ENRtool – BesTest results

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Energy Performance Assessment
of Existing Non-Residential Buildings

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Contents

1 Introduction

The calculation method (Soethout et al. 2006) of the ENRtool (Wittchen & Grau, 2007), developed in the EPA-NR project (Energy Performance Assessment for Existing Non Residential Buildings - EIE/04/125/S07.38651) is based on several available sources. Below a short overview of some of these sources, showing the global similarity between the methods is found.

The most important source of information consists of the emerging CEN standards. Wherever these standards are not available or are leading to more complexity than desirable for energy performance calculations, other sources have been used, like EPA-ED (Berben, 2004) and national developments, like the Dutch EPA-U (Berben & Elkhuizen, 2004).

1.1 Calculation structure of CEN

The calculation structure proposed by the CEN standards consists of the following modules (work items, WI):

- 'Component' level (WI-18+19+23-25+27+28+31):
    - Definitions and terminology;
    - External climate data;
    - Indoor conditions;
    - Overheating and solar protection;
    - Thermal performance of building components;
    - Ventilation and air infiltration.
- System and building energy needs for (WI-7-17+20-22+26):
    - Energy use for space heating and cooling (WI-14);
    - Heating systems (WI-7-10);
    - Cooling systems (WI-12);
    - Humidification;
    - Dehumidification;
    - Hot water (WI-11);
    - Lighting (WI-13);
    - Ventilation systems (WI-20+21).
- Total delivered energy; WI-4:
    - Procedures for asset and operational energy rating;
    - Procedures for recommended energy saving measures;
    - Specific procedures / input for existing buildings.
- Overall energy use, primary energy, CO_2 emissions; WI-2+4.
- Ways of expressing energy performance (leading to energy performance, to be compared to requirement); WI-1+3.
- Energy certification of buildings (leading to certificate); WI-1+3.

CEN often provide more methods for the same calculation, on different levels of detail. For the use of CEN work items in EPA-NR, it was necessary to choose which methods to implement. The most important work item for incorporation into the EPA-NR calculation engine was thus WI-14 on space heating and cooling.

The calculation method in ENRtool is based on a monthly quasi stationary method where space heating and cooling is calculated from the building model exposed to monthly average values for the standard climate, valid for the region where the building is located.

2 BesTest of ENRtool

The BestTest (Judkoff & Neymark, 1995) method was developed in an International Energy Agency (IEA) project. The method was developed for systematically testing of whole building energy simulation programs and diagnosing the sources of predictive disagreement. The final report contains results of eight state-of-the-art software tools available in the United States and Europe for various test cases each addressing a specific energy transport phenomenon.

Comparison of results from a simple tool like the ENRtool using monthly quasi stationary calculations with sophisticated, dynamic simulation tools as used in the BesTest comparison procedure is not a trivial task. Taken that into account, it was decided to run a limited number of BesTest cases (600-640 and 900-940) for the Denver climate. These cases were selected because of their nature, making it possible to do a reasonable comparison with the ENRtool.

2.1 Climate data

The Denver climate is not very applicable for a European energy calculation tool, but it has been used extensively for this kind of tests and results from other tools do exist for comparison.

- Annual average outdoor temperature: 9.71 °C,
- Annual horizontal solar: 1831.82 kWh/m² per year,
- Annual diffuse solar: 492.34 kWh/m² per year,
- Heating degree days: 3636.2 °C-days (base 18.3 °C),
- Cooling degree days: 487.1 °C-days (base 18.3 °C).
-

2.2 Building model

The building used in the BesTest case is a simple shoe-box shaped building without any real systems for maintaining the indoor climate and without much likeness with a real building. The energy consumption for space heating and cooling is thus energy demands, as the efficiency of the systems are not taken into account.

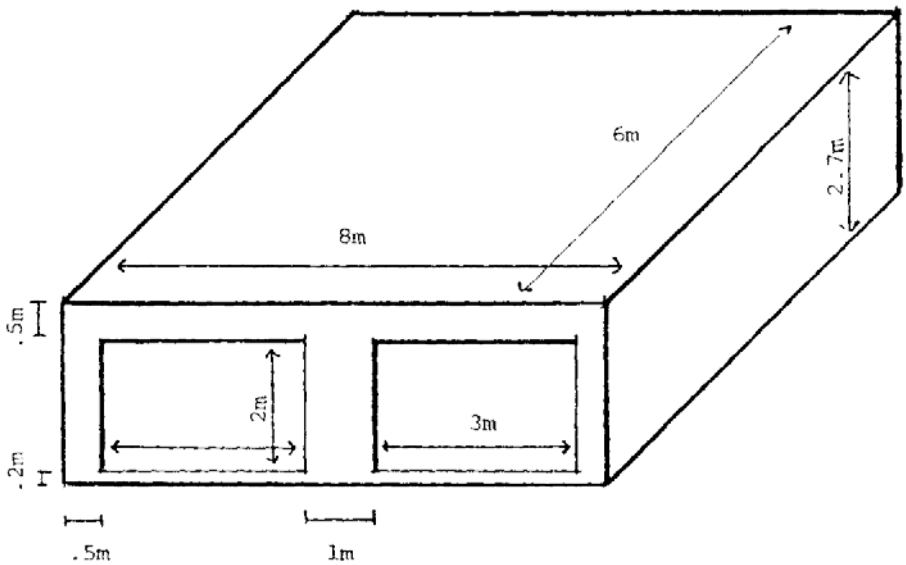

Figure 1. Isometric view if the BesTest example building, with indication of internal measures.

Building characteristics:

- Internal volume: 129.6 m³,
- Infiltration air change rate: 0.5 ACH, corresponding to 0.41 ACH at sea level,
- Heating set-point: 20 °C,
- Cooling set-point: 27 °C,
- Internal loads: 200 W, 8760 hours per year.

Table 1. Thermo-physical properties of the BesTest example building in series 600 and 900.

	600-series (lightweight)		900-series (heavyweight)	
Window:				
U-value	3.0	W/m²K	3.0	W/m²K
g-value	0,787		0,787	
Constructions (U-value):				
Walls:	0.514	W/m²K	0.512	W/m²K
Floor:	0.039	W/m²K	0.039	W/m²K
Roof:	0.318	W/m²K	0.318	W/m²K
Thermal mass:				
External walls	924.0	kJ/K	9219.0	kJ/K
Floor	936.0	kJ/K	5376.0	kJ/K
Roof	426,5	kJ/K	426.5	kJ/K
Spec. int. heat capacity[1)]	48	kJ/m²K	313	kJ/m²K
Spec. int. coupling coefficient $(\Sigma UA)/A_{gross}$	2.17	W/m²K	2.13	W/m²K

1) The internal specific heat capacity is, according to CEN TC89/WG4/N284, calculated as the thermal mass of the innermost 10 cm of all constructions divided by the heated floor area.

2.3 BesTest cases

Each BesTest case investigates a different energy transport phenomenon individually and can thus be used to identify possible problem areas in the simulation tools being compared.

Table 2. BesTest case used for verification of the ENRtool.

Case	Set-point	Glass (m²)	Orientation	Shade (m)
600	20 / 27	12	S	None
610	20 / 27	12	S	1.0 m H[2)]
620	20 / 27	6 / 6[3)]	E & W[3)]	None
630	20 / 27	6 / 6[3)]	E & W[3)]	1.0 m H[2)]
640	set back[1)]	12	S	None
900	20 / 27	12	S	None
910	20 / 27	12	S	1.0 m H[2)]
920	20 / 27	6 / 6[3)]	E & W[3)]	None
930	20 / 27	6 / 6[3)]	E & W[3)]	1.0 m H[2)]
940	set back[1)]	12	S	None

1) Night set-back to 10 °C from 23:00 to 07:00. Modelled as a time-weighted decline in heating set-point to 16.67 °C.
2) Shading coefficient is calculated in a dynamic thermal simulation tool and given as an annual average shading coefficient in ENRtool (see Figure 2).
3) The 12 m² windows moved from the South facade to 6 m² facing East and 6 m² facing West (see Figure 3 and Figure 4).

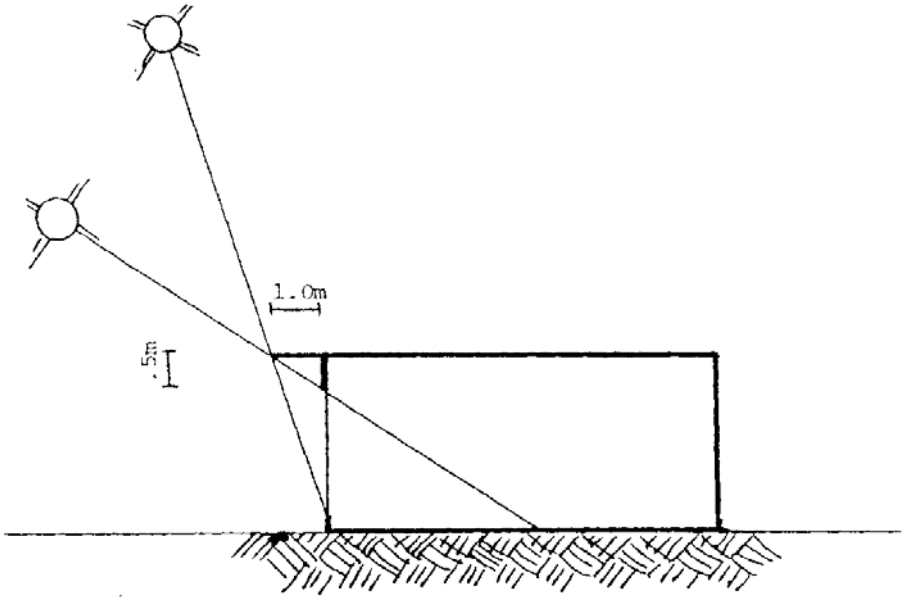

Figure 2. Sketch of horizontal shading over the South facing window.

