ISSN 1682-296X (Print)
ISSN 1682-2978 (Online)

Bio Technology

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

OPEN ACCESS Biotechnology

ISSN 1682-296X
DOI: 10.3923/biotech.2016.101.111

Review Article
Design of Power Generating Leaf Shade Building

[1]M.A. Dandu, [1]M.N. Norziany, [2]S. Wahaaj, [2]M. Hadi, [3]M. Faizul and [3]I. Haider

[1]Electrical Section, UniKL-BMI, Batu 8, Jalan Sg. Pusu, 53100 Gombak, Selangor, Malaysia
[2]Department of Mechanical Engineering, Pakistan Navy Engineering College, National University of Science and Technology, Karsaz, Karachi, Sindh, Pakistan
[3]Department of Mechanical Engineering, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia

Abstract

The core idea of this study is to propose a design of a building that is self-sustainable in terms of energy by harnessing renewable power from solar and wind energy sources. It utilizes the location with an innovative design and reducing energy consumption by implying advance green technologies, simultaneously. The building is shaded by a huge leaf like structure fulfilling multiple purposes: (1) Harnessing solar energy from installed photovoltaic (PV) modules, (2) Preventing it from direct sunlight and (3) Providing shade to reduce the cost of Heating Ventilation and Air Conditioning (HVAC). The building has three horizontal axis 100 kW turbines at three corners, directly exposed to coastal winds generating electricity, employed for three main purposes: (1) Harvesting the available wind energy at the site, (2) To support PV system in the times of low sun and (3) To earn revenue. Computer Aided Design (CAD) model has been presented to show design of the building. Annual electricity generation and consumption of the building has been estimated and the effect of leaf shading on HVAC and lighting applications has also been discussed. The building also takes advantage of net metering system. In order to ensure that our building saves sufficient energy and operates on ecofriendly processes the building is equipped with green features. This study proves that leaf shade, design of green buildings can be self-sustainable in terms of their energy requirements and electricity providing source.

Key words: Computational design, solar energy, wind energy, photovoltaic cells, green building

Received: April 09, 2016 Accepted: June 29, 2016 Published: August 15, 2016

Citation: M.A. Dandu, M.N. Norziany, S. Wahaaj, M. Hadi, M. Faizul and I. Haider, 2016. Design of power generating leaf shade building. Biotechnology, 15: 101-111.

Corresponding Author: S. Wahaaj, Department of Mechanical Engineering, Pakistan Navy Engineering College, National University of Science and Technology, Karsaz, Karachi, Sindh, Pakistan

Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

A serious energy crisis has troubled Pakistan for the last few decades. The crisis is not only affecting the daily life of people but is also hampering the collective development and advancement of the country. The global trend to meet energy demands is to utilize natural resources. Out of various natural resources such as solar and wind are considered to be viable sources for a country like Pakistan having high solar insolation and windy seashore[1,2]. For that reason, the government should consider renewable energy resources as a savior. In order to cater the current energy crises, generating power from natural resources like: Solar and wind energies is essential. Many scholars in Pakistan and throughout the world are working on energy issues for example Kafait Ullah has given an overview of the existing state of affairs of the electricity sector and main features of the electricity value chain in Pakistan. Ullah[3] also discussed the problems faced by the electricity sector. Mahmood *et al.*[4] gave the detailed overall energy assessment of Pakistan and estimated solar energy potential in Pakistan. Similarly, many funded programs are being appreciated by governments.

For an example, Pakistan Meteorological Department conducted a wind potential survey of the coastal areas of Pakistan. The Ministry of Science and Technology gave funding for this project. Under this project wind data was collected at 44 sites along the Sindh and Baluchistan Coast. (Pakistan Meteorological Department, 2003-2005). It has been analyzed how building shape and architecture affects building energy consumption. Du[5] examined Adland project as a case study in order to investigate how the building morphology, which is one aspect of the architectural quality, impacts the heating demand of buildings.

This study provides the design of the building with the aid of the CAD model, solar and wind energy analysis on the exemplary building that is located at the sea shore in Karachi. The estimation of the annual electricity generation and consumption by building and reduction in energy consumption of leaf shading is also provided. Furthermore, advanced green techniques are also discussed to make the building more energy efficient.

