A PROJECT REPORT

ON

"SELECTION OF APPROPRIATE COMBINATION OF RENEWABLE ENERGY SOURCES FOR ELECTRICITY CONSERVATION BY USING ANALYTICAL HIERARCHY PROCESS (AHP)"

Submitted by

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In partial fulfillment for the award of the Degree

Of

BACHELOR OF ENGINEERING

IN

MECHANICAL ENGINEERING

UNDER THE GUIDANCE

Of

Prof. ZAKIR ANSARI

DEPARTMENT OF MECHANICAL ENGINEERING

ANJUMAN-I-ISLAM

KALSEKAR TECHNICAL CAMPUS NEW PANVEL,

NAVI MUMBAI – 410206

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ANJUMAN-I-ISLAM

KALSEKAR TECHNICAL CAMPUS NEW PANVEL

(Approved by AICTE, recg. By Maharashtra Govt. DTE,

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CERTIFICATE

This is to certify that the project entitled

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To the Kalsekar Technical Campus, New Panvel is a record of bonafide work carried out by him under our supervision and guidance, for partial fulfillment of the requirements for the award of the Degree of Bachelor of Engineering in Mechanical Engineering as prescribed by **University of Mumbai**, is approved.

Project co-guide	**Internal Examiner**	**External Examiner**
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(Prof. Zakir Ansari)	(Dr. Abdul Razzak Honutagi)

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APPROVAL OF DISSERTATION

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(Internal Examiner) **(External Examiner)**

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Date: _____________

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Abstract

It started with review the historical data of energy consumption which can be compiled from the electricity bills. These data are important in order to understand the patterns of energy used and their trend. After obtaining the information on energy consumption, the next step is to set up an energy audit survey. this survey gives an information on present energy used. The energy utilization such as running hours of air-conditioning, lighting levels, locations of unnecessary air-conditioning and lighting due to unoccupied areas, temperature and humidity, chillers scheduling and setting, efficiencies of equipment's and machine and the areas of high energy consumption and the possibility to reduce consumption and renewable energy resources should be record for further analysis. In renewable energy resources we are moving toward the solar energy, wind energy and hybrid resources which can be easily installed in all the four building of whole AIKTC campus. We are going to select this resources based on their initial cost, area requirement, power generation, annual profit, maintenance cost, payback period. For selecting renewable energy resources based on those factors we are going to work with Analytical Hierarchy Process (AHP). It provides a comprehensive and rational framework for structuring a decision problem. The base of AHP is comparing variables by pair wise by Matrix relationship. In this way, pair wise of the effective variables give an alternative solution.

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Abbreviation and Notations

Symbols	Full Forms
T-5	Fluorescent Light
P-L	Plug in - Light Bulb
CFL	Compact Fluorescent Lamp
LED	Light-Emitting diode
FTL	Faster than Light
HAWT	Horizontal Axis Wind Turbine
VAWT	Vertical Axis Wind Turbine
NIWE	National Institute of Wind Energy
AHP	Analytic Hierarchy Process
PF	Power Factor
TSFC	Thin-Film Solar Cells
P_t	Total Power
M	Mass Flow Rate
λ	Tip Speed Ratio
γ	Solidity
O&M	Operation And Maintenance Cost
C.R	Consistency Ratio
C.I	Consistency Index
R.I	Random Index

Chapter 1

Introduction

This project is the vision to make AIKTC energy efficient and motivate the campus to implement Renewable Energy Sources. It is a fact that this campus uses huge amount of energy and it’s obvious that we are using huge amount of energy, and there are chances that some of the energy is being wasted somewhere in considerable amount. The purpose of the project is to conserve or generate the energy by selecting the appropriate methods and considering the following parameters.

Parameters: -

1. Initial Cost
2. Power Generated
3. Area Required
4. Maintenance Cost
5. Payback Period

AIKTC uses a huge amount of energy around 55000 to 60000 units and it is also very obvious that we waste quite a sizable chunk of it.

AIKTC energy bill keeps up around INR 5-6 lakh per month. This amount is huge and thus naturally attracts attention when we understand that quite a lot of energy is being wasted, which in turn would mean that huge amount of financial resources is being wasted.

Making the AIKTC energy efficient will not only help the institute to reduce its expenses but also helps us fulfill our moral responsibility of not wasting this precious resource, which is scarcely available to rest of the people of the country.

AIKTC is situated at New Panvel where electricity is not available for 24/7 and there is always electricity cut off for around 3-4 hours, in order to tackle these problems and as a technical institute, we should implement Renewable Energy Sources which will helps us to deal with the electricity shortage and will make the initiative towards “Green Campus”.

Alongside major improvements in energy efficiency and energy conversion, the extensive use of renewable energy sources such as solar and wind will make a major contribution to future sustainable energy systems.

This would act as a prototype project, the lessons learnt here can be put to practice to make AIKTC energy efficient and motivate the campus to implement RES. AIKTC have been chosen because they are quite familiar to us, are very accessible and have conspicuous energy wastage that can be reduced and there are also potential places at AIKTC for implementation RES.

We are confident that the results that will come out of this exercise are bound to be of interest to everyone and can be the first step to make AIKTC energetically not only the most efficient campus but also Green Campus in India.

Chapter 2

Literature Review

From the study of various technical papers, journals, reference books (of energy audit, renewable energy sources) and different literature on Analytical Hierarchy Process (AHP) by qualified and experience person.

After Studying various content on energy audit, renewable energy sources and AHP we are aware the different parameter which is required in energy audit and to find out the best and suitable combinations of renewable Energy Sources by using AHP.

2.1 Energy Audit

Energy Audit is the key to a systematic approach for decision-making in the area of energy management. It attempts to balance the total energy inputs with its use, and serves to identify all the energy streams in a facility. It quantifies energy usage according to its discrete functions. Industrial energy audit is an effective tool in defining and pursuing comprehensive energy management program.

As per the Energy Conservation Act, 2001, Energy Audit is defined as "the verification, monitoring and analysis of use of energy including submission of technical report containing recommendations for improving energy efficiency with cost benefit analysis and an action plan to reduce energy consumption".

2.2 Appliances and consumptions

We have collected the standard information's of electricity consumptions units of different electrical appliances and instruments.

Table 2.2.1: Electrical Appliance Typical Energy Consumption

Serial No.	Appliance	Consumption (Watts)
1	PC	80-150
2	Charger: mobile phone charger	1
3	Freezer - 15 cu. ft. (Upright)	1239 watt-hours/ day
4	Electric cooker with oven	1000-2500
5	Microwave	600-1500
6	Television - 25" color	150
7	Television - 19" color	70
8	Television - 19" color	70
9	Electric clock	3
10	Radiotelephone – Receiving mode	5
11	Vacuum cleaner - High Power	1600-2000
12	Radiotelephone - Transmitting Mode	40-150
13	Lights:100 watt incandescent	100
14	Lights:25-watt compact Fluorescent	28

15	Lights:50 watt DC incandescent	50
16	Lights:40 watt DC halogen	40
17	Lights: Compact fluorescent 40 watt Incandescent equivalent	11
18	Lights: Compact fluorescent 60 watt Incandescent equivalent	16
19	Lights: Compact fluorescent 75 watt Incandescent equivalent	20
20	Lights: Compact fluorescent 100 watt Incandescent equivalent	30
21	Air conditioner – Room	1000
22	Ceiling fan	40-60
23	Table fan	20
24	Laptop	20-60
25	Refrigerator/Freezer - 20 cu. ft. (AC)	1412 watt-hours/ Day
26	Refrigerator/Freezer - 16 cu. ft. (AC)	1205 watt-hours/ Day

2.3 Energy Conservations

Energy conservation refers to the reducing of energy consumption through using less of an energy service. Energy conservation differs from efficient energy use, which refers to using less energy for a constant service. Driving less is an example of energy conservation. Driving the same amount with a higher mileage vehicle is an example of energy efficiency. Energy conservation and efficiency are both energy reduction techniques. Energy conservation is a part of the concept of sufficiency.

Even though energy conservation reduces energy services, it can result in increased environmental quality, national security, personal financial security and higher savings. It is at the top of the sustainable energy hierarchy. It also lowers energy costs by preventing future resource depletion.

2.4 Energy Efficient Appliances

Appliances can account for up to 30 per cent of your home energy use. As our reliance on appliances increases and energy prices are also on the rise, choosing energy-efficient appliances becomes more important. The national standards for energy efficiency are improving the environmental performance of appliances all the time, so upgrading to a more efficient appliance can save you energy and money.

It's not only about having the right product—how you use appliances in your home can make a big difference. For example, washing your clothes with cold water can save up to 5 times more energy than a warm wash.

2.5 Capacitor Bank

A Capacitor Bank is a group of several capacitors of the same rating that are connected in series or parallel with each other to store electrical energy . The resulting bank is then used to counteract or correct a power factor lag or phase shift in an alternating current (AC) power supply. They can also be used in a direct current (DC) power supply to increase the ripple current capacity of the power supply or to increase the overall amount of stored energy.

2.6 Renewable Energy Sources

Renewable energy is energy that is collected from renewable resources, which are naturally replenished on a human timescale, such as sunlight, wind, rain, tides, waves, and geothermal heat. Renewable energy often provides energy in four important areas: electricity generation, air and water heating/cooling, transportation, and rural (off-grid) energy services.

Based on REN21's 2016 report, renewables contributed 19.2% to humans' global energy consumption and 23.7% to their generation of electricity in 2014 and 2015, respectively. This energy consumption is divided as 8.9% coming from traditional biomass, 4.2% as heat energy (modern biomass, geothermal and solar heat), 3.9% hydroelectricity and 2.2% is electricity from wind, solar, geothermal, and biomass. Worldwide investments in renewable technologies amounted to more than US$286 billion in 2015, with countries like China and the United States heavily investing in wind, hydro, solar and biofuels. Globally, there are an estimated 7.7 million jobs associated with the renewable energy industries, with solar photovoltaics being the largest renewable employer. As of 2015 worldwide, more than half of all new electricity capacity installed was renewable.

2.7 Solar Energy

Solar power in India is a fast-growing industry. As of 28 February 2017, the country's solar grid had a cumulative capacity of 9.57 gigawatts (GW). In January 2015, the Indian government expanded its solar plans, targeting US$100 billion of investment and 100 GW of solar capacity, including 40 GW from rooftop solar, by 2022. Commenting on the key importance India attaches to solar power, India’s Prime Minister Narendra Modi said at the historic COP21 climate conference in Paris last year. “The world must turn to (the) sun to power our future. As the developing world lifts billions of people into prosperity, our hope for a sustainable planet rests on a bold, global initiative. India's initiative of 100 GW of solar energy by 2022 is an ambitious target given the world’s installed solar power capacity in 2014 was 181 GW. India quadrupled its solar power generation capacity from 2,650 MW on 26 May 2014 to 10,000 MW on 10 March 2017. The country added 4 GW of solar power capacity in 2016, the highest of any year.

In January 2016, the Prime Minister of India, Narendra Modi, and the President of France, Mr. François Hollande laid the foundation stone for the headquarters of the International Solar Alliance (ISA) in Gwalpahari, Gurgaon. The ISA will focus on promoting and developing solar energy and solar products for countries lying wholly or partially between the Tropic of Cancer and the Tropic of Capricorn. The alliance of over 120 countries was announced at the Paris COP21 climate summit. One of the hopes of the ISA is that wider deployment will reduce production and development costs, and thus facilitate increased deployment of solar technologies, including in poor and remote regions.

India is one of the countries with the higher solar electricity production per watt installed, with an insolation of 1700 to 1900 kilowatt hours per kilowatt peak (kWh/KWp). On 16 May 2011, India's first solar power project (with a capacity of 5 MW) was registered under the Clean Development Mechanism. The project is in Sivagangai Village, Sivaganga district, Tamil Nadu. India saw a sudden rise in use of solar electricity in 2010, when 25.1 MW was added to the grid, and the trend accelerated when 468.3 MW was added in 2011. Recent growth has been over 3,000 MW per year and is set to increase yet further.

2.8 Wind Energy

Wind power generation capacity in India has significantly increased in the last few years and as of 31 January 2017 the installed capacity of wind power was 28,871.59 MW, mainly spread across the South, West and North regions. By year end 2015 India had the fourth largest installed wind power capacity in the world. The levelised tariff of wind power reached a record low of ₹3.46 (5.1¢ US) per kWh (without any direct or indirect subsidies) during auctions for wind projects in February 2017.

The potential for wind farms in the country was first assessed by Dr. Jami Hossain using a GIS platform to be more than 2,000 GW in 2011. This was subsequently re-validated by Lawrence Berkley National Laboratory, US (LBNL) in an independent study in 2012. As a result, the MNRE set up a committee to reassess the potential and through the National Institute of Wind Energy (NIWE, previously C-WET) has announced a revised estimation of the potential wind resource in India from 49,130 MW to 302,000 MW assessed at 100 m hub height. The wind resource at higher hub heights that are prevailing is possibly even more. In 2015, the MNRE set the target for Wind Power generation capacity by the year 2022 at 60,000 MW.

2.8.1 Wind Power in Maharashtra

Maharashtra is one of the prominent states that installed wind power projects second to Tamil Nadu in India. As of end of March 2016, installed wind power capacity is 4655.25 MW. As of now there are 50 developers registered with state nodal agency "Maharashtra energy Development Agency" for development of wind power projects. All the major manufacturers of wind turbines including Suzlon, Vestas, Gamesa, Regen, Leitner Shriram have presence in Maharashtra.

2.9 Analytic Hierarchy Process (AHP)

AHP stands for Analytic Hierarchy Process. It is a method to support multi-criteria decision making, and was originally developed by Prof. Thomas L. Saaty. AHP derives ratio scales from paired comparisons of criteria, and allows for some small inconsistencies in judgments. Inputs can be actual measurements, but also subjective opinions. As a result, ratio scales (weightings) and a consistency index will be calculated. A simple introduction to the method is given here.

Chapter 3

Problem Definition & Objectives

3.1 Problem Definition

Electricity Bill of AIKTC is enormous and it can be reduced by focused approach. Our approach will be to conduct detailed audit of campus and find out "how the energy is being used, where we are wasting energy, analysis of data in order to reduce electricity consumption". After complete analysis of data, suggesting alternative energy efficient electric appliances in order to conserve energy with detailed cost analysis and payback period. In order to get incentive or concession on Electricity Bill, PF should be greater than 0.95 and to increase the power factor, it's required to install capacitor bank of desired rating in order to get Required PF.

Due to shortage of Electricity at New Panvel and Energy is not available for 24/7 at AIKTC and on daily basis electricity is cut off for around 3-4 hrs. In order to overcome these problems, use of RES would be beneficial. Institute like IIT Bombay, IIT Kanpur and IIT Roorkee, they have installed RES for satisfying their daily consumption of electricity then as Technical Campus like AIKTC, why don't we installed RES?

The motive of this project is to conduct survey at AIKTC to find out which Renewable Energy Sources can be implemented at our Campus with detailed cost analysis and payback period.

3.2 Objectives

The objective of this project is to make AIKTC energy efficient and motivate the campus to implement Renewable Energy Sources.

In order to reach to our main objective, following objectives should be considered:

- Conduct Energy Audit at AIKTC, in order to acquire and analyze data and finding the energy consumption of these facilities.
- Calculate the wastage pattern based on the results of the above objective.
- Suggest feasible methods in order to conserve energy and reduce electricity bill.

  For example: (1) Use of Energy Efficient Appliances.

  (2) Use of Capacitor Bank.
- Conduct survey at AIKTC to find out feasible RES for our Campus.
- Forming number of permutation and combination of RES keeping budget in mind.
- Use of AHP tool to select best suited RES for our campus.
- Suggest the institute for implementation

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Chapter 4

Methodology

(A) Energy Audit

4A.1 Literature Survey: -

We have done all the literature survey related Energy Audit, Electricity Bill and different parameter which is required for conducting energy audit.

4A.1.1 List of Appliance in AIKTC

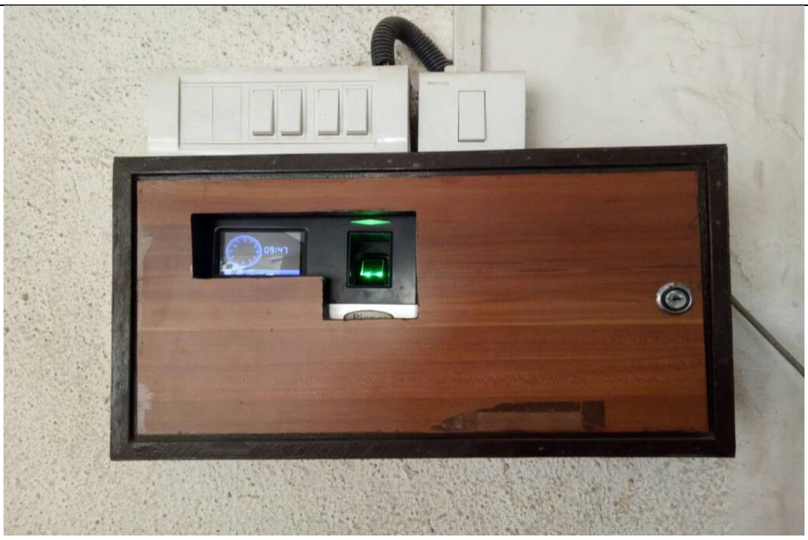
Table 4A.1.1.1: List of Appliances in AIKTC

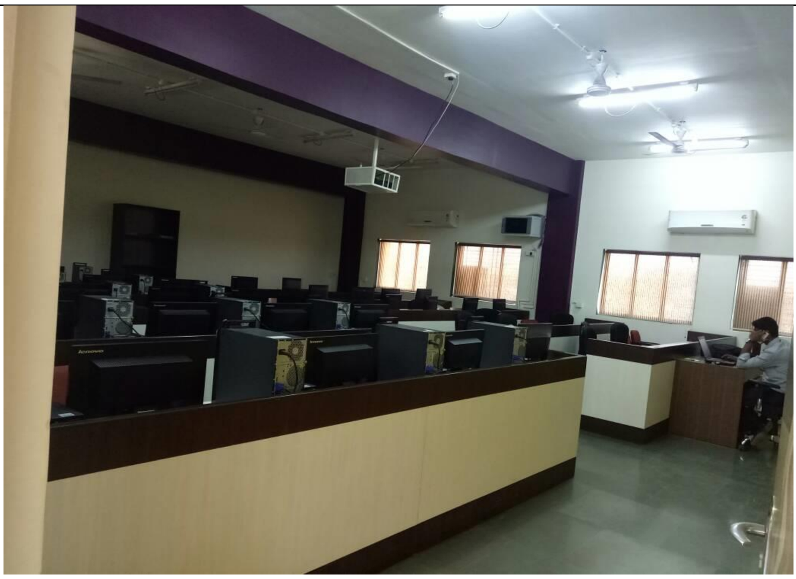
Sr. No.	Name Appliances	Image of Appliances
1	1400 mm Fan	

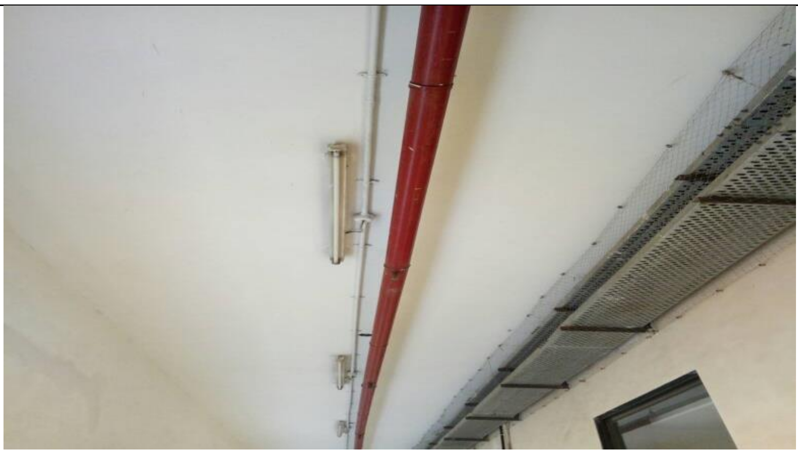
2	1200mm Fan	
3	Projector	
4	PL (1 x 4)	

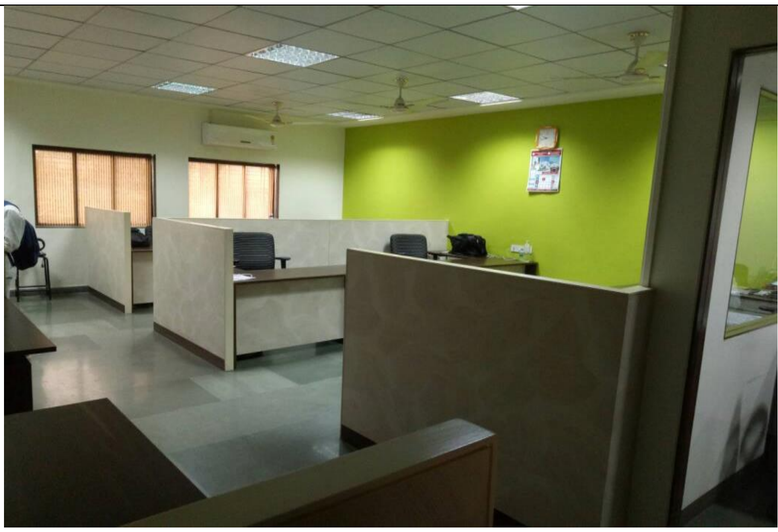
5	T-L	
6	Exhaust Fan	
7	CCTV Camera	

8	Lathe Machine	
9	Hanging Light	
10	Xerox Machine	

11	LED	
12	Biometric Finger Print	
13	Endura Light	

14	Fan (900mm)	
15	HP Laser Jet 1020	
16	Computers	

17	Purifier	
18	T-5 Tube Light	
19	1 Ton A.C.	

20	CFL	
21	PL (1 x 4)	

4A.2 Assumption

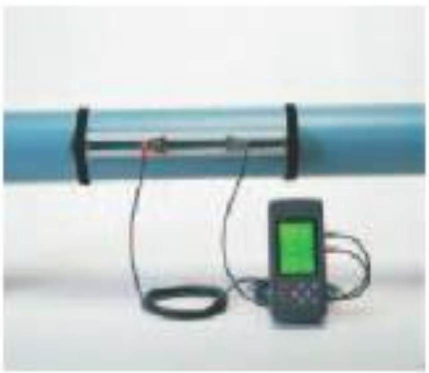
Following assumption were made for conducting Energy Audit: -

1. Appliances which are used on daily basis such as fans, lights, etc.
2. Appliances with higher Energy Consumption Rate such as lathe machine, Xerox machine, etc.

4A.2.1 List of Instrument for Energy Audit

Fig. 4A.2.1.1: List of Instrument for Energy Audit

 	**Electrical Measuring Instruments:** These are instruments for measuring major electrical parameters such as kVA, kW, PF, Hertz, kVAr, Amps and Volts. In addition some of these instruments also measure harmonics. These instruments are applied on-line i.e on running motors without any need to stop the motor. Instant measurements can be taken with hand-held meters, while more advanced ones facilitates cumulative readings with print outs at specified intervals.
	**Combustion analyzer:** This instrument has in-built chemical cells which measure various gases such as O_2, CO, NO_X and SO_X.
	**Fuel Efficiency Monitor:** This measures oxygen and temperature of the flue gas. Calorific values of common fuels are fed into the microprocessor which calcu-lates the combustion efficiency.
	**Fyrite:** A hand bellow pump draws the flue gas sample into the solution inside the fyrite. A chemical reaction changes the liquid volume revealing the amount of gas. A separate fyrite can be used for O_2 and CO_2 measurement.

	**Contact thermometer:** These are thermocouples which measures for example flue gas, hot air, hot water temperatures by insertion of probe into the stream. For surface temperature, a leaf type probe is used with the same instrument.
	**Infrared Thermometer:** This is a non-contact type measurement which when directed at a heat source directly gives the temperature read out. This instrument is useful for measuring hot spots in furnaces, surface temperatures etc.
	**Pitot Tube and manometer:** Air velocity in ducts can be measured using a pitot tube and inclined manometer for further calculation of flows.
	**Water flow meter:** This non-contact flow measuring device using Doppler effect / Ultra sonic principle. There is a transmitter and receiver which are positioned on opposite sides of the pipe. The meter directly gives the flow. Water and other fluid flows can be easily measured with this meter.

 Tachometer	 Stroboscope	**Speed Measurements:** In any audit exercise speed measurements are critical as thay may change with frequency, belt slip and loading. A simple tachometer is a contact type instrument which can be used where direct access is possible. More sophisticated and safer ones are non contact instruments such as stroboscopes.
		**Leak Detectors:** Ultrasonic instruments are available which can be used to detect leaks of compressed air and other gases which are normally not possible to detect with human abilities.
		**Lux meters:** Illumination levels are measured with a lux meter. It consists of a photo cell which senses the light output, converts to electrical impulses which are calibrated as lux.

4A.3 Analysis of Monthly Electricity Bill

In a corporate electricity bill three factors contribute significantly to the total amount. They are:

- **Active energy consumption**: - The total active or useful energy consumed by all loads connected to the feeders.
- **Power factor consumption**: - The total reactive power energy consumed by inductive or capacitive loads.
- **Maximum power demand**: - The peak power or the cumulative power rating of all connected loads at a particular point of time.

4A.4 Physical Survey of Campus

As a first step in this regard, 2 teams of total 4 students from the group were formed and each team was assigned a particular area or application of energy in the campus and note down all data's regarding energy consumption appliances which is used in daily basis and form the general layout for entering all data which is required for Energy Audit.

Following parameters are considered for Energy Audit:

1. Appliances and their consumption in terms of Wattage
2. Quantity
3. Hours of use

4A.5 Grouping and strategy

The following groups were formed with specific target areas and end uses assigned

Team 1: Data Collection

- ✓ Number of Appliances

This table gives the information about total number of appliances and consumption of those appliances in AIKTC.

Table 4A.5.1: Engineering Building

Appliances	Consumption (wattage)	Total Quantity
Fan (1400 mm)	60	242
Fan (1200 mm)	45	89
T-5	28	680
CFL (2 x 36)	72	26
P.L	36	156
FTL (4 x 18)	72	18
LED Strip	36	18 meter
LED (2 x 3)	6	18
CFL (2 x 14)	28	87
Printer 1020	40	20
A.C(1T)	1005	67
A.C (2T)	2020	2
P.C	275	118
Laptop	60	89
Projector	287	14

Hanging light	27	25
Security Camera	12	27
Table Fan	56	6
Exhaust Fan	25	6
A.C (1.5T)	1954	2
Biometric Sensor	8	1
Xerox Machine	650	1

Table 4A.5.2: Pharmacy Building

Appliances	Consumption (Wattage)	Total Quantity
Fan (1400 mm)	60	431
Fan (1200 mm)	45	58
Fan (900 mm)	36	2
Exhaust Fan	25	14
T-L	40	426
T-5	112	216
P-L	36	203
CFL (2 x 14)	28	16
LED	25	25
Endura LED	18	96
A.C (1T)	1005	25
A.C (2T)	2020	12
P.C	275	90
Laptop	60	5
Printer 1020	40	4
Biometric Sensor	8	1

Xerox Machine	675	1
Purifier	575	8
Projector	287	5

Table 4A.5.3: Diploma Building

Appliances	Consumption (Wattage)	Total Quantity
Fan	80	705
Table Fan	40	13
Exhaust Fan	25	8
T-5	28	15
T-L	40	722
P-L (1 x 2)	72	110
CFL	14	82
Spot Light	3	4
A.C (1T)	1500	40
Printer 1020	100	14
P.C	275	373
Projector	287	40
Printer A3	150	9
Biometric Sensor	4	1
Xerox Machine	1500	3
Purifier	1500	9
Lathe Machine	1500	26
Refrigerator	150	1
Laptop	60	7

Table 4A.5.4: Architecture Building

Appliances	Consumption (wattage)	Total Quantity
Fan (1400mm)	60	153
Fan (1200mm)	45	14
Wall Fan	56	19
T-5	28	356
A.C (1T)	1005	8
P.C	275	17
Printer 1020	150	2
Projector	287	3
CCTV	14	2

Team 2: Data analysis and data logging

This table gives the information how much energy consumed by every building of AIKTC.

Table 4A.5.5: Engineering Building

Floor	Wattage Per Day
Ground Floor	185119.38
First Floor	234879.66
Second Floor	277035.66
Total Consumption (w-hr.)	647034.99
No. of Units	647.03
Total no. of Units per Month	19410.9

Table 4A.5.6: Architecture Building

Floor	Wattage Per Day
Basement	9145.184
Ground Floor	13059.08
First Floor	41444.54
Total Consumption (w-hr.)	63648.804
No. of Units	63.648
Total no. of Units Per Month	1909.44

Table 4A.5.7: Diploma Building

Floor	Wattage Per Day
Ground Floor	224656.36
First Floor	183865.38
Second Floor	248253.02
Third Floor	146448.01
Total Consumption (w-hr.)	803222.77
No. of Units	803.22
Total no. of Units per Month	24096.6

Table 4A.5.8: Pharmacy Building

Floor	Wattage Per Day
Ground Floor	119112.49
First Floor	173624.47
Second Floor	90985.35
Third Floor	101229.2
Total Consumption (w-hr.)	484951.51
No. of Units	484.95
Total no. of Units per Month	14548.5

Table 4A.5.9: Total No. of Units of Campus

Buildings	Total No. of Units Per Month
Engineering	19410.9
Pharmacy	14548.5
Architecture	1909.44
Diploma	24096.6
Total	59965.44

4A.6 Data Collection

Following points were considered for data collection.

