PROCESS-CENTERED MODELING EXPERIENCE FROM ARCHITECT'S PERSPECTIVE: A CASE STUDY IN A RESIDENTIAL BUILDING IN İZMİR

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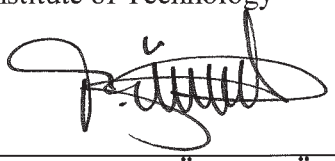

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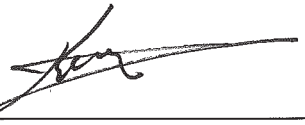

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ABSTRACT

PROCESS-CENTERED MODELING
EXPERIENCE FROM ARCHITECT'S PERSPECTIVE:
A CASE STUDY IN A RESIDENTIAL BUILDING IN İZMİR

Predicting current energy demand and future energy consumption of buildings is the challenging experience for architects. Although there are various dynamic simulation tools that enable them to calculate building energy performance, the complexity of tools poses problems to model, understand process-centered simulation studies and interpret the results.

This thesis aims to present, test, verify and criticize the modeling, simulation and calibration processes of residential building from architect's perspective. One of the effective ways to overcome global warming problem is by immediate involvement of architects into energy modeling process. Therefore, the study criticizes the role of architect in process-centered modeling.

Process-centered modeling is tested with existing residential building conditioned with air-source heat pump in İzmir-Turkey. Indoor and outdoor environment were monitored from July 2009 to June 2010. Digital model of the building was created by using DesignBuilder dynamic modelling tool, and calibrated for three different periods of heating, cooling and transition. The problems faced during modeling and simulation based on professional knowledge of the architect and simulation tool was exemplified. Finally, the survey was conducted to verify the role of architect tool users in modeling process.

Consequently, case study exemplified how the architect conducts a process-centered modeling, and survey showed how his/her modelling experience and knowledge is essential for right management of design process. Mechanical systems modeling is still challenging issue requiring knowledge and experience for architect users..

ÖZET

MİMARIN BAKIŞ AÇISIYLA SÜREÇ-ODAKLI MODELLEME DENEYİMİ: İZMİR'DE BİR KONUTTA ALAN ÇALIŞMASI

Binaların mevcut enerji talebi ve gelecekteki enerji tüketimini tahmin etmek mimarlar için zorlu bir deneyimdir. Her ne kadar bina enerji performansını hesaplayabilmelerini sağlayan çeşitli dinamik simülasyon araçları olsa da, araçların karmaşıklığı model oluşturma, süreç-merkezli simülasyon çalışmalarını anlama ve sonuçları yorumlama konusunda sorun oluşturmaktadır.

Bu tez, bir konutun modelleme, simülasyon ve kalibrasyon süreçlerini mimarın bakış açısından sunmak, test etmek, doğrulamak ve eleştirmeyi amaçlamaktadır. Küresel ısınma probleminin üstesinden gelebilmenin en etkili yollarından biri de mimarların enerji odaklı modelleme sürecine derhal dahil olmalarıdır. Dolayısıyla bu çalışma, mimarın süreç-odaklı modellemedeki rolünü değerlendirmektedir.

İzmir'de hava kaynaklı ısı pompasıyla iklimlendirilen mevcut bir konutta süreç-odaklı modelleme deneyimi test edilmiştir. İç ve dış iklim koşulları Temmuz 2009 Haziran 2010 arasında izlenmiştir. Evin dijital modeli DesignBuilder dinamik modelleme aracı kullanılarak oluşturulmuş, ısıtma, soğutma ve geçiş dönemi olarak üç farklı periyotta kalibre edilmiştir. Modelleme ve simülasyon sırasında, mimarın karşılaştığı mesleki bilgi ve simulasyon aracına dayalı sorunlar örneklenmiştir. Son olarak, mimar kullanıcıların modelleme sürecindeki rolünü doğrulamak üzere anket yapılmıştır.

Sonuçta, alan çalışması mimarın süreç-odaklı modellemeyi nasıl yürüttüğünü örneklemiş, anket ise modelleme deneyim ve bilgisinin tasarım sürecini doğru yönetmede nasıl önem kazandığını göstermiştir. Mekanik sistemlerin modele entegrasyonu mimar kullanıcılar için halen bilgi ve tecrübe gerektiren bir konudur.

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LIST OF ABBREVIATIONS

2D	Two Dimensional
3D	Three Dimensional
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
Ave	Average
CAD	Computer Aided Design
COP	Coefficient of Performance.
CV-RMSE	Root-Mean-Squared Error
DB	DesignBuilder
DSG	Design Simulation Group
E+	EnergyPlus
EER	Energy Efficiency Rating
HVAC	Heating, Ventilation and Air-Conditioning
IWEC	International Weather Year for Energy Calculation
IBPSA	International Building Performance Simulation Association
LEED	Leadership in Energy and Environmental Design
Max	Maximum
MBE	Mean Bias Error
Min	Minimum
n	Number of Observations
NREL	U.S Department of Energy's National Renewable Energy Laboratory
RH	Relative Humidity (%)
T	Temperature (ºC)
T_m	Measured Temperatures (ºC)
TTMD	Turkish Society of HVAC and Sanitary Engineers
U value	Overall Heat Transfer Coefficient (W/m²K)
BESTEST	Building Energy Simulation Test
BPS	Building Performance Simulation
T_i	Indoor Temperature (ºC)

To	Outdoor Temperature (ºC)
LEED AP	Leadership in Energy and Environmental Design Accredited Professional
USGBC	US Green Building Council
BIM	Building Information Modelling
M&V	Measurement and Verification

CHAPTER 1

INTRODUCTION

1.1. Problem Statement

Predicting energy consumption is essential for future planning, managing, and conserving for building energy. In recent years, several energy prediction tools have been developed to estimate and reduce energy consumption in buildings, causing approximately 40% of total energy use and 36% of total CO_2 emissions (European Commission, 2016). In order to solve the increasing energy problem, a large number of scientifically approved building simulation tools have been developed, predicting the exact consumption. In general, users of these tools are researchers, building physicians, building energy analysts, engineers and architects. One way of achieving a reduction on building energy use will come from the ambition of these users of simulation tools.

In order to achieve higher building performance, the inclusion of architects in energy simulations has recently been a subject of much argumentation. In the literature on building simulation practices, studies have been carried out explaining the role of architects among other simulation tool users, and the difficulties they face. The general consent on that architects should be included in the building performance simulation has brought about the transformation that more automated, architect-friendly software were developed to be used by architects more easily. Thus, they enabled taking accurate design decisions in early stages, and help them make better geometric decisions by learning how to conduct energy efficiency studies.

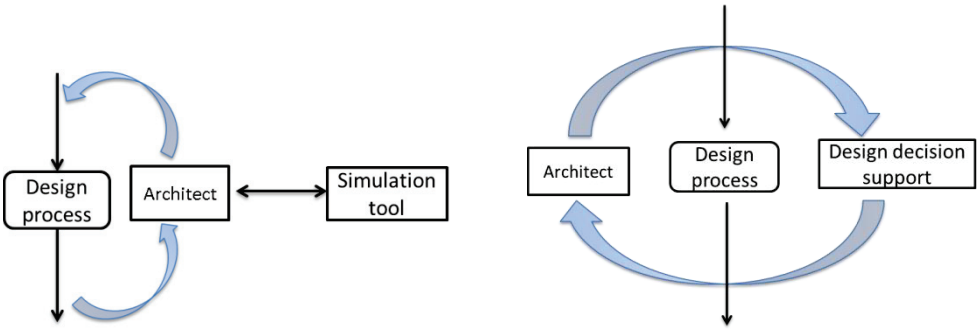
It is essential for architects not only to test ideas, but also to develop and present new ideas. Therefore, the architect should also be involved into simulation process. The development of 'simplified' simulation tools for architects has attracted great interest from the research community. Several researches have been conducted about how to simulate architects' design queries, how to make quick and efficient decisions easily, and how to identify simulation processes by recognizing simulation tools. Donn (1997) underlined that users' expectations from tools were more of a smart design assistant, thus most of the existing building simulation research and development efforts focused

on improving tools at full speed. Accordingly, the software developers were determined to make the software easier to use and to produce user-friendly software. More studies have been carried out on the concept that defines the building simulation program as 'architect friendly' (Donn, 1997).

Attia, Beltrán, De Herde, and Hensen (2009) identified a number of criteria for 'architect friendly' simulation tools used in daily architectural design applications by conducting an online survey from mid-December 2008 until mid-January 2009. The evaluation of tools indicated that these tools fail in terms of interoperability of building modeling and accuracy, and ability to simulate the complex and detailed building components while meeting the criteria for usability, information interface management and integration of intelligent design knowledge base.

Nowadays, what role architects play in the simulation process and what the new trends are in the simulation studies constitute common research area in the building simulation practice. Since the complexity of modeling in buildings increases, researchers have begun to make their work more process oriented. In Morbitzer, Strachan, Spires, Cafferty, and Webster (2001) wrote article namely 'Integration of Building Simulation into the Design Process of an Architecture Practice', it is stated that the simulation should not only be used for final performance confirmation, but also as a part of the design process. They pointed out that simulations should actually be performed in the design practice. In order to create a holistic design approach with simulation for all design stages, architects must determine the design approach to be applied.

A relevant statement with this thesis in the literature, belonging to Clarke, Strachan and Pernot (1993), defines two different approaches for the use of simulation programs by architects in the architectural design process: translation-based approach and design friendly approach. The former essentially expresses the design process where the designer is constantly in between data models (CAD and energy models) (Figure 1.1.a) The latter is a more accurate approach embedded in computer supported design environment where the design process is integrated with tools, i.e. architect-friendly simulation tools (Clarke, Strachan, and Pernot, 1993)(Figure 1.1b).



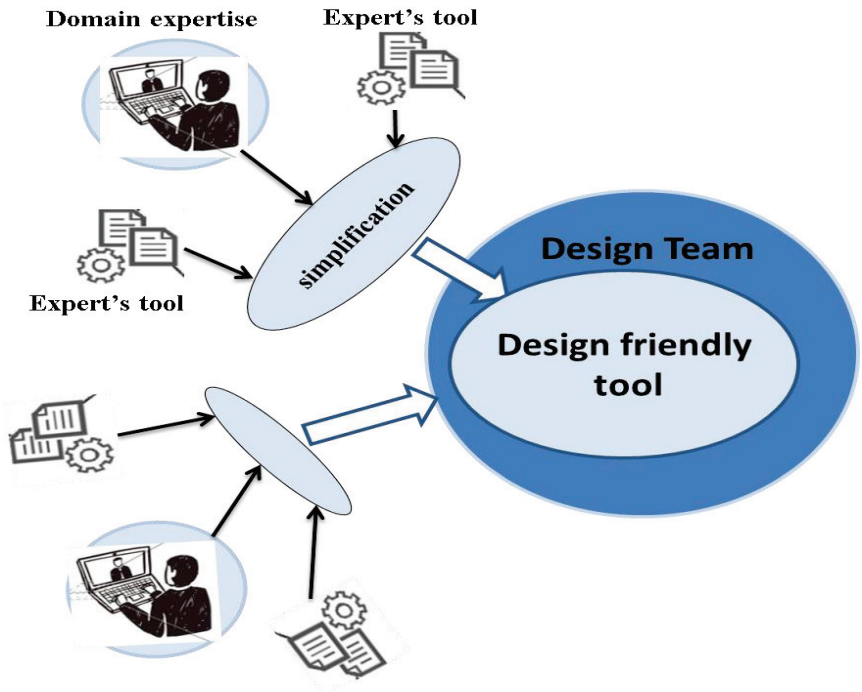
(a) (b)

Figure 1.1. (a) Translation-based approach, (b) Design friendly approach (Source: Clarke et al.1993)

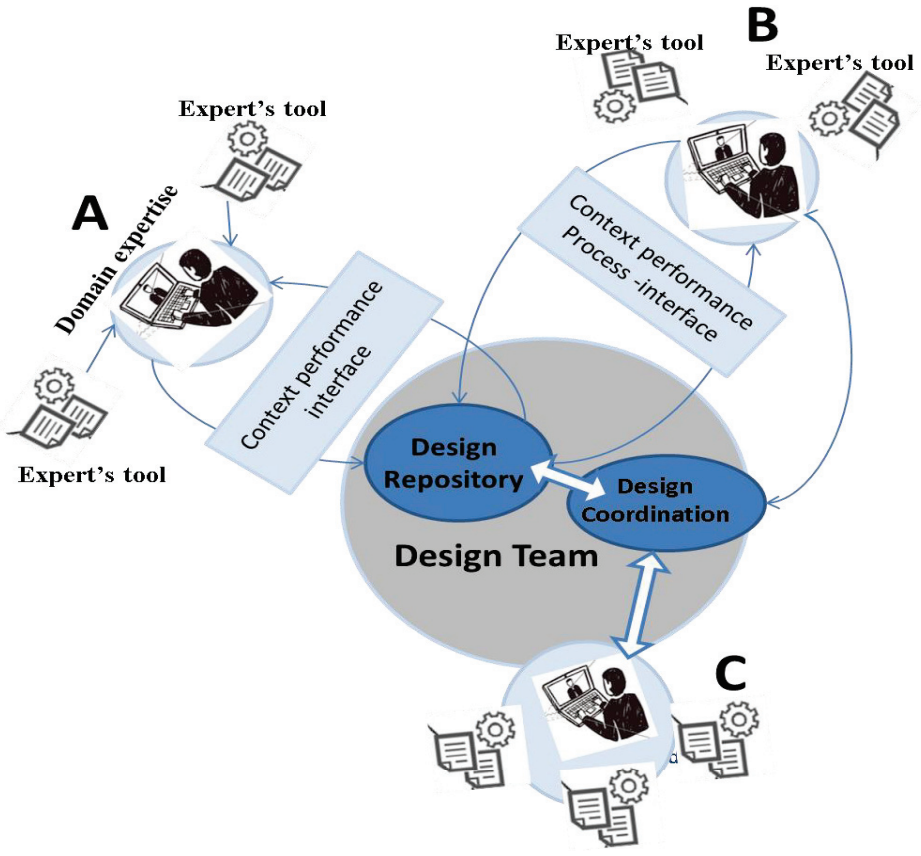
Common research field in building simulation practice for recent years is the process-centered modelling in architectural design. Augenbroe (2004) presents two trends on integration of energy simulations into the architectural design: tool-related and process-related. The primary factor of the former trend is the exclusion of the specialist and its expertise from simulation process. Here, designer friendly tools make a program that requires expertise easy to use with little information, while eliminating the need for specialist and long-term accumulation of modelling knowledge. It also simplifies the modelling process (Figure 1.2.a).

The second, process-centered, is to improve the design context and to receive external support (Figure 1.2.b). In variant B, the progress and management of process is crucial to conduct complex simulation task required by current building practice. It requires team work. Design team took role instead of a single tool. The user of BPS becomes a central design manager, i.e. coordinator, for collecting alternatives and coordinating effective simulation experts in the field. The process carried out throughout modeling has become more essential then easy usability of the programs especially in the modelling of complex structures including advanced engineering systems, such as the integration of intelligent building systems and renewable energy systems (Augenbroe, 2004).

Integrating modeling into design will increase energy and environmental performance of buildings. Yet, building simulations are currently not fully involved into the design process. The correct processes to be followed in the simulation are essential due to the complexity of the design process and the advanced technologies applied in the construction industry. If there is an integrated team approach in the simulation process, low-energy design can be achieved with less effort and time for energy modeling in the early stages.



(a)



(b)

Figure 1.2. Integration of energy simulations into the architectural design: (a) Tool-related (b) process-cantered (Source: Augenbroe, 2004)

Architects who are the team leaders in the design process should understand the basics of energy modeling and determine their processes accordingly. Although a single simulation program for architect users is easy and useful, it may be necessary to use different user interfaces for different design stages. It is the fact that the simplified architect-friendly programs mentioned here may not be valid for all stages, because different design objectives and scopes can be observed at different building design stages. Architects can learn how to make early use of energy oriented solutions in typical buildings and make better geometric decisions with simplified tools. However, architects' knowledge can be insufficient especially in more detailed stages of design; engineers and other experts can provide guidance based on their experience to guide the simulation team on the right path.

This thesis argues that architects, energy modeling analysts and engineers should work within the team understanding to integrate different type of models into design process, to provide the best balance of speed, design flexibility and prediction of energy consumption. Architects may not be able to dominate all modeling processes (requiring engineering knowledge) due to their design-oriented perspectives. The role of architects in modeling studies that require profound expertise should be the role of coordinator, managing the process, integrating teams, at least knowing which software should be used for the model. However, they may not make the whole model alone.

1.2. Aim of the Study

The main purpose of this research is to present, test, verify and criticize the modeling, simulation and calibration processes of a building from an architect's point of view. It presents the self-experience process to show architects' capability and incapability in an advanced modelling process.

The most effective way to avoid the effects of global warming is by the immediate involvement of architects in this energy conscious process. Therefore, in this thesis, main objective is to evaluate how the simulation process is carried out by an architect who knows the possibilities and limitations of the simulation process. The thesis scrutinizes following main research questions:

1. How essential is the degree of expertise of the simulation tool user?

2. How architects can do energy modelling of the residential building with mechanical system?
3. What role should architects play in energy simulation?
4. To use the simulation tools what knowledge should the architect as an energy analyst have?
5. How should the simulation analysis process be planned for architects?
6. How to select right building performance simulation tool in the right time of modelling process and design stage?

How should the architect cope with the obstacles and problems encountered during the simulation process?

7. How the integration and control function of the renewable energy source should be built into modelling?
8. How should architects follow complex modelling?
9. How important are the collaborations with experts?

1.3 Research Methodology

In this thesis, there are several applied methods in order to understand the possibilities and limitations of the simulation process and to know how the simulation process is performed by an architect. This thesis consists of seven chapters. The first chapter demonstrates the problem statement, aims, objectives, assumptions and limitations of the study.

This research continues with literature review to investigate the latest state of the building performance simulation studies, simulation tools and processes in chapter two. Recent studies on the necessity of validation and validation and calibration of the progression of building energy simulation models have been presented through literature research. In addition, the general approach to the energy modeling profession as to who can use building simulation tools has been approached, and a literature review has been conducted to find out where the architects are located in this profession.

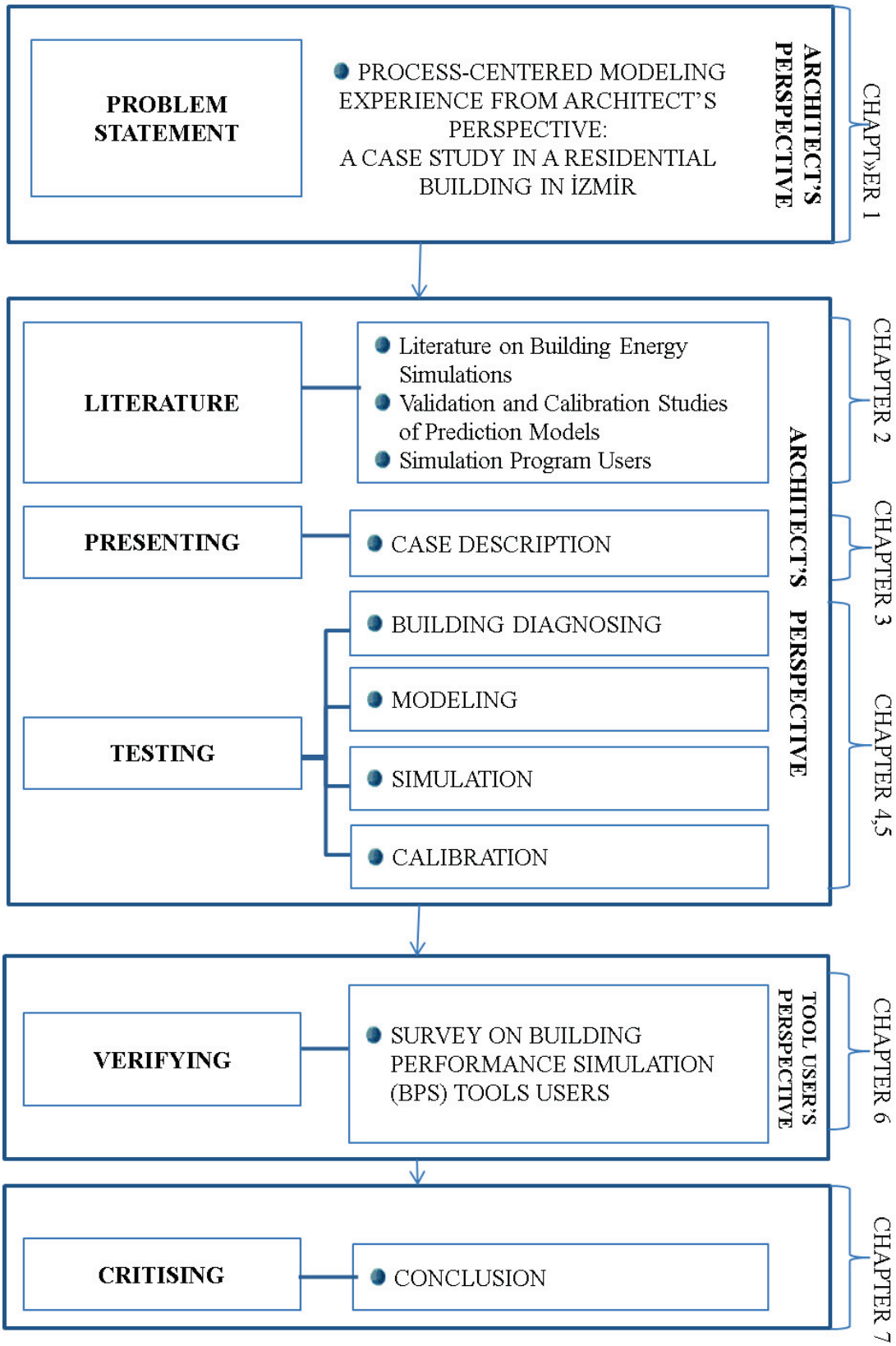


Figure 1.3. Workflow of the research methodology, used in the thesis

The general structure of the thesis research methodology is divided into three sections: presentation, testing and criticizing and shown in Figure 1.3. During one year of the study, many meetings were held with responsible architect Fatma Şahin Gündoğan and Mechanical Engineer Can Hasanoğlu from Sem Architectural Office. All information about the building was collected before modeling.

Presenting: The third chapter is called 'Case Study', where the field study and modeling methods are applied and presented. First, the location and geography of the building were defined, and the plans and sections describing the architecture were presented. And before entering the model, the materials used in the construction were noted. Then, methods such as working in the field and completing the measured data were determined. At the end of this section, the heating and cooling of the building with the alternative energy source is explained in detail.

Testing: This part of the thesis is presented in chapters four and five. It consists of three main parts: Building Diagnosis, Modeling and Calibration. In the Building Diagnosing part, the parameters to be used for modeling of the building and its surroundings are collected (see chapter four). The measurement of local climate data and all parameters including building temperature and energy performance indicators were monitored for a total of one year between July 2009 and June 2010. Architectural drawings and images of the building were taken from the construction company. The building has three floors with a gross area of 300 m^2. For the unmeasured climate data onsite, it is derived from the meteorological station at İZTECH (between June 1 - August 31th, 2009 and December 1st, 2009 - February 28th, 2010). In addition, indoor climate conditions and energy consumption of the heat pump are measured simultaneously from the data loggers and power analyzer in the building.

In the modeling part of the test phase, DesignBuilder V: 4.2 building energy performance simulation tool is used. For HVAC system air source heat pump components, more precise and detailed results were required in modeling, but the initial versions of DB were insufficient in modeling. After updating of the software in time, modeling was continued with the new version of DesignBuilder V: 6.0 the impact of the user on performance is excluded from the scope of modeling.

During the calibration stage, the calibration process was carried out in three different models for heating, cooling and transition season. First, a calibration process was performed on the transition model without HVAC. This model was then simulated with different HVAC systems to calibrate the heating and cooling time.

At the end of the calibration work, the results obtained from the digital model were compared with the measured actual energy consumption values of the heated and cooled area, and then the error rates of the calibrated models were calculated. According to the simulation results, if the model is different from the measured results, it is necessary to recalibrate the model by checking all settings until the results are close to the measured data to reach the calibrated model. It is best to make reliable estimates after comparison of output parameters, indoor temperatures, cooling and heating coil load (kW), hourly comparable simulated and measured data. Based on the outputs obtained from the performance analysis results, it is focused on examining some model parameters in model calibration; electrical measurement and weather data, HVAC equipment, indoor conditions. The evaluations of the simulation results for three seasons are presented in the discussion section of chapter five.

Verifying: In this part of the thesis, as a validation of the research, a questionnaire which confirms the previous presentation and test stages is included. Since simulation in the Detailed Design Stage is a subject that requires expertise and is of the opinion that architects only use a tool that finds only limited application. Therefore, it is necessary for architects to carry out more process-oriented work. This survey was prepared from the architect's point of view to help verify the results of the test section. It was conducted between 26 June to 10 July 2019, among the experienced users of simulation tools in Turkey and abroad by using an online form published in different groups related. Online Google questionnaires were used to enable users of BPS tools to evaluate their answers effectively and reach users in the international platform. The purpose of the survey was to record user experiences and identify the challenges they faced, and in particular to know the role of architects in the simulation process. In general, the questions were left open, but options were prepared for the questions we wanted to obtain statistical results. It was seen that the participants expressed their opinions better with open questions and it was more useful in analyzing the survey results. This verifying part of the research and the results of the survey are presented in detail in chapter six.

Criticizing: In the final part of the thesis in chapter seven, the derived conclusions from survey results and the calibration studies performed during the test phase are presented and discussed. The problems experienced in the modeling part are explained in this section supported by the answers of the survey users in concluding remarks. Finally, as an architect using the simulation tool, the results and possible

further studies are summarized in chapter seven and provide recommendations for future research.

1.4 Limitations and Assumptions

Some limitations and assumptions were encountered at various stages of this research. Limitations are as follows.

Missing Data: For some technical reasons, some of the loaded data is missing. Climatic data were downloaded with approximately three-week visits to the study area. Therefore, data losses have occurred due to the storage capacity of the Station. Non-data data were filled with other data provided from the meteorological station of the Izmir Institute of Technology in the Gülbahçe region of İzmir. The same problem has also been observed with mini data loggers that measure internal temperatures and relative humidity.

Missing data (2009);	
08. August:	28.08.2009 (13:20) and 30.08.2009(16:50)
09. September:	17.09.2009 (11:20) and 01.10.2009 (00:00)
10. October:	08.10.2009 (10:50) and 10.10.2009 (16:50)
11. November:	20.11.2009 (16:00) and 28.11.2009 (17:00)
12. December:	16.12.2009 (11:30) and 18.12.2009 (18:30)
Missing data (2010);	
01. January:	-
02. February:	03.02.2010 (14:30) and 08.12.2010 (20:00)
03. March:	03.03.2010 (16:50) and 24.03.2010 (21:50)
04. April:	11.04.2010 (17:20) and 31.04.2010 (24:00)
05. May:	01.05.2010 (00:10) and 08.05.2010 (19:10)
	26.05.2010 (13:50) and 31.05.2010 (24:00)
06. June:	01.06.2010 (00:10) and 10.06.2010
	26.06.2010 (19:50) and 26.06.2010 (22:00)
07. July:	29.07.2010 (17:20) and 31.07.2010 (24:00)
08. August:	01.08.2010 (00:00) and 02.08.2010 (20:30

Determining the most appropriate mechanical system:

When starting the model, it is necessary to determine the most appropriate mechanical system representing the current system in the simulation tool. Here are some limitations to Design Builder. The ability to simulate renewable energy systems has not been developed. Heat Pump HVAC templates with underfloor heating and cooling system are not included in the program templates. The best thing to do here is to know the capabilities of the simulation tool and decide which method best represents the current system. Therefore, to obtain a low margin of error, the mechanical system library of building simulation programs must be rich and adaptable.

For example, the EER value, which indicates the cooling capacity, is not available in db. We have to enter the cooling capacity as the COP value indicating the heating capacity. In this way, it is not possible to correctly enter the catalogue data of the heat pump.

CHAPTER 2

STUDIES ON DYNAMIC PREDICTION METHODOLOGIES IN BUILDINGS

Global warming and climate change are due to increased greenhouse gas concentrations through the use of fossil fuels and other non-renewable energy sources (IPCC, 2010). Carbon emissions from energy use in buildings are one of the most important in general emission scenarios. The building sector was responsible for nearly half (35.11%) of Turkey energy consumption in 2013 as it is declared in the report published in 2013 by The Turkish Ministry of Energy and Natural Resources (MENR, 2013).

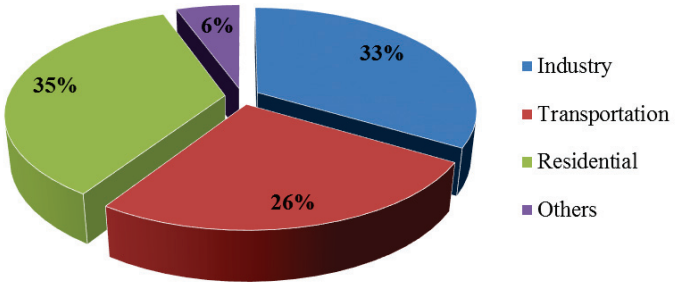


Figure 2.1. The total energy consumption of the sectors in Turkey (Source: MENR, 2013)

According to Turkstat, Turkey's greenhouse gas emissions (CO equivalent), approximately in the year 2011 from 124% in the last decade has increased the energy sector and 72% of total emissions emitted (TurkStat, 2014). The energy consumed by houses and buildings is 40% of the total EU energy consumption and is the main contribution to greenhouse gas (GHG) emissions (Figure 2.1). This percentage is the most considerable for possible saving in recent years in Turkey.

The energy industry has changed some laws when it comes to efforts to reduce energy consumption and carbon emissions. Moreover, began to take steps in energy efficiency to be seen as a source of management policy. Accordingly, a new law 'Energy Efficiency Law' was prepared. It was published on 2 May 2007, the main objectives of this law; to reduce energy consumption, to avoid waste, to ease the burden of energy costs on the economy and the use of energy resources to protect the

environment in Turkey. The Energy Performance Directive of the Buildings (EPCD) published that in every country new methodologies should be developed to calculate and reduce the energy performance of buildings. Accordingly, Energy Performance of Buildings Directive in 2009, entered into force in Turkey. Then, efforts to develop a methodology measuring the energy consumption called BEP-TR, has begun. BEP-TR, an internet-based semi-dynamic simulation method, was developed to determine the energy performance classes of buildings.

Since the energy consumption of buildings constitutes one third of our primary energy (EPCD, 2010), energy consumption predictions have recently become a common research topic, thus forecasting methods, saving energy and began to gain importance in Turkey to improve the energy performance of buildings in order to reduce environmental impact.

In order to analyses building performance, many researches have done to predict energy consumption of the buildings. For the new buildings, to increase sustainability criteria of it and to design them with high-performance ideas .and retrofitting work for the existing buildings with the least energy consumption studies will provide the highest level of comfort and offer to the user wellness area.

In this context, simulations of buildings are helping to improve solving building performance problems related to design, construction, building operation stages with the most appropriate way. For this reason, today, simulation tools are used for new buildings as an integral part of the design and for retrofitting ideas in the works of building energy performance analyses for existing buildings.

2.1 Literature on Building Energy Simulations

Aiming to build high-performance new buildings with sustainability criteria and improve retrofitting ideas for the existing buildings the dynamic simulation tools are used and developed by many researchers. Since building simulation began in the 1960s, it has become the most important subject of energy researchers in the 1970s (Hong, Chou, and Bong, 2000). Literally, many building energy programs have been developed and in are used in the last 50 years.

Crawley, known as the dean of simulators, was one of the founders of the IBPSA-USA (International Association of Building Performance Simulation), which was previously hosted by the US Department of Energy. The main objective of IBPSA-

USA is to promote and promote the science of building simulation to improve the design, construction, operation and maintenance of new and existing buildings in the United States. At the end of 2014, IBPSA was given the management of the building energy simulation tools web directory (BEST-D) by the Ministry of Energy (BEST).

Some of the design simulation tools are available for all building analyses, and some have only too many simulation tools specialized for lighting, ventilation, HVAC components and systems, and all other aspects of building energy performance. In the literature, Crawley presented a publication in which the characteristics and capabilities of twenty large energy simulation programs were updated and compared. BLAST, BSim, DeST, DOE-2.1E, ECOTECT, Ener-Win, Energy Express, Energy-10, EnergyPlus, eQUEST, ESP-r, IDA ICE, IES/VES, HAP, HEED, PowerDomus, SUNREL, Tas, TRACE, and TRNSYS. Crawley gives the comparison of the tools in the tables to showing the many different of ways and solutions indicated by these programs; zone loads, general modelling features building envelope and daylighting, climate data currency, economic evaluation , user interface, links to other programs, and availability, renewable energy systems HVAC equipment, HVAC systems , results reporting. He mentioned, almost all of the programs are concerned to thermal mass, but some tools are only using the temperature value for designing and sizing calculations. A few tools quite offered automatic sizing. Most tools have adequate HVAC settings zone by zone. Nevertheless, unless having more trials with the tools to experiment how dealing with HVAC settings, it wouldn't be easy to decide which one is better tool to use it. As a result they noted that there are many nuances of 'capability' that the developers found difficult to communicate. For example, there are several levels of resolution one tool may do a simplified solution while another may have multiple approaches for that feature. At the end of his research he added that the users can choose the best tool from the IEA BESTEST link that is dynamic web-based community resource.

Hong et al. (2000) has also given an answer to the question how to choose a simulation program. According to him nowadays it is a common fact that there are more than one BSP that can meet the requirements for any given problem. However, there is no single simulation tools that can perform all kind of building simulation (Hong et al., 2000). Energy simulators are faced with the challenge of selecting a suitable tool from the existing ones. Which BSP can be chosen is unfortunately not clear. Selection must be made after carefully evaluating the user's needs and matching them to the capabilities

of the BSP.

Jankovic (2012), one of the researchers wrote the book called Design Tools and Design Methods; he has also focused on several dynamic simulation software packages in his book and declared some advantages and disadvantages of them. If building performance simulations are done efficiently and accurately determined the building environmental impacts, it will help to increase indoor environment quality and play an important role improving the efficiency of users for the simulation tools. Computer based simulation programs are formulating the building and building energy, acoustic, visual and thermal comfort analyses and collecting all complex calculations in one tool. The simulation tools are helping also to design new buildings as a whole systems and integrate the best optimized mechanical systems with different developed alternatives, also improving the communication between architects and engineers who have different work disciples to be able to work together effectively (Jankovic, 2012). Table 2.1 at the end of this section provides an overview of the importance and application of building energy simulations to integrated buildings.

2.1.1 Studies for New Buildings

Doğan, Saratsis and Reinhart (2015) presented the workshop results of the students in Graduate School of Design at Harvard University. Based on DesignBuilder / EnergyPlus, the energy simulation as a 90-minute game in the class suggested and evaluated the fun form of the teacher. The game was between simulation experts volunteer students most of whom had previously taken a full semester course on energy simulations and first year architectural students .The authors also showed that architects could also do energy modelling through the game, suggesting the spread of an energy modelling "culture" in architecture schools. Moreover, they can learn how to read results from the experts during the game. To seeing them running the simulations, they might get inspired to learn how to use the advanced tools themselves. The aim of the game was to reduce the energy consumption of an office building with a floor area of 2940 m^2 (31,600 ft2).The authors generated simulation templates of the eleven building forms, each with a premade library of the game's design choices given before the game. Consequently, each design can be made more than 400,000 in less than three minutes. The simulations took three to eight minutes on the first student's laptop. In the experiment, they loved to practice and play all groups reported finding as effective and

interesting teaching methods. Another idea was to provide them with a catalogue of the effectiveness of various energy conservation methods in different building types and climates (Doğan, Saratsis, and Reinhart, 2015).

Andarini (2014) has studied o on office buildings in Jakarta. He focused on new office building design simulations, building shell optimization, and high-efficiency office equipment and HVAC simulations. .The annual energy consumption of the system has decreased by 43%. Energy-Plus based dynamic thermal simulation tool Design-Builder is used for building energy simulations. In this study, thermal simulations for two different purposes are presented. The first simulation scenario was for a new building design and the second for a renovation project, the result shows that reducing energy consumption of air conditioning systems for more beneficial after improved the building's facades of the existing building (Andarini, 2014).

Friess, Rakhshan, Hendawi and Tajerzadeh (2012) investigated energetic performance of a series of typically applied insulation strategies for the housing units in Dubai In this study, the effect of the insulation strategies on the energetic performance was studied with both in the initial design phase and in the retrofit applications with hourly simulations. Design Builder/EnergyPlus were used as a simulation tool. The simulation model is calibrated against the collected consumption data and the experimental infiltration measurements of the actual building. As a result, only 30% energy savings have been achieved by appropriate suitable external insulation strategies (Friess, Rakhshan, Hendawi, and Tajerzadeh, 2012).

Han-Soo and Kyung-Soon (2016) studied on a LEED project. The energy-simulated building is a tower building in Seoul. In their research, energy simulations of a building modelled proposed tower building with the Trace 700 for LEED certifications. It is intended to have LEED New Construction (NC) certification by reducing energy cost of 10%. According to the building type, the total score that can be obtained with energy simulation is 19-21 pounds maximum. In addition, in the LEED rating, which is 110 points in total, this value is quite high. They used Revit for the building geometry modelling. Once a template is created, the data with gbXML extension is transferred to Trace 700 for energy simulation. The zones of building are modelled according to the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 90.1, Table G3.1. Energy simulation shall be implemented with the proposed model as an actual designed building and baseline model following the guidelines of ASHRAE 90.1-2007, Appendix G. The energy

simulation was done for two different models. The newly designed building (Proposed Building) and the baseline model which has following the guidelines of ASHRAE 90.1-2007, Appendix G. Energy consumption rates were compared between these two model. When the simulation results were compared, the energy saving rate for the proposed situation was 27.9%.

2.1.2. Studies for Existing Buildings

In the article named 'Streamlining Energy Simulation to İdentify Building Retrofits' in ASHRAE Journal, Pappas and Reilly (2011) are talking about their analyse process of retrofitting studies of the existing buildings. Their companies have recently been commissioned to conduct energy audit assessments to the three government buildings in U.S. For all three buildings, they agreed to make a comprehensive audit review with NREL (U.S Department of Energy's National Renewable Energy Laboratory.) They then created a calibrated building energy model that is used to calculate annual energy cost savings and provides life-cycle cost analysis and advices. The case building was extent building. It has been constructed in 1960. The building has been used as Office Space for Government Institutions. They aimed to reduce % 10 of the annual energy cost of the building. They started developing the model by entering all the building envelope data of the existing building.

They simplified the building geometry as much as possible, and divide them to a large extent. They tried to model the exterior wall, roof and window areas correctly. The total modelling time spent on the building was only 3 hours and the total run time of modelling them on a 64-bit desktop computer was around 16 seconds with an IntelCore2Quad processor. They focused mostly on lighting and HVAC measures. They kept the actual building model as much as simple. They saw they can still obtain accurate models even for a bit more complex buildings with only with doing the appropriate simplifications. This was very helpful in using the time for them. Always need more time for designing and analysing than the time need for modelling. The speed of modelling was more important for them when choosing the simulation tool and improving the process. For that reason they selected DOE-2.2 with the eQuest interface as suitable modelling tool. According to the calibrated model, the annual renewal package will reduce the annual energy cost by 36%.

Pedrini (2002) used simulation tools for analysing energy performance of the existing buildings in Brazil. They developed a method used to model more than 15 buildings. The purpose of the model is only to use existing data to estimate the building's energy consumption. As a building energy analyst, it is not necessary to see the building so the distance between analyst and building is not important.it is not so important that the analyst is away from the building and the distance between the buildings is not important. In this context, this is a powerful advantage for energy analysts. They had a standard methodology with a project in six cities around the country .which was operated for commercial and public buildings. On the stage of the research they used the computer simulation to analyse to apply the methodology presented in their paper here. They took the actual data of the buildings from Energy Audit Company. This study is one of the best examples to describe a calibration process. A systematic analytical study was conducted in 6 remote cities by the energy analysts. This 20-year-old building was difficult to be monitored. Derived data was not matching with the available plans. HVAC systems were not representing the same as design plans 20 years ago. As a result of their research, energy analysts have offered some solutions to illustrate the best way to model, but they have made recommendations, such as a more user-friendly simulation tool (Pedrini, Westphal, and Lamberts, 2002).

Chowdhury, Rasul, and Khan (2006) investigated application of low energy cooling systems to the existing buildings and reducing the load on cooling systems of commercial buildings Queensland, in Australia. Low energy cooling systems provide better comfort and energy consumption compare to the traditional systems He compared of different low energy cooling systems performance are compared with those of a chilled ceiling radiant cooling. DesignBuilder as an interface of EnergyPlus based dynamic thermal simulation engine used for the simulating the case building model. Climate data were used to use the whole of the year 2002. Simulations were made as daily time steps. The temperature cooling set point was 24°C and the heating set point was 24 ° C. Results are showing that the chilled ceiling technique is better compared to the other low energy operating system. An annual energy saving of up to 13% has been accomplished (Chowdhury et al., 2006).

