Energy efficiency intervention and preservation in residential built heritage

Analysis, proposal and results in the Gros district of San Sebastian

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Abstract – By the second decade of the 20th century we were already aware of the importance of achieving greater energy efficiency in the existing building stock. To that end it is fundamental to carry out a massive energy intervention on the residential building stock. But to be able to undertake this massive intervention one of the dilemmas that most concerns the different European Governments as well as the academic and research world should previously be solved. The dilemma is what happens when we try to undertake this energy intervention on residential built heritage. This paper deals with the proposal for energy intervention on the residential built heritage of the Gros district, in the city of San Sebastian. The objective of this research is to obtain energy improvement in buildings of this urban area and help to elucidate how much historic European cities could improve energy efficiency without losing their heritage values.

Keywords – energy efficiency; residential; built heritage; intervention; preservation

1. INTRODUCTION

There is currently a dilemma, within the building sector, that has not yet been resolved: how to improve the energy efficiency of buildings in historic European city centres without losing their heritage values. This generates a dichotomy that is difficult to solve. On the one hand, since the commitment assumed in the Kyoto Protocol [1], the EU has set up an energy saving policy in regard to the building sector. To this end, the EU underlines the importance of an energy intervention in the existing building stock in order to achieve greater energy efficiency. This has been transposed in several European Directives, such as Directive 2002/91/EC [2], Directive 2010/31/EU [3], or Directive 2012/27/EU [4]. On the other hand, there is increasing awareness concerning existing buildings as a part of the built heritage. This concern is expressed both by the different public administrations and by the citizenship. This means that, at present, more and more buildings are being protected by some kind of urban planning [5]. Some urban planning programmes such as the PEPPUC of San Sebastian [6] are being revised to include more historic buildings with the aim of protecting them.

Nevertheless, this dichotomy between the need for energy intervention and the conservation of the existing building stock has not yet been resolved by current
legislation. Recent surveys indicate that this is not an easy problem to solve [7]. The research presented in this paper aims to dilute the problem of this dichotomy and it is based on the PhD thesis “The Energy Intervention in Residential Built heritage. Analysis of Gros District in Donostia/San Sebastian” [8] defended in the year 2017 at the Department of Architecture of the UPV/EHU.

2. THEORY OF ENERGY INTERVENTION IN BUILT HERITAGE: TEIBH

The need and appropriateness of energy interventions in existing buildings is beyond doubt. But there is also a need to protect most of the historic buildings, among other reasons due to the increasing need for interventions regarding energy efficiency. Facing this dichotomy a “Theory of Energy Intervention in Built Heritage”, or TEIBH, is proposed. This theory aims to break the incompatibility between the need for energy efficiency improvement of existing building stock and the conservation of the heritage values of these buildings. For this purpose, the TEIBH proposes a series of intervention degrees. The TEIBH gives a scale of values in which the energy intervention and the conservation of the heritage is extended or reduced depending on the original value and energy performance of the building. For this purpose a 5 degree scale is developed.

The first degree, or Grade 0, is not an intervention per se. It consists of a preliminary analysis of the current state of the buildings, both from the point of view of their heritage value, as well as their energy performance result. With these heritage and energy values we can begin to assess which intervention degree we should establish for each building.

Grade I or “Conservation/Restoration/Reconstruction”, relates to the most monumental buildings. In this case, the heritage value is so important that it must prevail over the energy achievement. The scale is ascending, thus some monumental buildings will not have any type of energy intervention, while other less monumental buildings could improve some aspects of their efficiency.

Grade II or “Selective Intervention” refers to buildings that, despite not having a high degree of official protection, have an important heritage value. This heritage value can be an urban, architectonic or constructive value. In Grade II, although the heritage value prevails, the energy intervention must be carried out.

In Grade III or “Massive Intervention”, the energy objective begins to predominate over the conservation values of the buildings. A “massive” intervention is undertaken on the envelope of the existing building. This means that the configuration of the original building starts to be modified in order to achieve a good energy result.

Finally, in Grade IV or “Invasive Intervention”, what absolutely prevails is energy efficiency over the original building shape and its original heritage values. These buildings are considered not to have any heritage value. Therefore, the aim of the intervention must be to achieve the highest energy performance of the existing building. Through this “massive” intervention, it should be achieved a passive house building or a nearly zero-energy building (NZEB), insofar as the original building allows it.
3. ANALYSIS: THE APPLICATION OF THE “TEIBH” ON THE GROS DISTRICT

3.1 PRACTICAL APPLICATION OF THE TEIBH
For the proposal of TEIBH not to be just a simple theoretical solution, a practical application of the theory for a specific case has been made in the Gros District in the city of San Sebastian. For this purpose, and before starting to assess the impact that an energy intervention by way of applying the TEIBH in this area would have, an in-depth analysis of the main characteristics of the district has been conducted. The analysis is related to a heritage point of view of the buildings as well as to an energy efficiency performance point of view.