4A.6.1 Visual Inspection

Initially a “walk through” audit was conducted. The rooms of all 4 buildings of AIKTC & areas where energy is being used were investigated and following parameters were recorded.

1. The connected load and its wattage were noted.
2. Number of appliances which are daily used were noted.
3. Number of appliances which are rarely used were noted.
4. Number of appliances which are never used were noted.
5. Actual usage of appliances per day were noted depending on the time table.

All these data were noted down on a sheet of paper in a generalized form for the simplicity to understand for data analysis and detailed calculation

4A.6.2 Interviews with faculty and Staff

Interviews were conducted with relevant personnel on campus to determine whether there are any energy conservation policies are in place at campus. Interviewees included Mr. Kiran, Head of Maintenance Department, and Mr. Arshad, Assistant of Mr. Kiran, whom Mr. Kiran recommended to us. Interviewees were conducted in-person with Mr. Kiran and Mr. Arshad to get some additional information on Electricity Bill, PF, Capacitor Bank, Peak Load, etc. and verification of appliances and their wattage.

During the Visual Inspection, number of appliances which are daily, rarely and never used are noted and actual usage of appliances per day. But during this process, we found that there are certain number of appliances which are used for 9hrs per day regardless of load or time table of the rooms/labs. In order to get accurate data, we interview the lab assistant of each room in order to get actual usage of each appliances and trace out which appliances are daily, rarely and never used.

4A.7 Data Analysis and Detailed Calculations

After collection of all data's pertaining to Energy Audit, these data go through the analysis process where we cross-check the collected and find out whether the collected data is actually correct or not. If data collected found to be wrong, then the we conduct "walk through" audit for that particular area.

After Data Analysis, we started with the Calculations. The calculations were in the following sequences:

1. Calculate the Energy Consumption of each appliance per day.
2. Calculate the Total Consumption of each room.
3. Calculate Total Consumption of each floor by adding all consumption of each room on one floor.
4. Calculate Total Consumption of each building by adding consumption of all floors in one building.
5. Calculate Total Consumption of AIKTC in terms of wattage by adding consumption of all 4 building at AIKTC.
6. Convert the Total Consumption of AIKTC in terms of no. of units.
7. Multiply these no. of units with "30" to get no. of units per month.
8. Multiply this no. of units with the Energy Charged (Rs. /kWh) to get monthly Charges to be paid.

All the data’s pertaining to Energy Audit such as data collection, data analysis and detailed calculation for each building are logged into an Excel sheet and it’s print out are attached at the end of the black book.

4A.8 Validation of Results

After detailed calculation results were validated with the electricity bill and found that the results were approximately matching.

Table 4A.8.1 Total units per month consumption

Buildings	Total No. of Units Per Month
Engineering	19410.9
Pharmacy	14548.5
Architecture	1909.44
Diploma	24096.6
Total	59965.44

Electricity Bill of AIKTC

Maharashtra State Electricity Distribution Co. Ltd.

MAHAVITARAN
Maharashtra State Electricity Distribution Co. Ltd

ELECTRICITY BILL FOR THE MONTH OF MAR 2016

No.201603256574396

Washi Circle 565 Panvel (U)Dn. 031 PNL City sub_dn 125

Consumer No. 028519026060 ANJUMAN
Consumer Name PRESIDENT ANJUMAN -I-ISLAM PANVEL
Address PLOT NO-16, SECTOR-16,
NEW PANVEL (WEST)

Village TL-PANVEL, DIST-RAIGAD		Pin Code	410206
Connected Load (KW)	3,280.00	Sanct. Load (KW)	3,280.00
Contract Demand (KVA)	715.00	Sanct. Demand	715.00
50 % of Con. Demand (KVA)	357.50	Meter No.	076-00381549
Date of Connection	29-10-2002	Tariff	78 HT-IX B II
Supply at: HT Prev. Highest OCT DTC		Bill Demand 320 Elec. Duty	02 PART A

BILL DATE	04-04-2016	
DUE DATE	18-04-2016	6,54,820.00
IF PAID UPTO	11-04-2016	6,49,230.00
IF PAID AFTER	18-04-2016	6,67,910.00

Last Receipt No./Date	: WSR1604045 / 10-03-2016
Last Month Payment	: 4,55,860.00
D.G.Set (KVA)	: 0.00
Scale/Sector	: Small Scale /Private Sector
Activity	: COLLEGE & UNVRSITIES
Seasonal	: N
Load Shedding Ind	: I
Express Feeder Flag	N
Feeder Voltage (KV)	: 22

Current	31-03-2016	255919.600	260052.500	25985.100	28.640	29.060
Previous	29-02-2016	250457.100	254388.500	24570.000		
Difference		5462.500	5664.000	1415.100		
Multiplying Factor		10.0000	10.0000	10.0000	10.000	10.0000
Consumption		54625.000	56640.000	14151.000	286.400	290.600
LT Metering		0.000	0.000	0.000	0.000	0.000
Adjustment		0.000	0.000	0.000		
Assessed Consump		0.000	0.000	0.000	0.000	0.000
Total Consumption		54625.000	56640.000	14151.000	286.000	291.000

Billed Demand (KVA)	358.000	@ Rs.	220.000
Assessed P.F.	0.000	Avg. P.F.	0.968
Billed P.F.	0.968	L.F.	0.000

Consumption Type	Units	Rate	Charges Rs.
Industrial	0	8.41	0.00
Residential	0	5.81	0.00
Commercial	54,625	8.41	459396.25
E.D on (Rs)	Rate (%)	Amount Rs.	
0.00	9.3	91211.03	
5,70,068.96	16	0.00	
0.00	21	0.00	

Zone	Units	Demand	Charges Rs.
A Zone	6,905	48.00	-10,357.50
B Zone	28,071	282.00	0.00
C Zone	15,432	291.00	12,345.60
D Zone	4,217	68.00	4,638.70

SIX LAKH FIFTY -FOUR THOUSAND EIGHT HUNDRED TWENTY ONLY

Demand Charges			78,760.00
RLC Refund			0.00
Energy Charges	+Addl Charges		4,59,396.25
TOD Tariff EC			6,626.80
FAC @		Ps/U	25,285.91
Electricity Duty			91,211.03
Other Charges +Genco Charge			0.00
Tax on Sale @	8	Ps/U	4,370.00
P.F. Penal Charges / P.F.Inc.			-11,401.38
Charges For Excess Demand			0.00
EHV Rebate			0.00
Debit Bill Adjustment			0.00
Total Current Bill			6,54,816.71
Current Interest	31-03-2016		0.00
Principle Arrears			1.39
Interest Arrears			0.00
Total Bill (Rounded) Rs.			6,54,820.00
Delayed Payment Charges Rs.			13,096.33
Amount Payable After	18-04-2016		667910

Amount Rounded to Nearest Rs. (10/-)

Security Deposit Held Rs.	10,30,500.00
Addl. S. D. Demanded Rs.	0.00
S.D. Arrears Rs.	0.00

Bill Month	FEB-16	JAN-16	DEC-15	NOV-15	OCT-15	SEP-15
Units	35,091	45,823	35,849	36,176	61,690	53,387
Bill Amount	4,54,789	5,68,824	4,95,469	5,00,319	7,83,253	6,61,046

Fig. 4A.8.1: Electricity bill of AIKTC

(B) Energy Efficient Appliances

4B.9 Potential Energy Savings

During the Energy Audit, there are some places where we are wasting energy and it can be conserved by suggesting the appropriate instructions. We found that the Energy can be saved or conserved by the following methods:

1. Use of Energy Efficient Appliances
2. Use of Capacitor Bank

4B.9.1 Energy Efficient Appliances

During our survey, we found that AIKTC still uses Outdated Energy Appliances in huge numbers specially in Diploma and Pharmacy Buildings. Because of which Energy required is more and hence electricity bill is enormous.

In order to reduce the Electricity Bill, Conserve Energy and making the first step towards Green Campus, first we need to replace Outdated Energy Appliance with Latest Energy Efficient Appliances.

In accordance with that, we proposed the following light and fans which would be the best if it replaced with Outdated Lights and Fans and benefits of this change will give fruitful results. Accordingly, depth analysis of these categories were carried out. The outcome / suggestions is listed below:

4B.9.1.1 Proposed Appliances

1. Havells Fusion 1200mm Fan (45 W)
2. Syska T5 (6W)

4B.9.1.2 Calculations for Proposed Appliances

[A] For Diploma Building

<u>Calculations for Fan</u>:

Existing Fans wattage per hour = 80 W

Total no. of fans available in Diploma Building = 705 nos

Energy consumed by the fans=705 X 80 X 8 X 30 = 13536 kW

Per unit charges is = Rs. 8.41

Amount =Rs. 113837.76

<u>Proposed</u>

Proposed Fans wattage per hour = 45 W

Total energy consumed by fan = 705 X 45 X 8 X 30 = 7614 kW

Amount = Rs. 64033.74

<u>Savings</u>

If we use proposed appliances = 113837.76 - 64033.74

= Rs. 49804.02

We Save Rs. 49804.02 in every months

Assume we sell all the existing fans at depreciation of 50% to 60%

We sell one fans at Rs 700,

= 700 X 705

= Rs. 493500

Cost of one proposed fans is Rs 2300

Total Cost of 705 Fans = 705 X 2300 = Rs. 1621500

Additional cost requires = 1621500 - 493500

= Rs. 1128000

Savings Per Month = Rs. 49804.02

Payback period = total cost r to purchase fans/Savings per month

= 1128000/49804.02

= 1.887 years

Calculations for Lights:

Existing light wattage per hour = 40 W

Total no. of lights available in Diploma Building = 722 nos

Energy consumed by the fans = 722 X 40 X 8 X 30 = 6931.2 kW

Per unit charges is = Rs. 8.41

Amount = Rs. 58291.392

Proposed

Proposed Light wattage per hour = 6 W

Total energy consumed by fan = 722 X 6 X 8 X 30 = 1039.68 kW

Amount = Rs. 8743.7088

Savings

If we use proposed appliances = 58291.392 - 8743.7088

= Rs. 49547.68

We Save Rs 49547.68 in every months

Assume we sell all the existing Lights at depreciation of 50% to 60%

We sell one Lights at Rs. 100

= 722 X 100

= Rs. 72200

Cost of one proposed Light is Rs. 352

Total Cost of 722 Lights = 722 X 352 = Rs. 254144

Additional cost requires = 254144-72200

= Rs. 181944

Savings Per Month = Rs. 49547.68

Payback period = total additional cost /Savings per month

= 181944/49547.68

= 0.306 years

[B] For Engineering Building

Calculations for Fan:

Existing Fans wattage per hour = 60 W

Total no. of fans available in Engineering building = 242 nos

Energy consumed by the fans = 242 X 60 X 8 X 30 = 3484.8KW

Per unit charges is = Rs. 8.41

Amount = Rs. 29303.804

Proposed

Proposed Fans wattage per hour = 45 W

Total energy consumed by fan = 242X45X8X30 = 2613.6kW

Amount = Rs. 21980.37

Savings

If we use proposed appliances = 29303.804 - 21980.37

= Rs. 7323.428

We Save Rs. 7323.428 in every months

Assume we sell all the existing fans at depreciation of 50% to 60%

We sell one fans at Rs 700

= 700 X 242

= Rs. 169400

Cost of one proposed fans is Rs 2300

Total Cost of 705 Fans = 242X2300 = Rs. 556600

Additional cost requires = 556600 – 169400

= Rs. 387200

Savings Per Month = Rs. 7323.428

Payback period = total additional cost/Savings per month

= 387200/7323.428

= 4.40 years

Calculations for Lights:

Existing light wattage per hour = 40 W

Total no. of lights available in Engineering Building = 156 nos

Energy consumed by the lights = 156 X 40 X 8 X 30 = 1497.62 kW

Per unit charges is = Rs. 8.41

Amount = Rs. 12594.81

Proposed

Proposed Light wattage per hour = 6 W

Total energy consumed by lights = 156 X 6 X 8 X 30 = 224.64 kW

Amount = Rs. 1889.22

Savings

If we use proposed appliances = 12594.81 - 1889.22

= Rs. 10705.58

We Save Rs. 10705.58 in every months

Assume we sell all the existing Lights at depreciation of 50% to 60%

We sell one Lights at Rs. 100

= 156 X 100

= Rs. 15600

Cost of one proposed Light is Rs. 352

Total Cost of 157 Lights = 156X352 = Rs. 54912

Additional cost requires = 54912 – 15600

= Rs. 39312

Savings Per Month = Rs. 10705.58

Payback period = total additional cost /Savings per month

= 39312/10705.58

= 0.306 years

Calculations for Lights:

Existing light wattage per hour = 28 W

Total no. of lights available in Engineering Building = 680 nos

Energy consumed by the lights = 680 X 28 X 8 X 30 = 4569.6kW

Per unit charges is = Rs. 8.41

Amount = Rs.38430.33

Proposed

Proposed Light wattage per hour = 6 W

Total energy consumed by Lights = 680 X 6 X 8 X 30 = 979.2 kW

Amount = Rs. 8235.67

Savings

If we use proposed appliances = 38430.33 - 8235.67

= Rs. 30195.26

We Save Rs. 30195.26 in every months

Assume we sell all the existing Lights at depreciation of 50% to 60%

We sell one Lights at Rs. 100

= 680 X 100

= Rs. 68000

Cost of one proposed Light is Rs. 352

Total Cost of 680 Lights = 680 X 352 = Rs. 239360

Additional cost requires = 239360 – 68000

= Rs. 171360

Savings Per Month = Rs. 30195.26

Payback period = total additional cost /Savings per month

= 171360/30195

= 0.4729 years

[C] For Pharmacy Building

Calculations for Fan:

Existing Fans wattage per hour = 60 W

Total no. of fans available in Pharmacy Building = 431 nos

Energy consumed by the fans = 431 X 60 X 8 X 30 = 6206.4 kW

Per unit charges is = Rs. 8.41

Amount = Rs. 52195.82

Proposed

Proposed Fans wattage per hour = 45 W

Total energy consumed by fan = 431 X 45 X 8 X 30 = 4654.8 kW

Amount = Rs. 39146.86

Savings

If we use proposed appliances = 52195.9 - 43496.52

= Rs. 13048.95

We Save Rs.13048.95 in every months

Assume we sell all the existing fans at depreciation of 50% to 60%

We sell one fans at Rs 700

= 700X431

= Rs. 301700

Cost of one proposed fans is Rs 2300

Total Cost of 705 Fans = 431 X 2300 = Rs. 991300

Additional cost requires = 991300-301700

= Rs. 689600

Savings Per Month = Rs. 13048.95

Payback period = total additional cost/Savings per month

= 689600/13048.95

= 4.40 years

Calculations for Lights:

Existing light wattage per hour = 40 W

Total no. of lights available in Pharmacy Building = 426 nos

Energy consumed by the lights = 426 X 40 X 8 X 30 = 4089.6 kW

Per unit charges is = Rs. 8.41

Amount = Rs. 34393.53

Proposed

Proposed Light wattage per hour = 6 W

Total energy consumed by lights = 426 X 6 X 8 X 30 = 613.44 kW

Amount = Rs. 5159.03

Savings

If we use proposed appliances = 34393.53 - 5159.03

= Rs. 29234.49

We Save Rs. 29234.49 in every months

Assume we sell all the existing Lights at depreciation of 50% to 60%

We sell one Lights at Rs. 100

= 426X100

= Rs. 42600

Cost of one proposed Light is Rs. 352

Total Cost of 426 Lights = 426X352 = Rs. 149952

Additional cost requires = 149952 – 42600

= Rs. 107352

Savings Per Month = Rs. 29234.49

Payback period = total additional cost /Savings per month

= 107352/29234.49

= 0.30 years

[D] For Architecture Building

<u>Calculations for Fan:</u>

Existing Fans wattage per hour = 60 W

Total no. of fans available in Architecture Building = 153 nos

Energy consumed by the fans = 153 X 60 X 8 X 30 = 2203.2 kW

Per unit charges is = Rs8.41

Amount = Rs. 18528.91

Proposed

Proposed Fans wattage per hour = 45W

Total energy consumed by fan = 153 X 45 X 8 X 30 = 1652.4 kW

Amount = Rs. 13896.68

Savings

If we use proposed appliances = 18528.91 - 13896.68

= Rs. 4632.23

We Save Rs.4632.226 in every months

Assume we sell all the existing fans at depreciation of 50% to 60%

We sell one fans at Rs 700

= 700 X 153

= Rs. 107100

Cost of one proposed fans is Rs 2300

Total Cost of 153 Fans = 153X2300 = Rs. 351900

Additional cost requires = 351900 – 107100 = Rs. 244800

Savings Per Month = Rs. 4632.22

Payback period = total additional cost/Savings per month

= 244800/4632.22

= 4.40 years

Calculations for Lights:

Existing light wattage per hour = 28 W

Total no. of lights available in architecture building = 356 nos

Energy consumed by the lights = 356 X 28 X 8 X 30 = 2392.32 kW

Per unit charges is = Rs8.41

Amount = Rs. 20119.41

Proposed

Proposed Light wattage per hour = 6 W

Total energy consumed by Lights = 356 X 6 X 8 X 30 = 512.64 kW

Amount = Rs. 4311.3

Savings

If we use proposed appliances = 20119.41 - 4311.3

= Rs. 15808.108

We Save Rs. 150808.108 in every months

Assume we sell all the existing Lights at depreciation of 50% to 60%

We sell one Lights at Rs. 100

= 356X100

= Rs. 35600

Cost of one proposed Light is Rs. 352

Total Cost of 356 Lights = 356 X 353 = Rs. 125312

Additional cost requires = 125312 – 35600

= Rs. 89712

Savings Per Month = Rs. 15808.108

Payback period = total additional cost /Savings per month

= 89712/15808.108

= 0.47 years

4B.9.1.3 Matrix Table for Energy Efficient Appliances

Table 4B.9.1.3.1 Energy efficient appliances for AIKTC

	Diploma Building		Engineering Building			Pharmacy Building		Architecture Building	
	FANS	LIGHTS	FANS	LIGHTS	T-5	FANS	LIGHTS	FANS	T-5
Existing W/hr	80	40	60	40	28	60	40	60	28
Proposed W/hr	45	6	45	6	6	45	6	45	6
Quantity	705	722	242	156	680	431	426	153	356
Current Cost (Rs.)	113837	58291	29303	12594	38430	52195	34393	18528	20119
Proposed Cost (Rs.)	64033	8743	21980	1889	8235	39146	5159	13896	4311
Sale Cost (Rs.)	700	100	700	100	100	700	100	700	100
Cost of One Proposed (Rs.)	2300	352	2300	352	352	2300	352	2300	352
Additional Cost (Rs.)	112800	181944	387200	39312	171360	689600	107352	244800	89712
Saving/Month (Rs.)	49804	49547	7323	10705	30195	13048	29234	4632	15808
Payback Period (Monthly)	22	4	50	3.5	5.5	53	3.6	52	5.6

4B.9.1.4 Recommendations

After discussion with the group members and project guide, we recommend AIKTC to replace the outdated appliances such as fans and lights from Diploma and Pharmacy Building with the proposed one, because the quantity of outdated appliances are enormous and leads to lots of energy waste. If we do these changes then the energy can be conserved and Electricity Bill will be reduced.

4B.9.1.5 Conclusions

For Diploma Building (Fans & Lights)

1. Savings per month = 0.49 Lakhs & 0.495 Lakhs
2. Payback Period = 1.88 years & 0.306 years

For Pharmacy Building (Fans & Lights)

1. Savings per month = 0.13 Lakhs & 0.29 Lakhs
2. Payback Period = 4.4 years & 0.3 years

(C) Capacitor Bank

4C.9.2 Use of Capacitor Bank

Power factor is the ratio of working power to apparent power. It measures **how effectively electrical power is being used.**

Low power factor means you're not fully utilizing the electrical power you're paying for. A high power factor signals efficient utilization of electrical power, while a low power factor indicates poor utilization of electrical power.

Power Factor Incentive

(Applicable for HT I, HT II, HT IV, HT V, HT VI and IX categories, as well as LT II (B), LT II (C), LT III, LT V (B), LT X (B) and LT X (C) categories)

Whenever the average power factor is more than 0.95, an incentive shall be given at the rate of the following percentages of the amount of the monthly bill including energy charges, reliability charges, FAC, and Fixed/Demand Charges, but excluding Taxes and Duties.

Sr. No.	Range of Power Factor	Power Factor Level	Incentive
1	0.951 to 0.954	0.95	0%
2	0.955 to 0.964	0.96	1%
3	0.965 to 0.974	0.97	2%
4	0.975 to 0.984	0.98	3%
5	0.985 to 0.994	0.99	5%
6	0.995 to 1.000	1.00	7%

4C.9.2.1 Current Status of Capacitor Bank

Current Power Factor of AIKTC: - 0.95

Load per month (P): - 58866.24 kW

<u>Total Installed Capacitor Bank at AIKTC</u>: -

At Transformer = 300 kVAR

At Engineering Building = 200 kVAR

At Pharmacy Building = 80 kVAR

At Diploma Building = 75 kVAR

Total Installed Capacitor = 905 kVAR

To increase the power factor, it's required to install capacitor bank of desired Rating in order to get Required PF.

4C.9.2.2 Calculations for Capacitor Bank

<u>Case -1:</u> - If power factor is increased from 0.95 to 0.96:

From Table, Multiplier to improve PF from 0.95 to 0.96 = 0.037

Required Capacitor kVAR = Load in kW X Table Multiplier

= 58866.24 X 0.037

= 2178.05 kVAR

Rating of Capacitor to be connected = $\frac{2178.05}{3} = 726.0169$ kVAR

Incentive or Concession = 1%

Charges to be paid = 495065.07 X (1 - 0.01)

= Rs. 490114.4

Saving = 495065.07-490114.4

= Rs. 4950.67

Note: - With the given installed Capacitor Bank, we should get PF 0.96, but in "DIPLOMA BUILDING" only 75 kVAR Capacitor Bank is installed & the load is more as compare to other buildings & hence the Power Factor is decreased to (0.945 to 0.95).

Therefore, to increase the PF, add Capacitor of 150 kVAR in Diploma Building.

Initial Cost add Capacitor of 150 kVAR = Rs. 300000

Area Required = 2.25m^2

Payback Period = $\frac{Initial\ Cost}{Saving} = \frac{300000}{4950.67} = 60$ months

<u>Case -2</u>: - If power factor is increased from 0.96 to 0.97:

From Table, Multiplier to improve PF from 0.96 to 0.97 = 0.079

Required Capacitor kVAR = Load in kW X Table Multiplier

= 58866.24 X 0.079

= 4650.43 kVAR

Rating of Capacitor to be connected = $\frac{4650.43}{3} = 1550.14$ kVAR

Incentive or Concession = 2%

Charges to be paid = 495065.07 X (1 - 0.02)

= Rs. 485163.76

Saving = 495065.07- 485163.76

= Rs. 9901.31

Use APFCP 350 kVAR

Initial Cost = Rs. 670833

Area Required = 1.47m^2

In Order to get PF of 0.97, add Capacitor of 700 kVAR

Initial Cost = Rs. 1341666

Area Required = 2.94m^2

Payback Period = $\frac{Initial\ Cost}{Saving} = \frac{1341666}{9901.31} = 135.5$ months

<u>Case -3</u>: - If power factor is increased from 0.97 to 0.98:

From Table, Multiplier to improve PF from 0.97 to 0.98= 0.126

Required Capacitor kVAR = Load in kW X Table Multiplier

= 58866.24 X 0.126

= 7417.14 kVAR

Rating of Capacitor to be connected = $\frac{7417.14}{3} = 2472.33$ kVAR

Incentive or Concession = 3%

Charges to be paid = 495065.07 X (1 - 0.03)

= Rs. 480212.12

Saving = 495065.07- 480212.12

= Rs. 14851.95

Use APFCP 350 kVAR

Initial Cost = Rs. 670833

Area Required = 1.47m^2

In Order to get PF of 0.98, add Capacitor of 1400 kVAR

Initial Cost = Rs. 2683332

Area Required = 5.88m^2

Payback Period = $\frac{Initial\ Cost}{Saving} = \frac{2683332}{14851.95} = 180.6$ months

Case -4: - If power factor is increased from 0.98 to 0.99:

From Table, Multiplier to improve PF from 0.98 to 0.99= 0.187

Required Capacitor kVAR = Load in kW X Table Multiplier

= 58866.24 X 0.187

= 11007.98 kVAR

Rating of Capacitor to be connected = $\frac{11007.98}{3} = 3669.3$ kVAR

Incentive or Concession = 5%

Charges to be paid = 495065.07 X (1-0.05)

= Rs. 470311.8

Saving = 495065.07- 470311.8

= Rs. 24753.27

Use APFCP 350 kVAR

Initial Cost = Rs. 670833

Area Required = 1.47m^2

In Order to get PF of 0.99, add Capacitor of 2800 kVAR

Initial Cost = Rs. 5366664

Area Required = 11.76m^2

Payback Period = $\frac{Initial\ Cost}{Saving} = \frac{5366664}{24753.27} = 216.8$ months

Case -5: **-** If power factor is increased from 0.99 to 1.0:

From Table, Multiplier to improve PF from 0.99 to 1.0= 0.328

Required Capacitor kVAR = Load in kW X Table Multiplier

= 58866.24 X 0.328

= 19308.1 kVAR

Rating of Capacitor to be connected = $\frac{19308.1}{3} = 6436$ kVAR

Incentive or Concession = 7%

Charges to be paid = 495065.07 X (1-0.07)

= Rs. 460410.5

Saving = 495065.07- 460410.5

= Rs. 34654.57

Use APFCP 350 kVAR

Initial Cost = Rs. 670833

Area Required = 1.47m^2

In Order to get PF of 1.0, add Capacitor of 3500 kVAR

Initial Cost = Rs. 6708330

Area Required = 14.7m^2

Payback Period = $\frac{Initial\ Cost}{Saving} = \frac{6708330}{34654.57} = 193.5$ months

4C.9.2.3 Matrix Table for Capacitor Bank

Table 4C.9.2.3.1 Selection of capacitor bank

Power Factor	Rating of Capacitor	Concession	Initial cost	saving	payback period
	(kVAR)	(%)	(Rs.)	(Rs.)	month
0.96	726.0169	1	1341666	4950	271
0.97	1550.14	2	2683332	9901	271
0.98	2472.33	3	5366664	14851	361
0.99	3669.3	5	7379163	24753	298
1	6436	7	1274994	34654	348

4C.9.2.4 Recommendation

After discussion with the group members and project guide, we recommend the AIKTC to increase power factor from 0.95 to 0.97 because the initial cost and payback period is less as compared to other cases and we would get Rs. 9901 savings every month.

Following parameters are the requirement and the benefits of increasing PF to 0.97:

1. Rating of Capacitor (kVAR) = 1550.14
2. Concession (%) = 2
3. Initial Cost (Rs.) = 2683332
4. Savings per month (Rs.) = 9901
5. Payback Period (Month) = 271

(D) Renewable Energy Sources

4D.1 Literature Survey

We have done all the literature survey related RES, Solar Energy, Wind Energy, Hybrid Energy, AHP and different parameter which is required for finding the best suitable Renewable Energy Sources for our campus.

4D.1.1 Survey for Area

The area is given by using google map area calculations tool.

