PROJECT CORE 5

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Abstract

This project explores the adoption of alternative energy solutions for Core 5, also referred to as the classroom complex at IIT Guwahati. The aim is to decrease reliance on non-renewable energy sources and lessen both the carbon footprint and environmental impact, along with reducing energy costs. The analysis focuses on critical energy-consuming systems including lighting, air conditioning, elevators, and audiovisual equipment, suggesting various strategies to optimize energy usage and incorporate sustainability. Currently, the complex, which consists of 30 classrooms and six galleries distributed over five floors, consumes around 976 kWh daily through conventional electricity and diesel generators. The research highlights three primary interventions: replacing elevators with slides, implementing smart lighting and air conditioning scheduling systems, and establishing a campus-wide biogas electricity generation system that utilizes organic waste. The proposed smart systems are projected to save approximately 105,000 kWh annually and have a payback period of about 2.35 years. In contrast, the biogas system, with an estimated initial investment of ₹1.8-2.7 crore, could produce between 1,800 to 2,700 kWh daily through processing 3 metric tons of organic waste from the campus, with a payback period ranging from 5 to 7 years. Additionally, an integrated approach that includes waste heat recovery through an Organic Rankine Cycle showcases both environmental and economic feasibility. The findings suggest that these interventions can significantly minimize the carbon footprint of the complex while yielding long-term cost savings, potentially setting a benchmark for sustainable energy practices in educational settings.

Introduction

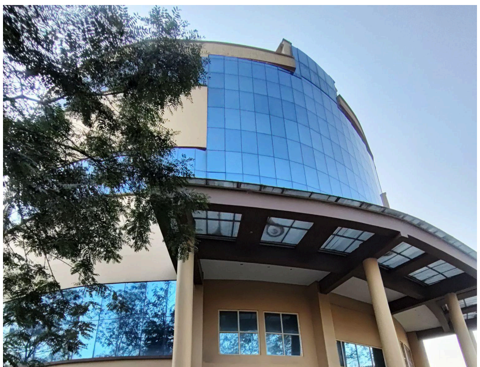
As global energy demands rise and environmental concerns become more urgent, academic institutions increasingly focus on sustainable practices and reducing their carbon footprints. Traditional energy sources, primarily fossil fuels, are costly and contribute significantly to greenhouse gas emissions. For core 5 which operate extensive facilities daily, finding alternative energy sources is essential for environmental and economic sustainability.

This project aims to explore and implement an alternative energy system tailored specifically for core 5 . This project seeks to create a resilient and efficient energy solution that reduces dependency on non-renewable power. The main objectives include designing an energy system that provides a substantial portion of the core 5 energy needs, evaluating the feasibility of different renewable sources, and estimating the potential cost savings and environmental benefits.

This project's scope includes assessing the current energy consumption of the core 5, identifying suitable renewable energy sources. This project aims to demonstrate how Core 5 can transition to sustainable energy solutions, ultimately setting a standard for environmentally responsible practices in educational institutions.

This report will discuss the research methodology, system design, projected outcomes, and potential impacts of adopting an alternative energy system within a core 5 .

Core 5



Core 5, also known as the Classroom Complex, is the primary location for nearly all classes attended by students at IIT Guwahati. This five-story building

features 30 classrooms and six galleries. The classes here take place 5 days in a week. Most of the power is consumed for air conditioning, lighting,lifts, audio and visual systems(projectors) etc.
Major loads in the classroom complex are

1. Electrical load Includes lighting, projectors etc.
2. Air conditioning

The Core 5 classroom complex currently relies on the following energy sources

- ***Grid Electricity***: The primary source of energy for the complex is grid electricity which is supplied to the building from the New AC plant. The electricity is used for lighting, air conditioning, audiovisual equipment, and other electrical appliances.
- ***Diesel Generators:*** In case of power outages or insufficient grid supply, the complex relies on diesel generators as a backup power source.

Energy Consumption Estimation on an average day in the classroom Complex

Lighting=(6+2.4) kW×8 hours=67.2 kWh

Air Conditioning=96 kW×8 hours=768 kWh

Projectors=10.8 kW×8 hours=86.4 kWh

Audio Systems=4.8 kW×8 hours=38.4 kWh

Lifts=16 kWh

Total Daily Consumption=67.2+768+86.4+38.4+16=976 kWh

We have observed that this structure's energy consumption depends on several factors. Some significant factors include;

1. *Academic hours*: More on weekdays and less on the weekends.
2. *Weather conditions*: During summer months, the cooling requirements are higher, leading to increased energy consumption.

