Feasibility Analysis of NUST as a Low Carbon Community

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Approval Sheet

Certified that the contents and form of this thesis titled "FEASIBILITY ANALYSIS OF NUST AS A LOW CARBON COMMUNITY" submitted by Ms. Urooj Saeed, Ms. Hania Munir, Mr. Fahad Abdul Hanan, Mr. Junaid Ahmed Khan have been found satisfactory for the requirement of the degree.

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Abstract

Climate change is an emerging concern that needs to be addressed and taken care of. GHG emissions are the leading cause of climate change which has significant impacts on the human health as well as the environment. For this purpose, a new concept known as 'low carbon development' has been introduced which has attracted attention from many countries. This project is a productive approach that aims at combining both climate protection and sustainable development. The concept of low carbon development has its roots in the UNFCCC adopted in Rio in 1992. A low carbon community has a minimum contribution to the greenhouse gas emissions into the atmosphere.

Acknowledgements

First and Foremost we would like to thank Allah for granting us success in our project.

We extend our deepest Gratitude to our supervisor Dr. Salahuddin Azad whose constant support, guidance and encouragement throughout the course of the project enabled us to achieve success. He always encouraged us to innovate and think outside the box and motivated us to take up a project aimed at having an impact on the community.

Urooj Saeed

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Dedication

We would like to dedicate this project to our supervisor and our parents whose constant love, support, guidance and prayers have allowed us to be who we are today.

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1) Introduction

Pakistan is a third-world country and there is a dire need of developing a system that promotes sustainable development as well as safeguard our environment from the harmful emissions that are gradually deteriorating our surroundings. Climate change is an emerging concern that needs to be addressed and taken care of. GHG emissions are the leading cause of climate change which has significant impacts on the human health as well as environment. For this purpose, a new concept known as 'low carbon development' has been introduced which has attracted attention from many countries worldwide in order to improve the standard of living and alleviate poverty especially in low-income countries like Pakistan. This project is a productive approach that aims at combining both climate protection and sustainable development.

1.1) What is Low Carbon Development?

- The concept of low carbon development has its roots in the UNFCCC adopted in Rio in 1992. In the context of this convention, low carbon development is now generally expressed using the term low-emission development strategies (LEDS - also known as low-carbon development strategies, or low-carbon growth plans).

1.2) What is Low Carbon Economy?

- A low-carbon economy (LCE), low-fossil-fuel economy (LFFE), or decarbonized economy is an economy based on low carbon power sources that therefore has a minimal output of greenhouse gas (GHG) emissions into the biosphere, but specifically refers to the greenhouse gas carbon dioxide

1.3) CO2 Concentration in environment

- CO_2 concentration has increased by 40% since pre-industrial times, from 280 ppm to nearly 400 ppm.

1.4) Why do we need to reduce carbon dioxide emissions?

- Greenhouse gases such as **carbon dioxide** that trap heat, helping warm the globe. The surge in **carbon dioxide** levels due to human activity since the Industrial Revolution is now causing an overall warming of the planet that is having impacts around the globe.

1.5) Low carbon development COP 23

- Low carbon investment opportunities and challenges were the central agenda of Conference of Parties (COP23) While Indonesia advanced the first “Low Carbon Development Initiative” in this very conference.
- A low carbon community has a minimum contribution to the greenhouse gas emissions into the atmosphere.
- A low carbon economy is an economy based on low carbon power sources that has minimal output of greenhouse gas emissions into the biosphere.

2) Problem Statement

"To identify CO_2 emissions sources, calculate emissions from sources and devise methods to reduce CO_2 emissions within the NUST campus and feasibility analysis of NUST as a low carbon community."

3) Objectives

- To carry out Low Carbon Planning at NUST
- To analyze the Feasibility of Low Carbon Infrastructure
- To suggest the Low Carbon Management System

4) Methodology:

We adopted the following methodology to identify CO_2 emissions sources and calculate emissions from sources and then devise methods to reduce CO_2 emissions within the NUST campus. Our methodology is as follows:

Identification of CO2 emission sources

- Identification of CO_2 emission sources in NUST (electricity, gas, vehicles, Solid Waste)

Estimation of energy consumption by NUST

- Calculation of total Electricity consumption
- Calculation of total gas consumption

CO2 Emissions Calculation

- Calculation of total CO_2 emissions by electricity, gas, vehicles and Solid Waste

Proposed solutions

- To replace electricity, calculation of the number of solar panels.
- To replace gas, calculation of number of solar thermal collectors
- To replace Gasoline vehicles, estimation of number of Electric Vehicles
- Estimation of numbers of Cycles required for NUST
- Estimation of proposed off- campus parking lots locations.

CO2 sequestration by trees

- Estimation CO_2 sequestration rate by trees

General Survey

- Carrying out general survey questionnaire analysis and interviews.

Cost Estimation

- Cost Estimation of Solar panels
- Cost estimation of solar thermal collectors
- Cost estimation of EV cars.

