Maximizing energy efficiency in hotel HVAC systems: An energy modelling approach to comparing Chilled water and Variable Refrigerant Flow (VRF) systems

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Abstract - *The paper presents a five-star, four-story hotel project in Bangalore with 2 basement levels for parking and services, ground floor for public areas, and 95 guest rooms from the second to sixth floor. The design focuses on meeting functional requirements while avoiding over-sizing equipment, ensuring cost efficiency, and providing maximum comfort to occupants. Two HVAC systems (Chill water and VRF) have been considered for the project, based on international standards like LEED v4 and ASHRAE 62.1 for maximum cost efficiency and highest indoor air quality.*

Key Words: HVAC, chilled water, energy efficiency, VRF systems, energy modelling

1.INTRODUCTION

The paper presents a five-star, four-story hotel project in Bangalore with 2 basement levels for parking and services, ground floor for public areas, and 95 guest rooms from the second to sixth floor. The design focuses on meeting functional requirements while avoiding over-sizing equipment, ensuring cost efficiency, and providing maximum comfort to occupants. Two HVAC systems (Chilled water and VRF) have been considered for the project, based on international standards like LEED v4 and ASHRAE 62.1 for maximum cost efficiency and highest indoor air quality.

The net use of energy has been on the rise throughout the world, leading to climate change and increasing greenhouse gas emissions due to increased energy generation from fossil fuels. Even though mitigation measures have been implemented around the world, significant efforts are still required to limit the rise in the global temperature to the 2 °C as stated in the Paris Agreement.[1] The amount of energy that can be saved in buildings through energy modeling can vary depending on the specific building and design options that are evaluated. Building sector accounts for approximately 40% of the total world final energy consumption and around one-third of the greenhouse emissions, therefore, it plays an important role to reduce the impact on the environment.{2} However, studies have shown that energy modeling can lead to significant energy savings in buildings. By and large, HVAC consumption in developed countries accounts for half the energy use in buildings and one fifth of the total national energy use.[3]

2. Air conditioning systems

2.1 Chilled Water Systems:

Chilled water systems are generally used in medium and large size buildings. These systems act as centralized cooling systems providing cooling to or even multiple buildings. Chilled water systems provide cooling to facilities by using chilled water to absorb heat from the building's spaces.

The system utilizes a machinery known as Chiller, which consists of four primary components viz: Compressor, Evaporator, Condenser, and an Expansion device. These four fundamental components are present in every chiller, irrespective of size, shape and type. Also, there are three main circuits associated with a chiller, which are very important to get desired cooling. The first, is the refrigeration circuit, which is the refrigeration cycle; the second, chilled water circuit, in which the heat is transferred from the building to chiller via heated water and then chilled water sent back to building, and the third, condenser circuit, in which heat is transferred to cooling tower, acting as a heat ejection source.

The chilled water supply (CHWS) is the name given to the water that exits a chiller, typically at a temperature of around 43 °F (~6°C). This CHWS is then pumped through the chiller and distributed to various air conditioning units within the building, such as air handling units (AHUs) and fan coil units (FCUs). As the chilled water passes through a heat exchanging coil in these units, it cools the coil, which is then blown with air by a fan to provide cold air to the building's space. The supply air temperature for AHUs and FCUs is typically around 55 °F (~12°C). After leaving the heat exchanging coil, the chilled water returns to the chiller, where it is cooled again, and the cycle repeats. There are two types of chilled-water systems: air-cooled and water-cooled.

Air-cooled chillers are most often installed outside buildings and extract heat from chilled water by releasing heat directly into the surrounding air. Water-cooled chillers are most often installed inside buildings. They differ from Air-cooled chiller in the fact that it extracts heat from the chilled water by dissipating it into a second isolated water line called the condenser water line. Condenser water flows through the chiller and absorbs heat which is then ejected via cooling tower located outside buildings.

Due to centralized air-conditioning, it provides organized configuration and simplifies the maintenance process. They provide better energy efficiency and cut down money on energy consumption in the long run.

2.2 Variable Refrigerant Systems:

It is a ductless, large system for HVAC, which uses refrigerant for both heating and cooling. VRF constantly controls the amount of refrigerant entering each zone to ensure overall comfort and energy efficiency. A VRF system is based on the flow of refrigerant between an external condensing unit and multiple internal evaporators (usually fan coil units). Each internal evaporator serves a different heat zone within the building and the refrigerant flow to each evaporator is adjusted based on local requirements. This provides a high degree of flexibility, allowing the performance of the outdoor condenser to adapt to the overall internal demand, allowing the overall system to operate at optimum efficiency.

VRF systems achieve high efficiency by making use of inverter compressors. An inverter system enables the compressor to ramp up or down as per requirements of individual space. In a system without an inverter, the compressor will always run at full capacity. Basically, it's either on or off. Inverter systems operating at low speeds and capacities can have significant efficiency gains.

Broadly, a VRF system can be either a two-pipe or three-pipe system.

The 2-pipe system can cool or heat all zones (heat pump system). The 3-pipe system can heat and cool simultaneously by heating some zones and cooling others. Heat recovery allows heat from zones requiring cooling to be used to heat zones requiring heating. This has a higher capital cost, but heat recovery allows for very efficient operation and reduces running costs.

An immediate advantage of VRF systems is reduced energy consumption. According to Trane technologies, VRF systems can save 30-40% energy compared to his traditional HVAC systems. Most VRF systems are inherently scalable and can be built component by component regardless of the desired size of the final system. This makes VRF systems ideal for large new buildings and older buildings undergoing major renovations and since requirement of ducts is absent, these systems can be implemented practically anywhere, regardless of the type of existing HVAC system.

VRF systems are ideal for buildings with multiple areas, varying heating and cooling requirements, and where good local control is required, examples, range of commercial buildings, office spaces, banks, hotels where some rooms may be vacant, and others have very high heat demands; etc.

In India, these two air conditioning systems are widely utilized due to the abundance of materials and parts from numerous suppliers and manufacturers. To choose the most efficient and cost-effective option for our building project, we will perform a detailed comparison of both systems and make an informed decision.

3. Occupancies & ventilation requirements

It is extremely important to account for the occupant density and ventilation requirements of the occupants in order to accurately determine the Actual Heat Load of the building. Following are the occupant density and Ventilation requirements as per the ASHRAE 62.

Fig 1. Occupancy details from ASHRAE

TABLE 6-1 MINIMUM VENTILATION RATES IN BREATHING ZONE
(This table is not valid in isolation; it must be used in conjunction with the accompanying notes.)

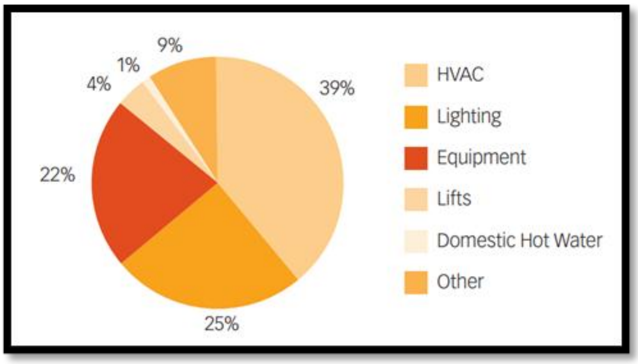
Occupancy Category	People Outdoor Air Rate R_p		Area Outdoor Air Rate R_a		Notes	Default Values: Occupant Density (see Note 4)	Default Values: Combined Outdoor Air Rate (see Note 5)		Air Class
	cfm/person	L/s·person	cfm/ft²	L/s·m²		#/1000 ft² or #/100 m²	cfm/person	L/s·person	
Hotels, Motels, Resorts, Dormitories									
Bedroom/living room	5	2.5	0.06	0.3		10	11	5.5	1
Barracks sleeping areas	5	2.5	0.06	0.3		20	8	4.0	1
Laundry rooms, central	5	2.5	0.12	0.6		10	17	8.5	2
Laundry rooms within dwelling units	5	2.5	0.12	0.6		10	17	8.5	1
Lobbies/prefunction	7.5	3.8	0.06	0.3		30	10	4.8	1
Multipurpose assembly	5	2.5	0.06	0.3		120	6	2.8	1

4. Breakdown of the energy use in buildings:

HVAC systems account for a significant portion of the energy consumption in commercial and residential buildings, with cooling and heating alone representing up to 50% of the total energy use. This makes HVAC systems a prime target for energy efficiency improvements.[5] The exact percentage of HVAC's impact on building load depends on various factors such as the size and location of the building, the climate, the type of HVAC system used, and the efficiency of the system.

For example, in a hot and humid climate, the HVAC system may consume as much as 70-80% of a building's total energy consumption due to the need for air conditioning. In a temperate climate, the HVAC system may consume less energy, accounting for 40-50% of total energy consumption.

Fig 2. Building energy use breakdown of a typical office building



Source: Guide to Best Practice Maintenance and Operation of HVAC Systems for Energy Efficiency (January 2012), Pages 36–37 http://ee.ret.gov.au/energy-efficiency/non-residential-buildings/heating-ventilation-and-air-conditioning-hvac

It can be easily understood that from the total energy input of a building, a major and a significant value is taken by the HVAC systems. By having a control on this value, the performance of the building can be impacted. The US Department of Energy reports that energy modelling can lead to energy savings of up to 40% or more in some cases [6].

A thorough energy audit and simulation can identify any operational and design anomalies and lead to improved performance and reduced energy waste, ultimately saving cost over time. When designing or renovating a building, it's crucial to consider the significant impact of the HVAC system on building load. Implementing energy-efficient HVAC systems and maintaining them properly can minimize their impact, lower energy expenses, and support a sustainable future.

