Determining retrofit technologies for building energy performance

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\textbf{ABSTRACT}

Worldwide, the building sector is responsible for consuming more than 36\% of the final global energy and produces 39\% of carbon dioxide emissions. Accordingly, sustainable retrofit is an important method to achieve energy reduction and sustainable development. However, the lack of information on retrofit technologies and their benefits trigger stakeholder's opposition to retrofit actions. The Energy Performance Certificate tool can be used to overcome the knowledge gap and boost energy saving by strengthening its recommendation report with retrofit technologies for energy performance. Therefore, this paper attempts to determine the best retrofit technologies to be highlighted in the Energy Performance Certificate's recommendation report by considering stakeholder's opinions. For this purpose, a model based on Quality Function Deployment has been developed. The model analyzes the data regarding stakeholder's expectations when deciding to retrofit, and the potential retrofit technologies used. To validate the applicability of the proposed model, a case study was conducted in Romania. The findings are expected to contribute to improving the quality of the Energy Performance Certificate, as reflecting stakeholder's opinions combined with sustainable concepts to achieve significant energy savings.

\textbf{1. Introduction}

Building and construction industry has played a significant role in improving the population's quality of life and in meeting the demands and needs of society. Despite the contribution of the construction industry, statistics show that it is highly unsustainable in terms of its impact on both the environment and economy. Globally, the construction sector is responsible for consuming more than 36\% of the total energy produced and contributes to 39\% of global carbon dioxide emissions (UN Environment, and IEA 2018; Alsanad 2015). Additionally, the International Energy Agency's Reference Technology Scenario shows that final energy demand in the global buildings sector will increase up to 30 \% by 2060 if there is no more ambitious effort to address low carbon and energy-efficient solutions for buildings and construction industry (IEA 2017). With this, The International Energy Agency has released 25 energy efficiency policy recommendations to reduce energy consumption and carbon dioxide emissions. If the recommendations are enforced worldwide, 7.6 gigatonnes of carbon dioxide emissions could be saved annually by 2030 (Park et al. 2015). Herewith, in the last few decades, numerous countries have introduced energy performance certification as a key policy instrument that can help the government to reduce energy consumption in the building sector (IEA 2010; Park et al. 2015). This certification process helps the consumers on achieving a specified level of energy performance in their buildings.

The energy efficiency retrofitting for existing buildings is considered as an excellent method to achieve the targets of energy reduction and sustainable development (Pardo-Bosch, Cervera, and Ysa 2019; Gabrielli and Ruggeri 2019). Although retrofit projects have many benefits, it is still a complicated area to be accessed (Liang, Shen, and Guo 2015; Ali, Rahmat, and Hassan 2008). An energy-efficient retrofit project is more complex and riskier than a general retrofit project because of the lack of information about the existing building (Liang, Shen, and Guo 2015; Ali, Rahmat, and Hassan 2008), complicate financial sharing (Liang, Shen, and Guo 2015), and increased stakeholder interactions (Klotz and Herman 2009; Liang, Shen, and Guo 2015). Therefore, the owner and tenant should have the essential knowledge about sustainable retrofit and technical methods to lead an excellent performance improving decision-making from the retrofits (Anagnostopoulos, Arcipowska, and Mariottini 2015). However, many studies show that owners and tenants have a lack of knowledge about how, when, and why a building should be sustainably retrofitted (Bernstein et al. n.d.; Lapinski, Horman, and Riley 2006; Menassa and Baer 2014). Same studies also imply that it is difficult to align stakeholders’ demands and financial sharing properly (Chun and Cho 2018).

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Since the lack of information about the retrofit process represents an issue, Energy Performance Certificates (EPC) is considered to provide solutions to it (Anagnostopoulos, Arcipowska, and Mariottini 2015). The objectives of EPCs are to provide significant information to the owner and act as a catalyst to transform the market mechanism sustainably. To achieve this purpose, they suggest a recommendation report to encourage stakeholders who have the willingness to retrofit. The recommendation report can be divided into two categories: standard and tailor-made. The standard recommendations provide the general potential of building components. In this case, the building owner might not be motivated enough to carry out retrofit implementation. On the other hand, the tailor-made EPC recommendations give the individual building owner proper support through closer intervention to the stakeholders and help them deal more intensively with energy issues (Geissler and Altmann 2015). Many studies, including the one by The Buildings Performance Institute Europe (2018), have emphasized that the EPCs have a positive impact on consumers including homeowners and tenants as they offer essential information about energy performance (Arcipowska et al. 2014; Comerford, Lange, and Moro 2018; van Middelkoop, Vringer, and Visser 2017).

On the other hand, a study by Individual Building Renovation Roadmaps (iBROAD) (2018) about the current use of EPCs in its eight partner countries shows that the recommendations included are often considered as being too generic and that EPCs play a minor role when owners decide to retrofit. Some of its findings point that EPCs’ recommendation reports are not documented by experts or do not suggest system optimization methodologies and scenarios in Belgium, Germany, and Romania. Concerted Action-Energy Performance of Building Joint (2015) also states that there is a lack of clear definitions of tailor-made and standard EPCs, as well as of what type of information should be included in the report. Also, that more detailed retrofitting advice is required to support stakeholders in the decision-making process for retrofitting than what EPCs currently provide. Considering the literature containing negative opinions, the EPCs cannot reach their full potential in driving energy savings and to minimize the information deficit that the stakeholders have when retrofitting.

Therefore, the objective of this research is to develop a model that evaluates the impact of different retrofit technologies on stakeholder’s expectations for retrofit actions. The model aims to set the priority of retrofit technologies to support the stakeholder’s decision-making to retrofit and to develop a process to integrate the findings with the existing EPC’s recommendation. Through the conduction of surveys and analyses, the ranking of the retrofit technologies and how the stakeholder’s demands affect the hierarchy of those methods will be determined. These factors will be determined relative to stakeholders’ perceptions concerning the economic, social, and environmental sustainable concept. Moreover, the retrofit technologies will be classified into four main technical categories of sustainable retrofit: (1) mechanical, (2) plumbing, (3) electrical, and (4) building envelope systems, respectively.

Furthermore, this research conducts a case study using the proposed model based on the Quality Function Development technique. As a result of the case study, the relationship between Energy Performance Certificates and the sustainable retrofit process will be identified. It will also help to comprehend the stakeholders’ motivation to retrofit sustainable and technical methods with the potential to fulfill stakeholders’ needs. In this context, this research intends to provide valuable information about the stakeholders’ drivers to retrofit and technical methods that can satisfy those drivers.

