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THE SAMPLES OF ENERGY MODELLING FOR ENERGY EFFICIENT GREEN BUILDING DESIGN IN TURKEY

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ABSTRACT

The interest on voluntary green building certification systems is increasing in the last decade in Turkey. Thus the energy performance modeling and simulations are gradually taking part in the building design stages. The aim of the paper is to discuss the several real building examples of energy performance simulations in Turkey and so to lay out the effects of utilizing energy performance simulations on different levels of building design. The given examples generally discuss the problems of inefficient system designs, not setting sustainable design objectives on early design stages, building owners' special requierements and simulation tool restrictions.

INTRODUCTION

The increased interest on voluntary green building certification systems, such as LEED, BREEAM, etc., in Turkey affects the conventional design process and forces it to evolve. Under the scope of the certification, maximization of the obtainable points especially on building energy performance credits depends on integrated building design process. Integrated building design can be achieved if architectural, mechanical, electrical and all other design groups can discuss and analytically measure the impacts of each design alternatives on building energy performance and then determine the building design in light of this analysis together. According to Moe, buildings would be more sustainable depending on integrity of its design teams and practices (Moe, 2008). That kind of design process is gradually being adopted to construction market in Turkey.

As building energy performance is the combined result of architectural, mechanical and electrical systems, it is deficient to decide each parameter independently from each other for a high performance sustainable building design. Each team should be aware of that, constructing a building is to constitute an interacted system to the environment which it will be stand and it will be affected by seasonal and daily climatic changes (Goulding, et al., 1993). For that reason, the crucial benefits of building energy performance modelling and simulation tools and consultancy on measurements to increase the building energy efficiency are being considered among building design groups. However, energy performance analysis, as a part of the integrated design approach, is still incompetent.

In this paper, it is aimed to discuss the real building energy performance analysis examples some with highly aware of the importance of the integration of the building energy performance analysis to design phases and some not. In addition, the problems, which are occurring from priorities of each design group or building owner, design approaches and economic aspects, are asserted.

ENERGY PERFORMANCE SIMULATION SAMPLES

In this paper, several examples for energy performance simulation are summarized to display different problems on different building design stages. These examples are all planned to be certified under LEED or BREEAM Green Building Certification Systems. As these systems are not local for Turkey, there are also problems with standards and assessment methodology while simulating the building energy performance. It is clear that a robust and credible building environmental assessment scheme will play a key role in assessing building energy performance. This is especially so for countries that does not have their own schemes and meanwhile undertake energy assessments for buildings (Roderick, et al., 2009). However, as it is explained before, in this paper, the problems occurring from the inefficient system design concept, non-integrated design approach or simulation tool restrictions will be stated.

Renewable energy and mechanical system integration

As an example of inefficient system design concept and renewable energy integration in mechanical system as a solution for a residential raw house unit example with two floors in Izmir will be summarized (Figure 1). The project has applied for BREEAM Green Building Certification program and energy performance analysis is realized for four representative units. In this paper, the results of energy performance analysis for only one unit are disclosed. The energy performance of the unit is determined by comparing the primary energy consumptions of proposed building and baseline building. Baseline building is modelled according to the Reference Building Definition of Turkish National Energy Performance Calculation Methodology (BEP-Tr). The predicted energy performances of actual and baseline buildings are simulated by EnergyPlus dynamic building simulation tool.

Figure 1 3D model and energy performance geometric model of the raw house units

The heating, cooling and domestic hot water loads are designed to be met by air-to-air heat pump system. Table 1 and Table 2 summarize the proposed and baseline building energy consumptions by means of fuel type.

Table 1
Energy consumption of the residential building

	ELECTRICITY [KWH/M^2]	NATURAL GAS [KWH/M^2]	DHW [KWH/ M^2]
Lighting	14.89	0.0	0.0
HVAC	35.64	0.0	0.58
Other	9.85	0.0	0.0
Total	60.39	0.0	0.58

Table 2
Energy consumption of the baseline building

	ELECTRICITY [KWH/M^2]	NATURAL GAS [KWH/M^2]	DHW [KWH/ M^2]
Lighting	13.58	0.0	0.0
HVAC	26.2	37.21	0.58
Other	9.85	0.0	0.0
Total	49.63	37.21	0.58

Table 3
Percentage improvement compared to baseline building

	TOTAL PRIMARY ENERGY [KWH/M^2]	PERCENTAGE IMPROVEMENT [%]
Proposed Building	142.52	7.65
Baseline Building	154.33	

According to the given energy consumption values of proposed and baseline building, the percentage of improvement value is calculated as 7,65 as shown in the Table 3. Total energy consumptions of proposed and baseline residential unit is converted to primary energy by multiplying the national conversion factors of 1 for natural gas and 2.36 for electricity.

