

Assessment of HVAC Systems: Case Study of a Shopping Mall

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Abstract: The energy consumed by heating, ventilating, and air conditioning (HVAC) systems has been increasing over the last decades. Use of HVAC systems in commercial areas has become a necessity in urban cities such as - Ernakulam. The rapid increase in the use of HVAC systems has been attributed majorly to protection from high thermal exposures. The building sector accounts for approximately 40% of our energy use. To reach existing environmental target energy use will have to be reduced in all building types. This analysis focuses on

assessment or evaluation of existing condition of the hvac systems in different areas within the building Oberon mall, Ernakulam. The outcomes of this paper are the energy consumption of the building by comparative analysis of the Energy Performance Index of the building with the Bureau of Energy Efficiency guidelines.

Keywords: HVAC systems, E.P.I Index, Energy consumption, Energy Efficiency.

INTRODUCTION

Energy is an indispensable part of human life. People's life is inextricably linked with energy, and energy will also have a significant impact on social stability. In view of the urgency of energy conservation and the huge consumption of energy in the building industry.

Environmental pollution, energy shortage and population expansion have become the three major problems facing the world today, and they are also the key topics that human beings must explore normal ways to conduct research to achieve sustainable development

In India, Total energy consumption per capita remains around 0.6 toe (2020), half the Asian average. Electricity consumption per capita reached 940 kWh in 2020, about a third of the Asian average.

Due to the Covid-19 crisis, total energy consumption fell by 5.6% in 2020 to 885 Mtoe, and increasing rapidly over 2010-2019(4%/year).

The commercial Building sector represents about 18% of energy consumption in Kerala. The commercial sector energy

sale is 2507 MU with a total consumption of about 13870 MU.

The goal of the analysis reported in this Chapter is to minimize the total energy consumption is to study the existing condition of Oberon mall and to analyse the building by its function and energy consumption pattern and to understand the existing material (Building envelope parameters).

study the energy efficiency, energy audits and to find the E.P.I from the electricity bill and by collecting the data from different standards to simulate the model using E-quest.

Simulate the model by considering the changes up to 2009 - 2010 and to find the difference in the E.P.I, by simulating the model considering the changes up to 2019.

This paper presents case study of a hospital building, keeping a focus on HVAC system, and details out:

- Energy efficiency measures adopted in the building.
- Results of the building energy simulation during the building design.
- Comparison of predicted and actual energy performance.

Context study:



Figure 1: Oberon mall, Ernakulam

Oberon Mall is a shopping mall located in the Indian city of Kochi. The mall was opened formally on 2 March 2009, though it was launched in 2008. The cost of construction of the mall is about ₹1 billion. It is built on an area of 350,000 square feet (33,000 m2) across five floors of shops.

It also has office spaces and covers grounds of up to 6 acres spread across 4 floors of shopping and a spacious basement car parking, Oberon mall promises you the most convenient and indulgent shopping experience. To enhance the shopping experience, Oberon is also adorned with PVR’s four-screen multiplex with a capacity of nearly 700 seats as well as a state-of-the-art Fun zone.

Shopping area, Fun Zone spreads over 5000 sqft with an array of entertaining activities including, dashing cars, arcade & video games, water shooting, air hockey, pool zone, redemption games, children’s play area with train rides, jungle kingdom, bouncy, and much more. PVR Cinemas is the primary entertainment and family leisure activity offered by the mall.

Basement with parking slots and services, ground floor with open exhibition space, retail shops, restrooms and services and first floor include the retail shops like Reliance trends. Second floor with retail shops, restrooms and services and Third floor with Co- working office and retail shops with restrooms and service area, Fourth floor with P.V.R, Food court and fun zone with restrooms and service area. Fifth floor with administration and office for Oberon management with special lounge and reception (figure 2 and 3).

Activity Area Allocation:

Ground Floor: Retail shops: 60.8 % and Atrium space: 36 % and Restrooms: 3.2 %. First Floor, second floor, third floor and fourth floor with Retail shops: 74.3 %, Atrium: 22.5 % and Restrooms: 3.2 %. Fifth floor: Office Space: 96.8 % and Restrooms: 3.2 %.

