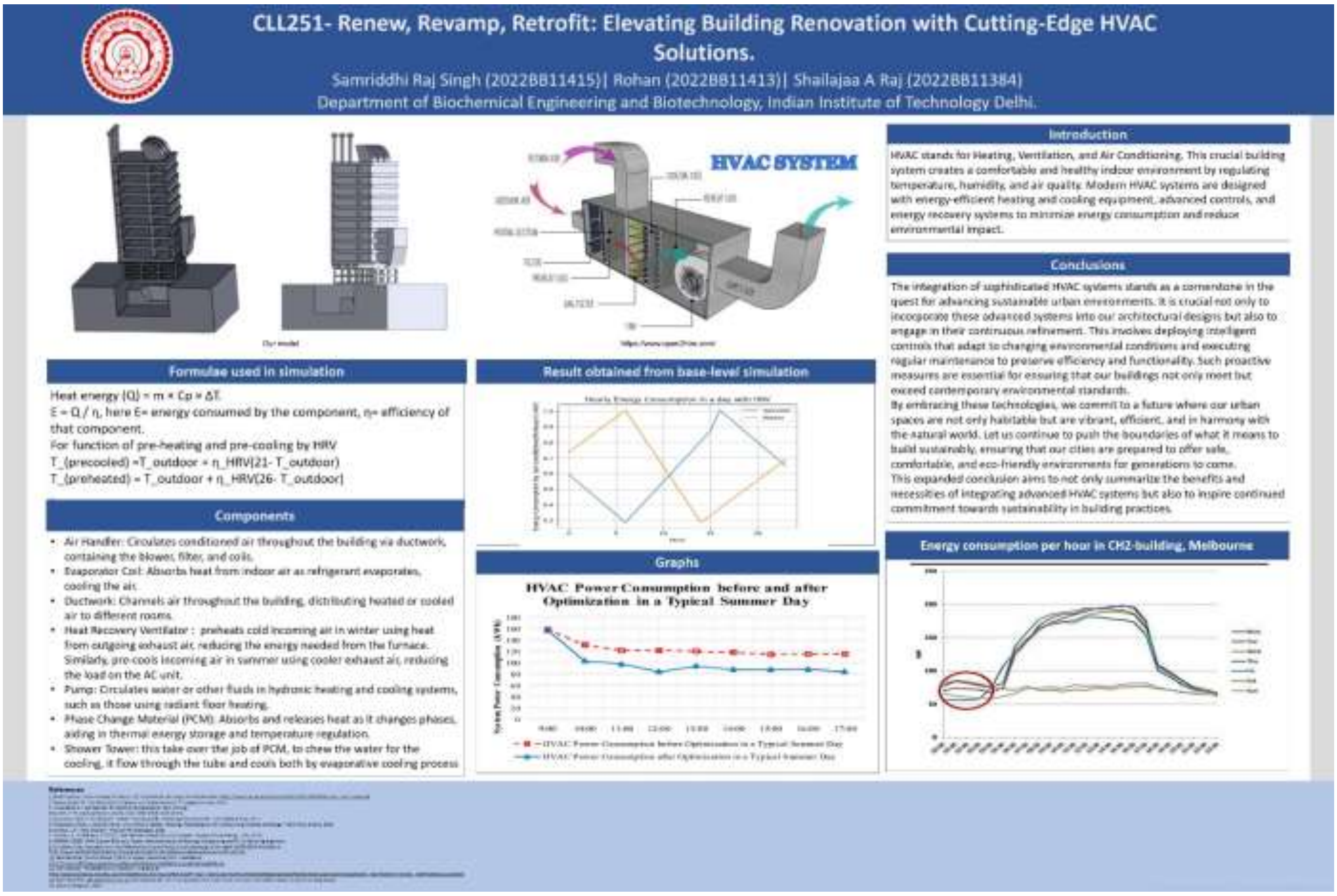
CLL251: HEAT TRANSFER FOR CHEMICAL ENG

Project Report

PEER-EVALUATION FORM

S No.	Name of the team member	Entry Number	Ranking
1.	Shailajaa A Raj	2022BB11384	5
2.	Samriddhi Raj Singh	2022BB11415	5
3.	Rohan	2022BB11413	5

POSTER*



CLL251- RENEW, REVAMP, RETROFIT: ELEVATING BUILDING RENOVATION WITH CUTTING-EDGE HVAC SOLUTIONS.

