ISCTE Business School
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PAYBACK PERIOD ANALYSIS of USING GREEN ENERGY Within the Scope of SMART URBAN REGENERATION and SELECTION of GREEN VEHICLES in TURKEY

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Abstract

In today's world, number of people who live in cities allocate almost 50% of the world population and it is expected to be reached 80% in the following years. Therefore, smart urban regeneration pursuant to use of green energy and green mobility gain critical role for sustainable environment.

The study documented in this paper has been carried out in order to change people's perception on expensiveness and immaturity of using green energy and green vehicles by giving quantitative results for Turkey case. Importance and benefits of using green energy and green vehicles within the scope of urban regeneration will be highlighted.

Consumption comparison between current and energy efficiently retrofitted house is analyzed with the help of software such as Hourly Analyze Program by Carrier. In addition, electric generation via photovoltaics is observed with PV*Sol.

Greening the vehicles offer wide range of benefits including reduction of fuel consumption that plays very important role on both household economy and environment. In order to highlight economic benefits, diesel-gasoline vs. hybrid-electrical vehicle comparison is made.

After benefits are shown and consumption analysis are done, initial aim has been achieved through the payback period analysis of retrofitting the building that designed as elementary family house and greening the personal vehicles regarding to initial investments and savings in Turkey.

Keywords: Smart Urban Regeneration, Green Energy, Green Vehicles, Payback Period

JEL Classification: M21 and O33

Resumo

O número de pessoas que vivem em cidades aproxima-se dos 50% da população mundial, sendo que é esperado que se alcance os 80% nos próximos anos. Desta forma, uma regeneração urbana inteligente baseada na utilização de energia e mobilidade verde têm vindo a ganhar destaque para a criação de um ambiente sustentável.

Este estudo foi realizado com o objetivo de mudar a perceção das pessoas sobre o custo e a maturidade do uso de energia verde e de veículos mais sustentáveis, disponibilizando um conjunto de resultados no contexto da Turquia. A importância e os benefícios do uso de energia verde e veículos ecológicos no âmbito da regeneração urbana será destacado.

A comparação entre consumos gerados pelo uso de eletricidade gerada tradicionalmente e aquele que deriva do uso de eletricidade proveniente de uma casa reequipada de forma eficiente e sustentável é analisado com a ajuda de softwares como o Hourly Analyze Program da Carrier. A geração elétrica através de células fotovoltaicas é analisada com o programa PV * Sol.

A utilização de veículos sustentáveis oferece inúmeros benefícios, incluindo a redução do consumo de combustível que desempenha um papel muito importante quer para a economia familiar, quer para o meio ambiente. A fim de destacar os benefícios económicos, a comparação veículo diesel-gasolina vs. híbrido- elétrico é feita.

Após a identificação dos benefícios suportada pela análise de consumo, desenvolveu-se uma análise ao *payback period* relativa à adaptação ecológica quer do edifício concebido como casa de família elementar, quer dos veículos pessoais considerados, tendo em conta os investimentos iniciais e a realidade económica na Turquia.

Palavras-chave: Smart Regeneração Urbana, Energia Verde, Veículos Verdes, Período de Retorno

Classificação JEL: M21 e O33

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Abbreviations and Acronyms

Acronym	Description
HAP	Hourly Analyze Program
m^2	Square Meter
XPS	Extruded Polystyrene
cm	Centimeter
U	Thermal Transmittance Coefficient
PVC	Polyvinyl Chloride
DHW	Domestic Hot Water
HVAC	Heating, Ventilating, & Air Conditioning
€	Euro
m^3	Cubic Meter
EPS	Expanded Polystyrene
LED	Lighting Emitting Diode
W	Watt
PV	Photovoltaic
BIPV	Building Integrated Photovoltaic
kW	Kilowatt
kWh	Kilowatt Hour
EV	Electric Vehicle
EU	European Union
EC	European Commission
CO_2	Carbon Dioxide
lt	Liter
gr	Gram
km	Kilometer
Km/h	Kilometers Per Hour

BMW	Bayerische Motoren Werke
yr	Year
BEC	Building Energy Certificate
e.g.	Exempli Gratia (Latin)
PC	Personal Computer
SCC	Smart Cities and Communities

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1 Introduction

This paper has been prepared in order to communicate the master dissertation thesis that has been undertaken within the scope of the Instituto Superior de Ciências do Trabalho e da Empresa 2nd year Business Administration course.

1.1 Definition of the Problem Context

According to Environment Protection Agency (2012), atmosphere is overloaded with carbon dioxide and other hazardous emissions by human activities. As a result, those gases trap the heat at the atmosphere and causes steady temperature increase on the planet that create harmful and significant impact on climate, environment and health. Furthermore, fossil fuels are spent in a non-sustainable manner although fossil fuels are finite and reserves cannot be replenished naturally. In addition, concentration of fossil fuels is getting more technically challenging and expensive since it is available only in a certain region

As the world population increased, the number of buildings to live in and vehicles to travel is increased. Even tough and environmental and economic benefits of using green energy is started to prove by authorities, citizens still have prejudice on green energy systems due to small number of accomplished examples and objective quantitative results. (Aksu & Yenilmez, 2016)

In addition, Erdal (2008) states that Turkey is a country whose energy resources rely heavily on outside. Therefore, cost of energy is highly expensive (Demirbaş, 2001). Also, environment policies are one of the essential titles pursuant to cohesion policy of EU that Turkey should fallow to meet the membership requirement as a candidate country.

1.2 Research Problem Addressed

Increasing environmental problems on earth, excessive population growth and industrialization are the basis of the problems faced in the new century of environmental planners and designers (Kırzıoğlu, 2000). Özbalta (2003) claimed that it is necessary to develop an energy system that is disturbing the ecological balance in urban regeneration. Thus, people must be more aware about importance of using green energy and green vehicles due to global warming effects in the last decade.

Research problem will address the following question: How long is the payback period for green energy systems? Is it match with people's negative thoughts and discouragement about green energy systems or is it just the opposite.

1.3 Brief Statement About the Research Methodology Used

Cost/Benefit or Cost/Saving analysis provides simple and very useful set of tools for citizens to make rational investment decisions about which green energy actions are the most cost-effective to implement. From simple to complex there are many levels of this type of analysis (Sitarz, 2008).

According to Mear (2011), simple cost payback method is used in order to ensure readers to make rational decisions on building retrofitting within the scope of urban regeneration. In this method, total investment cost of the retrofitting is divided by the annual energy cost saving occurred by the retrofitting. The result of the division gives the number of years that is required to pay retrofitting's initial cost.

Reliable simulation programs such as Hourly Analyze Program (HAP) for current and retrofitted building energy consumption and PV*Sol for electric generation by photovoltaic, have been used for analyzing the savings and contributions.

Cost is calculated from price offers from corporate firms for building interventions and price lists from official websites of vehicle companies. It should be noted that current prices are considered to have objective results.

Payback period methodology including three different cases which are best, worse and base, is used to enlighten the reader about purchase decision of green vehicles instead of conventional vehicles.

1.4 Value of the Thesis

This paper is intended as a resource for any citizen who seeks to participate green energy system users. Its mission is to enlighten citizens against their prejudice and change their perception on expensiveness and immaturity of green energy and green vehicle usage within the scope of urban regeneration. In addition, savings and benefits of these systems will be highlighted during this paper.

1.5 Thesis Structure

The dissertation is structured into 5 main sections, namely:
Chapter 1 of the report, successively define the content and format of the thesis. Chapter 2 express previous studies on smart building interventions and green mobility.

Chapter 3 summarizes the demo house audit and simulation result of the current situation versus the expected results as a function of boundary conditions, which then serve as a basis to evaluate feasibility of the suggested retrofitting actions. Additionally, it indicates comparison between environment friendly green vehicles and conventional vehicles.

Chapter 4 summarizes the results of building retrofitting action in terms of economical and thermal transmittance (U Value). In addition, economic analysis of mobility interventions including base, best and worst case can be found in this section.

Chapter 5 briefly explains the barriers in front of smart urban regeneration model that create prejudice on people to put into practice. Also, it remarks the outcomes of the smart urban regeneration model and economic analysis of interventions.

2 Literature Review

In field of existence, brain power of human race trumps over any physical strength of animals so far. Creatively modifying the environment and building stable houses allowed humans to secure safety goals thanks to this ability. In fact, without safe and comfortable living zone crafting of dishes and weapons, which are vital elements for early humankind, would not be possible to done. More than for paintings and writings, most of the civilizations are mentioned and known for the buildings they left behind (Smart Cities and Communities, 2013).

According to Mega's (2005) study, buildings are responsible for 45% of the total energy consumption in the European Union that is caused by heating, cooling, ventilation, lighting, appliances and equipment's demand. Higher levels of indoor comfort, growing use of complex electronic systems and equipment at homes and offices and increasing living space per capita cause more energy consumption. It is estimated that European people spend their 90% of time indoors, thus the impact of energy consumption in buildings is pervasive.

As the population of the World increase, the number of construction on the planet increase. Due to recent atmospheric & environment pollution reports building design gain vital importance. Thankfully, potential new house buyers looking for not only a comfortable but also smart and environment friendly houses nowadays. Therefore, new buildings are started to be registered to third-party green building certification institutions by construction companies. This trend can be seen as sale and marketing strategy; however, it is also effective way of increasing the number of smart houses (Kibert, 2016). In addition, people should have been showing same sensitivity when it comes to urban regeneration and renovation of houses.

In addition, a directive has published by the European Union that indicates all Member States shall ensure not only all new buildings are nearly zero-energy buildings by 31 December 2020 but also new buildings occupied and owned by public authorities are nearly zero-energy buildings after 31 December 2018. (European Parliament and the Council of the European Union, 19 May 2010) Therefore, building retrofitting interventions are very essential to reduce not only energy demand but also carbon emission.

Green energy and transportation technologies are key to obtain societal and economic benefits and improve citizens' quality of life. Majority of the interrelations between technology and people can be represented by green technologies. When energy production, distribution and use, mobility and transportation are related and go hand in hand, a big task offering new interdisciplinary opportunities to turn cities smarter. Is already open in the common area (REMOURBAN, 2015).

Furthermore, internal combustion engines have been dominating personal transportation since approximately last century. In fact, in urban areas almost half of the total pollution occurred by the use of fossil fuels in transportation which generates harmful emissions (Kikuchi, 2009). In order to achieve cleaner urban mobility, specific efforts on new fuels and technological innovations are started to dedicated by local authorities. Pyke & Brown (2010) stated that electric vehicles are about to experience rapid growth in both developed and developing vehicle markets. If broad adaption of the electric vehicle satisfied, environmental footprint of transportation and dependency on the petroleum will be decreased dramatically.

2.1 Building Retrofitting

The use of renewable energy sources and ecological planning in urban regeneration is quite a new issue. After the major earthquake occurred in 1999, this issue become even more important. Thanks to urban regeneration, renewable energy usage has been increased in smart buildings. Renewable energy sources are geothermal, solar, wind, sea-based, biomass and hydraulic energy (Duygu, 2002).

Researches and articles about urban transformation and renewable energy sources are available in literature. One of them was made by Şenlier in 1994. He defined the definition of ecological restrictions, content and method in cities.

In the first case, it should be noted that citizens have no problem to resort to the financing for televisions, mobile phones, PC and appliances, that is, equipment that often have costs in the order of magnitude of the investments related to smart cities and energy efficiency, but possess the advantage of generating cash flows and have returns comparable or better than typical investment opportunities available in the bank for the same subjects (Aksu & Yenilmez, 2016).

According to US General Services Administration (2009), numerical analysis of the green buildings are the followings: green buildings have 7.5% higher value, 8.5% lower operational cost and 3.5% greater occupancy ratio than traditional buildings. Additionally, they provide a 6.6% total return on investment according to the 2008 McGraw-Hill Construction Smart Market Report. Consequently, green buildings on average generate greater investment returns than those that are not. In other words, life cycle cost of green buildings is lower than newly built conventional buildings.

In addition, Re-use of existing structures enables the preservation of resources as well as the cultural and architectural characteristics pertaining to one's country. Attention to detail regarding the siting of buildings can also contribute to occupants' quality of life. Thus adopting a holistic approach to construction is critical in deciding to build green.

2.1.1 Insulation

In low-energy buildings, where heating demand is high, the whole building envelope should be insulated very well. Building elements which distinguish outside from the inside accepted as building envelope. Objective of the thermal insulation is ensuring comfortable indoor climate irrespective of outside climate and temperature that is determined by the weather (Yenilmez, 2015).

The passive house resource (2016) has stated if the insulation is insufficient to prevent heat transfer, heat is lost through the building envelope and vis-à-vis for hot periods. Therefore, heat flow is needed to be restricted regardless of the climate.

2.1.2 Glazing

Windows are one of the most essential components of buildings as they provide natural daylighting, ventilation and visual interface between interior and exterior spaces. Window types may have a direct effect on energy efficiency for buildings both in positive and negative ways in accordance with its properties. Double or triple glazing, inert gas filling or low-e coating applications for windows are the main solutions that increase window efficiency (Strong, 2012)

2.1.3 LED Lighting

Fluorescent lamps are replaced with LED panels due to their low energy consumption and high hour of lifespan while comparing to the others. Also, there is no need any maintenance for LED panels. In addition, LEDs retain their luminous flux and color temperature until the end of their life cycle. Besides, LEDs offer decorative solutions (U.S. Department of Energy, n.d). In addition to LED panel retrofitting, applique lamps are used in bedroom, bathrooms and at the stairs in order to offer comfort zone.

2.1.4 Photovoltaics

The studies on how to benefit from solar energy has gained momentum especially after 1970s. Later on, thanks to technological advances in solar energy, the cost of using solar energy has decreased. In addition, after some analysis and tests conducted by experts, solar energy has been classified as a clean energy source (Administration, General Directorate of Electrical Power Resources Survey and Development, n.d). Türe (2011) stated that countries who have limited fossil fuels should adopt solar energy as one of their primary energy sources. Since Turkey doesn’t have enough fossil fuel reserves, it is wise to adopt solar energy.

Integration of the photovoltaic (PV) into the building envelope is called Building Integrated Photovoltaic (BIPV). According to Oliver & Jackson (2001), BIPV can serve dual function which are building skin replacing conventional building envelope materials and power generator. Since BIPV serving as building envelope material and power generator, it can not only provide savings in electricity costs and materials, reduce use of fossil fuels and emission of ozone depleting gases but also add architectural value to the construction.

In today's market, a wide variety of BIPV systems are available. Façade systems and roofing systems are main categories of them. Façade system includes glazing, curtain wall products and spandrel panels whereas roofing system includes tiles, shingles, standing seam products, and skylights (Strong, 2011)

2.2 Mobility

Nowadays, hybrid and fully-electric vehicles are becoming a mainstream reality. Hybrid vehicle has gasoline engine and electric motor at the same time. Hybrid vehicle uses electric motor at low speed, for short distance and while waiting at the red light (Graham,2001). On the other hand, hybrid vehicle uses gasoline engine for performance drive, high speeds and long drive. Differently, fully-electric vehicle only consumes stored electric at the batteries. According to Simpson (2006), Gallagher (2011) and Erjavec & Arias (2007), green vehicles offer many benefits as following;

Fuel cost: As World population increase, the number of vehicle and therefore the amount of oil consumption increase. As a result, the number of oil reserves decrease, the number of oil price increase according to supply-demand relation. Fuel cost benefits of the green vehicles probably the most obvious benefit. Hybrid vehicle saves approximately 40% fuel in the urban and 20% on the highway. The only fuel cost for electric vehicle is electric consumption while charging the battery.