FLOOR:	GROUND FLOOR:	FIRST FLOOR:	SECOND FLOOR:	THIRD FLOOR:	FOURTH FLOOR:	FIFTH FLOOR:
	TWIN BIRDS	RELIANCE TRENDS	RELIANCE TRENDS FOOTWEAR	HP WORLD	FOOD COURT	ADMIN
	STYLE PAY	BASICS	PAYLESS SHOES	LENOVO	PLAY ZONE	
	WILD CRAFT	WRANGLER	GINI & JONY	INCU SPACE	P.V.R	
	LOUIS PHILIPPE	CITYMAX	SOLO	VISMAY	L'OREAL SALOON	
	VANHUESEN	DOC N MARC	SPACE FOR RENT	JOCKEY	SPACE FOR RENT	
SPACES	ALLEN SOLLY	STYLE PAY	SPACE FOR RENT	FUNSKOOL 1		
	PETER ENGLAND		SPACE FOR RENT	FUNSKOOL 2		
	K.F.C		RELIANCE DIGITAL	FOSSIL		
	ACCESSORIES STORE		EASY BUY			
	BEST BUY SHOPPE					
	DOMINOS					

Figure 2: Area allocation

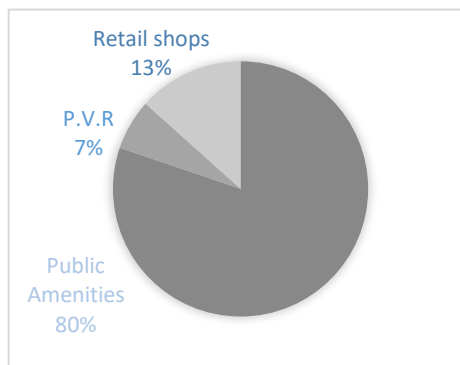


Figure 3: Area allocation in percentage

Energy efficiency measures implemented: To improve the energy performance in the building, following measures were implemented:

- System details - Retail strip mall System with Variable Air volume with centrifugal system having Coefficient of performance: 5.7.
- Lighting power density (7 days/week) with time period: 1 hr interval (0.00 -1.00) to (23:00 – 24:00).
- Occupancy: Retail and circulation with weekdays and weekends separately.
- Equipment (7 days/week) and Elevator weekdays and weekends separately.
- HVAC system 7 days/week.

(According to Schedule for shopping mall from ECBC 2017).

Results and Discussions: Overall energy performance:

The energy performance was evaluated to understand the change in energy consumption pattern using equest software. Building opened for public from 2009 by installing air cooled

chillers and it is replaced by water cooled chillers in 2019. The electricity consumption data for 12 months collected during the monitoring (Figure 4).

SPACES	AREA	ELECTRICITY BILL / 2 MONTH (RUPEE)		ENERGY CONSUMPTION / 2 MONTH		ENERGY CONSUMPTION /
		AVERAGE	MIN	MAX	MIN	
FIFTH FLOOR :						
ADMINISTRATION						
FOURTH FLOOR :						
FOOD COURT & PUBLIC AMENITIES			15,00,000	30,00,000	33333.33	66666.7
PLAY ZONE						
P.V.R	8,000	1,80,000	2,40,000	4000	5333.33	32000
L'OREAL SALOON	360	11,000	15,000	2444.44	3333.33	20000
SPACE FOR RENT						
THIRD FLOOR :						
HP WORLD	133.3	3000	4000	666.6667	888.8889	5333.33333
LENOVO	116.667	3000	3500	666.6667	777.7778	4666.66667
INCU SPACE	716.667	15000	21500	3333.333	4777.778	28666.66667
VISMAY	100	2400	3000	533.3333	666.6667	4000
JOCKEY	200	4500	6000	1000	1333.333	8000
FUNSKOOL 1	200	5000	8000	1111.111	1777.778	10666.66667
FUNSKOOL 2	200	5000	8000	1111.111	1777.778	10666.66667
FOSSIL						
SECOND FLOOR :						
RELIANCE TRENDS FOOTWEAR		2333.33333	45000	70000	10000	15555.56
PAYLESS SHOES						
GINI & JONY	250	5000	7500	1111.111	1666.667	10000
SOLO	250	5000	7500	1111.111	1666.667	10000
SPACE FOR RENT			10,000		2222.222	13333.33333
SPACE FOR RENT			10,000		2222.222	13333.33333
SPACE FOR RENT			10,000		2222.222	13333.33333
GROUND FLOOR :						
RELIANCE TRENDS		2000	50000	60000	11111.11	13333.33
BASICS		250	5000	7500	1111.111	1666.667
WRANGLER						
CITYMAX		300	6000	9000	2222.22	3333.33
DOC N MARC		333.3	8000	10000	1777.778	2222.222
STYLE PAY		200	5000	6000	1111.111	1333.333
GROUND FLOOR :						
TWIN BIRDS		200	4500	6000	1000	1333.333
STYLE PAY		200	4500	6000	1000	1333.333
WILD CRAFT		250	5000	7500	1111.111	1666.667
LOUIS PHILIPPE		250	5000	7500	1111.111	1666.667
VANHUSEN		250	5000	7500	1111.111	1666.667
ALLEN SOLLY		250	5000	7500	1111.111	1666.667
PETER ENGLAND		250	5000	7500	1111.111	1666.667
K.F.C		500	10000	13500	2222.222	3000
ACCESSORIES STORE		100	2000	3000	444.4444	666.6667
BEST BUY SHOPPE		250	5000	7500	1111.111	1666.667
DOMINOS		500	12000	15000	2666.667	3333.333
			36,57,500		807444.A	4844666.647