SITE DESCRIPTION

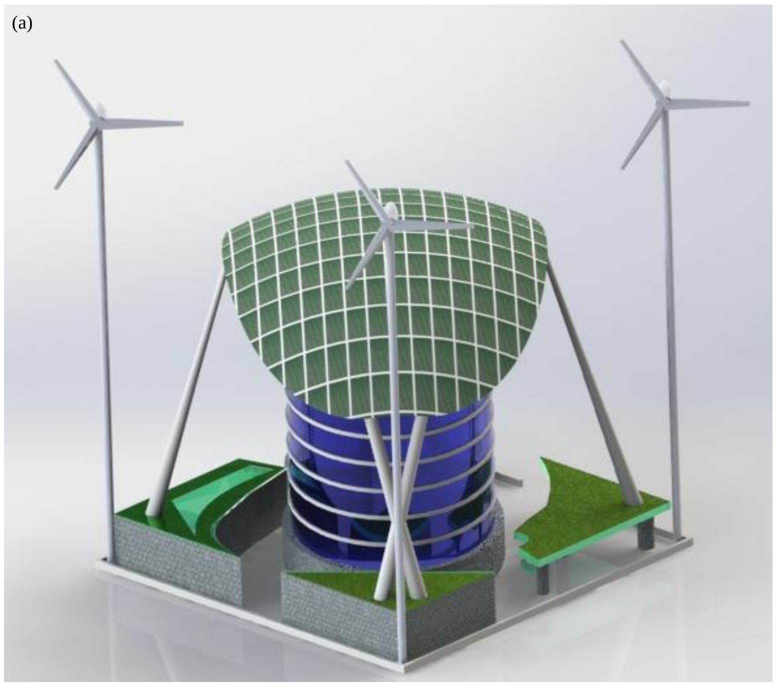
The building is located on the sea shore of DHA phase 8 near Coastal Ave, Karachi, Pakistan has coordinates 24.750, 67.081 as shown in Fig. 1. The total area of the building is 2300 m^2, which comprises of main building covered by leaf shaped structure and three wind turbines. The core object of this building is to harness maximum solar and wind energy taking advantage of its site. The site is selected on the grounds that the development of the city is inclined to that area. Additionally the site is near the sea, which is of great attraction to tourists and also has well developed infrastructural facilities. All the systems that can provide comfort and ease to the dwellers are incorporated in this building. The building focuses on generating its power, using environmentally safe processes and desires for minimum pollution.

Fig. 1: Screen shot taken from google earth showing the aerial view of the building construction site

CAD MODEL

The building is designed on software desault systemes solid works to give the schematic of innovative ideas for harvesting maximum solar and wind energy irrespective of the mechanics, internal architecture etc., involved in building as shown in Fig. 2a, b. One notable feature of the design is that both the energy sources are being generated within the allotted area of the building.

(a)



(b)

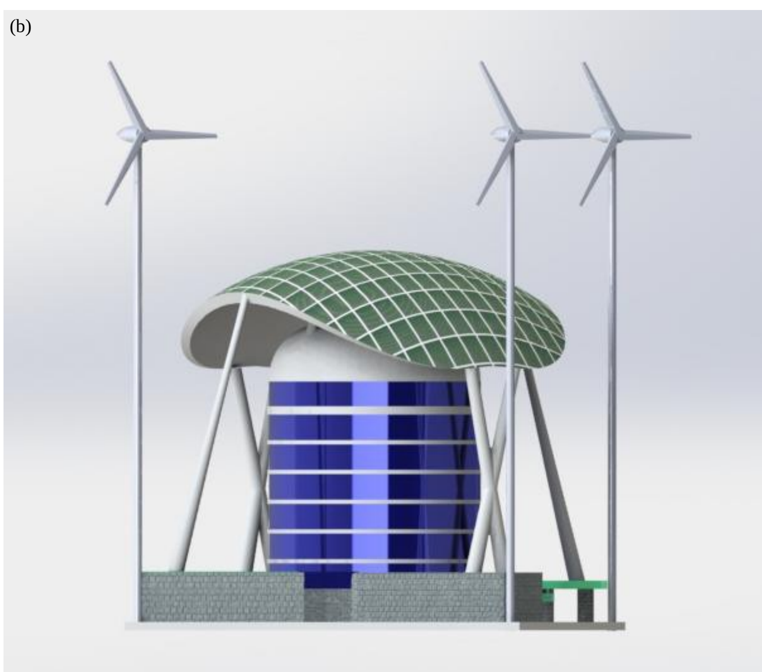


Fig. 2(a-b): Rendered image of CAD model designed on software solid works showing leaf like structure and wind turbines

ANALYSIS OF SOLAR ENERGY

The building is shaded by a huge leaf like structure fulfilling multiple purposes: (1) Harnessing solar energy from installed photovoltaic (PV) modules, (2) Preventing it from direct sunlight and (3) Providing shade to reduce the cost of Heating Ventilation and Air Conditioning (HVAC). Solar panels can face sun more adequately than the ones placed on window exteriors and on flat roofs. The distribution of solar panels on this structure will be in accordance with the position of the sun at different timings of the day and the angle of the sun at our location in different seasons.

Solar insolation is the amount of electromagnetic energy incident on the surface of the earth. The graph of solar insolation vs day time defines the variation of solar energy with respect to time as shown in Fig. 3. Solar panels will have tilt sensors so that sunlight falls normal, imparting maximum of the energy. Tilt sensors will rotate the panels according to the sun's daily trajectory as the power generation mainly depends on solar azimuth and altitude angles[6]. Solar irradiance is the power per unit area produced by the sun in the form of electromagnetic radiation. Irradiance levels vary at different times of the year, depending on the seasons, the weather and the time of day.

Pakistan receives a considerable amount of sunshine hours during the year as a whole. The annual average sunshine of the country is 8 h day^{-1}. January has the lowest sunshine with 6.1 h day^{-1} and June experiences the highest sunshine of above 9 h day^{-1}. The annual sunshine of Pakistan increases from January to June and starts to decrease in August. In September there is a little rise and then there is a continuous drop till December. The Coastal Belt usually, records high sunshine period as compared to the rest of the country and is more suitable for solar energy[7]. The trend of total number of sunshine hours in Karachi is almost same as of Pakistan as shown by statistical data in Fig. 4. At construction sites we have averaged 1700-2200 h of sunshine year^{-1} and solar radiation approximately 2000 kWh m^{-2} as shown in Fig. 5. Both the average number of sunshine hours and solar irradiation level are suitable for optimal working on solar panels.

