Energy and Buildings 119 (2016) 267–282

Contents lists available at ScienceDirect

Energy and Buildings

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

On the usefulness of a cost-performance indicator curve at the strategic level for consideration of energy efficiency measures for building portfolios

Markus Christen[a,*], Bryan T. Adey[a], Holger Wallbaum[b]

[a] Institute of Construction and Infrastructure Management (IBI), Swiss Federal Institute of Technology ETH Zurich, Stefano-Franscini-Platz 5, 8093 Zurich, Switzerland
[b] Department of Civil and Environmental Engineering, Chalmers University of Technology, Göteborg 412 96, SE, Sweden

ARTICLE INFO

Article history:
Received 21 November 2013
Received in revised form 20 January 2016
Accepted 16 February 2016
Available online 6 March 2016

Keywords:
Strategic building portfolio management
Sustainable construction
Budgeting
Refurbishment
Energy efficiency measures
Law of increasing relative costs
Renewable energy
Cost-Performance-Indicator CPI-curve

ABSTRACT

There is an increasing desire by managers to reduce the amount of energy consumed by the buildings in their portfolio. Energy efficiency measures on existing buildings, however, are often economically feasible only if executed at the same time as the execution of necessary maintenance and refurbishment measures. At the strategic level it would be useful to be able to better plan the costs and benefits of energy efficiency measures so that decisions could be made to execute them when the opportunity arises.

In this paper, a Cost-Performance-Indicator (CPI) curve is proposed to indicate additional costs and benefits of energy efficiency measures at a strategic level, and evidence is given that corroborates the hypothesis that energy efficiency measures follow the law of increasing relative costs. The usefulness of the CPI curve is demonstrated through two case studies. An example is provided and the potential is discussed for using this curve for the planning and budgeting of refurbishment and energy efficiency measures, and as a tool to explain the relation between costs and benefits of measures enhancing building energy efficiency, including the production of renewable energy, to investors.

1. Introduction

As the existing building stock accounts for up to 40% of the total world energy consumption (World Business Council for Sustainable Development WBCSD [1]), and a large share of this energy is being produced from non-renewable fossil fuels, the existing building stock offers the single largest potential for energy conservation, and consequently reduction of CO_2 emissions. Example efforts to improve the technical-economic options of buildings owners are the development of passive (using less than 15 kW h/m^2.a), zero emission and plus energy buildings. An example effort to ensure that countries improve the energy efficiency of their buildings is the European Energy Performance of Buildings Directive (EPBD [2]), which requires in its article 9 that from 2020 all new buildings be nearly all zero-energy ones. A new study also shows considerable economic benefits of energy efficient building refurbishment (Ecofys [3]).

Refurbishment measures (RMs) and energy efficiency measures (EEMs), of which there are two types, energy conservation measures (ECMs) and energy production measures (EPMs), are closely linked and intertwined, yet they are often planned and treated separately. For example, painting an exterior wall of a building as a RM and adding insulation to that wall as an ECM both need scaffolding. If executed simultaneously synergies can be achieved resulting in lower combined costs. It follows that, in this case, since the scaffolding would already be available for the RM, that the additional cost of the ECM would be less than if it was executed alone. As the benefit of the ECM would remain the same, this reduction in cost would increase its net benefit, which would increase the chances that a building owner would execute it. In order to investigate the viability of executing EEMs at the same time as RMs, it is necessary to understand the costs of the RMs that would be incurred with or without the execution of the EEMs [4], which from a focus on the EEM are sometimes referred to as "anyway costs"[1] and "additional

* Corresponding author.
E-mail addresses: christen@ethrat.ch (M. Christen), adey@ibi.baug.ethz.ch (B.T. Adey), holger.wallbaum@chalmers.se (H. Wallbaum).

[1] Defined as "Set of actions, products and services necessary to guarantee the regular, safe and legal functions and aesthetics of an existing building" in IEA Annex 56 [5].

http://dx.doi.org/10.1016/j.enbuild.2016.02.056
0378-7788/

costs", respectively. In addition to ECMs, there are also measures that result in the production of energy from renewable sources. These EPMs are to be considered simultaneously with ECMs when determining how to modify the buildings within a building portfolio.

The use of the proposed cost-performance indicator or CPI curve will help decision makers take into consideration the costs and benefits of RMs and EEMs, correctly at the strategic level, i.e. without the double counting of costs for both measures if they are executed together. Through its use, there will be an increased number of EEMs planned and executed, due to the increase in knowledge with respect to the costs and effectiveness of EEMs and, therefore, change in the actions of owners [6–9]. It is based on the estimation of the additional costs of EEMs and their impact on performance. The remainder of this paper is divided into seven sections. As there is a great variation in the terminology in this field, in Section 2 the definitions used in the paper are explained. Section 3 identifies deficiencies of existing methods and the need for a new instrument. Section 4 contains the development and potential application of the CPI curve, which is illustrated with the data presented in the two case studies. Section 5 presents the strategic planning process without and with the CPI method and contains an example of the usefulness of the CPI curve. Section 6 contains a discussion of the method and of the significance of the shape of the CPI curve. Section 7 contains the conclusions of the paper and the need for further studies, respectively.

