INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact factor: 4.295
(Volume 4, Issue 3)
Available online at: www.ijariit.com

Heat load inspection cum energy audit of AutoCAD laboratory in the department of mechanical engineering, St. John college of engineering and management

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ABSTRACT

A lot of productive activities are ongoing to bring our systems from Energy consumption to Energy Saving. In spite of the clean corridors and orderly placed laboratory instruments along with the energy conservative measures taken by teaching as well as non-teaching faculty, St. John College of Engineering, Palghar is facing comfort related issues due to addition of new infrastructure, which is restricting the advantage of green and eco-friendly environment from spreading all over the structure. The AutoCAD laboratory is an example of this scenario. A project was undertaken so that it's Cooling Load and Energy consumption required by the system was analyzed. The aim was to calculate, design and suggest several implementations and modifications that will bring about desired comfort without altering the infrastructure. This will reduce the cooling load required and will save the electricity consumption. The rated power calculated for the single laboratory was around 30MW per year, which can be optimized if the appliance changes are made. The project further discusses some implementations, such as passive cooling, non-conventional methods of cooling and ventilation that will directly affect the humidity instead of heat load. Energy Audit is mostly done independently which restricts its generalization and puts it on its standard level of singular energy-saving implementation. EA when done with other activities and Inspections such as HLC, the simultaneous changes in readings can be observed accordingly. This helps in avoiding excessive calculation and future implementation of such audits.

Keywords: *Energy Audit, Heat Load Calculation, Energy Consumption, Spreadsheet.*

1. INTRODUCTION

The basis of this project is Heat Load Calculation. The appliance load alone increased the load with a 6 TR (Tonnage of Air Conditioning). With that much amount of refrigeration also interpreted that it's most reliable source and point of interest when it comes to Energy Saving. Hence a laboratory comprised of so many electronic devices was set for reference area of this project. The Heat load calculation is inspired by calculations done on industry or firm level. Various data books and handbooks were referred in order to come up with a heat load spreadsheet that will help with the calculations. UAΔT was the base formula for calculating the heat load. Assumptions for few conditions have to be made for the calculations since those are not standard all around the world hence deflection with actual calculations is ought to occur. Instead, a clearance will be taken which will neglect the error and the comparative result occurred will be more amplified. The energy audit is the second step in this project with the load previously taken, the rated electricity consumption is provided before the audit starts. The audit is heavily inspired by the *IIT Roorkee Energy audit* with extra parts such as different implementations are suggested while considering the life of the product for comparison a spreadsheet has to be created. The implementation is the final and most philosophical scope of this project which is born from the parental subjects i.e. Heat Load Calculation and Energy Audit.

2. METHODOLOGY

*A. **Main steps:*** Before making any Calculation of the project main steps were prepared as follows:

a. Set scope of this project i.e. depth of study and effects of it till which calculations can be implied.
b. Conduct Heat Load Calculations.

c. Conduct Energy Audit.
d. Make useful modification in appliance loads, spreadsheet and conduct energy audit again.
e. Suggest the Implementations along with their costing.
f. Check the effect of Implementation with their Cooling load.

B. ***Heat Load Calculation***: for the reference area was done using following steps:

Pre-requisites:

a) Select the reference area where heating is significant.
b) Identify the problems related to cooling and ventilations.
c) Take reviews from the occupants.
d) Identify number and type of appliances along with load which can be checked in the handbook.
e) Prepare or find a spreadsheet (Excel) for heat load calculation.
f) Obtain handbook from trusted sources such as HVAC solutions firm.
g) Take dimension, orientation and all the structural details that comprise of the type of walls and glasses.
h) Check the standard data i.e. sun gain, Temp Difference and U-Factor from Handbook.
i) Set inside desired conditions as per required.
j) Input location, Area, True Ceiling Height, Volume, Name of Reference Area.

Thermal formulae applications:

a) Set the formulae in excel sheet of heat load calculation.
b) Put all the structural data obtained from the step above.
c) Make the columns for U-factor, Surface Area, and Temperature gain.
d) Use multiplication formula for these three rows and get the 4^{th} row of British thermal unit per Hour.
e) Set a Bypass factor.
f) Calculate Apparatus Dew Point Temperature from a psychrometric Fig. or find using standard conditions and allot the data to a spreadsheet.
g) Calculate overall Sensible heat load and Latent Heat Load using formulae listed below.
h) Calculate sensible heat load factor.
i) Calculate the amount of fresh air required for the occupants.
j) Calculate Grand Total Heat and convert it to the tonnage of refrigeration.