Estimation of Payback period

- Solar panels payback period
- Total investment payback period

Savings by this project

- Estimation of annual savings by the project

5) Total Energy Consumption by NUST

5.1) Annual Electricity Consumption by NUST

Table 1 shows the electricity consumption data for NUST for a period of one year from the month of January to December. The month of June shows the maximum consumption i-e 1344000 kWh with a total electricity consumption of 11112000kWh/yr.

Table 1: Total Electricity Consumption by NUST

Month	**Consumption in kwh**
January	864000
February	816000
March	648000
April	744000
May	1008000
June	1344000
July	1008000
August	1032000
September	1032000
October	816000
November	1104000
December	696000
Total	**11112000kWh/yr**

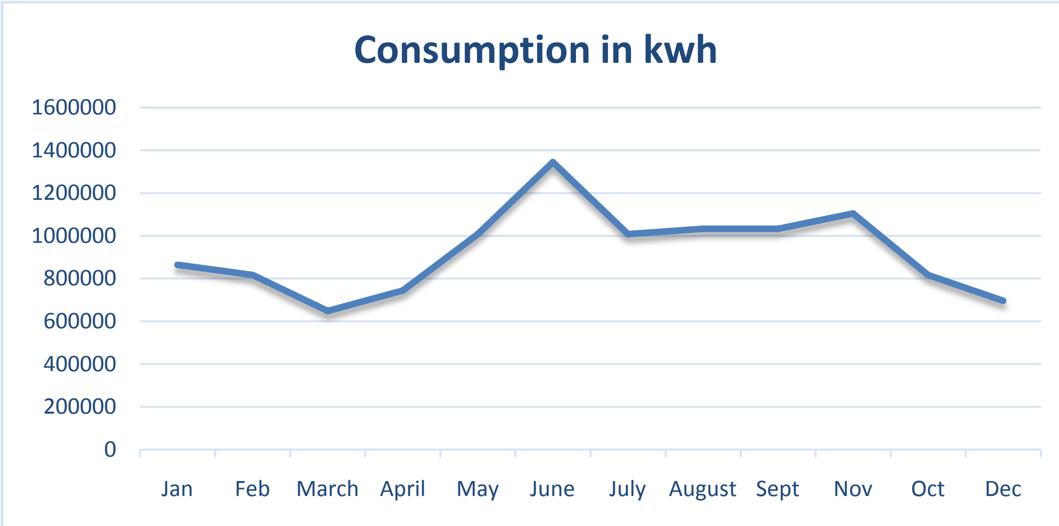

Figure 1: Electricity Consumption by NUST

Figure 1 shows the trend of electricity consumption by NUST for year 2017 from January to December. The electricity consumption fluctuates on a monthly basis exhibiting increasing trend in the summer months and decreasing trend in the winter months. Here, the peak can be observed in the month of June which depicts that electricity consumption was maximum in this month.

5.2) Annual Gas consumption by NUST

Table 2 shows the gas consumption data for NUST for a period of one year from the month of January to December. The month of March shows the maximum consumption i-e 6101 MBTU that resulted due to unexpected gas leakages with a total gas consumption of 35637.225MBTU.

Table 2: Total gas consumption by NUST

Month	Consumption of gas in MBTU
January	5397.733
February	5586.806
March	6101.16
April	2134.873
May	1487.575
June	1345.65
July	1466.322
August	1443.366
September	1242.283
October	1871.702
November	2460.799
December	5098.956
Total	**35637.225**