3.2 FIVE ARCHITECTONIC/CONSTRUCTIVE STYLES
One of the consequences of this analysis has been the classification of the entire Gros residential building stock into five Architectonic / Constructive Styles. Architectonic, because of the time and style when the buildings were built. Constructive, because of the configuration of the structural elements and the envelope that forms them. This analysis has only been carried out on buildings of residential use, as these are the most numerous in the building sector. The intervention carried out in them will be what will decide if the energy efficiency objectives dictated by the EU will be achieved or not.

The first style obtained is the Nineteenth-century Style. This style is characteristic of the 19th century San Sebastian city centre style, developed in the Ensanche Cortazar expansion district. In the case of Gros, there is the peculiarity that in most cases the buildings have structures made of concrete. These buildings date from the first two decades of the 20th century and represent 44 percent of the total buildings in the area. The second style obtained is the Rationalist Style representative of the architectonic revolution that took place during the third decade of the 20th century around the Modern Movement. That revolution occurred both in the architectonic style and constructive typology. This style represents 21 percent of the buildings and was developed during the 1930s and 40s. The third is the Postwar Style, characterized by the post civil war period and followed by the period of autarchy in Spain during the 1940s and 50s. This style is represented in 19 percent of the Gros district buildings. The fourth and fifth styles are based on the Development Period that occurred in Spain during the 1960s and 70s. This period is characterized by the strong economic growth that occurred all
around Europe and, in the case of Spain, especially for the construction sector. It has been divided into two because there are great differences between their constructive solutions. The First Development Style covers 8 percent of the total buildings of Gros, as does the style of the Second Development.

3.3 HERITAGE AND ENERGY ANALYSIS OF THE FIVE STYLES
After determining the five styles, the next step was to analyze the styles from a heritage and energy point of view. First, the characteristics of the existing residential built heritage of the Gros district were analyzed. For that purpose, the current law that protects this residential built heritage was applied: the Special Plan for the Protection of Urban Built Heritage of San Sebastian (PEPPUC). This document covers the Spanish and Basque laws on built heritage protection, and also reflects the protection established by the Council of San Sebastian as part of its municipal urban planning. PEPPUC proposes several grades of protection for the different heritage buildings. These grades range from Grade A, referring to monumental buildings, to Grade D, referring to buildings with just an urban environment value. The higher grade of protection, the fewer interventions of the
protected buildings can be allowed. Based on this classification, it was analyzed how these grades are distributed in the Gros district. In terms of energy, two surveys were carried out. First, a more superficial urban survey, and secondly a more exhaustive analysis of the energy performance of the five Architectonic / Constructive Styles. The analysis of the five styles includes the volume and shape of each style, the materials used for the envelope elements, and the energy values of these materials.

![Figure 4. Façade solution and transmittance of the five Architectonic/Constructive Styles.](image)

With this analysis, and with the values obtained, we were able to define what Grade 0 established by the TEIBH would be. As a result, it was possible to consider what the most appropriate energy intervention for each building should be, as well as its heritage conservation degree. Thus, we could foresee a balanced intervention obtaining an improvement in the energy efficiency of the building without losing its heritage values.

### 4. PROPOSAL: FIVE INTERVENTION GRADES

After conducting the scope analysis of the district the TEIBH was applied in the Gros district. Now, the five Intervention Grades should be taken into account and applied to the five Architectonic / Constructive Styles. For this purpose, and from a heritage point of view, the PEPPUC classification of the different grades was introduced into the five Intervention Grades of the TEIBH. Thus, PEPPUC's Grades A and B are covered by TEIBH's Grade I, Grades C and D are covered by Grade II, and Grade D is covered by Grade III. For Grade IV it is considered that there are no heritage values for those buildings to be protected, so no PEPPUC grade is applied.

