# Energy and Lighting Performance of Buildings in the Neighbourhood Ciudad de los Angeles, Before and After Refurbishing.

Pérez, M[1]; Cuerda, E[1]; Neila, J[2].

[1] PhD Student, Technical University of Madrid, Spain
[2] Professor, Technical University of Madrid, Spain

***Abstract:*** *The Spanish Ministry of Economy and Competitiveness is funding the SHERIF Research Project, which falls under the INNPACTO program. This project aims to increase the rate of the existing building refurbishment from the energy efficiency point of view by designing a facade system that must be an economical, flexible and integrated solution[1]. Under this project has been performing several tasks regarding the constructive characterization and energy evaluation of the thermal behaviour of facades on existing buildings[2,3,4]. In order to perform the latter task, in which this article will focus, has been developing a survey of various buildings in the neighbourhood Ciudad de los Angeles, which has as main objective the comparison between the actual energy and light behaviour of different buildings, prior and posterior to any refurbishment works have been undertaken. The evaluation of the actual performance of buildings before and after being refurbished is aimed to determine the impact of the work developed as well as learn from the work performed for future interventions.*

***Keywords: refurbishment, evaluation, methodology, bioclimatic, facade, monitoring.***

## 1. Introduction

The main objective of this study was to acquire the data needed to assess the actual energy performance of the buildings before and after refurbishment interventions in order to compare them[5]. This analysis was carried out in the neighbourhood of Ciudad de los Angeles in the city of Madrid, a pilot neighbourhood in which it is developing a comprehensive rehabilitation plan[6,7]. Four different types of buildings were analyzed in this neighbourhood. In each, were chosen buildings that have not been refurbished and others of the same type in which these works have been performed. On the one hand, characteristics related to the thermal behaviour of the facade were evaluated and on the other hand, natural lighting characteristics were analyzed.

## 2. Typologies Selected

To select the types in which the measurements were made, it was considered the most representative and characteristic facades situated in the neighbourhood. The Municipal Housing Company of Madrid is a partner in this project and they are developing a refurbishment plan in this area, so this made it possible to collect information about these buildings and contact with the occupants, the thing that usually is very complicated. Have been studied for each typology, one refurbished building and another without refurbishment

works. Then, we selected 2 different dwellings for each building in different floors. In total, 4 typologies, 8 buildings, 16 dwellings.

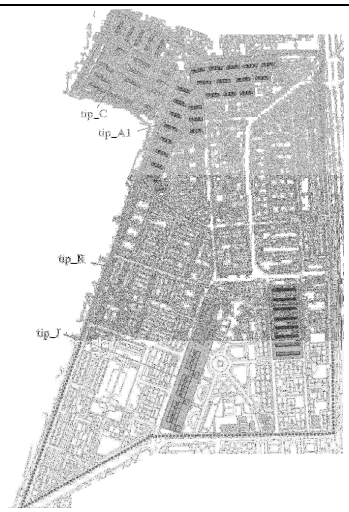
| | |
|---|---|
|  | **Typology C:** it is a Multi-Family house. The opaque part of the facade in solid brick ½ foot thick + air chamber 5cm + 4cm hollow brick + plastered and painted. There are 30 buildings of this type, making up a total of 300 dwellings. |
| | **Typology A1:** it is a Multi-Family house. The opaque part of the facade in solid concrete wall (30 cm think) + plastered and painted. There are 48 buildings of this type, making up a total of 480 dwellings. |
| | **Typology R:** it is a Multi-Family house. The opaque part of the facade in solid brick one foot think. There are 8 buildings of this type, making up a total of 240 dwellings. |
| | **Typology J:** it is a Multi-Family house in H shape. The opaque part of the facade in solid brick ½ foot thick + air chamber 5cm + 4cm hollow brick + plastered and painted. There are 10 buildings of this type, making up a total of 200 dwellings. |

*Fig. 1 Representative building typologies selected on Ciudad de los Angeles neighbourhood.*

## 3. Measuring Instruments

Previous to performing measurements in buildings a weather station was installed on the roof of a building in the neighbourhood of Ciudad de los Angeles, which has been collected data for one year data: air temperature, relative humidity, solar radiation Global, wind speed and direction. Subsequently these data are going to enable to analyze the microclimate in which the buildings are and then we can determine the most appropriate actions to improve the refurbishment interventions.