With the aid of CAD model total surface area of the upper portion of leaf was found to be 2000 m^2 which can be changed as per requirement and construction constraints. Area available for proper allocation of solar panels can be estimated to 1700 m^2, keeping the distance between each panel and other equipment under consideration.

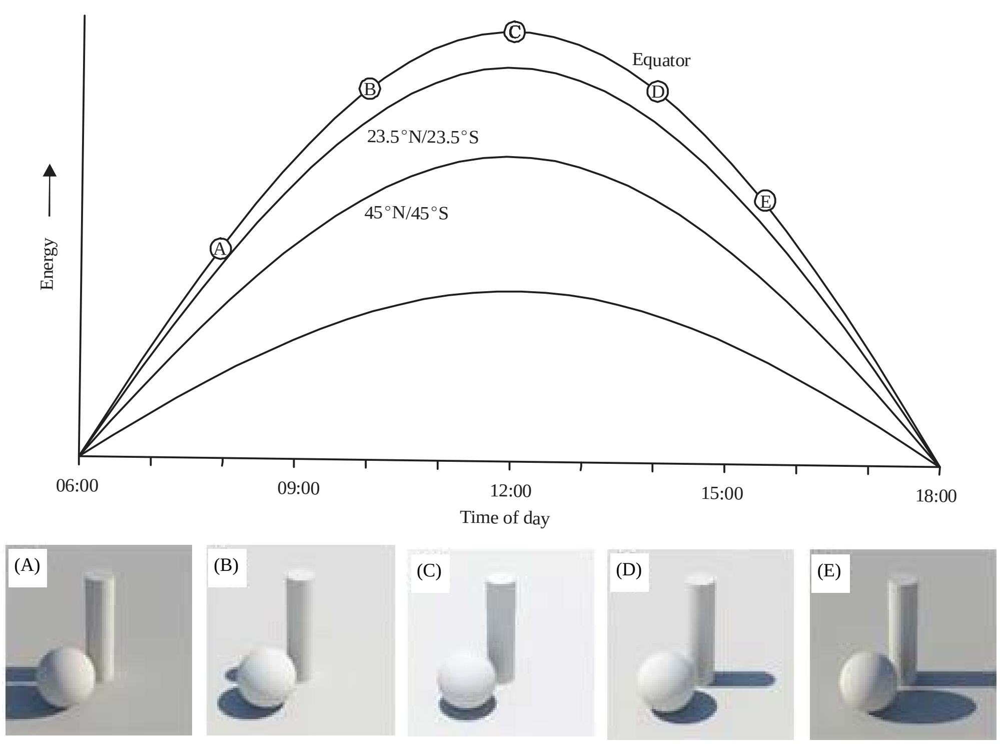
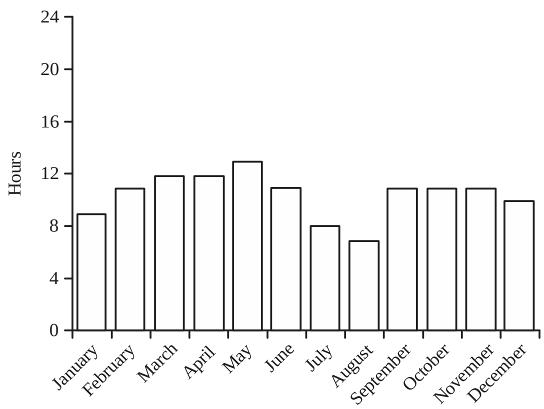


Fig. 3: Graph illustrates the relationship between latitude, time and solar energy during the equinoxes. The illustrations show how the time of day affects the angle of incoming sunlight (revealed by the length of the shadow) and the light's intensity (NASA illustration by Robert Simmon)



(h)

Fig. 4: Statistics showing average No. of sunshine hours in Karachi in different months (holiday-weather.com)

