International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Energy Performance Analysis of Terminal Building of Pokhara International Airport

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A B S T R A C T

Building heating and cooling is needed in a building to maintain a comfortable environment for the human living and working inside the building. Commercial building like airport needs space heating and cooling throughout the year to make as comfortable environment for the passengers and to maintain working temperature different special equipment which is used inside the terminal building of an airport. Pokhara International airport is the third international airport of Nepal. It is an ICAO category 4D airport and consists of a single runway. The terminal building of Pokhara international airport serves as terminal for both domestic and international passengers. This study is about the energy consumption by space heating and cooling system installed in terminal building of Pokhara international airport. Heating and cooling system consumes almost 50 percent of the total energy consumption of the terminal building. Thus, the energy consumption of HVAC system of the terminal building must be optimized. This study simulated the cooling and heating load of terminal building in Autodesk Revit which is 2277.03 kW and 1195.72 kW respectively. The study also conducted theoretical cooling load calculation with varying air change per hour to study the impact of fresh air load in the system. The cooling load at 2ACH, 1.5ACH and 0.7 ACH was 3243.58 kW, 2722.9 kW and 1889.81 kW respectively. This study also simulated building energy use intensity in Autodesk Insight which is 495 kWh/m2/yr. Heat recovery calculation was also done in this study to see the opportunity to reduce energy consumption of the space heating and cooling system of the building which amounts to 123.48 kW.

Keywords: HVAC system, energy analysis, Heat recovery

1. Introduction

The international airport known as Pokhara International Airport is situated in the Nepalese region of Gandaki. It will eventually replace the former domestic airport, which is 3 km (1.9 mi) to the east of it. The airport, which is the third international airport in Nepal, officially opened for business on January 1, 2023, while STOL flights to Jomsom are being conducted out of the former airport. One million people are anticipated via the airport each year. The runway at Pokhara International Airport is designated 12-30 and measures 45 meters in width and 2500 meters in length, falling within the ICAO 4D Category. . Runway 30 has an ILS System Precision Approach CAT-1 (PA1) facility, while Runway 12 has a Non-Precision Approach (NPA) facility. There are eight domestic parking lots and three international parking spots at the airport. The B737 series and other related aircraft types are anticipated to be among the most common kinds of aircraft using the airport. An HVAC system based on a water-cooled chiller provides air conditioning for the terminal building of Pokhara International Airport. The main structure of Pokhara International Airport, the terminal building, is almost entirely covered by an HVAC system.

About 50% of a building's total energy usage is accounted for by its HVAC (heating, ventilation, and air conditioning) systems (Liu et al., 2015b). In contrast to split AC equipment, which permits a single interior and outdoor unit, an air-cooled chiller-based HVAC system employs an outdoor chiller to supply heated or cooled air via a duct system to nearly the whole building. The operating electricity consumption, peak heating/cooling load, and energy use intensity of Pokhara International Airport's terminal building are the subjects of this study. In addition to lowering energy consumption, proper building envelope systems increase the energy efficiency of the structure. It can save a significant amount of energy. Reducing the operational electricity usage of HVAC systems is the focus of this research.

This thesis aims to analyze the energy performance of Pokhara International Airport's terminal building through an energy analysis. Energy data collecting, including fuel and power usage, as well as an evaluation of the building's envelope, HVAC system, lighting, and other energy-consuming systems are all part of the analysis. The thesis will also examine a number of energy-saving techniques, including HVAC systems.

Figure 1: Night view of Terminal Building of Pokhara International Airport

The aviation sector contributes substantially to greenhouse gas emissions worldwide. Because airport terminal buildings use a lot of energy for lighting, ventilation, heating, air conditioning, and other building services, they account for a significant amount of this carbon footprint. Thus, it is essential to evaluate the Pokhara International Airport terminal building's energy performance and find ways to cut down on energy use and carbon emissions.

The outcomes of this thesis will provide valuable insights into the energy performance of terminal building of Pokhara International airport and inform policymakers and airport operators on the best energy-efficient strategies to adopt. Furthermore, it will contribute to the development of sustainable aviation practices, which is critical for reducing the aviation industry's impact on the environment.

In this building energy analysis, it has been done only to analyze how much Heating and Cooling load can be reduced. This study has been done to analysis how much difference fresh air rate make to increase the energy efficiency of the building. And also conduct heat recovery calculation from exhaust air.

