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Comparison of Calculation Methods in Designing a Nearly Zero Energy Building Refurbishment

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Abstract

RePublic_ZEB [1] is an IEE funded research project, which aims to develop economically sustainable strategies and policies to enforce the refurbishment of the public building stock towards nZEB levels, according to EU 20/20/20 target. In the research project the nZEB regulations of the participant countries were compared, a common definition of nZEB was proposed. In order to develop strategies and guidelines about refurbishment of the public building stock towards nZEBs reference buildings were defined and costs/benefits analyses of the packages of measures for the refurbishments were performed.

To determine the cost optimal and nearly zero energy levels building energetic calculations were performed on a student hostel with three different methods: the Hungarian calculation method according to national standards for building energetic calculations, an excel tool developed by a participant members of the research project and dynamic simulations run with TRNsys.

This paper presents the results of the three different methods.

Keywords - zero energy building, calculation methodologies, dynamic simulation

1. Introduction

1.1. Context

EPBD [2] and EPBD recast [3] required the Member States (MS) to work out a calculation methodology, with which the energy consumption of the buildings can be comparative established. The national requirements, the cost-optimal levels and nearly-zero energy buildings can be rated according to this methodology in every MS. The basis of these methodologies could be the European standards, such as:

- EN 15603:2008. Energy performance of buildings - Overall energy use and definition of energy ratings [4];
- EN ISO 13790:2008. Energy performance of buildings - Calculation of energy use for space heating and cooling [5];
- EN 15316:2007 (series). Heating systems in buildings - Method for calculation of system energy requirements and system efficiencies [6];
- EN 15243:2007. Ventilation for buildings - Calculation of room temperatures and of load and energy for buildings with room conditioning systems [7];
- EN 15193:2007. Energy performance of buildings - Energy requirements for lighting [8];
- EN 15459:2007. Energy performance of buildings - Economic evaluation procedure for energy systems in buildings [9]

As the usage of these standards were not compulsory, there can be differences between the methodologies of the MSs, and therefore the calculated energy consumption of the buildings. The aim of this article is to present the differences between the results calculated with the Hungarian calculation method according to national standards, the European standards and with dynamic simulations. The calculations were made within the RePublic_ZEB project.

1.2. RePublic_ZEB Project

RePublic_ZEB [1] is an IEE funded research project, which aims to develop economically sustainable strategies and policies to enforce the refurbishment of the public building stock towards nZEB levels in the countries of South-East of Europe, according to EU 20/20/20 target. In order to achieve this goal, nZEB definitions were collected, the public building stock was analyzed [10], reference buildings were determined in every participant country, and energy efficiency measures were set up for every building. The expected output is the definition of cost optimal packages of measures for the public buildings towards nZEB.

2. Methodology

In order to get comparable results from the different participant countries, a common excel tool was used to calculate the primary energy consumption of the buildings and the global costs of the packages of measures. As the methodology of this tool can differ from the national methodologies, the calculation of the energy consumptions were made according to them, too. The results were compared with outputs of dynamic simulations.

The common calculation excel tool is developed by Corrado and Paduos at Politecnico di Torino, Italy. The run of this tool consists of two parts: the first part calculates the monthly energy needs and primary energy consumptions of the building according to the European standard EN ISO 15603:2008 [4]; the second part is a sequential search-optimization technique to calculate of the cost-optimal energy performance. The operation of this tool was presented in [11].

The Hungarian calculation method according to national standards presented in the law is based on harmonised EN standards, but contains simplifications on several points. The meteorological data are taken in account with average of the heating or cooling season of the last 100 years, the internal heat gain is attached to the function of the building, etc. All these simplifications are to the benefit of the safety, so the calculated energy consumption can be higher than the measured.

The dynamic simulations were run in TRNsys 17 with the usage of the average of the last 30 years of weather, actual usage times and internal heat gains.

As the cooling energy demand calculation is incredibly simplified in the calculation method according to national standards and the different system losses appear similarly in all the methods, the differences will be shown on the calculation of the heating energy demand. Both the conditions before refurbishment and after each scenarios were calculated and analysed.

3. Calculations

3.1. Reference building

The reference building is a student hostel located in South-East of Budapest, Hungary. The six-storey building consists of two blocks of rooms connected with a corridor on every storey. The walls are made of reinforced concrete panels built in early 1980-ies, the windows are double-pane windows and about 30 years old. The main parameters are shown in Table 1.

Table 1. Main preferences of the reference building

Gross volume	V_g	22509	m^3
No. floors	n	6	-
Net floor area	$A_{f,n}$	8311	m^2
Area of building envelope	A_{env}	6494	m^2
	A_{env}/V_g	0,289	

The U-values of the structures before the refurbishment are shown in Table 2.