Something similar was done for the energy values that must be achieved for each grade of the TEIBH. This scale of grades has been distributed through seven levels of energy intervention. Each of these levels means an energy improvement in the elements that compose the entire envelope of the building. These levels were distributed in the following way: Level 0 or E0 is the level that refers to the current state of the building; Level 1 or E1 means the replacement of the joinery; Level 2 or E2 refers to the thermal insulation of the interior courtyards of each plot; Level 3 or E3 refers to the thermal insulation of the roof; Level 4 or E4 refers to the thermal insulation of the rear façade; Level 5 or E5 refers to the thermal insulation of the main façade; and finally, Level 6 or E_{lim} is the reference...
concerning what the energy performance value of the building would be if it were a new building instead of an existing one. In this way, it is progressively determined, in each level, how each element of the building complies with the Spanish regulation on energy saving, the DB-HE "Energy Saving" [9]. In this law, the maximum heat transmittance for each element of the envelope of the building is established. These energy levels were introduced into the grades of the TEIBH. Thus, for TEIBH Grade I the energy level introduced is E0. This level is a zero-value due to the importance of the heritage values of Grade I buildings. For Grade II, Levels E1, E2 and E3 were introduced. And for Grade IV the maximum level or E6 were introduced, since it is considered that this intervention would be equivalent to a NZEB.

In this way, what is established by the TEIBH for each Intervention Grade is applied. That is, achieving progressive energy efficiency improvement as the energy intervention is applied, in the same way as the heritage value of the buildings decreases. This is what has been done for the Gros district case.

Table 1. TEIBH application in Heritage and Energy Intervention Levels.

<table>
<thead>
<tr>
<th>TEIBH</th>
<th>PEPPUC</th>
<th>Energy Intervention Level</th>
<th>Type of Intervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade 0</td>
<td>All</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Grade I</td>
<td>Grade A</td>
<td>Level 0 – E0</td>
<td>No intervention</td>
</tr>
<tr>
<td></td>
<td>Grade B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade II</td>
<td>Grade C</td>
<td>Level 1 – E1</td>
<td>Joinery replacement</td>
</tr>
<tr>
<td></td>
<td>Grade D</td>
<td>Level 2 – E2</td>
<td>Interior courtyards insulation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Level 3 – E3</td>
<td>Roof insulation</td>
</tr>
<tr>
<td>Grade III</td>
<td>Grade D</td>
<td>Level 4 – E4</td>
<td>Rear façade insulation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Level 5 – E5</td>
<td>Main façade insulation</td>
</tr>
<tr>
<td>Grade IV</td>
<td>None</td>
<td>Level 6 – E6</td>
<td>NZEB</td>
</tr>
</tbody>
</table>

5. EVALUATION AND RESULTS: 5 CASES SELECTED

5.1 SELECTION OF FIVE CASES

With all these data, a calculation study was conducted to find out what energy improvement results can be achieved for each level in real cases. For this purpose, five models of real buildings were selected. This selection was made through a comparative process based on the most common urban building typology in the area. On the one hand, the closed block is the most abundant building type in the Gros district accounting for 53 percent of the buildings. On the other hand, the plot with two exterior façades and two dividing walls is the most numerous with another 53 percent. For this reason, this urban typology was chosen as the most representative model. After a preliminary selection of 25 buildings, five each style, five of them were chosen as an existing representative model of the rest of the area, one for each Architectonic / Constructive Style.
5.2 EVALUATION

Once the five models were chosen, Grade 0 of each building was analyzed. In other words, the reality of each model was considered in terms of heritage protection and energy performance. We analyzed how each building is considered by the PEPPUC for heritage protection. It was observed that, in most cases, buildings are poorly protected. Regarding energy performance, energy consumption was estimated for each building, giving an energy classification as established in Spanish R.D. 235/2013 on Energy Efficiency [10]. Hence, energy efficiency level E0 was obtained. After obtaining the initial data, each of the following Intervention Grades of the TEIBH was introduced, according to the pre-established energy levels. First, the replacement of the joinery or Level 1 (E1) was carried out. After that, the interior courtyards of the plot were insulated as established in Level 2 (E2). Third, the roof was insulated, Level 3 (E3). Fourth, the rear façade was insulated as in Level 4 (E4). Finally, the main façade was insulated, Level 5 (E5). A final calculation was made for Level 6 (ELim), to determine what energy performance results these buildings would have if they had been built today with the insulation values determined by the current Spanish energy efficiency regulations. Both Level E0, energy performance of the current building, and Level ELim, a new building taking into account new legislation demands, allow us to compare values with each of the proposed interventions or levels.

