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Energy Performance Assessment of an Academic Building by Energy Audit and Thermography

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Abstract. Energy efficiency is the world's most important fuel according to the latest study from the International Energy Agency [1]. Energy audit is a scientific process which determines the types and costs of energy use in the building. It is the primary step towards achieving energy efficiency improvements in a building. An energy audit was conducted on an academic building in the University of San Carlos, the Lawrence Bunzel Building which houses the School of Engineering. A comprehensive inventory of all energy consuming devices was carried out including the offices and classroom schedules. This was facilitated with instrumentations by taking ambient and room data coupled with thermal imaging. The results showed that 64.97% of the total energy consumption of the Lawrence Bunzel Building is from cooling equipment (predominantly air-conditioning units). Lighting only contributes about 9.19%; however, most lighting fixtures in the building still use fluorescent tubes. Thermal imagery also showed an extensive insulation and air infiltration problems. These results can be used as basis Energy Conservation Opportunities (ECO) to be developed and recommended in order to achieve energy efficiency in academic buildings.

1. Introduction

Global energy consumption has already reached 13.5 billion tonnes of oil equivalent (TOE) in 2017 with a 2.2% increase prior to 2016 which is way above its 10-year average of 1.7%. Also, this consumption is supplied mostly from fossil fuels by 85% [2]. Although there are many alternatives like wind, geothermal, solar and biomass energy; there is no sensible solution to fossil fuel independence yet.

The Philippines also displayed a significant growth in energy consumption at 6.9% from 40.6 million TOE in 2016 to 43.3 million TOE in 2017. Of this total consumption, 87.75% comes from non-renewables such as coal, natural gas, and oil-based fuels. Projections indicate that the Philippines' energy demand will steadily surge in proportion to its population increase and economic developments. And because the Philippines is a net fossil energy importer, it depends heavily on imports of oil for transport, and coal for power generation. On average, nearly half the country's primary energy supply is imported [3]. According to these data, the energy status of the Philippines can be summarized as follows:

1. The Philippines is not energy self-sufficient and dependency on imported energy sources is increasing year by year.
2. Cost of energy is increasing and the country is highly vulnerable to rising costs for fuel imports and global oil price volatility.

Under these circumstances, energy efficiency and renewable energy sources hold an important role to overcome fossil fuel dependency and fluctuating energy costs. It has been considered that energy efficiency and renewable energy to be both the basic foundations for energy sustainability [4], however, energy efficiency outshines as the simplest, cheapest and fastest solution.

Energy wastage from inefficient energy use is a serious problem which threatens energy and environmental sustainability. In the United States alone, according to U.S. Department of Energy, only about 16% of all commercially produced energy flowing through performs useful work. The remaining 84% of it is wasted. About 41% of this energy is automatically considered as heat loss but the remaining 43% is unnecessarily wasted [5]. This wasted high-quality energy is a resource that can be used at a lower cost and with a lower environmental impact than any other energy resource. An energy audit is the first step to determine this wastage by highlighting how much and where energy was consumed.

The Lawrence Bunzel which houses the School of Engineering building is one the oldest building in the University of San Carlos. It is therefore appropriate to start the energy audit in our own building to set as an example in energy efficiency strategies.

2. Theoretical Background and Literature Review

The term energy audit is commonly used to describe a broad spectrum of energy studies ranging from a quick walk-through of a facility to identify major problem areas to a comprehensive analysis of the implications of alternative energy efficiency measures. Audit is required to identify the most efficient and cost-effective Energy Conservation Opportunities (ECOs) or Measures (ECMs)

Performing an energy assessment is an essential precursor to implementing energy saving measures in a building. If a building's energy consumption is not measured and validated, then sensible recommendations are not possible as the analysis and possible recommendations are usually based on guesswork.

Common types/levels of energy audits are distinguished below, although the actual tasks performed and level of effort may vary depending on the objectives. Generally, four levels of analysis can be outlined [6].

Level I – Walk-through audit: This inspection is based on visual verifications, study of installed equipment and operating data and detailed analysis of recorded energy consumption collected during the benchmarking phase;

Level II – Detailed/General energy audit: This level of analysis can involve advanced on-site measurements and instrumentation tools to further provide evidence on how the building utilizes energy. Thermography can be conducted on this stage.

Level III – Investment-Grade audit: Detailed Analysis of Capital-Intensive Modifications focusing on potential costly ECOs requiring rigorous engineering study

There are several studies in the past employing variants of these methods which includes the following:

Annunziata et al (2014) investigated on enhancing the energy efficiency in public buildings in Italy and the role of local energy audit programs. They found out that energy audits and other factors influence energy efficiency in public buildings [7].

