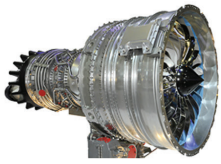
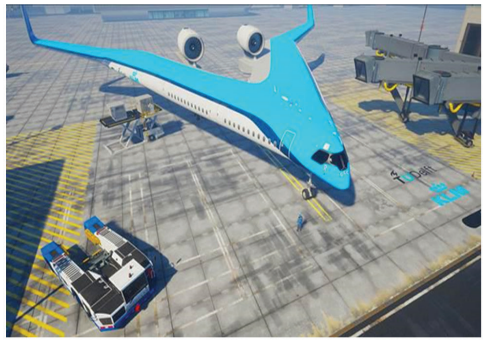
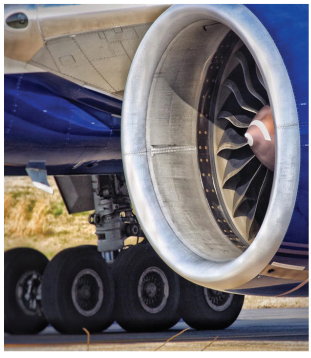
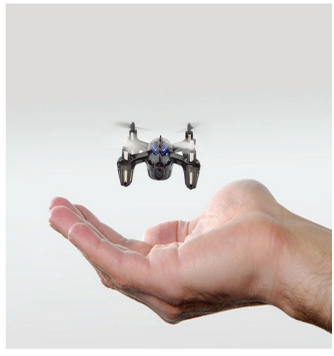
INTERNATIONAL INNOVATIVE APPROACHES IN ENGINEERING & TECHNOLOGY









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PREFACE

International Innovative Approaches in Engineering & Technology

Technological improvements in engineering and science have been developed very fast. For Guven Plus Group Limited Company, most important part of the publication comes from academic books that have gained quite good prejtice due to doing national or international scale of job. The book printed out by Guven Plus Group Lt. called ".International Innovative Approaches in Engineering & Technology "consist of 10 Chapters with manys scientific articles covering experimental, theoretical, analysis and evaluations. They have discussed their results with participants people.

They have included many interesting topics/titles such as "bor minerals from sources to end use", "effect of carbon nano tubes on mechanical properties of polymeric composites"," surface completeness for ostenite stainless steel as an implant material", "improvements of heat-treatment process for Al7075 alloys"and,"prediction of tribological behaviour on some polymeric materials" etc. many other important topics also will be found out in this book. Each of this section in the book, academicions/researchers have prepared with own contributions and consists of original study.

Many interesting topics and subjects regarding Enginnering Technologies have been discussed in this book, which will be light for academicians and researchers. In addition, it will also replace for catalogue of Higher Education Institute (HEI), other institution's libraries and individual's archieves.

We wish to express our thanks to our authors, rewievers of these papers for making them available, technical teams for assisting me in making ready for printing the book.

Prof. Dr. Yusuf ŞAHİN
Assist. Prof. Senai YALÇINKAYA
December, 2021

ENERGY MODELING FOR BUILDING DESIGN

Hamdi Levent KOÇALİOĞLU[1], *Ayhan ONAT*[2]

Abstract: Buildings account for roughly 40% of primary energy use and 70% of overall electricity use and are frequently identified as a key target for reducing carbon emissions. New and existing buildings energy efficiency can be improved in a variety of ways, and energy models can be used to compare different strategies. Building energy modelling (BEM) is the process of analyzing a building's annual energy consumption using a computer-based simulation tool by enacting a numerical model of the building. A single building simulation can take seconds to hours to complete, depending on the level of detail and complexity of the analysis. BEM has several advantages for both new construction and retrofit projects. In new construction projects, BEM can be used to compare energy-efficiency options and assist in the finalization of design decisions for new construction buildings. In retrofit projects, it aids in optimizing the efficiency of existing buildings and evaluating retrofit options. The engine of any modeling software drives its performance and functionality. While many modeling programs use the same engine, each has its own interface, giving it a unique look and, in many cases, design and modeling options. The US Department of Energy's DOE-2 and EnergyPlus engines are the most widely used. While DOE-2 is more widely used and industry accepted, EnergyPlus is newer and has more features. The IES Virtual Environment uses Apache SIM, a newer entrant in the building energy use analysis field. The energy modelling output is generally as accurate as the input data used for the thermal model. Thus, simulation accuracy is dependent on dynamic input parameters like occupancy and weather data, which are difficult to model accurately, especially early

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in the design process. The weather data used in the simulation has a big impact on the outcome.

Keywords: Building Energy Modeling, Building Performance Simulation, Building Energy Modeling Softwares

INTRODUCTION

Buildings account for roughly 40% of primary energy use and 70% of overall electricity use and are frequently identified as a key target for reducing carbon emissions. Improving the efficiency of building design has become a significant strategic effort for the entire industry. Building energy modeling has been recognized as a critical tool for enhancing the design of energy-efficient buildings.

Building Energy Modeling (BEM) is the process of analyzing a building's energy use using computer-based simulation tool. The simulation tool operates through a numerical model that presents a building's thermal model. External weather conditions, orientation of the building, building's geometry, construction materials, user schedules, and HVAC system equipment will all be input into the building model by an energy modeler. The calculation engine solves thermodynamic and building science equations. Based on required complexity level of the analysis, simple energy simulation runtime can be a couple of seconds or even hours to complete. The building's zone heating and cooling loads, several systems energy use and costs breakdown, natural daylight mapping, and other significant energy and occupant comfort related parameters are typically reported for annual performance. Figure 1 shows an image of typical workflow of building energy modeling process.

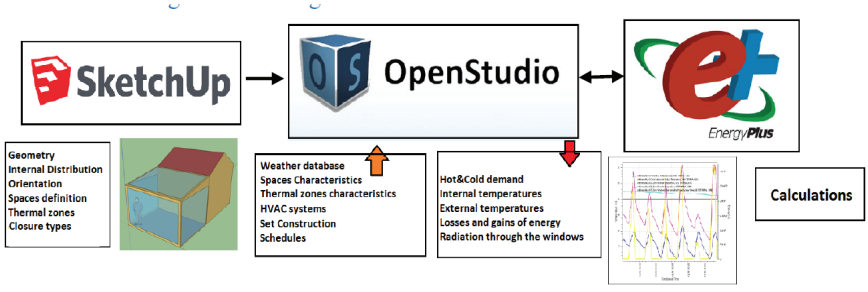

Figure 1. Typical Building Energy Modeling Workflow

Prior to construction, BEM can be utilized for comparing energy-efficient design options and help to finalize design decisions. It also assists existing buildings in maximizing their efficiency or evaluating retrofit options. BEM incorporates building performance simulation and comprehensive equipment study using specific tools for indoor air quality, daylighting, occupant comfort, and natural ventilation. Figure 2 illustrates an example of 3D representation of buildings' thermal model created in DesignBuilder software.

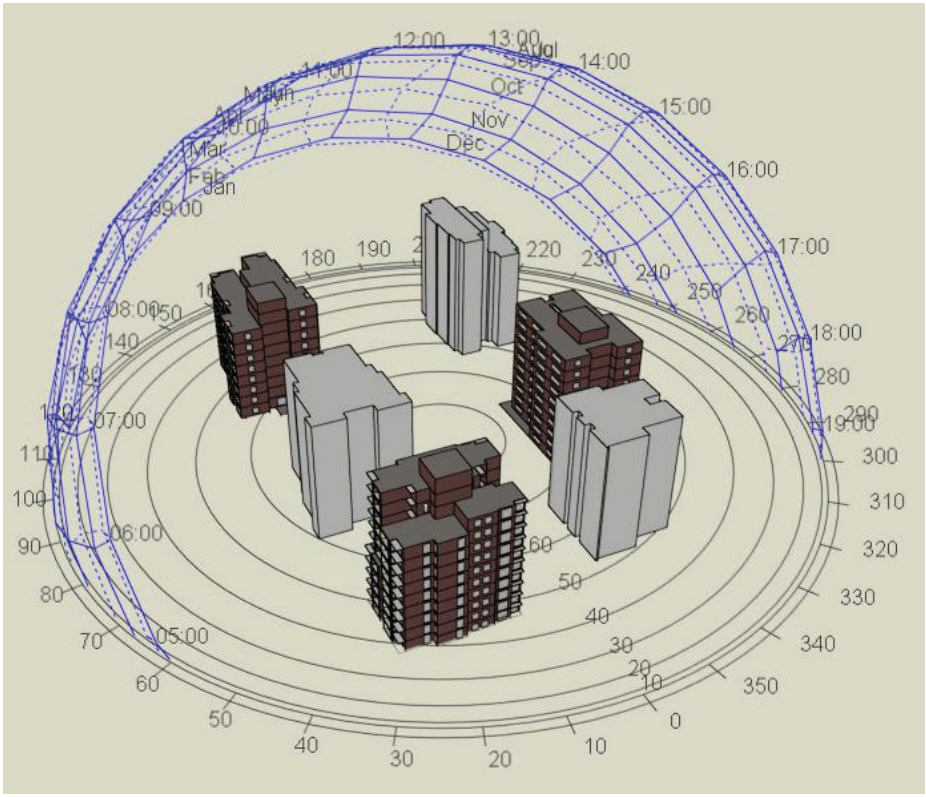

Figure 2. Typical 3D Representation of Buildings

The majority of whole-building simulations include:

- *The geometry of the building, the floor plan, the construction materials, elements, and systems*
- *Typical weather data for the location*

- *Heat transfer, both instantaneous and delayed*
- *Divided thermal zones for building*
- *Day, week, and season variations for occupants, interior and exterior lighting, receptacle equipment, thermostat setback and setpoints, and operation of HVAC systems*
- *End-use Breakdown of Each Energy System*
- *Cost Breakdown of Each Energy Type*

What are the Benefits of BEM?