2. Literature review

2.1. Critical factors in the success of a sustainable retrofit process

The sustainable retrofit was defined as the “upgrade” of components or elements of a building with the scope of improving the building’s environmental performance (Tan et al. 2018a). The “retrofit” also refers to other terms in literature such as refurbishment, rehabilitation, renovation, improvements, and repairs on existing buildings (Liang, Peng, and Shen 2016). Moreover, sustainable retrofit is defined as “any kind of upgrading of the building fabric, systems or controls to improve the energy performance of the property.” (P. Brown, Swan, and Chahal 2014). In this respect of energy performance improvement, previous studies about the retrofit processes pointed out two critical factors for successful sustainable retrofit activities. These factors are lack of information about the retrofit process and the selection of retrofit technologies to be used in the retrofit process.

Studies have shown that lack of information about the process and implications of sustainable retrofitting is one of the main obstacles to consider sustainable retrofit along with financial barriers (Gohardani, Klintberg, and Folke 2015; Murphy 2014; Baek and Park 2012). Sustainable retrofit projects involve complex processes usually unfamiliar to stakeholders. The stakeholders can be defined as people who have a significant interest in the building, its operation, and the outcome of the retrofit; the owner and the tenant (Menassa and Baer 2014). Moreover, the building’s owner generally becomes a subject who decides whether a building should be sustainably retrofitted. Therefore, owners should have the essential knowledge about sustainable retrofit and technical methods.
to have an excellent retrofitting performance result (Anagnostopoulos, Arcipowska, and Mariotti 2015). With this, the Energy Performance Certificate can be seen as a reaction to the “information deficit” referring to building owner’s lack of knowledge of actions to carry out in order to enhance the energy performance of their building (Gonzalez Caceres 2018; Hoicka, Parker, and Andrey 2014).

Another critical factor that affects the success of sustainable retrofit is the selection of the retrofit technologies applied in the retrofit process. D’Agostino, Cuniberti, and Bertoldi (2017) stated that the benefits of sustainable retrofit could be achieved by applying a proper combination of efficient retrofit technologies. Also, Tryson (2016) considered that availed technologies are the basement to improve building performance. Two aspects are deducted from these statements; technical intervention is the primary measure in improving the building’s performance, while innovation and implementation of new advanced technologies control economic growth, stakeholder satisfaction, and environment protection (Tan et al. 2018b). Therefore, access to retrofit technologies and its advancement should be considered as significant factors affecting sustainable retrofit.

2.2. Comparision of the energy performance certificates

Building energy certification includes programs and policies that evaluate the performance of a building and its energy service systems. Certification may focus on rating operational energy use or the expected energy use of the building. It can be voluntary or mandatory for all or parts of the buildings sector. (UN Environment and IEA 2018). According to the International Energy Agency’s 2018 Global Status report, 85 countries have adopted building certification programs. Despite the use of certification programs is growing, there is still a lack of large-scale adoption of full mandatory certification programs outside the European Union (UN Environment and IEA 2018)), which means that tracking of building energy performance over time and subsequent disclosure are still limited.

In the European Union, the Energy Performance Certificate (EPC) was implemented as a requirement by the Energy Performance of Building Directive 2002 (recast 2010) with most Member State requiring the EPC by 2008. Its goal is, first to reduce the carbon dioxide emissions by increasing the investment in energy efficiency and second to serve as an information tool for stakeholders (Anagnostopoulos, Arcipowska, and Mariotti 2015). The Certificate represents a report on the calculated energy performance of a specific building with a rating scale between A and G, with A being the most energy-efficient environment-friendly and G the least energy-efficient environment-friendly. in the United States of America, similar efforts to European’s EPC were initiated in 2009 through the ASHRAE Building Energy Quotient (Building EQ), a program to drive the reduction of energy use in commercial buildings by indicating the energy performance of buildings in an effective way. The ASHRAE’s program (www.ashrae.org 2019) provides a method to rate buildings’ energy performance both for designed and operating stages (Hotel 2011). Besides the EU and the U.S.A, building energy efficiency rating systems are implemented in Asia as well. For example, South Korea adopted a similar system to the EPCs from the EU, named Building Energy Efficiency Certification, to systematically control the energy consumption and greenhouse gas emissions of its existing buildings.

A comparison of these certification types can be seen in Table 1. As shown in the table, Europe Union’s certificates can be used for all building, whereas in the case of the U.S.A and South Korea, the applicable types of the building are limited, and there is no compulsory program for post-certification management, the management of energy efficiency in buildings is practically non-existent, compared to Europe. Also, ways that can improve the energy efficiency of the building are implemented just in Europe and the U.S.A with the mention that U.S.A’s certificate focusing on commercial buildings does not boost energy efficiency for residential buildings. Among the various energy performance certificates, this research continues the discussion based on the most enforced and influential one, the European EPC.

| Classification | Europe | U.S. A | South Korea |
|----------------|--------|--------|-------------|
| EPBD Energy Performance Certificate | Mandatory | Voluntary | Voluntary |
| Building Energy - Efficiency Certification System | -Commercial Buildings | -Apartments and commercial buildings |
| Energetic performance evaluation and recommendations to improve energy efficiency | -Energy reduction rate |
| Energy efficiency | -Building energy efficiency |
| Means to improve the building’s energy performance | -Analysis of “primary energy requirements per annual unit area,” such as air conditioning, hot water supply, lighting, ventilation |
| Ways that can improve the efficiency of housing | -Building energy efficiency |
a compulsory recommendation report, which contains a list of methods to be taken to boost energy savings. This recommendation report is considered especially crucial for improving the energy efficiency of existing buildings (Geissler and Altmann 2015). Not only it can provide an overview of the improvement potential of the thermal envelope of the building (e.g., external walls and windows) but also can take into consideration how to optimize or replace the energy performance of the mechanical systems (e.g., heating, cooling), plumbing system (hot water system) and electrical system (lighting fixture).