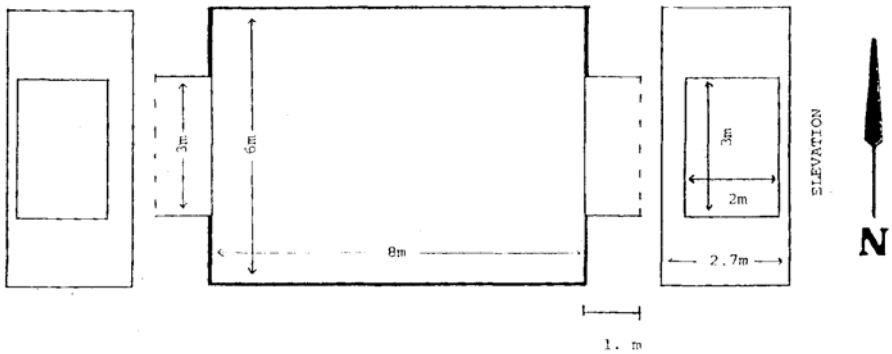

Figure 3. Plan of BesTest example building in the cases where the windows are moved to the East respectively West facing facade and with shading around the windows.

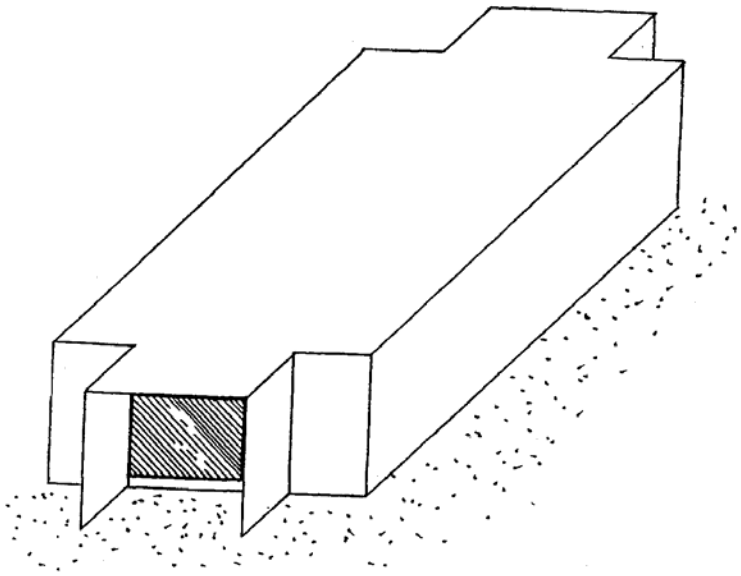

Figure 4. Isometric view of BesTest example building with East and West facing windows with shading around the windows.

3 Results

The results regarding annual heating and cooling demand calculated by the ENRtool and the dynamic simulation tools that were part of the original BesTest performed by IEA are shown in the figures in the following.

Heating demand is shown in red colours and cooling demands in blue colours. Results from the ENRtool are shown as a green bar.

The two horizontal lines in each graph indicate the 95 % confidence interval based on the results of the eight tools in the original BesTest project. There is thus a 95 % probability that the “true” value is between this upper and lower limit.

3.1 Case 600

Case 600 is the basic lightweight building model with all-time heating and cooling set-points of 20 respectively 27 °C. The infiltration rate is 0.5 air changes per hour, corrected to 0.41 air changes per hour as input in the ENRtool, because of the correction due to altitude at the geographical location of the building.

The building has two 6 m² windows located in the South facade of the building.

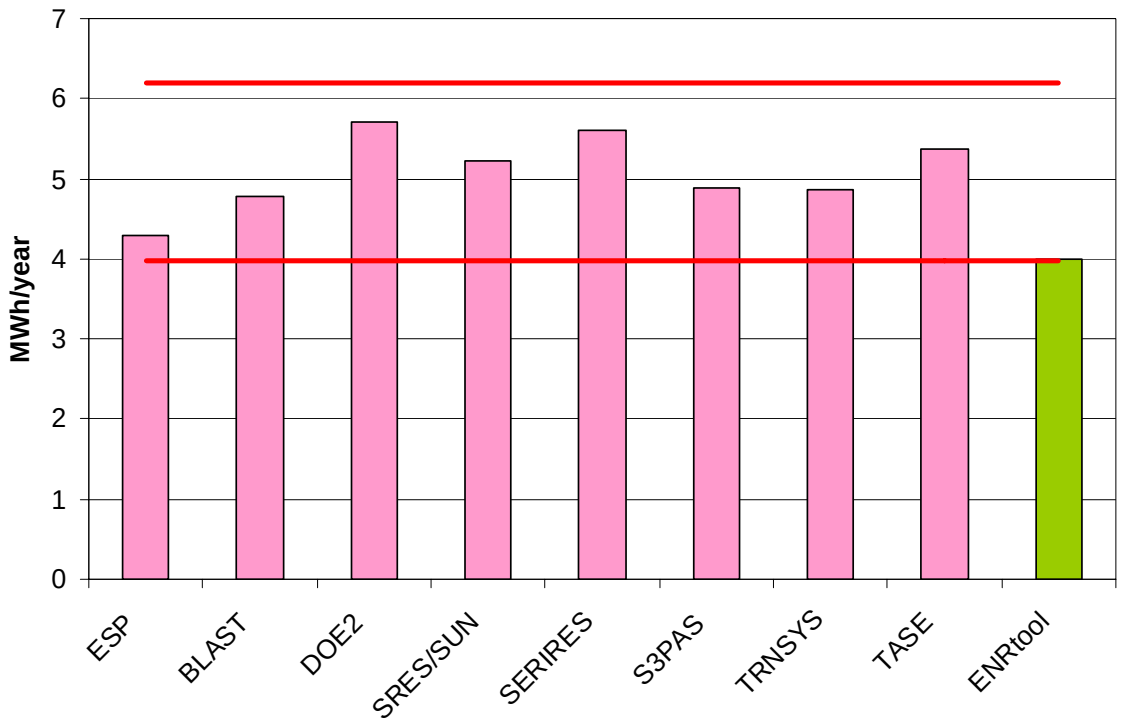

Figure 5. Annual heating demand in case 600.

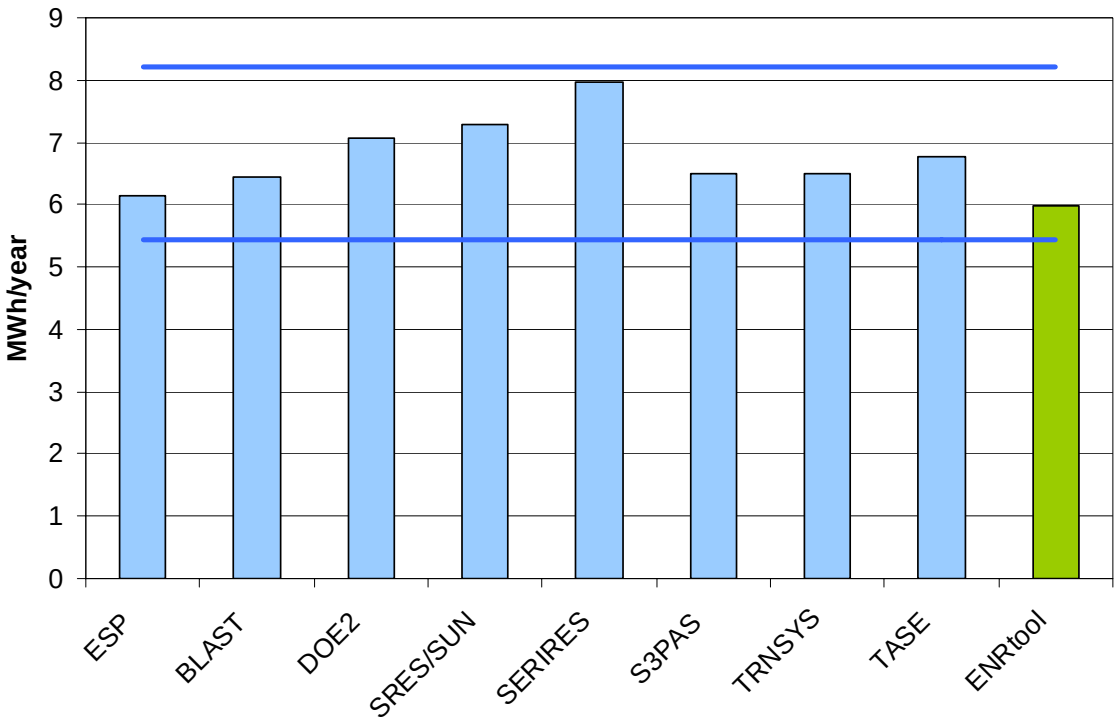

Figure 6. Cooling demand in case 600.