Ahmad Sabry An-Naggar1 and Mohamed Aly Ibrahim (2017) studied on energy performance of a residential building in Egypt, which consist of three floors and six apartments 100 m^2 floor area for each apartment was investigated. The case building

modelled in Design builder. Comparisons were made. East orientation was selected for the building and outdoor temperature was 42°C. Exterior wall and roof materials (layers) data entered from the existing building. The occupancy; their number and metabolic rate, lighting and equipment as default for residential buildings data entered as internal gains. Finally HVAC input data was selected system as Split Unıt, the C.O.P. is 2.25 and the operating hours are 7 hours per day for the two air-conditioned zones. As a result the energy analyses for the different wall, roof materials were studied, and compared. After using thermal insulation (Glass wool blanket) with thickness 0.05 m in walls and roof of the last floor, simulations results were showing Energy saving of about 40% of the energy consumed by the air conditioner (An-Naggar, Ibrahim, and Khalil, 2017).

2.1.3 Modelling for Green Buildings and Certifications

In recent years, green building has become a trend in the construction industry to promote environmentally friendly and energy efficient design. In the literature, there are three areas of study for the Building Information Modelling (BIM) sustainable applications focusing; First one is BIM-support in building life cycle, second is in sustainable building elements and third one is in the green building assessment (GBA) processes. BIM can greatly simplify green building assessments. It is effective in sustainable elements analysis, such as energy performance, CO2 emissions and lighting. With the GBA process, BIM tools can help users understand the requirements and provide necessary building operations towards the target certification (Azhar, Carlton, Olsen, and Ahmad, 2011).

It is useful to have consistent metrics that are used in quantitative and qualitative evaluation of building performance to provide efficient green building design and construction. These systematic portfolios of metrics are often referred to as "green building rating systems". Fowler and Rauch (2006) have identified green building rating systems as tools that examine the performance or expected performance of the whole building. An assessment scheme has been developed to compare with other buildings through the rating. In the workplace, more sustainable properties have improved steadily. Building owners and developers have begun to see green as a promising profit source (Fowler andRauch, 2006).

As a result to reduce building’s energy consumption, numerous domestic and

international green building certification programs are made and already in operation. More and more countries have developed their own Green Building certification systems, such as LEED in the U.S., CASBEE in Japan, BREEAM in the U.K, EEWH in Taiwan, to certify buildings in terms of "green" levels. LEED (Leadership in Energy and Environmental Design) developed by the U.S. Green Building Council (USGBC) has become one of the most popular certification systems for Green Buildings in the world according to the credit system; there are targeted loans for the project to reach different LEED certification levels. Silver, gold and platinum certificates are given to buildings as their scores increase (Kibert, 2016).

All these assessment methods are internationally available certification schemes used to measure the environmental sustainability of new and existing buildings. LEED, or Leadership in Energy and Environmental Design, it has become a growing business prototype in supporting sustainability in the AEC industry due to governmental endorsement and the efforts of the USA Green Building Council (USGBC). Available for virtually all building, community and home project types, LEED provides a framework to create healthy, highly efficient and cost-saving green buildings. LEED certification is a globally recognized symbol of sustainability achievement (USGBC, 2011). It is used common green building rating system in the world.

Wei Wu (2010) includes a wide range of work on building information modelling in his research named integrated building information modelling and green building certification:. In his research firstly conducted a feasibility survey to investigate two fundamental questions in the BIM and LEED integration: Firstly, what LEED certification requires; and secondly, what functionality BIM possesses to assist compliance with such requirements. Based on the match-up of LEED certification requirements with the functionality inventory of popular BIM software solutions, a framework was then established to prepare the theoretical foundation for pragmatic solutions to support this integration. The BIM–LEED application model was created to handle practical problems at the credit level that might occur in actual LEED projects (Wu, 2010).

Energy simulation is a built-in and critical requirement for the design and implementation of sustainable buildings. Simulation tools such as EnergyPlus, DOE-2 and Energy-10 were developed much earlier than BIM is widespread adoption. Together with BIM's energy simulation, it helps designers create an integrated interface that provides a more reliable and consistent structure information model for analysis and

provides more accurate simulation results. Building performance varies considerably with respect to building types, functions (e.g. office, retail, residential and school) and stages of life cycle (e.g. new construction, operation and maintenance). A rating system should be specific to what type of buildings are evaluated and documented. For instance, the current LEED family includes rating systems of LEED-NC (new construction); LEED-EB (existing building); LEED-O&M (operation and maintenance); LEED-CS (core and shell); LEED-CI (commercial interior); and LEED-H (homes) (Wu, 2010).

There are some problems in integrating simulations into the renovation of existing buildings. The availability of data in existing buildings is problematic. The biggest challenge is the collection of performance data and system parameters. Using simulation tools can be one of the most powerful methods in principle, providing ample and detailed output. However, the use of simulation tools to calculate energy performance in an existing building is usually not very cost-effective in practice. It is evident that the renovation of existing buildings is crucial to ensure the energy efficiency of green buildings. The certificates given to the existing buildings are given the rating names according to their countries. According to this, LEED-EB in the US, CASBEE-EB in Japan (Wu, 2010). However, in this thesis, since there is a modeling of a building in the field work, in this part of this thesis, a few case studies are discussed in order to examine the design process of simulations for existing buildings in certification studies.

Zhou et al. (2016) aim to examine the effectiveness of technologies and operational strategies when transforming and certifying an existing building into an office building. Added that lack of generic, effective and user-friendly tools for practical energy performance assessment and diagnosis is a serious limitation for implementing energy enhancement measures in existing buildings (Zhou et al., 2016).

In the United States, there has been a substantial reduction in taxes on existing buildings that have received the "Energy Star" certificate (Kaza, Lester, and Rodriguez, 2013) In Japan, solar PV systems are encouraged to be used in existing buildings, and excess electricity generated from the solar PV system can be supplied to the grid for some compensation (Chowdhury 2014). All these policies are incentive programs that show that retrofitting work in existing buildings is one of the most important factors for energy efficiency.

2.2 Validation and Calibration Studies of Prediction Models

This part deals with the validation and calibration process of simulation models. Firstly the terms of validation and calibration is explained. Secondly, the necessity of Validation and recent works on validating and calibration progress of building energy simulation models are presented through literature research.

Earlier validation researches have been done in the National Renewable Energy Laboratory (NREL Solar Energy Research Institute) in the US. Judkoff, Wortman and Burch (1988) published a report about a methodology for validating building energy analysis simulations, in this report it is mentioned how to validate energy simulation programs that are presented the works done at the Solar Energy Research Institute. Actually, the aim of the report was not to validate building energy simulations. A survey conveyed between users to define which software are used mostly and defined their qualities through the answers. It is indicated that more detailed level of simulations are needed for building energy modelling. As a conclusion, after elimination of some software's they decided to do a comparative study between four simulation programs DOE, BLAST, DEROB, and SUNCAT. They compared the results of each simulation program with actual measured data from site. It is found that they have almost similar error results and suitable for the validating method (RD Judkoff, Wortman, and Burch, 1982).

Building energy analysis simulations are having important role in building energy performance evaluation. Since simulation techniques used widely, program credibility gets more important. Therefore, Validation methodologies are essential part of accreditation (Clarke et al., 1993). Calibration is a process and part of the validation methodology as described in the Clarke's (1993) studies. The calibration process can be used to identify the cause of poor program performance and can be useful to develop possible solutions. Clark has indicated the calibration progress by an example in his paper; Assuming that the simulation program has not sufficient for modelling of the convective processes at internal surfaces by the validation methodology. He studied measured and predicted air and surface temperature data again and it is found that the problem is with the convection coefficients. After studied on sensitivity analyses agreed that increased convection coefficients would lead the similar results between measured and predicted surface and air temperature. In addition, measured data can be used for the other alternative solutions that have been indicated in validation methodology

(Clarke et al., 1993).

Validation is strong research methodology that is used to determine whether the findings are accurate from the researcher, or the participants. John W. Creswell and Dana L. Miller's (2000) research, validation was called like authenticity and credibility As for the building energy analyses simulations, a validation is a detailed process of confirming that the simulation done correctly or not, that it is operating effectively, and that it is predicting without error.

Measurement and verification (M&V) method is required to evaluate the energy simulation results for determining the energy saving of retrofitting solutions for existing buildings. M&V is a process that measures and confirms the energy savings provided by energy efficiency solutions.

As for Calibration approaches of energy conversation methods, there are two recommended statistical indices should be calculated to indicate that the model is calibrated. These statistical values that need to be calculated are MBE and CV-RMSE

MBE shows how well the energy consumption is predicted by the model when the simulation values are compared to the measured data. Positive values show that the model predicts actual values and negative values show that the model predicts below the actual values. The CV-(RMSE) value indicates that general uncertainty of the energy consumption of the entire building. The lower the CV-(RMSE).The better the calibration is always positive.

Many validation and calibration studies have been done in order to identify the error between actual data and simulation results. Extensive research has been undertaken focusing on reviewing the consumption conditions of building energy. Mahdavi and Orehouing (2008) indicated systematically approach for the entire process for building simulation in his researchers. In this approach, he explored the example of traditional hammam building located in Cairo. After data collection process, he studied on the result of the collected data and simulation of the Hammam building to have the calibrated simulation mode l (Mahdavi andOrehounig, 2008)It was used to estimate the performance of the building and alternate renovations of the existing buildings. Local climatically conditions have been monitored between February 2006 and April 2007. And found that noticeable differences between local and metronome data in Egypt. For that reason strongly advised that to do simulation with data from local weather station to have real indoor climate data. At the end of the calibration studies, Prof Mahdavi and his team obtained the good matching between the results of simulation and the

measurements. Subsequently they planned to use this model to renovating works for these traditional Hammam buildings (Mahdavi, Orehounig, Mikats, Lambeva, and El-Habashi, 2007)

Another example application of the calibration methodology is in the field of Passive Solar Architecture known as PASSYS projects. Jensen (1993) aimed to determine the performance of conservatories in one of the projects. It was studied on test cell units in this research. After modelling it is obviously appeared that the performance of conservatory has been predicted successfully in validation method. After calibration of the model it was possible to test different passive solar components like lightweight reference wall the same wall with the addition of thermal mass, a wall with transparent insulation, a trombe wall, a curtain wall and a timber-frame wall with different glazing types. As a result in this PASSYS project they simply applied the validation/ calibration methodology to the model. Firstly the simulation to obtain model predictions then define the problem areas on the model on this derived high quality data set, and applying needed modifications to produce calibrated model (Jensen, 1993).

In order to evaluate the energy performance of the VRV air-conditioning system, Zhou and Wu (2007) has developed a new simulation module and validated experimentally in their study. They used EnergyPlus as building energy simulation program. This study is plot research for the energy features of VRV systems. They found the EnergyPlus is the most appropriate simulation engine for the HVAC-related functions. Firstly the differences between average monitored and predicted data for the total cooling energy and power use are compared. And also they examined the COP and PLR simulation of the VRV system here. VRV system simulation module predictions verified with the data which are measured from 24 to 30 August 2006. After comparison of simulation and reality results for the cooling energy at 26 August, it is found that the results are following each other well. The average error is 15.09% and the maximum error is 27.09 %. When they validate the COP value of VRV system they found the differences between test COP and COP value in simulation module there is less error in the beginning 5.66% and average is almost 5.66%, and max is 10.17%.

Monetti and Davin (2015) studied on calibrating building energy models using monitored data. The case study is the two-storey test building located in the Ulg environmental campus, in Arlon, Southern Belgium. The building has total gross floor area of 162 m^2. All construction and energy consumption data is collected. The energy model of the case study was created in EnergyPlus (version 7.0). The building was

Table 2.1. Main characteristics of the studies on prediction methods with a systematic literature review

PUBLICATION DATE	AUTHORS	TYPE	COUNTRY	PROJECT PHASE	RESEARCH TYPE	ENERGY PERFORMANCE	SIMULATION TOOL	CALIBRATION	CERTIFICATE	METHOD
2000	T. Hong, S. k. Chou and Y. T. Bong,	article	Singapore	review of methods	comparison		ALL			
2002	Pedrini	article	Brazil	existing building	commercial and public buildings		DesignBuilder, EnergyPlus			calibration, validation, monitoring
2006	Ashfaque Ahmed Chowdhury	article	Australia	existing buildings	commercial buildings	+	DesignBuilder, EnergyPlus	+		calibration, validation, monitoring
2007	Ardeshir Mahdavi, Kristina Orehounig, Nina Mikats, Lyudmila Lambeva, and Alaa El-Habashi	article	Egypt	existing buildings	Hammam Building	+	TAS 2006	+		calibration, validation, monitoring
2008	Dru B. Crawley , Jon W. Handb, Michae¨l Kummertc, Brent T. Griffithd	article	USA	review of methods	comparison	+	ALL			
2008	x. Zhao, F. Magoulès	article	France	review of methods	comparison		ALL			
2010	BUILDING PERFORMANCE MODELS	book		review of methods	comparison		ALL			
2010	Wei Wu	thesis	USA	ALL	ALL		IES<VE>/Revit		LEED	BIM and LEED integration
2011	Aleka Pappas	article	USA	existing buildings	office building	+	ALL	+		calibration, validation, monitoring
2011	Christoph F Reinhart, Timur Dogan, Diego Ibarra, and Holly	article	USA	experimantal	office building	+	DesignBuilder, EnergyPlus		LEED	
2011	Daniel Fern´andez	article	SPAIN	new and existing building	office building		DesignBuilder, EnergyPlus	+		
2011	Friess, Wilhelm Alexander, Rakhshan, Kambi, Hendawi, Tamer A. Tajerzadeh, Sahand	article	UAE	new and existing building	residantial house	+	DesignBuilder, EnergyPlus	+		
2012	Ming-Tsun Kea, Chia-Hung Yeha, Jhong-Ting Jian	article	Taiwan	existing building	office building	+	eQUEST	+		calibration, validation, monitoring
2013	Kaza, Lester, & Rodriguez	article	USA	ALL	ALL				LEED and Energy Star	Certification
2014	RahmiAndarini	article	Indonesia	new and existing building	office building	+	DesignBuilder, EnergyPlus	+		simulation, building envelope optimization
2015	Han-Soo Ryu and Kyung-Soon Park	article	Korea	new building	skyscraper	+	REVIT- TRACE 700		LEED NC	
2015	Valentina Monetti, Elisabeth Davin , Enrico Fabrizio , Philippe André , Marco Filippi	article	ITALY	existing building	residantial building	+	EnergyPlus	+		calibration, validation, monitoring
2016	Zhou Zhihua, Zhang Shuzhen Wang and Chendong	article	CHINE	existing building	office building	+	eQUEST	+	Three-Star Green Building Label	Retrofitting, monitoring, simulation
2016	Christoph F Reinhart, Timur Dogan, Diego Ibarra, and Holly	article	CHINE	existing building	office building	+	eQUEST	+	Green Building (ESGB)	calibration, validation, monitoring
2017	Ahmad Sabry An-Naggar1, Mohamed Aly Ibrahim 2, Essam E. Khalil3	article	EGYPT	existing building	residantial building	+	DesignBuilder, EnergyPlus			monitoring, simulation
2017	Xinxin Lianga, Yaodong Wanga, Mohammad Royapoora, Qibai Wub, Tony Roskillya	article	UK	existing building	residantial building	+	DesignBuilder, EnergyPlus	+		calibration, validation, monitoring

monitored over a short period of time and an optimization-based calibration work was carried out. In winter, a short one-hour follow-up calibration was performed on an hourly basis. Validating the calibrated model was conducted. The Mean Bias Error (MBE), the Root Mean Square Error (RMSE) and the Coefficient of Variation of the CV-(RMSE) are calculated and verified to be consistent with the ASHRAE guideline limits respectively ±10% and 30% on hourly basis. Good results were not obtained in the initial calibration studies. (MBE and CV-(RMSE) have always been outside the threshold limits (Monetti, Davin, Fabrizio, André, and Filippi, 2015).

2.3 Simulation Program Users

A literature review was made about the simulation tool users in the studies conducted on the spread of simulation tools. The main objective of this section is to emphasize the studies that describe the qualifications of building energy analysts in the literature and the difficulties and experiences they face. Examines the literature review of the ways in which the use of tools is integrated into projects: who makes simulations and how design teams combine simulation with their work as a normal part of the design process.

IBPSA organizes forums to promote training and research in the field of building energy modeling and simulation, to ensure standardization, to accelerate integration and to promote technology transfer between users. Several papers have been presented at the IBPSA 2003 conference held in Eindhoven on 11-14 August 2003..The paper by Augenbroe and Hensen (2004) presents discussed the recent developments in the field of building behavior simulation and In the review of all articles in this conference of IBPSA (Augenbroe andHensen, 2004). The main theme of the conference was sim ‘’Simulation for Better Building Design’’. The authors stated that the use of simulation is gaining more and more attention. It is generally seen that the building simulation discipline is constantly evolving and maturing, and the model's reliability is continually improved. As a result, the agenda has changed from the discussion of the features of the software to the effective simulation process of teams that have total control over the tools. It is certain that there is still an undeniable difference in design and engineering disciplines. In spite of these differences, better adaptation of simulation tools to decision-making processes, team support of increased design strategies and quickly evaluated developing alternative design needs to be in the simulation process,.

Therefore, over time, users should better manage simulation inputs and make better modeling assumptions.

It is fundamental to have a good interaction between engineering analysis and design. Augenbroe (2004) states his observations that on the effectiveness of simulations depend on the quality of the tools as well as the technical skills of the users (Augenbroe, 2004). He emphasized that in the absence of good interaction between engineering analysis and design, building simulations will not contribute to successful building design. For that reason, there should be improvements in two main areas for the simulation profession: First is related to the tools, development of the usability of the tools is required, second is process related, integration of the simulation tools into the design process. The author argues that 'simplified' tools developed in the past for architects are perceived as an increase in computer power and that simulation tasks are increasingly performed by non-specialists. He compared designer-friendly tools to design-integrated tools. The difference is that in the first case, the field information has to be reduced and limited, while in the second, the design context is enriched and externally supplied. This means that; in the second option, design context information and analysis results alternate between the internal design team and remote experts and their simulation tools. The second design process allows for easy data exchange between different perspectives and views. As a result, it would be correct to do simulations in design practice.

In fact, users of all simulation tools need to know when to implement building simulation as part of their current decision-making process and when they need to be involved in design processes (Anderson, 2014; C. A. Morbitzer, 2003). As most simulation tools are not easily available and not compatible with the working methods and needs of architects the integration of it will be difficult to design face.

Throughout the simulation process, roles can often change. In the drafting phase of the architectural design, architects will have more information to quickly evaluate the relationship of buildings with the environment, and in the later stages there will be engineers who are specialized in using the tools (A. Morbitzer, 2003)

Bambardekar and Poerschke (2009) in their article ‘the architect as performer of energy simulation in the early design stage’ had general observation from the literature review; there is very limited software available to help architects. According to the determination, architects have difficulties such as choosing suitable energy simulation tools at the design stage, using simulation to make decisions and converting design

demands into simulation models (Bambardekar andPoerschke, 2009).

Surveys can be conducted for different purposes. There are many surveys on this subject intended to determine the roles of users of simulation tools. It was conducted to understand the role of employees in the design team in the simulation (Donn, 1997). The potential participation of architects in simulation was examined with a critical view. This survey was conducted in both New Zealand and the USA in early 1996 among simulation tools users such as BLAST, DOE2 and SUNCODE. Participants in both surveys were those who developed and used simulation tools. However, the general purpose of the survey was to look at the people involved in the construction sector who could use the simulation tools. 50% of the participants were engineers, architects and designers. The main topics were: The degree of expertise of users in the use of simulation tools; Use of specialized simulation tools; expected improvements in the simulation tools; which type of simulation tools are mostly used; perceived roles of architects, engineers and program developers in the design analysis process as a team.

In another survey research, Attia (2010) was questioning about the development of simulation tools and examined the development and processes of these tools according to the needs of architects and engineers (Attia, 2010). It is a kind of survey that shows how users benefit from these tools in design phases. The survey aims to help users perceive the most important criteria of the last commonly used simulation tool.

The selection criteria of the simulation tools were used to form the basis of the questionnaire questions. The survey was conducted among architects, engineers, designers and newly graduated students interested in sustainable building design in the United States, which has just begun simulation. In his research, he collected selection criteria under 5 main headings according to the difficulties of using the tools. First; the availability and interfaces of the tools, The second criteria; intelligent Design Knowledge Base Integration (IIKB), The knowledge base can explain the behavior of the building and at the same time help the user of the simulation tool to make accurate predictions and to make decisions, third; accuracy and simulating detailed and complex Structural elements; the ability of building simulation tools to adapt to rapidly changing building technologies, to simulate passive design techniques, renewable energy systems in high performance and to obtain detailed results, fourthly; Modeling (IBM); This criterion is a criterion that allows the use of simulation tools together, facilitating information sharing and fast data transfer between them. It allows data to be stored

across multiple disciplines and project participants can work between different software applications.

Anderson (2014), another architect and energy analyst, who explores the place of architects in simulations, has collected her observations and research in a book guiding architects on energy simulations. He showed that architects can make better design decisions by using simulation tools in the design stages of their projects, thus avoiding expensive technology in the future for the project to be energy efficient. According to Anderson's (2014) interpretation, today, just as mechanical designers are excluded from the geometric design process, architects are also excluded from the energy appraisal of their buildings. Energy simulations in the early stages of the design include solar energy, daylighting and many concept studies comparing a number of energy uses. He mentioned that there are many known leading architectural firms who are aware of these applications in design processes. For example Skidmore, Owings, Merrill and DLR Group have a team of architects and analysts who use simulation tools in the design phase (Anderson, 2014).

Anderson (2014) interviewed with these architectural firms using simulation tools, as well as interviews with engineers and researchers. There are only three companies that have mechanical engineers in their companies; the other four companies have energy modelers, but not mechanical engineers. Many of them can use Ecotect, but they are ready to switch to other programs. And most of them can still use the Radianca program. Rhino and Grasshopper are used by almost half of the companies. And many of the companies interviewed here think that it would be better to complete this competence in design staff within the firm, rather than receiving additional services in energy simulation. These companies have explained why they cannot work together enough with mechanical engineers. In view of the fact that customers do not want to make engineering decisions until architectural decisions and basic geometry are completed. Moreover, the fact that engineers do not have the interest and experience to try different alternatives and run models without detailed information and input; this is the biggest obstacle to their working together. The reason for the simulations to be carried out in-house is not to disregard the role of mechanical engineers, but to try to involve only those who can perform more analysis into the preliminary project team.

Anderson (2014) concluded that most important thing is that companies should have Design Simulation Groups (DSG) within their organization. These people in DSG are expected to be the key persons between architect and engineer. They are expected to

be the people who understand building typology, can prepare fast and graphical presentations, are aware of the energy simulation process, and are prone to 3D software and programs.

It is important that all program users follow the latest developments and revised versions. To this end, websites of many organizations, universities and research laboratories have been updated; Department Of Energy (DOE), Energy Systems Research Unit (ESRU), International Building Performance Simulation Association (IBPSA, 2006), Users of building energy simulation tools (BLDG-SIM) (Ulukavak Harputlugil, 2007).

2.3.1 Simulation Sector in Turkey

Turkey to minimize the effects of climate change and contribute to global efforts "National Climate Change Strategy" has developed n; According to this strategy; between 2010 and 2020 period, climate change mitigation action plans will be made. This Strategy will guide the actions to overcome climate change in the 2020 period and if necessary, it will be updated. In the same way, as foreseen in the European Union Directive 2010/31 / EU, the implementation of renewable energy sources in buildings and the Energy Performance Regulation and Energy Identification Document (EKB) applications in buildings are targeted (Ilaria, Giovanna De, Argun, Anna, and Vincenzo, 2019). For this purpose, the Energy Identity Document shows how much energy the building consumes and uses renewable energy sources. In addition, BEP-TR database records and evaluates the data on this issue and aiming to increase the use of renewable energy resources over time. Turkey has set its goals to contribute with their own resources against climate change. By 2023, if the necessary incentives are provided, it aims at commercial and service building applications with at least 10.000.000 residences in which heat-insulated and energy-efficient systems are applied within the defined standards.

According to the latest laws, after the publication of the national building energy performance calculation methodology BEP-TR, Ganiç andYılmaz (2014) pointed out the need to develop this national calculation methodology as another step. Given both the EU harmonization process and development in the environment and economy, this calculation method should be more compatible with national market conditions for cost-optimal analysis. Research on existing building renovations agrees on its outstanding

environmental and economic benefits. Therefore, in this study, especially in terms of the development of the Turkey national cost optimal energy efficiency calculation method it focuses on the creation of national renewal scenarios in market conditions. in countries with different climatic regions such as Turkey, It is very important to investigate the evaluation methods of energy performance of buildings and develop different application models. When Turkey was considered to have five different climatic zones, it is adapted to two different climatic zones in the sample survey conducted in the building. Therefore, the effects of different regional climates were analyzed by analyzing the building in two sample cities. Ankara was chosen as the mild dry climate and Antalya as the warm humid climate.

These two climatic zones also differ according to heating and cooling energy consumption. EnergyPlus dynamic modeling tool was used in the modeling. During the creation of sub-categories for reference buildings, climatic conditions are effective in the definition of the reference building as well as the building characteristics. Therefore, categorization of reference structures by climatic regions is essential for cost optimization analyzes, especially for countries with climate diversity, such as the Mediterranean countries. At the end of the study Ganiç andYılmaz (2014) stated that long-term and detailed research procedures are needed to identify the appropriate reference buildings and they emphasize that inappropriate reference building definitions will adversely affect large amount of buildings at national level.

In order to contribute to the development of studies in the field of building performance modeling and simulation, which requires profound expertise in the theoretical field and challenging work in these fields, academic-based volunteer organizations have been established all over the world. These organizations, known as IBPSA (International Building Performance Simulation Association), operate in many countries. As IBPSA-Tr, BinSimDer (Building Performance Modeling and Simulations Association) was established in Turkey to guide and develop building simulation technology (Yılmaz, 2012).

Currently in the construction sector in Turkey, more than 250,000 mechanical, civil and electrical engineers and architects more than 50,000 works. Although only a small percentage is related to building simulation there are, however, about 3,000 professionals to whom IBPSA is involved. This is potentially important, as IBPS in Turkey in the community has not been very active lately. IBPS restructuring opportunities in Turkey now was born and TTMD (Turkish Society of HVAC and

Sanitary Engineers union) has offered to support the IBPS activities in its field in Turkey. IBPS new organization in Turkey completed work on in a short time and published on their websites. According to the news published on the website of HVAC and Sanitary Engineers Association (TTMD), the first step in the cooperation between IBPSA, and TTMD was held in Turkey on 21 October 2017 (IBPSA, 2017). By questioning the meaning of simulation for Turkey, improve the quality of building performance and become more efficient it is intended for higher studies. Focusing on some specific projects is important and listed as the priority objectives. TTMD will take over this new formation from BinSimDer, even though BinSimDer (2012) would continue to work in this new entity and TTMD will have the new formation of IBPSA in Turkey. With the support of the IBPSA, the simulation industry in Turkey will be expanded in order to improve building performance by working under the TTMD umbrella (IBPSA, 2017).

In Ulukavak Harputlugil (2007)'s study, after explaining the definition and operation process of building energy simulations, examines the benefit of simulation based performance improvement method by exemplifying the energy analysis of a building that has been designed. In addition, the place of building energy simulation applications in architectural design process is questioned. In the first stages of the process, the suggestions of the program users for the implementation studies are given and the difficulties encountered are listed. In the Ulukavak Harputlugil (2007)'s study, it provides a summary of the current situation and concludes with a series of suggestions for program developers and users, listing the objectives for future work.

Harputlugil (2010) interviewed with the users of building simulations and examined the current position of building simulation tools in her publications. Many simulation programs for building performance analysis range from simple to detailed and comprehensive. Simulation programs are very difficult to categorize because many of them contain multiple functions and the programs themselves are constantly changing and evolving. Harputlugil (2010) states that program users should always consider these four important issues.

- For the quality and performance of design, awareness is increased from the early stages.
- Simulation can be used for all kinds of projects.
- There is a wide range of time and cost required for simulation. Choosing at this point requires experience.

- It is necessary to use the program appropriate to the application level of the project.

Finally, Kalaycıoğlu and Yılmaz's (2019) article published in TESKON made an inference on the general understanding of building energy performance simulations in our country. In our country, simulation is still not seen as a design tool, but mostly on projects that have applied to voluntary green building certification systems, emphasizing that the building is not used to determine the energy performance level of the building for scoring. The purpose and function of building energy performance simulations are not well understood. For certification systems, there is a misconception that if the building energy performance simulation tool is used, the energy performance of the building will improve. This stems from seeing simulation as a goal, not a tool. Building energy performance simulations should be used by the experts and involved in the design process to assist the design team in decision-making processes. This requires an initial design process that is difficult to adapt to and changes process management, but by implementing integrated design strategies, the simulation-supported energy-efficient design process can be managed. (Kalaycıoğlu andYılmaz, 2019)

CHAPTER 3

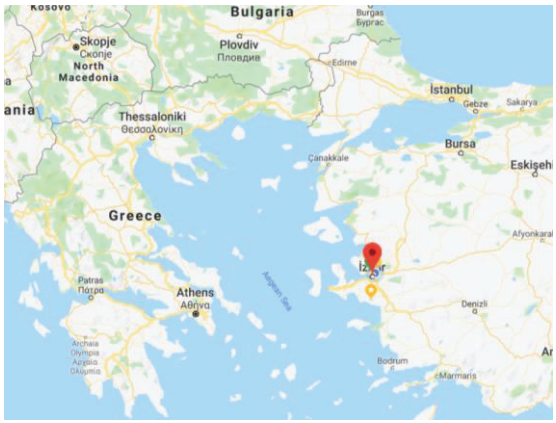
CASE DESCRIPTION

Housing industry plays an important role for energy efficiency in buildings. It was the reason of selecting the case building as the housing block. Therefore, the case building is searched by considering common design properties of existing and ongoing housing projects in İzmir, Turkey. Besides in this study, a complex structure which includes advanced engineering systems, energy efficient building, requires modelling technical knowledge. Finally, the low-rise residential building in the private housing group is specified for the case study with help of discussions with the several architectural offices.

This chapter presents the case study in Kaynaklar, Izmir-Turkey designed for low energy building conditioned by air source heat pump. The case building has been examined through the thermal and energy performance, climatic conditions and location characteristics.

3.1 Location and Climate

The building performance analysis study is conducted in a private house in Kaynaklar, Izmir located on the west coast line in Turkey (Figure 3.1). The building is situated in the suburban area, gradually isolated land from the crowd of city. The precise location is the latitude 38°21'35'' N, the longitude 27°14'25'' E and altitude is 334.65 yds According to the available weather data, highest monthly average temperature being 25◦C in July and August, winter temperatures fall to an annual monthly average minimum of 8◦C in January. Average monthly ground temperatures vary from 10◦C to 22◦C. Monthly averages for relative humidity are in the range of 49% (July) and 80% (January). Average monthly wind speed is almost constant over the year between 3 m/s and 5 m/s, with a tendency for North directions in summer. The monthly averages for global horizontal radiation lie in the range between 176 W/ m2 (December) and 519 W/ m2 (July). All monthly averages were calculated using Climate Consultant 6, WEB 2019(Climate Consultant, 2019).



(a)

(b)

(c)

Figure 3.1. (a) location of İzmir, (b) Location of case in İzmir map, (c), aerial view on vicinity of case building (Source: Google Map, 2019)

The prevailing winds are between north and northwest. According to the measurements, the average wind speed in the investigated area of 4.38 m/sec. The highest wind speed reached on 18 November 2009, 18 m/s (64.79 km/h).

3.2 Building Layout

The building selected as the case study is one of the residential buildings in

'Kaynaklar Konakları' in Izmir. Architectural plans and the images of the building were acquired from the construction company. The site plan and the location of the building are shown at.Figure 3.2 (a). The photos belong to the building facades can be seen in Figure 3.2 (b) and (c).

(a) Site Plan

(b) (c)

Figure 3.2. (a) Site view, (b) Northwest view of the case building, (c) east view

The building has three floors with gross floor area of 520 m^2. The ground floor has living, dining room, kitchen, office part including WC and room. The basement has hobby saloon with sauna and massage saloon, garage, laundry room and technical room where all home automation systems are housed. Furthermore, there are three bedrooms with private bathrooms aligned around a corridor at the first floor. The living room, bathrooms, entrance halls and kitchens facing outside in every plan schema, except technical room is below the ground level does not have any opening facing to façade.

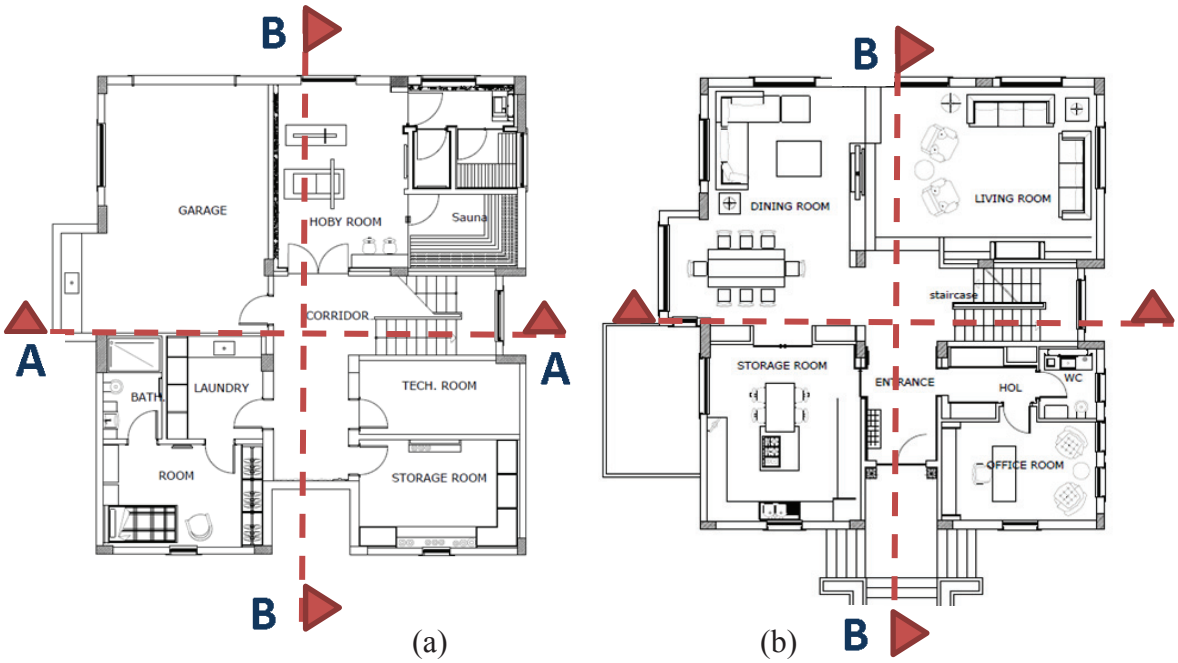


Figure 3.3. (a) Basement Floor Plan, (b) Ground Floor Plan

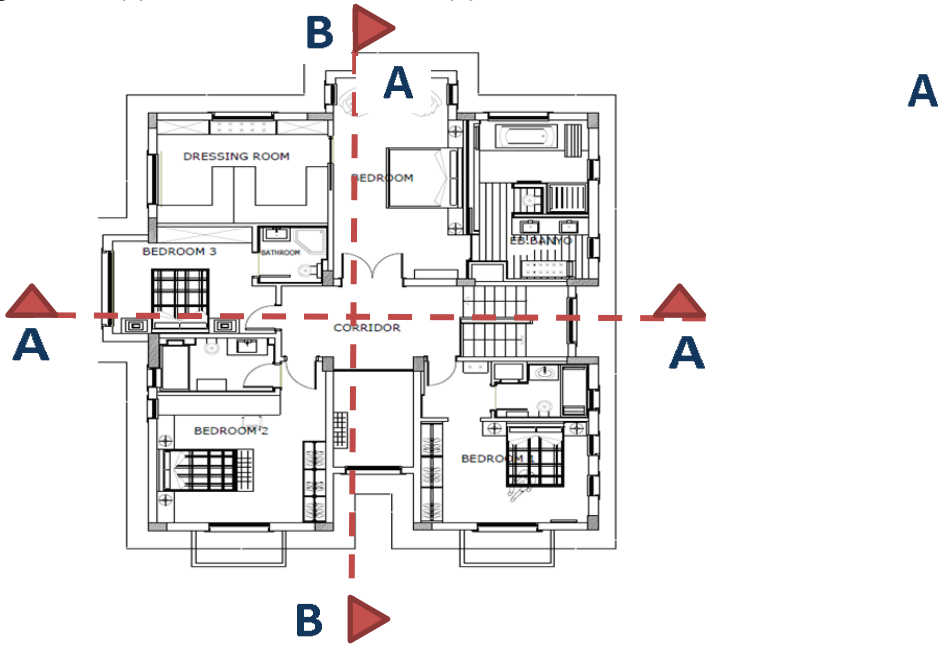


Figure 3.4. First Floor Plan

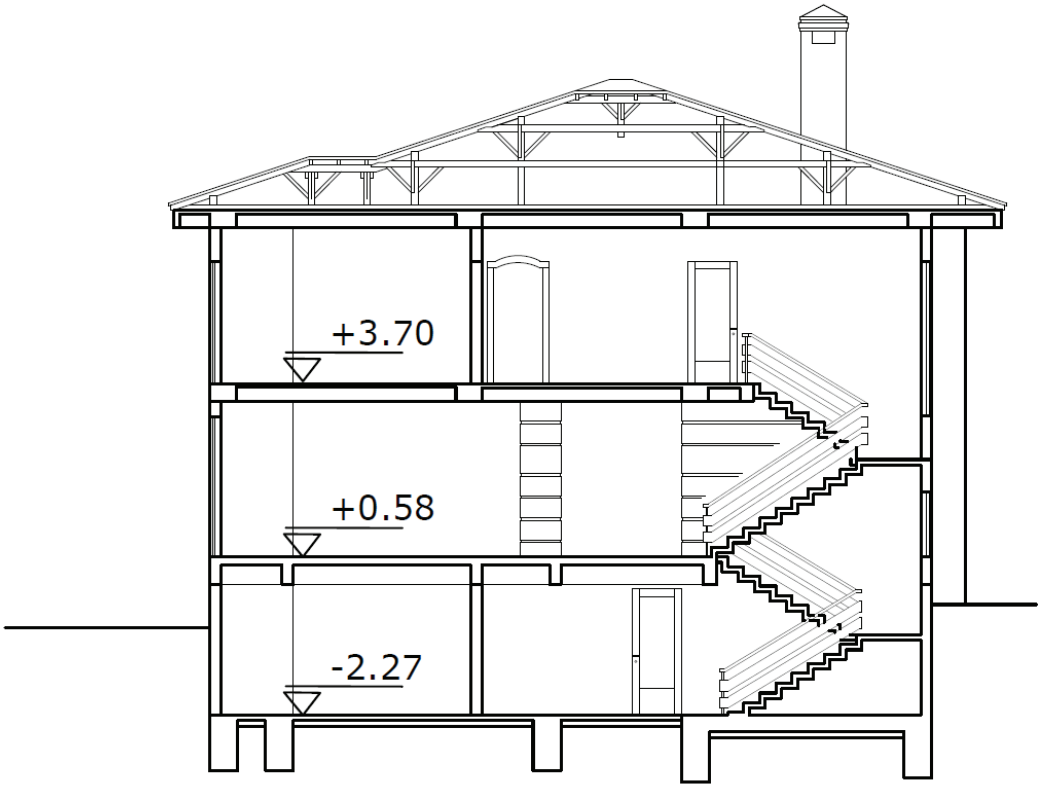
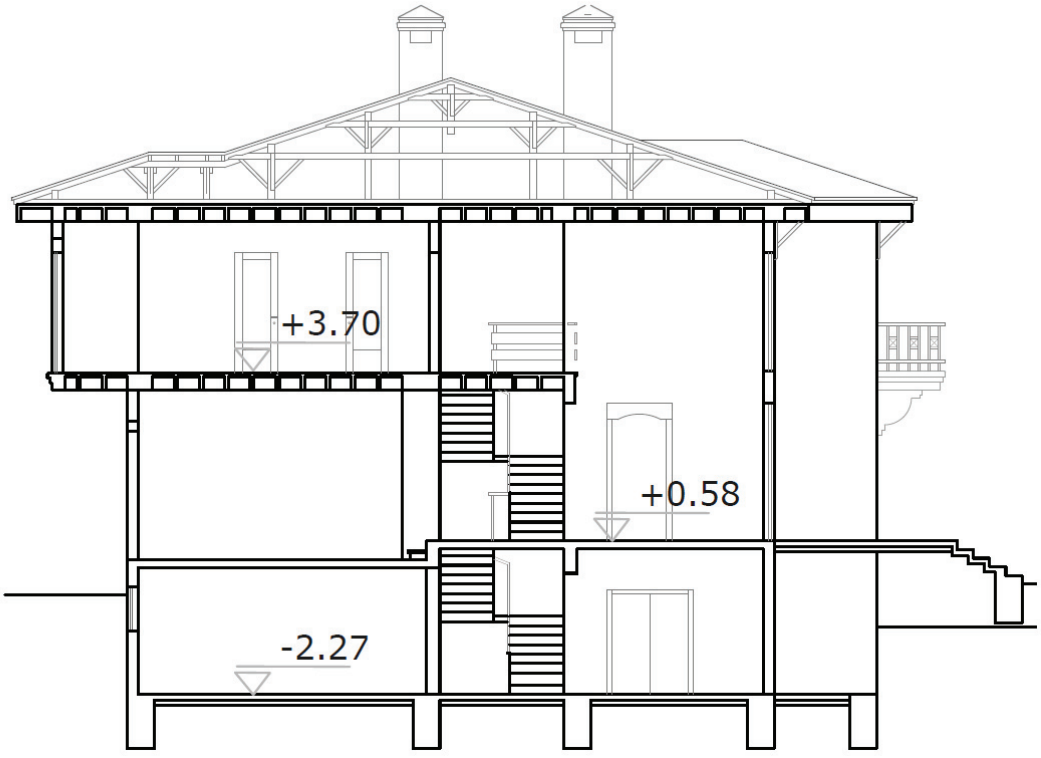


Figure 3.5. A-A Section of case building



(b)

Figure 3.6. B-B Section of the case building.