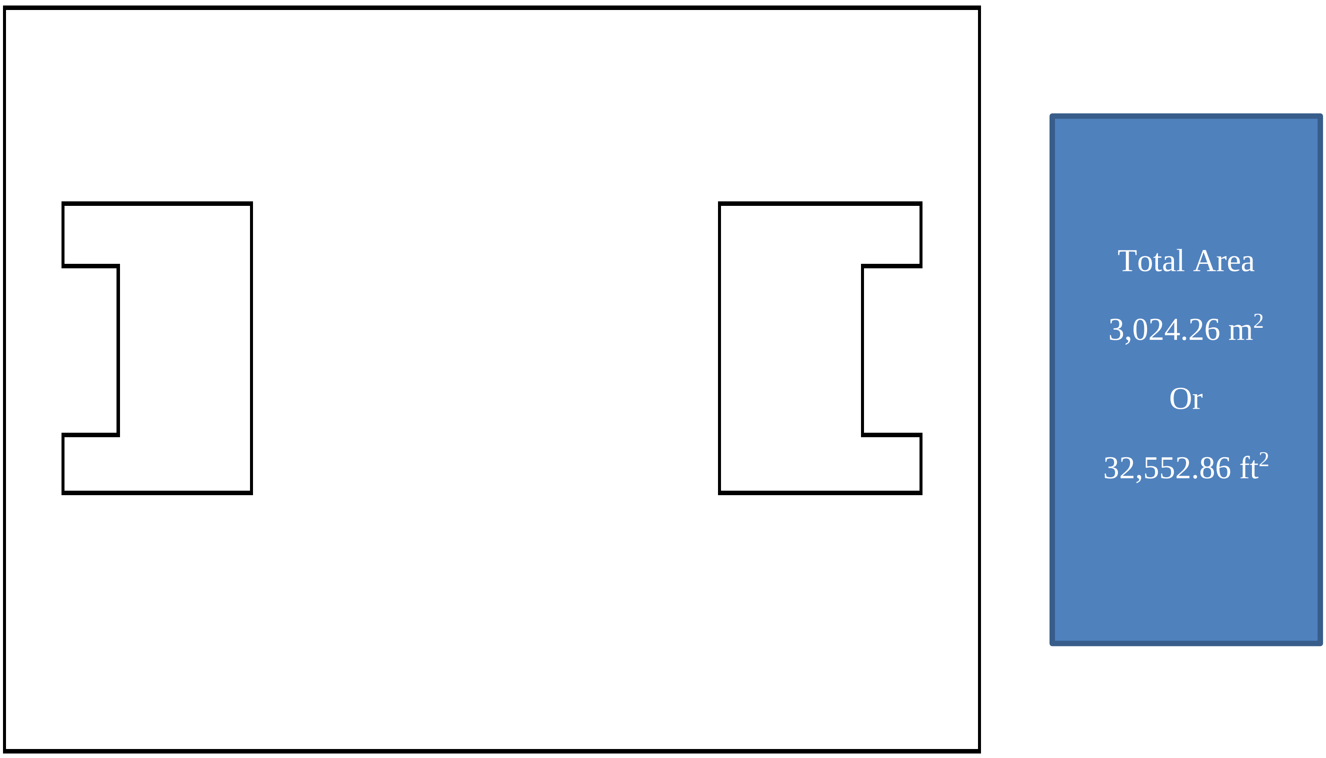


Fig. 4D.1.1.1: Area of Engineering Building

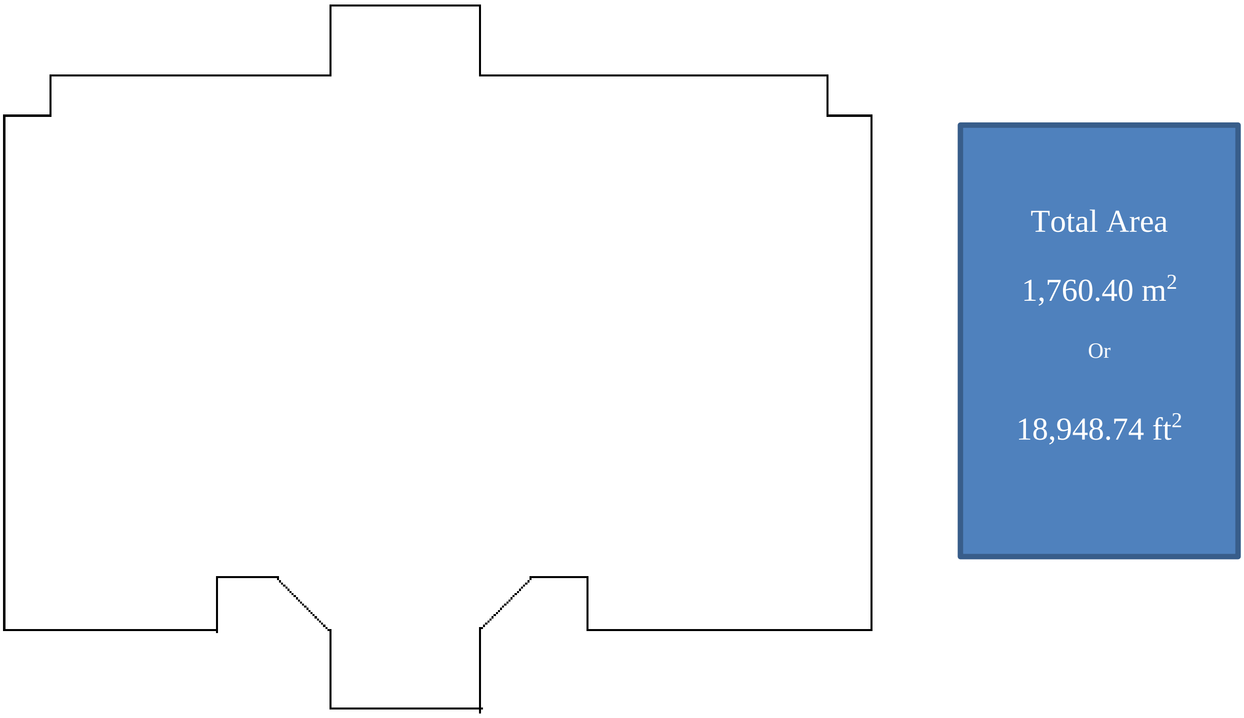


Fig. 4D.1.1.2: Area of Pharmacy Building

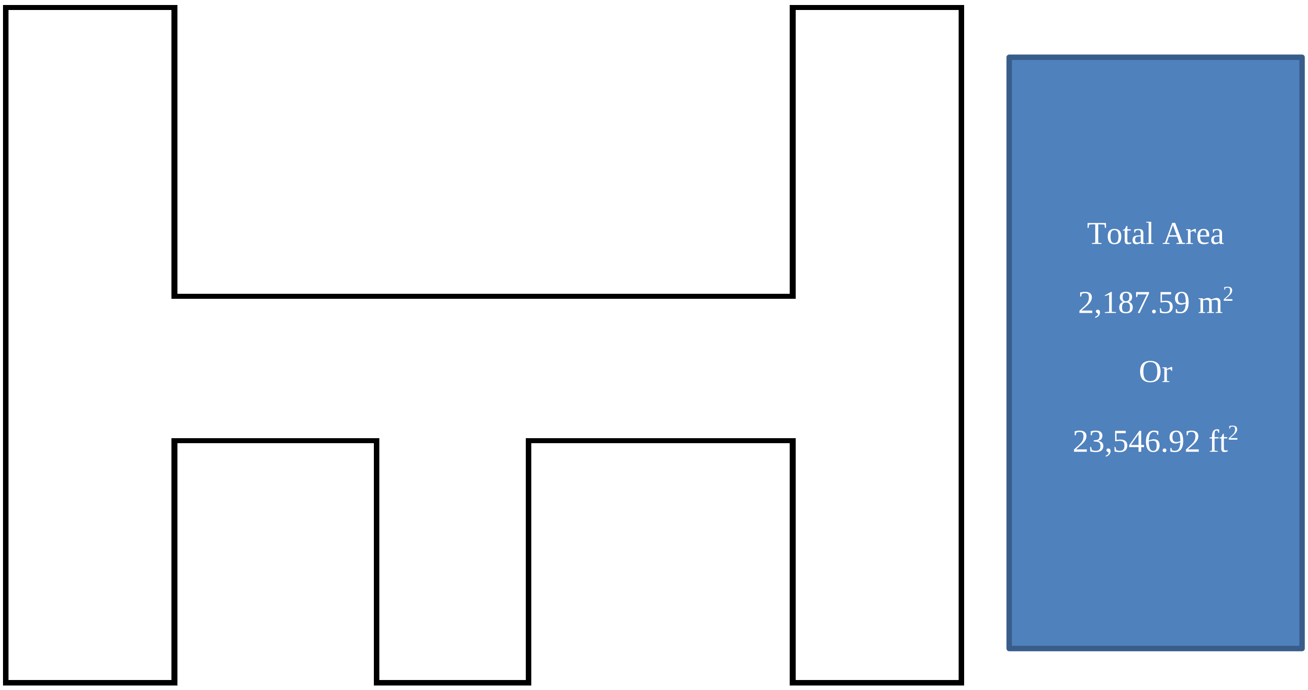


Fig. 4D.1.1.3: Area of Diploma Building

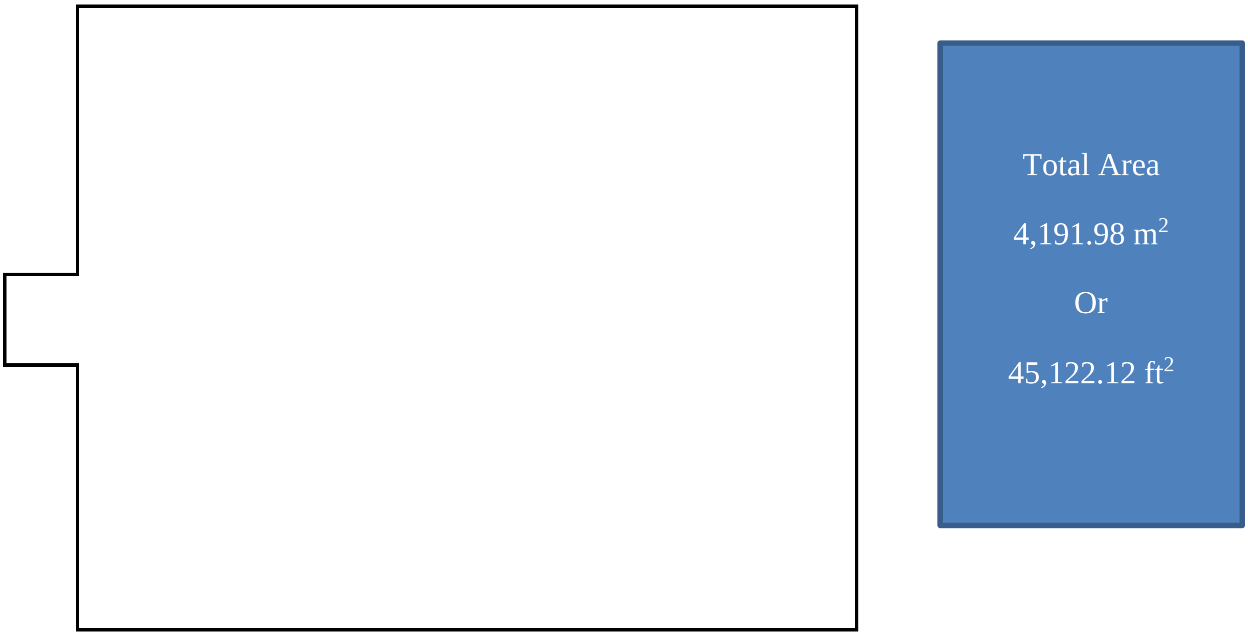


Fig. 4D.1.1.4: Area of Architecture Building

Table 4D.1.1: Areas of AIKTC

Sr. No.	Name of Building	Area in $feet^2$
1	**Engineering**	**32552.86**
2	**Pharmacy**	**18948.74**
3	**Architecture**	**45122.12**
4	**Diploma**	**23546.92**

4D.1.2 Survey for Wind Velocity

The bellow table shows velocity for a week by using anemometer

Table 4D.1.2.1: Wind velocity for one week

Velocity	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
North	3.25	3.24	2.58	2.86	2.42	2.96	3.46
South	2.13	1.26	1.38	1.58	1.87	1.61	2.21
West	5.54	5.47	4.59	5.80	6.14	6.42	5.94
East	1.26	0.8	1.3	1.51	1.6	1.45	1.77

4D.1.2.1 Anemometer

It is device used to measured velocity of wind. We are used anemometer for find out wind velocity across the campus.

Fig. 4D.1.2.1.1: Anemometer

4D.2 Physical Survey of Campus

We have conducted the physical survey of campus to find out which type RES can be installed at our campus and ideal places for installation of RES.

During the survey we found that there are following 3 type RES can be installed at our campus:

1. Solar Energy
2. Wind Energy
3. Hybrid (Solar + Wind)

After finding out the best suitable RES for our campus, we began with finding out ideal places for installation of RES. For this matter we conducted the another physical survey for site selection for RES.

4D.2.1 Site Selection for Solar Energy

During the survey, we found that the terrace of all 4 buildings (i.e. Engineering, Pharmacy, Architecture and Diploma) are ideal potential places for installation of Solar Panels or Solar Energy. Since the terrace areas are only used for keeping the water tank and remaining areas are useless. It would be beneficial for the campus to use terrace area.

The terrace area of all 4 buildings are calculated and shown below:

Fig. 4D.2.1.1 Area selection for installation of solar panel

4D.2.2 Site Selection for Wind Energy

Wind velocity of air increases with increase in height. Because of this reason we conducted the survey on roof top of all 4 buildings to find out the wind velocity of air at different locations of all 4 buildings with the help of anemometer.

We found that the Engineering building and Pharmacy building are ideal places for installation of Wind Turbine. Because wind velocity ranges from 1.4 m/s to 6.2 m/s during day time and these ranges further increases during night time.

Wind energy is available at Engineering and Pharmacy building but terrace area available at Pharmacy building is less and therefore we are focusing RES only for Engineering Building.

Fig. 4D.2.2.1: Area selection for installation of wind turbine

Fig. 4D.2.2.1: Area selection for installation of wind turbine

4D.3 Solar Energy

What is solar energy?

According to the Environment Protection Agency, solar energy is defined as energy derived from the sun's radiation. Solar energy sustains life on earth. It is also becoming increasingly common that this energy is converted and used as an alternative to fossil fuels.

Solar energy can be harnessed using a range of technologies such as solar photovoltaic, solar heaters and solar thermal electricity. It is considered an environmentally friendly source of energy because it comes directly from the sun; it does not involve the burning of fossil fuels. The primary limitation of solar energy is that it is not always available, and methods of storage and stop-gap are required for when it is cloudy or raining outside.

Active solar energy involves equipment or an action to convert solar energy into a useful form. One example of active solar energy is the use of solar cells to convert energy from the sun into electrical energy that can be used in the home.

Passive solar energy does not require any specific action or equipment. An example of passive solar energy is strategically placing windows in a home to allow sunlight to enter and provide heat.

4D.3.1 Types of Solar Panels

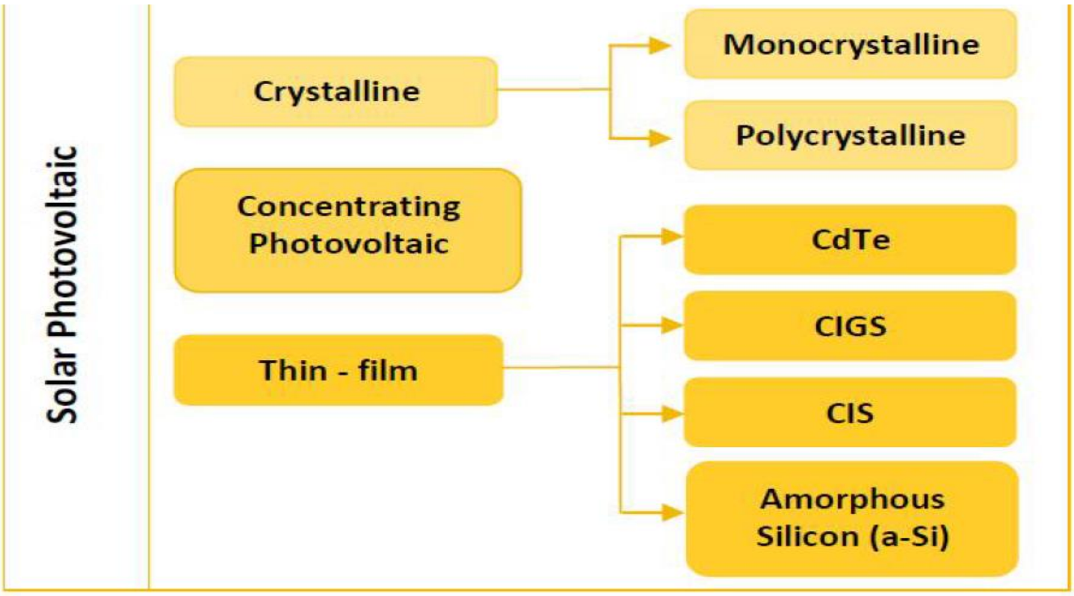


Fig. 4D.3.1.1 Major Classifications of Types of Solar Panels

1. Crystalline Silicon (c-Si)

Almost 90% of the World's photovoltaics today are based on some variation of silicon. In 2011, about 95% of all shipments by U.S. manufacturers to the residential sector were crystalline silicon solar panels.

The silicon used in PV takes many forms. The main difference is the purity of the silicon.

But what does silicon purity really mean? The more perfectly aligned the silicon molecules are, the better the solar cell will be at converting solar energy (sunlight) into electricity (the photoelectric effect).

The efficiency of solar panels goes hand in hand with purity, but the processes used to enhance the purity of silicon are expensive. Efficiency should not be your primary concern. As you will later discover, cost-and space-efficiency are the determining factors for most people.

I. ***Monocrystalline silicon*** **(c-Si):** often made using the Czochralski process. Single-crystal wafer

cells tend to be expensive, and because they are cut from cylindrical ingots, do not completely

cover a square solar cell module without a substantial waste of refined silicon. Hence most *c-Si*

panels have uncovered gaps at the four corners of the cells.

Ribbon silicon is a type of monocrystalline silicon: it is formed by drawing flat thin films from

molten silicon and having a multicrystalline structure. These cells have lower efficiencies than Poly-Si, but save on production costs due to a great reduction in silicon waste, as this approach does not require sawing from ingots.

Fig. 4D.3.1.2: Monocrystalline Silicon

II. ***Poly- or multicrystalline silicon*** **(Poly-Si or mc-Si):** The first solar panels based on polycrystalline silicon, which also is known as polysilicon (p-Si) and multi-crystalline silicon (mc-Si), were introduced to the market in 1981. Unlike monocrystalline-based solar panels, polycrystalline solar panels do not require the Czochralski process. Raw silicon is melted and poured into a square mold, which is cooled and cut into perfectly square wafers. Poly-Si cells are less expensive to produce than single crystal silicon cells, but are less efficient. Crystalline silicon has average 15% efficiency.

Fig. 4D.3.1.3: Polycrystalline silicon

2. Thin films

The various thin-film technologies currently being developed reduce the amount (or mass) of light absorbing material required in creating a solar cell. This can lead to reduced processing costs from that of bulk materials (in the case of silicon thin films) but also tends to reduce energy conversion efficiency average 7 to 10% efficiency), although many multi-layer thin films have efficiencies above those of bulk silicon wafers They have become popular compared to wafer silicon due to lower costs and advantages including flexibility, lighter weights, and ease of integration.

Fig. 4D.3.1.3: Thin Films

1. Monocrystalline Silicon Solar Cell

- ✓ The efficiency rates of monocrystalline solar panels are typically 15-20%.

(Their E20 series provide panel conversion efficiencies of up to 20.1%)

- ✓ Since these solar panels yield the highest power outputs,190W square meter
- ✓ Require the least amount of space compared to any other types(6-9squm) (1kwp)

Space Requirement

- ✓ Monocrystalline solar panels live the longest.
- ✓ Tend to perform better than similarly rated polycrystalline solar panels at low-light conditions.

Performance

- ✓ Monocrystalline solar panels are the most expensive. (0.75$/W) (PRICE/WATT)
- ✓ Monocrystalline solar panels tend to be more efficient in warm weather

2. Polycrystalline Silicon Solar Cells

- ✓ Pc s p tend to have slightly lower heat tolerance than monocrystalline solar panels. (This technically means that they perform slightly worse than monocrystalline solar panels in high temperatures.)
- ✓ The efficiency of polycrystalline-based solar panels is typically 13-16%.
- ✓ Lower space-efficiency. (8-9msqu) (1kwp)

Space Requirement

- ✓ Polycrystalline solar panels are the less expensive. (0.62$/W)
- ✓ Since these solar panels yield the highest power outputs,180W square meter

3. Thin-Film Solar Cells (TFSC)

- ✓ Thin-film module prototypes have reached efficiencies between 7–13%
- ✓ High temperatures and shading have less impact on solar panel performance
- ✓ But they also require a lot of space (13-20msqu) (1kwp)
- ✓ They are cheap
- ✓ Thin-film solar panels tend to degrade faster than mono- and polycrystalline solar panels,

Better performance in weak sunlight environment Silicon thin film PV with high absorption coefficient also brings the benefit of module installation against any direction of sunlight.
Better performance at high ambient temperature Silicon thin film PV with low temperature coefficient has much better capability in hot environment High energy yield.

Limited Space

For those who don’t have enough space for thin-film solar panels (the majority of us), or if you want to limit the amount of space their PV-system takes up, crystalline-based solar panels are your best choice (and they would likely be your best choice even if you had the extra space). There are not a whole lot of solar installers and providers that offer thin-film solar panels for homeowners at this point

Both mono- and polycrystalline solar panels are good choices and offer similar advantages

Monocrystalline solar panels are slightly more expensive, but also slightly more space-efficient. If you had one polycrystalline and one monocrystalline solar panel, both rated 220-watt, they would generate the same amount of electricity, but the one made of monocrystalline silicon would take up less space.

Lowest Costs

If you want the lowest costs per rated power, or in other words, pay as little as possible for a certain amount of electricity, you should investigate if thin-film solar panels could in fact be a better choice than mono- or polycrystalline solar panels.

4D.3.2 Solar Cell Comparison Chart – Mono-, Polycrystalline and Thin Film

Below is a chart that lists the most used solar cell technologies today, their specifications, and how they compare against each other. Thin film solar cells include amorphous silicon, cadmium telluride (CdTe) and copper indium gallium selenide (CIS/CIGS)

Table 4D.3.2.1: Comparison of Mono-, Polycrystalline & Thin Film

	Monocrystalline	Polycrystalline	Amorphous	CdTe	CIS/CIGS
Typical module efficiency	15-20%	13-16%	6-8%	9-11%	10-12%
Best research cell efficiency	25.0%	20.4%	13.4%	18.7%	20.4%
Area required for 1 kWp	6-9 m2	8-9 m2	13-20 m2	11-13 m2	9-11 m2
Typical length of warranty	25 years	25 years	10-25 years		
Lowest price	0.75 $/W	0.62 $/W	0.69 $/W		
Temperature resistance	Performance drops 10-15% at high temperatures	Less temperature resistant than monocrystalline	Tolerates extreme heat	Relatively low impact on performance	
Additional details	Oldest cell technology and most widely used	Less silicon waste in the production process	Tend to degrade faster than crystalline-based solar panels Low availability on the market		

4D.3.3 Grades

Grade – A normally means a panel has no visible defects and all the major possible defects are covered by manufacturer's standard warranty.

Grade – B usually means the panel has some "cosmetic imperfections" or "cosmetic blemishes" of the above, but has the "same" electrical output as Grade – A.

Grade – C solar cells are those with a flaw that affects the power output, so the output power is somehow lower than A and B Grade cells, and the price is lowest.

Grade – D modules are generally considered unusable and thrown out by manufacturers.

Tier 1 solar panel manufacture characteristics

1. Uses the best grade of silicon to produce solar cell (higher the grade, the longest the solar cell will last and the better it will perform)
2. Produces some of the best performing solar panels at reasonable price.
3. Is vertically integrated, meaning they make their own cells and wafers.
4. Control each stage of the manufacturing process with advanced robotics processes invests heavily in R&D.
5. Produce 1GW of solar panels in a year.

Tier 2 solar panel manufacture characteristics

1. Uses partial robotics in their manufacturing process, and rely more on manual work from human production lines.
2. Produces good panels at good prices.
3. Invest only a little in R&D.
4. Is small to medium in scale

Tier 3 solar panel manufacture characteristics

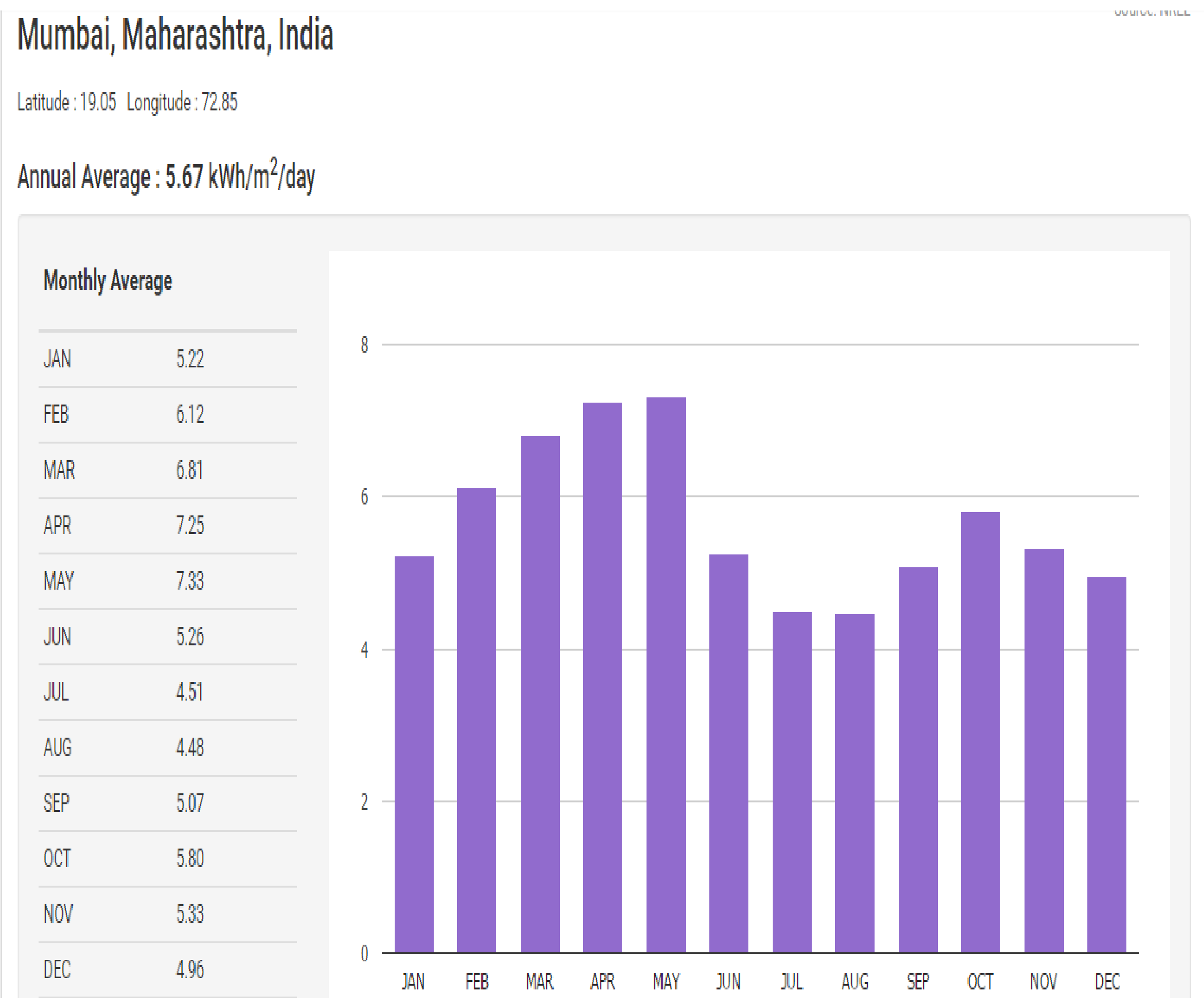
1. These are typically assemblers rather than pure panel manufacturers-i.e. they assemble others manufacturers cells into a panel.
2. Uses human production lines for manual soldering of solar cells instead of advanced robotics.
3. Quality can vary operator to operator and day to day.
4. No investment in R&D.

4D.3.4 light intensity, Color Variation, Manufacturer, Price, Calculation, Validation

4D.3.4.1 Intensity of Light

The below graphs represents annual average of intensity of light in Mumbai for two previous years (2015 & 2016). It is also providing monthly available intensity of light in kwh per m^2 per day.

Fig. D.3.4.1.1: Intensity of light in Mumbai in 2015

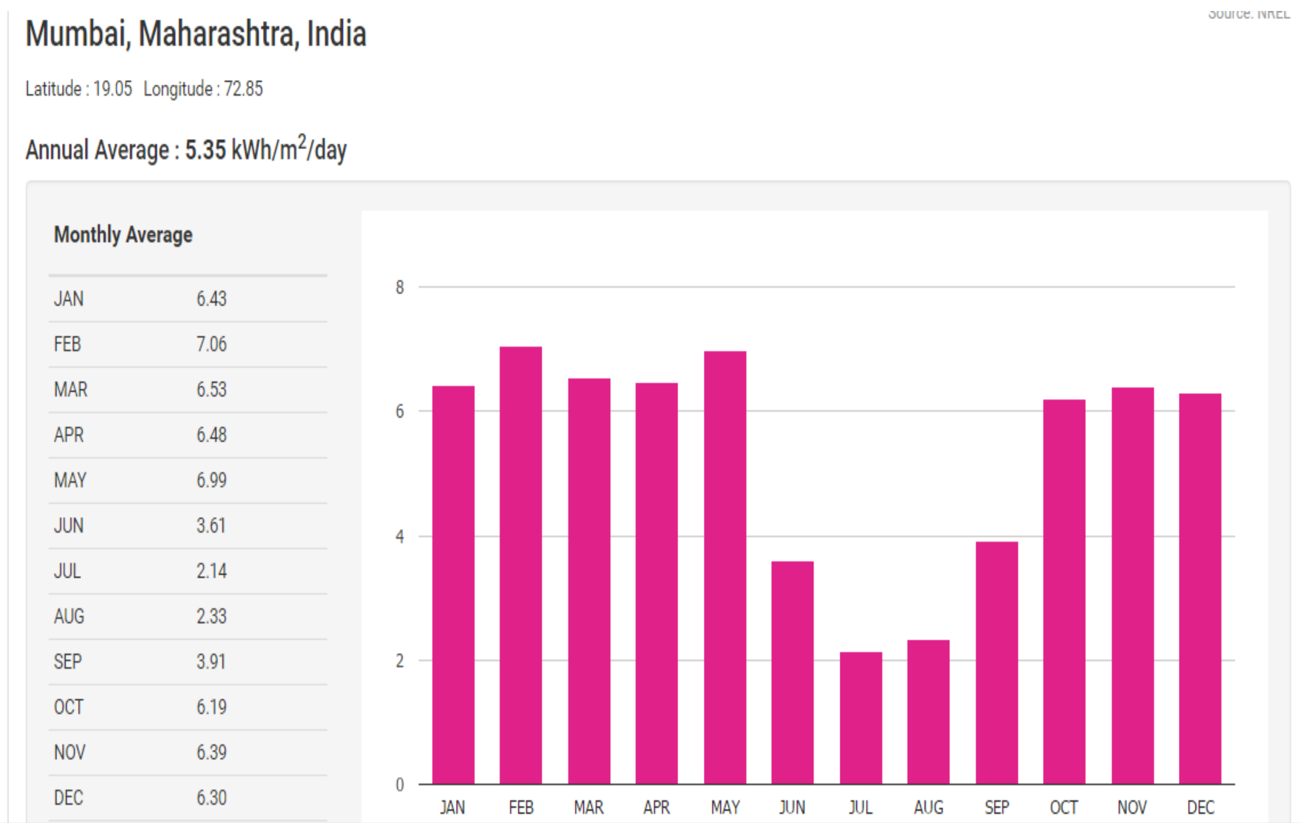


The bellows table gives the information about monthly average daily values (average, maximum, minimum) of climatic parameters for site.