2. Methodology

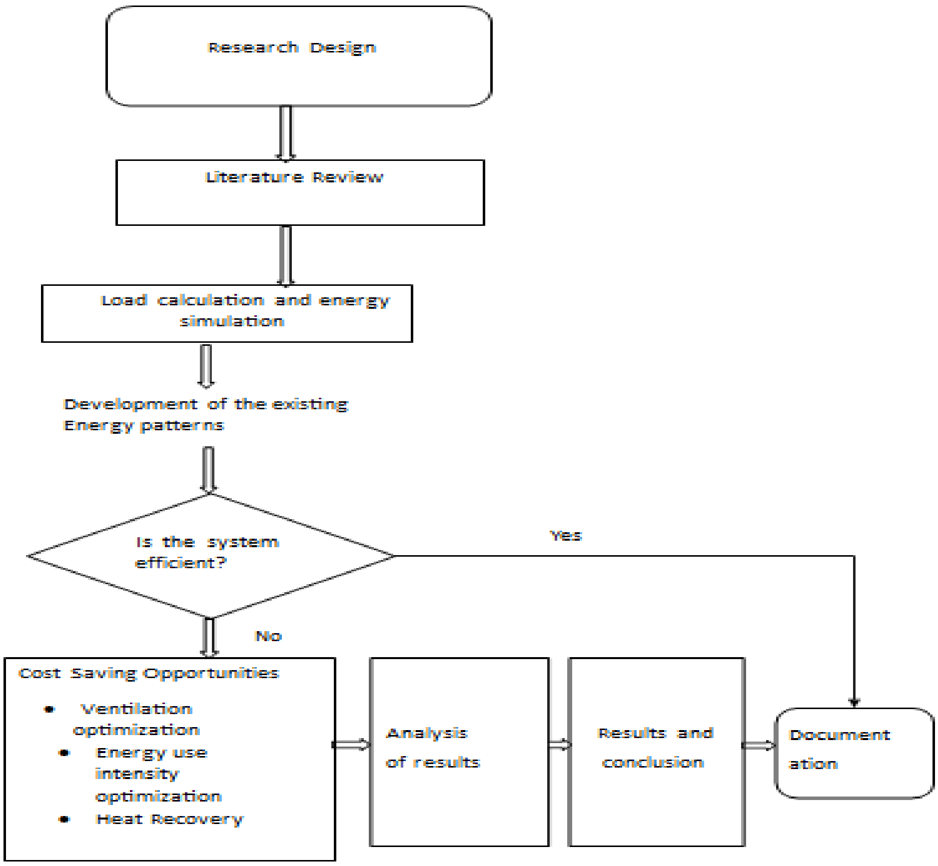
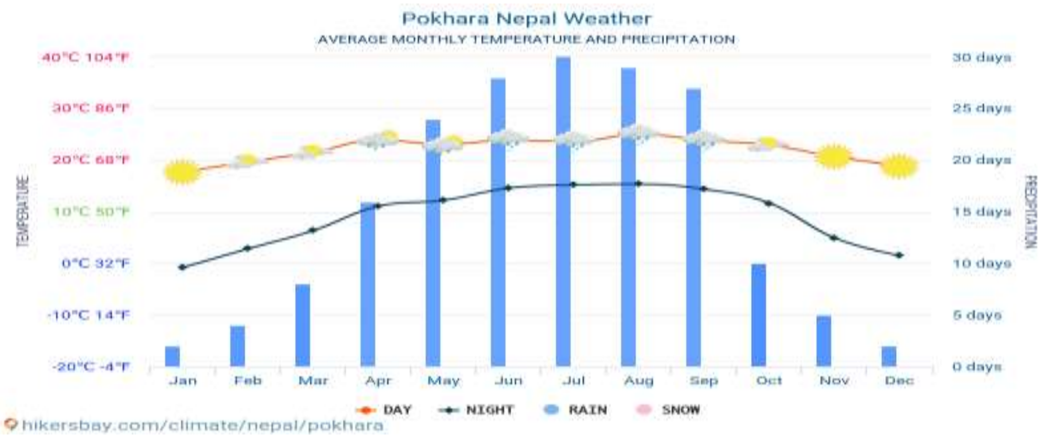


Figure 2: Research Framework

The main energy consumption factor for the terminal building is Heating, Ventilation and air conditioning system. It almost utilizes more than fifty percent of total energy consumption. This study focuses on the existing design energy consumption scenario of terminal building and the ways of reducing energy consumption by heating, ventilation and air conditioning system. The study also focuses on ways of recovering waste heat energy from the heating, ventilation and air conditioning system. The methodology is shown in Figure 2