Samriddhi Raj Singh (2022BB11415)| Rohan (2022BB11413)| Shailajaa A Raj (2022BB11384)

Department of Biochemical Engineering and Biotechnology, Indian Institute of Technology Delhi.

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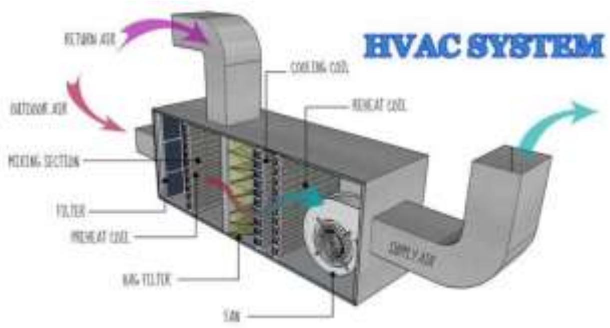
Abstract: This report outlines the design and implementation of a sustainable building with an advanced HVAC system aimed at reducing energy consumption and ensuring occupant comfort. Inspired by the CH2 building in Melbourne, our project integrated innovative design strategies and cutting-edge technologies to achieve our objectives. The building design prioritized passive strategies such as orientation, shading, and natural ventilation, while the HVAC system incorporated high-efficiency heat pumps, energy recovery ventilation, and demand-controlled ventilation. Python simulations were conducted to assess system performance, demonstrating significant reductions in energy consumption while maintaining indoor air quality and thermal comfort. A video presentation highlights the building's sustainable features and the operation of the HVAC system. Overall, our project showcases the feasibility and practicality of sustainable design principles for infrastructure development.



INTRODUCTION

In response to the growing concern over environmental sustainability and the need for energy-efficient infrastructure, our project was undertaken to design and demonstrate a building that exemplifies sustainable practices, particularly in its HVAC (Heating, Ventilation, and Air Conditioning) system. With a focus on reducing energy consumption, minimizing environmental impact, and ensuring occupant comfort, our project sought to integrate advanced HVAC technologies and innovative building design strategies.

Buildings are significant contributors to energy consumption and greenhouse gas emissions, with HVAC systems often being major culprits due to their reliance on fossil fuels and inefficient operation. Therefore, our project aimed to address these challenges by designing a building that significantly reduces its dependence on traditional HVAC systems while providing a comfortable indoor environment. Taking inspiration from successful sustainable buildings like the CH2 building in Melbourne, which has set a benchmark for green architecture, we set out to create a structure that not only minimizes energy consumption but also showcases the practicality and feasibility of sustainable design principles.

PROJECT OBJECTIVES

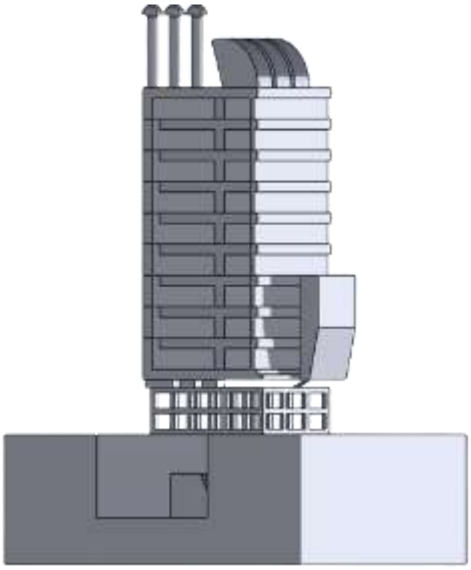
Design a building with reduced dependence on air conditioning: We aimed to create a building that utilizes passive design strategies to minimize the need for mechanical cooling and heating. Create a comfortable indoor environment for occupants: Our goal was to ensure that the indoor environment meets comfort standards for temperature, humidity, and air quality. Minimize pollution and energy consumption associated with HVAC systems: We aimed to design and implement an HVAC system that reduces energy consumption and minimizes greenhouse gas emissions.