Table 4D.3.4.1.2: Monthly average daily values of climatic parameters

Month	Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature
	°C	%	kWh/m²/d	kPa	m/s	°C
January	17.3	46.7%	4.23	97.7	2.7	19.1
February	20.7	41.2%	5.09	97.5	2.8	23.6
March	26.6	31.1%	5.92	97.2	2.9	30.9
April	31.9	24.5%	6.60	96.8	3.1	37.6
May	34.1	32.0%	6.51	96.4	3.3	39.6
June	31.6	55.2%	5.45	96.1	3.3	34.6
July	27.9	76.3%	4.32	96.2	2.9	29.2
August	26.6	81.5%	3.93	96.4	2.5	27.2
September	26.3	73.6%	4.51	96.7	2.4	27.2
October	25.4	50.9%	5.04	97.2	2.0	27.0
November	21.9	40.0%	4.51	97.6	2.1	23.3
December	17.9	45.4%	4.00	97.8	2.3	19.1
Annual	25.7	49.9%	5.01	96.9	2.7	28.2
Measured at (m)					10.0	0.0

Fig. D.3.4.1.3: Intensity of light in Mumbai in 2016



4D.3.4.2 Intensity with Color Variation

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Table- 4D.3.4.2.1: Based on color wavelength, intensity and Voltage & current of PV Panel

Table 4D.3.4.2.1: Intensity of color variation

Color of the acrylic sheet	Wavelength(nm)	intensity	voltage	current
Red	650	78	15.0	0.56
Yellow	580	150	16.5	0.57
Blue	445	119	9.1	0.31

Calculate the power & Spectral Response based on the light intensity and wavelength as shown in:

Table-4D.3.4.2.2: Where w is the Power of light falling on the panel Table-4D.3.4.2.2: Color Vs. Power & spectral Response of PV panel.

Table 4D.3.4.2.2: Intensity of color variation

Color of the acrylic sheet	Power of light falling on the panel(pin) = intensity of light * area of panel	Spectral response(A/W) = current/pin
Red	78 * 0.31 = 24.18	0.023
Yellow	150 * 0.31 = 46.5	0.01
Blue	119 * 0.31 = 36.89	0.008

As we shown in Fig.4D.3.4.2.1 graph the Power is increasing based on the different colors wavelength and Fig-4D.3.4.2.2 shown the Power Vs Spectral Response of the PV Panel.

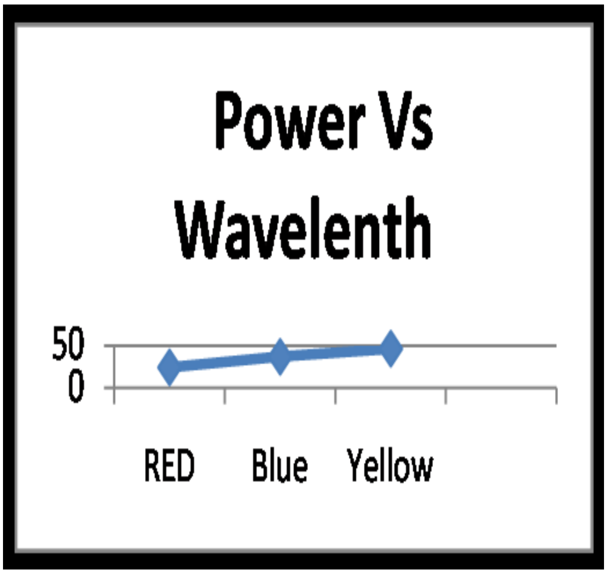


Fig.4D.3.4.2.1: Power Vs Color with different wavelength

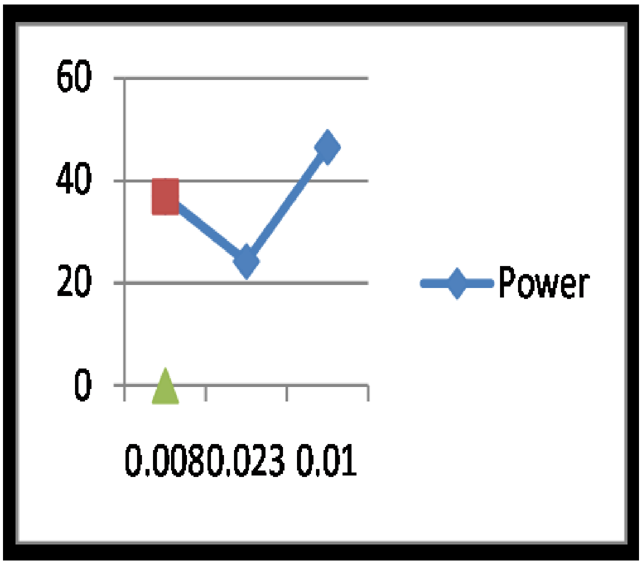


Fig-4D.3.4.2.2: Power Vs Panel Response

4D.3.4.3 Manufacturer in India

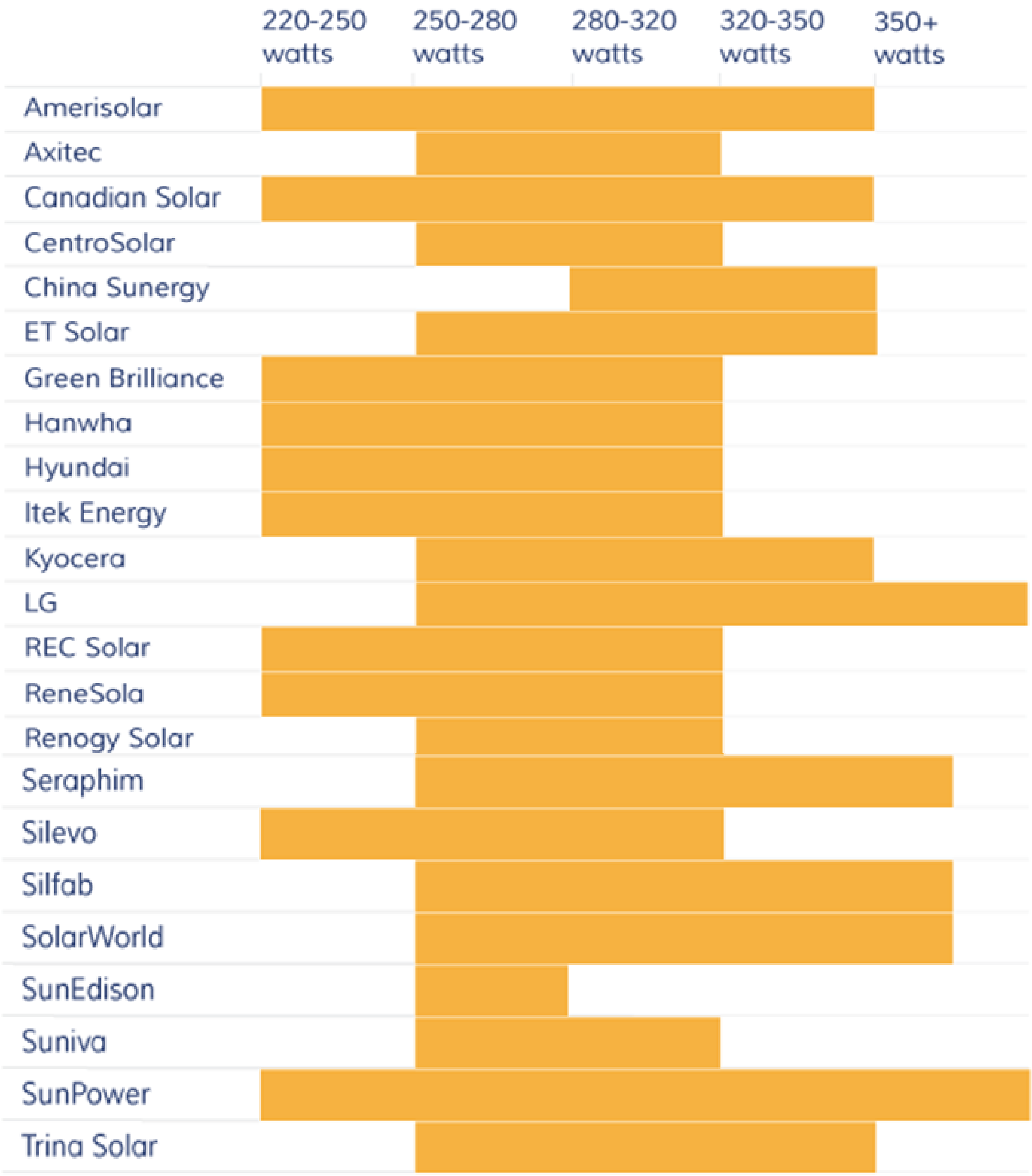
It is related to manufacture in India with average, maximum, minimum for solar panel manufacturer.

Table 4D.3.4.3.1 Power Output in Watt of Solar Manufacturer

Solar Panel Manufacturer	Minimum	Maximum	Average
Amerisolar	240	330	285
Axitec	250	320	273
CentroSolar	225	325	279
China Sunergy	250	320	278
ET Solar	250	340	295
Green Brilliance	230	300	266
Hanwha	245	315	280
Hyundai	220	305	259
Itek Energy	270	310	290
Kyocera	260	330	295
LG	275	365	312
SunPower	235	435	340
SolarWorld	250	350	292
REC Solar	240	320	267
Renogy Solar	250	300	268
Trina Solar Energy	250	345	287

This gives information about rang power produced by solar panel manufactures.

Table 4D.3.4.3.2: Range of power output of solar panel manufacture



4D.3.4.4 Solar Panels Price

As per our research (on e-commerce sites selling solar PV) and resources from the solar PV industry, cost of a PV module (just the panel) **costs anywhere between Rs 30 to Rs 50 per watt of power generated** (depending on the quantity you are buying).

1. If you are living in an area where power cuts are less frequent and you want to implement solar PV system to reduce your **electricity bills** then the best solution would be to go for a **Grid Connected Solar PV System.** It will cost you anywhere between 60,000-90,000 per kWp (cost varies based on the type of **inverter** and panels you choose).

2. If you are living in an area where there are frequent power cuts, then the best solution for you would be to go for an **"Off Grid" Solar PV System**. Off Grid Solar PV system will include batteries, which are an expensive part of the system and these would need replacement every few years (4-7 years). A typical Off Grid Solar PV System would cost about Rs 1-1.25 lakhs.

3. There are two types of Solar PV Cells: Monocrystalline and Polycrystalline. The difference between the two is that Monocrystalline is made of single silicon crystal whereas Multi-crystalline PV is made up of multiple crystals. A monocrystalline is more efficient in converting solar energy into electricity per sq. meter area than a multi-crystalline PV. Thus the space required for the same amount of wattage is less in monocrystalline PV panel. Thus it is costlier than a Multi-crystalline PV. The modules available in India are mostly "Polycrystalline".

Table 4D.3.4.4.1: Manufacture, model, wattage, efficiency%, price for solar panel

Manufacture	Model	Wattage (Wp)	Efficiency %	Price	Price Per Wp
Solar Universe	SUI-250P-60	250	15	8514.00	34.00
Shan solar	Ruby 60 250	250	15	8790.00	35.00
Navitas green solutions	NS300	300	16	10837.00	36.00
PV power tech	ECO 250	250	15	9031.00	36.00
Trina	Trina 310W 72 cell	310	16	11655.00	38.00
Zytech	ZT300P	300	16	11500.00	38.00
Futuresun	FU 260 P	260	16	10065.00	39.00
Seraphim	SRP-260-6PB	260	16	10168.00	39.00
Goldi green	goldi 250MM	250	15	10176.00	41.00
UREnergy	URE 250 60P	250	15	10168.00	41.00
Astralian premium solar	APSP-70/36	75	15	3442.00	46.00
Su-Kam	Su-Kam 250W/24V72 Cell	250	16	13300.00	53.00
Waaree energies Ltd	WS-10/12	10	9.52	588.00	59.00
Aleo	S18-260	260	16	12647.00	49.00
Navita green solution	NS255	255	16	9486.00	37.00
Manufacture	Model	Wattage (Wp)	Efficiency%	Price	Price Per Wp
Solar Universe	SUI-250P-60	250	15	8514.00	34.00
Shan solar	Ruby 60 250	250	15	8790.00	35.00
Navitas green solutions	NS300	300	16	10837.00	36.00
PV power tech	ECO 250	250	15	9031.00	36.00
Trina	Trina 310W 72 cell	310	16	11655.00	38.00
Zytech	ZT300P	300	16	11500.00	38.00
Futuresun	FU 260 P	260	16	10065.00	39.00
Seraphim	SRP-260-6PB	260	16	10168.00	39.00
Goldi green	goldi 250MM	250	15	10176.00	41.00
UREnergy	URE 250 60P	250	15	10168.00	41.00

Astralian premium solar	APSP-70/36	75	15	3442.00	46.00
Waaree energies Ltd	WS-10/12	10	9.52	588.00	59.00
Aleo	S18-260	260	16	12647.00	49.00
Navita green solution	NS255	255	16	9486.00	37.00

Please note that lower the efficiency, more panels you would need to get the same amount of electricity and it will occupy more rooftop area.

Table 4D.3.4.4.2: Solar Panel Deals

Company name	Series	type	Power range	Efficiency
Resun solar	RS6S-P	Polycrystalline	280-325	15.23-18.55%
Propsolar	PS-P672	Polycrystalline	259.9-320	13.17-16.51%
Topsky Energy	TNP-245-270W	Polycrystalline	245-270	15-16.51%
Future Solar	FSM260	Monocrystalline	260-285	16.01-17.43%
TN Solar	TN-60-6M	Monocrystalline	235-255	14.25-17.25%
Anhui Daheng Energy	DHM72	Monocrystalline	290-300	1502-17.08%
Changzhou GS Energy	GSM60	Monocrystalline	245-275	15.09-16.94%
Luxen Solar Energy	LNSF-315M-33	Monocrystalline	315-330	16.23-17%
Jiangsu kairui technology	KRP 72 Series	Polycrystalline	300-320	15.46-16.49%
Dokio	DSP100-300M	Monocrystalline	100-310	16.49-16.49%
JS Solar	JS195W-215W	Monocrystalline	195-215	15.28-16.84%
Sungold solar	Flexible 140	Monocrystalline	140-140	20.8-20.8%
Jiangsu Runda PV	RS200M-72	Monocrystalline	190-210	14.8-1.4%

Propsolar	Ps-P660	Polycrystalline	204.9-275	12.32-16.82%

It is general value of different capacity of solar panel manufactured by manufactures.

Table 4D.3.4.4.3 Solar Outcomes for Different Capacity of Panels

CAPACITY (KW)	**INITIAL COST RS**	**POWER GENERATION ANNUAL O/P(KW-h)**	**POWER GENERATION MONTHLY O/P(KW-h)**	**AREA REQUIRED sq. foot**	**PAYBACK PERIOD (YEARS)**
2	284152	1700	141.67	150.695	23
3	405931	2550	212.5	226.042	19
3.5	487117	2975	247.91	274.47	20
4	568304	3400	283.33	301.389	20.5
4*2=8	1136608	6800	566.67	602.779	20

4D.3.4.5 Calculations

We have done the calculations of solar panels by using 4 kW capacity of panels which can be installed by selecting different percentage (i.e. 2%, 3%, 5%, 10%, 15%) of total terrace areas of all 4 buildings to find out following parameters:

1. Area Required
2. No. of 4 kW Capacity Panels
3. Solar System Size
4. Total Cost of Installation
5. Typical Annual Output
6. Typical Monthly Output
7. Annual Maintenance Cost
8. Typical Profit Over 20 Years
9. Typical Profit Over 1 Year
10. Payback Period

[A] For Engineering Building

Total terrace area of engineering building: 32552.86 sqft.

We are taking 4KW capacity solar system combination.

Only percentage area of installation is being changed.

When we are taking 2% of total area of engineering building.

= 32552.86*2/100

= 651.05 sqft

4KW capacity solar panel

=651.05/301.389

= 2 no's

Solar system size

= 2*4

= 8 kW

Total cost of installation

= 2*568304

= Rs. 113660

Typical annual output

= 3400*2

= 6800 kWh

Typical monthly output

= 6800/2

= 566 kWh

Annually Maintenance cost

= 1.2% *initial cost

= 1.2/100*1136608

= Rs.13639

Typical profit over 20 year

= 548007.50*2

= Rs.1096015

Typical profit over 1 year

=1096015/20

= Rs.54800

Payback period

=1136608/54800

= 20 yrs.

In the same way we have done the calculations for (3%, 5%, 10%, 15%) terrace area of Engineering Building. And results are shown in the following tabular form.

Table 4D.3.4.5.1: FOR ENGINEERING BUILDING

PERCENTAGE AREA (%)	AREA (Sqft)	NO OF 4kW CAPACITY PANEL	SOLAR SYSTEM SIZE (kW)	TOTAL COST OF INSTALLATION (Rs)	TYPICAL ANNUAL OUT PUT (kWh)	TYPICAL MONTHLY OUT PUT (kWh)	MAINTENANCE COST ANNUALLY (Rs)	TYPICAL PROFIT OVER 20 YEAR (Rs)	TYPICAL PROFIT OVER 1 YEAR (Rs)	PAYBACK PERIOD (years)
2	651.05	2	8	1136608	6800	566	13639	1096015	54800	20
3	976.58	3	12	1704912	10200	850	20458	1644023	82201	20
5	1627.643	6	24	3409824	20400	1700	40917	3288045	164402	20
10	3255.286	11	44	6251344	37400	3116.67	75016	6028082	301404	20
15	4882.92	16	64	9092864	54400	4533.33	109114	8768120	438406	20

[B] For Pharmacy Building

Total terrace area of pharmacy building: 18948.78 sqft.

We are taking 4KW capacity solar system combination.

Only percentage area of installation is being changed.

When we are taking 2% of total area of pharmacy building.

= 18948.78*2/100

= 378.97 sqft

No of 4KW capacity solar panel

= 378.97/301.389

= 1 no's

Solar system size

= 1*4

= 4 kW

Total cost of installation

= 1*568304

= Rs. 568304

Typical annual output

= 3400*1

= 3400 kWh

Typical monthly output

= 3400 /12

= 283.33 kWh

Annually Maintenance cost

= 1.2% *initial cost

= 1.2/100*568304

= Rs. 6819

Typical profit over 20 year

= 548007.50*1

= Rs. 548007.50

Typical profit over 1 year

= 548007.50/20

= Rs. 27400

Payback period

= 568304/27400

= 20 yrs.

In the same way we have done the calculations for (3%, 5%, 10%, 15%) terrace area of Pharmacy Building. And results are shown in the following tabular form.

Table 4D.3.4.5.2: PHARMACY BUILDING

PERCENTAGE AREA (%)	AREA (Sqft)	NO OF 4kW CAPACITY PANEL	SOLAR SYSTEM SIZE (kW)	TOTAL COST OF INSTALLATION (Rs)	TYPICAL ANNUAL OUT PUT (kWh)	TYPICAL MONTHLY OUT PUT (kWh)	MAINTENANCE COST ANNUALLY (Rs)	TYPICAL PROFIT OVER 20 YEAR (Rs)	TYPICAL PROFIT OVER 1 YEAR (Rs)	PAYBACK PERIOD (years)
2	379	1	4	568304	3400	283.33	6819	548007.5	27400	20
3	568.5	2	8	1136608	6800	566.67	13639	1096015	54800	20
5	947.4	3	12	1704912	10200	850	20458	1644023	82201	20
10	1895	6	24	3409824	20400	1700	40917	3288045	164402	20
15	2842.3	10	40	5683040	34000	2833.33	68196	5480075	274003	20

[C] For Architecture Building

Total terrace area of architecture building: 26173.30 sqft.

We are taking 4KW capacity solar system combination.

Only percentage area of installation is being changed.

When we are taking 2% of total area of architecture building.

= 26173.30*2/100

= 523.46 sqft

No of 4KW capacity solar panel

= 523.46/301.389

= 2 no's

Solar system size

= 2*4

= 8 kW

Total cost of installation

= 2*568304

= Rs 1136608

Typical annual output

= 3400*2

= 6800 kWh

Typical monthly output

= 6800 /12

= 566.67 kWh

Annually Maintenance cost

= 1.2% *initial cost

= 1.2/100*1136608

= Rs. 13639

Typical profit over 20 year

= 548007.50*2

= Rs. 1096015

Typical profit over 1 year

= 1096015/20

= Rs. 54800

Payback period

= 1136608/54800

= 20 yrs.

In the same way we have done the calculations for (3%, 5%, 10%, 15%) terrace area of Architecture Building. And results are shown in the following tabular form.

Table 4D.3.4.5.3: Architecture Building

PERCENTAGE AREA (%)	AREA (Sq.ft)	NO OF 4kW CAPACITY PANEL	SOLAR SYSTEM SIZE (kW)	TOTAL COST OF INSTALLATION (Rs)	TYPICAL ANNUAL OUT PUT (kWh)	TYPICAL MONTHLY OUT PUT (kWh)	MAINTENANCE COST ANNUALLY (Rs)	TYPICAL PROFIT OVER 20 YEAR (Rs)	TYPICAL PROFIT OVER 1 YEAR (Rs)	PAYBACK PERIOD (years)
2	523.5	2	8	1136608	6800	566.67	13639	1096015	54800	20
3	785.2	3	12	1704912	10200	850	20458	1644023	82201	20
5	1309	4	16	2273216	13600	1133.33	27278	2192030	109601.5	20
10	2617	9	36	5114736	30600	2550	61376.83	4932067	246603	20
15	3926	13	52	7387952	44200	3683.33	88655	7124097	356204	20

[D] For Polytechnic Building

Total terrace area of polytechnic building: 23547.02 sqft.

We are taking 4KW capacity solar system combination.

Only percentage area of installation is being changed.

When we are taking 2% of total area of polytechnic building.

= 23547.02*2/100

= 470.94 sqft

No of 4KW capacity solar panel

= 470.94/301.389

= 2 no’s

Solar system size

= 2*4

= 8 kW

Total cost of installation

= 2*568304

= Rs. 1136608

Typical annual output

= 3400*2

= 6800 kWh

Typical monthly output

= 6800 /12

= 566.67 kWh

Annually Maintenance cost

= 1.2% *initial cost

= 1.2/100*1136608

= Rs. 13639

Typical profit over 20 year

= 548007.50*2

= Rs. 1096015

Typical profit over 1 year

= 1096015/20

= Rs. 54800.75

Payback period

= 1136608/54800.75

= 20 yrs.

In the same way we have done the calculations for (3%, 5%, 10%, 15%) terrace area of Polytechnic Building. And results are shown in the following tabular form.

Table 4D.3.4.5.4: POLYTECHNIC BUILDING

PERCENTAGE AREA (%)	AREA (Sqft)	NO OF 4kW CAPACITY PANEL	SOLAR SYSTEM SIZE (kW)	TOTAL COST OF INSTALLATION (Rs)	TYPICAL ANNUAL OUT PUT (kWh)	TYPICAL MONTHLY OUT PUT (kWh)	MAINTENANCE COST ANNUALLY (Rs)	TYPICAL PROFIT OVER 20 YEAR (Rs)	TYPICAL PROFIT OVER 1 YEAR (Rs)	PAYBACK PERIOD (years)
2	470.94	2	8	1136608	6800	566.67	13639	1096015	54800.75	20
3	706.41	3	12	1704912	10200	850	20458	1644022.5	82201	20
5	1177.35	4	16	2273216	13600	1133.33	27278	2192030	109601.5	20
10	2354.7	8	32	4546432	27200	2266.66	54557	4384060	219203	20
15	3532.05	12	48	6819648	40800	3400	81835	6576090	328804	20

4D.3.4.6 Validation of Data by Using a Technical Paper

The selection of the best solar panel for the photovoltaic system design by using AHP.

What is the difference between Solar STC and Solar PTC?

STC stands for Standard Test Conditions. These are measured under lab conditions of 1000W per sq. meter of “sunlight” with a standard spectrum etc. It is a nominal or name plate value. For instance, a Kyocera 180Watt panel is 180Watts (STC). An array made from 10 of these panels is considered 1,800Watts (STC). When talking about the array size, the STC number is always used. It is a handy way of comparing arrays to each other, etc.

PTC stands for PVUSA Test Condition. This is much closer to real world conditions. The PTC value is used by California to figure your rebate. A Kyocera 180W panel is 156W (PTC)

Some blogs and websites are defining PTC as “Performance Test Conditions” but this is simply wrong. I have also seen “Pacific Test Conditions” or some such thing. Don’t believe everything you read.

Oh by the way, PVUSA stands for Photovoltaics for Utility Systems Applications. To makes matters more complicated, it is originally called Photovoltaics for Utility Scale Applications.

Our friends at Go Solar California tell us:

PTC refers to PVUSA Test Conditions, which were developed to test and compare PV systems as part of the PVUSA (Photovoltaics for Utility Scale Applications) project. PTC are 1,000 Watts per square meter solar irradiance, 20 degrees C air temperature, and wind speed of 1 meter per second at 10 meters above ground level. PV manufacturers use Standard Test Conditions, or STC, to rate their PV products. STC are 1,000 Watts per square meter solar irradiance, 25 degrees C cell temperature, air mass equal to 1.5, and ASTM G173-03 standard spectrum. The PTC rating, which is lower than the STC rating, is generally recognized as a more realistic measure of PV output because the test conditions better reflect "real-world" solar and climatic conditions, compared to the STC rating. All ratings in the list are DC (direct current) watts.

4D.3.4.6.1 Calculation for Validation

1. PTC= (PV USA Test Condition)

I= 1000 W/m^2 AM =1.5G spectrum

Ambient temperature =20

Wind velocity =1m/sec

2. STC = (Standard Test Condition)

I =1000 w/m2   AM =1.5G Spectrum

Tcell =25c

(AM stand for air mass)

PTC power rating (W) =185.9 Watt

STC power rating per unit of area =172.3 $watt/m^2$

No. of cells =96

Panel prices =Rs 25728 (By using government support 36% of cost)

Area =$1.16m^2$ = 12.486 ft^2

Material = Monocrystalline

Now, for generation of 4 Kw

No of panels = 4000/185.9 = 22

Hence (no of panels = 22)

Area for 22 nos of panels =22 * 12.486

=274.692 ft^2

Cost for 22 nos of panels =22 * 25728

= Rs. 566016

Payback Period =566016/ (Capacity * avg. light an hrs.* Days * unit cost)

=566016/ (4 * 2.25 * 365 * 8.41)

=20.5 years

4D.3.4.7 Manufacture in Maharashtra & India

Table 4D.3.4.7.1: Solar panel manufacturers in Maharashtra

MANUFACTURER	ADDRESS	CONTACT NO
Green Eco Tech	NxtA Wing, 8th Floor, Regus, Reliable Tech Park Thane Belapur Road, Behind Reliable Plaza, Airoli, Navi Mumbai-400708, Maharashtra, India	**+91-08048622091**
Sunshine Energy (I) Pvt. Ltd	A/603, Avirahi Homes, 4 - IC Colony, Link Road, Borivali West Borivali West Mumbai - 400103 Maharashtra,India	+91-08071677284
City Solar Enterprises	No. 36, Shiv Shakti Vikas Mandal, Devipada Borivali East Mumbai - 400066 Maharashtra,India	+91-08048610713
Sparq TechnologiesOffice	Office No. 1,Above K. K. Textiles Shanta Jog Marg, Mumbai-400089, Maharashtra, India	**+91-08042538753**
GREEN SEAL	Unit 14, Building 1, Dias Industrial Estate, Sativali Naka, Vasai East Mumbai - 401208 Maharashtra,India	+91-08071650523
Happy Moments	Gala No. 3A, Ramnath Mishra Compound, Y.T. Road Dahisar East	+91-08046044120

	Mumbai - 400068 Maharashtra,India	
Abha Energy	9-D, Thacker Industrial Estate, N.M. Joshi Marg, Delisle Road Delisle Road Mumbai - 400011 Maharashtra,India	+91-08045317849
Powermax Energies Pvt Ltd	202, Matoshree, Mithagar Road, Mulund East Mulund East Mumbai - 421201 Maharashtra,India	+91-08079453662
Revoltcreations Solar Solutions Llp	D 2, 011, C Wing, Sector 1, Vashi Vashi Navi Mumbai 400703 Maharashtra, India	+91-8048583129
Trimurti Solar System & Electricals	No. 1, Shilpa CHS, Ground Floor, Opposite ICICI Bank, Ram Maruti Road Extension Shilpa Chs Thane - 400602 Maharashtra, India	+91-08071678020
Maharashtra Control Panels Pvt. Ltd.	Plot No. 12, Asangaon Industrial Complex, Mumbai-Nashik Road Shahapur Thane - 421301 Maharashtra,India	+91-08071810243
Mega Power System	Shop No. 6, B Wing, Ground Floor, Saidham Building Shastri Nagar Dombivli - 421202 Maharashtra, India	+91-08049471074

Techno Associates Vidyut Pvt. Ltd.	W-160, MIDC, Phase II, Dombivli East Dombivli East Thane - 421204 Maharashtra,India	+91-08048622800
Phoenix Solar Power Solutions LLP	Flat No. 8, Plot No. 76-77, Sector CDC, Mahalaxmi Heritage, PCMC Mahalaxmi Heritage Pune - 411009 Maharashtra,India	+91-08048604449
Alliigator Automations Private Limited	Moshi Gandharvnagari, Bldg No 10A, Flat No 23, Taluka Haveli, Pimpri, Chinchwad Taluka Pune - 412105 Maharashtra,India	+91-08048604345
Rohan Industries	Serial No. 58, Plot No. 93 & 94, Sai Industrial Estate, Behind MSWC, Bhosari Bhosari Pune - 412105 Maharashtra,India	+91-08045328482
Lahs Green India Private Limited	Near Raghunath Nagar, Om Anand Industrial Estate Unit No. 27, 1st Floor, MS Road, Thane-400604, Maharashtra, India	**+91-08071599711**
RK Energy Technologies	124, Guru Nanak Udyog Bhavan, Industrial Estate Bhandup West Mumbai - 400078 Maharashtra, India	+91-08048605851
Satec Envir Engineering (India) Private Limited	C-102, 1st Floor, Waterford Building, CD Barfiwala Road Andheri West Mumbai - 400058 Maharashtra,India	+91-08079465415

Table 4D.3.4.7.2: Monocrystalline Solar panel manufacturers from India

Company name	Region	No of staff	Power range(Wp)
Access Solar Limited	India	100	3-300
Ajit Solar	India	120	75-280
Akshaya Solar Power	India	75	3-300
Alpex Solar	India	250	5-300
Aroma Solar	India	45	5-270
Artheon batteries	India	250	2.5-230
Electromac	India	30	3-270
Emmvee Photovoltaic	India	650	250-320
Goldi Green	India	**350**	3-345

Hitech Solar	India	150	3-315
IB Solar	India	110	3-300
Jain Irrigatio Systems	India	5000	10-305
Junna Solar	India	100	5-300
Raajratna Ventures	India	400	2 -300

4D.4 Wind Energy

Since earliest times, man has harnessed the power of the wind, with the first mill recorded as long ago as the 6th century AD. The technology has diversified over the years to include pumping water, grinding grain, powering sawmills and most recently generating electricity, now the fastest growing energy sector worldwide.

wind energy is an indirect form of solar energy since wind is introduced chiefly by the uneven heating of the earth's crust by the sun. The conversion of this wind energy into electrical power can reduce the power deficit to a large extent .in contrast to direct solar radiations, the non-conventional form of wind energy can be available continuously in selected wind locations. However, the extent of power generation can vary due to variable wind velocities during the days, place to place and season to season.