C. ***Energy Audit****:* The second Scope of this project i.e. Energy Audit was remodified than the normal version although the standards must be provided in future.

Calculation of Electricity Used:

a) Tabulate the appliances name, Rated Load and Numbers in the spreadsheet of an energy audit.
b) Use another column consisting of hours of usage per day and Days of working.
c) Multiply Load, Numbers, Hours and Days Column to make a final column i.e. Annual Usage of the appliance.
d) Calculate total appliance load.

Suggesting modification of Laboratory to lower appliances load:

a) Make another column in same spreadsheet for replacement of appliances.
b) Suggest the replacement of appliance without hampering its usefulness right in front of previous ones.
c) Make same 4 columns as a previous calculation to find total appliance load.
d) Calculate the life of the product.
e) Calculate the Energy Saved by the product.
f) Calculate the buyback period of the product.
g) Suggest implementation regarding those.

D. Abbreviations and Acronyms:

BTU – British Thermal Unit is an Empirical unit of Heat Transfer. It is conventional Unit for heat load calculation since it measures area in square feet and unit for U-factor is different.
A – Area of the surface.
ΔT – Temperature Difference / Sun Gain as per type of component.
U-Factor – Is the imperial unit of heat transfer coefficient. It changes with different heat load components with their different type. E.g. Single glazing window has a U-factor of 0.4, Double Glazing has U- Factor of 0.28 and Triple glazing window has U-factor as low as 0.10.
CFM – Cubic Feet per Minute is the imperial unit for discharge or flow rate. It is used to define air required for specific reasons such as occupants and dehumidification amount.
SQFT- Square Feet is an imperial unit of area. Most dimensions are measured using the same.
TR- Tonnage of Refrigeration. It is the standard Unit for the capacity of Air Conditioning System. One TR represents the amount of heat required to melt 1 tone of Ice in a period of 24 hours. It is 12000 BTU/Hour.
ADP- Apparatus Dew Point Temperature, in Fahrenheit is the temperature at which moisture starts forming in the system. This should be avoided as moisture will be a problem for electronic appliances.
EXP. – Exposure, It defines that respective structure is the interest of calculation for heat gain due to the sun.
QTY – Quantity, it is the amount in which a specific entity is present i.e. occupants and appliances.
RSH – Room Sensible Heat.
RLH - Room Latent Heat.
RSHF – Room Sensible Heat Factor is a relative factor i.e. Ratio of Room sensible heat to total heat.
RTH– Room Total Heat. It is the addition of room latent heat and room sensible heat.
DBT- Dry bulb temperature. It is the temperature of air when bulb of psychrometer is dry i.e. in absence of moisture.
WBT - Wet bulb temperature. A wet cloth is wrapped around the bulb of psychrometer and reading is noted.
RH%- Relative Humidity. The amount of water vapour present in air expressed as a percentage of the amount needed for saturation at the same temperature.
GR/LB - Grains of moisture per Pound is unit used to measure moisture present in the air. This can be found in databook for standard conditions.
ROOF EXP – Heat gain due to roof directly being exposed to sun and is only applicable for rooms below the terrace, Hence our reference area is not applicable.
Partition – It defines the wall where heat gain occurs as there is no air conditioning system beyond it.
CEILING – Heat gain due to the non-Air Conditioned area above reference area.
LIGHTS – Heat gain due to the luminosity of lights this includes both natural and artificial.
EA – Energy Audit Scope of the project.
HLC– Heat Load Calculation.
ACPH – Air Change per Hour (Amount of times when the air is completely changed in the reference area.)

3. CALCULATIONS

A. Empirical Relations:

- *Heat load (BTU) = Length (ft.) × Width (ft.) × Height (ft.) × 4*
- *Heat load (BTU) = Length (m) × Width (m) × Height (m) × 141*
- *Occupant BTU = number of people × 230*

- *Equipment BTU = total equipment watts × 3.4*
- *Lighting BTU = total lighting watts × 4.25*
- *Total heat load BTU = Area BTU + Total Window BTU + Occupant BTU + Equipment BTU + Lighting BTU*
- *Number of a/c units required= Total heat load BTU/Cooling capacity BTU*
- *Power Consumed by appliances = (Power Rating) × (Time of Usage) × (Power Factor)*
- *Time Of Usage = (Usage in a day in Hours) × (No of Days it is being used in an entire year)*
- *Cost = KWH × 9.32 (Assumed cost / Kwh is Rs. 9.32)*