5. Steps involved in energy modelling:

There are various steps involved in the process of creating an energy model in the trace software. These are general guidelines and the steps involved vary depending on the scale of the project and the specific process may vary depending on the version of TRACE 3D Plus being used and the complexity of the HVAC system.

1. The user creates a new project by opening TRACE 3D Plus and selecting "New Project" from the File menu. The user inputs a name for the project and selects a location to save the project file. The user sets up the project's time zone, weather data, and other relevant information.
2. The user defines the building by inputting the building geometry, such as the floor plan, walls, and roof. The user specifies the type of construction, insulation, and other relevant information for the building envelope. The user may also import existing building information from a CAD program or other software.
3. The user can also choose which room type will be the default when a room is drawn. The room will automatically be assigned the room type template selected as the default. Room types can be expanded to view the construction, internal loads, and airflow templates assigned to them. The assignments can be altered from the drop-down list.
4. The weather tab in the site and building section will allow the user to view or modify the design conditions of the selected location as well as view other locations in the map or the tree the selected location will show on the top of the tree and the map will be zoomed in to the specific location marked with a star.
5. The user will now proceed to the create building tab to draw our building when you click on the create building tab notice the three options that show g/b XML import draw building and building wizard. Upon selecting the image file, you will need to click a location on the image that will be lined up with the origin. The user can relocate the pictures origin simply use the origin tool and click a spot on the image where the new origin will be. The image is then scaled to match the true dimensions of the project.
6. Length and width values can be entered when using the drawing tools using these fields will create rooms or walls. They can also be used to add windows and other elements in the project.
7. Levels can be added above or below the original level by simply clicking the plus sign on either side of the current level indicator. The user can switch between levels by clicking on the number of the desired level levels of the building can also be reordered or deleted.
8. The user defines the HVAC system by choosing the type of HVAC system they want to model, such as a central air system, a ductless mini-split system, or others. The user inputs the system specifications, such as fan and pump sizes, coil sizes, duct sizes, and other relevant information. The user may also import system information from other software or equipment manufacturer's data.

9. The user defines the loads by inputting the heating and cooling loads for the building, including internal loads from people, lights, and equipment, and external loads from windows, roof, and walls. The user may also import load information from other software or use default values provided by TRACE 3D Plus.

10. The user runs the simulation and analyzes the results. They can view air and water flow, air temperature and humidity, energy consumption, and other relevant information. They can also compare the performance of the HVAC system to industry standards or other design criteria.

11. The user optimizes the system based on the simulation results by making adjustments to the HVAC system to optimize its performance and energy efficiency. They can adjust the system components, such as fans, pumps, coils, and ducts, or change the building envelope or load information.

12. The user repeats the simulation and analysis process until they are satisfied with the results. They can make changes to the system or building information and repeat the simulation as many times as needed.

13. The user saves the project and exports the results to share with others or use in other programs. They can export results in various formats, such as graphs, tables, and reports, for further analysis or presentation.

6. Project introduction:

The selected project is a five-star category four story hotel situated in the city of Bangalore and will comprise of 2 Basements for Parking and Services, Ground floor for Public areas and 95 Guest Rooms from Second Floor to Fourth Floor. The hotel name and brand have not been included for confidentiality purposes. The hotel plans and structural details were obtained from the architects. The rates of electricity and cost of equipment were obtained from HVAC vendors and contractors. The hotel was analyzed on TRACE 3D PLUS and the total cost was compared for a period of 20 years.

The report describes the project requirement and outlines the various mechanical and electrical systems to be adopted.

The design philosophy is to ensure fulfillment of all functional requirements in accordance with national and international standards and codes as well as local by-laws. While fulfilling the functional requirements, special efforts have been made towards optimization while ensuring adequacy of equipment and systems. Through these collective measures, functional adequacy has been ensured while avoiding over sizing in equipment and system as all oversized systems/equipment will cost more to owner, cost more to operate (as oversized system are inherently inefficient) and most importantly, over designed system is functionally inferior.

We have considered 2 of the most readily available HVAC systems available in India:

1. Chill water HVAC system
2. VRF HVAC system

The detailed analysis is given below.

Various international standards like LEED v4, ASHRAE 62.1 etc. have been considered while designing the HVAC system, to ensure maximum cost efficiency, along with ensuring the highest standard of comfort to the occupants. Adequate fresh air quantity shall be provided to air-conditioned spaces to maintain Indoor Air Quality (IAQ) generally as per ASHRAE standard 62.1-2010.

7. CODES AND REGULATIONS:

The following codes and standards have been used in the design:

- Accor (IBIS) Engineering Design Guidelines.
- National Building Codes: Building Services 2016
- The American Society for Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) standards:

• Ventilation for acceptable indoor air quality 62.1-2010.
• Energy standards for buildings 90.1-2007.
• ASHRAE handbooks:
• 2018 ASHRAE Handbook, Refrigeration.
• 2019 ASHRAE Handbook, Applications.
• 2020 ASHRAE Handbook, Systems and applications.
• 2021 ASHRAE Handbook, Fundamentals.

- Air Conditioning, Heating and Refrigeration Institute (AHRI).
- Sheet Metal and Air conditioning Contractors National Association (SMACNA):
- HVAC duct construction standards, metal and flexible, 1995.
- Energy Conservation Building Code (ECBC 2017)
- ASHRAE 52.1-1992, 52.2-2007.
- IMD Weather Data.

BUILDING ENVELOPE:

a) 'U'-value of exposed wall = **0.32 Btu/Hr/ft²/ºF**
b) U'-value of roof = **0.0951 Btu/Hr/ft²/ºF**
c) Fenestration
  i) Public area = 'U' value = **0.57 Btu/Hr/ft²/ºF** & SHGC = **0.6**
  ii) Guest rooms = 'U' value =**0.57 Btu/Hr/ft²/ºF** & SHGC = **0.6**

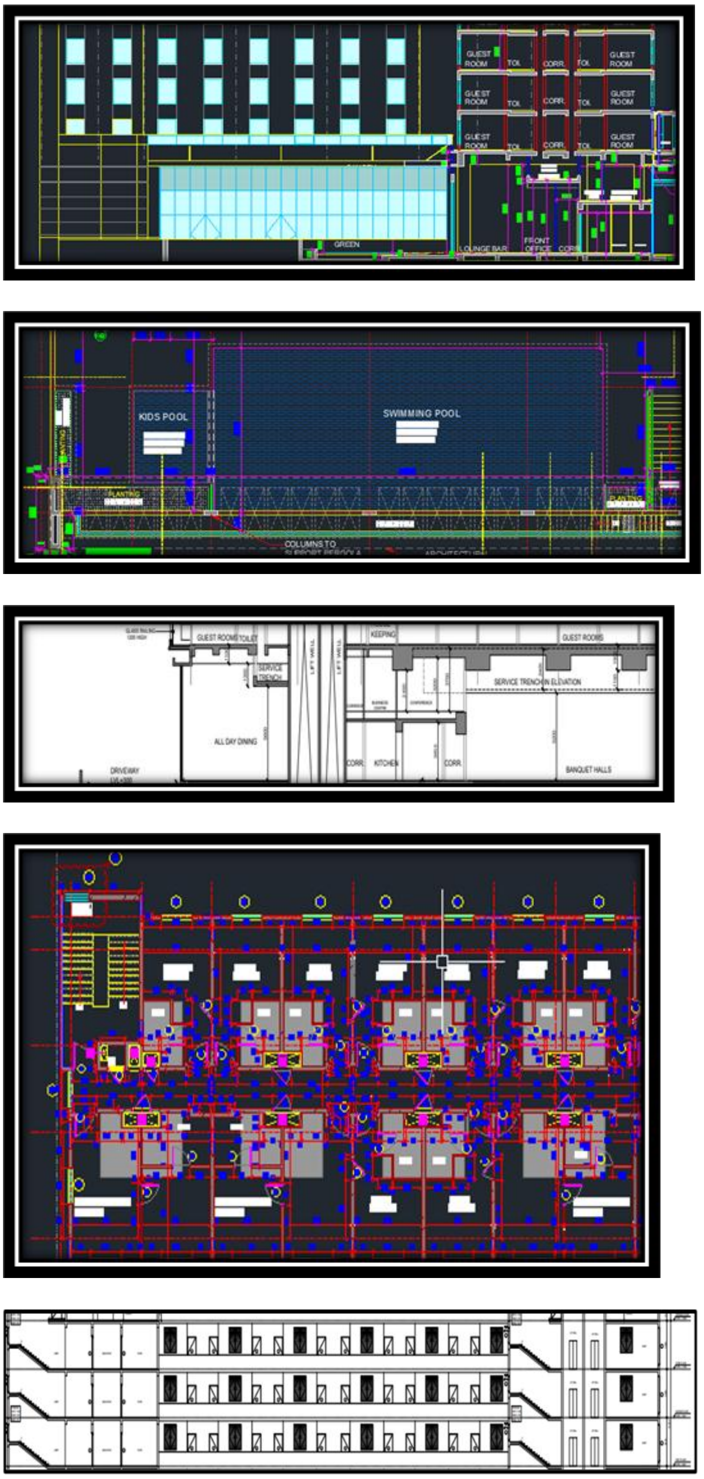
8. Hotel Specifications:

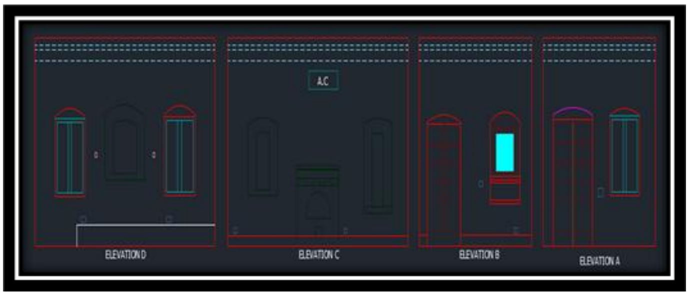
Fig 3. Site Location

The site and hotel details are made available to us from the architects. They specify in detail the various elements, rooms, lobbies, areas, elevations and give us information on the occupied and unoccupied areas in the hotel. The project is a five-star category four story hotel situated in the city of Bangalore and will comprise of 2 Basements for Parking and Services, Ground floor for Public areas and 95 Guest Rooms from Second Floor to Fourth Floor.