Energy security: Oil is a finite energy source, in other words oil reserves will be finished one day. Electric on the other hand, can be generated from renewables such as solar and wind energy. Therefore, electric as a source of energy is much more secure and available comparing to oil.

Tax benefits: Government implies tax deduction incentive on green vehicles in order to encourage more people while buying their next vehicle. Electric vehicle owners do not pay motor vehicle tax while hybrid owners pay lower than gasoline or diesel engine vehicle owners due to tax benefits of green vehicles. Not only tax benefit, but also grant is given by some governments.

Lower greenhouse gas emissions: Clean air and healthy environment is possible with reducing toxic emissions. Using hybrid vehicle reduce carbon and sulfur emissions significantly whereas electric vehicle eliminates greenhouse gas emission at all. For example, hybrid vehicle can reduce toxic emission 97% by using ethanol or biodiesel in place of gasoline.

Faster commuting times: In order to encourage more people for purchasing green vehicles, major highways are starting to add lanes that can be only used by these vehicles. In addition, free parking spaces are available for green vehicles at some carpark, parking garage and roadside park.

Power efficiency: Since, weight of the materials that are used in green vehicles are less than traditional vehicles, they can not only maneuver and handle easier but also consume less energy. Furthermore, EVs do not need transmission at any speed and any type of road. In reality, frictions are occurred while transmitting generated power from engine to the tires. Thus, green vehicles use power more efficiently than traditional vehicles.

Furthermore, European Commission set their mobility aims as green mobility and release directives often. For instance, commission announce comprehensive new strategy to reduce CO_2 emissions from new cars and vans sold in EU. According to new strategy, average emission is limited to 120 grams per kilometer for passenger cars. All manufacturer's newly registered vehicles must comply emission target by 2015. EC take this step forward and aims 95 grams of emission per kilometer for 2020. In addition, EC released proposal stating that information relating to fuel economy and CO_2 emission of new passenger cars must be available for consumer in order to enable them to make an informed choice. Additionally, commission offers super credit to the carmakers whose vehicles emit less than 50 grams of CO_2 gas per kilometer.

European Commission Research & Innovation (2012) declared another important milestone that address the needs to green vehicles are Energy for a changing world package which signed by EU leaders to cut greenhouse gas emission of their countries by 20% until 2020.

3 Methodology

3.1 Green Building Design

3.1.1 Demo House Audit

Demo House was built before the Turkish National Energy Efficiency Regulation was published in 2008. Therefore, the comfort conditions are extremely low and heating costs are quite high. There are other problems in practice regarding the aesthetic and improper practices during construction.

Building audit is aiming to analyze current situation of the buildings in terms of energy use and comfort. Below information was included for the buildings;

- Building Envelope
- Openings and shading elements
- Thermal bridges and airtightness

To determine the baseline energy, use of the district, below methodology have been used:

- Occupancy schedules, heating/cooling systems and equipment were collected from demo house,
- Thermal inspection conducted to determine heat loss/gains, bridges, air-tightness.
- Blower door test conducted to determine airtightness of the demo house.
- HAP (Carrier) energy simulation software used for energy modeling.

3.1.1.1 Current Status of the Demo House

Demo house has general architecture of two-story family house with 148 m^2 conditioned area that consists of 3 bedrooms, living room, 2 bathrooms and WC, kitchen and 2 verandas.

Figure 1 and 2, which are given below, represent overview and floor plans of the demo house respectively. Note that, figure 1 created via 3DS Max software while figure 2 created via AutoCAD software.

Figure 1: Demo House Overview

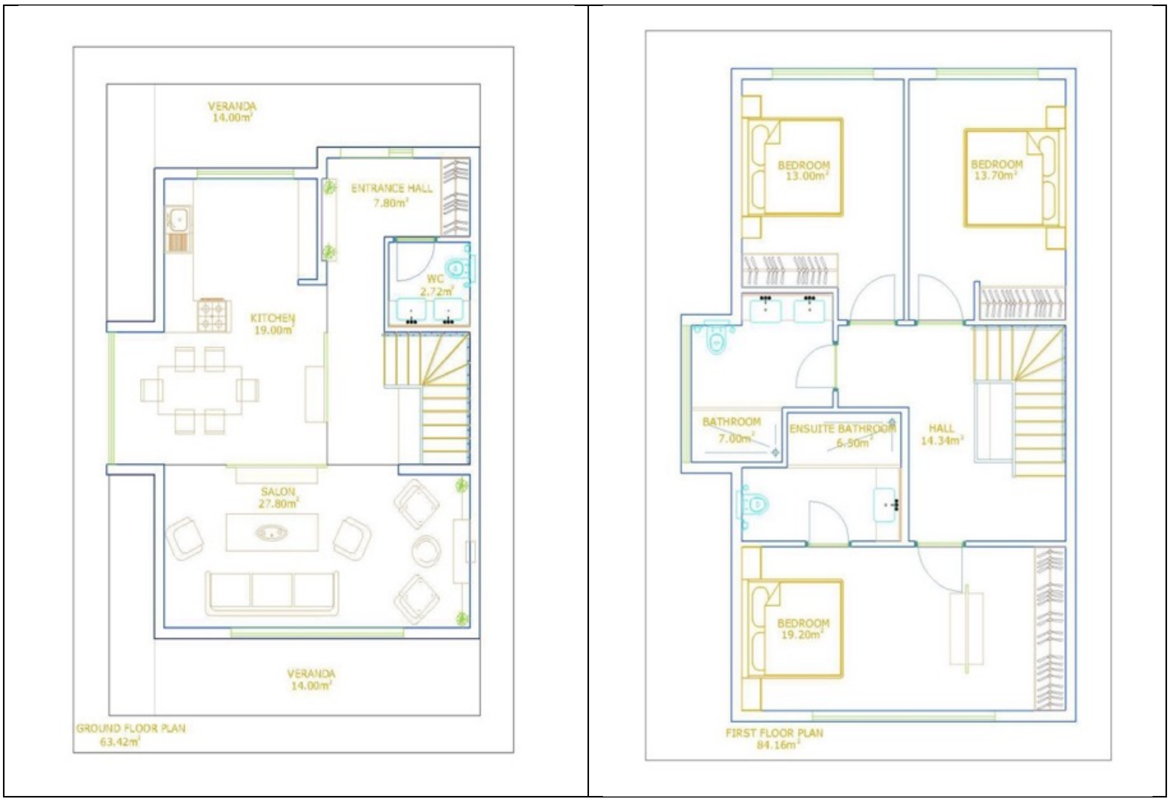
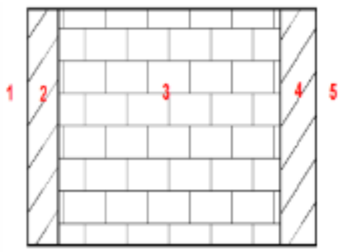
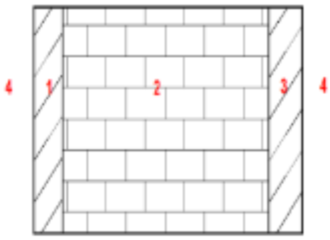
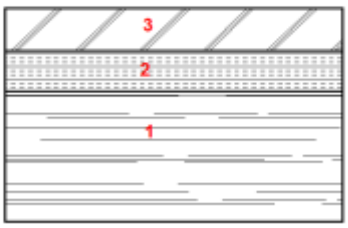
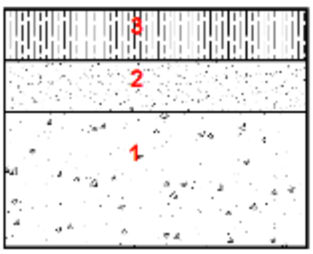


Figure 2: Floor Plans

3.1.1.1.1 Building Envelope

Demo House was built with carcass system. Load-bearing system is composed of reinforced concrete columns and beams that are sitting on a concrete foundation. In addition, Demo House has 19 cm brick wall, 3 cm Extrude Polistren (XPS) insulation and American siding coating.

Table 1: Demo House Element Description

Element description	**Detail**(section's sketch from inner face to outer face)	Picture
External wall 1. Internal Paint 2. Internal Plaster (2 cm) 3. Brick Wall (19 cm) 4. XPS (3 cm) 5. Siding (0,5 cm) **U-value = 0,617 W/(m²K)**		
Internal wall 1. Internal Plaster (2 cm) 2. Brick Wall (15 cm) 3. External Plaster (2 cm) 4. Paint (0,2 mm) **U-value = 0,45 W/(m²K)**		
Roof 3. Tile 2. Membrane (Waterproofing-3mm) 1. Pitched roof **U-value = 0,356 W/(m²K)**		
Ground floor 3. Tile finish 2. Cement finish 1. Concrete **U-value = 0,542 W/(m²K)**		

Glazing & Window Double glazed and PVC frame (4+12+4) **U-value =3.2 W/(m^{2}K)**		

Table 1 prepared according to Turkish Standards 825 and it indicates detailed description of the demo house elements such as internal and external wall, glazing and window, ground floor and roof. For instance, external wall has 5 layers including internal paint, 2 cm internal plaster, 19 cm brick wall, 3 cm XPS insulation and 0,5 cm siding. In addition to layers of the building elements, thermal transmittance value of the building elements is given in the table. For example, by looking at the first row it can be understood that external wall has 0,617 thermal transmittance value regarding to layers and thickness it has.

3.1.1.1.2 Openings & Shading Elements

Demo House's window units have polyvinyl chloride (PVC) frame with double-glazing. High infiltration heat losses are occurred due to poor condition of the PVC frame units. Blower test with rate of 4 air changes per hour confirms the heat losses through openings. (Kuban, 2015)

Table 2: Performance Evaluation of Current Window System

Type of Window	U-Value (W/m K)	Daylight Permeability %	Solar Energy Transmission %	Shading Coefficient
Double Glazed (4+12+4)	3,2	80	75	0,86

(Retrieved from: http://www.trakyacam.com.tr/Content/Pdf/Upload/isicam_performans.pdf)

Table 2 represents performance values of current window system. Current window system has high thermal transmittance with 3,2 (W/m K) that explains the reason of low performance. Furthermore, high daylight permeability and solar energy transmission occurs heat transfer through windows that causes inadequate air quality especially in summer. In addition, there are no shading elements in any of the windows. Demo House only have curtains and stores in order to prevent brightness of the sunlight, therefore shading coefficient of the window gains important role.

3.1.1.1.3 Thermal Bridges

Exterior parts of the reinforced concrete structure are insulated with 3cm XPS. However, insulation does not meet the required level of building code. Below, thermal bridges, heat losses and condensation on façade and interior wall are shown by thermal camera. Besides, heat losses have also been identified on roof cladding.

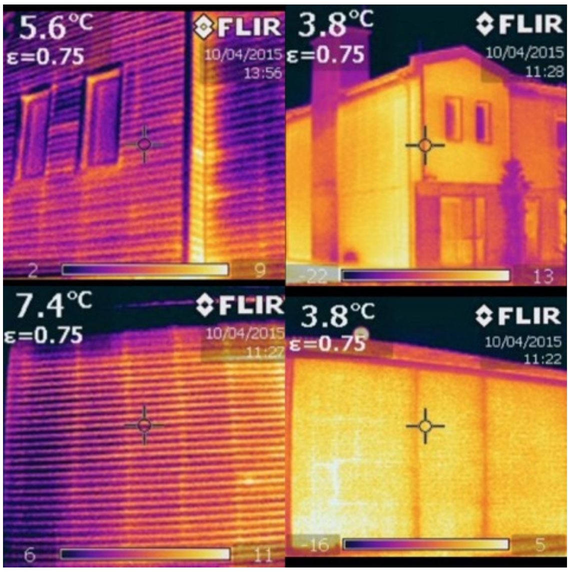


Figure 3: Thermal Bridges

Figure 3 is taken via thermal camera and express thermal bridges of the external wall. Colors indicates the amount of the heat loss, brighter the color more the heat loss.

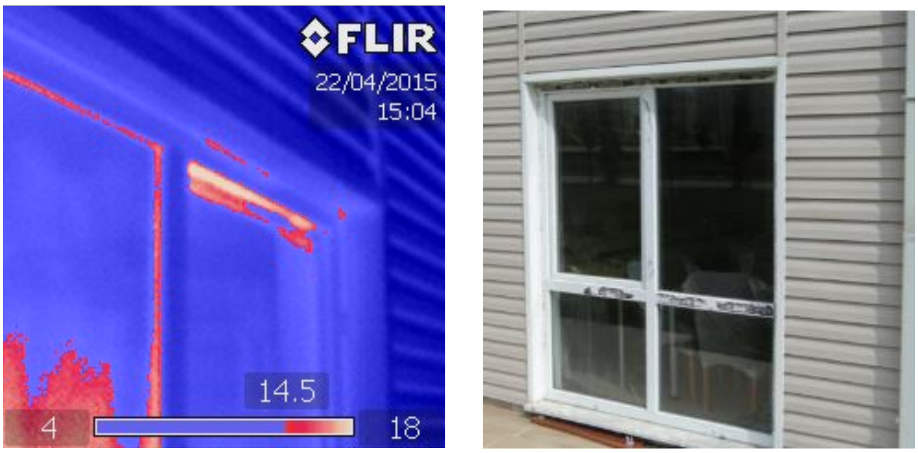


Figure 4: Heat Losses at Openings

Figure 4 states heat losses at openings. It can be interpreted that edges of the window cause heat losses since they are shown in reddish color. It explains that outside temperature is about 4 whereas window edges are 18, thus window edges causes heat losses and act as thermal bridge.

3.1.1.1.4 Airtightness

Blower door test was conducted on demo house in order to evaluate airtightness of the building. Test result calculated according to EN 13829, Method A. The result, which is 4.2 1/h, proves that demo house has very high infiltration losses through window units, doors and frames (Kuban, 2015). Sherman (1995) stated that high rate of air change per hour results significant energy losses at the building. Thus, conditions of the demo house are far from the global standards.

Figure 5: Blower Door Test

3.1.1.1.5 HVAC Systems and Domestic Hot Water

Demo House has individual gas fired boiler with 24 kW capacity to provide heating and DHW for the users. The heating distribution system consists of several horizontal pipes connected to a radiator in each room in each floor. Usually radiators are not equipped with thermostat to adjust individual room to desired comfort conditions; this results discomfort and inefficient energy use in the buildings.

Figure 6: Gas fired boiler and radiator within dwelling

Since there is not proper HVAC system available, fresh air is provided by opening windows and doors most of the time. Air leaks are also a way of natural ventilation but causing significant energy losses. The domestic hot water is supplied by individual boiler equipment which is also provides hot water for heating as described above.

