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On the implementation of an innovative energy/financial optimization tool and its application for technology screening within the EU-project School of the Future

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Abstract

A tool for the energy & financial optimization of the renovation of school buildings was developed based on an existing tool - ASCOT. The tool combines an energy calculation with a LCC-analysis, which are calculated simultaneously. The tool was then used for the screening of energy saving measures in school buildings in four European countries: Denmark, Germany, Italy and Norway. For Italy, the screening was carried out for three climates.

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*Keywords:*energy optimisation; LCC-analysis; screeninig; energy saving measures, different European climates

1. Introduction

The objective of this work was the implementation of an optimization tool - ASCOT - that in one calculation shows energy savings and the financial consequences of implementing one or more energy renovation technologies for school buildings.

The tool was in a next step used to screen a selected number of available building and system retrofit technologies for energy efficient school buildings for their impact on the energy performance. The innovative approach is that the tool provides information about the cost-efficiency (life-cycle-cost (LCC)) of the screened technologies for different climates and school typologies. The intended audiences for this work are designers and planners of school buildings.

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The idea is that Municipalities all over Europe can use the screening results and can find useful technologies for their specific school buildings. Also the work constitute background knowledge for further work in the School of the Future project, especially for the design guidelines and to the extension of the information tool and the tailored training to be conducted.

2. Preparing the tool for the task

The ASCOT tool is a monthly calculation tools based on current EN standards for energy calculations (ISO EN 13790)[1]. The tool has been developed over the past seven years by Cenergia Energy Consultants. The first version was called BYG-SOL[2], which was first developed to allow for an easy calculation and comparison of building energy saving technologies and renewable energy in the form of active solar heating systems and photovoltaic systems (PV). From the Danish Building regulation 2008 an onwards the renewable energy contribution is included in the so-called energy frame which is the basis for the Danish energy certification scheme. The idea of the tool is a simultaneous calculation of energy and costs, so the user in calculation gets the energy saving and financial consequences of the investments to save energy and/or harvest solar energy in the form of net present values (NPV), energy saving price and simple payback times.

BYG-SOL was developed for residential buildings. For the screening work within the School of the Future [3] it was therefore necessary to further develop the tool to accommodate for the calculation of school buildings. The main additions that was implemented was:

- School typologies and
- Calculation of daylight and artificial lighting needs

2.1. Adding school typologies

School buildings appear in many shapes and sizes with a variety of plan layouts, floors and building materials. After analysing existing school buildings in the participating countries (Denmark, Germany, Italy and Norway) three school typologies based on factors such as year of construction, geometry, utilisation, building and system technologies was developed to be representative for the majority of school buildings in these four countries: Side corridor, central corridor and compact plan, see figure 1. A fourth typology –the Open plan school was also considered and included in the Ascot developments: However, this typology was not included in the screening calculations, because it is quite similar to compact plan typology, except for the partition walls.

Each school has a threated floor area of 3000 m² and all classrooms have a distribution of the window/floor-area of 25 %. The compact floor is one floored building with at big roof area and the side and central corridor are three floored buildings with a smaller roof area but with a larger area of facades and windows.

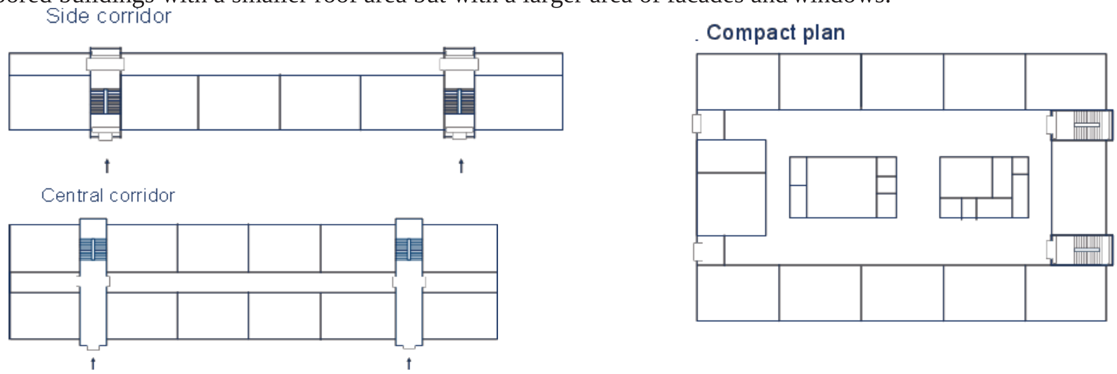


Fig. 1. Floorplans of the three school typologies selected for the screening calculations.