Details of the hotels structure and materials are obtained from the client and contractors, and they help us in entering the U – values and shading coefficients of the glass, partitions, slab, roofs, walls etc. This helps us to get a more detailed and accurate analysis, further increasing the accuracy of the results.

Fig 4. Architectural and CAD drawings of hotel and rooms





9. Design Criteria:

9.1 Climatic Design Conditions

The climatic design information as given by IMD/ASHRAE is used for design, sizing, selecting, installation, and dehumidification equipment, as well as for other energy-related processes. 8760 hours (365x24) IMD weather data has been used for detailed simulation using the most advanced TRACE-3D PLUS simulation software.

The external environmental conditions used in the mechanical design are as follows:

Location: Bangalore
Latitude: 12.9716° N, 77.5946° E

Summer

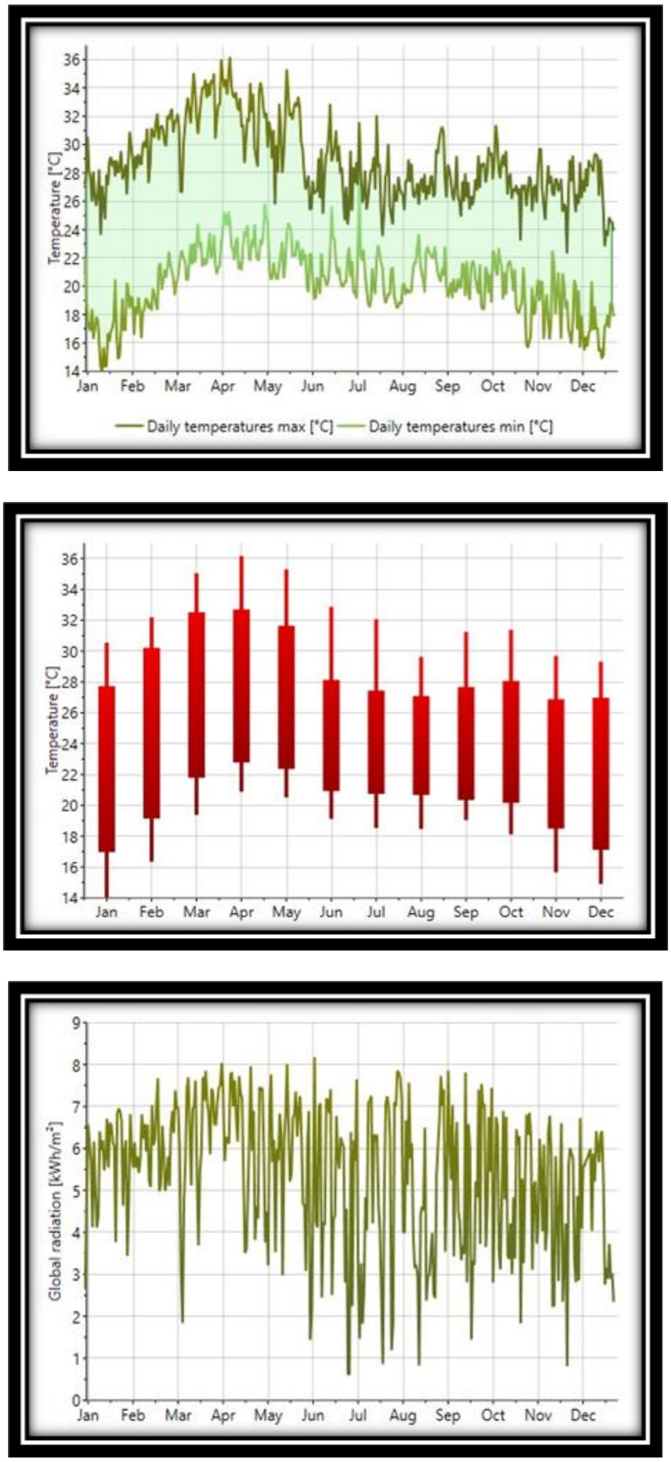
Dry Bulb Temperature : 95.9 Deg. F (35.5 Deg C)
Wet Bulb Temperature : 68.72 Deg. F (20.4 Deg C)

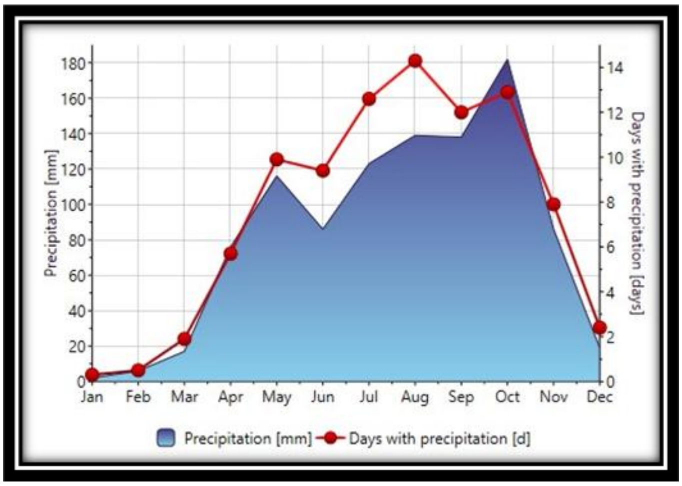
Monsoon
Dry Bulb Temperature : 86.5 Deg. F (30.3 Deg C)
Wet Bulb Temperature : 76.1 Deg. F (24.5 Deg C)

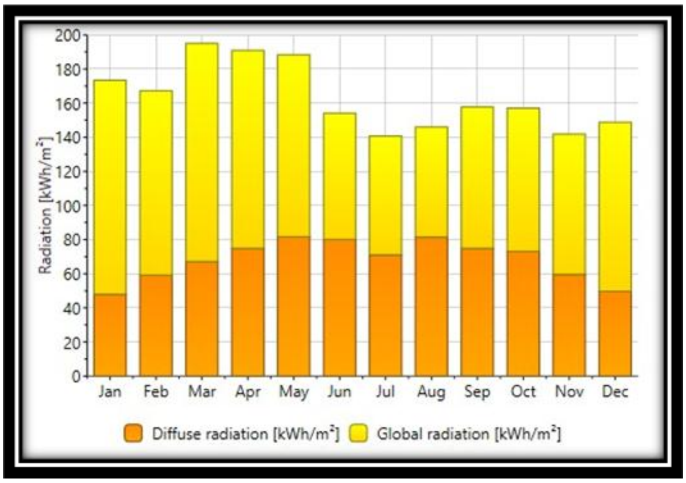
Winter
Dry Bulb Temperature :59.0 Deg. F (15.5 Deg C)
Wet Bulb Temperature :48.0 Deg. F (8.8 Deg C)

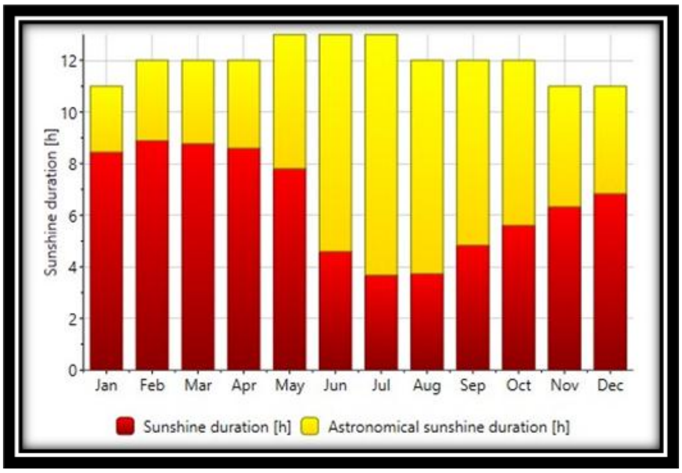
9.2 Weather Data:

Fig 5. Weather Data: (a) Daily Temperature Range (b) Average Temperature Variation Chart (c) Daily Global Radiation Chart (d) Precipitation chart (e) Diffused/ Global Radiation Chart (f) Sunshine Duration









10. INDOOR DESIGN CONDITIONS:

To reach comfort conditions and proper environment, it is necessary to maintain the design at a certain temperature and humidity within different areas to acceptable levels.