2.1 Site Location and Weather

The site is terminal building in Pokhara international airport. The latitude longitude coordinates for Pokhara are: **28°16'0.8"N, 83°58'6.64"E**. is metropolitan city in central Nepal, which serves as the capital of Gandaki province and the tourism capital of Nepal. The city is on the Shore of Phewa Lake, and sits at an elevation of approximately 822 m. The highest temperature ever recorded in Pokhara was 38.5 °C (101.3 °F) on 4 May 2013, while the lowest temperature ever recorded was 0.5 °C (32.9 °F) on 13 January 2012. The monthly temperature variation of Pokhara is shown in the figure no 3



Structure

Figure 3: Monthly temperature variation of Pokhara (source: hikersbay.com)

The location of site is shown in Figure 4

Figure 4: Location of Pokhara International Airport (source: Google maps)

2.3 Load calculation

The theoretical load calculation is done on the following basis

External walls, cooling load (cooling load coefficient) is formed by the roof of the heat transfer

Q = Ko · Fo · [(tlo- t dl) · Ca · Cp-tn] where

Ko Heat transfer coefficient, W / (m2 · °C)

Fo Area of the external walls and roof, m2 tlo Roof or wall temperature by cooling load calculated time value, ℃

tdl Location correction coefficient envelope, ℃

Ca The outer surface of the heat value correction factor

Cp An outer envelope surface of the solar radiation absorption coefficient of the correction value

tn Indoor temperature, ℃

Exterior windows

Q = Fch · Kch · CK1 · Ck2 · [(tlc + td2) -tn] where

Kch An outer window heat transfer coefficient, W / (m2 · ℃)

Fch Outside the window area, m2

tlc When the cooling load by calculating the temperature outside the window, ℃

td2 Cooling load of outer window is calculated by the temperature correction value

CK1 External heat transfer coefficient of the correction value of the window frame of a different type

CK2 There are facilities within the heat transfer coefficient of external window shading correction value

tn Indoor temperature, ℃

The inner envelope

Q = K · F · (tls-tn), tls = tw.pj + △ tls where

K Heat transfer coefficient of the inner envelope, W / (m · ℃)

F Area within the envelope, m2

tls Calculating an average temperature of the next room, ℃

tn Indoor temperature, ℃

tw.pj Location average daily outdoor air design temperature is calculated, ℃

△ tls Calculating an average next room temperature and the outdoor air-conditioning in summer calculation of the average temperature difference, ℃

The fresh air, permeation

Qr = Qs · CCL + Qq; Qs = n · Cr · q1, Qq = n · Cr · q2 where

Qr = Qs · CCL + Qq; Qs = n · Cr · q1, Qq = n · Cr · q2

Qr Cooling load caused by body heat, W

Qs · CCL Sensible heat cooling load, W

CCL Human sensible heat cooling load factor

Qq Latent heat cooling load, W

q1 Different working properties at room temperature

n The number of air conditioning in the room, people

Cr Clustering coefficient

q2 Each generates heat and latent heat, W

The illumination cooling load

Q = N · n1 · Ccl (incandescent and fluorescent lamp ballasts outside the air-conditioned room)

Q = (N1 + N2) · n1 · Ccl (surface mounted fluorescent lamp: air-conditioned room and then ballast installed)

Q = N1 · n1 · n2 · Ccl (concealed fluorescent: lamp in the ceiling safety glass)

N Incandescent power, W

N1 Fluorescent lamp power, W

N2 The ballast power, and generally 20% of the fluorescent lamp power, W

n1 the proportion of the lamp while using coefficients, i.e. using a power installation when the power by

n2 Consider the glass reflection coefficient of the ventilation ceiling, when the fluorescent lamp cover with small holes, in the use of natural ventilation ceiling, 0.5-0.6 taken, without vent cap fluorescent lamp, depending on the roof ventilation is taken to be 0.6 to 0.8

Ccl Cooling heat load factor formed by the illumination

The apparatus cooling load

q = n1 · n2 · n3 · n4 · N (electric equipment)

q = 1000 · n1 · n2 · n3 · N / η · Ccl (in process equipment and the motor chamber)

q = n1 · n2 · n3 · N · Ccl (process equipment in the room only)

q = n1 · n2 · n3 · Ccl · N (1-η) / η (motor chamber only)

