Building and Environment 106 (2016) 20–32

Contents lists available at ScienceDirect

Building and Environment

journal homepage: www.elsevier.com/locate/buildenv

An approach towards sustainable renovation—A tool for decision support in early project stages

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ARTICLE INFO

Article history:
Received 18 January 2016
Received in revised form
9 June 2016
Accepted 11 June 2016
Available online 14 June 2016

Keywords:
Building renovation processes
Evaluation procedure
Sustainability targets
Greenhouse gas emissions
Energy-efficiency
Embodied emissions

ABSTRACT

Reducing greenhouse gas (GHG) emissions through energy reduction in buildings is a high priority for policy-makers in the European Union and elsewhere. However, although long-term sustainability targets exist on the societal level, it is not obvious how these targets may trickle down to individual sectors and further down to specific organizations or buildings. The aim of this paper is to illustrate an approach for evaluating renovation measures in order to identify appropriate target levels in early project stages and what is needed to achieve a number of proposed sustainability targets. The evaluation approach is supported by a tool that can be seen as an aid to making rough estimations of the environmental impacts. Sustainability target levels in a Swedish context are presented for three issues: operational energy use, GHG emissions due to total energy use for building operation, and embodied GHG emissions due to production of materials. The approach to support well-grounded retrofit decisions is shown with a case study. The tool developed, in combination with a suggested step-by-step evaluation approach, provides an effective way to evaluate various potential improvements, and their consequences, in early project stages. However, other tools with similar functionality may be used. Results from the case illustration imply that it is possible to achieve the proposed sustainability targets for operational energy use by implementing nine measures. However, the targets for GHG emissions for operational energy use and embodied GHG emissions were not achieved because of an energy supply with too high a share of non-renewable fuels.

1. Introduction

Reducing greenhouse gas (GHG) emissions through operational energy reduction in existing buildings is a high priority for policy-makers in the European Union and elsewhere. Although long-term climate targets exist on the societal level, it is not obvious how these targets may trickle down to individual sectors and further down to specific organizations, buildings, or even projects. That is, what levels regarding, e.g., operational energy use or GHG emissions need to be targeted in individual projects to be in line with long-term targets at societal or sector levels?

Far-reaching renovations that achieve high reductions in energy demand and GHG emissions exist (see e.g. www.annex56.org) but are still rare [1]. Barriers to implementation of renovation processes for more sustainable buildings have been investigated by, e.g., Häkkinen and Belloni [2], Thuvander et al. [3], Cattano et al. [4], and Olsson et al. [5]. In addition to the fear of high investment costs and problems with profitability, key barriers identified in these studies include a lack of knowledge about sustainability issues, insufficient knowledge of building stocks, a lack of simplified evaluation tools (for decision making), and a lack of coordination between energy-saving and other measures. Finding ways to overcome similar barriers is crucial and requires identification and development of sustainability management procedures.

Moreover, the current unilateral focus on impact in the use stages is beginning to be questioned. More and more studies point to the fact that apart from the use stage, the product stage of building life cycle impact is becoming increasingly significant [6–12]. Thus, with an increasing significance of impacts associated with material production, the need for a life cycle perspective in renovation processes also becomes more apparent. A review of

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http://dx.doi.org/10.1016/j.buildenv.2016.06.016
0360-1323/

ongoing and recently ended projects in Europe found 36 projects and 11 tools dealing with various "sustainability aspects" concerning renovation of buildings [13]. Seven of the reviewed tools included Life Cycle Cost (LCC) calculations and six tools included some kind of life cycle approach or environmental assessment. Furthermore, the environmental assessments vary from simplified Life Cycle Assessments (LCAs) dealing with a few impact categories to just considering CO_2 emissions due to energy demand for building operation. There are a very limited number of identified tools that include a combination of an LCC and LCA approach.

Decisions about building design such as orientation, shape, structure, degree of insulation, size of windows, and type of HVAC systems are made early on in the building process, typically in the concept design stage, where knowledge of the future building is still limited. These decisions will then govern and restrict further detailed designs of the building, and thus its environmental performance over its life cycle [14–16]. This building process is similar both in new construction and in renovation of existing buildings; however, in renovation projects, many preconditions and boundaries are already fixed. According to Shi and Yang [17], there is an understanding that decisions made in the conceptual design stage have the largest impact on the overall environmental performance of the building.

