NUST H-12 CAMPUS AS A NET ZERO ENERGY CAMPUS (FEASIBILITY AND COST ESTIMATION)

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School of Civil and Environmental Engineering

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بسم الله الرحمن الرحيم

DEDICATED

TO

OUR FAMILY, TEACHERS AND COLLEAGUES

CERTIFICATION

This is to clarify that thesis entitled

NUST H-12 CAMPUS AS A NET ZERO ENERGY CAMPUS (FEASIBILITY AND COST ESTIMATION)

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Of the requirements

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DECLARATION

We hereby declare that the thesis titled, “NUST H-12 as net zero energy campus (Feasibility and cost estimation)”, submitted by us, is based on actual work carried out by us. Any references to work done by any other person or institution and any material obtained from other sources have been duly cited, referenced and acknowledged. We further clarify that the thesis has not been published or submitted for publication anywhere else.

ABSTRACT

In today's world climate change is a serious problem faced by all the countries. Therefore, to combat it the only way forward is to construct greener and less energy consuming buildings. Moving towards zero energy buildings is of high importance as buildings are the highest consumers of energy thus construction of greener buildings will lead to the conservation of already depleting fossil fuel reserves. These Net Zero Energy buildings will ultimately become a part of Net Zero Energy Communities.

With this pretext, our project is aimed to convert our university campus into a net zero energy campus which will lead to reduction in air pollution and lesser CO_2 emissions. This project will also bridge the research gap that exists between the academia and industry while setting a benchmark for future projects. This project is our contribution towards environmental conservation and reduction of pollution.

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Chapter 1

INTRODUCTION

This chapter offers an understanding of the basic concept of zero energy buildings as to why it is essential to shift to zero energy buildings

1.1 **Background**

In developing countries there is more need for inexpensive energy, as it can help in improving life standard. All the things that help people to better their quality of life and build better life, like, industry, modern agriculture, increased trade and better-quality transportation, are very much dependent upon reliable energy supply.

Most of the energy is produced from hydrocarbons. According to a report, in 2015 the 48.1% of total electricity generated in European Union countries is from conventional sources, which depicts that modern world is facing serious problems because of these conventional, fossil-fuel based, energy sources. These conventional sources are becoming scarce and also produce a lot of problems including emission of pollutant gasses that cause greenhouse emissions, acid rains, an increase in global warming and also the ever-increasing supply and demand gap. The total carbon emissions have increased many folds from 0.001 Billion metric tons (in 1827) to 10 Billion metric tons in till 2007 (Thomas A. Boden 2010) . Also, using the fossil fuels results in the addition of radioactive materials to the atmosphere. Just in the year 2000 five thousand tons of uranium and nearly twelve thousand tons of Thorium were released into the atmosphere(Finahari, Salimy et al. 2007).

Taking into account the economy, high fuel prices are also needs to be considered. According to the International energy agency, fossil fuel industry gains about 550 million dollars subsidies from governments across the globe. To face the complications or challenges, worldwide, the energy skeleton needs to be refashioned and replaced from fossil-fuels to renewable energy. This will not only result in low costs but also minimized pollutants and greenhouse emissions and will lead towards a sustainable environment in the light of monetary obligations and societal needs.

Types of renewable energy are solar, wind, geothermal, nuclear, hydropower, biomass and marine energies. These renewable energy sources can be used for different purposes like electricity production, air and water heating/cooling and off-grid like in rural areas and remote places. . If utilized in an efficient way these resources can guarantee a country’s energy security and will reduce its dependency on other countries.

1.2 Net zero energy buildings (NZEBs)

Net zero energy building is basically a new concept making its way into the rapidly advancing world. While it has started to make its way into countries such as USA, Australia among others, progress in our own country Pakistan has been relatively slow due to fewer developments in the research sector. And why is there a shift to net zero energy building vital in today's world? Pollution levels in the world are at a rise; countries such as Mumbai and Lahore are three times above the recommended air pollution levels set by WHO, residents of these cities are inhaling air that is equivalent to two packs of cigarettes a day. These levels of pollution are due to many reasons and one of them is the production of electricity on large scales using nonrenewable resources such as fuel and coal. The burning of these items produces harmful gases. All over the world huge power stations are burning these non-renewable fuels to light up our cities and every single day harmful fumes are increasing in the atmosphere and depleting the ozone.

1.3 The concept of NZEBs

Zero-energy buildings, also known as a net-zero energy building (NZEB) or a zero-net energy (ZNE) building is the one whose net energy consumption is equal to zero, i.e. the total amount of energy used by the building annually approximately equalizes to the amount of renewable energy created on the site, this energy can be produced by renewable as well as non-renewable means, preference is given to renewable means so that the non-renewable resources can be saved. While traditional buildings use on average 40% of the total energy produced by fossils fuels all around the world, zero energy buildings can harvest their energy from wind, solar and biogas among others.

Using non-renewable energy sources produce certain greenhouse gases that are fast depleting our ozone layer which protects us from the harmful rays from the sun. This is leading to the melting of snow at our North and South Pole as well as in other mountainous regions of the world. This melting is causing mass flooding all over the world whether it be USA or Pakistan. Another big advantage of these buildings is that they ultimately don't contribute towards the greenhouse emissions to the atmosphere as compared to the similar buildings running on non-renewable sources.

These buildings can be connected to the central grid for the storage of electricity they are producing or they can have independent storages. A group of zero energy buildings connected to a central grid is perhaps the best option for our future because in this way any energy produced by a building during its non-active hours will not be wasted, it will be transmitted to the grid station and be transferred to another building connected to the grid that may be lagging in its production.

Moving over to the cost effectiveness of these buildings, this factor depends a lot on the design phase. To conserve energy, zero energy building's design is way different from the conventional construction practice. Techniques can be applied which will make these buildings consume as less energy as possible. Some of these techniques are prevailing breezes, solar heat, Sunlight and the cool of the earth below a building are some of the techniques that can be used. They can be used to provide stable indoor temperatures and day lighting with minimum mechanical means.

NZEBs are normally optimized in such a way that they use solar thermal mass combined with passive solar heat gain and shading to stabilize quotidian temperature variations during the day.

1.4 Energy crisis in Pakistan

Pakistan is an underdeveloped and over populated country which needs stable sources of energy to cater for its needs and to progress. According to a study, approximately 38 % of the Pakistanis have no access to electricity. Currently, about 54% percent of the rural population has no approach to electricity, compelling them to carry along with a substandard existence of poverty and social conflict (Mirza and Khalil 2011). Pakistan uses maximum portion of its energy consumption for domestic purposes. Industrial sector uses 27.5% while Domestic sector consumes 45.9% of the total energy Consumption. Nearly half of this energy is consumed for cooling and heating purposes(Mirza and Khalil 2011).

Thermal power plants (Coal, oil and Natural gas) generate about 64% of the total electricity in Pakistan. The already fragile Pakistani economy is getting hammered by the high fuel prices. Also, these thermal power plants especially coal plants are having repugnant effects on ecological system and human health. According to a report, energy sector is responsible for 80% of the overall CO_2 emissions. It is estimated that CO_2 emissions will be three times in 2030 than in 2010 similarly nitric oxide and sulfur dioxide emissions are also estimated to increase by 4 to 7 folds as well.

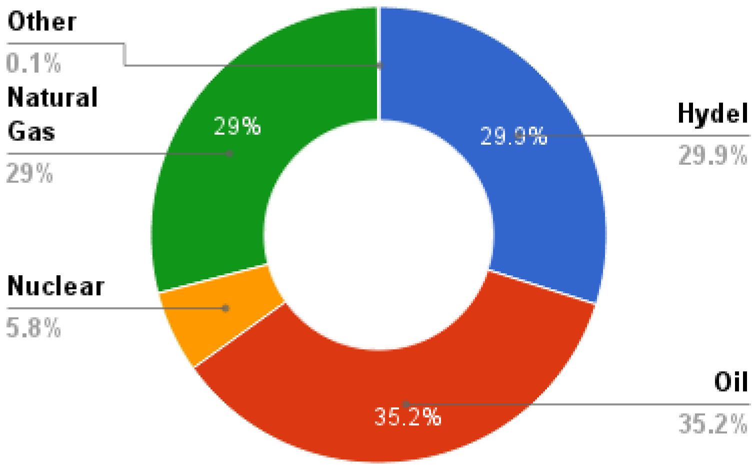


Figure 1 Sources of Power Generation in Pakistan

The electricity supply and demand gap has been increasing ever since and the shortfall did stretch to 4500 MW in 2010, 6620 MW in 2012 and remained over 5200 MW in 2013, which, on average, establishes over 50% of the country's total generating capacity of that time. The energy demand will be increasing in the foreseeable future at a swift rate of 8-10% per year according to (Shakeel, Takala et al. 2016).

1.5 Pakistan and net zero energy buildings

Pakistan is among the developing nations of this world. Limited resources and budget, uncertain political situations and security problems are major hindrances in the development of this country. As a result, progress in the construction industry as well as production of energy through nonrenewable energy resources has been negligible. This leads to another major problem of Pakistan. Pakistan is a country with very limited reserves of nonrenewable energy sources such as gas and crude oil. What Pakistan does have is a very huge supply of coal but as most of the times it is not the quantity that matters, it is the quality and the quality of the coal present in the reserves is not satisfactory.

The shift towards net zero energy buildings in Pakistan is also important because Pakistan is a country with very high levels of pollutions. Pollution levels as high as three times as those set by WHO are being observed in cities such as Lahore and Karachi. Smog created by these pollutants is blanketing the plain areas of Pakistan making it difficult for people to breathe as well as travel safely.