3.3 Building Materials and Construction Technique

The building is reinforced concrete skeleton system with aerated concrete (AAC), infill and 4 cm thermal external insulation layer (XPS) on the exterior walls of the building. Cappadocia tuff natural stone is used for decorative cladding purposes on the external walls. It is obtained from quarries in Cappadocia, Nevşehir, central of Anatolia in Turkey. The ground floor and basement exterior walls are covered with 3 cm natural stone Cappadocian tuff by the density of 1400 kg/m^3 and thermal conductivity value of 0.55 W/mK. Tuff stone is very spongy in nature so its density, thermal conductivity value and P-wave velocity is lower than other rocks. They are easily transportable, machine able, workable, good heat insulator, environmentally friendly, sufficiently elastic to sustain seismic loading in the area under study and more cost-effective than artificial stones (Yaşar, Tolgay, and Teymen, 2009).

There is 2 cm concrete plaster on the exterior walls of the first floor. The housing has a pitched roof, between the unheated roofs of the first floor there is 4.5 cm thick thermal insulation material is placed. The U values of the internal floors are changing according to the coating materials used in ranged from 0.42 to 0.73 W /m^2K. The walls, floor details and the corresponding heat transfer coefficients are given in Table 3.1 Building door and window openings are with aluminium frames is filled, and double glazing filled with 1.6 cm argon and total heat transfer coefficient value of it is 1.493 Wm^2K.

3.4. Heating and Cooling System of the building

The case building is an energy efficient residential building that contains full automation system that has touch screens in each room. A LAN-based home control system is used to control home functions; automatically switches off and on the lights, controls doors, windows and heating systems (Figure 3.7). This system is allowing to adjust the indoor temperatures wirelessly. In addition, it consists of elements that complete the system such as solar water heating system, collectors collecting solar energy, storage where heating water is collected and control system of air to water heat pump.

Table 3.1.Thermophysical properties of building components as built

BUILDING COMPONENTS	POSITION	MATERIAL NAME	THICKNESS (m)	CONDUCTIVITY (W/m.K)	SPECIFIC HEAT (J/kg.K)	DENSITY (kg/m3)	U VALUES (W/m².K)
Exterior wall (Basement & Ground floor)	Outermost	Cappadocia Tuff Natural Stone	0,03	0,55	1000	1379	0,367
	2	XPS Extruded Polystrene	0.045	0,034	1400	35	
	3	Plaster	0,02	0,5	1000	1300	
	4	Aerated Concrete	0,25	0,29	1000	350	
	Innermost	Plaster	0,02	0,16	1000	600	
Exterior wall (First floor)	Outermost	Plaster	0,02	0,5	1000	1300	0,403
	2	XPS Extruded Polystrene	0.045	0,35	1400	25	
	4	Aerated Concrete	0,25	0,29	1000	350	
	Innermost	Plaster	0,02	0,5	1000	1300	
Partition Wall	Outermost	Gypsum Plaster	0,01	0,4	1000	1000	1,312
	2	Plaster(coarse)	0,02	0,72	1000	1400	
	3	Aerated Concrete	0,10	0,24	1000	750	
	4	Plaster(coarse)	0,02	0,72	1000	1400	
	Innermost	Gypsum Plaster	0,01	0,4	1000	1000	
Internal floor / General	Outermost	Plaster	0,02	0,5	1000	1300	0,446
	1	Aerated Concrete	0,10	0,12	1004	550	
	2	Cast Concrete	0,10	1,13	1000	2000	
	3	PUR Polyurethane Board	0,05	0,28	1590	35	
	4	Floor Screed	0,04	1,14	650	2100	
	Innermost	Timber flooring layer	0,03	0,14	1200	650	
Ground floor /Basement	Outermost	Cast Concrete	0,10	1,13	1000	2000	0.359
	1	isolation layer	0,05	0,04	840	30	
	2	Cement screed	0,07	0,41	840	1200	
	Innermost	Granite flooring layer	0,03	1,1	1000	1800	
Pitched Roof	Outermost	MW Stone Wool(rolls)	0,05	0,04	840	30	0,,402
	2	Cast Concrete	0,07	0,2	1000	2400	
	3	Asmolene	0,25	0,25	1000	750	
	4	Plaster	0,03	0,03	1000	1100	
	Innermost	Gypsum Plaster	0,01	0,03	1000	1000	
External Glazing	Outermost	Generic LoE clear	0,06	—	—	—	1,493
	2	Argon	0,13	—	—	—	
	Innermost	Generic LoE clear	0,06	—	—	—	
Window Frame	single layer	Aluminum	0,08	—	—	—	5,881
Door	single layer	Solid hardwood	0.042	—	—	—	2,557

Figure 3.7. Touchscreen home automation control units
(Photography: Rahşan A. Gülmez Raafat, 2009)

Air source heat pump is used as heating and cooling system in the building. Heat pumps are known to be used for heating or cooling the space using the energy of the air in the atmosphere as the heat source. Heat pumps, which take advantage of the current temperature of the air, can transfer their energy to the water or air on the load side. Commonly used air source heat pumps are air-to-air heat pumps, often referred to as "air conditioning". However, in this building, floor heating and cooling system, which transfers its energy to water, was used as the air-to-water heat pump system. As cooling system, floor cooling is applied in the same way using floor heating pipes. All the spaces of the house except the garages cooled and heated from the floor. The water temperatures passing through the pipes in the floor were set at 14°C for the cooling season and 35°C for the heating period. The heat pump has 16 kW single-phase outdoor units. There is a solar PV system converts the sun's energy into direct electrical current system. Calculated heat loss of the house is 13500 kcal/h. 1 kWh of electricity achieved by solar photovoltaic panels can support the heat pump, and 8 kWh energy can be stored in the accumulators. And central air to air heat-pump system with the connected to solar collectors on roof to produce hot water. In addition, addition to those 500 litres of hot water can be stored in a thermos boiler that is connected to these solar collectors directly.

Figure 3.8. Air to Water Heat pump
(Photography: Rahşan A. Gülmez Raafat, 2009)

3.5 Underfloor Heating and cooling system

In the underfloor heating and cooling system, REHAU pipes are used in all air-conditioned rooms of the building (except the garage). The same piping system was used for the floor cooling period. Therefore, the selected pipe was said to be suitable for both cooling and heating. In order to use the cooling efficiently from the floor, it was seen that the insulation was installed in the column installation. This cool water is also circulated through the circulation pump to the appropriate equipment to cool the space.

Figure 3.9. REHAU underfloor piping for heating and cooling (a) (b)
(Photography: Rahşan A. Gülmez Raafat, 2009)

The collectors are used as TDS with flow adjustment and suitable for thermostat connection. Collectors are important for product life and energy saving of underfloor heating and cooling system. They serve to distribute the hot or cold water coming from the heat source and cooling unit according to the season to the laid pipes and collect it and send it back to the heat source (Figure 3.9). Here the return and return valves on the collector are the same as the group of pipes where the air is applied and there are the same numbers of conditioned rooms.

3.6 Occupancy, Lighting and Electrical Devices

Since the case building had been functioning as the demo-house during the measurement period and there was no regular record on visitors, data, short-term user/visitor impact on thermal performance was neglected in the modelling. Accordingly, several assumptions based on the author's observations have been done for internal loads of the building. The usage of artificial lighting, domestic hot water, electrical and other cooking equipment is excluded in the model arrangements.

CHAPTER 4

METHODOLOGY

Building energy modelling requires a systematic approach composed of the collection, investigation and reproduction of data to be used in the simulation process. This chapter shows how the data is collected and investigated for building diagnosing, how the digital model is produced after the building's documentation data such as geometry, construction, mechanical, environmental data of the building and how process of the calibration works. The model is simulated to predict indoor conditions and energy consumption in the building between July 2009 and June 2010. In order to estimate the required energy in the residential unit in a realistic way, the use of calibrated digital performance simulation model is the effective tool to improve energy performance. The measurement study carried out inside the house is utilized to improve prediction capability of the model. Figure 4.1 shows the workflow for the methodology of testing and verifying process.

4.1 Onsite Data Monitoring

4.1.1 Thermal Parameters: Monitoring of Climatic Data

In the case building, which is located in the Kaynaklar, Buca, a weather station Davis Vantage Pro-2 portable weather station was installed in the next building of the house. The scheduled one-year environmental data collection in this building the measurement was started on July 15, 2009, was terminated on 06 of October 2009.During this installation the device has been located carefully to the north direction and paid attention to not have no any other barriers in front of it to affect measurements. Depending on the storage capacity of the station, the climatic data has been downloaded by visiting the workspace approximately every three weeks .In the line with the follow-up study the dry bulb temperature, relative humidity, wind speed, wind direction, collecting atmospheric pressure, and the horizontal plane falling intermediate global radiation value of the external environment data of this rural area. Collected all these data has been converted to average hourly data.

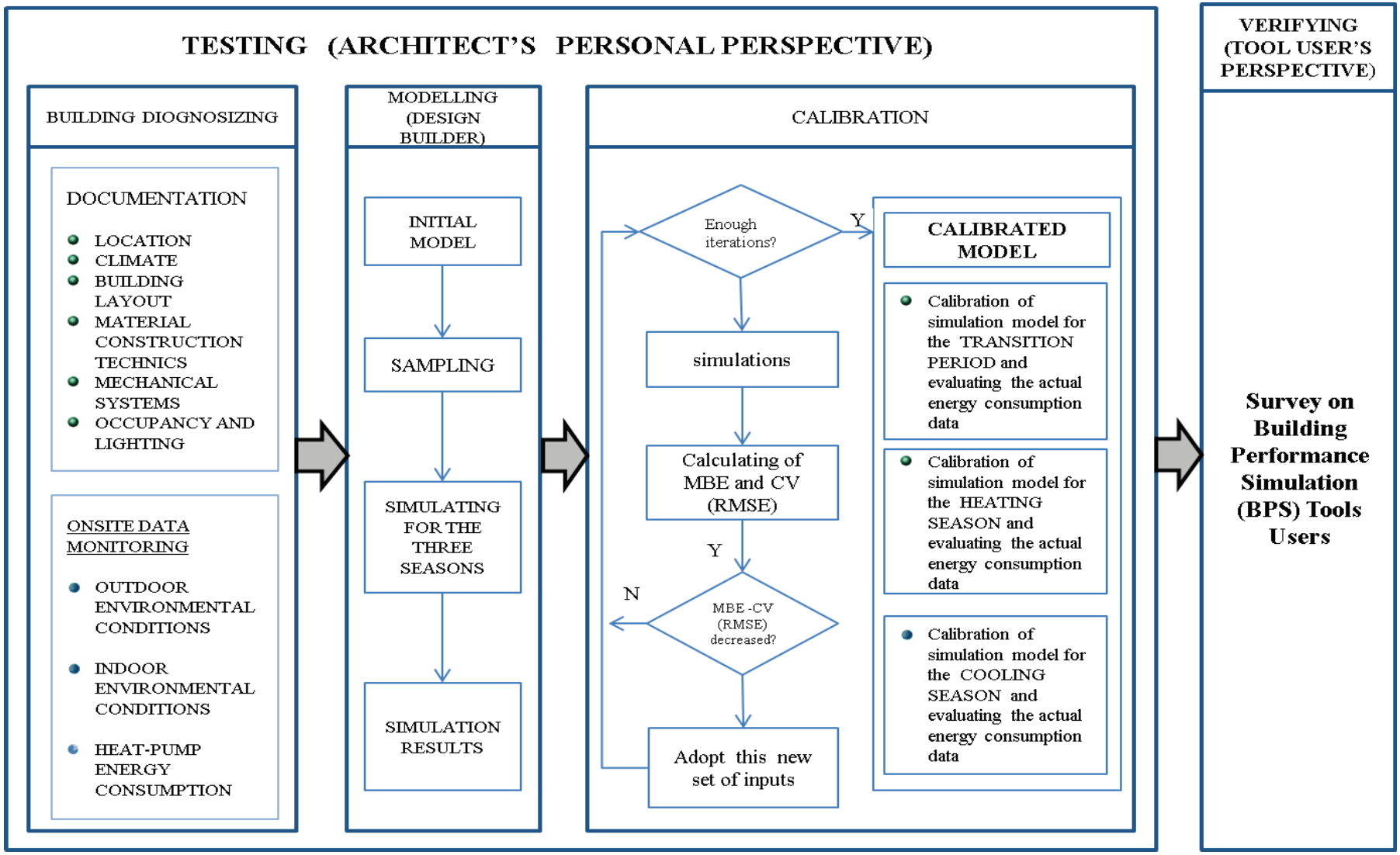


Figure 4.1. Workflow for the methodology of testing and verifying process

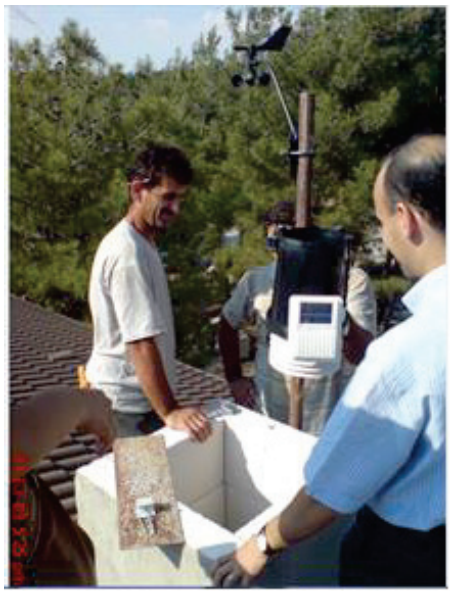


Figure 4.2. Installation portable weather station on neighbor roof
(Photography: Rahşan A. Gülmez Raafat, 2009)

4.1.2. Monitoring of Internal Environmental Conditions

The main objective of observing the environmental conditions in this dwelling is to examine how the indoor thermal conditions inside can effect from the environment, to be able to see the relationship between external and inside, thus be able to make some determinations for the impact of the building envelope on the seasonal and daily thermal performance of housing. Another objective is to provide basic data for the calibration of performance prepared digital building models. For these reasons, inside the three-storey residential building 16 data loggers were placed in the spaces facing to different directions and they are considered to have different thermal responses in the winter and the transition period of the whole year (Figure 4.3).

Table 4.1. Data logger locations

Code	Hobo Locations
HF-1	1.ST FLOOR - BEDROOM (NORTHWEST)
HF-2	1.FLOOR - BEDROOM (EAST)
HF-3	1.FLOOR - BEDROOM (SOUTH)
HF-5	1.FLOOR - GALLERY
HF-6	1.FLOOR - BEDROOM (SOUTH)
HB-8	BASEMENT - HOBBY ROOM
HB-9	BASEMENT - LOUNDRY
HG-12	GROUND FLOOR - OFFICE ROOM

Figure 4.3. Data loggers measuring dry bulb temperature, relative humidity and lighting levels, (Photography: Rahşan A. Gülmez Raafat, 2009)

16 total ONSET HOBO-12 data recorders are located about 150 cm in height from ground level to not have direct sunlight and measuring of the dry bulb temperature, the relative humidity and light levels have been recorded every 10 min.

Again, depending on the storage capacity of the device, the indoor data has been downloaded by visiting the workspace approximately every three weeks. Collected all these data has been converted to average hourly data. 8 data logger results are selected to be presented here in (Table 4.1); the locations are shown in the "red circles" of Monitoring Energy Consumption for Cooling and Heating (Figure 4.4).

The electricity consumption of air source heat pump has been measured with a network analyser ENTES MPR 63, the data is recorded in every fifteen minutes by connecting to the housing with remote access the total consumed energy of the heat pump is stored in a portal made with Ethernet connection and collected data was followed instantly numeric and graphically.

The electricity consumption of air source heat pump, ENTES MP with 63 network analyzer is recorded every fifteen minutes (Figure 4.5). Housing with remote access by connecting to the total energy consumed by heat pump is stored in a portal made with Ethernet connection and data collected was followed instantly numeric and graphic. The measurement period between July 1st, 2009 and June 10th, 2010, water supply temperature was set to be 14°C for cooling purpose and 35°C for heating measured consumption values were converted to per hour for use in later calibration run.

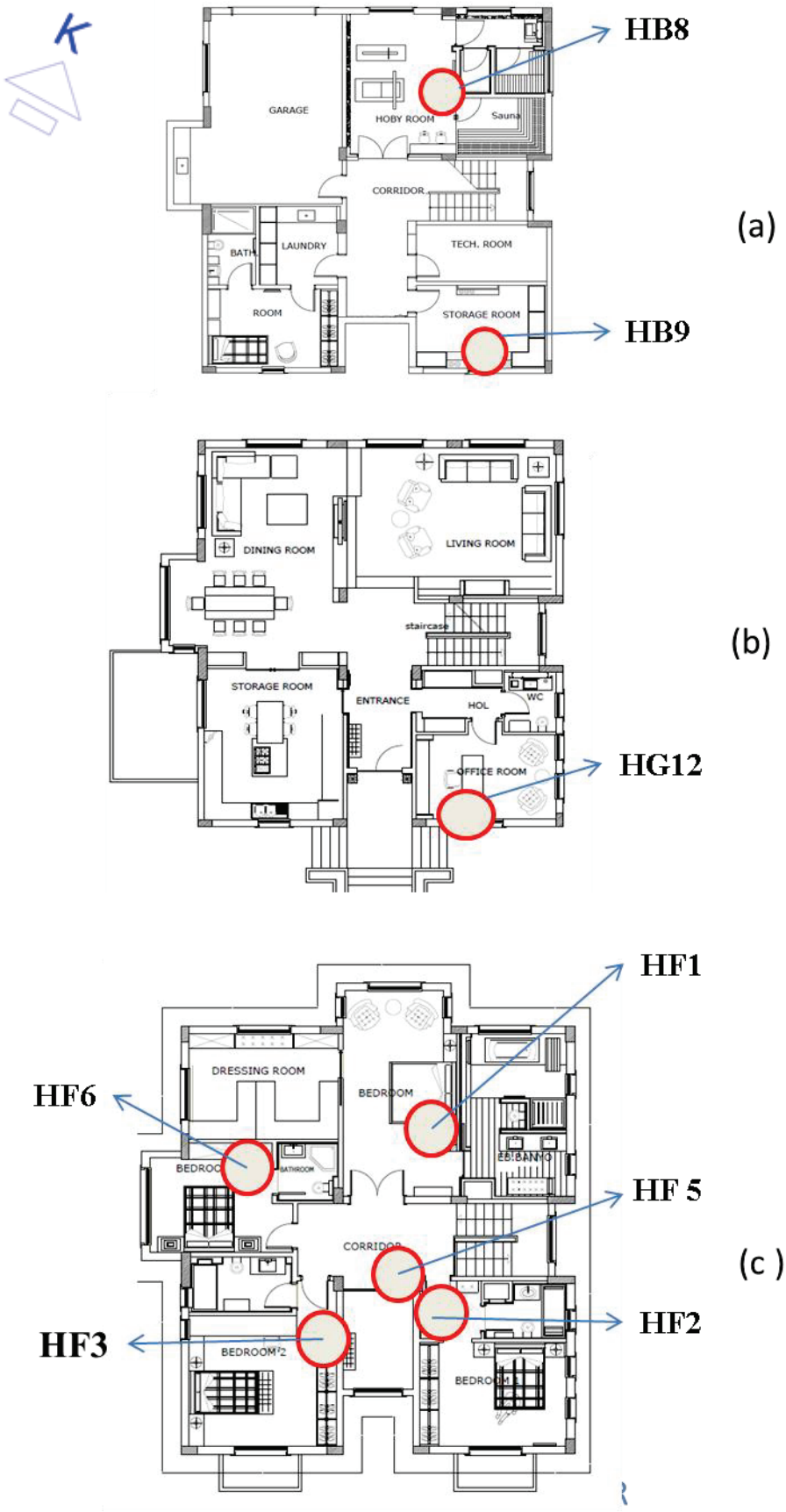


Figure 4.4. Basement (a), ground floor (b) and first floor plans (c)

Figure 4.5. Air source heat pump (indoor unit) (right) and network analyser (left) (Photography: Rahşan A. Gülmez Raafat, 2009)

4.2 Building Performance Simulation Model

The building performance simulation models help users evaluating environmental performance and identifying energy efficiency potential of buildings. In this study, the commercially licensed dynamic building performance software, DesignBuilder v.4.2 and v.6.0, whose reliability has been proven by BESTEST procedure, is utilized to predict detailed hourly energy consumption by using local climate data (Ron Judkoff andNeymark, 1995). DesignBuilder (DB) is one of the advanced modelling tools with user-friendly interface, using EnergyPlus (E+) as the calculation method. The architects, engineers and energy auditors analyse energy consumption and carbon emissions in buildings with this software.

Preparation of Weather Data

Dynamic building performance programmes use a variety of climatic data formats based on location-specific meteorological data, prepared according to the average of particular years. Each software often creates its own format. IWEC (International Weather Year for Energy Calculation) climate format represents different climatic parameters measured at different points of the world between 1982 and 1999 (Ashrae, 2001). It was compiled to create a typical year's climate data of the U.S. National Climate Data Centre by ASHRAE published in 2001 (Ashrae, 2001). EPW (Energy plus Weather) extension was created for E+, free dynamic modelling software developed by the US Department of Energy, as an extension of the typical years of climate data in IWEC format. In this research, available weather data in IWEC format with EPW extension is used to create location-specific climate data. The weather data for modelling software is prepared by transferring the measured weather data of case area over the existing hourly climatic data of Izmir in IWEC format.

The values of dry bulb temperature, relative humidity, wind speed, wind direction and horizontal global radiation, and atmospheric pressure are provided by the located weather station on the roof of next housing unit. The measured data with 15 minute- interval is converted to hourly averages. And a new local climate data file has been prepared. In addition, missing data due to various reasons is obtained by another weather station located in Izmir Institute of Technology in Gülbahçe-Urla, Izmir

Modelling of the Case Building

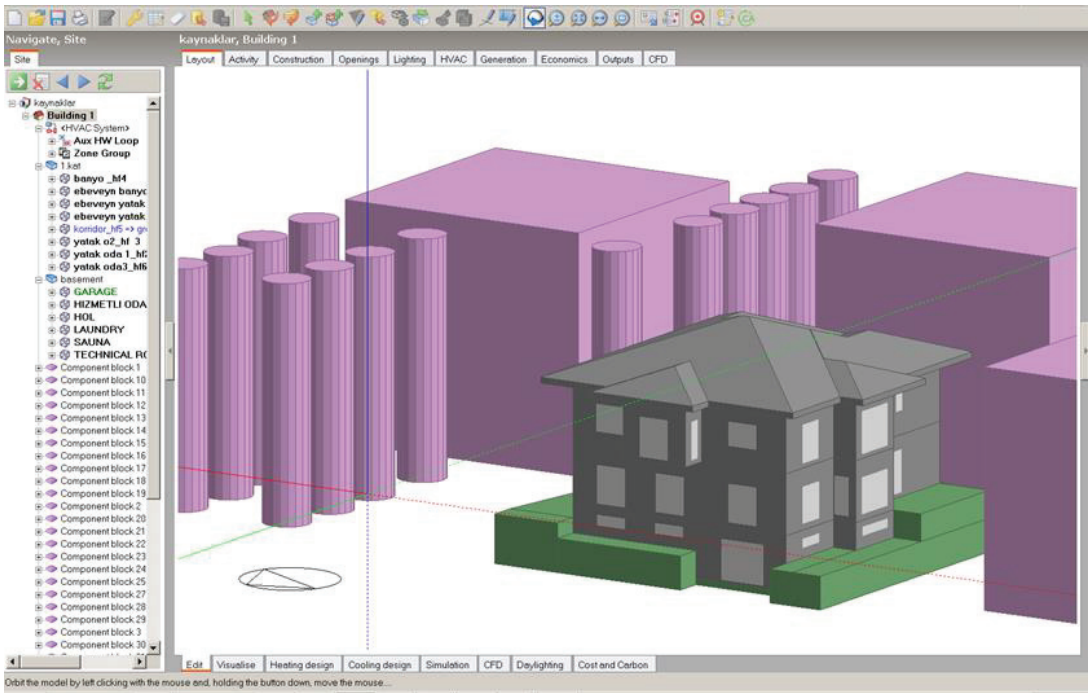


Figure 4.6. Model of residential building and its surroundings

In the modelling stage, after determining the surrounding roads, buildings and landscape elements on the map, land was created on the model based on the data obtained. CAD floor plans were converted to DXF files and transferred to DB by drawing the model over DXF format drawing. Besides, the building is modelled with surrounding buildings and trees. The heated or unheated spaces on all floors to be included in the energy calculations are separated by dividers. The building is divided into total 16 thermal zones, of six is on the basement, three on the ground floor, and seven on the first floor Each room is modelled as separate zones, of which were monitored by the single data logger (Figure 4.8).

For shading, the shutter elements on window openings were modelled by choosing appropriate type offered from shading elements in the software options (Figure 4.7).

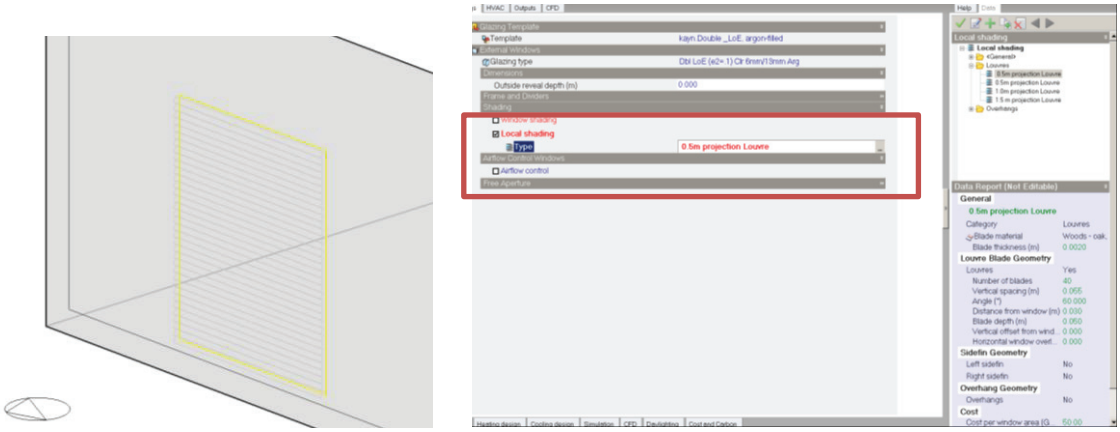
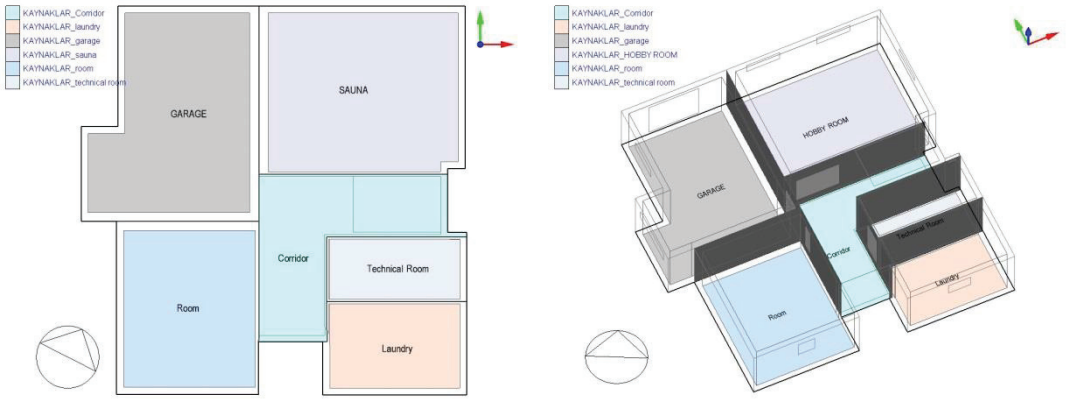


Figure 4.7. Local shading component

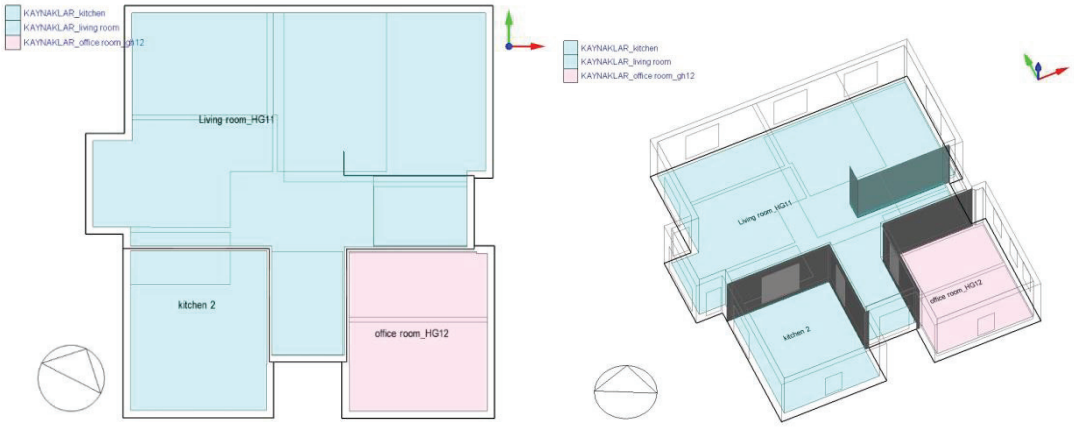
The airtightness values of housing envelope and openings, the air leakage arising from doors, windows, frames or any cracks on walls were observed per each room, and no particular difference among spaces was realized. Since the case building was newly constructed, the infiltration rate was assumed as 0.4 ac.h-1 prior to the calibration. In the case building used as a demo-house, the user impact on thermal performance was neglected as there was no regular visitor input. It is shown in the Table 4.2.

Table 4.2 Settings before calibration in model

		Basement		**Ground Floor**	**First Floor**				
		HB8	**HB9**	**HG12**	**HF1**	**HF2**	**HF3**	**HF5**	**HF6**
User Density (m^2/pers.)	**BC**	-	-	-	-	-	-	-	-
	AC	-	-	-	-	-	-	-	-
Thermostat Temperature (^{0}C)	**BC**	22	22	22	22	22	22	22	22
	AC	20	21	19	26	26	26	24	24
Setback Temperature (^{0}C)	**BC**	28	28	28	28	28	28	28	28
	AC	22	22	21	27	28	28	28	28
Infiltration ($ac.h^{-1}$)	**BC**	0.2	0.2	0.2	0.2	0.2	0.2	0.7	0.2
	AC	0.4	0.4	0.4	0.4	0.4	0.4	0.7	0.4



(a)



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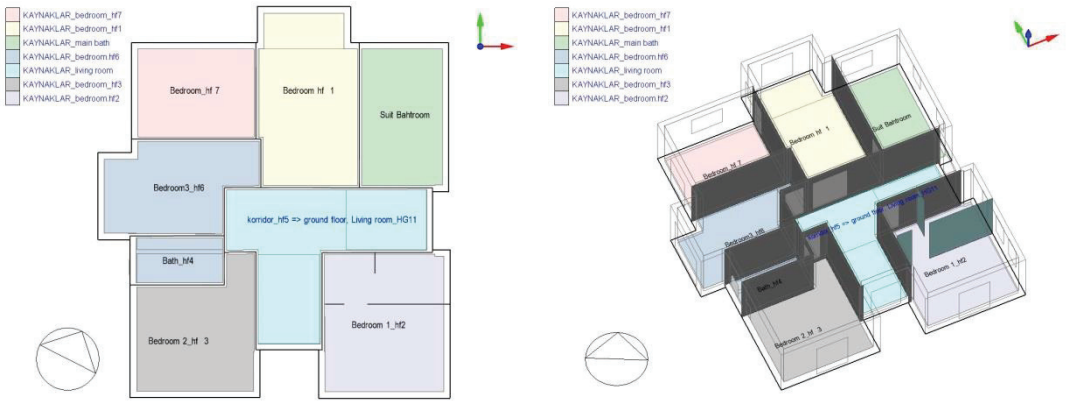


(c)

Figure 4.8. Thermal zones in DB v.4.2; (a) basement, (b) ground floor, (c) first floor; (note that each colour represents a separate thermal zone)

4.2.1 Model Calibration

In this study, it is targeted that to prepare a digital model that can predict the future thermal performance and energy consumption of the building profile in reasonable error rates. Calibration studies, is very important for the accuracy and availability of digital models and it is very necessary. Approaching of the Calibrated building performance model is given in the details of some guides: the International Performance Measurement and Verification (IPMVP) Protocol and the United States Association of Sanitary Engineers (ASHRAE) 14-2002 .In the calibration process, the simulation results are compared with the experimental data, and the data are continuing it until get close the real time measured data.

In this study, the calibration approach is applied by using the hourly data. During model calibration, the two types of data are used: indoor air-dry bulb temperature (° C) and the energy consumption of the heat pump (KW).

In order the identify parameter combinations that produce the best fit the measured data , first the calibrated model outputs and measured data are compared in terms of standard error of mean (MA: Mean Error) and the mean square error of the square root of the total (CV-(RMSE):Root Mean Square Error) are calculated.

These two indicators are considered as statistical comparison method calculating the error rate in ASHRAE and IPMVP guide. An efficiency of 0 indicates that the model predictions are as accurate as the mean of the observed data whereas efficiency less than zero. After the sufficient number of experiments, it is expected to reach an acceptable level of error rate. Hourly error rates are presented in Table 4. In this research, the Coolant error rate of the model for the period between the date 17 and 24 August 2009 is calculated by using Equation 1 and 2 below.

Table 4.3. Hourly error rate values

STATISTICAL INDICES	**ASHARE 14-2002**		**IPMVP**	**MVFEP**
HOURLY (%)	MBE	±10	±20	±10
	CV-RMSE	30	20	30

$$\text{CV-RMSE (\%)} = (100/T_{ma})*[1/N*(S\ (T_s-T_m)^2)]^{1/20} \quad (4.1)$$

$$\text{MBE (\%)} = (100/T_{ma})*[S\ (T_s-T_m)]\ /N \quad (4.2)$$

Where:

N: is the number of observations.

T_{ma}: average measured temperatures for N observations.

T_s: simulated hourly temperatures.

T_m: measured hourly temperatures.

4.2.2 General Modelling Approach for Cooling with Air-Source Heat Pump

As for the cooling energy, the building performance program Design Builder v.4.2 has calculated loads of the spaces in the created building performance model. When the considering the under floor cooling system by the heat pump of existing building there are some difficulties has encountered in the modelling. The main problem was that the latest version of the software has not developed enough for the used heat pump template. Another problem is that the software doesn't have defined templates showing under floor cooling applications in HVAC. With the software support team help, cooling loads are calculated by selecting the template of the chilled ceiling Figure 4.9 shows a chilled ceiling diagram prepared for the refrigeration applications on the software interface for the three main floors to ceiling.

The cooling capacity and values entered here only to get cooling energy consumption of the building. The cooling capacity of it is 13.12 kW. The model was created from ready-made templates in DesignBuilder HVAC systems. As a result, Design Builder structure modelling V4.2 was used for cooling period to know cooling load for the summer period (17-24 August 2009).

Throughout the modelling of the mechanical system of this housing there was another problem encountered in the process of calculating building's heating energy load, understood that is not possible to use the same calculations of the ceiling of the cooling applications in design builder software. In addition, it is not enough for modelling to know the cooling load only using design builder tool for the simulations. With the software support team given advice that is only possible doing it with EnergyPlus software Therefore, the file has been converted into the extension of the EnergyPlus model 'IDF' formats. This new format in the heat pump modelling, more

detailed data input is required.

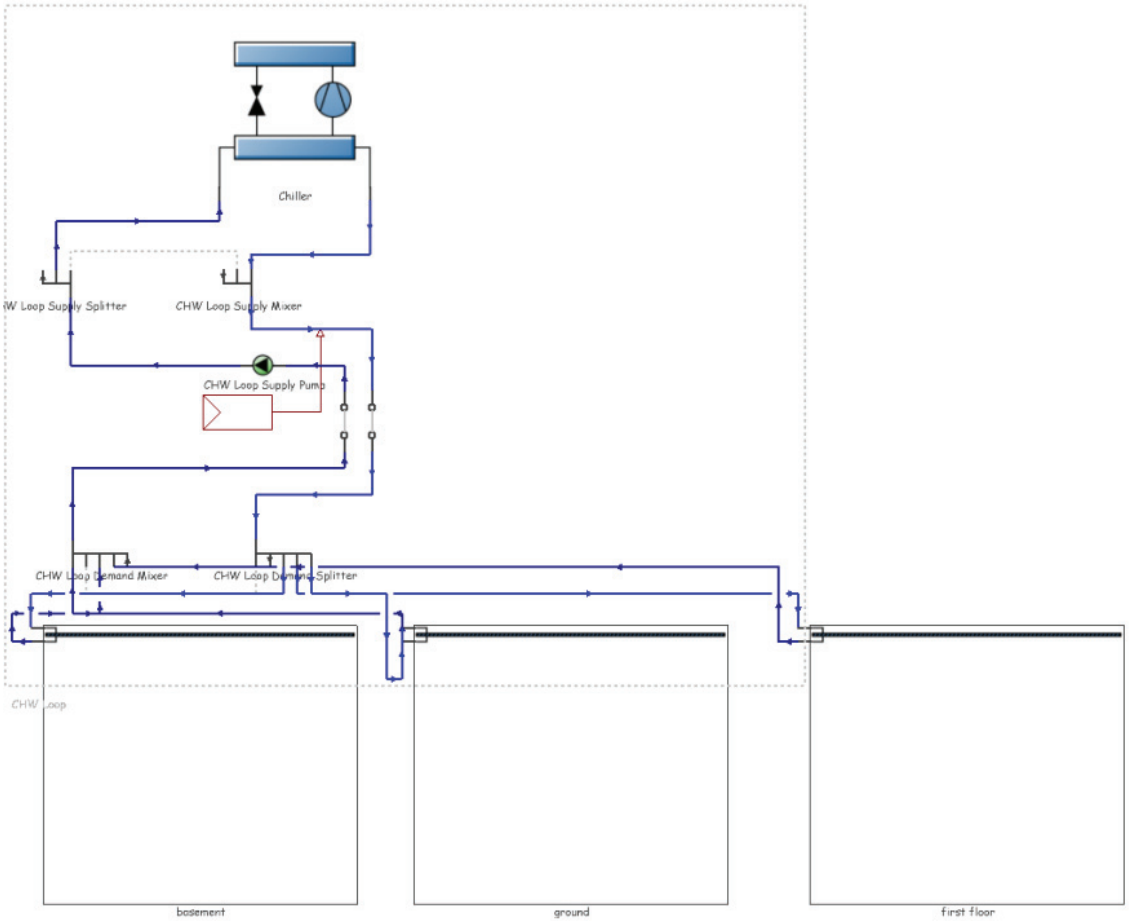


Figure 4.9. Prepared chilled ceiling diagram for the heat pump for the cooling period modelling in the Design Builder software

In the applications of the cooling systems the ceiling of the building, cold water pipes are mounted to the ceiling in order to cool the spaces. This application is mounted in a plasterboard ceiling panel which is based on the conventional cooling system. Ceiling panels can be typically from thin metal structures or just drywall. Here the cooling system is advantageous with the little Floor-to-ceiling height in places. We can say that it is not suitable for the spaces with high heat gain because it has a limited cooling system capacity. Maximum cooling capacity of the chilled beam system could be only 70 W/m^2. In our model the capacity the heat pump has been careful not to exceed this value.

As distinct from the normal applications of ceiling cooling here, the cold-water pipes are embedded into floor pavement in the performance model. In the all other

places except the garage in the model ceiled sealing data entered and the pump efficiency required by the template (COP) has been accepted as 4, 22.

Therefore, the temperature settings of chilled ceiling at HVAC template have been repeatedly controlled. In order to keep the indoor temperature close to the measured value, a layer of insulation layer to the slab has been entered into the model to prevent possible heat gains from the floor of unheated spaces.

4.2.3 General Modelling Approach for Heat Pump for Heating

The floor heating model has been developed in Design Builder software for the purposes of the parameter identification and estimation of energy usage in case building for heating time. The catalogue information entered in the model for the heat pump. The heat pump unit has Monobloc system combines all the features of heating and cooling (with optional domestic hot water) into one unit. The heating capacity and values entered here only to get heating energy consumption of the building. Heating Capacity of it is 16.05 kW. The model was created from ready-made templates in Design Builder HVAC systems; the underfloor heating system was designing for winter period (1-10 January 2010)

It was tried to select the system closest to the existing mechanical system among the ready-made HVAC systems in the DB. Design Builder's default HVAC system; Air to Water Heat Pump (ASHP) Hybrid with Gas Boiler, Nat Vent; was used to represent existing HVAC system in building. Due to current limitations in the Design Builder software, heated floor were not available options for heating and instead were modelled as fan coil units or water radiatorsz has close to having a flexible system working for Design Builder v6.0. New HVAC templates include ASHP with options for integrated boiler (modelled within the water heater component) or in a separate hot water loop connected by a fluid to fluid HX component (Figure 4.10).

Underfloor Heating System

Under Floor heating systems are low temperature radiant systems with hot water pipes embedded in the ground layer. Accordingly, the surface should be wide and with low temperature. These systems typically use low flow temperatures of around 40-55°C compared with around 80°C for traditional low temperature hot water heating systems using radiators and convectors. Lower return temperatures enable more efficient operation using condensing boilers and heat pumps.