As seen in Figure 1, the EPC recommendation report can be issued by an Accredited Energy Auditor (AEA) after he/she inspects the property. AEA can determine what type of report will issue, either “standard” or “tailor-made.” The standard report shows the general improvement potential of the upgrading or replacement of heating, air conditioning, and hot water systems for energy efficiency or thermal performance (e.g., U-value) of the roof, floor, external walls and windows according to the building type and age (Geissler and Altmann 2015). This information, however, does not have a significant potential to motivate enough the owner to carry out retrofit actions. On the other hand, the tailor-made EPC recommendation report not only indicates the energy efficiency potential of the building but also suggest specific renovation methods, such as the fitting of heating and domestic hot water system, the quality of the windows or the thickness and quality of the insulation, according to conditions of a specific building. If it provides appropriate information, the tailor-made recommendation can give better support to the owner’s decision-making in what needs to be done about the energy of the building. However, from previous research, it can be found that most of the EU Member States do not require this level of precision in practice, the Korean Energy Certificate has no recommendation report, and the U.S.’s Building EQ provides actionable recommendations about estimated costs and payback information to be used to improve building energy performance, but it is not applicable for residential buildings.

Moreover, a study about stakeholder’s attitudes conducted in 10 EU countries from 2007 to 2011 on domestic EPCs suggested that 80% of respondents were aware of EPCs, and 60% found EPCs easy to understand. However, the recommendations were considered less easy to understand, and only 17% of owners in the U.K recognized that the EPC had recommendations included (Better Buildings Partnership 2018). Another study made by Geissler and Altmann (2015) and Petran, Geissler, and Vlachos (2017) showed that in many countries, the EPC presents only a general recommendation about the renovation. The information is not sufficiently detailed for decision-making on renovation projects. Specific retrofit methods plus financial incentives and payback periods are missing.

Reports by the Evaluation of the Directive 2010/31/EU indicate that the recommendation report is affected by a lack of information on how to plan and implement improvements of energy efficiency in building overtime or the absence of an appropriate retrofit list of actions (Gonzalez Caceres 2018). In this aspect, the report concluded that policies regarding recommendations should explore new approaches to remove these barriers. For example, some countries (e.g., Austria) are developing tools and procedures to produce on-site tailor-made recommendation packages, which can show clear benefits of retrofit (Geissler and Altmann 2015). Moreover, the usefulness of the EPCs could be increased through a better-documented recommendation report containing the information about well-organized retrofit
processes, since owners and tenants tend to undertake retrofit actions when supporting data is given (Anagnostopoulos, Arcipowska, and Mariottini 2015; iBRoad project 2018; Gonzalez Caceres 2018). Therefore, by using the proposed model, the recommendation report can be better documented in the direction of effective energy savings by highlighting the first retrofit technologies to be applied. Also, by considering stakeholder’s opinions into the developing process of the model, the stakeholder can participate actively in the process of selecting the retrofit technologies. As a result, the owner will be able to obtain better incentives and be motivated to retrofit.

3. Quality function deployment (QFD)

Quality Function Deployment is a customer-driven methodology in which customer’s needs are systematically translated into product specifications. (Chun and Cho 2015, 2018; Oh, Cho, and Kim 2017). More specific it is “a method for structured product planning and development that enables a development team to specify the customer’s wants and needs, and then to evaluate each proposed product or service capability systematically in terms of its impact on meeting those needs.” (Delgado-Hernandez, Bampton, and Aspinwall 2007).

The QFD was first used in the Kobe shipyards during the 1960s by Mitsubishi Heavy Industries for ships, which needed early design freezes, and in the 1970s it was used by Toyota to investigate rust prevention in vehicles. The methodology was developed in a four-phase quality technique (house of quality, part deployment, process planning, and operations planning) by Clausing, carrying the opinion of the customer from the high-level system to monitoring the product in production (Cudney and Gillis 2017; Wood et al. 2016). In the first phase, the house of quality (HoQ) is seen as a major tool that offers a way to match the design of the product with the opinion of the customer or customer requirements (Cudney and Gillis 2017). As shown in Figure 2, HoQ contains rooms, each of which holds information specific to achieve targets of the research. The room (A) represents a list of customer requirements. It contains customer needs or their expectations for a particular task. Room (C) refers to a list of technical characteristics that can have an impact on one or more of the customer demands. The room (E) maintains an interrelationship matrix between technical characteristics and the fourth room (D) registers a relationship matrix between the customer requirements and technical characteristics. The rooms (B) and (F) contain calculation algorithms for prioritizing the customer’s demands and technical characteristics (Coble, Richard, and Blatter 1999; Singhaputtangkul et al. 2013). The order presented by the letters A to F is generally followed during the process of HoQ.

Many researchers selected QFD as a tool due to the need for improved safety, reliability, delivery, sustainability, and decision-making. Studies identified QFD as a mean for meeting the customers’ requirements in construction projects. Also, Mallon and Mulligan (1993) demonstrated that QFD methodology could be used to prioritize different requirements and be a tool for making more accurate decisions. They presented an example of applying QFD to construction using a minor renovation of a computer workroom. Initial customer demands were established and prioritized by customer importance, which was then compared to the competitor’s workroom. As a result, the methodology allowed the design team to create ideas while aligning with the customers’ demands to reduce future changes. (Mallon and Mulligan 1993).

Alarcón and Mardones et al. (Alarcón and Mardones 1998) applied the methodology of the HoQ to select the technical responses that would be the most effective to

Figure 2. The House of Quality (Cohen, 1995).
avoid the defects in the designs detected in the exploratory study. Dikmen et al. (Dikmen, Birgonul, and Kiziltas 2005) used HoQ as a strategic decision-making tool to design marketing plans in the Turkish house-building sector, resulting in a satisfied company because it considered customers requirements in a structured way. Delgado-Hernandez, Bampton, and Aspinwall (2007) used QFD to analyze and identify customer’s requirements by operating a case study comparing a new construction with an existing children’s nursery. The use of QFD resulted in on-time delivery of the project and higher customer satisfaction. Several studies with the subjects of sustainability, green buildings, and Leadership in Engineering and Environmental Design (LEED) have also addressed QFD. Shi and Xie (2009) developed a methodology that combined the fuzzy set theory and QFD to analyze green construction programs in order to reduce environmental problems. Gillis and Cudney (2014) applied QFD to ensure that new construction met LEED guidelines, which promote sustainable design and construction. Also, Wood et al. (2016) applied green construction principles with quality function deployment. They proposed a combined approach named House of Quality Green Design for the construction of green hospitals, which facilitate the determination of demanded qualities by end-users such as safety mechanisms during an emergency, use of natural light and ventilation, and materials free from toxicity that were environmentally friendly.

