OZYEGIN UNIVERSITY

DEPARTMENT OF CIVIL ENGINEERING

CE 441 SENIOR PROJECT REPORT

IMPROVING THE PERFORMANCE OF HERITAGE BUILDINGS WITHIN THE SCOPE OF SUSTAINABLE RENOVATION AND BIM (Building Information Modeling)

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1 INTRODUCTION

Sustainability, is gaining more important in people's lives day by day. Sustainability is a rapidly developing issue in many sectors over the last 30 years. The first studies were published in 1987 by the UN in the Brundtland Report. According to the report, social, environmental and economic development should be done together for sustainability. In general, it is tried to provide development without investigating the environmental impact all over the world (Brundtland, 1987).

The concept of sustainability in the construction sector has revealed the idea of green building. The green building aims to minimize the impact on the environment and reduce the energy consumption needed by the building. Architectural, structural and mechanical solutions are introduced to these problems. Green building practices are increasing worldwide and standard rules are introduced by many countries. So some countries have their own green building certification systems. For example, England use BREEAM, US use LEED, Italy use ITACA protocol. For Turkey there is a new organization ÇEDBİK works for certification of green buildings and sustainability in construction sector.

Energy consumption and management is the most effective factor in building a green building. The ability to convert existing structures into a green building is also ensured by energy efficiency. According to the study conducted in the European Union countries, the residential and commercial buildings have 40% of the energy consumption (EPDB, 2010). Residential areas alone cause 21% energy consumption (C. Balaras, 2007). In 2007, The European Union published the Energy Action Plan. According to this plan, sustainability, environmental safety and competitiveness were highlighted. The aims according to the plan to be reached by 2020, reduce energy consumption, increase energy efficiency and use renewable resources in residential areas. In this plan, especially in new buildings to increase energy efficiency will be a priority. In addition, some renovation work in existing buildings will increase energy performance of buildings and reduce consumption.

Implementation of energy efficiency studies in existing structures other than future structures is important for the continuity and continuity of sustainability. There are very important structures in Europe and Turkey for world heritage. In the last 10 years in Europe, there are sustainability studies with renovation works in historical buildings. In the historic structure in Turkey it is only observed example of a green building. As in today's buildings, the use of Building Information Modeling (BIM) increases the energy efficiency of the building. Energy modeling is facilitated by BIM assistance. This accelerates the work done.

Turkey also increases the importance of sustainability in the construction industry. There is a growing demand for new buildings. According to a report published by the USGBC, Turkey ranks eighth place with 245 green building projects in 2018 and in the last 3 years; it is among the top 10 countries (Stanley, 2018). Turkey shows the importance given to energy efficiency, Energy Efficiency Law published in 2007. Turkey is trying to track energy steps taken by the European Union.

In this project, Fatih Pavilion in Topkapı Palace, which has an important place in Turkish History, has been studied as a case. Fatih Pavilion which has 3 floors and 10 rooms with a terrace has been used as a treasure building since the 15th century. Due to the fact that it is situated in an unsuitable ground area, cracks have started on walls. The main purpose of the ongoing renovation works is to solve these static problems and to solve the ventilation problems especially in the summer. Due to the historical value of Fatih Pavillion, the renovation works should be done very carefully. Material selection is also important in order not to disturb the originality of the structure and to not damage it.

In this article, studies that can be done to increase energy performance in historical buildings are investigated. It is planned to carry out an improvement study, which is made prioritizing sustainability. As a result of these studies, it was aimed to gain a green building identity in a historical building. Since the case is an important structure in terms of history, it is desirable to set an example for the new buildings. During these studies, studies will be done by using BIM. The energy modeling to be carried out through the 3D model will increase the efficiency. The most appropriate renewal model will be selected for the building by making life cost calculations.

2 LITERATURE REVIEW

Museums and historic buildings reflect the history of a nation and are the most important works of protection. In Turkey and in the rest of the world, the challenge is accepted for comparing other buildings in order to find examples of energy analysis of historical buildings while working with meticulous works against museums and works. The reason is to build energy-cost analysis ahead of time before it's built. However, for historical buildings, this is getting a little harder. Since historical buildings are not to have any kind of damage. There is already material fatigue in the aforementioned buildings. Due to these difficulties, states are not too keen on analyzing energy in their renovation work.

When literature review is performed, it can be said that Italy has signed important projects in this area. For instance Fondazione Musei Senesi Project. According to Michela Rota, Stefano Paolo Corgnati, Luigi Di Corat (2015) 43 museums of Italy were gathered under one community. On the other hand, preliminary energy audit on a network of museums was carried out, energy cost analysis in museums was investigated and data of energy cost and consumption was collected through a checklist developed ad hoc. Also, this buildings' HVAC and other systems rating with GBC LEED® Historic Building. Michela Rota, Stefano Paolo Corgnati, Luigi Di Corat (2015) claimed that, the aim of these applications is to increase the energy efficiency of buildings, to reduce the environmental impact of buildings and to reduce the amount of consumption and to minimize the environmental factors.

Another example is from Amsterdam, Netherlands. Although it is not a historical building, it is a good example for the energy analysis of museums. R.P.Kramer, M.P.E Maas, M.H.J Martens, A.W.M van Schijndel, H.L. Schellen (2015) argues that, a hydrothermal building model was built for this museum. With the optimum setpoint strategy, the energy demand of the building can be greatly reduced (77% according to the reference situation). This strategy also improves thermal comfort and collection protection.

Swift Hall at Vassar College in America is also a striking example. It's originally built in 1902. It was decided to do renovation work in this building. "Energy Modeling and life-cycle costing can help identify simple steps to make a historic building more energy efficient, addressing both preservation and sustainability concerns" (John H. Cluver, Brad Randall, 2010). This sentence clearly shows the importance of energy analysis in renovation works. In this building, replacing light fixtures, replacing mechanical systems with new solutions, installing insulations and slate roofing are examples of energy saving methods. In addition, this roofing system has a lot advantages (prestigious, durable, aesthetic, natural, etc.). Also, they use energy modeling system while renovation works.

If we look at Turkey Baylosuites can be a good example. With reference to Grapido Yayıncılık (2012), residential project has taken the Turkey's first LEED-certified historical building renovation project. During the renovation work, all materials were considered to be local materials. In this way, carbon dioxide gas released during product delivery is reduced to a minimum level. Thanks to the water-saving fixtures and the sanitary ware used in the building, natural water resources were protected and the water used in the project was reduced by 28% compared to other buildings using water efficiently.

3 METHODOLOGY

3.1 Estimation of Current Status of the Building and Energy Saving Potential

The main idea for this step is forming a base model in digital platform. Base model is going to give vital values about the current status of the building. Annual energy use and its cost, carbon footprints, wind loads, heating and cooling loads are going to help to determine the weak and strong points of the existing building. By collecting these data, prioritizing the improvements on the building can be performed more accurately.

3.1.1 Collecting Drawings of Existing Building

Providing detailed information and project drawings was the first and time consuming phase. Need of approval from Republic of Turkey Ministry of Culture and Tourism to perform scientific study was necessary. Within the two weeks, our intention was approved and drawings are handed.

3.1.2 Creation of 3D Model

After collecting the drawings of Fatih Mansion, 3D model of the building is created in Revit (Figure1). This phase is completed in two weeks. While the main focus of this study is going to be energy usage and energy saving potential, created model should contain all the physical properties of the building. That is going to lead an accurate base model. To form a solid base model, inputted data should be also specific. That is why, chosen building materials in the model match with the existing building. Stone exterior walls, interior stone walls with plaster, variable slabs materials like brick or marble, marble columns, wooden doors and windows, wooden roof with lead covering are examples of which define the physical properties. These materials and its properties are inputted to the model.

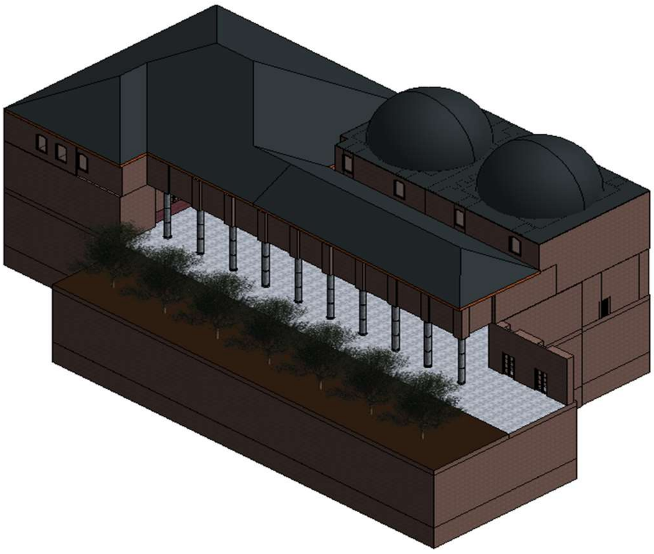

Figure 1: 3D Model

Figure 2: Front View

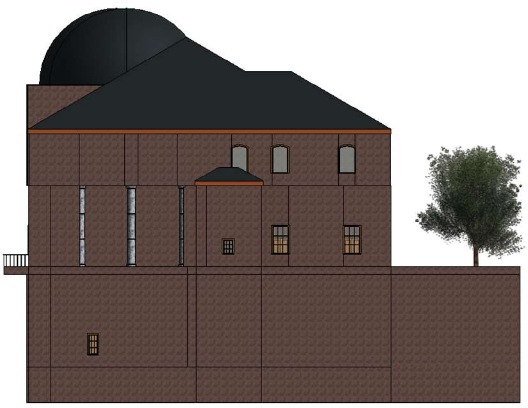

Figure 3: Left View

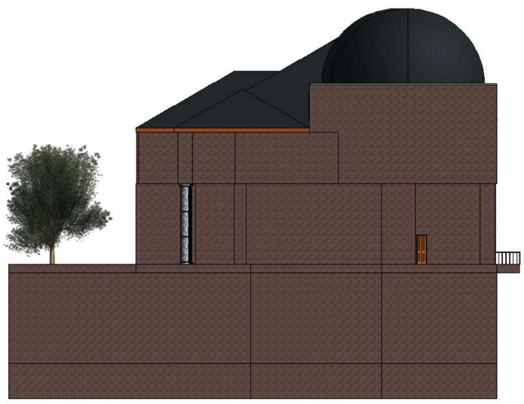

Figure 4: Right View

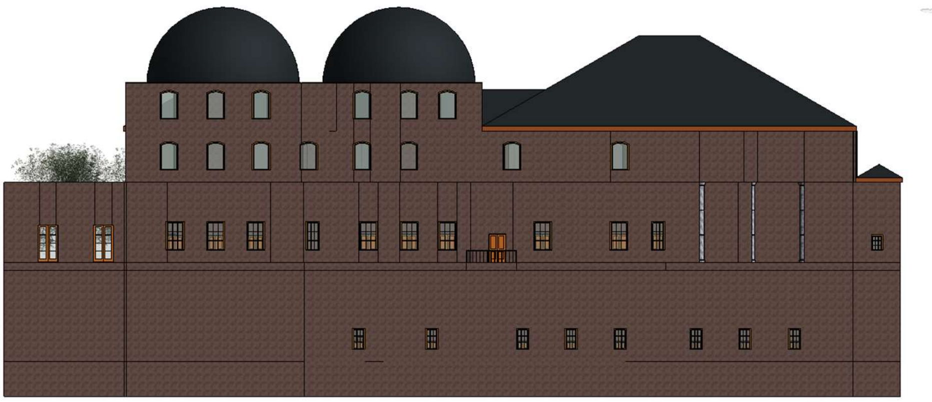

Figure 5: Back View

3.1.3 Formation of Base Energy Analytical Model

Created 3D model in Revit is an architectural model. For analyzing the model in energy perspective, it is needed to convert in an energy model in Revit. While converting the model into energy model, Revit asks to use conceptual masses, building elements or both. In the study, using either conceptual masses or building elements is going to get more realistic results because of conceptual masses include room spaces and building elements include properties of used materials. After all of that, energy analytical model is created (Figure 2).