3.2 Case 610

Compared to case 600 an external, horizontal shading device was added to the building model. The shading device extends 1 meter from the facade and is located 0.5 meter above the upper edge of the South facing windows.

ENRtool is not capable of calculating the shading factor due to overhangs directly in the interface. The shading coefficient has thus been calculated in the dynamic simulation tool BSim (Wittchen et al, 2000-2007), using the same climate data as being used in the ENRtool. The shading factor was calculated as the total annual amount of solar radiation on the South facing windows in the case with the horizontal shading device (case 610) divided by the amount of solar radiation reaching the windows without shading (case 600). The shading correction factor was calculated to be 0.841218, which was applied to the transparent constructions as the F_o factor in the generic interface of the ENRtool.

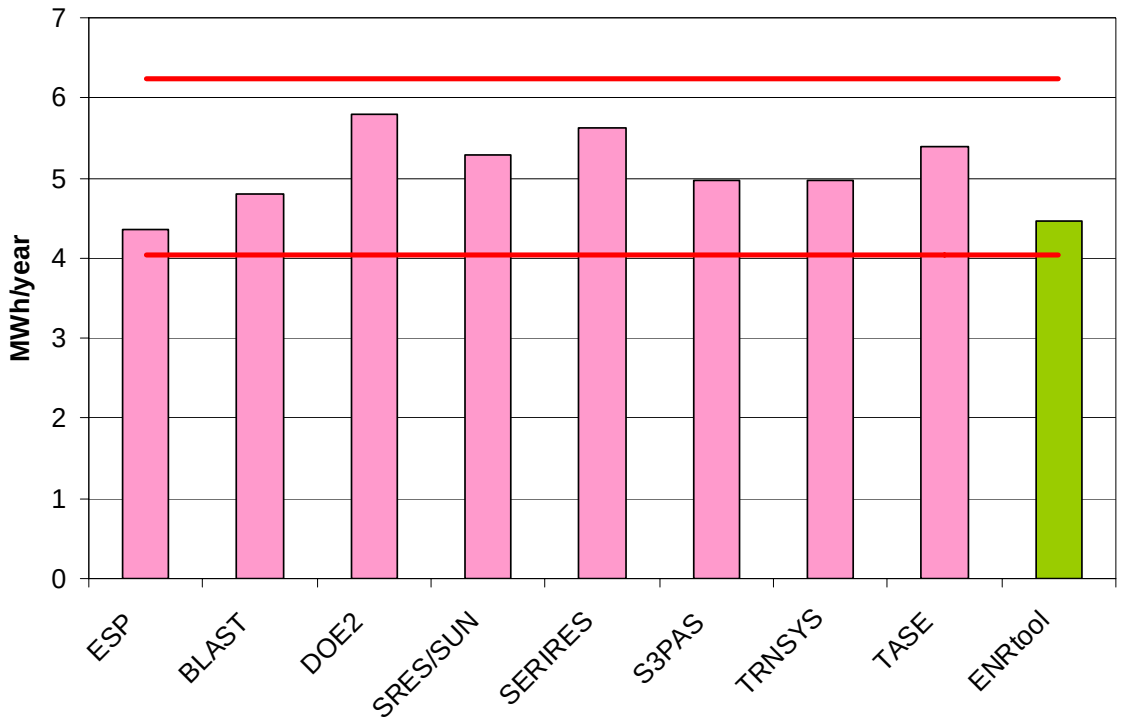

Figure 7. Annual heating demand in case 610.

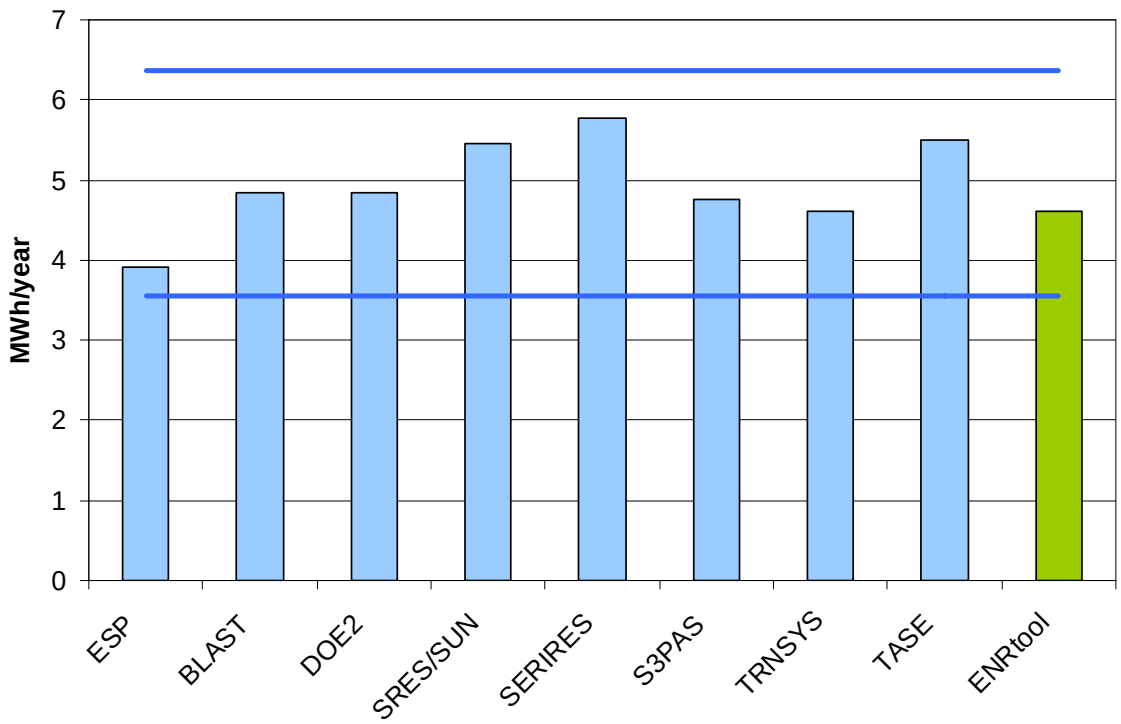

Figure 8. Annual cooling demand in case 610.

3.3 Case 620

Compared to case 600, case 620 have the two windows moved from the South facade to the East and West facade respectively. There are thus 6 m² windows facing East and 6 m² facing West.

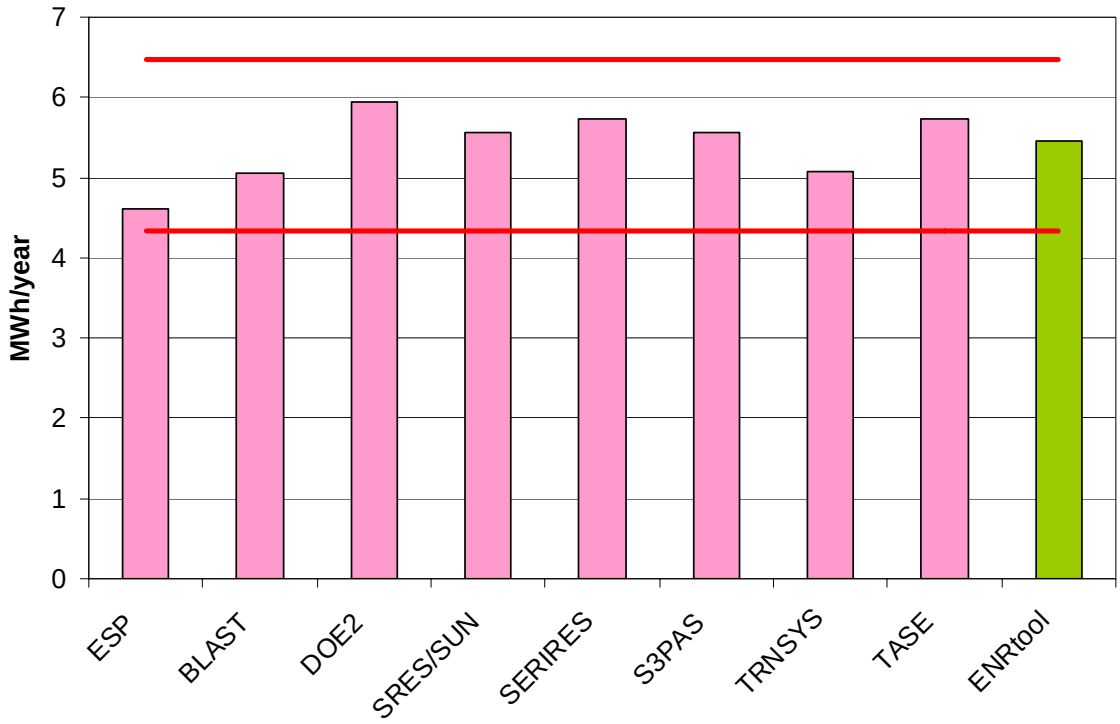

Figure 9. Annual heating demand in case 620.