N Installation of electric power equipment, W

n1 at the same time than using the coefficient, i.e., while using a power installation and the total installed power, generally 0.5 to 1.0

n2 Installation coefficient, i.e. ratio of the maximum power and the actual consumption of the installed power is generally 0.7 to 0.9 preferably

n3 the load factor, i.e. the average actual hours than the maximum design power and power consumption of the solid, and generally 0.4 to 0.5

n4 Ventilation insulation coefficient

η Motor efficiency, product samples by Richard, generally preferable 08 ~ 0.9

Ccl Electrical equipment and appliances cold heat load factor

2.4 Building energy simulation

Building energy simulation of the terminal building of pokhara international airport was done in AutoCAD Revit and Insight. First, the building model was created in AutoCAD Revit and collected information about the physical properties of the building was selected according to the options available on the Autodesk Revit. Necessary HVAC zones were created and the load simulation was done. Then after the energy simulation was conducted in AutoCAD Insight to simulate energy use intensity of the terminal building.

2.5 Air to Air heat recovery

Heat recovery is the process of extracting heat energy from the waste product. In this study, a opportunity was studied to recover heat from the exhaust air. Theoretical heat recovery from the exhaust was calculated. The recovered is exchanged with the supply air, thus reducing the overall energy consumption of HVAC system. The heat recovery is calculated on the basis of following formula

Sensible heat recovery = CFM*1.08*△t

Where CFM is the flow rate of air

△t is the temperature difference of supply air and exhaust air

3 Results and discussions

Cooling load calculation mainly depends on the envelope of the building, internal gains and fresh air permeation. Cooling load calculation of terminal building of Pokhara International Airport was done using radiant load calculation method.

3.1 Cooling load with value of 2ACH (Air change per Hour)

Cooling load(kW)	Fresh air Cooling load(kW)	Total cooling load(kW)
1160.8627	2082.724579	3243.587279

Table 1: Cooling load at 2ACH

3.2 Cooling load with value of 1.5ACH (Air change per Hour)

Cooling load(kW)	Fresh air Cooling load(kW)	Total cooling load(kW)
1160.8627	1562.043434	2722.906134

Table 2: Cooling load at 2ACH

3.3 Cooling load with value of 0.7ACH (Air change per Hour)

Cooling load(kW)	Fresh air Cooling load(kW)	Total cooling load(kW)
1160.8627	728.9536027	1889.816303

Table 3: Cooling load at 2ACH

3.4 HVAC load simulation

Building model of terminal building of Pokhara International Airport was created in Autodesk Revit by giving various information regarding the size, material and location of the building.

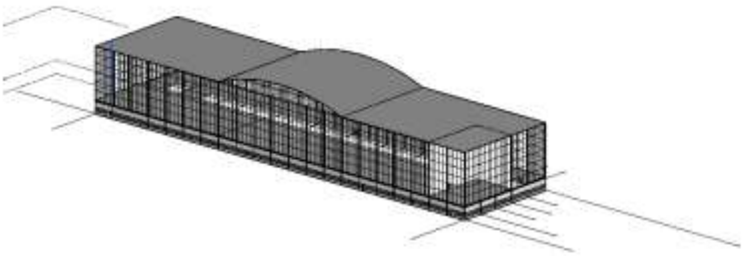


Figure 5: Building model created in Autodesk Revit

After creating the model of the building, HVAC zones were created and HVAC load calculation was simulated by using the software simulation feature.

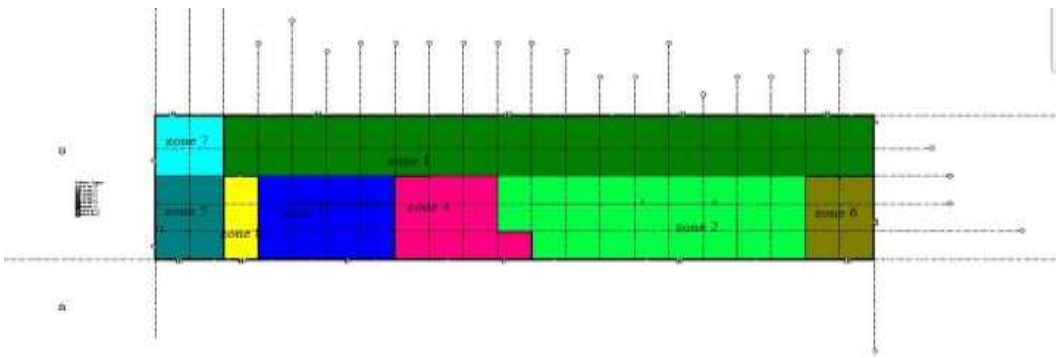


Figure 7: HVAC zones created in Autodesk Revit

No.	HVAC zone	Instant Sensible [KW]	Delayed Sensible [KW]	Latent [KW]	Total [KW]
1	zone 1	211.52	590.86	69.96	872.35
2	zone 2	131.96	368.62	43.64	544.23

