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Clean Energy Solutions for Sustainable Environment

Could renewable energy affect the form of the city?

"Wind energy as a special parameter"

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Abstract

The urbanized surface of the old continents could be double in little more than a century due to the transit of the world from villages to cities (according to the UN) beside the rapid growing in the world population, these will lead to large numbers of environmental problems, one of these problems is that the energy consumption per person will increase so more energy will be produced. [1]

Electricity from fossil fuels such as oil, coal and natural gas negatively affect the environment at each step from production till consumption, and relaying mainly on these resources of energy to apply this new huge demand will lead to producing more CO2 gas in the atmosphere which will case rising of earth temperature in a rapid rate while electricity generated using sources other than fossil fuel reduces the environmental impacts.

Buildings consumes approximately 39% of the energy and 74% of the electricity produced annually in the United States (according to LEED BD+C version 3), and as a rule of thumb the better the energy performance of a building, the fewer greenhouse gases are emitted, So relying on renewable energies to supply urban areas with the power needed is the solution for this problem and is considered an important approach for our cities to be more sustainable.
The major shift in the vision of sustainable cities is the potential of buildings to produce energy. This will entail a whole host of solutions (solar, wind power and so forth) that will make cities more interesting as well as sustainable. And in this paper we will try to introduce the main parameters and components of these renewable energies which can affect the form of the city and the important dimensions that should be taken into consideration when designing a new sustainable city.

Keywords: Renewable energies; Wind energy; Small scale wind turbines; Horizontal / Vertical wind axe turbines; Wind corridors; Wind energy in Egypt.

1. Renewable Energies (Solar, Biomass and Wind power)

- Solar thermal power will likely provide a major share of the renewable energy needed in the future, since solar radiation is by far the largest potential renewable resource. About 1 % of the earth's deserts covered with solar thermal plants would have supplied the world's total energy demand for the year 2000.
- Biomass is a term used to describe plant material used as an energy source for either buildings or transportation. The astonishing thing about biomass is that we can produce it relatively quickly. If one considers that 1,000kg of dry biomass has about the same energy content as 400kg of crude oil,22 one can appreciate the potential. Biomass is considered to be CO_2 neutral because its combustion does not result in a net increase in atmospheric CO_2; this is because such crops absorb CO_2 during photosynthesis. It is accepted, however, that its production and transport currently require fossil fuel and therefore, strictly speaking, there will be some net CO_2 emission.
- Compared with other renewable energy technologies, wind energy is the closest to being competitive with fossil-based systems. These facts should dispel any uncertainty about the future role of wind in the energy scenarios of the twenty-first century. Energy production costs are less expensive at those good wind sites in terms of installed cost per kilowatt than PV which makes it an attractive proposition as a building integrated power source. [2]

2. Wind energy – History and development

Wind turbines are available in a wide range of sizes, from small battery charging units with rotor diameters less than 1 meter to very large wind turbines with rotor diameters greater than 100 meters with a capacity of several megawatts. The choice of turbine size depends on the site chosen and the scale of the required development.

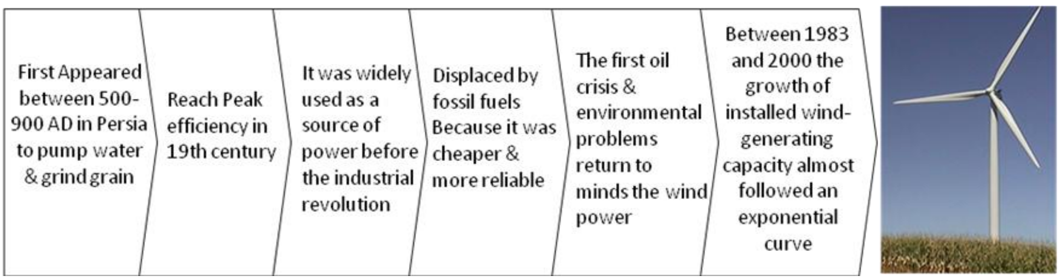


Fig.1 Wind Turbines from appearance till now.