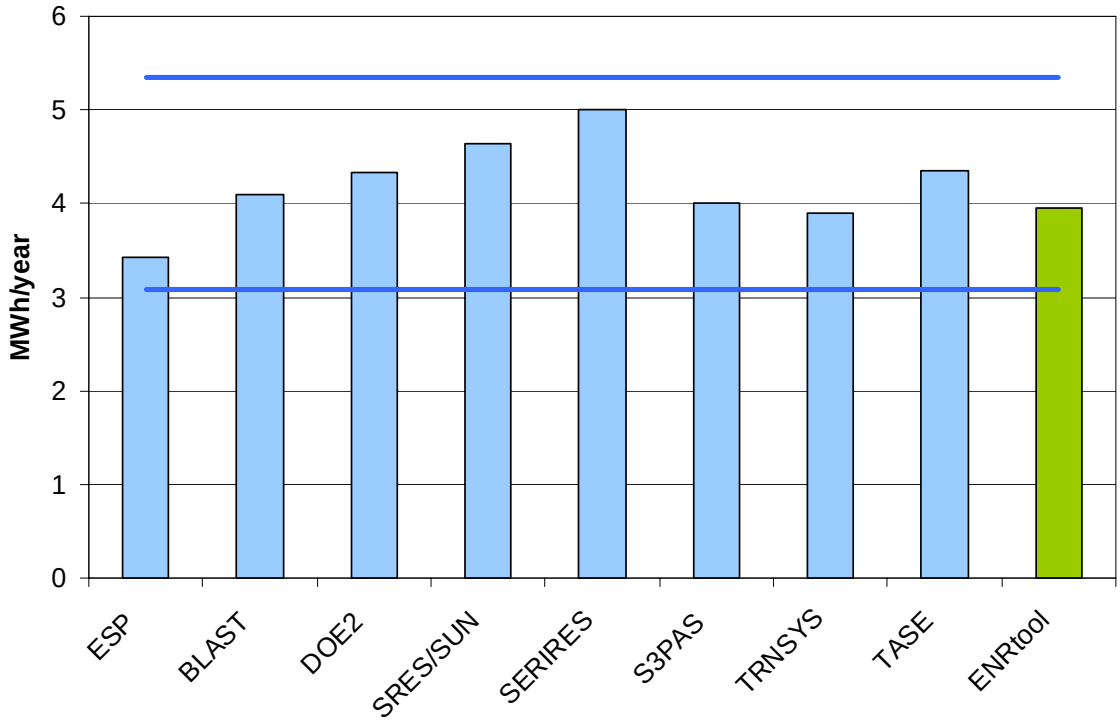

Figure 10. Annual cooling demand in case 620.

3.4 Case 630

Compared to case 620, horizontal and vertical shading devices have been added to the East and West facing windows. The geometry of the shading devices are as given in Figure 3 and Figure 4.

As for case 610, ENRtool can not calculate these shading coefficients in its generic user interface, and it has thus been calculated in the dynamic simulation tool BSim. The shading coefficient was calculated to be 0.65233.

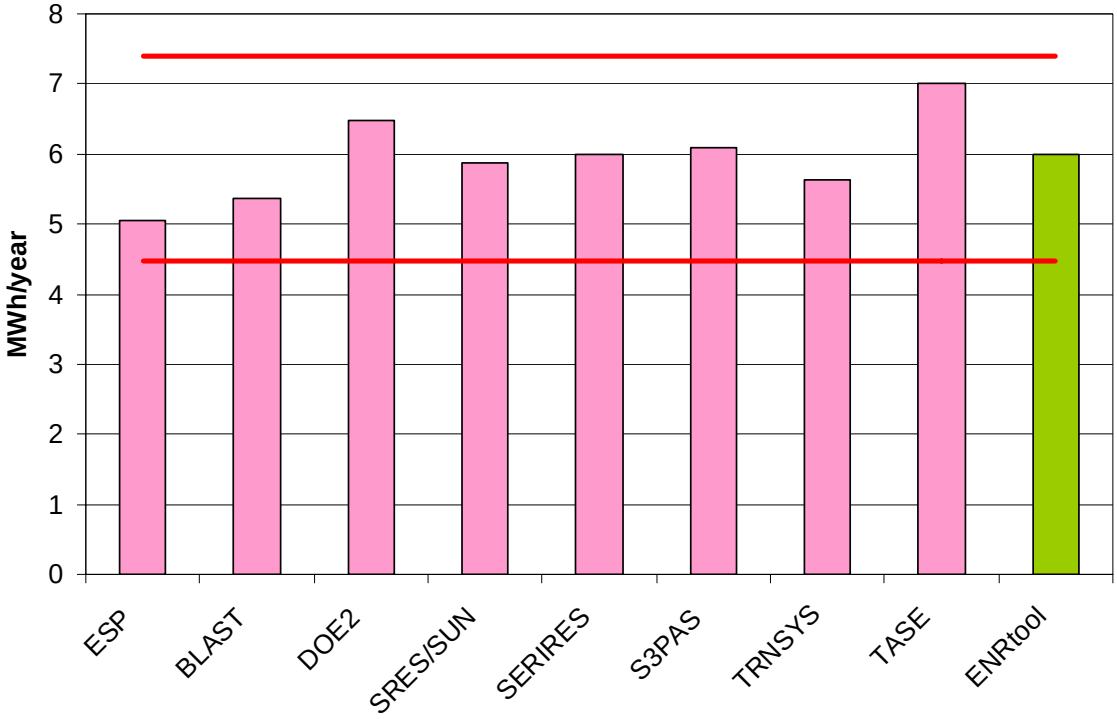

Figure 11. Annual heating demand in case 630.

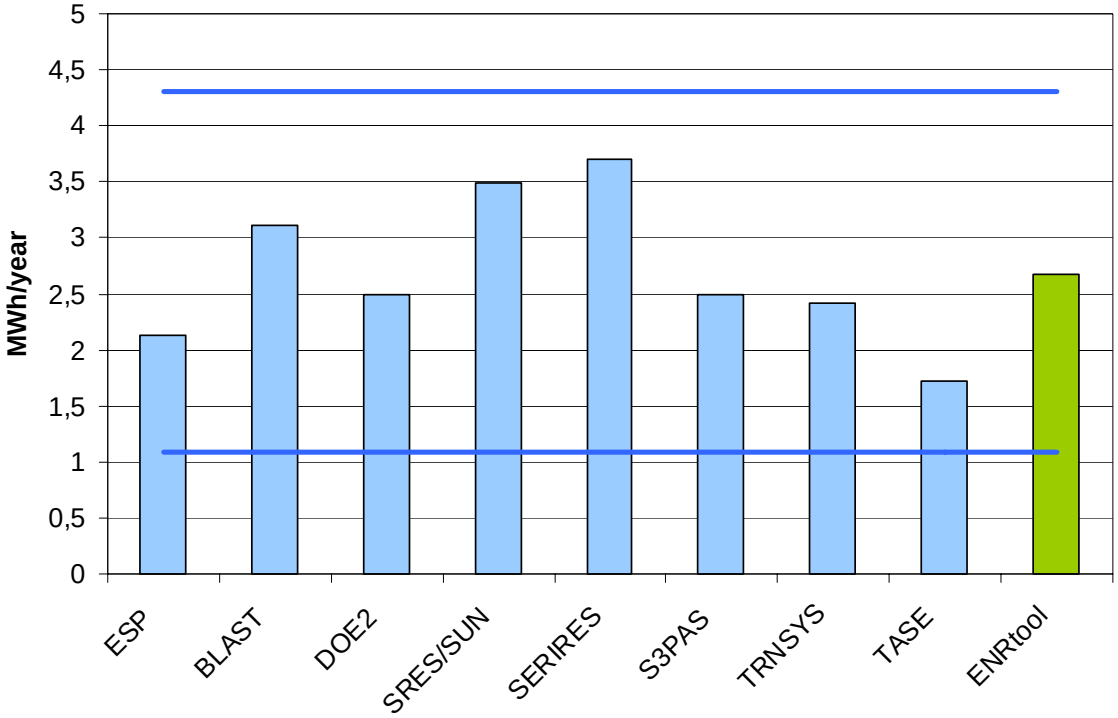

Figure 12. Annual cooling demand in case 630.

3.5 Case 640

Case 640 is similar to case 600, but with night set back of the heating set point from 20 °C to 10 °C from 23:00 to 07:00. This control strategy can not be modelled directly in the ENRtool and was thus modelled as a time-weighted decline in heating set-point to 16.67 °C at all time.