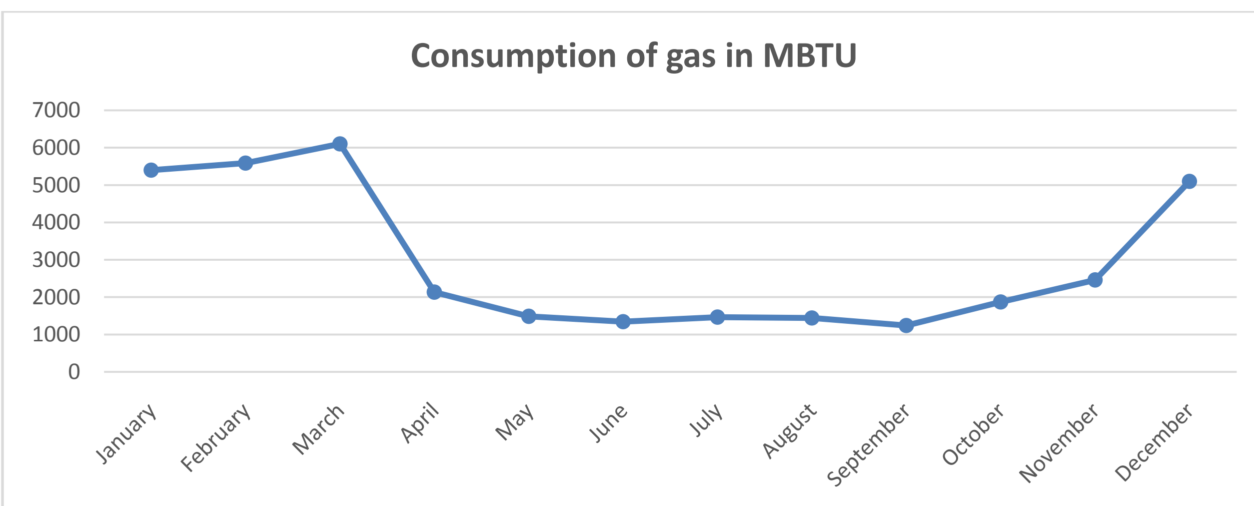

Figure 2: Gas consumption by NUST

Figure 2 shows the trend of gas consumption by NUST for year 2017 from January to December. This graph clearly shows the increasing trend in winter months and how it decreases drastically in the summer months. The peak can be observed at the month of March which might have resulted due to unexpected gas leakages.

6) CO2 emissions calculations

6.1) Total CO_2 emissions by Electricity

For the calculation of CO2 emissions by electricity, data was collected from PMO-NUST and Emissions factors for specific electricity production source were used.

Electricity consumption data (source): Project Management Office(PMO) NUST

Formula used: (Consumption MWh) × 1122.9 lbs CO_2/MWh × 1/(1-losses) MWh delivered/MWh generated × (1 metric ton/2,204.6 lb) = Metric Tons CO_2

(11112 MWh) × 1122.9 lbs CO_2/MWh × 1/(1-0.17) MWh delivered/MWh generated × (1 metric ton/2,204.6 lb) = 6792 Metric Tons CO_2

6792 Metric tons of CO are produced by 11112000kWh consumption of electricity for the year 2016. Pakistan is already relying on Coal Power Plants to compete its electricity demands. More Coal Power Plants are being installed under China Pakistan Economic Corridor (CPEC) that is going to increase emissions from electricity generation. Therefore, clean and renewable energy is the future need for Pakistan to reduce emissions.

According to World Data Bank, Distribution and transmission losses in Pakistan are 17%.

6.2) Total CO2 emissions by gas:

Pakistan was relying on natural gas from last many decades and its resources of natural gas are depleting very rapidly. Replacing the gas based appliances by clean technology, like solar thermal collector, will not only decrease the pressure on gas consumption but it will also decrease the emissions from gas consumption.

For the calculation of CO2 emissions by gas, data was collected from PMO-NUST and Emissions factor for natural gas was used.

Gas consumption data (source):Project Management Office(PMO) NUST

Emission factor for Natural Gas: Natural Gas= 53.07 kg CO_2 / MBTU

Formula used: CO_2 emissions by Gas= Emission Factor × Consumption of gas

CO_2 emissions by Gas **=** 35637.225 ×53.07 = 1891 Metric Tons CO_2

Calculation(Source): US Energy Information Administration(EIA)

6.3) Total CO2 emissions by vehicles

Economic projects, like CPEC, will increase the number of vehicles on the road. Infrastructure is already been developed by the government. As the number of vehicles on the road will increase, their corresponding emissions will also increase. Therefore, replacing the convention gasoline vehicles by electric vehicles is the need of time. Clean technology will reduce the emissions from vehicles and it will also promote the sustainable development in Pakistan.

Data Source: Manual Data Collection of peak hours at Gate No.1 and Gate No.10 over the duration of one week

Hostel Vehicles Data : Deputy Director Hostels Office

Average Mileage of Vehicles: PakWheels

Emission Factor For Gasoline= 8887 g CO_2 / gallon

Emission Factor For Diesel= 10180 g CO_2 / gallon

Formula used: Number of vehicles ×(Emission Factor /Mileage of Vehicles (MPG))= CO_2 emissions (g /mile)

CO_2 emissions (g / mile) × No. of Miles traveled per day = CO_2 emission (g/day)

Total CO_2 emissions per day × No. of days in a year = Annual CO_2 emissions by vehicles

- Calculation is done separately for diesel based and gasoline based vehicles
- Average distance covered by NUST owned vehicles is 10 Km per day
- Average distance covered by Visitor vehicles is 4 Km per day

Total Annual Vehicle tailpipe emission in NUST= 1533 Metric Tons

Calculation (source): USEPA

6.4) Total CO2 emissions by Solid Waste

Solid waste has become a huge problem in the world, especially in developing and underdeveloped countries. There are three main principles with which solid waste pollution can be controlled i.e. reduce, reuse and recycle. The first step is to reduce the generation of solid waste onsite and then separate the reusable portion of solid waste. 3rd step is to segregate the recycle portion of solid waste like plastics, tin packs and paper. The remaining solid waste is to be dumped carefully in the landfill site. Through proper dumping, energy can be recovered from the solid waste in this form of methane.