Pakistan is also a country in which 39% people are below the poverty line and the rates of electricity just keep on rising which is making it difficult for the general public to afford this luxury. Other than this energy production in Pakistan is never stable, it is very rare that the energy produced meets the required energy requirements which results in load shedding.

The solution to various problems of Pakistan is maybe zero energy buildings, these buildings will not require power from the main electric grid of Pakistan managed by Pakistan, thus reducing stress on it. It will also reduce the levels of air pollution in Pakistan as more and more buildings convert to zero energy building producing their energy through renewable means. Pakistan is a country where people get loads of sunshine, high wind speeds in some areas, and tons of garbage produced each day which can be used to produce biogas. Another main advantage that it can achieve is the relief it will bring to the pockets of general public as it is a onetime major investment and after that you reap the benefits of it. This one-time major investment can also be reduced if these steps are implemented on a major scale. Thus, zero energy buildings are very suitable to the current situation of Pakistan.

1.6 NUST H-12 as a net zero energy campus

Zero energy building is basically an obscure concept that has no definite meaning as of yet. There are many definitions of it as of yet and our project basically is implementing these definitions on our university campus which spans over 707 acres and houses around 7000 students and around 800 faculty members.

Catering to such a huge number produces electricity bills in excess of 9 million PKR rupees excluding the finances spend on the generators providing backup power.

These finances can be greatly reduced if NUST was to convert into a net zero energy campus. Example can be taken from Massachusetts institute of technology campus which has been converted to a net zero energy campus.

And why is NUST suitable for NZEC?

NUST has acres of land which are still of no use where a solar park could be set up, sunlight is also not a problem in this area.
Other than this wind energy can also be used to generate electricity as well as biogas as huge amounts of garbage is deposited at the back side of NUST. NUST also has its own grid station which can be used to regulate the flow of power to all the buildings of NUST.

A major advantage is that NUST is the leading university of Pakistan, if NUST were to adopt the concept of net zero energy buildings it would provide a boost to this concept in Pakistan seeing that since a major campus is running on itself, so a single building can also do that.

1.7 Objectives

The objectives of our project are as follows:

- Calculating NUST electricity demand including future consumption by taking the percentages of previous increments
- Checking suitability of renewable energy sources within NUST.
- Calculating the cost of setting up and maintenance of suitable renewable energy sources
- (through software)
- Proposing suitable locations to set up these sources seeing future expansion of NUST.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

Net zero Energy campus (NZECs) or Net zero energy buildings (NZEBs) is a very new concept and although research work is being done in developed countries on this topic but it has not been defined properly yet. To clear this concept many research papers have been written to understand what NZEBs mean and the factors that play a major role in these buildings. Moreover, findings of each paper have led to the understanding of this concept and the processes being involved, thus the following discussion aims to explain in-depth the concept of NZEBs.

2.2 NZEBs

A zero-energy buildings, also known as a net-zero energy building (NZEB) or a zero net energy (ZNE) building is the one whose net energy consumption is equal to zero, i.e. the total amount of energy used by the building annually approximately equalizes to the amount of renewable energy created on the site, this energy can be produced by renewable as well as non-renewable means. Most of the NZEBs get half or more of their energy from the central grid and return approximately the same amount at other times according to (Marszal, Heiselberg et al. 2011). Buildings that may produce energy more than their requirements over the year are called "energy-plus buildings" and buildings that needs slightly more energy than they produce are called "near-zero energy buildings" or "ultra-low energy houses". In the United States and European Union traditional buildings consume approximately 40% of the total fossil fuel energy and are contributes significantly to greenhouse gases. The principle of zero net energy consumption can be viewed as a method to reduce carbon emissions by reducing the world’s dependence on fossil fuels. Most zero-energy buildings use the local electrical grid for energy storage but some might be independent of the grid. Energy is usually produced on-site through energy producing technologies like wind, solar and biomass while at the same time reducing their net consumption using highly efficient HVAC and lighting technologies

2.3 Solar energy

The sun is the biggest source of energy. It is approximately 4.6 billion years old. The sun still has about five billion years of hydrogen fuel left to burn so it is the most renewable source we have and it can be used without causing greenhouse emission and it does have any other harmful by-products either. Amongst the various renewable energy resources, solar energy has the potential to solve energy crisis of our country.

According to the federal bureau of Pakistan statistics, in the 1980s almost 440 KW of solar energy systems were installed across different areas of Pakistan but due to the unavailability of equipment's and incompetency of technical staff they do not meet the requirements.

2.3.1 Photovoltaic cells

The direct conversion of solar energy into electricity at the atomic level is known as Photovoltaic. This phenomenon is known as photoelectric effect that causes them to absorb photons of light and release electrons. When these free electrons are captured, an electric current is produced which can be used as electricity (Green 1982).

A French physicist, Edmund Bequerel, in 1839 first noticed this effect. He found that whenever some certain materials were exposed to the rays of light they would produce small amounts of electric current. But it was in the late 1960s when the space industry tried to take advantage of this technology to provide power to their spacecraft's in space. Through space this technology advanced and the initial costs started getting lower.

A typical silicon PV cell is composed of a thin wafer consisting of an ultra-thin layer of phosphorus-doped (N-type) silicon on top of a thicker layer of boron-doped (P-type) silicon. At the top surface of the cell an electrical field is created where these two materials are in contact, known as the P-N junction. When sunlight strikes a PV cell's surface, this electrical field provides the light-stimulated electrons with momentum and direction; as a result a flow of current is generated when the solar cell is connected to an electrical load according to (Fahrenbruch and Bube 2012).

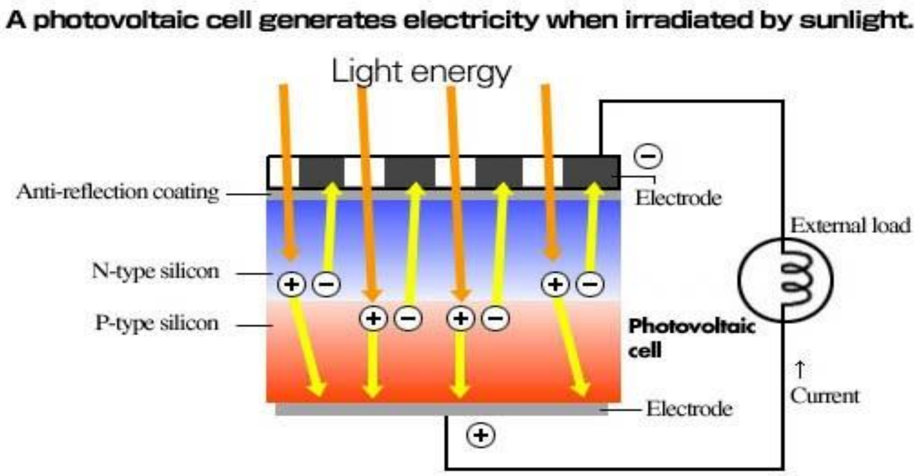


Figure 2 a photovoltaic cell

A single solar cell's capacity is very less so to increase the output a number of PV cells are electrically connected and mounted on a frame type structure known as PV module. They are designed in such a way that they supply electricity at a specific output. The electrical current produced depends upon the intensity of the light a module is striking.

To further increase the output, many modules are combined to form an array by wiring them together. Larger the surface area more electricity will be produced.

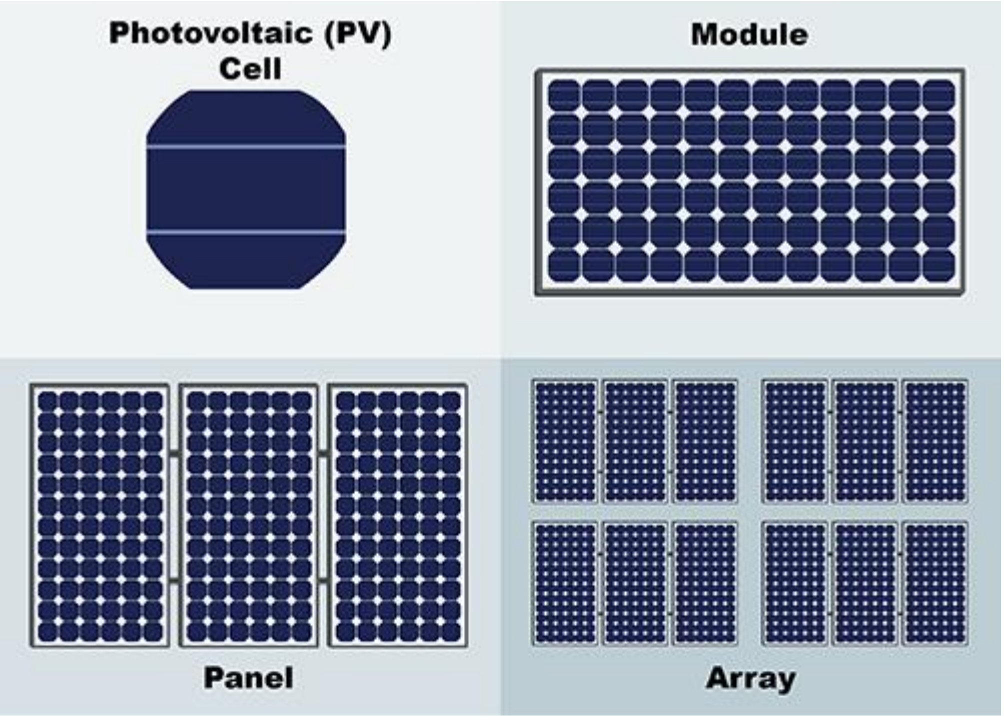


Figure 3 Photovoltaic cell

2.3.2 Types of solar panels

Solar panels are of different types depending mainly upon the purity of silicon. Greater the purity more will be its efficiency. Purity of silicon basically relates to the alignment of molecules. The more perfectly aligned they are, the better photoelectric effect will occur and more power would be produced. According to (Bagher, Vahid et al. 2015) different types of modules available in the market are following.

