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DEVELOPMENT OF A SOFTWARE BASED SYSTEM TO APPLY TURKISH BUILDING ENERGY PERFORMANCE DIRECTIVE

Kurtulus Erinc Akdogan
Proline Integrated Intelligence Corporation, Ankara, Turkey
kurtulus.akdogan@pro-line.com.tr

Demiray Ustaoglu
Proline Integrated Intelligence Corporation, Ankara, Turkey
demiray.ustaoglu@pro-line.com.tr

Kemal Akoglu
Proline Integrated Intelligence Corporation, Ankara, Turkey
kemal.akoglu@pro-line.com.tr

Can Fil
Proline Integrated Intelligence Corporation, Ankara, Turkey
can.fil@pro-line.com.tr

Tolga Tastan
Proline Integrated Intelligence Corporation, Ankara, Turkey
tolga.tastan@pro-line.com.tr

Gulsu Ulukavak Harputlugil
Çankaya University, Faculty of Architecture, Ankara, Turkey
gharputlugil@cankaya.edu.tr

Abstract

This work is about the software named BEP-TR (Building Energy Performance -Turkey), which is developed upon request from Turkish Ministry of Environment and Urbanization to apply building energy performance directive nationwide to improve the energy efficiency of buildings in Turkey. Directive requires that each building in the country must have an energy performance certificate (EPC) indicating the ratings of energy consumption and greenhouse gas (GHG) emission of the related building. BEP-TR software is designed mainly to issue EPC for buildings considering each phase of EPC preparation process and tasks of associated institutions and individuals. BEP-TR is mainly composed of two software applications called BEP-BUY and BEP-IS. BEP-BUY is a desktop application, which allows user to design a building stored in XML project file and calculate its energy consumption and greenhouse gas emission to determine its corresponding ratings. EPC application for the designed building, which meets standards required by government is done by sending the project file of the building through BEP-BUY to the BEP-IS. BEP-IS is an internet based software which is under the control of the ministry. BEP-IS confirms the calculations made for the building using the received project file and initiates the process of preparing EPC. BEP-IS provides users who takes part in this process interfaces designed as web pages. Users and their authorizations are managed by fully authorized users defined for the ministry through BEP-IS. Besides BEP-IS stores and reports data related with processes and users. There are two other modules called library and calculation which are embedded in both BEP-BUY and BEP-IS. Library module stores the data related with structural materials, which are determined to be useable in building construction. Calculation module contains the national calculation method developed to calculate greenhouse emission and energy consumption of a building using properties of materials selected from library module. In this study, as an example a building is designed and its energy consumption is calculated using BEP-BUY.

Keywords

Building Energy Performance, Energy Performance Certificate, Sustainable Development

1. Introduction

Energy is fundamental for functioning of world's economy and its development. As it is the driving force for many sectors such as industry, transportation and buildings, our improving

standards of living and growing world population raises the global demand for energy continually. Increased energy use brings with it the most important global issue, climate change. Burning fossil fuels to produce energy generates greenhouse gases (GHG) mostly Carbon dioxide (CO_2) but also Sulphur dioxide (SO2) and Methane (CH4), which traps infrared radiation (heat) from escaping the atmosphere causing global warming and climate change. Global total primary energy supply (TPES) mainly relies on fossil sources accounting for 82% of the TPES and 32.2 $GtCO_2$ global CO_2 emissions in 2013 (International Energy Agency [IEA], 2015). It is estimated that over the period 1880 to 2012, global surface temperature rise 0.85°C (Intergovernmental Panel on Climate Change [IPCC], 2013). Assuming no additional mitigation efforts beyond those in place today, the average global temperature rise above pre-industrial levels is projected to reach almost 4°C by the end of this century (IEA 2012; IPCC 2014a) and almost 6°C in the long term (IEA 2012). Impact of 4°C global temperature rise is devastating and its foreseen consequences are substantial species extinction, global and regional food insecurity and water scarcity, inundation of coastal cities. In 2010, parties to the United Nations Framework Convention on Climate Change (UNFCCC) agreed warming should be limited to below 2°C (United Nations Framework Convention on Climate Change [UNFCC], 2010) to avoid the most serious effects of global warming. To reach the globally agreed-upon target of limiting average global temperature increase to 2°C, 2°C Scenario (2DS), mentioned in International Energy Agency's (IEA) publication Energy Technology Perspectives 2012 (IEA 2012), sets the target of cutting energy-related CO_2 emissions by more than half in 2050 (compared with 2009).