3	zone 3	60.70	169.55	20.07	250.33
4	zone 4	50.58	141.30	16.73	208.62
5	zone 5	30.19	84.350	9.98	124.53
6	zone 6	30.16	84.27	9.97	124.42
7	zone 7	21.97	61.39	7.26	90.64
8	zone 8	15.00	41.91	4.96	61.87
	Total	**552.13**	**1542.28**	**182.61**	**2277.03**

Table 4: Cooling Load simulation result in Autodesk Revit

No.	**HVAC zone**	**Instant Sensible [KW]**	**Delayed Sensible [KW]**	**Latent [KW]**	**Total [KW]**
1	zone 1	-284.35	-136.87	-36.86	-458.09
2	zone 2	-177.40	-85.39	-22.99	-285.79
3	zone 3	-81.59	-39.27	-10.57	-131.45
4	zone 4	-68.00	-32.73	-8.81	-109.55
5	zone 5	-40.59	-19.54	-5.26	-65.39
6	zone 6	-40.55	-19.52	-5.25	-65.33
7	zone 7	-29.54	-14.22	-3.83	-47.59
8	zone 8	-20.16	-9.70	-2.61	-32.49
	Total	**-742.23**	**-357.27**	**-96.21**	**-1195.72**

Table 5: Heating Load simulation result in Autodesk Revit

3.5 Building energy simulation in AutoCAD Insight

After creating building energy model in AutoCAD Revit, building energy simulation was done in AutoCAD Insight with the given building information, site location and other data. The energy use intensity of the terminal building of Pokhara International Airport 495kwh/m^2/yr. Figure6 shows the output of energy simulation in Insight