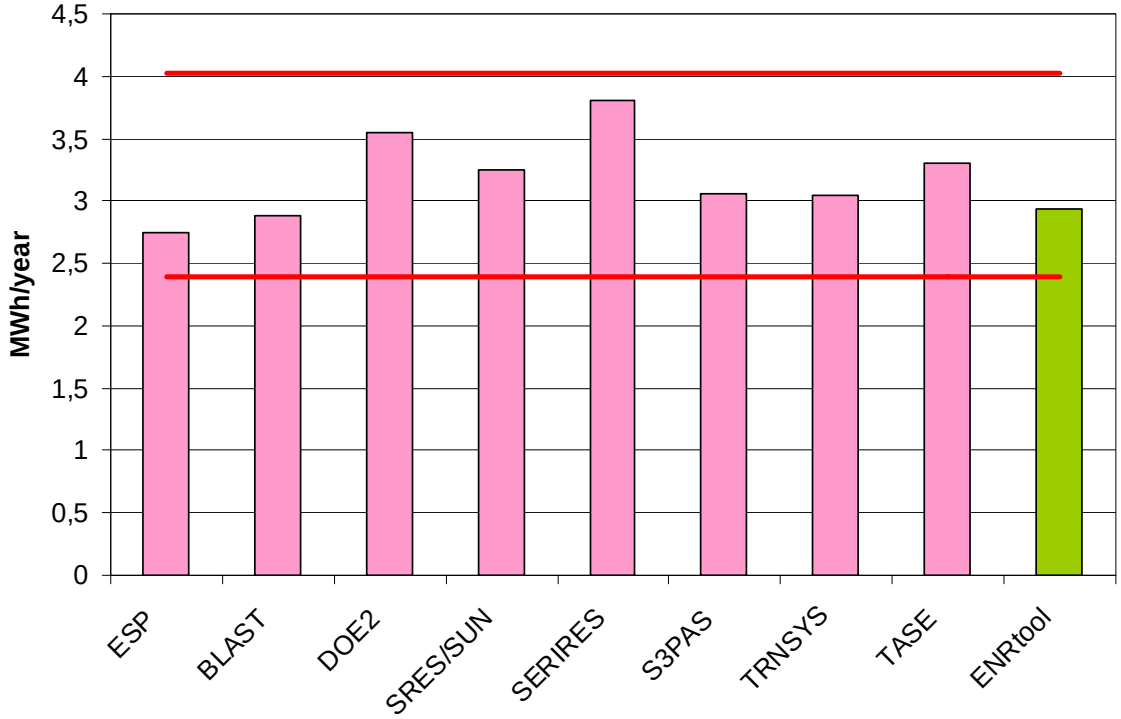

Figure 13. Annual heating demand in case 640.

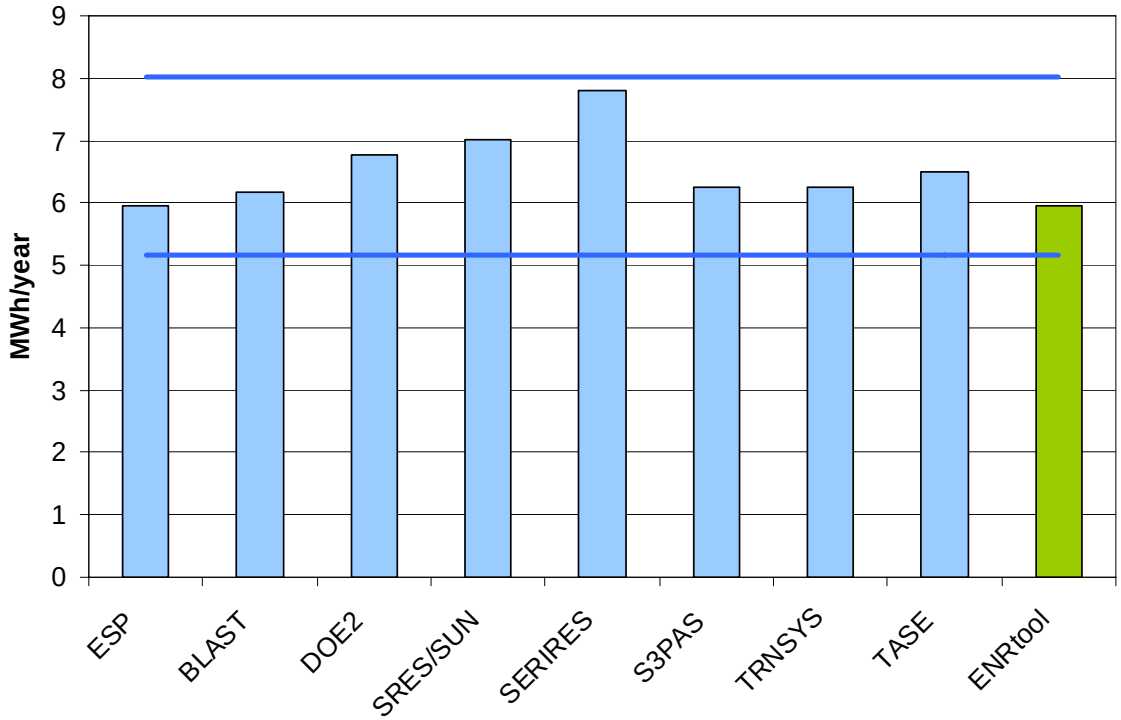

Figure 14. Annual cooling demand in case 640.

3.6 Case 900

In the 900-series the internal heat capacity of the building has been changed to a higher value, which is more in line with what is found in real buildings. Beside this, the cases are identical to the cases in the 600-series.

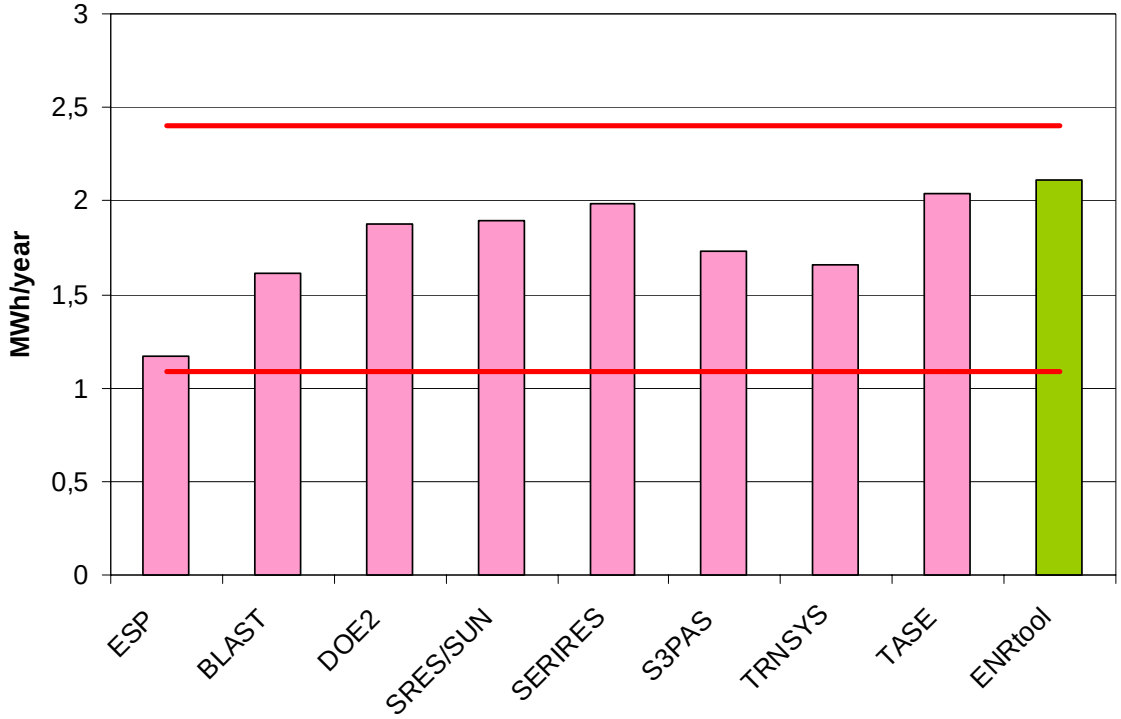

Figure 16. Annual heating demand in case 900.

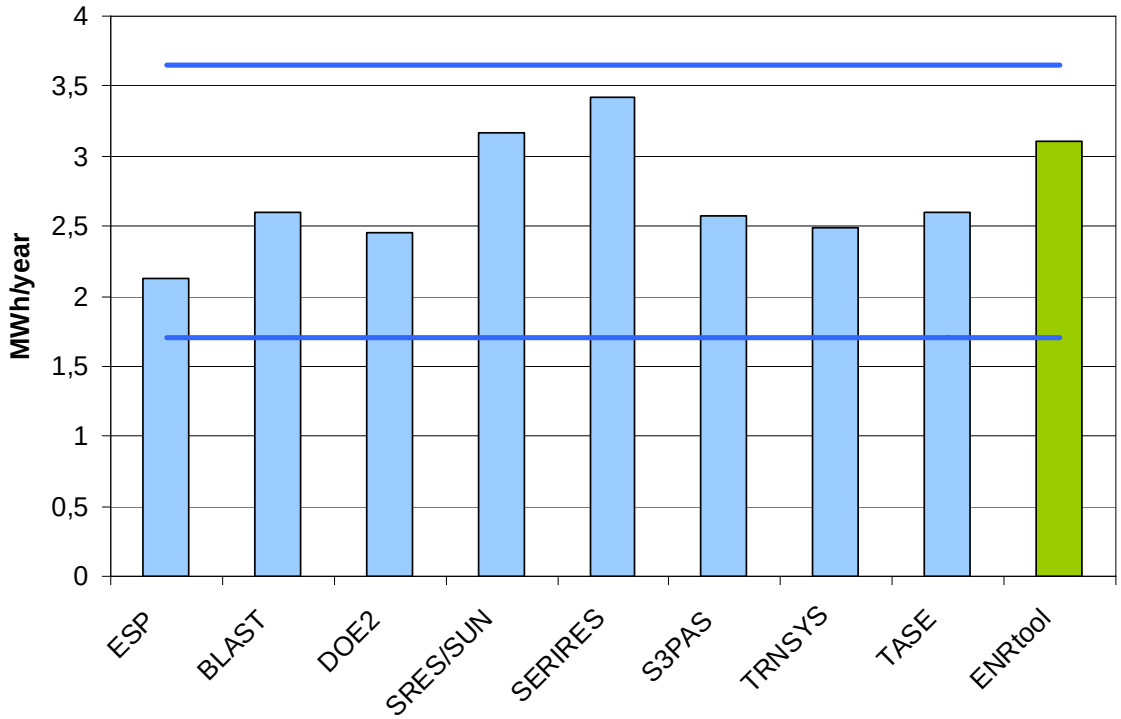

Figure 17. Annual cooling demand in case 900.