Building sector has a key role in halving the CO_2 emission since it has the largest share in global energy consumption, 35% of global final energy use and about one-third of global CO_2 emissions taken into account both direct and indirect energy-related CO_2 (IEA, 2013). To reach CO_2 reduction target, 2DS estimates that buildings sector must reduce its total carbon dioxide (CO_2) emissions by over 60% by 2050 (IEA, 2012). On the other hand if no action is taken to improve energy efficiency in the buildings sector, energy demand is expected to rise by 50% by 2050 (IEA, 2012; IPCC, 2014b). This sharp rise is caused by the massive growth in new construction in developing countries, the inefficiencies of existing building stock worldwide, and improved living standards. These factors offers at the same time opportunities for delivering significant and cost-effective GHG emission reductions. Recent advances in technology, design practices and know-how, coupled with behavioral changes, can achieve a two to ten-fold

reduction in energy requirements of individual new buildings and a two to fourfold reduction for individual existing buildings largely cost-effectively or sometimes even at net negative costs (IPCC, 2014b). However to unlock this potential countries must develop building related policies to overcome barriers avoiding the transformation in this sector. Building energy codes and standards defining minimum energy performance requirements are effective instruments to reduce building energy consumption and related CO_2 emission. Various building energy codes developed for different types of buildings, climatic and other conditions are being applied in many countries. In European Union in 2002, to reach the emission reduction goals agreed upon in Kyoto Protocol, building energy codes regarding minimum energy requirements is introduced with the directive (2002/91/EC), energy performance of buildings directive (EPDB) and it is revised in 2010. Directive emphasize that buildings sector represents %40 of consumed energy and has got substantial potential for cost-effective energy savings (The European Parliament and The Council of the European Union, 2010).

Similar to the trend in the World, Turkey as a developing country is experiencing the increase in energy demand due to urbanization, population growth, and economic development resulting the increase in CO_2 emissions. Turkish Ministry of Energy and Natural Resources reported that final energy consumption is 41.6 million tonnes of oil equivalent (Mtoe) in 1990 (Ministry Of Energy And Natural Resources, 2006), more than doubled reaching up to 89.4 Mtoe (Ministry Of Energy And Natural Resources, 2015). As a result, the greenhouse gas emission measured 218,2 million tonnes of carbon dioxide equivalents ($MtCO_2eq$) in 1990 (Turkish Statistical Institute [TSI], 2015), more than doubled in 2013 reaching up to 459,1 $MtCO_2eq$ (TSI, 2015). Building sector, accounting for 35% of final energy consumption (Ministry Of Energy And Natural Resources, 2015) is taking the first place before industry. The analysis of general directorate of electric power resources survey and development administration indicate that building sector has 35% energy saving potential (General Directorate Of Electric Power Resources Survey and Development Administration, 2009) while analysis of World Bank shows it has 30% energy saving potential (World Bank, 2011). In order to realize this potential and as a part of the compliance process with European Union regulations, Turkish Ministry of Public Works and Settlement legislated building energy performance (BEP) directive in 2008 which is based on the EU's energy performance of buildings directive (EPBD). BEP directive is revised in 2010 due to revisions in EPBD, requirements of the calculation method, flaws in the directive