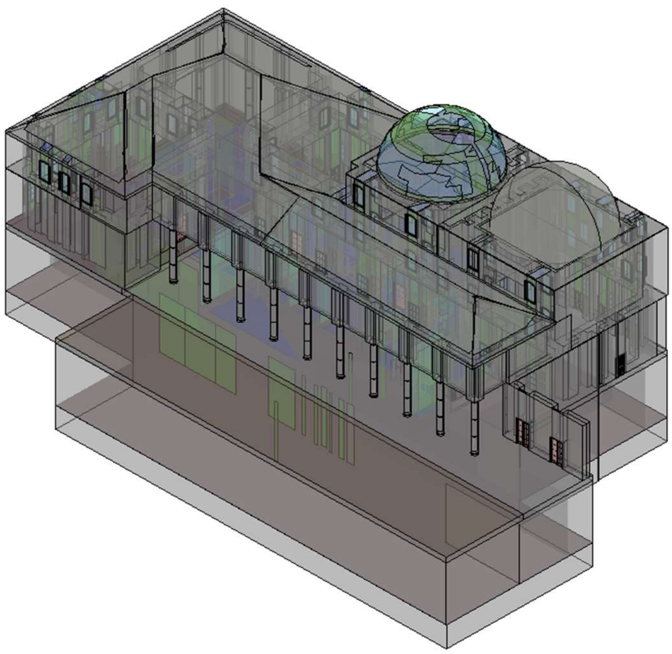

Figure 6: Energy Analytical Model

3.1.4 Determination of Energy Saving Potential

For better understanding the parameters of the energy model, Base analysis has run without any improvement and the values can be seen below. In Figure 7, it can be seen that annual cost of Fatih Mansion is 64015TL. It can be understood in Figure 8 that critical points of heating loads are windows and walls. This means that heat loss become true in these points. Also, In Figure 9, the critical points of the structure when it is under cooling pressure are windows again and the number of occupants. This means that, the number of occupants should be under control. By following these data, improvements that is going to be designed should be on windows and walls primarily.

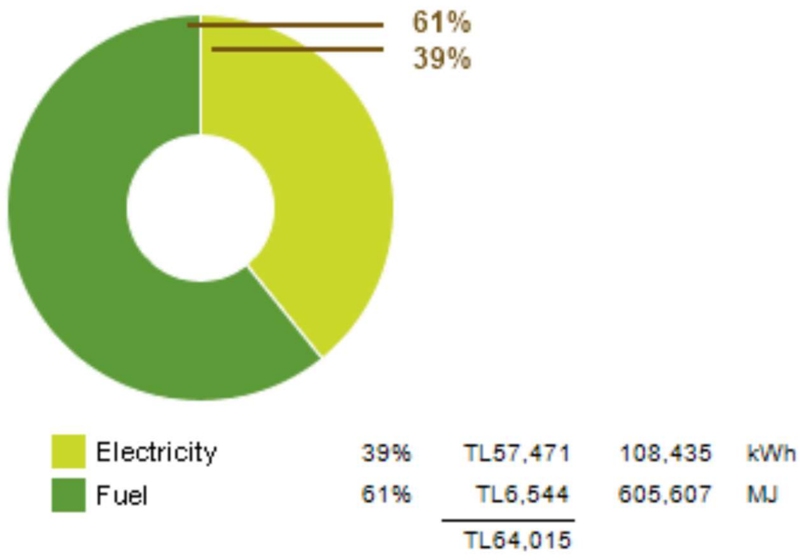

Figure 7: Annual Energy Use/Cost

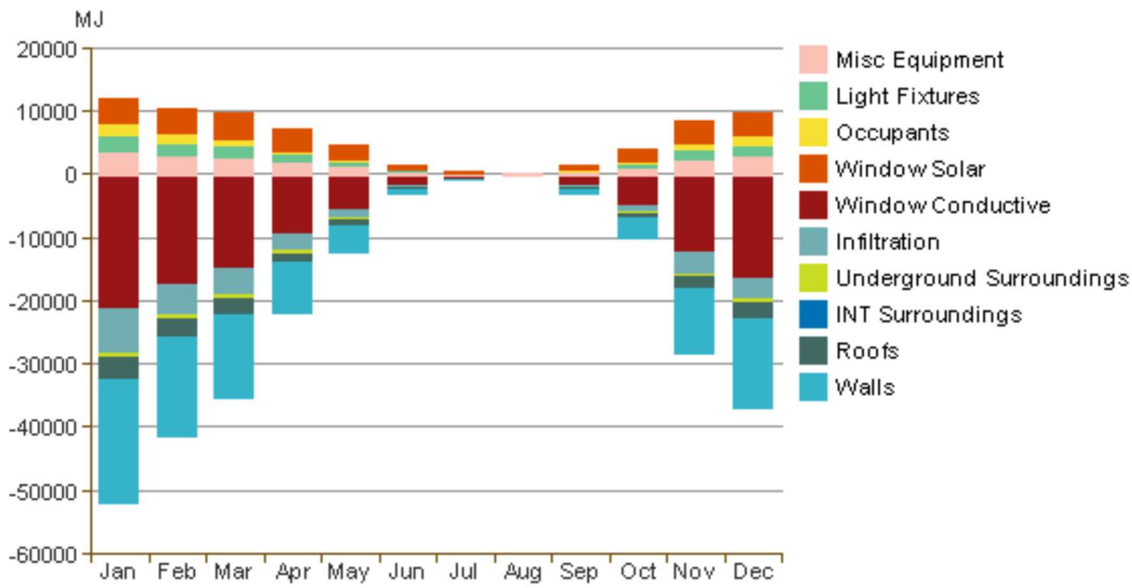

Figure 8: Monthly Heating Load

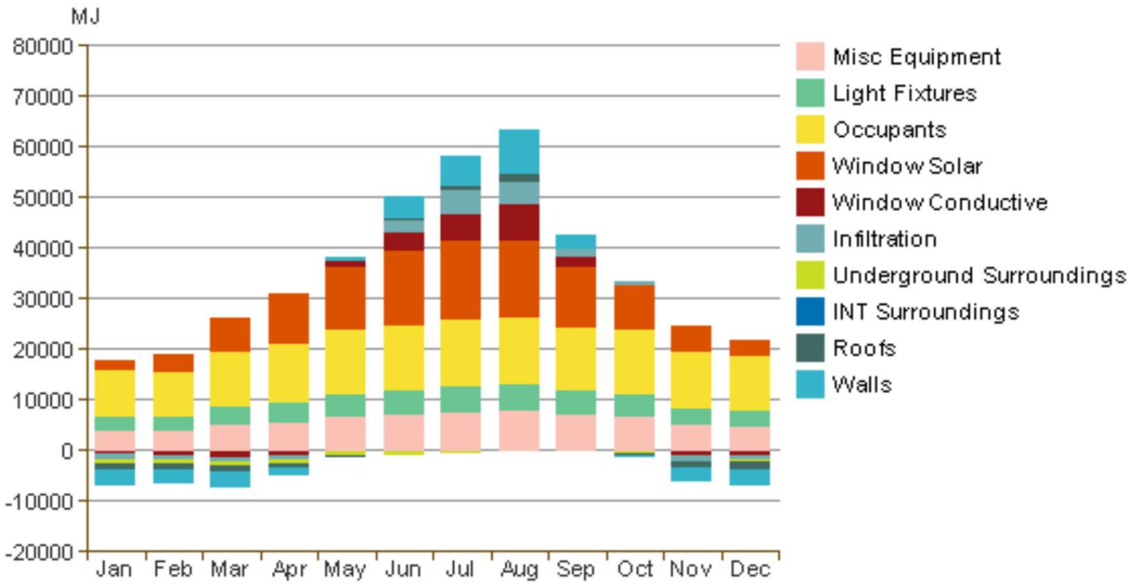

Figure 9: Monthly Cooling Load

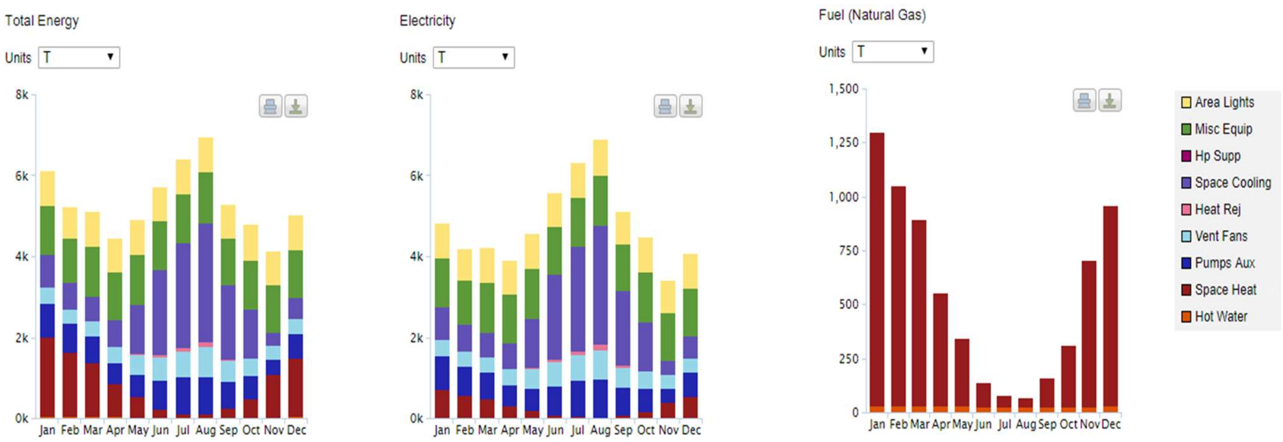

Figure 10: Monthly Detailed Base Run Cost Analysis

3.2 Implementation of Energy Efficiency Measurements to the Model

In order to examine the energy analysis and energy improvements of the model it has drew from Revit, the model has transferred and run it from the Green Building Studio. There was a challenge in regulating the model's energy analysis and energy efficiency. This difficulty is due to the fact that the building is a historical (heritage) structure. So, all the desired improvements are not applicable. The improvements should be applied without disturbing the originality of the building. For example, size or shading of the glazing cannot changeable. So, the types and layers of the glazing has been changed.

After that, different cases in order to be able to make improvements by reducing energy consumption and cost through base run have created. Each case has created from GBS (Green Building Studio) through the base run and transferred the energy and cost data to Excel. The cases that analyzed were not the most effective ones, but the most efficient cases that can be applied to the project and will not disrupt the originality are the following in Table 1.

	Total Annual Cost			Total Annual Energy				
	Electric	Fuel	Energy	Electric(kwH)	Fuel(MJ)	Annual CO2 Emissions (Mg)	Life Cycle Cost	Details
Base Run	57,471.00 ₺	6,544.00 ₺	64,014.00 ₺	108436.00	605608.00	30.20	871,896.00 ₺	No Improvement
Case 1	49,543.00 ₺	3,895.00 ₺	53,438.00 ₺	93477.00	360518.00	18.00	727,840.00 ₺	HVAC (PSZ, ASHRAE 90.1-2010, 10.8 EER, 75F Economizer)
Case 2	41,450.00 ₺	3,859.00 ₺	45,309.00 ₺	78207.00	357222.00	17.80	617,124.00 ₺	HVAC (PTAC, ASHRAE 90.1-2010, 11 EER, Gas Boiler)
Case 3	45,576.00 ₺	6,849.00 ₺	52,425.00 ₺	85993.00	633906.00	31.60	714,054.00 ₺	Lighting (LPD %100 Less Than Base Run),Occupancy/Daylighting sensors & controls
Case 4	6,219.00 ₺	6,219.00 ₺	62,915.00 ₺	106,974	575595.00	28.70	856,923.00 ₺	Roof (Wood Frame Roof with High Insulation)
Case 5	56,011.00 ₺	5,979.00 ₺	61,990.00 ₺	105,682	553370.00	27.60	844,327.00 ₺	Walls Insulation (All sides, Massive Wall with High Insulation)
Case 6	53,011.00 ₺	5647.0.00 ₺	58,658.00 ₺	100,021	522588.00	26.10	798,936.00 ₺	Glazing (Super Insulated 3-pane Clear Low-e)

Table 1: Cases Data

3.2.1 Analyzing the Model with Improvement Combinations

After creating cases, combinations with different cases has been created to find the optimum scenario. The combinations are below in Table 2.