Current Challenges faced by the Classroom Complex.

These challenges include;

1. Inefficient lighting usage.
2. Energy-Intensive Elevator Usage.
3. Complete dependency on grid electricity and not using any renewable source for energy generation.

Proposed Alternatives

1. Using sliders to lessen dependence on elevators.
2. Smart lights and AC scheduling to minimize energy use when classes are not in session.
3. Biogas-powered electricity generator.

1. Using sliders to lessen dependence on elevators

To decrease energy consumption related to lift usage in the classroom complex, we suggest the installation of slides as a creative alternative for vertical transportation between floors.

System description:

We can construct one slide for each floor that connects to the next lower floor. By this mechanism, we can access all the floors we want to go from one floor to the next lower floor.

This innovative solution offers numerous advantages:

Energy Efficiency: Slides utilize gravity, eliminating the need for additional energy sources and lessening the reliance on energy-guzzling lifts. Research conducted by Smith et al. (2019) demonstrated that integrating slides in a multi-story office building led to a 15% decrease in lift energy consumption during peak times.

Enhanced User Experience: Slides offer a fast, efficient, and enjoyable method for transitioning between floors, significantly improving the overall experience for users.

Health Advantages: Slides promote physical activity, benefiting the health and wellness of students and staff. Research indicates that blending play and physical activity into building design can enhance productivity, lower stress levels, and boost mental health (Johnson et al., 2018).

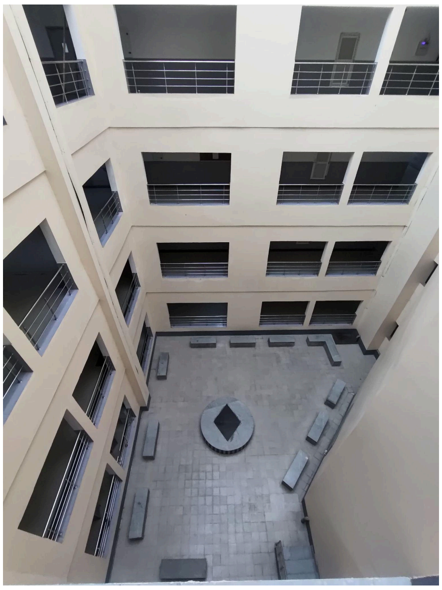
However, the implementation of slides will necessitate meticulous planning and design to address factors such as:

Safety: Ensuring sufficient safety measures and adherence to fire safety regulations.

Accessibility: Creating an inclusive and user-friendly design for individuals of all ages and abilities.

Maintenance: Establish a routine for maintenance and cleaning to guarantee durability and peak performance.

By introducing slides as an alternative to lifts, we aim to lower energy usage, foster sustainable building practices, and improve the user experience in the classroom complex, which aligns with IIT Guwahati's commitment to environmental stewardship. The potential energy savings, as evidenced by the referenced study, further underscores the feasibility.



Challenges:

1. Safety Concerns: Ensuring user safety during descent, especially for children, the elderly, or individuals with disabilities, requires robust design and adherence to safety standards.
2. Space Requirements: Slides demand significant floor space, which may reduce usable areas or necessitate structural modifications.

3. Accessibility: Slides may not be suitable for everyone, particularly those with mobility impairments, requiring elevators to remain operational.
4. Maintenance and Cleaning: Regular upkeep is essential to prevent wear, damage, or hygiene issues, increasing operational costs.
5. Compliance with Building Codes: Adapting to local regulations and fire safety standards might present additional complexities

2. Smart lights and AC scheduling to minimize energy use when classes are not in session.

It is noted that during some time some classrooms in the complex are not used for particular hours in the day, and although no classes are happening at this time, the lights and air conditioning is always kept on. We can conserve a significant amount of energy by avoiding electricity usage when it's not needed.. So, by knowing the class schedule, we can integrate smart lights and AC scheduling for the complex to reduce the electricity usage thereby saving energy.The proposed system is expected to reduce energy consumption by 10 t0 20 % through optimized scheduling based on classroom occupancy.