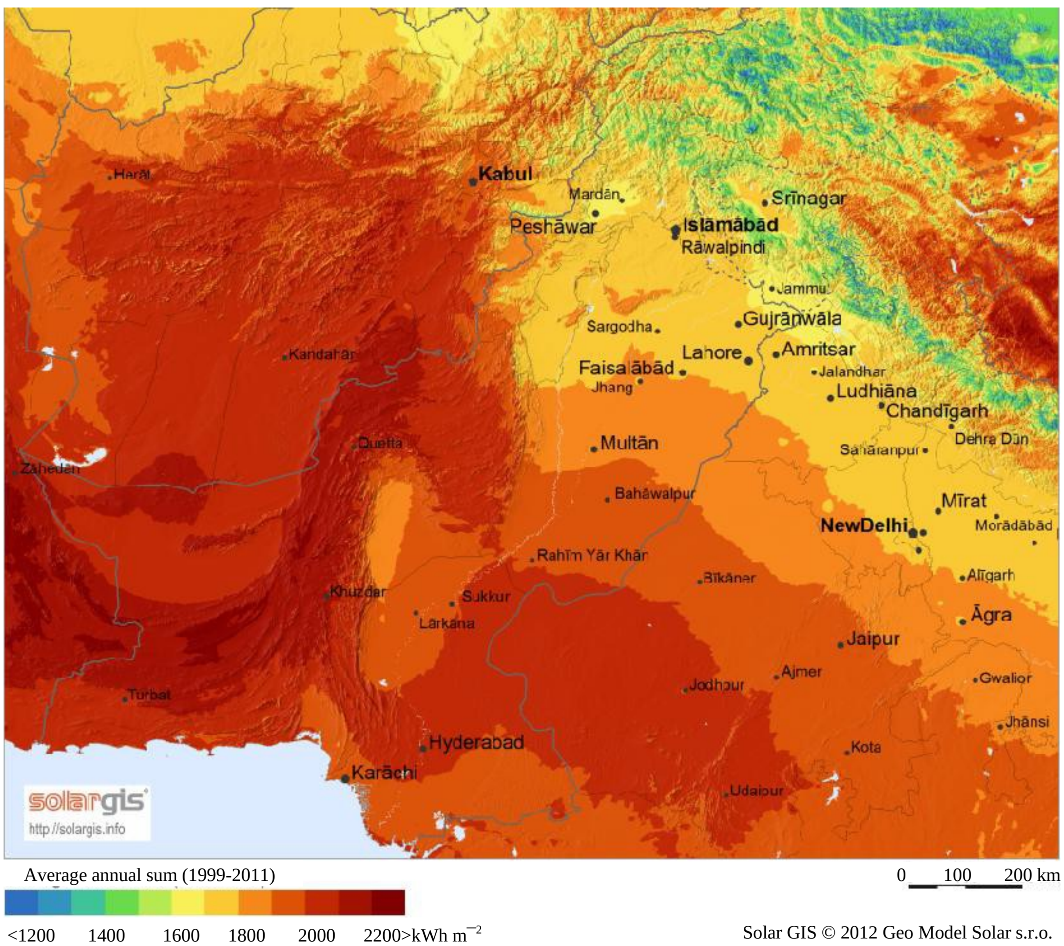


Fig. 5: Horizontal irradiation in Pakistan and surrounding regions by solargis.info

Annual solar energy output: Electricity generated annually by the PV system is as follows[8]:

$$E = A \times r \times H \times PR \quad (1)$$

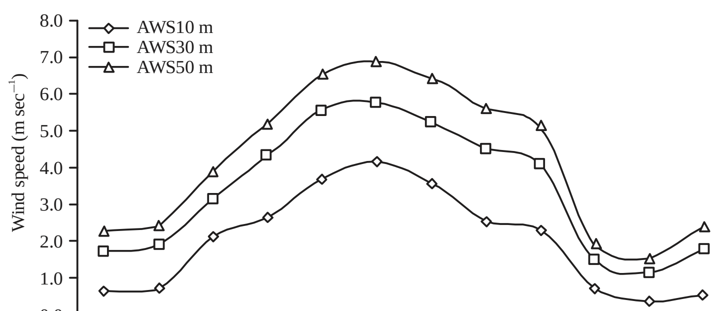
where, A is total solar panel area (m^2) = 1.9×930 = 1700 m^2, r is solar panel yield (%) = 15%, H is annual average solar radiation on tilted panels (shadings not included) = 2000 kWh m^{-2}, PR is performance ratio, coefficient for losses (default value) = 0.75.

By putting the above values, we get E = Energy (kWh) = 382500 kWh year^{-1}.

ANALYSIS OF WIND ENERGY

More than a tourist place, sea side in Karachi is well suited place for wind turbines installation. Three corners of the building will have large scale horizontal axis wind turbines that can harness wind energy adequately[9]. The rated power of one turbine will be 100 kW. The wind turbine system will be employed for three main purposes: (1) To harvest the available wind energy at the site, (2) To support PV system in the times of low sun, (3) To earn revenue. In the times of high demand such as in summers, usage of air conditioners will be at peak, then electricity from wind turbines will be utilized. When there is low demand, then this excess electricity will be supplied to grid to earn revenue. The variation of wind speed on our coastal belt is also in accordance with the demand of air conditioning and heating. Figure 6 shows that, the wind speed is appreciably high from the months of April-September, the period when air conditioners are generally used in Karachi. Heating is not a significant problem in a coastal city like Karachi where even the lowest average temperature in the month of January doesn't fall below 10°C. So, in the months of low wind speed (winter season), HVAC applications requirement do not demand great amount of electricity, however, the PV system is available to fulfill any emergency requirement.