BEM has several advantages for new design and existing building projects. BEM, for instance, aids in the development of an integrated design process (IDP). Project stakeholders establish and agree on outcome-based goals through IDP. BEM provides the team with the information they need to make critical, cost-effective design decisions which mostly includes both initial cost and total operation costs for a year. The cost of energy modeling is often a small additional increase in total budget, but it could result in effective cost savings. When it comes to energy efficient building design, system integration, and renewable energy, quantifying performance tradeoffs could help an owner maximize their return on investment.

In general, BEM can be useful for a project in three different purposes.

Lower Initial Costs

BEM can lower a building's initial cost by including effects of thermo-physical properties of of building materials and controlling systems holistically to optimize them and properly sizing zone, system, and plant equipment. Additionally, BEM can also significantly minimize project change orders. Moreover, BEM can be useful for providing the necessary evidence in order to apply for incentives programs.

Lowering Operating Costs

BEM can help to save money on building's annual operating costs by allowing to compare different operation and control alternatives

which are affecting energy use. In addition, BEM could aid life cycle assessment by selecting efficient materials/systems which might be costly up front yet reduce significant energy and maintenance costs in the long run.

Improved Occupant Comfort

BEM can assist in identifying ways to make employees more productive while reducing absenteeism. Improved occupant comfort has been linked to enhanced building envelope, appropriate fresh air rates, maximized use of daylighting, and personal equipment operation and control, according to research. BEM presents large sets of data to improve thermal comfort for occupants.

Another use of BEM is monitoring and informing existing buildings control and operation. Facility managers can identify performance gaps through comparison of BEM outputs with building actual utility bills. To ensure that everything is working properly, BEM can be used for benchmarking to make comparison for HVAC system energy use. Performance gaps can be resolved with revealing those gaps in optimum operational period to make adjustments for enhancement.

What is the Purpose of BEM?

Facility managers are increasingly recognizing the value of BEM through retrofit opportunities with guiding energy efficiency measures decisions, so it's becoming more common to include it in building energy efficient retrofit projects. Additionally, BEM might be necessary to show compliance with energy use improvement from baseline buildings in several certification rating systems.

BEM could help to achieve wide range of goals. The applications are divided into three categories based on their general modeling purpose: comparing, complying, and predicting. There are several parameters (purpose, complexity, scope) that can all be influenced by the underlying goal. Understanding the differences between efforts can assist defining the project modeling scope and securing the services required.

Comparison Model

Most modeling efforts rely on BEM to compare energy efficient design options for zone, system, and plant level equipment. Performance comparisons are almost always included in the process.

Comparing performance allows the design team to compare and contrast different design concepts quickly. For example, simulating specific glazing types to see how they affect several key parameters such as heating and cooling load demand, lighting systems energy use. Energy efficient options may be combined to understand harmonious effects for reducing the need for air conditioning, using passive measures, and decrease initial costs.

The goal of creating baseline case for potential savings prediction can be guiding design decisions. As a result, a modeler may concentrate on characterizing important items in detail while relying on standard values for less-important items. Figure 3 shows a graph comparing actual annual energy use with simulated annual energy use.

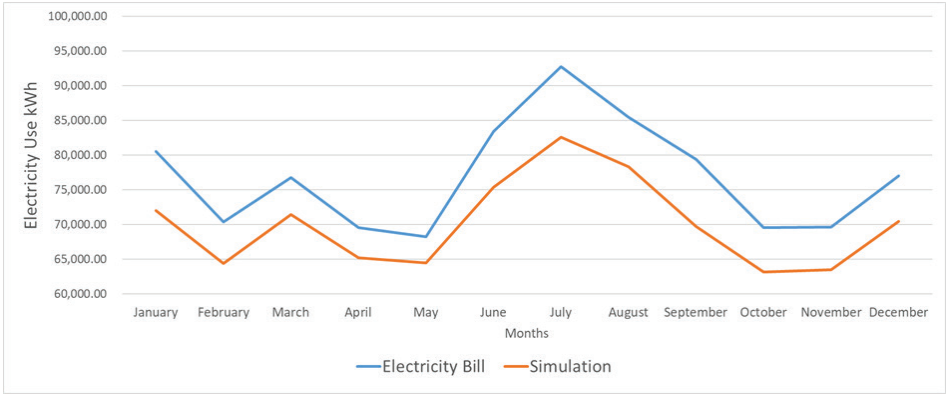

Figure 3. Graph Comparing Actual Electricity Use with Simulated Electricity Use

Compliance Model

The proposed and baseline case models are two models to make a comparison analysis for energy performance as part of compliance modeling. The baseline case is a building that ensures code compliance program's reference standard.

For instance, the Leadership in Energy and Environmental Design (LEED) program of the United States Green Building Council (USGBC) awards performance credits over to a baseline case costs. The ASHRAE 90.1 Standard serves as the LEED reference baseline. The energy model must be in compliance ASHRAE 90.1 Appendix G to create the base case model. Many of the base case model input parameters, e.g., climatic region, building construction area, and building height are dependent on design model details; while other data inputs, e.g., zone, system, plant equipment minimum efficiency requirements, are documented in the 90.1 Standard Appendix G. Even if LEED modeling's ultimate goal is certification, it can also be used to compare design options. As a result, both comparison and compliance scope should be included in the certification modeling effort.

Prediction Model

Energy models that incorporate utility bills data sets can depict the building's current energy use and anticipate the renovated building's energy use. Developing a complex detailed model requires time and effort. Several building systems, such as lifts, escalators, and large exhaust fans, must be added in energy model, although those systems will remain constant throughout design variations. Additionally, the model must incorporate current occupant and HVAC system operation profiles, which might be challenging to get even while the building is operational. Furthermore, the model's weather data input must be relevant to its location.

The majority of building energy modelling inputs start with common occupancy patterns, and ideal operation of building HVAC systems. However, there might be unexpected problems during construction, such as improper installation or control sequence of HVAC system. Therefore, for parameters that are unknown during design, the latter must rely on assumed input values. However, after full occupancy completed and utility bills data gathered, building energy model calibration can be performed for those outputs.

Making direct connection between design and operation can give valuable feedback to project teams. This contributes to mutual understanding of energy efficient design and alternative solutions. Moreover, elements that are underperforming can be identified and corrected using the performance gap analysis between calibrated simulation model and final construction model.

Building Energy Modeling Types and Uses

The performance of a proposed model will be compared to baseline model in terms of annual energy use and costs. In both models, number of operational assumptions will be identical (e.g., climate zone file, occupancy schedules). When compared to the baseline model, the model results will be expressed as energy and cost reduction for proposed model. This method is best for determining energy reduction target prior to design development. Prediction of energy performance will provide numerous expected results to make energy efficient design decisions and through that sensitivity analysis can be performed. The level of model accuracy associated with the chosen inputs will ideally decrease in design deve progresses. The system methodology works well for establishing comparison levels when utility bill data collected, and full occupancy completed. The most unpredictable input to any building simulation is the use and behavior patterns of the occupants.

The Energy Model as a Comparative Tool

Throughout the design process, modeling can help the project team. Multiple design alternatives can be compared side by side for a quick and low-cost assessment for several alternatives. Design decisions have a wide range of consequences that aren't easy to predict. The cross effects between building thermal properties and HVAC systems control and operation can be analyzed and quantify with reliable building simulation modes. In general, a computer simulated analysis is required to complete a cost-effective analysis of a design decision.

The Predictive Energy Model

The annual energy use and costs of the building will be estimated using a predictive energy model. This data can be helpful with cost assessment of life cycle and renewable energy systems. If the project team wishes to use modelling outputs, there should be an integrated discussion among project teams. Standard energy modelling comparative analysis frequently lack the details and cost schedules needed to accurately forecast future costs.

Life Cycle Cost Analysis

Life Cycle Cost Analysis (LCCA) is a methodology for assessing building's economic performance over its whole life. Occasionally referred to as "whole cost accounting" or "total cost of ownership,". LCCA represents a compromise between the initial financial investment and long time period of building's operating costs. Initial investment cost, operating costs, short- and long-term maintenance costs are included in the analysis. Inflation and projected fuel cost adjustments are also taken into account by the LCCA. While the initial capital costs are significant, they are not able to reflect a complete image. Powerful energy modelling output will be useful to adjusting project's budget and performing fine-tuning of design decisions.

Modeling Documentation for Building Rating Certification

Numerous green building rating systems involve building energy modelling documentation to receive points for reduced energy consumption over a baseline. Under the USGBC's Leadership in Energy and Environmental Design rating system (LEED) criteria, point allocation for the primary energy credit is based on a building energy use and cost comparison over a code-compliant reference building. LEED define reference model based on ASHRAE 90.1 guidelines. There is no necessitates for the use of any specialized software. However, ASHRAE 90.1 has some specific performance prerequisites for building modelling tools.