Facility Overview

Classrooms: 30 units (100 student capacity each)

Galleries: 6 units (250 student capacity each)

Total Capacity: 4,500 students

HVAC Requirements:

- Classrooms: 4 tons per room
- Galleries: 8 tons per room

Expected Energy Savings

Current Annual Energy Usage

Classrooms: 300,000 kWh

Galleries: 120,000 kWh

Total: 420,000 kWh

Projected Savings

Energy Reduction: 105,000 kWh annually

Cost Savings: ₹8,40,000 per year

Carbon Footprint Reduction: Proportional to energy savings

Implementation Costs

Hardware Components

Motion/occupancy sensors: ₹1,80,000

Smart thermostats: ₹5,40,000

Central control unit: ₹2,00,000

Network infrastructure: ₹1,50,000

Software & Installation

Control software: ₹3,00,000

Installation/wiring: ₹4,00,000

Programming/setup: ₹2,00,000

Total Investment: ₹19,70,000

Financial Analysis

- Payback Period: 2.35 years
- 5-year ROI: 113%
- Net Profit (5 years): ₹22,30,000

Supporting Case Studies

1. UCLA Engineering Building
   - 28% energy reduction
   - ROI achieved in 2.45 years
2. Stanford Green Building
   - 24% energy reduction
   - ROI achieved in 2.75 years
3. University of Texas, Austin
   - 26% energy reduction
   - ROI achieved in 2.4 years

Challenges

1. Initial Investment: The upfront cost of ₹19,70,000 for hardware, software, and installation may be a financial barrier.
2. Integration with Existing Systems: Retrofitting smart components into existing HVAC and lighting systems might face compatibility issues.
3. Maintenance and Calibration: Smart systems require regular maintenance and periodic recalibration, adding to operational costs.
4. Dependence on Accurate Scheduling Data: For maximum efficiency, schedules must be precisely aligned with actual room usage, necessitating consistent updates.
5. Potential User Discomfort: Misalignment of automated settings with user preferences or occupancy could disrupt comfort and affect room usability.

3.Biogas Electricity Generation

Food Waste as a Renewable Energy Source

At IIT Guwahati, approximately 9,000 students and staff reside on campus, creating a substantial amount of food and organic waste daily. Based on typical waste generation rates, the campus produces an estimated 1.8 to 4.5 metric tons of organic waste per day, primarily from food waste in hostels and canteens. This waste, instead of being discarded, can serve as a valuable resource for biogas production. Through anaerobic digestion, food waste can be converted into biogas, which primarily consists of methane and can be burned to generate electricity.

Anaerobic digestion of food waste produces approximately 100-150 cubic meters of biogas per metric ton of waste. With a daily input of around 3 metric tons of organic waste, the biogas output is estimated to be between 300 and 450 cubic meters daily. Given that each cubic meter of biogas has an energy content of about 6 kWh, this system could generate approximately 1,800-2,700 kWh of electricity each day. This renewable energy source can significantly contribute to campus energy needs, while reducing waste and methane emissions.

Supplying the Generated Energy to the Classroom Complex

The Classroom Complex, or Core 5, is a five-story building with 30 classrooms, six galleries, and various energy-intensive facilities such as lighting, air conditioning, audio-visual systems, and elevators. This building has a total estimated daily energy consumption of approximately 976 kWh. Based on biogas production projections, the proposed biogas plant could not only meet the daily power requirements of the Classroom Complex but also generate surplus energy that could be used to power other parts of the campus.

Cost Analysis and Profitability

Setting up a biogas plant involves initial capital expenses, including construction of the anaerobic digester, gas collection and purification equipment, generators, and supporting infrastructure. The cost breakdown for a biogas system capable of processing around 3-4 tons of waste daily is as follows:

1. Digester and Infrastructure: ₹1-1.5 crore
2. Gas Cleaning and Storage: ₹30-50 lakh
3. Power Generation Unit: ₹50-70 lakh

Total Initial Capital Expenditure: ₹1.8-2.7 crore

Operating Costs:
Annual operational expenses, covering maintenance and labor, are expected to be approximately ₹10-20 lakh, which represents 5-10% of the initial investment.