The annual wind direction is shown in Fig. 7. Most wind is often out of the West (31% of the time) and Southwest (23% of the time). The wind is least often out of the Southeast (1% of the time), South (2% of the time), East (3% of the time), Northwest (5% of the time) and North (5% of the time). Therefore, wind turbines will be positioned at three corners facing West and South west directions and will be taller than the building. So, despite its large rotor diameter it can rotate freely without disturbing the leaf structure and the outside view from building as shown in Fig. 2 and 8. From the



Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.7	0.7	2.1	2.7	3.7	4.2	3.6	2.6	2.3	0.7	0.4	0.5
1.7	1.9	3.2	4.3	5.5	5.8	5.2	4.5	4.1	1.5	1.2	1.8
2.3	2.5	3.9	5.2	6.6	6.9	6.5	5.7	5.1	2.0	1.6	2.4

Months

Fig. 6: Showing the average wind speed in Karachi throughout the years of 2003-2005 at the heights of 10, 30 and 50 m (Pakistan Meteorological Department, 2003-2005)

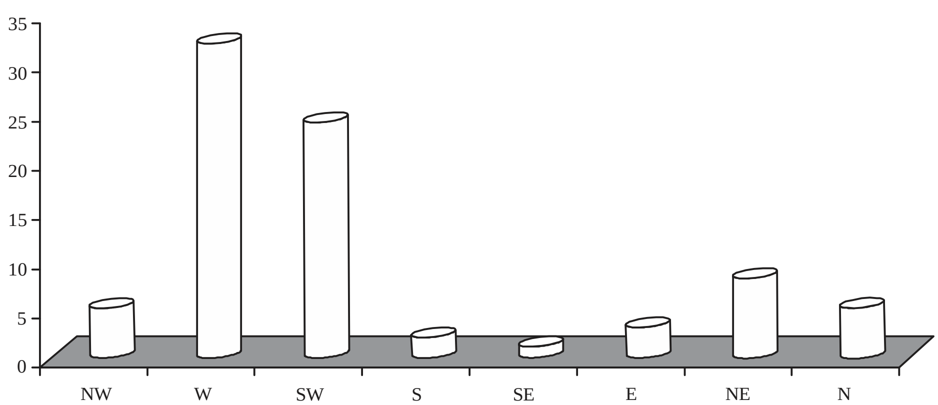


Fig. 7: Annual wind direction showing wind direction in percentages

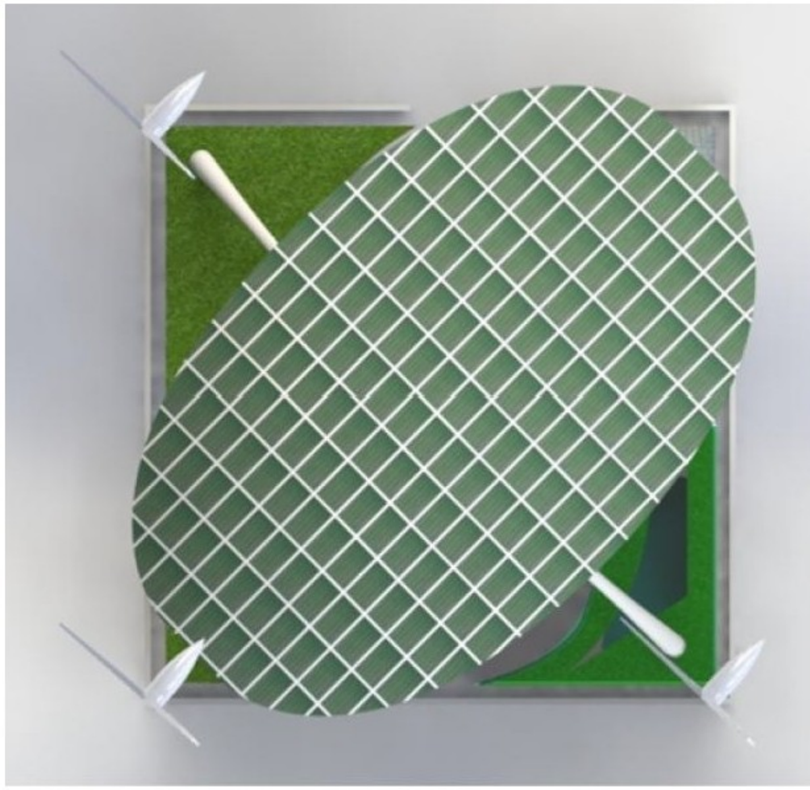


Fig. 8: Rendered image of top view of CAD model designed on software solid works showing top view of leaf like structure having multiple solar panels and wind turbines facing west

references (Pakistan Meteorological Department, 2003-2005) as shown in Fig. 6 we can infer that wind speed at 30-50 m height have the potential to generate electricity. At 50 m height, we have consistent average wind speed of 5.0 m sec^{-1} during 6 months of the period, from April-September, which is very suitable for the wind turbines. The highest wind that was recorded is 6.9 m sec^{-1} in the month of June.

Among many suitable turbines Polaris America P21-100 can be selected (Fig. 9). It few specifications are rated power output: 100 kW, rotor diameter: 21.2 m, blade material: Fiber glass/resin, working wind speed: 3-25 m sec^{-1}, cut-in wind speed: 2.7 m sec^{-1}, rated wind speed: 12 m sec^{-1}, cut-out wind speed: 25 m sec^{-1} etc.