As such, the indoor design temperature conditions applied in the design of the project shall be according to Table 1 below:

Location	Room Temp. (1) (°C)	Room Relative Humidity (2) % RH	Room Noise level (NC)	Outdoor Air (10) CFM	Ventilation A.C HR^{-1}
Guest Room	24 (±1°C)	< 60%	37	26 per room (TFA) (As per ASHRAE)	26 CFM exhaust from wash room. (Exhaust)
Reception	24 (±1°C)	< 60%	35	7.5 CFM/ person + 0.06 CFM / sq.ft.	-
Restaurant	24 (±1°C)	< 60%	45	7.5 CFM/ person + 0.18 CFM/ sq.ft	-
Kitchen	28 (±1°C)	< 65%	55	As per ASHRAE 62.1	As per ASHRAE 62.1
Meeting Room	23 (±1°C)	< 60%	40	5 CFM/ person + 0.06 CFM/ sq.ft	-
Bar	24 (±1°C)	< 60%	40	7.5 CFM/ person + 0.18 CFM/ sq.ft	-
BOH	24 (±1°C)	< 60%	40	5 CFM/ person + 0.06 CFM/ sq.ft	-
ADD / Pre-function	24 (±1°C)	< 60%	40	7.5 CFM/ person + 0.18 CFM/ sq.ft	-

TABLE 1: Temperature, Humidity, ventilation and NC criteria

Notes:

1. The tolerance levels shown indicate the range of temperatures due to the operation of the controls systems.

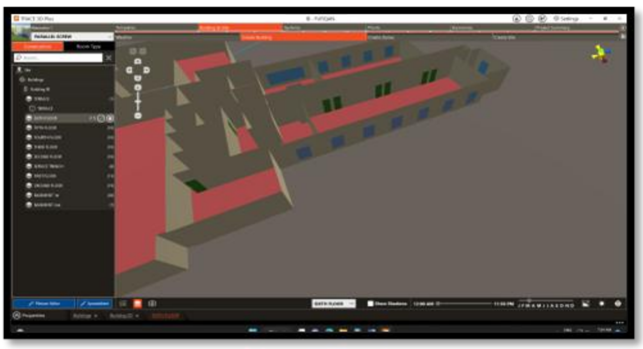
10.1 BUILDING DESING:

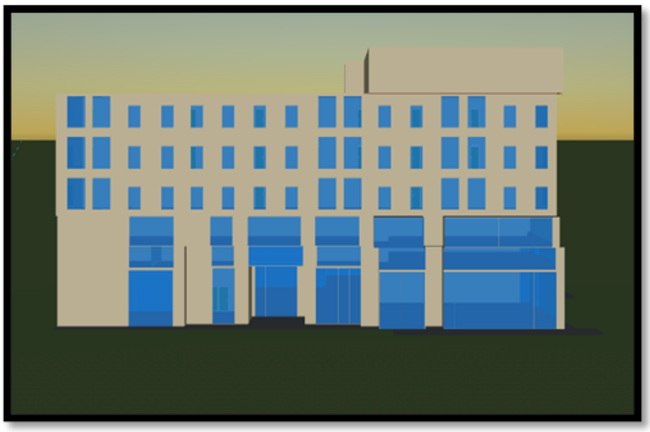
The hotel type was selected to be a standard hotel. This helped in classifying the various room types and occupancies already available in the TRACE 3DPLUS library as per ASHRAE guidelines.

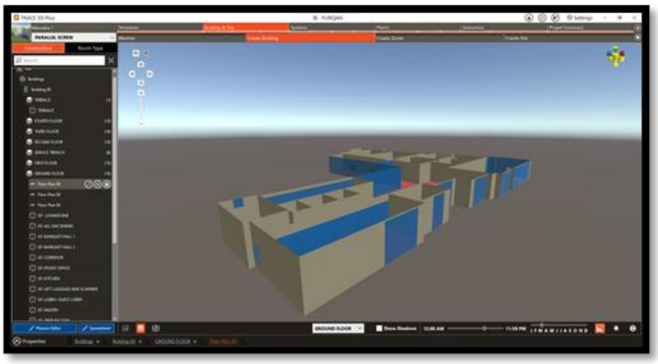
The project AUTOCAD or architectural layouts are obtained. These are then inserted into the TRACE 3DPLUS file to get reference points to draw the building on a floor-by-floor basis. This can further help us gain much more detailed and accurate model of the hotel.

The detailed plans help in classifying and building each room according to specified widths and help to further simplify the design process. The finished building matches the important features of the building perfectly. As far as energy modelling is considered, it is a highly accurate match.

Fig 6. Building model generation







(f)

10.2 ROOM TYPES:

The next process requires the various rooms generated to be dissociated in various room types. The pre-installed room types are selected from the library and then associated with each, and every space or room built in the area.

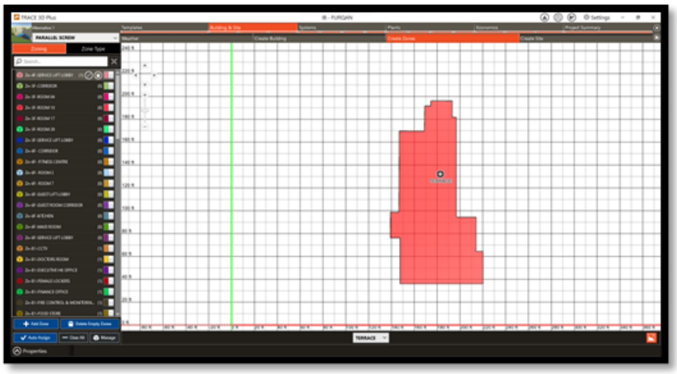
There are various room types to select from including kitchen, guest room, lobby, corridor, etc. this helps to specify the room occupancy, ventilation requirement, heating requirement, heat load etc. This further allows us to accurately predict and room heating and cooling requirements, in turn allowing us to calculate the room total electricity consumption by the HVAC equipment.

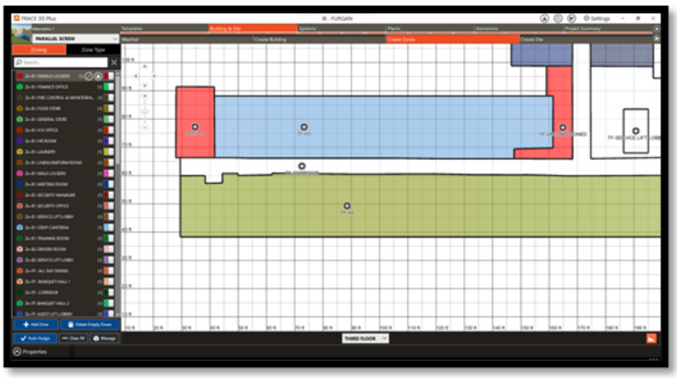
10.3 Zone types:

A "zone" is to be a collection of rooms which share a single air diffuser and/or terminal device(s). For example, if a unit or AC unit is applied to a zone, all of the rooms in the zone share the single fan coil terminal unit. All rooms within in a zone share the parameters in the zone's respective zone type. The purpose of zone types is to establish the heating and cooling setpoints, drift points, supply path, return path, and ASHRAE 62.1 effectiveness ratios at a template level rather than zone by zone.

Thus, establishing zones allows us to further simplify calculations, and insert a specific zone type or parameter for a large number of similar rooms. For e.g., a hotel with 500 rooms can be made a single zone on each floor. Then, if any changes are required, we only need to edit the individual floor level zones, rather than all the 500 rooms.

Fig 7. Building zone wise categorization.





(b)

11. HVAC System Alternatives:

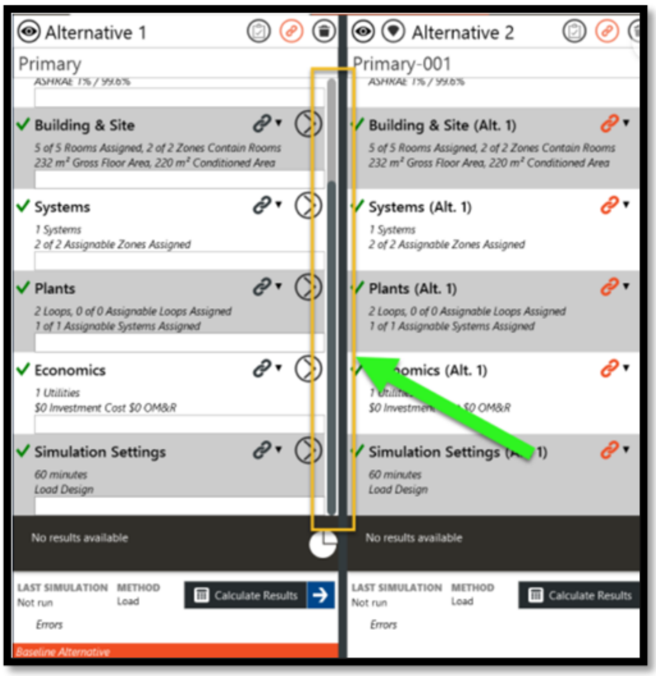
TRACE 3D PLUS allows the user to create multiple scenarios and testing conditions. The purpose of a computer model is to test scenarios prior to construction. To facilitate in testing scenarios, TRACE 3D Plus allows the user to have up to 16 alternatives. The alternatives may be linked, copied, made

new, or any combination of these. For example, The building may be linked, the systems may be copied for small changes, the plants may be linked to a different alternative, and the simulation settings may be completely different. Alternative 1, is elevated as the main or "base" alternative throughout many reports.
These alternatives can then be used to generate reports and comparisons between various scenarios. We create 2 alternatives in this case:

1. Screw chiller
2. VRF system

Both these systems are extremely common in India and are economical under different conditions.

Fig 8. Alternatives configuration



11.1 SYSTEMS:

There are various types of air conditioning systems we can choose from in trace. These can be classified into various types. These must first be accessed from the system library. The system library has several options to choose from.