Table 2. U-values of the structures before the refurbishment

Walls	U_{wl}	1,12	W/m^2K
Windows	U_w	2,6	W/m^2K
	g_w	0,75	-
Roof	U_r	0,53	W/m^2K
Floor	U_f	0,3	W/m^2K

3.2. Energy efficiency measures

The Energy efficiency measures applied to the structures (walls, windows and roof) of the reference building are listed in Table 3. All the measures were designed to perform the cost-optimal requirements and also higher levels were analysed.

Table 3. Energy efficiency measures

Structure		Nr.	Value
Walls	U_{wl} [W/m^2K]	1	0,23
		2	0,21
		3	0,19
Windows	U_w [W/m^2K]	1	1,1
		2	1,0
	g [-]	1	0,61
		2	0,33
Roof	U_r [W/m^2K]	1	0,17
		2	0,16
		3	0,15

The packages of measures can contain only one measure, or even three measures, one for each structures. In the calculations all the packages of measures containing only one measure, the package containing all the lowest quality measure, the package containing all the highest quality measures were analysed. An additional package contains the walls and roof with the lowest heat transmittance and windows with higher g-value. All the calculated packages are shown in Table 4.

Table 4. Packages of measures

No. of package	Walls	Roof	Windows
1	existing	existing	existing
2	1	existing	existing
3	2	existing	existing
4	3	existing	existing
5	existing	1	existing
6	existing	2	existing
7	existing	3	existing
8	existing	existing	1
9	existing	existing	2
10	1	1	1
11	3	3	2
12	3	3	1

4. Results

The results show that the calculation method according to national standards results higher energy demand than the other two methodologies which have only small deviation.

The results of the calculations are shown on Figure 1. The differences between the results are shown on Figure 2. The heating energy demand with the existing structures is 60 ± 2 kWh/m^{2}a according to the excel tool and the simulations, but much higher, 72,2 kWh/m^{2}a according to the calculation method of the national standards. The results with refurbishing only the walls are 46,8 – 48,0 kWh/m^{2}a, the difference between the excel tool and the simulation is only 1,1 – 1,6 %, but it is 62,5 – 63,1 kWh/m^{2}a calculated with the calculation method according to national standards, which is more than 30% higher than the other results.

The calculations of refurbishment of the roof have a slight deviation: the differences between the excel tool and the simulation are higher: 6,7 – 6,8 %, but the differences between the simulation and the calculation method according to national standards are lower: 16,9 – 17,0 %. The refurbishment of the windows show the highest difference with the excel tool, 10,0 – 20,0 %, close to the calculation method according to national standards: 13,1 – 20,3 %. The results show, that the windows with lower U-value and lower g-value can result higher heating energy demand, but this does not appear in the calculations with the excel tool. The mixed packages show differences according to the windows' parameters: the packages containing windows with higher U-value show only 3,9 – 4,5 % difference between the calculation with simulation and the excel tool, but 45,7 – 46,9 % between the calculation with simulation and the calculation method according to national standards. The package containing the windows with lower U-value shows 19,0 % difference between the calculation with simulation and the excel tool, and 33,5 % difference between the calculation with simulation and the calculation method according to national standards.

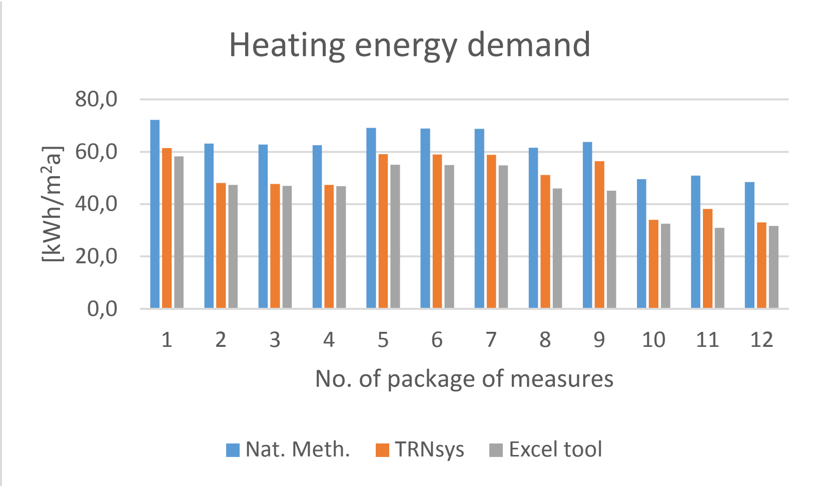

Fig. 1 The heating energy demand of the different packages of measures calculated with different methodologies

