Reference Building Establishment Procedure for the Residential Buildings in Turkey

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Abstract
The European Directive on the Energy Performance of Buildings (EPBD Recast, Directive 2010/31/EU), introduced the “cost optimality” concept in order to take economic effects into account while analyzing the energy performances of the buildings. The cost optimal methodology framework involves several stages starting with the establishment of the reference buildings representing the building stock. This stage is important since all of the following analyses are applied on these reference buildings with the aim of achieving generalized solutions.
A research project was conducted in order to define the procedure of reference building establishment and adapting the cost optimal methodology in Turkey. This paper displays the sample reference building definition procedure followed in this project.

Istanbul is selected as a pilot city for this study since this city contains various building types and user profiles. Twenty six reference buildings were defined in three categories: single family houses, apartment buildings and luxury high-rise residences. The reference buildings and their properties are also presented in this paper.

The research shows that there is available data about the physical properties of the building stock in Turkey. However, there is very little information about the thermo-physical properties, user profiles and HVAC systems which are needed to calculate energy performances of the buildings. The existing building stock needs to be deeply analyzed by the authorities considering the energy performance related measures and the reference buildings are required to be defined also for other regions of Turkey by following a similar procedure.

Keywords – reference buildings, energy performance of residential buildings
1. Introduction

The recast of Energy Performance of Buildings Directive (Directive 2010/31/EU, EPBD Recast) was enacted in 2010 and declared the obligations about the cost optimality concept [1]. According to EPBD Recast, calculation of the cost optimal level of minimum energy performance requirements at national level is compulsory for the Member States (MS). In order to guide these calculations, a methodology framework is provided within the EU Regulation supplementing EPBD Recast [2]. MS are obliged to follow this framework in order to develop their national calculation methods and to calculate cost optimal levels using these methods.

The first stage of the cost optimal methodology framework is the establishment of the reference buildings that represent the typical and average building stock at national level [3]. Reference building definition procedure is important since the following energy and cost calculations are needed to be applied on these buildings in order to find out the cost optimal levels for the national building stock.

Turkey is an EU candidate country and follows the EU legislation within the harmonization process. The legal practices addressing directly EPBD Recast targets are not convincing yet but there are academic research that focus on EPBD and the cost optimality calculations [4]. A research project supported by the Scientific and Technological Research Council of Turkey (TUBITAK) was conducted in order to examine the current position and to propose a procedure for reference building establishment and a national cost optimality calculation method for Turkey. This paper displays the reference building definition procedure followed in the research project and the main outcomes.

2. The Main Structure of the Research

In this research, the reference building definition procedure was applied on a pilot area in order to provide a sample study and a general frame for the national and local authorities and also for further research. Istanbul city was selected as the pilot area since this city involves the 20% of the all housing units in Turkey and also contains many different variations of building types and user profiles together [5].

This research focused on the residential buildings as the pilot typology. Because, the 80% of the buildings in Turkey are residential and there are still new constructions [5]. In addition, according to EPBD Recast and supplementary guides, residential buildings have priority since these buildings represent the majority of the building stock.

At the initial stages of the research, the main categories were defined for the residential reference buildings: Single family houses, apartment blocks and luxury high rise residential buildings. These categories were entitled correspondingly as SFH, APT and R.
For this pilot research, only building renovations were considered and the reference buildings were defined for the existing residential buildings.

In order to establish the reference buildings, this study involves statistical data collection, review of the national and international standards, meetings with the experts and examination of the real buildings.

3. Analyses on the Existing Building Stock

In order to draw a picture of the stock, general information about residential buildings was collected. It was explored from this initial review that, number of residential buildings were significantly increased in Turkey after the revision of the Mass Housing Law in 1984 [6]. As shown in Figure 1, building census in 2011 also confirms that most of the existing housing units occupied by households in Turkey were constructed after this year [5]. In addition, currently in Turkey there is a legal procedure for demolishing and reconstructing the existing buildings which are at earthquake risk [7]. Therefore old residential buildings are rapidly changing, especially in big cities. For this reason, this study focused on residential buildings constructed after 1984.

In addition to the categorization based on the typology, after the initial survey, the reference buildings were categorized according to also their construction periods based on the revision dates of the national mandatory heat insulation standard TS825 [8]. This standard is the only obligatory in terms of energy performance of the buildings constructed in Turkey. Therefore, the changes in this standard are very important for the reference building definition procedure. TS825 standard became mandatory in 1985 and was revised in 2000 and 2009. Therefore the reference building categories were established as 1985-1999 (first period), 2000-2008 (second period) and 2009-2012 (third period) for this research.