Kumar et al (2015) conducted an energy audit in a residential house and found out that the wastage of energy is mostly done by the domestic users [8].

Corgnati et al. (2008) focused on impact of internal thermal conditions on building energy demand exhibiting an example of "simulation only" performance evaluation study [9].

Masoso and Grobler (2008) focused on the phenomena of "insulation increases cooling load". Simulations are carried out by EnergyPlusTM on a hot climate (Botswana) on an existing building. [10].

Rhodes et al (2015) uses BEopt (EnergyPlusTM) with energy audits and surveys to predict actual residential energy usage. They determined that geometry adjustments do not significantly contribute (about 1%) to a home's overall energy results [11].

Marinosci et al (2015) performed a preliminary energy audit of the historical building of the School of Engineering and Architecture of Bologna. Special attention has been focused on the energy consumption for heating during the winter season [12].

In the Philippines, it is found out that there is very little to zero studies neither researched nor published conducted to determine building energy performance. The sole study for academic buildings was done by Peñas II et al (2015) when they assessed and created the electrical energy profile of Pamantasan ng Lungsod ng Maynila. The result of the study has generated a simulated energy consumption footprint of the university and can be used as basis for recommending energy conservation measures to reduce the energy consumption cost [13].

3. Methodology

A systematic procedure is applied for conducting the energy efficiency assessment study in the academic building of the University San Carlos-Technological Center. It helps to identify energy consumption, wastage, and opportunities for improving energy practices. This aids carbon emission reductions and can make strides for cost-benefit applications for the institution. Hence, awareness in using the scientific tools for energy performance study and analysis is the need of the present day for all kind of energy users.

3.1 Pre-Site Work

This is the first step of the audit which includes obtaining approvals, collection of historical energy utility data and creating a building profile based on the architectural layout and plans of the building. The map on Fig 1 shows the overhead view of the Lawrence Bunzel building where the energy audit was conducted. It is located 10.3521° N, 123.9134° E which is the oldest building in the University of San Carlos- Technological Center in Talamban, Cebu City which was constructed on 1963.

Figure 1 Location of the Lawrence Bunzel Building (Image Credit: Google Earth)

3.2 Site Visit

This is the main stage of the energy audit which is the comprehensive inventory of all energy consuming equipment inside the building. The devices, equipment or appliances will be categorized into the following groups:

1. Cooling – air-conditioning units (ACU), fans, etc.
2. Lighting – fluorescent tubes, emergency lights, etc.
3. Classroom and Office Equipment – computers, projectors, etc.
4. Appliances –refrigerators, rice cooker, radio, etc.
5. Laboratory Equipment – incubators, chiller, etc.
6. Others – fountains, smoke detectors, CCTV, etc.

In order to compute the total energy consumption of a room, quantity, wattage information, and room schedules are procured.

Energy consumption is computed using the formula:

$$E = Pt \qquad (1)$$

Where:

E = energy consumed by the device, in watt-hour
P = power, in watts
t = amount of time the device is used, in hours

3.3 Thermography

Together with the visual inspection, thermal imaging camera was employed to qualitatively assess the airtightness and thermal bridge of an air-conditioned room.

4. Results and Discussions

4.1 Energy Use Profile

Fig. 2 shows the energy use profile of the Lawrence Bunzel Building.