No. of Solid Waste Transport Trolleys= 4

(* solid waste is dumped to landfill site on 6 days a week basis)

Daily Solid Waste generation = 32.5 m^3 /day (*Measuring the Volume of fully filled trollies)

Annual Solid Waste generation = 10191.28 m^3

10191.28 m^3 = 13330 $(yd)^3$

Mixed MSW (Residential, Institutional, Commercial) Standard Volume-to-Weight Conversion Factors 1 $(yd)^3$ = 275 lbs of MSW

13330 $(yd)^3$ = 3665750 lbs = 1662756 kg

Methane Emission Calculation

Methane emission (A) = $(M \times TS \times MCF \times DOC \times DOC_F \times F \times (16/12) - R) \times (1-OX) \times 1000$

M = Total mass of material

TS = Total solid content (fraction, e.g. 0.25)

MCF = Methane correction factor (0.4)

DOC = Degradable organic carbon (fraction, e.g. 0.44)

DOCF = Fraction of DOC dissimilated i.e 0.77

F = Fraction of methane in landfill gas (default is 0.5)

R = Recovered methane (kg) i.e 0

OX = Oxidation factor (default is 0)

Methane emission = 37462225 g/ kg of material

gCO_2–equivalent/ kg =(g of methane / kg)×25

gCO_2–equivalent/ kg = 37462225 × 25 = 936555625 g = 1032 Tons

N_2O emissions from landfill

IPCCC emission factor for *N_2O emissions = 0.0003 kg N_2O/kg of waste*

Total Annual MSW= 1662756 kg

Total Annual N_2O Emissions= 499 kg N_2O

CO_2–equivalent/ kg= 499 × 298= 148702 kg = 164 tons/ year

Total Emissions from solid waste= 1196 tons/year = 1085 Metric Tons

6.5) Total CO Emissions by Cigarettes

Open Smoking has also become an important issue in the society. To tackle that, smoking corners are suggested for the smokers. Smoking corners will not only help to reduce the number of smokers but it will also reduce the number of cigarettes smoked per day.

No. of cigarettes Smoker = 1300

Average cigarettes smoked = 14/day

1 cigarettes = 12 mg CO

14 cigarettes / personnel = 168 mg CO/day

For 1300 personnels = 218400 mg CO /day

Annual Emissions = 80 kg of CO

6.6) Inventory of CO_2 emissions in NUST

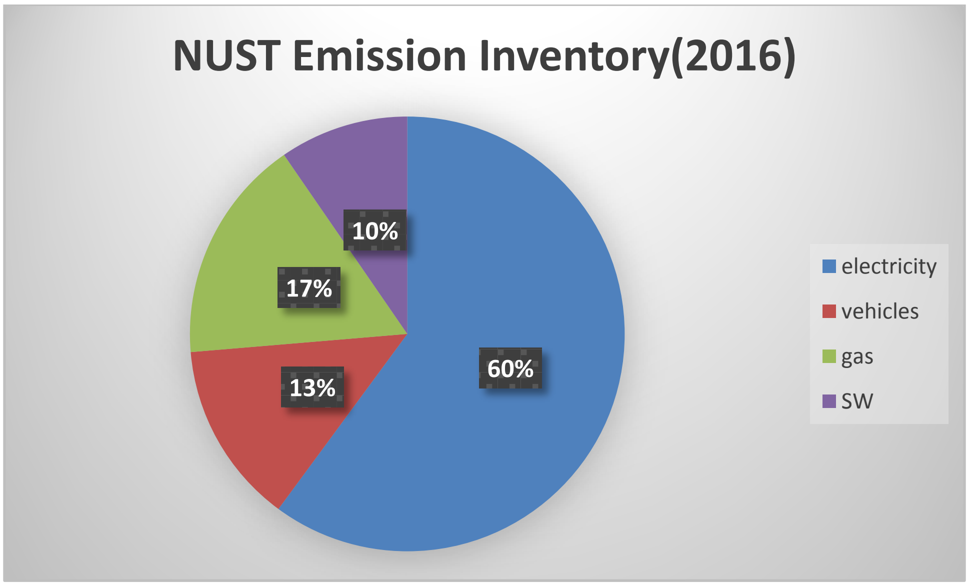

Figure 3: CO_2 emissions inventory of NUST

Figure 3 shows the CO2 emission inventory of NUST which determines significant sources of carbon dioxide within the NUST campus. The sources contributing to CO2 emissions are electricity, gas, vehicles and solid waste. The blue part shows the emissions by electricity which is the major contributor in this case at 60% followed by gas at the second place which is being illustrated by the green portion at 17%. Vehicles and solid waste have a minor contribution at 13% and 10% respectively. The above inventory was developed in order to determine the need to reduce CO2 emissions in future.