Measurement and Verification

The term "Measurement and Verification" (M&V) refers to the process of planning, measuring, collecting, and analyzing data in order to verify and report energy savings for an individual building. After full occupancy has been completed, energy models are constructed for measurement and verification. The model is built using actual equipment and building systems, and the energy use outputs are analyzed to actual utility data measurements. Because the true energy performance of the building is known, modelling for measurement and verification process typically involves calibrated energy model with adjusted several inputs, most notably for the building's actual operational conditions, until the modeled energy consumption matches the actual measured data. Once calibrated, the model can be used to estimate the cost savings associated with various measures and can normalize for the input data variation in HVAC system operation and climatic properties, for example. In case of the energy use isn't within the expected range, it's possible that the equipment isn't calibrated correctly or isn't working properly. If problems are discovered, additional tracking can be used to ensure that the problems have been resolved.

Asset Evaluation

An asset evaluation uses a building energy model to assess the physical attributes of the building based on the components specified in the design (such as mechanical systems, building envelope, orientation, etc.). A few states in the United States are requiring such an assessment at the time of sale or lease. There are programs in place in the United Kingdom and Europe that require an asset rating. The asset evaluation must be compared to some benchmark performance standard in order to obtain an asset rating. This benchmark could be the ASHRAE Standard 90.1 baseline model, or a standard prototypical building developed by the US Department of Energy's Commercial Building Benchmark Model project.

Energy Modeling Throughout the Design Process

Energy modeling should be used to assist in integrating and optimizing the energy performance of a building during design process. Furthermore, it requires early evaluation of system solutions among different disciplines in order to develop the best-fit solutions for the developing design, thereby avoiding drastic design changes late in the design phase. Figure 4 shows an image of synthesis of several factors for integrated design.



Figure 4. Integrated Design Synthesis

Throughout the construction process, there will be several consultants using early/late design model to understand and analyze the constructed site conditions. Following stages explain the necessity of energy modeling and the measures that must be taken during each design phase.

- *Predesign*
- *Schematic Design*
- *Design Development*
- *Construction Documents*

Energy efficient design should be considered with every decision in order to construct high-performance buildings. Benefits in energy efficient design are rarely achieved through a single big idea; rather, they are achieved through the combination of a hundred small ideas to achieve high performing buildings. A room with a light color partition walls and ceilings, for example, can influence how well it receives natural light. Reflection of more light from those components can be combined with proper daylighting sensors, could support cutting down on required lighting energy use. Partition walls color decision generally chosen at the end of the design development phase and if not properly coordinated with the energy model, they can have unintended consequences.

Pre-Design and Conceptual Design

At the conceptual and schematic stages of design, energy modeling can be extremely useful. Most of the data gathered through energy modelling could be used to aid project's design team during the preliminary stages for little to no cost. Changes become increasingly costly and difficult to implement as the design progresses. The energy model outputs can ensure that everyone on the design team is on the same page.

Building energy modelling can be used for analysis of climatic and environmental factors during the pre-design and conceptual design stages. Those factors reviews are necessary for developing building position and type of space use which are compatible to surrounding boundaries. Large sets of climatic inputs can be transformed to single reference data file and extends using a variety of modeling software packages. A wind rose and dry bulb temperature floodplot weather study for an entire year for Antalya are shown in Figure 5 and Figure 6, respectively. Those data give quick overview for project's site weather properties.

Energy modelling facilitates the start of discussions among project teams to consider energy efficiency targets. Create energy use intensity targets and improvement goals using the energy model.

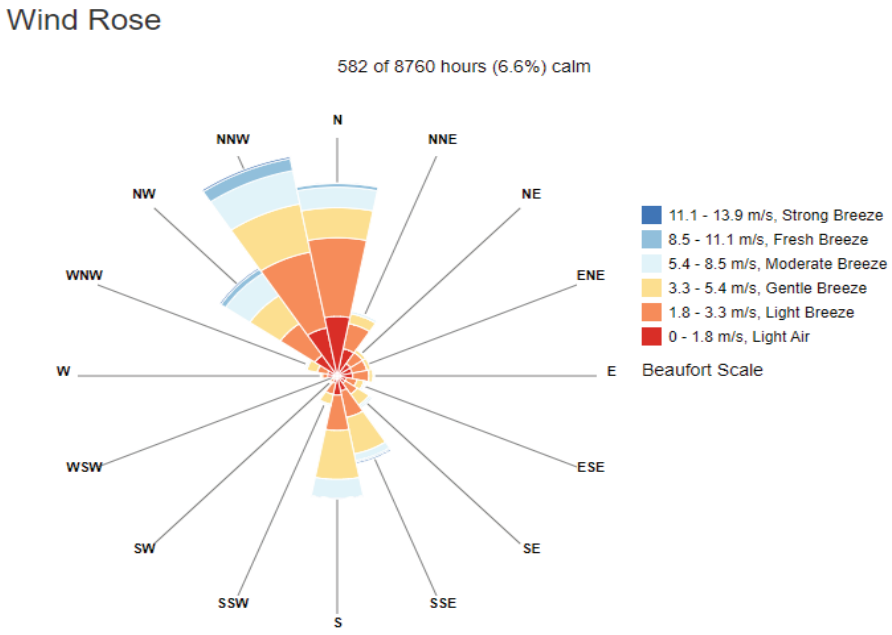

Figure 5. Wind Rose- Annual Wind Speed Changes

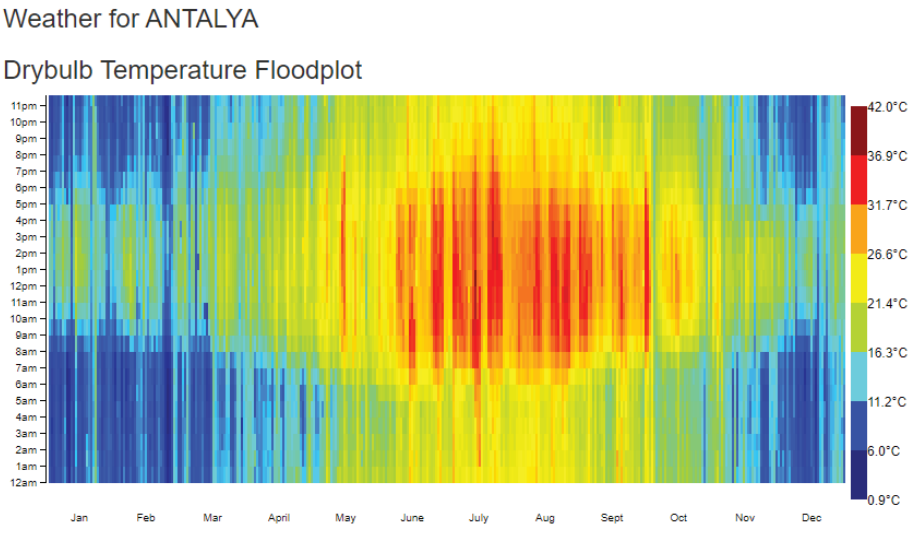

Figure 6. Dry Bulb Temperature Floodplot Through the Year

There are several ways that collected data can assist to design phase.

Climate Awareness:

- *Wind Direction*
- *Variations of Outdoor Temperature*
- *Analysis of Solar Radiation*

Occupant Comfort:

- *Space Temperatures*
- *Outdoor Air Rates*
- *Space Light Levels*

Operation Profiles

- *Assess Energy Efficient Design Alternatives*
- *Targets for Energy Use Intensity*

Schematic Design

At the schematic stages of design, energy modelling could help design team to evaluate several concept alternatives. Alternative room layout, window distribution, location of main heating and cooling plants can be designed and positioned. Even though those arrangements might develop to be mainly practical, they could all have an impact on the occupants' energy use and comfort on that modelling can aid to finalize. For the model outputs, for example, adding more insulation material might bring extra initial cost that results in lower operating costs year after year, also lower HVAC equipment costs might be cover additional costs of insulation. The design concepts of the selection of the equipment can be discussed in the latter stage. Choosing an energy efficient design option to use must be done at the early design stage and then, starting a discussion on energy efficient design ideas. Figure 7 illustrates an image of pedestrian comfort level analysis created for visualization of wind speed for a high-rise building.