Previous research had shown that QFD, could be the right approach to be used in researches that need to align conflicting opinions of customers and when different requirements are needed to be prioritized in decision making. Therefore, since the objective of this study is to identify the primary retrofit technologies that can fulfill the owner and tenant’s requirements by analyzing their needs, QFD seems to be the adequate tool to be used for this research.

4. House of quality model development for sustainable retrofit

A vital barrier that limits the decision to undergo sustainable retrofitting has been a conflict of interest between stakeholders, due to contrasting perspectives on how and why a building should be retrofitted (Menassa and Baer 2014).

One of the useful guidelines for sustainable retrofit, EPC recommendation report, has a limitation in that it should capture the attention of the owners in order to improve the quality of the result by introducing technical and financial information relevant to the users, such as costs, savings, funding opportunities and how and when to carry out the methods (Gonzalez Caceres 2018). Therefore, this research proposes a model that integrates the stakeholder’s interest and their requirements in the EPC’s recommendation report which have fundamental guidelines but is required to overcome the barrier of opposition and lack of knowledge concerning the sustainable retrofit process. Hence the HoQ was selected as a tool to address the problem of integrating the varying requirements of the building stakeholders in the decision-making of selecting sustainable retrofit methods, as shown in Figure 3. Additionally, with the use of the HoQ model, the study intends to determine a correlation between the building stakeholder demands and considered retrofit technologies. This correlation will help to identify the primary retrofit technologies that should be emphasized in the EPC’s recommendation report.

Data needed for the study is collected and examined using an adapted HoQ with five essential steps that provide its general framework as seen in Figure 3. For this study, the Planning matrix was not used. The planning matrix’s role is to compare customer requirements of a project with levels of performance or satisfaction for those same requirements on a competitor’s

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**Figure 3.** Determining retrofit technologies process.
building or project and then to set targets for improvement. Since this research is analyzing the retrofit technologies that have the most impact on the decision to undergo a sustainable retrofit inter-related with the three sustainable pillars, there is no need for planning matrix comparison. The remaining steps in developing the model are explained as followed.

4.1. Identifying the possible requirements of the Stakeholders

The first step in developing the model is to identify a list of possible requirements stakeholders have when deciding to retrofit the building. These requirements are independent variables which consist of “what” the stakeholders desire to obtain after they retrofit. Considering that stakeholders are motivated by the pillars of sustainability: social, economic, environmental, or by technical reasons, the requirements were developed by collecting, grouping, and sorting a list of requirements created from a literature review. Thus, an extensive literature review was conducted, and 15 potential stakeholder requirements considering the sustainable criterion were identified to be necessary for a sustainable retrofit process, as shown in Table 2. These requirements will be included in a survey that can be conducted by the Accredited Auditors while inspecting the building.

The level of importance of these requirements introduced in a survey is expected to be different among the stakeholders. For example, owners might rank the “Reduce energy cost” requirement higher compared to tenants who might place “Improve occupant’s health” demand in a higher rank. Depending on the stakeholder’s requirements, the technical retrofit methods can change, while owners can be interested in retrofit technologies that can bring economic benefits, tenants might be more interested in technologies to improve the social aspects, as health, productivity or aesthetical quality of the building. The HoQ will translate these differences among stakeholder’s requirements by using mathematical formulas.

The primary role of the analysis of the stakeholder’s requirements is for them to rate each need based on its importance in addition to defining the scope of a project. In this research, each requirement is seen as the benefit resulting from possible sustainable retrofit actions. The importance rating for each stakeholder requirement is defined as the importance of each requirement in justifying the investment of resources into a retrofit project. This total importance rating for each stakeholder requirement is independent of the total technical importance for the retrofit technologies in meeting the various demands of the stakeholders. The importance of the requirements will be measured on a scale of 1 to 5, while 1 is at the most importance and 5 is at the least importance. And, as a result, to be used in the process of analyzing the data, the averaged importance of all stakeholders’ requirements will be chosen for the development of the relationship matrix, as shown in Figure 4, column named as “Stakeholder importance rating”.

4.2. Identifying the technical methods that can fulfill the stakeholder’s requirements

The second step in developing the model is to identify the technical methods that can fulfill the stakeholder’s requirements. The technical matrix represents the design response as “how” some retrofit technologies will meet the needs of the stakeholders.

| Sustainable concept | Stakeholders requirements | Reference |
|---------------------|---------------------------|-----------|
| Environmental       | Increase energy efficiency | (Poel, van Cruchten, and Balaras 2007; Papadopoulos, Theodosiou, and Karatzas 2002; Juan, Gao, and Wang 2010; Rey 2004) |
|                     | Increase carbon neutrality | (Juan, Gao, and Wang 2010; Scofield 2009; Nemry et al. 2010; Gaterell and McEvoy 2005; Papadopoulos, Theodosiou, and Karatzas 2002) |
|                     | Facilitate renewable energy | (Papadopoulos, Theodosiou, and Karatzas 2002; Menassa and Baer 2014) |
|                     | Meet regulatory requirements | (Fuerst and McAllister 2011; Poel, van Cruchten, and Balaras 2007; Papadopoulos, Theodosiou, and Karatzas 2002) |
|                     | Minimize environmental impact | (Scofield 2009; Papadopoulos, Theodosiou, and Karatzas 2002; Lapinski, Horman, and Riley 2006; Juan, Gao, and Wang 2010; Rey 2004) |
| Economic            | Reduce energy cost         | (Juan, Gao, and Wang 2010; Rey 2004; Scofield 2009; Papadopoulos, Theodosiou, and Karatzas 2002) |
|                     | Increase the return of investment | (Gaterell and McEvoy 2005; Papadopoulos, Theodosiou, and Karatzas 2002; Juan, Gao, and Wang 2010; Rey 2004) |
|                     | Increase property value     | (Entrop, Brouwers, and Reinders 2011; Bernstein et al. n.d.; Menassa and Baer 2014) |
|                     | Achieve lower total ownership costs | (Menassa and Baer 2014; Bernstein et al. n.d.; Fuerst and McAllister 2011) |
|                     | Achieve lower total ownership costs | (Juan, Gao, and Wang 2010; Menassa and Baer 2014; Entrop, Brouwers, and Reinders 2011; Scofield 2009; Fuerst and McAllister 2011) |
| Social              | Improve occupant’s health   | (Rey 2004; Lapinski, Horman, and Riley 2006; Klotz and Horman 2009; Menassa and Baer 2014) |
|                     | Improve occupant’s comfort  | (Menassa and Baer 2014; Bernstein et al. n.d.; Menassa and Baer 2014) |
|                     | Improve occupant’s productivity | (Menassa and Baer 2014; Lapinski, Horman, and Riley 2006; Klotz and Horman 2009; Menassa and Baer 2014) |
|                     | Improve the aesthetic quality of the site | (Klotz and Horman 2009; Menassa and Baer 2014) |
|                     | The necessity to comply with policy or legislation | (Menassa and Baer 2014; Poel, van Cruchten, and Balaras 2007; Papadopoulos, Theodosiou, and Karatzas 2002) |
When choosing among a variety of proposed methods, the decision-maker must reconcile environmental, energy-related, financial and legal regulation and also social factors to reach the best possible compromise to satisfy the final occupant needs and requirements (Asadi et al. 2012). In order to determine the technical methods to be included in the model, a literature review was conducted. The Building Research Establishment defines the main components on which refurbishments are made as thermal elements such as walls, roofs, and floors; fittings such as windows and entrance doors and building services like lighting, heating, and cooling; and the operation of pumps (Li, Ng, and Skitmore 2017). Asadi et al. (2012) and Desmedt, Vekemans, and Maes (2009) show in their studies the importance of considering building envelope as a technical issue during building retrofit. Additionally, a study about the transformation through renovation of an apartment building in Athens concluded that significant energy-efficiency solutions are energy efficient lighting by using LED and light pipes, energy efficient HVAC, passive heating/cooling, heat pumps integrated with heat recovery and thermal storage and renewable energy systems based on solar thermal and photovoltaics (Synnefa et al. 2017).