3.1.1.2 Energy Consumption Analysis of the Current House

In this section, energy consumption of the demo house will be analyzed via HAP software. Significant percent of the electric consumption is made by lighting and appliances in the kitchen, living room, bedrooms and bathrooms. In fact, basic appliances' and lighting's electric consumption corresponds to 91% of the total electric consumption. HVAC only consumes electric in order to supply energy for the pumps that enables hot water circulation inside the dwelling. On the other hand, natural gas only consumed in order to heat the dwelling and domestic water. Therefore, HVAC is the only responsible action that consumes natural gas.

In total, 925 m3 natural gas and 4.119 kWh electric is consumed annually to meet the house energy demand in the current situation, in other words before retrofitting.

Table 3: Energy Consumption Analysis of the Current House

Type of Energy Use	Annual Natural Gas Consumption [m3]	Annual Electric Consumption [kWh]
HVAC	925	367
Basic Appliances & Lighting	X	3.752
TOTAL	925	4.119

Table 4: Detailed Monthly Energy Consumption of the Current House

HVAC Monthly Energy Use	Natural Gas (m3)	Electric (kWh)	Basic Appliances & Lighting Monthly Energy Use	Natural Gas (m3)	Electric (kWh)
January	266	62	**January**	X	296
February	190	55	**February**	X	268
March	106	60	**March**	X	296
April	22	53	**April**	X	330
May	X	X	**May**	X	341
June	X	X	**June**	X	330
July	X	X	**July**	X	341
August	X	X	**August**	X	341
September	X	X	**September**	X	330
October	4	17	**October**	X	296
November	109	58	**November**	X	287
December	229	61	**December**	X	296

Table 4 indicates monthly electric and natural gas consumption with purpose of use. The results are taken from HAP energy simulation software that calculate the energy consumption of the buildings regarding to schedule scenarios. Predictably, natural gas consumption increase in winter and reach the maximum in January. The top three months are January, December and February in terms of gas consumption. In March and November, which are known as mid-session months, gas consumption is at medium level. There isn't any gas consumption from May until September. On the other hand, electric consumption shows more stable behavior and it's change range is very small when compared to natural gas consumption.

3.1.1.3 Energy Expense of the Current House

In the previous section, energy consumption analysis of the current house was investigated. By using section 3.1.1.2 consumption values, this section will help us to understand energy expenses of the current house. It should be noted that expenses are calculated according to energy prices in Turkey. Heating the dwelling cost 265€ of natural gas and 38€ of electric consumption. One could query why electric is used while natural gas is the energy source of heating. Electric is needed to run the boiler pump which enables hot water circulation inside the radiator. On the other side, basic appliances and lighting costs 394€ annually. In total 265€ of natural gas and 432€ of electric is consumed annually to meet the current house energy demand for a comfortable living zone.

Table 5: Energy Expense Analysis of the Current House

Type of Energy Use	Annual Natural Gas Expense [€]	Annual Electric Expense [€]
HVAC	265	38
Basic Appliances & Lighting	X	394
TOTAL	265	432

Table 6: Energy Expense of the Current House (Monthly-Detailed)

HVAC Monthly Energy Use	Natural Gas [€]	Electric [€]	Basic Appliances & Lighting Monthly Energy Use	Natural Gas [€]	Electric [€]
January	76	7	**January**	X	31
February	54	6	**February**	X	28
March	30	6	**March**	X	31
April	6	6	**April**	X	35
May	X	X	**May**	X	36
June	X	X	**June**	X	35
July	X	X	**July**	X	36
August	X	X	**August**	X	36
September	X	X	**September**	X	35
October	1	2	**October**	X	31
November	31	6	**November**	X	30
December	65	6	**December**	X	31

Table 6 states natural gas and electric expense with purpose of use. As it is expected, natural gas bill is higher in winter than in summer and mid-session. Highest bill costs 76€ in January. On the other part, electric expenses are much more stable but in total slightly higher than natural gas expense. In other words, electric consumption does not show difference between seasons as natural gas consumption shows. Current house electric expense is around 30€ per month.

3.1.2 Retrofitted House Audit

3.1.2.1 Insulation

3.1.2.1.1 Insulation of the Façade

The objective of thermal insulation in buildings is to sustain a comfortable and hygienic indoor climate throughout the year, decreasing the heating and cooling demands (Thermal Insulation, n.d). Strategies to reach these targets are the use of innovative or standard low cost techniques or a combination of them. In this case, EPS, XPS and Rockwool and options, which are widely available at the market, are evaluated.

These solutions include the use of standard thermo-hygrometric materials, innovative high-performance products (thermal insulating paint or/and panel, or/and waterproofing membrane) and colors to optimize the solar absorption and reflection of the external envelope (Yenilmez, 2015). It is decided to implement Rockwool to reach the desired U value for the external wall which is 0.2 W/m^2K. Rock wool has many advantages, such as high thermal resistance, fire and sound-proofing, availability as a local and natural material; widely available implementation, capability. Facades at demo house will be coated with 150 mm rockwool.

A Rockwool material is based on basalt as the main raw material. Through melting at high temperature, the material becomes a bio-fiber and is manufactured using high-speed centrifugal equipment. After additions of special adhibitor and dust-prevention oil it is formed. (Dahl, Clausen & Hansen, 2011)

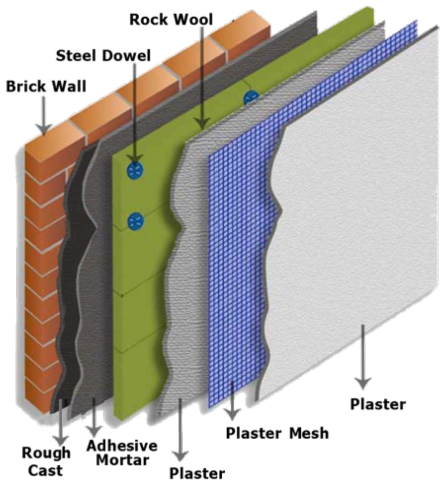


Figure 7: External Thermal Insulation Layers

Table 7: Thermal Insulation description

	Thickness (mm)	Conductivity (W/m K)
Cement mortar	6	0.35
Rockwool insulation	150	0.037
Brick	190	0.39
Cement mortar	15	1.60
Lime mortar	5	0.70
	U-Value	0.204

Figure 8: Rockwool insulation material

Table 7 states outside wall layers and corresponding conductivity of materials. Values are calculated from TS - 825. According to above table, after insulation is implemented to the outside wall, the U value changes from 0.617 to 0.204 W/m2K.

3.1.2.1.2 Insulation of the Attics

Easiest and cost effective way of roof insulation is to use mineral wool materials which also show high thermal performance and fire resistance (Energy Saving Trust, n.d). Glass wool, locally produced and installed is well-known insulation material which can be easily installed on existing insulation material, in this case 8-10 cm glass wool.

Isover (n.d) expressed the glass wool production as following: "*Glasswool is made from natural sand to which recycled glass (cullet) and fluxing agents are added. The material is melted at 1100°C in an electric furnace, and then forced through precision drilled holes in high speed spinning disks, to form fibers. Binding products and other additives required to give specific characteristics to different products are then added as fibers that fall onto moving collection belts. The glasswool mat is then polymerized, heated and passed through compression rollers where it is cured to provide a product of the required thickness and density*". In total 300 mm glass wool will be implemented as a blanket application at the garret of the building.

Table 8: Roof insulation Layers

	Thickness (mm)	Conductivity (W/m K)
Additional Mineral wool insulation	200	0.035
Existing Mineral wool insulation	100	0.040
Reinforced concrete slab	120	2.5
Lime mortar	5	0.70
	U-Value	0.128

Figure 9: Glasswool insulation material

Table 8 indicate roof layers property and corresponding conductivity of the layer materials. By applying roof insulation, U value of the attic changes from 0.350 to 0.128 W/m^{2}K according to Turkish Standard 825.

3.1.2.1.3 Cost of the Insulation Retrofitting

Table 9: Cost of the Insulation Retrofitting

Insulation Retrofitting	Price [€/m2]	Application Area [m2]	Total Cost [€]
Façade Insulation	35	145	5.075
Attic Insulation	10	80	800

Table 9 express façade (outside wall) and attic (roof) insulation cost details. Labor cost is taken into consideration while preparing above table. Before starting to analyze insulation costs, it should be noted that labor costs are cheaper in Turkey when comparing to European countries. Table express that unit price of façade insulation is higher than attic insulation. It is simply because, cost of materials and application to insulate outside wall is more expensive than attic insulation. Even tough application area of the façade insulation is less than attic, cost of insulating outside wall is more expensive than attic due to difference at unit price cost. According to price offer that is received from world-wide known insulation company, cost of façade insulation is 5.075€ whereas cost of attic insulation is 800€ in this case.

3.1.2.2 Glazing

Comparison of properties for the two different triple glazing are provided under Table 10 below. Triple glazing insulating glass units designed to improve the thermal efficiency of residential properties; reduce the amount of heat loss through the windows and can also allow more heat/energy from the sun through the glass. Cross section of a triple glazing window is shown in figure 10 which is given below.

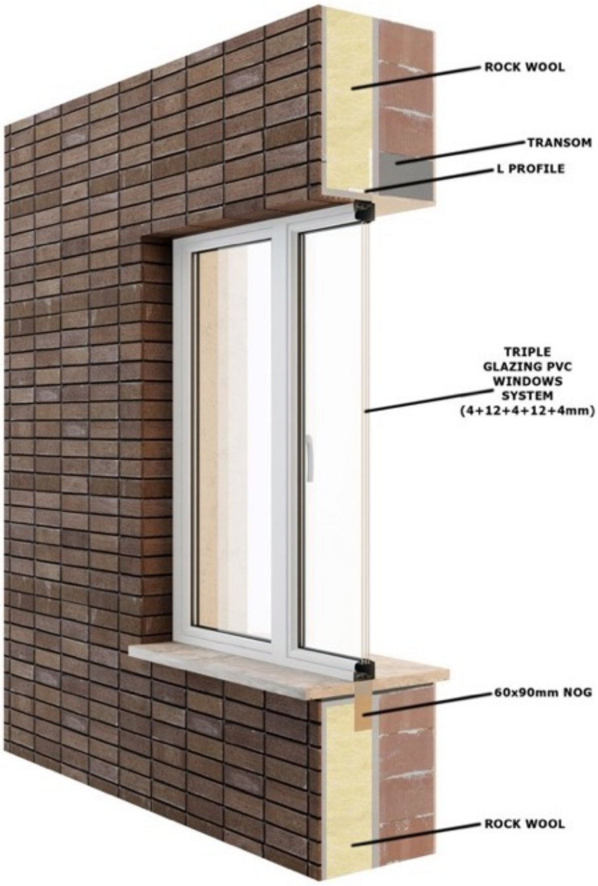


Figure 10: Triple glazing sections

Table 10: Comparison of two different triple glazing unit

<table>
<tr><th colspan="2"></th><th>Heat Retaining Glazing</th><th>Non – Heat Retaining Glazing</th></tr>
<tr><td colspan="2" rowspan="3">Thickness &Air Space Information (mm)</td><td>4*+9+4+9+*4</td><td>4*+9+4+9+*4</td></tr>
<tr><td>4*+12+4+12+*4</td><td>4*12+4+12+*4</td></tr>
<tr><td>4*+16+4+16+*4</td><td>4*+16+4+16+*4</td></tr>
<tr><td colspan="2" rowspan="3">Nominal Thickness (mm)</td><td>30</td><td>30</td></tr>
<tr><td>36</td><td>36</td></tr>
<tr><td>44</td><td>44</td></tr>
<tr><td rowspan="2">Daylight (EN 410)</td><td>Transmittance %</td><td>69</td><td>63</td></tr>
<tr><td>Reflectance Outdoor %</td><td>14</td><td>13</td></tr>
<tr><td rowspan="5">Solar Energy (EN 410)</td><td>Reflectance Outdoor %</td><td>28</td><td>30</td></tr>
<tr><td>Absorption %</td><td>34</td><td>38</td></tr>
<tr><td>Direct Transmittance %</td><td>39</td><td>32</td></tr>
<tr><td>Solar Factor</td><td>0,48</td><td>0,39</td></tr>
<tr><td>Shading Coefficient</td><td>0,55</td><td>0,45</td></tr>
<tr><td rowspan="6">Thermal conductivity (U value) W/m²K (EN 673)</td><td rowspan="3">Dry Air</td><td>1,2</td><td>0,9</td></tr>
<tr><td>0,9</td><td>0,7</td></tr>
<tr><td>0,7</td><td>0,6</td></tr>
<tr><td rowspan="3">**Argon</td><td>1,2</td><td>0,9</td></tr>
<tr><td>0,9</td><td>0,7</td></tr>
<tr><td>0,6</td><td>0,6</td></tr>
</table>

(Retrieved from: www.sisecamduzcam.com.tr)

After careful inspection of above table, it is decided that existing conventional window units will be replaced with PVC framed triple glazed windows (heat retaining) with a U-value of 1,2 W/m^2K in order to minimize heat losses and increase thermal efficiency.

3.1.2.2.1 Cost of Glazing Retrofitting

Table 11: Cost of Glazing Retrofitting

Glazing Retrofitting	Price [€/m2]	Application Area [m2]	Total Cost [€]
Triple Glazing	120	45	5.400

Table 11 shows triple glazing retrofitting cost details. First of all, cost of glazing retrofitting table prepared in accordance with received price offer from from one of the best national producer that is given in APPENDIX C. Total cost is calculated as turnkey price; therefore, unit price includes labor cost as well. Cost of replacing standard double glazing windows with argon filled triple glazing is 5.400€.

3.1.2.3 Lighting

Below figure 11 represents lighting retrofitting plan for each floor and figure 12 shows LED panels configuration after implementation.

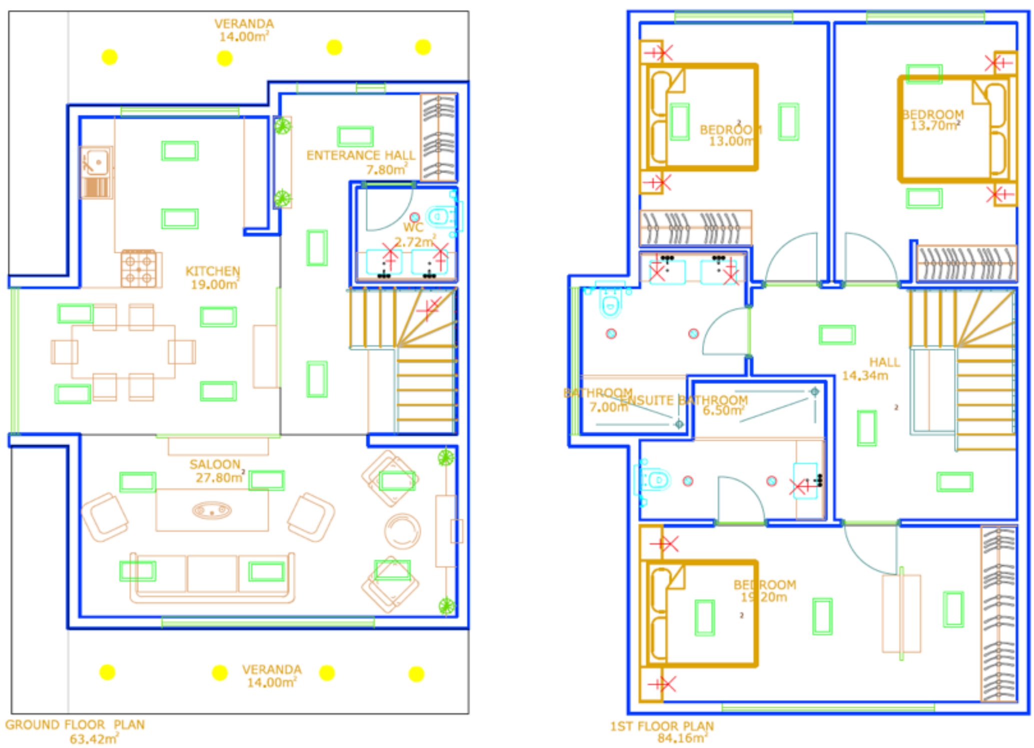


Figure 11: Lighting Retrofitting Plan

Figure 12: LED lights

3.1.2.3.1 Cost of Lighting Retrofitting

Table 12: Cost of LED Lighting Retrofitting

Lighting Retrofitting	Price [€/Unit]	Application Quantity [Unit]	Total Cost [€]
30x60 cm 18/20W LED Panel	35	25	875
12W Downlight LED Armature	15	5	75
12W Surface Mounted Etange LED Armature	15	8	120
5W Surface Mounted Applique	30	12	360

Table 12 indicates cost details of LED lighting retrofitting. Current bulbs are replaced with twenty-five 30x60 cm 18/20W LED panels, five 12W downlight LED armatures, eight 12W surface mounted etange LED armatures and twelve 5W surface mounted appliques. In total, lighting retrofitting costs 1.430€.