		Total Annual Cost			Total Annual Energy			
# of Combinations	Contained Cases	Electric	Fuel	Energy	Electric(kwH)	Fuel (MJ)	Annual CO2 Emissions (Mg)	Life Cycle Cost
Combination -1	Case-3, Case-4	44694.0. ₺	6478.0. ₺	51172.0. ₺	84328.0. ₺	599585.0. ₺	29.90. ₺	696984.0. ₺
Combination -2	Case-5, Case-3	44010.0. ₺	6230.0. ₺	50239.0. ₺	83037.0. ₺	576544.0. ₺	28.80. ₺	684276.0. ₺
Combination -3	Case-5, Case-1, Case-4	48244.0. ₺	3257.0. ₺	51501.0. ₺	91027.0. ₺	301452.0. ₺	15.0. ₺	701457.0. ₺
Combination -4	Case-4,Case-3,Case-6	40476.0. ₺	5598.0. ₺	46074.0. ₺	76369.0. ₺	518119.0. ₺	25.80. ₺	627543.0. ₺
Combination -5	Case-1, Case-3, Case-6	35155.0. ₺	4044.0. ₺	39199.0. ₺	66330.0. ₺	374294.0. ₺	18.70. ₺	533907.0. ₺
Combination -6	Case-2, Case-5, Case-4	40604.0. ₺	3351.0. ₺	43955.0. ₺	76611.0. ₺	310181.0. ₺	15.50. ₺	598681.0. ₺
Combination -7	Case-4,Case-5,Case-6	50674.0. ₺	4671.0. ₺	55344.0. ₺	95611.0. ₺	432291.0. ₺	21.60. ₺	753805.0. ₺

Combination -8	Case-2,Case-3,Case-4	29674.0. ₺	4109.0. ₺	33783.0. ₺	55989.0. ₺	380268.0. ₺	19.0. ₺	460139.0. ₺
Combination -9	Case-1, Case-3, Case-4,Case-5	36353.0. ₺	3708.0. ₺	40061.0. ₺	68591.0. ₺	343153.0. ₺	17.10. ₺	545642.0. ₺
Combination -10	Case-2, Case-3, Case-4, Case-5	29064.0. ₺	3759.0. ₺	32823.0. ₺	54838.0. ₺	347908.0. ₺	17.40. ₺	447063.0. ₺
Combination -11	Case-3, Case-4, Case-5, Case-6	38635.0. ₺	4867.0. ₺	43502.0. ₺	72896.0. ₺	450416.0. ₺	22.50. ₺	592505.0. ₺
Combination -12	Case-1,Case-3,Case-4,Case-6	34905.0. ₺	3876.0. ₺	38781.0. ₺	65859.0. ₺	358681.0. ₺	17.90. ₺	528203.0. ₺
Combination -13	Case-2,Case-3,Case-4, Case-6	28192.0. ₺	3815.0. ₺	32007.0. ₺	53193.0. ₺	353035.0. ₺	17.60. ₺	435944.0. ₺
Combination -14	Case-1,Case-3,Case-5,Case-6	34044.0. ₺	3602.0. ₺	37647.0. ₺	64235.0. ₺	333374.0. ₺	16.60. ₺	512756.0. ₺
Combination -15	Case-2, Case-3, Case-5, Case-6	27722.0. ₺	3615.0. ₺	31337.0. ₺	52306.0. ₺	334560.0. ₺	16.70. ₺	426824.0. ₺
Combination -16	Case-1, Case-3, Case-4,Case-5,Case-6	33807.0. ₺	3425.0. ₺	37232.0. ₺	63786.0. ₺	316989.0. ₺	15.80. ₺	507107.0. ₺
Combination -17	Case-2, Case-3, Case-4,Case-5,Case-6	27602.0. ₺	3466.0. ₺	31069.0. ₺	52080.0. ₺	320797.0. ₺	16.0. ₺	423164.0. ₺

Table 2: Combination Data

When the combinations have analyzed, the optimum combination in terms of the lowest Life Cycle Cost is the 17th combination has been seen in Table 2.

3.2.2 Creating the Optimum Scenario

The life cycle cost to find the optimum scenario among the combinations has been considered. It was more sensible to choose the maximum efficient combination to find minimum life cycle cost. All the improvements that could make while creating the Combination-17 were considered. Attention has been paid to the fact that the structure has the following features; roof and wall insulation, 3-pane glazing, daylight and user sensor lighting and the most efficient HVAC system. It was realized that the life cycle cost of base run, which is 871,896.00TL, can be reduced to 423,164.0TL by the help of Combination-17.

Energy end use charts for Combination-17 shown below in Figure 11.

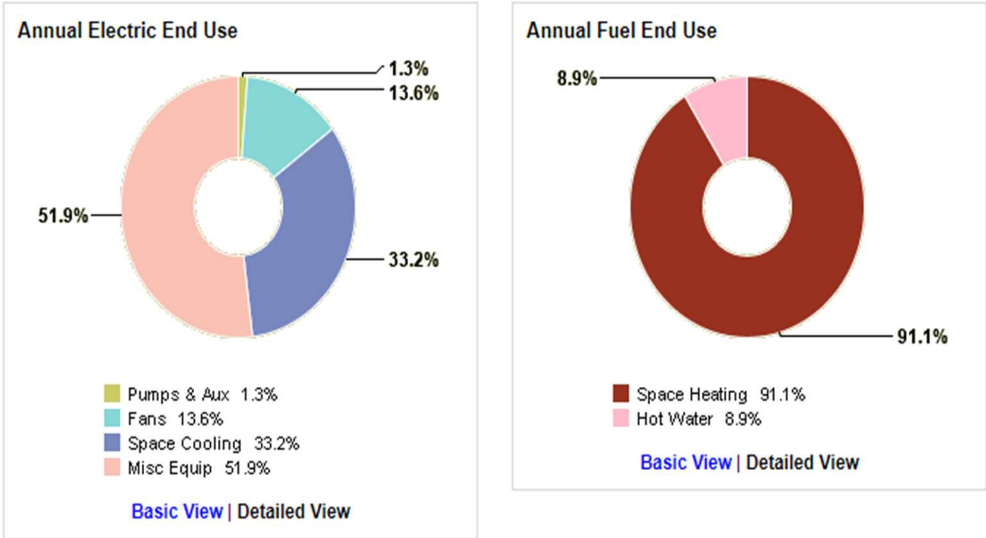

Figure 11: Annual Electric and Fuel Consumption of Combination-17

3.3 Cost Analysis

Aim of this step is to determine the investment cost of the project at the present. To perform cost analysis, it is divided into two parts as construction cost which contains estimated equipment and labor work planned in MS Project. Then the material cost is estimated with the quantities of materials calculated in CAD drawings of the project and market investigation.

3.3.1 MS Schedule

MS Project was preferred due to its applicability to BIM. At the same time, the MS Project can be used to quickly change the schedule; resource usage can be connected to the planned work to highlight the use of MS Project. When planning in MS Project, the information learned in the field trip to the project area is taken into consideration. Things to do for this project are grouped under 3 headings. These are Civil Works, Electrical Works and Mechanical Works which showed in Appandix-A. In this planning, Civil Works has three main functions as Mobilization, Disassembly, and Renovation. The work to be done in the renovation is determined according to the cases determined in the energy efficiency measurements. It is assumed that renovation of the selected case will be carried out for energy efficiency measurements. As a result of these studies, the walls and the roof were improved with stone wool and plaster. Efficient HVAC units are used to indoor air quality of the building, and also high efficiency bulbs are used in lighting. In addition, the windows have been renovated and the old windows have been replaced by double-glazed windows. After entering the works, the resources list was created in MS Project and necessary resources were distributed for the works.

3.3.2 Material Costing

	# of Units	Length in Meters (m)	Area (m2)	Unit Cost	Material Cost
HVAC					
AC Unit	6,00	-	-	10000,0, ₺	60000,0, ₺
External Component	6,00	-	-		
Ventilating Trunk	-	50,10	-	370,0, ₺	18537,196, ₺
Vent Stack	12,00	-	-	365,0, ₺	4380,0, ₺
Insulation			-		
Walls					
Stone Wool	-	-	1767,69	37,470, ₺	66235,344, ₺
Plaster	-	-	1767,69	22,0, ₺	38889,180, ₺
Paint	-	-	1767,69	22,0, ₺	38889,180, ₺
Roof					
Stone Wool	-	-	1549,00	35,820, ₺	55485,180, ₺
Plaster	-	-	1549,00	22,0, ₺	34078,0, ₺
Paint	-	-	1549,00	22,0, ₺	34078,0, ₺
Glazing					
Windows	43	-	112,23	90,0, ₺	10100,70, ₺
Light Fixtures					
Bulb	43	-	-	25,0, ₺	1075,0, ₺
Control Equipments					1075,0, ₺
			Total Material Cost		**362822,781, ₺**

Figure 12: Material Costs

To determine the material cost according to the renovations decided in the previous steps, quantities are calculated with the help of project drawings in AutoCAD. Then, market investigation was made with phone calls with the suppliers. Estimated material cost can be seen in Figure 12.

3.3.3 NPV and IRR

Cos-based sensitivity analysis is made with several cases and combinations which contains the most effective renovations for reducing the annual operating cost of the building. NPV and IRR are for use of capital budgeting and investment planning to see the profitability of a project (Kenton, 2019), (Hayes, 2019). In the analysis, it is made with the investment costs of every scenario and expected annual savings from the renovations. In Figure 13, NPV and IRR calculations can be shown. These calculations are made in US Dollars. Because, governmental risks and the possible impacts of current uncertainties intercept the estimation of discount rate for future 15 years. Current FED interest rate is between 2.25-2.5% (Bankrate, 2019). But, the chosen discount rate for the project is 5% due to the fact that the project has risks of increase in interest rates. Optimum chosen scenario is Combination 17 which contains all improvements. Such as, wall, roof insulation, HVAC improvement, glazing and light fixture renovations. That is why Combination 17 is the most costly combination and has low profitability although it has the most savings of annual operating cost.

Years	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	NPV	IRR
Case 3	$1.918,33	$ 1.931,50	$ 2.028,08	$ 2.129,48	$ 2.235,95	$ 2.347,75	$ 2.465,14	$ 2.588,39	$ 2.717,81	$ 2.853,71	$ 2.996,39	$ 3.146,21	$ 3.303,52	$ 3.468,70	$ 3.642,13	$ 3.824,24	$25.674,52	106%
Case 6	$2.862,12	$ 892,67	$ 937,30	$ 984,17	$ 1.033,37	$ 1.085,04	$ 1.139,29	$ 1.196,26	$ 1.256,07	$ 1.318,88	$ 1.384,82	$ 1.454,06	$ 1.526,76	$ 1.603,10	$ 1.683,26	$ 1.767,42	$9.890,26	36%
Case 2	$15.344,87	$ 3.117,50	$ 3.273,38	$ 3.437,04	$ 3.608,90	$ 3.789,34	$ 3.978,81	$ 4.177,75	$ 4.386,64	$ 4.605,97	$ 4.836,27	$ 5.078,08	$ 5.331,98	$ 5.598,58	$ 5.878,51	$ 6.172,44	$29.190,85	24%
Case 5	$36.699,62	$ 337,33	$ 354,20	$ 371,91	$ 390,51	$ 410,03	$ 430,53	$ 452,06	$ 474,66	$ 498,39	$ 523,31	$ 549,48	$ 576,95	$ 605,80	$ 636,09	$ 667,90	$31.880,57	-15%
Case 4	$25.710,86	$ 183,17	$ 192,33	$ 201,94	$ 212,04	$ 222,64	$ 233,77	$ 245,46	$ 257,73	$ 270,62	$ 284,15	$ 298,36	$ 313,28	$ 328,94	$ 345,39	$ 362,66	$23.094,20	-17%
Combination 15	$47.458,27	$ 5.446,17	$ 5.718,48	$ 6.004,40	$ 6.304,62	$ 6.619,85	$ 6.950,84	$ 7.298,38	$ 7.663,30	$ 8.046,47	$ 8.448,79	$ 8.871,23	$ 9.314,79	$ 9.780,53	$ 10.269,56	$ 10.783,04	$30.344,11	12%
Combination 13	$48.266,85	$ 5.334,50	$ 5.601,23	$ 5.881,29	$ 6.175,35	$ 6.484,12	$ 6.808,32	$ 7.148,74	$ 7.506,18	$ 7.881,49	$ 8.275,56	$ 8.689,34	$ 9.123,81	$ 9.580,00	$ 10.059,00	$ 10.561,95	$27.940,30	12%
Combination 17	$77.896,33	$ 5.490,83	$ 5.765,38	$ 6.053,64	$ 6.356,33	$ 6.674,14	$ 7.007,85	$ 7.358,24	$ 7.726,15	$ 8.112,46	$ 8.518,08	$ 8.943,99	$ 9.391,19	$ 9.860,75	$ 10.353,79	$ 10.871,47	$544,15	5%
Disc. Rate	5%																	

