EE 399 Project Course

Optimizing Energy Usage for the IITGN Campus

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Abstract— **This study analyzes the monthly energy consumption patterns at the Indian Institute of Technology Gandhinagar (IITGN) campus. It examines how energy usage changes with the academic calendar, seasonal variations, and future predictions. The study also identifies the main areas within the campus responsible for energy consumption, including academic areas, hostel facilities, and chiller plants, which collectively account for 80-90% of the total energy consumed. The study also delves into a detailed assessment of the electricity bill, breaking down its components to understand how energy consumption patterns impact the monthly electricity costs. This study also assesses the efficiency of rooms with different dimensions and occupancy levels. The study aims to determine the optimal balance between room dimensions and occupancy for maximizing cooling efficiency by simulating various room sizes and occupancy scenarios. The analysis considers factors such as heat transfer rates, occupant heat generation, and the impact of solar radiation, providing insights into how room design and occupancy levels affect energy efficiency.**

I. INTRODUCTION

India's energy consumption for residential and commercial buildings is predicted to rise by 2.7 percent per year between 2015 and 2040, more than double the global average. Electricity's proportion of India's total commercial energy consumption is expected to rise from 59% in 2015 to 65% in 2040. Various energy efficiency efforts in India, such as the Standards and Labeling program and the Energy Conservation Building Codes [1], impact building energy use.

The key components under the guidelines are energy management and control, and they play a critical part in India's energy conservation aim [1]. According to the EIA's International Energy Outlook 2017 (IEO2017) [2], India will have the fastest rise in building energy demand through 2040 among all regions of 10 the world. In the IEO2017 Reference case, India's energy consumption for residential and commercial buildings is predicted to rise by 2.7 percent per year on average between 2015 and 2040, more than double the global average. Electricity's proportion of India's total commercial energy consumption is expected to rise from 59% in 2015 to 65% in 2040. Various energy efficiency efforts in India, such as the Standards and Labeling program and the Energy Conservation Building Codes [5], have an impact on building energy use.

A. Problem Statement

IIT Gandhinagar (IITGN) faces challenges related to high energy consumption and inefficiencies in its current energy use practices. The campus experiences high energy demand awareness among students and staff about energy conservation practices.

B. Motivation

An academic campus encompasses various teaching, research, administration, and accommodation facilities, each contributing differently to energy consumption. The energy usage of such institutes is closely linked to their academic calendars. The rapid expansion of Indian academic campuses due to urbanization has significantly impacted the economy and the environment. With many facilities and long operational hours, academic campuses consume more energy than other types of buildings. In recent years, there has been a notable increase in energy consumption to meet growing demands, including the need for improved indoor conditions through air conditioning and lighting upgrades and the modernization of research facilities. However, these advancements often result in higher electricity bills, straining the campus's financial resources. To maintain conducive research environments while addressing budget constraints, it is imperative to implement energy-saving measures through technological advancements or efficient energy management. Identifying potential energy consumption patterns and implementing energy-saving strategies are significant challenges for academic campuses. Moreover, these campuses have growing recognition for the importance of sustainable energy practices to ensure a sustainable energy future.

C. Objective

The objective is to optimize energy use at IITGN by implementing sustainable and cost-effective strategies. This includes conducting energy audits to identify areas for improvement, improving building envelopes, increasing the use of renewable energy sources, and promoting behavioral changes to reduce energy consumption. The goal is to reduce energy costs, lower the carbon footprint, improve indoor comfort, and enhance IITGN's reputation as a sustainable campus. The implementation plan involves a phased approach, collaboration with energy experts, and monitoring and evaluation of energy use to assess the effectiveness of the strategies

Introduction

A. Energy Consumption Structure

IIT Gandhinagar's campus's energy consumption structure is divided into five categories: academic area, hostel area, chiller plant, treatment plant, and miscellaneous connections to shops and street lights. In 2024, these areas accounted for approximately 90% of the total energy consumption.

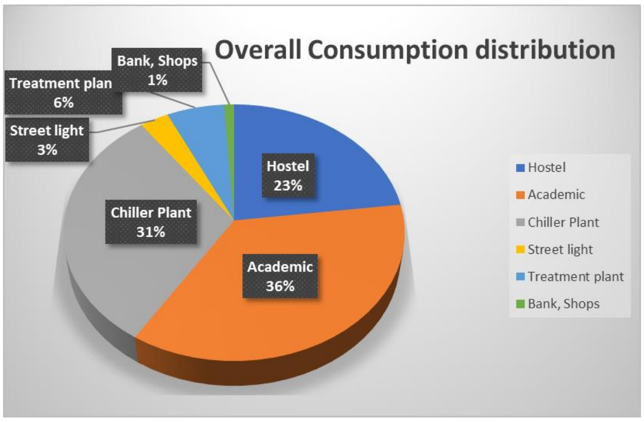

Fig. 1: Distribution of electrical energy consumption across different areas of the IITGN campus.

B. Topology of Distribution Network

This paper examines the energy consumption profile of the ring main distribution network at IIT Gandhinagar. The primary distribution network (11 kV) uses underground cables of 3Cx240 sq.mm, while the secondary distribution network (415 V) uses 3.5Cx300 sq.mm underground cables. The active main distribution network at IIT Gandhinagar is divided into two rings. Ring-1 is connected to five substations (Infra main, hostel, WTP, AB-I & AB-II) with a total length of 4270 m, while ring-2 is connected to two substations (Sport complex & research park) with a total length of 2880 m. The distance between each substation and its respective penal room is approximately 20 m.

Each substation is equipped with two winding dry-type transformers: primary delta (11 kV) and secondary star (415 V). Despite being costlier than oil-cooled transformers, dry-type transformers are preferred for their environmental friendliness, safety, lack of fire hazard, ease of installation, and ability to support overloads. All transformers have a vector group of Dyn11, and tapping is in the range of +10% to -10% in steps of 2.5%.