Advantages of wind energy are that it is cheap, clean and non-polluting. Main disadvantages are that it is erratic, its availability at specific locations with high capital cost and causes sound pollution.

4D.4.1 Causes of Wind

Winds can be broadly classified as planetary and local wind.

1. Planetary winds are caused due to greater solar heating of earth's surface near the equator as compared to solar heating near the northern or southern poles.it causes the hot air to rise from equator to poles in easterly direction and cold air from poles flows back westerly to the equator near the earth's surface. The direction of motion of these winds with respect to earth is affected by the rotation of the earth. In actually, the phenomenon of wind direction and its magnitude is quite complex since it is affected by uneven layer of heating of air, frictional resistance, obstructions caused by mountains, buildings, trees etc.

2. Local winds are caused due to differential heating of land and water in coastal area. Due to solar radiations, the land mass surface becomes hotter than water.it causes the air above the land to heat up and become hotter than the air above water since it is not heated fast, because part of heat is absorbed by water and partly to evaporator water. Lighter hot air above the land rises up and cooler air of higher density above sea water moves towards the land to replace the hot air. It causes shore breezes. At night the direction of breeze is reserved since the land mass cools to sky more rapidly than the mass of sea water.

Another mechanism of local winds is caused by the hills and mountains sides. The air during the day at higher slopes above the land heat ups more rapidly compared to the lower land surfaces. It causes the cooled air from land to move up along the slopes causing wind. The process is reversed at night where the cool heavy air from slopes flows downwards.

For the selection of particular type of wind turbine which is suitable or feasible for our campus, we went through the classification of wind turbine and technical specification of different wind turbines to find out which wind turbine falls in our boundary. We set the instruction of criterion for selection process of wind turbine. These criterions are as follows:

1. Minimum wind velocity required to run the turbine
2. Area required for the installation
3. Power generated
4. Initial investment (cost)
5. Maintenance cost

4D.4.2 Types of Wind Turbine

There are two types of wind turbine as shown in below

1. Horizontal Axis Wind Turbine
2. Vertical Axis Wind Turbine

Classification of wind Turbine

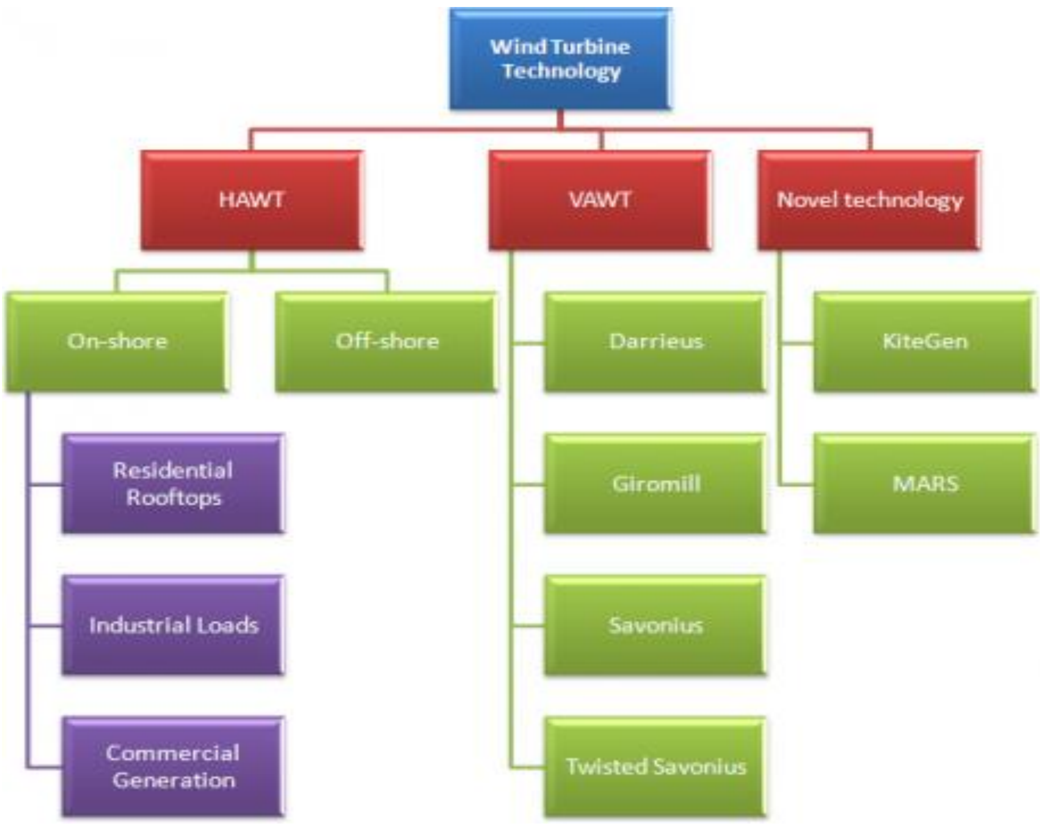


Fig.4D.4.2.1: Classification of Wind Turbine

1. Horizontal Axis Wind Turbine (HAWT)

Horizontal axis wind turbines have the main rotor shaft and electrical generator at the top of a tower, and they must be pointed into the wind. Small turbines are pointed by a simple wind vane placed square with the rotor (blades), while large turbines generally use a wind sensor coupled with a servo motor. Most large wind turbines have a gearbox, which turns the slow rotation of the rotor into a faster rotation that is more suitable to drive an electrical generator. Since a tower produces turbulence behind it, the turbine is usually pointed upwind of the tower. Wind turbine blades are made stiff to prevent the blades from being pushed into the tower by high winds. Additionally, the blades are placed a considerable distance in front of the tower and are sometimes tilted up a small amount. Downwind machines have been built, despite the problem of turbulence, because they don't need an additional mechanism for keeping them in line with the wind, and because in high winds, the blades can be allowed to bend which reduces their swept area and thus their wind resistance. Since turbulence leads to fatigue failures, and reliability is so important, most HAWTs are upwind machines.

HAWT Advantages

1. The tall tower base allows access to stronger wind in sites with wind shear. In some wind shear sites, every ten meters up the wind speed can increase by 20% and the power output by 34%.
2. High efficiency, since the blades always move perpendicularly to the wind, receiving power through the whole rotation. In contrast, all vertical axis wind turbines, and most proposed airborne wind turbine designs, involve various types of reciprocating actions, requiring airfoil surfaces to backtrack against the wind for part of the cycle. Backtracking against the wind leads to inherently lower efficiency.

HAWT Disadvantages

1. Massive tower construction is required to support the heavy blades, gearbox, generator and an additional yaw control mechanism to turn the blades toward the wind.
2. Downwind variants suffer from fatigue and structural failure caused by turbulence when a blade passes through the tower's wind shadow (for this reason, the majority of HAWTs use an upwind design, with the rotor facing the wind in front of the tower).
3. HAWTs generally require a braking or yawing device in high winds to stop the turbine from spinning and destroying or damaging itself.

2. **Vertical Axis Wind Turbine**

VAWTs, have the main rotor shaft arranged vertically. The main advantage of this arrangement is that the wind turbine does not need to be pointed into the wind. This is an advantage on sites where the wind direction is highly variable or has turbulent winds. With a vertical axis, the generator and other primary components can be placed near the ground, so the tower does not need to support it, also makes maintenance easier. The main drawback of a VAWT is that it generally creates drag when rotating into the wind. It is difficult to mount vertical-axis turbines on towers, meaning they are often installed nearer to the base on which they rest, such as the ground or a building rooftop. Hence these models are not frequently used for off-shore installations which if used might require water proof casings that adds to extra costs. Also, offshore installations require very high height towers. The wind speed is slower at a lower altitude, so less wind energy is available for a given size turbine. Air flow near the ground and other objects can create turbulent flow, which can introduce issues of vibration, including noise and bearing wear which may increase the maintenance or shorten its service life. However, when a turbine is mounted on a rooftop, the building generally redirects wind over the roof and these can double the wind speed at the turbine. If the height of the rooftop mounted turbine tower is approximately 50% of the building height, this is near the optimum for maximum wind energy and minimum wind turbulence. Various types of VAWT are:

1. **Darrieus wind turbine:** "Eggbeater" turbines, or Darrieus turbines, were named after the French inventor, Georges Darrieus. They have good efficiency, but produce large torque ripple and cyclical stress on the tower, which contributes to poor reliability. They also generally require some external power source, or an additional Savonius rotor to start turning, because the starting torque is very low. The torque ripple is reduced by using three or more blades which results in greater solidity of the rotor. Solidity is measured by blade area divided by the rotor area. Newer Darrieus type turbines are not held up by guy-wires but have an external superstructure connected to the top bearing.

2. **Giromill:** It is a subtype of Darrieus turbine with straight, as opposed to curved, blades. The cycloturbine variety has variable pitch to reduce the torque pulsation and is self-starting. The advantages of variable pitch are: high starting torque; a wide, relatively flat torque curve; a lower blade speed ratio; a higher coefficient of performance; more efficient operation in turbulent winds; and a lower blade speed ratio which lowers blade bending stresses. Straight, V, or curved blades may be used.

3. **Savonius wind turbine:** These are drag-type devices with two (or more) scoops that are used in anemometers, Flettner vents (commonly seen on bus and van roofs), and in some high-reliability low-efficiency power turbines. They are always self-starting if there are at least three scoops.

4. **Twisted Savonius:** Twisted Savonius is a modified savonius, with long helical scoops to give a smooth torque, this is mostly used as roof wind turbine or on some boats (like the Hornblower Hybrid).

VAWT Advantages

1. No yaw mechanism is needed because they have lower wind startup speeds than the typical the HAWTs.
2. A VAWT can be located nearer the ground, making it easier to maintain the moving parts.
3. VAWTs situated close to the ground can take advantage of locations where rooftops, mesas, hilltops, ridgelines, and passes funnel the wind and increase wind velocity.

VAWT Disadvantages

1. Most VAWTs have an average decreased efficiency from a common HAWT, mainly because of the additional drag that they have as their blades rotate into the wind.
2. Having rotors located close to the ground where wind speeds are lower due and do not take advantage of higher wind speeds above.

This is shows the different component in wind turbines.

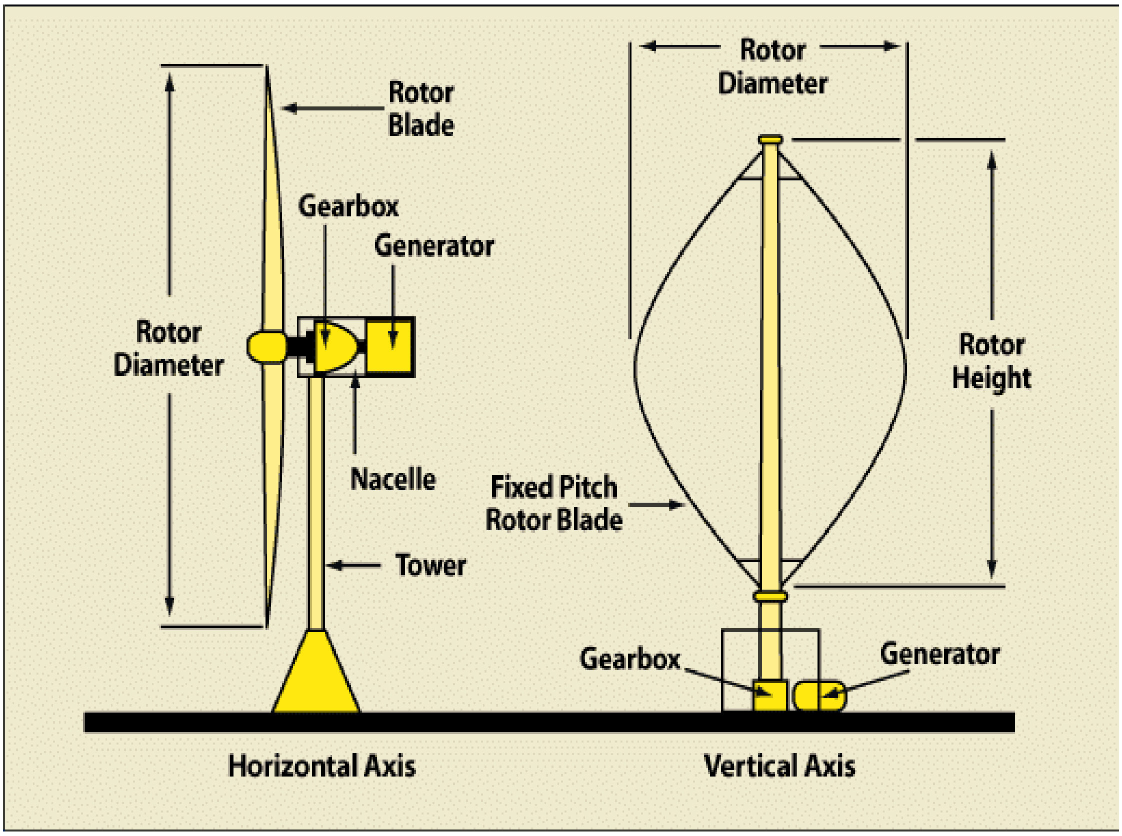


Fig. 4D.4.2.2: Horizontal and Vertical Wind Turbine

Table 4D.4.2.1: Distinguish Between HAWT & VAWT

Sr. No.	Performance	Horizontal Wind Turbine	Vertical Wind Turbine
1	Power Generation Efficiency	50% - 60%	Above 70%
2	Electromagnetic Interference	Yes	No
3	Steering Mechanism of The Wind	Yes	No
4	Blade Rotation Space	Quite Large	Quite Small
5	Gear Box	Above 10KW,Yes	No
6	Wind-Resistance Capability	Weak	Strong (It Can Resist The typhoon Up To 12-14 Class)
7	Noise	5-60db	0-10dB
8	Starting Wind Speed	High (2.5-5m/s)	Low (1.5-3m/s)
9	Ground Projection Effects on Human Beings	Dizziness	No Effect
10	Failure Rate	High	Low
11	Maintenance	Complicated	Convenient
12	Rotating Speed	High	Low
13	Effects on Birds	Great	Small
14	Cable Stranding Problem	Yes	No
15	Power Curve	Depressed	Full
16	Installation Height	High (Need To Avoid The Terrain turbulence)	Low (Not Afraid Turbulence)
17	Installation	Just in Open Area Like	Any Location

4D.4.3 How a Wind Turbine Work?

The core component of a wind turbine is the generator which converts mechanical energy into electricity. We've known since the early 19th century that if you turn a conductor in a magnetic field then it creates electricity, according to Faraday's Law. So the wind provides the movement and torque and the generator does the rest.

For an industrial scale turbine, like the ones you see on wind farms, there will normally be an anemometer that is attached to a control panel. The turbine is activated at wind speeds of over 8 miles per hour but the machine is shut off with speeds in excess of 55 mph to prevent damage.

The gear box is used to change the slow motion we see from the blades turning to the faster motion of the axis which actually drives the generator. This is one of the costliest parts of the wind turbine, changing speeds of 30 to 60 revolutions per minute into a thousand rpm. It's one of the areas that researchers and developers are looking to make more efficient so that a greater current of electricity can be produced at slower speeds.

To cope with varying wind directions, a yaw drive is often used to move the blade array into the oncoming wind. The generator produces an AC current that is fed into the grid and used to power the surrounding homes.

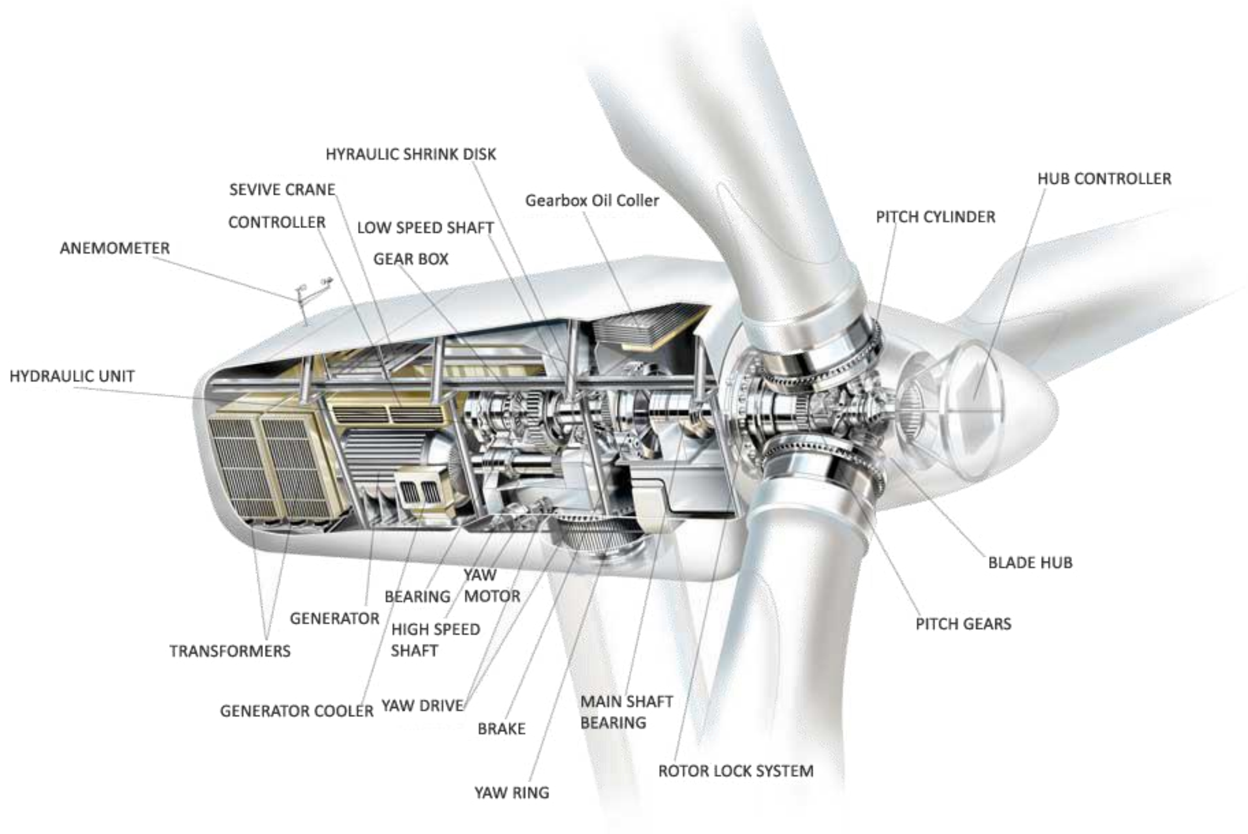


Fig.4D.4.3.1: Industrial Wind turbine components diagram

4D.4.4 Domestic Wind Turbines

As with solar panels, domestic wind turbines need the right components to supply your house with electricity. The generator will produce a DC current that has to be converted into AC by an inverter and there are batteries that can be used to store energy for later use.

if you want a wind turbine installed for domestic use then you really need to have a remote location where other buildings and infrastructure won't get in the way. There are two different types of domestic wind turbine (LINK): Roof mounted and free-standing. The idea of putting a wind turbine on your roof seems like a good idea but the problem is that these don’t produce enough power to make you truly independent of the grid and produce all your own power.

You get more output from a free-standing wind turbine that operates similarly to the ones you see in wind farms. The cost of downside of free-standing turbines is more as compare to a building mounted turbine. It is approximately 8 to 10 times of building mounted turbine.

The truth is that wind power is currently more viable for those in a remote location (that is outside of urban and suburban areas) that has a good, strong and steady wind source. The size of the array needed to produce enough electricity for domestic use is often too prohibitive for anyone else. However, much research and development is being undertaken to make wind power more effective and there may be turbines in the future that can be used in our cities and towns in much the same way as solar power is today.

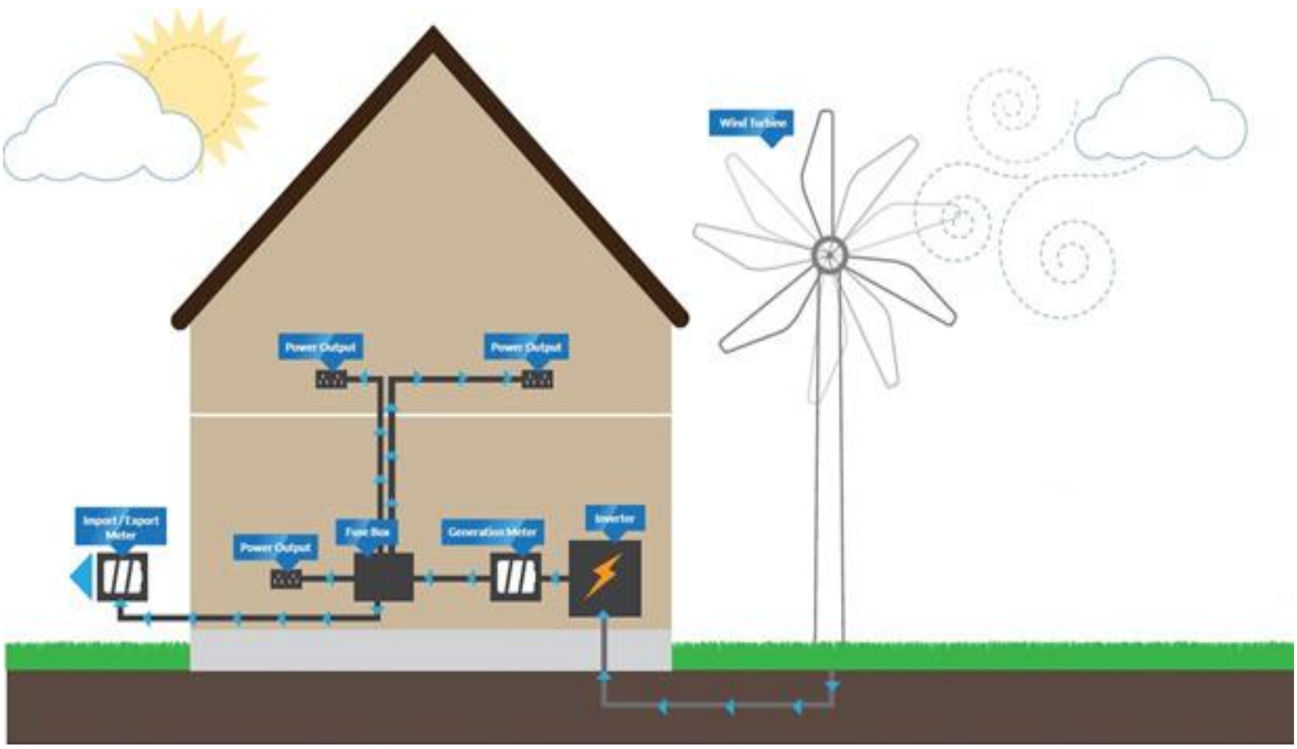


Fig. 4D.4.4.1: Installation of turbine for Domestic Purposes

1. **Roof Mounted Wind Turbines:**

if you have a high roof that gets enough wind speed on a regular basis then you may well consider installing a roof mounted wind turbine. They vary in power from about 0.5 kW to 2.5 kW and can be used to supplement your electricity supply. Before you take the option of getting a roof mounted turbine you need to understand that it will probably not provide all the electricity you need (though it may well take the edge of increasing fuel bills over the next 20 years). It almost certainly will not provide you with enough energy to profit from the Feed in Tariff.

The average cost of a roof mounted wind turbine is around INR165415 which will also need to be maintained (The Energy Savings Trust estimate that this could cost INR 8270 to INR16541 per year)

2. **Free Standing Wind Turbine:**

For those that are serious about using wind as a means of providing renewable energy for a local source and perhaps benefitting from the Feed in Tariff, free-standing wind turbines offer a much more effective option. They are also more expensive to install.

Cost depends on the size and the output that is desired. A 1.5 kW turbine would cost approximately INR578953 and deliver around 2,600 kW over a year depending on your location and wind speeds. A larger array that has a 15 kW capability would cost in the region of INR5789531and return approximately 36,000 kW of energy over a year.

For all wind turbine systems, you also need to take into account the maintenance costs and the price that needs to paid if you have to apply for planning permission. A wind turbine is built to last over 20-25 years but a number of important parts may need replacing before that date such as batteries or the inverter that converts your DC current to AC.

3. Impact on Property Price

One other thing that you will need to take into account before installing a wind turbine on your premises is the effect that it may have on the property price. There is not much evidence currently available that having one installed with have a large adverse effect but a lot may depend on how efficient your system is. Of course, it will also depend on your location. If your wind turbine is on farmland and producing a good return on the Feed in Tariff it is more likely to add value to any sale. If you have a roof mounted system that simply takes the edge off your energy bills, you might find that aesthetic principles come into play.

The table below gives you a rough idea of the initial costs of domestic wind turbine systems:

Table 4D.4.4.1: Initial costs of domestic wind turbine

System size	Indicative system cost (incl. VAT @5%)	Approx. yearly system output*
1kW (roof-mounted)	Rs. 124061	1,750kWh
1.5kW (pole-mounted)	Rs. 578953.	2,600kWh
2.5kW (pole-mounted)	Rs. 1033844	4,400kWh
5kW (pole-mounted)	Rs. 1943628	8,900kWh
10kW (pole-mounted)	Rs. 3721841	21,500kWh
15kW (pole-mounted)	Rs. 5789531	36,000kWh

Depending on the type and size of the turbine, there are also annual system maintenance costs which one must bear in mind, though these tend to be relatively small. Since they rely on relatively simple mechanical processes, the turbines themselves tend to have a long life, and typically come with a service warranty period of 10-20 years. If the **wind turbine** system contains batteries for the storage of the electricity generated, these will probably need to be replaced around every 5 to 10 years.

4D.4.5 Size of Wind Turbine

Wind turbine technology has developed rapidly in recent years and Europe is at the hub of this high-tech industry. Wind turbines are becoming more powerful, with the latest turbine models having larger blade lengths which can utilize more wind and therefore produce more electricity, bringing down the cost of renewable energy generation.

As we are known that diameter of blade is directly proportional to power generation from wind turbine. so, if we are increase diameter of wind 2 times then power produces by 2 times.