Figure 13: NPV and IRR calculation

Figure 14: NPV Diagram

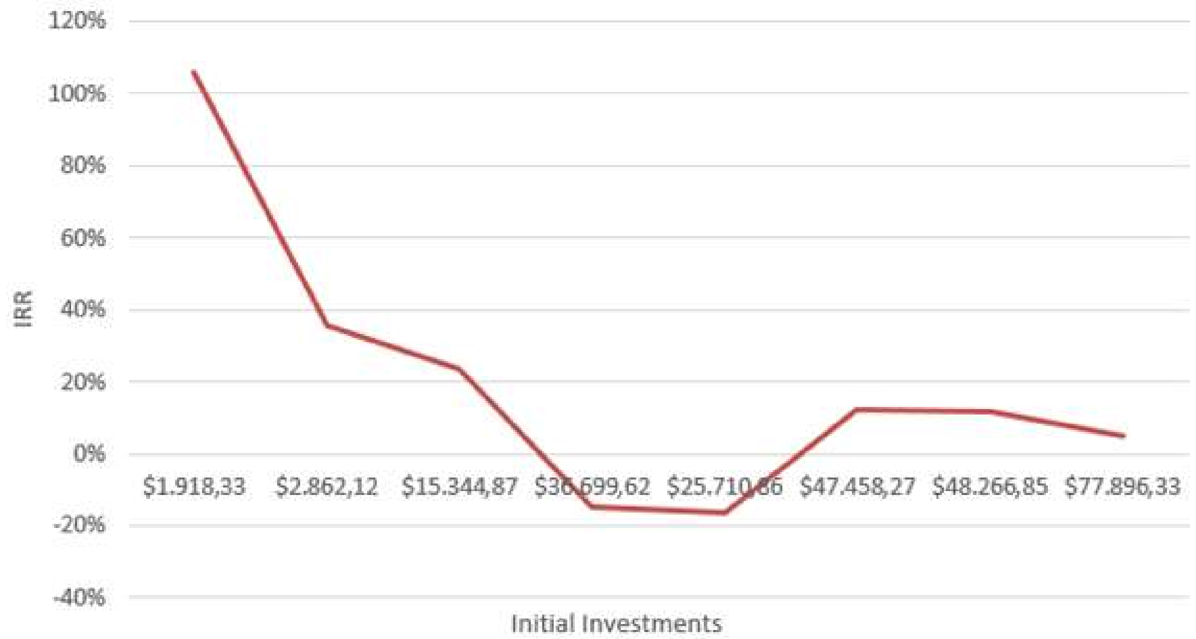

Figure 15: IRR Diagram

3.4 Risk Analysis

When an investment to a project is at present, the uncertainties of a project create risks of the investment. Despite making detailed work plan and cost-based analysis related to the plan, theoretical assumptions are not always fit to the site conditions. “The objectives of project risk management are to increase the likelihood and impact of positive events, and decrease the likelihood and impact of negative events in the project” (PMI, 2013)

3.4.1 Risk Identification

This process can be performed with several techniques. One of the most useful techniques for identifying risks is Delphi technique. “The Delphi technique is a way to reach a consensus of experts” (PMI, 2013). The risk assessment reports of Anadolu (2013), a consultancy company, helped identifying general construction risks, insulation, window application and electrical, mechanical risks of a project.

3.4.2 Qualitative Risk Analysis

As PMI (2013) mentions that qualitative risk analysis is performed with prioritizing the identified risks for future analysis and combine the probabilities of occurrence with the risks to gain benefit of reducing the level of uncertainty. In the risk assessment reports, there are many risks can be taken into consideration. But, performed site investigations allow elimination of irrelevant risks and prioritize the related ones especially for Fatih Mansion. Prioritized risks can be seen below in Figure 16.

Qualitative | Quantitative

Risk			Pre-Mitigation (Data Date = 11/05/2019)					Mitigation			Post-mitigation				
ID	T/O	Title	Probability	Schedule	Cost	Performance	Score	Response	Title	Total Cost	Probability	Schedule	Cost	Performance	Score
001	T	Working w/o giving training of HSE	L (20%)	VH (57)	N (0,00?)	VH	24	Reduce	Monthly giving trainings to the workers	225,00?	VL (5%)	H (27)	N (0,00?)	L	4
002	T	Unkown number of personel at site when emergency occur	L (20%)	VH (57)	N (0,00?)	VH	24	Transfer	Assigning security guard at the entrance	6.000,00?	VL (5%)	H (27)	N (0,00?)	L	4
003	T	Fire Threat	VL (5%)	VH (60)	VH (900.000,00?)	VH	8	Reduce	Ocurrance of fire extinguisher	300,00?	VL (5%)	VH (60)	VH (900.000,0...	M	8
004	T	Spacing of stair runs are short	H (60%)	L (7)	N (0,00?)	L	7	Accept		0,00?	H (60%)	L (7)	N (0,00?)	L	7
005	T	Stair inclines are not suitable	H (60%)	L (7)	N (0,00?)	L	7	Accept		0,00?	H (60%)	L (7)	N (0,00?)	L	7
006	T	Electric cable insulation is low	L (20%)	H (30)	H (375.000,00?)	H	12	Reduce	Changing damaged eletric cables	300,00?	VL (5%)	VL (2)	L (52.500,00?)	M	2
007	T	Electrical grounding	L (20%)	H (30)	VL (15.000,00?)	VH	24	Reduce	Periodic Controls	225,00?	L (20%)	L (6)	L (52.500,00?)	L	3
008	T	Moist and wet working areas	L (20%)	H (30)	H (375.000,00?)	H	12	Reduce	Insulation of working area	300,00?	VL (5%)	L (7)	M (112.500,00?)	M	2
009	T	Fire of dye and insulation materials when stocking	VL (5%)	VH (60)	VH (900.000,00?)	VH	8	Reduce	Stock materials far from work site	0,00?	VL (5%)	VL (2)	L (52.500,00?)	L	1
010	T	Lack of warning signs	L (20%)	H (27)	N (0,00?)	H	12	Reduce	Increasing the number of working signs	300,00?	VL (5%)	N (0)	VL (15.000,00?)	L	1
011	T	Generator usage in closed areas	L (20%)	M (15)	VH (900.000,00?)	H	24	Avoid	Do not use generator	0,00?	N (0%)	N (0)	N (0,00?)	H	0
012	T	Rainy weather	H (60%)	M (15)	L (52.500,00?)	L	14	Accept	Creating free floats for roof construction	0,00?	H (60%)	M (15)	L (52.500,00?)	L	14
013	T	Explosive materials for welding (mechanical)	L (20%)	H (30)	N (0,00?)	H	12	Avoid	Use bolted connections	0,00?	N (0%)	L (7)	N (0,00?)	L	0
014	T	Having personal belongings of workers in the site	M (40%)	H (30)	H (375.000,00?)	H	20	Reduce	Security check after work hours	0,00?	L (20%)	L (7)	L (52.500,00?)	L	3
015	T	Smoking in working area	M (40%)	H (27)	H (375.000,00?)	M	20	Avoid	Prohibition of smoking	0,00?	N (0%)	N (0)	VL (15.000,00?)	VL	0
016	T	Fall from high levels	L (20%)	VH (56)	VH (900.000,00?)	VH	24	Reduce	Safety belts and helmets	300,00?	VL (5%)	L (8)	L (52.496,00?)	L	1

Figure 16: Qualitative Risk Analysis

To proceed further phase, prioritized risks should be mitigated and the risk occurrence and the impact of negative events should be reduced. Risk mitigation options which can be seen in Figure 16 are acceptance, avoidance, reduction and transfer. Risk acceptance is used when the impact of risks are uncontrollable and acceptable. The risks with ID numbers 004, 005 and 012 are the examples of accepted risks. Rainy weather is an uncontrollable risk which may impact on roof insulation. On the other hand, stair problems which observed in site investigation can cause harmful accidents and the accidents effect the schedule and indirectly the cost of the project. The options for these risks are nothing different than accepting them. Transfer is an option for considerable moderate and low impacted risks. Risk transfer is generally used when it can be more economic than any other strategy. The risk with ID 002 is an example of transferring a risk. Avoiding or mitigating a risk is a good strategy for critical risks with high impacts. ID numbers 11, 13 and 15 are the examples of risk avoidance. For mechanical and electrical purposes, generator usage in closed areas has one of the highest risk scores and not using any generator for Fatih Mansion completely eliminates this risk. On the other hand, chemical substances for insulation can be explosive that is why stocking should be any other area. Last avoidance example is observed in site investigation. Smoking in construction area is also may cause explosion, fire or schedule delays, lack of work qualities at best. That is why, the risk should be avoided with prohibition of smoking. Other risks with ID numbers 1, 3, 6, 7, 8, 10, 14 and 16 are mitigated risks.

3.4.3 Quantitative Risk Analysis

"Perform quantitative risk analysis is the process of numerically analyzing the effect of identified risks. The key benefit of this process is that it produces quantitative risk information to support decision making in order to reduce project uncertainty" (PMI, 2013). This numerical analysis is usually generated by computers. Simulating the project with probabilistic distributions is almost unreal without using computational process. Because, the number of differentiation is limited by hand. On the other hand, if the number of cases increase, results is going to be either accurate or precise. For this project simulations are generated ten thousand times with Beta distribution. The reason for choosing this kind of distribution is "beta and triangular distributions are frequently used in quantitative analysis" (PMI, 2013).

3.4.4 Comparison of Results

According to the created work plan in MS Project, the project duration is shown as 105 days and construction cost as 104.520,00 TL without considering material costs. Because, material data are not inputted to the MS Project schedule is used for the procedure. These results are deterministic which external factors did not included into account. Before risk data are inputted pre-risk simulation is generated with Beta distribution. According to the Figure 18, the probability of completing the project in 105 days is 36% and completing the project within the deterministic cost has 48% probability, Figure 17.

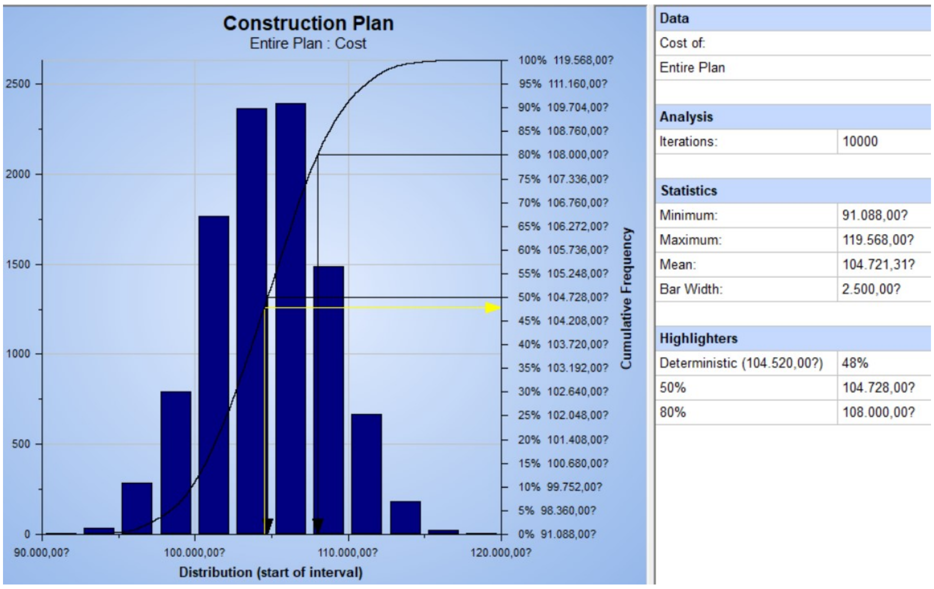

Figure 17: Pre-Risk Simulation Cost Diagram

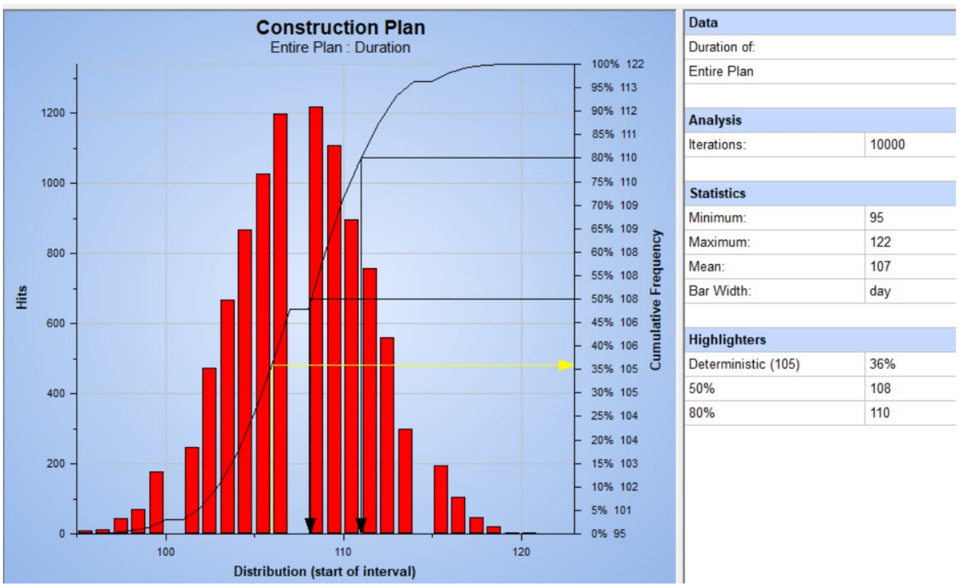

Figure 18: Pre-Risk Simulation Duration Diagram

After including the risks to the project, simulation has run again to see the impacts of risks registered and it can be seen in Figure 19 and Figure 20 that the probability of completing the project within planned duration and budget reduced below 1%. Also the cost increased over ten times and the project duration is almost doubled with 80% probability. This shows that considering only deterministic results would lead to a guaranteed bankruptcy.