For better structure, the chosen technologies were organized according to the interventions made for the mechanical system, electrical system, plumbing system, and building envelope. The detailed list can be seen in Table 3.

### 4.3. Development of the relationship matrix

The primary purpose of the relationship matrix is to establish a connection between the stakeholder’s requirements and the technical methods applied. Additionally, it highlights which retrofit technology supports the fulfillment of each stakeholder’s demands. The relationship between the requirements and the technical methods is weighed on a scale of 0-relationship, 1-weak relationship, 3-medium relationships, and 9-high relationship.

#### Table 3. Technical methods used in retrofitting a building.

| Mechanical System                  | Electrical system                  | Plumbing system                  | Building envelope                  |
|------------------------------------|------------------------------------|----------------------------------|-----------------------------------|
| Replacement of Heating system      | Lighting fixtures                  | Replacement of Domestic hot and cold-water system | Applying an external thermal insulation system |
| Replacement of Water heating system| Replacement of Electrical system   | Recycling methods of residual water | Replacement of windows and doors   |
| Total:                             |                                    |                                  | Roof renovation                    |

#### Table 3. Technical methods used in retrofitting a building.

| Stakeholder’s requirement | Technical Requirements (How) | Stakeholder’s requirements (What) |
|--------------------------|-----------------------------|-----------------------------------|
| Importance rating        |                             |                                   |
| 1                        |                             |                                   |
| 2                        |                             |                                   |
| 3                        |                             |                                   |
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#### Figure 4. HoQ Model derived from the survey data.
relationships. For example, an expert may think that the "replacement of Heating system and air conditioning system" has a high ability to increase energy efficiency, while another expert may consider it to have a small capacity of increasing energy performance.

The development of the relationship matrix will be perceived through two surveys. The first survey will analyze the importance of the requirements from the owner’s and tenant’s perspective. The second survey will investigate the potential of each technical method in fulfilling the stakeholder’s needs from an expert’s perspective. The importance ratings from these surveys are calculated into a technical importance factor given by Equation (1):

\[
T.I = \text{Importance of requirement} \times \text{Relationship (S.R)}
\]

(1)

where \(T.I\) means Technical importance

\(S.R\) means the relationship between stakeholder’s requirement and technical method according to Accredited Energy Auditor’s opinion

4.4. Developing the technical correlation matrix

The technical correlation matrix aids in the development of the relationship between the technical methods and identifies where these units must work together; otherwise, they will be in a design conflict. This component, the roof, is one of the most valuable parts as it represents the effects, either negative or positive, each retrofit technology has on another. It offers a quick visual for an Accredited Energy Auditor and owner to understand the impacts one retrofit technology will have on another technical method. This can also provide a quick reference for any Auditor to realize that communication with another auditor or engineer may be necessary especially if a negative effect is found in the cell. When working with the technical correlation matrix to clarify the relationship among requirements, the question “If technical requirement X is improved, will it help or hinder technical requirement Z? Needs to be addressed (Tapke et al. 2013). The following symbols are used to represent what type of impact each requirement has on the other: “+” positive correlation, “-” no correlation, and “-” negative correlation. These symbols are then entered into the cells where a correlation has been identified. To analyze the correlation between different requirements the next method was used. Each requirement was marked whether it’s better for it to be lower or higher as importance. These ratings were used for interpretation and a better understanding of the correlation.

4.5. Developing the technical targets matrix

The technical targets represent the final output of the matrix, and they are obtained calculating the relative weights of the technical methods with Equation (2). The sum of technical importance that was calculated at point 4.3 for each stakeholder requirement and each technical retrofit method in the relationship matrix is taken and entered in the technical targets’ matrix. The sum is then equated into a single value which is used for a decision-making comparison.

\[
\text{Relative weight} = \left(5 \times T.I_{\text{Max}} (T.I)\right)
\]

(2)

The technical method with a relative weight equal to 5.00 represents the most crucial consideration to focus on the recommendations included in the EPC.

5. Case studies

A case study with the proposed method, using the House of Quality, was conducted in Romania to reveal the necessary technical methods that can fulfill the needs that owners and tenants of a residential building have when retrofitting. The case study illustrates how the House of Quality is used stepwise, and its result can be used to improve the Energy Performance Certificate in Romania.

5.1. The context of the case study

Romanian buildings stock accounts for the largest share of energy use, which is mainly due to their overall poor energy performance. The household sector and the tertiary sector, together, accounted for 46% of total national energy consumption. Up to 80% of the CO2 emissions from the Romanian building stock could be reduced through a comprehensive renovation program (Arcipowska et al. 2014). Therefore, Romania needs a rapid enhancement of energy efficiency in existing buildings for a timely reduction in energy use.