3.7 Case 910

Like case 610, equipped with a horizontal shading device 0.5 meter above the South facing windows.

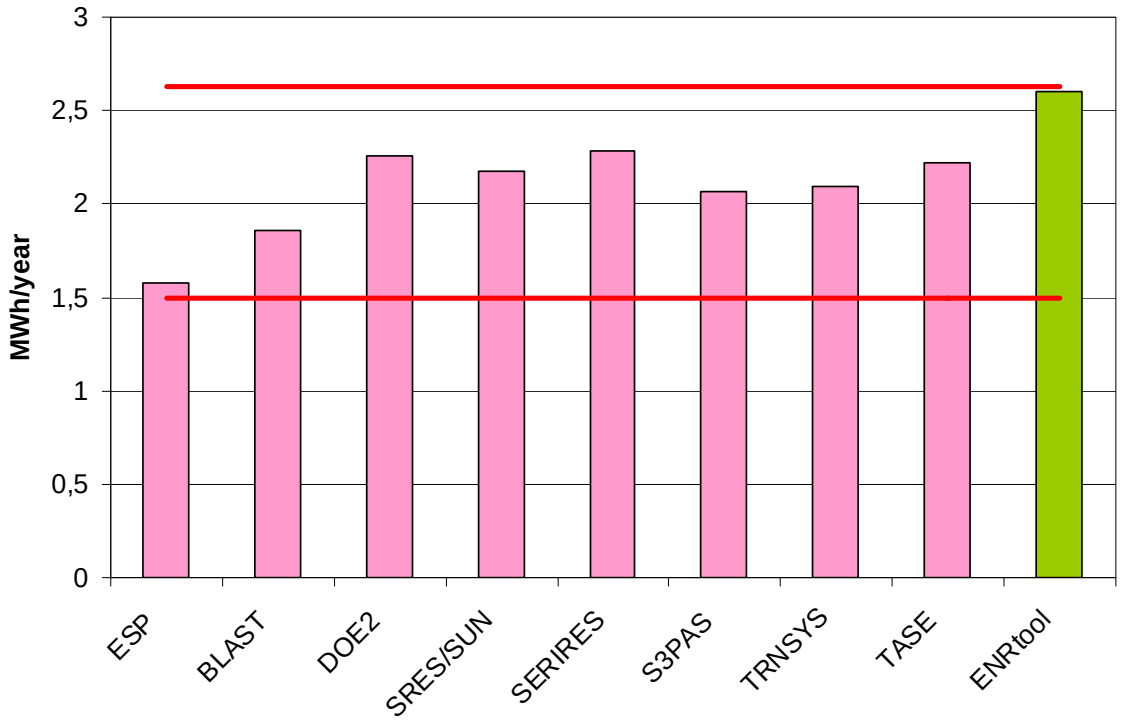

Figure 18. Annual heating demand in case 910.

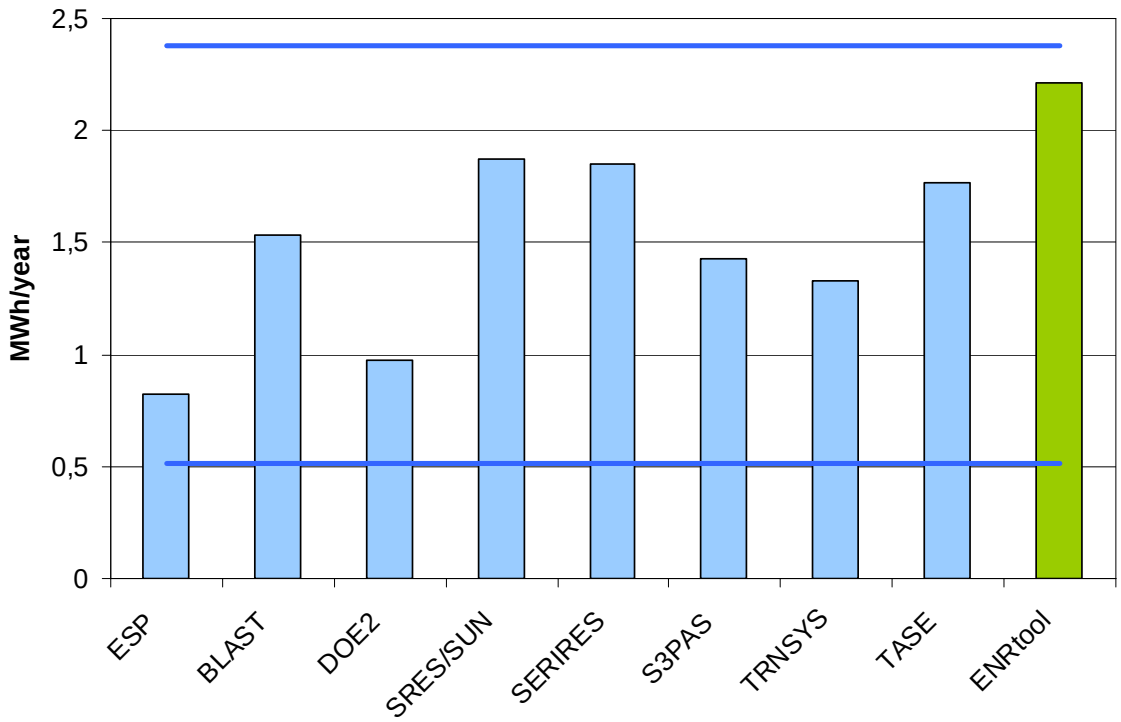

Figure 19. Annual cooling demand in case 910.

3.8 Case 920

Like case 620, case 920 have 6 m² windows moved from the South facade to the East facade and 6 m² to the West facade.

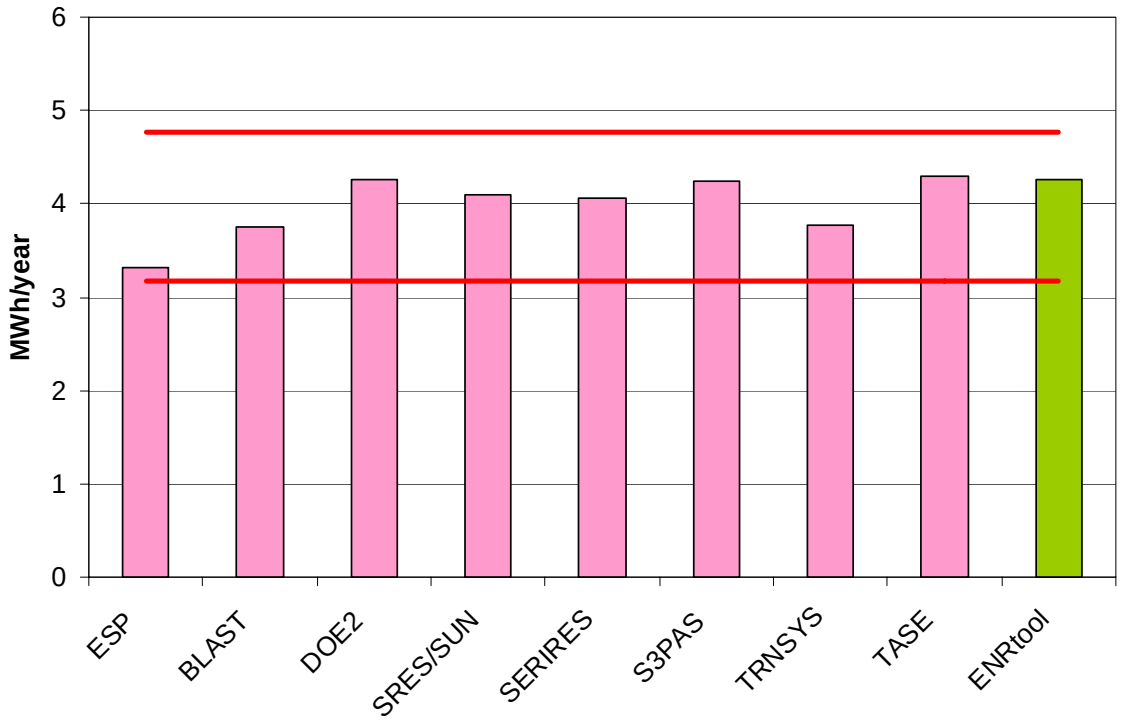

Figure 20. Annual heating demand in case 920.