3.1.2.4 Photo-Voltaic

Solar energy is tried to use at the maximum level. 8 kW power is to be integrated on the roof of demo house as Building Integrated Photovoltaic (BIPV) system. Six strings and five arrays configuration will be implemented (6x5). In this system, photovoltaic panels are mounted on the roof after removing the tiles. Since weight of panels and tiles are almost equal, static of the building will not be affected. Therefore, BIPV systems not only produce electricity but also act as a roof element.

Figure 13: BIPV and Carport System

Additionally, a 7 kW solar energy system will be established on the carport canopy. Six strings and four arrays configuration will be implemented (6x4). Carport canopy system will satisfy two different benefits, which are production of electricity and preserve car from the direct sunlight. In total these two on-grid systems will provide 15 kW.

Table 13 prepared by using PV*Sol simulation program. Location is selected as Anadolu University Airport, which is 4 km far from demo house, since it was the nearest location that is available at simulation program in Eskisehir. Furthermore, panels are selected from AXITEC Gmbh and inverter is selected from SMA for both systems. (See APPENDIX B)

Table 13: Solar Energy Contribution

Intervention	Annual Electricity Generation (kWh)
Building Integrated Photo-Voltaic (8kWp)	10.129,20
Carport Application (7kWp)	7.959,40

Table 13, indicates the annual electricity generation by PV systems, in other words annual solar energy contribution on demo house electricity demand. 8 kW BIPV generates 10.129,20 kWh while 7kW carport application does 7.959,40 kWh annually. In total, 18.088,6 kWh electricity generated by implemented Photo Voltaic systems.

If the systems are improved, more solar contribution can be gained. With today's technology only 13-14% of the available irradiation can be transferred into electricity generation with mass produced cells (Honsberg & Bowden, n.d).

3.1.2.4.1 Cost of Photo-Voltaic Retrofitting

Table 14: Cost of the Photo-Voltaic Application

Photo- Voltaic Retrofitting	Price [€/kW]	Application Power [kW]	Total Cost [€]
BIPV	1.150	8	9.200
Carport PV Application	1.250	7	8.750

Table 14 represents photo-voltaic application cost. Carport PV application unit cost is more expensive than BIPV because it contains cost of the carport construction. All unit costs include labor cost, therefore total cost is calculated as turnkey price. BIPV system costs 9.200€ for 8 kW installed power while Carport PV system costs 8.750€ for 7 kW installed power. In total PV systems cost 17.950€ for 15 kW installed power.

3.1.2.5 Energy Consumption Analysis of the Retrofitted House

In this section, energy consumption of the retrofitted house is analyzed. (See APPENDIX A) According to table 15, lighting and appliances in the kitchen, living room, bedrooms and bathrooms are main responsible of the electric consumption. Indeed, lighting's and basic appliances' electric consumption account for 95% of the total electric consumption. HVAC action consumes electric in order to supply energy for the pumps that enables hot water circulation inside the dwelling. On the other side, natural gas only consumed in order to heat the dwelling and hot domestic water. Thus, HVAC is the only responsible action that consumes natural gas.

In total, 235 m3 natural gas and 2.908 kWh electric is consumed annually to meet the house energy demand after retrofitting.

Table 15: Energy Consumption Analysis of the Retrofitted House

Type of Energy Use	Annual Natural Gas Consumption [m3]	Annual Electric Consumption [kWh]
HVAC	235	146
Basic Appliances & Lighting	X	2.762
TOTAL	235	2.908

Table 16: Monthly Consumption Analysis of the Retrofitted House

HVAC Monthly Energy Use	Natural Gas (m3)	Electric (kWh)	Basic Appliances & Lighting Monthly Energy Use	Natural Gas (m3)	Electric (kWh)
January	77	24	**January**	X	226
February	50	22	**February**	X	204
March	18	24	**March**	X	226
April	X	17	**April**	X	236
May	X	X	**May**	X	244
June	X	X	**June**	X	236
July	X	X	**July**	X	244
August	X	X	**August**	X	244
September	X	X	**September**	X	236
October	X	4	**October**	X	226
November	24	23	**November**	X	218
December	65	24	**December**	X	226

Table 16 states monthly electric and natural gas consumption with intended use. As mentioned before, results of HAP energy simulation software, which calculates the energy consumption of the buildings regarding to schedule scenarios, is used to prepare above table. As expected in the northern hemisphere, natural gas consumption increase in winter reach the maximum in January and decrease in spring and reach zero in April until November. January, December and February are the three months that has highest natural gas consumption. Natural gas is consumed at medium level in March and November, which are known as mid-session months. From May until September natural gas is not consumed. On the other hand, electric consumption shows more stable behavior and it's change range is very small when compared to natural gas consumption.

3.1.2.6 Energy Expense of the Retrofitted House

In section 3.1.2.5, energy consumption analysis after retrofitting was investigated. Using consumption values expenses are calculated. (See APPENDIX A) Note that expenses are calculated according to energy prices in Turkey and converted into Euro. This section will help us to see how much energy is used for each action.

According to table 17, in order to heat the dwelling 67€ of natural gas and 15€ of electric is consumed. On the other hand, basic appliances and lighting costs 288€ annually. In total 67€ of natural gas and 303€ of electric is consumed annually to meet the retrofitted house energy demand for a comfortable living zone.

Table 17: Energy Expense Analysis of the Retrofitted House

Type of Energy Use	Annual Natural Gas Expense [€]	Annual Electric Expense [€]
HVAC	67	15
Basic Appliances & Lighting	X	288
TOTAL	67	303

Table 18: Energy Expense of the Retrofitted House

HVAC Monthly Energy Use	Natural Gas [€]	Electric [€]	Basic Appliances & Lighting Monthly Energy Use	Natural Gas [€]	Electric [€]
January	22	7	**January**	X	24
February	14	6	**February**	X	21
March	5	6	**March**	X	24
April	6	6	**April**	X	25
May	X	X	**May**	X	26
June	X	X	**June**	X	25
July	X	X	**July**	X	26
August	X	X	**August**	X	26
September	X	X	**September**	X	24
October	X	2	**October**	X	23
November	7	6	**November**	X	24
December	19	6	**December**	X	31

Table 18 tells us monthly electric and natural gas consumption with intended use. Above table created via HAP energy simulation software regarding to determined schedule scenario inputs. Most expensive natural gas bill come out in January as it is expected. Not only January but also December and February has high natural gas consumption. Mid-sessions have medium consumption therefore medium expense. After retrofitting natural gas is not consumed from May until September. It can be seen that natural gas is consumed more in winter. On the contrary, electric expense shows more stable behavior when compared to natural gas expense. Also its expense change rate is much more stable.

3.2 Mobility

3.2.1 Technical Specifications of Vehicles

Diesel, Gasoline, Hybrid and Electrical Vehicle comparison is shown below. It should be noted that Turkish citizens are paying one of the most expensive taxes on vehicles ranging from %60 to %200, depending on engine volume (İstanbul Vergi Dairesi Başkanlığı, 2016).

Assume that household decide to change vehicles that they have. He or she have a tendency to buy environment friendly vehicle since people are talking about latest developments on hybrid and electrical vehicles. Therefore, one of the household is oscillating between diesel and electrical vehicle while other person is thinking to purchase whether gasoline small segment vehicle or a hybrid one. However, he or she is uncertain whether this investment worth or not. In order to solve this uncertainty, comparison between vehicles' consumption and payback period analysis of the investment have been made in the section 4.2.1.

Table 19: Technical Specifications of Hybrid and Gasoline Yaris

Vehicle	Fuel Consumption (lt/100km)	$C0_2$ Emission (gr/100km)
1.5 Yaris Hybrid Cool	3,3	82
1.33 Yaris Style Multidrive S (Gasoline)	5,1	119

(Retrieved from: https://www.toyota.com.tr/new-cars/yaris/index.json#/publish/compare_engines/selection=1NZ-FXE-15H--77ECVT)

Table 19 states fuel consumption and CO_2 emission of the hybrid and gasoline vehicles. Hybrid vehicle not only has lower fuel consumption but also lower CO_2 emission. In fact, most of the time catalog consumption values don't meet the real cases mostly because urban traffic. However, one can trust hybrid vehicle consumption and emission catalog values since electrical engine covers all the demand between 0 and 40 km/h, which causes main consumption and emission at start. Therefore, in real life it is expected hybrid vehicle consumes approximately 2 liters of fuel and 40 gr of emission less than gasoline vehicle per 100 km.

Figure 14: Yaris Hybrid and Yaris Style Multi-drive S

Above figure represents hybrid Yaris (electric-gasoline engine) and Yaris style multi-drive S (gasoline engine) vehicles.

Table 20: Technical Specification of BMW i3 and 2.16d

Vehicle	Fuel Consumption (lt/100km)	Fuel Consumption (kWh/100km)	C02 Emission (gr/100km)
BMW i3	X	12,9	0
BMW 2.16d Active Tourer	4,0	X	105

(Retrieved from: http://www.bmw.com.tr/tr/all-models/bmw-i/i3/2013/technicaldata.html#tab-0)

Table 20 states fuel consumption for diesel and electricity for electrical vehicles and CO_2 emission for both vehicles. Diesel vehicle consumes around 4 liters while electrical vehicle consumes 12.9 kWh per 100 km. It should be noted that, electrical vehicle doesn't have any CO_2 emission.

Figure 15: BMW 2.16d Active Tourer and BMW i3

Above figure shows BMW 2.16d Active Tourer (diesel engine) and BMW i3 (electric engine) vehicles.

3.2.2 Mobility Expenses

Table 21: Consumption Assumptions of Vehicles

Vehicle	Fuel Consumption (lt/100Km)	Energy Consumption (kWh/100Km)	Annual Diesel Consumption (€/15.000Km)	Annual Gasoline Consumption (€/15.000Km)	Annual Electricity Consumption (€/15.000Km)
BMW i3	x	12,9	x	x	193,5
BMW 2.16d Active Tourer	4,0	x	675	x	x
1.5 Yaris Hybrid Cool	3,3	x	x	673,2	x
1.33 Gasoline Style Multidrive S	5,1	x	x	1040,4	x

Table 21 indicates, annual energy consumption and its monetary equivalent for 15.000 Km annual driven distance. As expected, electrical vehicle has the lowest fee by far for charging the vehicle for specified distance. Moreover, Hybrid and diesel vehicle have almost the same fee for filling the tank to cover specified distance. Hybrid and diesel vehicle's oil consumption fee is lower than gasoline vehicle but higher than electrical vehicle. Furthermore, gasoline vehicle has the highest oil consumption fee to cover specified distance even though it has small engine volume comparing to the others.

Table 22: Tax and Maintenance Assumptions

Vehicle	Annual Motor Vehicle Taxes (€)	Annual Maintenance Cost(€)	Total operating expenditures
BMW i3	x	50	50
BMW 2.16d Active Tourer	550	300	850
1.5 Yaris Hybrid Cool	312	140	452
1.33 Gasoline Style Multidrive S	312	140	452

Table 22, indicates annual motor vehicle taxes in Turkey in 2016 and annual maintenance cost which are taken from Toyota and BMW service. Turkish government is collecting annual motor vehicle tax related to engine volume and age of the vehicle. Therefore, the newer car and higher engine volume, the higher tax. In terms of maintenance cost, Diesel BMW has the highest expense due to expensive spare parts and heavy maintenance of diesel vehicles. Toyota models maintenance costs are slightly lower than diesel BMW, however higher than BMW's electrical vehicle. According to Toyota authorized service, there is no maintenance cost difference between hybrid and gasoline model. On the other hand, electrical vehicle has the lowest maintenance cost due to EV working principle's simplicity.

Insurance cost is neglected since decision will be made depending on the engine of the vehicle and comparison is made between same brand.

4 Findings

4.1 Building Retrofitting

This section will inform us about the results of building retrofitting. In addition, by looking carefully at this chapter one can make decision to invest on green energy system easier than before. Cost of building retrofitting, annual retrofitting saving and payback period analysis of the intervention is investigated respectively.

Table 23: Cost of Building Retrofitting

Building Retrofitting	Unit Price [€/Unit]	Quantity [Unit]	Cost [€]
Façade Insulation	35	145	5075
Attic Insulation	10	80	800
Triple Glazing	120	45	5400
30x60 cm 18/20W LED Panel	35	25	875
12W Downlight LED Armature	15	5	75
12W Surface Mounted Etange LED Armature	15	8	120
5W Surface Mounted Applique	30	12	360
BIPV	1150	8	9200
Carport PV Application	1250	7	8750

Cost of building retrofitting summary is given in Table 23 with type of retrofitting action. It also shows unit price and applied quantity of regarding retrofitting action. Photo-voltaic retrofitting is more expensive than other building retrofitting since their unit prices are the highest. Lighting retrofitting cost 1.430€ while new insulation cost 5.875€ in total. Due to façade insulation's high unit price and quantity façade insulation cost much than attic insulation. Replacing double glazing with triple glazing cost 5.400€. All in all, building retrofitting actions cost 30.655€.

Table 24: Annual Retrofitting Savings

Type of Energy	Building Envelope Saving [€]	Photo-Voltaic Implementation Saving [€]
Natural Gas	198	X
Electric	129	2171

Table 24 express result of retrofitting actions in terms of savings annually. Note that in Turkey government guarantee to buy electric generation which derives from renewable energy for 10 years with price of 0.12 Euro cent. In this case it is assumed that all generated electricity is sold to the national grid since system was installed as on-grid system. Therefore, biggest contribution comes from photo-voltaic implementation which saves 2.171€ annually. Photo-Voltaic does not have any effects on natural gas saving. On the other hand, building envelope contributes 198 of natural gas and 129€ of electric savings annually. In total, building envelope retrofitting saves 327 of energy annually. All in all, as a result of building retrofitting actions 2.498€ can be saved annually.