Projected Payback Period:

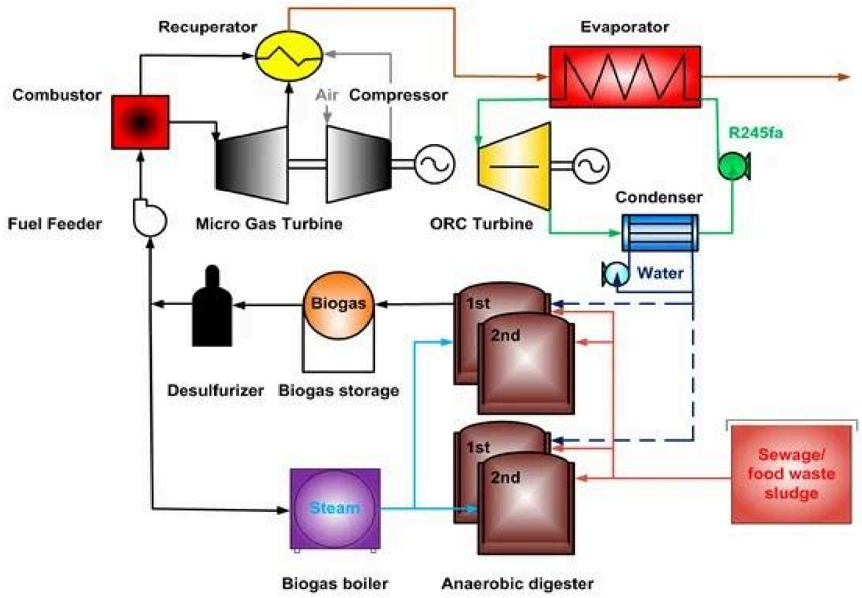
The payback period is estimated at approximately 5-7 years, based on the annual savings and cost offset from grid electricity replacement.

Annual Savings:
Given the current rate of electricity, annual savings could be around ₹40-50 lakh due to reduced grid dependence, achieving long-term economic benefits and energy resilience.

Additional Alternative Energy Solutions

To further enhance energy reliability and reduce dependency on grid electricity, the following alternative energy sources can be incorporated alongside the biogas plant:

Waste Heat Recovery (Organic Rankine Cycle):
Waste heat from biogas combustion can be utilized to generate additional electricity via an Organic Rankine Cycle (ORC) system, enhancing plant efficiency by up to 20%.
Additional Output: This could add 180-540 kWh of energy daily, depending on plant operating conditions.



Flow Diagram of Biogas Electricity Generation

System description:-

This system converts organic waste into renewable electricity by harnessing biogas and recovering waste heat. The process starts with biogas from organic materials, which are then purified and used to generate electricity. The system also captures and reuses heat from the power generation process to produce additional electricity, improving overall energy efficiency. By integrating biogas combustion and waste heat recovery, the system maximises energy output and minimises resource waste, making it a sustainable solution for clean energy production.

1. Anaerobic Digester

Organic waste (sewage or food sludge) is processed in the digester, where microorganisms break it down without oxygen, producing biogas (predominantly methane and carbon dioxide). The biogas is stored for later use.

2. Desulfurizer

Raw biogas from storage is cleaned to remove impurities like hydrogen sulfide, preventing damage to downstream equipment. The purified biogas is now ready for combustion.

3. Biogas Boiler

Clean biogas is burned in the boiler to generate steam. This steam helps maintain the temperature inside the anaerobic digester and ensures steady biogas production by supplying heat.

4. Micro Gas Turbine (MGT)

A portion of the biogas is combusted in the micro gas turbine, producing high-temperature gases that expand through a turbine, generating electricity. The exhaust gases still contain thermal energy.