B. Heat Load Calculations:

Heat Gain in BTU / Hour

= [Area of Part] × [Sun Gain] × [U- Factor (for walls and glasses)

= [Quantity] × [U-factor] × [Standard Heat gain] (Occupancy and appliances)

= [Area] x [Temperature Difference] x [U- Factor] (for Partition, Ceiling and Floor)

All above is calculated and put into sheet of sample work

Sensible Heat Factor:

RSH= 1.08 × (cfm sa) × (t_{rm} – t_{sa})
= cfm sa × 1.08 (112-75)
= 39.96 cfm sa

RLH= 0.68 × (cfm sa) × (W_{rm} – W_{sa})
= cfm sa × 0.68 (108.32-70.88)
= 25.45 cfm sa

RSHF = (RSH)/ (RSH+RLH)
= RSH / RTH
= 0.61

These factors are used to calculate supplementary loads due to duct gain, fan and pump horse power gain and should be used where appropriate.

Effective Room Sensible Heat:

ERSH = 1.08 x cfm da × (t_{rm} – tadp) × (1 – BF)
= 1.08 x 15 × (112-75) × (1- 0.6)
=239.76

i.e. 15 cfm required for people inside as per health concerns and avoid nausea like effects.

C. *Energy Audit*

a. Energy and cost saving calculation for Laser Printer

Power consumption by Laser Printer (Printing) =600W

Normalized operating hours 2 hours in a day

Energy consumed per day = 600×2
= 1200 W-hr.
= 1.2 kWh

Energy cost per day = 1.2× (Rs.9.32)
= Rs. 11.184

Energy cost per month for 24 working days = 11.184×24
= Rs. 268.416

Annual energy cost = 268.416×12
= Rs. 3220.992

Power consumption by Laser Printer (Standby) = 27 W

Normalized operating hours **4 hours** in a day
Energy consumed per day = 24×4
= 108 W-hr
= 0.108 kWh

Energy cost per day = 0.108×9.32
= Rs. 1

Energy cost per month for 24 working days = 1×24
= Rs.24

Annual energy cost = 24×12
= Rs.288

Therefore, Total annual energy cost = Rs. (3220.992+288)
= **Rs. 3508.992**

b. Energy and cost saving calculation for an inkjet printer
Power consumption by inkjet printer = 27W

Normalized operating hours 2 hours in a day
Energy consumed per day = 27×2
= 54Wh
= 0.054kWh

Energy cost per day = 0.054× (Rs. 9.32)

= Rs.0.503

Energy cost per month for 24 working days = 0.503×24
= Rs.12.078

Annual energy cost = 12.078×12
= Rs.144.94

Power consumption by inkjet printer (Standby) = 0.9W

Normalized operating hours 4 hours in a day
Energy consumed per day = 0.9×4
= 3.6Wh
= 0.0036kWh
Energy cost per day = 0.0036× (Rs.9.32)
= Rs.0.0335

Energy cost per month for 24 working days = 0.0335×24
= Rs.0.8052
Annual energy cost = 0.8052×12
= Rs.9.66

Therefore, Total annual energy cost = 144.94+9.66
= **Rs.154.603**

Net cost of saving by replacing all laser printer with inkjet printer = 3508.992 -154.60
= **Rs. 3354.389**

Payback period calculation:

Investment on 1 inkjet printer= Rs.15,945
Payback period = 15,945/3354.389
≈ 4.75 years

Replacing fluorescent tube light with LED tube light

a. Usage of 28 W fluorescent tube light consumes specified energy:

Total number of tube lights = 12

Total energy consumed by the tube light = 12×28
= 560 kWh

Normalized operating hours 10 hours in a day
Energy consumed per day = 560×10
= 5600 W-hr
= 5.6 kWh

Energy cost per day = 5.6×9.32
= Rs.52.192

Energy cost per month for 24 working days = 52.192×24
= Rs.1252.608

Annual energy cost = 1252.608×12
= **Rs.15031.296**

c. Usage of 16W LED tube light consumes specified energy
Total number of tube lights = 12

Total energy consumed by the tube light = 12×16
= 192 kWh

Normalized operating hours 10 hours in a day
Energy consumed per day = 192×10
= 1920 W-hr
= 1.92 kWh