and public feedbacks. BEP directive obliges each building to have energy performance certificate (EPC) proving that related building satisfies minimum energy efficiency requirements (Ministry of Public Works and Settlement, 2010). In 2010 in order to prepare EPC, a software system called BEP-TR which is based on a custom developed national calculation method to assess energy performance of the buildings, is released. Due to errors observed regarding calculation method it is revised in 2014. Upon request of Turkish Ministry of Environment and Urbanization, a second version of BEP-TR (BEP-TR v2) based on the revised calculation method was started to be developed by Proline Integrated Intelligence Corporation in 2014. This study explains the general working principles of BEP-TR v2, its architecture and EPC preparation process. In the first section, brief information about EPC and BEP-TR is given. In following section software architecture of BEP-TR is explained in detail. In the last section an example EPC preparation process will be demonstrated.

2. EPC and BEP-TR Software

The main purposes of BEP directive are protecting environment, utilizing energy and energy resources effectively and avoiding waste of energy in buildings. BEP directive specifies requirements to be satisfied in terms of greenhouse gas emission and energy consumption in the design of new buildings and important retrofits in existing buildings. In the directive it is defined that a building is new if its construction license is acquired after 01.01.2011. Incase construction license of building is acquired and construction is started before 01.01.2011 or completed before this date it is considered as an existing building. BEP directive introduced the obligation to have EPC for new buildings starting from 01.01.2011 and existing buildings until 02.05.2017. EPC is a document showing that the building having this certificate satisfies the minimum energy and emission requirements mentioned in the directive. EPC includes data related with minimum energy requirement of the building, its class of energy consumption, isolation properties and efficiency of heating and/or cooling systems. As defined in the directive, EPC is aimed to serve as a tool to make energy efficiency standards applicable to the buildings in daily life. For example, for new buildings it is obliged to acquire EPC to get occupancy permit. If a building is in the market to be sold, bought or rent, it is necessary to have EPC for the building.

The most important data on EPC related to a building is the classes of energy and CO_2 emission it belongs to. Turkey is divided into four regions according to latitude that in each

region a reference indicator (RI) showing primary energy consumption is determined for each type of building. A reference indicator is selected for the building analyzed depending its location and type. A reference scale varying from A to G is formed by multiplying selected RI with two coefficients to form a range, which corresponds a class. To find energy class of building, the annual primary energy consumption of a building per square meter is calculated using a national calculation method and the range where resulting value falls into gives the energy class of the building. Deriving amount of emission from the consumed energy and using the previously determined reference indicators for emission, the same method is applied to find emission class of the building which is selected from scale varying A to G. Class A indicates the least amount of energy consumption and the least amount of greenhouse gas emission while class G indicates the highest level. BEP directive requires that new buildings applying for EPC cannot have energy consumption and CO_2 emission more than class D.

Turkish Ministry of Environment and Urbanization uses a software system called BEP-TR to evaluate energy performances of buildings and prepare EPC for them. New and existing buildings belonging to different types such as house, office, education building, hospital, hotel, and shopping and trade centers are evaluated using BEP-TR in terms of energy performance. For evaluation, BEP-TR employs a national calculation method which was developed to determine the energy and emission classes building belongs to. In BEP-TR system, Ministry defines and controls the whole process and users. Ministry can access all data in the system, can define users and their level of authorization. Ministry defines EPC assessors who are authorized to prepare EPC and the companies where those assessors are employed. Ministry provides a personal username and password for EPC assessors who became eligible for this duty by passing the related examination. EPC assessor applies for EPC for a building by producing a project file using designed module of BEP-TR and sending it to the system using his/her personal username and password. Energy performance of building is evaluated by using national calculation method with building data in the project file which was sent to central data base. Project file satisfying requirements is proceeded to next phase for system confirmation. In the last step EPC is given to the owner of the building signed by EPC assessor.