7) Results and Discussions and Proposed Solutions

Our results and discussions include:

- Calculation of CO_2emissions by Electricity
- Calculation of CO_2 emissions by Gas
- Calculation of Vehicles tailpipe emissions
- Identification of CO_2 emission sources in NUST
- Estimation of NUST's annual expenditures on Electricity
- Estimation of NUST's annual expenditures on gas
- Low Carbon modification and CO_2 reduction compared with before modification.
- Trees Plantation estimation for CO_2 sequestration.
- Cost estimation of Infrastructure modification
- Solar paneling cost estimate
- EV cars cost estimate
- Off campus Parking design and cost estimate
- Investment Payback period estimation

Proposed Solutions

7.1) Replacement of Electricity with Solar Panels

Solar cells, also called photovoltaic (PV) cells by scientists, convert sunlight directly into electricity. PVgets its name from the process of converting light (photons) to electricity (voltage), which is called the Photo Voltaic effect. Renewable energy sources produce little to no global warming emissions. Generating electricity from renewable energy rather than fossil fuels offers significant public health benefits. Renewable energy can provide affordable electricity and can help stabilize energy prices in the future.

Solar panels calculation for electricity

For the replacement of Electricity, we calculated the number of solar panels to fulfill the electricity consumption.

Solar panels calculation:

The maximum energy consumption came out to be 1,344,000 Kwh of Electricity, according to which the required number of solar panels are calculated. A loss factor of 30 % is used which comprises loses such as irradiance, soiling (dirt), shade, tilt, snow, incidence angle, inverter efficiency, environmental conditions, light induced degrading, connections, wiring etc. The peak hours are the hours when the electricity usage is maximum, that is 8 hrs for educational institutes like NUST. Solar panels of 600 watts are recommended for use with batteries of 12 volts with 2 days of autonomy each. Using all these parameters the number of solar panels required for NUST are 12,133 solar panels along with 7000 batteries. There can be multiple options for energy conservation. Solar System can be hybridized with electricity during night hours. A hybrid solar system is good option for the areas with much variability in the availability of solar energy. The calculations of solar panels are shown below:

Max energy required = 1,344,000 Kwh

Energy required per day = 44,800 Kwh / day = 44,800,000 Whrs / day

Using,

Loss Factor = 30 %

Peak hrs = 8 hrs

(44,800,000 Whrs / day) * 1.3 = 58,240,000 Watts

(58,240,000 Watts) / 8 hrs = 7,280,000 Watts per hr

Using 600 Watts Solar Panels

Number of solar panels required for NUST are = 12,133 Solar Panels

Using 12 V Batteries with 2 days Autonomy

Number of Batteries required = 7000 Batteries

Placement of solar panels on all buildings of NUST

Here this picture is a depiction of how NUST would look after the placement of solar panels on all buildings of NUST. Placement of solar panels on roofs would require lesser space area also it would be a more efficient system. Figure 5 shows the bird's eye view of NUST campus with solar panels displayed on the rooftop of every building. By replacing conventional electricity sources by solar energy, NUST campus would certainly look like this.

Figure 4: A bird's eye view of solar panels displayed over the rooftops of NUST buildings

7.2) Solar Thermal Collectors

Solar thermal collectors are classified by the United States Energy Information Administration as low-, medium-, or high-temperature collectors. Low-temperature collectors are generally unglazed and used to heat swimming pools or to heat ventilation air. Medium-temperature collectors are also usually flat plates but are used for heating water or air for residential and commercial use.

Solar Thermal Collectors Calculation

1 solar thermal collector gives= 1 MBTU/day

Number of collectors required to give= 35637MBTU/yr

Number of collectors required= (35637MBTU/ 1 MBTU/day) * 1 * (1 yr/365 days)= 98 Solar Thermal Collectors would be required to fulfill NUST's requirement of gas.

7.3) Green Building Concept

Green building (also known as green construction or sustainable building) refers to both a structure and the application of processes that are environmentally responsible and resource-efficient throughout a building's life-cycle: from planning to design, construction, operation, maintenance, renovation, and demolition.

7.4) Electric Vehicles

An electric car is an automobile that is propelled by one or more electric motors, using electrical energy stored in rechargeable batteries. Compared with cars with internal combustion (IC) engines, electric cars are quieter and have no tailpipe emissions. When recharged by low-emission electrical power sources, electric vehicles can reduce greenhouse gas emissions. No Emissions: Electric cars are 100 percent eco-friendly as they run on electrically powered engines. It does not emit toxic gases or smoke in the environment as it runs on clean energy source. They are even better than hybrid cars as hybrids running on gas produce emissions.

7.5) Bicycles Estimation for NUST

Provision of on campus cycling facilities would help the people to connect to green transport. The goal of bike system is to connect people to green transport. It would be really convenient for the people as it is really very cheap and requires no fuel. The Bicycle stations project would require an initial investment and after that it would be a great earning source. Only small maintenance cost would be applied once in a while. CYKIQ, an on-campus transport system at NUST, has already been implemented by NUST student entrepreneurs which owes almost 125 bicycles. It charges 15 rupees per hour for utilizing its facility. Total students in NUST are 7196 so approximately 500 bicycles would be required. The number of bicycles can vary according to the need or requirement.