As a Member State of the European Union, Romania needs to meet the requirements imposed by the European Commission regarding energy consumption in buildings. Therefore, in 2001 the Romanian government adopted the Energy Performance Certificate as a voluntary system, following the transposition of the Energy Performance of Buildings Directive (EPBD) into national law in 2005, and the revision in 2013 and 2016. The Romanian EPC is mandatory for new and existing buildings when either sold or rented and the compliance control is conducted only by checking the form and information within the EPC (Buildings Performance Institute Europe 2018). The EPC contains information about specific energy consumption related to space heating, domestic hot water installations, lighting, mechanical ventilation, and space cooling. This information is enough to evaluate the energy performance of the certified building, but the detailed technical information, which should be provided in the EPC’s annex, is often incomplete and retrofit recommendations often are missing. To enhance
the EPC’s value, changes in the format of EPC and the system are required. Hence, by this case study, it is intended to shape a better structure of the Romanian EPC by improving the recommendations part, taking into consideration the owner and tenant’s opinion.

5.2. Survey

To investigate the requirements that Romanian owners and tenants have, and the retrofit technologies which have an impact on those requirements, two descriptive web surveys were conducted.

5.2.1. Understanding stakeholders’ requirements to retrofit

The first survey had a role in studying the primary needs of the Romanian owner or tenant when they retrofit. More precisely it addressed the following research question: “Which requirements boost owners and tenants to retrofit?” The structure of the questionnaire was designed in three different sections: (1) occupier’s background, (2) building background and (3) requirement’s importance ranking considering the three pillars of the sustainability: environment, economic and social. In the case of the rating questions, the option to “Randomize Rows for Each Respondent” was activated to make sure the order implied by the researcher will not influence the respondent’s choices. The indexes assigned for the ranking were from 5 to 1, with 5 to be an extremely important need and 1 to be not an important need. The parameter of sampling interest was from the population of residential buildings and the sampling frame comprised the occupiers of the house from different areas of Romania. The unit of analysis was the individuals, and the sampling size was determinate based on the target population, represented in this case just by owners and tenants. The questionnaire was accessed by 233 people with 152 complete and valid answers. Among the 152 respondents, 67.11% were owners, and 32.89% were tenants. Regarding the owner’s propriety, 54.90% own an apartment, 39.22% one-family dwelling and 5.88% multiple-family dwelling, in the tenant’s case, 80% were tenants of an apartment, 14% of a family dwelling, and 6% of a multiple-family dwelling. For a better understanding of the building stock, the respondents were asked in which year was the building built, and when it was renovated last time. The results show that 6.58% of the buildings were built before 1950, 9.87% between 1950–1969, 48.68% between 1970–1989, 16.45% between 1990–2009, and 18.42% between 2010–2018. It can be concluded that most of the buildings from this study, 65.13% were built before 1990. This aspect highlights the importance of retrofiting in Romania. Regarding the situation of renovation, 23.68% of buildings were never renovated, 46.04% were renovated between 1 and 4 years ago, 16.45% were renovated between 5 and 10 years ago, and 13.82% more than 10 years ago.

5.2.2. Understanding which retrofit technology can fulfill stakeholder’ requirements

The second survey had a role in studying the primary retrofit technologies which can fulfill the needs of the owners and tenants. More accurately it addressed the following research question: Which retrofit technology has the most significant impact in satisfying what the owner or tenant expects to achieve as a result of the retrofit process? The questionnaire was sent through email, accompanied by an abstract of the research study.

The structure of the questionnaire was divided into two parts: (1) the expert’s background and (2) a study of the relationship between the retrofit technologies and stakeholder’s demands. The respondents were asked to grade the relationship between the retrofit technologies and their potential for fulfilling the stakeholder’s requirements. When grading the technical method, the system type (mechanical, electrical and plumbing system, and building envelope) and sustainability concepts: environmental, economic and social, had to be considered. The indexes assigned for the relationship were 9-3-1-0, indicating a high relationship, a medium relationship, a weak relationship or no relationship. The sampling for this survey was purposeful, and the respondents were experts who have working experience with Energy Performance Certificates and are Accredited Auditors to undergo energetic examinations on existing buildings. The target population was represented by 1000 energy accredited auditors certified as energetic auditors until 19 September 2018 by Romanian’s Ministry of National Development and Public Administration. Thirty-six persons returned the questionnaire, with 25 complete and valid responses. Among the 25 experts who assessed the survey 12% have less than 10 years 42 working experience in construction, 72% have between 11 and 20 years of experience, and 16% more than 21 years. The experience working as an accredited energy auditor of the participants was 28% less than five years, 64% between 5 and 10 years and 8% more than 10 years of experience.

The understanding of which retrofit technology can fulfill stakeholder’ requirements was also possible with the help of these Accredited Auditors who have experience in the field. Therefore, they are also part of the validation of choosing retrofit technologies with the potential to achieve the best energy savings.

5.3. Analyzing the data collected from the survey

The results of the surveys were combined into an average data and introduced in the HoQ rooms as seen in Figure 4. The first survey results on the left
side of the HoQ, in the “Stakeholder’s requirement” room, and the second survey’s results in the relationship matrix room.

In order to develop the relationship matrix, the technical importance of each retrofit technologies was calculated by multiplying stakeholder’s importance rating by the relationship defined by the experts. The next step after developing the relationship matrix was to check the technical correlation between the technical method proposed. The objective of this step is to highlight any methods that might conflict with each other. In this case, however, as can be seen in Figure 4, no negative correlation was identified between the technical methods, and only positive one or no correlation was interpreted.

The technical targets represent the final output of the matrix. These technical targets were obtained by calculating the relative weights of the technical methods. After the technical importance for each method was obtained, the sum of technical importance was calculated for each of it. The sum was then equated into a single value on a scale of 1 to 5, as it can be seen at the bottom of Figure 4. This scale represents a prioritized relative weight for a decision-making comparison.

5.4. Findings of the case study

The primary output of the HoQ is the highlight of the five most critical retrofit technologies which have significant potential to fulfill owner’s and tenants’ requirements when deciding to retrofit. The results achieved in Table 4, demonstrated that the five most essential retrofit technologies which can contribute to the success of energy efficiency and satisfy the owners at the same time are: (1) application of an external thermal insulation system, (2) replacing the existing windows and doors, (3) roof renovation, (4) replacement of the heating system and air conditioning system and (5) replacement of the water heating system. Those points should be highlighted during the development of EPC’s recommendation report as they have a higher potential to fulfill the needs valued by the users. These findings align as well with the results of 26 case studies about deep energy renovations, which states that the improvements to the thermal envelope (wall, roof, windows) are major technologies to be used when deep energy savings are desired. The same study suggests that to cut back heating energy up to 80 to 90%, a holistic concept of combined building’s thermal envelope and HVAC renovation should be used (Staller, Für Nachhaltige Technologien, and Gleisdorf 2017).