5.3 RESULTS

A gradual improvement in energy efficiency is observed in all energy intervention levels carried out in the different style models. In this regard, it can be said that the results vary considerably in terms of the percentage of energy improvement obtained according to each intervention level. Thus, the intervention level that visibly improves energy performance of the buildings in all the style models is the Level E1 or the replacement of joinery, amounting to around 30 percent in most cases. With intervention Level E2 or insulation of the interior courtyards improved energy efficiency of between 20 and 30 percent is achieved, depending on the model. Intervention Level E3 or roof insulation, improves energy efficiency of the buildings less, around 10 to 15%. And with the last two intervention levels,
Level E4 or insulation of the rear façade, and Level E5 or insulation of the main façade, each intervention improves the building energy efficiency by around 10 to 15 percent for each case. These results indicate that, without having an impact on the most valuable elements of the buildings, from a heritage point of view, Levels E4 and E5 or the envelope façades, 65 to 75 percent of energy efficiency improvement can be obtained in buildings. Now, if we compare the energy performance of each style model at every intervention level we can see that for Level 0 (E0) the Nineteenth-century Style, Postwar Style and Second Development Style, have a better energy performance than the Rationalist Style or First Development Style. For the following energy interventions carried out, (Levels E1, E2, E3 and E4), the Nineteenth-century Style is the one that obtains greatest achievements along with the Rationalist Style. The other three styles obtain a less pronounced energy improvement. Finally, and after concluding all the interventions, in Level 5 or E5, we observe that the model, which obtains better results, is the Nineteenth-century Style, whereas, the First Development Style is the model that obtains the worst energy performance results after all the intervention levels.

Table 2. Different intervention levels results for each style model conclusions

<table>
<thead>
<tr>
<th>Intervention</th>
<th>19th Century Style Model</th>
<th>Rationalist Style Model</th>
<th>Post-war Style Model</th>
<th>1st Development Style Model</th>
<th>2nd Development Style Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 0 – E0</td>
<td>162.37</td>
<td>201.22</td>
<td>167.64</td>
<td>193.02</td>
<td>154.75</td>
</tr>
<tr>
<td>Level 1 – E1</td>
<td>134.22</td>
<td>180.40</td>
<td>142.48</td>
<td>175.69</td>
<td>134.13</td>
</tr>
<tr>
<td>Level 2 – E2</td>
<td>99.86</td>
<td>145.13</td>
<td>126.09</td>
<td>153.64</td>
<td>118.73</td>
</tr>
<tr>
<td>Level 3 – E3</td>
<td>99.29</td>
<td>134.05</td>
<td>113.42</td>
<td>135.65</td>
<td>106.26</td>
</tr>
<tr>
<td>Level 4 – E4</td>
<td>77.71</td>
<td>116.66</td>
<td>102.48</td>
<td>126.05</td>
<td>98.18</td>
</tr>
<tr>
<td>Level 5 – E5</td>
<td>60.35</td>
<td>96.45</td>
<td>92.72</td>
<td>115.35</td>
<td>89.12</td>
</tr>
<tr>
<td>Level 6 – $E_{lim}$</td>
<td>61.41</td>
<td>61.73</td>
<td>61.79</td>
<td>61.72</td>
<td>61.74</td>
</tr>
</tbody>
</table>

On the one hand, based on this survey and for the case of the Gros district, it could be concluded that a detailed study of each building would be necessary before the energy intervention. Applying the TEIBH, we have seen that a progressive energy intervention can be made. This energy intervention must be adapted to each building of the different styles according to its own energy need and heritage value. However, in summary, and based on the analysis performed, it can be said that the intervention in every style is carried out to Level E3, achieving an energy improvement of 60-75 percent. This means that these energy interventions do not have an impact on the heritage values of the buildings, as they do not touch the main protected elements of the envelope, the façades. On the other hand, it can be said that for any type of building or area where a heritage value and a need for energy intervention are foreseen, a preliminary analysis should be made. As we have seen in the case of Gros District, a preliminary analysis can help to determine the best way to start an energy intervention, considering the conservation of the built heritage values. We must not forget that we are in a process in which most of the buildings face interven-
tions regarding energy efficiency in a relatively short period of time. A previous survey would help us foresee the possible results before starting it blindly. Finally, the question is whether we must lose part of the built heritage values in order to obtain an energy improvement that in any case will never be optimal since it is carried out on existing buildings. We must not forget that the dual objective is not only to achieve a more efficient historic city from an energy point of view, but also one that is recognizable from a built heritage point of view.

6. REFERENCES (EXAMPLES)