After the frame of the research had been defined and categorization had been proposed, the following stage of the research was to collect information related to physical properties, transparency ratios, number of floors, thermo-
physical properties (heat transfer coefficients, solar heat gain coefficients, air change rates, material properties…) and HVAC system properties within this frame. Thus, statistical data was examined for the available information.

The statistical information related to number of floors, wall materials, heating systems, heating system fuel types and domestic hot water systems are available in the database of Turkish Statistical Institute (TUIK) [9]. However the statistics specific for Istanbul are available only for the buildings constructed in 1992 and following years. Therefore, for the years between 1985 and 1991, the building statistics at national level were analyzed and compared with the local statistics of Istanbul for the years between 1992 and 1999. It is reported that, the building properties converge with each other for these two periods therefore the reference buildings were defined according to the local statistics. The results of the related local data are given with Figure 2, Figure 3, Figure 5, Figure 6 and Figure 7. For the luxury high rise residential buildings, there was no any specific available statistics in the database.

As seen from Figure 2, single family houses constructed in the first period mostly have 2 floors while the single family houses constructed in the second and third periods mostly have 3-floors. The statistics for apartment buildings show that the apartment buildings constructed in the first period commonly consist 4 floors. Apartments constructed in second and third periods mostly have 5 floors. Although these statistics were considered for the reference building establishment procedure, samples of apartment buildings with more than 10 floors were also analyzed and reference buildings were established to represent these buildings. Because there are existing mass housing areas consist these apartments and in addition these buildings individually affect more people than the low rise buildings. In example, according to the TUIK Population and Housing Census, 23% of the households lives in apartments with 6 or more floors [5].

Another available statistical data is about the external wall materials of the residential buildings. This information is provided by TUIK for the second and third construction periods. As shown from Figure 3, the main
wall material is brick for SFH and APT buildings and for both construction periods. This information was used to identify the wall constructions of reference buildings that provide the required heat transfer coefficients.

Fig. 3 Main wall materials of single family houses (SFH) and apartments (APT) in Istanbul according to the construction years (TUIK).

There is not any available statistical information about the wall layers or the heat transfer coefficients, therefore the buildings are assumed as they provide the maximum limit values allowed in the national heat insulation standard TS825 as displayed in Table 1 below [8].

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<tbody>
<tr>
<td>External Wall</td>
<td>1.37 W/m²K</td>
<td>0.6 W/m²K</td>
<td>0.6 W/m²K</td>
</tr>
<tr>
<td>Roof</td>
<td>0.77 W/m²K</td>
<td>0.4 W/m²K</td>
<td>0.4 W/m²K</td>
</tr>
<tr>
<td>Floor</td>
<td>1.25 W/m²K</td>
<td>0.6 W/m²K</td>
<td>0.6 W/m²K</td>
</tr>
<tr>
<td>Window</td>
<td>1.51 W/m²K*</td>
<td>2.8 W/m²K</td>
<td>2.4 W/m²K</td>
</tr>
</tbody>
</table>

*The weighted average of wall and window heat transfer coefficients.

Similarly, other passive system properties of the reference buildings such as solar heat gain coefficients and air change rates were considered as in the national standards and regulations of Turkey [10].

In order to analyze transparency ratios of the facades, facade photos were taken, online street views were analyzed and the architectural projects were examined. The samples are given with Figure 4. It is determined from these analyzes that, the transparency ratio is between 10-20% for single family houses and between 20-30% for apartments. However, the apartment buildings oriented at the coast of Istanbul have a transparency ratio around 40% in order to benefit from the view. The transparency ratio of the luxury high rise residences constitute a wide range as being between 20% and 70%. Therefore, the references of luxury high rise residential buildings differentiated according to their transparency ratios as well.
The most challenging stage is to gather the information about the HVAC systems of the existing building stock. Since the target is to achieve entire energy models of the reference buildings by using energy simulation software, detailed information is required about the HVAC systems. However, there is only information about the heating system type, heating system fuel type and domestic hot water system (DHW) for the second and third construction periods. Besides the statistical data, national standards about HVAC systems are inadequate as well. For this reason, especially for determining the reference HVAC systems, meetings were arranged with the experts from both market and academia.