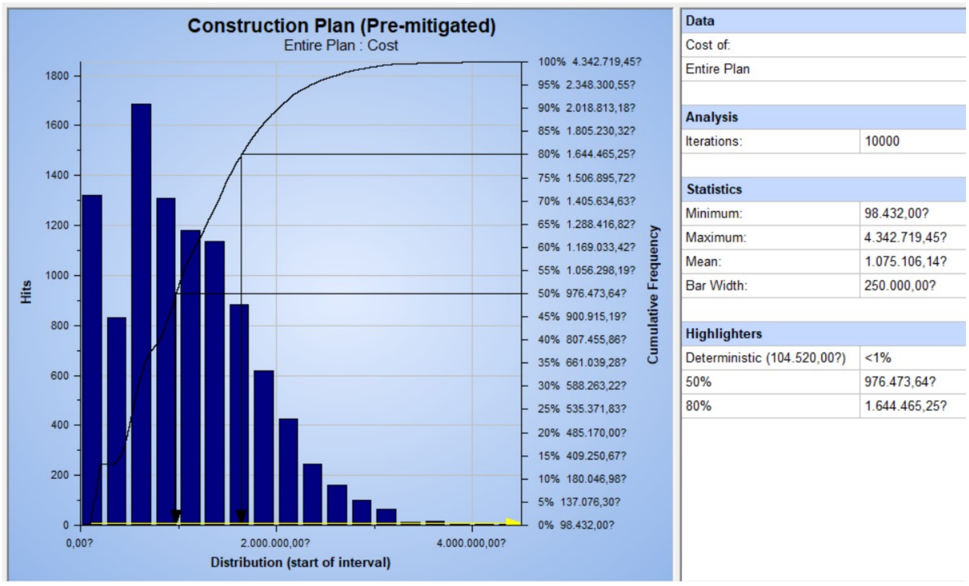

Figure 19: Pre-Mitigated Simulation Cost Diagram

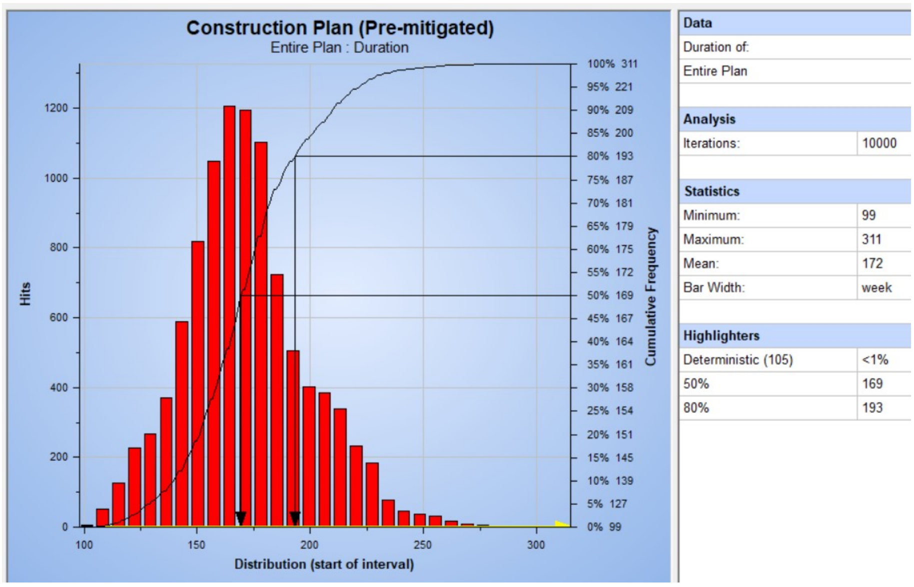

Figure 20: Pre-Mitigated Simulation Duration Diagram.

For finalizing the quantitative risk analysis, mitigated risk responses should be into consideration. By doing that, any chance of bankruptcy would be eliminated and accurate cost analysis can be performed. The results of post-mitigated simulation can be seen below in Figures 21 and 22. These results shows that estimated project duration is going to be 134 days and construction cost as 240.158,67 TL with 80% probability. Increase in duration is 29 days and the construction cost is almost doubled. This analysis shows the importance of risk analysis when performing cost estimation and planning of projects.

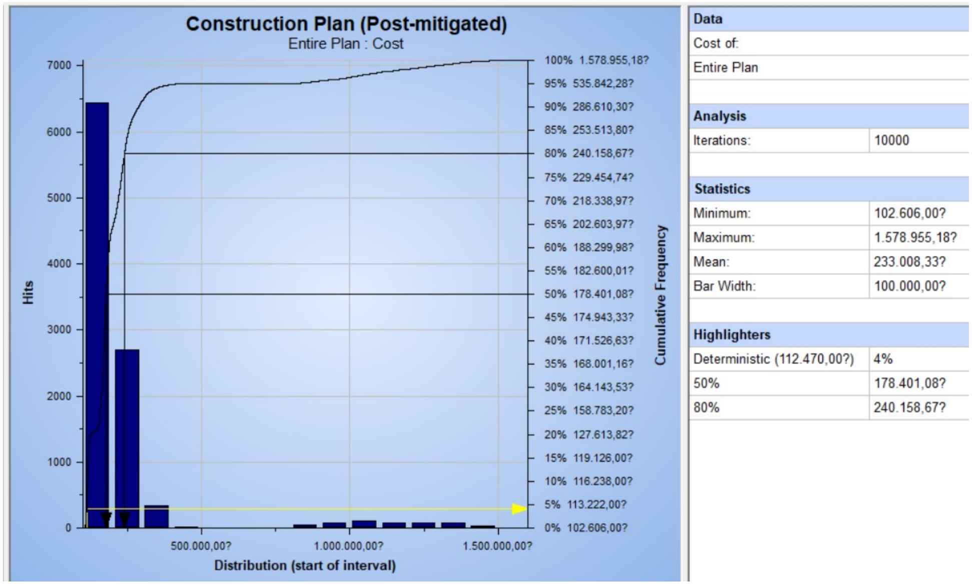

Figure 21: Post-Mitigated Simulation Cost Diagram

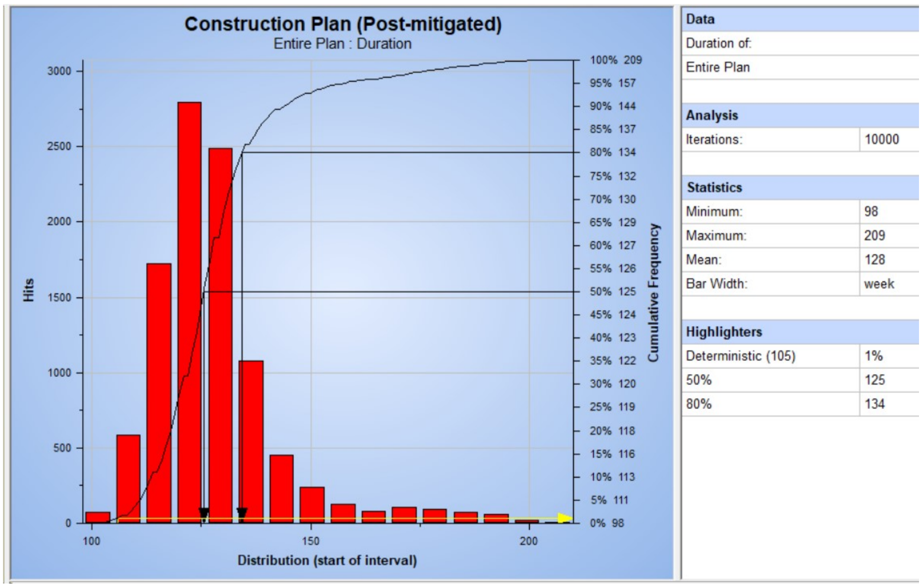

Figure 22: Post-Mitigated Simulation Duration Diagram

4 WORK PLAN AND PROGRESSION

The work plan and progression is shown below.

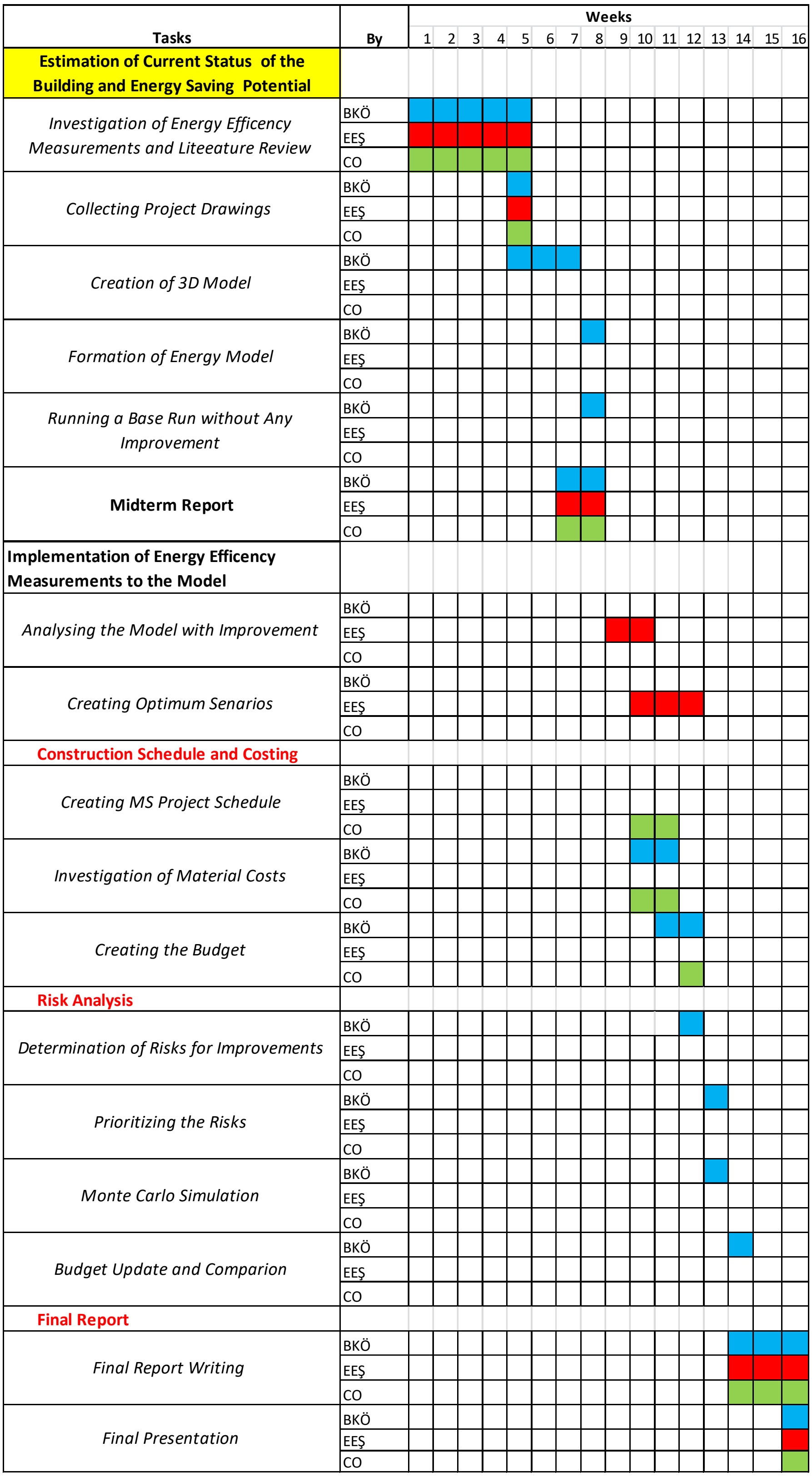

Figure 23: Work Plan

5 IMPACT OF THE PROJECT

5.1 Physical Impact

As the case of the project is Fatih Mansion in Topkapi Palace. The aims of the renovations contain the preservation of the current situation of the building. The reason behind this is the structure is a cultural heritage building. Disassembly during operations may damage the building. The plaster and paint that will be made in order to protect the cultural values of the structure should be made in a way that will not harm the historical texture. The usability of the plaster to be selected should be checked not only way in the performance, it should be control to usability on the historical structure. Ventilation systems to be built into the building will solve the existing ventilation problems. This will increase the effect on the protection of the exhibits within the structure.

5.2 Social Impact

The building, which has been analyzed and improved, is a museum having historical background and important legacies. While making the necessary improvements, humidification and temperature conditions of historical artifacts were taken into consideration. Thus, the problem of sweating in historical monuments has been tried to be minimized and it is aimed to extend the life of historical artifacts. Furthermore, the comfort of the visitors was taken into consideration with the HVAC and insulations improvements. These improvements have an important role in exhibiting the Turkish culture and in the satisfaction of the visitors.