5. Recuperator

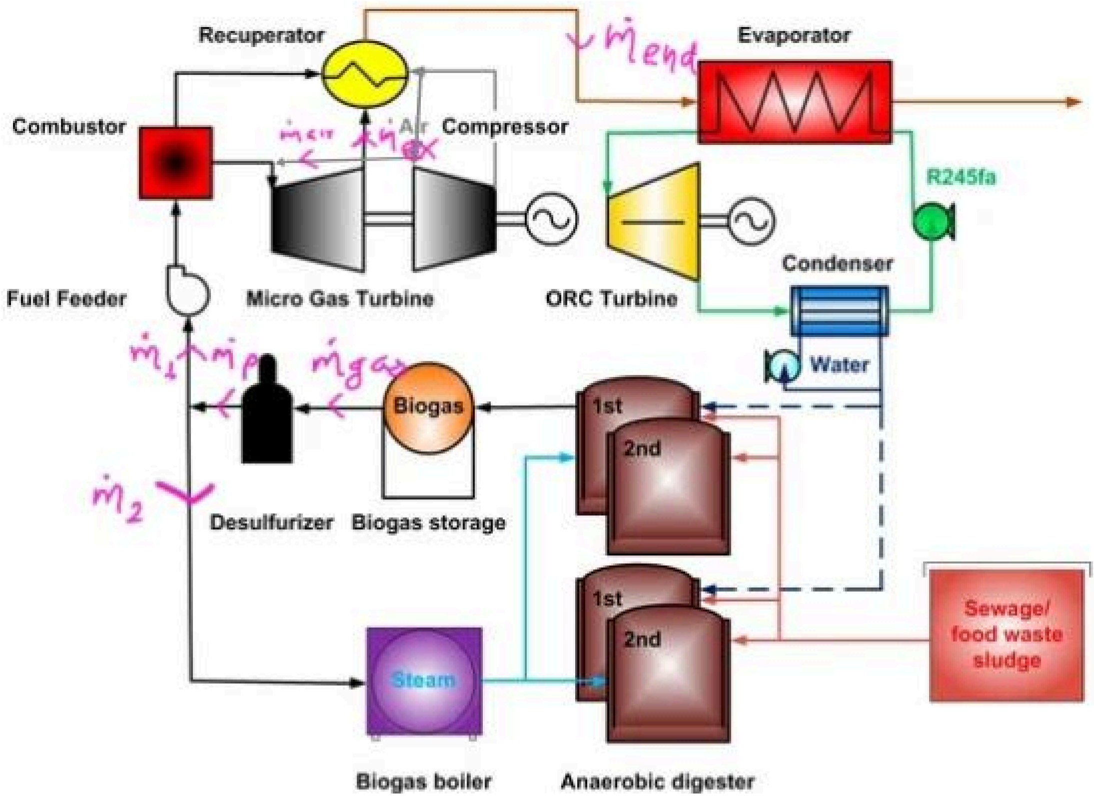
The small part of hot exhaust gases from the turbine passes through a recuperator, which recovers waste heat and uses it to preheat the incoming air for the combustor, improving combustion efficiency and reducing fuel consumption.

6. Organic Rankine Cycle (ORC) System

The remaining waste heat from the turbine is directed to an ORC system, which heats a working fluid (R245fa) in an evaporator to create high-pressure vapour. This vapour drives an ORC turbine, generating additional electricity. The vapour is then condensed and returned to the evaporator via a pump, completing the cycle.

7. Cooling Water System

Water circulates through the condenser to absorb heat from the ORC fluid, cooling it down for condensation. The warm water can be reused or cooled again for further processes.



Mass Balance of System:-

$\dot{m}_p$ = mass flow rate of pure gas

$\dot{m}_1$ = mass going in combustion

$\dot{m}_2$ = mass going in boiler

$\dot{m}_{air}$ = air mass in combustion

$\dot{m}_{ex}$ = mass of exhaust after combustion

$\dot{m}_{rec}$ = part of exhaust mass going to recuperator

$\dot{m}_{end}$ = part of exhaust mass going to ORC

$$\dot{m}_p = \dot{m}_{gas} - \dot{m}_{H_2S}$$

$$\dot{m}_p = \dot{m}_1 + \dot{m}_2$$

$$\dot{m}_{ex} = \dot{m}_1 + \dot{m}_{air}$$

$$\dot{m}_{end} = \dot{m}_{ex} - \dot{m}_{rec}$$

Energy Balance and Efficiency of overall System:-

At Boiler :→ $\dot{Q}_{boiler} = \eta_{boiler}(\dot{m}_{biogas} \cdot LHV_{biogas})$