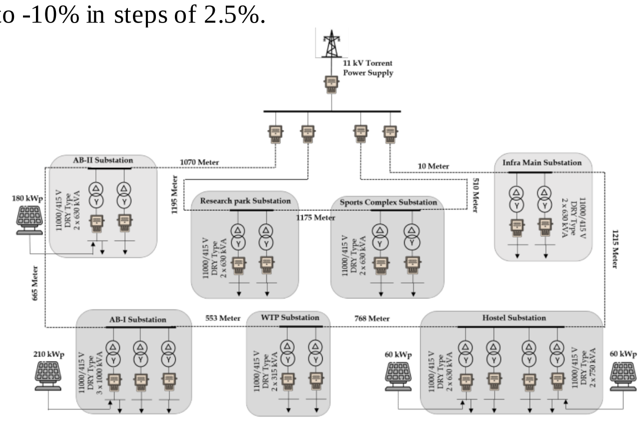

Fig. 2: Single line diagram of IITGN active ring-main distribution network.

DATA ANALYTIC AND DISCUSSIONS

A. Monthly Energy Consumption

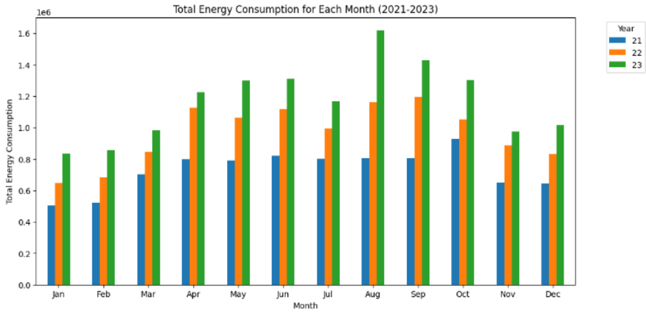

Fig. 3: Monthly Total Energy consumption for year 2021, 22, 23

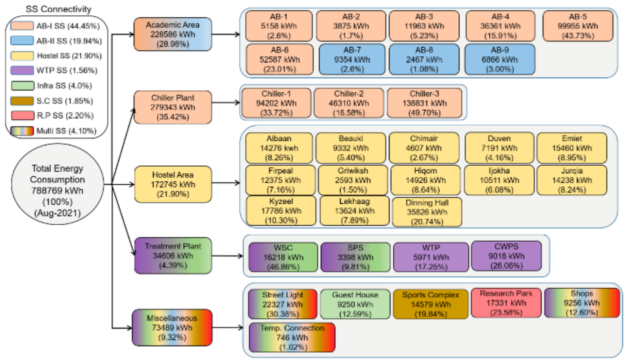

Fig. 4: Energy consumption structure of IITGN campus (August-2021)

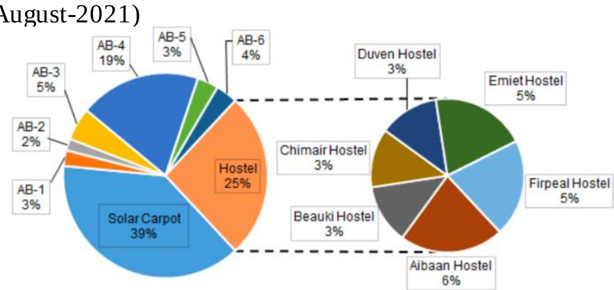

Fig. 5: Solar PV generation share (%) for all sites in IITGN

An analysis of electricity consumption growth rates from 2021 to 2023, highlighting key trends, seasonal variations, and fluctuations over time. The analysis is based on the average growth rates for each month across the specified period, providing insights into the dynamics of electricity usage patterns.

Table 1: Percentage change in energy consumption w.r.t previous year

Month	Average Growth Rate
January	28.90%
February	28.17%
March	18.30%
April	18.83%
May	22.25%
June	26.71%
July	20.59%

August	41.92%
September	35.94%
October	18.04%
November	23.16%
December	25.91%

Key Findings:

- **Seasonal Variations and Peak Growth:** The analysis reveals significant seasonal variations in electricity consumption growth rates, with August and September peaking at 41.92% and 35.94%, respectively.
- **Lowest Growth Periods:** October exhibits the lowest average growth rate at 18.035%, indicating a period of reduced electricity consumption.
- **Range of Growth Values:** The range of average growth rates spans from 18.035% in October to 41.92% in August, underscoring the fluctuating nature of electricity consumption.
- **Fluctuations Over Time:** Certain months, such as April and November, show significant fluctuations in growth rates, pointing to potential shifts in consumption patterns or the impact of external influences.
- **Yearly Comparison:** The highest growth rates for most months occurred in 2021, indicating a more pronounced increase in electricity consumption during the earlier part of the analyzed period.

Seasonal Variations and Fluctuations:

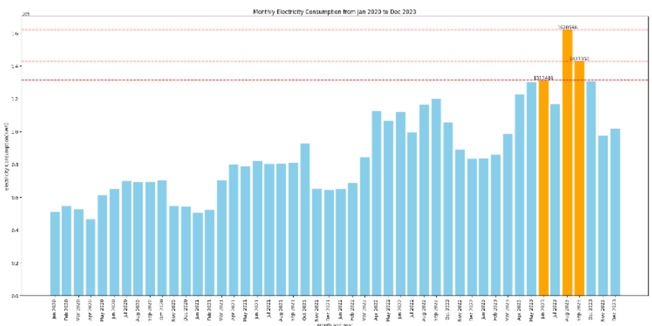

Fig. 6: Total energy consumption from Jan-20 to Dec-23

- Summer Increase: There's a noticeable increase in electricity consumption during the summer months (May to July), which could be attributed to the use of cooling systems like air conditioners.
- Yearly Growth: There's a general upward trend in electricity consumption year over year, indicating growing demand or increased usage patterns.
- Seasonal Peaks: The peaks in summer and towards the end of the year become more pronounced with each passing year, suggesting that these seasonal trends are becoming more significant over time.