5.3 Environmental Impact

Care was taken to ensure that the improvements made to the building were environmental and sustainable. Therefore, it was taken care to reduce the using fuels and electricity to a minimum level. The following figure which analyzed from Green Building Studio is given in terms of Energy Use Intensity of Base Run and Combination-17 (Figure 24).

Name	Date	User Name	Floor Area (m²)	Energy Use Intensity (MJ/m²/year)
ject Default Utility Rates				
Project Default Utility Rates	--	--	--	--
Base Run				
Enderun Hazinesi Model_Energy Analysis (2)	4/29/2019 2:03 PM	kaan.ozarda	390	2,552.0
combination-17	5/8/2019 12:56 AM	erkam.sardag	390	1,302.4

Figure 24: Comparison of Base Run and Combination-17 with respect to Energy Use Intensity

The tables 3, 4 and 5 show the energy consumption of the base run and combination-17 (values in tables are derived from Green Building Studio).

	Annual CO_2 Emissions		
	Electric (Mg)	Onsite Fuel (Mg)	Large SUV Equivalent (SUVs / Year)
Base Run	0	30.2	3
Combination-17	0	16	1.6

Table 3: Annual CO2 Emissios Data

	Annual Energy			
	Energy Use Intensity (EUI) MJ/m^2/Year	Electric kWh	Fuel (MJ)	Annual Peak Demand (kW)
Base Run	1302.00	108436.00	605608.00	32.6
Combination-17	1302.00	52080.00	320797.00	23.10

Table 4: Annual Energy Consumptions Data

	Lifecycle Energy	
	Electric (kW)	Fuel (MJ)
Base Run	3,253,071	18,168,228
Combination-17	1,562,400	9,623,895

Table 5: Lifecycle Energy Data

As shown in the tables, the energy and carbon emission values were greatly reduced. Base run's Lifecyle Electric value is 3,253,071 kW while Combination-17's of 1,562,400 kW. Also, Base run's Lifecycle Fuel value is 18,168,228 MJ while Combination-17's of 9,623,895 MJ. As it is seen from the values, improvements in energy consumption have been reduced by approximately 50%.

5.4 Economic Impact

Since the improvements made decrease energy use, consumption costs decreased directly. Energy and Lifecycle costs are shown in Table 6.

	Annual Energy Cost	Lifecycle Cost
Base Run	64,016.00 ₺	871,896.00 ₺
Combination-17	31,069.00 ₺	423,164.00 ₺

Table 6: Annual and Lifecycle Costs Data

Since high-efficiency materials were used in improvements, there was a slightly 50% decrease in consumption costs. Detailed monthly cost consumption of Combination-17 can be seen in Figure 25.

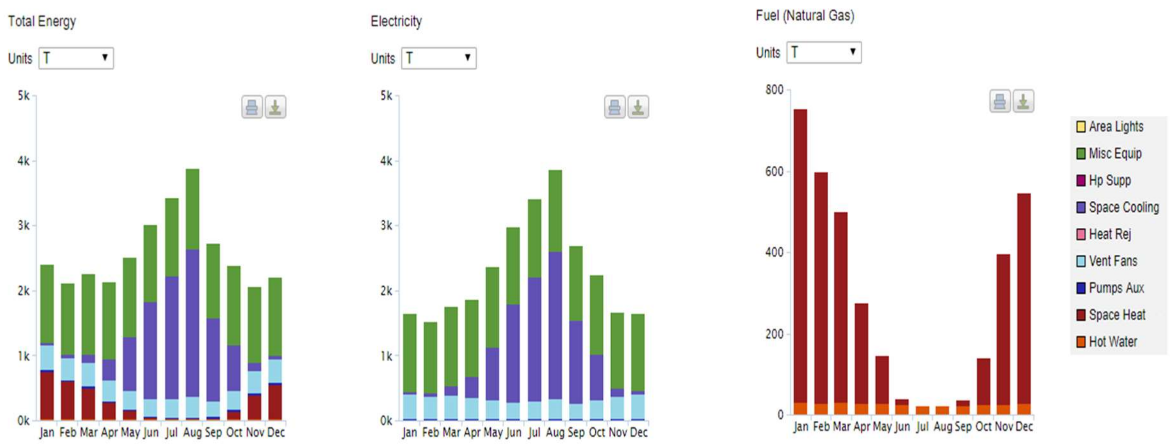

Figure 25: Annual Energy Consuption of Combination-17

6 CONCLUSION

The present work discusses strategies of energy efficiency on existing historical building and demonstrates detailed cost calculations. Significant results have been achieved in reducing energy consumption through improvements. This decline shows the increase in building performance and is an important factor in turning the building into a green building.

The decrease in the operation cost also indicates that the investment will be received. The selection of the optimum condition, 50% cost saving can be achieved each year. Detailed cost analysis enables the project to be seen after 15 years and gives a detailed idea for the investment.

Increasing energy efficiency is the most important factor in reducing the environmental impact of the building. As was the case in this work, the renovation of the building's environmental impact was reduced. A 50% decrease in energy consumption leads to a reduction in environmental damage. By actualizing this theoretical analysis into real life, Fatih Mansion has a huge potential of getting LEED Gold Certificate in the existing buildings category. Also, it can be one of the oldest buildings has accomplished this statue.

In this article, the effects of energy efficiency studies were shown during the renovation of the historical buildings. In Turkey, because of the absence of this kind of work before a historic building in energy efficiency makes this project an example. Sustainability for historical buildings is a new idea for Turkey but because of the projects on green buildings last years, projects can be seen in this subject in the near future.

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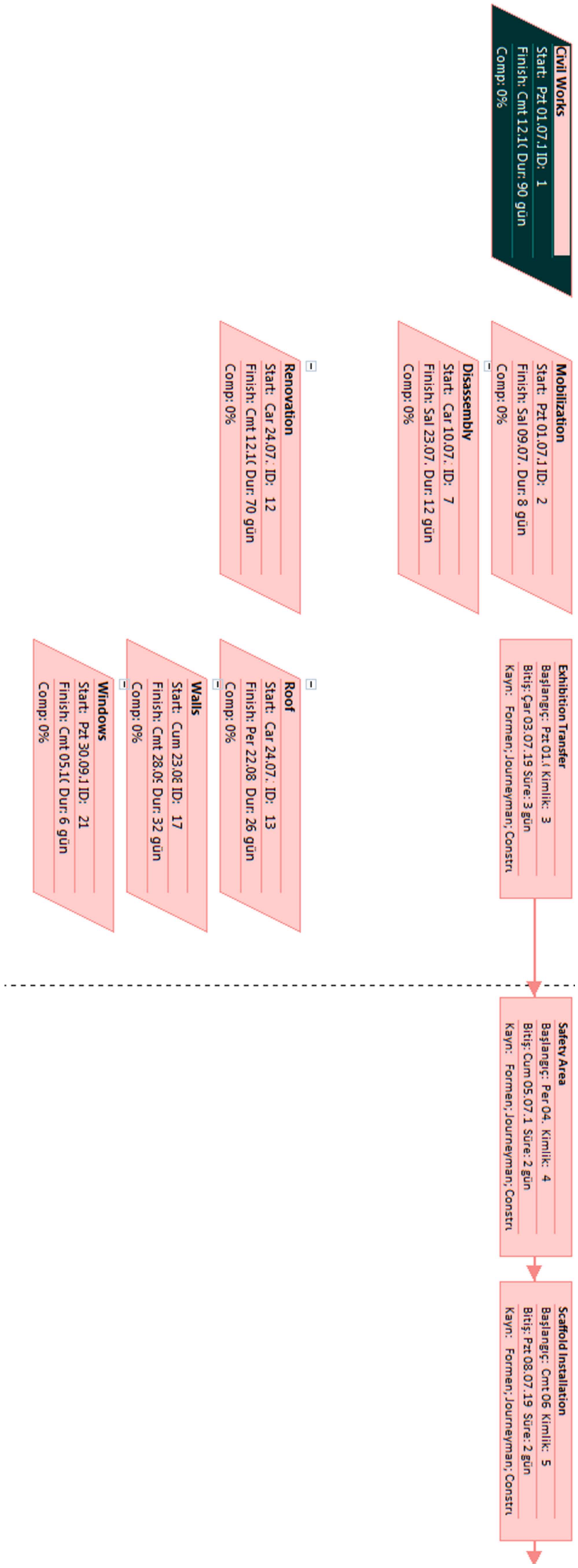
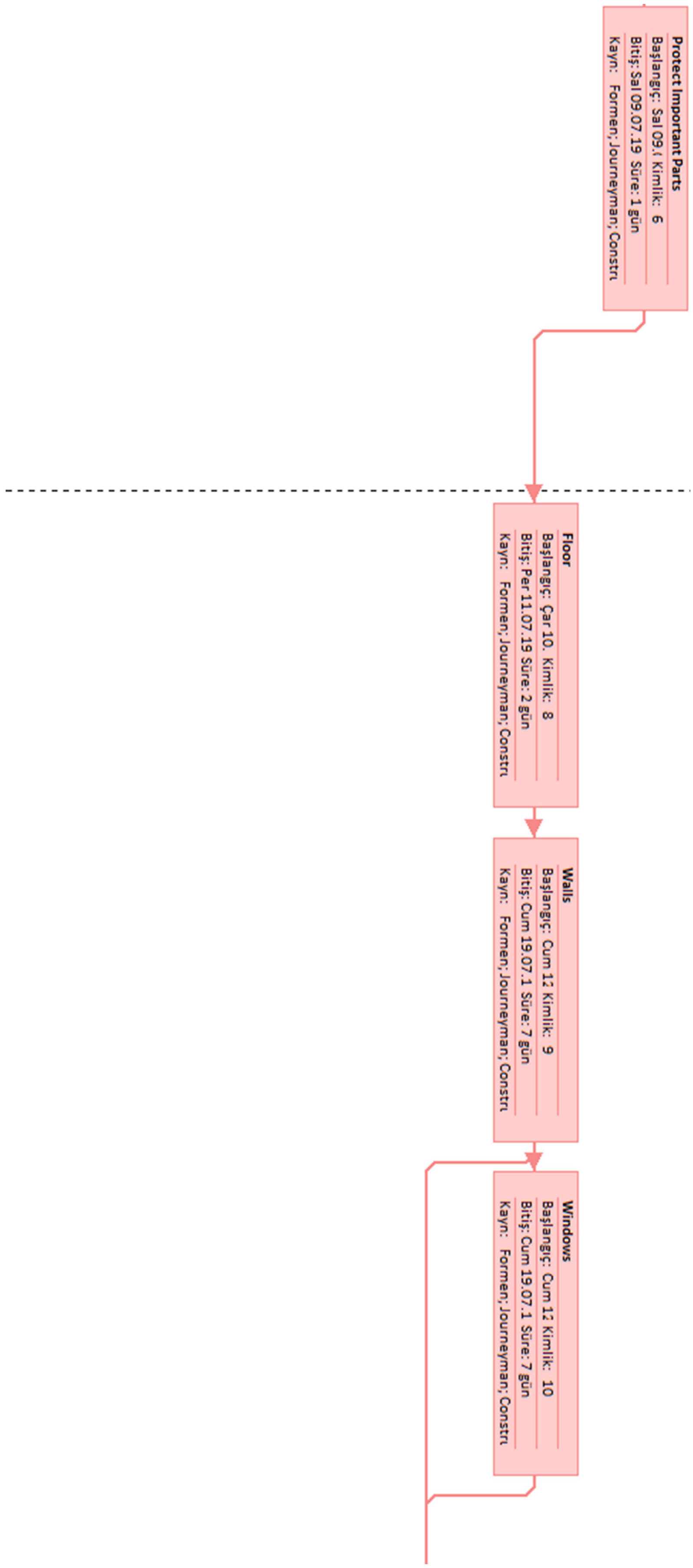
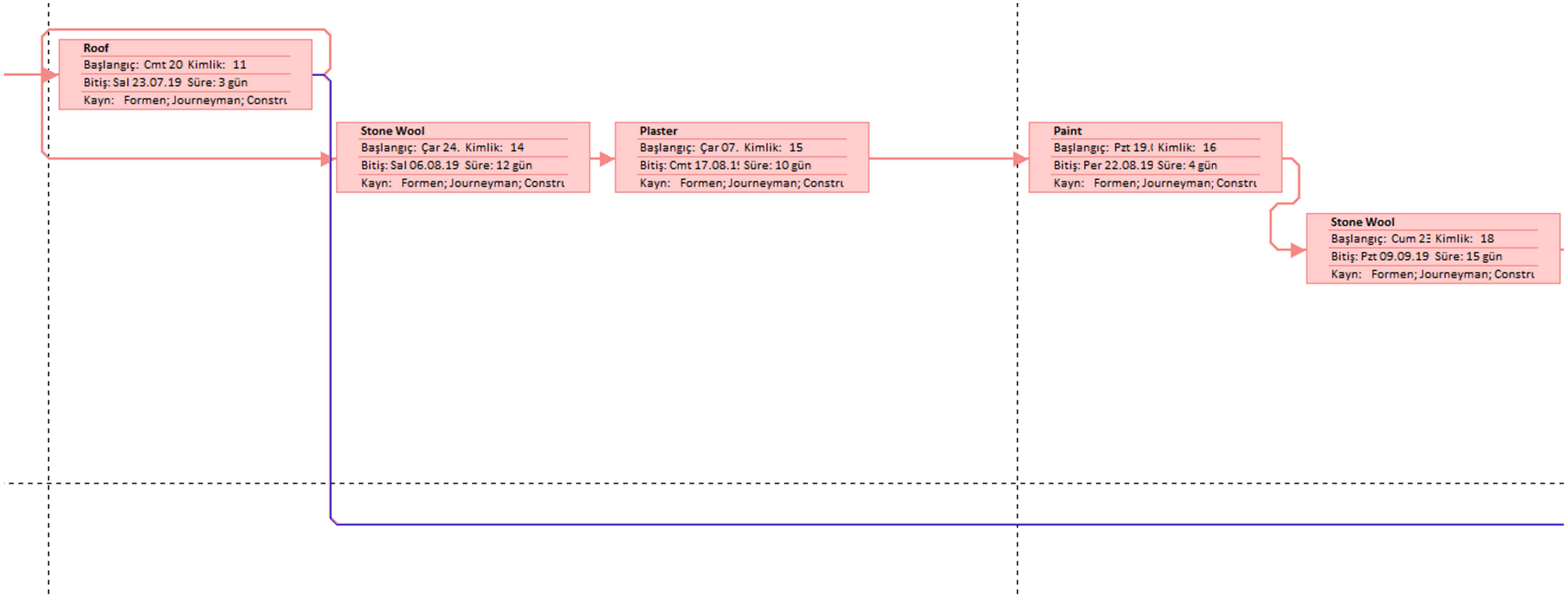
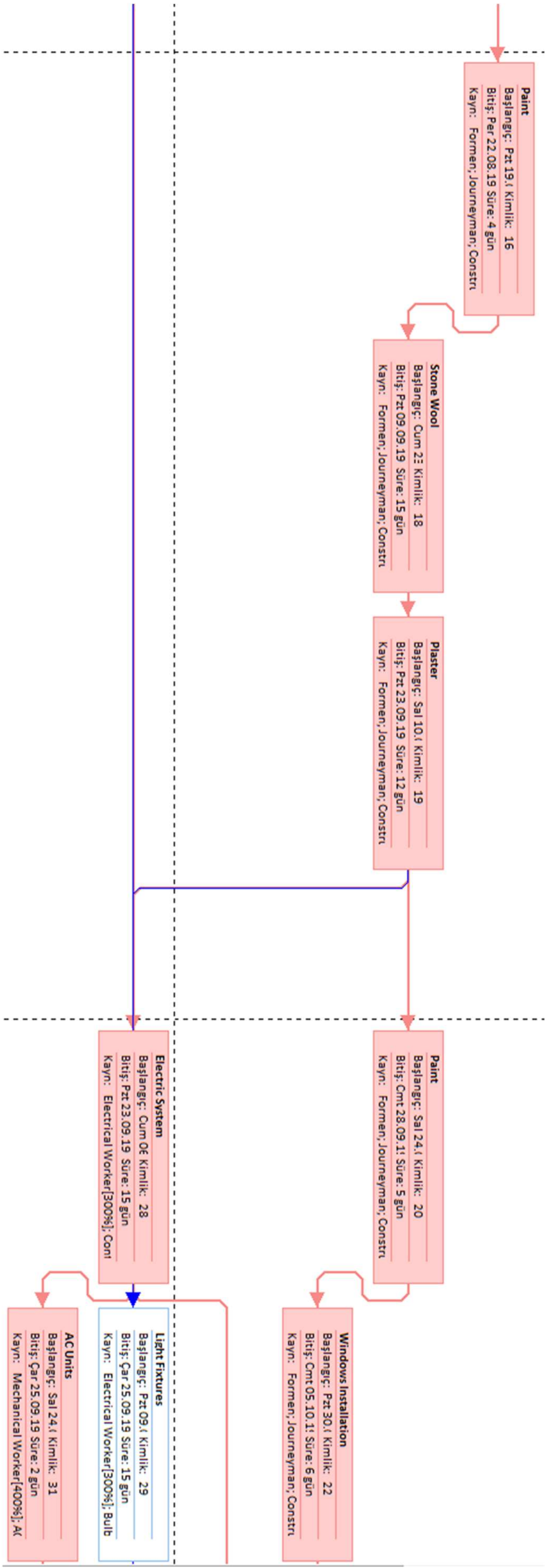
8 APPENDIX-A