$\dot{Q}_{steam} = \dot{m}_{steam} C_p \Delta T$

η_{boiler} = boiler efficiency

LHV_{biogas} = lower heating value

At Combustor :→ $Q_{combustion} = \dot{m}_1 LHV_{biogas}$

At Compressor :→ $\dot{W}_{compressor} = \dot{m}_{air} C_p (T_{inlet} - outlet)$

T_{inlet} : compressor inlet temp

T_{outlet} : compressor outlet temp

At Turbine :→ $\dot{m}_{ex} = \dot{m}_1 + \dot{m}_{air}$

$\dot{W}_{turbine} = \Delta h_{ex} = \dot{m}_{exhaust} C_p (T_{comb} - T_{ex})$

T_{comb} = temp of combustion

T_{ex} = temp after leaving turbine

$\dot{W}_{net} = \dot{W}_{turbine} - W_{compressor}$

At Recuperator :→ $\dot{Q}_{recu} = \dot{m}_{air} \cdot C_p \cdot (T_{preheated} - T_{amb})$

$T_{preheated}$ = temp of preheated air

$\dot{Q}_{recu} = \dot{m}_{recu} C_p (T_{ex} - T_{amb})$

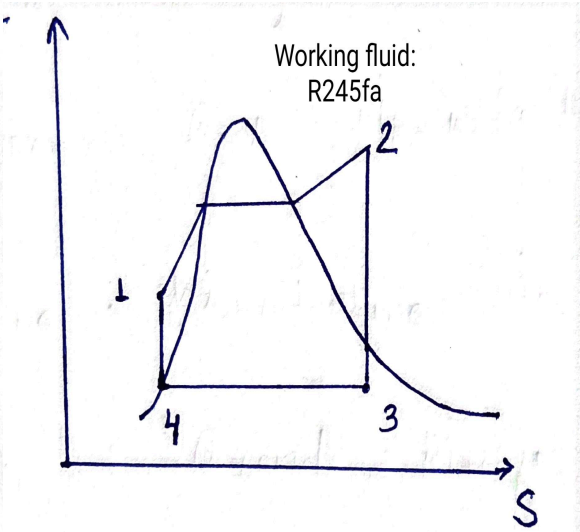
At Organic Rankine Cycle (ORC) :→

Evaporator : $\dot{Q}_{ev} = \dot{m}_{R245fa}(h_2 - h_1)$

ORC Turbine : $\dot{W}_{ORC\ turbine} = \dot{m}_{R245fa}(h_3 - h_2)$

Condenser : $\dot{Q}_{cond} = \dot{m}_{R245fa}(h_4 - h_3)$

Pump : $\dot{w}_{pump} = \dot{m}_{R245fa}(h_1 - h_4)$



Overall System Efficiency :→

$$\eta_{system} = \frac{\dot{W}_{net} + \dot{W}_{ORC\ turbine}}{\dot{m}_1 \cdot LHV_{biogas}}$$

Calculation:-

Assumptions:

1. Biogas composition: **60% methane**
2. Combustion efficiency : **90%**
3. Air-fuel ratio: **17:1**
4. Isentropic efficiency of micro gas turbine : **85%**
5. LHV of Methane = **50 MJ/kg**

-Our daily energy requirements of core 5 is assumed to be **97.6kW** for 10 hours.

-The required chemical energy from biogas combustion can be calculated as follows:

= 97.6kW/0.9 = 108.44 kW

= 108.44kW * 3.6 = 390.384 MJ/hr (1kW = 3.6 MJ/hr)

- from given LHV of methane:

Mass flow rate of biogas = (390.384MJ/hr) / (50MJ/kg) = 7.808 kg/hr

Heat of combustion = 390.384 * (0.9) = 351.35 MJ/hr

-Micro gas turbine work output:

Work = (efficiency) * (heat of combustion) = (351.35MJ/hr) * (0.85) = 298.65 MJ/hr
= (298.65) / (3.6) = 82.96 kW

-Organic Rankine Cycle turbine:

ORC turbine efficiency = 70%

Available heat to ORC = 50MJ/hr (assumed based on similar set up)

W = (50MJ/hr) * (0.7) = 35MJ/hr = 9.72 kW

OVERALL SYSTEM EFFICIENCY:-

= (Total work output) / (required chemical energy)

= (82.96 + 9.72)kW / (108.44)kW

= 85.5 %

Implementing a biogas electricity generation system at IIT Guwahati is a feasible and economically advantageous project. The daily organic waste generated by the campus can be effectively converted into biogas, producing sufficient energy to meet the power needs of the Classroom Complex. With an initial investment of ₹1.8-2.7 crore, the system's annual energy savings offer a payback period of approximately 5-7 years, after which the campus can benefit from ongoing savings and energy self-sufficiency.