Table 25: Economic Analysis of Building Retrofitting

Total Retrofitting Cost [€]	Annual Retrofitting Saving [€/yr]	Payback Period [yr]
30.655	2.498	12,3

Table 25 states economic analysis of building retrofitting including total cost, annual saving and payback period. In previous sections total retrofitting cost and annual retrofitting savings are analyzed. In this section as the main objective of the thesis payback period is calculated. Payback period can be calculated as total retrofitting cost divided by annual retrofitting saving. As a result, all building interventions amortize itself in 12 years and 4 months.

Table 26: Summary of the U-Value of building elements

Building Elements	Before Retrofitting (W/m^2K)	After Retrofitting (W/m^2K)
External Wall	0,617	0,204
Internal Wall	0,45	0,45
Roof	0,356	0,128
Ground Floor	0,542	0,542
Internal Floor	1,83	1,83
Window	3,2	1,2

Table 26 indicates thermal transmittance rate of building elements in case of before and after retrofitting condition. According to table that is calculated via Turkish Standards 825, biggest thermal transmittance decrease seen for glazing alteration. 15 cm rock wool insulation also has significant effect on external wall thermal transmittance that decrease from 0,617 to 0,204. Also, rate of attic thermal transmittance decreased after intervention. Since there is not applied interventions on internal wall, ground floor and internal floor, thermal transmittance rate of this elements remain same.

4.2 Mobility

4.2.1 Payback Period Analysis of Mobility Decisions

Table 27: Price of Vehicles

Vehicle	Price (€)
BMW i3	48.000
BMW 2.16d Active Tourer	39.920
1.5 Yaris Hybrid Cool	20.560
1.33 Gasoline Style Multidrive S	19.220

Table 27 represents brand new vehicle prices in Turkey. Electrical vehicle has the highest price since market did not reach maturity level yet. Furthermore, another

BMW vehicle, which is 2.16d Active Tourer, has the second highest price due to its brand, luxury and comfort.

On the other hand, gap between hybrid and gasoline hybrid is much closer comparing to BMW's electrical and diesel vehicle. In fact, before making economic analysis, which includes payback period, the difference between initial investments should take into account because it is assumed purchasing decision will be made eventually.

Table 28: Initial Investment

Intervention	Price Difference (€)
Purchasing EV vehicle instead of Diesel vehicle	8080
Purchasing Hybrid vehicle instead of Diesel vehicle	1340

Table 28 represents the price difference of possible decisions. If a person decided to purchase EV instead of diesel vehicle, he or she should invest additional 8080 €. When it comes to hybrid or diesel vehicle decision, price difference is 1340 € which is slightly lower than abovementioned decision.

Table 29: Oil Prices

OIL	Gasoline 95 Octane Shell V-Power	Diesel Shell V-Power
COST (€/lt)	1,36	1,125

(Retrieved from: www.shell.com.tr/products-services/on-the-road/fuels/fuel-pricing.html)

Table 29 shows oil prices in Turkey on 25.03.2016. Gasoline price per liter is almost 25 cents higher than diesel.

Table 30: Energy Prices Considered

Prices	Unit price (€/kwh)
Electricity | Combined	0,1
Electricity | Afternoon	0,18
Electricity | Night	0,06
Natural Gas	0,03

(Retrieved from: http://www.emra.org.tr/en/home)

4.2.1.1 Base Case

Base case is prepared according to 15.000 annual driven distance, current tax application and maintenance expenses in the market. Furthermore, it is assumed that vehicle is charged mixed periods of the day. Therefore, electricity price for charging is 0,1 €/kWh.

Table 31: Savings Assumption (Base Case)

Intervention	Fuel Saving (€)	Tax Saving (€)	Maintenance Cost Saving (€)	Total Saving (€)
Purchasing Electric Vehicle instead of Diesel vehicle	482	550	250	1282
Purchasing Hybrid vehicle instead of Gasoline vehicle	367	0	0	367

Table 31 express saving assumption of the base case which can be also considered as a normal case. If a decision is made on purchasing EV instead of diesel vehicle, person can make 482€ fuel saving, 550€ tax saving and 250€ maintenance cost saving. In total, EV ensure 1282€ saving while comparing with diesel vehicle when considering all savings. On the other hand, purchasing hybrid vehicle rather than gasoline vehicle provide 367€ fuel saving. There is no cost difference between hybrid and gasoline vehicle on tax and maintenance. Therefore, fuel saving is equal to total saving.

Table 32: Payback Period (Base Case)

Intervention	Payback Period of Initial Investment (yr)
Purchasing Electric Vehicle instead of Diesel vehicle	6,3
Purchasing Hybrid vehicle instead of Gasoline vehicle	3,65

Table 32 express time period of return on investment of the base case. Payback period analysis is considered as initial investment difference divided by total savings. The initial cost difference between EV and diesel vehicle, recover itself in 6 years and 4 months with the help of electric vehicle's savings. Decision whether to purchase hybrid or gasoline vehicle cover itself in 3 years and 8 months.

4.2.1.2 Best Case

Best case is assumed according to 20.000 annual driven distance and current tax and maintenance expenses in the market. Moreover, Electrical Vehicle is charged only during the night. As a result, electricity price for charging is 0,06125 €/kWh due to night tariff rates in Turkey. Additionally, Maintenance cost difference assumed same because if price increase for a spare equipment or parity of Turkish Lira lose value against Euro, then all prices will increase. Therefore, difference will remain same.

Table 33: Savings Assumption (Best Case)

Intervention	Fuel Saving (€)	Tax Saving (€)	Maintenance Cost Saving (€)	Total Saving (€)
Purchasing EV vehicle instead of Diesel vehicle	742	550	250	1542
Purchasing Hybrid vehicle instead of Gasoline vehicle	490	0	0	490

Table 33 refers saving assumption of the best case, which is explained above. If a decision is given in favor of purchasing EV, one can make 742€ fuel saving, 550€ tax saving and 250€ maintenance cost saving. Totally, EV supply 1542€ saving while comparing with diesel vehicle when considering all savings. Otherwise, purchasing hybrid vehicle rather than gasoline vehicle provide 490€ fuel saving. There is no cost difference between hybrid and gasoline vehicle on tax and maintenance. Therefore, fuel saving is equal to total saving.

Table 34: Payback Period (Best Case)

Intervention	Payback Period of Initial Investment (yr)
Purchasing EV vehicle instead of Diesel vehicle	5,2
Purchasing Hybrid vehicle instead of Gasoline vehicle	2,7

Table 34 indicates payback period of best case. Payback period analysis is considered as initial investment difference divided by total savings. The initial cost difference between EV and diesel vehicle, recover itself in 5 years and 3 months with the help of electric vehicle's savings. Decision whether to purchase hybrid or gasoline vehicle reimburse itself in 2 years and 9 months.

4.2.1.3 Worst Case

Worst case is prepared according to 10.000 annual driven distance and current tax and maintenance expenses in the market. Moreover, Electrical Vehicle is charged only during the afternoon, which is between 17:00 and 22:00. As a result, electricity price for charging is 0,18 €/kwh due to night tariff rates in Turkey. Additionally, Maintenance cost difference assumed same because if price increase for a spare equipment or parity of Turkish Lira lose value against Euro, then all prices will increase. Therefore, difference will remain same.

Table 35: Savings Assumption (Worst Case)

Intervention	Fuel Saving (€)	Tax Saving (€)	Maintenance Cost Saving (€)	Total Saving (€)
Purchasing EV vehicle instead of Diesel vehicle	217	550	250	1017
Purchasing Hybrid vehicle instead of Gasoline vehicle	245	0	0	245

Table 35 explains saving assumption of the worst case, which is explained above. If a decision is given in favor of purchasing EV, person save 217€ of fuel, 550€ of tax saving and 250€ of maintenance costs. In total, EV supply 1017€ saving while comparing with diesel vehicle when considering all savings. On the other hand, purchasing hybrid vehicle instead of gasoline vehicle provide 245€ fuel saving. There is no cost difference between hybrid and gasoline vehicle on tax and maintenance. Therefore, fuel saving is equal to total saving.

Table 36: Payback Period (Worst Case)

Intervention	Payback Period of Initial Investment (yr)
Purchasing EV vehicle instead of Diesel vehicle	7,9
Purchasing Hybrid vehicle instead of Gasoline vehicle	5,5

Table 36 indicates payback period of worst case. Payback period analysis is considered as initial investment difference divided by total savings. The initial cost difference between EV and diesel vehicle, reimburse itself in 7 years and 11 months with the help of electric vehicle's savings. Decision whether to purchase hybrid or gasoline vehicle reimburse itself in 5 years and 6 months.

5 Conclusions

5.1 Implications

Economic analysis of building retrofitting including total cost, annual saving and payback period is observed within this paper in the previous sections. All retrofitting interventions regarding to green building costs 30.655 €. In return of initial investment, retrofitted building save 2.498 € annually. As a result, all building interventions amortize itself only in 12 years and 4 months. If an arbitrary building's life is estimated as 50 years, 12 years and 4 months to have green building is an encouraging result.

Economic analysis of green mobility is investigated in base, best and worst case regarding to different assumptions and scenarios. The initial cost difference between EV and diesel vehicle, recover itself with the help of electric vehicle's savings in 6 years and 4 months, 5 years and 3 months and 7 years and 11 months in order of base, best and worst case. Decision whether to purchase hybrid or gasoline vehicle cover itself in 3 years and 8 months, 2 years and 9 months and 5 years and 6 months respectively to base, best and worst case. Once again, payback periods are not too much as people afraid of.

To sum up, analyzed results and researches mentioned in this paper can help to change people's perception on expensiveness and immaturity of using green energy and green vehicles by presenting quantitative and objective results.

5.2 Limitations and Barriers in front of Smart Urban Regeneration

Although many cities and houses have been involved in smart urban regeneration, neither single way of regeneration nor authoritative source of prescription is available. Thus, smart regeneration using green technology is already experienced yet little understood phenomenon despite numerous of organizations, private and financial institutions and companies have participated in such interventions before (Aksu & Yenilmez, 2016).

The Governance is an important issue involving different aspects of green mobility and energy. In this sense, considerable number of items concerning the Governance that must be considered as crosscutting barriers that limiting a proper implementation on low energy districts and mobility is highlighted as below; (Demir & Yenilmez, 2016)

- ✓ **Low Awareness about Environment:** There is very little awareness about how decreasing energy consumption can relate to environment and CO_2 emissions. Most of the investors are taking into account the financial aspect of the projects and seeing the relatively high initial costs the investors usually waive the investment decisions waiting for the prices to drop. Low environmental awareness is also an ethical issue arising from the perspective of humans seeing the world as a resource for their well-being. Environmental awareness is needed to be built with three approach that are systematic approach for education, sustainable and integrated approach for increasing local knowledge.
- ✓ **No Incentives or Subsidies from Public, Unclear Regulations:** Although there have been many efforts to promote energy efficiency and regulations, there are no clear control mechanisms, which undermines the efforts. By 2017 all existing buildings are supposed to have a Building Energy Certificate (BEC) in Turkey, however there is widespread consensus that date will be extended.
- ✓ **Knowledge and know-how:** Public organizations have drawbacks about new innovative actions since they are lacking in knowledge on how to set them up and what the benefits are.
- ✓ **Lack of Best Practices:** Best practices of renewable energy technologies are a good way to encourage people to take action by explaining the benefits of energy efficiency. There might be some doubts in citizens' minds about the benefits and initial investment cost of insulation, green vehicles and solar energy. Best practices can easily answer these questions and therefore accelerate the investments. The government and some public bodies have started projects in public buildings as showcases.
- ✓ **Low municipal awareness on innovative funding schemes**: Municipalities and other public organizations are too much focused on politics and show very little attention on new funding schemes.

- ✓ **Lack of communication within the Local Authority departments:** There is not a cross vision in the context of greening policy (E.g.: Planning / energy / work / mobility). A holistic approach is needed because crosscutting interventions require more than the usual level of interdepartmental collaboration and sharing of expertise.
- ✓ **Slow decision process**: There are too many hierarchical levels in governmental and public organizations.
- ✓ **Nervousness about new technology:** Public organizations fear of taking a wrong decision because of bad communication and the use of public money.

Financial issues, as in previous cases, sometimes are critical matters to have a correct performance. There are several aspects to bear in mind: (Rogers & Hunt, 2005)

- ✓ **Economic crisis:** Observed by the lack in financial means and no knowledge on how to access to funds.
- ✓ **Lack of funding:** No knowledge of mechanisms and funding sources.
- ✓ **Cuts in subsidies and financial incentives:** Governments of many Countries (both federal and regional) have cut in subsidies related to energy efficiency (e.g.: Solar panel incentives for citizen in Germany)
- ✓ **Costs of infrastructures and heavy procedures of procurement:** Costs of infrastructure and heavy procedures of procurement in many Countries is an important barrier in front of green technology.
- ✓ **High initial costs:** The building owners tend to focus on shorter-term cash flows as opposed to longer term running costs. Although there is a high Net Present Value of the project according to financial analysis, most of the time the decision is negative due to the high initial costs.

Public Procurement processes for Smart Cities have been identified as another critical cross-cutting issue. According to Smart Cities and Communities (2013), the points that weaken a suitable implementation of sustainable solutions are:

- ✓ **Heavy procurement procedures:** The procedures, in many countries, are very heavy and complex (involve too many stakeholders, at federal, regional and local level).

- ✓ **"Lowest price" against "best offer":** It is difficult to identify the best value for money.
- ✓ **Delays in the public procurement process:** Changing anything in the public procurement process takes a lot of time as it requires so many level of validation at federal/regional and local levels.

In conclusion, it can be highlighted that cities are vitiated by a lack of adaptation and flexibility to changes, growth and new challenges. The convergence of multiple stakeholders’ interests is crucial in order to achieve a more sustainable future.

6 Bibliography

Administration, General Directorate of Electrical Power Resources Survey and Development. (n.d). ***Solar energy.*** Retrieved September 2016, from General Directorate of Renewable Energy: http://www.eie.gov.tr/eie web/english/solar/gunes_index_e.html

Aksu, M., & Yenilmez, B. (2016). ***Model for replication potential***. Paper presented at the periodical meeting of the EU funded REMOURBAN project, Madrid.

Dahl, T. W., Clausen, A. U., & Hansen, P. B. (2011). The human impact on natural rock reserves using basalt, anorthosite, and carbonates as raw materials in insulation products. ***International Geology Review,*** *53*(8), 894-904.

Demir, C., & Yenilmez, B. (2016). ***Report on non-technical barrier and legal and normative issues.*** Paper presented at the periodical meeting of the REMOURBAN project, Brussels.

Demirbaş, A. (2001). Energy balance, energy sources, energy policy, future developments and energy investments in Turkey. ***Energy Conversion and Management,*** 42(10), 1239 - 1258

Duygu, E. (2002). Bir Elimizde Fosil Yakıt, Bir Elimizde Ayna, Umrumuzda mı Dünya veya Biyokütle Enerjisi. ***T.M.M.O.B. Elektrik Mühendisleri Odası,*** *41*(412).