3. The Architecture of BEP-TR

BEP-TR system is designed to incorporate the whole process starting from application to confirmation of EPC for a building. As shown in Figure 1, BEP-TR is mainly composed of two separate software BEP-IS and BEP-BUY. BEP-BUY is a desktop application that is used to calculate energy consumption and greenhouse gas emission of a building by creating its model in computer environment. After completing the calculations a project file of the building is created in XML format and it is sent using BEP-BUY to BEP-IS through online internet connection as shown in Figure 1. BEP-IS is an internet based software running on the servers residing at ministry. BEP-IS checks the Project file of the building sent from BEP-BUY and conducts confirmation process. Related to this process, defining user accounts and managing authorizations are within the scope of BEP-IS. Users of BEP-TR access the internet pages designed according to their authorization level through BEP-IS. As shown in Figure 1, there are calculation module and library module residing under BEP-BUY and BEP-IS software. Calculation module contains the National Calculation Method which is developed for BEP-TR to calculate energy consumption and GHG emission of the building. Library module keeps data related with materials that are used in the buildings in a database which is essential for calculations. The calculation and library modules that BEP-IS and BEP-BY employs are identical with each other. However building materials data stored in the library module needs to be updated which is done using BEP-IS. To make the same updates in the library module of BEP-BUY, it needs to establish online internet connection with BEP-IS.

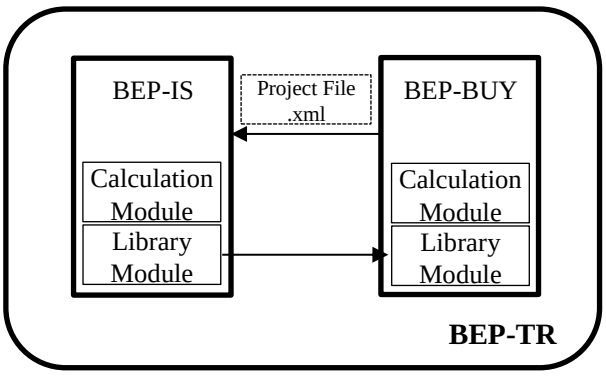

Figure 1: *Software Architecture of BEP-TR*

3.1 BEP-BUY

BEP-BUY is used to apply for EPC of a building and to prepare necessary data file required for this application. Using BEP-BUY, data file of a building in XML format is prepared and then it is sent to BEP-IS. In order to form data file, user must identify and bring together all of the structural information of the related building which are necessary to calculate the amount of its energy consumption and CO_2 emission. BEP-BUY is a desktop application which is designed to run without the need for installation and it can be downloaded from the webpage of ministry. Application can be run on any operating system without the need for any type of license.

As user starts BEP-BUY application, a project file, which is required for EPC application, is defined and general data related with the project and the building are provided. Under this project, a 2D building plan is drawn using the tools provided by BEP-BUY and all of the building elements are defined on this plan. BEP-BUY offer two methods to draw building plan. In the first one, building plan is formed hierarchically in layers such as floor, zone, wall, door, flooring, windows, doors using drawing tools and providing structural information for each layer. In the second method, rather than drawing from scratch, previously building plans produced in DXF format using a computer aided design software is loaded to BEP-BUY to serve as base for drawings. Drawing tools and layer design is applied onto this loaded file. If the file is designed in layers as done in BEP-BUY then these layers can also be loaded to BEP-BUY. After confirming that building is designed correctly using BEP-BUY confirm function, the energy consumed by the building is calculated using calculate function of BEP-BUY which uses the custom developed national calculation method residing in the calculation module. If the results are meeting the requirements of BEP directive, project file of designed building is sent using submission function of BEP-BUY to BEP-IS in other words to the ministry for confirmation of EPC.

BEP-BUY stores defined projects and library from which structural elements of buildings in its local database requiring no additional installation. Due to having a local database, BEP-BUY can be run offline without need for internet connection. However for certain operations BEP-BUY needs to establish internet connection with the part of BEP-TR which is BEP-IS. The project file of designed building can be sent by BEP-BUY to BEP-IS when there is online

connection. On the other hand, in order to keep the library module of BEP-BUY up-to-date with the one in BEP-IS, BEP-BUY needs to be operating online.

