Proceedings of International Conference on Technological Challenges for Better World 2019

Infrared Imaging as a Means of Promoting and Analyzing Energy Efficiency in Buildings: The Case of an Academic Building in the University of San Carlos

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Keywords: energy efficiency, thermal imaging, thermal bridging, efficient building envelope

Abstract. Thermal imaging or infrared thermography is the process of transforming an infrared image into a radiometric one, which allows temperature values to be read from the image. Thermal Imaging is used for diagnostic control when building or renovating a building. Heat losses in commercial and domestic buildings can account for up to 50% of the total energy consumption and comes from air leakage through various factors. Thermal imaging is effective for the detection and visualization of hot spots and can help to identify areas of waste and problems related to energy loss, missing insulation, radiant heating, water damage on roofs and a lot more. This study is presenting a critical application of infrared imaging in the field of energy efficiency of buildings. Thermography has been used as one of the highlights of the energy audit process done to one of the academic buildings of the University of San Carlos. After explaining its background, the applicability of thermography in energy audit has been described, considering well-established A quantitative approach is the most common to detect thermally significant defects of the building in study thus, a specific procedure for the energy audit has been reported. Several energy defects have been discovered upon using thermography on the air-conditioned rooms of the building during the energy audit. The research aims to serve as a reference for energy auditors and thermographers to promote and qualitatively detecting specific energy defects.

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% [1]. Although there are many alternatives like wind, geothermal, solar and biomass energy; there is no sensible solution to fossil fuel independence yet.

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 [2], 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 [3]. 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 purpose of this research therefore is to conduct an energy audit by using comprehensive thermal imaging qualitative analysis on the rooms and spaces with Air-Conditioning Units (ACU) in the Lawrence Bunzel Building of the University of San Carlos.

Thermographic technology can help support building energy efficiency initiatives. In the past few decades, thermal cameras have emerged as a popular tool for surveying building energy efficiency. Modern handheld thermal cameras are capable of measuring temperatures, assessing heat loss, identifying missing or degraded insulation, and locating sources of moisture. Thermal cameras offer a non-destructive means of diagnosing building conditions, and can rapidly visualize information that would otherwise be difficult to collect and communicate.

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 using infrared imaging technology.

2. Theoretical Background and Literature Review

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.

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 [4].

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 [5].

Corgnati et al. (2008) focused on impact of internal thermal conditions on building energy demand exhibiting an example of "simulation only" performance evaluation study [6].

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. [7].

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 [8].

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 [9].

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 [10].

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. 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.

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

Together with the visual inspection, thermal imaging camera was employed to qualitatively assess the airtightness and thermal bridge of an air-conditioned room. The proponent used the FLIR C2 Thermal Imaging System. FLIR is the world leader in thermal imaging and FLIR C2 was specifically designed for the building industry to check for structural inefficiencies. Shown below in Fig. 2 is the image of this device.

Fig. 2 FLIR C2 Thermal Imaging System

4. Results and Discussions

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. 2 to Fig. 5.