Recommendations:

Demand Management: Implement targeted strategies for demand management during peak growth periods to ensure a stable and efficient electricity supply.
Infrastructure Planning: Consider seasonal variations and monthly fluctuations in growth rates for infrastructure development and capacity planning.
Policy Development: Formulate policies addressing external factors influencing electricity consumption, aiming to mitigate the impact of sudden fluctuations.

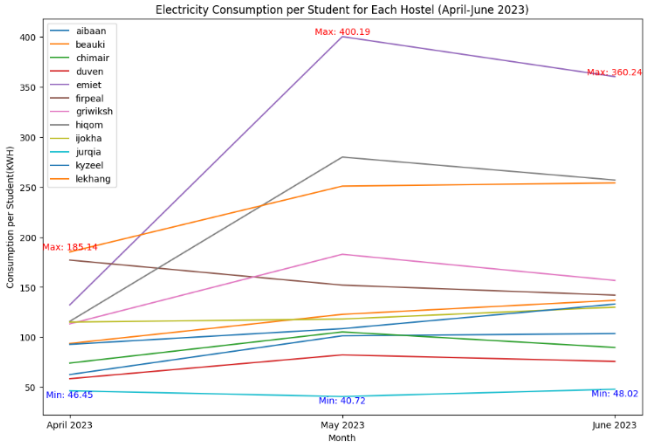

Fig. 7: Energy consumption per capita for every hostel in summer.

The electricity consumption per student for each hostel from April to June 2023 reveals interesting patterns and trends. Hostel E stands out with consistently high consumption, peaking at around 350 kWh in May, likely due to the presence of facilities such as a mini library, shop (Mahaveer, Tea Post), and student lounge, which are often active hubs requiring continuous electricity usage. Although there was a slight decrease in consumption in June, it remained above average compared to other hostels. Hostel H follows as the second-highest consumer, maintaining a steady consumption around 200 kWh throughout the period, possibly influenced by its connection with shops (Dawat, Go Insta, VS), which could contribute to a more stable demand with fewer fluctuations.

Hostel L also exhibits a high level of consumption, particularly in April and May, possibly due to its size or amenities. The consumption per student for Hostel L was consistently above 200 kWh during these months, indicating a notable demand for electricity. Hostel G shows a similar pattern, with consumption peaking at around 180 kWh in April and then gradually decreasing in May and June, suggesting a possible adjustment in usage habits or efficiency improvements.

On the other hand, Hostel J demonstrates relatively low consumption levels throughout the period, with consumption per student consistently below 50 kWh. This could be attributed to its smaller size or fewer amenities requiring electricity. Hostel D also maintains a relatively low consumption rate, hovering around 70 kWh per student, indicating potentially efficient energy practices or fewer energy-intensive facilities.

Overall, these insights highlight the varying electricity consumption patterns among hostels, emphasizing the importance of understanding specific factors that contribute to consumption levels in each case. Factors such as hostel size, amenities, and usage habits play a significant role in determining electricity consumption, and efforts to manage and reduce consumption should consider these factors for effective outcomes.

B. *Chiller Plant*

Fig 8. Actual Image of Chiller plat at IITGN

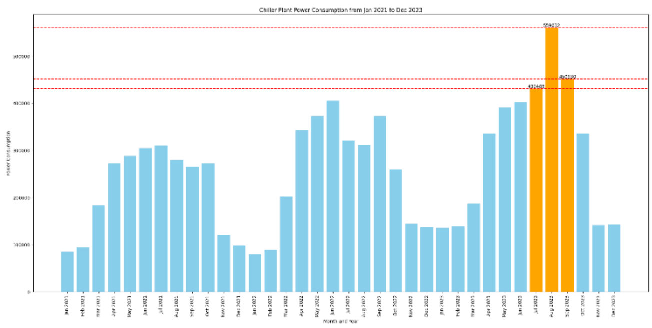

Fig. 9: Power consumption of chiller plant from Jan'21 to Dec'23

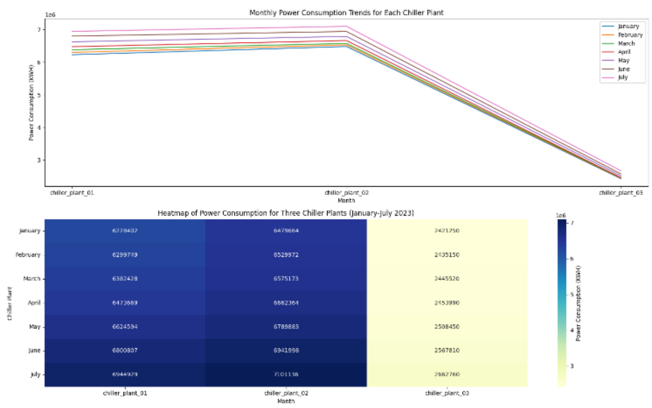

Fig. 10: Power consumption in Chiller Plant at IITGN

The power consumption data for three chiller plants from January to July 2023 reveals distinct patterns in their energy usage. Chiller Plant 01 and Chiller Plant 02 both exhibit a consistent upward trend in power consumption over the months, with noticeable spikes in May and June. These spikes likely correspond to increased cooling demand during the warmer months. In contrast, Chiller Plant 03 shows a relatively stable power consumption pattern, with minor fluctuations but no significant increase over the period. The heatmap provides a clear visualization of these trends, highlighting Chiller Plant 01 as the highest consumer of power, followed by Chiller Plant 02 and then Chiller Plant 03. These insights can be valuable for optimizing energy usage, identifying opportunities for efficiency improvements, and ensuring effective management of cooling systems in the future.