METHOD USED

To achieve our objectives, we employed the following methodology:

Building Design:

Utilized SolidWorks for 3D modeling to create a detailed representation of the building design. Demonstrating how will our building look after incoorperating component of hvac system.



Python Simulations:

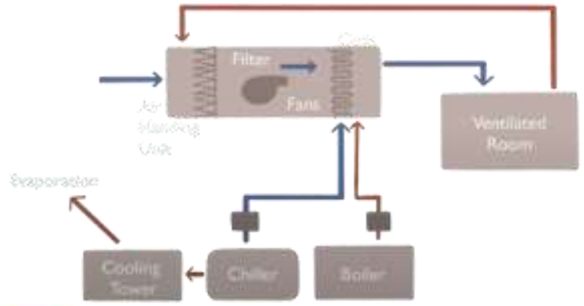
Utilized Python for simulations to evaluate the performance of the HVAC system under various conditions. Analysed factors including energy consumption, indoor air quality, thermal comfort, and system efficiency.

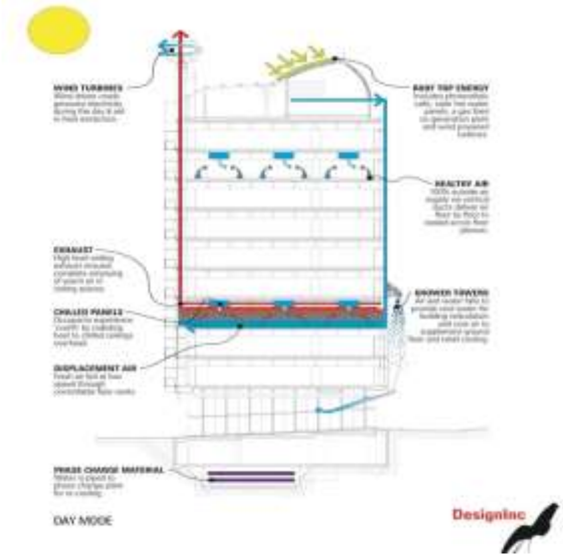
Video Presentation:

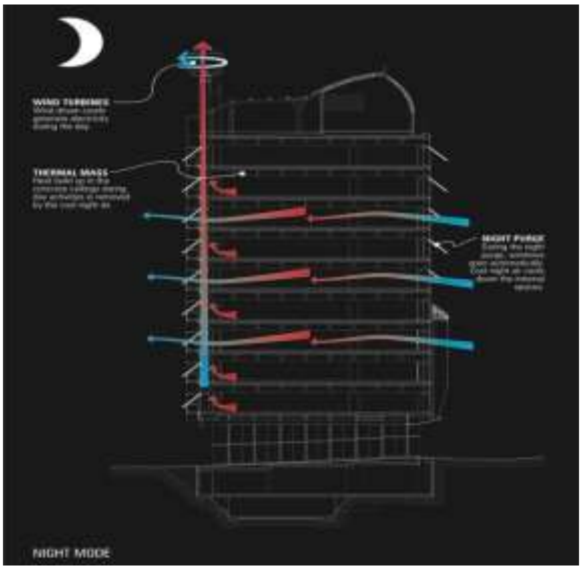
Created a video to visually demonstrate the functionality of the HVAC system and the building's sustainable features by using canva. The video provides a walkthrough of the building design and highlights the operation of the HVAC system.

COMPONENTS:

1. Air Handler: - The air handler is a crucial component of HVAC systems, responsible for circulating conditioned air throughout the building via ductwork. It typically contains a blower, which forces air through the system, a filter to remove impurities from the air, and coils to heat or cool the air as needed.
2. Evaporator Coil: - The evaporator coil plays a key role in the cooling process of HVAC systems. It absorbs heat from indoor air as refrigerant evaporates within the coil, effectively cooling the air before it is circulated back into the building.
3. Ductwork: - Ductwork refers to the network of channels that distribute heated or cooled air throughout the building. These channels allow air to flow from the HVAC unit to various rooms, ensuring consistent temperature levels throughout the building.
4. Heat Recovery Ventilator (HRV): - A heat recovery ventilator is designed to exchange indoor air with fresh outdoor air while simultaneously recovering heat from the outgoing air. This helps improve indoor air quality by removing pollutants and excess moisture, while also preventing energy loss by retaining heat from the exhaust air.
5. Pump: - Pumps are essential components in hydronic heating and cooling systems. They circulate water or other fluids through the system, ensuring that heated or cooled fluid reaches its destination, such as radiant floor heating systems or chilled water systems.
6. Phase Change Material (PCM):- Phase change materials (PCMs) are substances capable of absorbing and releasing large amounts of heat as they change from one phase to another (e.g., solid to liquid or liquid to gas). In HVAC systems, PCMs are used for thermal energy storage and temperature regulation, helping to stabilize indoor temperatures and reduce energy consumption.
7. Shower Tower:- This take over the job of PCM, to chew the water for the cooling, it flow through the tube and cools both by evaporative cooling process







HOW IT WORKS

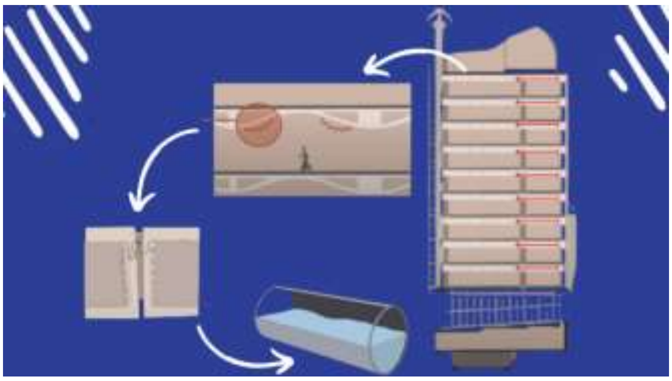
During the daytime, chilled water from three large tanks in the basement, each filled with nearly 10,000 small stainless steel bowls of PCM (Phase Change Material) that freezes at 16 degrees Celsius, is pumped to the ceiling panels. Water flows through metal tubes attached to precast concrete ceiling units, transferring heat to the PCM bowls. This process continues until the PCM bowls start to melt, signaling shutdown.

At this point, five durable lightweight fabric tubes, 13 meters tall and 1.4 meters in diameter, take over, circulating water for cooling. The top of these tubes pulls air in, inducing air movement. Water is cooled by evaporative cooling, and pre-cooled water assists the PCM.

During the night, air is drawn up through the exhaust air shaft and propelled upwards by a chimney and wind-driven turbine. The wavy precast concrete ceiling panel cools during the night, increasing thermal mass and creating cavities for exhaust air. This process repeats daily.

The cool air is then fed into the ground floor lobby, shops, and arcade to assist in cooling spaces.
During the night, air is drawn up through the exhaust air shelf and propelled upwards by the chimney, assisted by a roof-mounted wind-driven turbine.

The building's ceiling is made of a 7-inch precast concrete panel, which cools during the night. Its wavy design increases the surface area of thermal mass and creates cavities for exhaust air



COMPONENTS

Components of HVAC Systems and Their Principles:

1. Air Handler:

The air handler circulates conditioned air throughout the building using principles of fluid mechanics. The blower creates airflow, while the coils utilize heat transfer to either cool or heat the air as needed.

2. Evaporator Coil:
The evaporator coil relies on principles of heat transfer to cool indoor air. As refrigerant evaporates within the coil, it absorbs heat from the air, effectively cooling it before circulation.

3. Ductwork:
Ductwork employs principles of fluid mechanics to distribute air throughout the building. The network of channels ensures consistent airflow and temperature levels in different rooms.

4. Heat Recovery Ventilator (HRV):
HRV systems utilize principles of heat transfer to exchange indoor and outdoor air. They recover heat from outgoing air and transfer it to incoming air, maintaining indoor temperatures while improving air quality.

5. Pump:
Pumps in HVAC systems operate on principles of fluid mechanics to circulate water or other fluids. They ensure that heated or cooled fluid reaches its destination, such as radiant floor heating systems or chilled water systems.