The calculations performed to find the weights of stakeholder’s needs are essential to highlight the demands that require attention. According to the obtained results, the three most essential stakeholders’ demands have been ranked as “Improved occupants health,” “Reduce energy cost,” and “Increase energy efficiency.”

Moreover, if the relationship matrix of the HOQ matrix given in Figure 4 is investigated

- column-wise, the significance and contribution of each technical method in satisfying overall stakeholder needs can be seen. The technical methods, namely “application of an external thermal insulation system,” replacing the existing windows and doors” and “roof renovation” can have the highest contribution in the overall success of a project.
- row-wise, the contribution of all the technical methods in satisfying the stakeholders’ need is observed. The stakeholders need namely; “increase energy efficiency,” “Reduce energy cost” and “Improve occupant’s comfort” have been linked with the highest number of technical methods. So, they have been the owner/tenant’s needs that could be handled with the highest number of technological means.

Analyzing the model by sustainable pillars, as can be seen in Table 5, an average relative weight of 5 was given for economic, followed by 4.61 for the environmental and 4.38 for the social impact. Moreover, stakeholders perceive the “environmental” aspect as a more important outcome of the retrofit process when compared with social benefits like “improving occupant’s productivity” or “improving aesthetic quality of the site.” Furthermore, the stakeholders indicate the following needs as having the lower importance as principles behind their sustainable retrofit goals: Economic: “Improve chances for renting” and “Increase return of investment”; Environmental:

![Table 4](image)

| Retrofit technologies | Technical importance score (T.I) | Importance (%) | Relative Weight | Priority rank |
|-----------------------|---------------------------------|----------------|----------------|--------------|
| Mechanical System     | Replacement of Heating system and air conditioning system | 232.73 | 12% | 3.93 | 4 |
|                       | Replacement of Water heating system | 213.98 | 11% | 3.61 | 5 |
| Electrical system     | Lighting fixtures | 192.83 | 10% | 3.26 | 7 |
|                       | Replacement of Electrical system | 164.48 | 8% | 2.78 | 8 |
| Plumbing system       | Replacement of Domestic hot and cold-water system | 196.35 | 10% | 3.32 | 6 |
|                       | Recycling methods of residual water | 139.70 | 7% | 2.36 | 9 |
| Building envelope     | Application of an external thermal insulation system | 295.97 | 15% | 5.00 | 1 |
|                       | Replacement of windows and doors | 292.25 | 15% | 4.94 | 2 |
|                       | Roof renovation | 257.22 | 13% | 4.35 | 3 |
Increase carbon neutrality and Facilitate renewable energy; Social: Improve aesthetic quality of the site and Improve occupant’s productivity.

To analyze where a conflict between owners and tenants may exist, a HOQ analysis was made separately for each group. The same steps made to determine the priority rank for all stakeholders were followed for analyzing responses provided by individuals within each of the tenants and owners stakeholder. The technical importance and priority rank are presented in Table 6. As it can be observed with little difference in relative weights, for both groups, owners, and tenants the retrofit technologies from building envelope have the highest potential in meeting stakeholders’ sustainable retrofit requirements. Technologies related to the mechanical system also received a high rating for technical importance, with relative weights that ranked the mechanical system as the second most important system to address when issuing the EPC’s recommendation report. The electrical system and the plumbing are following in ranking for both the owner and tenants as the third and fourth important system, with the mention that the retrofit technology “Replacement of Domestic hot and cold-water system” was considered to have more potential to fulfill stakeholders’ requirements than the electrical system’s technologies. Although this comparison demonstrated that owners and tenants agree concerning the ranking of the retrofit technologies that can fulfill sustainable requirements when adding more stakeholder groups, as managers and designers, or having a different social background the results may be different. Therefore, in practice, when using this model, conflicts that may appear can be analyzed more quickly and taken into consideration.

6. Discussions
This research presents a model for identifying the retrofit technologies which should be highlighted in the Energy Performance Certificate recommendation report, in order to boost the energy performance of the existing buildings. The interest of stakeholders during the retrofit process should be considered when choosing the retrofit technologies for the recommendation report, mostly because they play an essential role in determining how, why and if the retrofit methods will be implemented. Decision-making support towards sustainable renovation would cause

| Sustainable concept | Stakeholders requirements | T.I | ΣT.I | Relative Weight |
|---------------------|----------------------------|-----|------|-----------------|
| Environmental       | Increase energy efficiency | 206.67 | 654.59 | 4.61 |
|                     | Increase carbon neutrality | 95.70 |       |                 |
|                     | Facilitate renewable energy | 91.60 |       |                 |
|                     | Meet regulatory requirements | 131.39 |       |                 |
|                     | Minimize environmental impact | 129.23 |       |                 |
| Economic            | Reduce energy cost | 216.68 | 709.58 | 5.00 |
|                     | Increase the return of investment | 100.45 |       |                 |
|                     | Increase property value | 133.54 |       |                 |
|                     | Improve chances for renting | 96.46 |       |                 |
|                     | Achieve lower total ownership costs | 162.45 |       |                 |
| Social              | Improve occupant’s health | 155.14 | 621.33 | 4.38 |
|                     | Improve occupant’s comfort | 172.91 |       |                 |
|                     | Improve occupant’s productivity | 83.19 |       |                 |
|                     | Improve aesthetic quality of the site | 77.75 |       |                 |
|                     | The necessity to comply with policy or legislation | 132.34 |       |                 |

Table 5. Importance by sustainable aspects.