3. Basics Technical Information

3.1. Components of wind turbine

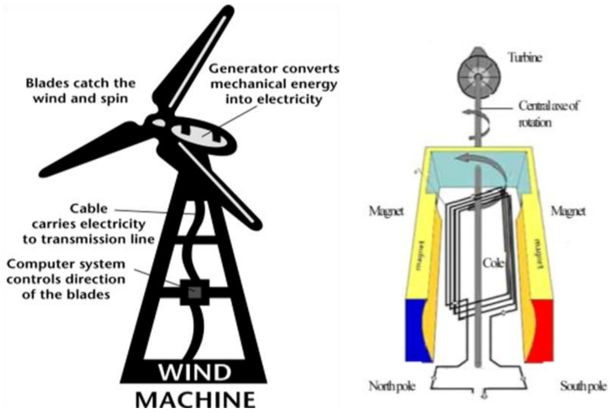


Fig.2 (a) Main components of the wind turbine (b) Diagram for the turbine & generator

3.2. Operation principles

Modern wind turbines are designed on the aerodynamic principles of lift (Eldridge, 1980; Dunn, 1986) similar to that of aircraft wings or sail boats (tacking upwind). Lift forces are created on an aerofoil, its leading edge is oriented at a small angle to the direction of the incoming wind. The lift force (only) turns windmill blades for useful power output. [3]

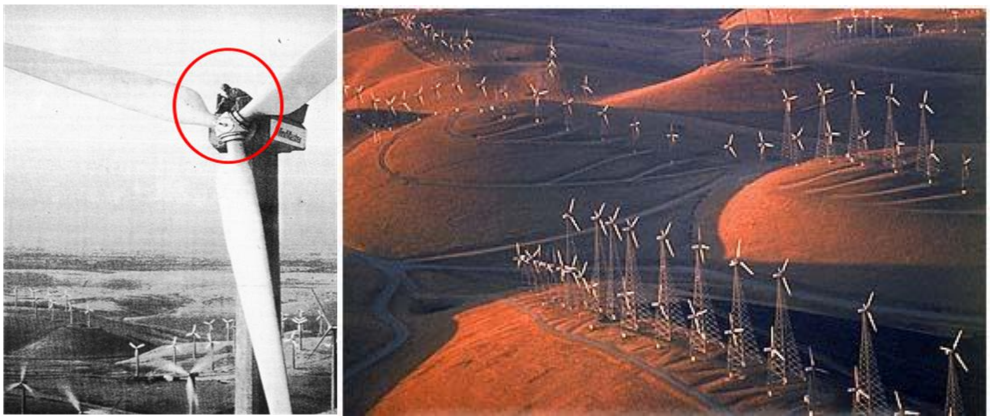


Fig. 3 Medium size wind turbines, Wind master turbines at Altamont Pass, CA. (b) Vestas turbines at Techavhpi, CA. (Courtesy of the American Wind Energy Association)

3.3. Spacing of Turbines

Wind turbines need to be positioned so that the distances between them are around 3-10 rotor. This spacing represents a compromise between compactness, which minimizes capital cost, and the need for adequate separations to lessen energy loss through wind shadowing from upstream machines. The required spacing will often be dependent on the prevailing wind direction as illustrated in Figure 4 below, which shows a possible layout for a UK site with a typical South Westerly prevailing wind direction. [4]

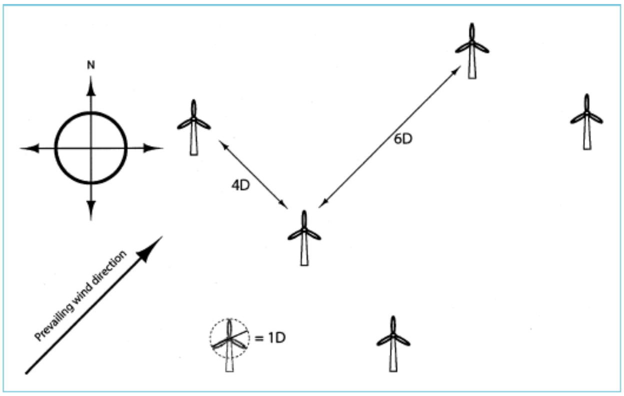


Fig.4 Example turbine spacing in a wind farm with a south westerly prevailing wind direction