As seen from Figure 5, 6 and 7, the common heating system contains radiators and boiler(s). In apartments, there are mostly individual boilers rather than a central boiler. However, according to the Building Energy Performance Regulation, the buildings with total area more than 2000 m² and constructed after 2009 are obliged to have a central heating system [11]. The heating system fuel type is dominantly natural gas for both single family houses and apartments. These data were considered in reference HVAC systems definition procedure and applied on the reference buildings.
Fig. 6 Heating system fuel types of single family houses (SFH) and apartments (APT) in Istanbul according to the construction years (TUIK).

Fig. 7 Domestic hot water systems of single family houses (SFH) and apartments (APT) in Istanbul according to the construction years (TUIK).

DHW systems of single family houses and apartments constructed in the second period are mostly combi-boiler as seen from Figure 7. Although the common domestic hot water system appears as solar collector for the last period, considerable amount of them are used to support the main hot water systems of buildings. Therefore the solar collectors were not assumed as the main system of the reference buildings. For single family houses and apartments the main systems were considered as combi-boilers. But, in accordance with the national regulation, for apartments that has as area larger than 2000m², a central heat exchanger combined with a central boiler were established [11].

Using these initial data gathered from the statistics, standards and researches, reference buildings were established as a draft and discussed with experts in a workshop. According to the contributions, reference buildings were modified and additional reference buildings were established. With regard to the outcomes of the workshop, the reference apartment buildings were established based on the statistics, standards and samples while single family houses and residences were defined by analyzing selected sample buildings since these buildings do not have repetitious major characteristics.

The HVAC system properties such as cooling systems, ventilation systems, efficiencies of all HVAC system components and the lacking information especially for the buildings constructed in first period were investigated and discussed separately for each reference building category through meetings with experts. According to outcomes of the meetings, the
cooling systems are established as multi-split air conditioners for single family houses, split air conditioners for apartments and fan coils for luxury high-rise residential buildings. The ventilation systems of single family houses and apartments are natural ventilation while the ventilation system of the luxury high rise residences is mechanical with air handling units.

4. User Behavior

In order to prepare the energy performance simulation models and perform analyzes on the reference buildings, user behaviors and schedules are also required. Therefore, “reference user” was also defined in this research based on the limited statistical data.

According to 2011 Population and Housing Census, average household size is 3.6 in Istanbul [5]. Additionally, according to Income and Living Conditions Survey of TUIK, 54% of the household in Turkey consist of a couple with children [12]. Therefore, in this research it is assumed as in each apartment flat a family consists of parents and two children lives.

Moreover, in accordance with the Family Structure Surveys published by Ministry of Family and Social Policies [13]:
- 67% of women older than 18 years old are housewives in Turkey.
- Family members frequently come together at weekends (80%) and dinners (81%). 64% of families in Turkey, make breakfast together often.

Considering all these statistical information, people, equipment and lighting schedules were defined for the reference user (family with 4 people).

As an exception, for 1+1 flats in luxury high rise residential buildings, a family consist of a couple without any children was established. These families constitute 15.8% of Turkish households [12].

5. Reference Buildings

According to the background research, 26 reference residential buildings were established for Istanbul in three building typologies and in three construction periods. The energy simulation models of these buildings were prepared using Design Builder and EnergyPlus energy performance simulation softwares [14]. These models were displayed in Table 2 together with their codes. The reference building code is explained in Figure 8. Some of the reference buildings were in the same geometry but they are different in terms of their thermo-physical properties and HVAC systems.

Fig. 8 Instruction for the reference building codes.
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<tr>
<td>Single Family Houses</td>
<td>SFH111</td>
<td>SFH112</td>
<td>SFH121</td>
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<tr>
<td>Apartments</td>
<td>APT211</td>
<td>APT212</td>
<td>APT221</td>
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<td>APT213</td>
<td>APT214-A</td>
<td>APT222-A</td>
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<td>APT214-B</td>
<td>APT215</td>
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<td>APT216</td>
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<td>APT223</td>
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<td>Luxury High Rise Residential Buildings</td>
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<td>R321</td>
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<td>R333</td>
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</table>
6. Conclusion

In this research, national surveys required to establish reliable reference buildings were determined. It is obtained that, information about the thermo-physical properties, user profiles and HVAC systems are not sufficiently detailed in Turkey. Therefore, the existing building stock needs to be deeply analysed before the establishment of the reference buildings at national level. Because, establishment of the reference buildings is an important procedure since it directly affects the cost optimality calculations. In example, although APT216 and APT223 are the same in terms of their geometry and facades, different results were received for their cost optimal levels. Thus, reported inadequacies are required to be removed to develop new policies and further studies. In addition, the sample procedure used in this research is needed to be applied at national level and to involve non-residential buildings as well.

Acknowledgment

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References