Energy cost per day = 1.92×9.32
= 17.89

Energy cost per month for 24 working days = 17.89×24
= Rs.429.4656

Annual energy cost = 429.4656×12
= Rs. 5153.58

Net cost of saving by replacing all fluorescent tube light with LED tube light = 15031.296-5153.58
= Rs. 9877.7088

Payback period calculation:
Investment on 1 LED Tube light = Rs.699
The total cost of replacement = 12×699
= Rs.8388
Payback period = 8388/9877.7088
≈ 0.84 years

4. SUGGESTED IMPLEMENTATIONS

In this suggestion we are going to implement which theoretically fulfil the purpose of the project. Hence, we claim the purpose of the project both quality and quantitative wise and calculations are drafted.

A. The inclusion of Shades:

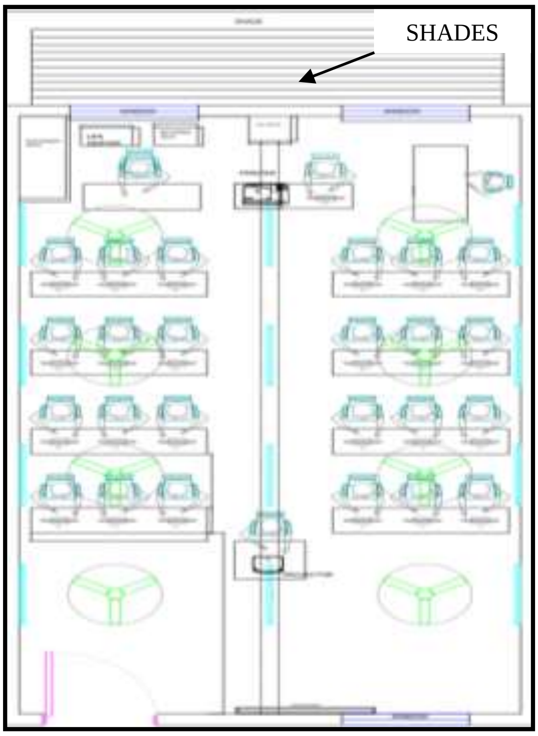

Fig. 1: Implementation of Shades

Table 1: Cost of Shades

PARAMETER	VALUE
Costing (Including Installation)	Rs. 20000-30000
Maintenance	Low
Operation	Manual

B. Ventilation Through Ducts:

Fig. 2: Concept Model

Table 2: Cost of the Ventilation system

Equipment	COST (Rs)
Induced Fan	9240
Exhaust Fan	5760
Ducting Cost	2500
TOTAL (Including Installation accessories**)**	**19000**

C. Adaptive Approach:

The adaptive approach to thermal comfort has gained unprecedented exposure and rising status recently among the thermal comfort community at the apparent expense of the heat balance approach for the evaluation of naturally ventilated buildings. The main appeal of this adaptive approach lies in its simplicity whereby the comfort temperature is expressed as a function of the outdoor air temperature only. The main responsibility for attaining thermal comfort is given to the individual, who is supposed to have some degree of control over the personal thermal environment. The adjustment of expectation enables a wider comfort temperature range in which occupants feel comfortable. Arguments in favour of the adaptive approach have been based on the results from a large number of field studies conducted across the globe involving the occupants of various types of buildings.

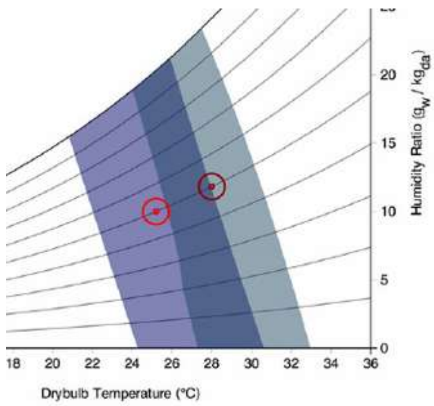

Fig. 3: Clo rating in the Psychrometric graph

The above represents a magnified area of the psychrometric Fig. where the clo zones can be seen. According to required *clo* the outside conditions can be relaxed down and cooling load for air conditioning system can be reduced.