3.4. The relation between rotor diameter and wind speed with the generated power:

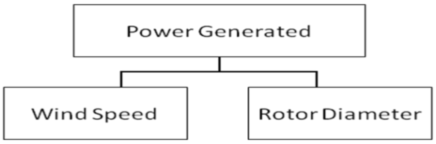
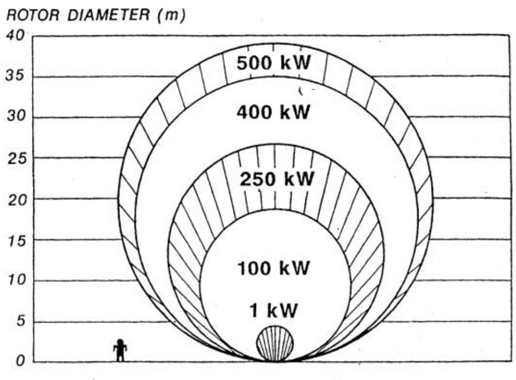


Fig.5 Factors affecting power generated from wind turbine.

There are two things worth noting:

1- An increase in the rotor diameter of a wind turbine will result in a greater than proportional change in rated power. The diagram below (figure 6 & 7) illustrates this [4].



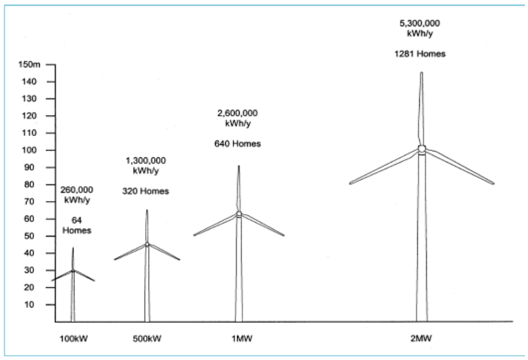


Fig.6 Showing relation between rotor diameter versus output power capacity (source: Boer 1994 American Solar Energy Association).

Fig.7 Approximate sizes of typical three-bladed turbines by installed capacity, also showing approximate annual energy output based on an average capacity factor of 0.3, the figure of the no. of homes supplied is based on the average UK household consumption of 4100 KW/year (OFGEM).

2- An increase in wind speed will result in a greater than proportional change in rated power. Rated power is proportional to the cube of the wind speed, and hence a doubling of wind speed will result in a roughly eight-fold increase in power output.