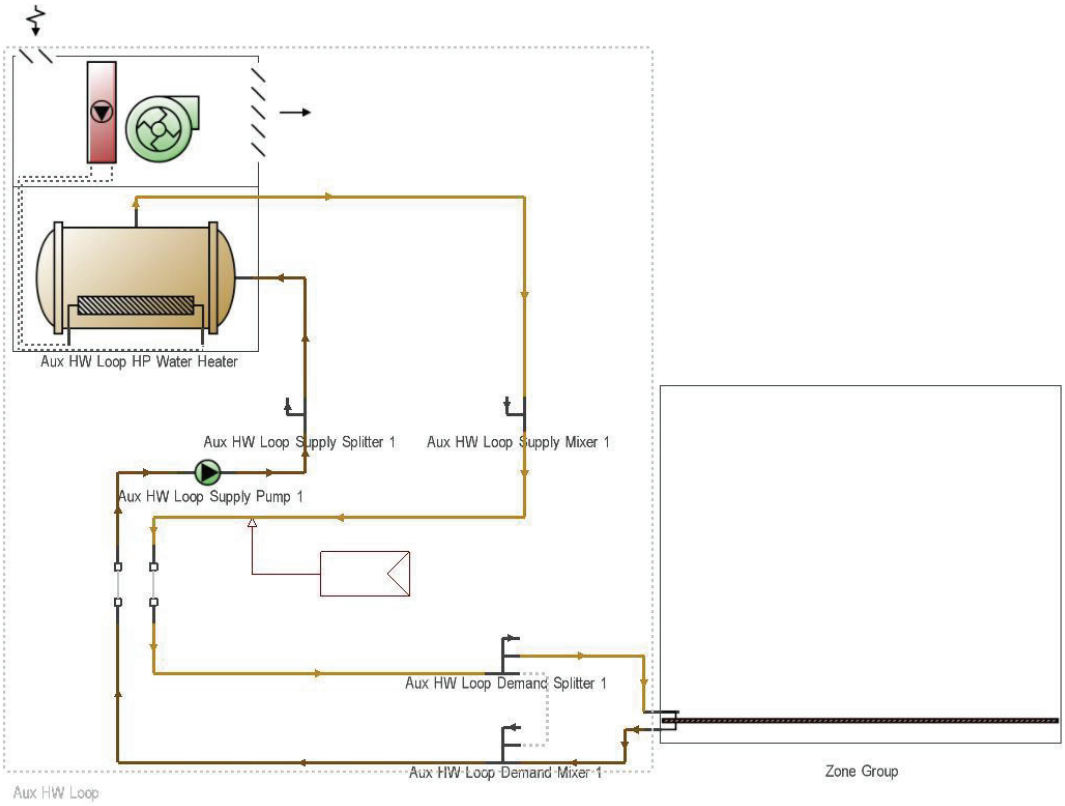


Figure 4.10. Modified detailed HVAC model diagrams in DB

Two types of heated floors are available: constant flow and variable flow. Variable flow heated floor is fully auto sizable. Heated floors can be connected to hot water loops by boiler, air source heat pumps and/or solar thermal systems.

The default settings of HVAC template for domestic hot water schedule modeled to run 24/7 at 80°C for hot water from the accumulation tank. The system schedule has been changed to the underfloor heating schedule which is always 40°C. Heating sizing supply temperature is 40 for each HVAC zones in the model

A heated floor is a zone component where hot water circulates the floor surfaces of the zone. In the underfloor heating systems of the zones, the system is placed as "internal source" in the floor construction. It is used to indicate where the hot water pipes are located in the simulation tool. It enables to determine the location of the hot water pipes embedded in the structure, specifying the heat transfer pattern in one-dimensional or two-dimensional. The two-dimensional solution method ensures accurate return of the return water temperature.

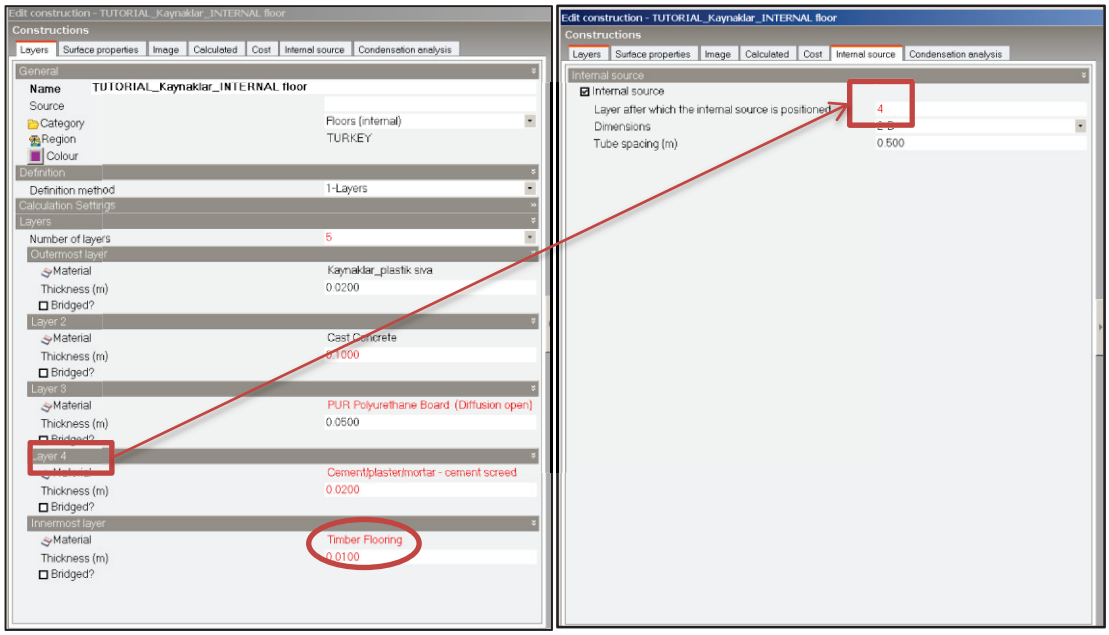


Figure 4.11. Hot water pipes positions

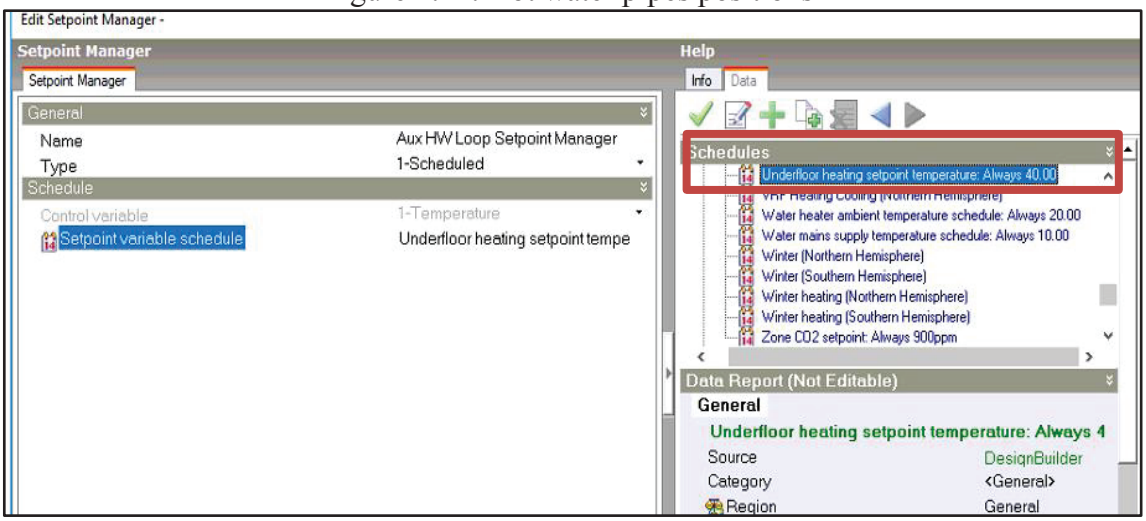
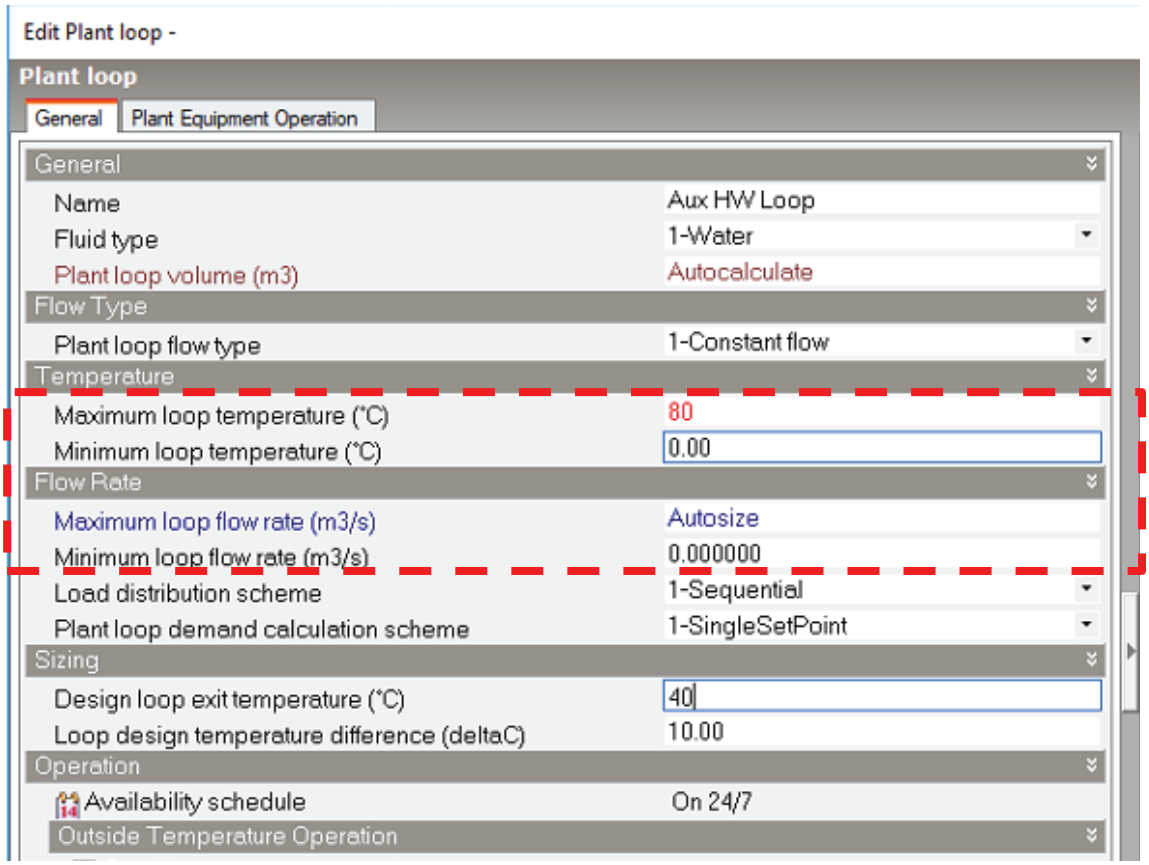
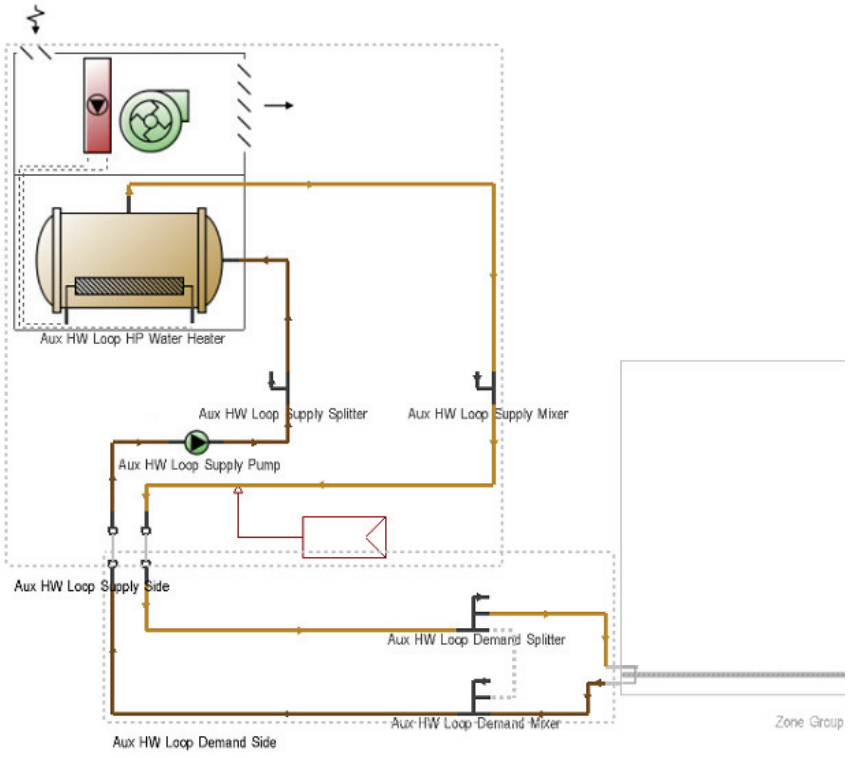


Figure 4.12. Set point manager for heated floor in DesignBuilder

For efficient underfloor heating, heated water pipes must be embedded in a thermal mass on the floor (Figure 4.11). This system should be carefully defined in relation to the thermal mass in the model. There may be excessive deviations in the results due to inconsistencies in the settings of good temperature. An unheated floor source cannot be heated from the floor. If the floor finishing has low conductivity (i.e. a thick pile carpet) then the heated floor will struggle to provide adequate to the room heating. In the underfloor heating settings, a condition was set as if the temperature of the water circulating in the pipes on the floor would always be 40 degrees (Figure 4.12).



(a)



(b)

Figure 4.13. Heated floor, plant loop data settings (a), diagram (b)

4.3 Survey on Users of Thermal Simulation Programs

During June and July 2019, a survey conducted between experienced simulation tools users in Turkey and abroad by using telephone and mail. The purpose of the survey was to record user experiences and to identify what difficulties they faced and to understand the role of architects in the simulation process. Including Turkey and abroad, questions were prepared for users online and respondents were reached by telephone and email.

This survey aims to collect information from the users of energy simulation tools in the academic institutions and/or market (by academicians, architects, engineers, designers, LEED AP).

The questionnaire consists of 18 questions and takes approximately 10-15 minutes. The survey questions consist of the following three main headings.

1. Users' backgrounds and experiences with BPS tools;

2. Tools' integration into the design process and satisfaction with graphic outputs.

3. Usability, possibilities and limitations of simulation programs.

Google survey Form has been used to create surveys that help us effectively evaluate and communicate users of simulation tools. The questions were generally left open, but the statistical results of the options were more descriptive in the analysis of the answers.

The questionnaire was sent to online mailing list of IBPSA's-Bldg.-sim, which is open to all users who encounter problems during their simulations (BLDG-SIM). In addition to this mailing list, it has been published as a form in the LinkedIn 'EnergyPlus-Energy simulation group. This group was opened especially for this thesis to reach other users in international platform and has an increasing number of users every day to discuss the latest developments and general problems of EnergyPlus and Design Builder software's (EnergyPlus). This online survey was conducted for a period of 2 weeks from June 2019 to early July 2019. Apart from this, the questionnaire was sent only to certain users and researchers in Turkey and questions were discussed individually by phone and recorded. The English and Turkish versions of survey sheet can be found in Appendix A and Appendix B.

CHAPTER 5

RESULTS

This section presents full-year thermal and energy performance of the building, simulation model results and error rates of calibrations. The results obtained from the digital model are analysed to compare the actual energy consumption values with the measured ones. The error rates of the calibrated model are presented separately for heating, cooling and transition periods. Consequently, concrete observations and feedback are summarised about the limitations, inadequacies and capabilities of the dynamic modelling process and simulation methodology.

5.1 Data Analyses

5.1.1. Outdoor Environment Analysis

The dry bulb temperature (T) and relative humidity (RH) values recorded in the meteorological station located on the roof of the neighbouring building are illustrated in Figure 5.1.

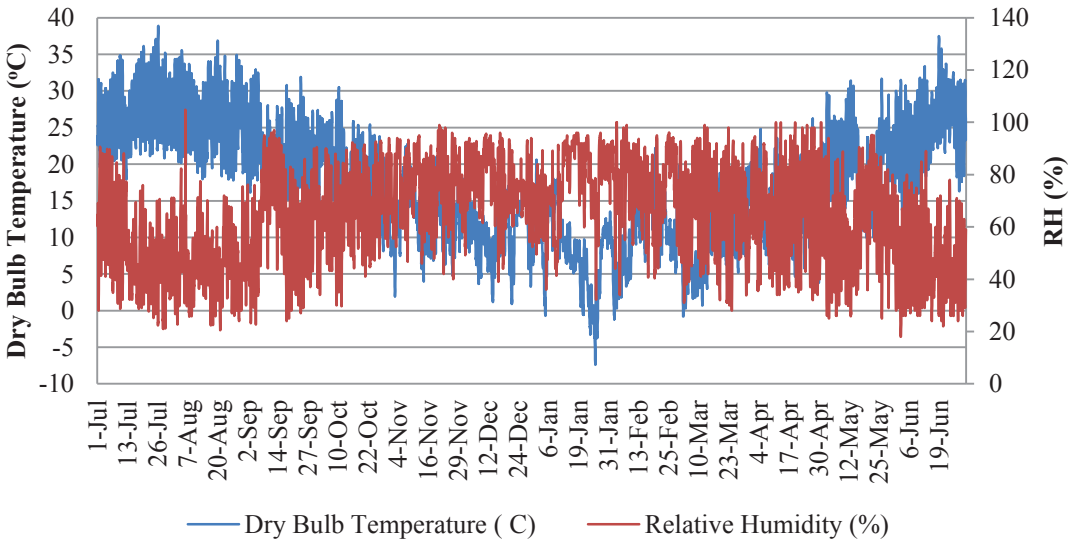


Figure 5.1. Outdoor dry bulb temperature and relative humidity for residential building in Kaynaklar (01.07.2009 – 30.06.2010)

According to the results for the total of one year from beginning of July 2009 to end of June 2010, the average temperature for winter months between December 2009 and February 2010 vary between 8°C and 11.1°C at Kaynaklar. The average temperature can reach up to 27.2°C in the summer months between June 2009 and August 2009. The prevailing winds are north and northwest. The annual average wind speed in the studied area is 4.38 m/s. The highest wind speed reached at November 18th, 2009 with the value of 18 m/s (64.79 km/h).

Outdoor Temperature: The black line in Figure 5.1. shows the outdoor dry bulb temeprature of private house in Kaynaklar. Through the studied year, the outdoor temperature ranges from -7.3°C to 38.9°C with 17.09°C for the outdoor average temperature. On January 26th, 2010 at 07:00, the minimum hourly outdoor temperature was monitored while the maximum recorded on July 26th, 2009 at 17:00.

Outdoor Relative Humidity: The outdoor relative humidity values range from 18% to 100%, while the annual average relative humidity was 65.3% for the studied period (Figure 5.1). The minimum relative humidity was recorded on the 3th of Jun at 19:00, while the maximum was recorded on August 7th, 2009 at 10:00. The hourly minimum, maximum and average values of outdoor dry bulb temperature and outdoor relative humidity are presented for each month with the yearly result (Table 5. 1)

Table 5.1. Measured outdoor temperature and relative humidity values for Private House, Kaynaklar (01.07.2009 – 30.06.2010)

Month	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb.	March	April	May	June	Yearly
Min TEMP	17.9	7.5	4.4	-2.4	2.3	2.8	9.5	18.1	19.9	20	25.3	20.3	-7.8
Max TEMP	38.9	23.7	20.5	19.5	20	22	27.8	33.6	33.7	38.3	38	35.2	38.9
Ave TEMP	27.2	15.1	12.8	9	10.4	12.1	16.8	24.5	26.4	30.1	30.8	27.3	17.1
Min RH	21.0	39	42.3	37.5	40.4	30.7	23.3	12	30.5	21	21	30.4	18
Max RH	90.6	98.7	94.4	99.2	87.9	99	82.5	71.9	77.2	66.6	72.7	91.3	100
Ave RH	51.4	68.7	77.6	70.4	65	69.3	54.3	49.7	53.7	45.2	51.8	56.9	35.7

5.2. Calibration Results

In this study, calibration of the building energy simulation has been made by comparing the measured and simulated indoor air temperature. The outdoor air temperature data were measured for one year and integrated into the simulation weather

data file. The cooling, heating and transition periods of the building were examined. Indoor and outdoor temperatures were examined seasonally and presented here with graphics.

Table 5.2. Meteorological Seasons and Simulation dates in one year (July 1st 2009 - June 30th 2010)

SEASONS	MONTHS	METEOROLOGICAL SEASONS	SIMULATION DATES
COOLİNG SEASON	JUNE	01.06.2009-30.08.2009	17-24.08.2009
	JULY		
	AUGUST		
TRANSITION TIME	SEPTEMBER	01.09.2009-30.11.2009	20-30.09.2009
	OCTOBER		
	NOVEMBER		
HEATING SEASON	DECEMBER	01.12.2009-28.02.2010	01-10..01.2010
	JANUARY		
	FRBRUARY		

Accordingly, simulations were made by integrating appropriate HVAC systems and simulated each for one-week periods. Date ranges have been chosen according to the data availability measured on site. Finally, simulation results were compared with those obtained from the actual measured temperature of each zone. First, the graphical result is presented and then the statistical error result for each zone.

5.2.1 Results of the Simulations Done for the Cooling Period (01.06.2009 - 31.08.2009)

5.2.1.1 Outdoor Weather Conditions (Summer Period)

The relative humidity in Kaynaklar is low when the temperature is high and less cloudiness times in the summer. It has increased during the cold period of the year. The values are starting to decrease during March and reaching the lowest rate in July. The average monthly relative humidity where the building located is approximately 60%. The climate data is shown in Table 5.2. The range of four climatic parameters can be seen in the period from 01.06.2009 to 31.08.2009.

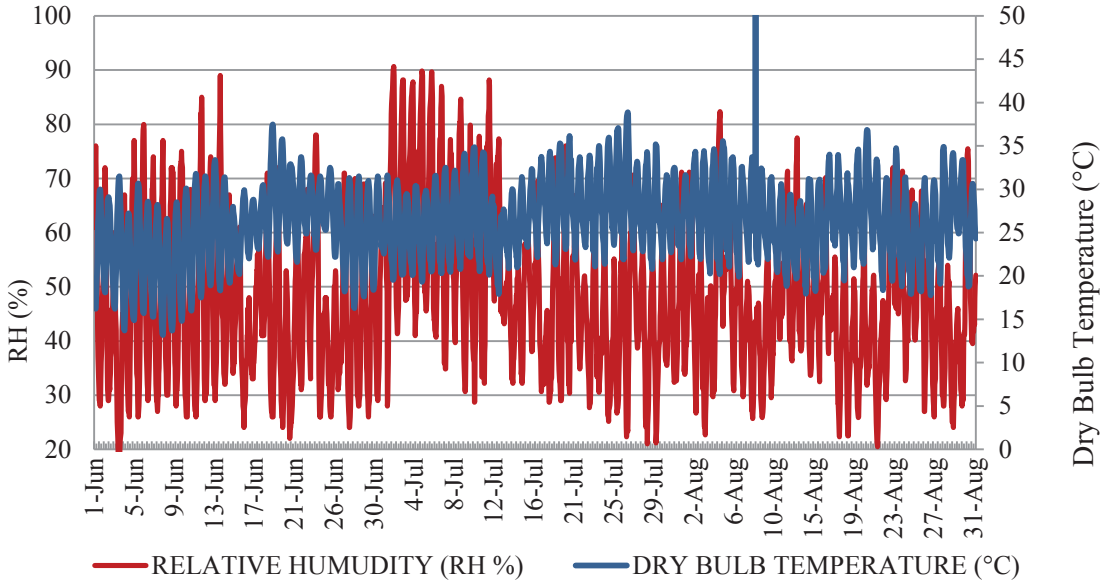


Figure 5.2. Comparison of T and RH values outdoor (daily values –from 1st June to 31th August 2009)

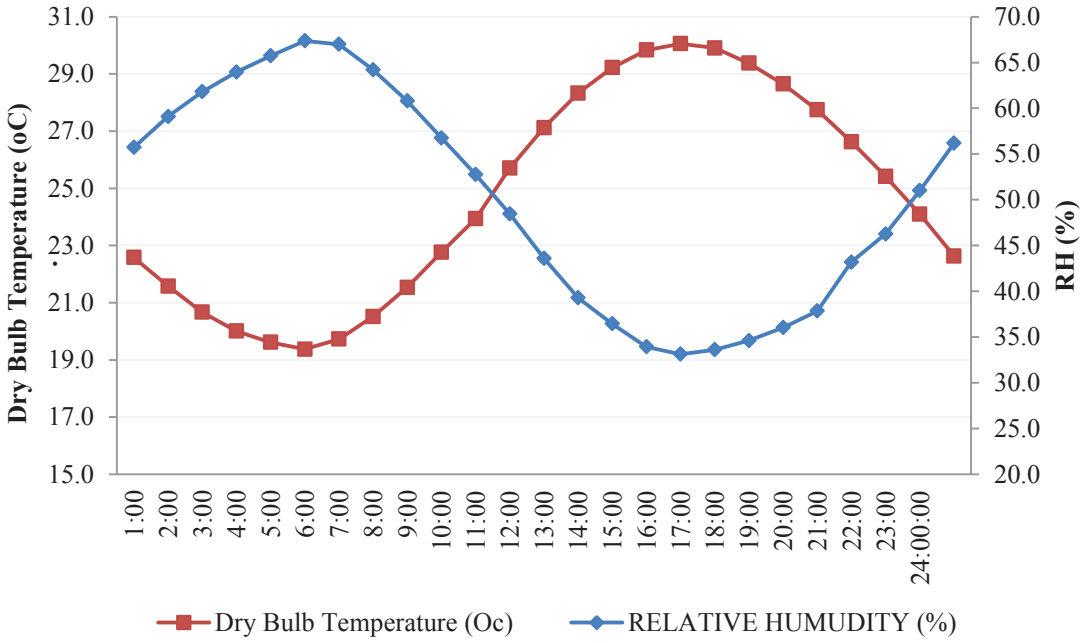


Figure 5.3. Comparison of T and RH values outdoor (mean hourly values – from 1st June to 31th August 2009)

Figure 5.2 shows the daily values of outside temperature and relative humidity which were measured between 1st June and 31th August where the temperature rates vary between 17.3°C – 37.3°C. The relative humidity percentages are between 20-93 %. The graph shows that there is an almost inverse relation between temperature and RH values if the peak values are analyzed (such as July 25th and August 23rd).

Figure 5.3 shows converted mean daily data into hourly values that conserves the mean daily value of the temperature and humidity. It can be seen here more clearly the relation of humidity and temperature outside. Coldest and warmest hours are 6:00 (without solar radiation, temperature decreases) and 17:00 respectively.

5.2.1.2. Indoor Climatic Conditions in Summer Period

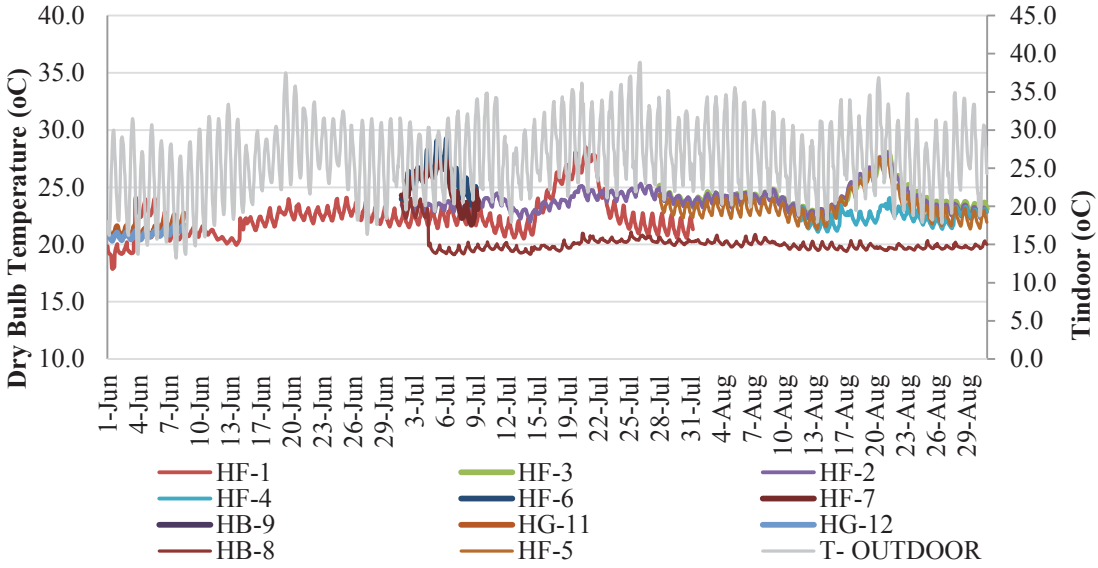


Figure 5.4. Measured daily indoor air temperature values for all monitored zones

Figure 5.4 shows measured indoor air temperature values for the 9 zones in the house between June 1st and August 31th 2009 where the temperature rates vary between 20.0°C -25 °C where outdoor temperatures are between 15°C and 37°C. During the warmest and coldest days in the summer period (between June 1st and August 31th 2009), the average indoor temperatures vary between 20°C and 25.0°C. On the following daily measurement charts, the ambient temperatures do not change during the hottest and coldest days of operation of the cooling system (Figure 5.5). It was observed that it was taken under control together with the building envelope (Figure 5.6). It is seen that the rooms on the upper floor are the most affected by the changes in the outside air temperature while the constant temperature was 20°C on coldest day. HF1, it has risen up to 25°C on warmest days with the 37, 5°C outdoor temperature.

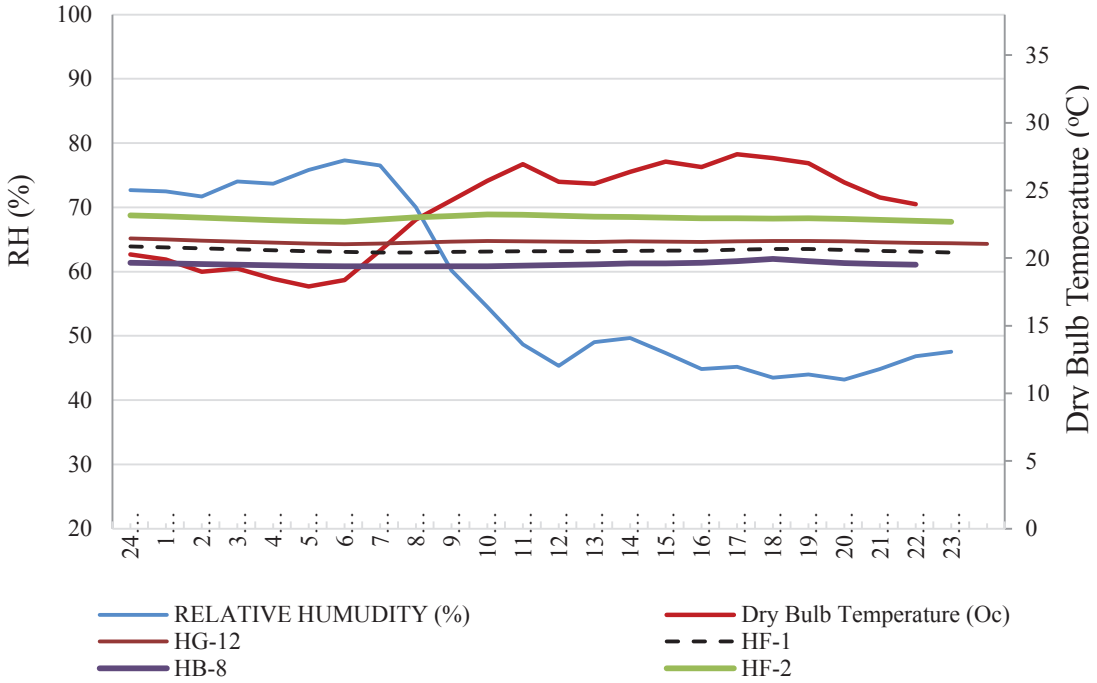


Figure 5.5. Measured indoor air temperatures in four locations in house in the coldest day in summer season: 13/07/2009

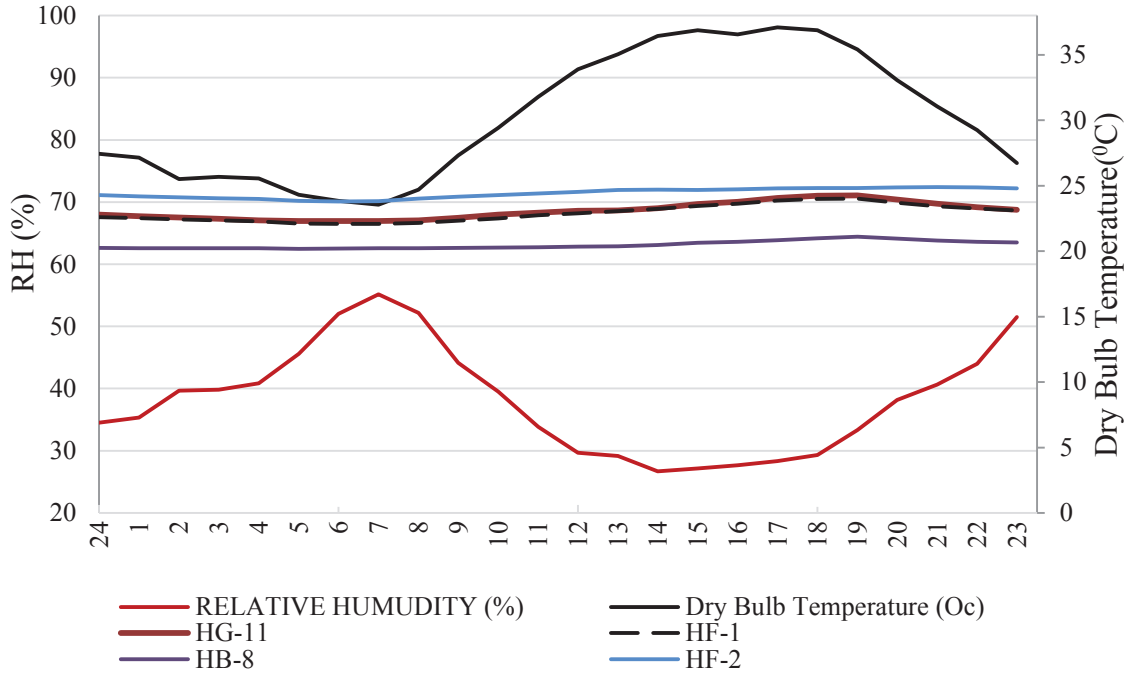


Figure 5.6. Measured indoor air temperatures in four locations in house Hottest day (25.07.2009)

5.2.1.3 Comparison of Indoor and Outdoor Climatic Conditions (Summer Period)

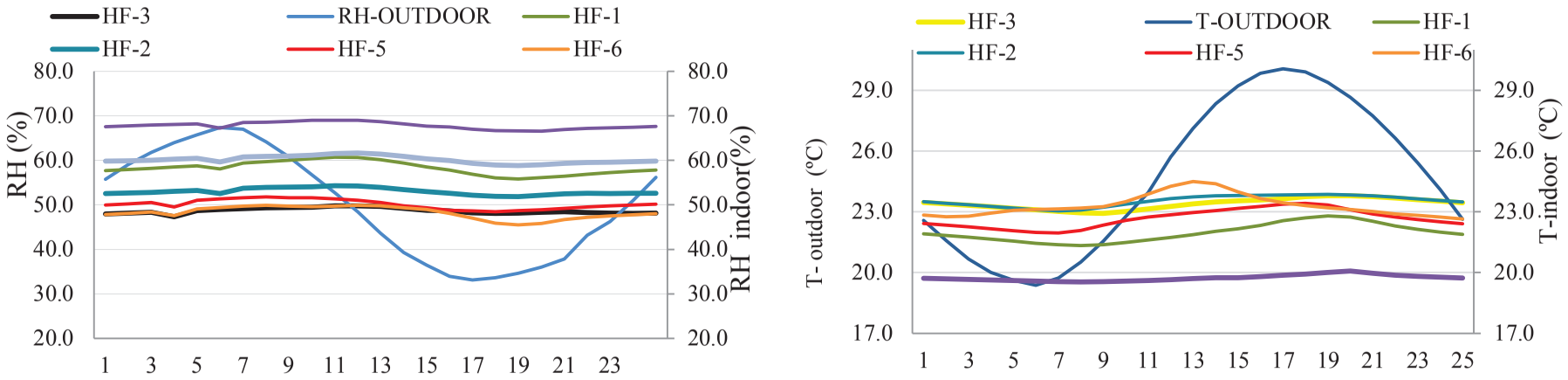


Figure 5.7.Average humidity and temperature values measured at 7 locations (mean hourly values – from 1st June to 31th Aug 2009)

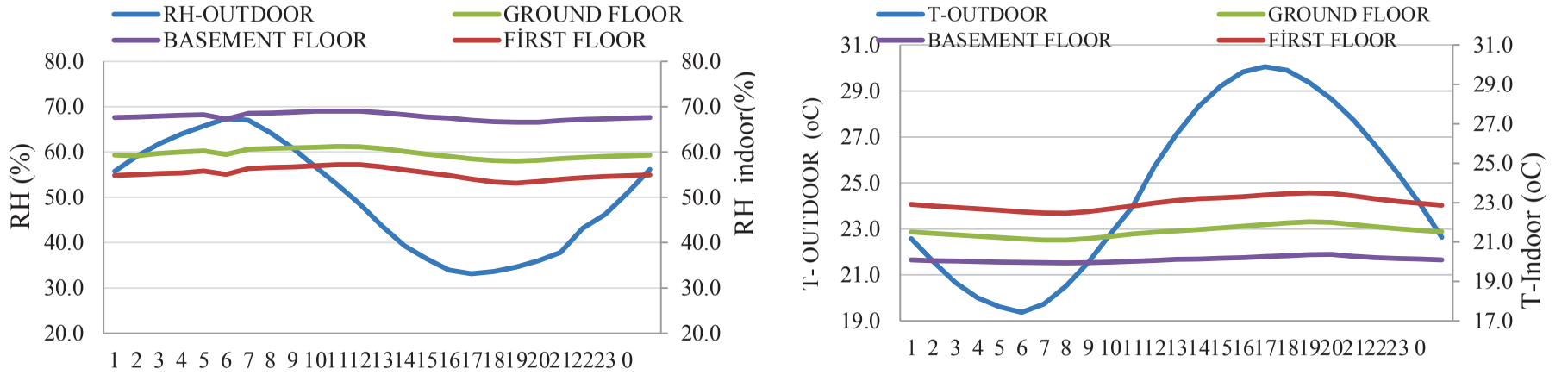


Figure 5.8. Average humidity and temperatures values measured at 3 floors (mean hourly values – from 1st June to 31th Aug 2009)

5.2.1.4 Comparison of Indoor Temperatures According to Measured Data and Simulation Results

For model calibrating, the building has divided into eight thermal zones and eight data loggers were installed in these zones. Indoor ambient air temperature and relative humidity data were recorded continuously every five minutes and compared with the temperatures obtained from the simulation results.

For these purpose more than one hundred trials has been achieved in the simulation. The energy consumption of the heat pump has been evaluated simultaneously in these trials too. As a result the calibrating results of the cooling period between 17th and 24th August 2009 are illustrated here as mean hourly values in Figure 5.9, Figure 5.10, Figure 5.11, Figure 5.12, Figure 5.13, Figure 5.14, Figure 5.15 and Figure 5.16 hourly and daily trends with a total of 16 chart.

As for these eight thermal zones the hourly error rates gained after the result of comparisons of the hourly measurements and simulation results can be seen on Table 5.5. It is seen that the error rate remains below the threshold. Therefore, we can say that the final calibrated model match well with the real data measured in the period of 17-24 August 2009.

Both the monitored and model data confirmed that the best results have been observed for the 'HF2-Bedroom (east)' and 'HF6-Bedroom (southwest)' at the places on the first floor. The hourly errors are very high at the 'HG12-Office Room on the ground floor and 'HB9-Hobby Room' in the basement. The temperature values obtained from the model are actually more stable at the basement, shows high-frequency bumpy features at ground and first floor. This high frequency bumpy feature shows more deviations at the First Floor Bedroom-Northwest (HF1) and First Floor Gallery Top Elevation (HF5). The possible cause of these deviations; manually opening and closing the windows and doors is that they do not meet certain timing, uncontrolled shading elements and unwanted air leaks of the building envelope.