From Fig. 6 and 9, generated power at the location will be variable in different months because wind speed fluctuations are very high but we can estimate each turbine power output in kW on the average monthly wind speed by using power curve graph and can infer that annual generation will provide great excess units. These excess units will be used to earn revenue. For example, in June, we have wind of average speed of 6.9 m sec^{-1} on which turbine power output is 26 kW so on rough estimation from three turbines, building will get $26\times3\times24\times30$ = 56160 kWh only in the month of June. Report "An investigation on wind power potential of Karachi" by Pakistan Meteorological Department has briefly presented trend of wind turbine power output in each month, which satisfies our desired requirements.

ANNUAL ELECTRICITY CONSUMPTION

Based on evaluation of estimated data attained for the desired construction zone, Table 1-4 shows annual energy consumption of houses, corridors and HVAC applications. Table 1 and 2 summarize the annual electricity consumption of households and corridors in the building, respectively (offset has been considered in every calculation). Table 3 shows the annual energy consumption by HVAC applications, which has been set in accordance with seasonal trends in Karachi. In Table 4 it has been determined that net estimated energy demand is 372708 kWh, which can be met with the assistance of solar and wind power which is generated by the building itself. As variations can occur within our building

Polaris AMERICA LLC

Wind velocity (m sec^{-1})	Wind velocity (mph)	Grid power (kW)
1	2.2	0.0
2	4.5	0.0
3	6.7	1.6
4	8.9	5.1
5	11.2	10.0
6	13.4	17.3
7	15.7	27.4
8	17.9	40.9
9	20.1	57.2
10	22.4	74.5
11	24.6	91.1
12	26.8	100.0
13	29.1	100.0
14	31.3	100.0
15	33.6	100.0
16	35.8	100.0
17	38.0	100.0
18	40.3	100.0
19	42.5	100.0
20	44.7	100.0
21	47.0	100.0
22	49.2	100.0
23	51.4	100.0
24	53.7	100.0
25	55.9	100.0

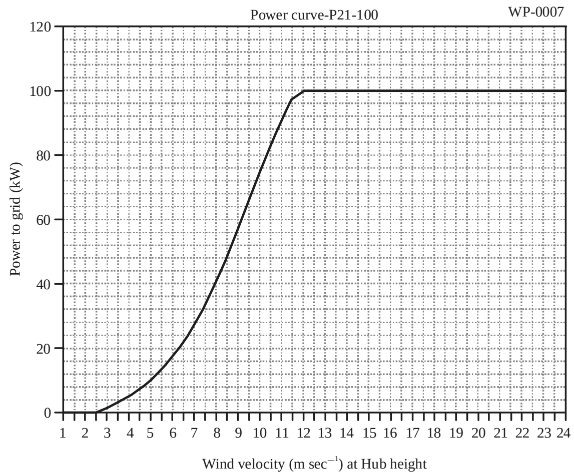


Fig. 9: Power curve of Polaris America LLC turbine P21-100

Table 1: Showing estimated energy consumption of a household in building

Appliances	Watts	Quantity	Average usage (h day^{-1})	Approximately (kWh day^{-1})
Led bulbs	12	8	10	0.96
Tube lights	40	2	3	0.24
Fans	60	4	15	3.6
Kitchen exhaust fan	45	1	2	0.09
Toilet exhaust fans	30	2	0.4	0.024
Refrigerator 16 cu ft	500	1	8	4
Led 37 inch TV	60	1	10	0.6
Laptop	65	1	4	0.26
Electric iron	1000	1	0.5	0.5
Desktop computer	120	1	2	0.24
Washing machine	400	1	0.2	0.08
Vacuum cleaner	650	1	0.2	0.13
Sewing machine	75	1	0.2	0.015
Toaster	800	1	0.4	0.32
Microwave	600	1	0.25	0.15
Blender	385	1	0.02	0.0077
Cell phones	6	4	3	0.072
Stereo	110	1	0.5	0.055
Coffee maker	900	1	0.25	0.225
Hair dryer	1500	1	0.166	0.249
Wi-Fi router	6	1	24	0.144
Dish washer	1800	1	0.8	1.44
Water coolers	200	1	3	0.6
Dehumidifiers	250	1	2	0.5
Estimated electricity requirements for a four rooms household in building per day				14.5017
Estimated annual consumption of single household			14.5017×365	5298.12
Therefore annual consumption 42 households, 7 floors×6 households on each floor			5298.12×42	222311

Table 2: Showing estimated energy consumption in corridors

Appliances	Watts	Quantity	Average usage (h day^{-1})	Approximately (u day^{-1})
LED bulbs	12	88	24	25.344
Dehumidifiers	500	7	3	10.5
Two elevators	Figures by manufacturer kone			20
Reception	300	1	12	3.6
Estimated electricity requirements for corridors in building per day				49.444
Estimated annual consumption of corridors			49.444×365	21697.06

Table 3: Showing estimated energy consumption air conditioning and heating

Appliance	Watts	Quantity	Average usage (h day^{-1})	Approximately (kWh day^{-1})
In summers (March-October)				
Air conditioners	1200	50	8	480
Space heater	1500	25	0	0
Estimated electricity requirements for air conditioners per day				480
Estimated consumption for 8 months of this trend			480×8×30	115200
In winters (November-February)				
Air conditioners	1200	50	1	0
Space heater	1500	25	3	112.5
Estimated electricity requirements for air conditioners per day				112.5
Estimated consumption for 4 months of this trend			112.5×4×30	13500
Annual consumption in air conditioning and heating				128700

Table 4: Showing annual electricity consumption in building

Different sectors of building	Annual consumption (kWh)
Households	222311
Corridors	21697
Air conditioning and heating	128700
Total consumption	372708

demands, a certain offset has been considered in the parameters of wattage, appliances quantity and per day usage.