6. Phase Change Material (PCM):
PCMs are based on principles of heat transfer and thermodynamics. They absorb and release heat as they change phases, aiding in thermal energy storage and temperature regulation to stabilize indoor temperatures and reduce energy consumption.

7. Shower Tower:
The Shower Tower utilizes principles of heat transfer and fluid mechanics. Water flows through the tower, where it is cooled by evaporative cooling, similar to how sweat cools the skin. This cooled water then circulates to provide cooling throughout the building.

NUMERICAL CONCEPTS

Formulae

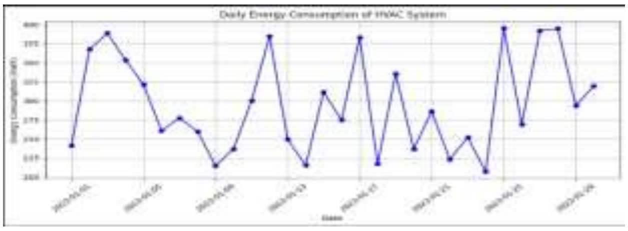
Several key calculations are used in the design and evaluation of HVAC systems, including:

- Heat Load Calculation: $Q = m \times Cp \times \Delta T$, where Q is the heat load, m is the mass flow rate of air, Cp is the specific heat of air, and ΔT is the temperature difference.

GRAPHS

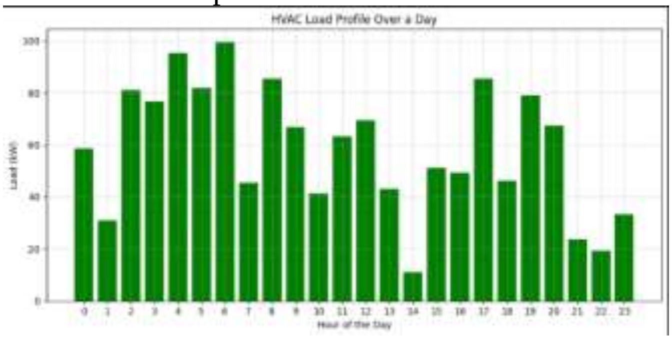
Daily Energy Consumption Graph

This graph will show the daily energy consumption of an HVAC system, useful for identifying patterns or inefficiencies.



HVAC Load Profile Over A Day

Here is the load profile



AIM OF THE PYTHON SIMULATION*

A basic level simulation has been done which reflects the hourly energy- consumption profile of air-conditioners/furnace.
Components highlighted are:

1. An air-conditioner.
2. A furnace.
3. A heat recovery ventilator.

It is just represented in the code that how much energy does an air-conditioner and a furnace consume if we incorporate a heat recovery ventilator (HRV) to reduce the load on them.

TOOLS USED

Python and its library Matplotlib, Pandas have been used as our tools.

ASSUMPTIONS AND CONSIDERATIONS

1. Volume of the building system = 200 cubic. Metre = volume of air to be heated or cooled.

2. These temperature profiles replicate the pattern of temperature in Delhi.

Two seasons, summers and winters are considered:

Here, 0th hour corresponds to 12 am.

- In summers, the outdoor temperature of a day varies as follows:

Temperature in degree Celsius = -1.07*(time in hours) + 33.42, between 0 hrs to 6 hrs.

Temperature in degree Celsius= 1.36*(time in hours) + 18.82, between 6hrs to 16hrs.

Temperature in degree Celsius = -1.07*(time in hours) + 59.14, between 16hrs to 24 hrs.

- In winters, the outdoor temperature of a day varies as follows:

Temperature in degree Celsius = -0.9375*(time in hours) + 10.625, between 0 hrs to 6 hrs.

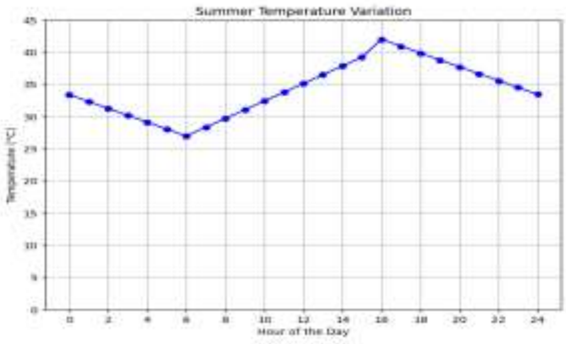
Temperature in degree Celsius = 1.875*(time in hours) - 6.25, between 6 hrs to 14 hrs.