Energy Saving Trust. (n.d). ***Roof and loft insulation.*** Retrieved from http://www.energysavingtrust.org.uk/home-insulation/roof-and-loft

Environment Protection Agency. (2012). ***Inventory of U.S. greenhouse gas emissions and sinks: 1990-2012***. Washington DC: E.P.A.

Erdal, G., Erdal, H., & Esengün, K. (2008). The causality between energy consumption and economic growth in Turkey. ***Energy Policy,*** 36(10), 3838-3842.

Erjavec, J., & Arias, J. (2007). ***Hybrid, electric and fuel-cell vehicles.*** Clifton Park, NJ: Thomson Delmar Learning.

European Comission Research & Innovation. (2012). ***Green cars initiative***. Retrieved August 2016, from European Comission: http://ec.europa.eu/research/transport/road/green_cars/index_en.htm

European Parliament and the Council of the European Union. (19 May 2010). ***Directive 2010/31/EU on the energy performance of buildings.*** Recast of the energy performance of buildings directive (pp. 13-35). Brussels: Offical Journal of the EU.

Gallagher, K. S. (2011, January). Giving green to get green? Incentives and consumer adoption of hybrid vehicle technology. ***Journal of Environmental Economics and Management,*** *61*(1), 1-15.

Graham, R. (2001). ***Comparing the benefits and impacts of hybrid electric vehicle options.*** Retrieved from http://www.ourenergypolicy.org/wp-content/uploads/2011/11/2001_07_EPRI_ComparingHybridElectricVehicleOptions.pdf, 2011

Honsberg, C., & Bowden, S. (n.d). ***Efficiency and solar cell cost.*** Retrieved September 24, 2016, from PV Education: http://www.pveducation.org/pvcdrom/design/efficiency-and-cost

Isover Saint - Gobain. (n.d). ***Glasswool.*** Retrieved from Isover Technical Insulation: http://www.isover-technical-insulation.com/about-us/our-materials/glasswool

İstanbul Vergi Dairesi Başkanlığı. (2016). ***Motorlu taşıtlar vergisi tarifeleri.*** Retrieved September 21, 2016, from http://www.ivdb.gov.tr/pratik/oranlar/mtvtarife.htm

Kırzıoğlu, I. M. (2000). ***Yeni yüzyılda çevre plancıları ve tasarımcılarının sorunları ve olası etkinlikleri.*** Ankara: T.M.M.O.B. Peyzaj Mimarları Odası.

Kibert, C. J. (May 2016). ***Sustainable construction: Green building design and delivery*** (4 ed.). Florida: John Wiley & Sons.

Kikuchi, S. (October 2009). ***Artificial intelligence in transportation analysis: approaches, methods, and applications.*** Elsevier.

Kuban, B. (2015). ***Report of the audits in Tepebaşı demo site.*** Paper presented at the periodical meeting of the EU funded REMOURBAN project, Nottingham.

Mear, R. S. (2011). ***Green building: project planning and cost estimating***. Kingston: John Wiley & Sons, Inc.

Mega, V. (2005). ***Sustainable development, energy and the city: A civilizitation of visions and actions.*** New York: Springer.

Oliver, M. & Jackson, T. (2001). Energy and economic evaluation of building-integrated photovoltaics. ***Energy,*** 26(4), 431-439

Özbalta, T. G. (2003). Sürdürülebilir Mimarlık Bağlamında Güneş Pili Uygulamaları. ***II. Yenilenebilir Enerji Kaynakları Sempozyumu***. İzmir: YEKSEM.

Pyke, D., & Brown, S. (July 2010). Electric Vehicles: The role and importance of standards in an emerging market. ***Energy Policy**, 38*(7), 3797-3806.

REMOURBAN. (n.d). ***About the project.*** Retrieved October 2016, from http://www.remourban.eu/The- Project/ABOUT.kl

Rogers, C. D., & Hunt, D. V. (2005). Barriers to sustainable infrastructure in urban regeneration. ***Engineering Sustainability**, 158*(2), 67-81.

Sherman, M. (1995, September). The use of blower-door data. ***International Journal of Indoor Environment and Health**, 5*(3), 215-224.

Simpson, A. (2006). ***Cost-benefit analysis of plug-in hybrid electric vehicle technology.*** Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.491.7761&rep=rep1&type=pdf, November 2016.

Sitarz, D. (2008). ***Greening your business: A hands-on guide to creating a succesful and sustainable business*** (1. ed.). Carbondale, IL, United States: Earthpress.

Smart Cities and Communities. (2013). ***Public procurement for smart cities.*** Smart Cities Stakeholder Platform.

Strong, D. (2012). ***The distinctive benefits of glazing: The social and economic contributions of glazed areas to sustainability in the built environment.*** U.K: David Strong Consulting.

Strong, S. (2011). ***Building integrated photovoltaics.*** (National Institute of Building Sciences) Retrieved from Whole Building Design Guide: http://www.wbdg.org/resources/bipv.php

Şenlier, N. (1994). Sürdürülebilir Kent Gelişimi İçin Tasarımda Mikroklimatik Etmenler. ***Kentsel Tasarım ve Ekoloji, Tasarıma Ekolojik Yaklaşım, 5.Kentsel Tasarım ve Uygulamalar Sempozyumu*** (pp. 196-2016). İstanbul: M.S.Ü Matbaası.

Türe, E. (2001). ***Hydrogen energy.*** Ankara: TUBITAK Press.

The passive house resource. (2016). ***Thermal insulation.*** Retrieved from Passipedia : http://www.passipedia.org/planning/thermal_protection/integrated_thermal_protection

Siegen University. (n.d). ***Thermal insulation.*** Retrieved from: http://nesa1.uni-siegen.de/wwwextern/idea/keytopic/6.htm

U.S. Department of Energy. (n.d). ***LED lighting.*** (Government) Retrieved September 2016, from Energy: http://energy.gov/energysaver/led-lighting

US General Services Administration. (2009). ***Benefits of green buildings on costs, the environment and jobs.*** Retrieved from GSA: http://www.gsa.gov/portal/content/103662

Yenilmez, B. (2015). ***Technical definition of the Tepebaşı demo site***. Unpublished EU funded project report, Eskişehir.

APPENDIX A: Simulation Results of Building Retrofitting

i. Retrofitted Situation

Table 1. Annual Costs

Component	RETROFITTED SITUATION (TL)
Air System Fans	0
Cooling	0
Heating	201
Pumps	108
Heat Rejection Fans	0
HVAC Sub-Total	**310**
Lights	208
Electric Equipment	661
Misc. Electric	0
Misc. Fuel Use	0
Non-HVAC Sub-Total	**869**
Grand Total	**1.179**

Table 2. Annual Cost per Unit Floor Area

Component	RETROFITTED SITUATION (TL/m²)
Air System Fans	0,000
Cooling	0,000
Heating	1,549
Pumps	0,835
Heat Rejection Fans	0,000
HVAC Sub-Total	**2,384**
Lights	1,597
Electric Equipment	5,088
Misc. Electric	0,000
Misc. Fuel Use	0,000
Non-HVAC Sub-Total	**6,686**
Grand Total	**9,070**
Gross Floor Area (m²)	130,0
Conditioned Floor Area (m²)	130,0

Note: Values in this table are calculated using the Gross Floor Area.

Table 3. Component Cost as a Percentage of Total Cost

Component	RETROFITTED SITUATION (%)
Air System Fans	0,0
Cooling	0,0
Heating	17,1
Pumps	9,2
Heat Rejection Fans	0,0
HVAC Sub-Total	**26,3**
Lights	17,6
Electric Equipment	56,1
Misc. Electric	0,0
Misc. Fuel Use	0,0
Non-HVAC Sub-Total	**73,7**
Grand Total	**100,0**

Table 1. Annual Costs

Component	RETROFITTED SITUATION (TL)
HVAC Components	
Electric	108
Natural Gas	201
Fuel Oil	0
Propane	0
Remote HW	0
Remote Steam	0
Remote CW	0

HVAC Sub-Total	**310**
Non-HVAC Components	
Electric	869
Natural Gas	0
Fuel Oil	0
Propane	0
Remote HW	0
Remote Steam	0
Non-HVAC Sub-Total	**869**
Grand Total	**1.179**

Table 2. Annual Energy Consumption

Component	**RETROFITTED SITUATION**
HVAC Components	
Electric (kWh)	345
Natural Gas (M3)	235
Fuel Oil (na)	0
Propane (na)	0
Remote HW (na)	0
Remote Steam (na)	0
Remote CW (na)	0
Non-HVAC Components	
Electric (kWh)	2.762
Natural Gas (M3)	0
Fuel Oil (na)	0
Propane (na)	0
Remote HW (na)	0
Remote Steam (na)	0
Totals	
Electric (kWh)	3.107
Natural Gas (M3)	235
Fuel Oil (na)	0
Propane (na)	0
Remote HW (na)	0
Remote Steam (na)	0
Remote CW (na)	0

Table 3. Annual Emissions

Component	**RETROFITTED SITUATION**
CO2 Equivalent (kg)	459

Table 4. Annual Cost per Unit Floor Area

Component	**RETROFITTED SITUATION (TL/m²)**
HVAC Components	
Electric	0,835
Natural Gas	1,549
Fuel Oil	0,000
Propane	0,000
Remote HW	0,000
Remote Steam	0,000
Remote CW	0,000
HVAC Sub-Total	**2,384**
Non-HVAC Components	
Electric	6,686
Natural Gas	0,000
Fuel Oil	0,000
Propane	0,000
Remote HW	0,000
Remote Steam	0,000
Non-HVAC Sub-Total	**6,686**
Grand Total	**9,069**
Gross Floor Area (m²)	130,0
Conditioned Floor Area (m²)	130,0

Note: Values in this table are calculated using the Gross Floor Area.

Table 5. Component Cost as a Percentage of Total Cost

Component	RETROFITTED SITUATION (%)
HVAC Components	
Electric	9,2
Natural Gas	17,1
Fuel Oil	0,0
Propane	0,0
Remote HW	0,0
Remote Steam	0,0
Remote CW	0,0
HVAC Sub-Total	**26,3**
Non-HVAC Components	
Electric	73,7
Natural Gas	0,0
Fuel Oil	0,0
Propane	0,0
Remote HW	0,0
Remote Steam	0,0
Non-HVAC Sub-Total	**73,7**
Grand Total	**100,0**

1. Annual Costs

Component	Annual Cost (TL/yr)	(TL/m²)	Percent of Total (%)
HVAC Components			
Electric	108	0,835	9,2
Natural Gas	201	1,549	17,1
Fuel Oil	0	0,000	0,0
Propane	0	0,000	0,0
Remote Hot Water	0	0,000	0,0
Remote Steam	0	0,000	0,0
Remote Chilled Water	0	0,000	0,0
HVAC Sub-Total	**310**	**2,384**	**26,3**
Non-HVAC Components			
Electric	869	6,686	73,7
Natural Gas	0	0,000	0,0
Fuel Oil	0	0,000	0,0
Propane	0	0,000	0,0
Remote Hot Water	0	0,000	0,0
Remote Steam	0	0,000	0,0
Non-HVAC Sub-Total	**869**	**6,686**	**73,7**
Grand Total	**1.179**	**9,069**	**100,0**

Note: Cost per unit floor area is based on the gross building floor area.

Gross Floor Area	**130,0**	m²
Conditioned Floor Area	**130,0**	m²

1. HVAC Costs

Month	Electric (TL)	Natural Gas (TL)	Fuel Oil (TL)	Propane (TL)	Remote Hot Water (TL)	Remote Steam (TL)	Remote Chilled Water (TL)
January	19	66	0	0	0	0	0
February	17	43	0	0	0	0	0
March	19	16	0	0	0	0	0
April	13	0	0	0	0	0	0
May	0	0	0	0	0	0	0
June	0	0	0	0	0	0	0
July	0	0	0	0	0	0	0
August	0	0	0	0	0	0	0
September	0	0	0	0	0	0	0
October	3	0	0	0	0	0	0
November	18	21	0	0	0	0	0
December	19	56	0	0	0	0	0
Total	**108**	**201**	**0**	**0**	**0**	**0**	**0**

2. Non-HVAC Costs

Month	Electric (TL)	Natural Gas (TL)	Fuel Oil (TL)	Propane (TL)	Remote Hot Water (TL)	Remote Steam (TL)
January	71	0	0	0	0	0
February	64	0	0	0	0	0
March	71	0	0	0	0	0
April	74	0	0	0	0	0
May	77	0	0	0	0	0
June	74	0	0	0	0	0
July	77	0	0	0	0	0
August	77	0	0	0	0	0
September	74	0	0	0	0	0
October	71	0	0	0	0	0
November	69	0	0	0	0	0
December	71	0	0	0	0	0
Total	**869**	**0**	**0**	**0**	**0**	**0**

1. HVAC Energy Use

Month	Electric (kWh)	Natural Gas (M3)	Fuel Oil (na)	Propane (na)	Remote HW (na)	Remote Steam (na)	Remote CW (na)
Jan	61	77	0	0	0	0	0
Feb	54	50	0	0	0	0	0
Mar	60	18	0	0	0	0	0
Apr	42	0	0	0	0	0	0
May	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0
Jul	0	0	0	0	0	0	0
Aug	0	0	0	0	0	0	0
Sep	0	0	0	0	0	0	0
Oct	10	0	0	0	0	0	0
Nov	58	24	0	0	0	0	0
Dec	60	65	0	0	0	0	0
Totals	345	235	0	0	0	0	0

2. Non-HVAC Energy Use

Month	Electric (kWh)	Natural Gas (M3)	Fuel Oil (na)	Propane (na)	Remote HW (na)	Remote Steam (na)
Jan	226	0	0	0	0	0
Feb	204	0	0	0	0	0
Mar	226	0	0	0	0	0
Apr	236	0	0	0	0	0
May	244	0	0	0	0	0
Jun	236	0	0	0	0	0
Jul	244	0	0	0	0	0
Aug	244	0	0	0	0	0
Sep	236	0	0	0	0	0
Oct	226	0	0	0	0	0
Nov	218	0	0	0	0	0
Dec	226	0	0	0	0	0
Totals	2.762	0	0	0	0	0

ii. Current Situation

Table 1. Annual Costs

Component	CURRENT SITUATION (TL)
Air System Fans	0
Cooling	0
Heating	794
Pumps	115
Heat Rejection Fans	0
HVAC Sub-Total	**910**
Lights	519
Electric Equipment	661
Misc. Electric	0
Misc. Fuel Use	0
Non-HVAC Sub-Total	**1.181**
Grand Total	**2.090**

Table 2. Annual Cost per Unit Floor Area

Component	CURRENT SITUATION (TL/m²)
Air System Fans	0,000
Cooling	0,000
Heating	6,111
Pumps	0,888
Heat Rejection Fans	0,000
HVAC Sub-Total	**6,999**
Lights	3,994
Electric Equipment	5,088
Misc. Electric	0,000
Misc. Fuel Use	0,000
Non-HVAC Sub-Total	**9,082**
Grand Total	**16,081**
Gross Floor Area (m²)	130,0
Conditioned Floor Area (m²)	130,0

Note: Values in this table are calculated using the Gross Floor Area.