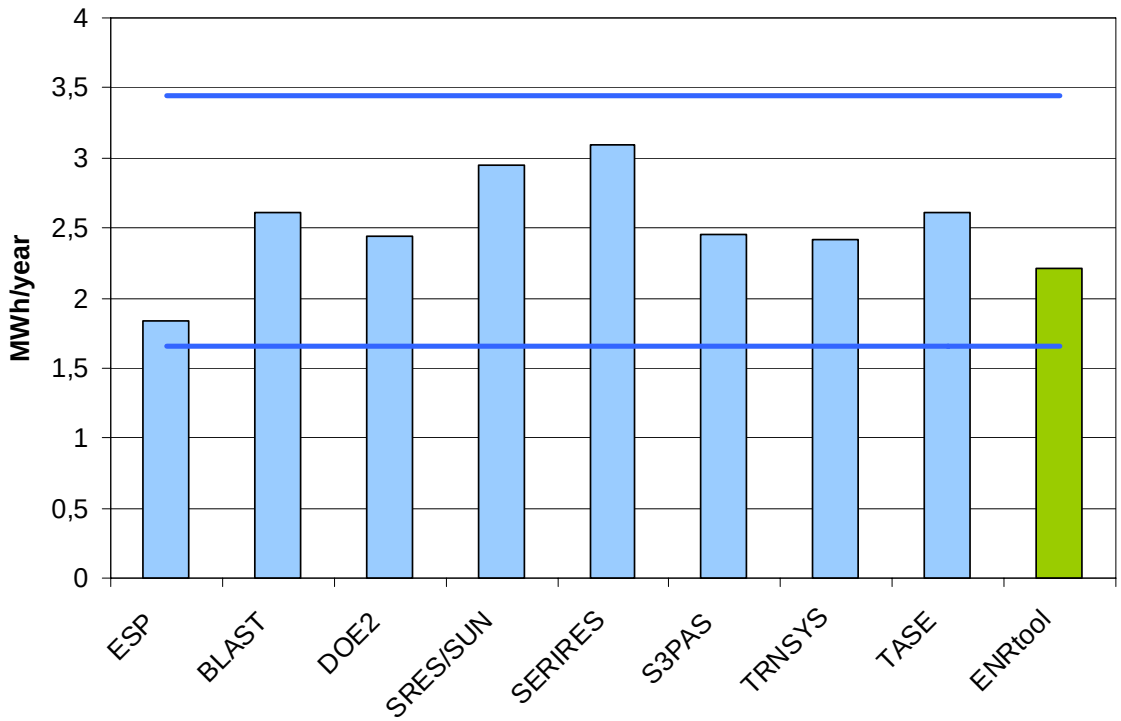

Figure 21. Annual cooling demand in case 920.

3.9 Case 930

Case 930 is like case 920 but equipped with horizontal and vertical shading devices on the East and West facing windows.

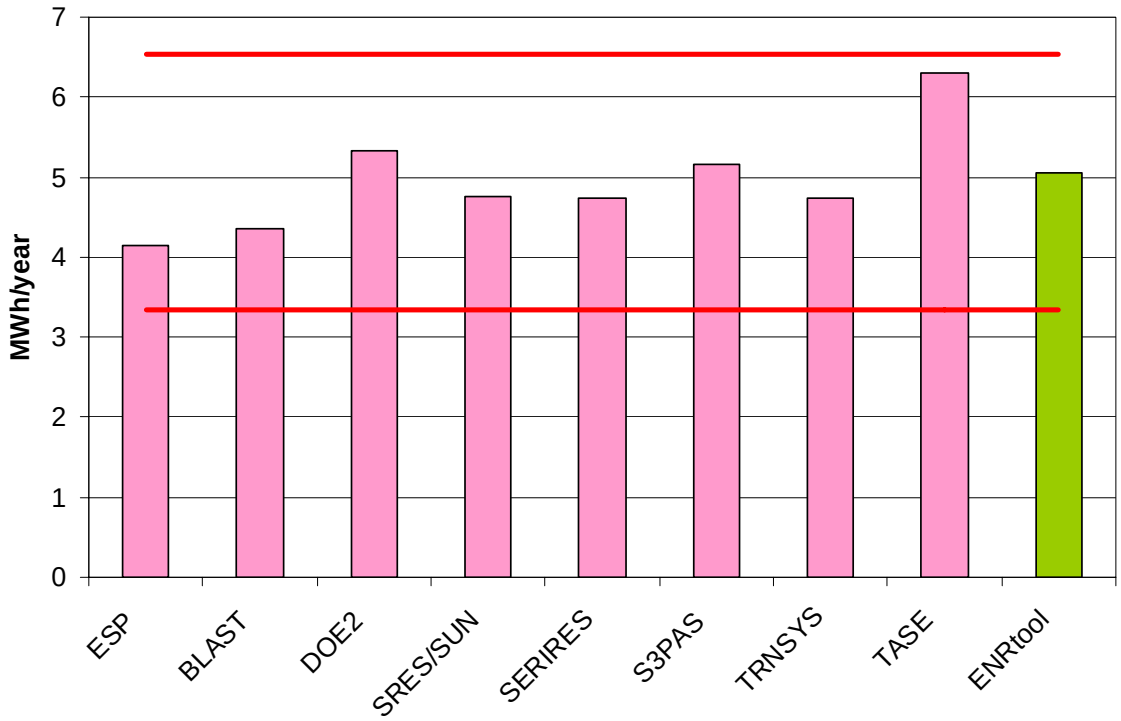

Figure 22. Annual heating demand in case 930.

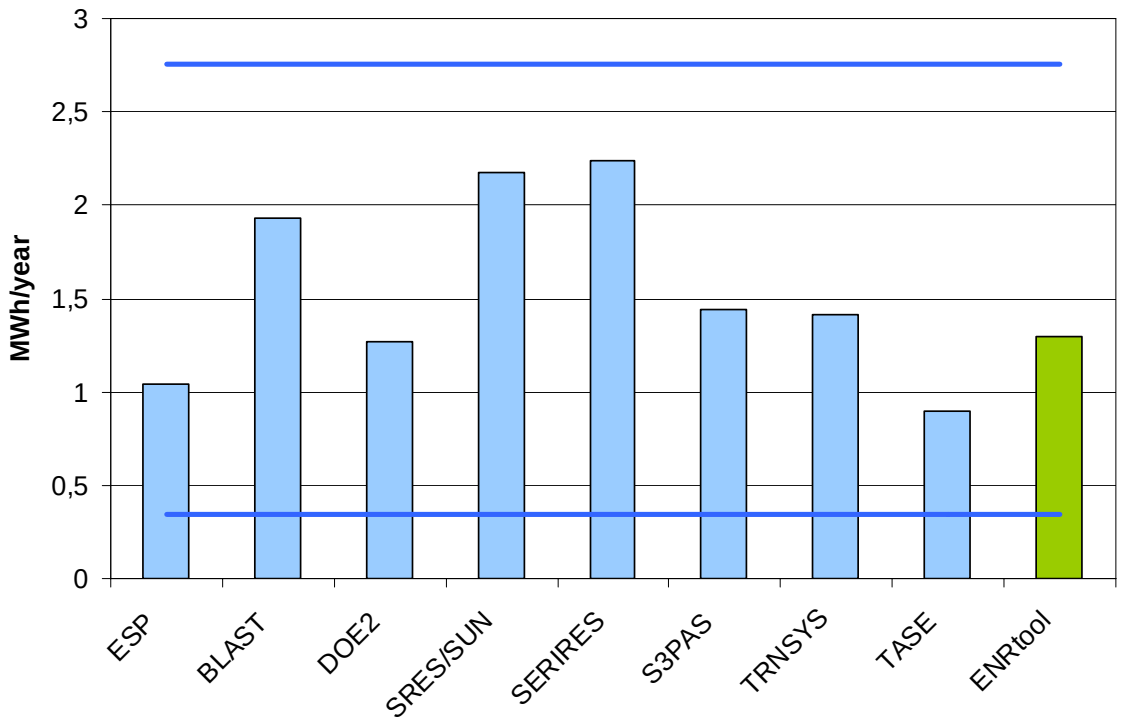

Figure 23. Annual cooling demand in case 930.

3.10 Case 940

Like case 640, case 940 is identical with case 900 in geometry, but with a night set-back to 10 °C for 8 hours each night. This is modelled as a general set point temperature of 16.67 °C.