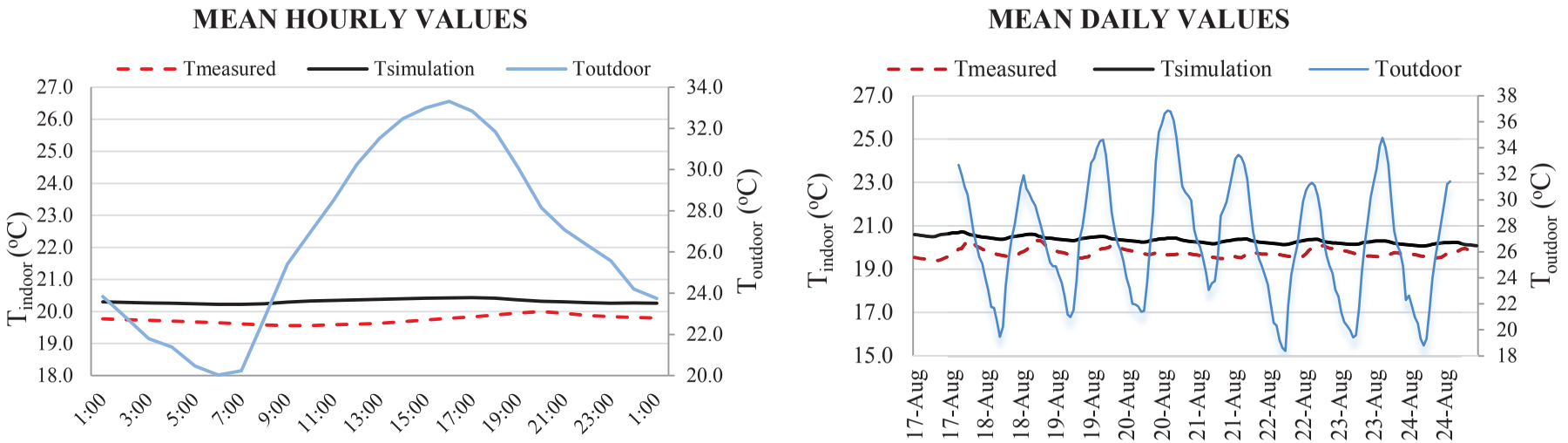


Figure 5.9. Mean hourly and daily temperature values of hobby room at basement floor (HB8) (17-24.08.2009)

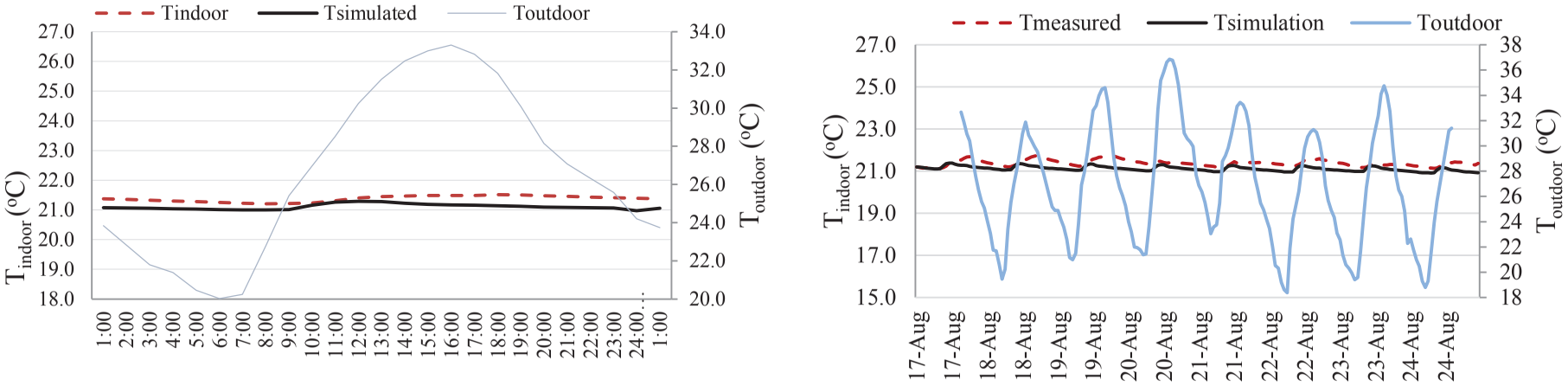


Figure 5.10. Mean hourly and daily temperature values of laundry at basement floor (HB9)(17-24.08.2009)

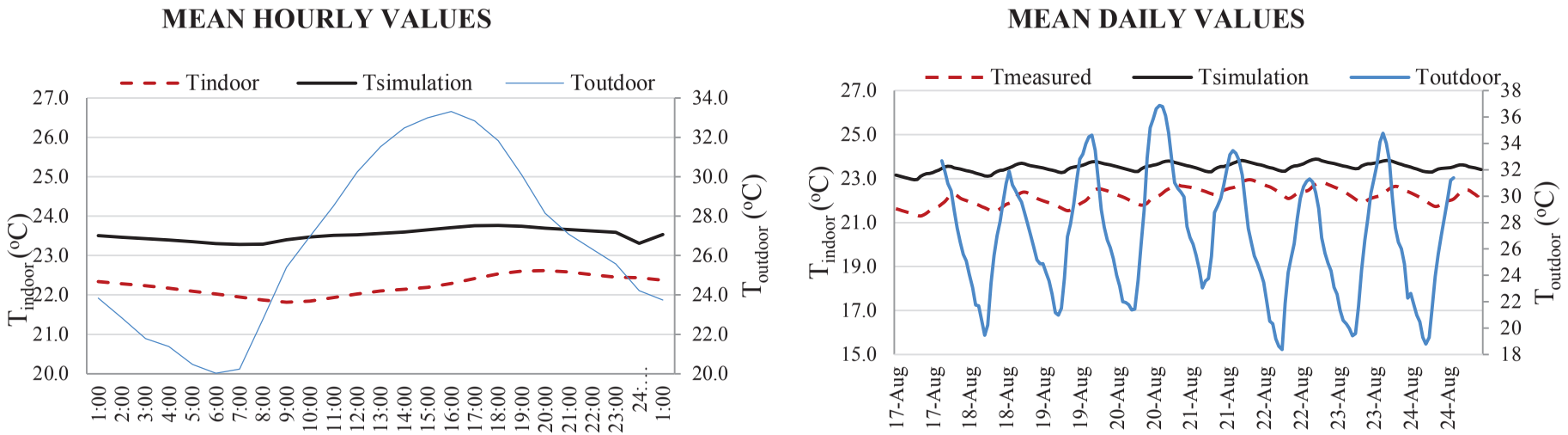


Figure 5.11. Mean hourly and daily temperature values of office room at ground floor (HG12) (17-24.08.2009)

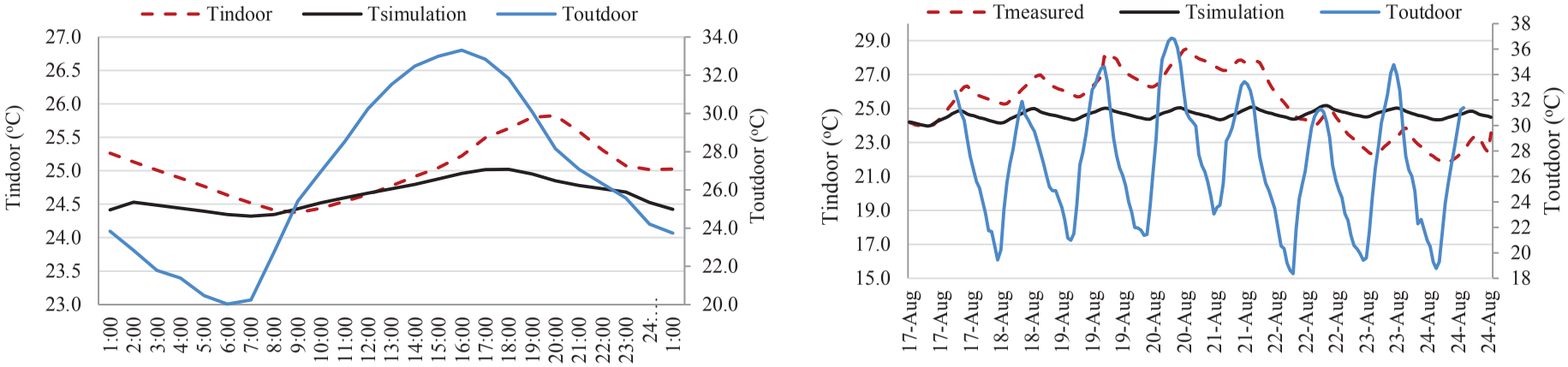


Figure 5.12. Mean hourly and daily temperature values of North West bedroom at first floor (HF1) (17-24.08.2009)

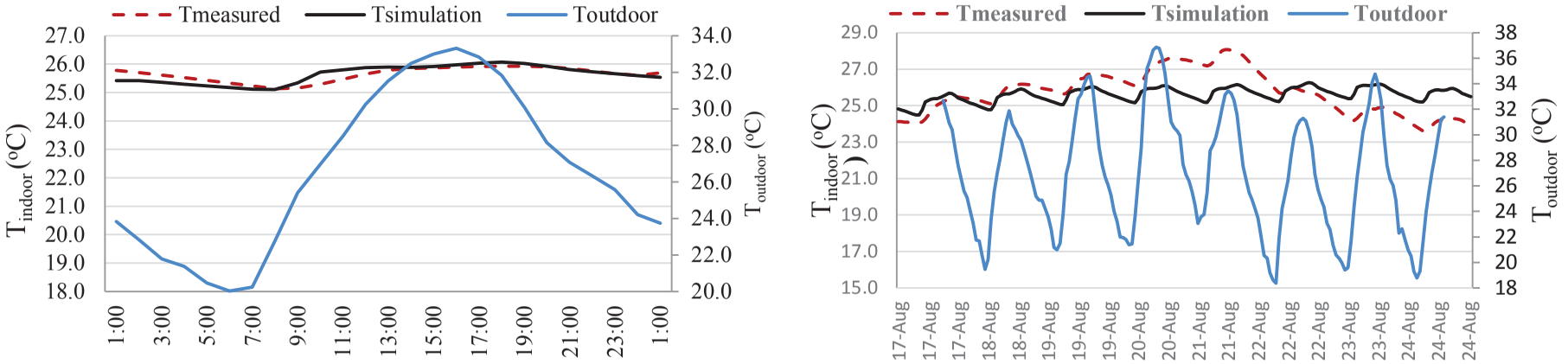


Figure 5.13. Mean hourly and daily temperature values of east bedroom at first floor: (HF2) (17-24.08.2009)

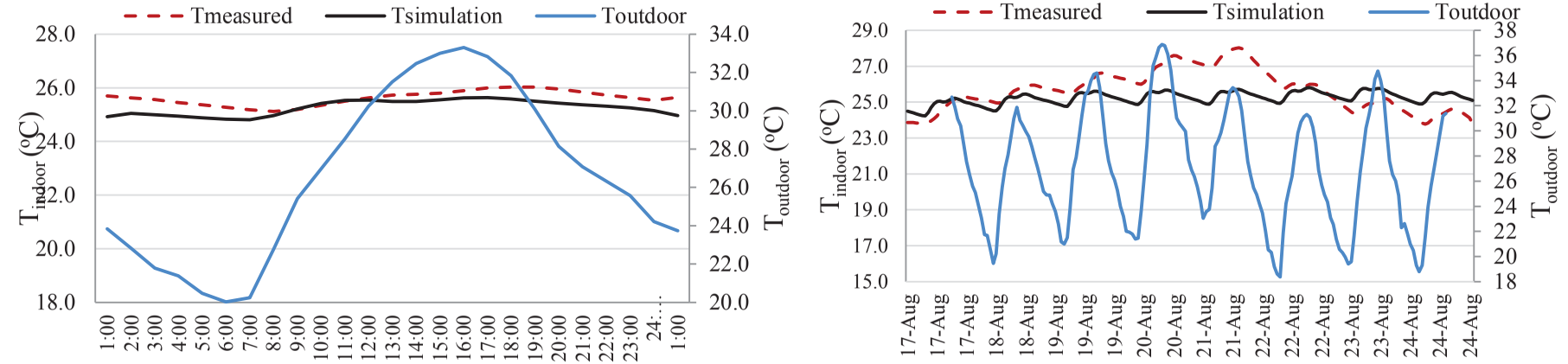


Figure 5.14. Mean hourly and daily temperature values of south bedroom at first floor (HF3) (17-24.08.2009)

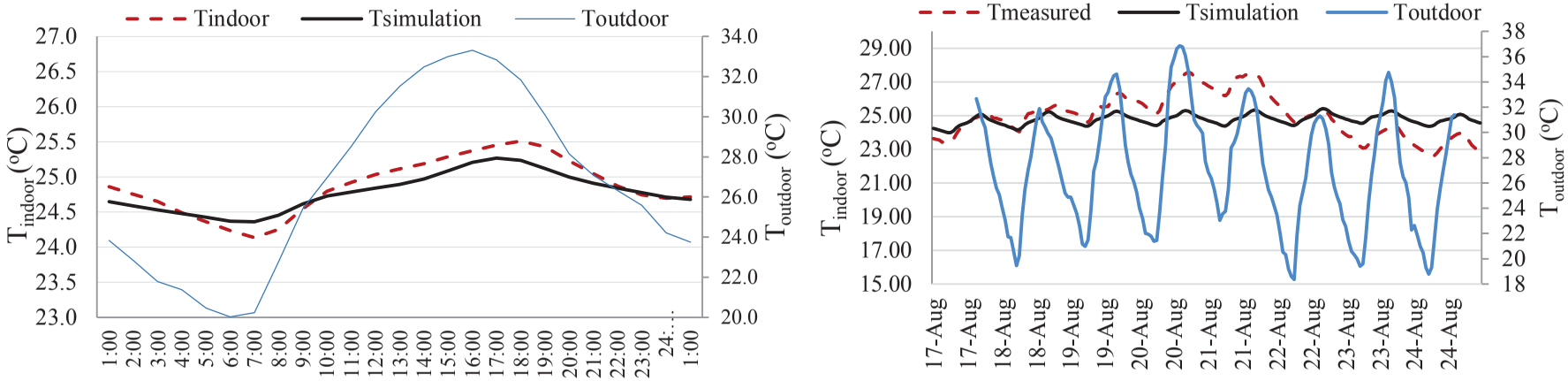


Figure 5.15. Mean hourly and daily temperature values of entrance gallery at first floor (HF5) (17-24.08.2009)

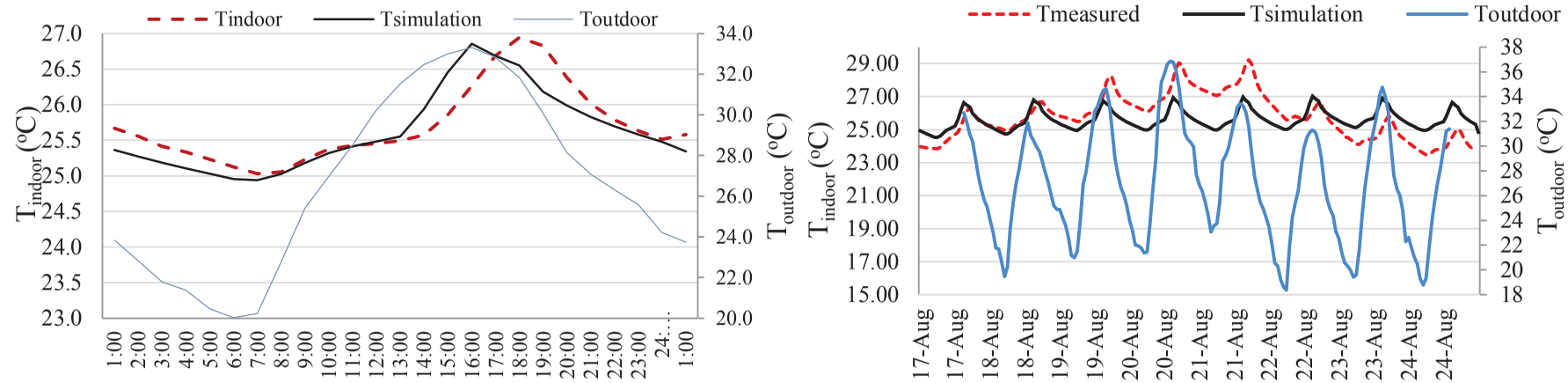


Figure 5.16. Mean hourly and daily temperature values of south west bedroom at first floor (HF6) (17-24.08.2009)

In addition, also the software limitations of the HVAC modelling system increase the margin of error. The only place is not calibrated well is Office room at ground floor. The main reason of the errors in this space is the door constantly left opened and had directly affected the large heat of the thermal conditions of the other zones to staircase hall - kitchen-dining room with lounge functions. It has been difficult to identify the HVAC thermostat settings of the model, finally a great number of combinations and experiments has been done with the thermostat temperature values given in Table 5.4and the results are illustrated in Table 5.5.

Table 5.3. Hourly error rates based on simulation and actual indoor temperature

Indoor Temp (°C)	BASEMENT		Ground Floor	First Floor				
	HB8	HB9	HG12	HF1	HF2	HF3	HF5	HF6
MBEhourly (%)	1.38	3.21	5.99	-0.81	-0.51	-1.71	-1.01	-0.81
CV(RMSE) hourly	-1.23	3.03	6.10	4.75	4.37	4.36	4.81	4.75

Table 5.4.Thermostat settings of heat pump system for zones

		Basement		Ground Floor	First Floor				
		HB8	HB9	HG12	HF1	HF2	HF3	HF5	HF6
User Density.(m^2/pers.)	BC	-	-	-	-	-	-	-	-
	AC	-	-	-	-	-	-	-	-
Thermostat Temperature (^{0}C)	BC	22	22	22	22	22	22	22	22
	AC	20	21	19	26	26	26	24	24
Setback Temperature (^{0}C)	BC	28	28	28	28	28	28	28	28
	AC	22	22	21	27	28	28	28	28
Infiltration ($ac.h^{-1}$)	BC	0.2	0.2	0.2	0.2	0.2	0.2	0.7	0.2
	AC	0.4	0.4	0.4	0.4	0.4	0.4	0.7	0.4

5.2.1.5 Comparison of Electric Consumption of Heat Pump According to Measured Data and Simulation Results

The electricity consumption of the heat pump has been taken into account in the calibrated building performance models as well. Among the factors that affect the energy consumption in the simulations, there are the data capacity of the heat pump, the setback thermostat temperatures, and the air tightness values in the places. Their effects on consumption are estimated by making many experiments here. The result of the cooling of calibration results period between the dates 17 - 24 August 2009 are presented here as intraday average hourly, and the daily trend).

is showing that the measured and simulation hourly error rates obtained by comparing the results.

According to recorded measurement data on site, cooling consumption of the heat pump is to be about 1.02 kW by hourly. In the calibration process, the observed differences can be seen with the measured indoor temperature from the actual temperature values of the model and determined that the space temperatures are not controlled adequately in the simulation model.

With regard to energy consumption of the heat pump, the error rate remains below an acceptable level. ASHRAE 14-2002 based MBA: -10.47% <10%; CV (RMSE): 22.53% <30%). Therefore, it is not considered that the model has sufficiently been calibrated. The biggest problem encountered in this process, as the specifications required by the heat pump system cannot adequately defined in Design Builder v.4.2.

Table 5.5. The error rates of the simulation and actual energy consumption (space cooling) by hour.

	MBE Hourly (%)	CV (RMSE)Hourly (%)
Energy(KW)	-10,47	22,53
ASHRAE 14-2012	±10	30

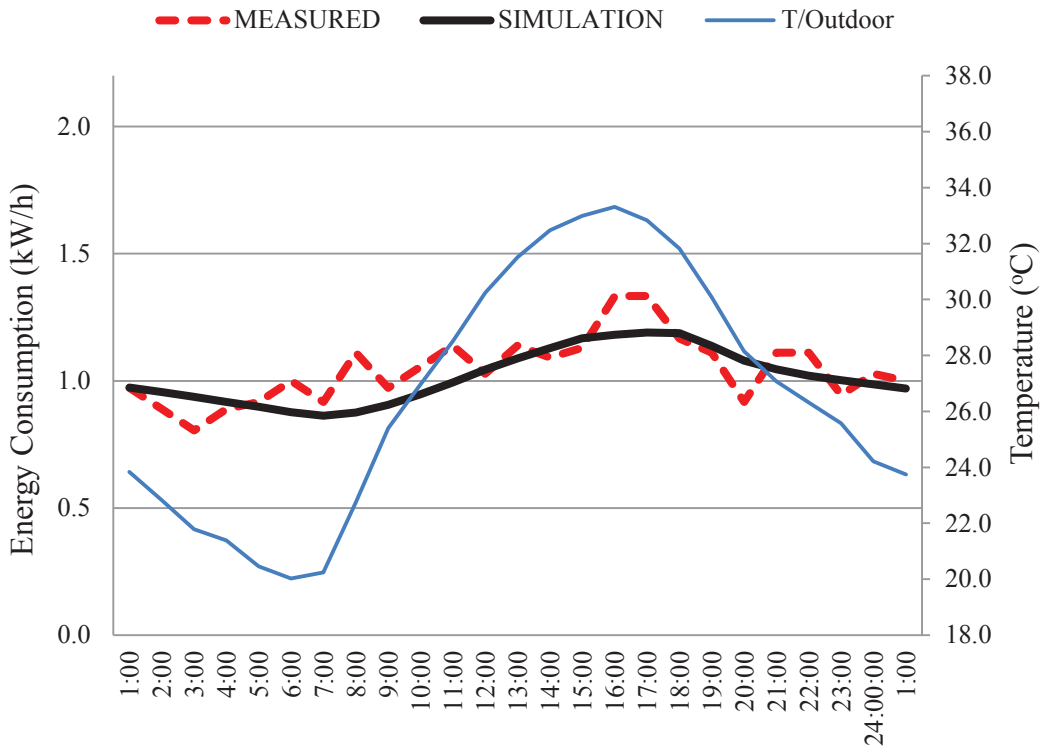


Figure 5.17. Simulation versus measured hourly electric consumption of Heat Pump (mean hourly values - 17-24 August. 2009)

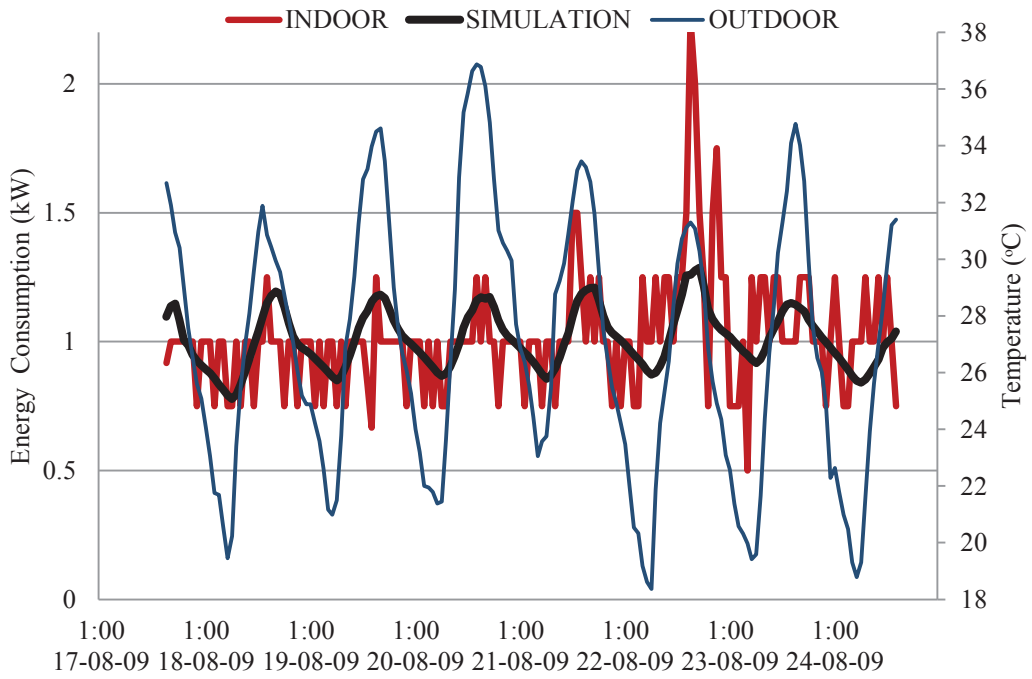


Figure 5.18. Simulation versus measured daily electric consumption of heat pump (mean daily values - 17-24 August 2009)

5.2.1.6 Evaluation of the Simulation Results of Cooling Season

In this study, a dynamic simulation model of a detached dwelling is located in Izmir was designed to analyse the energy performance of thermal cooling period and the minimum error rates. Results are presented here. Climatic data and building information into the digital model were collected from site measurements performed in 2009 in the cooling season, by using calibration method, it has been tried to have nearly simulation results to the measured data. The calibration process is presented in detail here. After calibration, the thermal performance values with the energy consumption of the air source heat pump for cooling period between 17 and 24 August 2009 were obtained in this simulation model. Based on these results the following points can be highlighted as follow here:

- Preparation of a structure of the digital performance model, calibration, and interpretation of simulation results require good knowledge and experienced users. Users should know how to deal with the factors that affect the performance of the building. This research specifically brings the importance of the experienced users who has knowledge about building physics, mechanical and conditioning. Building performance modelling is expanding continuously and that requires time and effort to work on professionally and it is expected the user's own development. In this research a special climate modelling system such as air source heat pump that forces the knowledge of the discipline of architecture, It can be seen that the architects and mechanical engineers need to work together to feed each other's knowledge.
- The library of the mechanical system of simulation software should be rich and adaptable to be able to have the less error rates in the calibration results. In this research the system of ceiling cooling (chilled ceiling) describes the structure is cooled by air-to-water heat pump as mechanical system in the Design builder. The percentage of the error rates can be reduced or increased by the ability of the system modelling and the restrictions of the software.
- On-site monitoring of the spaces and operating modes of them should be carefully recorded on the calibration period. During these periods 'turn off and the amount and duration of the openings of the building envelope, the use of shading elements periods, the use of the doors which block the air flow amount between the interior spaces should be noted carefully. These factors are as important as the identifying the correct modelling of the building and the environment physical properties for the

calibration process.

- In this thesis the ground soil temperatures were found that to be the most effective parameters to change of the space temperatures in the spaces at basement floor.
- Results of the calibration studies showing that the first-floor space temperatures vary from the lower floors due to heating gain problems from the sun directly.
- Infiltration rates of the building envelope should be indicated after measuring it; this will ensure that all the results of the calibration close to the truth.
- Results of the calibration studies showing that the first-floor space temperatures vary from the lower floors due to heating gain problems from the sun directly

5.2.2 Results of the Simulations Done for the Transition Period

5.2.2.1. Outdoor Weather Conditions Weather Information

The current data of whether files have been chosen while no any HVAC system used in the building. to simulate, the local weather files were taken from the station mounted on the roof of the adjacent building. For the calibrating model used only representative month of September. Outside measurements were started at 19.00 am of September 20 and were completed at 8.00 pm of September 30, during 10 days and recorded every 10 minutes.

Table 5.6. Comparison of T and RH values outdoor (daily values –from 1st June to 31th August 2009)

Month	Sep	Oct	Nov	Yearly
Min TEMP	11.90	8.10	1.97	1.97
Max TEMP	32.92	30.50	22.78	32.92
Ave TEMP	21.74	18.64	12.64	17.67
Min RH	22.67	29.67	40.00	22.67
Max RH	97.00	94.00	99.00	99.00
Ave RH	61.83	67.77	76.23	68.61

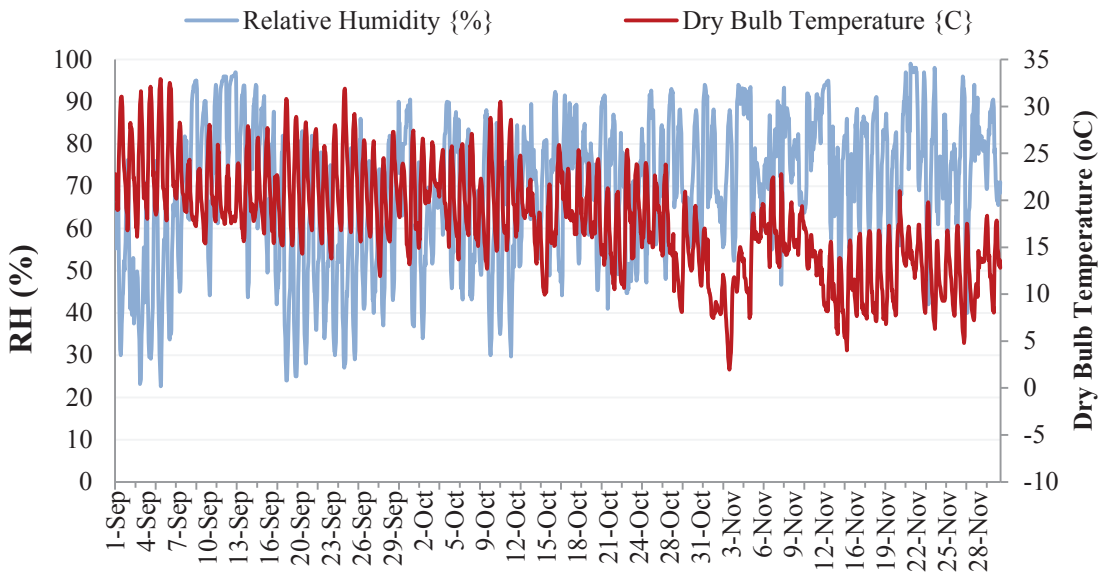


Figure 5.19. Comparison of T and RH values outdoor (daily values –from September 1st to November 30th. 2009)

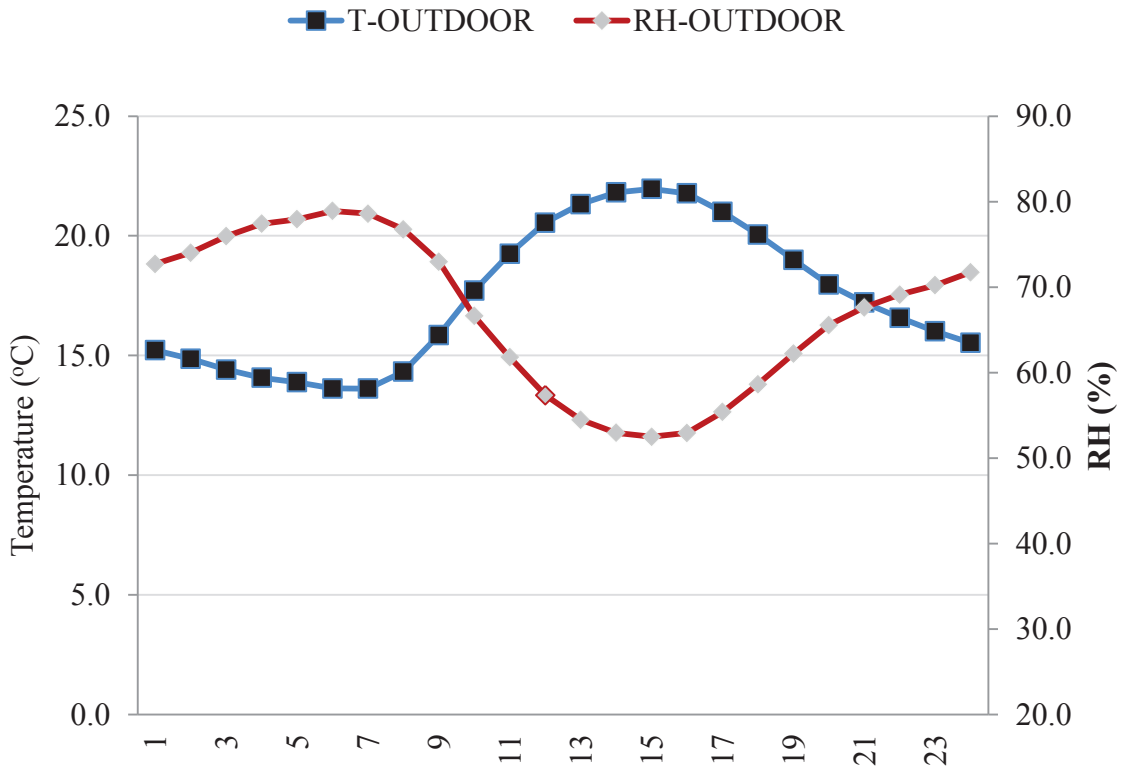


Figure 5.20. Comparison of T and RH values outdoor (mean hourly values – from Sep 1st, 2009 to November 30th, 2009)

5.2.2.2 Indoor Climatic Conditions

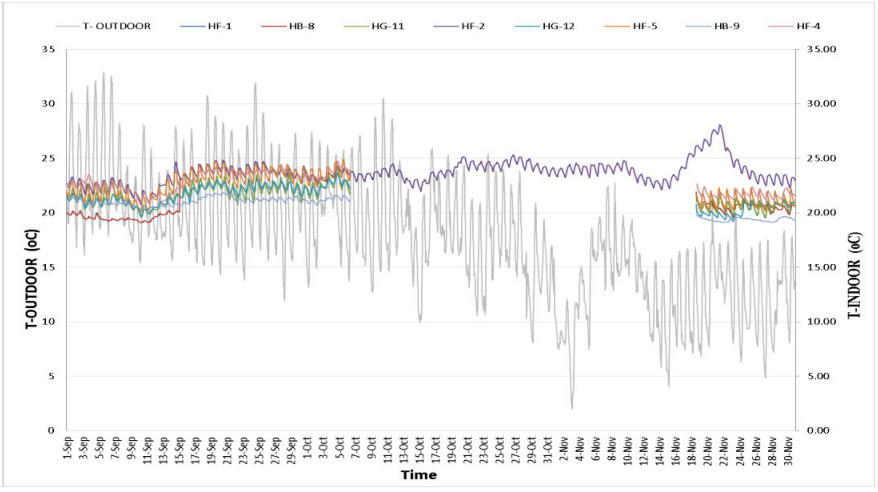
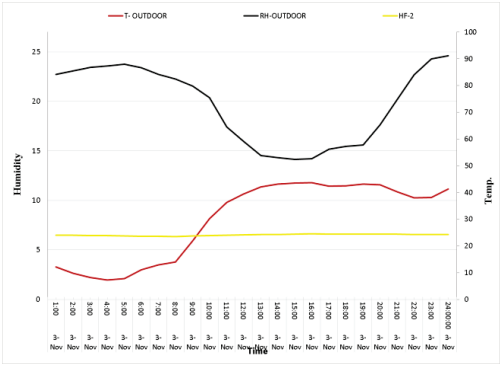


Figure 5.21. Measured daily indoor air temperature values for all monitored zones (from Sep 1st, 2009 to November 30th, 2009)

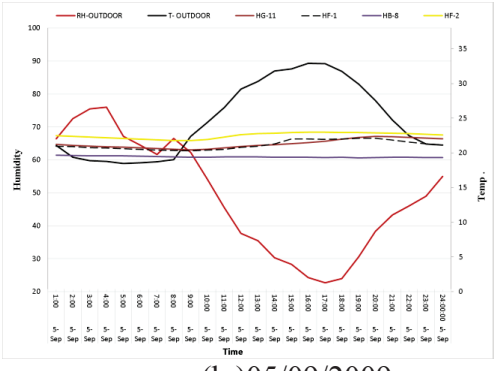
According to the indoor measurements we have done inside the building we have found that three floors represent different indoor conditions inside the house. Thermally the building was modelled in terms of three distinct zones. Before start to do our calibration work, we made some judgments based on onsite monitoring results here.

03/11/2009 COLDEST DAY



(a) 03/11/2009

05/09/2009 HOTTEST DAY



(b)05/09/2009

Figure 5.22. (a), (b) Measured indoor air temperatures in 4 locations in house in coldest and hottest days in summer season.

5.2.2.3 Comparison of Indoor and Outdoor Climatic Conditions

Figure 5.23 and Figure 5.24 show the comparison of outdoor temperature and actual indoor temperatures in 7 zones in the house (T_{mean} – (from Sep 1st, 2009 to November 30th, 2009) In the temperature comparison of the rooms on the upper floors, it is seen that the envelope of existing building is not affected too much by the sudden changes of the environmental conditions. In HF5, sudden changes were observed generally during the transition period, the comfort conditions are provided at indoor temperatures in all zones of the building.

