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Usability of energy performance assessment tools for different use purposes with the focus on refurbishment projects

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ABSTRACT

Many energy performance assessment methods are available. There are both dynamic and steady state methods, of which initial data may be based on statistics or physical models. However, many of the tools are not suitable in refurbishment projects because of the difficulties in defining the input values for the building and user behaviour. The objective of the study was to review the existing energy performance assessment tools and make conclusions for the new type of tools needed especially by small companies in refurbishment projects. The study concluded that the right combination of ease-of-use and accuracy is important. This can be achieved with the help of dynamic calculation engine, carefully defined local data and well-selected default values and – on the other hand – with the help of openness which enables the users to access the default values and give detailed true data when that is available. This combination enables both rough estimations in early phases and more accurate assessment when better information is available. The research developed a new tool based on these principles and carried out a wide survey among potential users. The survey supported the preliminary understanding and highlighted further needs of SMEs in refurbishment projects.

1. Introduction

The recast of the European energy performance directive [14] lays down requirements for the application of minimum requirements to the energy performance of existing buildings, building units and building elements that are subject to major renovation. The energy performance of buildings should be calculated on the basis of a methodology, which may be differentiated at national and regional level.

Currently there are many tools for energy simulations; professionals are typically using dynamic simulations but also rough tools for quick first estimation exist. Due to the nature of simulations, considerable amount of information on very detailed level is needed. Getting reliable input values and the data concerning occupancy and user behaviour, however, may be problematic. In addition, different types of methods and tools may be needed for new buildings than for refurbishment. The determination of initial data is a specific problem in energy performance assessment and design of building refurbishment. Because the energy-efficiency now needs to be considered in all significant refurbishment projects of buildings, there may be an increasing demand for energy performance assessment tools that are suitable and appropriate for different kinds of professionals in building sector and also for small enterprises and those, who are not experts in running simulations.

The category of micro, small and medium-sized enterprises (SMEs) consists of enterprises which employ fewer than 250 persons and which have an annual turnover not exceeding 50 million euro, and/or an annual balance sheet total not exceeding 43 million euro [13]. In accordance with this definition, for example in Finland 99% of building companies are SMEs [55]. While HVAC designers and energy consultants may especially focus on the high-level professional use of simulation methods, the efficient use of energy performance simulation methods and tools based on these methods may be challenging for contractors, facility managers, housing managers, architects and some other SMEs although they would possibly benefit from the use of energy performance assessment tools in building and refurbishment projects.

The paper presents a critical review of energy performance simulation methods and tools based on these methods. The paper assesses the usability of energy performance assessment tools in different phases of building processes with special focus on refurbishment projects of residential buildings. The paper also assesses the importance of the complexity of energy performance simulation methods and lack of suitable tools as the barrier in building

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and refurbishment projects especially from the view point of SMEs. Finally the paper presents the functions and characteristics of a tool that was specifically developed for the use of SMEs in refurbishment projects, and further studies the needed functionalities and features by interviewing stakeholders and with the help of an enquiry.

2. Approach and objectives

As the starting point of our study we hypothesise the following general statements:

- there is a high number of energy performance assessment tools based on few simulation methods
- there are tools both for rough and quick assessment as well as for that kind of detailed assessment that considers comprehensively different aspects of building having an influence on the energy performance of buildings
- very accurate assessment can be done, if correct and complete information about the design/building and user behaviour is available
- the usability of many tools is impaired because of the difficulty to define input values concerning the design/building and user behaviour
- despite the abundance of available tools for the energy performance assessment, there is still lack of tools that support easy but relatively accurate assessment of potential energy savings in building refurbishment
- tools that support easy but relatively accurate assessment of potential energy savings in building refurbishment would especially be needed by building professionals in small companies that are not experts in energy performance simulation.

Our objective is

- to analyse and make conclusions about the current availability and usability of energy performance simulations tools with the focus on the usability in refurbishment projects by SMEs

- to create an energy performance assessment tool that is suitable for the use of SMEs in refurbishment projects by building professionals that are not experts in energy performance simulations

- to assess the usability of this tool in building refurbishment projects by SMEs and increase understanding about the needed functionalities.

3. Methods

3.1. Research methods

We assessed the availability and usability of tools with the help of a literature study. We studied 53 articles and other sources that review and present energy performance assessment tools and methods. The articles were quite recent articles dated mostly in 2005–2015. We made qualitative research by outlining the types of tools and assessing their usability especially in refurbishment projects.

We made conclusions about the usability and shortcomings of current tools and developed an energy performance assessment tool especially for the use of SMEs in refurbishment projects. Our hypothesis was that the main challenge from the usability point of view is the difficulty to define the input values that characterise the building and the alternative refurbishment methods.

We made qualitative and quantitative research with the help of two surveys. The first one studied the barriers for SMEs in refurbishment projects. The second studied the current use of tools and the usability of the new tool.

The limitation of this study is that the surveys are conducted in Finland. However, it will benefit a larger audience as the building and refurbishment practices around the world have overlapping processes.

3.2. Methods used in the development of the assessment tool

Energy performance assessment tool E-PASS was developed for the use of small companies in refurbishment projects. The tool was developed and tested in a European research project [40] and the tool is available on web [12].

This paper focuses on studying the functionality of the tool especially based on the solution of the user interface. However, this Section explains the overall structure and assessment methods of the tool as background information. The functionality of the tool is described in detail in Section 6. E-PASS consists of a calculation engine, database and user interface.

The calculation basis of the calculation engine follows the principles of [27]. The method is a dynamic hourly based heating and cooling simulation method. The simulation model used is based on a resistance — capacitance (R-C) model. It uses an hourly time step. All building and system input data can be modified for each hour enabling the modelling of the various user profiles. The thermal inertia of structures and dynamic impact of solar on the heating and cooling of the building is also taken account.

The test reports of the functioning and accuracy of the tool are available through the E-PASS web page. The validation information include the validation report of the calculation core and the validation report that compares the results of E-PASS with the results of IDA Indoor Climate and Energy simulation software with regard to selected cases. The testing report of the functionality of E-PASS is also available on the web page of the tool [12].

The database of E-PASS includes data about building stock, refurbishment methods, life cycle cost and greenhouse gas emissions. At present, the Finnish database is available. However, E-PASS application can be localised by providing the local information with an Excel template. The templates for multi-storey residential buildings, small houses and office buildings are available on the E-PASS web page. When the local data is provided with the Excel file, it can be imported easily to the E-PASS database to localise the tool.

The current database of E-PASS covers small houses, blocks of flats and office buildings in Finland. The Finnish data about the building stock and refurbishment methods is based on earlier results of a series of Nordic and European projects [24], [61] and [43]. The included refurbishment methods are all available in the market with competitive prices. The refurbishment methods were outlined and assessed in European research projects [25,63,43,41].

The tool calculates energy consumption (for space heating and hot water, space cooling and appliance electricity), greenhouse gas emissions and life cycle costs. All included data is based on information collected by VTT within a series of European and Nordic research projects. The costs of refurbishment methods cover investment and annual energy costs. The assessment method is based on [28] (life cycle costing). Annual energy costs are based on present unit costs (€/kWh/a). As a comparison, it is possible to use the demand for profit (6%) for invested capital. The investment costs are presented as average values. However, recognised real unit costs are recommended to be used. The variation depends on project and building size, needs of extra work and present trade cycle and may be between −15 … + 30%. The investment cost includes all material, labour and sub cost caused by demolition, patching and construction of systems, structures and surfaces. The theoretical share of direct energy saving actions is not given separately. The cost calculations and data are based on the Finnish national cost optimal calculation results [49,24,42].