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Assessing the reliability of Turkish building energy performance tool (BEP-TR2) by case tests

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Abstract. This paper aims to draw a general picture of the simplified software for calculation building energy performance based on Turkish Regulations called BEP-tr.v2, which was released at the end of 2017. Even the tool has a simplified calculation methodology, the discussion in this paper is going to be focused on assessing the accuracy of the tool by test cases. The assessing procedure for the tool has two steps. In the first step, box type cases are analyzed, and the results are compared with the results of a detailed energy simulation tool (BES) to perceive the percentage of deviations. In the second step, a current building is selected to use as a test case. The model results are compared with the real consumptions of the building to see the convergence rate of the tool (Bep-TR2). The results showed that the net energy calculation procedure of the methodology needs to be improved.

1 Introduction

Many countries today are developing strategies to improve energy performance of buildings and reduce energy consumptions depending on their improved laws and regulations in this regard. In most regulations, there are arrangements that also includes the labelling of energy performance of buildings. By this energy labels, mostly known as Energy Identification Certificate, the energy consumption predicted during the design of the buildings is determined and made available for follow-up throughout the lifetime of the buildings. One of the most important factors determining the success of building energy regulations is the ability to ensure the accuracy of the process carried out to obtain the building label [2-4].

Many countries use a variety of software to help with this process. Some countries allow the use of detailed Building Energy Simulation (BES) programs; some regulations use simplified and customized software. Naturally, compared to BES, the simplified program is preferred because it requires less input and effort by the end users. Similarly, a simplified tool, which is mandatory for labelling in Turkish regulation - BEP-tr was first released in 2010 [5]. However, there were several problems announced by the users of BEP-tr many of whom are mechanical engineers. Based on the critics related with national calculation software (BEP-tr), Ministry of Environment and Urbanization was decided to renew the methodology and release a second version of the software (BEP-tr.v2). The process of developing the new methodology was finalized on May 2014. Shortly after, the implementation process was started for BEP-tr.v2. Actually, developing a methodology was only one angle of this process. Implementation of methodology into a software has been another, very critical process that should be carried out very attentively [6].

In this paper, an accuracy process of BEP-tr.v2 was presented by test cases and several inconsistencies were discussed.

1.1 Overview of Turkish simplified software for Energy Identification Certificate (BEP-tr.v2)

There are four applications consisting of multi-layered architecture in the technical specification describing the implementation of Turkish BEP methodology. These applications are defined as below:

BEP-BUY: The desktop application belongs to the Ministry, working offline and online to generate the data file in XML format and transmit it to the BEP-MY
BEP-IS: BEP Operating System,
BEP-MY: The application performing calculations according to National Calculation Methodology.
BEP-ONAY: EKB (Energy Identification Certificate) approval application

Among these applications BEP-IS runs completely web based and forms the administrative control mechanism of the Ministry as authorization, user information, reports etc. Whereas BEP-BUY can run entirely on desktop and offline as a user interface for the end user to develop complete building models and information inputs (Figure 1). BEP-MY provides results

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by transmitting the data from user interface to calculation algorithm. Calculation takes place on web based online system in the control of Ministry. The result obtained after calculation is used for issuing the Energy Identification Certificate for related building. This application is also included in the online system.

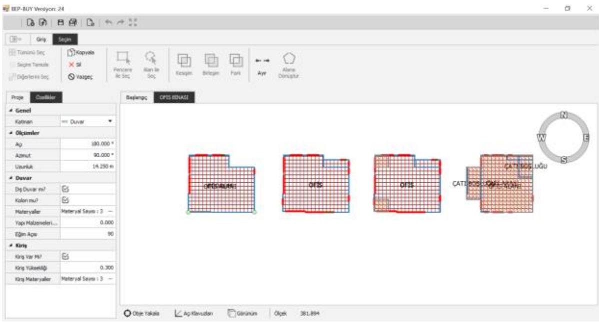

Fig. 1. Screenshot of BEP-tr.v2 desktop module.

The most critical structure here is BEP-MY. The entire algorithm of the calculation methodology was needed to be implemented in this module in an accurate way. Besides, forming the BEP-BUY and establishing the coordination accurately between the two applications, defines another critical situation.

Basically, the calculation module should provide the ability of identifying all parameters have effect on building, for determination of net energy consumption of building in the most possible approximate way. This requires the involvement of all parameters that have energy transfers between themselves. Since any possible complicacy here will cause the calculation turn out mistaken results, it has to be treated in utmost care.