2. Definitions

2.1. Functionality

In this work, it is considered that a building is constructed to meet an initial set of requirements, or in other words, to provide a certain level of service. If a building provides this level of service, it is considered to be 100% functional. A building can cease to meet initial requirements in two basic ways; (1) the building deteriorates, (2) the building requirements change. The latter can be subdivided into (a) changes in building standards, e.g., increases in the expected energy efficiency, and (b) changes because it is needed for another purpose, e.g., modification of a warehouse to be an apartment building. The amount of deterioration is expressed as a % loss of the initial functionality. The energy efficiency, generally measured by the energy performance index (EPI [10]), is an aspect of the functionality.

It is considered that the costs of RMs are directly proportional to the cost of reconstructing the building with the same functionality, today [11]. The costs of enhancement measures are, in general, not directly proportional to the accompanying change in functionality. There is, however, a relationship between them, at least for energy efficiency improvements, such as a more comfortable indoor environmental quality.

2.2. Value

The proposed method uses the reconstruction value, i.e. the expected cost of reconstruction of the building on a green-field site, as a base value. Costs of investigated interventions are then expressed as a percentage of the reconstruction value. This facilitates the understanding of the method by normalizing the costs of measures on buildings of different size and type, and by normalizing costs over time. Estimates of this value can be obtained using either cost-indexed original construction costs, or the amount for which the building is insured, which is usually based on the so called reinstatement value, which reflects the reconstruction costs at a certain point in time (e.g., at the start of the insurance contract). Care must, however, be taken to account for deviations from these values, and the actual reconstruction costs, if a high level of detail is required. It is also noted, that these values are also not necessarily identical with the commercial market value, fair value or value of assets in the balance sheet also called the financial book value.

2.3. Measures

In order to ensure that a building continues to provide the desired level of service or functionality it is necessary to execute measures. In general, these can be classified as (1) maintenance measures (MMs), (2) refurbishment measures (RMs) and (3) enhancement measures (EMs) of which EEMs are a subset. MMs are relatively inexpensive measures that slow deterioration and, therefore, slow the loss of functionality of the building. The costs of such measures are normally included in expenses[2] and have no effect on the value of assets[3] in the balance sheet. RMs are relatively expensive measures that improve the functionality of the building up to and possibly beyond the initial functionality, e.g. to comply with new legal requirements. The costs of RMs are normally included in investments[4] and have an effect on the value of assets in the balance sheet. EMs are relatively expensive measures that improve the functionality of the building beyond the initial functionality, e.g. adding another floor on top of the building. The costs of EMs are also normally included in investments and have an effect on the value of assets in the balance sheet. A description of each type of measure is given with respect to the reason for execution, the department responsible and budget request process, the effect that measure is expected to have on functionality, how the costs of the measure are taken into consideration by accounting and the effect on the balance sheet, and the normal source of funding in Table 1. The effect expected on the functionality of the building due to the execution of the measure is illustrated in Fig. 1.[5]

To execute interventions on buildings in an optimal way, it is necessary to analyze and plan all measures together [12]. Unfortunately due to organizational structures and internal regulations this is not always done.

2.4. Costs and benefits

Costs, in this paper, are defined as the impacts that are incurred during the execution of measures by the owner of the building. They are grouped as shown in Table 2, where if a measure is executed the costs for the lowest category are counted first, then the costs for the second, etc.

Benefits are defined as the impacts that are incurred both during and following the execution of measures that are not directly related to the execution of measures. They are grouped as shown

[2] Expenses—Operating expenditures (OPEX), in the context of this paper the amount of money spent or costs for maintenance and operation of a building.

[3] Value of assets are the value entered on the balance sheet, which is used, for example, to help determine the amount of tax to be paid.

[4] Investment—Capital expenditure (CAPEX), in the context of this paper the amount of money spent or costs to improve the functionality of a building.

[5] It is noted that the exact definitions of a measure may vary from organization to organization, and even between persons within the same organisation. This decision depends on multiple factors such as internal accounting and/or taxation principles, legislation of the rental market, the actual condition vs. advances in building technology, standards and regulations, types of requirements, financing of the measures, and responsibility for planning and execution. The explanations we have given here, are, however, exact enough to demonstrate the proposed method and can easily be adapted to a specific organisation if desired.

[11] There are numerous rating labels on the market, either specific to energy consumption or covering other aspects of sustainability. As part of their corporate identity and responsibility, organisations often demand a certain rating of the buildings they occupy. The rating may result in a higher value of the labelled building in the market [15] and thus enhances its functionality.