Handling of daylight and artificial light

Electrical lighting is quite important for the overall energy consumption of school buildings. For the handling of daylight and artificial light ad hoc routines had to be implemented by specific applications not yet properly covered by reliable EU standards. In this case a new feature to handle daylight and electrical lighting was added to the tool, in order to introduce a more accurate prediction respect to the reference standard EN 15193:2008 Energy performance of buildings – Energy requirements for lighting.

2.2. Using the tool

The Ascot tool has been developed as an MS Excel tool consisting of a number of interlinked excel-sheets. On the first page the specification of the reference buildingis selected, see figure 2.

On the following sheets of the tool more reference building specifications are selected and then the energy saving measures – also in pull down menus. The results then appear immediately.

3. Screening of energy saving technologies

Using the above mentioned three typologies as the basis reference buildings was set up for the most typical schools in each of the four countries. A survey of retrofit technologies for improved energy performance and indoor environment quality was made covering the following topics:

- Reduction of heat losses from the building envelope
- Optimal handling of gains
- Heating, cooling, ventilation and lighting systems / energy efficiency
- Energy supply/generation systems

For each of these topics the most relevant retrofit technologies were identified resulting in the following list of technologies to be screened:

- Additional roof insulation
- Additional floor insulation towards basement/crawl space/cellar
- Exterior wall insulation
- Window replacement
- Building energy management system (BEMS)
- Balanced mechanical ventilation system with heat recovery of the exhaust air (MVHR)
- Electrical lighting system with controls
- Integration of PV
- Solar DHW
- New high efficiency gas boiler
- New condensing gas boiler
- District heating system
- Electrical heat pump

The technical characteristics and the cost of implementing each of these technologies were established in each of the four countries: Denmark, Germany, Italy and Norway and introduced into the ASCOT tool. The ASCOT tool then allows a comparison between a reference building and different sustainable concepts for the renovation of the building.

The impacts of the different measures were then analyzed with the ASCOT calculation tool regarding energy use, investment and operational costs and with simulation tools for indoor environment quality. The calculations were carried out for one representative climate in Norway, Germany and Denmark and for 3 representative climates in Italy, typical of northern, central and southern regions.

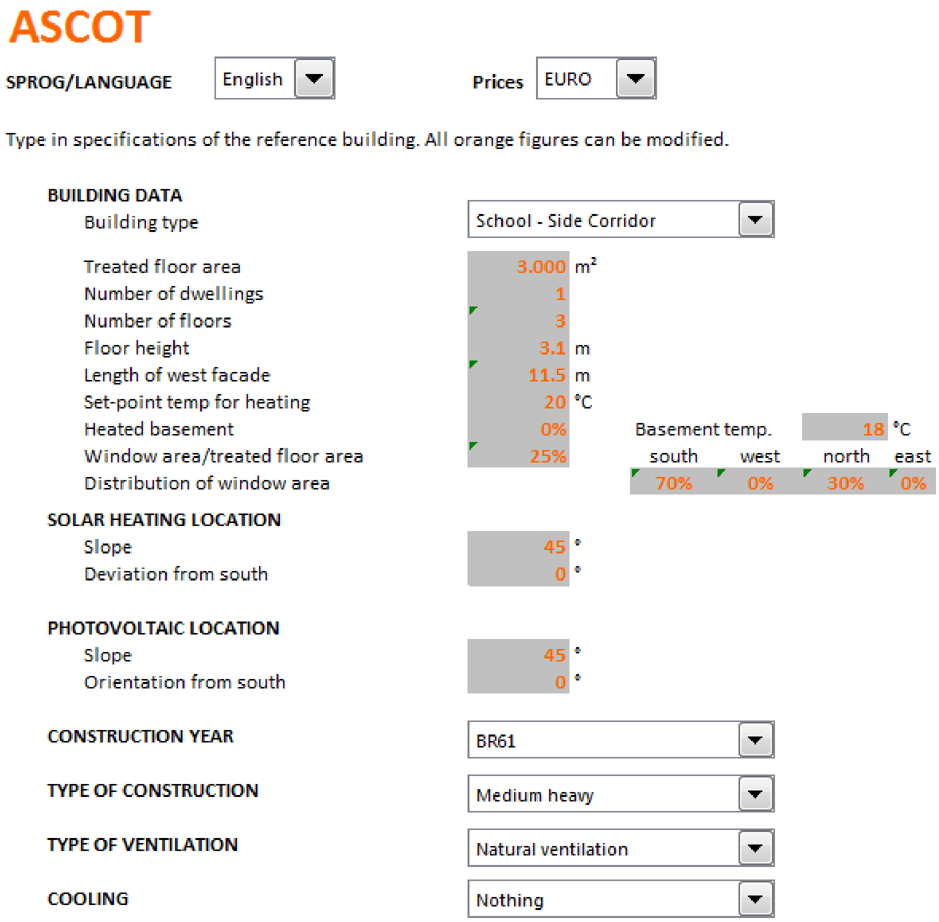


Fig. 2. Selecting the reference building in ASCOT.