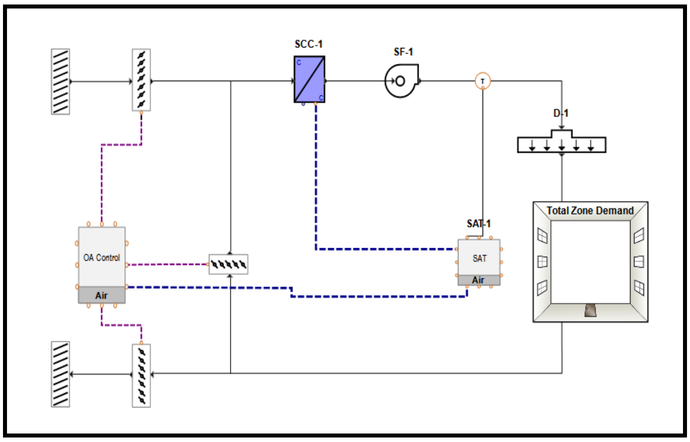
1. Variable volume units
2. Constant volume units
3. Heating only units
4. Double duct
5. Chilled beam

And many more such systems. For our consideration, we use the constant air volume systems. This is because, constant volume systems can be easy to control and reduce on capital costs.

Variable volume systems involve extra control and equipment. The most important is the modulating dampers and pressure sensors which are needed to be installed at the various rooms. This increases capital costs in the form of increased first costs. Furthermore, this also needs more complex controlling mechanisms.

We have chosen the following constant volume system.

Fig 9. Sample cooling unit



The selected system consists of various components like an Outdoor air control and dampers for outdoor and room return air. The outdoor air is required for ventilation. We then have the cooling coil by the name SCC -1. The air passes through this cooling coil and then reaches the room through the supply damper named D1. SAT 1 refers to the temperature sensor present in the room.

11.2 Configuring systems:

In order to configure systems, we go to the configure systems tab. Since the project is a hotel the setpoints are taken according to ASHRAE standards for internal comfort.

Assigning zones to systems:
Once a system has been designed, it needs zones to be assigned to it. This is done easily in the assign zones tab of the program. Separate systems are applied for areas with separate zones. We have the following zones made in the project.

1. Lobby
2. Basement -1
3. Basement – 2
4. First floor
5. Second floor
6. Third floor

7. Fourth floor
8. Fifth floor
9. Sixth floor
10. Ground floor
11. Banquet
12. All day dining.

All these systems have their individual setpoints and ventilation conditions based on ASHRAE ventilation and indoor air quality comfort guidelines. The zones can be assigned to each system easily by the assign zones tab.

Each and every zone can be assigned to various system by clicking on the system and then on the zone. Spaces which are unconditioned can also be mentioned here to allow ease in the selection.

The next is the configure zone equipment tab. This allows the setting up and adjusting of the equipment or Fan coil unit in the respective rooms or zones. Mostly, 1.5 TR fan coil units are used in the hotel rooms and the same have been used in the above project.

11.2 Plant Configuration:

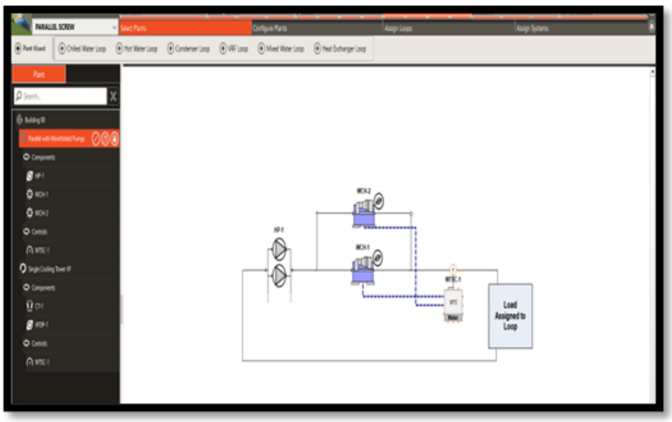
There are prebuilt plant systems in TRACE 3D PLUS. The program gives the option of automatic plant selection, however depending on the two systems and the Indian subcontinent, we select different units and plants.

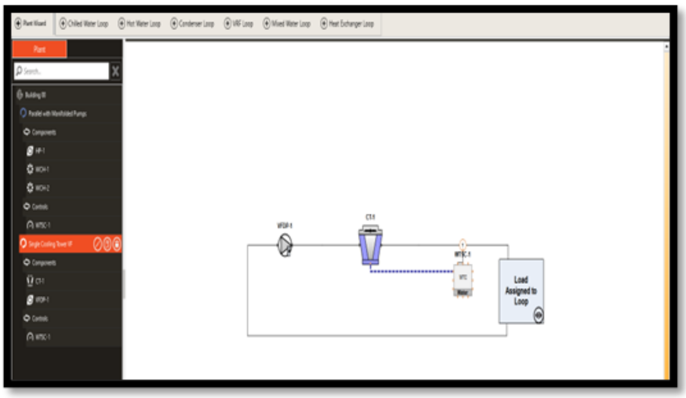
In the chill water system, there are two loops selected:

1. The chiller loop including two chillers with manifolded pumps.
2. The cooling tower loop.

Here, water cooled chillers are used as the plant is located in Bangalore, where the conditions allow the installation of cooling towers.

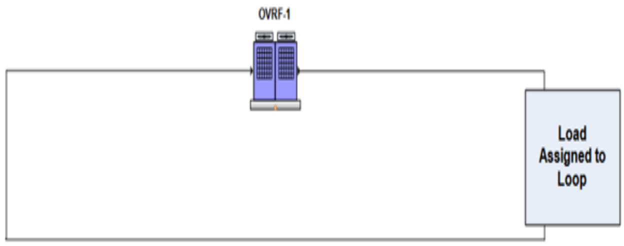
Fig 10. Plant configuration





In the VRF system, only one loop is considered as the indoor units are connected to larger outdoor VRF units.

Fig 11. VRF loop configuration



The given equipment and loops are the basis of the analysis of the two alternatives. We now run analysis on both the systems and get the results in the project summary tabs of both alternatives.

12 Calculations and Results:

The project summary tab contains the tab for the analysis and displaying the results. The load report is calculated on both the selected alternatives. The System Component Summary report is the main load design report for populating specifications and equipment schedules. This report provides the heating/cooling rate, airflow, air conditions and water conditions of each coil. The system airflows are calculated based on the heating and cooling airflows required by the rooms and zones, plus any system level overrides applied. System rules are then applied to decide how the heating and cooling airflows should relate.

The program generates the required load design report. It consists of:

1. Title Page
2. Room Cooling Loads by Component
3. Room Heating Loads by Component
4. Zone Cooling Loads by Component

5. Zone Heating Loads by Component
6. System Component Summary
7. Design Psychometrics
8. Outside Air and ASHRAE 62.1 Analysis
9. Plant Summary
10. System Cooling Checksums
11. System Heating Checksums

The program generates the reports based on the various parameters entered and the rooms designed.

13 Reports:

13.1 Project Summary:

The project summary is created by the TRACE software. The total ventilated or conditioned area is 73,344 ft^2. This is almost 49.1% of the building area. The weather location conforms to Bangalore.

13.2 Heat Load Summary:

TABLE 2: Heat Load Summary

S. No.	Floor & Area Name	Area (Sqft)	Lighting kkW		Occ.	Eqp. Load		Fresh Air	Design Cooling Load	Dehumidified CFM
			BTU/hr	kW		BTU/hr	kW	CFM	TR	
					BASEMENT 2					
1	ENIGNEERING OFFICES	401	1742	0.51041	5	2237	0.65544	48	2.2	1045
2	IBMS BATTERY ROOM	228	279	0.08175	0	1413	0.41401	224	1.6	615
3	SERVICE LIFT LOBBY	119	441	0.12921	2	621	0.18195	30	0.5	188

TOTAL TONNAGE FOR BASEMENT 2 = 5 TR

S.No.	Floor & Area Name	Area (Sqft)	Lighting kkW		Occ.	Eqp. Load		Fresh Air	Design Cooling Load	Dehumidified CFM
			BTU/hr	kW		BTU/hr	kW	CFM	TR	
					BASEMENT 1					
1	CCTV	106	367	0.10753	1	521	0.15265	6.3	0.8	300
2	DOCTOR'S ROOM	59	248	0.07266	1	320	0.09376	3.6	0.3	163
3	EXECUTIVE HK OFFICE	56	181	0.05303	1	220	0.06446	3.4	0.3	120
4	FEMALE LOCKERS	166	603	0.17668	8	952	0.27894	81.5	2.3	930
5	FINANCE OFFICE	257	864	0.25315	3	1266	0.37094	15.1	1	493
6	FIRE CONTROL ROOM	185	800	0.2344	2	902	0.26429	11.1	1.4	660
7	FOOD STORAGE	314	614	0.1799	1	1504	0.44067	18.8	2.2	1006
8	GENERAL STORE	196	372	0.109	1	1051	0.30794	11.7	1.3	647
9	HK OFFICE	53	233	0.06827	1	312	0.09142	3.2	0.9	369
10	HR ROOM	115	410	0.12013	1	580	0.16994	6.9	0.5	243
11	LAUNDRY	412	584	0.17111	3	8564	2.50925	1236	8.2	TFA
12	LINEN/UNIFORM ROOM	216	579	0.16965	5	984	0.28831	323.5	1.2	428
13	MALE LOCKERS	279	791	0.23176	8	1385	0.40581	137.5	2.4	945
14	MEETING ROOM	70	291	0.08526	1	350	0.10255	4.2	0.5	220
15	SECURITY MANAGER	55	279	0.08175	1	360	0.10548	3.3	0.5	234
16	SECURITY OFFICE	40	258	0.07559	1	273	0.07999	2.4	0.8	320
17	SERVICE LIFT LOBBY	123	635	0.18606	1	742	0.21741	30	1.3	579
18	STAFF CAFETERIA	588	2089	0.61208	60	11096	3.25113	547	6	2095
19	TRAINING ROOM	229	658	0.19279	25	1071	0.3138	342	2.1	796

