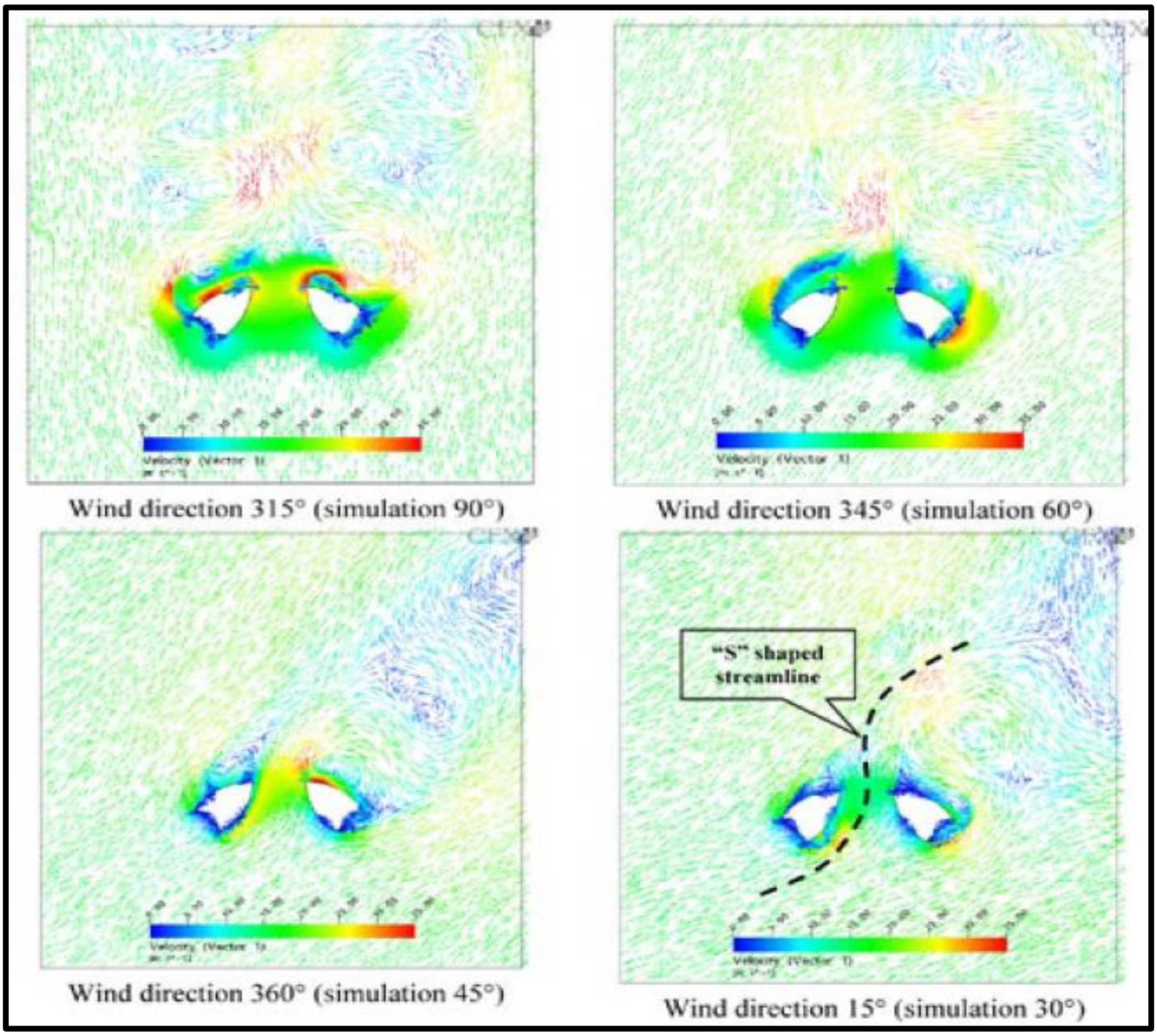


Fig 17.*CFD Simulation to Study Wind Pattern.*

Horizontal Axis Wind Turbines (HAWT) are usually mounted on a pole, but at Bahrain World Trade Center the wind turbines have been mounted over bridge and in the direction of the prevailing winds to yield maximum wind energy. The shape of the building invites the wind in to the turbines.

The key components of HAWT on this project comprise of the following; -

- Nacelle: including enclosure with gearbox, generator, cooling system and associated control system.
- Rotor.
- Bridge.
- Control, Monitoring and Safety Systems.
- Electrical Building Interface.
- The power yielded by the HAWT rounds around to 1,100 and 1,300 MWh power per year which amounts to 11% to 15% of the total electrical consumption. If calculated in terms of carbon emission, it will equate to an average of 2,900 kg C (oil burning power station) or 2,000 kg C (gas burning power station).
    - Wind turbine Details: - Energy Yield: -

Fig 18.*Barain WTC Wind Turbines.*

Fig 19.*Barain WTC Wind Turbines with the Bridge*

Table 7. *Wind Turbine Details.*

Nominal Electrical Power Generated	225 kW
Power Regulation	Stall
Rotor Diameter	29 M
Rotor Speed At Full Load	38 rpm
Air Brake	Centrifugally Activated Feathering Tips
High Speed Mechanical Brake	Fail Safe Type Disc Break
Low Speed Mechanical Brake	Cliper Type
Generator	Closed, 4 Pole Asynchronous Induction. 50 Hz
Yawn System	Fixed Yawn
Cut In Wind Speed	4 m/s
Cut Out Wind Speed	20 m/s (5 Minute rolling average) – Reduced from 25 m/s for This Application
Maximum Wind Speed For Blades	80 m/s (any direction) Class IV Hurricane = > 69 m/s

Table 8. *Wind Turbine Energy Yeild.*

Turbine #1	340 to 400 MWh/Year
Turbine #2	360 to 430 MWh/Year
Turbine #3	400 to 470 MWh/Year

Economical factor

The cost of investment in a wind turbine / wind mill farm is not something that can get neglected with anyone's eye so easily. Right from installation to O&M, everything is costly; but if looked at the positive side of the same, wind energy has the potential to produce enough electricity to get the user off the grid.

The following table will give a brief review of the evolution of costs from 2012 to 2018 (in Euros)

Cost components (millions of euros per MW of installed capacity)	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*
Wind generator	0,81	0,78	0,76	0,74	0,73	0,71	0,70	0,68	0,67
Internal electrical installations	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06	0,06
Electrical substation and power lines	0,18	0,18	0,18	0,18	0,18	0,17	0,17	0,17	0,17
Engineering design and construction	0,10	0,09	0,09	0,09	0,09	0,09	0,08	0,08	0,08
Additional expenses	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02	0,02
Total construction cost	1,17	1,14	1,12	1,08	1,07	1,05	1,03	1,01	1,00
Operating cost	0,06	0,06	0,05	0,05	0,05	0,05	0,05	0,05	0,05

Fig 20. *Cost Evolution Chart.*

Conclusion

Our future lies in the hand of such clean and green technologies. These techs will prove to be "Noah's Ark" for our future. More improvements and research needs to be done with the help of permutations and combinations that will lead us to gain more knowledge not only on the mentioned technologies but many more technologies to come.

The following paper is just a glimpse into one technology that is being used in both residential and commercial sector. Use of such technologies will lead to reduce carbon emission and carbon footprint, structure will be able to produce their own energy and on depend on any other source for it; this will also give an opportunity to them to be independent of any sort of grid and also save economically.

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