Table 1 Types of Solar Panels

Solar Cell Type	Efficiency-Rate	Advantages	Disadvantages
Polycrystalline Solar Panels (p-Si)	13-17%	Cheap	Temperature sensitive shorter life
Mon crystalline Solar Panels (Mono-SI)	~22%	Very efficient, high life	Expensive
Thin Film Amorphous Silicon Panels (A-SI)	~7-10%	Relatively low costs; easy to produce & flexible	Limited life
Concentrated PV Cell (CVP)	~40%	Very high efficiency rate and performance	Very expensive, cooling system needed (to reach high efficiency rate)

2.3.3 PV system

Simply producing power through arrays is not enough. A proper system has to be designed to produce convert control distribute and store the energy produced according to (Yazdani and Dash 2009). This system comprises of

- A mounting system
- Combiner Box to wire modules
- A charge controller
- Solar inverter
- Battery Bank for storage
- Miscellaneous components

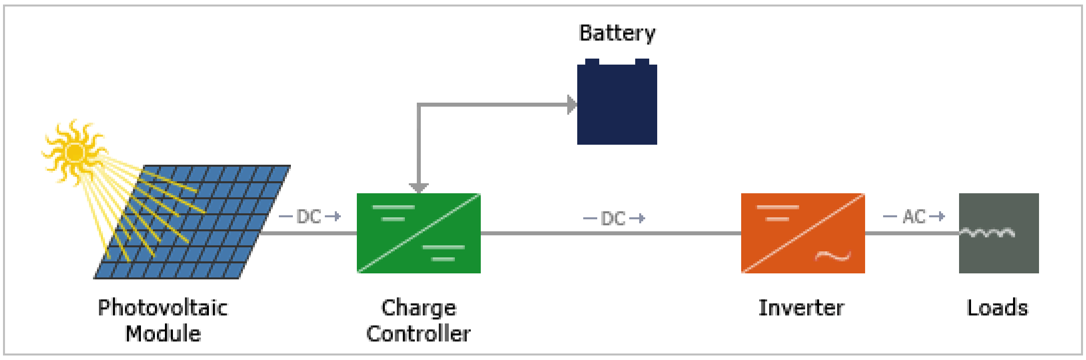


Figure 4 PTV System

2.3.3.1 Mounting system

PV mounting systems are used to adhere the panels to ground roofs or a pole. Typically, they are made of aluminum or brass. To achieve a greater efficiency, solar panels have to work at cooler temperatures and mounting them properly allows for cooling the airflow around the panels.

2.3.3.1.1 Types of mounting systems

Generally, tree types of mounts are common

- Flat roof mount
- Ground mounts
- Solar carports

2.3.3.2 Combiner box

A combiner box is used to link the panels in parallel by wiring each module’s output to the combiner box’s terminals.

2.3.3.3 Charge controller

A charge controller is used to regulate the current that is being fed into the batteries or system by PV modules to prevent the overcharging of batteries and also to block the current dripping back into the arrays at night.

2.3.3.4 Solar inverter

It is one the most important component of the PV system. The main purpose of the inverter is to convert the dc current produced by the PV modules into ac current so that can be then fed into the system.

2.3.3.5 Battery bank

Battery bank is an optional component depending upon the type of the photovoltaic system being used and whether the grid is connected to the electricity grid or not. Size of the bank depends upon the size of the projects and the type of PV system being used.

2.3.4 Types of PV systems

PV systems are of three types as mentioned in (Sick 2014).

2.3.4.1 On-grid system

This is the most common type of grid used. The PV system is connected to the local grid directly and there is no need of batteries. Any electricity that is generated is sent off to the grid (other than directly used at home) and a tariff is paid for the energy that is exported.

2.3.4.2 Off-grid system

In this type of system instead of transmitting additional power to grid it is stored in batteries and there is no attachment to the local grid. Due to higher cost of batteries and inverters, this system is comparatively expensive than the on-grid system.

2.3.4.3 Hybrid system

This system is a mixture of the both on grid and off grid system. On grid systems can take advantage of batteries as well i.e. storing the energy generated at day and then using it at night. Once the stored energy is consumed the grid can be then used as a backup source as shown in the figure.

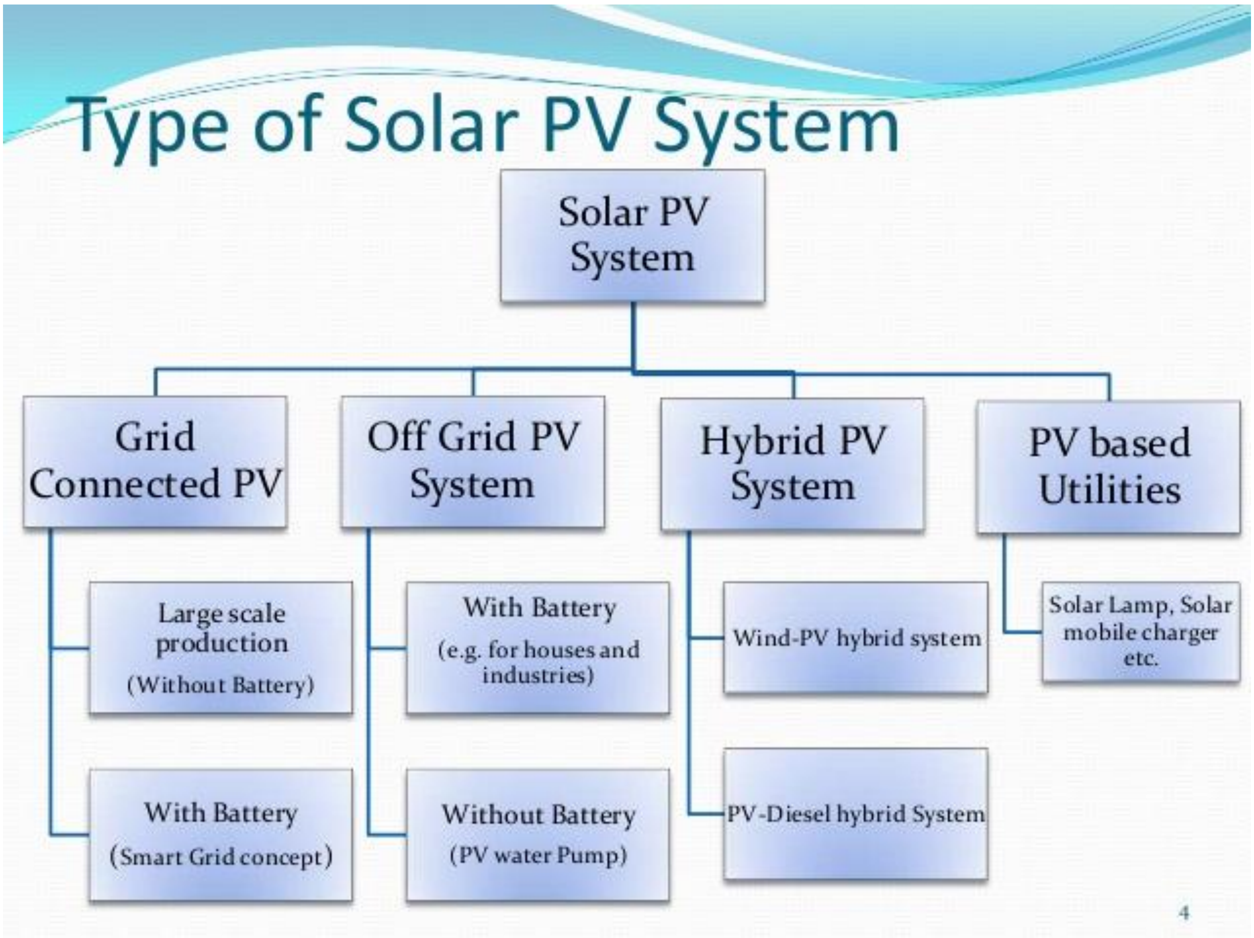


Figure 5 Types of Solar PV System

2.4 Wind energy

The natural movement of the air particles in a specific direction is known as wind. These particles naturally have a velocity and hence they have kinetic energy. That kinetic energy can be converted into mechanical power using wind turbines and subsequently this mechanical power can be converted into electric power via generators.

2.4.1 Wind turbines

A wind turbine is used to convert the kinetic energy possessed by wind into mechanical energy which can then be used for different purposes. With the help of latest technology wind turbines nowadays are capable of converting a great amount of wind energy into electricity. All this is achieved due to the blades which are developed using latest tools and equipment's.

To explain its working in the simplest way possible if the blowing wind is able to make the blades rotate we will receive electricity via the generators attached. Basically, the blades are connected to a rotor which in turn is connected to the main shaft. The main shaft is connected with the generator. When blades move due to wind speed they ultimately spin the generator which subsequently produces electricity (Mathew 2006).