Temperature in degree Celsius = -0.9375*(time in hours) + 33.125, between 14 hrs to 24 hrs.

These temperature variations are defined by considering linear variation of temperatures with respect to time

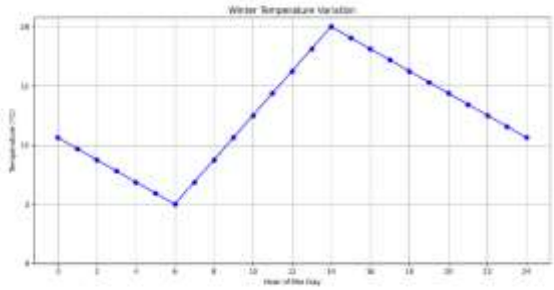
- Summer boundary conditions:

Maximum temperature = 42 degrees Celsius, achieved at 4 pm.
Minimum temperature = 27 degrees Celsius, achieved at 6 am.



- Winter boundary conditions:

Maximum temperature = 20 degrees Celsius, achieved at 2 pm.
Minimum temperature = 5 degrees Celsius, achieved at 6 am.



- Also, summer days don’t vary in temperature-profile for different days and similarly, winter days don’t vary in temperature-profile for different days.

3. Assuming density of air to be constant as 1.2 kg/cubic-metre and the specific heat capacity of air to be 1.005kJ/kg-Kelvin.

4. Comfortable temperature range is 21 degrees Celsius to 26 degrees Celsius. (in this temperature range, the heating and the cooling functions do not happen).

5. In summers, we intend to drop our room temperature to as low as 21 degrees Celsius and in winters, we intend to rise our room temperature to as high as 26 degrees Celsius.

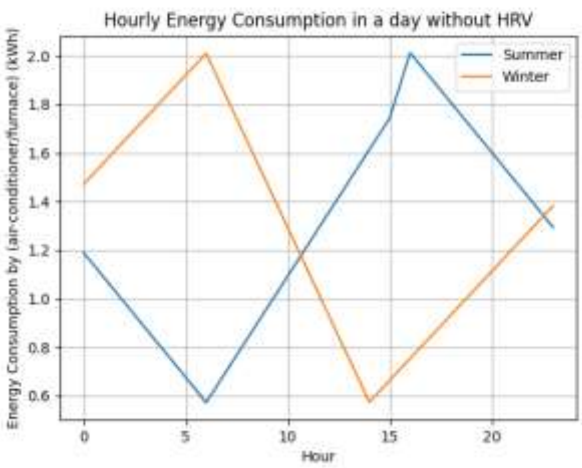
6. The system is in operation all the time**.**

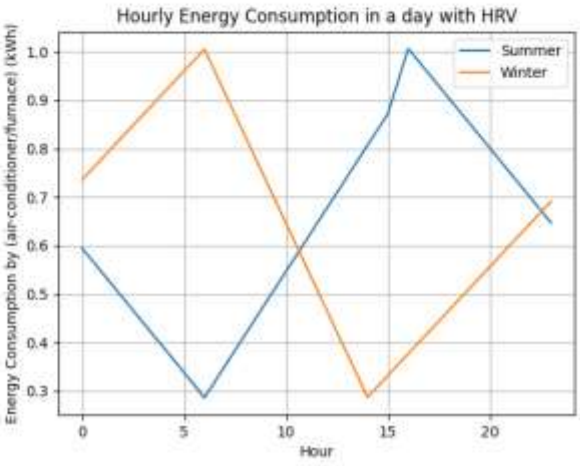
7. Before the operation, indoor temperature=outdoor temperature.

EQUATIONS FOR CALCULATIONS

- Heat energy (Q) = m × Cp × ΔT.
- T_precooled = T_outdoor + η_HRV(21-T_outdoor)
- T_preheated = T_outdoor + η_HRV(26-T_outdoor)
- Mass (m) = ρ × V
- Actual energy consumption by the components (E) = Q / η. Here η is the efficiency of the component.