TOTAL TONNAGE FOR BASEMENT 1 = 35 TR

S. No.	Floor & Area Name	Area (Sqft)	Lighting kkW		Occ.	Eqp. Load		Fresh Air	Design Cooling Load	Dehumidified CFM
			BTU/hr	kW		BTU/hr	kW	CFM	TR	
					GROUND FLOOR					
1	LOBBY	3502								
2	LOUNGE BAR	677	37106	10.8721	161	33191	9.72496	509	25.4	11161
3	GUEST LOBBY	300								
4	FRONT OFFICE	300	387	0.11339	2	542	0.15881	6.4	0.3	163
5	PANTRY	68	267	0.07823	3	357	0.1046	26	0.4	155
6	RETAIL 2	113	344	0.10079	2	356	0.10431	26.2	0.4	167
7	CORRIDOR	1084	3784	1.10871	43	3544	1.03839	1626	5.9	1709
8	KITCHEN	744	2346	0.68738	52	12846	3.76388	526	4.9	1674
9	LEFT LUGGAGE+SCANNER	322	822	0.24085	5	962	0.28187	74.9	1.4	665
10	RETAIL	785	1950	0.57135	12	3107	0.91035	182	3.5	1569
11	SERVICE LIFT LOBBY	147	441	0.12921	2	621	0.18195	30	0.5	188
12	STORE	576	754	0.22092	4	2198	0.64401	34	1.6	793
13	ALL DAY DINING	2130	5836	1.70995	152	33796	9.90223	1535	25.2	11816
14	BANQUET HALL 1	1350	11184	3.27691	206	10004	2.93117	1650	11.8	4248
15	BANQUET HALL 2	1350	11185	3.27721	210	10004	2.93117	1625	11.6	4164
16	PRE-FUNCTION	1051	7570	2.21801	160	7558	2.21449	1257	19.1	6000

TOTAL TONNAGE FOR GROUND FLOOR = 110 TR

S. No.	Floor & Area Name	Area (Sqft)	Lighting kkW		Occ.	Eqp. Load		Fresh Air	Design Cooling Load	Dehumidified CFM
			BTU/hr	kW		BTU/hr	kW	CFM	TR	
					FIRST FLOOR					
1	CORRIDOR	1163	3293	0.96485	3	5329	1.5614	26	2.1	953
2	GUEST LIFT LOBBY	151	456	0.13361	5	705	0.20657	30	0.3	113
3	IT SERVICES	329	887	0.25989	3	1443	0.4228	19	0.7	311
4	KITCHEN	3512	9993	2.92795	23	15456	4.52861		TFA	
5	OWNERS OFFICE	191	499	0.14621	1	846	0.24788	11	0.4	191
6	SERVICE LIFT LOBBY	151	441	0.12921	1	621	0.18195	30	0.3	124
7	UNASSIGNED	131	359	0.10519	1	526	0.15412	8	0.5	222

TOTAL TONNAGE FOR FIRST FLOOR = 5 TR TFA

S.No.	Floor & Area Name	Area (Sqft)	Lighting kkW		Occ.	Eqp. Load		Fresh Air	Design Cooling Load	Dehumidified CFM
			BTU/hr	kW		BTU/hr	kW	CFM	TR	
					SECOND FLOOR					
1	CORRIDOR	1706	5190	1.52067	3	2710	0.79403	2560	17	TFA
2	GUEST LIFT LOBBY	428	675	0.19778	8	1093	0.32025	30	0.8	421
3	SERVICE LIFT LOBBY	124	441	0.12921	1	621	0.18195	30	0.3	130
4	ROOM 1	186	481	0.14093	3	818	0.23967	26	0.5	217
5	ROOM 2	182	460	0.13478	3	795	0.23294	26	0.48	207
6	ROOM 3	180	460	0.13478	3	795	0.23294	26	0.48	207
7	ROOM 4	181	460	0.13478	3	795	0.23294	26	0.48	207
8	ROOM 5	181	460	0.13478	3	795	0.23294	26	0.48	207
9	ROOM 6	181	460	0.13478	3	795	0.23294	26	0.48	207
10	ROOM 7	175	459	0.13449	3	782	0.22913	26	0.47	205
11	ROOM 8	385	1045	0.30619	6	1719	0.50367	52	0.93	467
12	ROOM 9	175	459	0.13449	3	782	0.22913	26	0.47	205
13	ROOM 10	602	1671	0.4896	6	2723	0.79784	52	1.6	650
14	ROOM 11	175	459	0.13449	3	782	0.22913	26	0.47	205
15	ROOM 12	209	556	0.16291	3	929	0.2722	26	0.6	270
16	ROOM 13	175	459	0.13449	3	782	0.22913	26	0.47	205
17	ROOM 14	186	481	0.14093	3	818	0.23967	26	0.5	217
18	ROOM 15	385	1045	0.30619	6	1719	0.50367	52	0.93	467
19	ROOM 16	385	1045	0.30619	6	1719	0.50367	52	0.93	467
20	ROOM 17	176	459	0.13449	3	782	0.22913	26	0.47	205
21	ROOM 18	385	1045	0.30619	6	1719	0.50367	52	1.2	641
22	ROOM 19	385	1045	0.30619	6	1719	0.50367	52	0.93	467
23	ROOM 20	385	1045	0.30619	6	1719	0.50367	52	0.93	467
24	ROOM 21	186	481	0.14093	3	818	0.23967	26	0.5	217
25	ROOM 22	175	459	0.13449	3	782	0.22913	26	0.47	205
26	ROOM 23	385	1045	0.30619	6	1719	0.50367	52	1.3	610
27	ROOM 24	186	481	0.14093	3	818	0.23967	26	0.5	217
28	ROOM 25	174	459	0.13449	3	782	0.22913	26	0.47	205
29	ROOM 26	385	1045	0.30619	6	1719	0.50367	52	1.3	612
30	ROOM 27	385	1045	0.30619	6	1719	0.50367	52	1	471

TOTAL TONNAGE FOR SECOND FLOOR = 34.4 TR

S. No.	Floor & Area Name	Area (Sqft)	Lighting kkW		Occ.	Eqp. Load		Fresh Air	Design Cooling Load	Dehumidified CFM
			BTU/hr	kW		BTU/hr	kW	CFM	TR	
THIRD FLOOR										
1	CORRIDOR	1712	5190	1.52067	3	2710	0.79403	2560	17	TFA
2	GUEST LIFT LOBBY	240	675	0.19778	8	1093	0.32025	30	0.8	421
3	SERVICE LIFT LOBBY	124	441	0.12921	1	621	0.18195	30	0.3	130
4	ROOM 1	186	481	0.14093	3	818	0.23967	26	0.5	217
5	ROOM 2	186	481	0.14093	3	818	0.23967	26	0.5	217
6	ROOM 3	180	460	0.13478	3	795	0.23294	26	0.48	207
7	ROOM 4	181	460	0.13478	3	795	0.23294	26	0.48	207
8	ROOM 5	181	460	0.13478	3	795	0.23294	26	0.48	207
9	ROOM 6	182	460	0.13478	3	795	0.23294	26	0.48	207
10	ROOM 7	175	459	0.13449	3	782	0.22913	26	0.47	205
11	ROOM 8	185	481	0.14093	3	818	0.23967	26	0.6	233
12	ROOM 9	174	459	0.13449	3	782	0.22913	26	0.47	205
13	ROOM 10	602	1671	0.4896	6	2723	0.79784	52	1.6	630
14	ROOM 11	175	459	0.13449	3	782	0.22913	26	0.47	205
15	ROOM 12	175	459	0.13449	3	782	0.22913	26	0.47	205
16	ROOM 13	185	481	0.14093	3	818	0.23967	26	0.5	217
17	ROOM 14	175	459	0.13449	3	782	0.22913	26	0.47	205
18	ROOM 15	186	481	0.14093	3	818	0.23967	26	0.5	217
19	ROOM 16	170	459	0.13449	3	782	0.22913	26	0.47	205
20	ROOM 17	183	481	0.14093	3	818	0.23967	26	0.5	217
21	ROOM 18	177	459	0.13449	3	782	0.22913	26	0.47	205
22	ROOM 19	181	460	0.13478	3	795	0.23294	26	0.48	207
23	ROOM 20	176	459	0.13449	3	782	0.22913	26	0.47	205
24	ROOM 21	385	1045	0.30619	6	1719	0.50367	52	1.3	646
25	ROOM 22	174	459	0.13449	3	782	0.22913	26	0.47	205
26	ROOM 23	178	460	0.13478	3	795	0.23294	26	0.48	207
27	ROOM 24	385	1045	0.30619	6	1719	0.50367	52	0.93	467
28	ROOM 25	186	481	0.14093	3	818	0.23967	26	0.5	217
29	ROOM 26	175	459	0.13449	3	782	0.22913	26	0.47	205
30	ROOM 27	186	481	0.14093	3	818	0.23967	26	0.5	217
31	ROOM 28	170	459	0.13449	3	782	0.22913	26	0.47	205
32	ROOM 29	188	481	0.14093	3	818	0.23967	26	0.5	217
33	ROOM 30	174	459	0.13449	3	782	0.22913	26	0.47	205
34	ROOM 31	173	459	0.13449	3	782	0.22913	26	0.7	304
35	ROOM 32	169	459	0.13449	3	782	0.22913	26	0.7	302
36	ROOM 33	385	1045	0.30619	6	1719	0.50367	52	1	467