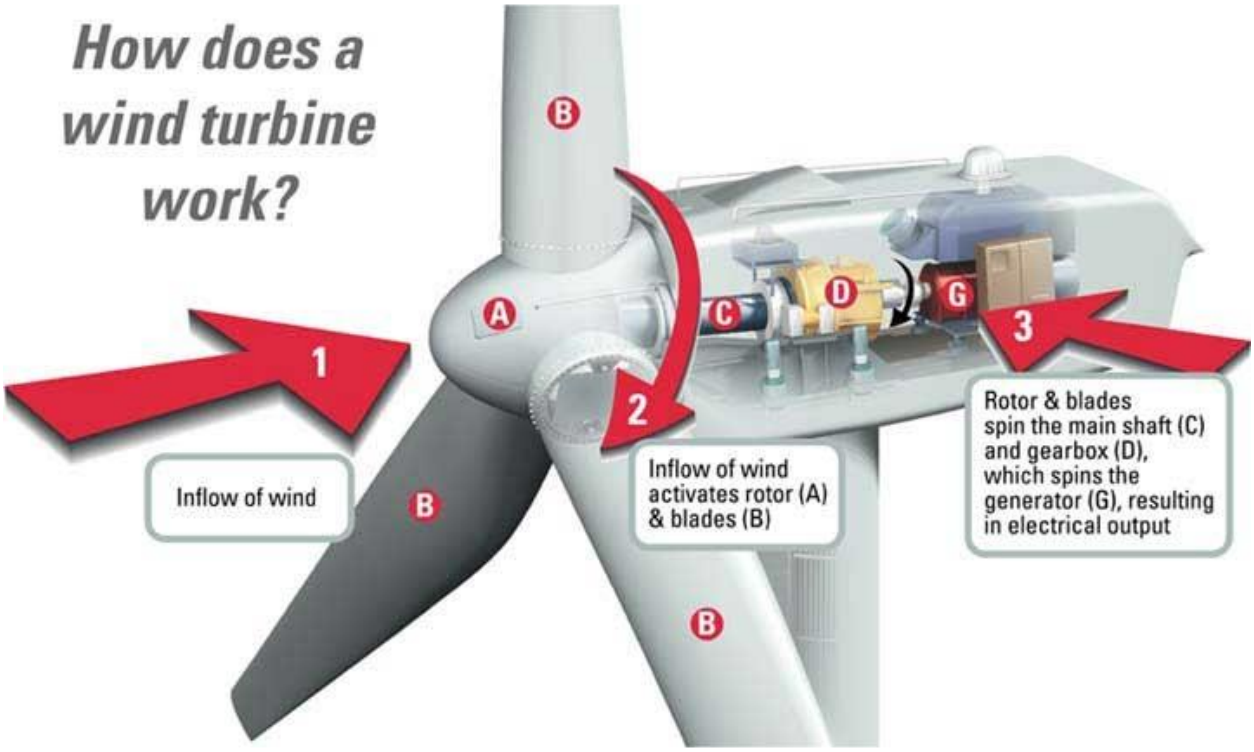


Figure 6 Working of a Wind Turbine

2.4.2 Wind class

To optimize the turbine performance location weather conditions of the area wind speed gust and turbulence needs to be considered. Considering the parameters of average wind speed, turbulence faced and the extreme gusts that can occur in 50 years the International Electro Technical Commission (IEC) has assorted them into following classes (Fingersh, Hand et al. 2006).

Table 2 Wind Class

Class	Category	Wind Speed
IEC Class I	High Wind Speed	10.0 m/s
IEC Class II	Medium Wind Speed	8.5 m/s
IEC Class III	Low Wind speed	7.5 m/s
IEC Class IV	Ultra low speed	6.5 m/s

2.4.3 Software

Different design software's are available online for solar and wind energy analysis. These software's helps in the feasibility analysis design process simulations modeling and visualizing of solar and wind. We needed to do the feasibility analysis so we chose the software's related to that.

2.4.3.1 PC1D

PC1D is commercial software which is used for solar cell modeling. Since our work was related to the feasibility analysis and it did not involve the understanding of device physics so this software wasn't used.

2.4.3.2 Retscreen expert

This software was developed by the government of Canada. This software not only helps with the identification of the sites but also helps with the assessment and development of the technical and monetary aspects the renewable energy sources and energy efficiency projects. This software was used to determine the irradiance insolation and solar capture of NUST. Moreover, the number of solar panels and their effective area was also calculated using this software.

For the analysis of wind energy ret screen was used. Through this software the annual average wind speed of Islamabad was calculated and then feasibility analysis was carried out.

2.4.3.3 Wind data generator (WDG)

WDG is world renowned software used for wind modeling and to design wind turbines. It can be used to create a wind atlas at any location on earth giving us the wind speed about that particular area at any height. This software not only takes in account the wind speed but also focuses on the inflow angles shear turbulence and weather data as well. This is what makes this software superior to others. However due to the unavailability of this software we couldn't use it for the prefeasibility analysis and ret screen was used.

Chapter 3

METHODOLOGY

3.1 First objective

Our first objective was calculating NUST electricity demand including future consumption by taking the percentages of previous increments

3.1.1 Gathering of NUST electricity bills and generator data

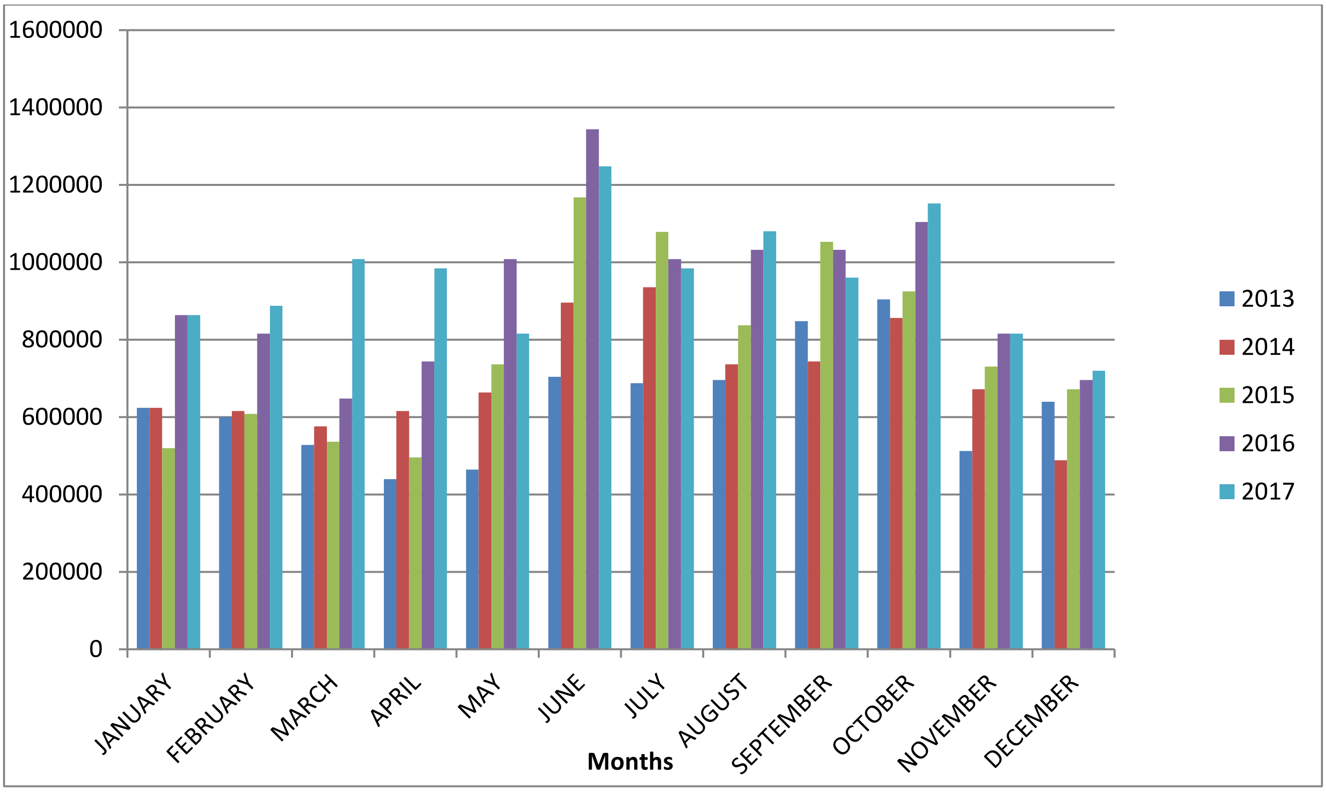
In order to get the consumption pattern of NUST electricity demand the bills of Islamabad electric supply company(IESCO) of the past five years of National university of sciences and technology (NUST) were obtained from the project management office NUST. Since our country has gone through huge amount of load shedding so the generators data of the past five years had also been extracted. The units were added up together and the consumption was as follows:

Table 3 NUST Electricity bills and Generator data

IESCO KILOWATTHOUR UNIT CONSUMPTION (NUST)						
		YEARS				
MONTHS						
		2013	2014	2015	2016	2017
JANUARY		624000	624000	520000	864000	864000
FEBRUARY		600000	616000	608000	816000	888000
MARCH		528000	576000	536000	648000	1008000
APRIL		440000	616000	496000	744000	984000
MAY		464000	664000	736640	1008000	816000
JUNE		704000	896000	1167840	1344000	1248000
JULY		688000	936000	1078800	1008000	984000
AUGUST		696000	736000	837120	1032000	1080000
SEPTEMBER		848000	744000	1053360	1032000	960000
OCTOBER		904000	856000	924720	1104000	1152000
NOVEMBER		512000	672000	730560	816000	816000
DECEMBER		640000	488000	672000	696000	720000

The graphical representation of the data is as follows:

Figure 7 NUST Electricity Data



3.1.2 Analyzing the data

No particular trend was identified in the NUST. To be on the safe side the data of the year 2017 was taken as the base value for all further calculations as this was the year with the least load shedding and there was minimal use of generators.