For the calculation module, the accurate definition of net energy relation is essential. In the net energy relation; the net energy need for heating and cooling of the building creates data for the energy balance of building systems. Energy balance is divided into two, as energy at building level and energy at system level. The definition of hourly heat loss and heat gain ratio belongs to each zone determines the energy amount needed for that zone. Hence, in the calculation of net energy, to avoid the possible complicacy that interacting systems can cause and to add an operability compatible with calculation methodology, it is agreed that the calculation methodology is to be divided into sub-modules and assessed step by step.

Three basic sub-modules defined in the calculation module.

Architectural module forms the basis for the net energy calculation can take place. Within itself, the architectural module includes: i) Geometry module is important for the accurate definition of the geometric data of the building; ii) Solar Gains Module is a sub-module must operate with the values gathered from climate data and required hourly calculation for sure; iii) Ventilation module defined as two phases. Phase-1 includes air exchange rates depending on air leakage. This value is also used in the Phase-2. Phase-2 defines the ventilation calculation of zones with air conditioning systems operated and ventilated mechanically; iv) Internal gains module requires the involvement of all components producing heat into the calculation hourly; v) Heat transfer module requires the calculation of heat transfer coefficients of opaque and transparent components separately for the heat transfer calculation.

Mechanical module, is the definition of the mechanical system design required for sustaining the energy balance for each zone. Here, together with the calculation of the energy amount needed for air conditioning system, heating system and domestic hot water; definition and calculation is made for the renewable energy (solar energy, heat pump). With the renewable energy calculation, the ratio of energy supply will be met by renewable ways is in the determination of net energy need is calculated. Mechanical module uses the intermediate results obtained by all sub-modules included in architectural module during the calculation. Because, the results obtained by architectural module are necessary for the system design mechanical module and definition of its capacity.

Lighting module, includes the calculation of the energy consumed for interior lighting purposes in buildings. The result obtained by this module does not present any information only by itself. This sub-module can give independent result if related data input is provided. Yet, the heat gain obtained by lighting devices is expected to produce inputs for total hourly gains belong to each zone.

2 Methodology

There are basically three evaluation / testing methods of energy analysis software; i) Empirical validation (with real building or laboratory setup), ii) Analytical verification (analytical solution based on mathematical facts), iii) Comparative test (comparison of the software itself or other software).

The first two verification methods provide a practical benefit in the evaluation of relatively small, relatively complex systems. However, it is more acceptable to evaluate many different and interacting parameters at the same time and to test the relationship between them, often when compared with their own results or with other software(s) considered to be reliable. This latter method was applied in this study.

The accuracy process for testing the Bep-tr.v2 software's calculation module is designed to facilitate testing of each module individually, as well as testing the ability of modules to work together and achieve the result.

Accordingly, in the calculation module test process, 4 case definitions are made. Each case has been created in a structure that has become increasingly complex, as it will be linked to the next case.

The test begins with a "lighting" calculation, whose share in net energy calculation is relatively less than the other modules, but listed in the resulting performance. The calculation of the lighting module in its own flow is compared with the results of the "Relux" lighting calculation program [7] which has been accepted in various scientific studies. This work will be referred to hereafter as Case-1. The summary information about Case-1 is given in Table 1 at the Annex.

In the second stage of the test, the calculations of solar gains and internal gains in the architectural module were tested. With a single-zone, uncomplicated model, only the algorithm in question is correctly processed. The model in this study is called Case-2 and has a very similar structure to the definition of the BESTEST basic case [1]. The results are compared with the Design Builder software [8], which generates an Energy-Plus supported account. The summary information for Case-2 is given in Table 1.

The test is planned in a structure that allows the third stage heat transfer and ventilation to be tested, as well as to allow the net energy calculation to be checked. A 3-zone model was constructed to provide the level of complexity required for this work. Zones are similar to Case-2 and were derived from it. This model is called Case-3. The results were compared with the Design Builder software, which generates an Energy-Plus supported calculation. The summary information about Case-3 is given in Table-1.

The assessment of Case-3 was also used to test the performance of mechanical systems. In order to make this evaluation, the results of the Carrier-Hap software were used and the results of this program and Bep-tr.v2 results were compared.

At the fourth and final stage of the test, a study is conducted to test the operation of the entire process in a complicated structure and at the actual building size. In this phase, an existing building with real energy consumption was modelled, and how the results obtained can be approached in real time. This model is called Case-4. The summary information of Case-4 is given in Table-1.