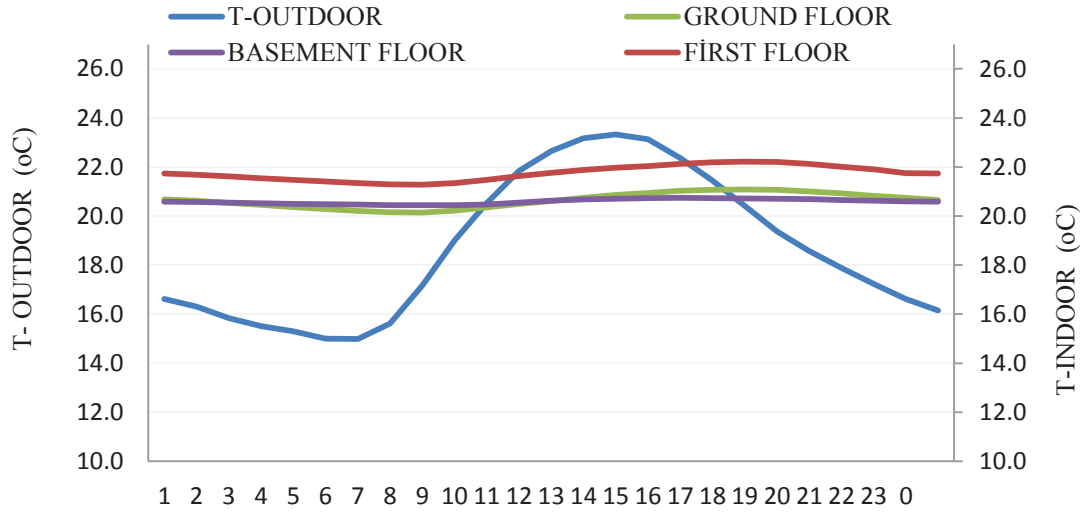


Figure 5.23. Average temperature values measured at 7 locations (mean hourly values from Sep 1st, 2009 to November 30th, 2009)

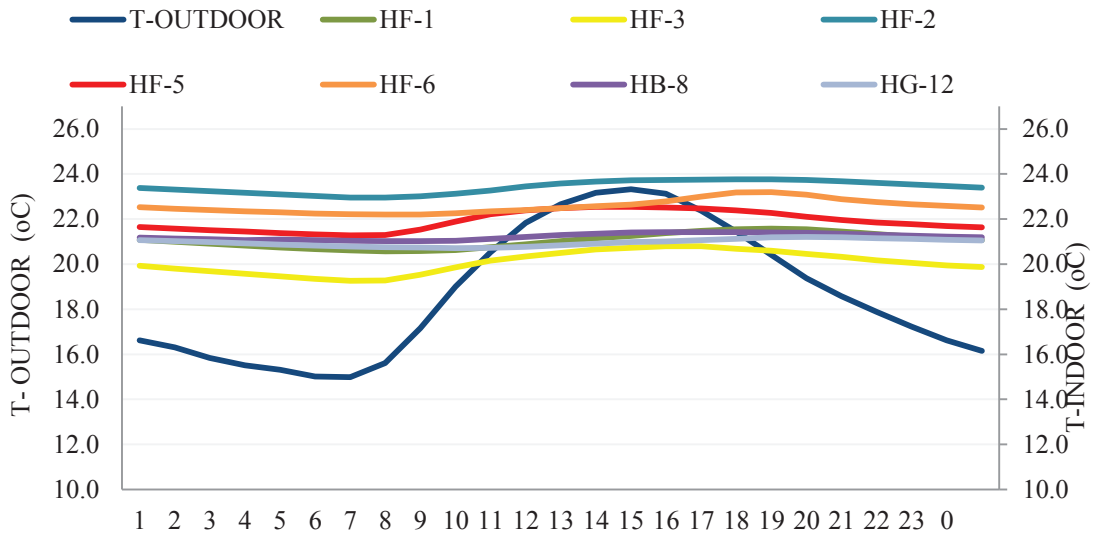


Figure 5.24Average Temperatures values measured at 3 floors (mean hourly values – from Sep 1st, 2009 to November 30th, 2009)

5.2.2.4 Comparison of Indoor Temperatures According to Measured Data and Simulation Results

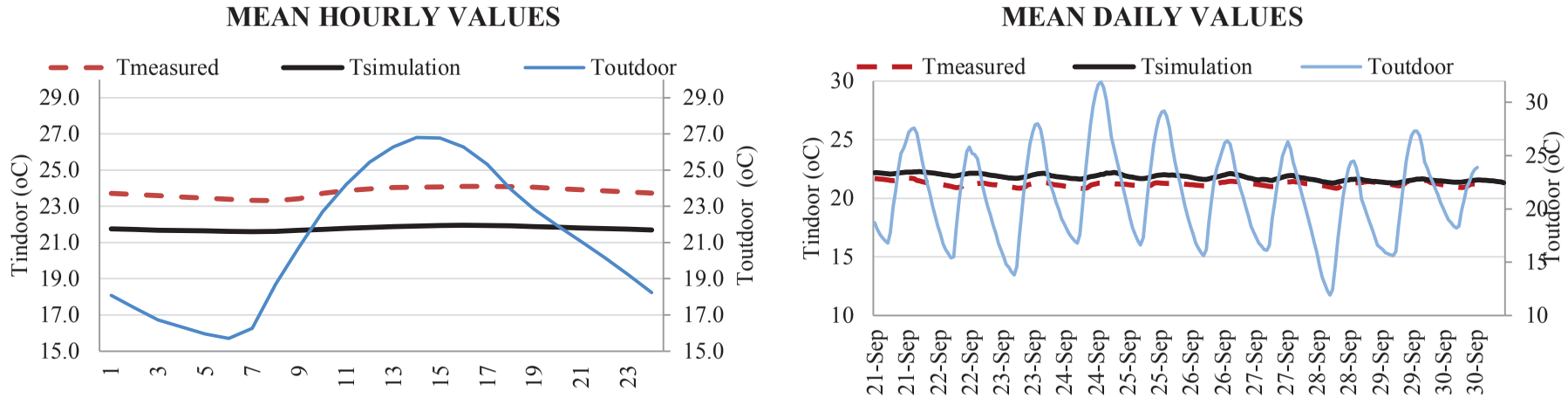


Figure 5.25 Mean hourly and daily temperature values of hobby room at basement floor (HB8) (21-30.09.2009)

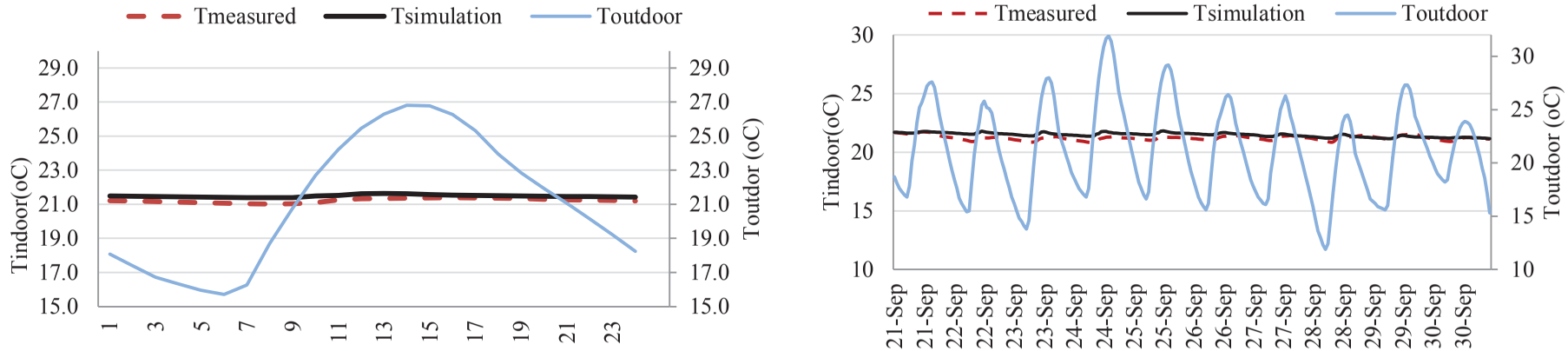


Figure 5.26. Mean hourly and daily temperature values of laundry at basement floor (HB9) (21-30.09.2009)

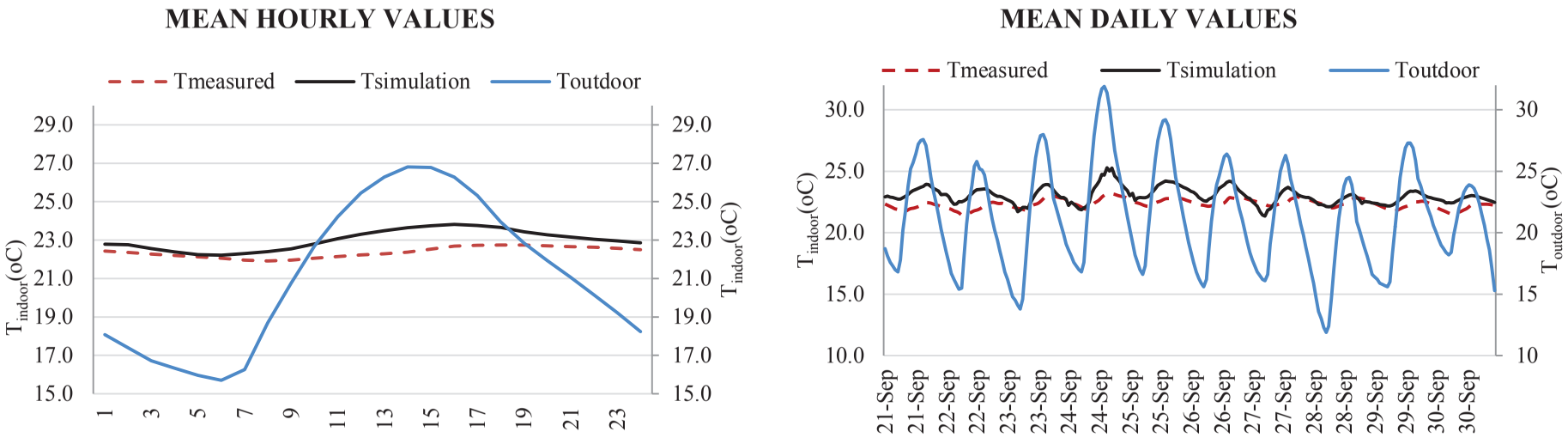


Figure 5.27. Mean hourly and daily temperature values of office room at ground floor (HG12) (20-30 Sep. 2009)

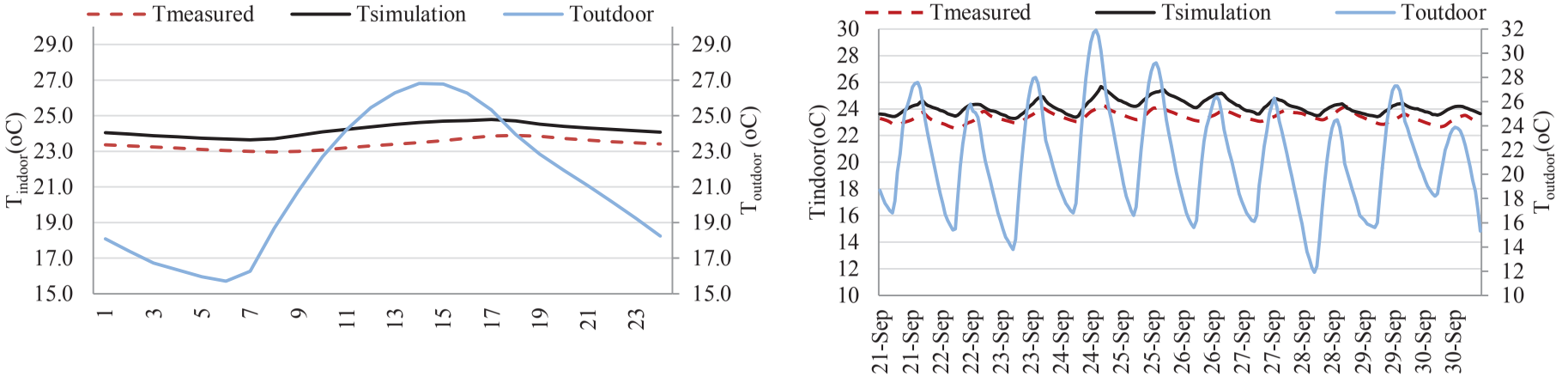


Figure 5.28. Mean hourly and daily temperature values of North West bedroom at first floor (HF1) (20-30 Sep. 2009)

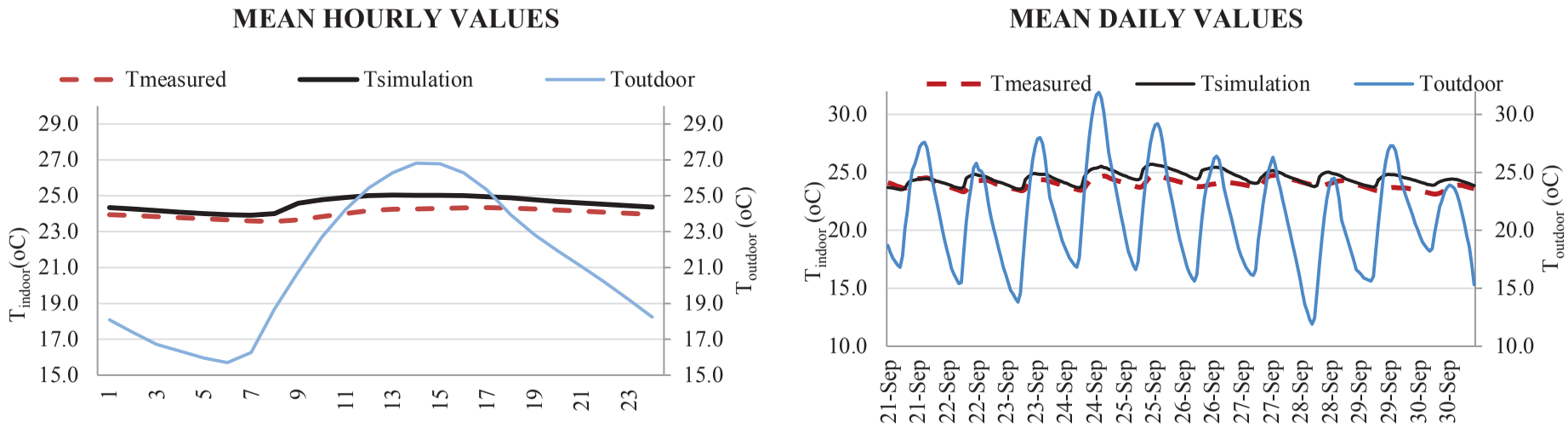


Figure 5.29. Mean hourly and daily temperature values of east bedroom at first floor (HF2) (20-30 Sep. 2009)

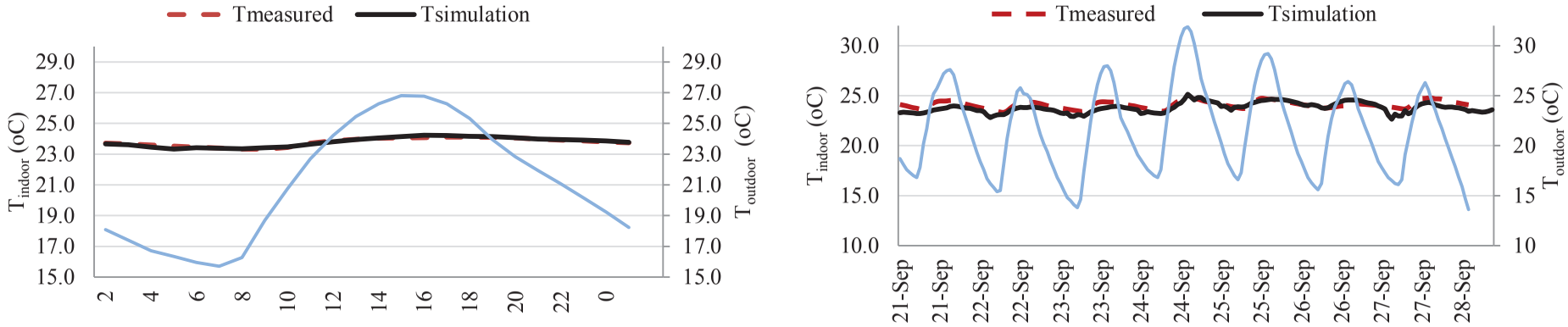


Figure 5.30. . Mean hourly and daily temperature values of south bedroom at first floor (HF3) (20-30 Sep. 2009)

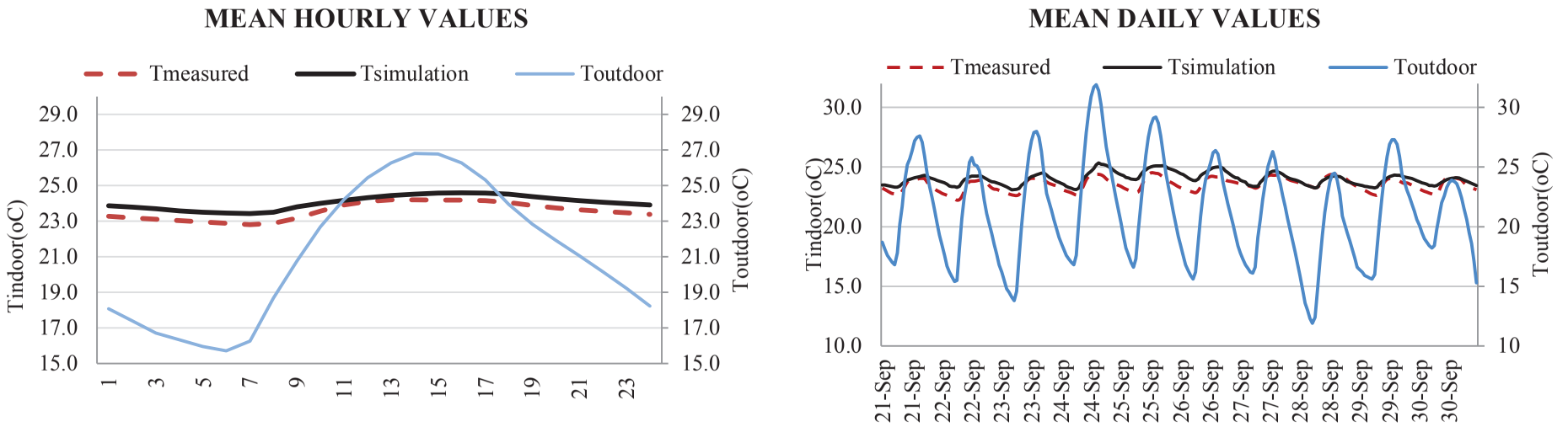


Figure 5.31. Mean hourly and daily temperature values of entrance gallery at first floor (HF5) (20-30 Sep. 2009)

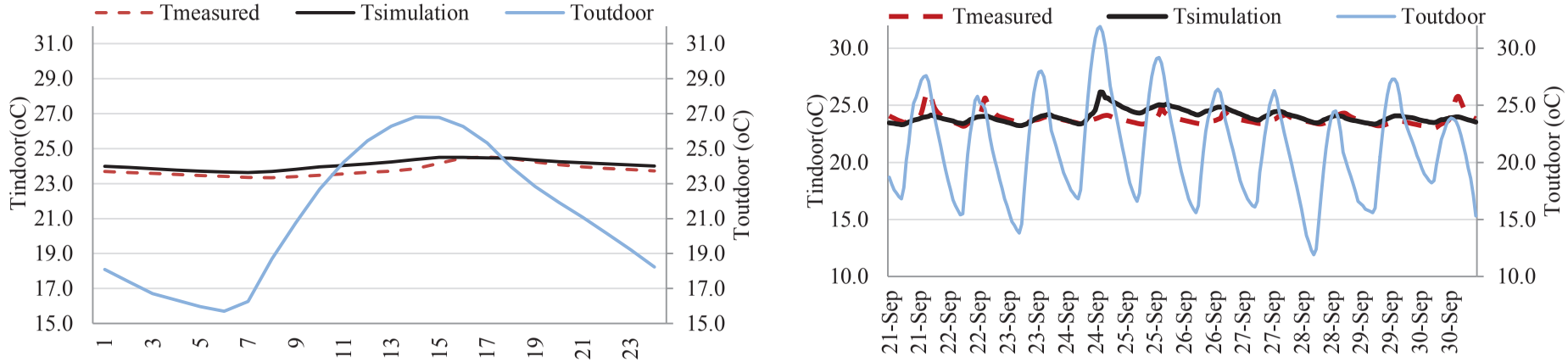


Figure 5.32. Mean hourly and daily temperature values of south west bedroom at first floor (HF6) (20-30 Sep. 2009)

5.2.2.5 Evaluation of the Simulation Results of Transition Season

The data of online monitoring has already completed. Data from the local weather station were used in the entire building simulation. These initial simulations are performed using a Design Builder, an EnergyPlus based dynamic simulation engine. When the calibration studies are continued to improve the model, the simulation results obtained from the rooms for each floor are as follows.

Basement floor;

The indoor temperature of the sauna is 2-4 degree higher then Laundry and servant room on the basement floor. The reason for it is an uninsulated wall between the sauna and garage which is unheated space. It is again due to the large metal garage door of this space and the garage is to direct exposure of the external factors.

Compared to other places in the basement, sauna has more openings. Laundry and maid rooms in the house have no temperature difference between day and night temperatures, approximately 21 to 22 degrees and the environment affected by external factors. One of the reasons of that the presence of buildings and there are many trees around the east and south direction of this building and providing effect of their shading. Another reason of that are the outer walls of places that are mostly being exposed to the ground soil. As a result, we decided to use the monitored data of Sauna for the simulations.

Simulation studies performed in the basement floor during the calibration of the laundry and servants in the rooms, the simulation did not affect the simulations. This shows that the building is still going through a more cooling-down regime. Usually the wall between the unheated garage and the heated sauna is well insulated, but the simulation temperature is close to the earth temperature 24 s, since the insulation in the building shell is interrupted in the outer wall area or the foundations that come into contact with the soil. Therefore, simulation and real measurements in the Sauna section show close proximity to each other.

Ground floor;

The results indicate that the coldest space on the ground floor is stairwell (hg13). the temperatures of cavity of the stairs and living Room in the hall are watching the same trends with differences between them only the average temperature is only 1.4°C .The reason for this, the presence of many trees overshadowing at western front of the building where the stairwell located and there is current of cool air coming from

the basement floor.

The temperatures in the living room and office room (with hobo numbers h11-h12) have reached to the max temperatures of daytime degrees, but measurements illustrate that the temperature of the living room is lower than the office room 0.4°C. This explains that there are increased heat losses because of the larger openings of the living room. Thus, decided to use the data of office room for the calibrated simulations.

The openings that are facing south and west don't have and window shutters or blinds.

First Floor;

Generally, these floor temperatures, due to the problems of the heat gain from direct sunlight and the airtightness vary greatly from the lower levels of this building.

Warmest room of first floor is bedroom 2 which is overlooking to the south east (hobo number: HF2).

The coldest place between the rooms is Master Bedroom (HF1). The room airtightness is of this room is very low. The reason for this: the windows openings are provided with not enough air tightness.

The gallery space is located in the HF5 does not show a balanced heat distribution. The reason for that is just being right on the entrance door to the main entrance hall and due to less access control of this door.

Air sealing is the best interest of the bedrooms facing south facades (HF3 and HF2) in this floor. Although the difference in temperature between the two rooms is very small, due to the high number openings of the facades of the room (HF2), heat losses of this room might be so high in this room so it can be colder than the other room (HF3). In the same room although there are a lot of openings of this space, the indoor temperature is always low because of the shading elements more permanently closed during all day.

5.2.3 Results of the Simulations Done for the Heating Period

The calibrated model during the transition period was used for modelling in heating season. For that reason the accuracy of the infiltration value had to be checked first. Then the system selection has been checked to be included in the model. The time required for heating should be integrated with the actual situation and an accurate Schedule should be prepared accurately. Then the entire catalogue data must be fully

entered in the model. Default should be considered on the inputs that are thought to be left, and if necessary, logical corrections had to be done once these corrections have been made; Simulations were made several times for the closest simulation results close to the measurement results. In order to balance the entire system, each zone has been individually edited for the HVAC system.

In simulations, the natural ventilation and window shading were turned-off, one at a time, to isolate building's energy consumption.

5.2.3.1 Outdoor Weather Conditions

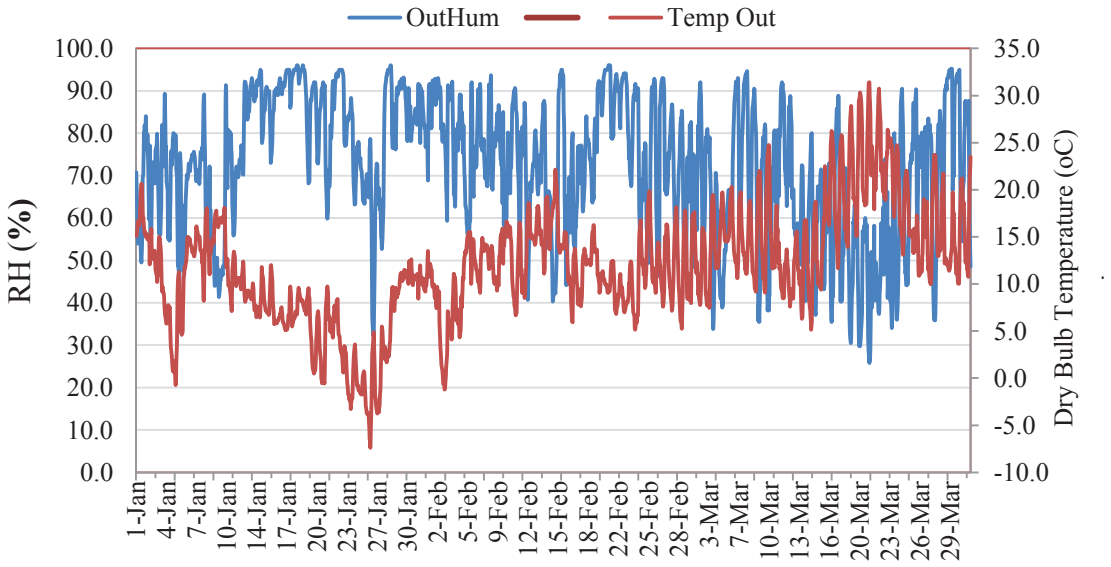


Figure 5.33. Comparison of T and RH values outdoor (daily values – from 1st Dec 2009 to 28th Feb. 2010)

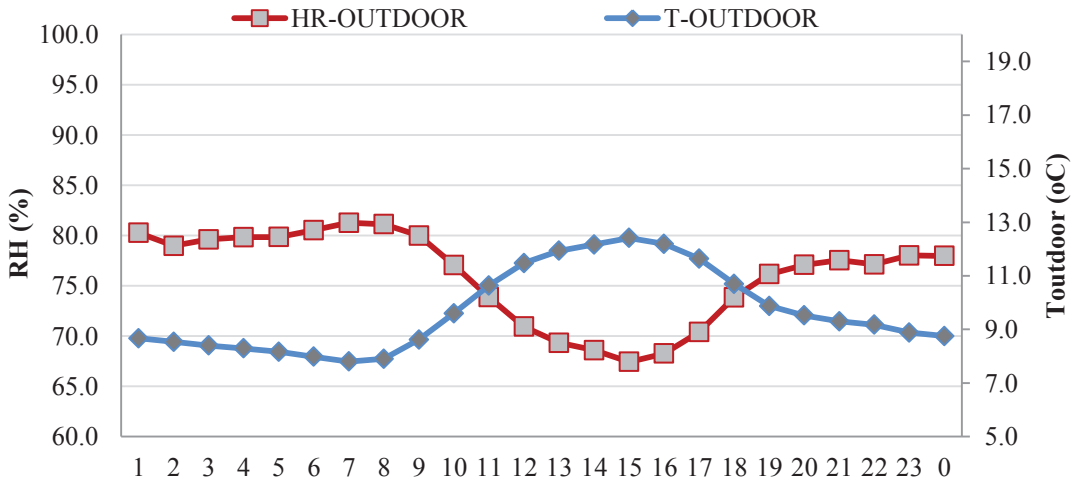


Figure 5.34. Comparison of T and RH values outdoor (mean hourly values — from 01.12.2009 to 28.02.2010)

5.2.3.2 Indoor Climatic Conditions

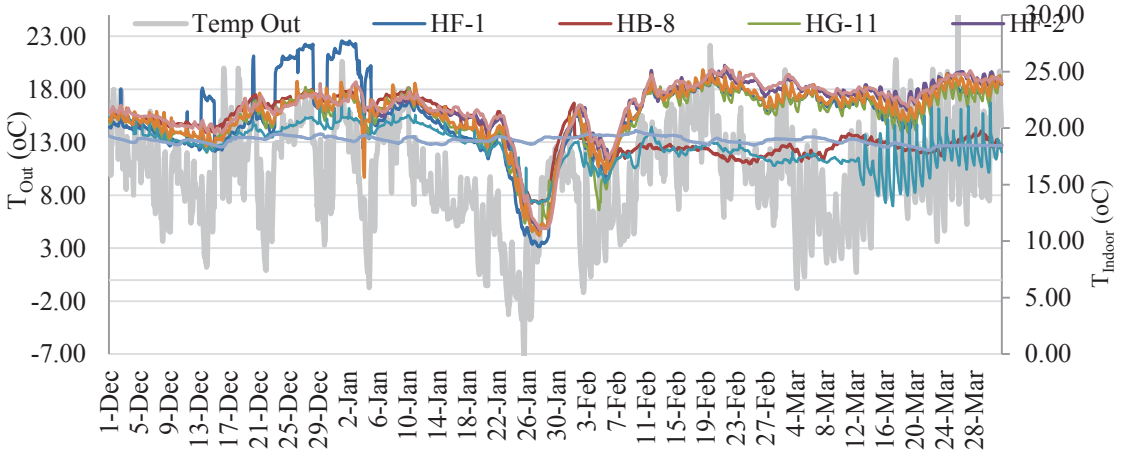


Figure 5.35. Measured indoor air temperatures in the house (daily values – from December 1st, 2009 to February 28th, 2010)

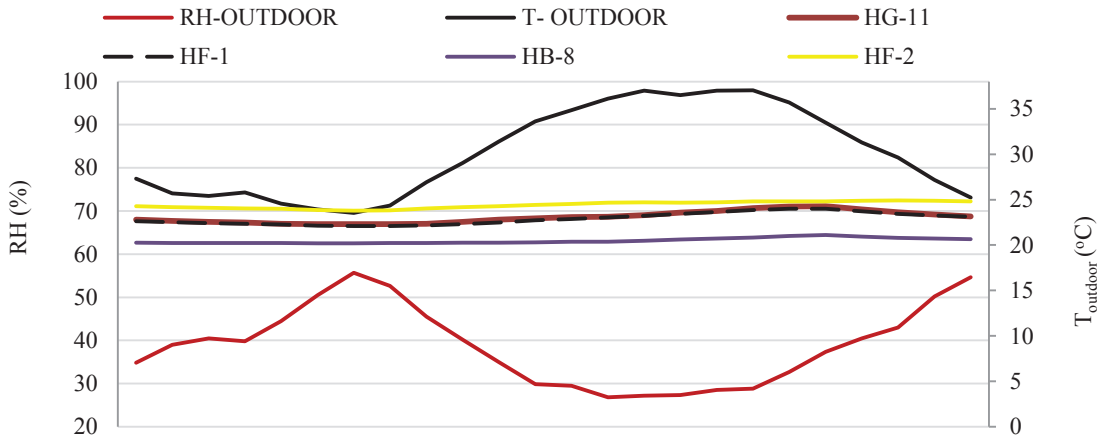


Figure 5.36. Measured indoor humidity and air temperatures in four locations in house in the hottest day in winter season

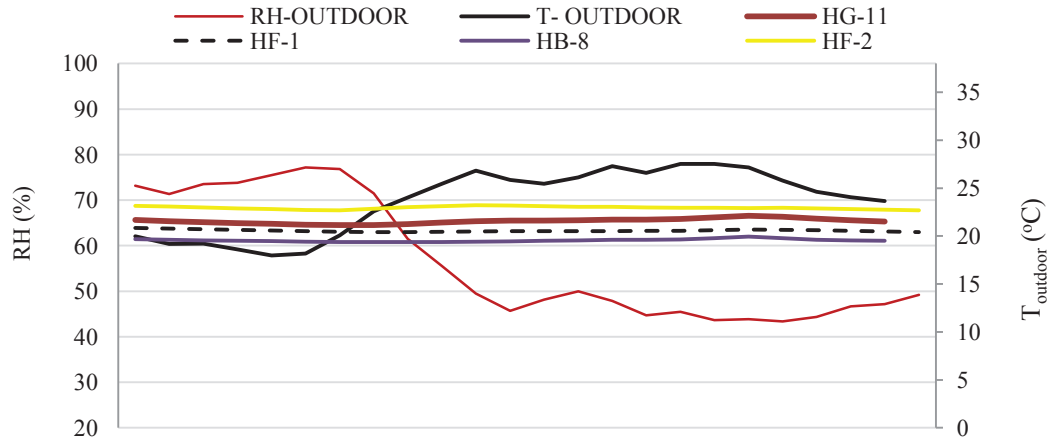


Figure 5.37. Measured indoor humidity and air temperatures in four locations in house in the coldest day in winter season:

5.2.3.2 Comparison of Indoor and Outdoor Climatic Conditions

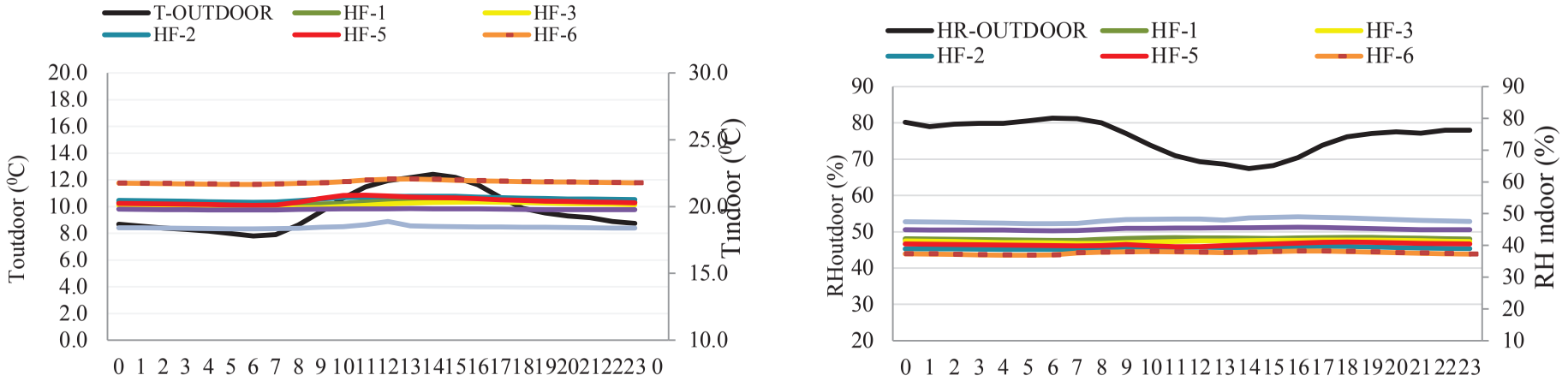


Figure 5.38. Average air Temperature and Humidity values measured at 7 lo(mean hourly values, from December 1st, 2009 to February 28th, 2010)

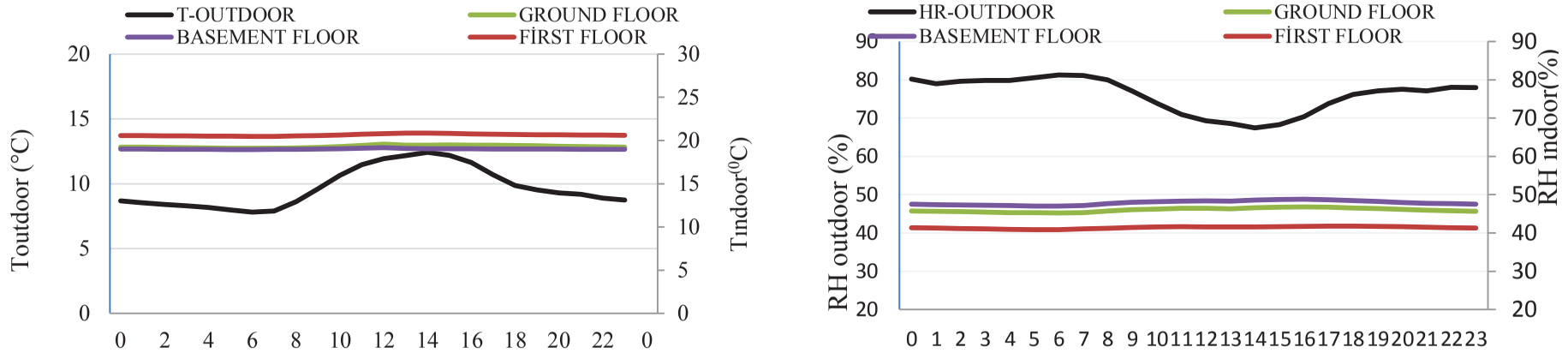


Figure 5.39. Average air Temperature and Humidity values measured at 3 floors in house (mean hourly values, from December 1st, 2009 to February 28th, 2010)

5.2.3.3 Comparison of Indoor Temperatures According to Measured Data and Simulation Result

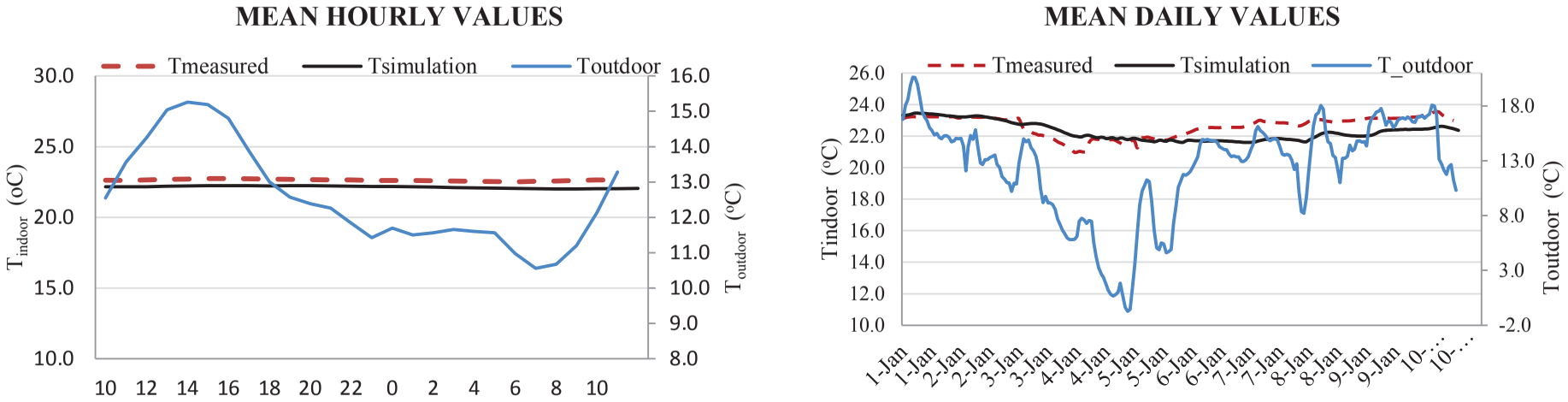


Figure 5.40. Mean hourly and daily temperature values of hobby room at basement floor (HB8) (01-10.01.2010)

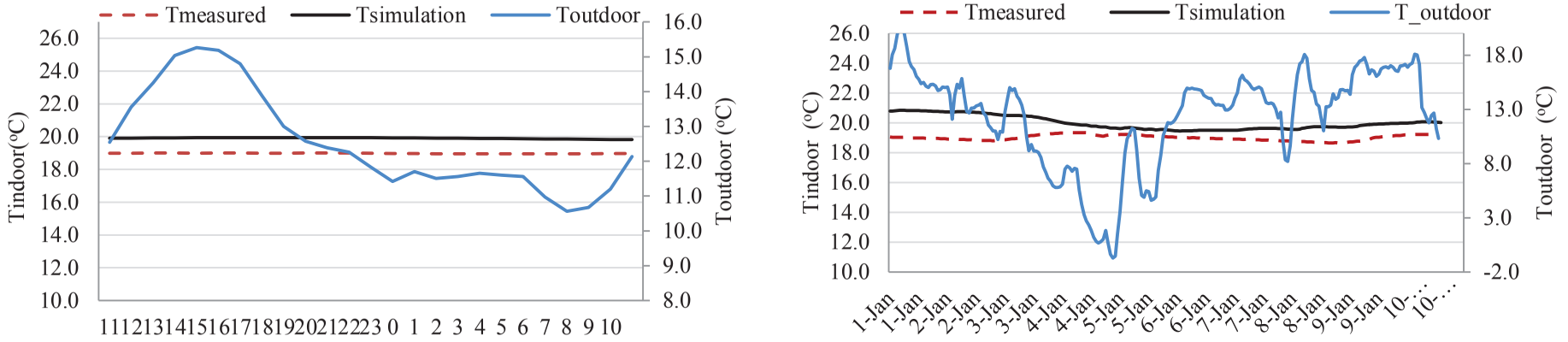


Figure 5.41. Mean hourly and daily temperature values of laundry at basement floor (HB9) (01-10.01.2010)

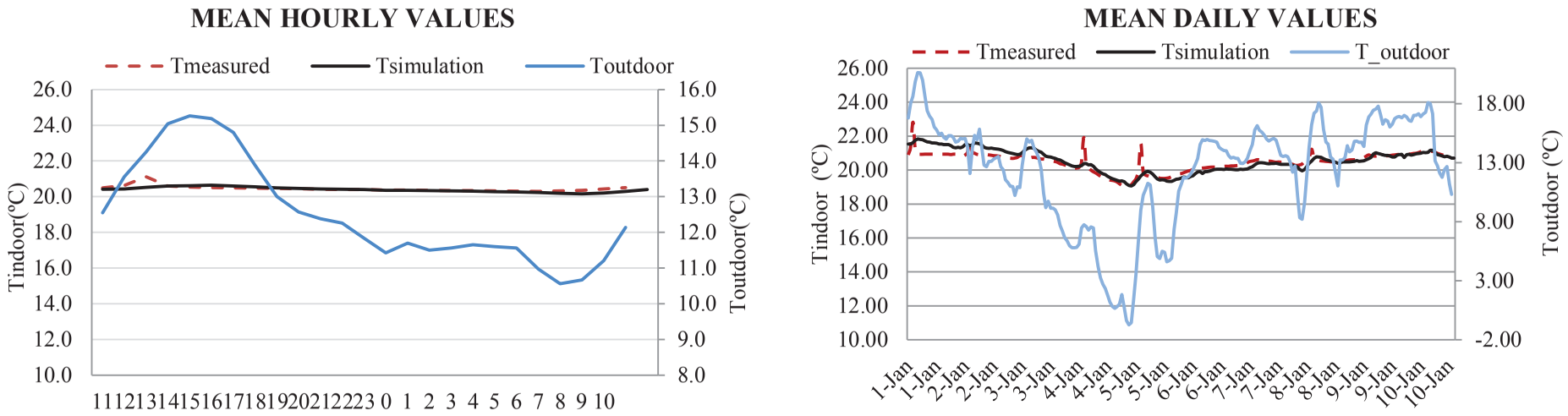


Figure 5.42. Mean hourly and daily temperature values of office room at ground floor (HG12) (01-10.01.2010)

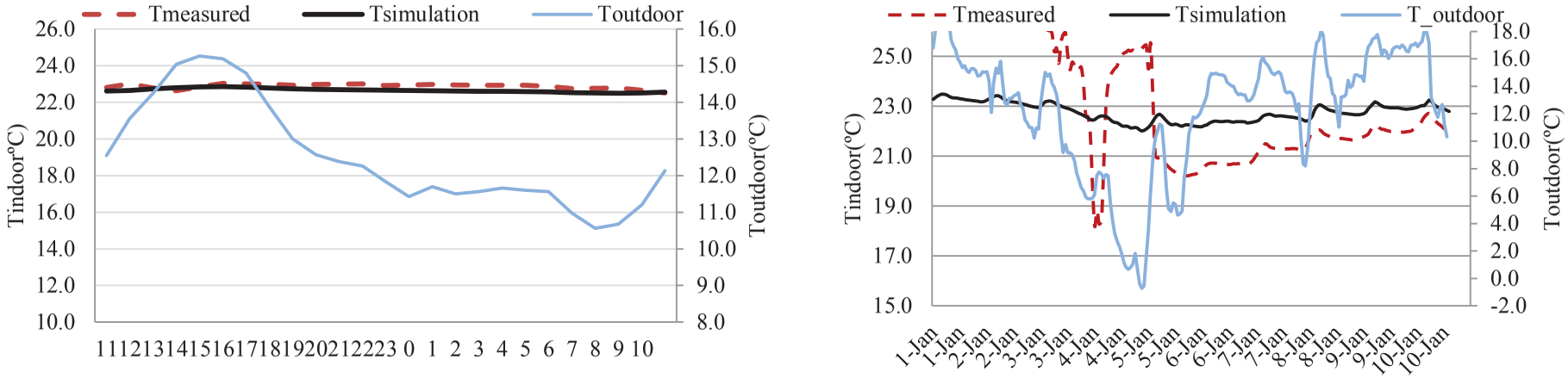


Figure 5.43. Mean hourly and daily temperature values of North West bedroom at first floor (HF1) (01-10.01.2010)

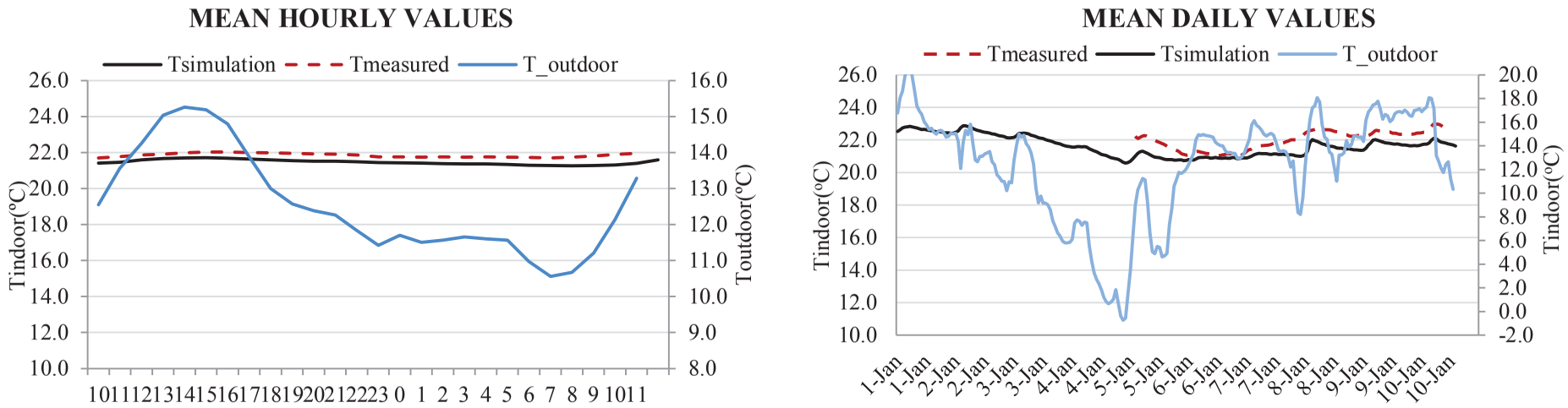


Figure 5.44. Mean hourly and daily temperature values of east bedroom at first floor (HF2) (01-10.01.2010)