Using the 10% increase the estimated power consumptions of year up to 2025 was calculated. Contingencies for future expansions of NUST were also made. These results are as follows:

From these results the consumption of the year 2025 was calculated that also compensated for future expansion of NUST and all further calculations to see the feasibility of different renewable energy resources were made based on this value.

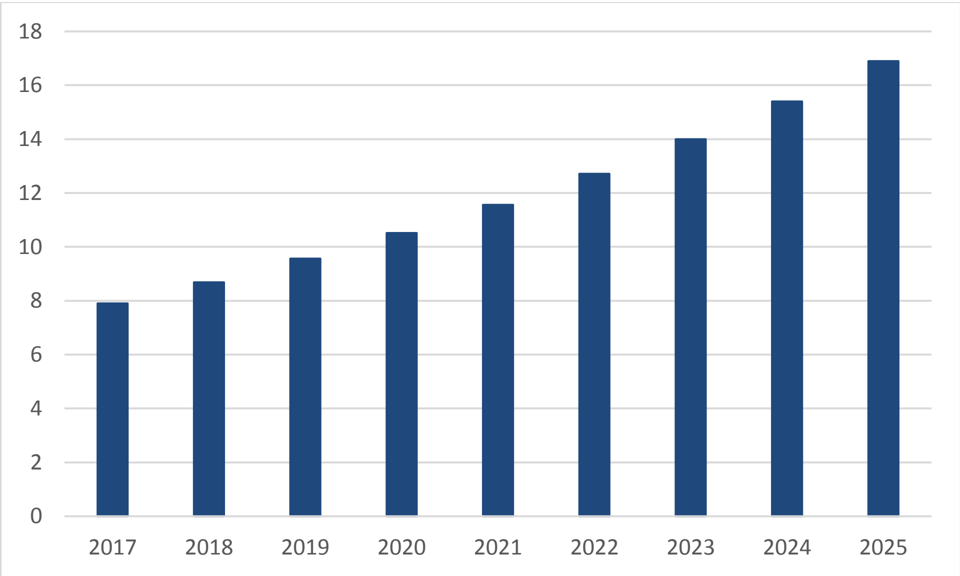
The expected consumptions of the years up to 2025 are as follows:

Table 4 Yearly Consumption

YEAR	CONSUMPTION (MW)
2017	7.9
2018	8.69
2019	9.56
2020	10.52
2021	11.56
2022	12.72
2023	14
2024	15.4
2025	16.9

The graphical representation of this data is as follows:

Figure 8 Yearly consumption



3.2 Second objective

The second objective was to check the suitability of renewable energy sources within NUST.

3.2.1 Biomass feasibility check

This step included checking the feasibility of production of energy through biomass. Energy production by biomass is a tricky process. It can be done by incineration of waste products or by letting it decompose which is a long term process. The suitable method for energy production in NUST H-12 campus seemed to be through incineration.

3.2.1.1 Components of biomass

The basic components of waste that are required in energy production by biomass are as follows:

- Crop residue
- Animal manure
- Municipal solid wastes

These are the materials which when burned will have the most effective energy production. All these materials can be easily burned too and not much heat is required in burning them

The main components of waste produced by NUST are:

- Paper
- Metal
- Human waste

Out of these the only effective waste material is human waste.

3.2.1.2 Important pointers about biomass

A second important point that was taken into consideration was the separation of these wastes, as metals and plastics had to be separated as they don't burn or melt at such low temperatures. So additional cost would be incurred as a result of setting up a waste separation plant.

Thirdly, burning as always causes smoke pollution and burning of such waste at such high temperatures would expel harmful components into the air which create breathing problems. Even if these harmful components are not released into the air, smoke alone is enough to cause breathing problems from the faculty and students who live on the campus in the faculty residencies and in the hostels.

3.2.1.3 Cost of energy production by biomass

Setting up cost per kW: PKR 300,000

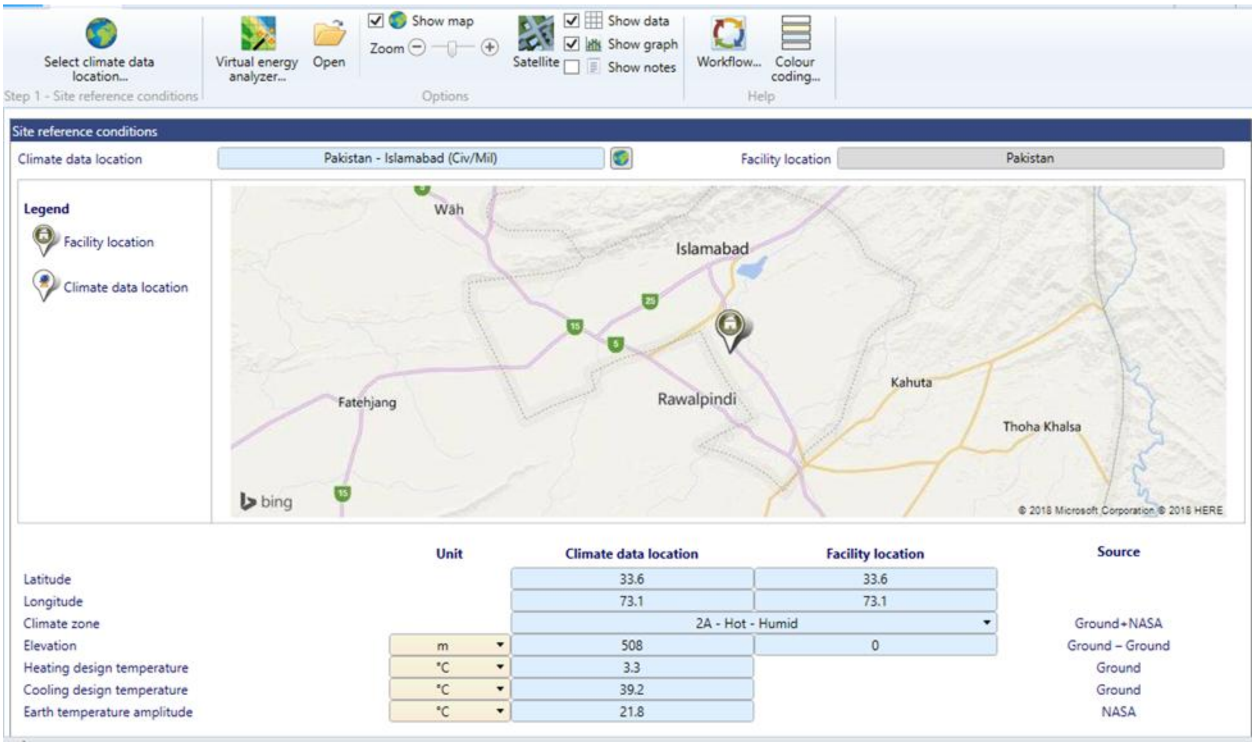
Cost of energy produced: PKR 80 – PKR 15

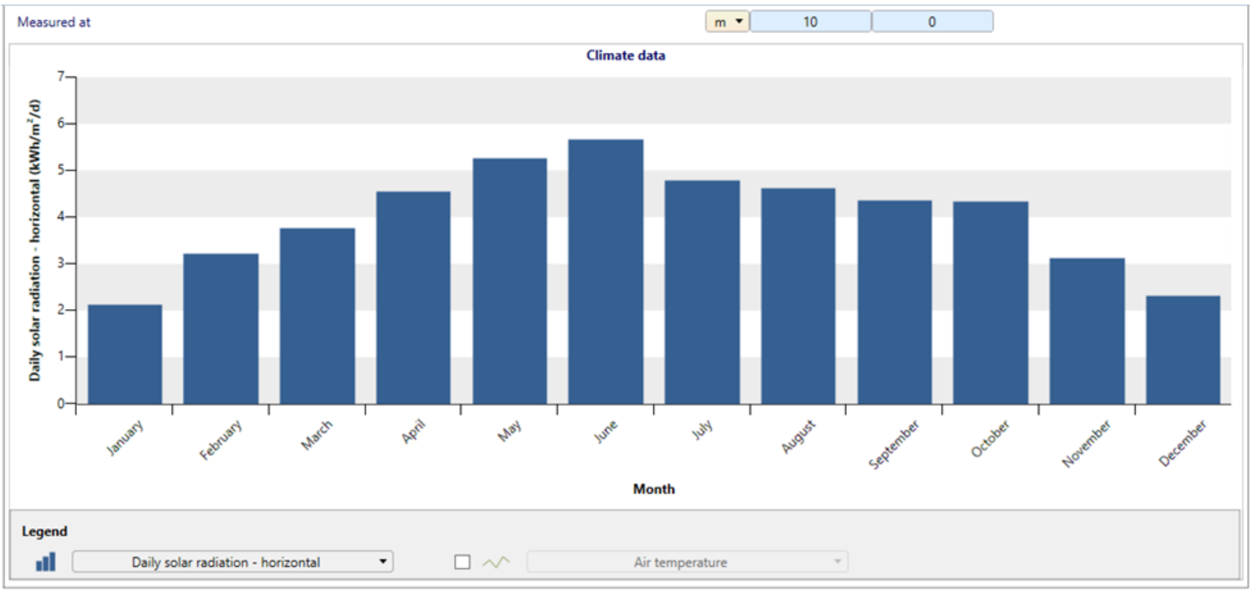
3.2.2 Solar energy feasibility check

The next step was to determine whether the solar was feasible or not and to calculate the number of solar panels required to cover the needs and the area it will take.