It was the design decision of the mechanical design team to use one system for heating, cooling and domestic hot water demand of the residential unit. However according to the energy performance analysis of the residential unit, high electricity consumption due to domestic hot water production by air-to-air heat pump system is occurring. In this case the percentage of improvement is not enough for a green building certification. Furthermore the design group and the building owner wasn't convinced to use another system for DHW.

Taking into account of high solar energy potential of Izmir and the reduction need of electricity consumption due to domestic hot water, the integration of solar panels to heat pump system for domestic hot water production is proposed and simulated. The energy consumption results of the proposed system for the residential unit is given in the Table 4.

Table 4
Energy consumption of the residential unit by the integration of renewable energy

	ELECTRICITY [KWH/M^2]	NATURAL GAS [KWH/M^2]	DHW [KWH/ M^2]
Lighting	14.89	0.0	0.0
HVAC	20.15	0.0	0.58
Other	9.85	0.0	0.0
Total	44.89	0.0	0.58

The percentage improvement is re-calculated after the integration of solar panels for domestic hot water production to the mechanical system. Table 5 displays the percentage improvement obtained by the renewable energy usage.

Table 5
Percentage improvement compared to baseline building by renewable energy integration

	TOTAL PRIMARY ENERGY [KWH/M^2]	PERCENTAGE IMPROVEMENT [%]
Proposed Building	105.94	30.35
Baseline Building	152.10	

Percentage improvement on primary energy consumption of residential unit is increased from 7.65% to 30.35% by integrating the solar energy to the mechanical system and so higher points in BREEAM Green Building Certification Program. As the mechanical design team and the building owner were not aware of the solar panels' contribution to the energy performance of the residential unit without energy performance simulations, the real energy consumptions would be higher during the life cycle of the building. Consequently energy performance simulations should be integrated to building design phases to maximize the mechanical system efficiencies of the buildings.

Building envelope optimization

Building envelope is one of the primary architectural elements of building energy performance. During conventional architectural design, building envelope materials and constructions are decided considering aesthetic issues, constructional benefits and economic criteria. In this way, the building envelope's effect on building energy performance is often not being properly taken into consideration. Substantially, building envelope materials not only affects the energy requirements, but also the maintenance and operating issues during the life cycle of the building (Hegger, et al., 2008).

Figure 2 3D model and energy performance geometric model of the factory building

In this example, the building envelope design studies for a factory building in Istanbul are explained. EnergyPlus dynamic building simulation tool is used to optimize and test the building energy performance, thermal and visual comfort. During the early design phase of the building, the building envelope construction is analysed with several alternatives including insulation thickness, different opaque and transparent material types.

Table 6

Effect of building envelope optimization to building energy performance

	REFERENCE BUILDING ENERGY DEMAND [KWH/M^2]	ENERGY DEMAND WITH OPTIMIZED ENVELOPE [KWH/M^2]
Heating	47.07	6.72
Cooling	30.21	27.20
Lighting	17.43	15.53
Total	94.71	49.45

According to the analysis results, it is determined an envelope construction which optimizes low energy consumptions and high user thermal and visual comfort. Table 6 summarizes the energy demands of the factory building with envelope construction proposed by the architectural design group (reference building) and with optimised envelope construction. In total energy demand, 48% of decrease is obtained by the optimization studies.

Here it is discussed a second example of an office building in Ankara about building envelope studies during later phases of the architectural design (Figure 2). By the reason of finalized material decisions, only the insulation material thickness could be changed. Table 7 summarizes the insulation thickness changes to the total building energy consumptions.

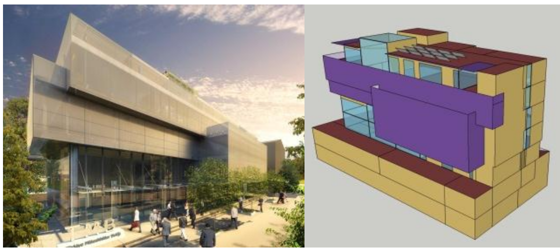

Figure 3 3D model and energy performance geometric model of the office building

As seen from the Table 7, insulation thickness would not be an effective modification just by itself to improve the building energy performance.