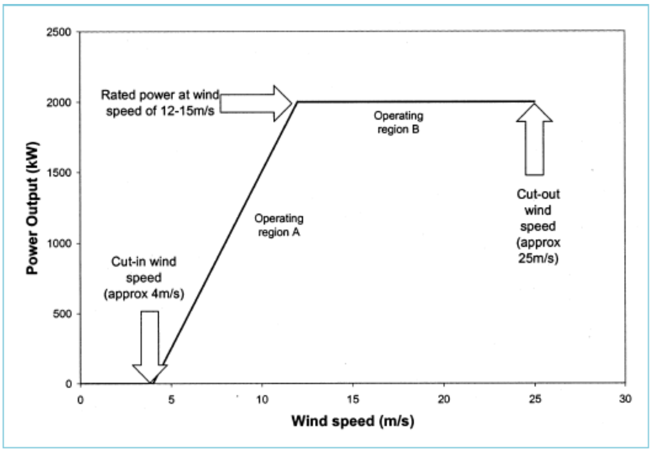


Fig.8 Representation of a wind turbine operating regime

These are both best explained in relation to wind turbines

- Operating regime as shown in figure 8 above, which shows the relationship between the wind speed and power output. The simplest indicator of the wind resource available at a given location is the annual mean wind speed at the site (usually given at the hub height of the turbine).
- A machine located on a site which has an annual mean wind speed of 6 meters per second will typically produce only half as much energy as the same machine on a site where the annual wind speed is 8 meters per second.
- The mean wind speed at hub height will determine the energy captured at a site.
- Below cut-in there is insufficient energy in the wind for the wind turbine to generate electricity. In the operating region ‘A’ between cut-in and rated wind speed a wind turbine will attempt to maximize the energy capture from the wind. In the operating region ‘B’ between rated wind speed and cut-out a wind turbine is required to limit the energy capture from the wind, such that the rated power is not exceeded. Above the cut-out wind speed the wind turbine must stop and park the rotor in order to protect itself.
- The turbine is controlled by its own computer system, which provides both operational and safety functions.

Table.1 a comparison between power generated and wind velocities for different sizes of wind turbines.

At two heights above ground level								
For 10m in diameter wind turbine								
Wind velocity (m/s)	0	4.4	5.1	5.6	6	6.4	7	9.4
Power generated (W/m2)	0	100	150	200	250	300	400	1000
For 50m in diameter wind turbine								
Wind velocity (m/s)	0	5.6	6.4	7	7.5	8	8.8	11.9

Power generated (W/m2)	0	200	300	400	500	600	800	2000

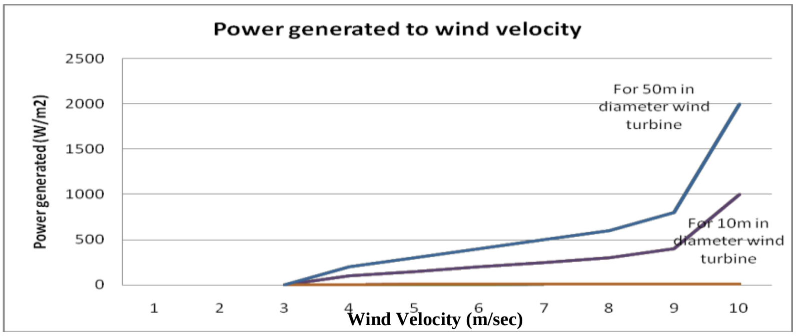


Fig.9 Power generated to wind velocity for 10m & 50m in diameter wind turbine.

(Note that the relationship of wind power with wind velocity is not linearly proportional or even quadratic but varies rather as the third power of velocity.)

4. Offshore Wind Turbine

Beside onshore wind turbine there is another type of wind turbines according to place of construction which is offshore wind turbine.

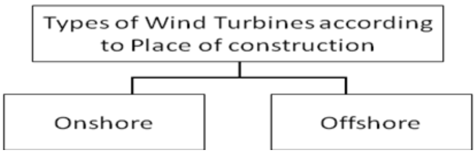


Fig.10 Types of wind turbines according to place of construction

Offshore wind energy is a promising application of wind power, particularly in countries with high population density, and difficulties in finding suitable sites on land. Construction costs are higher at sea, but energy production is also higher.

Fig.11 Offshore wind turbines near Copenhagen

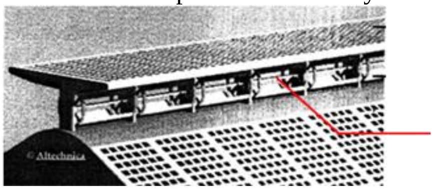
Denmark leads European offshore wind power in 2009. Offshore wind turbines with a combined capacity of 577 MW were installed in Europe in 2009 and Denmark accounted for 230 MW of the expansion.

5. Small scale wind turbine

This section is mainly concerned with small-scale wind generation that can operate as embedded generation in buildings and this is where some of the most interesting developments have taken place. In this context "small" means wind machines that are scaled from a few watts to 20 kW Machines between 1 and 5 kW may be used to provide either direct current (DC) or alternating current (AC). They are mainly confined to the domestic level and are often used to charge batteries. The larger machines are suitable for commercial, industrial buildings and groups of houses.

Table 2. Comparison between Small scale wind Turbines located in an Urban Context & Large Scale Wind Turbines Located in Wind Farms.