Civil Works
Start: Pzt 01.07.1 ID: 1
Finish: Cmt 12.1(Dur: 90 gün
Comp: 0%
Mobilization
Start: Pzt 01.07.1 ID: 2
Finish: Sal 09.07. Dur: 8 gün
Comp: 0%
Disassembly
Start: Car 10.07. ID: 7
Finish: Sal 23.07. Dur: 12 gün
Comp: 0%
Renovation
Start: Car 24.07. ID: 12
Finish: Cmt 12.1(Dur: 70 gün
Comp: 0%
Exhibition Transfer
Başlangıç: Pzt 01.(Kimlik: 3
Bitiş: Çar 03.07.19 Süre: 3 gün
Kayn: Formen;Journeyman;Constru
Roof
Start: Car 24.07. ID: 13
Finish: Per 22.08 Dur: 26 gün
Comp: 0%
Walls
Start: Cum 23.0{ ID: 17
Finish: Cmt 28.0(Dur: 32 gün
Comp: 0%
Windows
Start: Pzt 30.09.1 ID: 21
Finish: Cmt 05.1(Dur: 6 gün
Comp: 0%
Safety Area
Başlangıç: Per 04. Kimlik: 4
Bitiş: Cum 05.07.1 Süre: 2 gün
Kayn: Formen;Journeyman;Constru
Scaffold Installation
Başlangıç: Cmt 06 Kimlik: 5
Bitiş: Pzt 08.07.19 Süre: 2 gün
Kayn: Formen;Journeyman;Constru



Protect Important Parts
Başlangıç: Sal 09.(Kimlik: 6
Bitiş: Sal 09.07.19 Süre: 1 gün
Kayn: Formen;Journeyman;Constr
Floor
Başlangıç: Çar 10. Kimlik: 8
Bitiş: Per 11.07.19 Süre: 2 gün
Kayn: Formen;Journeyman;Constr
Walls
Başlangıç: Cum 12 Kimlik: 9
Bitiş: Cum 19.07.1 Süre: 7 gün
Kayn: Formen;Journeyman;Constr
Windows
Başlangıç: Cum 12 Kimlik: 10
Bitiş: Cum 19.07.1 Süre: 7 gün
Kayn: Formen;Journeyman;Constr


Roof
Başlangıç: Cmt 20 Kimlik: 11
Bitiş: Sal 23.07.19 Süre: 3 gün
Kayn: Formen; Journeyman; Constr
Stone Wool
Başlangıç: Çar 24. Kimlik: 14
Bitiş: Sal 06.08.19 Süre: 12 gün
Kayn: Formen; Journeyman; Constr
Plaster
Başlangıç: Çar 07. Kimlik: 15
Bitiş: Cmt 17.08.1 Süre: 10 gün
Kayn: Formen; Journeyman; Constr
Paint
Başlangıç: Pzt 19. Kimlik: 16
Bitiş: Per 22.08.19 Süre: 4 gün
Kayn: Formen; Journeyman; Constr
Stone Wool
Başlangıç: Cum 2 Kimlik: 18
Bitiş: Pzt 09.09.19 Süre: 15 gün
Kayn: Formen; Journeyman; Constr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Bitiş: Per 22.08.19 Süre: 4 gün
Kayn: Formen;Journeyman;Constru
Stone Wool
Başlangıç: Cum 23 Kimlik: 18
Bitiş: Pzt 09.09.19 Süre: 15 gün
Kayn: Formen;Journeyman;Constru
Plaster
Başlangıç: Sal 10.(Kimlik: 19
Bitiş: Pzt 23.09.19 Süre: 12 gün
Kayn: Formen;Journeyman;Constru
Electric System
Başlangıç: Cum 06 Kimlik: 28
Bitiş: Pzt 23.09.19 Süre: 15 gün
Kayn: Electrical Worker[300%];Cons
Paint
Başlangıç: Sal 24.(Kimlik: 20
Bitiş: Cmt 28.09.1! Süre: 5 gün
Kayn: Formen;Journeyman;Constru
AC Units
Başlangıç: Sal 24.(Kimlik: 31
Bitiş: Çar 25.09.19 Süre: 2 gün
Kayn: Mechanical Worker[400%];AC
Light Fixtures
Başlangıç: Pzt 09.(Kimlik: 29
Bitiş: Çar 25.09.19 Süre: 15 gün
Kayn: Electrical Worker[300%];Bulb
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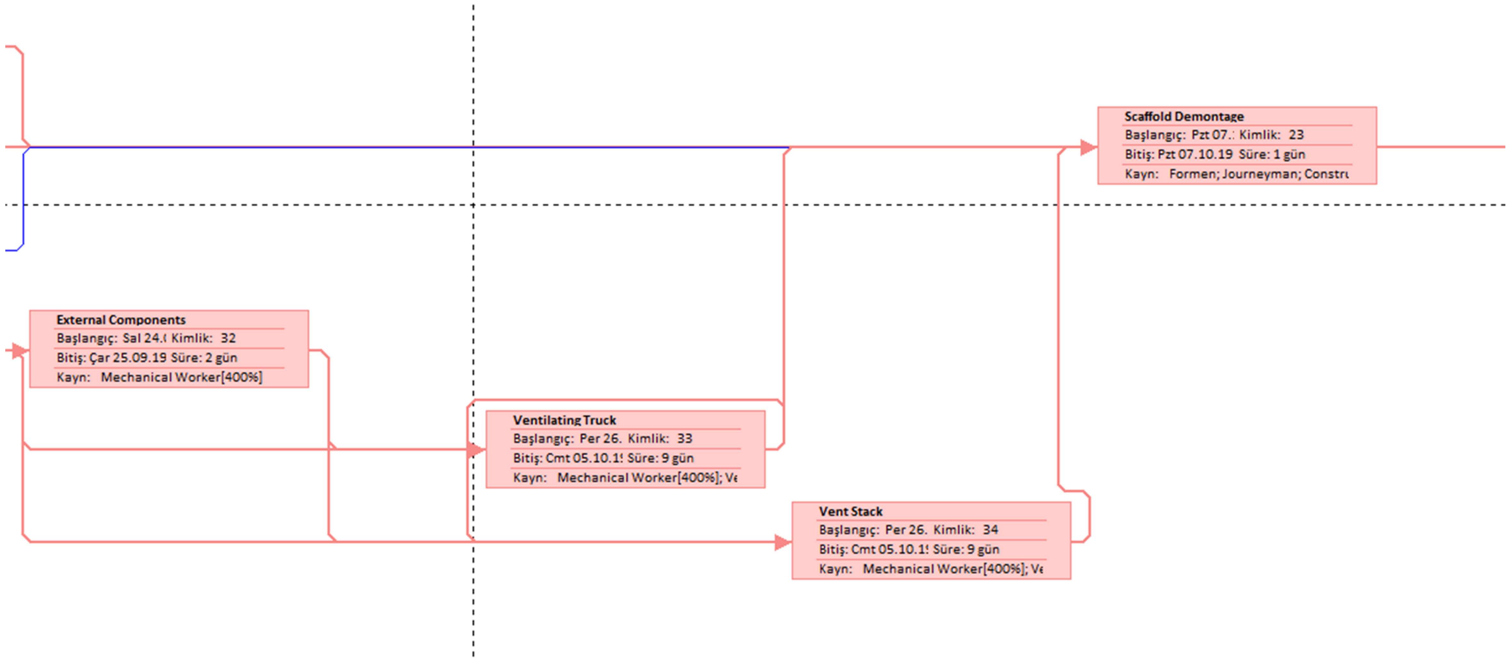
Kayn: Formen;Journeyman;Constru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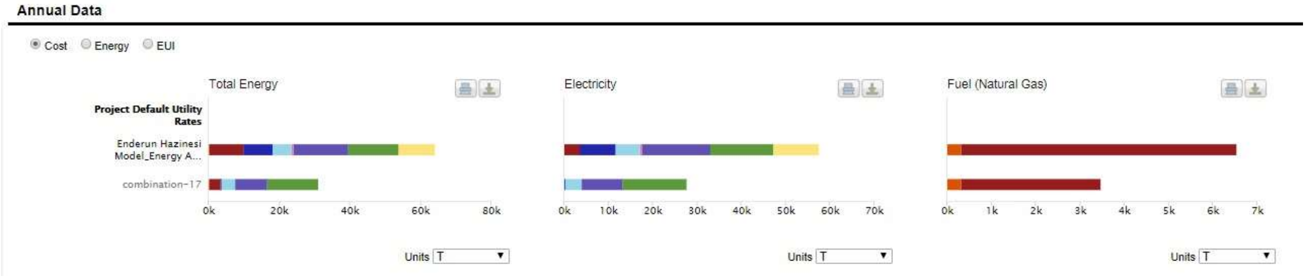
Ventilating Truck
Başlangıç: Per 26. Kimlik: 33
Bitiş: Cmt 05.10.1! Süre: 9 gün
Kayn: Mechanical Worker[400%]; Ve
Vent Stack
Başlangıç: Per 26. Kimlik: 34
Bitiş: Cmt 05.10.1! Süre: 9 gün
Kayn: Mechanical Worker[400%]; Ve
Scaffold Demontage
Başlangıç: Pzt 07.: Kimlik: 23
Bitiş: Pzt 07.10.19 Süre: 1 gün
Kayn: Formen; Journeyman; Constru