REDUCTION IN ENERGY CONSUMPTION BY LEAF SHADE

Electricity consumption by the household sector is about 45.5% and the rest is dominated by other sectors (Pakistan economic survey 2009-2010). Building design techniques can greatly enhance the reduction in energy consumption. Most of energy in households is consumed by HVAC and lighting. We must eradicate dependence on fossil fuel resources and replace them with cleaner solutions like renewable sources i.e., wind energy, solar energy and biomass. Moreover, we must decrease the consumption to increase the efficiency of our building. Before spending time and capital on renewable sources, the first consideration should be on building efficiency and thus has been preferred as our first move towards the green initiative.

From Fig. 8 and 10 the building is covered by electricity generating leaf shade structure, providing the additional advantage of shading and thereby not allowing the sunlight to directly fall on the large part of building exterior. Shading minimizes the incident solar radiation and cool the building effectively dramatically affecting the building energy performance[10]. It is important to note that the major axis of the leaf is along east to west which is path of sun with slight variations throughout the year, so the building will not be hampered from sunlight in the times of peak hours which is the primary reason of increasing the temperature of the building and since sunlight is not incident on building exteriors directly so there will be much less absorption of energy to be released at night, consequently reducing cooling loads in building and decreasing the number of hours that air conditioners and fans operate. In the study, a decrease in the indoor temperature by about 2.5-4.5°C is noticed for solar shading. Results with modified insulation and controlled air exchange rate showed a further decrease of 4.4-6.8°C in room temperature[11]. The heat will be absorbed by the leaf shade structure only from the offsets between solar panels but it will not be trapped because of huge convection area, thus it will be sent back into the environment. This analysis ensures a significant reduction in the energy consumption of the building by means of leaf shade as compared to conventional buildings.

Lightings are continuous running energy consumption activities. Although the building is equipped with LED lights which consumes minute energy but day lighting is an important aspect in building architecture and guarantees a reduction in energy consumption by utilizing natural source. Since the leaf shade design bears huge amount of sun rays, day lighting will be accomplished by use of glazing windows which will allow irregular reflection of light at the times of morning and evening providing ambient sunlight to enter after eliminating heat factor from it. The internal design of the building is in such manner thatall the houses are at the corners, therefore they all will have a greater share of sunlight and in that way every one of them will consume less power in lighting, assisting us to further reach our goal.

NET METERING SYSTEM

For customers that generate their own electricity, net metering allows for the flow of electricity both to and from a customer's facility through a single, bidirectional meter. The net metering system is used where renewable energy systems are adopted. The building will be connected to the grid. In case of system failure or shortage of generation of power from solar and wind, the grid will supply the electricity to the building. But since the building has excess electricity in the

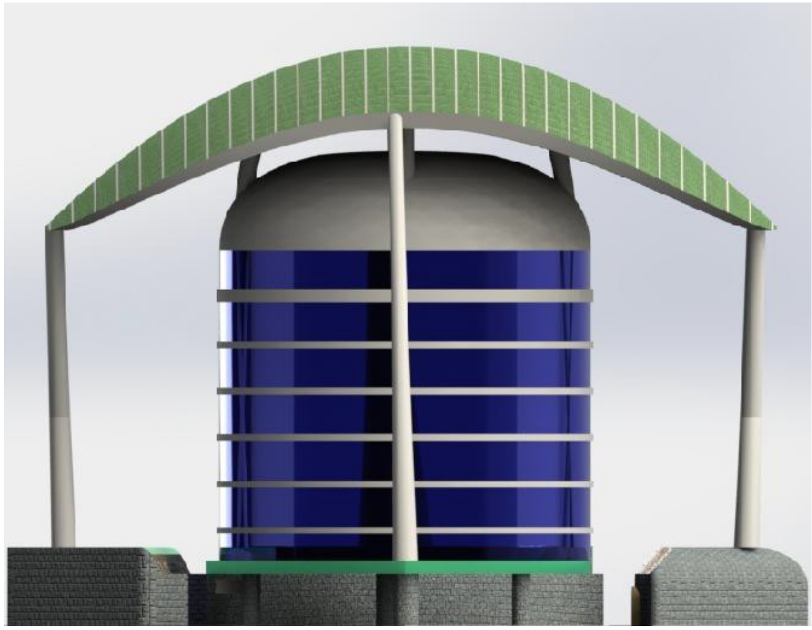


Fig. 10: Side view of CAD model without turbines. Showing shade by leaf structure

Table 5: Showing different techniques to improve the energy efficiency of building