Large Scale Wind Turbines Located in Wind Farms	**Small Scale Wind Turbines Located in an Urban Context**
Locating the turbine on a low level from ground leads to: 1-Increase wind turbulence 2- Locating the turbine in a less speed wind region, so a large scale wind turbine is used to provide an Appropriate amount of energy	Locating the turbine on a high level from ground leads to: 1-Reduce wind turbulence 2 -Locate the turbine in a better wind speed region (since the wind speed is directly proportional to height) and thereby produce more energy that can offset its small size.
Using large scale wind turbines leads to consume more materials (in extraction & manufacture processes) which increase the negative impact on the environment and the initial cost for every produced KW (lower efficiency)	Using Small scale wind turbines lead to reduce the manufacturing materials, and thus reduces the negative impact on the environment, also it reduces the initial cost for every produced KW (Higher efficiency)
A long electric cables Should be provided between the location of energy production (in the wind farm) and the location of energy use.	No need for these long cables since the location of producing and consuming energy is the same, which has a great benefit on the environment and the initial costs.
Effect the city land uses significantly since it needs a dedicated large vacant area to generate electricity (lower environmental & economical value)	Has no effect on the city land uses at all, which is reflected on the economical and environmental value positively. Economical value: doesn't need this large area of land since it's located on the roof of the existing buildings, thus it save the land value that was allocated to energy production. Environmental value: reduce the negative impact of human development on nature.

<table>
<tr>
<td>Generating energy from wind farms will lead to a direct visual impact outside the city which cannot be treated by architecture methods
</td>
<td>Can be located inside the city within a certain urban requirements taking into account to not affect the visual composition of the city.

unobservative small scale wind turbines on building's roof</td>
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<td colspan="2">Conclusion: For human settlements, sustainable development Principles in general and LEED Principles in particular require achieving a high human density to reduce the infrastructure, building materials and facilities … ect. Consequently installing small scale wind turbines over medium and high rise buildings (to achieve the appropriate height to generate electricity and the targeted human densities) is a better approach than relying on wind farms to generate this power.</td>
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6. Types of small scale wind turbines

There are essentially two types of wind turbine, and they look very different vertical axis machines with rotors that rotate about a vertical axis, and horizontal axis machines whose rotating shafts are aligned horizontally, most wind turbines installed today are of the horizontal axis type. [5]

Wind turbines are defined by the size (diameter) of the rotor and rated power or capacity.

6.1. Horizontal axis machines

Horizontal axis machines are much more in evidence than the vertical axis type in this scale. These machines have efficient braking systems for when wind speed is excessive the height of the tower is normally at least twice the length of a blade. The blades need to be far enough from the ground to minimize turbulence and to maximize the energy capture of the wind turbine.

6.2. Vertical axis machines

Vertical axis turbines are particularly suited to urban situations and to being integrated into buildings. They are discrete and virtually silent and much less likely to trigger the wrath of planning officials. Presently, there are several versions of vertical axis machines available. This type has even been the basis for an art work as in a sports stadium at Yurigoaka, Japan. [6]

Fig.12 Horizontal axes machine located on a building

Fig.13 Savonius turbine type 1 & 2

Table 3. Comparison between Horizontal and Vertical axe machines.

Horizontal axe machine	**Vertical axe machine**
much more in evidence so Have a better cost benefit due to economy of scale of production	Less in evidence so a lower cost benefit due to economy of scale of production occurs
Automatic start-up	Some very small vertical axis machines need mechanical start-up which can be achieved either by an electric motor or a link to a Savonius-type rotor
Higher output	Have a high output power to weight ratio and able to operate at lower wind speeds
In urban situations where there can be large variations in wind direction and speed, this necessitates frequent changes of orientation and blade speed, this not only undermines power output it also increases the dynamic loading on the machine with consequent wear and tear	Much more effective in urban environment not affected by changes in wind direction or turbulence (since wind patterns in the built environment are complex as the air passes over, around and between buildings).
there are noise problems with this kind of machine especially associated with braking in high winds	virtually silent
They can be visually intrusive	Much less visually intrusive
They can be sited on roofs only	They can be sited on roofs or walls