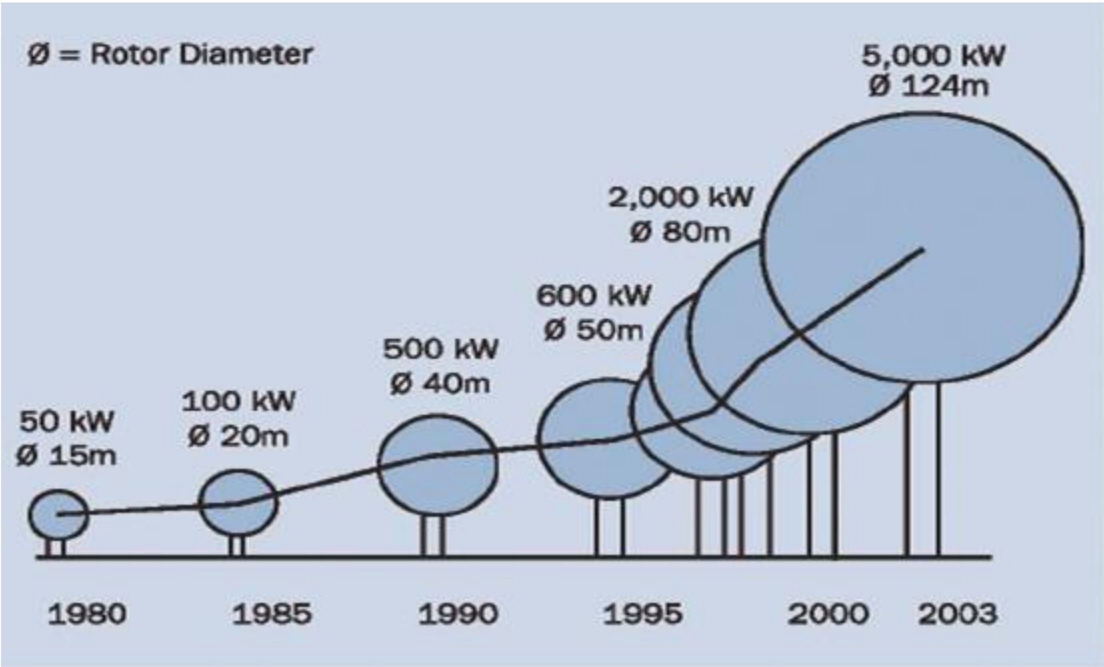


Fig. 4D.4.5.1.1: Growth in size of commercial wind turbine design

4D.4.6 Total Power & Maximum Power Available at Wind Turbine

1. **Total Power Available at Wind Turbine**: The flow of wind due to its density difference approach frontal area of wind turbine which has particular kinetic energy which can be transmitted to wind turbine in order to get total power which is given by,

$$P_t = 0.5 \text{ x } m \text{ x } u_1^2$$

Where, m = Mass Flow Rate which is given by: - $m = \rho \text{ x } A \text{ x } u_1$ (kg/s)

A = Area of Rotor or Swept Area = $\frac{\pi}{4} \text{ x } D^2$ (meter^2)

D = Diameter of Rotor (meter)

$$P_{K.E.} = 0.5 \text{ x } \rho \text{ x } A \text{ x } u_1^3$$

From equation (2), we will observe that the total power available at wind turbine is directly proportional to cube of incoming wind velocity (u_1). therefore, slight change in wind velocity which is used to power generation.

2. **Maximum Power**: when the wind flows over the wind turbine the velocity of wind decreases due to this decrease in velocity. There is kinetic energy difference. i.e.

$$P_{max} = \frac{1}{4} \text{ x } \rho \text{ x } A \text{ x } (u_1^3 - u_1 \text{ x } u_2^2 + u_2 \text{ x } u_1^2 - u_2^3)$$

So, Maximum condition is given by

Hence, $u_2 = \frac{1}{3} \text{ x } u_1$

Now, Maximum Power $= P_{max} = \frac{8}{27} \text{ x } \rho \text{ x } A \text{ x } u_1^3$

Where, u_1 = Inlet Wind Velocity at Blade of turbine,

u_2 = Exist Wind Velocity at Blade of turbine

3. **Betz's Law** : Betz's law stated that no wind turbine can be more efficient than $\frac{16}{27}$ i.e. 59.26%. It is given by a German physicist Albert Betz.

The efficiency of wind turbine is given by

$$\eta_{max} = \frac{\text{Maximum Power (Pmax)}}{\text{Total Power (Pt)}}$$

$$\eta_{max} = \frac{\frac{8}{27} \text{ x } \rho \text{ x } A \text{ x } u13}{0.5 \text{ x } \rho \text{ x } A \text{ x } u13}$$

$$\eta_{max} = \mathbf{0.5926 \text{ x} 100\%}$$

$$\eta_{max} = \mathbf{59.26\%}$$

4. **Torque & Axial Thrust on Blades**:

Forces acting on blades of a propeller type wind turbine are of two types:

1. Circumferential force acting on the blades in the direction of wheel rotation. It provides the torque, T on wind Turbine shaft.

   Torque, $T = \frac{P}{W} = \frac{P}{\pi DN/60} = \frac{60P}{\pi DN}$ (N.m)

   Where, N = Speed of rotor in r.p.m.

   P = Power in Watts or Nm/s

   D = Diameter of rotor blades in m.

   $T_{max} = 60 \text{ x } \frac{2}{27} \text{ x } \frac{\rho D u13}{N}$

2. **Axial Thrust or Axial Force**, F_x is the force acting on turbine rotor in axial direction. It can be expressed as:

   $F_x = 0.5 \text{ x } \rho \text{ x } A \text{ x } (u_1^2 - u_2^2)$

   For maximum axial force: $u_2 = \frac{1}{3} \text{ x } u_1$

Therefore , $F_x = \frac{\pi}{9} \text{ x } \rho \text{ x } D^2 \text{ x } u_1^2$

From above equation, it is clear that the maximum axial thrust is very large and it increases with the square of rotor diameter and the wind velocities. The designer of the wind turbines is required to tackle such large axial thrust. For practical reasons, the diameter of the wind turbine rotors has to optimized from technical and economical considerations.

3. **The tip speed ratio**, λ is defined as the ratio of the blade tip speed to the free stream wind speed, u_1.

   Lambda, $\lambda = \frac{Blade\ Tip\ Speed\ ,ub}{Free\ Stream\ Wind\ Speed,\ u1}$

   If ω is the angular speed of rotor in radian/s and R is the radius of tip of the rotor blade, then $u_b = \omega \text{ x } R$.

   Note that $u_b = \omega \text{ x } R$ is applicable to horizontal axis wind turbines. However, in case of vertical axis wind turbines u_b represents the peripheral speed at the middle of the blade length.

4. **Solidity**, γ is defined as the Ratio of the blade area to the swept frontal area of the wind turbine.

   In case of horizontal machines if n is no of blades, u is mean chord length and R is radius of rotor blades then,

   $$\text{Solidity, } \gamma = \frac{Blade\ Area}{Swept\ Area} = \frac{n\ x\ u}{R}$$

   For vertical axis turbines, γ is taken as $\frac{n\ x\ u}{2R}$.

   Rotor having high solidity use drag force and turn slower while the rotor having low solidity use lift force and turn at higher speeds like propeller type wind turbine which use aerofoil blades.

   The solidity and tip speed ratio for important type of wind turbines is given in table below:

Table 4D.4.6: Solidity and Tip Speed Ratio

Sr. No.	Type of Rotor	Solidity, γ	Tip Speed Ratio, λ	Torque, T
1	Propeller (1 to 3 blades)	0.01 – 0.1	4 – 16	Low
2	Multibladed	0.7	1	High
3	Savonius	1	1	High
4	Darrieus	0.1 – 0.2	5 - 6	Low

4D.4.7 List of Different types of Wind Turbine

1. Whisper H40
2. Whisper H80
3. Whisper 175
4. Whisper 500
5. BWC XL1
6. Southwest Wind Power Sky-Stream 3.7 (VAWT)
7. Bergey Excel
8. Proven WT 15000 @ Hub Height 30m
9. WT6500 Class 4 Wind (5.5 – 6 m/s)

4D.4.7.1 Figure of Different Wind Turbine

Fig. 4D.4.7.1.1: Whisper H40 Fig. 4D.4.7.1.2: Whisper H80 Fig. 4D.4.7.1.3: Whisper 175

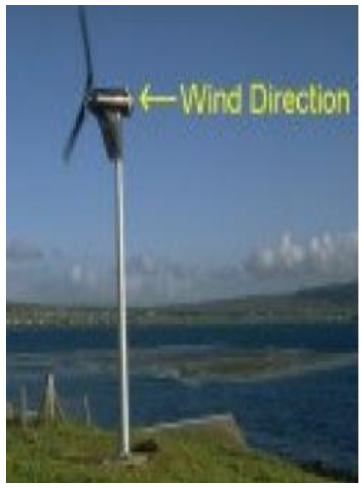


Fig. 4D.4.7.1.4: BWC XL1 Fig. 4D.4.7.1.5: BWC XL1 Fig. 4D.4.7.1.6: Proven WT6500

Fig. 4D.4.7.1.7: Bergey Excel

Fig. 4D.4.7.1.8: Honeywell WT6500

4D.4.7.2 Power Curve of WT6500

The below diagram shows the power curve of WT6500 Wind Turbine.

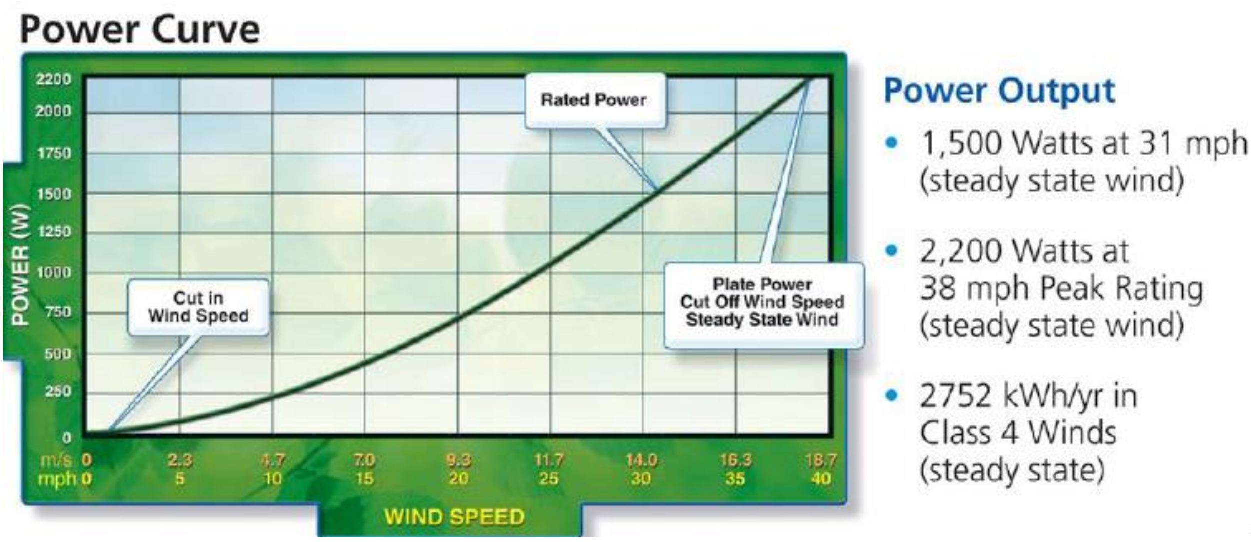


Fig. 4D.4.7.2.1: Power curve of Honeywell WT6500 wind turbine

Above power curve is give relation between power against Wind velocity. As we can see according to power curve WT6500 wind turbine produce electricity at 2mph wind Velocity.

➢ **Cut in Wind Speed**:

The minimum wind velocity is required to run the wind turbine is known as Cut in Wind Speed.

➢ **Rated Power**:

The maximum wind velocity is required to give maximum output by wind turbine is known as Rated Power.

➢ **Cut Out Speed**:

Braking or Damaging the system of wind turbine for given wind speed.it is known as cut out speed.

Honeywell Wind Turbine: Model WT6500

Wind Speed (m/s)	Wind Speed (MPH)	% At Wind Speed Class 4 Site	Annual Hours (h/yr)	Hours At Wind Speed (h/yr)	WT6500 Power Curve Data in Class 4 Wind (W)	WT6500 Annual Energy Generation in Class 4 Wind (Total = 2752 kWh/yr) (kWh/yr)
0	0	0.00	8,760	0	0	0
0.5	1.11	0.00	8,760	0	5	0
1.5	3.33	6.61	8,760	579	14	8
2.5	5.55	10.04	8,760	880	40	35
3.5	7.77	12.22	8,760	1,070	82	87
4.5	9.99	13.04	8,760	1,142	140	160
5.5	12.21	12.63	8,760	1,106	214	237
6.5	14.43	11.30	8,760	990	305	302
7.5	16.65	9.41	8,760	824	411	339
8.5	18.87	7.35	8,760	644	535	344
9.5	21.09	5.41	8,760	474	674	319
10.5	23.31	3.75	8,760	329	829	272
11.5	25.53	2.46	8,760	215	1,001	216
12.5	27.75	1.53	8,760	134	1,189	159
13.5	29.97	0.90	8,760	79	1,394	110
14.5	32.19	0.51	8,760	45	1,614	72
15.5	34.41	0.27	8,760	24	1,851	44
16.5	36.63	0.14	8,760	12	2,105	26
17.5	38.85	0.07	8,760	6	2,374	15
18.5	41.07	0.03	8,760	3	2,660	7
19.5	43.29	0.00	8,760	0	2,962	0
20.5	45.51	0.00	8,760	0	3,280	0
21.5	47.73	0.00	8,760	0	3,614	0
22.5	49.95	0.00	8,760	0	3,965	0
23.5	52.17	0.00	8,760	0	4,332	0
24.5	54.39	0.00	8,760	0	4,715	0
						2,752

Fig. 4D.4.7.2.2: Testing Values of Honeywell Wind Turbine (WT6500)

NOTE: THE HONEYWELL WIND TURBINE DATA FOR ENERGY GENERATION IS MEASURED AGAINST WIND SPEEDS AT STEADY STATE.

The above table is shows the testing result of model WT6500 wind turbine. It is given by windtronics. Diameter of WT6500 is 6 feet.

So, according to above data of Honeywell wind turbine model WT6500 we understand that it is suitable to our campus as per requirement like minimum height due to airport site near to AIKTC.

4D.4.8 Manufacture

Table 4D.4.8.1: Wind manufacture near Mumbai

Name	Address	State
Elecon Engineering India Ltd.	P.B. No.6 Anand Sojitra Road, Vallah Vidyanagar Gujarat - 388120	Gujrat
Kenersys India Pvt Ltd	Industry House, Survey No.49, Mudhwa, Pune - 411036	Pune (city)
Suzlon Energy Ltd	Godrej Millennium,5th Floor 9, Koregaon Park Road, Pune - 411011	Pune (city)
Nu power Technologies Private Limited	7th Floor, Tower – 1, Equinox Business Park, Off Bandra Kurla Road, L.B.S. Road, Kurla (W),Mumbai - 400070	

Table 4D.4.8.2: Wind manufacture in India

Name	Address	State
Acciona Windpower India Private Limited	C1-001, Towerc, Ground Floor, The Millenia, No. 1&2 , Murphy Road,Ulsoor,Bangalore,Karnatka-560008	Karnatka
Garuda Vaayu Shakthi Limited	5D, PM Tower, No.37, Greams Road, Thousand Lights, Chennai-600006	Chennai
Inox Wind Limited	Inox Towers, Plot No.17,Sector – 16-A,Noida,Uttar Pradesh – 201301	Uttar Pradesh
Global Wind Power Limited	No.15, Soundara Pandiyan Street, Ashok Nagar, Chennai - 600083	Chennai

4D.4.9 Wind Energy Cost Analysis

In general, generation technologies, the cost of electricity is primarily affected by three main components:

1. Capital and Investment cost,

2. Operation and Maintenance (O&M) cost,

3. Fuel cost.

However, studies of the cost of wind energy and other renewable energy sources could become flawed because of a lack of understanding of both the technology and the economics involved. Misleading comparisons of costs of different energy technologies are common. It is misleading to think that the amount of funds needed to pay for the purchase a wind turbine is a cost or expenditure. Even the realized profit cannot be considered as a cost.

Specifically, the cost of electricity in wind power generation includes the following components:

1. Economic depreciation of the capital equipment,

2. Interest paid on the borrowed capital,

3. The operation and maintenance costs,

4. Taxes paid to local and federal authorities,

5. Government incentives and tax credits,

6. Royalties paid to land owners,

7. Payment for electricity used on a standby mode,

8. Energy storage components, if used,

9. The cost of wind as fuel is zero.

But we are only considering initial investment or initial cost and maintenance & operational cost only.

1. DISCOUNT RATE

The discount rate (i) is chosen depending on the cost and the source of the available capital, considering a balance between equity and debt financing and an estimate of the financial risks entailed in the project.

It is advisable to consider the effect of inflation, and consequently using the real interest rate instead.

2. NET PRESENT VALUE

The net present value of a project is the value of all payments, discounted back to the beginning of the investment.

For its estimation, the real rate of interest “r” defined as the sum of the discount rate i and the inflation rate s:

Real rate of interest = Discount rate + Inflation Rate

$r = i + s$

is used to evaluate future income and expenditures.

If the net present value is positive, the project has a real rate of return which is larger than the real rate of interest “r”. If the net present value is negative, the project has a lower rate of return.

The net present value is computed by taking the first yearly payment and dividing it by (1+r). The next payment is then divided by (1+r)2, the third payment by (1+r)3, and the n-th payment by $(1+r)^n$. Those terms are added together to the initial investment to estimate the net present value.

$$\textit{Net present value} = \frac{P1}{(1+r)^\wedge 1} + \frac{P2}{(1+r)^\wedge 2} + \ldots\ldots + \frac{Pn}{(1+r)^\wedge n}$$

3. **REAL RATE OF RETURN**

The real rate of return is the real rate of interest “r” which makes the net present value of a project exactly zero. The real rate of return is a measure of the real interest rate earned on a given investment.

The computation of the real rate of return requires an iterative procedure to find the roots of the expression for the present value. One approach is to make a guess that is substituted into the equation. If the guess is too high, the net present value is negative. If the guess is too low, it becomes positive. The Newton-Raphson iteration method can make the iterative approach converge rapidly.

4. ELECTRICITY COST PER UNIT ENERGY

The electricity cost per kW.hr is calculated by first estimating the sum of the total investment and the discounted value of operation and maintenance costs in all years. The result is discounted for all future electricity production: each year's electricity production is divided into $(1+r)^n$, where n is the project lifetime. The income from electricity sales is subtracted from all non-zero amounts of payments at each year of the project period.

5. DEPRECIATION COST

Depreciation is a term used in accounting, economics and finance to spread the cost of an asset over the span of several years. In simple terms, it can be said that depreciation is the reduction in the value of an asset or good due to usage, passage of time, wear and tear, technological outdating or obsolescence, depletion, inadequacy, rot, rust, decay or other such factors.

We cannot calculate the economic depreciation of an investment unless we know the income from the investment. Depreciation is defined as the decline in the capital value of the investment using the internal rate of return as the discounting factor. If the income from the investment is not known, the rate of return is not determined, thus one cannot calculate economic depreciation.

The tax depreciation or accounting depreciation is sometimes confused with

economic depreciation. However, tax or accounting depreciation is a set of mechanical rules which must not be used when the true cost of energy per kW.hr is sought.

6. STRAIGHT LINE DEPRECIATION

Straight line depreciation is the simplest and most often used method in which we can estimate the real value of the asset at the end of the period during which it will be used to generate revenues, or its economic life. It will expense a portion of the original cost in equal increments over the period. The real value is an estimate of the value of the asset or good at the time it will be sold or disposed of. It may be zero or even negative. Accordingly:

$$\text{Annual depreciation expense} = \frac{Original\ Cost - Real\ Value}{Life\ Span} \quad \text{(rupees/year)}$$

Annual depreciation expense = 2.5% of total turbine cost in rupees (rupees/year)

= 2.5% x 16,08,000

= 4020 rupees/year

A linear depreciation of 2.5 percent per year over a 20 years' lifetime of INR16,08,000 turbines is shown in fig.

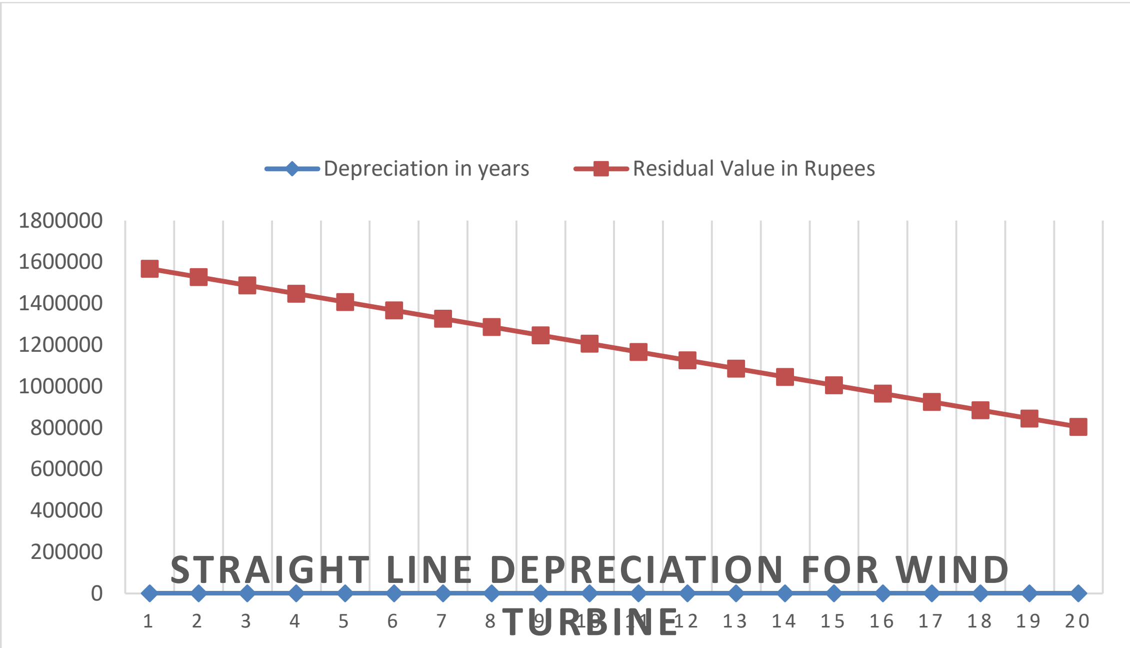


Fig. 4D.4.9.1: Straight line depreciation at 2.5 percent per year over a 20 years' period for a wind turbine

Table 4D.4.9.1: Linear depreciation schedule over a 20 years' useful lifetime

Linear depreciation	**Percent of total cost per year**	**Rs./year**	**Residual Value (Rs.)**
1	2.5	40200	1567800
2	2.5	40200	1527600
3	2.5	40200	1487400
4	2.5	40200	1447200
5	2.5	40200	1407000
6	2.5	40200	1366800
7	2.5	40200	1326600
8	2.5	40200	1286400

9	2.5	40200	1246200
10	2.5	40200	1206000
11	2.5	40200	1165800
12	2.5	40200	1125600
13	2.5	40200	1085400
14	2.5	40200	1045200
15	2.5	40200	1005000
16	2.5	40200	964800
17	2.5	40200	924600
18	2.5	40200	884400
19	2.5	40200	844200
20	2.5	40200	804000

7. PRICE AND COST CONCEPTS

The words: "cost" and "price" are sometimes mistakenly used as synonyms. The price of a product is determined by supply and demand for the product. Some people assume that the price of a product is somehow a result of adding a normal or reasonable profit to a cost, which is not necessarily the case; unless it is applied to a government controlled monopoly.

Thus in general:

Price = Cost + Profit + Taxes + Installation + Fuel

+ Operation and maintenance - Government incentives and tax credits +f(scarcity)

8. WIND TURBINES PRICES

Wind turbine prices may vary due to transportation costs, different tower heights, different rotor diameters, different generators sizes and the grid connection costs.

To determine the prices of wind turbines, it is erroneous to divide the turnover in rupees by the volume or sales or MW to obtain the price of a turbine in Rs. / MW:

$$\text{Price} \neq \frac{Turn\ Over}{Volume} \qquad \text{(Rs./ MW)}$$

It must be realized that some of the manufacturers' deliveries are complete turnkey projects including planning, turbine nacelles, rotor blades, towers, foundations, transformers, switchgear and other installation costs including road building and power lines. The manufacturer sales figures also include service and sales of spare parts.

The manufacturers' sales include licensing income, but the corresponding rated power in MWs are not registered in the company accounts. Sales may vary significantly between markets for high wind turbines and low wind turbines. The prices of different types of turbines are quite different. The patterns of sales, types of turbines, and types of contracts vary significantly from year to year and depend on the different locations and markets.

The safest approach is to obtain the prices from the price lists and to consider the price in units of Rs. /m^2 of rotor swept area.

9. PRODUCTIVITY AND COSTS

A unique aspect of wind energy production is that its productivity and costs depend on the price of electricity, and not vice versa as in other energy systems.

Cost = f (price of electricity)

Price of electricity ≠ Cost

The annual production per m2 of rotor swept area in a location. This has no relationship to the different wind resources. It is instead related to the different prices for electricity at the different locations.

10. INSTALLATION COSTS

Another unique feature of wind energy is that a high cost of generating electricity is not necessarily a result of high installation cost. One incurs a high installation cost whenever a good wind resource is available and hence cheap generating costs are available in a remote area.

High installation costs can be afforded, typically when a good wind resource exists since the power produced by a wind turbine is proportional to the cube of the wind speed. The installation costs include the costs for extension of the electrical grid and the grid reinforcement. The costs of electrical cabling can be significant, affecting whether a wind farm is located next to an existing medium voltage power line or far from a power line.

Average installation costs cannot be used, since the electricity price per kw.hr delivered to the grid depends upon the distance to the grid. Installation costs may road construction and grid connection amounting to about 30 percent of the turbine cost.

11. **Maintenance and operational Cost:**

The operation and maintenance cost can be estimated as either a fixed amount per year or a percentage of the cost of the turbine. This could also include a service contract with the wind turbine manufacturer.

We are considering maintenance and operational cost 1.5% of turbine price in rupees per year as per **Economics of Wind Energy by M. Ragheb.**

It is given by

Operations and maintenance = 1.5% of turbine price in rupees per year --- (Ref.

Operations and maintenance = 1.5% x 16,08,000

Operations and maintenance = 24120 rupees per year

4D.4.10 Selection of Wind Turbine for AIKTC

The below table shows different types of wind turbine with initial cost, power generation, number of wind required, wind diameter & payback period.

Table 4D.4.10.1: Different type of wind turbine model

Model	Kwh per Month	No. of Wind Turbine	Total Kwh per Month	Cost per Wind Turbine in RS.	Total cost In RS.	Payback Period in years	Rotor Diameter in Feet	Kwh per Year
WhisperH40	30	20	600	100165	2003300	33	7	7200
WhisperH80	60	20	1200	133665	2673300	21	10	14400
Whisper175	170	10	1700	365485	3654850	20.5	15	20400
Whisper500	500@5.5m/s	2	1000	475365	950730	10	15	12000
BWC XL1	55	20	1100	113565	2271300	20	8.2	13200
Southwest Wind Power Skystream3.7 (VAWT)	400@5.5m/s	5	2000	361733	1808665	9	12	24000
Bergey Excel	1500@5.5m/s	2	3000	1467300	2934600	10	22	36000
Proven WT15000 @ Hub Height 30m	5626.2@10.5m/s	1	5626.2	3762376	3762376	7	29.5	67514.4
WT6500 Class 4 Wind (5.5-6m/s)	2500 kwh/year	4	10000 kwh/year	402000	1608000	19.1	6	10000

We have gone through different models of Wind Turbine and Technical Specification and we select the WT6500 Class 4 Wind (1-6m/s).

4D.4.10.1 Selection of Area for Installation of Wind Turbine

- Selection of wind turbine is WT6500 (class 4 wind)
- Power produce by WT6500 is 2500kWh per turbine per year
- No of turbine = 4
- Cost per wind turbine = Rs. 4,02,000
- Total cost of 4 turbines = 4 x 4,02,000 = Rs. 16,08,000
- Cost of one unit is 8.41 rupees according to Electricity Bill of AIKTC

Area Required by WT6500 Wind Turbine

Diameter is given Windtronics.

Diameter of WT6500 Wind Turbine = 6 feet.

Area of WT6500 Wind Turbine $= \frac{\pi}{4} \times D^2$ (ft^2)

Area of WT6500 Wind Turbine $= \frac{\pi}{4} \times 6^2$

Area of WT6500 Wind Turbine = 28.274 ft^2

Payback Period

Payback Period $= \frac{\text{TOTAL INSTALLATIONS COST IN RUPEES}}{\text{COST OF UNIT IN RUPEES x TOTAL POWER PRODUCE PER YEAR}}$ **(in years)**

Total installations cost in rupees = no. of wind turbine x cost per wind turbine

= 4 x 4,02,000

= Rs. 16,08,000.

Total power produce per year = no. of wind turbine x power produce per turbine per year

= 4 x2,500

= 10,000 kW-h/year

Payback Period = $\frac{\mathbf{16,08,000}}{\mathbf{8.41\ x\ 10,000}}$ = 19.12009512 years

Area Required

Available area in engineering building = 3024.26 m^2 (i.e. 32552.86372 ft^2).