As per engineering toolbox following are some of the cloth resistance value which can be changed accordingly

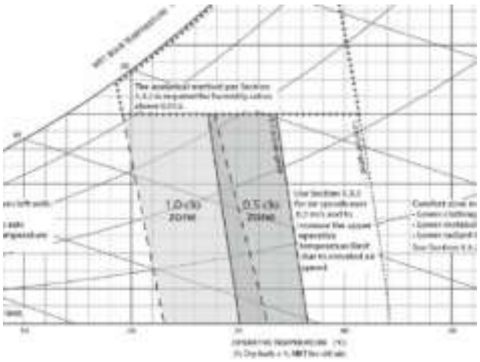

Fig. 4: Clo Values as per ISHRAE Handbook

D. Ant Studio Cooling Equipment (Deki Cooling):
Working:

- The temperature of the air flow around the installation was recorded after it was set up.
- It was noticed that the hot air entering the installation was above 50 degrees Celsius at the velocity of 10m/s.
- Water recycled from the factory at room temperature was to allow running on the surface of cylinders using a motor.
- This process cooled sthe hot air passing through the earthen pots.
- It was observed that after achieving the cooling effect, the temperature around the setup drop down to 36 degrees Celsius while the temperature remained high at 42 degrees Celsius.
- The air flow was recorded as 4m/s.
- The temperature drops by 6-8 degrees around the installation when the atmospheric temperature is above 40 degrees.
- While the recycled water might need regular maintenance to clean the pores on the exterior surface, regular water is recommended for long term performance.

Table 3: Tentative costing of *Deki cooling system*

Equipment	COST (Rs)
Earthen Pots	8000
Fan	5320
Cooling Water	5000
TOTAL	**18320**

Table 4: Clo values according to the clothes used

Shirts	Tube top	0.06
	Short sleeve	0.09
	Light wear with long sleeves	0.15
	Light shirt with long sleeves	0.20
	Normal with long sleeves	0.25
	Flannel shirt with long sleeves	0.30
	Long sleeves with turtleneck	0.34
Trousers	Shorts	0.06
	Walking shorts	0.11
	Light trousers	0.20
	Normal trousers	0.25
	Flannel trousers	0.28
	Overalls	0.28
Coveralls	Daily wear, belted	0.49
	Work	0.50

5. EFFECTS OF IMPLEMENTATIONS

The implementations suggested will have following effects on cooling load and occupants.

A. Inclusion of Shades:
Change in BTU due to inclusion of shades is as below:
Change in Heat Load
= Effect of sun gain avoided due to glass + Effect of sun gain avoided due to sun through walls
= 54 × 150 × 0.4 + 249 ×46 × .35
= 7250 BTU / HR
= 0.6 TR
= 2124 W / HR.

B. Ventilation through ducts:
The humidity present in the room is 88% when calculated normally, but due to excessive appliances, occupants no facilities for ventilation causes intense humid conditions and heating.
This implementation provided increased ventilation and made the inside conditions almost equivalent to outside conditions which were more comfortable considering existing one.
The fan used was 400 cfm which provides 2 ACPH for the reference area.

C. Adaptive Approach:
The clo Value decreased the tonnage by 0.5 for the reference area. As the Area increases the clo value will reduce the heating load hence ultimately reducing energy consumption.

D. *Deki Cooling* System:
The system will decrease the temperature with minimum 5ºC. The system will be effective, energy saving as well as an aesthetic for the campus.

6. RESULTS

Due to reference area being just a small part of the campus the change obtained in loads and results of implementation were moderate. The significance of the same will increase as the application and area of inspection increase.

The final readings obtained in this analysis are as below:

A. Changes in Heat Load Due to Implementation of Shades
= 2124W

Changes in Heat Load due to Energy Audit = 3.5TR

B. Change in Heat Load Due to Replacement on Appliances = 1.3 TR

C. Changes in Heat Load due to Adaptive Approach= 0.6 TR

D. Total Effective Change due to Implementations=1.9 TR

E. Energy Saved due to Replacement = 5087 KW/Hr

F. Replacements Suggested :
a. Laser Printer with Inkjet Printer.
b. CPU+ Monitor with Laptop.
c. Fans (Resistance Regulator) with Remote Controlled Fans.
d. Fluorescent Tube lights with LED Tube lights.