When mounted on roofs tend to transmit vibrations through the structure of the buildings Because of the bending moment produced by the tower under wind load so they require substantial foundation support	less stressed mechanically by turbulence (well balanced, transmitting minimum vibration and bending stress to walls or roofs)
A necessity of a high mast is required to minimize turbulence and to maximize the energy capture	A further advantage is that the electricity generator is located beneath the rotors and therefore can be located within the envelope of the building
it is a robust and tested technology	particularly successful
Conclusion: In built environment, Such conditions tend to favor vertical axis machines as opposed to the horizontal versions in residential zones, while in commercial, office parks and manufacture zones (where noise factor is not the main Priority) horizontal machines would be more reliable to generate more power, (or a combination between horizontal axe on roofs and vertical axe on walls could be achieved to reach maximum efficiency of generating electricity)	

7. Enhancing performance of wind turbines

- Enhancing performance of wind turbines will never stop at a level, many trials have been done and will continue in the future to achieve this goal.
- A development from the 1970s has placed to the horizontal axis machines, the turbine blades inside an aerofoil cowling. A prototype developed at the University of Rijeka, Croatia, claims that this combination can produce electricity 60% more of the time compared with conventional machines.
- This is because the aerofoil concentrator enables the machines to produce electricity at slower wind speeds than is possible with conventional turbines.
- The cross-section of the cowling has a profile similar to the wing of an aircraft which creates an area of low pressure inside the cowling. This has the effect of accelerating the air over the turbine blades. As a result, more electricity is produced for a given wind speed as well as generating at low air speeds.
- This technology can generate power from 1 kW to megawatt capacity. It is being considered for offshore application. The device is about 75% more expensive than conventional rotors but the efficiency of performance is improved by a factor of five as against a conventional horizontal axis turbine (see Fig. 14). [2]
- The most common vertical axis machine is the helical turbine as seen at the Earth Centre, Doncaster (see Fig. 15). In that instance it is mounted on a tower but it can also be side-hung on a building. Another variety is the S-Rotor which has an S-shaped blade.

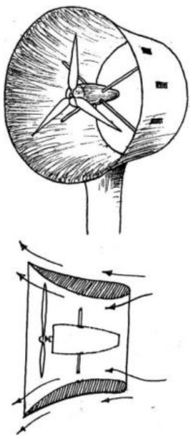

Figure 14 Wind turbine with clowing wind concentrator.

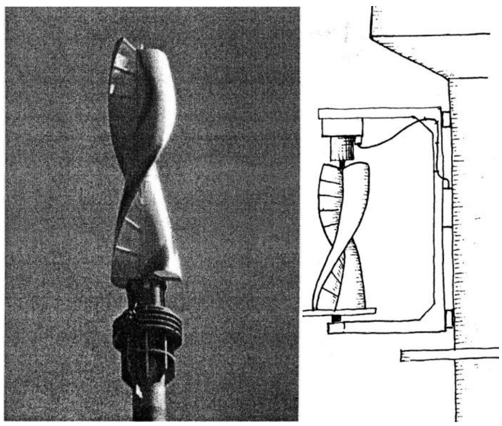

Figure 15. Helican turbine on a column at the Earth Centre, Doncaster.

The Darrieus-Rotor employs three slender elliptical blades which can be assisted by a wind deflector. This is an elegant machine that nevertheless needs start-up assistance. (See Fig. 16). Presently, there are several versions of vertical axis machines available.

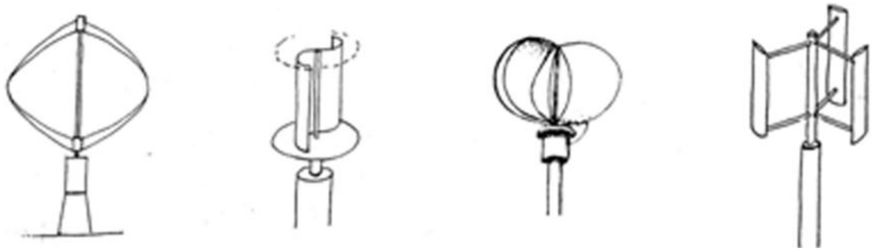

Figure 16 Left: .S-Rotor; top centre: Darrieus-Rotor; bottom centre: Lange turbine; right: H-Darrieus-Rotor

However, they are still undergoing development. When it is fully appreciated that these machines are reliable, silent, low maintenance, easy to install and competitive on price, it is likely the market will expand rapidly.