C. *Energy Consumption and Prediction Trends Analysis*

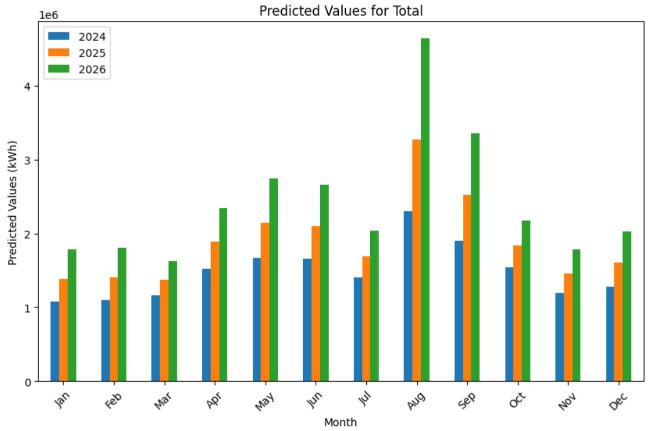

Fig. 11: Predictions for Total energy consumption of year 24, 25, 26 by CAGR values of the past year trends of year 21, 22, 23.

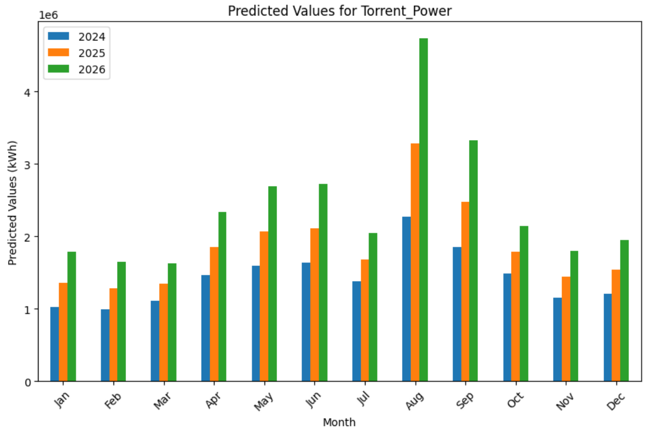

Fig. 12: Predictions for Torrent power of year 24, 25, 26 by CAGR values of the past year trends of year 21, 22, 23.

The predicted values for total power consumption at IITGN reveal a consistent upward trend over the three-year period from 2024 to 2026, indicating a sustained increase in electricity demand or usage. Notably, there are substantial yearly increases in total power consumption, with the figures for January 2024 starting at 1,075,727 kWh and escalating to 1,787,567 kWh by December 2026. This significant growth points to an expansion in electricity usage or infrastructure at IITGN. Despite the overall upward trajectory, the predicted values also exhibit monthly fluctuations within each year, which could be attributed to seasonal changes, academic schedules, or campus activities. The peak of predicted total power consumption is in August, reaching up to 4,729,336.93 kWh by December 2026, suggesting that August may experience the highest electricity demand, possibly due to increased academic activities, research projects, or other campus-related events during this period.

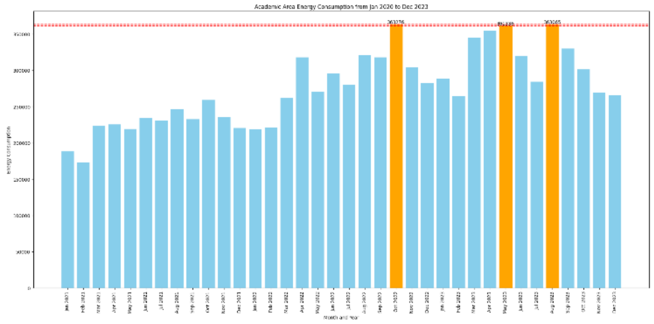

Fig. 13: Academic area power of the years 2021, 2022, 2023.

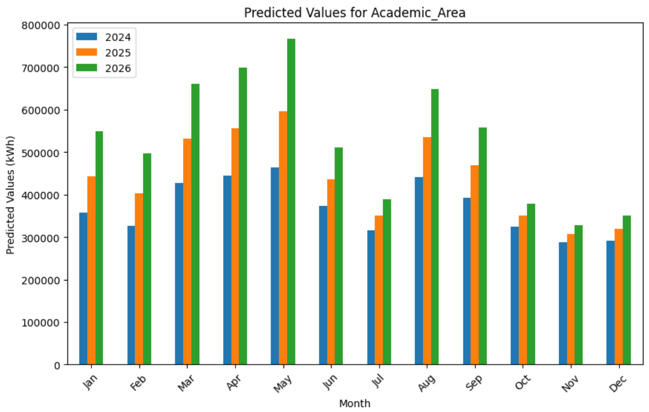

Fig. 14: Predictions for Academic area power of year 24, 25, 26 by CAGR values of the past year trends of year 21, 22, 23.

The analysis of power consumption data within the Academic Area reveals a consistent upward trend, indicating an escalating demand for electricity in educational settings such as classrooms, labs, offices, and research areas over the observed period. Annually, there is a discernible escalation in energy consumption, with predictions showing a continuous increase from January 2024 through December 2026, highlighting a persistent rise in energy use in academic environments. Despite the overarching growth, power usage experiences periodic variations throughout the months of each year, potentially due to the academic calendar, research endeavors, fluctuations in student numbers, and seasonal shifts. This anticipated surge in electricity usage mirrors the expanding energy requirements tied to academic operations, encompassing teaching, experimentation, computing, and administrative tasks. As academic offerings grow, so does the necessity for electrical power to facilitate education, learning, and research activities. The forecasted increase in energy consumption within the Academic Area emphasizes the critical need for infrastructural enhancements and energy management approaches.

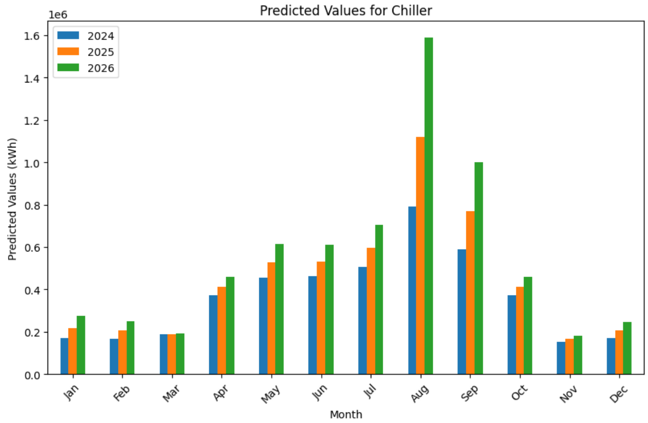

Fig. 15: Predictions for Chiller power of year 24, 25, 26 by CAGR values of the past year trends of year 21, 22, 23.