3.2 BEP-IS

BEP-IS software, which is hosted on servers determined by the ministry, is an internet based application compatible with all internet browsers. BEP-IS has three main tasks such as evaluation of the project file of the building requiring EPC, which is sent from BEP-BUY, managing confirmation process of EPC and administration of BEP-TR system. In the first task as project file in XML format of a building reaches to BEP-IS as shown in Figure 1, the calculations done by BEP-BUY is repeated using the same method used in BEP-BUY which is national calculation method residing in calculation module of BEP-IS. If the energy performance class of the building which is determined from result of calculation does not satisfy the requirements, project is rejected otherwise confirmation process is initiated. As a second task, BEP-IS manages the confirmation process of EPC through the webpages developed for related users who take responsibility in this process. Following to the submission of user name (National ID) and a password from home page of BEP-TR, an interface, which is organized depending on the user type and authorization level opens up. These interfaces confines users taking permitted actions.

Third task that BEP-IS is responsible for is controlling and managing BEP-TR system. Fully authorized users defined for the ministry lie at the top of controlling and confirmation mechanism. These users are allowed to monitor, create and modify data of other users. As they can determine the authorization level of other users, they can define new user types and related authorization level. BEP-IS stores data of all users such as access data (individual or company, date of operation) and actions (file sending, deletion) and reports on demand of users from ministry. Fully authorized users directs the companies which are authorized to prepare EPC and EPC assessors. Users defined for consulting firms of energy efficiency, professional chambers and universities, which are providing training for being EPC assessor, submit data related with training, data of candidates who are successful at training and their firms, to the database via BEP-IS. Fully authorized users employed in the ministry opens an account for the EPC assessor who is affiliated to a firm after checking the national ID and surname of EPC assessor whose data are submitted to the system by confirming EPC assessor’s identity data obtained from Turkish Central Population Administration System.

3.3 Library Module

Library module is a database where data related to structural elements of buildings such as transparent, opaque and illumination materials are stored. This module is used by BEP-IS and BEP-BUY. Following to completion of drawing of a building plan for each layer, elements of this layer are defined by selecting them from the corresponding material list stored inside the library module. Material lists can be modified by an authorized user through BEP-IS. In order to keep library module in BEP-BUY identical with the one BEP-IS, enabling check updates function of BEP-BUY, an online connection must be established with BEP-IS.

3.4 Calculation Module

Calculation module calculates the amount of energy consumed and greenhouse gas emitted by using national calculation method developed based on international standards and it determines the energy performance class of the building. Calculation module performs calculation by using the project file in XML format formed by BEP-BUY and BEP-IS for the related building. Calculation module is divided into submodules to determine energy consumption accurately by defining the necessary parameters and to make calculation method applicable by avoiding complexity. Thus all of the parameters, which are interacting with each other can be included in the calculation at the same time. Calculation module is divided into three modules such as architecture, mechanics and illumination. In architecture submodule, a geometrical model of the building consisting of all structural elements is created and building is divided into zones. Zone is defined as building sections which are similar in terms of usage properties. For example, each floor of an apartment can be defined as zone. The effect of sun on the modeled building is considered using simple hourly calculation method, which uses data related with local insolation time measured at the region where building is located. Heat transmission parameters are calculated hourly based on the air passage and climatization systems. The effect of all of the components producing heat such as illumination, devices and people are considered on an hourly basis in the calculation. In the last phase of calculation, hourly heat transmission coefficient values of transparent and opaque elements for each zone are determined.

The energy spent for indoor illumination which forms a significant portion from energy consumption in the buildings are calculated independently from the other submodules using an illumination submodule. Another task of this submodule is providing hourly data related with the

heat production originating from illumination. The last submodule used in building energy performance calculation is mechanics module. This module is related with the design of mechanisms providing living conditions determined for the define zones of the building. The amount of energy consumed by climatization and heating systems employed for adjusting ambient temperature and water heating systems are calculated in this submodule. In addition to this, calculations related with renewable energy sources are performed in this submodule too. The outputs of architecture and illumination submodules form a basis for the calculations in mechanics submodule.