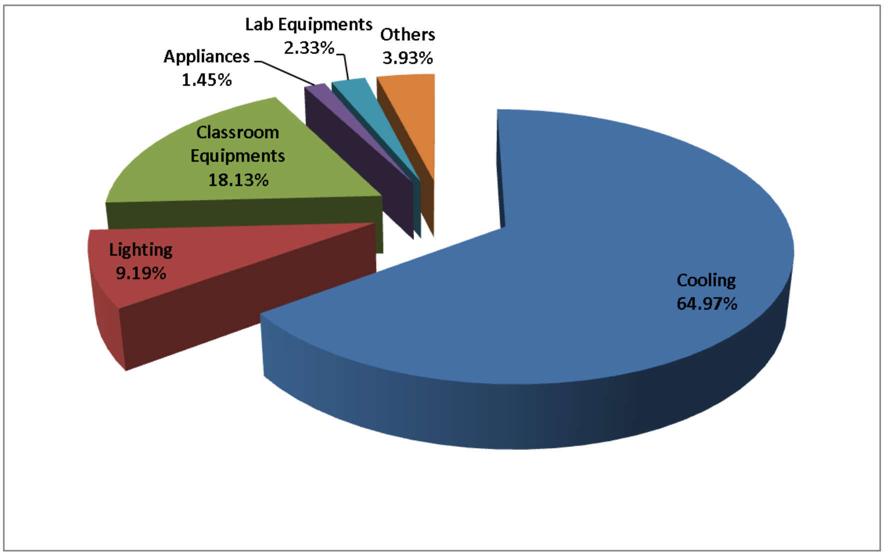


Figure 2 Energy Use Profile of the Lawrence Bunzel Building

Based on these results, it is observed that that major energy consumer of the building is the cooling facility. It has about a two-thirds share of the total energy consumption of the buildings.

Fig. 3 also shows the energy use profile of the Lawrence Bunzel Building per room type and Fig 4 for the energy use profile per floor level of the building.