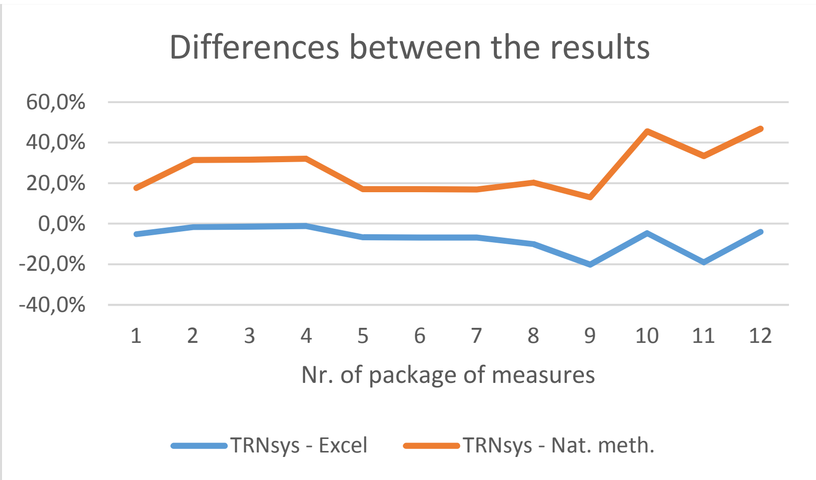

Fig. 2 The differences of the results calculated with different methodologies

The possible savings predicted by the different methodologies were also analysed. The results are shown on Figure 3, the differences between the results are shown on Figure 4.

In most cases the calculation method according to national standards showed the lowest predicted savings and the simulation showed the highest savings. The highest the difference is when the package contains the windows with low g-value, which might be a bug in the software.

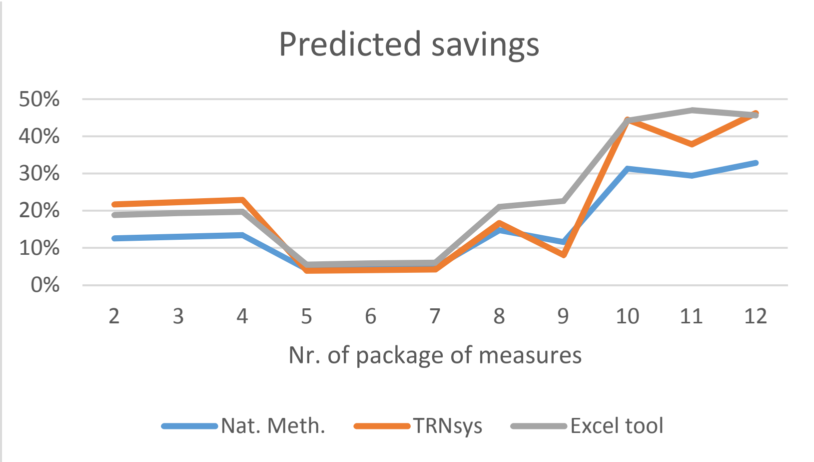

Fig. 3 The possible savings predicted by different methodologies

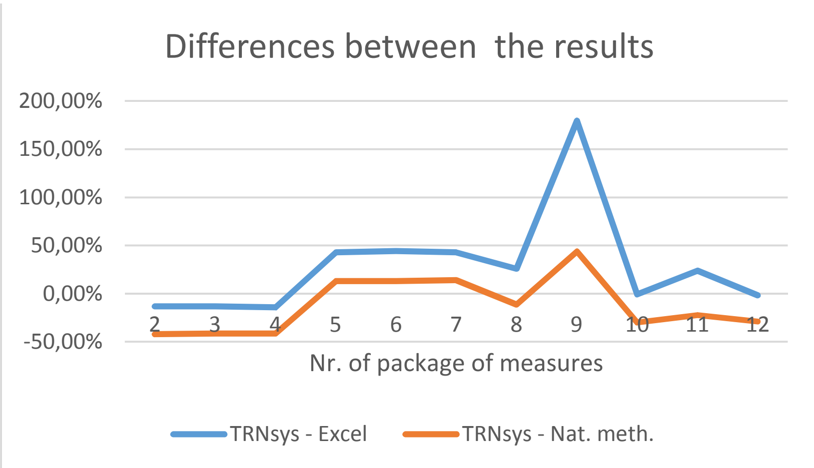

Fig. 4 The differences of the results calculated with different methodologies

5. Conclusions

In the present work the same packages of measures for refurbishment of a public building were calculated with different methodologies. The results showed, that the simplifications of the Hungarian calculation method according to national standards can result higher calculated heating energy demand, and lower predicted energy saving. Besides the excel tool based on the European standards can be much closer to the result of a dynamic simulation. This study highlights the importance of reasonable choice of methodology when calculating the effects of the refurbishment of a building.

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