3.2.2.1 Ret screen simulations

Ret screen was used for this purpose. Using the location of Islamabad the average daily solar horizontal radiation was calculated.





NUST H-12 solar capture was ideal.

3.2.2.2 Important pointers of solar energy

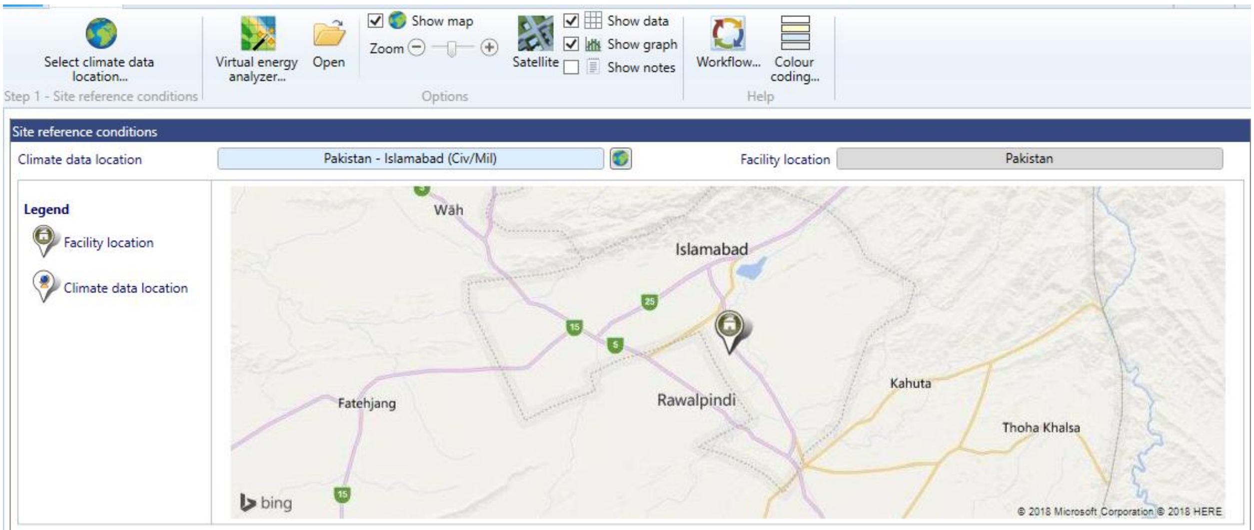
NUST had already received proposals of setting up solar power from firms such as sky electric and CAS-EN department. A huge amount of empty space is available inside NUST. Huge amounts of sunlight available throughout the year.

3.2.3 Wind energy feasibility check

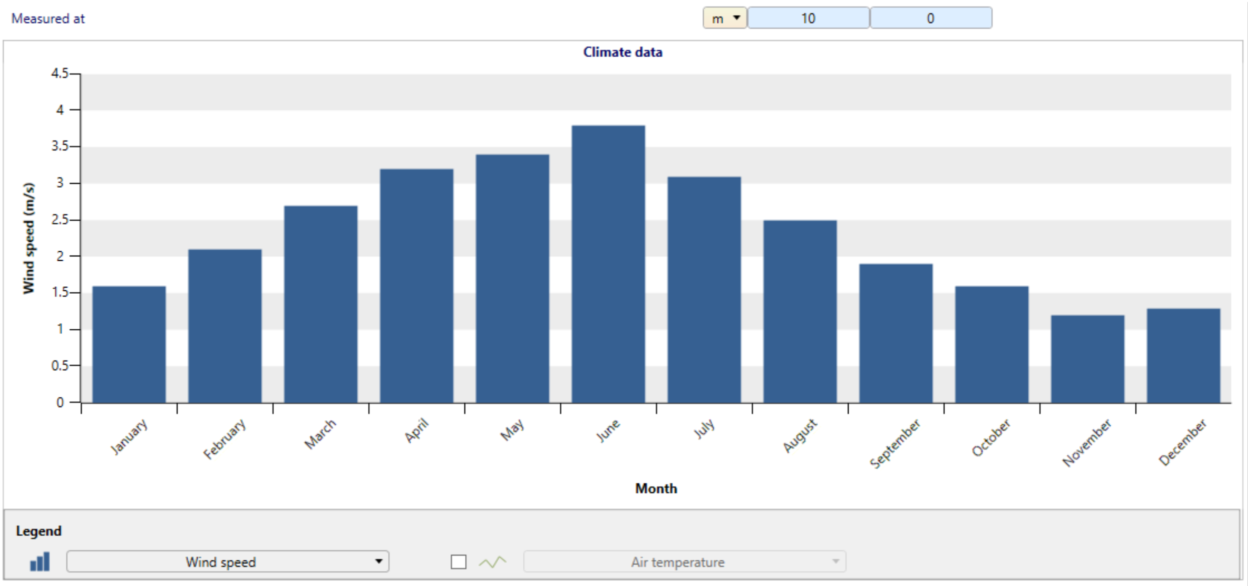
To see whether the wind power was feasible for NUST, calculations and research work was planned.

3.2.3.1 Ret screen simulations

Ret screen software was used to import the data for this particular location. The first step was to calculate the annual average wind speed in Islamabad region. The results were as follows



	Unit	Climate data location	Facility location	Source
Latitude		33.6	33.6	
Longitude		73.1	73.1	
Climate zone		2A - Hot - Humid		Ground+NASA
Elevation	m	508	0	Ground – Ground
Heating design temperature	°C	3.3		Ground
Cooling design temperature	°C	39.2		Ground
Earth temperature amplitude	°C	21.8		NASA



From the software it was found that the average annual speed that NUST experiences is 2.4m/s at a height of 10 meters from the ground.

Table 5 Wind Speed

Wind Speed	Month
m/s	
1.6	Jan
2.1	Feb
2.7	Mar
3.2	Apr
3.4	May
3.8	June
3.1	July
2.5	Aug
1.9	Sep
1.6	Oct
1.2	Nov
1.3	Dec
Average 2.4	

According to International Electro technical Commission (IEC) NUST lies in a class IV neighborhood i.e. the wind speed is very low to produce electrical power. Due to such low speed a large wind turbine cannot be installed here because it would be of no use. But small wind turbines are also not financially viable here because for that the average wind speed needs to exceed at least 6 to 8 meters per second

3.2.3.2 Market survey

Due to low wind speed in major parts of Pakistan the trend of wind power is very less as compared to solar power. Most of the companies operating in Pakistan are international. Very few of them are local so doing a survey and getting a quotation was a tough task but we did manage something.

Table 6 Market Survey

SHARIF INTERNATIONAL

RENEWABLE ENERGY | ENERGY CONSERVATION | AVIATION

Hummer 5kW/10kW On-grid Wind Turbine System Pricelist

Date: 18th, April, 2018

S/N	Description of the goods	H6.4-5kW Ex Khi	H8.0-10kW Ex Khi
1	Wind generating system	$9,413	$14,655
2	On-grid rectifier, dump load & inverter system	$4,725	$9.975
3	Hydraulic tower	$7,200	$11,415
4	Freestanding tower	$4,455	$6,600
5	Guyed tower	$2,250	$2,700
Total with hydraulic tower		$21,338	$36,045
Total with freestanding tower		$16,380	$31,230
Total with guyed tower		$13,905	$27,330

Sharif International Company was kind enough to provide us with this quotation. So it would cost around 300,000 per kW of electricity provided if the conditions are ideal. Moreover the maintenance cost of a wind farm is somewhere between 35 to 50 percent of the initial cost so per kW can cost around 450,000 PKR.

3.3 Third objective

Calculating the cost of setting up and maintenance of suitable renewable energy sources (through software).

The only suitable renewable energy resource in NUST was solar.

The steps followed in calculating the total area required and the total cost of the project is as follows:

3.3.1 Optimum tilt angle

Optimum annual tilt angle for Islamabad region was found out to be 56 degrees from the vertical. This was calculated by taking a mean of the monthly optimum annual angles. Due to high cost and maintenance trackers were not used. Rather fixed mount solar panels are preferred.

3.3.2 Selection of panels

To determine the number of solar panels a type had to be selected. Since solar power is trending very much nowadays in Pakistan so there was a variety of solar panels available to choose from. The available solar panels are mentioned in chap 2.

We had to select between mono crystalline and poly crystalline solar panels as both were quite good, internationally recognized and readily available.

3.3.2.1 Mono Crystalline Benefits

- Have a higher efficiency
- Cost comparatively more
- Consumes less space
- Have a longer life span

3.3.2.2 Poly Crystalline Benefits

- Comparatively cheap
- More efficient in warm weather
- Less silicon is wasted in the process

3.3.3 Selection

Poly crystalline panels were selected to be used instead of mono because cost had to be kept in mind. Also since in Pakistan the average daily temperature is quite high so that can affect the efficiency of mono Si. Hence Poly Si were preferred.