The following measuring devices have been used to perform measurements:

- *The Infrared images* were taken with a camera FLIR-E series (pixel resolution 4,800 (80x60).
- *The U-value* was measured with the multifunction TESTO 435-2 instrument with surface temperature probe to determine U-value and radio probe of temperature and humidity.
- *The illuminance value* was taken with 3 photometric sensors Li-Cord 210 and a data-logger that store the data obtained.
- *The temperature and humidity indoor* was measured with a LOG 32 Data logger.

## 4. Methods Used For Data Collection And Analysis

The typology A1 was used as an example in order to explain this methodology because all the typologies follow the same procedure.

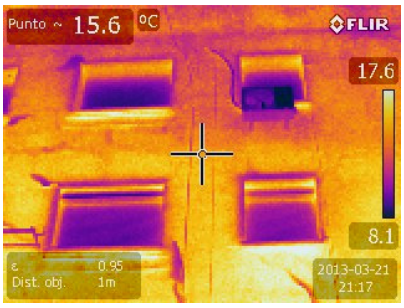
*Infrared Images*

The infrared exterior images were performed between 17 and 19 hours. The infrared interior images were performed mostly early in the morning. In both cases performing infrared images were avoided when the facade was getting direct solar radiation to prevent alteration of the information. Through the observation of images obtained the temperature in different part of

the facade were evaluated with the camera previously describe, located deficient's related to the loss or gain of heat.

*Infrared Outdoor Images*

The main difference found between the two infrared images is the discontinuity of colours. This indicates that there are discontinuities in the thermal behaviour of the facade. As, we can see in the non-refurbished building (left-hand side), specifically in the lower right window, how the predominant yellow colour indicates that the heating system was turned on inside the house, and these heat flow is being lost through the facade. By contrast, in the image on the right-hand side, the facade has a homogeneous behaviour (continuity of colours). Only vertical lines are observed, which correspond to the union of the facade panels without a difference in the hue observed.



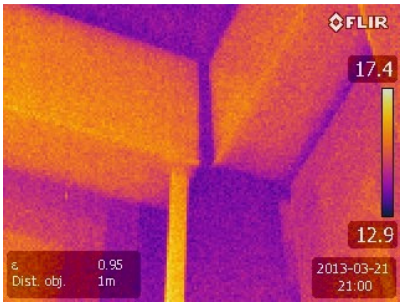

*Non-refurbished house*


*Refurbished house*

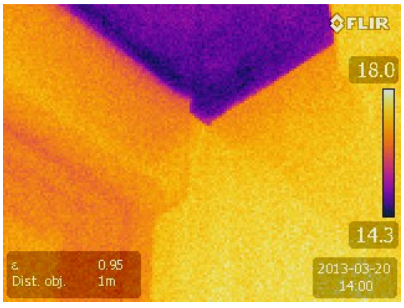
*Fig. 2. Infrared outdoor images on facade typology A1.*

*Infrared Indoor Images*

In the infrared image (left-hand side) it is possible to see a common problem in this kind of buildings, where the shutter boxes represent both an important loss of heat and infiltrations as well, because they are not insulated. However, in the right-hand side, there is no discontinuity in colour between the wall and the window.




*Non-refurbished house*




*Refurbished house*

*Fig. 3. Interior Infrared indoor images on facade typology A1.*

*U-Value*

A theoretical study has been made using mathematical calculations. Also "in situ" measurements have been performed in homes for 23 hours, collecting information every 10 min[8]. Measurements of 15 dwellings were performed on different days. In the theoretical study, the thermal transmittance was 1.65 kWh/m2 corresponding to the non-refurbished building. In refurbished building the thermal transmittance was 0.55 kWh/m2. In the "in situ"

study the thermal transmittance was 1.67 kWh/m2 in the non-refurbished building. While, in the refurbished building, the thermal transmittance value was 0.95 kWh/m2. Both theoretical and in situ measured data showed a large difference between the thermal behaviour of the refurbished and non-refurbished facades. According to the thermal transmittance measured "in situ", it can be concluded that the thermal behaviour of the opaque part of the facade improved by 77% after refurbished.