Techniques	Utility
Thermal mass	Keeps the interior structure of the building cool. Thermal mass like marble flooring is effective considering its availability in Pakistan. Beneath the marble we can use concrete for flooring
Reflector based sky lighting	Its use reduces the use of electrical lighting in day time
Mineral wool insulation	As it is hydrophobic, it also reduces failure risks due to leakages and is passively fire protective. It may not be natural or cheap like straw or other natural products but is best option for the type of building
Programmable thermostats	Heating and cooling losses from a building becomes greater as temperature difference increases. Programmable thermostats reduce the difference when this reduction is not a problem
Control air registers	They can control the amount of air that enters through air distributing duct for cooling or heating by automatic dampers or thermostats. Using them can reduce overall air conditioning and heating cost
Solar water heating	Solar water heating systems will be used as it is effective for laundry and is also needed in winter. Thermo-siphon flow makes solar water heater first choice as it doesn't require pumping up and down from heat collector to tank
Lighting control sensors	Occupancy sensors turn on light when room is occupied and turn off in absence of occupant. Motion detector focuses light on person and his nearest surrounding so as to reduce the quantity of bulbs for different locations. Photo sensors detect ambient light levels and adjust light with available natural light
	Low E-glass Low E-glasses will be used for windows in building to improve insulation and maintain indoor temperature, making the building more energy efficient

daytime and in windy days as shown above analysis, the total excess units of electricity produced by the building will be supplied back to the grid. If excess energy units equal the grid energy units then total bill reduces to zero. There is one more possibility, building can earn revenue by selling electricity to government in high sunshine hour's and windy days[12].

OTHER KEY FEATURES

In order to ensure that this building meets that international safety standards, the building design shall incorporate coastal building standards. Furthermore, to optimize the green energy utilization; techniques like thermal mass, reflector based sky lighting, mineral wool insulation, programmable thermostats, control air registers, solar water heating, lighting control sensors and low E-glass shall be applied. Since this study encircles only the power generation from solar panels and wind turbines we do not include the details of any of the above green techniques herein. However, we mention the utility of each of the green technique in Table 5.

CONCLUSION

The idea of using leaf like structure for harvesting solar energy is proving to be beneficial because not only it generates excess electricity but also provides shading to building, protecting it from direct sunlight and simultaneously reducing the cost HVAC applications thereby achieving the objective of zero billing and being environment friendly. The location and size of wind turbines are chosen in accordance with wind direction and location of the building providing excess electricity, taking advantage of available wind potential. As per our analysis annual electricity consumption by building after considering offsets is 372798 kWh and electricity expected to be generated by PV system by considering all loses is 382500 kWh which is in excess plus wind turbines will also be providing huge amount of energy in a year. The analysis on energy reduction gives by leaf shade ensures sufficient reduction in energy demand. On annual basis, we can conclude that building will achieve objective of zero billing and earn sufficient revenue. One notable point is both the energy sources are been harvested within the building area. The other key features make the building more energy efficient and environmental friendly. Overall the building can be regarded as the green building for safer and cleaner world.

REFERENCES

1. Ali, S.M.H., M.J.S. Zuberi, M.A. Tariq, D. Baker and A. Mohiuddin, 2015. A study to incorporate renewable energy technologies into the power portfolio of Karachi, Pakistan. Renew. Sustain. Energy Rev., 47: 14-22.
2. Ismail, A.M., R. Ramirez-Iniguez, M. Asif, A.B. Munir and F. Muhammad-Sukki, 2015. Progress of solar photovoltaic in ASEAN countries: A review. Renew. Sustain. Energy Rev., 48: 399-412.
3. Ullah, K., 2013. Electricity infrastructure in Pakistan: An overview. Int. J. Energy Inform. Commun., 4: 11-26.
4. Mahmood, A., N. Javaid, A. Zafar, R.A. Riaz, S. Ahmed and S. Razzaq, 2014. Pakistan's overall energy potential assessment, comparison of LNG, TAPI and IPI gas projects. Renew. Sustain. Energy Rev., 31: 182-193.
5. Du, L., 2012. The impact of building morphology on energy consumption. Master Thesis, Norwegian University of Science and Technology, Norway.
6. Maestre, I.R., J.L.F. Blazquez, F.J.G. Gallero and P.R. Cubillas, 2015. Influence of selected solar positions for shading device calculations in building energy performance simulations. Energy Buildings, 101: 144-152.
7. Khan, S., Mahmood-Ul-Hasan and M.A. Khan, 2012. Annual and seasonal distribution of sunshine in Pakistan 1931-1990. Proceedings of the International Conference on Water Resources and Wetlands, September 14-16, 2012, Tulcea, Romania, pp: 354-360.
8. Louis, J.R., S. Shanmugam and V. Nattuthurai, 2015. Efficient energy management using domotics controller and validation incorporating lab view in wind/solar/battery storage hybrid system. Aust. J. Basic Applied Sci., 9: 171-175.
9. Borg, M. and M. Collu, 2015. A comparison between the dynamics of horizontal and vertical axis offshore floating wind turbines. Philosophical Trans. Royal Soc. A, Vol. 373. 10.1098/rsta.2014.0076
10. Mahyari, A., 1997. Wind catchers. Ph.D. Thesis, Sydney University, Australia.
11. Maleki, B.A., 2011. Shading: Passive cooling and energy conservation in buildings. Int. J. Tech. Phys. Problems Eng., 3: 72-79.
12. NEPRA., 2014. Distributed generation and net metering rules. National Electric Power Regulatory Authority, Pakistan.