4. Preparing an EPC Application for a Building

In this section, preparation of the EPC application is explained with an example. It is assumed that a hypothetical building which is a six story apartment needs to obtain EPC. In this case, an EPC assessor uses BEP-BUY to create the project file required to apply for EPC. Project file contains essential data related to structure of building and its components to calculate energy consumed and GHG emitted. After launching BEP-BUY and creating the project, preferences for BEP-BUY is selected and general properties of the building are provided. Structural components of the building are defined on a model drawn by using BEP-BUY tools as shown in figure 2. Hypothetical building is a concrete building located in Ankara and it is classified as new building since it is assumed to be built in 2011 which is after the date BEP legislation took effect. In order to simplify example, impermeability data of the building are not defined and default types defined in BEP-BUY are used for the heating bridges. Photovoltaic system of the building are determined that its module type is mono crystalline silicon, its performance factor is non-ventilated module, its slope angle is 30° and its direction is south. Among mechanical systems, one type of heating system, cooling system and hot water system are assumed to be used throughout the building except basement entrance and corridors. Heating system is defined as combi boiler which has 100kW power. It is assumed that it is operating continuously during the day while it is switched off during the night. Cooling system is composed of locally wall mounted air conditioners having 44kW cooling power. Hot water system is designed such that each flat has its own system having 25kW power.

Following to determination of general properties, user can begin constructing building model in the form of layers such as story, zone, wall, floor, window, door and roof. BEP-BUY

offers drawing tools to create geometrical objects corresponding to building components in that layer. As building components are created, required data related with the object appears in a separate window to be determined by the user. In figure 2, the model of the hypothetical building which is created by using BEP-BUY is shown. Since layers lie on top of each other and the drawing of the building is 2D, layers cannot be seen separately except story layer. However by selecting a layer and unselecting the others, interested layer can be visible. As seen from the figure, for ease of design, each story is drawn separately and connected to each other with a reference point. Stories have identical measures such as 15m width, 20m length, 3m height and $300m^2$ area. Types of stories are defined as basement, ground floor or floor. In figure 2, first story is basement, second one is ground floor and the rest is classified as floor. In order to define various parameters causing energy consumption, each floor is divided into zones according to intended use such as flat, office, storage, store etc. As user draws the zones using drawing tools, a predefined type for each zone is selected. In figure 2, it is designed that zone type of basement, entrance hall and all corridors is 'core'. Zone type of the stores, gym and all flats are determined as 'flat'. There are differences between two zone types due to having different use. Firstly, core type zones don't have heating system while flat type zone has the one defined in the building properties. Secondly the light switches in core type zones are automatic while the ones in core type flat are manual. Wall, floor, window, door and roof layers are selected from the materials list appearing in the corresponding layer. Since the aim of this section is to describe how BEP-BUY is used for calculations, materials are not given to avoid unnecessary complexity. Designed building is firstly confirmed by BEP-BUY to check design errors. In the absence of errors, by activating calculation function of BEP-BUY, energy consumption of the building is calculated. The result of the calculation appear on user screen as given in Table 1. Resulting table indicates annual energy consumption in terms of final, primary and per usage area for each system and in total. According to annual energy consumption per usage area, designed building has rating C.