Energy modeling during schematic design can optimize and analyze:

- *Building Envelope*
- *The Form of The Building and Orientation*
- *Selection of HVAC Alternatives*
- *Zoning Strategies*
- *Daylighting Analysis*
- *Natural Ventilation Possibilities (Figure 8 shows CFD Analysis for Natural Ventilation)*

Energy modeling during schematic design key findings:

- *Peak Energy Demand*
- *Energy Use*
- *Thermal Comfort*

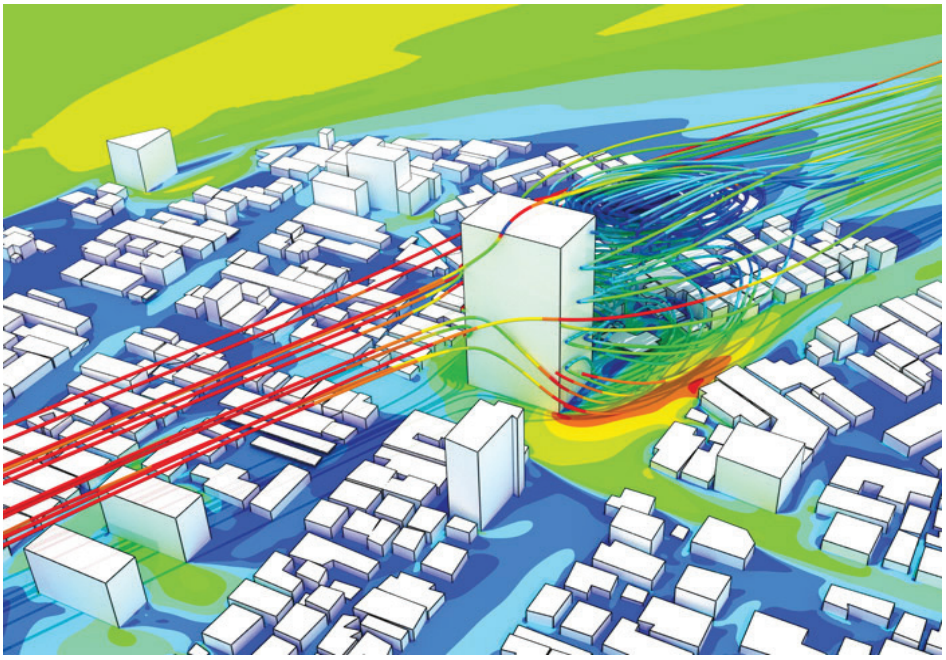

Figure 7. Pedestrian Comfort Level Analysis

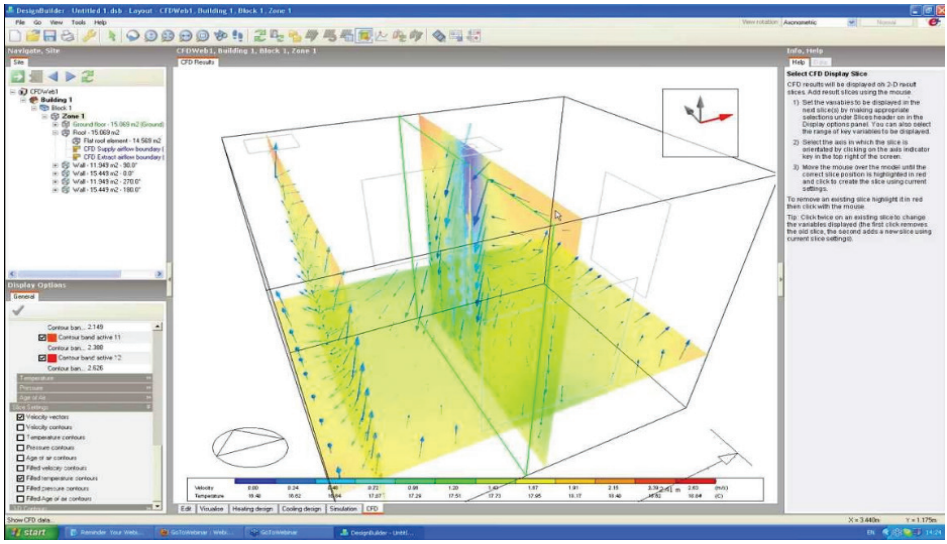

Figure 8. Natural Ventilation Analysis

Design Development

The building configuration and systems are refined during the Design Development phase. During this phase, project members continue to discuss key performance necessities for building envelope and glazing, daylighting zones, and shading element devices. All of these decisions can be aided by a robust energy model.

Analysis of Design Development Stage

- *Optimization of Building Walls and Fenestration*
- *Integration of Lighting Automation with Daylighting Sensors*
- *Integration of Mechanical Controls Systems*
- *Selecting Optimum HVAC System*
- *Energy Recovery Identification*

Construction Document

At the Construction Documents phase, energy modelling could help setting of heating and cooling design temperatures which directs zone level equipment sizing. Prior to construction, design team can optimize

HVAC system constant fan power, setback temperatures, and a variety of other settings. Parametric assessment can be performed by most of the modelling software that involves simulation runs for several parameters on minor changes to analyze project's targets like energy usage intensity, and load levelling strategies.

Performance Documentation

Simulate and compare methodology between proposed versus reference building models can be used to validate building performance. Hence, the project team is able to:

- *Evaluate the effects of construction changes*
- *Create documentation for LEED rating systems*
- *Support building recommissioning*
- *Verification of building performance as intended for below factors:*
  - *Air changes per Hour*
  - *Building Operation Profiles*
  - *Heating and Cooling Equipment Setpoint and Setback Temperatures*

Modeling Results and Technical Reporting

The Energy Simulation documentation provides a brief overview of the project's current energy effectiveness by key performance metrics. Each modeling report should include the following information:

- *Detailed Zone Level Equipment Summary*
- *Summary of Data Inputs*
- *Proposed List of Energy Efficient Design Parameters*

Designers can use the energy modelling data input summary and confirm that they are identical to project's system and equipment. A computer-based simulation can only work properly if its users input the correct data. Simple simulation reporting could present a parametric analysis to show cost effective design alternatives of adding one more layer to the external wall or upgrading current design heating system to highly efficient heat recovery equipment.

The simulation results report is perhaps the most important modeling summary. A quick review of the several building system's end-use breakdown of energy can be seen in this report. This information will be provided for both the proposed and existing designs, as well as any alternative designs that are being simulated. Most of the time, a baseline model generation is the first step for the preparation of a reference to compare design alternatives in order to find energy use or demand reduction. Building rating system certifications, and other documentation frequently require baseline models.

Most of the modelling report-based suggestions could include major changes to orientation of the building and methodology of construction early at the design process. Energy efficient design options must be concentrated on building envelope properties, passive and active measures for HVAC system, and system's sequence of operation in later design phases.

Important Modeling Outputs

- *Cost of Energy (Annually)*
  - *Electricity, Natural Gas, Chilled Water, etc.*
- *Use of Energy (Annually)*
  - *Heating, Cooling, Lighting, Pumps, Fans, DHW, etc*
- *Electricity and Natural Gas Demand*
- *Specific Energy Use (kWh/m^2)*

Energy Modeling Software

Building energy modeling program simulation engine is the most essential part of the software that solves mathematical models of the building elements, equipment, and so on 8760 times (one for every-hour), usually through a sequential process. Common results include annual energy consumption, annual energy cost, hourly profiles of cooling loads, and hourly energy consumption. Majority of software using similar simulation engines for modeling options. Both of DOE-2 and EnergyPlus, created by United States Department of Energy, are the most

widely used engines. DOE-2 has gained industrial recognition, while EnergyPlus has recent development with more features. Apache SIM, which is used in the IES Virtual Environment, is relatively new software product in the market. Apache SIM aims to provide a platform for evaluating all aspects of thermophysical properties of building envelope and HVAC systems control integration. On the other hand, Radiance can model daylighting potential and available for informing specific design considerations. Figure 9 illustrates an image of several energy modelling software programmes.

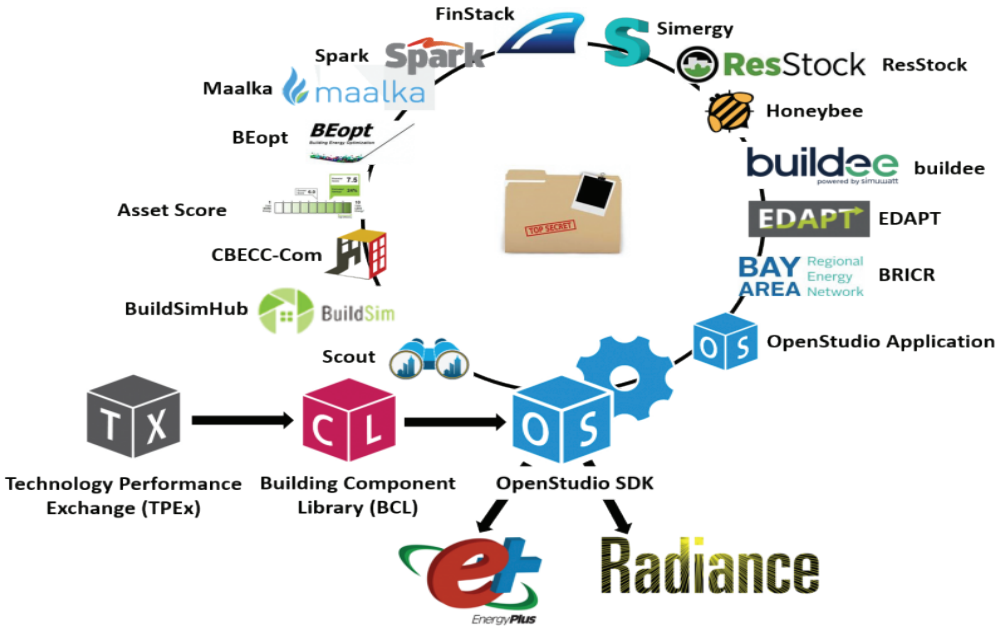

Figure 9. Energy Modelling Software Programmes

CASE STUDY

The building energy modeling study has been completed for a 5200 m^2, 10-floor residential building in addition to one basement floor mainly for technical areas. The general building information is provided in Table 1 for case study. Additionally, the building has reinforced concrete building with filled in brick walls and without heat insulation. The fenestration of the building consists of aluminum frames without ther-

mal break and double-pane clear glass with U-value of 2,4 W/m^{2}K. The building includes residential units, corridors, and common associated areas.