The analysis of predicted values and Compound Annual Growth Rate (CAGR) across different energy categories from January to December for the years 2024 to 2026 provides valuable insights into energy consumption and production trends.

Across various categories such as torrent power, Solar, total, academic area, and chiller, a general trend of positive CAGR signifies expected growth in energy consumption or production. This reflects increasing demand or capacity expansion in these areas, indicating a positive trajectory for energy-related activities.

However, notable fluctuations are observed, particularly in the Solar category, where the CAGR ranges from a high of 0.121 in February to a negative rate (-0.193) in June. This variability suggests that solar energy predictions are subject to more volatility, possibly due to seasonal variations or technological advancements impacting efficiency.

In contrast, the Academic Area category exhibits a significantly high CAGR of 0.147 in December, indicating a notable increase in energy consumption or production towards the end of the year, likely driven by heating demands or end-of-year academic activities.

The Chiller category consistently demonstrates positive growth, with the highest CAGR of 0.142 observed in August, indicating an increase in cooling demand or capacity. However, anomalies such as the decrease in Solar category CAGR during the summer months or the significant increase in Torrent Power CAGR in August warrant further investigation to understand underlying factors.

Predicted values for 2026 consistently exceed those for 2024 across all categories, aligning with the positive CAGR trends observed. Notably, Torrent Power and Total categories show substantial growth in predicted values, indicating an overall increase in energy consumption or production capacity over the years.

D. *Optimizing Room Size*

The simulation provides detailed insights into the thermal behaviour of rooms with varying lengths and initial temperatures. It demonstrates how the interplay of room characteristics and environmental conditions influences the rate and pattern of temperature changes over time.

Room Length Impact: Longer rooms, such as those with lengths of 6m and 7m, exhibit slower temperature changes compared to shorter rooms (4m and 5m). This is due to the greater thermal mass and surface area of longer rooms, which results in a more gradual approach towards the outside temperature. The thermal inertia of the longer rooms allows them to retain heat for longer periods, leading to a slower rate of temperature change.

Initial Temperature Influence: The initial room temperature significantly affects the rate of temperature change. Rooms with higher initial temperatures experience faster initial temperature drops, followed by a gradual approach towards the outside temperature. In contrast, rooms with lower initial temperatures show slower and more steady temperature decreases, indicating a more gradual response to the outside temperature.

Thermal Characteristics: The thermal resistance and heat capacity of the room play crucial roles in determining the rate of temperature change. A lower thermal resistance facilitates faster heat transfer, leading to quicker temperature adjustments. Conversely, a higher thermal resistance slows down heat transfer, resulting in a more gradual temperature change. The heat capacity of the room also influences the rate of temperature change, with rooms with higher heat capacities exhibiting slower temperature adjustments.

Practical Implications: These findings have practical implications for building design and energy management. For example, buildings with longer rooms may require different heating and cooling strategies to maintain comfortable temperatures, such as strategically placing heating and cooling sources. Additionally, the initial temperature of a room can impacts energy efficiency, as rooms with higher initial temperatures may require more energy to cool down. Understanding these thermal dynamics can inform decisions related to building insulation, HVAC system design, and energy-efficient building practices.

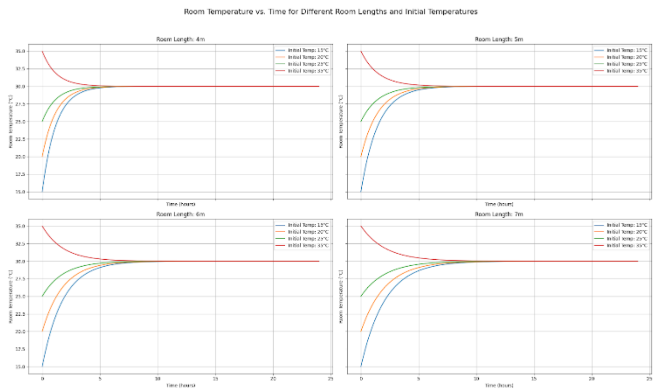

Fig. 16: Room temperature Vs Time for different Room length and initial temperature

The distribution of hostel rooms across 12 hostels reveals varying accommodation options for residents. AIBAAN offers a substantial number of single and double rooms, with 140 and 54 respectively, while BEAUKI provides 109 single rooms and 27 double rooms. CHIMAIR follows closely with 99 single rooms and 41 double rooms. DUVEN stands out for its 181 single rooms and a minimal 4 double rooms. EMIET offers 141 single rooms and 44 double rooms. FIRPEAL exclusively offers 210 single rooms. GRIWIKSH uniquely provides 13 triple rooms. HIQOM offers 69 single rooms and a significant 76 triple rooms. IJOKHA provides 56 single rooms and 49 triple rooms. JURQIA offers 48 single rooms and 60 triple rooms. KYZEEL and LEKHAAG, however, appear to offer only double and triple rooms, with 76 double and 88 triple rooms in KYZEEL, and 35 double and 63 triple rooms in LEKHAAG. These distributions suggest a range of accommodation options, with some hostels focusing on single or double rooms, while others provide a mix including triple rooms.

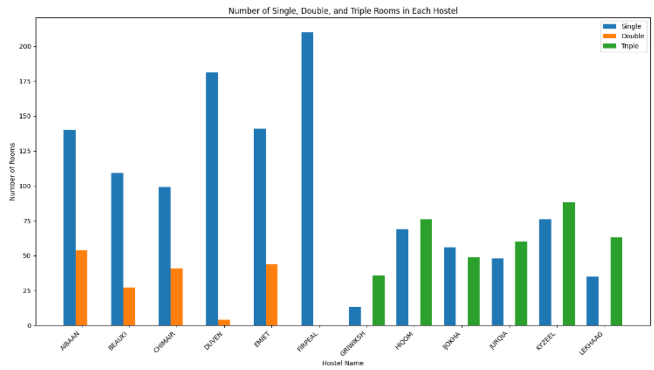

Fig. 17: Number of Single, double and triple Rooms in each Hostel.