Consider different % of available area in engineering building:

<u>Case 1</u>: Only 5% of total area (Engineering Building)

total available area = 5% of total area in $feet^2$

= 5% x 32552.86372

=1627.643 ft^2

No. of Wind Turbine can be Installed is given by:

No. of wind turbine = $\frac{\boldsymbol{TOTAL\ AVAILABLE\ AREA\ IN\ SQUARE\ FEET}}{\boldsymbol{AREA\ REQUIRED\ FOR\ WIND\ TURBINE\ IN\ SQUARE\ FEET}}$ = $\frac{\mathbf{1627.643}}{\mathbf{28.274}}$ = 57.57

No. of wind turbine = 58 nos

Installation Cost = no. of wind turbine x cost per wind turbine

=58 x 4,02,000

= Rs. 2,33,16,000

<u>Case 2</u>: Only 2% of total area (Engineering Building)

Total available area = 2% of total area in $feet^2$

= 2% x 32552.86372

=651.0573 ft^2

No. of wind turbine $= \frac{\boldsymbol{TOTAL\ AVAILABLE\ AREA\ IN\ SQUARE\ FEET}}{\boldsymbol{AREA\ REQUIRED\ FOR\ WIND\ TURBINE\ IN\ SQUARE\ FEET}} = \frac{\mathbf{651.0573}}{\mathbf{28.274}}$ = 23.0267

No. of wind turbine = 23 nos

Installation Cost = no. of wind turbine x cost per wind turbine

=23 x 4,02,000

= Rs. 92,46,000

<u>Case 3</u>: Only 0.5% of total area (Engineering Building)

Total available area = 0.5% of total area in $feet^2$

= 0.5% x 32552.86372

=162.764 ft^2

No. of wind turbine = $\frac{\textbf{\textit{TOTAL AVAILABLE AREA IN SQUARE FEET}}}{\textbf{\textit{AREA REQUIRED FOR WIND TURBINE IN SQUARE FEET}}} = \frac{\mathbf{162.764}}{\mathbf{28.274}}$ = 5.75

No. of wind turbine = 6 nos

Installation Cost = no. of wind turbine x cost per wind turbine

= 6 x 4,02,000

= Rs. 24,12,000

Case 4: Only 5% of total area (Engineering Building)

Total available area = 0.3% of total area in $feet^2$

= 0.3% x 32552.86372

=97.658 ft^2

No. of wind turbine = $\frac{\textbf{\textit{TOTAL AVAILABLE AREA IN SQUARE FEET}}}{\textbf{\textit{AREA REQUIRED FOR WIND TURBINE IN SQUARE FEET}}} = \frac{\mathbf{97.658}}{\mathbf{28.274}}$ = 3.45

No. of wind turbine = 4 nos

Installation Cost = no. of wind turbine x cost per wind turbine

= 4 x 4,02,000

= Rs.16,08,000

Table 4D.4.10.2: Selection of quantity and area for wind turbine

Cases	Available Area (A.A.) (ft^2)	Area Required by Wind Turbine (A.R.) (Ft^2)	Quantity $=A.A./A.R.$	Installation Cost (Rs.)
5%	1627.643	28.274	58	2,33,16,000
2%	651.057	28.274	23	92,46,000
0.5%	162.764	28.274	6	24,12,000
0.3%	97.658	28.274	4	16,08,000

Therefore, selecting only 0.3% of available area of engineering building because the initial cost is less as compare to other and payback period is also less.

Therefore, actual area required for installations of 4 Wind Turbine:

Actual area required = no. of wind turbine x area required per wind turbine

= 4 x 28.274

=**113.096 ft^2**

4D.5 Hybrid (Solar + Wind)

In Hybrid Energy, we are using various combination of Solar and Wind Energy in order to get different combination of Hybrid Energy. During selection of various combination of Hybrid Energy, we consider Budget factor too. **We are focusing Hybrid Energy only for Engineering Building only**.

4D.5.1 Various Combination of Hybrid (Solar + Wind)

1. Hybrid – 1: 2 X 4 kW capacity Solar and 4 X Wind Turbines
2. Hybrid – 2: 4 X 4 kW capacity Solar and 2 X Wind Turbines
3. Hybrid – 3: 2 X 4 kW capacity Solar and 6 X Wind Turbines
4. Hybrid – 4: 6 X4 kW capacity Solar and 2 X Wind Turbines
5. Hybrid – 5: 6 X 4 kW capacity Solar and 4 X Wind Turbines

4D.5.2 Calculations for Initial Cost, Power Generation, Area Required, Maintenance Cost, Payback Period

1. **Hybrid – 1: 2 X 4 kW capacity Solar and 4 X Wind Turbines**

   Initial Cost

   Initial cost = No. of solar capacity x initial cost of 4 kw capacity of solar + No. of wind turbine x initial cost of one WT6500

   = (2 x 568304) + (4 x 402000

   = Rs. 2744608

Power Generation

Power generation = No. of solar capacity x power generation from one 4 kw capacity solar + No. of wind turbine x power generation from one WT6500

= (2 x 3400) + (4 x2500)

= 16800 kWh/year

Area Required

Area Required = No. of solar capacity x area required for one 4kw capacity solar + No. of wind turbine x area required for one WT6500

= (2 x 301.389) + (4 x 28.75)

= 717.778ft^2

Maintenance Cost

Maintenance cost = 1.5 % of total cost

= $\frac{1.5}{100}$ x 2744608

=Rs 41169.12

Payback Period

Payback Period = $\frac{TOTAL\ INSTALLATIONS\ COST\ IN\ RUPEES}{COST\ OF\ UNIT\ IN\ RUPEES\ x\ TOTAL\ POWER\ PRODUCE\ PER\ YEAR}$ **(in years)**

= 2744608 / (8.41 x 16800)

=19.43 years

2. Hybrid – 2: 4 X 4 kW capacity Solar and 2 X Wind Turbines

Initial Cost

Initial cost = No. of solar capacity x initial cost of 4 kw capacity of solar + No of wind turbine x initial cost of one WT6500

= (4 x 568304) + (2 x 402000)

= Rs. 3077216

Power Generation

Power generation = No. of solar capacity x power generation from one 4 kw capacity solar + No. of wind turbine x power generation from one WT6500

= (4 x 3400) + (2 x 2500)

= 18600 kWh/year

Area Required

Area Required = No. of solar capacity x area required for one 4kw capacity solar + No. of wind turbine x area required for one WT6500

= (4 x 301.389) + (2 x 28.75)

= 1263.056 ft^2

Maintenance Cost

Maintenance cost = 1.5 % of total cost

$= \frac{1.5}{100}$ x 3077216

= Rs. 46158.24

Payback Period

Payback Period = $\frac{TOTAL\ INSTALLATIONS\ COST\ IN\ RUPEES}{COST\ OF\ UNIT\ IN\ RUPEES\ x\ TOTAL\ POWER\ PRODUCE\ PER\ YEAR}$ **(in years)**

= 3077216 / (8.41 x 18600)

=19.67 years

3. Hybrid – 3: 2 X 4 kW capacity Solar and 6 X Wind Turbines

Initial Cost

Initial cost = No. of solar capacity x initial cost of 4 kw capacity of solar + No of wind turbine x initial cost of one WT6500

= (2 x 568304) + (6 x 402000)

= Rs. 3548608

Power Generation

Power generation = No. of solar capacity x power generation from one 4 kw capacity solar + No. of wind turbine x power generation from one WT6500

= (2 x 3400) + (6 x 2500)

= 21800 kWh/year

Area Required

Area Required = No. of solar capacity x area required for one 4kw capacity solar + No. of wind turbine x area required for one WT6500

= (2 x 301.389) + (6 x 28.75)

= 775.278 ft^2

Maintenance Cost

Maintenance cost = 1.5 % of total cost

= $\frac{1.5}{100}$ x 3548608

= Rs. 53229.12

Payback Period

Payback Period = $\frac{TOTAL\ INSTALLATIONS\ COST\ IN\ RUPEES}{COST\ OF\ UNIT\ IN\ RUPEES\ x\ TOTAL\ POWER\ PRODUCE\ PER\ YEAR}$ **(in years)**

=3548608 / (8.41 x 21800)

=19.36 years

4. Hybrid – 4: 6 X4 kW capacity Solar and 2 X Wind Turbines

Initial Cost

Initial cost = No. of solar capacity x initial cost of 4 kw capacity of solar + No of wind turbine x initial cost of one WT6500

= (6 x 568304) + (2 x 402000)

= Rs. 4213824

Power Generation

Power generation = No. of solar capacity x power generation from one 4 kw capacity solar + no. of wind turbine x power generation from one WT6500

= (6 x 3400) + (2 x 2500)

= 25400 kWh/year

Area Required

Area Required = no. of solar capacity x area required for one 4kw capacity solar + no. of wind turbine x area required for one WT6500

= (6 x 301.389) + (2 x 28.75)

= 1865.834 ft^2

Maintenance Cost

Maintenance cost = 1.5 % of total cost

= $\frac{1.5}{100}$ x 4213824

= Rs. 63207.36

Payback Period

Payback Period = $\frac{TOTAL\ INSTALLATIONS\ COST\ IN\ RUPEES}{COST\ OF\ UNIT\ IN\ RUPEES\ x\ TOTAL\ POWER\ PRODUCE\ PER\ YEAR}$ **(in years)**

= 4213824 / (8.41 x 25400)

=19.73 years

5. Hybrid – 5: 6 X 4 kW capacity Solar and 4 X Wind Turbines

Initial Cost

Initial cost = No. of solar capacity x initial cost of 4 kw capacity of solar + No. of wind turbine x initial cost of one WT6500

= (6 x 568304) + (4 x 402000)

= Rs. 5017824

Power Generation

Power generation = No. of solar capacity x power generation from one 4 kw capacity solar + No. of wind turbine x power generation from one WT6500

= (6 x 3400) + (4 x 2500)

= 30400 kWh/year

Area Required

Area Required = No. of solar capacity x area required for one 4kw capacity solar + No. of wind turbine x area required for one WT6500

= (6 x 301.389) + (4 x 28.75)

= 1923.334 ft^2

Maintenance Cost

Maintenance cost = 1.5 % of total cost

= $\frac{1.5}{100}$ x 5017824

= Rs. 75267.36

Payback Period

Payback Period = $\frac{TOTAL\ INSTALLATIONS\ COST\ IN\ RUPEES}{COST\ OF\ UNIT\ IN\ RUPEES\ x\ TOTAL\ POWER\ PRODUCE\ PER\ YEAR}$ **(in years)**

= 5017824 / (8.41 x 30400)

=19.63 years

4D.5.3 Matrix Table for Hybrid (Solar + Wind)

This table gives the information about hybrid system likewise initial cost, power generation, area requirement, maintenance cost and payback period.

Table 4D.5.3.1: Different types of hybrid system

Type of Hybrid	Initial Cost (Rs.)	Power Generated (kW-h/year)	Area Required (sq. ft.)	Maintenance Cost (Rs./year)	Payback Period (years)
Hybrid -1	2744608	16800	717.778	41169.12	19.43
Hybrid -2	3077216	18600	1263.056	46158.24	19.67
Hybrid -3	354608	21800	775.278	53229.12	19.36
Hybrid -4	4213824	25400	1865.834	63207.36	19.73
Hybrid -5	5017824	30400	1923.334	75267.36	19.63

(E) Analytic Hierarchy Process

4E.1 Introduction

We have to make **decisions** on a daily basis. There are many decisions we make every day which are not very important, but about some of them we think more thoroughly because they are more important than others. In the **decision making process** we have our own criteria. For some decisions comparative process is simple and it can be expressed in units of measurement. For example, price, weight, height and many other values can be expressed in units of measurement. What about the criteria that cannot be expressed in such way? For example, quality, design, reliability, suitableness, pleasure etc. Moreover, what about those criteria depending on our own belief, taste or standards?

Have you ever been in a situation when A is much better than B, B is slightly better than Cand C is better than A on the one hand, but on the other hand the situation is opposite? Or A is two times better then B, B is three times better than C, and A and C are equally good? If not, then this is not a web site for you.

Decision making is an evaluation process including alternatives which are all satisfying a certain set of criteria. The problem appears when one has to choose only one alternative which satisfies the entire set of our personal criteria.

Did you know that there is one simple method that can help people make that choice and which takes into consideration things like your perception, intuition, rational and irrational, and the inconsistency of choosing among several options? The method is called **Analytical Hierarchy Process (AHP)**. It is based on the comparison of pairs of alternative solutions during which all alternatives are compared to one another and you, as a decision maker, express intensity and the level of preference towards one alternative in relation to the other according to the criteria you find important. In the same way, you compare criteria according to your own preferences and their intensity.

AHP is a strong and flexible decision making technique which helps in setting priorities and reaching optimal decisions in situations when quantitative and qualitative aspects have already been taken into consideration. By reducing complex decision making to comparisons between pairs of alternatives and by synthesizing results **AHP** helps not only in decision making but leads to a rational decision. Created in a way to reflect the way people think, **AHP** was developed by **Dr. Thomas Saaty** in the 1970ies while he was a professor at the Wharton School of Business. The method is still one of the most appreciated and widely used methods. Numerous institutions and companies use it in decision making process.

AHP is a mathematical method. Compared to other decision making methods and techniques AHP enables you, as the decision maker, to compare the significance of each alternative in relation to another one individually and within a criterion you find relevant. This preference-based method shows the best option. The value of the method is not only in finding the optimal result, but intermediate steps are clearly distinguishable, as well as the elements that contribute to the result the most.

4E.2 Theoretical and mathematical description of the method

The first step is to determine a set of elements that consists of alternatives and criteria we wish to consider. The next step is to form the set into a hierarchical structure consisting of the mentioned criteria and alternatives.

Upon defining that set, we begin developing the mathematical model by which we calculate priorities (weight, importance) of the elements on the same level in the hierarchical structure.

The entire process of the AHP method can be described in several steps:

1. The development of the hierarchical model of the decision making problem by defining the goal, criteria and alternative solutions.
2.

   On each level of the hierarchical model elements of the model are compared with one another in pairs, and the preferences of the decision maker are expressed with the use of the Saaty's scale.

In scientific literature that scale is more precisely described as a scale of five levels and four intermediate levels of verbally described intensities and corresponding numerical values for them on the scale from 1 to 9. The following table shows the values and their description used for the comparison of relevant values of the elements of the **AHP model**.

Intensity of Importance	**Definition**	**Explanation**
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance	Experience and judgment slightly favor one activity over another
5	Strong importance	Experience and judgment strongly favor one activity over another
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values	

Fig. 4E.2.1: Selection comparison value

4E.3 Let Us Describe It in More Detail.

The first step would be to define a set in which we list the elements of the selection - the set of alternatives from which we wish to choose the best one for ourselves. Then we define the criteria we will use to compare those alternatives. It is clear that you, as the decision maker, determine all of this. That fact alone guarantees that the decision will be based on your preferences

For the explanation of the following steps we will use mathematical language. If n is the number of criteria or alternatives whose weight (priority, importance) wi should be defined based on the assessment of the values of their ratios aij = wi/wj. If we form a matrix A from the ratio of their relevant importance aij, in case of consistent assessments equaling to aij= aik*akj , it will correspond to the equation Aw=nw

Matrix A has special characteristics (all her rows are proportional to the first row, all are positive and aij=1/aji is accurate resulting in only one of its eigenvalues being different from 0 and equal to n. If A matrix has inconsistent changes (in praxis that is always the case) the importance vector w can be calculated by solving the equation (A- Lambda I)w=0

The condition: SUMAwi=1 is true, where LAMDAmax is the biggest eigenvalue of A matrix.

Due to the characteristics of the matrix LAMDAmax ≥ n, and the subtraction LAMDAmax – n is used in the measuring of the assessment consistency. With a consistency index CI = (LAMDAmax -n)/(n-1) we calculate the consistency ratio CR=CI/RI where RI is a random index (consistency index for the n row matrixes of randomly generated comparisons in pairs – a table with calculated values applies.

Table 4E.3.1: Value of the random index RI

n	1	2	3	4	5	6	7	8
RI	0,00	0,00	0,52	0,89	1,11	1,25	1,35	1,40

n	9	10	11	12	13	14	15
RI	1,45	1,49	1,51	1,54	1,56	1,57	1,58

If CR≤ 0.1000 is true for matrix The assessments of the relative importance of the criteria (alternative priorities) are considered as acceptable. To the contrary, the reasons why the assessment inconsistency is acceptably high must be investigated.

It will often happen that the consistency ratio exceeds 0,1000. That should only be taken into account as an indicator of the inconsistency level of your selection. Despite the inconsistency, you will get a suggestion of the best alternative. That is the value of this method. You can always revise the chosen importance intensities and check which alternative is the best and to what extent compared to the following one.

4E.4 Calculations for AHP

Table 4E.4.1: AHP Matrix

AHP MATRIX							
Criteria							
Alternatives		Initial Cost (Rs.)	Power Saving (kwh/year)	Area Required (sq. feet)	Maintenance Cost (Rs./year)	Payback period (year)
	Solar Energy	1174628	6800	602.779	17619.42	20
	Wind Energy	1608000	10000	113.09	24120	19.1
	HYBRID-1	2744608	16800	717.778	41169.12	19.43
	HYBRID-2	3077216	18600	1263.056	46158.24	19.67
	HYBRID-3	3548608	21800	775.278	53229.12	19.36
	HYBRID-4	4213824	25400	1865.834	63207.36	19.73
	HYBRID-5	5017824	30400	1923.334	7526.36	19.63

Step 1: - Basic Calculation

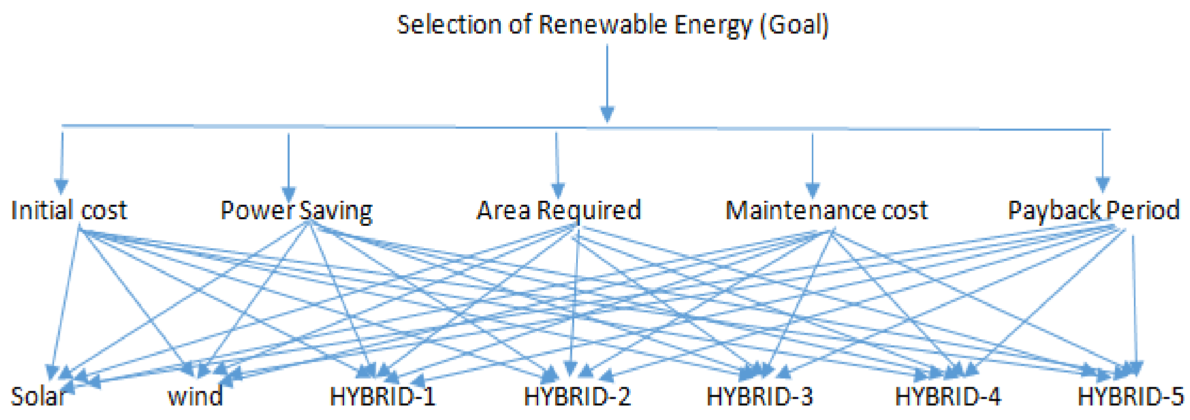
➢ **List of criteria:**

1. Initial cost
2. Power saving or generation
3. Area required
4. Maintenance cost
5. Payback period

➢ **List of alternative:**

1. Solar energy
2. Wind energy
3. Hybrid -1 (2x4kw capacity solar & 4xWT6500)
4. Hybrid-2 (4x4kw capacity solar & 2xWT6500)
5. Hybrid-3 (2x4kw capacity solar & 6xWT6500)
6. Hybrid -4 (6x4kw capacity solar & 2xWT6500)
7. Hybrid-5 (6x4kw capacity solar & 4xWT6500)

Goal's:



- **Ranking of criteria**

  It is given by group brainstorming.

Table 4E.4.2: Ranking criteria for understanding

Rank	Criteria
1	Initial cost
2	Power saving
3	Payback period
4	Maintenance cost
5	Area required

Step 2: Pairwise Comparison of Criteria and Consistency Ratio (CR)

NOTE: Number of Input required is given by

I/p required = $\frac{n(n-1)}{2}$ **, where n =Number of Criteria**

$= \frac{5(5-1)}{2} = 10$ **…Ans.**

The scaling is not necessary 1 to 9 but for qualitative data such as preference, ranking and subjective opinions, it is suggested to use scale 1 to 9.

Table 4E.2.1.2: Number of comparisons

Number of comparisons

Number of things	1	2	3	4	5	6	7	n
number of comparisons	0	1	3	6	10	15	21	$\frac{n(n-1)}{2}$

Table 4E.4.3: Pairwise Comparison of Criteria

A - Importance - or B?				Equal	How much more?							
1	◉ Initial Cost	or	○ Power Generation	○ 1	○ 2	○ 3	○ 4	○ 5	◉ 6	○ 7	○ 8	○ 9
2	◉ Initial Cost	or	○ Area Required	○ 1	○ 2	○ 3	○ 4	○ 5	◉ 6	○ 7	○ 8	○ 9
3	◉ Initial Cost	or	○ Maintenance Cost	○ 1	○ 2	○ 3	○ 4	◉ 5	○ 6	○ 7	○ 8	○ 9
4	◉ Initial Cost	or	○ Payback Period	○ 1	○ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	◉ 9
5	◉ Power Generation	or	○ Area Required	○ 1	○ 2	◉ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9
6	◉ Power Generation	or	○ Maintenance Cost	○ 1	◉ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9
7	◉ Power Generation	or	○ Payback Period	○ 1	○ 2	○ 3	◉ 4	○ 5	○ 6	○ 7	○ 8	○ 9
8	◉ Area Required	or	○ Maintenance Cost	○ 1	◉ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9
9	◉ Area Required	or	○ Payback Period	○ 1	◉ 2	○ 3	○ 4	○ 5	○ 6	○ 7	○ 8	○ 9
10	◉ Maintenance Cost	or	○ Payback Period	○ 1	○ 2	○ 3	◉ 4	○ 5	○ 6	○ 7	○ 8	○ 9

CR = 6.6% OK

AHP Scale: 1- Equal Importance, 3- Moderate importance, 5- Strong importance, 7- Very strong importance, 9- Extreme importance (2,4,6,8 values in-between).

<u>Step 3</u>: - Calculation to find Rank:

Table 4E.4.4: AHP Matrix of criteria and alternative

AHP MATRIX						
Criteria						
Alternatives		Initial Cost (Rs.)	Power Saving (kwh/year)	Area Required (sq. feet)	Maintenance Cost (Rs./year)	Payback period (year)
	Solar Energy	1174628	6800	602.779	17619.42	20
	Wind Energy	1608000	10000	113.09	24120	19.1
	HYBRID-1	2744608	16800	717.778	41169.12	19.43
	HYBRID-2	3077216	18600	1263.056	46158.24	19.67
	HYBRID-3	3548608	21800	775.278	53229.12	19.36
	HYBRID-4	4213824	25400	1865.834	63207.36	19.73
	HYBRID-5	5017824	30400	1923.334	7526.36	19.63

Table 4E.4.5: Preference of criteria

STEP 1	RANKING OF CRITERIA
Preference	CRITERIA
1	Initial Cost (Rs.)
2	Power Saving (kwh/year)
3	Area Required (sq. feet)
4	Maintenance Cost (Rs./year)
5	Payback period (year)

Table 4E.4.6: Criteria Matrix & Normalized Column Sum

1.1 Criteria Matrix

	Initial Cost (Rs.)	Power Saving (kwh/year)	Area Required (sq. feet)	Maintenance Cost (Rs./year)	Payback period (year)
Initial Cost (Rs.)	1	5	6	5	9
Power Saving (kwh/year)	1/5	1	3	2	4
Area Required (sq. feet)	1/6	1/3	1	2	2
Maintenance Cost (Rs./year)	1/5	1/2	1/2	1	4
Payback period (year)	1/9	1/4	1/2	1/4	1
SUM OF COLUMN	151/90	85/12	11	41/4	20

1.2 Normalized Column Sum

	Initial Cost (Rs.)	Power Saving (kwh/year)	Area Required (sq. feet)	Maintenance Cost (Rs./year)	Payback period (year)
Initial Cost (Rs.)	90/151	12/17	6/11	20/41	9/20
Power Saving (kwh/year)	18/151	12/85	3/11	8/41	4/20
Area Required (sq. feet)	15/151	4/85	1/11	8/41	2/20
Maintenance Cost (Rs./year)	18/151	6/85	1/22	4/41	4/20
Payback period (year)	10/151	3/85	1/22	1/41	1/20
SUM OF COLUMN	1	1	1	1	1

Table 4E.4.7: Row Average

1.3 Row Average						
	Initial Cost (Rs.)	Power Saving (kwh/year)	Area Required (sq. feet)	Maintenance Cost (Rs./year)	Payback period (year)	Row Average "X"
Initial Cost (Rs.)	90/151	12/17	6/11	20/41	9/20	0.557
Power Saving (kwh/year)	18/151	12/85	3/11	8/41	4/20	0.1856
Area Required (sq. feet)	15/151	4/85	1/11	8/41	2/20	0.1065
Maintenance Cost (Rs./year)	18/151	6/85	1/22	4/41	4/20	0.1066
Payback period (year)	10/151	3/85	1/22	1/41	1/20	0.0443
SUM OF COLUMN	1	1	1	1	1	1

Table 4E.4.8: Criteria Priority

1.4 Criteria Priority		
Category (Criteria)	Priority	Rank
Initial Cost (Rs.)	0.557	1
Power Saving (kwh/year)	0.1856	2
Area Required (sq. feet)	0.1065	4
Maintenance Cost (Rs./year)	0.1066	3
Payback period (year)	0.0443	5
SUM OF COLUMN	1	

Table 4E.4.9.1: Find Out Lambda Max.

1.5 Find Out " λmax"										
NOW, A*X = λmax *X										
A						X				X
1	5	6	5	9		0.557				0.557
1/5	1	3	2	4		0.1856		lambda-max		0.1856
1/6	1/3	1	2	2	x	0.1065	=		x	0.1065
1/5	1/2	1/2	1	4		0.1066				0.1066
1/9	1/4	1/2	1/4	1		0.0443				0.0443

Table 4E.4.9.2: Find Out Lambda Max.

A x X				X
3.0557	=	lambda-max	X	0.557
1.0069				0.1856
0.563				0.1065
0.54125				0.1066
0.2325				0.0443

Table 4E.4.9.3: Find Out Lambda Max. by Avg.

lambda-max	=	3.0557/0.5570
		1.0069/0.1856
		0.563/0.1065
		0.54125/0.1066
		0.2325/0.0443
	∑ Column	**26.52319**

$$\text{lambda-max} = \frac{26.52318826}{5} = 5.304638$$

Lambda-max = 5.304638

4E.5 Consistency Ratio (C.R.)

Consistency Index, C.I. = $\frac{\lambda max - n}{n-1}$

where, n = Number of Criteria = 5

C.I. = $\frac{5.304638-5}{5}$ = **0.076159413**

From Table of R.I. (Random Index)

R.I. = 1.12 for n=5

C.R. = $\frac{C.I.}{R.I.} = \frac{0.076159413}{1.12}$ **= 0.06799 x 100% = 6.799% < 10%**

C.R. = 6.799%

Hence, it is acceptable.