The analysis tool chain is shown in the following Figure 10. Design-Builder is used to create full three-dimensional architectural models that are then exported to EnergyPlus (v9.4) as an input file, which is used for analysis of both the existing and proposed designs reported here.

3D Architectural Model

Preliminary modeling and anaylsis

Existing & Proposed Design energy modeling, parameter definition and detailed analysis



Figure 10. Analysis Tool Chain

Table 1. Case Study Building Summary

General Information		
1	Building Area	5,200 m^2 (Residential Units: 3,700 m^2 Core Areas and Corridors: 1500 m^2)
2	Building Type	Residential Building
3	Location	Antalya
4	Climate Zone	ASHRAE 3A
5	HVAC system	Heating System: Natural Gas Fired Condensing Boiler Cooling System: AC split units No mechanical ventilation
Details of Energy Efficiency Measures		
1	Building envelope specific measure (solar control low-e glass and exterior wall and roof insulation)	
2	Highly efficient air conditioning units with SEER 5.6	
3	Efficient LED lighting systems	
4	External shading element design for windows on south façade	

Figure 11 shows typical building architectural floor plan for the case study building.

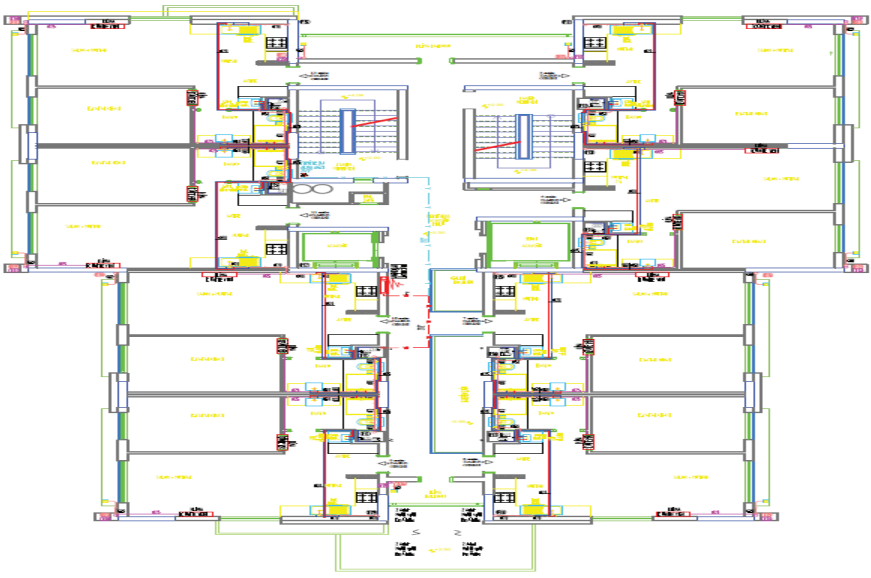

Figure 11. Case Study Building Typical Floor Plan

3D Thermal model is generated from building architectural drawings can be seen from Figure 12 and Figure 13, respectively.

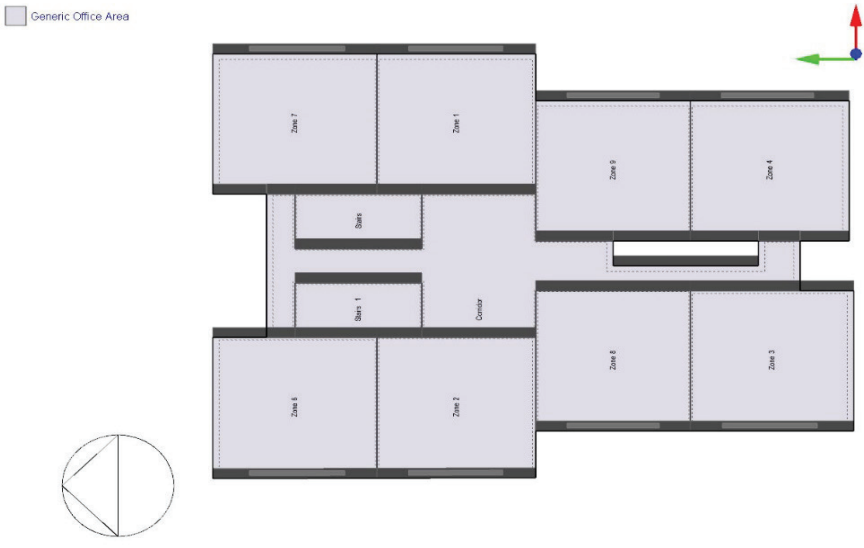

Figure 12. Case Study Building Thermal Model Typical Floor Plan

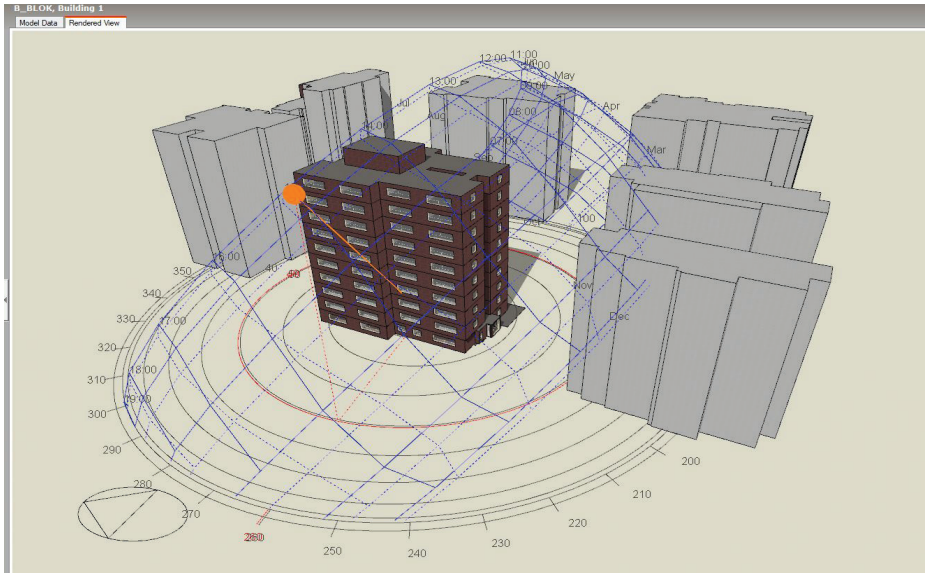

Figure 13. Case Study Building Perspective View

Methodology

A whole building energy simulation has performed for showing annual energy performance improvement compared to the existing building performance through proposed energy efficiency design measures.

Data Collection

The computer-aided design (CAD) drawings of the site, floor plans of the building and section details has provided for developing thermal model. MEP consultant has provided details of proposed design for lighting, envelope, and HVAC systems.

General Building Model

By following the modelling guidelines and evaluating each simplification methodology carefully, in order to avoid any significant impact on simulation results, a representative thermal model of the proposed building has prepared as shown in Figure 14.

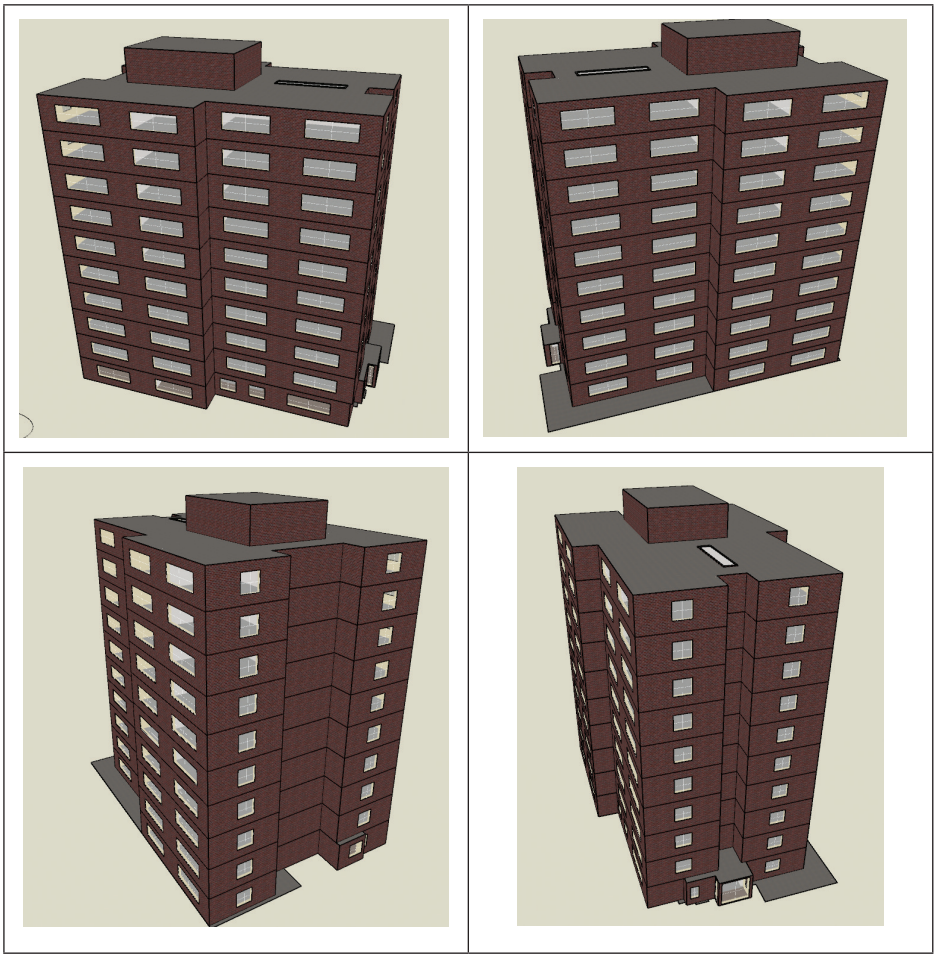

Figure 14. 3D Views of Building Thermal Model

The same methodology has applied for zoning while going through the floor plans. Briefly, both proposed and baseline models comprise of 79 conditioned and 37 unconditioned zones, simplified to enhance speed of the simulation runtime. Thermal model's basement floor and typical building floor can be seen in Figure 15.