The aim of this paper is to present an approach that enables improved decision-making in the renovation process with respect to supporting the achievement of long-term sustainability targets of the building stock. This is done through:

- The demonstration of a working procedure to discuss and formulate relevant but challenging environmental targets in early stages of a renovation project, as well as outlining a way to identify which measures could be focused on for reaching such targets. As part of the procedure an evaluation tool called BECEREN (Basic Energy, CO_2 and Cost Estimation in Renovation) is used. The tool can be seen as an aid to making rough estimations of the environmental impacts over the dominant life cycle stages of a building, addressing aspects such as contribution to climate change, energy demand, and cost;
- The introduction of long-term environmental targets regarding three important aspects: energy use for building operation, GHG emissions due to total energy use for building operation, and embodied GHG emissions due to the production of materials;
- The illustration of the above mentioned approach, combining the use of the tool and the long-term environmental targets, on a case study building.

The outline of the paper is as follows. In Section 2, the tool development process is described together with a general description of the BECEREN tool. Proposals of quantified target levels for some selected environmental aspects are presented in Section 3. The use of the tool in combination with the environmental targets is illustrated with a case study; the case study building is presented in Section 4. The tool was used to evaluate potential building improvements in the case study building; the evaluation procedure and the case study illustration are presented in Section 5. Section 6 discusses the results. It should here be noted that other tools or a combination of other tools, with the same purpose as the BECEREN tool could be used.

2. The BECEREN tool

2.1. The tool development process

The decision support tool originated in 2008 and has gradually been developed through a number of projects [7,14,18,19]. In the development process of the latest version of the tool, which is called BECEREN, a number of companies, including six Swedish property owners, were involved in a reference group. These companies represent both private and public actors, as well as both small and large organizations. A first version of the BECEREN tool was tested and discussed in a workshop with reference group companies and other stakeholders who were selected based on targeted end users of the tool. Participants attending the workshop were private and public property owners, consulting companies, governmental organizations, and external researchers. In total, 14 people representing 11 different organizations attended the workshop. Proposals that emerged during the workshop were embedded in later versions of the tool in order to consolidate its use among practitioners. In the existing version of the BECEREN tool, the energy calculation module was improved and an LCC module was added. In order to present the results from the economic evaluation in the most practitioner-oriented way, the LCC module was developed in an iterative way with the reference group and through separate discussions with targeted end-users.

2.2. General description of the BECEREN tool

The BECEREN tool's purpose is twofold. Firstly, it is designed to easily evaluate different improvement options for a specific building regarding energy use, contribution to climate change, and life cycle cost. Secondly, it is designed to elaborate relevant environmental targets for operational energy use and contributions to climate change in renovation projects while also determining an indicative figure of LCC for different measures. The BECEREN tool includes predefined improvement measures in contrast to similar tools where the user needs to input material requirements and costs for each improvement before the evaluation can start [20,21]. The different improvements in the BECEREN tool are classified in three categories: *improvement options,* which refer to any improvement; *improvement measures,* which relate to physical measures that cannot be seen as renovation measures (e.g., installing PV-cells); and *renovation measures,* which relate to physical improvements such as change of windows. The principal design of the BECEREN tool is shown in Fig. 1.

The user only needs to insert a limited amount of basic building data (see Fig. 1) in order to start the evaluation of a building. From entering the basic building data, the tool uses given values to present default values for optional building data parameters. Default values are based on typical designs from various eras. However, if available, the user can insert more accurate input for any of the parameters under Optional building data (see Fig. 1).

A number of default improvement options consisting of building envelope measures, additional improvement and optimization options, and different energy sources are included in the tool. All improvement options are described and, where suitable, priced, amounts of materials used are listed, and embodied GHG emissions are available for the included materials. The output sheet in the tool is where different improvement options and cost parameters are tested. Any combination of improvement options can be tested and the user immediately gets the results in tables and graphs. The current number of improvement options available to choose from in the BECEREN tool is shown in Table 1. This list of improvements is not a complete list of potential improvement options but rather a number of options that are typical but also different enough to allow for diversity. The list of options may be enlarged successively.

The results from an evaluation in BECEREN are presented as shown in Table 2. In addition to the table, there are also graphs and diagrams visualizing the results (see Section 5 for more details).

To ensure the transparency of all calculations within the BECEREN tool all equations, fixed parameters, and detailed information