7.6) Provision of off campus parking lots

To make NUST emissions free, off campus parking must be provided for the fuel vehicles so that they may not enter the NUST premises and produce tailpipe emissions. Off campus parking will help create an emission free environment in the NUST campus. electric vehicles can be used inside the campus.

7.7) Off-campus parking area estimation

We have proposed land area for the construction of off-campus parking lots. So that an estimated no. of 1300 vehicles can be accommodated outside the NUST premises.

Area available at Gate 1 is 13440 m2 or 3.32 acres

Figure 5 Gate 1 Proposed Parking Area

Area available at Gate 10 is 16250 m2 or 4 acres

Figure 6 Gate 10 Proposed Parking Area

7.8) Cool Roof technology

A cool roof is one that has been designed to reflect more sunlight and absorb less heat than a standard roof. Cool roofs can be made of a highly reflective type of paint, a sheet covering, or highly reflective tiles or shingles. Nearly any type of building can benefit from a cool roof.

7.9) Increase green land

Choose low maintenance trees to maximize carbon sequestration. All plants absorb carbon dioxide but trees are best. While all living plant matter absorbs CO_2 as part of photosynthesis, trees process significantly more than smaller plants due to their large size and extensive root structures. In essence, trees, as kings of the plant world, have much more “woody biomass” to store CO_2 than smaller plants, and as a result, are considered nature’s most efficient “carbon sinks”. It is this characteristic which makes planting trees a form of climate change mitigation.

CO2 Sequestration by Trees

Identification of Species

Calculation of Number of Trees Currently Planted in NUST

Manual calculation of Diameters of Trees

Data source: NUST Horticulture Department

Diameters Measurement: Manual Sampling of Diameters of trees in NUST using measuring tape.

Annual CO2 Sequestration by plants

Determine the total (green) weight of the tree

For trees with $D < 11$:

$W = 0.25D^2 H$

For trees with $D >= 11$:

$W = 0.15D^2 H$

Where

W(lb) = Above-ground weight (AGW)

D(inches) = Diameter of the trunk

H(feet) = Height of the tree in feet

Root Weight= 20% of AGW

So total tree green weight= 120% of AGW

Dry weight of the tree= 72.5% of total green weight

Weight of carbon in the tree= 50% of Dry Weight

Weight of carbon dioxide sequestered= 3.67 * weight of carbon

as $CO_2/C = 3.67$

Annual CO2 sequestration by trees

Annual CO_2 Sequestration by tree's = 1247 Metric tons/year

Green Area Ratio of NUST:

Total NUST area = 707 acres (2.86 km2)

Green area Ratio = Area occupied by trees / Total covered area

CDA Green area Ratio = 40 : 60 = 0.66

Green area Ratio of NUST = 575 m2 / 8468 m2 = 0.067

More Tree Plantation Proposed

- Since the GAR of NUST is very less as compared to the GAR required that is 0.66, more trees need to be planted to increase the greenbelt and CO2 sequestration. 394,000 (approx. 4 Lac) new trees need to be planted to meet the required Green Area Ratio. Proposed species are: Sumbal, Dates, Jaman, Alestonia, Jacaranda, Pine, Sukhchan, King Facus

Comparison of CO2 Emissions Vs Sequestration

40,000 trees sequester approx. 1247 Metric TonsCO_2 annually. Whereas the CO_2 emissions produced annually are 11,301Metric Tons annually. So further plantation of trees and grasses is required to increase the CO_2 Sink of NUST.

7.10) Smoke Corners

Designated smoking areas can be developed in the campus in order to reduce the concentration of carbon monoxide into the atmosphere.

7.11) Awareness Seminars

The project will be represented in different seminars, organizations and institutions to raise the awareness about Climate Change and Low Carbon Infrastructure.

7.12) General Survey

A general survey in NUST premises is conducted for our project and the feedback of the people is as below;