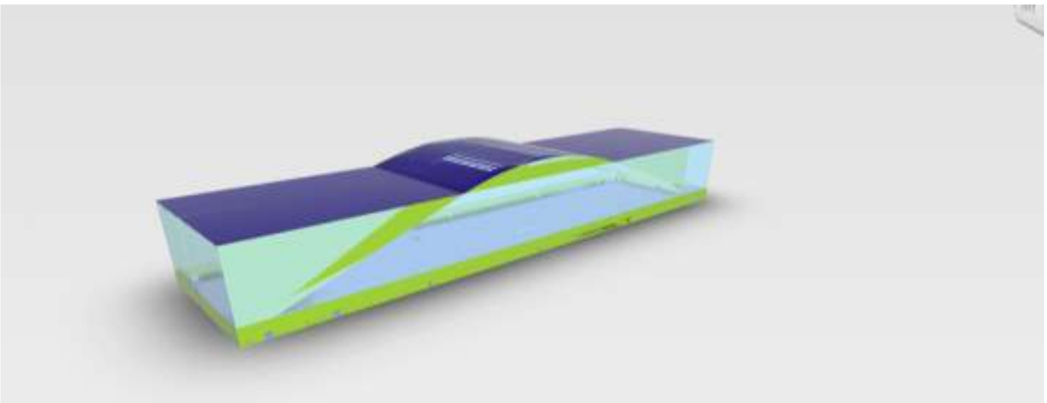


Figure 6: Energy model created by Autodesk Insight

The energy use intensity is shown in figure7a

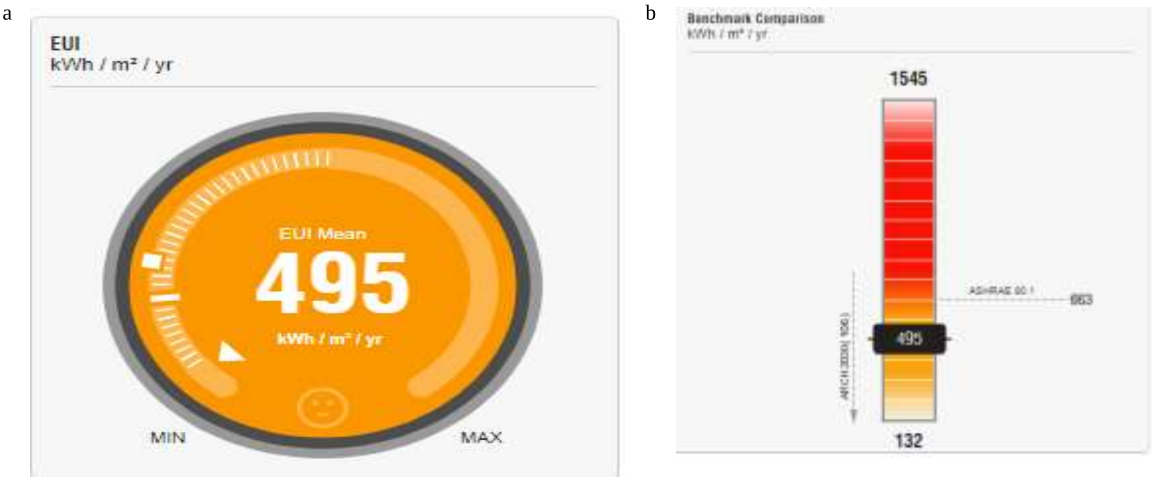


Figure 7a: Energy use intensity of terminal building; Figure 7b: Benchmark comparison of Energy use intensity with ASHRAE 90.1

Benchmark comparison of energy use intensity of terminal building of pokhara international Airport is shown in Figure 7b

3.6Heat Recovery through air-to-air heat recovery

From the load calculation, we can see that fresh air load is significant, heat recovery can be of a significant important for saving energy.

Based on the fresh air requirement, the following heat recovery calculation has been done.

CFM	Q(Btu/hr.)	kw	Efficiency	Q(kW)
30944.67	601564.45	176.41	70%	123.48

Table 5: Heat recovery calculation

From the table, we can see that 123.48 kW can be saved. This is almost 11% of total fresh air loads and almost 22% of the sensible load of the fresh air.

4. Conclusion

The study conducted on the energy analysis of terminal building of Pokhara international airport was done smoothly. The study was mainly focused on the analysis of HVAC energy analysis and different factors affecting the energy consumption of HVAC system. According the load simulation done on Autodesk Revit, the cooling load of the terminal building is 2277.03 kW and subsequently the heating load of the terminal building is 1195.72 kW. The instant sensible cooling load is 552.13kW, delayed sensible cooling load is 1542.28 kW and latent cooling load is 182.61 kW. According instant sensible heating load is -742.23 kW, delayed sensible heating load is -357.27 kw and latent heating load is -96.21 kW.

After the load analysis simulation of the HVAC system of the terminal building of Pokhara international airport was done, theoretical load calculation of the cooling load of the terminal building was conducted with varying air change per hour. The fresh air-cooling load at 2 air change per hour is 2082.72 kW, cooling load is 1160.86 kW and total cooling load is 32343.58 kW. At 1.5 air change per hour, the fresh air-cooling load is 1160.86 kW and total cooling load is 2722.9 kW. At 0.7 air change per hour, the fresh air-cooling load is 728.95 kW and total cooling load is 1889.81 kW.

Building energy simulation was done in Autodesk Insight, the building energy use intensity of the terminal building of Pokhara international airport is 495 kWh/m^2/yr. Comparing this energy use intensity of terminal building of Pokhara international airport with ASHRAE 90.1, which is 663, the energy use intensity of terminal building is very efficient.

The CBECS report indicates the EUIs of 14 types of buildings. This research has been used 5000 measured data, it presents the survey results that the EUI of office buildings is 293.1kWh/$m2$ /yr., and Healthcare is 592.2kWh/$m2$ /yr., respectively. 55 However, Transportation buildings such as airports terminal, bus stations, train stations, subway stations, and ship berthing facilities are very different in terms of functionality and operational characteristics (Kim, Shin and Ahn, 2020)

The heat recovery calculation of the exhaust air was done and the room wise heat recovery has been calculated which amounts to 123.48 kW which is almost 11% of the total fresh air load of the building and almost 22% of the sensible load of the fresh air load of the terminal building.

The study concludes that fresh air load is very crucial in determining the cooling load in the terminal building of Pokhara international airport. The cooling load of HVAC system sharply rise with the rise in air change per hour. The standard ventilation rates should be formulated for the different sections of a terminal building for efficient selection of air change per hour according to the climatic conditions. Heat recovery system should be utilized to recover the waste heat from exhaust heat which can tap heat energy from waste exhaust air.

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