8. Wind and form of the city - Designing wind corridors

- Design the wind corridors for the purpose of ventilation and generating power by wind turbines in the city is a new important dimension that should be taken into consideration when designing a new city.
- Wind directions, Buildings heights and spacing between them, percentage of buildings heights to street width ratio, percentage46 of openings in the buildings walls besides selecting the exact location of wind generated power nodes, determine the size and type of wind turbines all of them are the elements of the wind corridor that should be considered in the design.

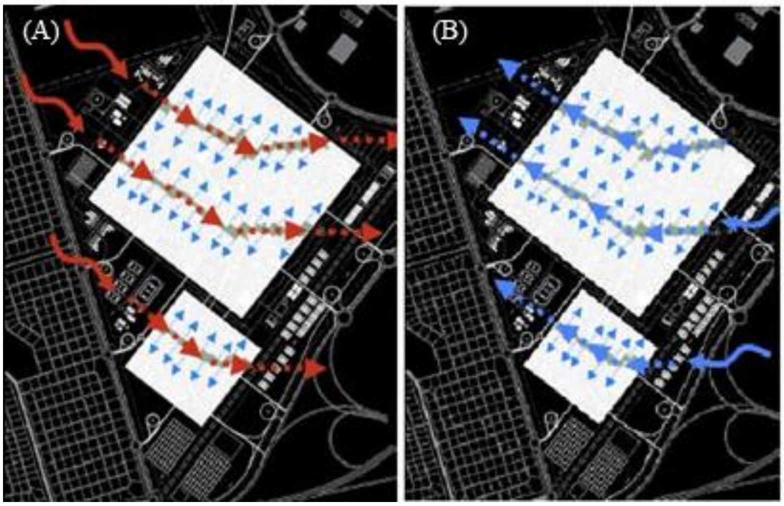

Figure 17 (a) Daytime / (b) Nighttime wind study through Masdar city indicates the use of wind corridor concept through the city.

9. Wind Energy in Egypt

9.1. Inventory and assessment of wind sources energy in Egypt

- Preliminary Studies and measurements have shown that Egypt enjoys a clear and rich wind energy sources in several areas in general and in the Gulf of Suez in particular, where they are considered one of the best regions in the world for the production of electricity using wind power.

- In March 2003, a detailed wind atlas for the Gulf of Suez was Issued, including a detailed statements for 13 of wind sites during 1991 - 2001 to evaluate the potential of wind energy in that region (Table 4)

9.2. Winds Atlas of Egypt

The winds Atlas of Egypt was released in December 2005, in cooperation with the Danish Factors of REZO and meteorology agency, pointing out the promising and appropriated areas to generate electricity from wind energy, it is considered the cornerstone upon which all decisions on the future wind projects locations, planning and feasibility studies are determined in Egypt.

- Wind Atlas of Egypt has been prepared based on more than 10 metering stations in different places of the Republic, aimed to collecting, calibration and analysis of data of wind speeds and directions in those places on a time scale of 1991 - 2005, using special analytical software, topographic maps, satellite imagery and field visits, then it has been focus on a 6 promising regions:

North East coast - North West Coast - Gulf of Aqaba - Gulf of Suez - Red Sea -Western Sahara

- The Atlas shows that there are sources of wind power that can be exploited, especially in the Gulf of Suez (Fig.18), where wind speed and density have an average between 7 to 10 m / s, 350 to 900 W / m 2 are estimated on the height of 50 m from the ground level.[7]