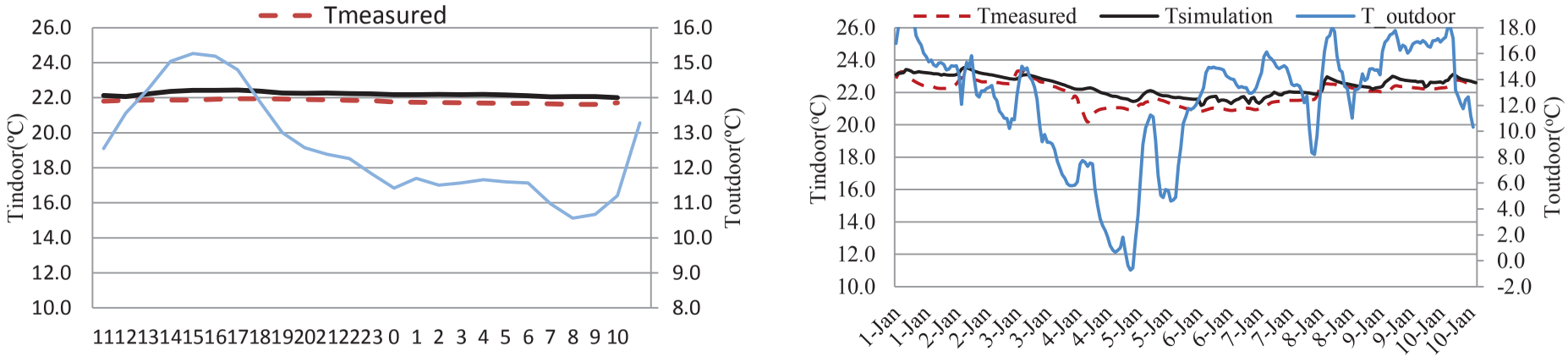


Figure 5.45. Mean hourly and daily temperature values of south bedroom at first floor (HF3) (01-10.01.2010)

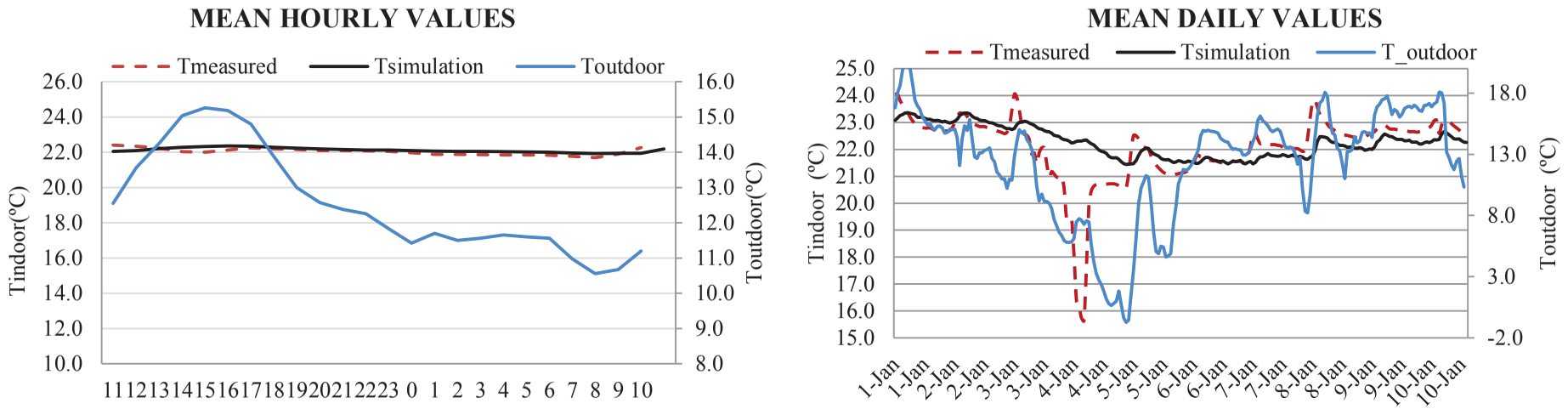


Figure 5.46. Mean hourly and daily temperature values of Entrance gallery at first floor (HF5) (01-10.01.2010)

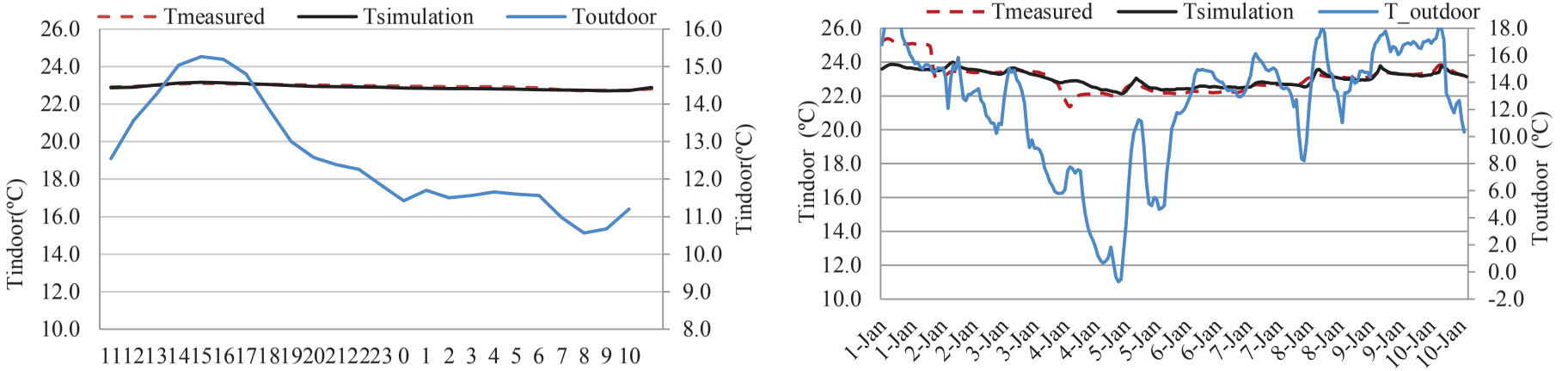


Figure 5.47. Mean hourly and daily temperature values of south west bedroom at first floor (HF6) (01-10.01.2010)

5.2.3.4 The Comparison of electric consumption of Heat Pump according to measured data and simulation results

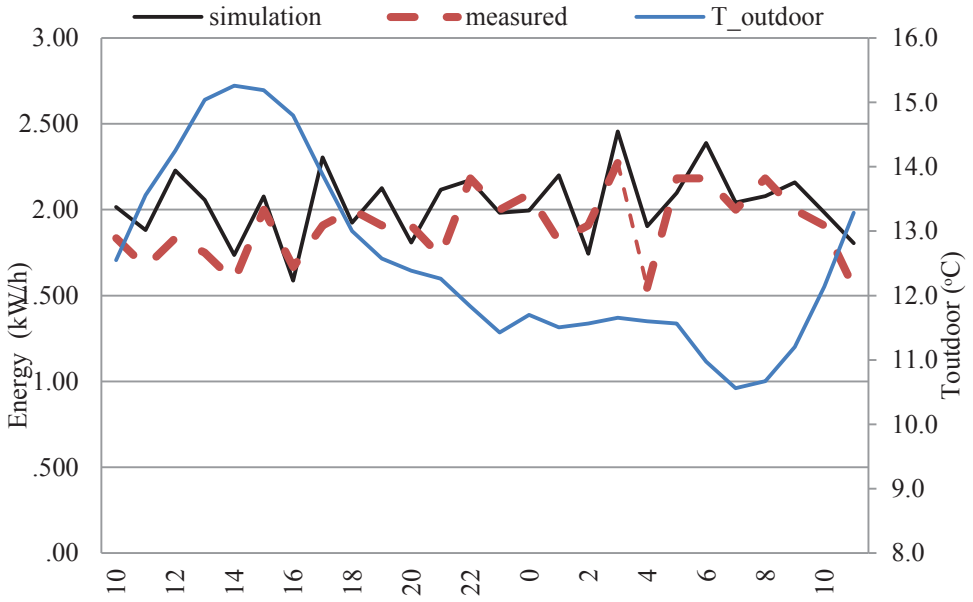


Figure 5.48. Simulation versus measured hourly electric consumption of Heat Pump (mean hourly values – 01-10 01.2010)

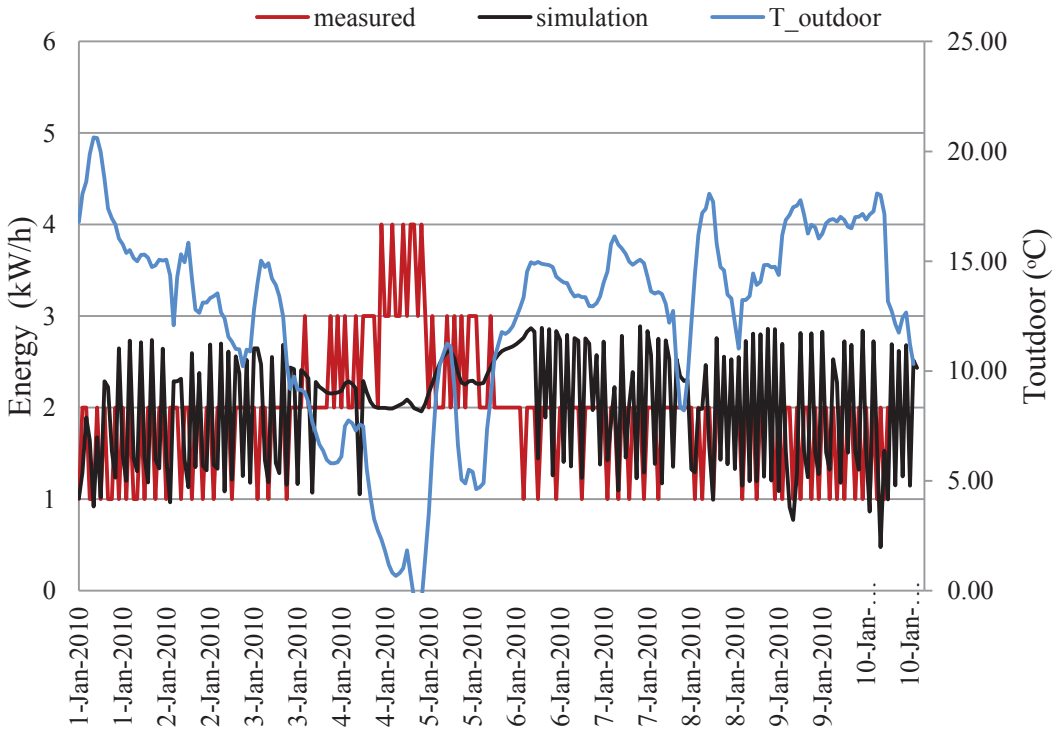


Figure 5.49. Simulation versus measured daily electric consumption of Heat Pump (mean daily values - 01-10.01 2010)

Table 5.7. The error rates of the simulation and actual energy consumption (space cooling) by hour.

	MBE Hourly (%)	*CV (RMSE) Hourly (%)*
Energy (KW)	3.50812	41.65
ASHRAE 14-2012	±10	30

5.2.3.5. Evaluation of the Simulation Results of Heating Season

1. The graphs for each zone showing the simulations and the real situation are parallel to the elevations and decreases, indicating that the building envelope is modelled correctly.
2. There are inconsistencies in default parameters. In the underfloor heating system, the difference between 2 °C and the water entering the zone is very low. The capacity of the accumulation tank is directly related to the building energy consumption, so the capacity of the storage tank must be entered correctly in simulations
3. The evaporator and condenser data are entered by default in the heat pump and it is important to enter the actual data of catalogue values of Heat pump.
4. Heat pump inlet and outlet water temperatures should be the same with real measurements.
5. As the building is naturally ventilated, the changes for heating loads are most related to the building infiltration part. The calibrated model in transition period has been used for the heating model here.
6. The simulations were run with and without both natural ventilation and local shading in the model. The addition of natural ventilation caused a 7.3 % increase in annual heating load.
7. The shading elements have a great impact on the heating loads; this is not surprising because of the large number of shade elements and glazed surfaces in the model. The annual heating load increases by % 30 with the addition of shades.
8. Due to limitations of Design Builder software, the simulation was done with another way to simulate air source heat pump for heating season; once the project exported out of Design Builder environment, tried using HVAC template: Zone: Water To Air Heat Pump using IDF editor. Run it once to make it expanded IDF file, i.e., *.EXPIDF and then change the coils from the available coils (air to water and water to air, total of 7 options) that are available in EnergyPlus. These templates were tested in

EnergyPlus 8.2 that were available. The good thing is that this template will support complete structure that have to do small changes to make it to simulation requirements.

9. Graphic curves in living room are very close to each other, airtightness and temperature settings can be controlled.

10. Office zone gets too warm; the temperature setting cannot be closer to the measured temperatures. This is due to soil temperatures.

CHAPTER 6

SURVEY RESULTS

This chapter introduces the online survey results of totally 22 respondents participated between June 26th, 2019 and July 17th, 2019. All respondents are the ones experienced with the BPS tools. The responses are presented in three sub-headings:

I. Users' backgrounds and experiences with BPS tools;

II. Tools' integration into the design process and satisfaction with graphic outputs;

III. Usability, possibilities and limitations of simulation programs.

The detailed responses of each participant are given in Appendix C.

PART I: Users' Background and Experiences with BPS Tools

1. Expertise of Users

The first question addresses the participants' personal information such as nationality, profession and expertise on use of energy simulation tools. Among 15respondents, eight USA, one Egypt, two (one of them in Turkish survey) Turkey, one Portugal and one TRNC (Turkish Republic of Northern Cyprus) and one Morocco are joined while seven did not specify their nationality (Figure 6.1). It is apparently stated that the majority are the building energy analysts as LEED AP and mechanical engineer who work on certification / grading analyzes in energy consulting companies. Only seven of the respondents are architects: two of them are LEED AP architects, three of academician and two of research architects (Figure 6.2).

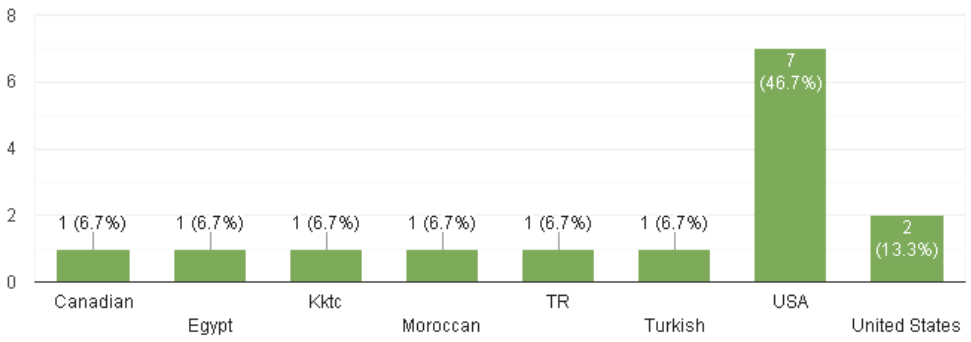


Figure 6.1. Nationalities of twenty three responders

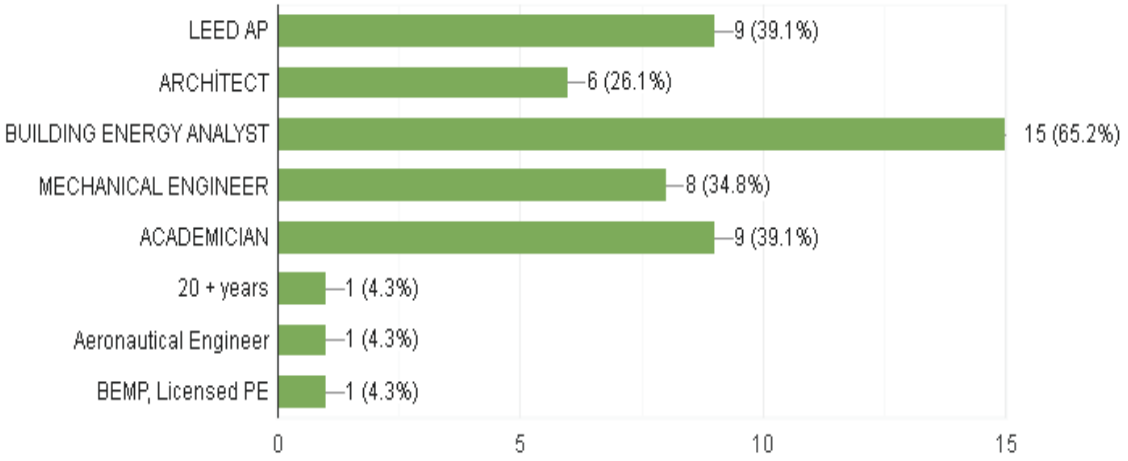


Figure 6.2. Areas of expertise of participants

2. General Simulation Studies of Users

The second question with multiple-choice responses investigates the type of simulation studies conducted by tool users. 81% of the participants use the tools in parametric analyzes where design alternatives are tested, while 71% of them used for simulating HVAC, lighting, hot water and solar energy systems in certification and rating (LEED V4) studies. Most of the users select all choices included into the question. They also express diverging responses to open-ended question such as energy auditing, development of new algorithms for FDD and MPC, load analysis and equipment sizing, feasibility, net-zero energy design, rate-payer study, large-scale analysis, simulation-supported policy development, examining the effects of new technologies and whole building energy simulation.

3. Competence Areas of Energy Analyst in Simulation

The question about the field specialized in simulation are answered by 19 respondents. A respondent expresses that energy analysts should have broad knowledge and be competent with all aspects of building energy issues. Furthermore, four of them state that specialization in simulation studies is unnecessary, because the expertise more than one field is more significant. One of the LEED AP-architect respondents conveys that using simulation tools is advantageous for understanding design. Although it is not a prerequisite, he states that competence in multiple fields increases the perception of ability and understanding in design process.

The other 15 people state that energy analysts need to specialize in one field. Energy analysts should have a strong knowledge of relevant areas, have full knowledge of building thermal behavior, understand energy requirements, and know HVAC

solutions. However, the response of one of the academician architect respondents is that the 'energy in buildings' field should be a mixture of both general and experts. Although he tends to supervise team members doing energy analysis, his specialty has been about daylight saving.

4. **Working with Group or Alone**

The comprehension of team spirit in simulation tasks are examined in this question. Most of the respondents working in the companies believe in the significance of working as a team. The answer of a participant from energy consultant company expresses that the team work may vary from project to project; they may work both alone, or as part of a larger team. In addition, he added that in LEED projects, architects are the team leaders to interpret energy simulation results, but they don't do much simulation, according to their experience.

5. **Specified Building Types for Simulation**

20 participants answered the question of which type of project they work. It is seen that there is no restriction on building types, ranging from small-scale housing projects to the large-scale projects such as hospitals, K-12 schools, municipal building projects, multi-store buildings, industrial buildings, shopping centers etc.

The response differencing from others points out the projects with complex HVAC systems (usually with integrated natural ventilation system) to the extent of competence of the tools they specialize in. There is no specialized building type; the complexity of current system leads to the tools they use. He said that they do business in central facility and regional systems. In short, the building simulation tool they use determines which type of building works.

6. **Consulting for the Architectural Offices**

The question on consulting for the architectural offices reveal an interesting result that the simulation tool users such as architects do not provide consultancy services to the architectural offices, whereas the respondents such as LEED-AP engineers provide consultancy. One of the architect participants depicts that architects are often interested in greenwashing with their designs, thus they choose to tend to be less collaborative with architectural offices.

7. **Role of Architects in Simulation**

For the question ‘whether architects have an important role in energy simulation, or not’, among 20 participants presenting their comments, 18 of which state yes. Almost all 18 respondents believe that architects have essential roles in simulations. The reason

for the negative answer given by the participant, who was an academician architect, is the thought that the architects are not capable of doing simulations.

One of the important comments to this question came from another architect. He said that this depends on the tool-boxes (e.g. graduate degree in architectural or building science) of the architect, and gave an example of Dru Crawley (an architect with a PhD in engineering). And he said that not any of architects can be like him. The "modeling" of any physical phenomenon can only be meaningful if the physical phenomena are correctly understood. Architects stated that might be in a trouble.

8. The role of architects in simulation

When asked that architects have an important role in energy simulation or not? 20 participants have answered YES and No with their comments. The response of 18 people was YES. Almost all participants of these 18 people believe that architects have important roles in simulations. The reason for the No answer given by the participant, who was an academician architect, was that the architects are not capable of doing simulations.

One of the important comments to this question came from another architect. He said that this depends on the tool-boxes (e.g. graduate degree in architectural or building science) of the architect, and gave an example of Dru Crawley (an architect with a PhD in engineering). And he said that not any of architects can be like him. The "modeling" of any physical phenomenon can only be meaningful if the physical phenomena are correctly understood. Architects stated that might be a trouble.

9. The knowledge of Architects as energy analysts

The question in this section was an open-ended question to allow the participant the opportunity to share or explain his/ her ideas.

Most of the participants are agreed on the required to have good knowledge of understanding of various building systems - thermal envelope, electrical (lighting and power), HVAC systems and how they operate - and their related performance criteria.

- Thermal transfer through building envelope, understanding thermal loads and knowledge about thermal systems and their performance.
- Building orientation, shading, building materials, etc.
- Limitations of schematic tools for complex building types.
- Ability to perform massing and site analysis.

One of the users declared that is not required to have ultimate knowledge of the

building’s energy systems, just its architectural contribution. They believe that it must be in engineer side.

One response is related to the Understanding of inputs/outputs data, it has to be at a high level, as well as understanding when models are intended to be predictive instead of comparative. Since both are so different issues.

According to one of the energy consulting company's comments, there is much software that makes extensive claims about their software capabilities. Architects should be able to choose the right one from a wide range of simulation tools on the market with knowing that the tools capabilities.

From an educational point of view of one Academician-architect-energy analyst, he stressed that education is important. He emphasized the necessity to provide simulation education in architecture schools (daylighting modelling at MIT, algorithmic processes, parametric analysis). Thus, he added that architects will have a stronger foundation. If the education not provided in their schools, the architecture students concerned apply for a Master's degree (for example, energy / building master) in engineering departments of other schools. And adding his notes in his response ‘’Long story short, untrained architects playing with energy simulation is like playing with matches in a hay barn.’’

Architects should be aware of the general understanding of the impact of early architectural design decisions on energy use.

10. Tool sufficiency for simulating mechanical systems by architects

Almost all participants stated that tools are sufficient only Architects should know how to use them properly. There will be a solution to this problem in teamwork. Some users told that architects don't have the knowledge to deal with mechanical systems without consulting engineers, especially for complex systems / buildings that require complex controls. There needs to be cooperation with engineers. Or otherwise architects must be trained in this.

PART II: Tools’ integration into the design process and satisfaction with graphical outputs

11. According to the design phases using the simulation tools

When asked which design phases are used simulation tools, users were given multiple options: Preliminary design stage, Design Development, Renovation Projects, Design Optimization. 21 people participated in this question. 19 u stated that they use simulation tools in all phases of the projects. Two people used in Retrofitting and

Design Optimization (Figure 6.3).

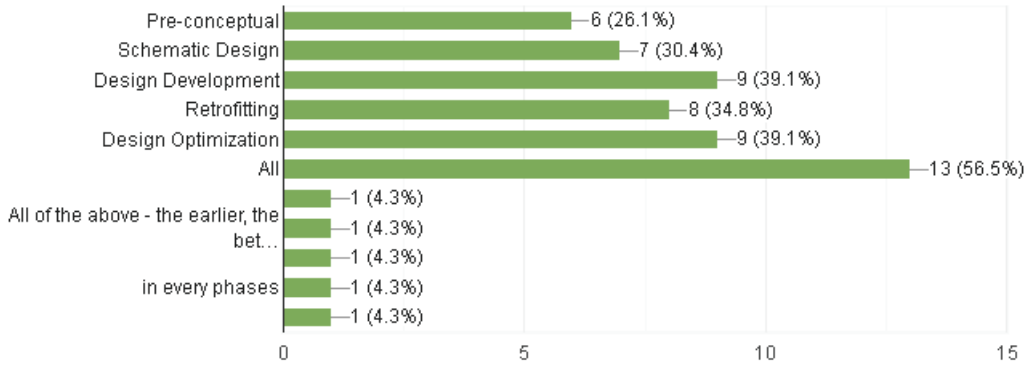


Figure 6.3. Design faces using simulation tools

12. Planning the simulation process

When the participants were asked how the simulation process worked for them, it was seen that almost each of the participants followed a different simulation process. This is normal considering that users come from different branches and different occupational fields. It can be seen that the process may also vary according to the projects and the targets determined

For example, according to the response of the Design Builder user, if the simulation is for building design, first obtain all the information about the building (architectural drawings, mechanical drawings, building bills, etc.), then modeling the geometry for zoning, internal loads (people, lights) , sockets, etc.). And data must be entered to determine the assignment of HVAC systems. In case of validation of new building technologies, it is sufficient to use a prototype model (commercial reference building, for example).

13. Chosen Simulation Tools

The users were asked which simulation tools they used and that multiple tools had to be used in a project. DB and EnergyPlus are among the most preferred vehicles. TRNSYS contains many mechanical systems that can be used in buildings. It is also easy to use as it makes it easy to add new systems to the types programmed in FORTRAN. In fact, the purpose of the survey is not to determine which tool is more successful. The important thing is which tool is preferred by which users. Each vehicle has different features in itself. However, although the users did not explain the reasons for their use, it is seen that DB and IESVE tools are widely used by architects and the answers are examined one by one (Figure 6.4).

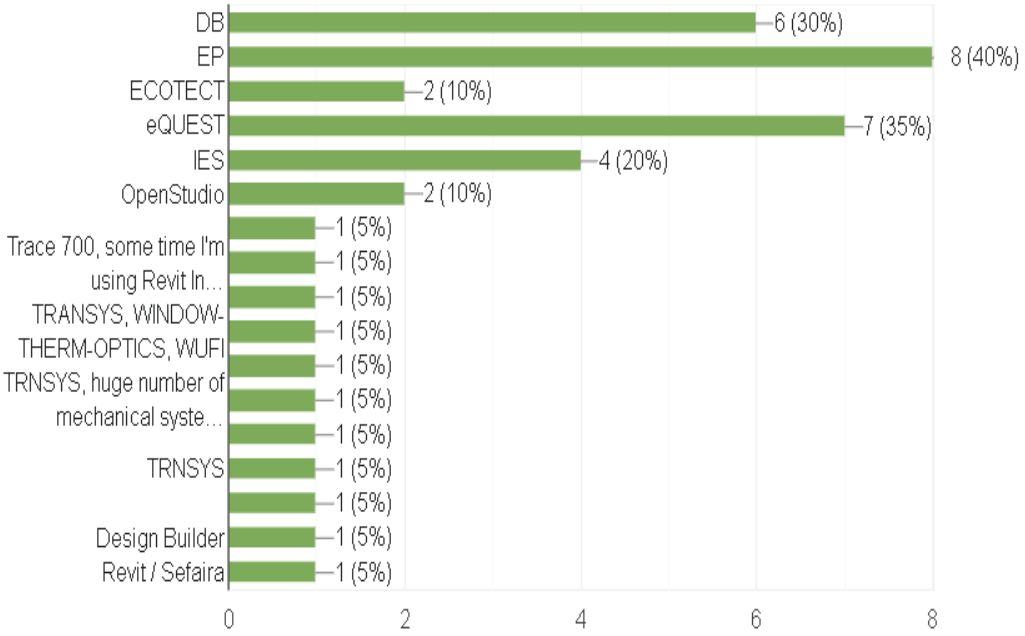


Figure 6.4. Selection of the BSP tools

14. Visual effectiveness of simulation presentations

The answers of the participants to this question; ECOTECT, TRACE700, TRACE3D, HAP, Energy +, ESP and Trnsys users find the graphical results sufficient for analysis. For DB users, the results of the Simulation tool are sufficient, but should be developed and simplified. In the previous question, the user who says that he uses TRNSYS here is that the tool results are in the form of too much raw data, so it may be necessary to use many different tools (though mostly Excel) to help the Design team visualize the analysis results. The graphical results for EQUEST are not enough, as conclusions are drawn**.**

PART III; Usability, possibilities and limitations of simulation programs

15. The Sufficiency of the tolls for complex and specific construction components

The answers of the participants to this question; DB; ECOTECT; There are some components that are not applicable, and the "equivalent" component sometimes makes assumptions that do not really match actual performance of the model. Another EP user (architect) is stated that he is pleased with the systematic development of the EP in order to offer periodically improved functionality. According to Trnsys users,

simulations sometimes produce far-from-reality results, with much uncertainty. As for the IES and; eQUEST users. For Trace 700 users, No, it only takes what the GBXML language allows.

16. **Comparative HVAC system recommendations at the preliminary design stage.**

In response of 20 people, it is often seen that comparative HVAC system recommendations can be made. The mechanical engineer using eQuest can compare different HVAC approaches, which is not difficult for eQuest, but only in a building design phase. Improving control in the HVAC system for an existing building is another.

17. **Integrating renewable energy systems to the tool**

eQUEST; IES users when answering this question No, the simulation that with TRACE3D, said it can integrate renewable systems. The user TRACE700 wrote that the software he was using not sufficient for that reason he prefer to work with other supporter tools. eQUEST only be made with the integration of the solar system, other systems is not possible. The DB user also said 'No', using PVW instead.

18. **Possibilities and limitations of the simulation tools**

According to a user who is a building energy analyst, mechanical engineer, academician; energy modeling tools lie at one end with a range of tools that have a lot of flexibility but require the user to have a high level of expertise and know a lot about the design and controls of the system. On the other hand, it is available in tools that can be used by modelers that offer less flexibility, but with less expertise and only a few details about the project. At the "flexible but complex" end of this range of vehicles they use. It has relatively few limitations but requires a high degree of expertise to use (TRNSYS user). In responses, users have commented that all limitations are too extensive, and cannot be written here. However, we can group some common constraints and possibilities selected here and list them as follows:

Limitations are;

- Lack of dayliglighting analysis, no natural ventilation analysis, LCA is missed (Trace 700, Revit).
- Occupancy, plug load, daylighting analysis (trnsys17)
- Operations - Use behavior - controls

- Lacks in the implementation of components: materials, thermal systems and renewable energy systems.
- CFD Analyses
- Very difficult to model high performance sequences of operations and equipment performance accurately.
- Cannot use renewable tools other than solar or passive building architectural features. VRF systems just added in latest version. Chilled beam and radiant options need work arounds. (eQuest)
- Large complex projects are slow to simulate, which slows down feedback to architectural design team.
- Input definition and quality assurance (e.g. who in the design team is responsible for what, systematization, steps taken to ensure quality control, easy & independent verification).
- Still complex, hard to use, hard to conduct uncertainty, sensitivity, and multivariate analysis.

Possibilities are;

- Tools give an opportunity while modelling and it is easy to use process of transferring data with other BIM tools (DesignBuilder).
- More adoption of design-phase/design-assist analyses (eQUEST;IES).
- with ongoing support and development (EnergyPlus).
- has much more features and is easier to use (DesignBuilder).
- Provides scripting options to automatically modify models, helping parametric analysis work (DesignBuilder and OpenStudio)

19. Future expectations for the developing of the tools

- Automation
- Fully integrating the simulation with BIM.
- BIM to BEM across all simulation tools
- more interactive with BIM and BMS
- Opportunatiy of .epw file generation and less eror while data transfer from BIM tools.
- Integrated and interoperable with design tools. For example, BIM tools should pull all relevant input data and equipment performance data,

template operating schedules from building type directly from a BIM tool as the design progresses in real time. Energy and performance modeling should be in real time and automatic - parametrically driven by design tools. They should not be standalone analytic tools that require duplication of input separate from design efforts.

- Simple, inexpensive, online tools. No EnergyPlus mysteries and difficulties.
- Better integration for Revit and arch tools to reduce energy model building overhead.
- Improved passage of data from one simulation tool to another so that the tools appropriate to predesign and early schematic design can pass their data on to the tools that are more appropriate for design development, retrofit, fault detection, etc.
- Looking forward towards NREL's efforts in streaming EP for small scale residential, that may solve a whole bunch of related issues for small scale existing commercial buildings.
- Expect/hope that someday, building energy simulation tools will have better interoperability with BIM tools (Revit, e.g.). Currently, there is a process of exporting a file (gbXML, e.g.) from a BIM tool and then importing that file into a building energy simulation tool. The imported file usually has issues that requires the energy analyst to address or start the model from scratch if there are too many issues.
- To have more integration with Intelligent Decision Support Systems,

CHAPTER 7

CONCLUSION

The primary objective of the study was to analyse the hourly energy consumption for the one-year performance of the building and to prepare the building energy model accordingly. Thus, it aims to present, test and criticize the modelling and simulation process for one of the prediction methods of building energy performance. The results presented here are based on the modelling procedure described in Chapter4 to enable the study of energy consumption in heating and cooling system. A case study model was modelled to illustrate all the simulation objectives and results applied. In the case study, it has shown what architects can do and how to deal with the details of detailed mechanical designs and energy models.

The case study has been examined through the energy performance, location, and climatic conditions. Method includes the sampling procedure, data collection and concludes with the construction and evaluation of the Design Builder model carried out in this study and same time evaluation and calibration of the modelling work was carried out again in Design Builder V.2.2.5 to V.6.0019 that is building performance analysis software program. At the end of the study the heating, cooling and transition seasons were simulated separately due to the factors affecting the prediction for each period to develop the three main periods to comply with the calibration. The results obtained with a digital model are compared with the actual measured values of energy consumption for space heating and cooling and the error rates of the calibrated models are presented. Consequently, concrete observations have been made about the advantages and disadvantages of the dynamic model and simulation method used here.

Izmir is the climatic zone of the existing building, so it is important to model the cooling period correctly. Since it is not possible to apply the floor cooling system of the existing building with design builder’s ready template, modelling was made by making changes on the template closest to the system. As an architect user, it was seen that the user's degree of expertise was important. Help was taken from the mechanical engineers and program developers for the integration of the appropriate system. The cooling system used for the cooling period modelling of the heat pump was used from the ceiling cooling system. In the building performance model, the data required by the

chilled ceiling pattern of the ceiling was entered for all the space other than the garage. And the pump efficiency (COP) was accepted as 4.22. During the modelling, some problems were encountered in integrating the system into the program.

As for the underfloor heating season, different template of mechanical system has been chosen for simulations. The most important one of these is that the application of cooling from the ceiling is not suitable for the calculation of the building's energy load for heating season. Design builder's default HVAC system; Air to Water Heat Pump (ASHP) Hybrid with Gas Boiler, Nat Vent; was used to represent existing HVAC system in building. The existing heat pump system in the Design-Builder software was operated with fan coils, the fan coils were changed to the floor heating. With this innovation in Design Builder v6.0 lately, there is no need to work on the Energyplus file separately. In short, two different systems for two different periods were studied. Design Builder v.4.2 was used for cooling time modelling and Design Builder v.6.0 was used for heating time modelling.

7.1 Conclusion Regarding Testing Phase of the Process

Case studies presented in this thesis are important in terms of seeing how the architect performs the simulation process properly. Finally, the results of a survey questioning the importance of the role of architect users in the process are explained here. The survey emphasizes how the architect runs the process and contributes to the integration of the building simulation process. However, the choice of the system that best describes the current system in modeling the mechanical system is still an issue that requires knowledge and experience for architect users.

- Preparation of a structure of the digital performance model, calibration, and interpretation of simulation results require good knowledge and experienced users. Users should know how to deal with the factors that affect the performance of the building. This research specifically brings the importance of the experienced users who has knowledge about building physics, mechanical and conditioning. Building performance modelling is expanding continuously and that requires time and effort to work on professionally and it is expected the user's own development. In this research a special climate modelling systems such as air source heat pump that forces the knowledge of the discipline of architecture, it can be seen that the architects and mechanical engineers need to

work together to feed each other's knowledge.

- The ability to simulate renewable energy systems should be improved in Design Builder. Due to the lack of this capability, heat pump underfloor heating and heat pump underfloor cooling are modeled here in two separate models. The default ready template of the HVAC system cannot be used for modelling in the cooling season, for example, no cooling capacity (EER) and no option for this input in the selected system in software. The percentage of the error rates can be reduced or increased by the ability of the system modelling and the restrictions of the software
- On-site monitoring of the spaces and operating modes of them should be carefully recorded on the calibration period. During these periods 'turn off and the amount and duration of the openings of the building envelope, the use of shading elements periods, the use of the doors which block the air flow amount between the interior spaces should be noted carefully. These factors are as important as the identifying the correct modelling of the building and the environment physical properties for the calibration process.
- As it is seen here there are sometimes need to use more than one simulation tools for modelling the structure. The Design Builder v.4.2 for modelling at cooling season of this house. For modelling, heating period EnergyPlus 8.2 programs was suggested to use to have more accurate results. The main reason for using these different tools are that Design builder is not developed sufficiently for the heat pump template. If the required templates provided sufficiently in a future version of used tool it will be more user friendly for the architects.
- First, when starting the model it is necessary to determine the most appropriate mechanical system from the beginning. It is not easy to correctly transfer the parameters of a comprehensive mechanical system to the system, and can further complicate this process. Therefore, it is necessary to select the most suitable or close system from the existing systems in the interface. What can be done here is to know the capabilities of the simulation tool used well and to decide the method that best expresses the current system. This was the biggest problem faced as an architect.
- Before selection of the mechanical system, the accuracy of the leakage value

must be checked. Then the cooling or heating system should be integrated into the model. Then the time interval of heating and cooling must be in line with the actual heating cooling time of the model, accurate schedule should be prepared.. The model should be modelled correctly to get the correct results.

- Design Builder is a simulation tool that requires very detailed data entry, so it may take time for different scenarios to be simulated and interpreted. So it is much more difficult and time consuming to perform calibration work without starting with the right assumptions. Most of the time these assumptions are important in building physics, so users' expertise levels are more important than anything else.
- No occupancy: occupancy is entered as zero in the model as there are no people living in the case building. The reasons for sudden temperature changes in non-living zones are not well understood, and modeling without the users of the building has led to uncontrolled results in simulation.
- All catalogue data for the heat pump must be entered exactly into the model. By default, entries considered to be dropped should be considered and, if necessary, logical corrections made. Once the correct assumptions are made, the model should be simulated again and the actual values should be checked with simulated field simulation outputs. Once each field is fixed separately, the entire system will stabilize. When the data entered into the mechanical system are not correct, estimates close to actual energy consumption results and room temperatures will not be made. It is a process that requires very long time for each period and requires detailed corrections.
- For modelling successfully with real and meaningful simulation results, it requires the understanding of the model and the review of reported errors. Sometimes the number of errors is important - one or two errors, such as convergence warming - errors, are probably not a problem in an annual simulation, in some cases there may be geometry errors. In this case, the results are likely to be meaningless. In such a case, re-simulation experiments should be carried out in the model. The harmless error data that is constantly encountered in the report may turn into fatal errors if they are neglected after a while. There are also some simulation errors that will report up to a certain time and then become fatal. Therefore, all errors must be categorized for correction. It was

difficult understand all these errors. Most users and application developers just don't know enough to make those calls on their own.

- The large datasets can be confusing but with the expert at the table to navigate the data the design direction can significantly be influenced and maybe changed!
- The interfaces which are determined according to which design stage will be simulated during the design process should be selected. Therefore the selected interfaces should include typical simulation options related to the particular design stage and the user's expertise and background.

7.2. Conclusion Regarding Verifying Phase of the Process

A total of 22 people participated in the survey, 7 of them did not specify their nationality.7 of the respondents are architects, 2 of them are LEED AP-Architects, 3 are academician Architects, and 2 are research architects 81% of the participants used the tools in parametric analyzes where design alternatives were tested and 71% of them used HVAC, lighting, hot water and solar energy in certification and rating (LEED V4) studies. For all the participants, the study areas are almost broad, with all the choices given to them being generally chosen. As for the necessity of specializing in one field, 15 people said that energy analysts need to specialize in one field. Energy analysts should have a strong knowledge of relevant areas, have full knowledge of building thermal behavior, understand energy requirements, and know HVAC solutions. In the role understanding of the employees as a company was especially important. Most of the company participants believed in the importance of working as a team in survey.

7.3. Recommendations and Further Study

- Architects don't have the knowledge to deal with mechanical systems without consulting engineers, especially for complex systems / buildings that require complex controls. It is definitely true that architects to play an effective role in the building design during the building simulation process in earlier times to design lower energy buildings. The modelling of special systems such as mechanical engineering, which pushes the knowledge of architecture discipline, demonstrates the necessity for mechanical engineers and architects to work together to feed each other. There needs to be cooperation with engineers. Or otherwise architects must be

trained in this.

- With the appropriate selected simulation tool, building energy analyst architects can compare design options in detail and have the ability to test ideas at any stage in real time of design. When choosing simulation tools, architect users should pay attention to the features of the programs being integrated into the design instead of being Designer-friendly. In this study, other programs could be used, the results of one or several programs could be taken and the best modelling tool could be chosen.
- The simulation process in this thesis has been 'process cantered' rather than 'tool cantered'. Design Builder, which is thought to be designer-friendly, was inadequate in the integration of complex systems as it was in this thesis, required serious domain knowledge and required external expert support. However, considering that Design builder is a very simplified tool, architects will have a high potential to support and improve design decision in the early stages of design. It requires a long time and team support for architects to perform current mechanical systems, especially renewable resource analyses in the existing buildings.
- Understanding of inputs / outputs at a high level, as well as understanding when models are intended to be predictive instead of comparative. The difference between the two types is very important.
- Understanding of various building systems - thermal envelope, electrical (lighting and power), HVAC - and their related performance criteria
- Architect energy analysts must have a complete knowledge of the building thermal behaviour, understand the energy needs and complete know-how of the HVAC solutions.
- The survey could have been longer, different interpretations could have been multiplied over time.