TOTAL TONNAGE FOR THIRD FLOOR = 37 TR

S. No.	Floor & Area Name	Area (Sqft)	Lighting kkW		Occ.	Eqp. Load		Fresh Air	Design Cooling Load	Dehumidified CFM
			BTU/hr	kW		BTU/hr	kW	CFM	TR	
FIFTH FLOOR										
1	CORRIDOR	1708	5190	1.52067	3	2710	0.79403	2560	17	TFA
2	GUEST LIFT LOBBY	240	675	0.19778	8	1093	0.32025	30	0.8	421
3	SERVICE LIFT LOBBY	124	441	0.12921	1	621	0.18195	30	0.3	130
4	ROOM 1	186	481	0.14093	3	818	0.23967	26	0.5	217
5	ROOM 2	182	460	0.13478	3	795	0.23294	26	0.5	207
6	ROOM 3	179	459	0.13449	3	782	0.22913	26	0.5	205
7	ROOM 4	181	460	0.13478	3	795	0.23294	26	0.5	207
8	ROOM 5	181	460	0.13478	3	795	0.23294	26	0.5	207
9	ROOM 6	182	460	0.13478	3	795	0.23294	26	0.5	207
10	ROOM 7	175	459	0.13449	3	782	0.22913	26	0.47	205
11	ROOM 8	185	481	0.14093	3	818	0.23967	26	0.6	237
12	ROOM 9	174	459	0.13449	3	782	0.22913	26	0.6	237
13	ROOM 10	180	460	0.13478	3	795	0.23294	26	0.6	237
14	ROOM 11	177	460	0.13478	3	795	0.23294	26	0.6	237
15	ROOM 12	182	460	0.13478	3	795	0.23294	26	0.6	237
16	ROOM 13	175	459	0.13449	3	782	0.22913	26	0.6	237
17	ROOM 14	175	459	0.13449	3	782	0.22913	26	0.47	205
18	ROOM 15	185	481	0.14093	3	818	0.23967	26	0.5	217
19	ROOM 16	175	459	0.13449	3	782	0.22913	26	0.5	205
20	ROOM 17	186	481	0.14093	3	818	0.23967	26	0.5	217
21	ROOM 18	170	459	0.13449	3	782	0.22913	26	0.47	205
22	ROOM 19	183	481	0.14093	3	818	0.23967	26	0.5	217
23	ROOM 20	177	460	0.13478	3	795	0.23294	26	0.48	207
24	ROOM 21	181	460	0.13478	3	795	0.23294	26	0.48	207
25	ROOM 22	176	459	0.13449	3	782	0.22913	26	0.47	205
26	ROOM 23	384	1045	0.30619	6	1719	0.50367	52	1.4	672
27	ROOM 24	328	1045	0.30619	6	1719	0.50367	52	0.93	467
28	ROOM 25	181	460	0.13478	3	795	0.23294	26	0.5	207
29	ROOM 26	167	459	0.13449	3	782	0.22913	26	0.5	205
30	ROOM 27	385	1045	0.30619	6	1719	0.50367	52	0.93	467
31	ROOM 28	186	481	0.14093	3	818	0.23967	26	0.7	307
32	ROOM 29	169	459	0.13449	3	782	0.22913	26	0.6	292
33	ROOM 30	185	481	0.14093	3	818	0.23967	26	0.5	217
34	ROOM 31	179	460	0.13478	3	795	0.23294	26	0.5	207
35	ROOM 32	173	459	0.13449	3	782	0.22913	26	0.7	309
36	ROOM 33	169	459	0.13449	3	782	0.22913	26	0.7	307
37	ROOM 34	381	1045	0.30619	6	1719	0.50367	52	1.1	502

TOTAL TONNAGE FOR FOURTH FLOOR = 40 TR

The total peak load for the hotel is **266.4 TR.** However, since the cooling required by different zones of the building varies throughout the day, it is not advisable to select the chillers at peak load capacity.

We have carried out a detailed simulation for 8760 hours to provide the block cooling load for the entire hotel, which comes out to be **254 TR** approx.

Plant Summary

Cooling Plant Summary

	Sizing Method	Peak Time Mo./Day/Time	Capacity (tons)	Flow Rate (gpm)	Percent of Peak Plant Capacity	Coil ΔT (°F)	Plant Temps (°F)	
							Supply	Return
Parallel with Manifolded Pumps	Block	1/1 00:00:00	254.46	608.21				

13.3 Cost Breakdown:

"When selecting an HVAC system, it is important to weigh the upfront costs (CAPEX) against the long-term savings (OPEX) to determine the most cost-effective option.[7]"

The cost of a chilled water system and a VRF system can vary depending on several factors, including the size of the building, the complexity of the system, and the location. Both types of systems can be expensive to install, but long-term costs, such as energy consumption, can be lower for more efficient systems.

Chill water systems typically have a higher initial cost due to the need for a central chiller and a network of pipes. However, they can be more cost-effective in larger buildings where the cost of the central chiller can be spread out over a larger area. VRF systems, on the other hand, tend to have a lower initial cost as they use individual outdoor and indoor units. However, they can be more expensive to install in smaller buildings due to the need for multiple outdoor and indoor units. In addition, VRF systems tend to have lower energy costs in the long run, as they are more efficient and offer more precise temperature control.

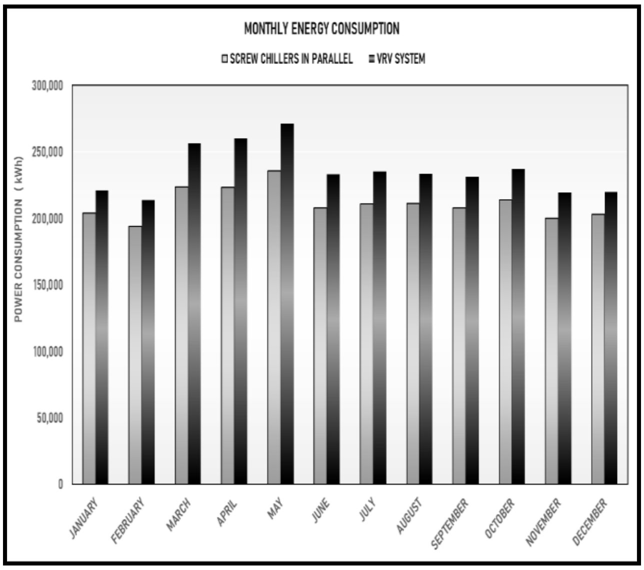
Overall, the cost of a chill water system and a VRF system can vary depending on the specific needs of the building and the location, as well as the cost of installation and maintenance. It's recommended to consult with an HVAC professional to determine which system would be the best fit for your building and budget.

13.4 Operational Cost:

In terms of energy efficiency, VRF systems tend to be more efficient than chill water systems in smaller buildings because they can adjust the amount of refrigerant flowing to each indoor unit based on the cooling/heating needs of that area. Chill water systems on the other hand are more suited for larger buildings and can be more cost effective for the same. To determine which system is better suited for our needs, we need to deeply analyze the reports and data which we get from the program. The program analyzes the heating load generated by the building during various months of the year. Based on the orientation of the sun, the heating load changes throughout the year. However, the system must be sized based on the peak load, as the system must be able to handle peak capacity generated by the building. The electricity consumption per month is given below as generated by the software.

TABLE 3: Monthly electricity consumption by chilled water and VRF systems : Table format and graphical representation

	Facility Electricity/Other/PARALLEL SCREW	Facility Electricity/Other/VRF
Jan	–	–
Jan	198,268,353.04	215,696,467.41
Feb	189,216,748.51	208,884,500.33
Mar	218,948,601.96	249,783,837.25
Apr	218,821,032.15	253,793,153.42
May	231,188,665.81	265,037,056.54
Jun	202,737,130.73	227,193,627.66
Jul	205,320,494.25	229,460,225.19
Aug	205,629,642.06	228,058,599.29
Sep	202,444,302.36	225,772,221.38
Oct	208,390,296.08	231,508,895.68
Nov	194,690,751.89	214,085,993.71
Dec	197,380,404.56	214,756,593.20



Here, we see that the electricity consumption is consistently less in the case of chill water system, as compared to the VRF system. The summation for the whole year is calculated. This difference in kWh is summarized below. The per unit commercial electricity cost for Bangalore is ₹10/unit.

TABLE 4: Comparison of annual OPEX of chilled water and VRF systems

	ELECTRICAL CONSUMPTION	ANNUAL OPERATING COST (INR/Annum)	TOTAL OPERATING COST	SAVINGS
	kWh	Cost of electricity @ INR 10/kWh	INR	INR
SCREW CHILLERS IN PARALLEL	2,532,853.32	25,328,533.25	25,328,533	2,986,148
VRV SYSTEM	2,831,468.12	28,314,681.23	28,314,681	REFERENCE

The results of the analysis are summarized in the table given above. The annual operating cost of the Chill water system is much lesser than the operating cost of the VRF system. The cost of commercial electricity consumption for the whole year is ₹2,53,28,533 and ₹2,83,14,681 in the case of chill water and VRF systems. The difference in cost is ₹29,86,148 per year, a significant number when considered during a life span of 30 – 60 years. Moreover, as the costs of electricity continue to rise, this gap will further widen.