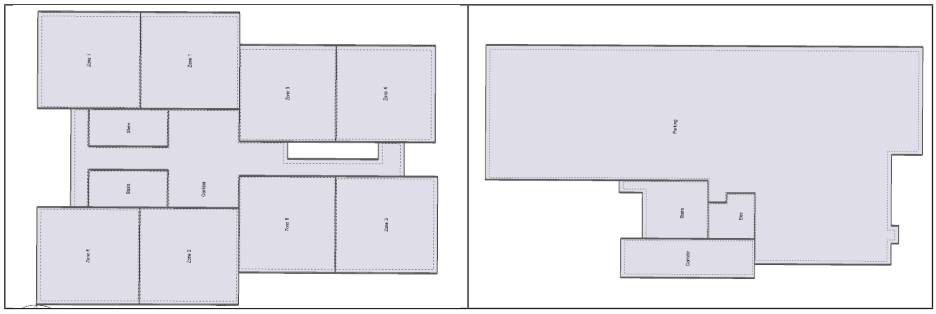

Figure 15. Plan Views for the Thermal Model

Climate and Site Data

The project's location defined as Antalya with required geographical data and can be seen in Figure 16.

The project's climate zone is climate zone 3A. The weather data file used in the simulation is "ANTALYA - TUR IWEC2 WMO#=173000" weather data file. A plot of the dry bulb and wet bulb temperatures from the climate data is provided in Figure 17.

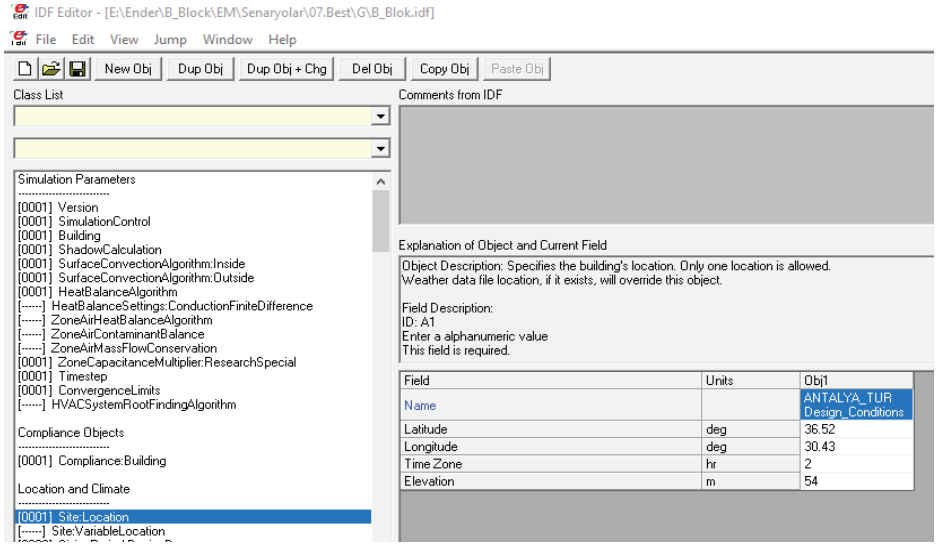

Figure 16. Energyplus Input File Site Location

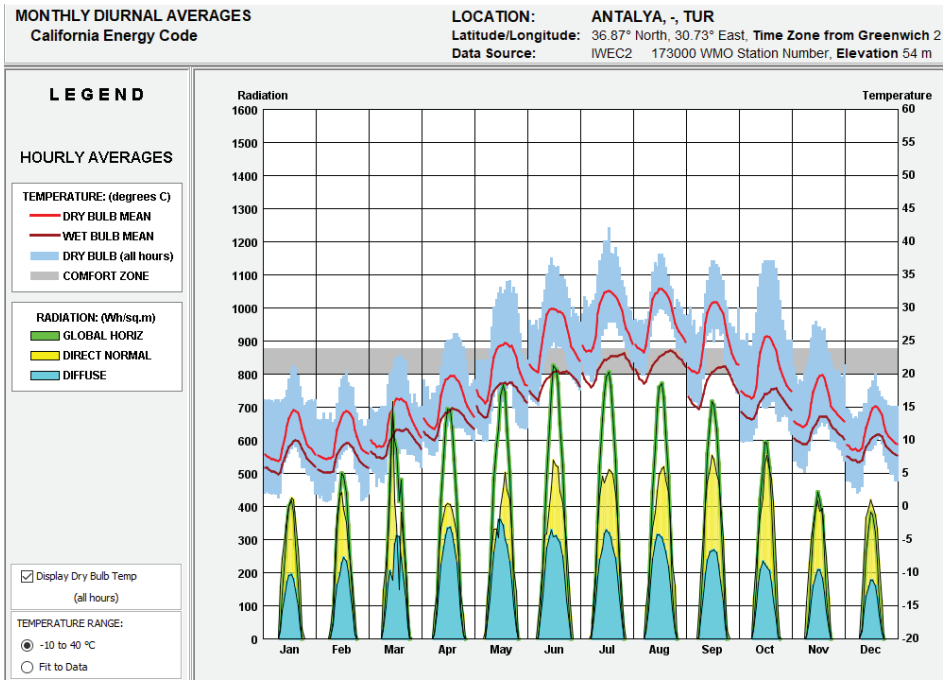

Figure 17. Ambient Dry Bulb and Wet Bulb Temperatures

Schedules

In performing computer simulation of building, schedules/profiles need to be defined and assigned to parameters such as:

- *Occupancy / people*
- *HVAC plant operation*
- *Interior lighting*
- *Interior equipment*
- *Infiltration*
- *Thermostat Setpoints*

In defining these schedules, a usage percentage is allocated on hourly basis, covering all 24 hours of a day and accounting for every single day of the year. The schedules/profiles used in the computer simulations are based on project's specifications and the same schedules/profiles are used in all computer simulations. Information about HVAC sys-

tems, lighting systems and operation hours are received from building facility manager and have used for building energy modeling analysis.

Existing Building Envelope

The existing building envelope and fenestration parameters are described in Table 2.

Table 2. Existing Building Envelope Detail

	Building Component	Detailed Explanation
Building Envelope	Roof	U = 0.450 W/m^{2}K
	Slab-On Grade Floor	U = 0.620 W/m^{2}K
	Walls	U = 0.700 W/m^{2}K U = 1.100 W/m^{2}K
	Glazing	U = 2.40 W/m^{2}K Solar Heat Gain Coefficient= 0.50 Visible Light Transmittance= 81% Shading – No shading device Window to Wall Ratio of project =21.8%

Existing Building HVAC and Lighting System

The existing building HVAC system detailed explanation is described in Table 3.

Table 3. Existing Building HVAC System Explanation

	System/Plant	Detailed Explanation
HVAC	HVAC System Description	The heating water is provided by one natural gas fired, wall type condensing boilers in the basement floor. Total heating capacity of boilers is 180 kW. Residential spaces are heated by baseboard heating system. Cooling demand of residential units is provided by split AC units. Additionally, ACs are used for dehumidification mode for all seasons to achieve thermal comfort conditions. The cooling capacity of AC units' range between 3.5 kW to 7.1 kW. Windows are used for natural ventilation in residential units.

The schematic view of modeled heating system of the existing building can be seen from Figure 18.

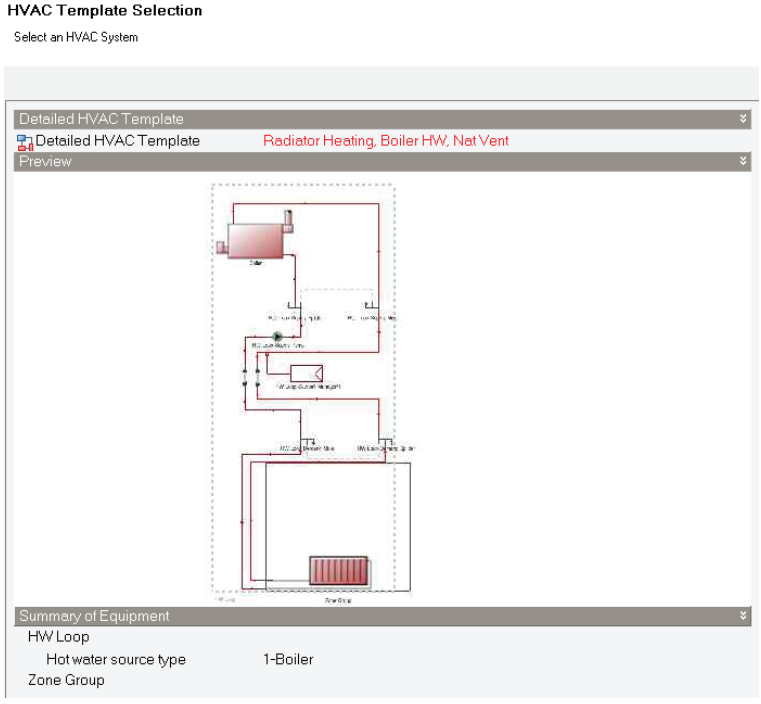

Figure 18. Heating System Schematic View for Building

The existing lighting power density is defined according to information that is provided from MEP Engineer and can be seen from Table 4.