Table 4E.3.1: Criteria Priority Matrix

	Category	Priority	Rank
1	Initial Cost	55.7%	1
2	Power Generation	18.56%	2
3	Area Required	10.65%	4
4	Maintenance Cost	10.66%	3
5	Payback Period	4.43%	5

4E.6 Alternatives

Table 4E.6.1: CASE -1 Initial Cost

Initial Cost (Rs.)	CASE -1 Initial Cost						
(Minimum)							
Initial Cost (Rs.)	Solar Energy	Wind Energy	HYBRID - 1	HYBRID - 2	HYBRID - 3	HYBRID - 4	HYBRID - 5
Solar Energy	1	2	3	4	3	2	4
Wind Energy	1/2	1	2	3	2	2	4
HYBRID - 1	1/3	1/2	1	2	1	1	2
HYBRID - 2	1/4	1/3	½	1	1	1	2
HYBRID - 3	1/3	1/2	1	1	1	1	2
HYBRID - 4	1/2	1/2	1	1	1	1	2
HYBRID - 5	1/4	1/4	½	1/2	1/2	1/2	1
Sum of Column	19/6	61/12	9	25/2	19/2	17/2	17

Table 4E.6.2: CASE -1 Initial Cost (Normalized Column Sum)

Normalized Column Sum								
Initial Cost (Rs.)	Solar Energy	Wind Energy	HYBRID - 1	HYBRID - 2	HYBRID - 3	HYBRID - 4	HYBRID - 5	Priority Vector
Solar Energy	6/19	24/61	3/9	8/25	6/19	4/17	4/17	0.30699
Wind Energy	3/19	12/61	2/9	6/25	4/19	4/17	4/17	0.21399
HYBRID - 1	2/19	6/61	1/9	4/25	2/19	2/17	2/17	0.11648
HYBRID - 2	3/38	4/61	1/18	2/25	2/19	2/17	2/17	0.08866
HYBRID - 3	2/19	6/61	1/9	2/25	2/19	2/17	2/17	0.10504
HYBRID - 4	3/19	6/61	1/9	2/25	2/19	2/17	2/17	0.11256
HYBRID - 5	3/38	3/61	1/18	1/25	1/19	1/17	1/17	0.05628
Sum of Column	1	1	1	1	1	1	1	1

Table 4E.6.3: CASE -2 Power Saving

Power Saving (kwh/year)	CASE -2 Power Saving						
(Maximum)							
Power Saving (kwh/year)	Solar Energy	Wind Energy	HYBRID - 1	HYBRID - 2	HYBRID - 3	HYBRID - 4	HYBRID - 5
Solar Energy	1	1/2	1/4	1/3	1/2	1/3	1/6
Wind Energy	2	1	1/2	1/5	1/2	1/2	1/5
HYBRID - 1	4	2	1	1/2	2	3	1/4
HYBRID - 2	3	5	2	1	3	5	1/3
HYBRID - 3	2	2	1/2	1/3	1	2	1/5
HYBRID - 4	3	2	1/3	1/5	1/2	1	1/7
HYBRID - 5	6	5	4	3	5	7	1
Sum of Column	21	35/2	103/12	167/30	25/2	113/6	321/140

Table 4E.6.4: CASE -2 Power Saving (Normalized Column Sum)

Normalized Column Sum								
Power Saving (kwh/year)	Solar Energy	Wind Energy	HYBRID - 1	HYBRID - 2	HYBRID - 3	HYBRID - 4	HYBRID - 5	Priority Vector
Solar Energy	1/21	1/35	3/103	10/167	1/25	2/113	70/963	0.04223
Wind Energy	2/21	2/35	6/103	6/167	1/25	3/113	28/321	0.05719
HYBRID - 1	4/21	4/35	12/103	15/167	4/25	18/113	35/321	0.1342
HYBRID - 2	3/21	10/35	24/103	30/167	6/25	30/113	140/963	0.21316
HYBRID - 3	2/21	4/35	6/103	10/167	2/25	12/113	28/321	0.08586
HYBRID - 4	3/21	4/35	4/103	6/167	1/25	6/113	20/321	0.06962
HYBRID - 5	6/21	10/35	48/103	90/167	10/25	42/113	140/321	0.39774
Sum of Column	1	1	1	1	1	1	1	1

Table 4E.6.5: CASE -3 Area Required

Area Required (sq. feet)	CASE -3 Area Required						
(Minimum)							
Area Required (sq. feet)	Solar Energy	Wind Energy	HYBRID - 1	HYBRID - 2	HYBRID - 3	HYBRID - 4	HYBRID - 5
Solar Energy	1	1/7	2	4	6	2	4
Wind Energy	7	1	4	7	5	3	7
HYBRID - 1	1/2	1/4	1	3	2	1/3	5
HYBRID - 2	1/4	1/7	1/3	1	1/3	1/5	2
HYBRID - 3	1/6	1/5	1/2	3	1	1/4	3
HYBRID - 4	1/2	1/3	3	5	4	1	4
HYBRID - 5	1/4	1/7	1/5	1/2	1/3	1/4	1
Sum of Column	29/3	929/420	331/30	47/2	56/3	211/30	26

Table 4E.6.6: CASE -3 Area Required (Normalized Column Sum)

Normalized Column Sum								
Area Required (sq. feet)	Solar Energy	Wind Energy	HYBRID - 1	HYBRID - 2	HYBRID - 3	HYBRID - 4	HYBRID - 5	Priority Vector
Solar Energy	3/29	60/929	60/331	8/47	9/28	60/211	4/26	0.18274
Wind Energy	21/29	420/929	120/331	14/47	15/56	90/211	7/26	0.40004
HYBRID - 1	3/58	105/929	30/331	6/47	3/28	10/211	5/26	0.10427
HYBRID - 2	3/116	60/929	10/331	2/47	1/56	6/211	2/26	0.04092
HYBRID - 3	1/58	84/929	15/331	6/47	3/56	15/211	3/26	0.0693
HYBRID - 4	3/58	140/929	90/331	10/47	3/14	30/211	4/26	0.17106
HYBRID - 5	3/116	60/929	6/331	1/47	1/56	15/211	1/26	0.03167
Sum of Column	1	1	1	1	1	1	1	1

Table 4E.6.7: CASE -4 Maintenance Cost

Maintenance Cost (Rs./year)	CASE -4 Maintenance Cost						
(Minimum)							
Maintenance Cost (Rs./year)	**Solar Energy**	**Wind Energy**	**HYBRID - 1**	**HYBRID - 2**	**HYBRID - 3**	**HYBRID - 4**	**HYBRID - 5**
Solar Energy	1	2	3	5	7	9	4
Wind Energy	1/2	1	2	4	5	7	3
HYBRID - 1	1/3	1/2	1	2	3	5	1/2
HYBRID - 2	1/5	1/4	1/2	1	2	3	1/2
HYBRID - 3	1/7	1/5	1/3	1/2	1	2	4
HYBRID - 4	1/9	1/7	1/5	1/3	1/2	1	5
HYBRID - 5	1/4	1/3	2	2	1/4	1/5	1
Sum of Column	3197/1260	1859/420	271/30	89/6	75/4	136/5	18

Table 4E.6.8: CASE -4 Maintenance Cost (Normalized Column Sum)

Normalized Column Sum								
Maintenance Cost (Rs./year)	**Solar Energy**	**Wind Energy**	**HYBRID - 1**	**HYBRID - 2**	**HYBRID - 3**	**HYBRID - 4**	**HYBRID - 5**	**Priority Vector**
Solar Energy	1260/3197	840/1859	90/271	30/89	28/75	45/136	4/18	**0.34879**
Wind Energy	630/31970	420/1859	60/271	24/89	4/15	35/136	3/18	**0.22925**
HYBRID - 1	420/31970	210/1859	30/271	12/89	4/25	25/136	1/36	**0.12307**
HYBRID - 2	252/31970	105/1859	15/271	6/89	8/75	15/136	1/36	**0.07183**
HYBRID - 3	180/31970	84/1859	10/271	3/89	4/75	5/68	4/18	**0.07446**
HYBRID - 4	140/3197	60/1859	6/271	2/89	2/75	5/136	5/18	**0.06598**
HYBRID - 5	315/3197	140/1859	60/271	12/89	1/75	1/136	1/18	**0.08662**
Sum of Column	1	1	1	1	1	1	1	1

Table 4E.6.9: CASE -5 Payback Period

Payback period (year)	CASE -5 Payback Period						
(Minimum)							
Payback period (year)	Solar Energy	Wind Energy	HYBRID - 1	HYBRID - 2	HYBRID - 3	HYBRID - 4	HYBRID - 5
Solar Energy	1	1/3	1/3	1	1	1/2	1
Wind Energy	3	1	1	2	3	1	2
HYBRID - 1	3	1	1	2	2	1	2
HYBRID - 2	1	1/2	1/2	1	1	1/3	1
HYBRID - 3	1	1/3	1/2	1	1	1/3	1
HYBRID - 4	2	1	1	3	3	1	3
HYBRID - 5	1	1/2	1/2	1	1	1/3	1
Sum of Column	12	14/3	29/6	11	12	9/2	11

Table 4E.6.10: CASE -5 Payback Period (Normalized Column Sum)

Normalized Column Sum								
Payback period (year)	Solar Energy	Wind Energy	HYBRID - 1	HYBRID - 2	HYBRID - 3	HYBRID - 4	HYBRID - 5	Priority Vector
Solar Energy	1/12	1/14	2/29	1/11	1/12	1/9	1/11	0.08571
Wind Energy	3/12	3/14	6/29	2/11	3/12	2/9	2/11	0.21529
HYBRID - 1	3/12	3/14	6/29	2/11	2/12	2/9	2/11	0.20339
HYBRID - 2	1/12	3/28	3/29	1/11	1/12	2/27	1/11	0.09045
HYBRID - 3	1/12	1/14	3/29	1/11	1/12	2/27	1/11	0.08535
HYBRID - 4	2/12	3/14	6/29	3/11	3/12	2/9	3/11	0.22936
HYBRID - 5	1/12	3/28	3/29	1/11	1/12	2/27	1/11	0.09045
Sum of Column	1	1	1	1	1	1	1	1

Table 4E.6.11: **Alternative Matrix**

Conclusion of AHP									
Alternative	**Initial Cost**	**Power Saving**	**Area Required**	**Maintenance Cost**	**Payback Period**		**Priority Criteria**		**Priority Alternative**
Solar Energy	0.30699	0.04223	0.18274	0.34879	0.08571		0.5570		**0.239271095**
Wind Energy	0.21399	0.05719	0.40004	0.22925	0.21529		0.1856		**0.206386551**
HYBRID - 1	0.11648	0.1342	0.10427	0.12307	0.20339	x	0.1065	=	**0.123021074**
HYBRID - 2	0.08866	0.21316	0.04092	0.07183	0.09045		0.1066		**0.104968109**
HYBRID - 3	0.10504	0.08586	0.0693	0.07446	0.08535		0.0443		**0.093541787**
HYBRID - 4	0.11256	0.06962	0.17106	0.06598	0.22936				**0.111029398**
HYBRID - 5	0.05628	0.39774	0.03167	0.08662	0.09045				**0.121781986**

Table 4E.6.12: **Selection of Alternative by Using AHP Priority**

Result of AHP			
Category (Alternative)	**Priority**	**Priority in Percentage**	**Rank**
Solar Energy	0.239271095	23.93%	1
Wind Energy	0.206386551	20.64%	2
HYBRID - 1	0.123021074	12.30%	3
HYBRID - 2	0.104968109	10.50%	6
HYBRID - 3	0.093541787	9.35%	7
HYBRID - 4	0.111029398	11.10%	5
HYBRID - 5	0.121781986	12.18%	4
Sum of Column	1	100%	

4E.5 Validation of Result by Using AHP Software

After getting the result for AHP by using manual calculation we find the software for validating our results. The name of the software is AHP version 1.2. this software was available on the internet for free. Validation of result by using AHP software is shown below:

Fig. 4E.7.1: Step 1(Enter Number of Criteria & Alternative)

Fig. 4E.7.2: Step 2 (Enter Criteria Matrix Value)

Fig. 4E.7.3: Step 3(Enter Initial Cost Matrix Value)

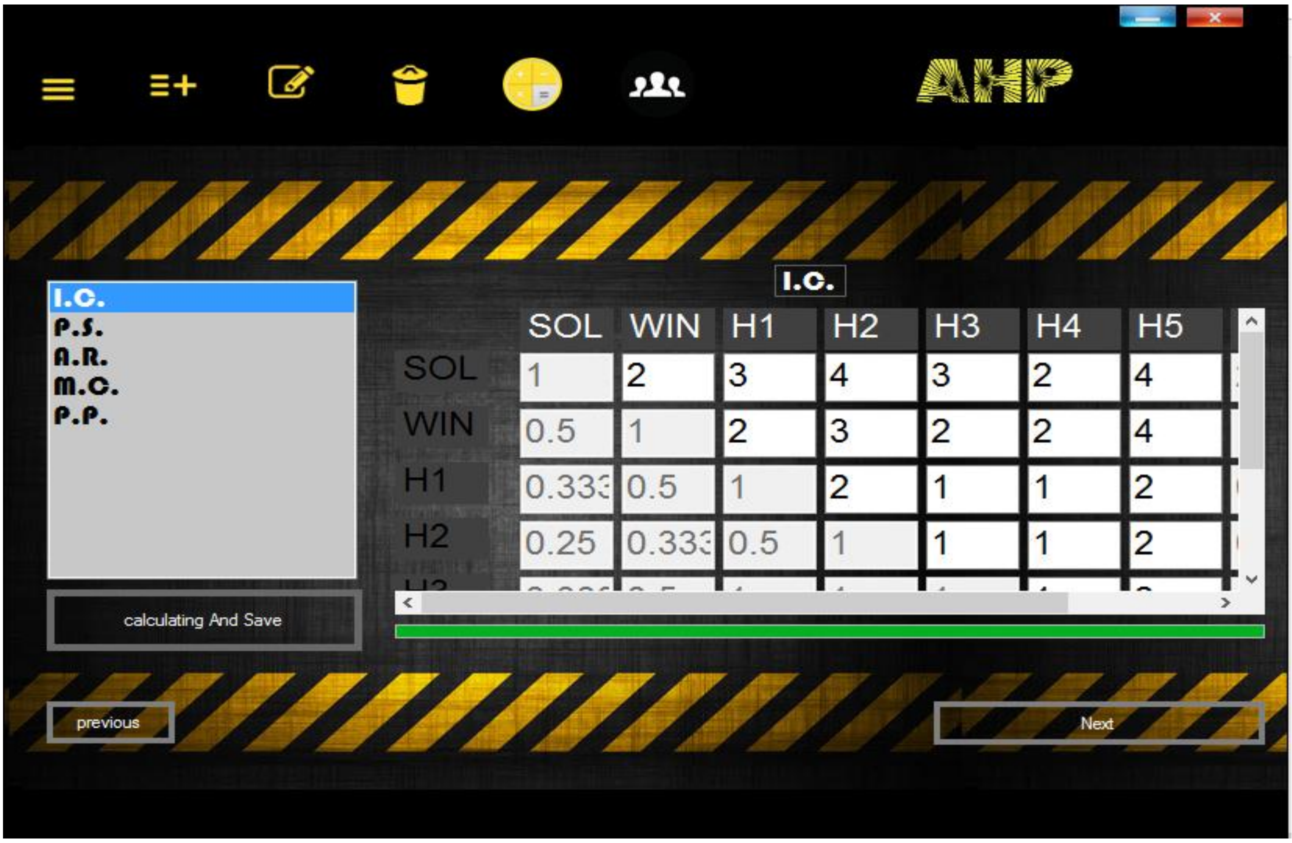


Fig. 4E.7.4: Step 4(Enter Power Generation or Saving Matrix Value)

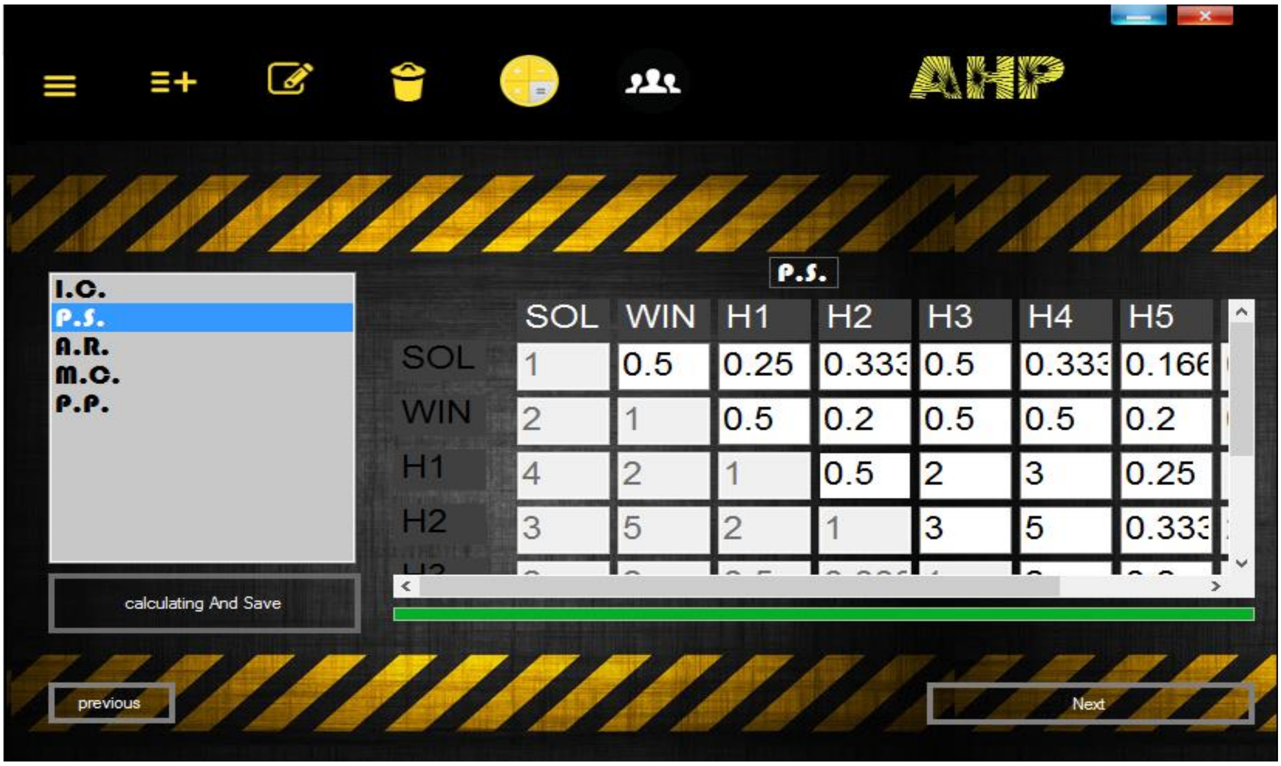


Fig. 4E.7.5: Step 5(Enter Area Required Matrix Value)

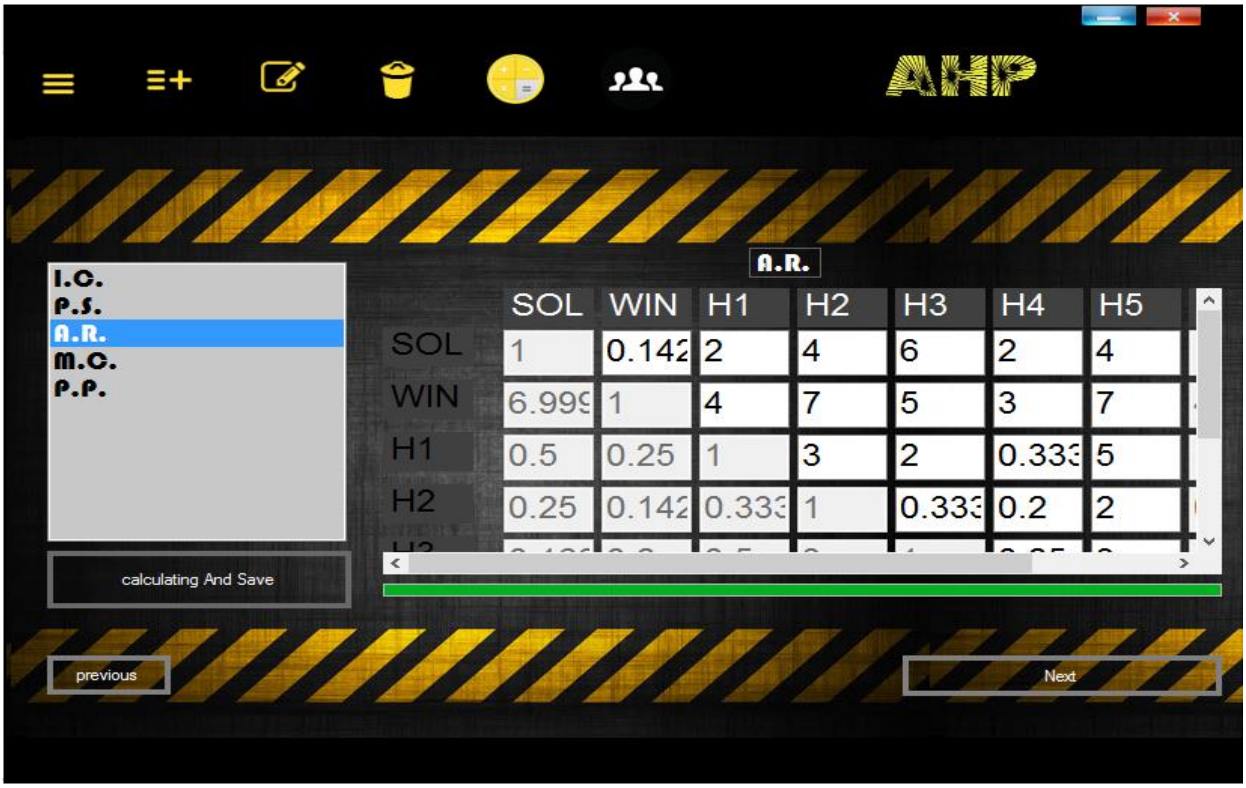


Fig. 4E.7.6: Step 6(Enter Maintenance Cost Matrix Value)

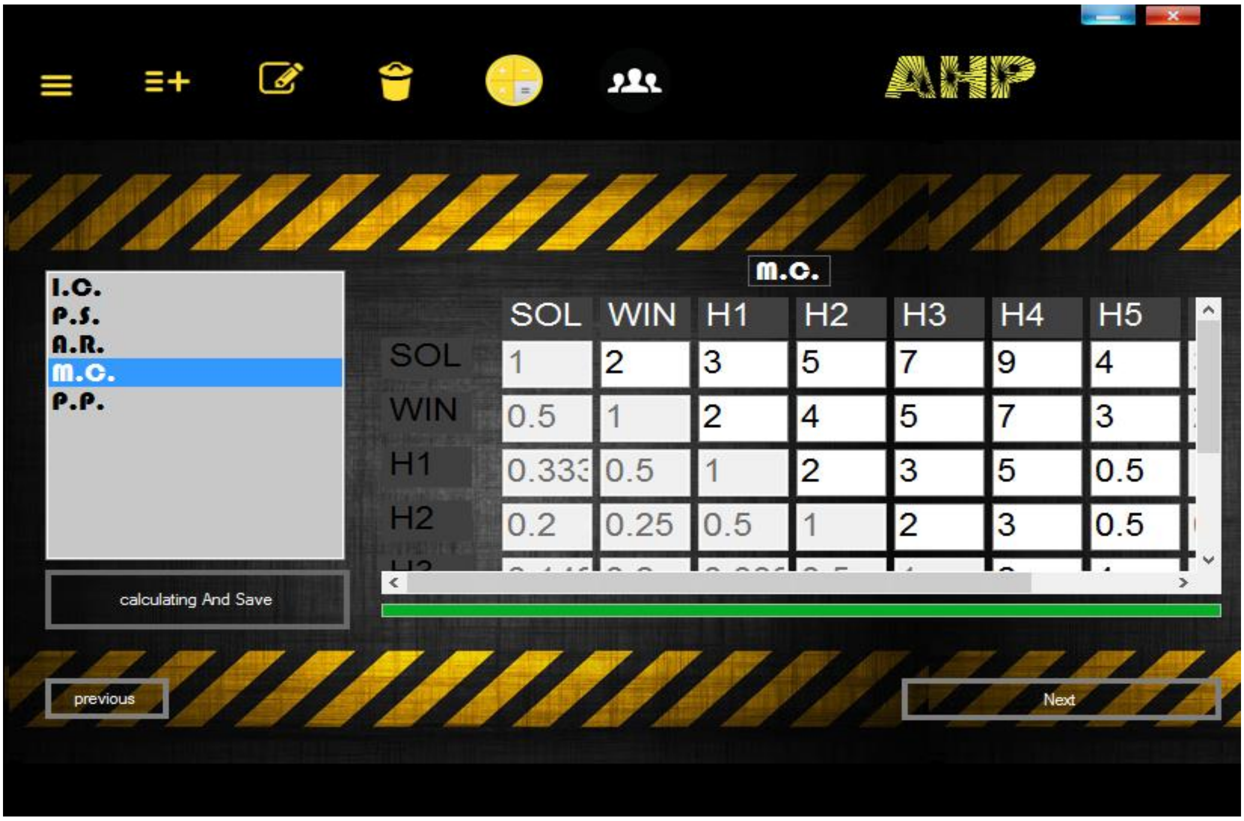


Fig. 4E.7.7: Step 7(Enter Payback Period Matrix Value)

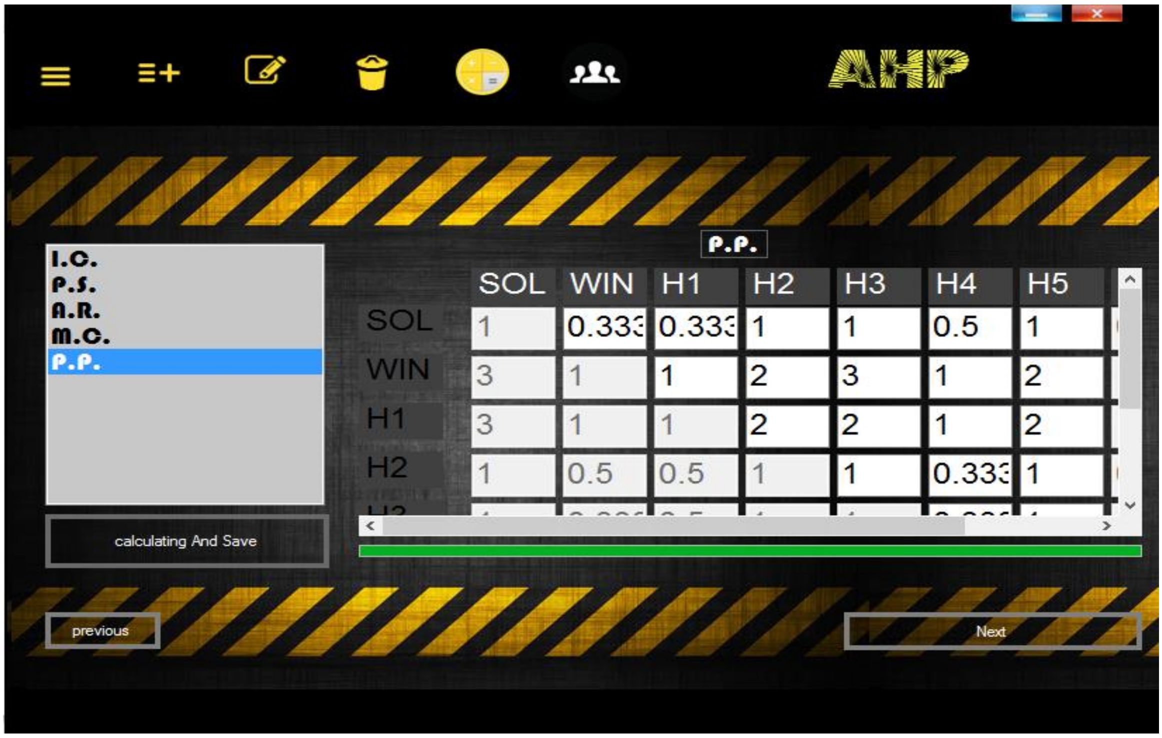
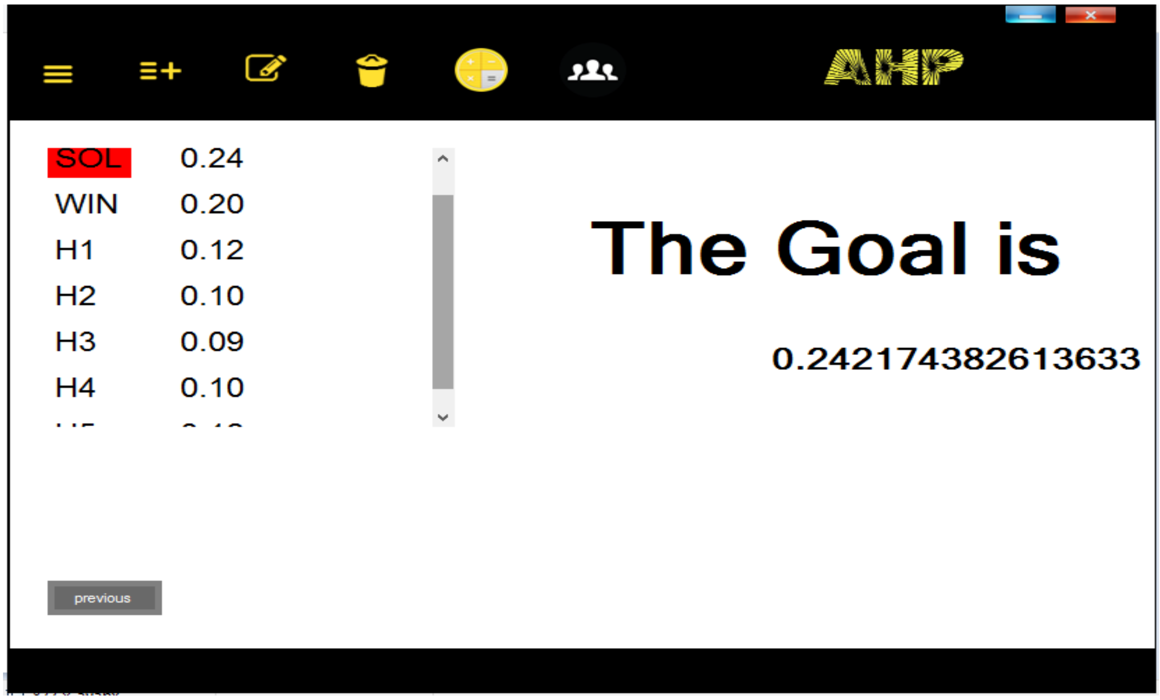


Fig. 4E.7.8: Step 8(Final Outcome)



The result we found by manual calculation is matches with the results we found by AHP software, hence results are validated

Chapter 5

CONCLUSION

1. At the time, the mankind is trying to re-establish the connection it once had with nature. An energy efficient AIKTC campus is a personal step toward the direction of renewable energy, environmental protection, and sustainable living. Having such an AIKTC campus helps owners to reduce their bills and provides an excellent investment. Furthermore, energy efficiency means healthier and more comfortable living that is in line with nature.
2. If you want to start saving money now, protect your health and the environment, do not hesitate to apply what this guide has taught you. Create a comfortable energy efficient campus and join the quickly approaching future of energy sustainability. Energy security have led to increasing interest and more development in renewable energy sources such as solar, wind and hybrid giving us clean, reusable energy to power our world.
3. The use of this energy is free, does not create pollution, having a backup system in case of a local or widespread power outage, and if used wisely can help us become less dependent on other costlier and damaging forms of power. After participating in this we hope you are able to see the benefits of this valuable resource and help change the future for energy use.

Chapter 6

Future Scope

1. Solar Passive Cooling Through Dehumidification

   By using solar passive cooling through dehumidification, the moisture content in the air is reduced and cooling is maintained by adsorption and evaporation.

2. Sun Danger Refrigerator

   To study and install a Sun Danger Refrigerator for chilling the water.

3. Solar Window Covering

   Turn all the window into transparent solar panel. Polysolar's latest glass has thin film photovoltaic technology embedded in the center of each panel. It is transparent but it controls glare and it reduces thermal gain.

4. Solar Passive Cooling Through ventilation

   The heated air rises up, is ducted outside and warm air from the room is drawn into this space due to the natural draught thus produced.as a result cool outside air enters the room from bottom Air vent.

5. Installation of renewable energy resources

   Based on all of the data of solar, wind and hybrid we can easily implement the renewable energy sources on each of the building.

   Which will beneficial for whole AIKTC Campus.

6. Make it as a project

   Based on all the outcomes, in future coming batches can install

   The solar panels, and wind turbine on terrace area of a building as a project.

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Annexure

Energy Audit Sheet

1. Polytechnic Building or Diploma Building
2. Engineering Building
3. Pharmacy Building
4. Architecture Building