Figure 4: E.P.I calculation from electricity bill for different spaces.

Energy consumption for this building is 48,44,666 kwh/year and the total area of the shopping mall is 34,967sqm. Hence the E.P. I from this case is 138 kwh/year/m². In this case, operational areas were only considered.

Case 1: In 2009, shopping mall have Air cooled chillers with Variable Air volume and centrifugal system having cooling capacity of 1350ton. Its having a set point temperature of 45F and operating for 12hr/day. EPI generated by using Equest software.

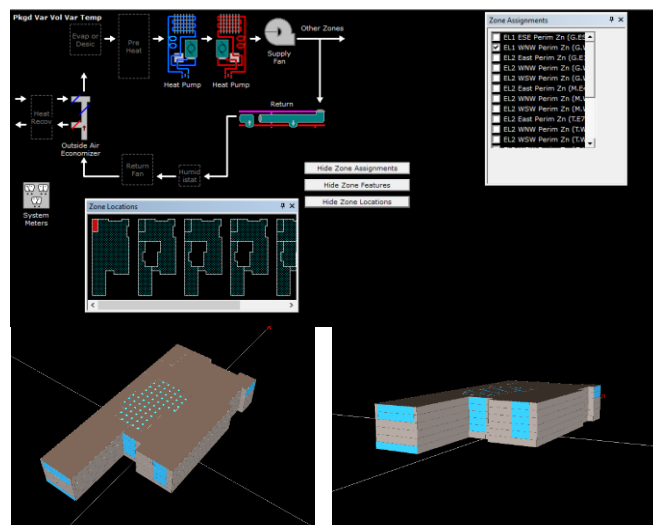


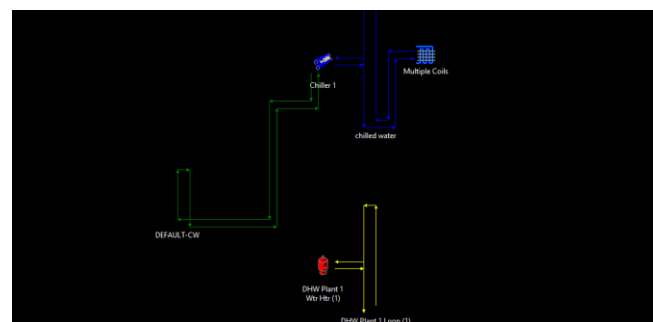
Figure 5,6,7,8: Output

Electric Consumption (kWh x000)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	163	150	165	164	168	159	162	153	156	166	159	167	1942
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	425	385	426	412	425	409	422	423	410	423	409	424	4952
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	29	26	29	28	29	28	29	29	28	29	28	29	337
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	267	241	267	258	267	258	267	267	258	267	258	267	3140
Total	883	801	887	862	889	853	879	882	852	884	854	886	1,04,12

generated from Equest software.

E.P.I: 297.76 from Ratio of total Energy consumption of the commercial building is 1,04,12,000kwh/year with its total area 34,967m².

Case 2: In 2019, shopping mall have Water cooled chillers with Variable Air volume and centrifugal system having cooling capacity of 410ton. Its having a setpoint temperature of 45F operating for 121hr/day EPI generated by using Equest software.