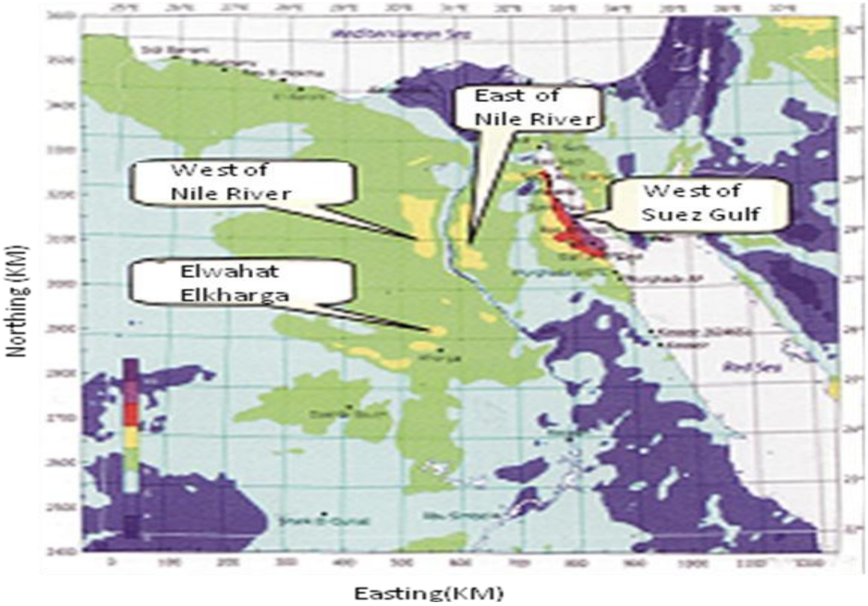

Figure 18 Wind map of Egypt, purple, red and yellow colours indicate regions having high wind speed (7-10.5 m/s) while blue colour indicate regions having low wind speed.

Table 4. the annual average wind speed on 25m height

Region	Average wind speed
Ras Sedr	7.5
Abodarg	8.8
Alzaafarana (north)	9.2
Alzaafarana	9.0
Alzaafarana (south)	7.5
Sant pole	8.4
Rasghareb	10.0
Altor	5.6
Oil gulf (north)	10.4
Oil gulf (north west)	10.5
Oil gulf	10.3
Oil gulf (south west)	10.8
Hurghada	6.7

- There are areas characterized by high wind speeds in the Eastern and Western desert - especially in the east and west of the Nile Valley, between latitudes 27 'N, 29' south, and north and west of Alkharga city , where the average wind speed and density of 7 - 8 m / s and 300 to 400 W / m 2 respectively.
- And regard the northwest of the Mediterranean coast from Alexandria to Salloum, this area is characterized by relatively low wind speeds than those previously mentioned.

9.3. Egyptian strategy for renewable energy

Renewable energy is planned to contribute by 20% from the total electric power generated by 2020, wind power is estimated to contribute by 12% from this energy by establishing wind farms connected to the grid with a total capacity of 7200MW (This would save around 13 million tones of CO_2 per year which is equals to 18% from the saved CO_2 in the whole European Union from wind power), which means providing wind farms with an average electric capacity of 600MW annually.

10. Conclusions

- Wind generation technology has a promising future, in the short to medium term than solar electric generation.
- Installing small scale wind turbines over medium and high rise buildings is a better approach than relying on wind farms to generate this power.
- In built environment, vertical axis machines are more reliable in residential zones, while in commercial, office parks and manufacture zones a combination between horizontal axe on roofs and vertical axe on walls could be achieved to reach maximum efficiency of generating electricity.
- Machines between 1 and 5 kW are mainly confined to the domestic level. The larger machines are suitable for commercial, industrial buildings and groups of houses.
- The elements of the wind corridor that should be considered in the design of new sustainable cities are Wind directions, Buildings heights and spacing between them, percentage of buildings heights to street width ratio, percentage of openings in the buildings walls besides selecting the exact location of wind generated power nodes, determine the size and type of wind turbines.
- Egypt enjoys a clear and rich wind energy sources in several areas in general and in the Gulf of Suez in particular.

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