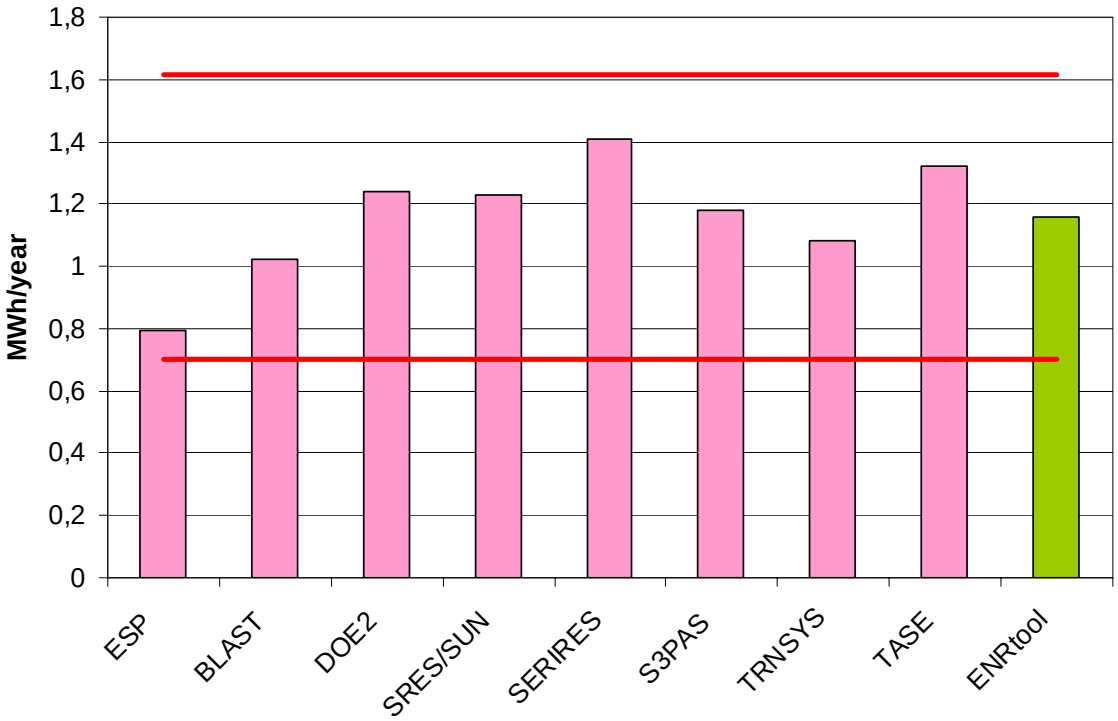

Figure 24. Annual heating demand in case 940, night set-back.

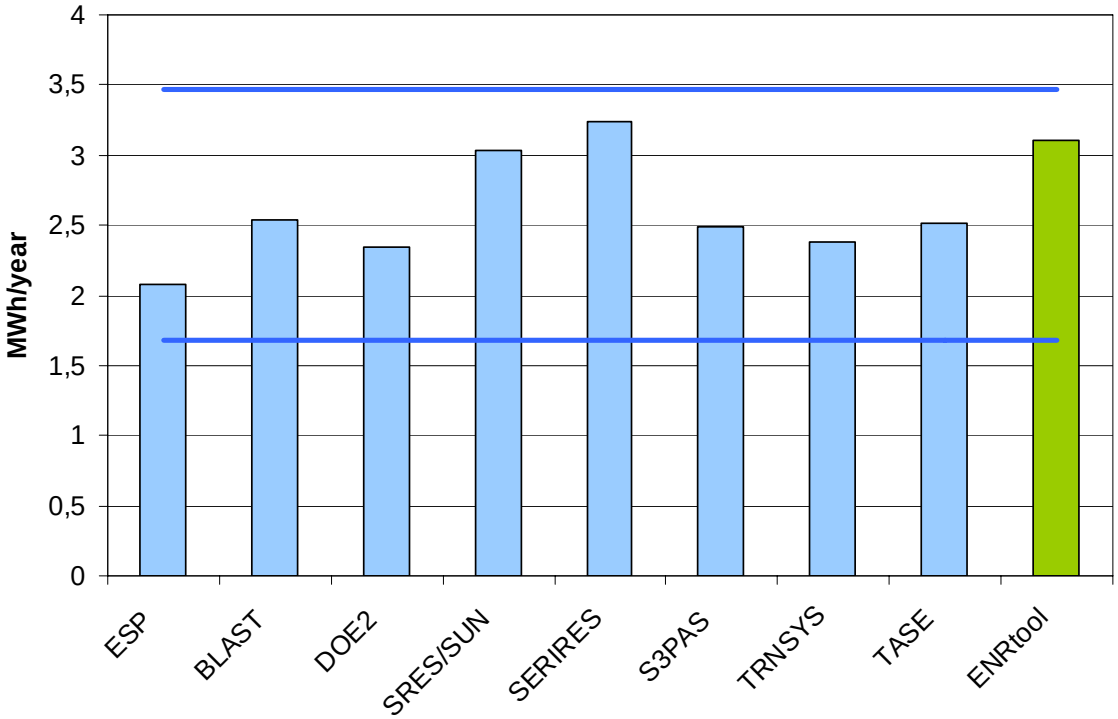

Figure 25. Annual cooling demand in case 940.

4 Conclusions

Results from ENRtool are within the acceptable limits from the results found by the tools in the BesTest for all the selected examples.

In general ENRtool performs well when compared to much more sophisticated, dynamic simulation tools, which are capable of taking into account all the given conditions of the climate and the building model. The calculated annual heating and cooling demand in the test buildings is as accurate by the ENRtool as by the dynamic simulation tool in the BesTest.

5 References

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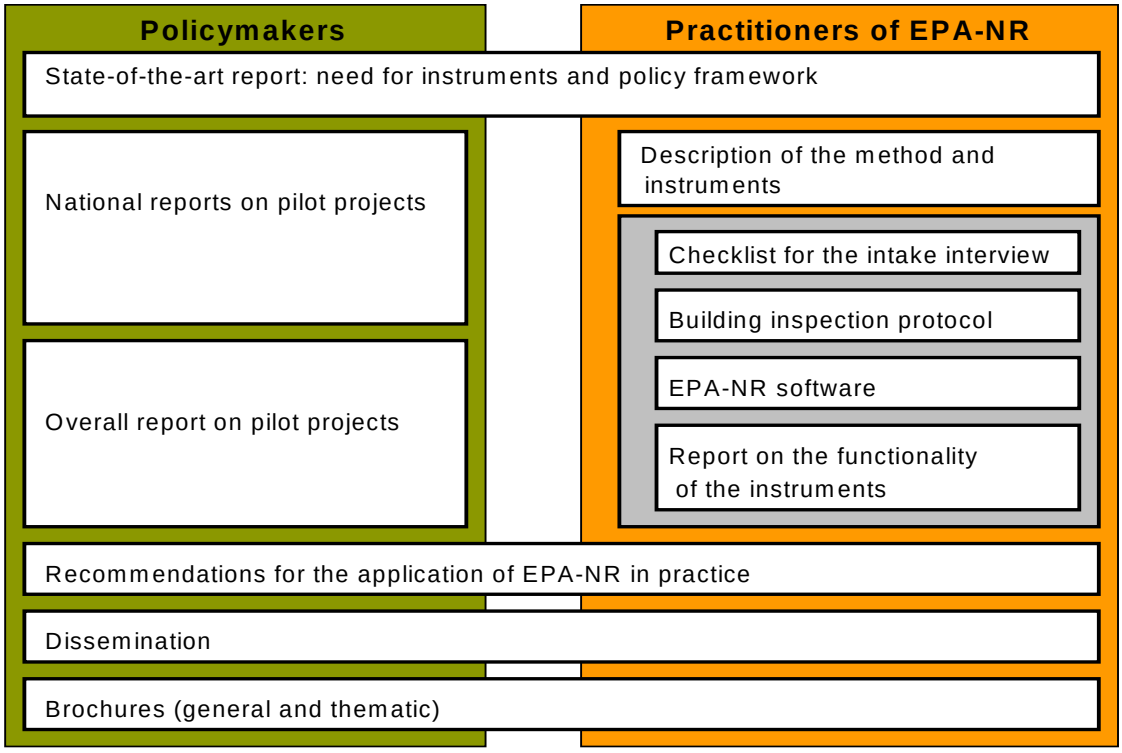
Project Description

EPA-NR is a project in the framework of the 'Intelligent Energy – Europe' Programme (IEE) of the European Commission. EPA-NR provides an assessment method for the Energy Performance Certificate according to the Energy Performance of Buildings Directive (EPBD) and offers additional advice for existing non residential buildings. The project, in which seven EU Member States are participating, is co-ordinated by EBM-consult, The Netherlands. It started in January 2005 and will last for two years.

The EPA-NR method consists of an energy calculation model and process supporting tools like inspection protocols, checklists and building component libraries. The EPA-NR method produces an Energy Performance Certificate for non-residential buildings with the possibility for additional advice. The two major target groups are policy makers and practitioners who are each addressed with a tailored set of deliverables.



The EPA-NR method:

- is in line with the EPBD and CEN-standards
- takes into account the local framework with respect to legislation, technical aspects, design- and building maintenance processes and acceptance by actors in the market
- is modular and flexible and therefore easily adjustable to the national context, the diversity in the market and new or modified CEN-standards
- is tested through pilot projects in seven EU Member States
- can be further developed and maintained at low cost due to the joint efforts
- offers additionally policy recommendations addressing all levels of authorities in Europe
- guarantees simple transfer to all EU Member States

Project Partners

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CSTB (France)
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