The simulations below provide a detailed analysis of cooling efficiency in rooms with varying dimensions and occupancy scenarios, considering the impact of solar radiation and the use of reflective paint on walls.

Without Reflective Paint: The first simulation examines the cooling efficiency based on room dimensions and occupancy scenarios. Larger rooms with higher occupant numbers require more cooling power to maintain the target temperature, resulting in lower cooling efficiency. Factors such as thermal conductivity, convective heat transfer, occupant heat generation, and HVAC power consumption are considered. The results highlight the complex interplay between room dimensions and occupancy patterns in determining cooling efficiency. The contour plots offer a visual representation of how different room sizes and occupancy scenarios affect cooling efficiency, providing insights into optimal room design for energy efficiency.

With Reflective Paint: In the second simulation, the effect of reflective paint on cooling efficiency is explored. Reflective paint reduces the impact of solar radiation on walls, decreasing the overall heat gain in the room. This leads to improved cooling efficiency across all room sizes and occupancy scenarios. The contour plots demonstrate the significant increase in cooling efficiency with the use of reflective paint, underscoring its potential to reduce cooling loads and energy consumption.

Practical Implications: The simulations have practical implications for building design and energy management.

They highlight the importance of considering room dimensions, occupancy patterns, and building materials in optimizing cooling efficiency. Implementing strategies such as reflective paint can substantially improve energy efficiency and thermal comfort, particularly in regions with high solar radiation. By providing a detailed analysis of cooling efficiency under different conditions, the simulations offer valuable insights for designing energy-efficient buildings and HVAC systems.

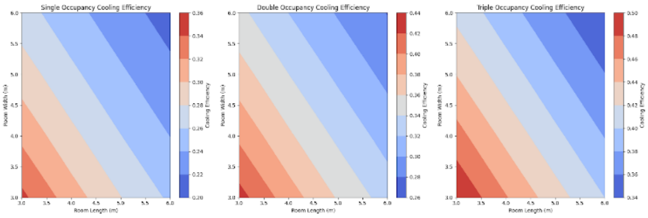

Fig. 18: Efficiency of different room sizes without paint

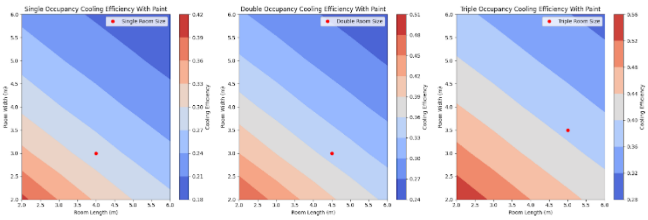

Fig. 19: Efficiency of different room sizes with paint

In the above simulation, several assumptions and values have been used to analyse the cooling efficiency of rooms with and without reflective paint on the walls. Here are the key assumptions and equations used:

Assumptions:

1. The room is rectangular in shape.
2. The room has a constant height of 3 meters.
3. The walls are made of a material with a constant thermal conductivity of 1 W/(m*K).
4. The room is in an environment with an outside temperature of 35°C.
5. The room is equipped with a fan, tube lights, and an air conditioner, and the power consumption of these devices varies based on the occupancy scenario.

Equations:

1. Heat transfer rate through conduction:
$\boldsymbol{Q_{conduction} = k \cdot A \cdot \Delta T / d}$

Where:
k is the thermal conductivity,
A is the wall area,
ΔT is the temperature difference, and
d is the wall thickness.

2. Heat transfer rate through convection:
$$\boldsymbol{Q_{convection} = h \cdot A \cdot \Delta T},$$

Where:
h is the convective heat transfer coefficient.

3. Cooling Efficiency = $\boldsymbol{Q_{ac}/Q_{total}}$

Where:
$\boldsymbol{Q_{total}}$ is the summation of heat of occup $\boldsymbol{Q_{total}}$ is the summation of heat transfer components, including conduction, convection, heat generated by occupants, fans, tube lights, air conditioning, and solar radiation on the walls.
$\boldsymbol{Q_{ac}}$ is the air conditioner's cooling capacity, which is the amount of heat energy removed from the room per unit of time.

Recommendation Policy:

- Room Dimensions: Aim for room dimensions that balance efficient air circulation with space requirements. Rectangular rooms are generally more efficient than irregularly shaped rooms.
- Insulation: Ensure walls, windows, and doors are well-insulated to minimize heat transfer. High-quality insulation can significantly improve cooling efficiency.
- Occupancy Management: Consider the expected occupancy levels when sizing the air conditioning system. Higher occupancy levels require larger cooling capacities.
- Reflective Surfaces: Use reflective paint or materials on walls and roofs to reduce heat absorption from sunlight, especially on walls facing direct sunlight.
- Energy-Efficient Appliances: Use energy-efficient fans, tube lights, and air conditioners to minimize heat generation and optimize cooling efficiency.
- Proper Ventilation: Ensure adequate ventilation to allow for fresh air intake and proper circulation, which can reduce the load on the cooling system.
- Room Height: Consider the height of the room, as taller rooms may require more energy to cool. Optimal height should balance ventilation and cooling efficiency.
- Regular Maintenance: Regularly maintain and service the air conditioning system to ensure it operates at peak efficiency.