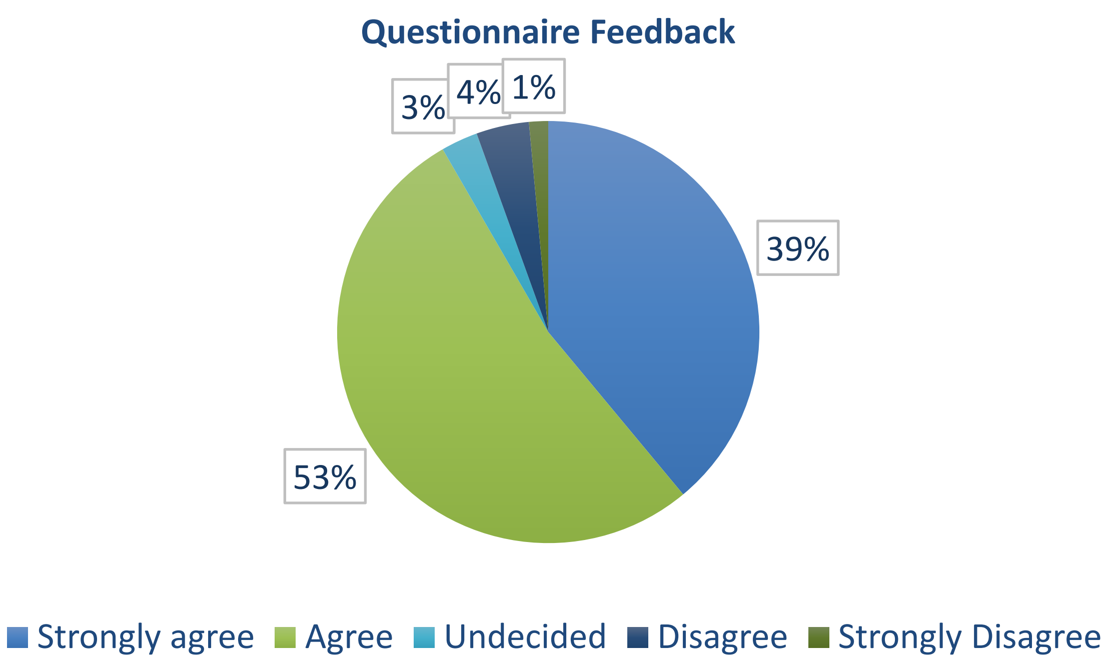

Figure 7: Pie chart displaying the results of our project's questionnaire

In figure 7, a pie chart displays the results of the questionnaire that we conducted in order to obtain the views of different people on the development of NUST as a low carbon campus. This pie chart depicts that 53% people are strongly partial to the idea of low carbon development.

8) Savings by this Project

8.1) Annual Electricity bills

Table 6 shows the electricity bills for NUST buildings and hostels during the year 2017. Approximately 94 million rupees are being spent on electricity that is being generated by fossil fuels. By adopting the low carbon strategy, we can save 94 million rupees of electricity bills annually.

Electricity Bills	Amount (Rs)
Electricity Bill Building (15-16)	65,398,443
Electricity Bill Building 2 (15-16)	5,221,611
Electricity Bill Hostels (15-16)	24,221,589
Total	94,841,643

Table 3: Annual electricity bills

8.2) Annual Gas bills

Table 7 shows the gas bills for NUST buildings and hostels during the year 2017. Approximately 26 million rupees are being spent on gas that is being generated by conventional non-renewable sources.

Sui gas Bills	Amount (Rs)
Sui Gas Bill Buildings (15-16)	7,063,760
Sui Gas bill Hostels (15-16)	18,994,506
Total	26,058,266

Table 4: Annual gas bills

Total Savings

Save approximately 120 Million Rupees Annually

9) Estimation of Expenses

9.1) Solar paneling cost estimation

11,500 solar panels along with 6,941 batteries are required to fulfill the electricity demand of NUST campus. For this an estimated amount of 389 Million Rupees would be required.

9.2) Solar thermal collectors cost estimation

1 Solar thermal collector costs 8000 Rs

98 Solar thermal collectors would cost = 78,400 Rs

9.3) EV cars cost estimation

The required number of vehicles for NUST campus would cost approximately 645 Million Rupees. Since this is a onetime measure, it would save the fuel expenses and would greatly reduce CO_2 emissions. Also it is a green transport system.

Type of vehicle	No. of Vehicles	EV Company	No. of cars required	Price (Rs)	Total Price
Buses	6	Chinese automaker BYD Auto	6	43671200	262027200
Coasters	7	Chinese automaker BYD Auto	7	43671200	305698400
Hiace	41	Electric mini van	41	331845	13605645
Water Bozer	3	Water Bozer	3	111580	334740
Master truck	2	Master Truck	2	111580	223160
Motorcycle 125cc	12	Jolta E- Bikes	12	35,000	420000
Motorcycle 70cc	12	Jolta E- Bikes	12	35,000	420000
Motor car	13	Super Power	13	650,000	8450000
Suzuki van	37	Electric mini van	37	331845	12278265
Shazore	2	Mini Truck	2	458824	917648
Nust owned cars	57	Super Power	57	650,000	37050000
Single cabin	3	China Hongdi	3	265476	796428
Fuel Bozer	1	Fuel Bozer	1	111580	111580
Fire Tender	2	Fire Tender	2	111580	223160
Tractor	9	Tractor	9	167370	1506330
Autoloader	2	Autoloader	2	111580	223160
Ambulance	2	Electric mini van	2	331845	663690
Rikshaw	9	Shuttle	9	11061	99549
Sezo Lab Truck	1	Mini Truck	1	458824	458824
Total					645507779

Table 5: Cost estimation for EV cars

Table 8 lists down the number of different types of electric vehicles required for replacing the fuel/gasoline cars. The price of all types of electric vehicles is listed against the respective EV company. The total price has also been calculated for determining the investment required in purchasing electric vehicles.