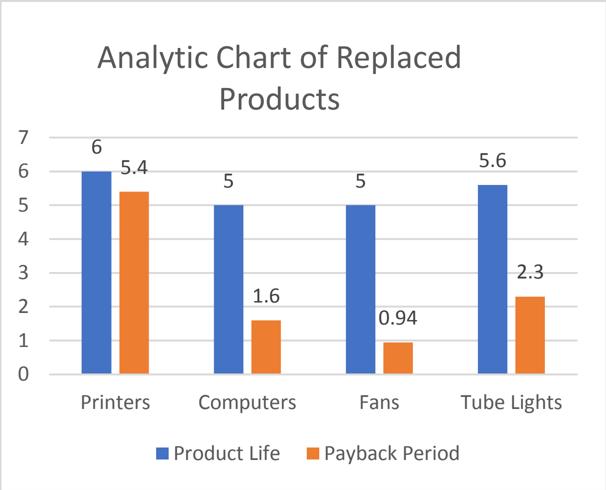

Fig. 5: Replacement Suggested

Since these have lower payback time for ROI than its life.
If the Red Bar in the graph is smaller than the Blue Bar then the product can be considered for replacement.

G. Effects of *Duct-Sox* Ventilation
   a. Low Cost.
   b. Sufficient Ventilation with 400 CFM blower (2.44 ACPH).
   c. Induced Fresh Air.
   d. Better Aesthetics.

H. Effect of different methods to bring in comfort.

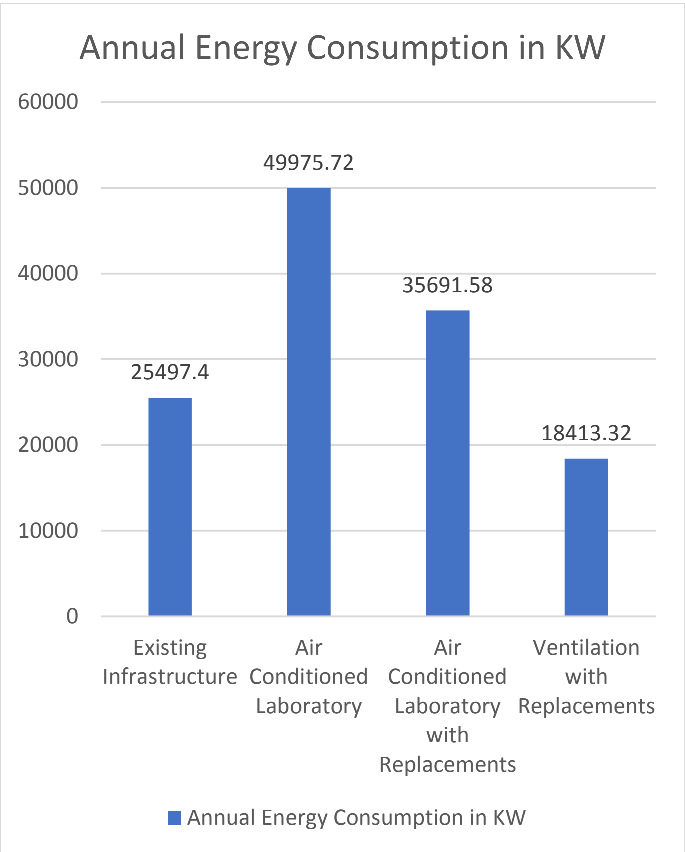

Fig. 6: Annual Energy Consumption

7. CONCLUSION

The implementation suggested should be considered by the institute as well as others with same problems regarding to ventilation and in future if more importance is given to the passive cooling then amount of energy saved will be tremendous on a national level and for industries the cost for conditioning system and electricity cost can decrease if energy audit and implementations are done before.

8. ACKNOWLEDGMENT

This successful implementation and progressing of this work would remain incomplete if the author fails to express sincere thanks and affectionate acknowledgement to certain people who had given their valuable time apart from their regular schedule and helping us for completion of this project work.

First of all, we are grateful to our project guide **Mr. Aniket Patil**, Assistant Professor Mechanical department SJCEM Palghar for suggestions and providing me the opportunities to conduct my studies on Heat Load Calculations and Energy Audit.

We express our deep sense of gratitude to **Mr. Rajesh Bisane,** Project Coordinator, **Mr. Shivaji Shelar**, HOD Mechanical Engineering Department SJCEM Palghar for their valuable support and departmental facilities provided for completion of project work. We express our sincere thanks to **Dr. G. V. Mulgund**, Principal SJCEM Palghar for permitting us to carry out project work in the institute. We also like to thank **Mr. Zaid Shaikh**, Assistant Engineer Pentagon pvt. ltd., Vikhroli, for allowing us to study, concept and technology of project work and help to implement in the real world.

Last but not least we would also like to thanks to our **Friends** and **Family** who directly and indirectly involve to the work co-ordination, financial co-operation and encouragement for completion of this study.

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