The results take into consideration:

- all investment and operation costs over the total lifetime of the building
- the savings from the investments with respect to sustainable issues (Heat, electricity, water) over the total lifespan of the building
- the reduced environmental impact from the energy savings

4. Examples of the screening results

This section reports some exemplary results obtained for the side corridor school, in order to show the calculation potentiality of the software and the effectiveness of energy renovation measures.The results presented here are used to compare how different energy systems renovation measures perform in energy, environmental and financial terms under different climatic conditions.

By means ofthe ASCOT calculations four indicators were calculated to evaluate the performance of the school building due to the selected renovation measures: the energy savings, the CO2 reduction, Pay Back Time and Net Present Value.

The results for two retrofit technology **systems** for energy efficient school buildings are presented:

1. Substitution of the old heating supply system with condensing boilers in all the countries where a traditional gas boiler was installed; in Norway where an electrical heating system was operating and condensing boilers are not so widespread this intervention was not considered. Current gas condensing boilerscan achieve efficiency values up to 0,96 at full load and even more efficient ones (η =1,00) at partial load. 0,75-0,85 are common values related to the old gas boilers.The graph in fig.3 shows results in terms of total saved primary energy: in this case corresponding to saved heating energy. Best results are verified in northern Italy and Denmark; central and southern Italy follow.

The graph in fig.4 highlights the environmental impact of this renovation measure in terms of CO_2-emission reduction. These results link to the previous ones: an increase of the overall efficiency of energy supply contribute to a substantial reduction of CO_2 emissions. Another factor influencing this parameter relies on the conversion factor for fuel emissions. The most relevant result is verified in northern Italy due to most saved energy, Germany reaches a value equal to Denmark due to a higher conversion factor.

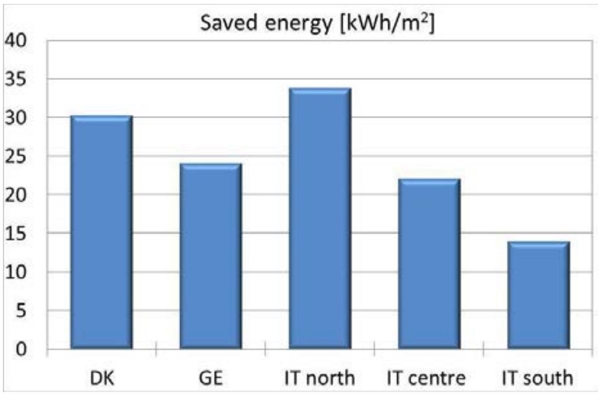


Fig. 3. Saved primary energy due to condensing boiler application

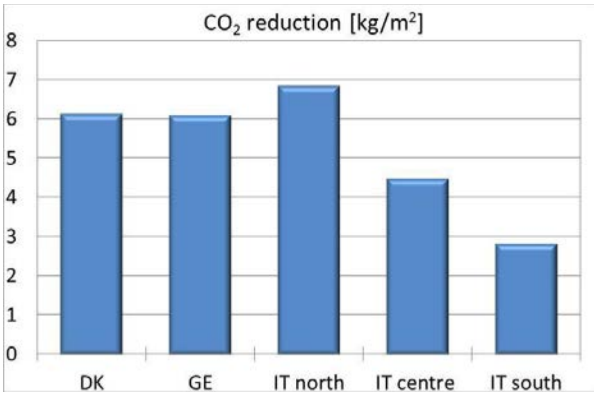


Fig. 4. CO2 reduction

The pay-back time (fig. 5) for the cost of replacing an existing boiler with a condensing boiler was calculated to between 4 and 10 years. In Italy the investment cost being always the same the graph shows increasing values from northern to southernlocations due to the decreasing saved energy. In Denmark a short PBT compare to a long PBT forGermany due to higher investment cost there.The Net Present Value vs. Investment cost per m² area show the profitability of the renovation measure. This index mainly depends on the initial investment and the expected economic lifetime as well as on financial parameters. The results are shown on fig.6. Northern Italy shows the best result, Denmark present a remarkable value due to high saved energy, central and southern Italy follow; Germany present a good NPV due to a longer physical lifetime of the investment respect the other countries.