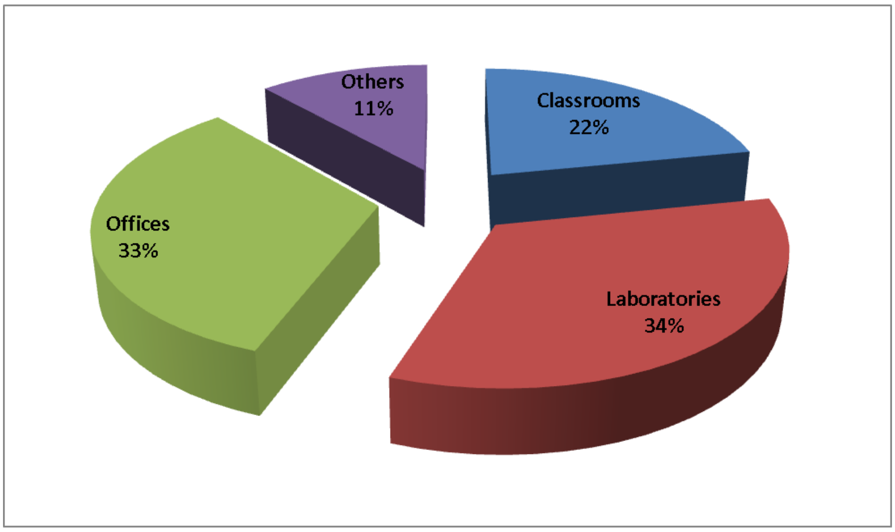


Figure 3 Energy Use Profile of the Lawrence Bunzel Building per Room Type

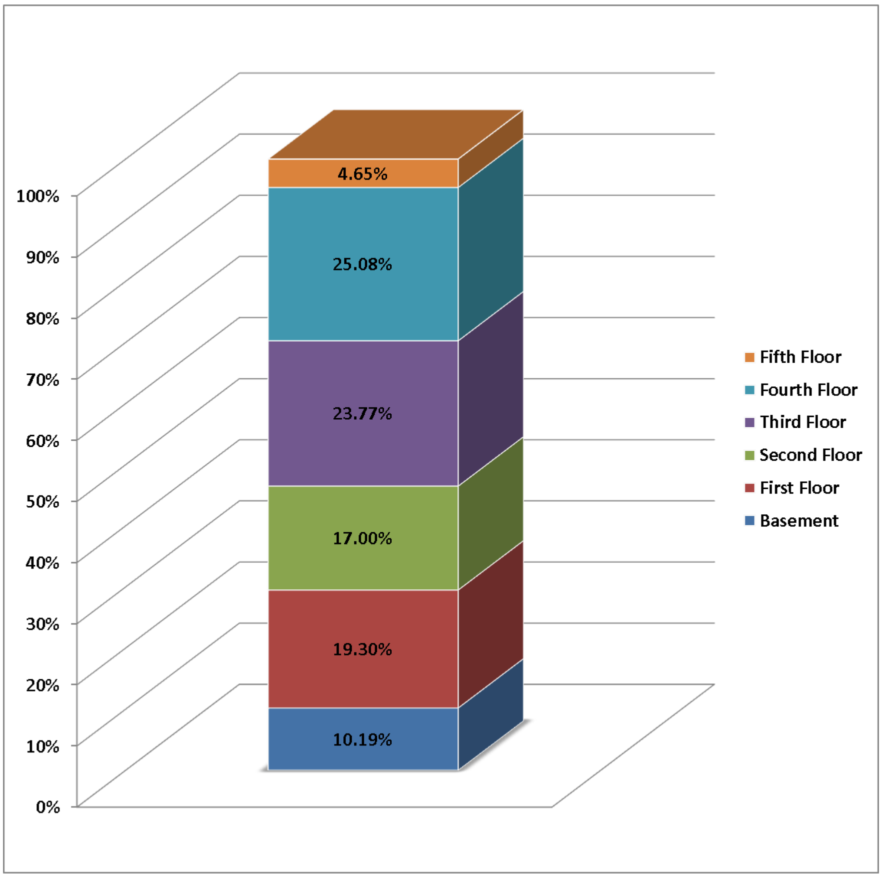


Figure 4 Energy Use Profile of the Lawrence Bunzel Building per Floor Level

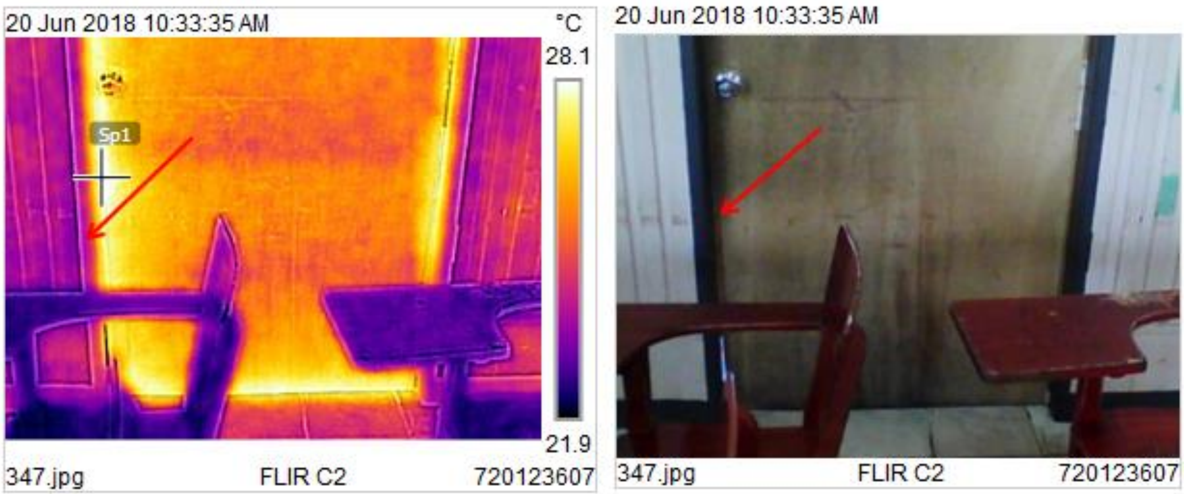
The data in Fig. 3 showed that even though the buildings are academic in nature, offices also have a big portion of the total energy consumption which means energy efficiency strategies should also be applied there. Fig. 4 can provide us an assessment on which floor level of the building has the higher energy consumption which can help us on focusing the Energy Conservation Opportunities be applied there.

4.2 Thermal Imaging

Thermal Imaging or infrared thermography is the art of transforming an infrared image into a radiometric one, which allows temperature values to be read from the image. So every pixel in the radiometric image is, in fact, a temperature measurement. A thermal imaging camera records the intensity of radiation in the infrared part of the electromagnetic spectrum and converts it to a visible image. Thermal imaging or infrared scanning is usually employed by energy auditors to check for thermal defects and assess insulation and air leakage problems of buildings. [14]

During the energy audit of the rooms with ACU's, the proponent took thermal images throughout the windows, doors, ceilings, and ACU to check for air-leaks, infiltration, and thermal bridge which cannot be seen with the naked eye. This process is one the major highlight of the energy audit as this was the first time that thermal imager was used to determine the efficiency of our air-conditioned rooms.

The results of the images are analyzed in Fig. 5 to Fig. 9.