3.3.4 Selecting manufacturer & model

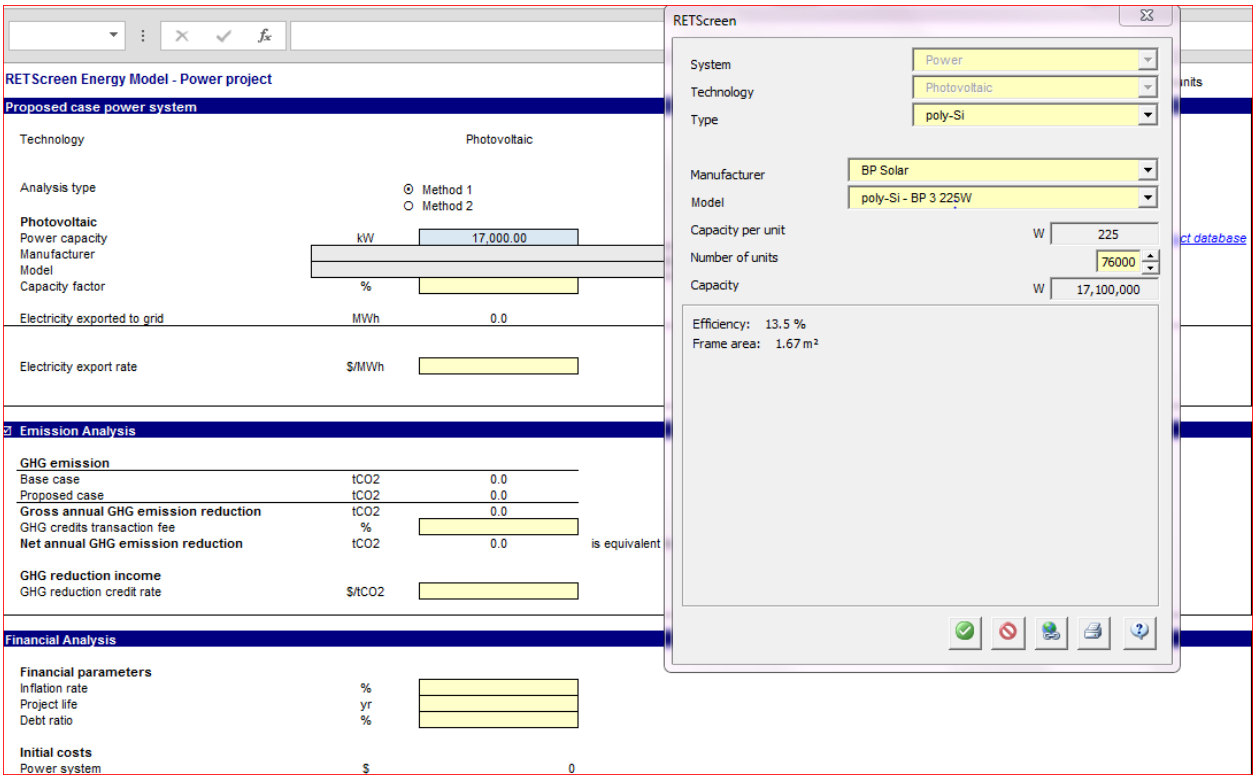
To proceed further we could not select a local manufacturer as its database was not uploaded in the software we were using. So we had to select an international manufacturer whose products were not only available in Pakistan but also it was present in the ret screen's database. Based on the factors "BP Solar Company" was selected. The model selected was "poly-si-bp 3 225W". General specs of this model are

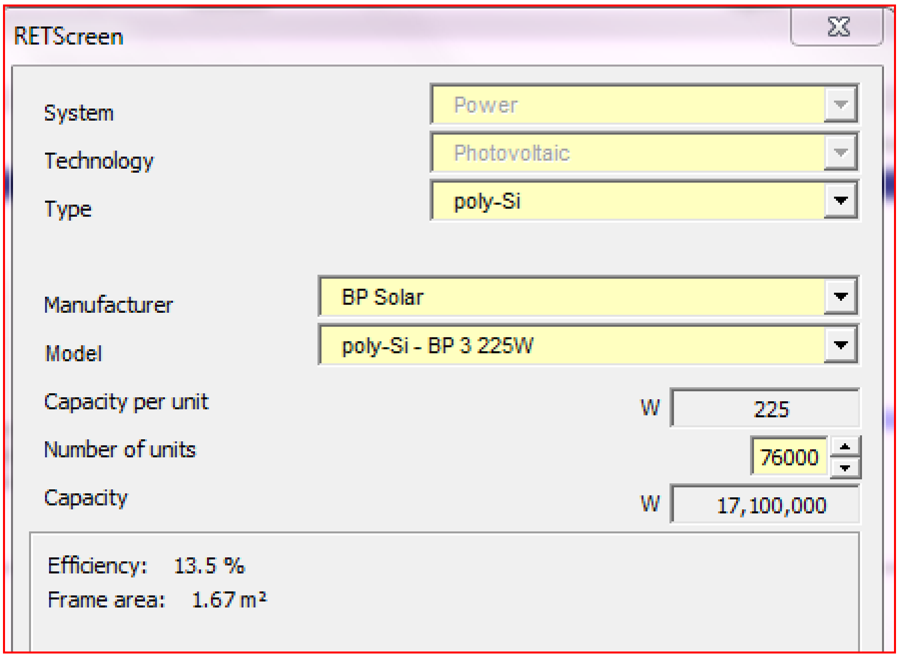
Table 7 Manufacturer and Model Data

STC Power Rating	225W
PTC Power Rating	201.2W
STC Power per unit of area	12.5W/ft^2 (134.2W/m^2)
Peak Efficiency	13.42%
Power Tolerances	-3%/+3%
Imp	7.59
Vmp	29.7V
Isc	8.13A
Voc	37.3V
NOCT	46°C

3.3.5 Calculations

The output of a single panel was 225 W. now from the software it was found that to generate 17 Mw of electricity a total of 75,556 panels had to be installed. To round off a total of 76000 panels will be installed which will be able to generate approximately 17.1 megawatt of electricity.





3.3.6 Space required

From the calculations shown above it was found out that each solar panel covers an effective area of 1.67 meter square. While designing a solar park there are a number of factors that has to be kept in mind such as the shadowing factor, the optimum tilt angle and any presence of tall buildings in the surrounding needs to be considered.

Keeping all of the above mentioned factors in mind and seeing the local trend a value of 5 acres per megawatt was selected. So for 17 megawatt solar plant around 85 acres of land will be required.

3.3.7 Losses

Although the inner losses of a solar panel are catered for the above given value but there are some losses related to the pv system. Some of the major losses are

Table 8 Losses Percentage

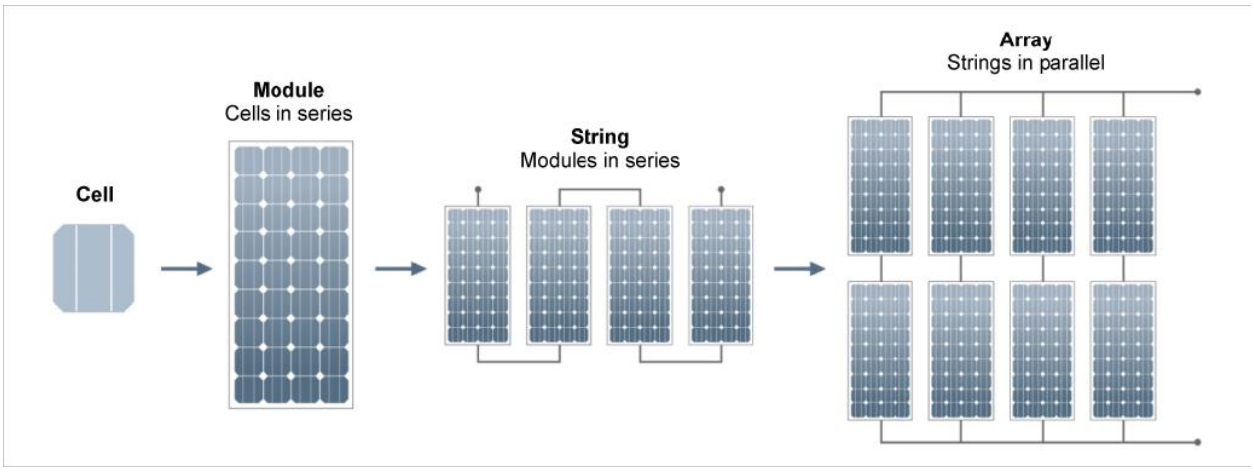
Losses	Percentage
Global tilted irradiation due to terrain shading	6
Module's polluted surfaces	3
Partial shading of strings by modules from the preceding rows	0.5
DC cable losses	1.5
Inverter losses	0.2
AC cable and transformer losses	0.7
Modules mismatch	0.5
Temperature losses	3
Total	15.4%

This means that each module will produce 225 w of power at its full efficiency but due to these losses only 190 w of electricity can be transmitted to the grid.

So based on these calculations and losses, the new number of the required solar panels are found to be approximately 90,000. So to produce 17 megawatt of electricity we need to install 90,000 solar panels.

3.3.8 Array sizing

How many modules should be placed in an array depends upon the size and capacity of the inverter. The size of a string can be anywhere between 8 to 5250W. The capacity of the inverter attached determines the number of strings in a single. Following diagram illustrates the concept of a string and array.



3.3.9 Cost analysis

From a market survey it was found out that different types of solar panels are available in Pakistan at different prices. Their prices range from pkr 65-300 per watt. The desired solar panel i.e. "poly-si-bp 3" had a price ranging from 100 to 150 pkr per watt. This price does not only include the price of a single panel bit also covers up the installation cost, Inverters cost, wire cost and other miscellaneous costs as well.