Table 7

Effect of thermal insulation thickness to building energy performance

INSULATION THICKNESS WALL/ROOF [M]	TOTAL ENERGY CONSUMPTION [KWH/M^2]
0.11 / 0.16	277.25
0.11 / 0.10	277.74
0.08 / 0.10	277.95

As a result, integrating the building energy performance simulations to design phases to measure and analyse each design alternative on the early building design phases is more effective. The energy performance simulations which are performed on later design phases are only to see the results of the current design.

Effect of natural ventilation on cooling loads

Another factory building which is planned to be built in İstanbul is selected to display how the building owner priorities affect the building energy performance (Figure 4). In the building cooling loads are very high even in heating period, because the thermal heat gains are very high, 90 W/m^2 average for whole building, due to electronic products manufacturing processes. According to previous researches in Europe, cooling loads may be decreased significantly by passive ventilation techniques (Santamouris, 2006). Thus a natural ventilation strategy based on indoor and outdoor air temperature differences is proposed to lower the cooling loads and tested by EnergyPlus dynamic building simulation tools.

Figure 4 3D model and energy performance geometric model of the factory building

In this example, design decisions on passive and mechanical systems are analysed by dynamic simulation tool DesignBuilder from the beginning of the design. Therefore, the design decisions were optimised according to energy modelling results and all other parameters, such as costs, aesthetics, application details etc., together. Then the optimised design decisions of the actual building are modelled and compared to ASHRAE 90.1 – 2007 baseline building.

During the optimization studies, the high cooling loads are tried to be decreased by investigating the properties of windows and window-to-wall ratios for solar gains, lighting strategies based on daylight control to decrease the internal gains and the insulation thickness of external wall in manufacturing zones which have extremely high heat gains from the process. However, the desirable improvement percentage couldn’t be achieved compared to baseline building. In accordance with these studies, the annual energy consumptions of heating, cooling and lighting in manufacturing zones are illustrated in Table 8.

Table 8

The comparison of annual energy consumptions in manufacturing zones between the actual and baseline of the factory

	HEATING ENERGY CONSUMPTION [KWH/M^2-YEAR]	**COOLING ENERGY CONSUMPTION [KWH/M^2-YEAR]**	**LIGHTING ENERGY CONSUMPTION [KWH/M^2-YEAR]**
Actual	2.40	351.63	65.90
Baseline	2.18	380.23	106.34

Natural ventilation strategy was decided to be utilized to decrease the cooling loads of the zones using operable windows and the automation system based on indoor and outdoor air temperature. Typically, the outdoor air is taken only if the outdoor air temperature is lower than the indoor air temperature. After the natural ventilation strategy is modelled by dynamic simulation tool, the annual energy consumptions of heating, cooling and lighting in manufacturing zones are illustrated in Table 9.

Table 9

The comparison of annual energy consumptions in manufacturing zones between the actual and baseline of the factory with natural ventilation

	HEATING ENERGY CONSUMPTION [KWH/M^2-YEAR]	**COOLING ENERGY CONSUMPTION [KWH/M^2-YEAR]**	**LIGHTING ENERGY CONSUMPTION [KWH/M^2-YEAR]**
Actual	2.44	295.49	65.90
Baseline	2.18	380.23	106.34

As seen from these tables, even the heating loads are higher than the baseline building; the cooling loads in manufacturing zones are significantly decreased by approximately 56kW/m2-year by the natural ventilation strategy.

On the other hand, the dust, which will be coming from the outside by natural ventilation strategy, certainly is not desirable for electronic manufacturing processes and the building owner priority is eliminating the dust totally even the design intent is set as achieving a green factory building. For that reason, ventilation might be supplied by using a free cooling strategy with air handling system using an economiser control based on indoor and outdoor air temperatures, and so the outdoor air might be filtered. However in this case, although the mechanical system efficiency is increased by free-cooling strategy, electrical energy consumption will be higher compared to natural ventilation because of operating the fans to take the outdoor air.

Although the studies to increase the energy performance of the building from the early phases of the design, here the functions of the building and building owner priorities limits some passive strategies that can be used to minimize the building loads.

Labyrinth system

The labyrinth system, which will be used as an auxiliary system for the air-handling units proposed for an office building in Ankara climate, is selected as an example for alternative systems proposed and simulation tool restrictions to model these alternative systems (Figure 2). In the proposed case, the fresh air used in air handling units is taken from the labyrinth system instead of outdoors. The labyrinth system is designed to be under the ground level and so it is not affected by outdoor air conditions. In addition, the labyrinth system is designed to be built with high thermal capacity concrete and the surface areas are increased to lengthen the outdoor air passage so the thermal exchange would be more effective. The labyrinth system layout is illustrated at Figure 1. In this way, the outlet air temperatures of labyrinth system are more stable during the year compared to outdoor air temperatures. The labyrinth system is planned to be effective especially during the cooling periods as night time cooling will be utilized inside the labyrinth and during the day the fresh air, which will be used in air handling units, will be precooled through the labyrinth system. Thus, the fresh air temperature decreases before entering to the air-handling units and so the energy consumption for cooling the building decreases.