Measurements

Sp1	28.1 °C

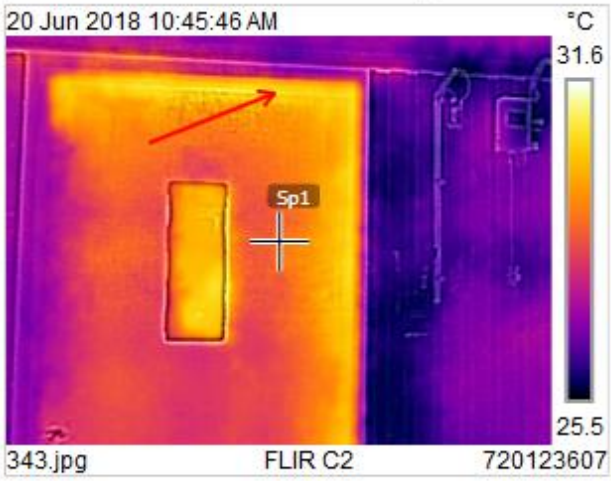
Parameters

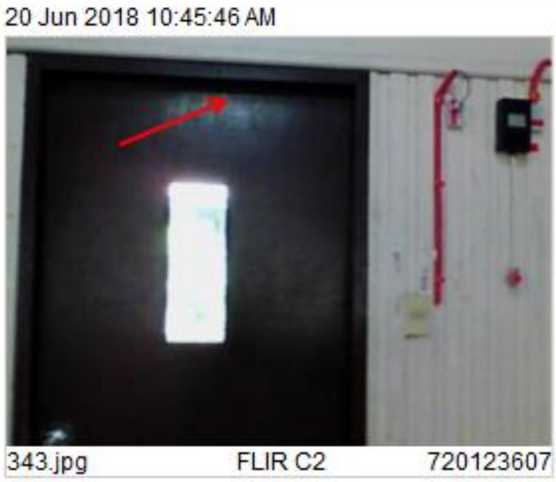
Emissivity	0.95
Refl. temp.	20 °C

Text annotations

Outside Temp	29 deg Celsius
ACU Setting	21 deg Celsius
Notes	Thermal leaks around the gaps of the door invisible to the naked eye.

Figure 5 Thermal Leaks around Doors in Room 347





Measurements

Sp1	27.2 °C

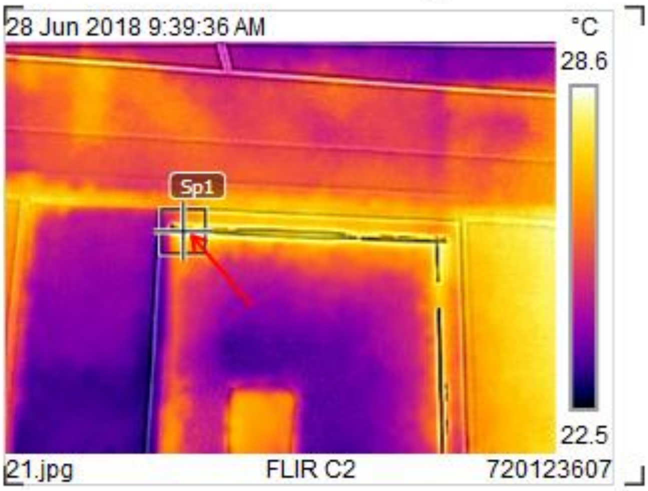
Parameters

Emissivity	0.95
Refl. temp.	20 °C

Text annotations

Outside Temp	32 deg. Celsius
ACU Setting	22 deg. Celsius
Room Temp	26 deg Celsius
Notes	Hot air infiltration visibly entering the conditioned room