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APPENDIX A

TURKISH VERSION OF SURVEY

İzmir Yüksek Teknoloji Enstitüsü, Mimarlık Bölümü

BİNA PERFORMANS SİMÜLASYONU (BPS) ARAÇLARI KULLANICI ANKETİ

Tarih:

Görüşülen Kişi:

Ofis Adres ve Telefonu:

Değerli Katılımcı;

Bu ankete katılımınız ve desteğiniz için çok teşekkür ederim. Fikirleriniz ve cevaplarınız İzmir Yüksek Teknoloji Enstitüsü Mimarlık Bölümü'nde yürütmekte olduğum Yüksek Lisans Tezim için çok değerli olacaktır. Simülasyon araçlarının olanaklarını ve sınırlamalarını bilen bir enerji analisti olarak sizin bilgi ve perspektifiniz mimarların simülasyon sürecindeki rolünü anlamamıza yardımcı olacaktır.

Bu anket, akademik kurumlarda ve/veya piyasada enerji simülasyonu araçlarını kullanan mimar, mühendis, tasarımcı, LEED AP, vb. bilgi toplamayı amaçlamaktadır.

Anket 18 sorudan oluşmakta ve yaklaşık süresi 10-15 dakika sürmektedir. Anket soruları, aşağıdaki üç ana başlıktan oluşmaktadır.

1. BPS araçlarıyla ilgili olarak kullanıcı geçmişi ve deneyimi;

2. BPS araçlarının tasarım sürecine entegrasyonu ve grafik çıktılardan memnuniyetleri

3. Simülasyon programlarının kullanılabilirliği, olanakları ve sınırlılığı

PART I: BPS araçlarıyla ilgili olarak kullanıcı geçmişi ve deneyimi

1. Enerji simülasyon araçlarının kullanımında uzmanlık dereceniz nedir?

Açıklama:

2. Ne tür simülasyon çalışmaları yapıyorsunuz? (Örneğin: tasarım alternatiflerinin test edildiği parametrik analizler, kullanıcı konforu analizleri,

sertifikalandırma / derecelendirme amaçlı analizler, veya diğer)

Açıklama:

3. Enerji analisti / akademisyen olarak bina performans simülasyonunda uzmanlaştığınız bir alan var mı? Bir enerji analistinin tüm alanlarda yetkin olması gerektiğine inanıyor musunuz?

Açıklama:

4. Enerji simülasyonlarını tek başınıza mı bir ekiple mi gerçekleştiriyorsunuz? Ekip ile ise hangi uzmanlarla çalışıyorsunuz? Sizinle birlikte çalışan mimar enerji analistleri var mı?

Açıklama:

5. Modellediğiniz birincil bina tipiniz nedir?

Açıklama:.

6. Mimarlık bürolarına danışmanlık hizmetleri veriyor musunuz?

Açıklama:

7. Mimarların enerji simülasyonunda önemli rolü olduğuna inanıyor musunuz?

Açıklama:

8. Simülasyon araçlarını kullanan enerji analisti bir mimar hangi bilgilere sahip olmalıdır?

Açıklama:

9. Simülasyon araçları, mimarların mekanik sistem önerileri yapması için yeterli midir? Mühendislerle işbirliği içinde olması gerektiğine inanıyor musunuz?

Açıklama:

PART II: BPS araçlarının tasarım sürecine entegrasyonu ve grafik çıktılardan memnuniyet

10. Simülasyon araçlarını projelerin hangi evrelerinde kullanırsınız?

(Ön tasarım aşaması / Tasarım Geliştirme / Yenileme Projeleri / Tasarım Optimizasyonu)

Açıklama:

11. Simülasyon analiz sürecinizi nasıl planlarsınız?

Açıklama:.

12. Hangi simülasyon aracını kullanıyorsunuz? Neden? Birden fazla simülasyon aracını kullanmak zorunda kaldığınız oldu mu? Hangi durumlarda?

Açıklama:

13. Sonuçları tasarım ekibine nasıl görselleştiriyorsunuz? Verileri iletmek için kullandığınız simülasyon aracının sonuç grafikleri yeterli mi?

Açıklama:

PART III: Simülasyon programlarının kullanılabilirliği, olanakları ve sınırlılığı

14. Kullanmakta olduğunuz simülasyon araçlarının karmaşık ve spesifik yapı bileşenlerini yeterince simüle etme kabiliyetine sahip olduğunu düşünüyor musunuz?

Açıklama:

15. Ön tasarım aşamasındaki mimari projelere kullandığınız simülasyon aracıyla karşılaştırmalı HVAC sistem önerileri getirebiliyor musunuz?

Açıklama:

16. Kullandığınız simülasyon araçlarında projeyle entegre bir yenilenebilir enerji sistemi simülasyonu yapmak kolay oluyor mu?

Açıklama:

17. Kullandığınız simülasyon araçlarının mevcut olanakları ve kısıtlamaları nelerdir?

Açıklama:

18. Bina enerji simülasyonlarının kullanım kolaylığına yönelik geliştirilmesi için gelecek beklentileriniz nedir?

Açıklama:

Çok teşekkürler

APPENDIX B

ENGLISH VERSION OF SURVEY

Izmir Institute of Technology, Department of Architecture

SURVEY ON BUILDING PERFORMANCE SIMULATION (BPS) TOOLS USERS

Date:

Name Surname:

Contact addresses:

Dear Participant;

Thank you very much for your participation and support to this survey. Your ideas and answers will be very valuable for my master thesis conducted in Izmir Institute of Technology, Department of Architecture in Turkey. As active energy analysts, your perspective and knowledge on the possibilities and limitations of simulation tools will enable us to understand the role of architects in the simulation process.

This survey aims to collect information from the users of energy simulation tools in the academic institutions and/or market (by architects, engineers, designers, LEED AP).

The questionnaire consists of 18 questions, and takes approximately 10-15 minutes. The survey questions consist of the following three main headings.

1. Users' backgrounds and experiences with BPS tools;
2. Tools' integration into the design process and satisfaction with graphic outputs
3. Usability, possibilities and limitations of simulation programs

PART I; Users' background and experiences with BPS tools;

1. What is your degree of expertise in the use of energy simulation tools?

Comments

2. What kind of simulation studies do you do (parametric analyses where design alternatives are tested, user comfort analyses, and certification / grading analyses, or other)?

Comments

3. As an energy analyst / academician, are you specialized in a specific simulation field? Do you believe that the energy analyst must be competent with all fields?

Comments

4. Do you run energy simulations alone or with a team? If you have a team, which experts do you work with? Are there any architects among the energy analysts that work with you?

Comments

5. What type of building do you model specifically?

Comments

6. Do you provide consultancy services to architectural offices?

Comments

7. Do you believe that architects have an important role in energy simulation?

Comments

8. What knowledge should architect as energy analyst have using simulation tools?

Comments

9. Are the simulation tools sufficient for architects to make mechanical system proposals? Or do you believe that there should be in cooperation with the engineers?

Comments

PART II: Tools' integration into the design process and satisfaction with graphical outputs

10. In which design phases would you use the simulation tools?

(Pre-conceptual / Schematic Design / Design Development / Retrofitting / Design Optimization)

Comments

11. How do you plan your simulation analysis process?

Comments

12. What building performance simulation tools do you use? Why? Have you ever had to use multiple simulation tools at the same time?

Comments

13. How do you visualize the results to the design team? Are the results of the simulation tool you use sufficient for your analyses?

Comments

PART III; Usability, possibilities and limitations of simulation programs

14. Do you think that the tools you are using are capable of sufficiently simulating complex and specific construction components?

Comments

15. Can you bring comparative HVAC system proposals with the simulation tool you use for pre-design architectural projects?

Comments

16. Is it easy to simulate a renewable energy system integrated with the project in the simulation tools you use?

Comments

17. What are the current possibilities and limitations of the simulation tools you use?

Comments

18. What are your future expectations for the development of building energy simulations for usability?

Comments

Thank you.

APPENDIX C

SURVEY ANSWERS

01) What is your degree of expertise in the use of energy simulation tools?	
Participant 01	20 + years
Participant 02	Leed architect
Participant 03	Leed ap;building energy analyst
Participant 04	Leed ap;building energy analyst;mechanical engineer;academician
Participant 05	Mechanical engineer
Participant 06	Architect; academician
Participant 07	Architect;building energy analyst;academician
Participant 08	Architect
Participant 09	Building energy analyst;mechanical engineer;academician
Participant 10	Leed building energy analyst; mechanical engineer
Participant 11	Aeronautical engineer
Participant 12	Leed ap;building energy analyst;mechanical engineer
Participant 13	Academician
Participant 14	Building energy analyst;mechanical engineer
Participant 15	Leed ap;building energy analyst;mechanical engineer;academician
Participant 16	Leed ap;building energy analyst
Participant 17	Building energy analyst;academician
Participant 18	Architect;building energy analyst;academician
Participant 19	Building energy analyst
Participant 20	Leed ap;building energy analyst;academician
Participant 21	Leed architect
Participant 22	Building energy analyst
Participant 23	Building energy analyst;mechanical engineer;bemp, licensed pe

02) What kind of simulation studies do you do?	
Participant 01	All the above
Participant 02	certification / grading analyzes,
Participant 03	parametric analyzes where design alternatives are tested;certification / grading analyzes,
Participant 04	parametric analyzes where design alternatives are tested; certification / grading analyzes,;energy auditing
Participant 05	parametric analyzes where design alternatives are tested; user comfort analyzes;certification / grading analyzes,
Participant 06	parametric analyzes where design alternatives are tested;user comfort analyzes;Development of new algorithms for FDD and MPC
Participant 07	parametric analyzes where design alternatives are tested;user comfort analyzes;certification / grading analyzes,
Participant 08	parametric analyzes where design alternatives are tested
Participant 09	parametric analyzes where design alternatives are tested;user comfort analyzes
Participant 10	certification / grading analyzes,;load analysis and equipment sizing
Participant 11	parametric analyzes where design alternatives are tested;certification / grading analyzes,
Participant 12	parametric analyzes where design alternatives are tested;user comfort analyzes;certification / grading analyzes,
Participant 13	parametric analyzes where design alternatives are tested;user comfort analyzes;certification / grading analyzes,
Participant 14	parametric analyzes where design alternatives are tested;certification / grading analyzes,
Participant 15	parametric analyzes where design alternatives are tested;user comfort analyzes;certification / grading analyzes,;feasibility, net zero
Participant 16	parametric analyzes where design alternatives are tested;certification / grading analyzes,;ratepayer work, large scale analysis
Participant 17	parametric analyzes where design alternatives are tested;user comfort analyzes;certification / grading analyzes,
Participant 18	parametric analyzes where design alternatives are tested;user comfort analyzes;certification / grading analyzes,;simulation-supported policy development
Participant 19	parametric analyzes where design alternatives are tested;Study effects of novel technologies.
Participant 20	certification / grading analyzes,;Whole building energy simulation
Participant 21	parametric analyzes where design alternatives are tested

Participant 22	
Participant 23	
03) As energy analyst / academician, are you specialized in a specific simulation field? Do you believe that the energy analyst must be competent with all fields?	
Participant 01	Specialised in a number of areas, energy analyst must be competent in the fields they work in.
Participant 02	Yes, LEED V4 Energy Modeling Analysis.
Participant 03	energy and daylight - competent in specific fields, and knowledgeable in ancillary topics
Participant 04	No. Not necessarily.
Participant 05	I am specialized in Energy and I work in the HVAC industry from my degree, in the past 20 years. A energy analyst must have a complet knowledge of the building thermal behaviour, understand the energy needs and complet know-how of the HVAC solutions
Participant 06	yes
Participant 07	It is important to have a strong knwoledge of the fields involved
Participant 08	I specialize in optimisation in building envelope with natural building materials. I believe that energy analyst must be specialized in a field for getting accurate results.
Participant 09	I specialize in optimization, and I agree with the second statement
Participant 10	HVAC, Lighting, Power, Envelope
Participant 11	I perform analysis on envelope, HVAC, lighting, DHW, and solar. Using eQuest allows me to be competent in all these areas. This is Whole Building Analysis
Participant 12	Primarily IESVE
Participant 13	Thermal comfort etc
Participant 14	I mostly do energy design assistance, compliance, and certification work, but I am interested in opportunities to learn daylighting, massing, and thermal comfort modeling. I don't think you need to be competent with all fields.
Participant 15	I try to remain somewhat general. I do think it is important to be competent in multiple fields. Answers to energy use challenges are going to be found in between traditional disciplines, not squarely in one field or another.
Participant 16	
Participant 17	
Participant 18	The "energy in buildings" field requires a mix of both generalists & experts. As a senior researcher/analyst, I tend to supervise team members - although I still work out key features for which I would be considered a specialist (e.g. daylighting).

Participant 19	No, I am not specialized. I do believe that energy analysts should have a broad knowledge base and be competent in all facets of building energy science.
Participant 20	Energy simulation for LEED buildings
Participant 21	I am a practicing architect. I would not classify myself as an energy analyst or academician, but do use energy analysis tools to understand design. I would not say that it is a prerequisite, but definitely increases perception of ability and comprehension when multiple fields are understood.
Participant 22	A building energy analyst should be able to perform all kinds of simulation at all level of details
Participant 23	I am 'specialized' in leveraging the doe2/eQuest platform. I believe competency and practice/experience with any software platform and energy simulation builds transferrable skills and I have no reservations in hiring others with deep energy analysis experience that doesn't include doe2/eQuest. I believe newer energy analysts are best advised to stick to a smaller subset of platforms until they can build competency/mastery, then to add supplementary tools to their toolbelt as the need arises. I believe experienced energy analysts naturally
04) Do you run energy simulations alone or with a team? If you have a team, which experts do you work with? Are there any architects among the energy analysts that work with you?	
Participant 01	Alone and in teams. Depends on project. Architects - sometimes but not always
Participant 02	Alone, some time I ask the design team to help in building the geometry.
Participant 03	Typically we work with both the architect and mechanical engineer of records to achieve better project outcomes; internal staff have background in both architecture and engineering.
Participant 04	Team. All energy modelers or mechanical engineers. No architect.
Participant 05	Both, usually in Portugal the energy simulation are must of them being practiced by Mechanical Engineers
Participant 06	with team of Mech Engineers and Physicists
Participant 07	Alone, and I'm an architect
Participant 08	I work alone. But, it must be a team consisting of experts with different fields.
Participant 09	Alone, no architects
Participant 10	As needed - will bring in consultants if needed on a case-by-case basis
Participant 11	I am semi-retired, but work remotely with Architects, engineers, and building owners. I do not work in an office, rather at home.
Participant 12	Team of engineers

Participant 13	Alone and PhD students
Participant 14	Generally alone, and not any architects.
Participant 15	This varies from project to project. we work both alone and as part of a larger team. On LEED projects often the architect is the team lead and is the primary recipient of energy simulation results but does not (in our experience) do much simulation themselves.
Participant 16	
Participant 17	Alone and with a team. I am an architect, I work with mechanical engineers.
Participant 18	Team. There is some overlap between team members (which is a good thing), yet each tends to concentrate on certain areas (e.g. one on HVAC selection, sizing & controls, another on envelope thermal bridging). Generally, people with training in architecture tend to be confined to input definition (e.g. geometry & zoning, de-rating effective R-values as a function of thermal bridging). Only architects with formal building science training could take on larger roles and tackle HVAC for instance.
Participant 19	I run energy simulations both alone and with a team of four people. We do not have architects on our team.
Participant 20	Alone
Participant 21	With a team. We work with many of our consultants. Some specific to energy modeling, some sustainability consultants, and some M/E/P consultants. Depends on the project.
Participant 22	I'm working alone
Participant 23	I operate individually, with teams in my company, and I also oversee 3rd party energy engineering teams. We hire architects on occasion, as required. Within my company, my teams most typically and minimally are comprised of one MEP engineer, one Automation engineers, and one Energy engineer. Larger projects involve design teams of 20+ internal employees, with hundreds involved after considering 3rd party contractors/architects/engineers who our team is overseeing.
05) What type of building do you model specifically?	
Participant 01	All
Participant 02	Commercial Buildings
Participant 03	commercial, institution, hi-rise residential
Participant 04	Office, schools, sport arenas, substations, college dorms, labs, ...
Participant 05	From small houses to hotels, hospitals, Airport, schools, offices, shopping mall, retails, industry process, most of every building scenario
Participant 06	All
Participant 07	Any kind

Participant 08	One-storey buildings in rural buildings such as building with natural building materials.
Participant 09	Residential
Participant 10	K-12, Higher Education, Government/Public facilities
Participant 11	K-12 school. hotels, offices, municipalities, military installations, shopping malls, big box retail, etc. Any building that can use my expertise.
Participant 12	Office, healthcare, higher education, labs, hotels, transit
Participant 13	Office
Participant 14	Primarily multifamily, but all buildings.
Participant 15	Because of the tool we use, we work primarily on buildings that have complex HVAC (often with integrated natural ventilation) systems. There is not a particular building type; the complexities of the system drive projects towards the tools that we use. We do a fair amount of work on central plant and district systems.
Participant 16	
Participant 17	All types
Participant 18	Both residential & commercial building stocks (excluding industrial facilities)
Participant 19	Mostly offices, but also other building types (schools, hotels, etc.).
Participant 20	Office Buildings
Participant 21	Commercial, Institutional, Cultural, Multiunit Housing, mixed use, and some lab.
Participant 22	Commercial buildings: Office, Healthcare, Schools, Multiresidential buildings.
Participant 23	I am most commonly modeling campuses of buildings within healthcare, industrial, K-12 & higher education markets, and for Federal (DoD) contracts.
06) Do you provide consultancy services to architectural offices?	
Participant 01	Yes
Participant 02	No, only to sustainability firm
Participant 03	yes
Participant 04	Yes.
Participant 05	yes
Participant 06	NO
Participant 07	Yes, I do
Participant 08	No.
Participant 09	No
Participant 10	Yes - was a principal in an Architectural firm for 6 years.
Participant 11	Yes, when asked. My work varies.

Participant 12	Yes
Participant 13	Sometimes
Participant 14	Yes
Participant 15	yes.
Participant 16	
Participant 17	Yes
Participant 18	Rarely (around 10% of annual revenues). In such cases, usually as an independent assessor for clients that are serious in achieving their goals. Unless some degree of independent compliance verification is in place, in my experience architects are generally interested in green washing their designs. I tend to be less cooperative in such instances, hence less than 10% of my work load.
Participant 19	Yes
Participant 20	Yes
Participant 21	no, we are an architectural office
Participant 22	Yes, always
Participant 23	I used to provide dew point envelope analyses and simulation-aided design services on a regular basis, however these days I more commonly am hiring/employing other architects as consultants to me to handle energy savings-driven construction design and specification services.
07) Do you believe that architects have an important role in energy simulation?	
Participant 01	Yes
Participant 02	Yes, especially for envelope and day lighting.
Participant 03	The architects are the primary contact with our clients in most scenarios - so YES!
Participant 04	Yes.
Participant 05	yes
Participant 06	NO
Participant 07	Of course
Participant 08	Yes. Exactly
Participant 09	Yes
Participant 10	Yes - even if simply understanding what needs to be analyzed and how to use output to inform design
Participant 11	Absolutely. If this is initial design, they have the power to make a great initial impact on a building, rather than having to retrofit poor design after the fact.
Participant 12	yes
Participant 13	Sure

Participant 14	Yes
Participant 15	absolutely
Participant 16	
Participant 17	Yes
Participant 18	That heavily depends on the individual architect or their "toolbox" (e.g. graduate degree in architectural or building science). No one would question Dru Crawley's experience and contribution in the field (he's an architect ... with a PhD in engineering); but the overwhelming majority of architects don't resemble Dru in any remote way. In many, many cases, architects can be a real nuisance. "Modelling" any physical phenomena can only make sense if one possesses a solid understanding of the physical phenomena in the first place. Can't say that about the majority of architects out there. (This isn't architect-bashing; I'm an architect).
Participant 19	Yes
Participant 20	Yes
Participant 21	Their most important role is in translating simulation outcomes to the client and broader project goals.
Participant 22	They should be open to our recommendations and results. Which is not the case now
Participant 23	They can, but they must recognize the value and purpose of energy simulation to their personal workflows, then step up to the table to engage engineers. Architects who generally treat energy simulation as "someone else's job/responsibility" are missing the point, and may be better off not trying to incorporate energy simulation into their workflow as that more commonly results in less productive/constructive results for all the effort involved. I sincerely wish more architects AND engineers AND building owners would pick up ownership and play a collaborative role in energy simulation.
08) What knowledge should architect as energy analyst have using simulation tools?	
Participant 01	As much as their fees/company ethos/knowledge and expertise allows - the more the better.
Participant 02	HVAC, Thermodynamics and Building Science knowledge.
Participant 03	understanding of various building systems - thermal envelope, electrical (lighting and power), HVAC - and their related performance criteria
Participant 04	Good knowledge of mechanical systems and how they operate.
Participant 05	already mention above (question nÂº3)

Participant 06	Architects cant do simulations well. They can do only building envelop optimization
Participant 07	Thermal transfer through building envelope, understanding thermal loads and knowledge about thermal systems and their performance
Participant 08	It has to be building physics.
Participant 09	Parametric design
Participant 10	See above. They should be able to at least fill out a ComCheck for the building envelope and calculate component and assembly R, U, and specific heat calculation to provide to consultants of alternate envelope assemblies.
Participant 11	Building orientation, shading, building materials, etc. Architects are not expected to have ultimate knowledge of the building's energy systems, just its architectural contribution. THAT takes an engineer.
Participant 12	Limitations of schematic tools for complex building types. Ability to performing massing and site analysis and envelope sensitivity.
Participant 13	Depends
Participant 14	Understanding of inputs/outputs at a high level, as well as understanding when models are intended to be predictive instead of comparative. The difference between the two types is very important.
Participant 15	It is easy to find software marketing that makes sweeping claims about software capabilities. In actual fact all of the software tools have limitations and provide estimates. Everyone on a design team (architects included) should have enough familiarity with the fundamental concepts that underlie energy modeling practice and tools so that they can understand what kinds of questions to ask of energy models and whether results are real or just marketing bluster.
Participant 16	
Participant 17	Building physics
Participant 18	Unless a given school of architecture has a strong basis in a related field (daylighting modelling at MIT, algorithmic processes, parametric analysis), then interested architects have no choice but to acquire relevant expertise elsewhere, usually from schools of engineering. Fortunately, there is growing awareness of this need within many engineering schools (e.g. master's in energy/buildings [involving energy simulation] ... usually requiring a "qualifying year of study" to get the basics). Long story short, untrained architects playing with energy simulation is like playing with matches in a hay barn.
Participant 19	General understanding of the impact that architectural design decisions have on energy use.
Participant 20	Integrative nature of buildings, and building systems

Participant 21	A general knowledge of terminology, and intent. Some knowledge of process is helpful, but not required.
Participant 22	Not sure to understand the question. The architect should have broad knowledge on the energy in buildings
Participant 23	Depends upon the application/needs, but independent of background/discipline (i.e. architects vs. engineers vs. computer scientists), energy analysts must build ownership in and attempt complete mastery in understanding a model's inputs AND outputs. Time should be invested in critically questioning and vetting your own results. If A + B = C, then what should happen if I tweak B? Now go simulate that - expected outcomes?
09) Are the simulation tools sufficient for architects to make mechanical system proposals? Or do you believe that there should be in cooperation with the engineers?	
Participant 01	Cooperation at detailed stage is very important, proposals of broad types are OK at earlier stages - in preference in liaison with engineers.
Participant 02	Cooperation with the engineers is always recommended specially when we have a sophisticated HVAC system.
Participant 03	When used properly, yes, the information from simulation tool(s) are adequate to begin mechanical system narratives
Participant 04	Engineers are required here.
Participant 05	The simulation dont tell you what whould be the best solution, and also dont do the detail design specification
Participant 06	Architects should not be given work on energy simulations
Participant 07	Yes, they are. If they haven't got a strong knowledge about developing a thermal system project they should ask engineers
Participant 08	I belive that it must be teamwork working with mechanical engineering.
Participant 09	I think architects do not have the necessary knowledge to be able to deal with mechanical systems alone without consulting engineers, especially for complexe systems/buildings that need complexe controls. Architects should be initiated to this during their training
Participant 10	Architects should not make mechanical systems proposals unless in consultation with an ME or an experienced owner who has a large portfolio or well defined MEP project requirements
Participant 11	ALWAYS cooperation is needed. There are Architects that THINK they know building systems, BUT...
Participant 12	No
Participant 13	Yes
Participant 14	There needs to be cooperation with engineers.
Participant 15	there absolutely needs to be cooperation between architects and engineers.
Participant 16	

Participant 17	No. I shpuld be in cooperation with engineers
Participant 18	(see above)
Participant 19	Some simulation tools are sufficient, but it is not viable to ask the architect to become proficient with them in addition to their design tools. They should work in cooperation with engineers and energy analysts who are trained in these simulation tools.
Participant 20	There must be collaboration with building engineers
Participant 21	in cooperation with engineers.
Participant 22	architects can't make mechanical systems. You need to have background and experience in it like engineers
Participant 23	Some architects are capable, and others are not. Has no bearing on the library of tools available in the world (free or at cost). Conversely, there are some mechanical system designers who could do an architect's job better, independent of the tools/resources at-hand. Cross-disciplinary experience is ALWAYS valuable in any profession which involves collaboration with others bearing unique and complex skill sets.
10) In which design phases would you use the simulation tools?	
Participant 01	All
Participant 02	For code compliance and permitting issuance.
Participant 03	All of the above - the earlier, the better
Participant 04	All of them.
Participant 05	in every phases
Participant 06	All
Participant 07	I usually work at design optimization phase, but I've also been involved in the other phases
Participant 08	Retrofitting ; Design Optimization
Participant 09	Pre-conceptual; Schematic Design; Design Development;Retrofitting;Design Optimization; All
Participant 10	Pre-conceptual; Schematic Design; Design Development;Retrofitting;Design Optimization; All
Participant 11	All
Participant 12	All
Participant 13	Pre-conceptual; Schematic Design; Design Development;Retrofitting;Design Optimization ; All
Participant 14	All
Participant 15	Design Development;Retrofitting;Design Optimization
Participant 16	Pre-conceptual;Schematic Design;Design Development;Retrofitting;Design Optimization;All

Participant 17	Design Development;Retrofitting;Design Optimization
Participant 18	All
Participant 19	All
Participant 20	Schematic Design;Design Development;Design Optimization;All
Participant 21	Pre-conceptual;Schematic Design;Design Development
Participant 22	Pre-conceptual;Schematic Design;Design Development;Retrofitting;Design Optimization
Participant 23	All
11) How do you plan your simulation analysis process?	
Participant 01	
Participant 02	Data Collection, Geometry, Envelope, Lighting and Daylighting, HVAC.
Participant 03	gathering info for architectural, lighting, and HVAC
Participant 04	First, and foremost, define the objective of the simulation. Then knowing the building and its systems, decide the tool to use. Go from there.
Participant 05	Always
Participant 06	Pre-Design to Commissioning
Participant 07	Asking for all the information of the building and organizing it based on the steps marked by the simulation tools
Participant 08	Selection of case building, Monitoring, Modelling, Calibration and Optimization process
Participant 09	
Participant 10	We use the spreadsheets NREL uses with E+ and Open Studio although most or our work is in TRACE 700 and TRACE 3D+
Participant 11	Review of drawings, discussion with Client what the purpose of the simulation is (this gives me an idea if I am performing simulation level of boxes on one extreme or the Taj mahal on the other).
Participant 12	Start as soon as we can. Model early and often for greatest impact. Structure around ASHRAE Std. 209 cycles.
Participant 13	Depends
Participant 14	Based on past experience of expected time spent. Getting the relevant information in a timely fashion is really the difficult step.
Participant 15	This changes from one project to another.
Participant 16	
Participant 17	

Participant 18	Really depends on the task at hand. Achieving targets for a building with limited means ($) is very different from doing building stock analysis. The degree of disclosure (e.g. documenting the assumptions and hypotheses for LEED versus government agency) also varies greatly and influences how we do things.
Participant 19	If it is for a building design, try to get all information about the building first (architectural drawings, mechanical drawings, utility bills if an existing building, etc.). Then, use that information to determine how to define geometry for zoning, assign internal loads (people, lights, receptacles, etc.), and HVAC systems. If validating novel building technologies, using a prototype model (commercial reference building, e.g.) is adequate.
Participant 20	in eQuest tool, using schematic wizard first, then moving to the detailed mode
Participant 21	at the beginning of the project following a goal setting meeting with the client and major stake holders.
Participant 22	process is a pingpong between the energy analyst and the client in order to refine the model until reaching the appropriate answers and solutions. It starts with hypothesis and asumptions and then the model grows to integrate all the decisions made during the life of the design
Participant 23	We have established a workflow which is flexible in some areas (primarily regarding the depth and type of energy analysis to be performed, which informs which software and tools we'll use to perform our study), and inflexible in others (such as internal QC and review of each others' work). It is important for a simulation development plan to allow for flexibility as new information is gathered - it is often appropriate to simplify or deepen a given analysis as new things are discovered during development.
12) What building performance simulation tools do you use? Why? Have you ever had to use multiple simulation tools ?	
Participant 01	IESVE - most robust, most relevant, most up to date with current needs. Multiple tools: yes
Participant 02	Trace 700, some time I'm using Revit Insight.
Participant 03	eQUEST;IES
Participant 04	DB;EP;eQUEST;IES
Participant 05	ECOTECT;TRACE700; TRACE3D; HAP; Energy+; ESPr; Transys
Participant 06	DB;EP;TRANSYS, WINDOW-THERM-OPTICS, WUFI
Participant 07	DB;EP;ECOTECT; eQUEST ;trnsys
Participant 08	DB
Participant 09	TRNSYS, huge number of mechanical systems available to be used into buildings, ease of adding new systems as types programmed in FORTRAN

Participant 10	TRACE 700, TRACE 3D+, Insight 360, GBS, Revit
Participant 11	eQUEST
Participant 12	IES
Participant 13	
Participant 14	EP ;eQUEST; IES
Participant 15	TRNSYS
Participant 16	EP; OpenStudio
Participant 17	DB;EP
Participant 18	EP; eQUEST; Radiance, native variants of DOE-2.X, various interfaces to either DOE-2.X or EP
Participant 19	DB;EP; OpenStudio
Participant 20	eQUEST; Design Builder
Participant 21	Revit / Sefaira
Participant 22	DB;EP;IES
Participant 23	eQUEST;PowerBI, Extensive Spreadsheet-based (Excel) calculations suited to problems too simple/complex for hourly/interval analysis packages listed above. Most projects involve leveraging multiple tools.
13) How do you visualize the results to the design team? Are the results of the simulation tool you use sufficient for your analyses?	
Participant 01	Reportage, graphical, tabular, model 'colored' graphical, model based results (i.e. shading/daylight). Further analysis of results or’re-presentation / re-packaging' of results is common due to company style of presentation.
Participant 02	It's sufficient for code compliance, design team is using their own software.
Participant 03	typically bar graph and pie chart - no, not sufficient nor dynamic enough
Participant 04	Reports with graphs and tables. Most often.
Participant 05	Usually yes, the results are enough, and I share the results with my team
Participant 06	No, we develop our own macro- and use R
Participant 07	I use spreadsheets to generate graphs and other tools, also the visualization results tools of the simulation software. Yes, they are
Participant 08	The results of the simulation tool are sufficient but it should be enhanced and simplified.
Participant 09	
Participant 10	Output from software packages and post processing in Excel
Participant 11	I use spreadsheets for comparison of Bse versus proposed, or between multiple simulation comparisons.
Participant 12	Use excel and PowerPoint in addition to graphics produced by the simulation software.
Participant 13	Yes

Participant 14	For compliance and LEED models, the results of the simulation tool are sufficient. For design assistance models, additional graphical information relevant to the questions being asked is very important.
Participant 15	The tools that we use provide a lot of raw data about the system. We use a lot of different tools (although mainly Excel) to help the rest of the design team visualize the results of the analysis.
Participant 16	
Participant 17	With graphics and tables. No they are not sufficient; I produce the graphics and tables.
Participant 18	Also really depends on the audience. Custom visualizations/presentations, depending on e.g. designer & client/owner of a building vs energy efficiency agency.
Participant 19	I use DesignBuilder's Results Viewer tool.
Participant 20	Yes
Participant 21	We usually repackage for final output to client. Internally, we just use the standard outputs.
Participant 22	Sometimes there is the need to go through Excel in order to visualize
Participant 23	Spreadsheets summarizing simulation outputs. At any point where I sense the simulation tool is insufficient for the task at-hand, I will either produce a new one and/or adopt a new tool for that specific problem.
14) Do you think that the tools you are using are capable of sufficiently simulating complex and specific construction components?	
Participant 01	Yes - within the constraints of the outcomes that are sought - i.e. if you want 8760 energy results there is little point in a detailed 3D thermal bridging model.
Participant 02	No, it;s only taking what GBXML language allows.
Participant 03	not always - but 85-90+% of product types/components would be available
Participant 04	Not always, but there are workarounds.
Participant 05	Yes and No, it cannot do CFD
Participant 06	90%
Participant 07	There are some components that are not implemented and the "equivalent" component sometimes is an assumption that don't really match the real performance
Participant 08	No. It is hard to simplify.
Participant 09	No, simulations produce results far away from reality sometimes, there is a lot of uncertainty

Participant 10	Yes - to the extent that minute complex construction details can significantly affect life cycle energy consumption. Details like thermal bridging have more effects on degradation of materials and reduced lifecycle of building components.
Participant 11	Absolutely.
Participant 12	yes
Participant 13	Yes
Participant 14	Yes and no. Thermal bridging of complex assemblies is difficult to quantify and I don't know of any software that doesn't just refer to the ASHRAE tables for assembly U Values
Participant 15	Yes. There are, of course, limitations to what the tools we use can and cannot analyze. It is critical for us to know what those limitations are so that we can modify our recommendations based on how certain we are that the technology we are trying to simulate is well modeled in the software.
Participant 16	
Participant 17	yes
Participant 18	Satisfied with how EP is systematically evolving to regularly offer enhanced functionality in this regard. Of course, there will always be a delay between version roll-outs and market innovations.
Participant 19	Yes
Participant 20	Yes
Participant 21	Yes
Participant 22	one tool isn't enough. sometimes tools are complementary to describe different level of details
Participant 23	Yes.
15) Can you bring comparative HVAC system proposals with the simulation tool you use for pre-design architectural projects?	
Participant 01	Yes
Participant 02	Yes, with limited system arrangement.
Participant 03	YES - this is what architects are missing!
Participant 04	Yes.
Participant 05	Almost always for significant (big) buildings
Participant 06	Yes
Participant 07	Yes, I can
Participant 08	I've never tried.
Participant 09	yes
Participant 10	Yes

Participant 11	Of course. eQuest is capable of comparing different HVAC approaches. Remember, this is only before a building is designed. Once you have a building in place, you are basically stuck with the HVAC system, and now need to improve its control.
Participant 12	yes
Participant 13	Yes
Participant 14	Yes.
Participant 15	This is a challenge. Yes, we can bring high level HVAC design alternatives to the predesign phase. However, often so little is known about the details of the project that those design alternatives must be very generic and therefore ignore a lot of details. Unfortunately, it is those details that are often the difference between project success and failure.
Participant 16	
Participant 17	yes
Participant 18	Sure, why not ... at least conceptually (auto sizing helps). I find the choice of a performance metric to be much more difficult to identify, discern and finalize with both design teams and agencies (e.g. annual energy (GJ), annual energy costs ($, which includes peak demand and hence sizing) or GHG, or all three?).
Participant 19	Yes
Participant 20	Yes, but manually using excel
Participant 21	yes
Participant 22	Yes
Participant 23	Yes.
16) Is it easy to simulate a renewable energy system integrated with the project in the simulation tools you use?	
Participant 01	Yes
Participant 02	No, I'm using other software since the software I'm using is not visual.
Participant 03	No - and it doesn't need to be.
Participant 04	Relatively yes.
Participant 05	Yes with TRACE3D you can integrate renewable systems
Participant 06	Yes
Participant 07	Depending on the renewable energy system
Participant 08	I've never tried
Participant 09	yes
Participant 10	Yes
Participant 11	Solar, yes. All others, no.
Participant 12	yes
Participant 13	Yes

Participant 14	Yes, but I'd probably just use PVWatts instead because it's so much easier unless I was doing a detailed cost or time of day study.
Participant 15	yes.
Participant 16	
Participant 17	yes
Participant 18	Pretty much. Complex grid interaction (e.g. storage, complex tariffs) is often a challenge.
Participant 19	Yes
Participant 20	No, I use PVWatts instead
Participant 21	yes, but hard to size etc at early phases we find.
Participant 22	Yes
Participant 23	Easy is a relative term, but I do not feel limited in this regard - Yes.
17) What are the current possibilities and limitations of the simulation tools you use?	
Participant 01	Too broad a question
Participant 02	No dayliglighting analysis, no natural ventilation analysis, LCA is missed
Participant 03	possibilities - more adoption of design-phase/design-assist analyses limitation - not enough adoption of above
Participant 04	This question is too vague however.
Participant 05	the energy simulation programmer depends on the king of results you are looking for, but no one of the ones that I use do CFD
Participant 06	Operations - Use behavior - controls
Participant 07	As I said before, there are some lacks in the implementation of components: materials, thermal systems and renewable energy systems
Participant 08	Possibilities are; it gives an opportunity while modelling and it is easy to use process of transferring data with other BIM tools. Limitations is; dificulty of modelling tools and
Participant 09	Limitations: Occupancy, plug load, daylighting analysis (trnsys17)
Participant 10	Very difficult to model high performance sequences of operations and equipment performance accurately.
Participant 11	Cannot use renewable tools other than solar or passive building architectural features. VRF systems just added in latest version. Chilled beam and radiant options need work arounds.
Participant 12	Large complex projects are slow to simulate, which slows down feedback to architectural design team.
Participant 13	So many
Participant 14	

Participant 15	In my opinion, energy modeling tools lie on a spectrum where on the one end are tools that have a great deal of flexibility but which require the user to have a high level of expertise and to know a lot about the design and controls of the system being modeled. On the other end are tools that offer little flexibility but which can be used by modelers who have less expertise and who know only a few details about the project. The tool we use is squarely on the "flexible but complex" end of the spectrum. It has comparatively few limitations but requires a high degree of expertise to use it.
Participant 16	
Participant 17	
Participant 18	Too many to list. I'll have to pick one: Input definition and quality assurance (e.g. who in the design team is responsible for what, systematization, steps taken to ensure quality control, easy & independent verification).
Participant 19	We primarily use EnergyPlus directly because it is the most state-of-the-art simulation engine with ongoing support and development. If we need to use an EnergyPlus interface, we prefer DesignBuilder over OpenStudio because it has much more features and is easier to use. Both DesignBuilder and OpenStudio offer scripting options to automatically alter models, which is a huge benefit for our parametric analysis work.
Participant 20	They are still complex, hard to use, hard to conduct uncertainty, sensitivity, and multivariate analysis.
Participant 21	
Participant 22	limitations on the description of new technologies
Participant 23	Struggling to answer this... "What are all the things which the tools I use can and cannot do?" I cannot write a succinct response to that and need a more specific prompt, sorry.
18) What are your future expectations for the development of building energy simulations for usability?	
Participant 01	Automation
Participant 02	Fully integrating the simulation with BIM.
Participant 03	BIM to BEM across all simulation tools
Participant 04	This question is too vague however.
Participant 05	more interactive with BIM and BMS
Participant 06	BIM integration
Participant 07	I hope that all these lacks will be solved
Participant 08	Opportunity of .EPW file generation and less error while data transfer from BIM tools.
Participant 09	integration of AI

Participant 10	Integrated and interoperable with design tools. For example, BIM tools should pull all relevant input data and equipment performance data, template operating schedules from building type directly from a BIM tool as the design progresses in real time. Energy and performance modeling should be in real time and automatic - parametrically driven by design tools. They should not be standalone analytic tools that require duplication of input separate from design efforts.
Participant 11	Simple, inexpensive, online tools. No Energy Plus mysteries and difficulties. I worked DOE2 since 1984, and welcomed the ease of eQuest when developed.
Participant 12	Better integration for Revit and arch tools to reduce energy model building overhead.
Participant 13	Depends
Participant 14	
Participant 15	improved passage of data from one simulation tool to another so that the tools appropriate to predesign and early schematic design can pass their data on to the tools that are more appropriate for design development, retrofit, fault detection, etc.
Participant 16	
Participant 17	
Participant 18	Looking forward towards NREL's efforts in streamline EP for small scale residential ... that may solve a whole bunch of related issues for small scale existing commercial buildings.
Participant 19	I expect/hope that someday, building energy simulation tools will have better interoperability with BIM tools (Revit, e.g.). Currently, there is a process of exporting a file (gbXML, e.g.) from a BIM tool and then importing that file into a building energy simulation tool. The imported file usually has issues that requires the energy analyst to address, or start the model from scratch if there are too many issues.
Participant 20	Expected to have more integration with Intelligent Decision Support Systems, that was my MSc thesis actually
Participant 21	
Participant 22	a better connection with BIM software's, more flexibility
Participant 23	I hope the developers of today's energy simulation platforms will grow to embrace "modeling broken states." Very little of what has been developed for rigorous hourly simulation provides for directly simulating real-world situations which I regularly must calibrate to, such as coil valves in stuck positions.