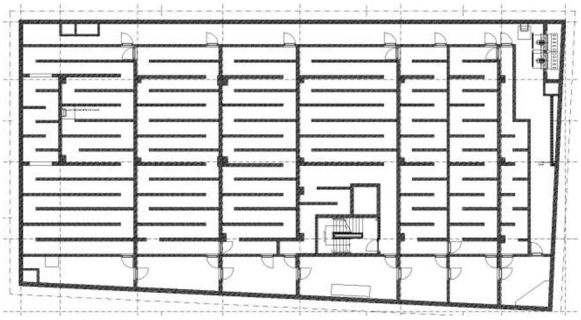

Figure 5 The labyrinth system layout located at the basement floor of the building

In the ideal situation, the proposed labyrinth system should be modelled using CFD tools, while the temperature distributions and airflow rates during the whole year in labyrinth system should be analysed. CFD analysis would provide the annual air temperatures and flow rates at the outlet of the labyrinth. Afterwards this data should be transferred to building energy performance simulation tool to calculate the effectiveness of the labyrinth system with hvac system of the building. On the other hand, obtaining the annual hourly data for temperatures and airflow rates using CFD tools, which will be needed by dynamic energy performance simulation software, is an extremely long process which needs too much time and labour.

Secondly, as a simplified methodology, the labyrinth system can be modelled as a group of thermal zones in the energy building. Whole geometry can be divided into smaller units in the model and each unit can be modelled as a thermal zone. Between each zone, an airflow network can be defined. Thereby while a predicted amount of air flows through each zone, its air temperature would change by taking into account of high thermal capacity concrete and so a similar to CFD analysis but a less precise data can be provided for the energy model. The airflow rates should be determined between each thermal zone, as the flow rates will affect the efficiency of the labyrinth system.

The second option was used to obtain the air temperature data, which is used as air inlet temperature to air handling units for the proposed building by using EnergyPlus. Airflow rates through labyrinth are determined as maximum supply airflow rates for air handling units by mechanic system designers. The data was described in dynamic energy simulation tool using a different programming language (EMS in EnergyPlus). The energy consumption of the building is illustrated using labyrinth system integrated with air handling units in Table 10.

Table 10
The effect of labyrinth system to the energy consumption of building

	TOTAL ENERGY CONSUMPTION [KWH/M^2-YEAR]	**NATURAL GAS ENERGY CONSUMPTION [KWH/M^2-YEAR]**	**ELECTRIC ENERGY CONSUMPTION [KWH/M^2-YEAR]**
Without labyrinth	158.15	188,553.07	167,863.42
With labyrinth	145.04	136,490.50	174,624.68

When the labyrinth system is integrated to air handling units annual total energy consumption decreases approximately 13 kWh/m2 although the annual electrical energy for cooling increases. The utility of labyrinth system bases on airflow rate, heating, cooling and ventilation requirements of the building. However, the hourly outlet air temperatures of labyrinth system are obtained by maximum AHU supply airflow rates determined by mechanical design group. Therefore, the utility of labyrinth system can vary in reality according to simulation model results.

According to the results of energy simulation, relatively low energy conservation is obtained when compared to the costs of constructing such a labyrinth. Because the climatic conditions of Ankara are heating dominant and the labyrinth system is more effective on summer conditions. Because the energy performance modelling is not integrated in the design phases, but only used to display the final energy consumptions of the building. Therefore an economically expensive investment is implemented without testing its effectives.

CONCLUSION

In this paper, the problems and the strategies and solutions proposed for these problems encountered during energy performance simulations for the projects, which are applied to green building certification programs, are illustrated. These problems and strategies include generally integration of building energy performance simulations to design phases, proposed inefficient systems and simulation tool usage.

In conclusion, when dynamic simulations to determine the building energy performance can be integrated to design phases of the buildings from the early stages, higher improvements on energy consumptions can be obtained. On the contrary, of general consideration, building energy performance simulations performed in the later phases of the building design can only states the building's energy performance of the current design, but not an improvement. After completion of the building design, performing building energy simulations to improve and optimize the energy performance of the buildings is causing a time waste and higher costs. In such cases, minimal modifications would be possible to increase the energy efficiency; however, these would not be enough to achieve a real green and sustainable building.

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