Case-1

In the first stage of the test, the operation of the lighting module, which is a stand-alone module, was tested. The lighting calculation with the defined lighting elements of a single zone office building was compared with the AESG-Lighting Energy Digital Indicator obtained in both the Bep-tr.v2 and the Relux Lighting design program. AESG is a numerical display of annual total lighting energy consumed in the building and was developed to determine the energy performance class.

Bep-tr.v2 lighting calculation and Relux lighting calculation results are given in Table 2.

Table 2. Comparison of lighting module calculations.

Case-1	Lighting	
	Bep-trV2	Relux
Base Model	660 kWh 29.46 AESG	659 kWh 29.4 AESG

Case-2

In the second phase of the test, two components of the architectural module, solar gains and internal gains are tested. In the test of the solar gains, the results were evaluated separately by defining the overhang, the right fin, the left fin and the opposite obstacles, taking into consideration the effect of the sun control elements.

Table 3 shows that there is a 33% deviation between the Bep-tr.v2 calculation results and the Design Builder results when the results related to the solar gains are examined. Climate is the most effective variable in the conclusions about solar gains. Changes in the values of solar radiation directly affect solar gains. In the Bep-tr.v2 program, hourly solar radiation data from the Turkish General Directorate of Meteorology is used, but a different climate database is included in the Design Builder program to compare the results. When two climate databases were compared with solar radiation data, it is seen that solar radiation is higher in the climate data accepted by Design Builder. This leads to higher gains from the sun.

For this reason, in Case-2, the results were questioned not by the overlapping of the results but by the definition of the solar control elements. The rate of change in solar gains is between 3-4%.

In internal gains, the difference does not exceed 10%, albeit with outcome differences based on assumptions between both methods of account. In addition, the rate of change based on heat gains in the kitchen area is almost the same (less than 1% change rate).

Case-3

In the third stage of the test, the tested virtual building was further elaborated into three zones. At this stage, the test was based on interrogating the heat transfer between zones and the identifiability of building load as heating and cooling load. Also, in Case-3, the results of calculations were compared according to two different usage types, namely residence and office.

Table 3. Comparison of the results of solar gains and internal gains.

Case-1	Solar Gains		Internal Gains	
	Bep-trv2	DB	Bep-trv2	DB
Base Case	4699 kWh	6934 kWh	2286 kWh	2081 kWh
Overhang (0.5 m) Kitchen area 6 m^2 /5W/m^2	3735 kWh	5691 kWh	2694 kWh	2431 kWh
Right Fin (0.5 m) Kitchen area 8 m^2 /6.7W/m^2	4198 kWh	6462 kWh	2831 kWh	2550 kWh
Left Fin (0.5 m) Kitchen area 10 m^2 /8.3 W/m^2	4193 kWh	6468 kWh	2928 kWh	2662 kWh

Obstruction (Dist:5 m, h:10 m) Kitchen area 12 m^2/10 W/m^2	2262 kWh	4337 kwh	2873 kWh	2781 kWh

Also, for Case-3, the energy consumption values of the defined mechanical systems are also compared. With the Design Builder, both the heating and cooling loads as well as the final energy consumption results are looked at; The results obtained with the Carrier-HAP program include final energy results based on heating and cooling. Table 4 gives the defined system details for Case-3 modeled in Bep-tr.v2. Table 5 compares the load comparison and Table 6 compares Bep-tr.v2, Design Builder and Carrier-HAP software results in the final energy context. The results were compared using heating and cooling energy consumption items. Use hot water and ventilation are not available as separate results in Design Builder. Relevant energy consumption can be broken down into system loads. For this reason, this comparison cannot be done with Design Builder. Although it is possible to obtain results for the usage hot water in the Carrier-HAP software, this work needs to be carried out separately, since it is necessary to match the input data. The first work with Carrier HAP is focused solely on the consumption of heating and cooling energy, and only the calculation results for the residential building have been obtained.

Case-4

The most important and final stage of the test is comparing actual building consumption with Bep-tr.v2 calculation results. The actual building is the Building of Ünlü Engineering Co. Ltd. in Ankara. The building's energy study was conducted, and the annual energy consumption was determined.
In the Ünlü Engineering building, the amount of natural gas consumed in one year (2017) was set at 54381 kWh/year. However, given that some of this consumption was spent on the use of hot water and cooking, it was assumed that the building consumes approximately 50000 kWh/year of heating energy. The same building was modeled in Bep-tr.v2 and annual heating energy consumption is 68087 kWh/year.