Table 3. Component Cost as a Percentage of Total Cost

Component	CURRENT SITUATION (%)
Air System Fans	0,0
Cooling	0,0
Heating	38,0
Pumps	5,5
Heat Rejection Fans	0,0
HVAC Sub-Total	**43,5**
Lights	24,8
Electric Equipment	31,6
Misc. Electric	0,0
Misc. Fuel Use	0,0
Non-HVAC Sub-Total	**56,5**
Grand Total	**100,0**

Table 1. Annual Costs

Component	CURRENT SITUATION (TL)
HVAC Components	
Electric	115
Natural Gas	794
Fuel Oil	0
Propane	0
Remote HW	0
Remote Steam	0
Remote CW	0
HVAC Sub-Total	**910**
Non-HVAC Components	
Electric	1.181

Natural Gas	0
Fuel Oil	0
Propane	0
Remote HW	0
Remote Steam	0
Non-HVAC Sub-Total	**1.181**
Grand Total	**2.090**

Table 2. Annual Energy Consumption

Component	**CURRENT SITUATION**
HVAC Components	
Electric (kWh)	367
Natural Gas (M3)	925
Fuel Oil (na)	0
Propane (na)	0
Remote HW (na)	0
Remote Steam (na)	0
Remote CW (na)	0
Non-HVAC Components	
Electric (kWh)	3.752
Natural Gas (M3)	0
Fuel Oil (na)	0
Propane (na)	0
Remote HW (na)	0
Remote Steam (na)	0
Totals	
Electric (kWh)	4.119
Natural Gas (M3)	925
Fuel Oil (na)	0
Propane (na)	0
Remote HW (na)	0
Remote Steam (na)	0
Remote CW (na)	0

Table 3. Annual Emissions

Component	**CURRENT SITUATION**
CO2 Equivalent (kg)	1.808

Table 4. Annual Cost per Unit Floor Area

Component	**CURRENT SITUATION (TL/m²)**
HVAC Components	
Electric	0,888
Natural Gas	6,111
Fuel Oil	0,000
Propane	0,000
Remote HW	0,000
Remote Steam	0,000
Remote CW	0,000
HVAC Sub-Total	**6,999**
Non-HVAC Components	
Electric	9,082
Natural Gas	0,000
Fuel Oil	0,000
Propane	0,000
Remote HW	0,000
Remote Steam	0,000
Non-HVAC Sub-Total	**9,082**
Grand Total	**16,080**
Gross Floor Area (m²)	130,0
Conditioned Floor Area (m²)	130,0

Note: Values in this table are calculated using the Gross Floor Area.

Table 5. Component Cost as a Percentage of Total Cost

Component	CURRENT SITUATION (%)
HVAC Components	
Electric	5,5
Natural Gas	38,0
Fuel Oil	0,0
Propane	0,0
Remote HW	0,0
Remote Steam	0,0
Remote CW	0,0
HVAC Sub-Total	**43,5**
Non-HVAC Components	
Electric	56,5
Natural Gas	0,0
Fuel Oil	0,0
Propane	0,0
Remote HW	0,0
Remote Steam	0,0
Non-HVAC Sub-Total	**56,5**
Grand Total	**100,0**

1. Annual Costs

Component	Annual Cost (TL/yr)	(TL/m²)	Percent of Total (%)
HVAC Components			
Electric	115	0,888	5,5
Natural Gas	794	6,111	38,0
Fuel Oil	0	0,000	0,0
Propane	0	0,000	0,0
Remote Hot Water	0	0,000	0,0
Remote Steam	0	0,000	0,0
Remote Chilled Water	0	0,000	0,0
HVAC Sub-Total	**910**	**6,999**	**43,5**
Non-HVAC Components			
Electric	1.181	9,082	56,5
Natural Gas	0	0,000	0,0
Fuel Oil	0	0,000	0,0
Propane	0	0,000	0,0
Remote Hot Water	0	0,000	0,0
Remote Steam	0	0,000	0,0
Non-HVAC Sub-Total	**1.181**	**9,082**	**56,5**
Grand Total	**2.090**	**16,080**	**100,0**

Note: Cost per unit floor area is based on the gross building floor area.

Gross Floor Area	**130,0**	m²
Conditioned Floor Area	**130,0**	m²

1. HVAC Costs

Month	Electric (TL)	Natural Gas (TL)	Fuel Oil (TL)	Propane (TL)	Remote Hot Water (TL)	Remote Steam (TL)	Remote Chilled Water (TL)
January	20	228	0	0	0	0	0
February	17	163	0	0	0	0	0
March	19	91	0	0	0	0	0
April	17	18	0	0	0	0	0
May	0	0	0	0	0	0	0
June	0	0	0	0	0	0	0
July	0	0	0	0	0	0	0
August	0	0	0	0	0	0	0
September	0	0	0	0	0	0	0
October	5	3	0	0	0	0	0
November	18	94	0	0	0	0	0
December	19	196	0	0	0	0	0
Total	**115**	**794**	**0**	**0**	**0**	**0**	**0**

2. Non-HVAC Costs

Month	Electric (TL)	Natural Gas (TL)	Fuel Oil (TL)	Propane (TL)	Remote Hot Water (TL)	Remote Steam (TL)
January	93	0	0	0	0	0
February	84	0	0	0	0	0
March	93	0	0	0	0	0
April	104	0	0	0	0	0
May	107	0	0	0	0	0
June	104	0	0	0	0	0
July	107	0	0	0	0	0
August	107	0	0	0	0	0
September	104	0	0	0	0	0
October	93	0	0	0	0	0
November	90	0	0	0	0	0
December	93	0	0	0	0	0
Total	**1.181**	**0**	**0**	**0**	**0**	**0**

1. HVAC Energy Use

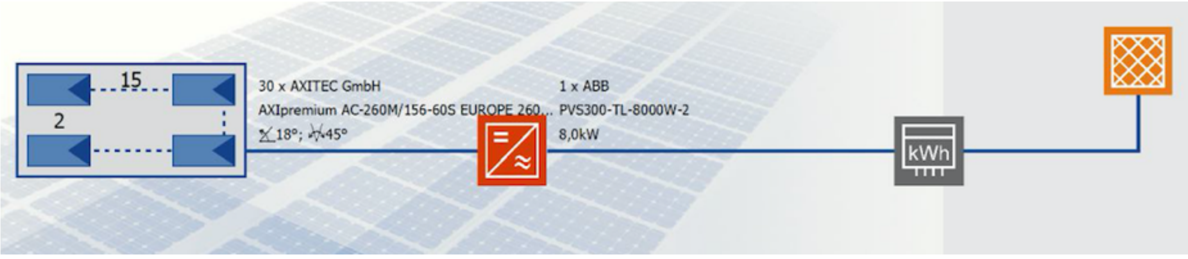
Month	Electric (kWh)	Natural Gas (M3)	Fuel Oil (na)	Propane (na)	Remote HW (na)	Remote Steam (na)	Remote CW (na)
Jan	62	266	0	0	0	0	0
Feb	55	190	0	0	0	0	0
Mar	60	106	0	0	0	0	0
Apr	53	22	0	0	0	0	0
May	0	0	0	0	0	0	0
Jun	0	0	0	0	0	0	0
Jul	0	0	0	0	0	0	0
Aug	0	0	0	0	0	0	0
Sep	0	0	0	0	0	0	0
Oct	17	4	0	0	0	0	0
Nov	58	109	0	0	0	0	0
Dec	61	229	0	0	0	0	0
Totals	367	925	0	0	0	0	0

2. Non-HVAC Energy Use

Month	Electric (kWh)	Natural Gas (M3)	Fuel Oil (na)	Propane (na)	Remote HW (na)	Remote Steam (na)
Jan	296	0	0	0	0	0
Feb	268	0	0	0	0	0
Mar	296	0	0	0	0	0
Apr	330	0	0	0	0	0
May	341	0	0	0	0	0
Jun	330	0	0	0	0	0
Jul	341	0	0	0	0	0
Aug	341	0	0	0	0	0
Sep	330	0	0	0	0	0
Oct	296	0	0	0	0	0
Nov	287	0	0	0	0	0
Dec	296	0	0	0	0	0
Totals	3.752	0	0	0	0	0

APPENDIX B: Simulation Results of Electric Generation from PVs

BIPV System Configuration

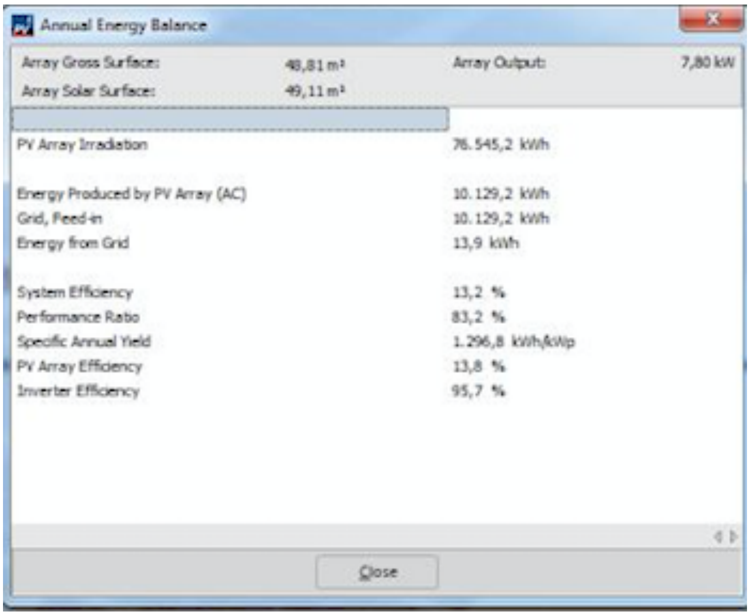


BIPV System Variant

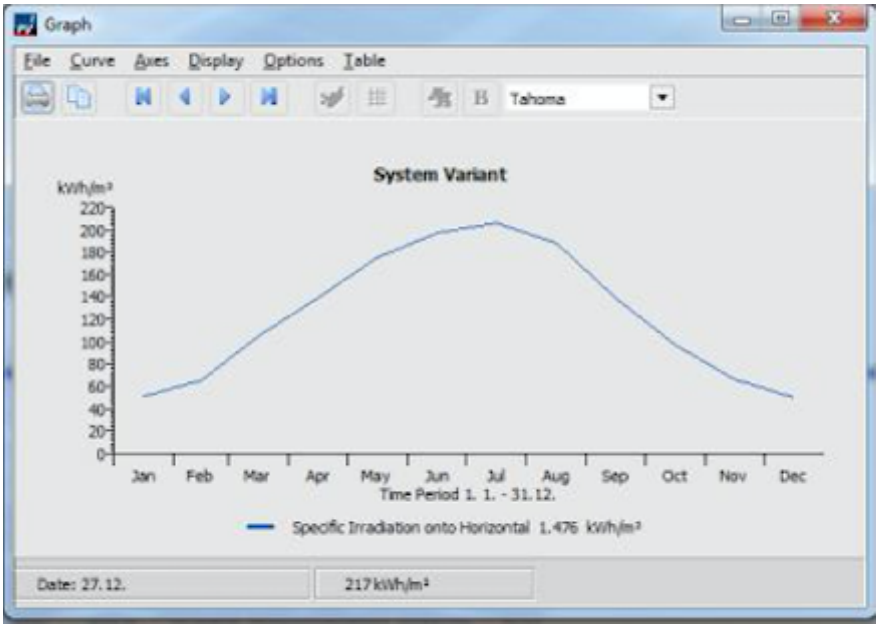
Project Name:	Solar System Design	01.04.2016
Variant Reference:	System Variant	

Location:	Eskişehir Anadolu Airport
Climate Data Record:	Eskişehir Anadolu Airport (1986-2005)
PV Output:	7,80 kWp
Gross/Active PV Surface Area:	48,81 / 49,11 m²
PV Array Irradiation:	76.545 kWh
Energy Produced by PV Array (AC):	10.129 kWh
Grid Feed-in:	10.129 kWh
System Efficiency:	13,2 %
Performance Ratio:	83,2 %
Inverter Efficiency:	95,7 %
PV Array Efficiency:	13,8 %
Specific Annual Yield:	1.297 kWh/kWp
CO2 Emissions Avoided:	8.962 kg/a