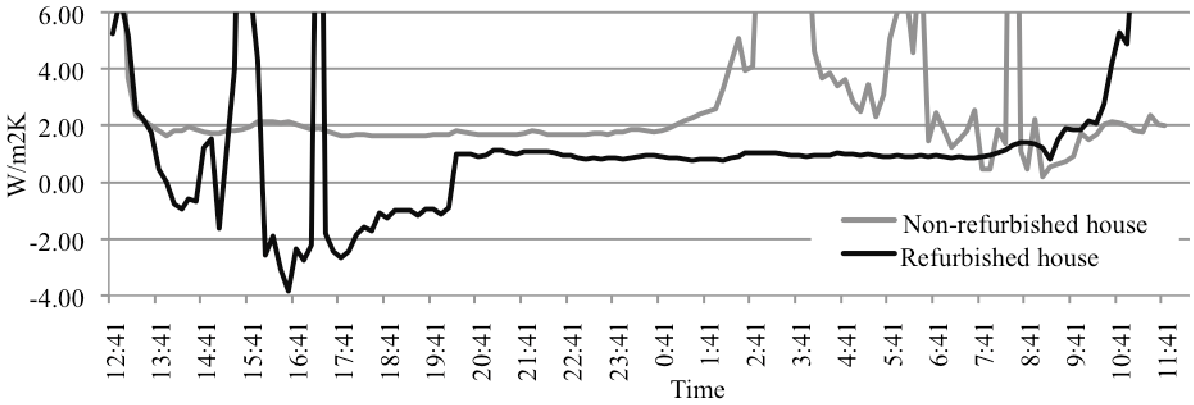
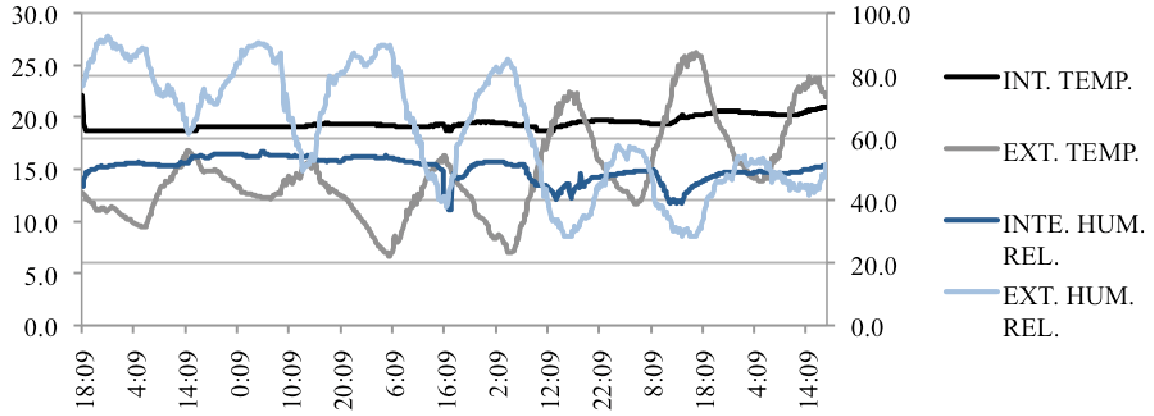



*Fig. 4. U-value (W/m2K) measured for 23 hours on the facade typology A1.*

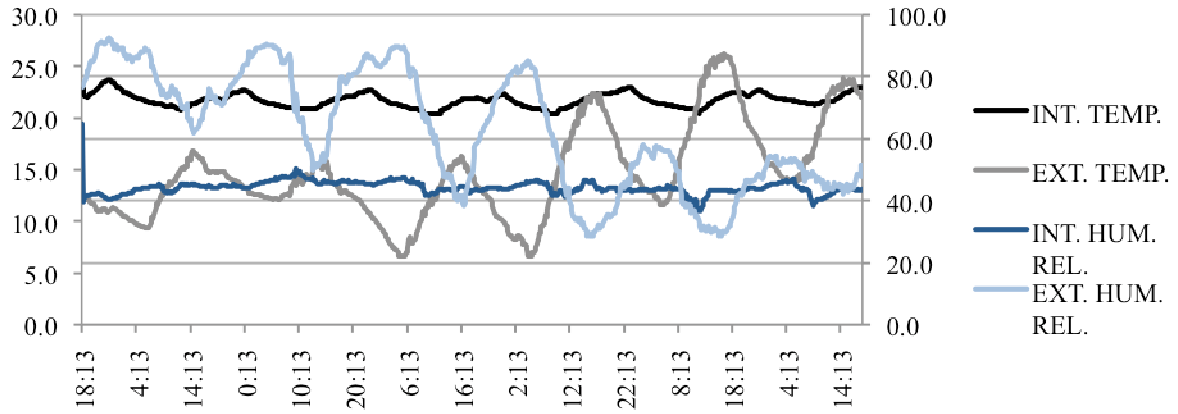
*Measuring Temperature And Humidity*

Indoor temperature and humidity were measured for one week in 8 dwellings, 4 refurbished and 4 non-refurbished houses. The houses were selected in different buildings but all of them were located at the same level. The air temperature and relative humidity were collected each 10 min.