Total Investment Estimation

Solar Panel investment required = 389,519,838 Rs

Electric Vehicles investment required = 645,507,779 Rs

Solar thermal collectors investment required = 78,400 Rs

Total Investment required = 1,035,106,017 Rs

Figure 7 shows the total investment that is required for carrying out this project. The green portion represents the investment required by electric vehicles i-e 50% which implies that half of the money would be invested on electric vehicles. The blue portion shows the investment required for installing solar panels on every building i-e 48.9% of money would be invested on solar panels. Only 1% investment is required for bicycles and 0.1% is required for solar thermal collectors that are being shown by purple and maroon portions respectively.

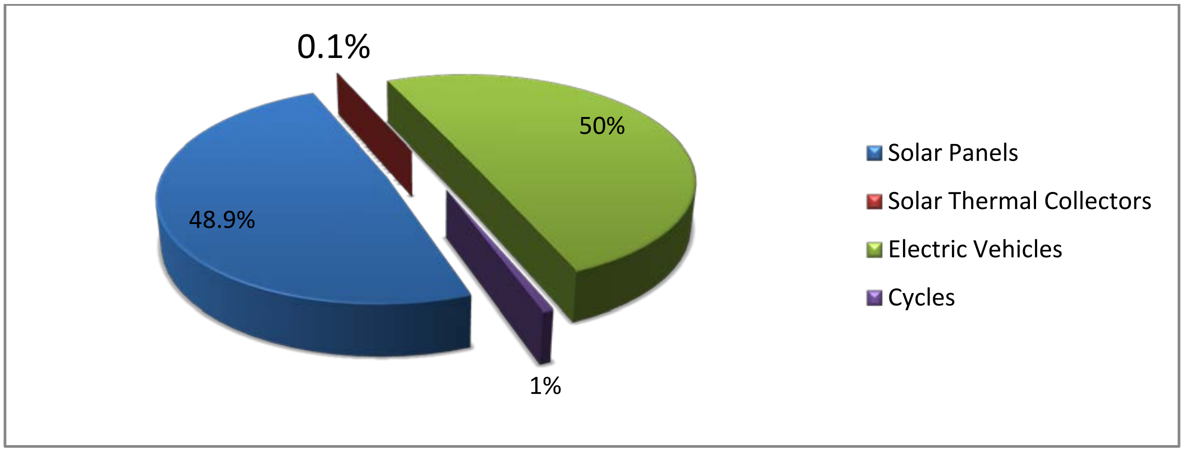

Figure 8 Total Investment Estimation

10) Payback Period Estimation

10.1) Solar Payback Period Estimation

The payback period is the time it takes for solar panel to pay for itself through reduced energy bills. The typical solar payback period in the U.S. is between 6 and 8 years. If your cost of installing solar is $20,000 and your system is going to save you $2,500 a year on foregone energy bills, your solar panel payback or "break-even point" will be 8 years ($20,000/$2,500 = 8).

Solar Panel Investment Payback period = Cost of Solar panels (Rs) / Electricity Bills (Rs)

Solar Panel Investment Payback period = 389,519,838.8Rs / 94,841,643Rs = 4.1 yrs.

10.2) Total Investment Payback Period Estimation

Total Investment Payback Period = Total Investment / Total savings per yr

Total Investment Payback Period = 1,035,106,017 Rs / 120,000,000 Rs

Total Investment Payback Period = 8 yrs approx.

Significant Reduction in CO2 emissions can be made

Total CO2 emissions by Electricity	6792	Metric Tons/yr
Total CO2 emissions by Gas	1891	Metric Tons/yr
Total CO2 emissions by Vehicles	1533	Metric Tons/yr
Total CO2 emissions by Solid Waste	1085	Metric Tons/yr
Total Emissions	11301	Metric Tons/yr

11) Summary

Emission Sources	Quantity of Emissions	Proposed solutions
Electricity	6792 Metric tons/ yr	12133 Solar Panels
Gas	1891 Metric tons/yr	98 Solar Thermal Collectors
Vehicles	1533 Metric tons / yr	200 Electric Vehicles
		500 bicycles
		Off- Campus parking lots at Gate 1 and Gate 10
Solid waste	1085 Tons / yr	On-site segregation, recycling, proper disposal
Cigarettes smoke	80 kg / yr (CO emissions)	Smoke corners suggested.

12) Conclusion

Hence, our project work gives us an insight into the concept of 'Low carbon development' and examines the strategies towards the reduction of CO_2 emissions. According to this feasibility analysis, it is concluded that approximately 11301 Metric Tons of CO_2 emissions can be reduced within the NUST campus by adopting these strategies. Furthermore, installation of solar panels can save 120 million rupees of electricity and gas bills annually. Though low carbon community might be a bit expensive initially but it does pay off at the end by palliating millions of tons of CO_2 emissions in the atmosphere.

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The End