Figure 6 Thermal Leaks around Doors in Room 343



Measurements

Sp1	27.2 °C

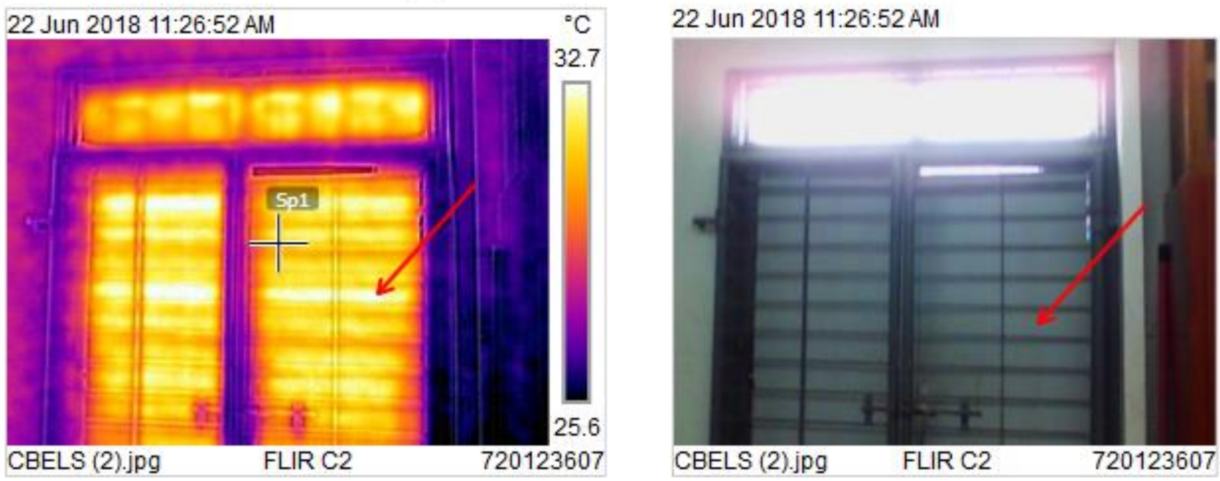
Parameters

Emissivity	0.95
Refl. temp.	20 °C

Text annotations

Outside Temp	29 deg. Celsius
ACU Setting	21 deg Celsius
Room Temp	27 deg Celsius
Notes	Air gaps around door

Figure 7 Thermal Leaks around Doors in Room 343



Measurements

Sp1	31.1 °C

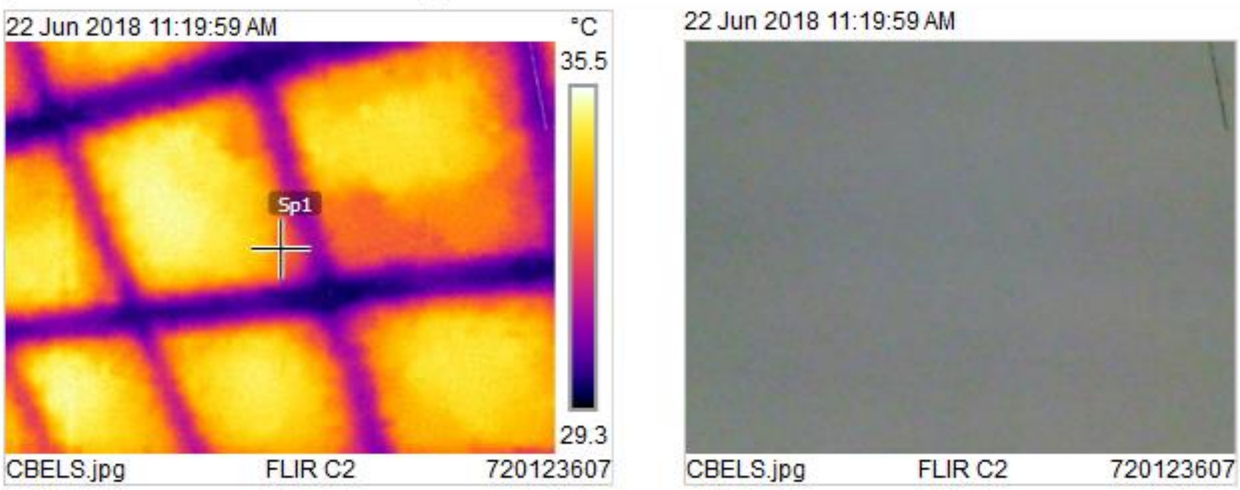
Parameters

Emissivity	0.95
Refl. temp.	20 °C

Text annotations

Outside Temp	33 deg Celsius
ACU Setting	16 deg Celsius
Room Temp	27 deg Celsius
Notes	Poor insulation around doors

Figure 8 Thermal Leaks around Doors in CBELS Office



Measurements

Sp1	33.2 °C

Parameters

Emissivity	0.95
Refl. temp.	20 °C

Text annotations

Outside Temp	32 deg Celsius
ACU setting	16 deg Celsius
Room Temp	27 deg Celsius
Notes	Thermal Image (ceiling)

Figure 9 Poor Heat Insulation of Ceilings of Top Floor Rooms

5. Conclusion

The energy performance assessment of the Lawrence Bunzel Building was based from the energy use profile and thermal imagery analysis. The resulting energy use profile from the energy audit conducted shows that cooling of the building comprised 64.9% of the total energy consumption followed by classroom equipment and lighting with 18.13% and 9.19% shares respectively. Further, thermography was also conducted which may have shown the reason for why cooling has a very large percentage of the total consumption as thermal and air leakage throughout the whole building was detected.

The results of the energy audit can point out the performance of the building on where and how it consumes energy. This is very important as it will serve as the basis for the Energy Conservation Opportunities (ECO) can be duly developed and recommended to reduce energy consumption costs and enhance energy efficiency strategies in our own academic buildings.

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