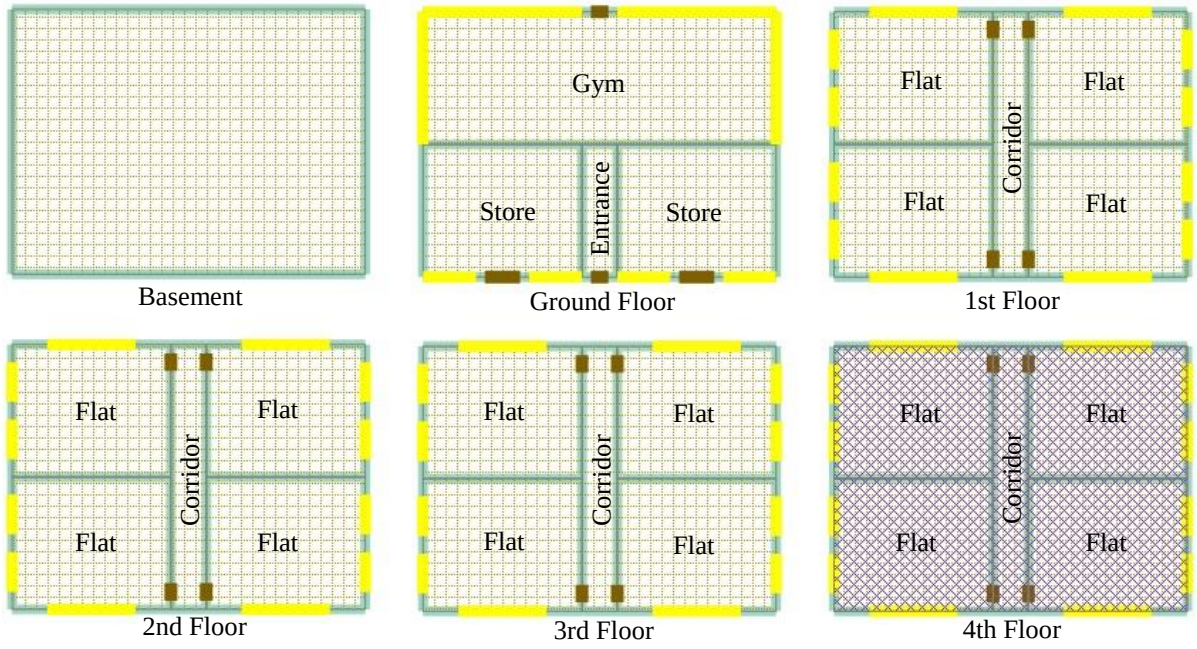

Figure 2: *BEP-BUY model of a six story apartment*

5. Conclusion

In this work, a software system called BEP-TR which is developed to apply energy performance directive for buildings in Turkey is explained. BEP-TR is developed to handle EPC preparation process starting from application to confirmation of EPC document. It consists of a desktop application called BEP-BUY and an internet based application called BEP-IS. BEP-BUY is used by EPC assessor to model a building, to do necessary calculations, to generate a project file and to apply with it for EPC. BEP-IS receives the application and confirms the project file by recalculating energy consumption and GHG emission of the building. In case project file meets requirements, BEP-IS manages the preparation of application by organizing related institutions and users. BEP-IS also serves as a tool to monitor the EPC preparation process and to manage all users. Fully authorized users of ministry use BEP-IS to define new users and modify authorization of existing ones, and to get report about their actions. In the last section of study, a hypothetical building is designed using BEP-BUY to explain its operation and to describe preparation of an EPC application for the building. Energy consumption of the designed building is calculated and energy rating of the building is found using BEP-BUY. The

BEP-TR system will be available soon for EPC preparation and public use. As EPC assessors and other users use and test its capabilities, depending on their feedback and performance of the system, improvements will be considered.

Table 1: *Calculated energy consumptions by BEP-BUY*

	Annual Energy Consumption			Renewable Energy		Rating
	Final (kWh)	Primary (kWh)	Per usage area (kWh/m^2)			
Total	251252.815	359026.592	240.066	0	0	C
Heating	172675.899	173585.07	127.169	0	0	
Hot Water	21840	51542.4	37.76	0	0	
Cooling	1791.762	4228.559	3.098	0	0	
Ventilation	0	0	0	0	0	
Illumination	54945.154	129670.563	72.039	0	0	
Photo Voltaic	0	0	0	0	0	
Cogeneration	0	0	0	0	0	
Total Area of Usage: 1365m^2 Total Area of Building: 1800m^2						

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