Table 4. Existing Building Lighting System Performance Specifications

	Space Type	Detailed Explanation
Lighting Power Density (W/m2)	Interior	Lighting power density of spaces in the building is identified as 6.33 W/m² based on lighting fixture quantities that can be seen below table. Luminaire Type Quantity Power (Watt) Total Power (kW) Fluorescent Type Luminaire 60 50 3.0 LED Type Luminaire 225 24 5.4

Existing Building Receptacle Loads

Receptacle loads are defined as 6.0 W/m² for both existing and proposed building models and no energy efficiency measures are recommended for them. Therefore, they kept identical in simulations.

Proposed Design Description

The proposed building model envelope and fenestration parameters are described in Table 5.

Table 5. Proposed Building Envelope Envelope Detail

	Building Component	Detailed Explanation
Building Envelope	Roof	U= 0.260 W/m²K
	Sla-b-On-Grade Floor	U= 0.500 W/m²K
	Walls	U= 0.300 W/m²K U = 1.100 W/m²K
	Fenestration	$U_{windows}$ = 1.3 W/m²K Solar Heat Gain Coefficient = 0.38 Visible Light Transmittance = 60% Shading – External shading elements on South façade

The proposed building model window performance parameters are defined with required thermophysical data and can be seen in Figure 19.

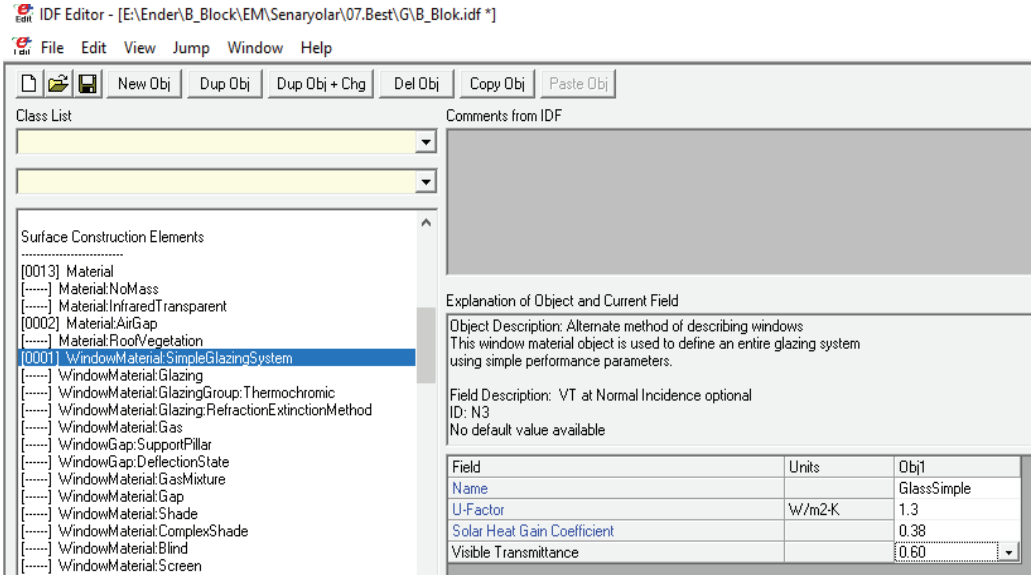

Figure 19. Energyplus Input File Window Material

The proposed building model HVAC system detailed explanation is described in Table 6.

Table 6. Proposed Building HVAC System Performance Specifications

	Systems/Plants	Detailed Explanation
HVAC	HVAC System Description	High efficiency multi-split inverter heat pump AC with cooling capacity of 22.4 kW. No energy efficiency measures proposed for the existing heating system.

The schematic view of modeled cooling system interior units of the proposed building model can be seen from Figure 20.

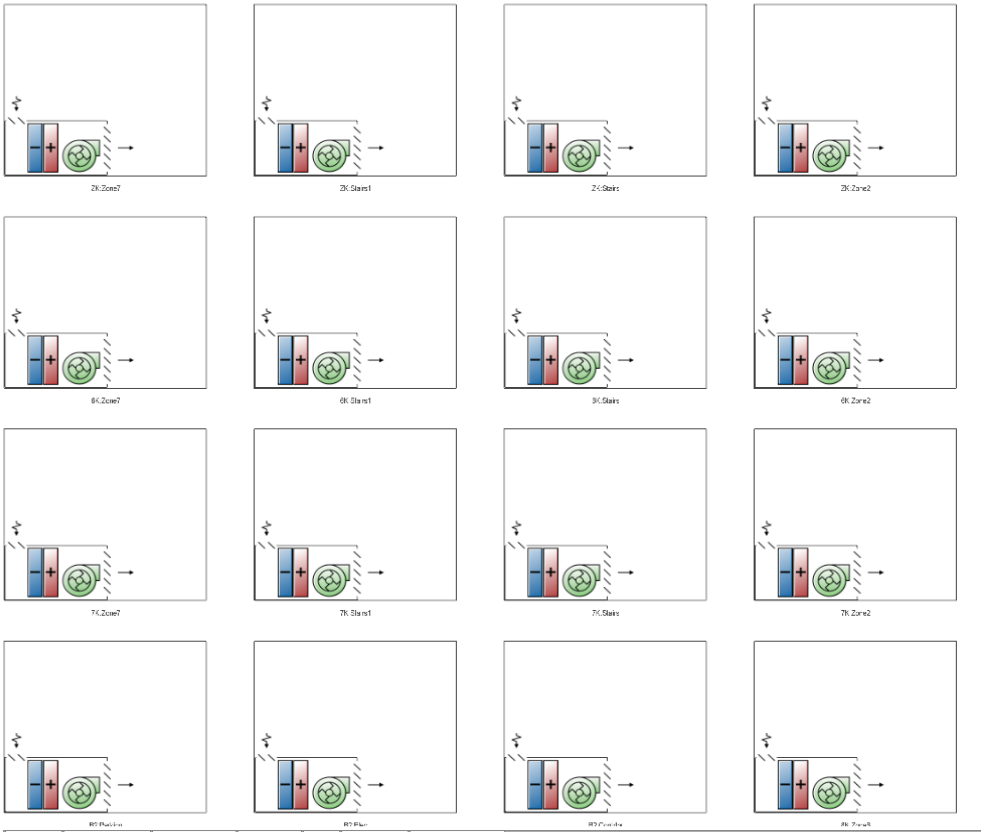

Figure 20. Cooling System Interior Units Schematic View for Building

The proposed design lighting power density is defined as space-by-space method in Table 7 below.

Tablo 7. Proposed Building Lighting System Performance Specifications

	Space Type	Detailed Explanation
Lighting Power Density (W/m2)	Interior	The proposed building lighting power for overall interior spaces is 4.55 W/m². **Space by Space LPD Value** **Electrical/Mechanical Room:** 6.60 W/m² **Corridor:** 4.65 W/m² **Residential Unit:** 4.30 W/m²

Proposed building model lighting system fixtures input can be seen from Figure 21.

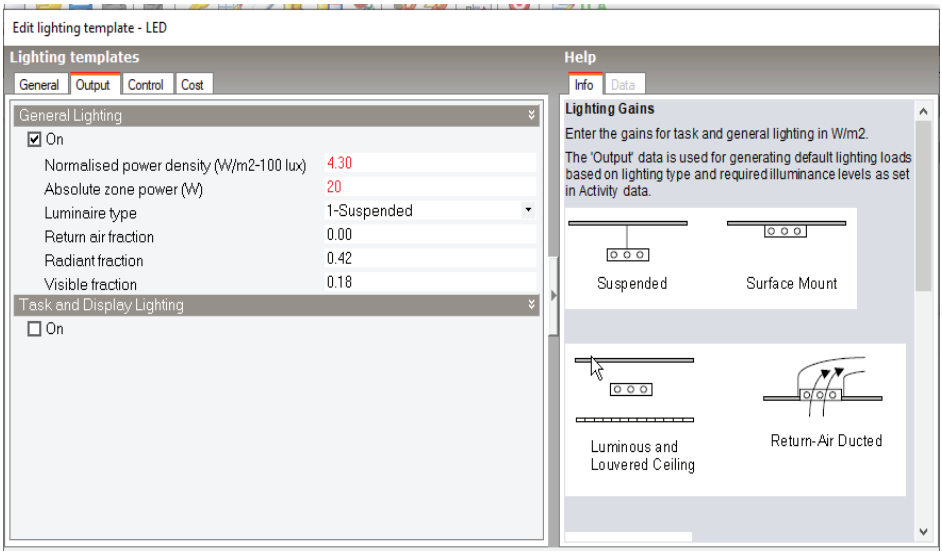

Figure 21. Lighting System View for Data Input

RESULTS

The energy modeling case study performed to demonstrate energy savings and cost analysis of the existing building and proposed energy

efficiency measures such as external wall insulation, replacement of AC units with highly efficient air conditioning units, interior lighting power reduction and external shading device design on South façade. There are two energy model simulation results that include existing building design and proposed design annual energy use breakdown for HVAC, lighting, receptacle equipment, domestic hot water system.