RESULT





Note that this slight deviation in straight line is due to minute decimal point difference while writing the slopes of the temperature versus time profile.

LIMITATIONS OF THIS SIMULATION

In practical applications, we must also need to take into account the other components of HVAC, take proper temperature dependency with respect to time, take air density variation with respect to temperature, calculate the energy consumed by each and every component of HVAC and not make the assumptions like above.

EXAMPLE OF CH2 BUILDING

The CH2 building in Melbourne stands as a landmark example of sustainable architecture, incorporating innovative HVAC systems to achieve high levels of energy efficiency and occupant comfort. Designed by architects from the City of Melbourne, CH2 (Council House 2) is a six-star Green Star-rated building, making it one of the most environmentally friendly office buildings in the world. Its design prioritizes sustainability and energy efficiency, with a particular focus on its HVAC systems.

HVAC Features of CH2: Natural Ventilation: CH2 utilizes a natural ventilation system, with operable windows and vents that allow fresh air to circulate throughout the building, reducing the need for mechanical cooling.

Phase Change Material (PCM): The building incorporates phase change material in its construction, which absorbs and releases heat to regulate indoor temperatures. This innovative feature helps to stabilize temperatures and reduce the building's reliance on traditional heating and cooling systems.

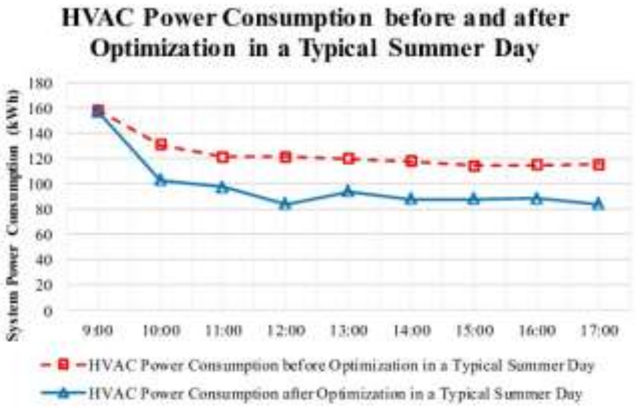
Heat Recovery Ventilation (HRV): CH2 employs heat recovery ventilation, which recovers heat from exhaust air and uses it to pre-heat incoming fresh air. This process improves indoor air quality while reducing energy consumption for heating.

Significance as an Example: The CH2 building serves as a compelling example of how innovative HVAC systems can
contribute to sustainable building practices. By analyzing CH2's HVAC features, we can gain valuable insights into the
benefits of energy-efficient systems, such as reduced energy consumption, lower operating costs, and improved indoor air qualitybenefits of energy-efficient systems, such as reduced energy consumption, lower operating costs, and improved indoor air quality. In our report, we draw inspiration from the design and performance of CH2 building to explore the potential of sustainable HVAC systems in other architectural contexts. By understanding the principles and technologies behind CH2's success, we can develop strategies for implementing similar solutions in various building projects.

CONCLUSIONS

Advanced HVAC systems are becoming increasingly important for creating sustainable cities. These systems should not only be incorporated into new buildings but also constantly optimised and improved. This can be achieved through smart controls that adjust to the environment and regular maintenance to keep them working efficiently. By taking these steps, buildings can meet and even surpass current environmental standards.

This advanced HVAC technology paves the way for a future where cities are not just livable but also efficient and environmentally friendly. This focus on sustainable building practices will ensure that cities remain safe, comfortable, and healthy places for future generations.



GITHUB LINK TO THE SIMULATIONS

1. https://github.com/Shailajaa2205/CLL251-PROJECT
2. https://github.com/Rohan080c/simulation-different-conditions-graphs

ACKNOWLEGEMENT

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[a] *Name: SAMRIDDHI RAJ SINGH Entry No. 2022BB11415*
[b] *Name: ROHAN Entry No.2022BB11413*
[c] *Name: SHAILAJAA A RAJ Entry No.2022BB11384*