Table 4. System details

Heating System	**Cooling System**
System Capacity: 50 kW Type: Central Medium: Air heating Heating temperatures: 55/45°C Piping type: Double pipe heating Piping insulation: After 1995 Pump Controller: Constant	System Capacity: 50 kW Type: Central System type: Air cooled condenser Chilled water outlet temperature: 6°C Chilled water temperatures: 6/12°C Pump Controller: Automatic
Hydraulic balance: Available Volume of storage tank: 0 m^3 Boiler Type: Condensing boiler Fuel type: Natural gas	
Domestic water system	**Air Conditioning System**
System Capacity: 50 kW Type: Central Circulation: Available Piping insulation: After 1995 Pump Controller: Available Volume of storage tank: 100 m^3 Boiler Type: Condensing boiler Fuel type: Natural gas	System type: Supply and Exhaust Heat Exchanger: Available Operating Mode: Year-round Daily operating hours: 8

Table 5. Comparison of heating and cooling loads calculations.

Case-3	Solar Gains (kWh)		Internal Gains (kWh)		Net Energy Heating kWh/ Cooling kWh	
Base Model (office)	**Bep-tr.v2**	**DB**	**Bep-tr.v2**	**DB**	**Bep-tr.v2**	**DB**
Zone-1 Gr. fl. 48 m^2	2930	4018	1427	1222	293 / 960	1254 / 799
Zone-2 Gr. fl. 48 m^2	3218	4316	1427	1222	289 / 975	1158 / 912
Zon-3 1. fl. 96 m^2	4329	7160	2854	2444	1340 / 795	2374 / 1959
Total	10487	15494	5709	4888	1923 / 2732	4786 /3670
Base Model (Residence)	**Bep-tr.v2**	**DB**	**Bep-tr.v2**	**DB**	**Bep-tr.v2**	**DB**
Zone-1 Ground Floor 48 m^2	3840	3877	2286	2081	1937 /1155	2665 /1008
Zone-2 Ground Floor 48 m^2	4181	4190	2286	2081	1926 /1158	2812 /1183
Zon-3 1. Floor 96 m^2	5633	7039	4353	4162	5071 /1030	5666 /2747
Total	13655	15106	8926	8324	8935 /3344	11143 /4938

Table 6. Comparison of heating and cooling net energy consumption.

BEP-tr.v2	Heating kWh	Cooling kWh	Domestic Hot Water kWh	Ventila tion kWh
Office	2766	1498	2757	333
Residence	13908	2055	5230	333
DB	Heating kWh	Cooling kWh	Domestic Hot Water kWh	Ventila tion kWh
Office	4860	3788	-	-
Residence	11114	5197		
HAP	Heating kWh	Cooling kWh	Domestic Hot Water kWh	Ventila tion kWh
Office	5544	5481	-	-
Residence	-	-	-	-

3 Results and Discussion

In this study, comparison was made over four different cases. The lighting, solar gains, internal gains, net energy and final energy results, which are included in the modules of the calculation methodology, were used for comparison. Regarding to the literature, it is seen that in similar comparisons, an overlap of the results obtained from different software tools is not expected. Each tool generates results based on certain assumptions within its own calculation algorithm, and it is not possible to access the backstage of the software because the vast majority of these tools are "black boxes". When we look at the literature, it is understood that a difference of about 10% between the programs is regarded as normal. Below are the evaluations of the results obtained with each case:

1. In Case-1, the results obtained with BEP-tr.v2 lighting calculator and Relux are almost the same. The lighting module is accepted as a module with accurate calculation.
2. In Case-2, the rate of change in solar gains is between 3-4%. This ratio is successful because it is below the acceptable 10% change rate.
3. In Case-2, the difference does not exceed 10%, with internal gains based on acceptance between the two methods of calculation. In addition, the rate of change based on heat gains in the kitchen area is almost the same (less than 1% change rate). For this reason, the calculation of internal gains is also acceptable.
4. In Case-3, in terms of heating and cooling net energy calculations, it is seen that in the calculations made as residential building, acceptable values are reached in terms of consumption of both heating energy and cooling energy. However, this is not the same to measurements made as office buildings. The operation of the system in the office is based on set point temperature values. This difference, which arises because the system continues to operate outside of the hours of occupancy, can be closer when the same system operation is defined in Design Builder.
5. Case-3 also compares the final consumption of heating and cooling energy. Here, system losses were also taken into consideration, which is defined as modelling. Here, the results of the two programs were compared with the results of Bep-tr.v2. Looking at office building results, Carrier-HAP results are closer to Design Builder and Bep-tr.v2 results are lower. The most likely reason for this is thought to be differences in internal gains and solar gains (depending on climate data). However, it is clear that these results require further evaluation.
6. The comparison of Case-3 and the final energy consumption of the model defined as the residence is done only between BEP-tr.v2 and Design Builder. Here, values are close to each other in terms of the consumption of the heating energy, and a difference of more than 50% in terms of the consumption of the cooling energy appears. Under these conditions, the calculation algorithm for Bep-tr.v2's cooling energy consumption should be reviewed.
7. Case-4 is the actual building heating energy consumption calculation. According to the results, it is seen that the result obtained with Bep-tr.v2 values very close to real consumption. Bep-tr.v2 results are acceptable in calculating the final energy consumption of the heating.

4 Conclusions

This paper contents energy calculation results comparison of the Bep-tr.v2 calculation methodology in various sub-modules with other programs that can do similar calculations.

The comparative analysis showed that when the modules (architectural systems module, mechanical modules and lighting systems module) are evaluated separately; the results are very closer to the ones with Building energy simulations (BES). This is true for real building's heating energy consumption comparison as well. On the other hand, the net energy calculation procedure of the methodology needs to be revised/improved based on the relevant standards. Besides all, it is necessary to underline that national calculation tool- BEP-tr2 is not a "design tool" but a "performance confirmation tool". Therefore, the tool cannot be used during early phases of design and the accuracy with real time results are essential for certification procedure that is defined in EPBD.

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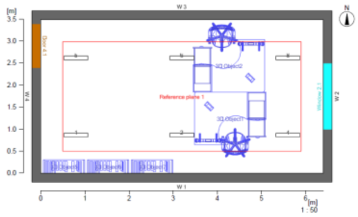
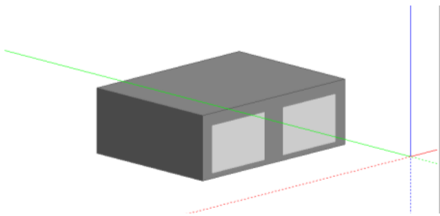
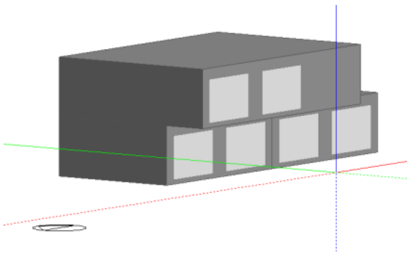
APPENDIX

Table 1. Details of each case.

Case	3D Model	Explanations		Test Modules
CASE-1		Sizes	Area: 22.4 m2 Volume: 6.4x3.5x2.7 m^3	- Lighting
		Window	1.5x2 m2 (south)	
		Operation	Office Building (occupancy hours: 8:00/17:00) **ZoneType: Private Office**	
		Lighting	D class12 Fluoresant (30 W)	
CASE-2		Sizes	Area: 48 m^2 H:2.7 m	- Solar gains - Internal gains
		Window	2 x 3x2 m^2 (south)	
		Envelope	Uwall: 0.471 W/m^2K; Uroof: 0.305 W/m^2K Ufloor: 0.432 W/m^2K; Uwin: 2.5 W/m^2K	
		Operation	Residence (occupancy: 7/24) **ZoneType: Flat**	
		Lighting	A class 2 incandescent 60 watt	
CASE-3		Sizes	Zone1 and Zone2 Area: 48 m2 Zone3 Area: 96 m2 H:2.7 m	- Solar gains - Internal gains - Net Energy
		Window	6 x 3x2 m2 (south)	
		Envelope	Uwall: 0.471 W/m^2K; Uroof: 0.305 W/m^2K Ufloor: 0.432 W/m^2K; Uwin: 2.5 W/m^2K	
		Operation	Office Building (occupancy hours: 8:00/17:00) **ZoneType: Open Office** Residence (Occupancy: 7/24) **ZoneType: Flat**	
		Lighting	A class 2 incandescent 60 watt	
CASE-4			Real Building (Ünlü Engineering Co. Ltd.)	- Net Energy

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