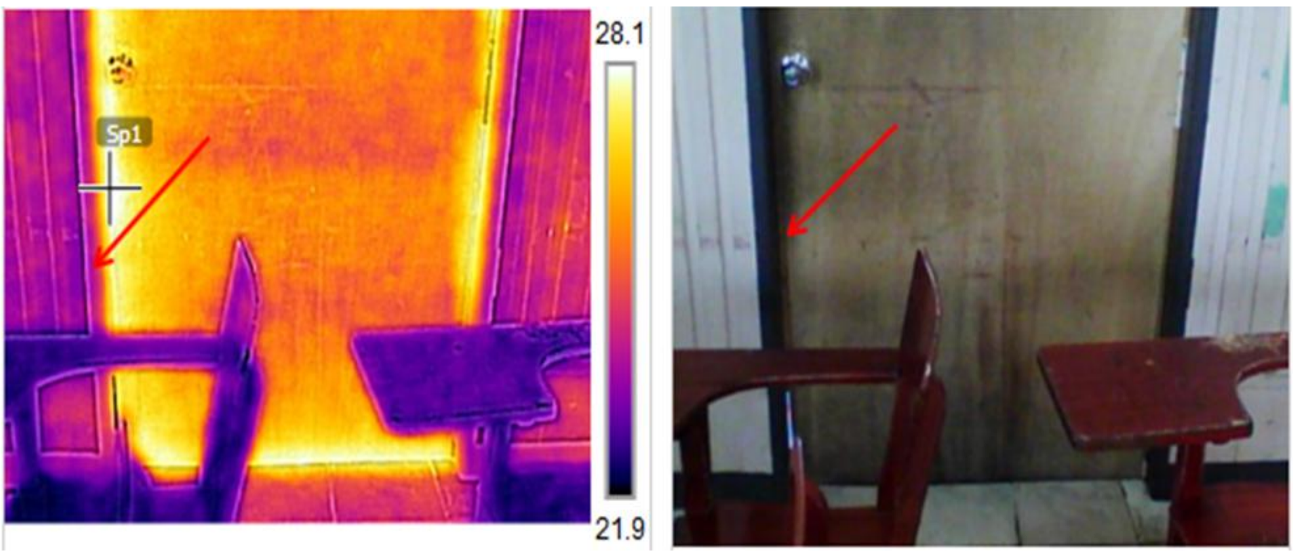

Fig. 2 Thermal Leaks around Doors in Room 347

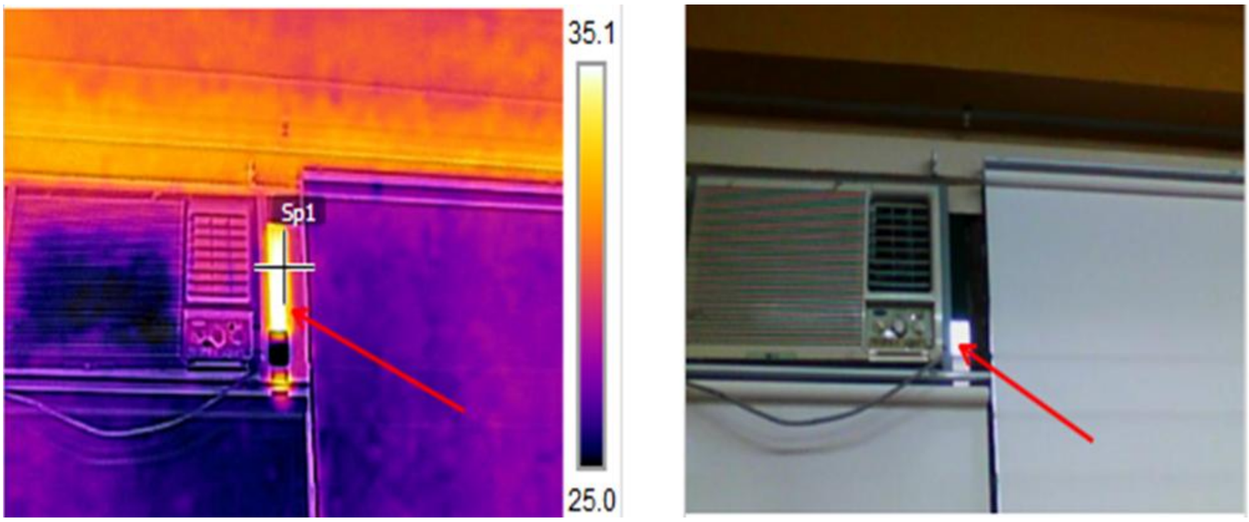

Fig. 3 Thermal Infiltration around Window-type Air Conditioner

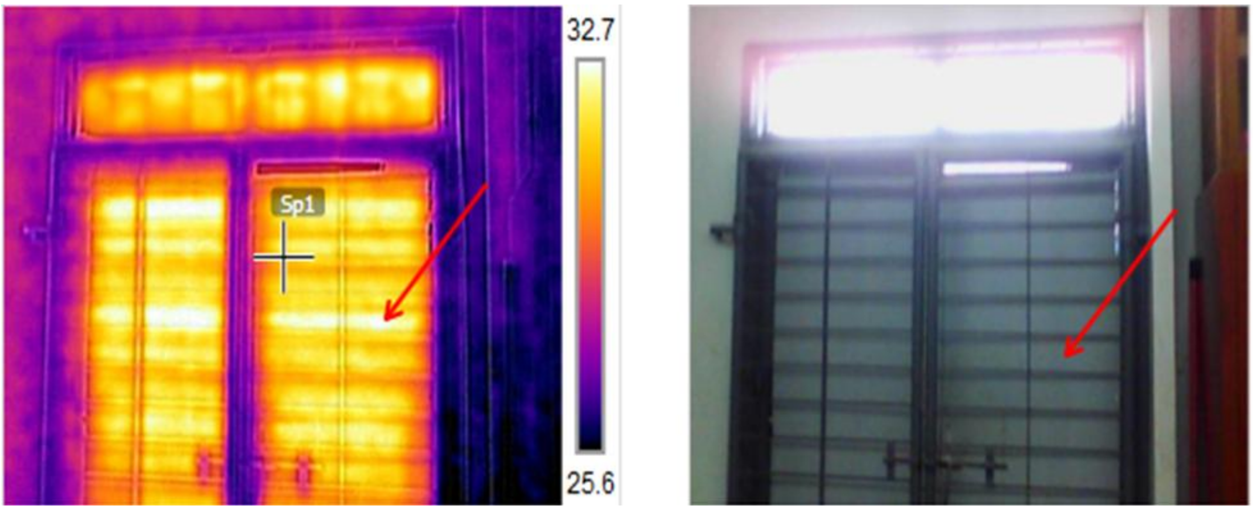

Fig. 4 Thermal Leaks around Doors in CBELS Office

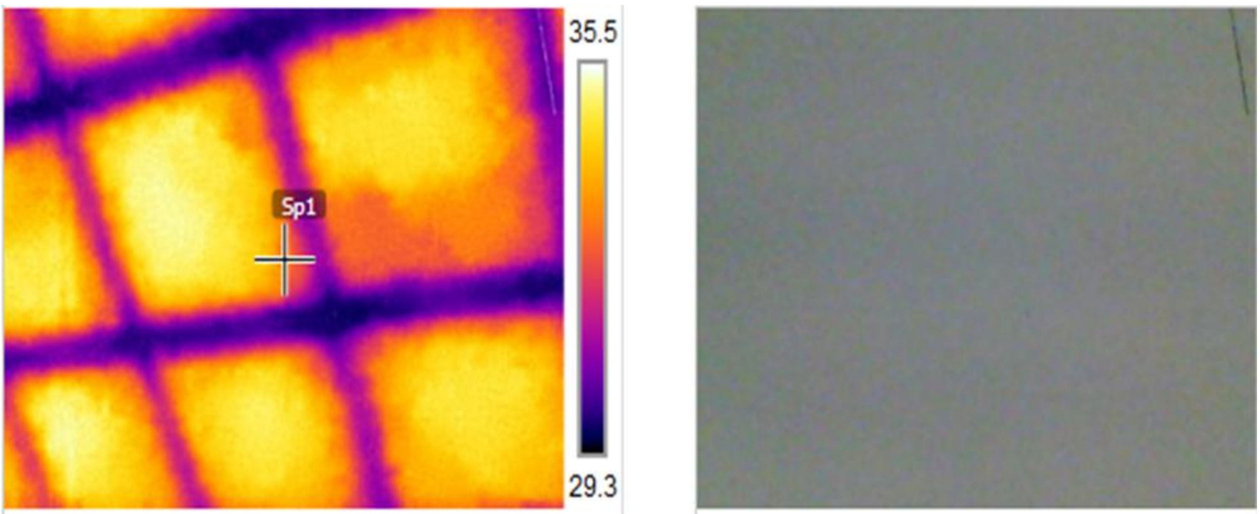

Fig. 5 Poor Heat Insulation of Ceilings of Top Floor Rooms

It has been noticed that Bunzel Building are not properly insulated and thermally sealed which is evident on these thermal images around windows, doors and around the ACU units (especially for window type ACU). However, these infiltration pathways for hot and humid air entering the conditioned- space can cause the ACU to run continuously. This is because the unit will struggle to reach and maintain the thermostat setting of the air-conditioners. This means higher electricity cost which explains the high consumption of the building. Further, the continuous running of ACU compressors can result in higher maintenance costs for the unit as these are designed to cycle off at least twice in an hour [11]. During the course of my energy audit where I spend several minutes or hours inside the room, I never noticed the ACU to cycle off. This clearly means that the ACUs was running continuously and still could not maintain the desired thermostat setting (as shown in the thermal imaging reports). Further, on the higher floors of each building where the ceiling is already below the rooftop, thermal images showed poor insulation on the ceilings. This causes additional load to the installed ACU which further make it hard for them to cycle off.

The main issue that was confirmed by the energy audit was the poor insulation and air-tightness of the air-conditioned rooms of both buildings. It was evident on visual inspection and thermal imagery the substantial gaps around doors, uninsulated windows, leaks around the window ACUs and the poor ceiling insulations of the buildings. The proponent wishes to recommend replacement of the window air-conditioners to split-types and more efficient models. However, this would not solve the root problem which is poor insulation and air leaks. The units will still run continuously if the hot and humid air freely enters the conditioned spaces. That is why it is recommended just for now to invest in proper insulation for the buildings.

5. Conclusion

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.

The energy audit by using thermal imagery showed poor insulation, air leaks, and thermal bridges which can be found in the rooms with ACU in the Lawrence Bunzel Building. This could further waste more energy as these will provide additional hot temperature and humidity in the room for the ACU to remove thus wasting more energy. Proper insulation of the buildings should be recommended to encourage energy efficiency in our academic buildings.

6. Acknowledgments

The researcher of this study is extending its gratitude to the administration of the University of San Carlos for the permission granted to conduct this study and to the DOST-ERDT Program for funding the research.

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