13.5 Capital/Installation Cost:

A complete comparison is only possible once all the various aspects of installing the systems are analyzed separately. This also includes the cost of purchasing and installing the various systems. Only then can the various costs be compared accurately.

The initial cost for installing the various systems can be provided by the manufacturers of various equipment once the heat load has been calculated. The heat load is 255 TR in the case of our hotel complex. Hence, we size the various systems according to the tonnage required.

Different manufacturers and suppliers provide equipment such as chillers and VRF units. Prices for certain common items are comparable across all companies, and the selection of appropriate pricing is based on quotations from multiple suppliers. We have compiled a summary of the costs involved in the systems.

TABLE 5: Comparison of CAPEX of chilled water and VRF systems

CHILLED WATER SYSTEM	COST (INR)	VRF SYSTEM	COST (INR)
Chilled water piping with inculation and control valves	9,500,000	Indoor and coutdoor units	17,500,000
Indoor units (Fan coil units)	1800,000	Refrigerant piping with insulation	1500,000
Ducting with insulation	9,500,000	Ducting with insulation	6,500,000
Grills/Diffusers/Dampers	2,000,000	Grills/Diffusers/Dampers	2,000,000
Toilet exhaust system	750,000	Toilet exhaust system	750,000
255 TR Chiller	6,250,000	Kitchen ventilation	2,900,000
320 TR Cooling Tower	600,000	Associated electrical costs	2,200,000
2 nos. 450 gpm Secondary water pumps	1400,000		
5 nos. 450 gpm Primary water pumps	1500,000		
2 nos. 820 gpm condensor water pumps	1000,000		
Kitchen ventilation	2,900,000		
associated electrical costs	2,500,000		
Heat pimps for space heating with accessories	1500,000		
Total Cost	41200,000	Total Cost	33,350,000

The initial and installation cost can be summarized in the above table. We see that the chilled water system costs ₹4,12,00,000 and the VRF system costs ₹3,33,50,000. This difference in cost is approximately ₹7,850,000. This is quite a significant amount and must be taken into consideration while comparing both systems. To make a fair comparison between the two systems, we need to consider both the upfront cost and the ongoing cost over the length of the evaluation period.

*The costs given here are averages of costs and quotations from various chiller and VRF manufacturers and suppliers, obtained after sending our custom requirements. These costs cannot be used as reference to obtain quotations from any manufacturers or suppliers.

13.6 Comparison:

To summarize, chilled water systems and VRF systems are both types of HVAC (heating, ventilation, and air conditioning) systems used for temperature control in buildings. The chilled water system operates by a central chiller that cools water and distributes it via pipes to different air handling units for cooling the air in the building. In contrast, the VRF system consists of independent outdoor and indoor units connected by refrigerant lines, providing greater temperature control flexibility in specific areas of the building.

Buildings have a limited lifespan, with 5-star hotels typically lasting between 25 and 50 years. 5-star hotels have a lifespan of 25-50 years. When choosing between options, long-term costs must be considered, not just initial cost. Both options were evaluated over 20 years, the typical lifespan of a VRF system. Results are tabulated below.

TABLE 6: Life cycle cost comparison of chilled water and VRF systems

CHILLED WATER SYSTEM	COST (INR)	VRF SYSTEM	COST (INR)
Installation Cost	41200,000	Installation Cost	33,350,000
Lifespan considered	20 years	Lifespan considered	20 years
Running cost per year	25,328,533	Running cost per year	28,314,681
Running cost for duration of life	506,570,660	Running cost for duration of life	566,293,620
Total Cost	547,770,660	Total Cost	599,643,620

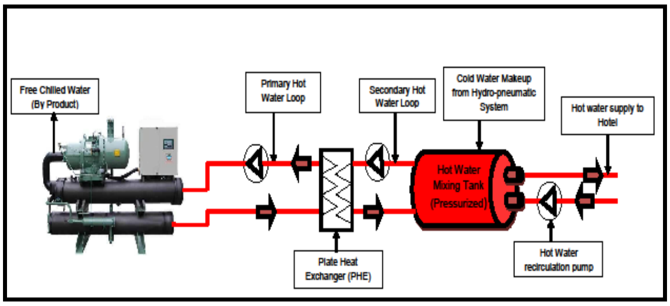
The cost of a chilled water system is significantly less when compared to the VRF alternative when analyzed over a 20-year life cycle. This difference in cost is substantial, with the chilled water system costing approximately ₹5,18,72,960 less than the VRF system for the operational time. This significant cost savings is a major factor that allows us to say that the chilled water system is a better alternative for the hotel project.

In addition to the cost savings, the chilled water system also offers other benefits. For example, it is typically simpler and easier to install, it requires less maintenance and it's more energy efficient. These benefits can lead to even more cost savings over time. This is an important consideration when looking to reduce the impact of the hotel complex on the environment. In conclusion, the chilled water system offers a combination of cost savings, ease of installation, lower maintenance requirements and better energy efficiency. Due to these benefits, the chilled water system has been selected as the preferred option for the hotel project.

13.7 Further Savings:

Based on above comparison it can be concluded that Water cooled Screw Chillers in parallel is the better option for our hotel complex. To further reduce electricity consumption, we can also pair it with heat exchanger and use the additional heat to generate simultaneous hot water for domestic use. This will allow us to use the heat given off by the chill water system and utilize it for the building. This configuration is also used in some hotels, but it is not feasible during winter months, when the chill water system is switched off.

Fig 12. Hot water reuse schematic



13.8 CONCLUSION:

Energy modelling and analysis has allowed us to analyze in detail the two most used alternatives in order to choose the most appropriate system for our hotel. Deciding upon the HVAC system is a big part of project planning as the MEP rooms, chillers and cooling towers take up a lot of the valuable space of the hotel. This may cause problems if they are decided after the hotel structure is made. Furthermore, the space for ducting and chill water piping is quite different than the space requirement for the refrigerant piping in VRF systems, causing structural changes to be made in the building. Hence, deciding on the HVAC system beforehand is essential.

Since our hotel is a large-scale project, the TRACE 3D PLUS data shows that a chill water system is best suited for our needs. Furthermore, based on the findings of this project, we conclude that energy modelling is a critical step in determining the most efficient and cost-effective systems for buildings. By conducting energy modelling, building owners and operators can gain a deeper understanding of their energy usage and identify opportunities for improvement. This approach can help to reduce energy consumption, decrease operational costs, and improve the overall sustainability of the building. Therefore, we recommend that all building projects should consider energy modelling as a standard practice to ensure that they are implementing the most efficient systems for their specific needs.

14 Inference:

LCC or Life Cycle Costing is a methodology used to evaluate the total cost of a product or asset over its entire lifespan. The goal of LCC is to assess the costs associated with designing, manufacturing, operating, maintaining, and disposing of a product or asset, in order to make informed decisions about its acquisition or development. LCC takes into account all of the costs associated with a product or asset over its life cycle, including both direct and indirect costs. Direct costs include the initial purchase price, installation, and maintenance costs, while indirect costs may include costs associated with downtime, energy consumption, and environmental impact. We have done the life cycle cost analysis which has successfully allowed us to determine the most optimum option for the hotel.

This paper also teaches the importance of energy modelling to ensure building efficiency. "Building energy modeling is an essential step in designing and operating energy-efficient buildings. Without energy modeling, building systems and components may be sized incorrectly, leading to inefficiencies and higher energy use." [8]

There are several different types of BEM, including whole-building energy simulation, envelope and systems simulation, and daylighting and lighting simulation. Envelope and systems simulation focuses on specific components of a building, such as the walls, roof, and windows, and is used to optimize their thermal performance.

Because every building and project is unique, it is crucial to conduct energy modeling for each individual project, rather than trying to apply a one-size-fits-all solution. Through energy modeling, we can evaluate various options and determine which systems will be most effective for a specific project. The modeling will provide a detailed report that can be used to inform the design and construction of the building.

It allows for the simulation of a building's energy performance before it is built, enabling the comparison of different design options and the selection of the most cost-effective and energy-efficient solution. Through energy modeling, we can identify opportunities to reduce energy consumption and costs, as well as demonstrate compliance with energy codes and regulations. Additionally, energy modeling can help to reduce a building's environmental impact and improve the indoor environment. Furthermore, energy modeling can also be used to monitor a building's energy performance after it is constructed and identify opportunities for further energy savings and improvements. Overall, energy modeling plays a crucial role in the design and operation of sustainable, comfortable, and energy-efficient buildings.

The amount of energy that can be saved in buildings through energy modeling can vary depending on the specific building and design options that are evaluated. However, studies have shown that energy modeling can lead to significant energy savings in buildings. For example, a study by the National Renewable Energy Laboratory found that energy modeling can lead to energy savings of 20-30% or more in commercial buildings.[9] Another study by the American Institute of Architects found that energy modeling can lead to energy savings of 15-25% or more in residential buildings.[10] In addition, the US Department of Energy reports that energy modeling can lead to energy savings of up to 40% or more in some cases.

Indian government must also start introducing regulation to ensure all buildings are compliant with the latest standards, and that energy modelling is done to ensure the most efficient and economical systems are installed to reduce our impact on the environment.

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