Figure 5 shows the indoor temperature and humidity measured between 9 and 17 of April in the A1 building typology. In this case, the user's behaviour (switching on and off the heating, opening and closing the windows for ventilation, etc.) will be one of the most important influences on this data. One of the differences that could be observed was that the average air temperature in the non-refurbished house was 19.5 ºC while in the refurbished house was 21.7 ºC. The temperature in the non-refurbish house was quite constant, possibly because the measuring instrument was placed in a room that is not often used by the occupants.




*5.a. Non-refurbished house.*




*5.b. House refurbished.*

*Fig. 5. Temperature and humidity Measured in typology A1.*

*Natural Lighting*

In order to study the lighting conditions of the houses the following measurements were made. Firstly, the reflectance of the surfaces of the room was measured: walls, floor, wardrobe and desk, this allowed the calculated of the average reflectance of the room was. The luminous transmittance of the windows was also measured. Secondly, natural lighting (illuminance) of the room was measured in one day by using these three sensors: one (S1) was placed in the window, another (S2) was located 80cm away from the window, and the last one (S3) was located 80cm away from the back wall of the room. Thirdly, the data of illuminance measured by the weather station (SE) were taken. Then, the measurements were selected when the sun was at its highest point (at 3 o'clock) in order to conduct the analysis. The results have been summarized in the following table:

| House Type | Refurbished house (Rh) | Non-refurbished house (N-rh) |
|---|---|---|
| Level | 3th. | 2nd. |
| Room activity | Bedroom Study area | Bedroom Study area |
| Illuminance on exterior sensor SE (lux)* | 56,605 | 53,671 |
| Illuminance on S1 (lux)* | 44,156 | 3,353 |
| Illuminance on S2 (lux)* | 1,486 | 93 |
| Illuminance on S3 (lux)* | 208 | 19 |
| Window-to-floor area ratio (%) | 13 | 13 |
| Average reflectance (%) | 49 | 59 |
| Luminous transmittance (%) | 75 | 94 |

*Tabla 1. Summary of data collected in the homes of A1 typology (south orientation).*

*(*)Measurement taken at 3 o'clock.*

Table 1 shows that although the window opening percentage with respect to the area of the room is 13%, the average reflectance varies between 49% and 59%. This is can be explained because the furniture this non-presents the same predominant colours. The luminous transmittance shows a difference between 75% and 94% due to the type of glass in the windows is not the same.

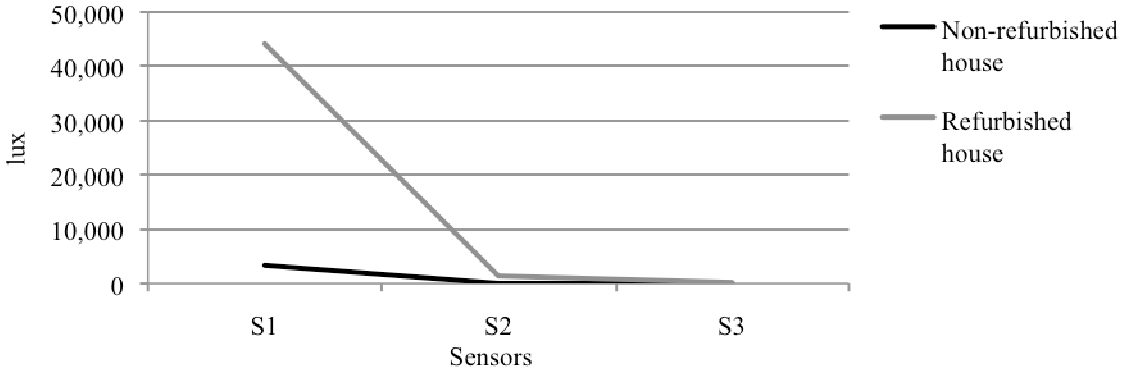



*Fig. 6. Illuminance taken in the typology A1 at 3 o'clock.*

Figure 6 shows the illuminance of each dwelling decreasing drastically in the second sensor (S2), which created a glare area between the first and second sensor. Also, it shows that the illuminance on the third sensor (S3) for both cases fails to get 300 lux, the minimum value to make any activity that does not require visual effort.