An average of 120 rupees per watt was assumed to be on the safe side and calculations were done based on this assumption. Also this value was assumed for the ground mount panels only. In case of car ports or parking sheds an additional cost of building the lightweight structure has to be added as well which was assumed to be 15 rupees per watt.

The total watts required were about 17,000,000 to be generated, and the price per watt for ground mounted modules came out to be Pkr 120, whereas the price per watt for solar car ports resulted in Pkr 135.

Nust has a total parking space available of around 3.17 acres, assuming that 90 percent of this land can be used for parking the Effective space comes out to be 2.85 acre or 11500 m^2.The surface area required for one panel is around 1.67-meter square. Therefore the No. of solar panels required are 6900 panels approximately. Which will generate a power of (6900 * 190) 1.31 Mw. Finally, the total initial cost ((17,000,000 – 1,310,000) * 120 + 1,310,000* 135)) becomes 2.06 billion Pkr. Life span of the project will be around 25 years. While the Maintenance cost per year will be 1.5% of the initial cost per year. Inflation rate calculated is about 5% (for the last 5 years). Maintenance cost for the first year resulted in 0.031 billion Pkr.

While for the next years an inflation rate of 5 percent has to be added. Therefore, the total maintenance cost for 25 years is about 1.47 billion Pkr

Total cost of the project over its life (initial cost + maintenance cost) comes out to be 3.53 billion

Funding options

- State Bank's Financing Scheme for Renewable Energy
- Donors/Funding Agency

State bank financing scheme for renewable energy

- Scheme is available from 1MW up to 50 MW with financing up to 6 Billion PKR
- Maximum Loan Period is 12 years
- Interest Rate applied by State Bank is 6%

Financing pattern

The annual amount (calculated by Annual Worth Analysis) NUST has to pay is 0.42 Billion for 12 years.

3.4 Fourth objective

The last objective was to propose some suitable locations to set up these sources seeing future expansion of NUST. This step was particularly tricky as the total area required for setting up the solar panels was 85 acres. NUST is huge but it has no area so large where buildings aren't already constructed or the NUST administration has not planned future expansion over there.

3.4.1 Factors considered

- Future expansion of NUST was a major factor, future plans were obtained from the project management office NUST so that the areas where buildings or other recreational areas are to be constructed can be neglected
- Another major factor was that the area had to be large enough so that one panels shadow doesn't fall on another panel, hence reducing its productivity.
- Some of the structures inside NUST are steel structures. Steel structures cannot take the load of the solar panels on them so those areas were also neglected for example the exam hall rooftop and NICE rooftop.
- Help was taken from CAS-EN department to see further limitations that any department might impose and through this approach we found that the principal of SCEE had not granted permission for solar panels to be erected on NICE rooftops.
- Car parking's were also considered, but we had to take into consideration those parking's that receive ample amount of sunshine throughout the day.

3.4.2 Locations selected

. (The area calculations were given to us by the ret screen software.)

- NICE parking
- NIT rooftop
- CIE rooftop

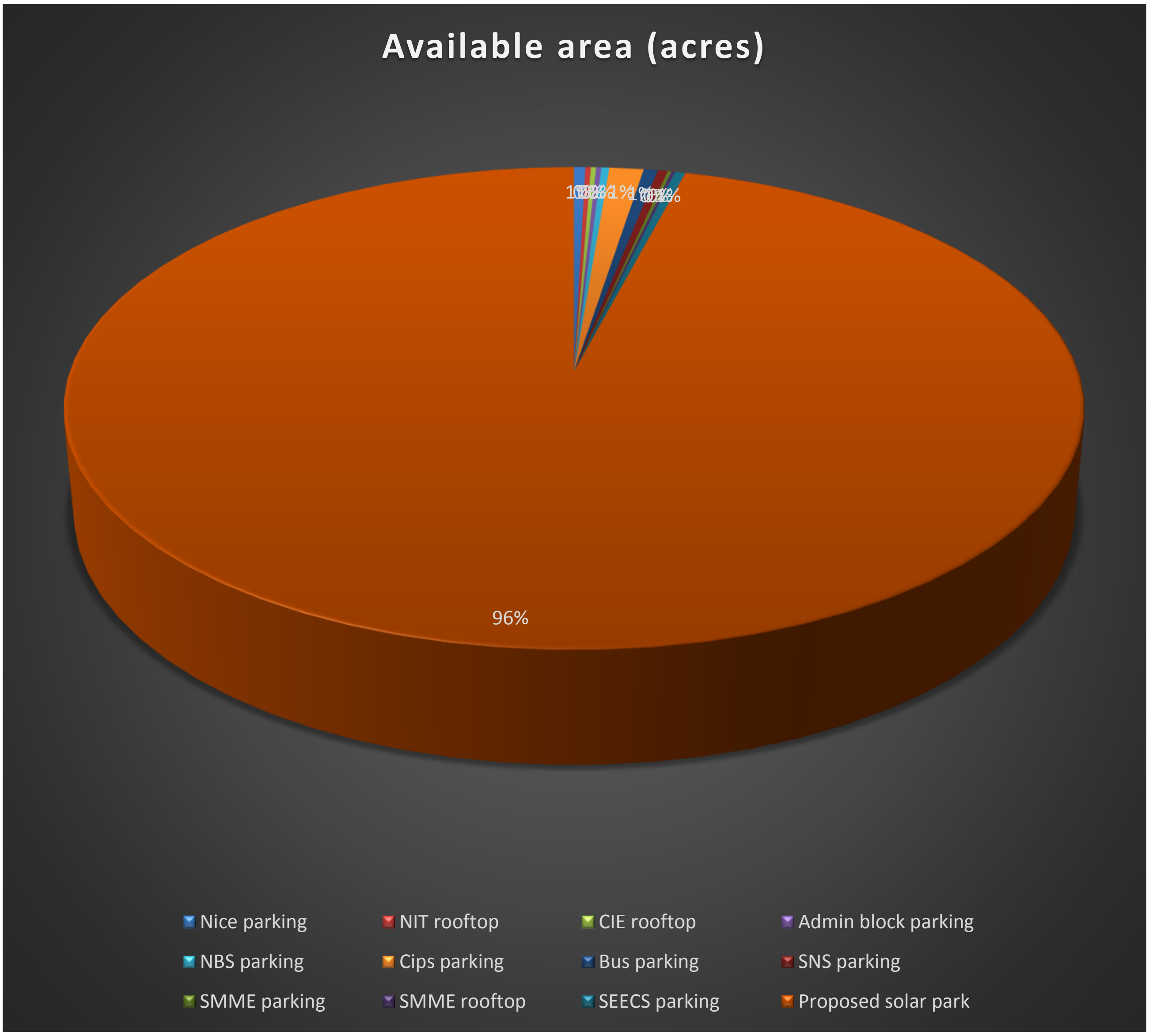
- Administration block parking
- NBS parking
- CIPS parking
- Bus parking
- SNS parking
- SMME parking
- SMME rooftop
- SEECS parking
- The solar park located on the hills running from gate-1 to gate-10 behind SCME.

The area of all these locations were summed up and their areas are as follows:

Table 9 Total areas

Required Area for 17 MW Production	
85 acres	
Location	**Available area (acres)**
Nice parking	0.37
NIT rooftop	0.18
CIE rooftop	0.17
Admin block parking	0.17
NBS parking	0.26
Cips parking	1.12
Bus parking	0.46
SNS parking	0.33
SMME parking	0.12
SMME rooftop	0.12
SEECS parking	0.34
Proposed solar park	85.5
Presently available area	89.14
For future expansion	12.12
Total area	101.26

The data represented on a pie chart showing the major contributors to the area:



Chapter 4

RESULTS AND CONCLUSIONS

Our results are as follows:

- Energy production by biomass and wind energy is not feasible.
- Energy production by solar is possible.
  Through calculations we arrived at the conclusion:
- Total consumption of power of NUST in 2017: 7.9 MW
- Estimated total consumption in 2025: 17 MW
- Type of solar panel selected: poly-si-bp 3 225W
- Total number of solar panels required (after losses): 90,000 (15.4% losses)
- Area required for 17 MW production: 85 acres
- Total initial cost = 2.06 billion PKR
- Total cost (maintenance + initial cost): 3.53 billion PKR
- Payback period for repayment of loan (best option): pay 0.42 Billion for 12 years only

Conclusion

Checking the sustainability of all the three renewable resources (solar, biomass, wind) it was concluded that solar is the most feasible option to make Nust a 'NET ZERO ENERGY CAMPUS'. Whereas biomass was not found a sustainable source because of unavailability of the required products to generate electricity. Secondly wind was not found to be a suitable option because of the finances involved initially and annually. Furthermore, even though nust will become a Net Zero Energy Campus it will have to rely on the local grid and bear some minimal maintenance cost as long as solar energy is being produced on campus.

4.1 Proposed Locations

Location	Available area (acres)
Nice parking	0.37
NIT rooftop	0.18
CIE rooftop	0.17
Admin block parking	0.17
NBS parking	0.26
Cips parking	1.12
Bus parking	0.46
SNS parking	0.33
SMME parking	0.12
SMME rooftop	0.12
SEECS parking	0.34
Proposed solar park	85.5

4.2 Visual representation of these locations

Figure 9 Proposed location of Solar panels in NUST

Figure 10 Proposed location of Solar Park

Figure 11 Solar panels in CIPS Parking

Figure 12 NBS Parking

Figure 13 Admin Block Parking

Figure 14 SEECS Parking

Figure 15 SMME Parking and Rooftop

Figure 16 SNS Parking and Bus Parking

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