9 APPENDIX-B


Annual Data
Cost Energy EUI
Total Energy
Electricity
Fuel (Natural Gas)
Project Default Utility Rates
Enderun Hazinesi Model_Energy A...
combination-17
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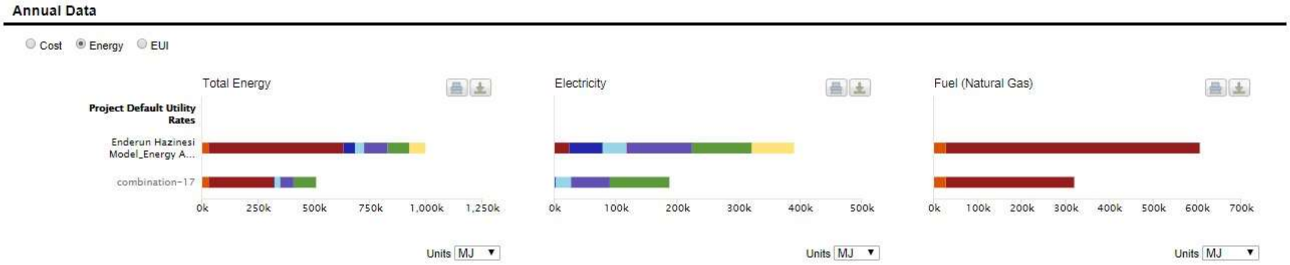
0k 10k 20k 30k 40k 50k 60k 70k
0k 1k 2k 3k 4k 5k 6k 7k
Units T


Annual Data
Cost Energy EUI
Total Energy
Electricity
Fuel (Natural Gas)
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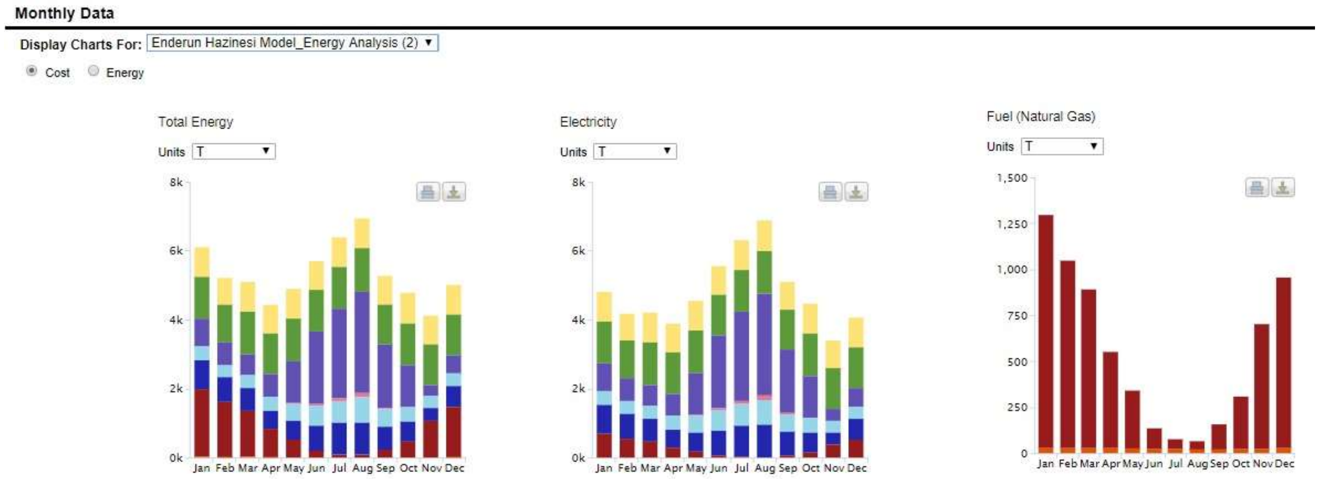
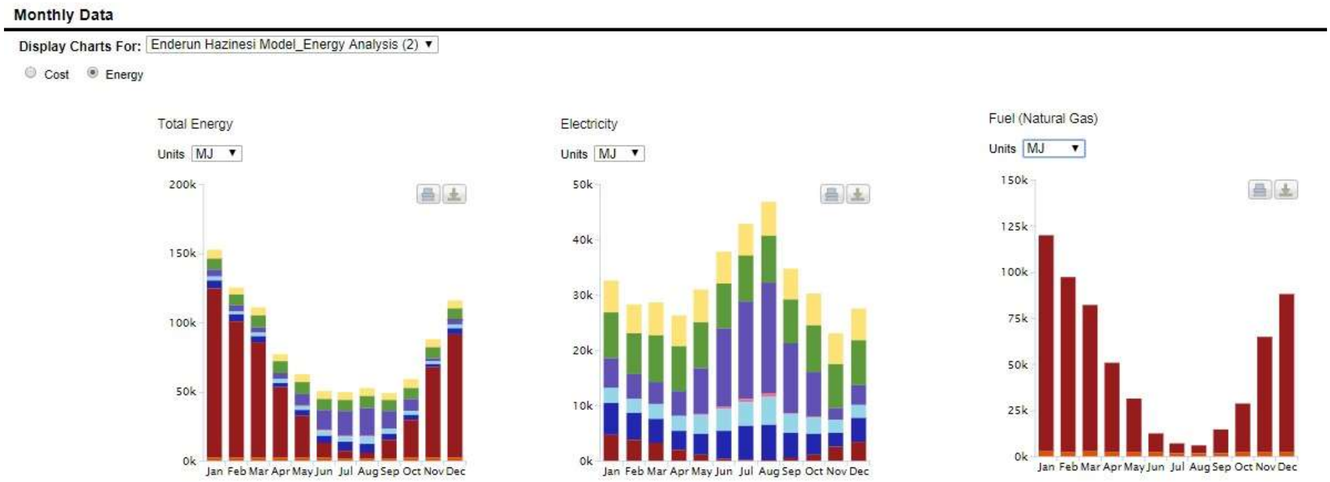
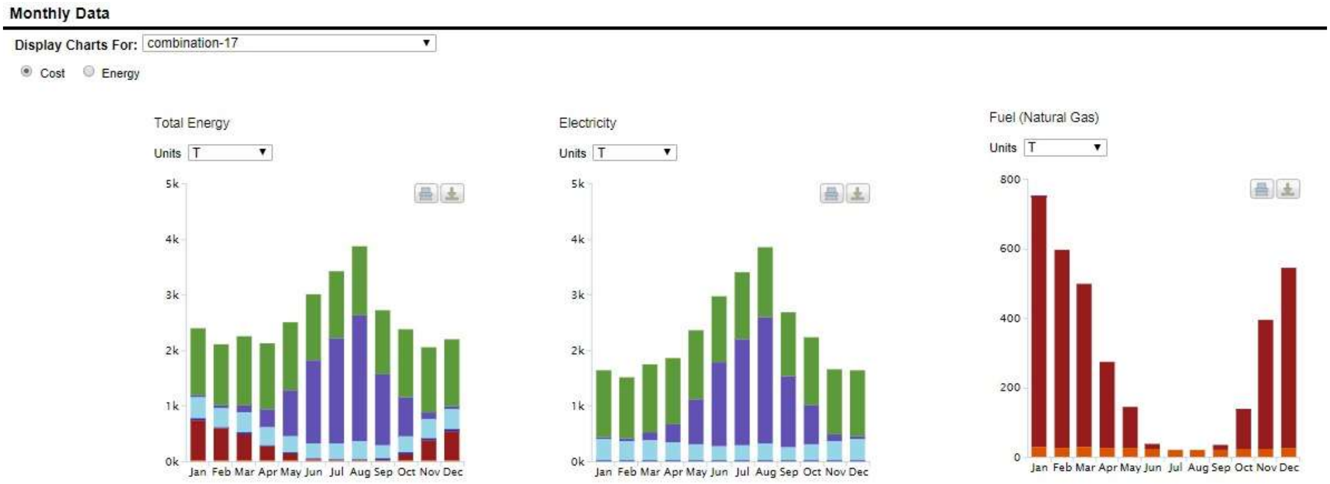
0k 250k 500k 750k 1,000k 1,250k
0k 100k 200k 300k 400k 500k
0k 100k 200k 300k 400k 500k 600k 700k
Units MJ


Monthly Data
Display Charts For: Enderun Hazinesi Model_Energy Analysis (2)
Cost Energy
Total Energy
Electricity
Fuel (Natural Gas)
Units T
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


Monthly Data
Display Charts For: Enderun Hazinesi Model_Energy Analysis (2)
Cost Energy
Total Energy
Electricity
Fuel (Natural Gas)
Units MJ
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


Monthly Data
Display Charts For: combination-17
Cost
Energy
Total Energy
Units T
Electricity
Units T
Fuel (Natural Gas)
Units T
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec

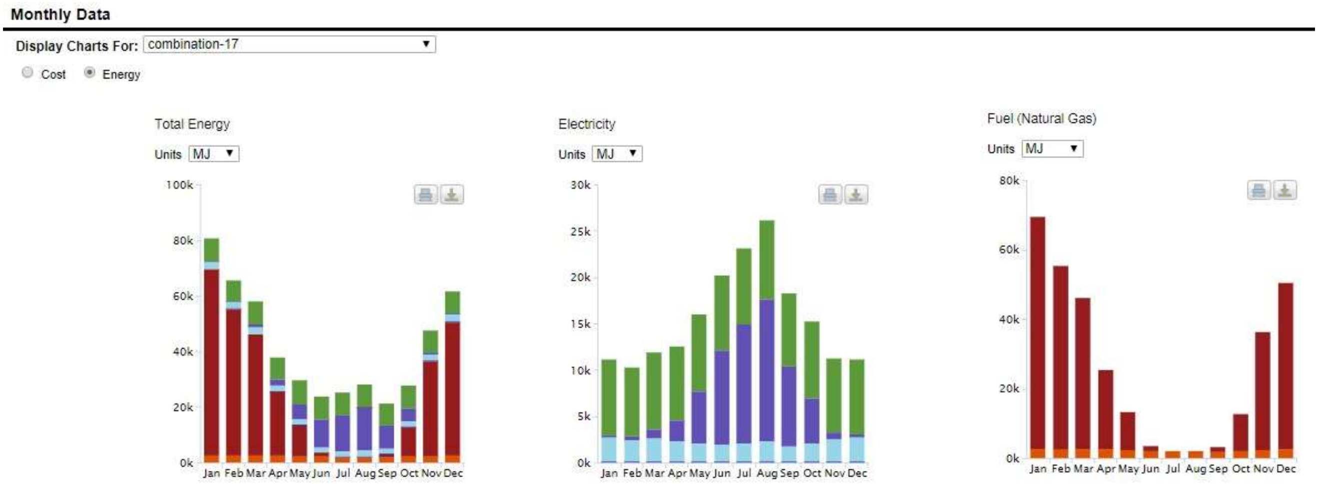

Monthly Data
Display Charts For: combination-17
Cost
Energy
Total Energy
Units MJ
Electricity
Units MJ
Fuel (Natural Gas)
Units MJ
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


Chart Sort:
Chronological
Alphabetical
Run Total
Area Lights
Misc Equip
Space Cooling
Heat Rej
Vent Fans
Pumps Aux
Space Heat
Hot Water