II. SOLAR ENERGY AT IITGN

*A. **Solar Energy Production and Prediction Trends Analysis***


Fig.20: Actual image of Solar PV installed at IITGN

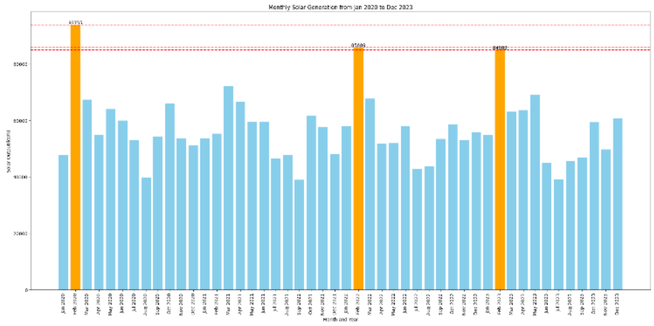

Fig. 21: Total Solar Energy Generation from Jan-20 to Dec-23

From 2020 to 2023, our solar output has remained relatively stagnant, as indicated by the average yearly outputs:

2020 Average: 58,761.17
2021 Average: 55,101.83
2022 Average: 58,035.83
2023 Average: 58,730.83

Despite some fluctuations between years, there hasn't been a consistent seasonal trend or notable growth in solar power generation. These variations suggest that factors beyond seasonal changes, like weather patterns, technological advancements, or shifts in demand, may be influencing our solar output.

Given the lack of significant growth in solar generation, it's imperative to assess and address potential barriers to improvement. This may involve exploring ways to enhance solar panel efficiency, expanding installation capacity, or implementing strategies to mitigate the impact of external factors on solar energy production. By identifying and addressing these challenges, we can work towards optimizing our solar power generation and achieving more consistent and sustainable energy output over time.

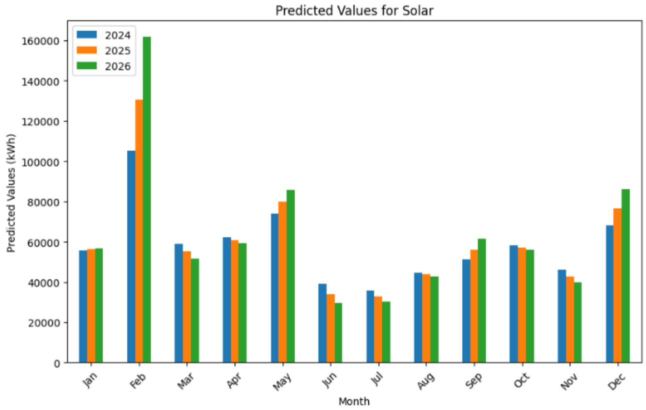

Fig. 22: Predictions for Solar Power Generation of year 24, 25, 26 by CAGR values of the past year trends of year 21, 22, 23.

The solar power generation at IITGN is marked by significant fluctuations across monthly and yearly periods, indicating that the current solar infrastructure may not be optimized for consistent energy production throughout the year.

Yearly Averages: Calculating the average predicted values for each year (2024-2026) reveals the following trends:

2024 Average: 57,169.81
2025 Average: 63,509.40
2026 Average: 63,785.49

Despite marginal increases in the average predicted values from 2024 to 2026, the overall growth in solar power generation remains minimal, suggesting that it is not keeping pace with potential demand or the abundant solar resource in Gandhinagar. This underperformance represents a missed opportunity, especially considering Gandhinagar's favorable climate with over 300 sunny days annually, ideal for solar power generation. The failure to fully capitalize on this abundant resource underscores an underutilization of natural advantages, highlighting the need for IITGN to invest in expanding its solar infrastructure. Such an investment would not only align with sustainability goals but also enhance energy security and resilience in the face of climate change.

B. Solar Energy Production Potential

Solar power production is subject to variations throughout the day, primarily influenced by the angle and intensity of sunlight hitting solar panels. The zenith of power generation often aligns with midday, when sunlight strikes the panels at right angles, maximizing energy conversion. This period, typically spanning from 11 a.m. to 4 p.m., witnesses the pinnacle of solar generation during daylight hours, offering an optimal window for energy capture.

The concept of peak sun hours holds significance in evaluating solar panel efficacy, denoting periods when solar irradiance reaches a standard of 1,000 watts per square meter. The duration of peak sun hours is contingent upon various factors, including geographical location, seasonal changes, and panel orientation. Despite fluctuations in weather conditions, solar panels sustain electricity generation even on cloudy days, albeit at reduced efficiency, typically operating at 10-25% of their full capacity. Notably, solar panels cease operation at night due to the absence of sunlight required for energy conversion.

In the context of IIT Gandhinagar, the potential for solar energy utilization across the hostel rooftops is notably high. The available rooftop space across the hostels at IIT Gandhinagar spans from 3,800 to 4,200 square feet. This expansive area provides a significant opportunity for the installation of solar panels to their maximum capacity. Based on precise calculations, it is estimated that, under optimal sunny conditions, these installations could generate approximately 290 kWh of electricity per day. However, it's important to acknowledge that solar energy production is inherently variable, influenced by weather conditions. On days characterized by overcast skies or rainfall, the output from the solar panels could decrease substantially, often by 50% or more.

Despite these fluctuations, the geographical positioning of Gandhinagar, where IIT Gandhinagar is located, is highly advantageous for solar energy projects. The region enjoys an abundance of sunlight, with an average of 270 to 300 sunny days annually. This climatic advantage ensures that, despite the expected daily variations in energy production, the overall annual energy yield remains robust, making Gandhinagar an ideal location for the deployment of solar energy solutions.

The relevance and potential impact of such a solar energy project at IIT Gandhinagar are further underscored by broader trends in the field of renewable energy. According to the International Energy Agency (IEA), solar power is experiencing rapid growth as a renewable energy source globally, thanks to significant advancements in photovoltaic (PV) technology that have improved efficiency and reduced costs. The commitment of the Indian government to increase renewable energy capacity, as demonstrated by initiatives like the National Solar Mission, reinforces the feasibility and critical importance of adopting solar energy solutions at institutional levels, including educational campuses like IIT Gandhinagar.

Moreover, the environmental implications of transitioning towards solar energy are profound. By decreasing dependence on fossil fuels, such initiatives can substantially reduce carbon emissions, thereby contributing to global efforts to combat climate change. Solar energy projects also align with sustainable development goals, promoting cleaner air and energy independence.