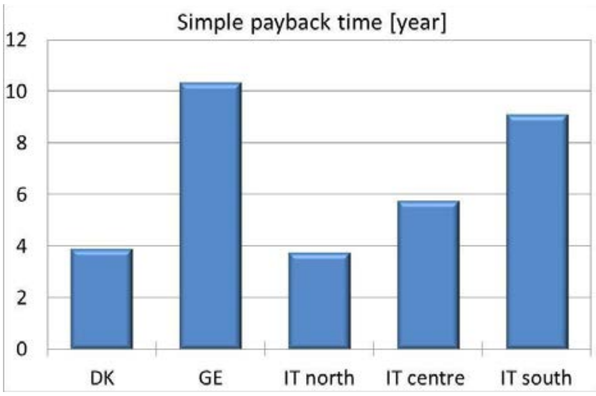


Fig. 5. Simply Pay Back Time

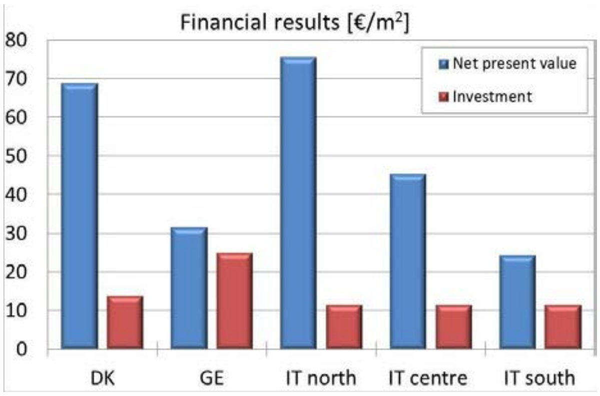
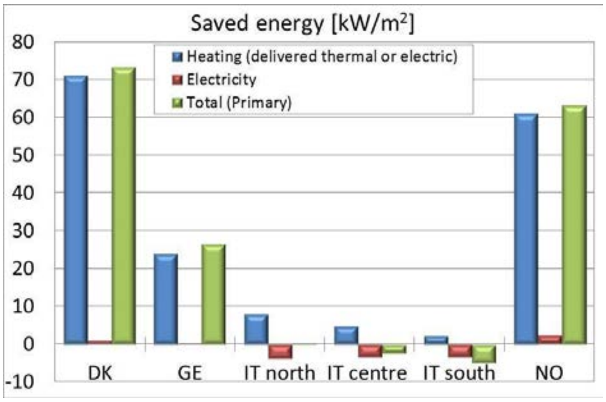


Fig. 6. CO_2Net Present Value vs Investment

2. Installation of a mechanical ventilation system

In the reference buildings of all the countries were natural ventilation except in Norway, where a mechanical exhaust system operated. A mechanical system with heat recovery (MVHR) was selectedas a renovation measure. System efficiency (90%) was used except in Germany (80%). Fig.7 shows results in terms of electricity, heating and total saved primary energy. Best results are found in Denmark and Norway, while in central and southern Italy they are negative due to the fact that electricity consumptions revealed to be higher than heating energy saving.

The environmental impact in terms of CO_2 emission relates to energy savings and show the best results in Denmark and Norway. Germany also reaches appreciable values due to a higher conversion factor. In northern Italy, no CO_2 reduction is found. In central Italy and southern Italy negative values reflect the electric energy consumptions.



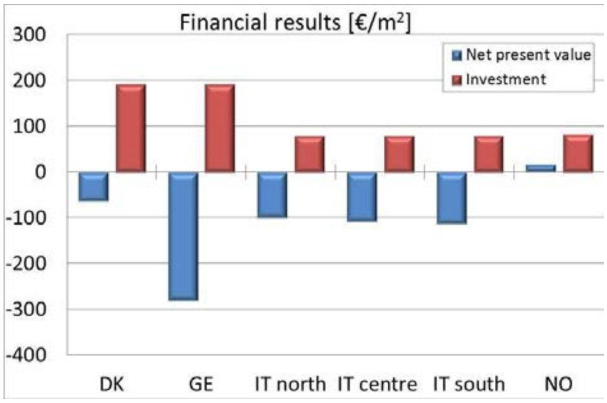


Fig. 7. Saved primary energy (electricity, heating and total) due to MHRV

Fig. 8. Net Present Value vs Investment

The financial evaluation concerns the Net Present Value vs Investment cost per m² of building area: as can be seen in fig.8 high initial investments result in negative NPV in all countries but Norway,where the more critical weather conditions lead to high energy savings. In Italy negative NPV depends on higher air flows of the MHRV system respect those due to natural ventilation. In Denmarkthe NPV is negative mainly due to high investment costs and this is even more evident in Germany.

5. Conclusions

The energy and financial evaluation tool ASCOT was developed further in this work to make it able to handle school buildings. This primarily meant the introduction of four school typologies and the handling of daylight and electrical lighting. The tool was used to screen a number of energy saving measures for four different European countries. Four reports, which can be found and downloaded from the website of the School of the Future project [1] present the results. These have further been used in the guidelines as well as an information tool also produced by this project.

Acknowledgements

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