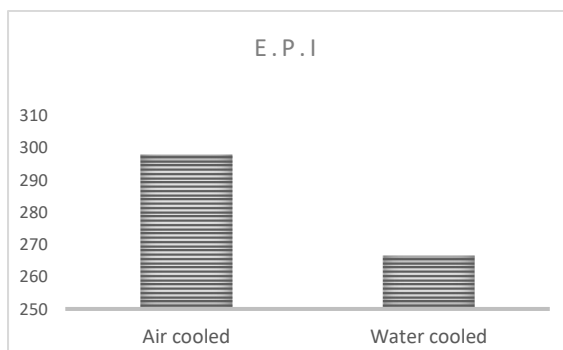


Electric Consumption (kWh x000)													
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Space Cool	-	-	-	-	-	-	-	-	-	-	-	-	-
Heat Reject.	-	-	-	-	-	-	-	-	-	-	-	-	-
Refrigeration	-	-	-	-	-	-	-	-	-	-	-	-	-
Space Heat	-	-	-	-	-	-	-	-	-	-	-	-	-
HP Supp.	-	-	-	-	-	-	-	-	-	-	-	-	-
Hot Water	-	-	-	-	-	-	-	-	-	-	-	-	-
Vent. Fans	464.7	422.4	453.5	437.3	466.0	438.6	464.7	453.5	452.3	464.7	466.0	466.0	5449.7
Pumps & Aux.	-	-	-	-	-	-	-	-	-	-	-	-	-
Ext. Usage	-	-	-	-	-	-	-	-	-	-	-	-	-
Misc. Equip.	30.7	27.6	30.1	29.3	30.6	29.2	30.7	30.1	29.5	30.7	29.7	30.5	358.7
Task Lights	-	-	-	-	-	-	-	-	-	-	-	-	-
Area Lights	300.4	269.9	294.6	286.5	299.6	285.7	300.4	294.8	288.2	300.4	290.8	297.9	35,09.1
Total	795.8	719.9	778.2	753.1	796.2	753.4	795.8	778.4	769.9	795.6	786.5	794.3	93,17.5

Figure 9,10: Output generated from Equest software.

E.P.I: 266.46 from Ratio of total Energy consumption of the commercial building is 93,17,500kwh/year with its total area 34,967m².

Analysis: Hence, the difference in E.P.I calculation: 31.33.



The energy performance of the building was evaluated under the BEE star rating of shopping mall which is the energy benchmarking and rating assessment for shopping malls.

EPI (kWh/Sqmtr/Year)	Star Label
450-400	1 star
400-350	2 star
350-300	3 star
300-250	4 star
below 250	5 star

Most commercial buildings in India have EPI between 200 - 400kWh/m²/year. Here the EPI for the building is 266kwh/year/m² with 4-star rating.

CONCLUSION:

An understanding on the energy consumption on HVAC system in shopping malls was the main objective. By undertaking research on this topic by evaluating the energy consumption directly from the electricity bill and also by using eQuest energy simulation software and which may be applied to wider range of buildings than commercial.

The preliminary study of the factors governing the Energy consumption in HVAC system was conducted through literature reviews of research paper, Journals, Articles and also through interviews. A detailed contextual study was conducted at Oberon mall, Ernakulam.

Calculated the E.P. I from the electricity bill collected from the users as step 1, and also evaluated by using eQuest software as step 2. It is a kind of post occupancy evaluation for 10 years.

The study was conducted on an interval of 10years as 2009 and 2019 by considering the renovations or alterations by the management over these periods of time. The replacement of

Air-cooled chillers with water cooled chillers lead to the reduction in energy consumption almost 11%.

The minor recommendations like increase in COP value, addition of insulation materials, Low E coating for exiting glasses etc to reduce the consumption and can be applied to the existing in future also.

This research aimed to identify effective energy consumption for commercial buildings especially shopping malls in Kerala. Based on a quantitative and qualitative analysis of energy consumption pattern with respect to their user pattern in Oberon mall, cochin.

It can be concluded that energy consumption in shopping malls is greater than other commercial buildings due to the HVAC consumption in operational energy. The results indicate that more than 75% of total energy consumption are due to the HVAC consumption (more than 10hr).

By analysing different users, typology of spaces, equipment's etc shows the energy overall HVAC consumption pattern in Oberon mall with the help of eQuest software.

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