Table 6. Technical Targets Matrix Results: Comparison by Stakeholder.

| Technical Requirements (How) | Technical Importance | Relative Weight | Priority rank |
|------------------------------|----------------------|-----------------|---------------|
|                              | T        | O        | T       | O       | T | O |
| Mechanical System            |          |          |          |          |   |   |
| Replacement of Heating system and air conditioning system | 231.94 | 232.73 | 3.93 | 3.93 | 4 | 4 |
| Replacement of Water heating system | 231.23 | 214.22 | 3.61 | 3.62 | 5 | 5 |
| Electrical system            |          |          |          |          |   |   |
| Lighting fixtures            | 192.04   | 193.12   | 3.25    | 3.26    | 7 | 7 |
| Replacement of Electrical system | 164.45 | 164.41 | 2.79 | 2.78 | 8 | 8 |
| Plumbing system              |          |          |          |          |   |   |
| Replacement of Domestic hot and cold-water system | 195.14 | 196.84 | 3.31 | 3.32 | 6 | 6 |
| Recycling measures of residual water | 139.72 | 139.61 | 2.37 | 2.36 | 9 | 9 |
| Building envelope            |          |          |          |          |   |   |
| External thermal insulation system | 295.13 | 296.2 | 5 | 5 | 1 | 1 |
| Replacement of windows and doors | 291.02 | 292.65 | 4.93 | 4.94 | 2 | 2 |
| Roof renovation              | 255.78   | 257.78   | 4.33    | 4.35    | 3 | 3 |

*T-Tenant; O-Owner
dialogues between stakeholders, but it also contributes to facilitating communication between practitioners from various professional fields and property owners, which is necessary to identify and balance all the values (Thuvander et al. 2012). The retrofit process produces a range of environmental, social and economic benefits (D. Brown, Sorrell, and Kivimaa 2019). It has been shown to improve not just energy efficiency but as well the occupant health and wellbeing (Willand, Ridley, and Maller 2015). Also, it produces unique benefits to owners, including increased property value, significant savings in energy bills, and improved thermal comfort (Aravena, Riquelme, and Denny 2016). However, the majority of stakeholders are not aware of the proportion of these benefits and may overlook future benefits, resulting in a reluctance to make investments in energy efficiency improvements (Frederiks, Stenner, and Hobman 2015; Aravena, Riquelme, and Denny 2016).

Considering that stakeholders as individuals having various perceptions and motivations to retrofit, their perceived importance of the three sustainable concepts will be different as well, corresponding to each owner’s need. Thus, the selection of the retrofit technologies should reflect these differences; for example, if the owner’s motivation is to obtain environmental benefits, methods such as “recycling of residual water” or “renewable energy” should be first considered before other methods. On the other hand, if the owner prioritizes the social drivers as comfort and productivity, then the decision-maker and the energy auditor should also prioritize the application of retrofit technologies as replacement of heating system and air conditioning system, which can significantly improve the thermal comfort of the occupant. All of these aspects need to be considered by the decision making in developing the recommendation report and selecting the best retrofit technologies to be applied. Therefore, the model of HoQ presented in this study can be used as a tool to analyze different scenarios and obtain the critical combination of retrofit technologies.

Moreover, this model can give insights about which of the three pillars of sustainability motivates the most an owner in the retrofit process. For example, although the motivation to encourage building retrofits at the government level is to reduce the adverse effect of excessive energy use on the global environment, economy and human health, the case study showed that the main reason to motivate stakeholders to retrofit is the economic aspect, in reality. Therefore, it can be concluded that the retrofit technologies included in the report would fulfill the financial requirements first and easily neglect the social and environmental aspects due to the risk of the final decision to be dictated by economic incentives. Hence, when using the proposed model, a combination of all the requirements should be taken into consideration.

The EPC recommendation report intends to provide valid support for the building owner to make it easier for him/her to decide the retrofit methods. This report can be issued a standard or in the form of a tailor-made list of actions. As presented in Figure 5, in order to obtain a reliable EPC and tailor-made recommendations, it is essential that an AEA inspects the building and gets information concerning the construction, technical systems, and stakeholder’s needs. This study suggests to the building inspection representatives (AEA) that using the proposed HoQ model to analyze stakeholder’s needs will allow to better incentives for them to retrofit. The stakeholder, together with the expert, will participate actively in the process of selecting the retrofit technologies. As a result, they will recognize more readily available retrofit methods which should be applied for a better retrofit performance.

7. Conclusions

The sustainable retrofit process represents a critical action in mitigating the negative impact of the building sector.

![Figure 5. Model application process.](image-url)
on the environment. However, being a complicated and risky process, the owners have a lack of knowledge about its actions. With this, the Energy Performance Certificate has significant potential to narrow the existent knowledge gap by offering information about the retrofit technologies with the ability to drive the stakeholder’s motivation to retrofit. However, due to its present format, the EPC is perceived more like a formal requirement than a guiding document containing useful information which can increase sufficiently building owner’s awareness of the energy performance of the building or retrofit process. Moreover, the experts emphasize that changes are required for EPC to be used more effectively and to have an actual impact on energy savings. Considering the fact that stakeholder’s needs should be considered to boost sustainable retrofit, this study developed a model that analyses the owner and tenant’s requirements in a matrix relationship with retrofit technologies through QFD methodology. This attempt made it possible to access the opinion of the stakeholders to find the primary retrofit technologies that can satisfy their demands.

By applying the proposed HoQ to the case study, the most critical retrofit technologies which satisfy stakeholder’s demands and can mitigate the building’s impact on the environment were found. Finding the primary methods, to be emphasized, it was possible to improve the actual recommendation part of the EPC. Through the introduction of these retrofit technologies in the EPC’s recommendation report in practice, the Accredited Energy Auditor can give more accurate information to the stakeholders and support their retrofit decision-making. The better the stakeholder’s satisfaction, the more successful the result will be obtained in energy efficiency using the retrofit process. Moreover, if the application of the proposed model lasts for a long time, the improved stakeholder satisfaction will bring a better reputation to the EPC’s recommendation report, meaning increase usage of EPC and significant energy savings. Furthermore, by considering the three pillars of sustainability in its process, this research’s findings encourage the application of sustainability in the construction industry. Consequently, it can be said that this research contributed not just to the body of knowledge but also to help stakeholders to encourage practical retrofit activities.

In this research, the data collection for assessing the development of the model was limited in Romania. Considering the differences depending on the application of case studies, this limitation needs to be addressed. Also, the stakeholder’s requirements and the retrofit technologies were collected by conducting a literature review. Thus, applying in practice or other case studies, the results can be varied depending on cultural and social background or stakeholder’s opinion. Besides this, the study focuses just on residential buildings with owners and tenants as stakeholders. Therefore, the application of the proposed model in the commercial building cases, which have a larger number of stakeholders involved in the decision making, it remained for further studies.

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