Harnessing Solar Energy at the Indian Institute of Technology Gandhinagar: A Strategic Initiative

Within the Indian Institute of Technology Gandhinagar (IITGn), the hostels present a unique opportunity for the adoption of solar energy solutions. The campus is distinguished by its 12 hostels, each with a name that adds to the character of the institution: Aibaan, Beauki, Chimair, Duven, Emiet, Firpeal, Griwiksh, Hiqom, Ijokha, Jurqia, Kyzeel, and Lekhaag. Each of these hostels features an approximate rooftop area of between 4,000 to 4,200 square feet. This specificity in measurement underscores the potential for a tailored approach to solar energy harnessing, with a collective rooftop space of around 48,000 to 50,400 square feet available across all hostels.

The detailed breakdown of available rooftop space across the hostels named Aibaan through Lekhaag not only highlights the feasibility of implementing a substantial solar grid but also showcases the potential for generating significant renewable energy within the existing infrastructure footprint. The spatial distribution and architectural design of these hostels are optimally aligned to accommodate the system requirements for a 250 kW solar grid, which typically spans between 25,000 to 32,500 square feet for conventional installations. This alignment ensures that the expansive rooftop area can be effectively leveraged to augment the overall power output, significantly contributing towards sustainable energy initiatives.

Moreover, considering the adoption of an integrated solar roof solution, such as the Ornate InRoof system, could further enhance the efficiency of this initiative. This innovative solution can accommodate approximately 26% more solar panels within the same area compared to conventional setups, thereby maximizing the energy generation capacity per square foot. Such an approach not only optimizes the spatial efficiency of the solar installation across the hostels but also ensures that the functional addition of solar panels integrates seamlessly with the architectural aesthetics, enhancing the visual coherence of the campus environment.

Financially, establishing a 250 kW solar grid across the hostels at IITGn is projected to require an investment in the range of ₹1.17-1.25 Crore, based on current market rates for on-grid photovoltaic (PV) systems. While this initial capital outlay may seem substantial, the long-term financial benefits, driven by substantial savings on energy bills, can lead to a relatively rapid payback period of 4-5 years. After recouping the initial investment, the solar infrastructure continues to generate clean, renewable energy at minimal operational costs, offering sustained economic and environmental benefits.

In conclusion, the strategic integration of a 250 kW solar grid across the hostels at IITGn, leveraging the specific rooftop areas of Aibaan, Beauki, Chimair, Duven, Emiet, Firpeal, Griwiksh, Hiqom, Ijokha, Jurqia, Kyzeel, and Lekhaag, represents a forward-thinking initiative. This approach not only capitalizes on the existing campus infrastructure for renewable energy generation but also aligns with the institution's commitment to sustainability and innovation. By harnessing solar energy, IITGn can significantly reduce its carbon footprint and operational energy costs, setting a precedent for environmental stewardship and fiscal prudence within the academic community.

Feasibility and Strategic Alignment

The requirement for space to deploy a 250 kW solar grid typically ranges between 25,000 to 32,500 square feet for conventional installations. Given the ample rooftop area available at IITGn, the campus is uniquely positioned to accommodate such a substantial solar infrastructure. This alignment between the available space and the requirements of a 250 kW solar grid underscores the practicality and strategic foresight of integrating solar energy solutions within the existing campus layout. It leverages the institution's infrastructure to foster renewable energy generation, thereby highlighting the potential for generating substantial renewable energy within the existing infrastructure footprint.

Technological Innovation and Aesthetic Integration

The potential adoption of advanced solar technologies, such as the Ornate InRoof system, represents an innovative approach to maximize the efficiency of this initiative. This system can accommodate approximately 26% more solar panels within the same area compared to conventional setups. Such an approach not only enhances the spatial efficiency of the solar installation but also ensures seamless integration with the architectural aesthetics of the campus. The functional addition of solar panels, thus, complements the visual coherence of the campus environment, enhancing both functionality and aesthetics.

Financial Considerations and Long-term Benefits

Establishing a 250 kW solar grid at IITGn is estimated to require an investment in the range of ₹1.17-1.25 Crore, reflecting the current market rates for on-grid photovoltaic (PV) systems. While this initial capital expenditure may seem substantial, it is essential to consider the long-term financial implications and benefits. Reducing energy expenditures facilitated by the solar grid can yield considerable savings, offsetting the initial costs within an estimated payback period of 4-5 years. Beyond this period, the solar infrastructure continues to produce energy at minimal operational costs, offering sustained economic benefits alongside its environmental advantages.

III. CONCLUSION

The Indian Institute of Technology Gandhinagar (IITGN) has demonstrated a strong commitment to sustainability and energy efficiency. With a campus spanning 400 acres, accommodating thousands of students, faculty, and staff, IITGN has implemented various measures to optimize energy consumption. This includes a distributed solar PV generation panel contributing to an average of 10-14% of the total monthly energy consumption, alongside a two-ring main distribution network and strategically located substations.

The campus's energy consumption pattern, largely driven by academic activities, chiller plants, and hostel operations, highlights the importance of efficient energy management. Despite challenges such as congestion at the Academic Block-I substation, IITGN prioritizes clean energy technology and environmental sustainability.

Looking ahead, IITGN's efforts serve as a model for other institutions, demonstrating the feasibility and benefits of integrating renewable energy sources and energy-efficient practices into campus operations. Through these initiatives, IITGN reduces its carbon footprint and fosters a culture of sustainability among its students and staff, paving the way for a greener future.

The importance of room size, occupancy, and energy-efficient practices in optimizing cooling efficiency. Increasing occupancy reduces cooling efficiency, emphasizing the need for balanced room dimensions and efficient appliances. Additionally, using reflective paint can further enhance cooling efficiency, showcasing the significance of sustainable practices in building design. Overall, these findings underscore the potential for improved energy management and sustainability in buildings through thoughtful design and technology integration.

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