Additional integration of waste heat recovery, and smart energy management systems could further improve energy efficiency, reduce the campus's carbon footprint, and set a precedent for sustainable practices in educational institutions. By adopting these renewable solutions, IIT Guwahati could become a model for eco-friendly campus infrastructure, showcasing how waste can be transformed into a sustainable energy resource.

Challenges

1. Initial Capital Requirement: The substantial upfront investment of ₹1.8-2.7 crore may challenge initial funding or financing efforts.
2. Operational and Maintenance Costs: Consistent costs for maintenance, waste management, and labor, around ₹10-20 lakh annually, add to operational expenses.
3. Waste Supply Consistency: Effective biogas production relies on a steady input of organic waste, necessitating consistent collection and sorting to avoid inefficiencies.
4. Technical Complexity: Integrating waste heat recovery (ORC system) and gas cleaning infrastructure requires sophisticated design and skilled personnel for optimal operation.
5. Environmental and Regulatory Compliance: Ensuring the plant meets environmental emissions and waste management standards requires careful adherence to regulations, adding to administrative oversight.

Result and Discussion

1. The proposed installation of slides in Core 5 aims to reduce lift energy consumption by up to 15%, saving approximately 876 kWh annually. Slides provide an energy-efficient, gravity-powered alternative, enhancing user experience and promoting physical activity. Key considerations include safety, inclusivity, and routine maintenance. Though modest in direct savings, this innovative solution aligns with sustainability goals and showcases a creative approach to reducing energy use and fostering well-being.
2. The introduction of smart lighting and AC scheduling in the Core 5 Classroom Complex could yield significant energy savings, with projected reductions of approximately 105,000 kWh annually—equivalent to ₹8,40,000 in cost savings and a

substantial decrease in carbon emissions. A payback period of 2.35 years and a 5-year ROI of 113% demonstrate both short- and long-term economic viability. Supporting data from similar institutions, such as UCLA's Engineering Building (28% reduction) and Stanford's Green Building (24% reduction), further affirm the efficacy of these systems in an academic setting. These savings enhance energy efficiency, reduce operational costs, and contribute to IIT Guwahati's sustainability goals.

3. Implementing a biogas plant for IIT Guwahati offers substantial energy and environmental benefits by converting organic waste into renewable electricity. The campus's organic waste—primarily from food in hostels and canteens—can be transformed into an estimated 300-450 cubic meters of biogas daily. This output would generate about 1,800-2,700 kWh of electricity each day, meeting the Classroom Complex's power needs and reducing reliance on grid electricity. The addition of a waste heat recovery system via the Organic Rankine Cycle (ORC) could further improve efficiency, adding 180-540 kWh of electricity daily and reducing resource waste.
4. Financial analysis reveals a projected payback period of 5-7 years, considering an initial investment of ₹1.8-2.7 crore. With annual savings estimated at ₹40-50 lakh, the biogas system promises long-term economic returns and energy self-sufficiency for the campus. Comparable implementations in academic and industrial settings highlight this project's feasibility and potential for promoting IIT Guwahati as a leader in sustainable campus infrastructure.

Conclusion

In this project we have analysed the Core 5 Classroom Complex energy utility, sources of energy and how the energy is being utilised. We have also discussed about the current challenges faced due to the current energy sources. After analysing we have proposed some alternative energy systems in which few of them are meant to generate energy and others are meant to conserve the energy and also meant to smart utilisation of energy.The installation of sliders reduced almost 15% of the energy that the heavy lifts consume. Based on case studies and analysis, implementing a smart HVAC scheduling system presents a viable investment opportunity with significant energy and cost savings. The system's payback period of 2.35 years and power savings of about 15 to 25% and the projected ROI makes it a financially sound decision. Implementing a biogas electricity generation system is a feasible and economically advantageous project. The daily organic waste generated by the campus can be effectively converted into biogas, producing sufficient energy to meet the power needs of the Classroom Complex. With an initial investment of ₹1.8-2.7 crore, the system's annual energy savings offer a payback period of approximately 5-7 years, after which the campus can benefit from ongoing savings and energy self-sufficiency.

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