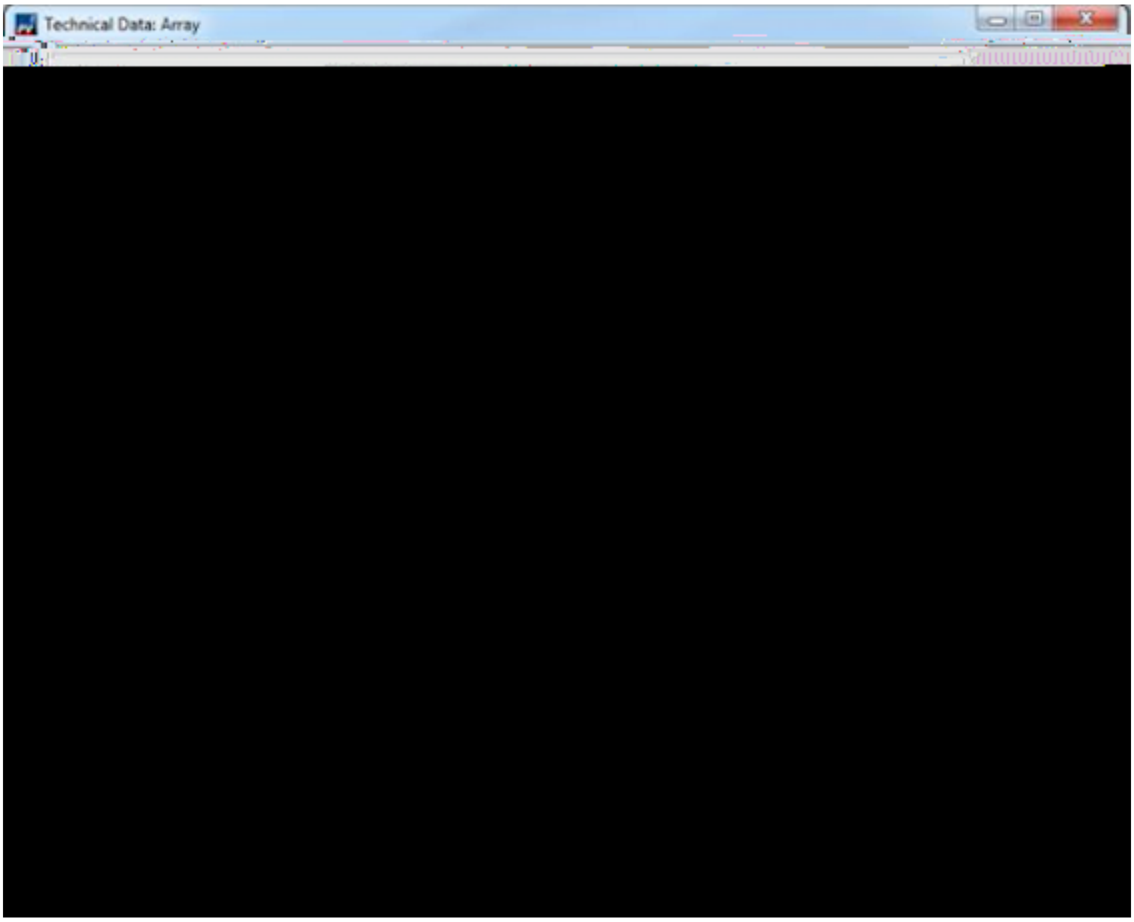
BIPV System Output



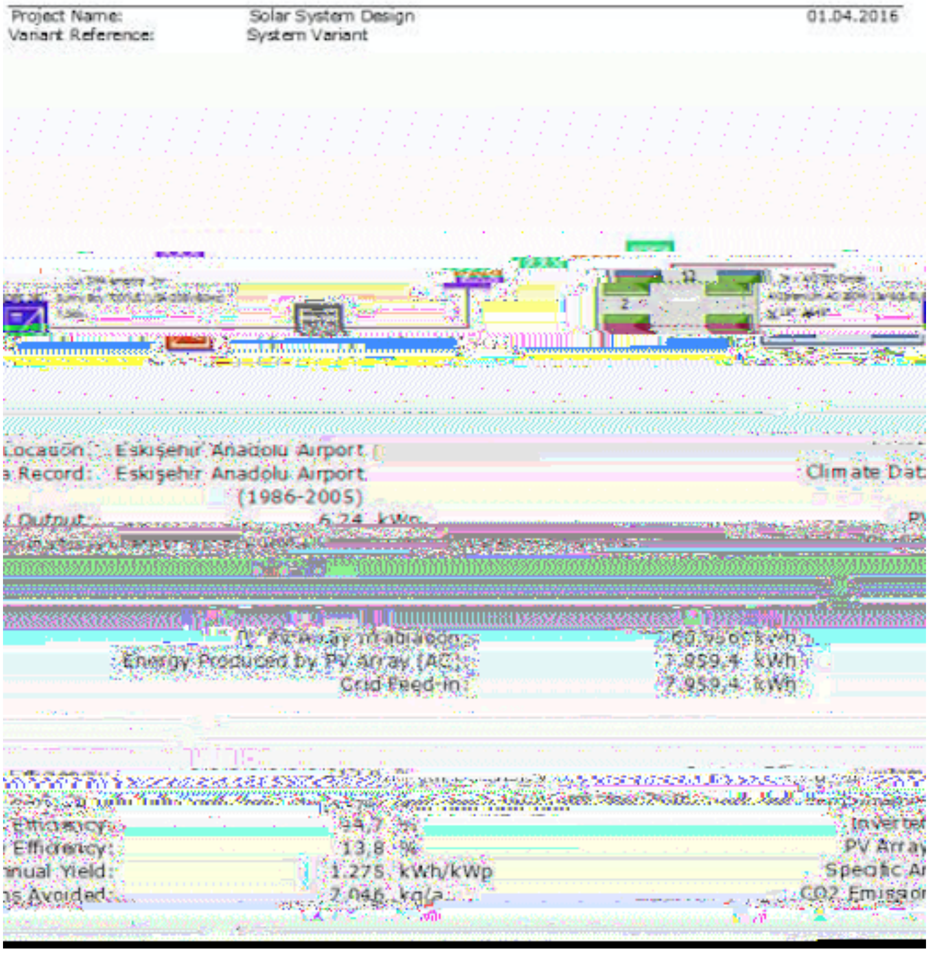
BIPV System Generation Graph



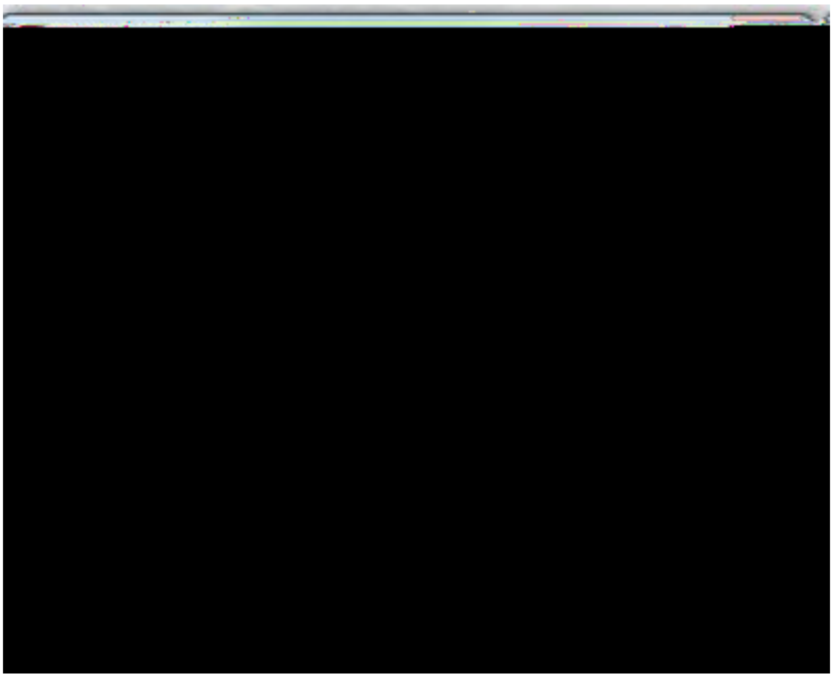
Carport System Inputs



Carport System Variant



Carport System Output



Carport System Generation Graph

APPENDIX C: Price Offers

Triple Glazing

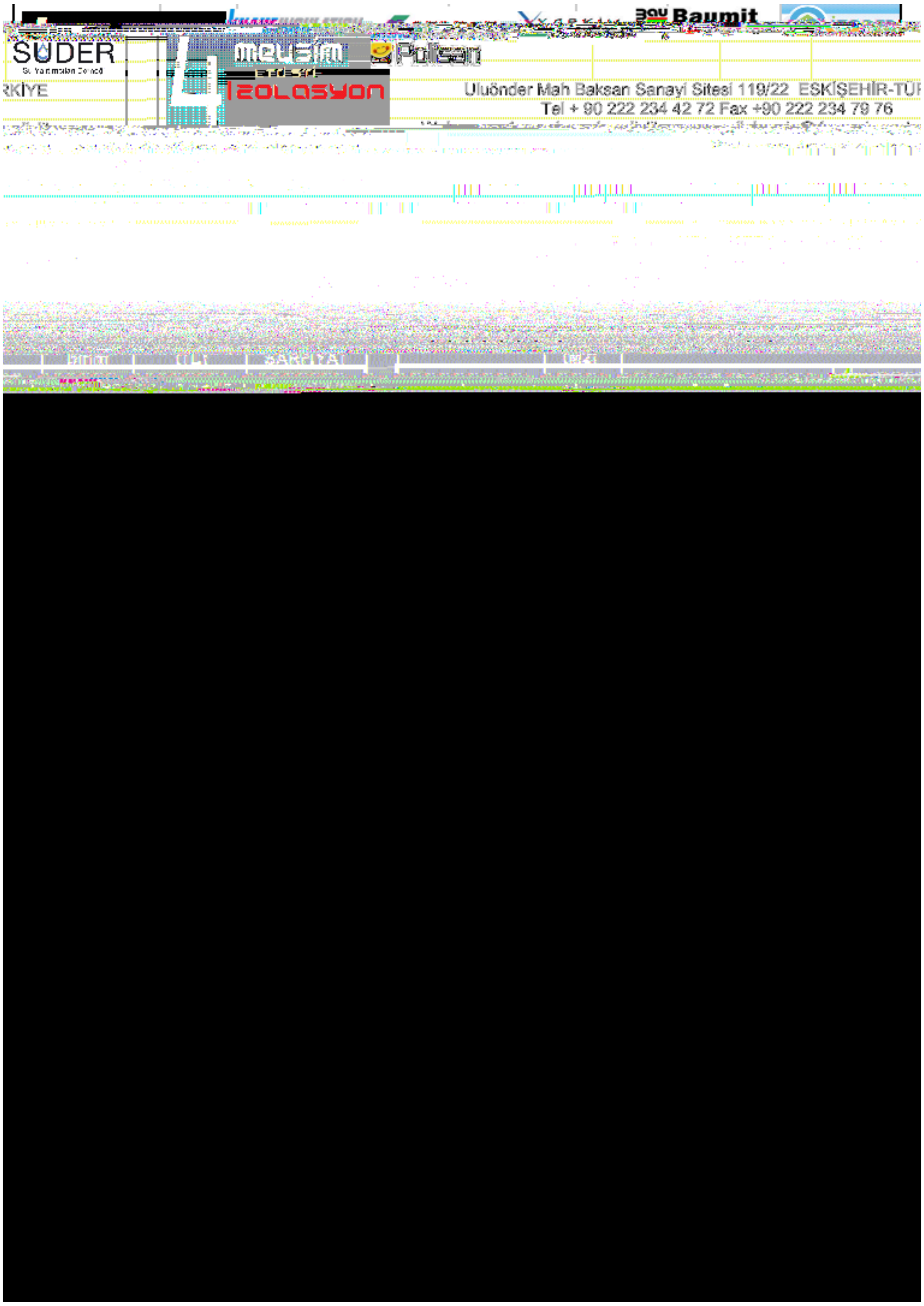
RÖPER İNŞAAT

31.8.2015

RÖPER İNŞAAT LTD.ŞTİ
ATATÜRK BULVARI NO:130/2
ESKİŞEHİR
TEL:0222-226 09 37-22[illegible]

[redacted]

Insulation


Uluönder Mah Baksan Sanayi Sitesi 119/22 ESKİŞEHİR-TÜR
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Photovoltaic

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TEKLİF FORMU

TEPEBAŞI BELEDİYESİ

ESKİŞEHİR

Proje: Çatı-Otopark Güneş Enerji Santrali Projesi

Tarih: 07.09.2016

Açıklama	Miktar	Fiyat	Tutar
8 kW BIPV	1	9200€	9.200,00€
7 kW Carport Canopy PV	1	8750€	8.750,00€

Teklif geçerlilik süresi 15 gündür

TOPLAM		17.950,00 €
KDV	18%	3.231,00 €
GENEL TOPLAM		21.181,00 €

Lighting

AYDINLATMA CETVELİ

ALANIN														
ADI	EN (m)	BOY (m)	ALAN (m²)	Yükseklik (m)	Askı Boyu (m)	h1 (m)	Oda İndeksi (k)	E (lüx)	Armatür Tipi	Armatür Işık Akısı (lm)	Aydın. Verimi ()	Gerekli Aydınlatma Seviyesi (lm)	Lamba Sayısı
MUTFAK	2,5	4,6	11,5	2,9	-		0,55852	150	TBS	1500	0,24	8984	6
MUTFAK 2	3,1	3,4	10,54	2,9			0,55915	150	TBS	3000	0,24	8234	3
SALON	3,3	6,8	22,44	2,9	-		0,76613	150	TBS	3000	0,31	13573	5
GİRİŞ HOL	1,2	5,8	6,96	2,9	-		0,34286	100	TBS	1500	0,24	3625	2
Y. ODASI 1	3,1	4,4	13,64	2,9	-		0,62713	50	TBS	1500	0,24	3552	2
Y. ODASI 2	3,2	4,4	14,08	2,9	-		0,63884	50	TBS	1500	0,24	3667	2
E. Y. ODASI	3	6,4	19,2	2,9	-		0,70433	50	TBS	1500	0,24	5000	3
BANYO	2,6	2,8	7,28	2,9	-		0,46488	100	TBS	1500	0,24	3792	3
E. BANYO	2,3	3,2	7,36	2,9	-		0,46144	100	TBS	1500	0,24	3833	3
GECE HOLÜ 1	1,5	2,7	4,05	2,9	-		0,33251	100	TBS	1500	0,24	2109	1
GECE HOLÜ 2	2,4	3,3	7,92	2,9	-		0,47913	100	TBS	1500	0,24	4125	3

	Renk Sıcaklığı	Lümen Değeri	Adet	Güç (W)	Fiyat ($)
30 cm x 60 cm 18/20 W LED Panel	3000 K /4000 K	1500	25	500	1000
12 W Downlight LED Armatür IP 44	3000 K /4000 K	840	5	60	100
12 W S/Ü Etanj LED Armatür IP65	3000 K /4000 K	840	8	96	140
5 W S/Ü LED Aplik IP 20	3000 K /4000 K	300	12	60	360
Toplam Maliyet (Dolar)					1600

BMW 216d Active Tourer

2 SERİSİ

Model	Donanım Paketi	Şanzıman	Yakıt Tipi	CC	BG	Yakıt Tüketimi lt/100 km (5)	Anahtar Teslim Satış Fiyatı (TL)
BMW 218i Active Tourer (2)	Joy	Otomatik	Benzin	1499	136	5,2	119.500
	Prestige	Otomatik	Benzin	1499	136	5,2	122.600
	Sport Line	Otomatik	Benzin	1499	136	5,2	126.500
	Luxury Line	Otomatik	Benzin	1499	136	5,2	131.000
	M Sport	Otomatik	Benzin	1499	136	5,2	134.900
BMW 216d Active Tourer	Joy	Otomatik	Dizel	1496	116	4,0	128.000
	Prestige	Otomatik	Dizel	1496	116	4,0	131.100
	Sport Line	Otomatik	Dizel	1496	116	4,0	135.000
	Luxury Line	Otomatik	Dizel	1496	116	4,0	139.500
	M Sport	Otomatik	Dizel	1496	116	4,0	143.400

BMW i3

BMW i3

Model	Donanım Paketi	Şanzıman	Yakıt Tipi	CC	BG/kW	Yakıt Tüketimi lt/100 km (5)	Anahtar Teslim Satış Fiyatı (TL)
BMW i3	Pure	Otomatik	Elektrik	0	170	-	149.500
	Premium Techno	Otomatik	Elektrik	0	170	-	156.500

Toyota Yaris Hybrid & 1.33 Style Multidrive

Gövde Tipi	Model	Tavsiye Edilen Liste Fiyatları (TL)
Yaris	1.0 Life	45,750
Yaris	1.33 Fun	53,250
Yaris	1.33 Fun Multidrive S	58,650
Yaris	1.33 Fun Skypack Multidrive S	60,550
Yaris	1.33 Fun Special	54,300
Yaris	1.33 Fun Special Multidrive S	59,700
Yaris	1.33 Fun Special Skypack Multidrive S	61,600
Yaris	1.33 Style	59,400
Yaris	1.33 Style Multidrive S	64,800
Yaris	1.33 Style Skypack Multidrive S	66,700
Yaris	1.33 Style Red	59,400
Yaris	1.33 Style Red Multidrive S	64,800
Yaris	1.33 Style Red Skypack Multidrive S	66,700
Yenilenen Yaris Hybrid Hybrid	1.5 Yaris Hybrid Cool	68,150
Yenilenen Yaris Hybrid Hybrid	1.5 Yaris Hybrid Spirit	76,150
Yenilenen Yaris Hybrid Hybrid	1.5 Yaris Hybrid X-Trend İnci Beyazı	77,450
Yenilenen Yaris Hybrid Hybrid	1.5 Yaris Hybrid X-Trend Barselona Kırmızısı	77,450
Yenilenen Yaris Hybrid Hybrid	1.5 Yaris Hybrid X-Trend Platinyum Metalik	77,450