In conclusion, when proposed energy efficiency measures are modeled through simulation software, the existing building design annual energy use calculated as 350.850 kWh, while proposed energy efficiency design annual energy use calculated as 226.420 kWh. As a result, proposed building annual energy use calculated 35,5% less energy use compared to existing building energy use.

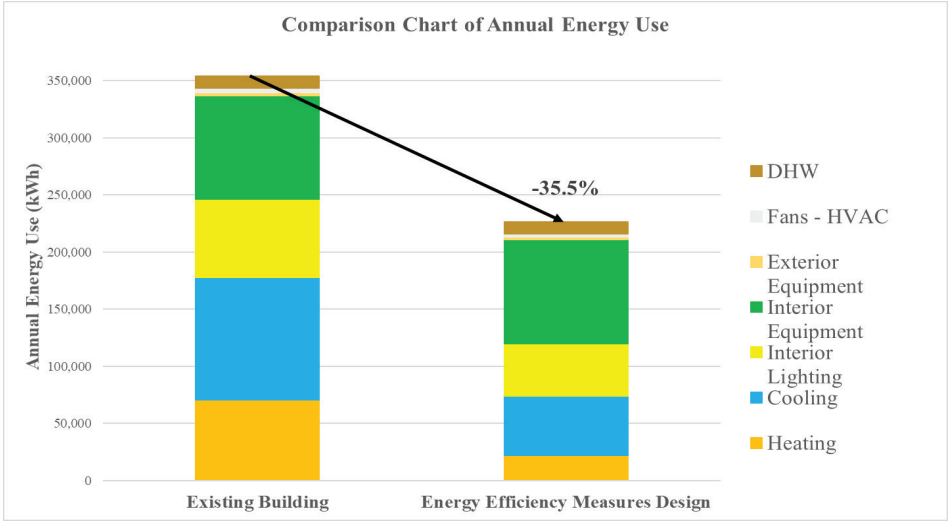

Figure 22. Existing vs. Proposed Design Energy End Uses

When proposed energy efficiency measures are modeled through simulation software, the existing building design annual energy cost calculated as 192.280 TRY, while proposed energy efficiency design annual energy cost calculated as 134.272 TRY. As a result, proposed building annual energy cost calculated 30,1% less energy cost compared to existing building energy use.

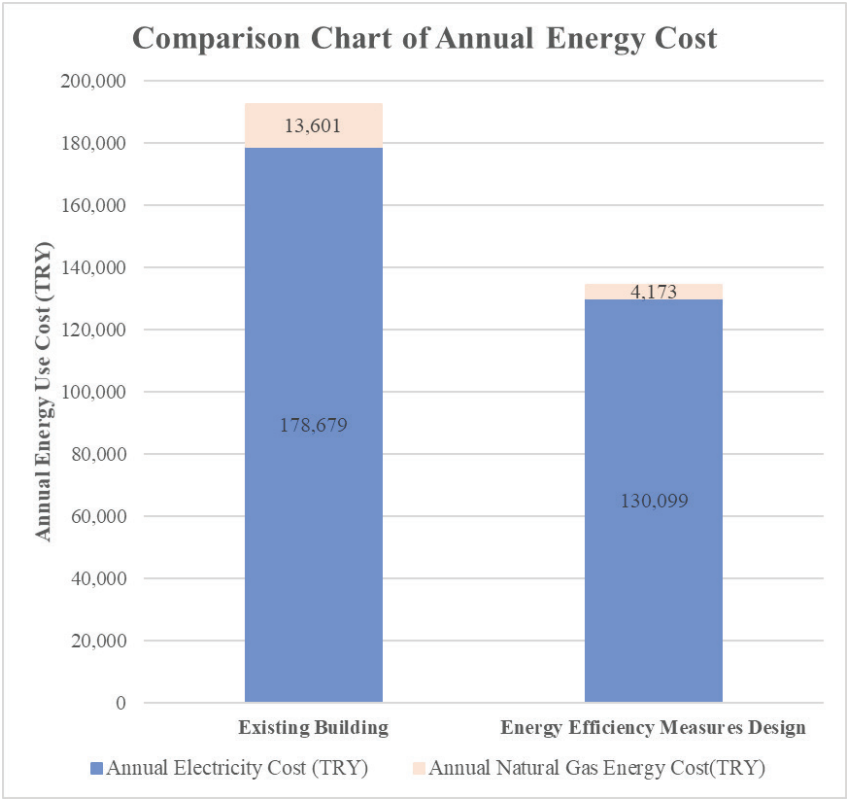

Figure 23. Existing vs. Proposed Design Energy Costs

Energy modeling is a complicated process that requires the integration of several disciplines in order to produce an accurate final product. The energy model's output will be used to make decisions about the current project as well as future ones. Energy modeling can be utilized as decision-making tool in complex facilities.

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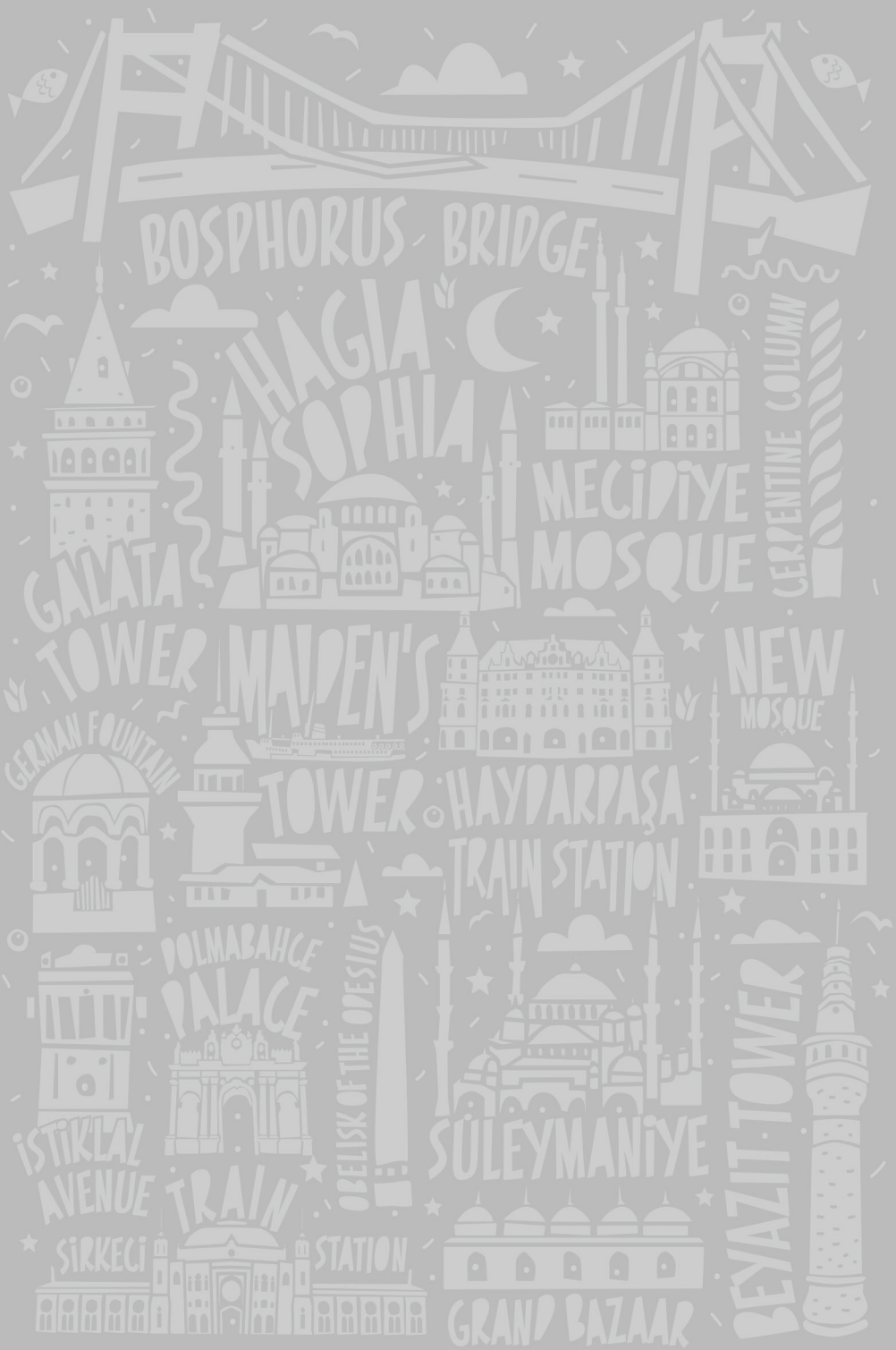

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