## 5. Results And Conclusions

This study has shown the procedure followed to acquire data related to the thermal and lighting behaviour of 16 homes in the neighbourhood of Ciudad de los Angeles. The various steps-taken to deal with this task have been detailed by selecting the types of buildings, describing the measurement equipment used, and showing the analysis in each subject. Table 2 summarizes the most important results:

| Building Typology | Typology R | | Typology J | | Typology C | | Typology A1 | |
|---|---|---|---|---|---|---|---|---|
| House type | Rh | N-rh | Rh | N-rh | Rh | N-rh | Rh | N-rh |
| U-value theoretical (kWh/m2) | 0.59 | 2.07 | 0.46 | 1.03 | 0.36 | 1.03 | 0.55 | 1.65 |
| U-value measured (kWh/m2) | 0.60 | - | 0.18 | 0.74 | 036 | 1.20 | 0.95 | 1.65 |
| Temperature indoor (ºC) | 21.8 | 19.7 | - | - | 21.0 | 19.1 | 21.7 | 19.5 |
| Illuminance on S1 (lux)* | 1,541 | 1,815 | 70,656 | 26,696 | 5,891 | 5,159 | 44,156 | 3,353 |
| Illuminance on S3 (lux)* | 56 | 55 | 151 | 112 | 205 | 37 | 208 | 19 |

*Tabla 2. Summary results, Refurbished house (Rh), Non- refurbished house (N-rh).*
*(*)Measurement taken at 3 o'clock.*

- *Infrared images* in the refurbished house (inside or outside images) showed a good behaviour while in the non-refurbished house these images showed different problems: losses of heat in the area below the window when the heating was on in the outside images, and infiltrations between the shutter box and the facade wall in the inside images.
- *Theoretical U-value* in some cases coincided with the thermal transmittance measure "in situ". This allowed to verifying the veracity of the layers that made up the facades of selected typologies.
- *Measured U- value* showed how the thermal behaviour of the opaque part of the facade has improved over 70% in every refurbished home. The improvement by typology has

been: R 251% improvement, J 311% improvement, C 233% improvement and A1 77% improvement.

- *Indoor temperature measurements* performed in winter showed that the average measured temperature at the refurbished dwellings were over 21ºC. On the other hand, the temperature in non-refurbished homes was around 19ºC. Therefore this temperature was below the values of thermal comfort. It is also important to emphasize that user's behaviour (switching on and off the heating, opening and closing the windows for ventilation, etc.) has an important influence on these data.
- *The illuminance* received in all dwellings (refurbished and non-refurbished) in the S1 was at least 1,541lux and 70,656lux maximum. However, the illuminance received at the S3 in any of the cases surpassed the 300lux, the minimum required for any activity that does not demand visual effort. These measurements are very difficult to compare in each typology because it implies both environmental factors (external illuminance, cloud cover) and physical factors (room level/floor, predominant colours in decorating, etc.).

The procedure followed allows the acquisition of the data needed to evaluate different situations in the pre- and post-refurbished buildings in order to compare them in simulation models.

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**Bibliography**

[1] Cuerda, E, Pérez, M, Neila, J. (2014). Facade Typologies as a Tool for Selecting Refurbishment Measures for the Spanish Residential Building Stock. *Energy and Building* 76 (2014) 119-129, doi:10.1016/j.enbuild.2014.02.054.

[2] Cuerda, E, Pérez, M, Neila, J. (2013). Assessment Tool for Energy Efficient Refurbishment of Existing Buildings. *39th International Association for Housing Science (IAHS). World Congress on Housing.* Milan.

[3] Pérez, M, Cuerda, E, Neila, J. (2013). Characterization and Classification of the Energy Performance of Facades According to Climate and Location. *Sustainable Buildings Construction Products & Technologies (SB13).* Graz.

[4] Cuerda, E, Pérez, M, (2014). Procedimiento de clasificación de tipos de fachada de edificios residenciales existentes y análisis de medidas de mejora para el cumplimiento de la normativa española. *CONSTEC.* Madrid.

[5] Neila Gonzalez, F. J. (2004). *Arquitectura bioclimática en un entorno sostenible*. 1ª edición, Madrid, Munilla-Lería, ISBN: 8489150648.

[6] De Luxan M. (2006). Estudio de las posibilidades de actuación con criterios de sostenibilidad en los barrios periféricos de Madrid.

[7] Gómez G. (2010). La rehabilitación y su alcance frente a los nuevos retos. *Congreso Internacional Rehabilitación y Sostenibilidad. El futuro es posible. R+S=F.* Madrid.

[8] UNE-EN ISO 7726. (2002). *Ergonomía de los ambientes térmicos. Instrumentos de medidas de magnitudes físicas*.