Energy Efficiency for Hot-Humid Climate Based On Openings and Roof Type, Adana Case

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***Abstract*— Traditional architecture presents appropriate design decisions with climatic conditions without using excessive energy. This study aims to demonstrate energy efficiency of traditional Adana houses based on openings and roof type with the goal of improving the overall energy performance of modern houses buildings in hot-humid climate. Effects of passive solar design techniques such as increasing window transparency, improving glazing type, adding shading elements over windows on south wall and roof type on traditional Adana house were analyzed by eQUEST program which uses the hourly base dynamic simulation approach. Energy model of five cases have developed to find their energy performance. Results of annually electric and gas consumptions were compared by using same building footprint and structural system in all cases. Consequently, compared to today's house with traditional Adana house that has the same heating and cooling area, energy consumption of traditional Adana house is totally 40% less than a modern Adana house. Application of passive solar design strategies on openings and selected green roof type in reference building have enhanced annually overall energy performance by 48%. Green roof has made contributions to a 6%, 55% saving in annual electric and gas use respectively. On the other hand, energy uses of both houses couldn't get reachable for TS 825 standards**.

Keywords*— *building energy efficiency; openings; green roof; hot-humid climate

I- INTRODUCTION

Today, The World's energy is used 27% in the transport sector, 30% in the building sector and 31% in the manufacturing (1). For example, In countries such as the US and the United Kingdom, the building sector consumes of order 36-40% of the total delivered energy (2-3). Increasing concern about global warming introduced the building industry with a challenge to reduce its energy consumption. In Turkey, based on distribution of net electricity consumption by sectors, it is seen that share of electric consumption in households is 22,2% in 2016 (TÜİK report, 2016). In about 80% of the energy used in buildings is spent for heating, cooling, air conditioning and hot water supply (Kutlu, 2017)

Traditional houses are considered adapted appropriately to their local climates and take better advantages of natural energy resources such as wind and sun. Discovering and applying architectural passive design strategies such as orientation and spatial organization, shading, material, utilization of natural ventilation, thermal mass or heat loss could support to enhance energy performance of building. Hence, energy consumptions can be reduced by employing those solutions instead of mechanical equipment. Achieving thermal comfort in hot and humid climate requires both cooling and dehumidification so selected design strategies is significant to minimize thermal impact from solar radiation. Purpose of this research is to show decreasing of building energy demand by analyzing identified traditional design techniques such as window openings, material, shading elements, glazing type and roof system. It has also gone through the effect of Cumba, structural element of traditional Adana houses, on energy consumptions of reference building.

A. Literature review

Some related previous studies have analyzed how to get better energy performance of houses in hot-humid climate as Adana. In İbrahim Aktoz's study, 15 dwellings which reflects the characteristics of their age was chosen from the beginning of 20th century up to 2000 and emphasis their thermal performance analysis simulated which two of those houses were traditional houses (Aktoz, 2000). The analysis was emphasis the material changes to optimize thermal performance calculated by SUNCODE-PC 5.7 programme.

Results given as;

- Selected double glass window and adding shading elements didn't contribute excessively to heating-cooling energy requirement. However, cooling loads decreased in an amount of 8,6% due to preventing from the sun radiation.
- When perlite was used for 2,5 cm blended outer plaster on exterior wall of house for isolation purpose, energy gain was 22%. However, little amount of cooling loads increased due to heat storage in spaces.

- 39,23%, maximum energy saving was obtained by optimization ways of thermal performance which is that adding shading device over south window, selecting perlite blended outer plaster and shaving panels fixed over inner wall surfaces. On the other hand, a little amount of total yearly cooling loads increased due to reason mentioned before.

Additional study has proposed an approach that make the design of exterior shading element. Specific dimensions of it has been determined with the help of the solar tool program at the latitude of Adana (Yüceer, 2010). Dimensions of shading element which is for 100/200 cm window on south facade has been found out to be 50/140 cm effective against the unwanted increase in temperature at Adana.

On the other hand, significance of cultural factors are acknowledged on some researches. Umar N., Karbeyaz C., Polar Ö.O. has a detail study about traditional houses of Adana as an example of vernacular architecture. According to their research, function and climate are the most important factors on typology such as exterior hall plan type and interior hall plan type in traditional houses of Tepebag and Kayalıbag. In this study, traditional houses classified as with or without courtyard (Umar et al.,2014). For example; houses with courtyard can be entered directly from the street and are related to non-Muslim community while the ones with courtyard are entered through a private courtyard or garden and related to Muslim community around the neighborhood. It assumed that cultural beliefs affect design decisions such as layout plan, building form, orientation of rooms. Hence, traditional house energy performance should be optimized as being aware of cultural meanings.

B. Architectural Features That Shape Traditional Adana Houses

Adana architectural features that have shaped traditional houses have been analyzed in two separate sections as spaces and building elements.

1) Spaces;

Parts that constitutes traditional Adana houses are rooms, 'sofa', 'hayat', 'Cihannüma'.

a) Rooms: It is a place of living that combines general functions that meet the needs of residents in the house.

Functions in the houses: There are warehouse, cellar, woodshed on ground floor which is the entrance floor.

Architectural plans: Rooms are lined up around the sofa at the first floor where is the actual living place.

Rooms are usually made in square or rectangular form. The interior dimensions of the head room are 3x4 m, 3x5 m, and ceiling heights are 3-3,5 m. The other rooms are 3x4 m (Fig. 1).

On the side wall of the room entrance is a built-in closet called 'yüklük'. Other cabinets are capped with 50-60 cm deep (Tülücü, 1999)

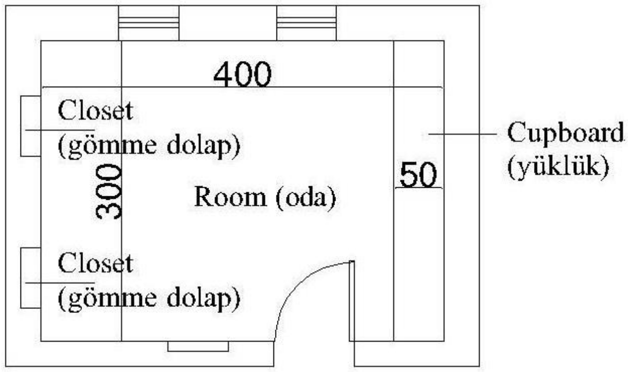


Fig. 1. *Room example used in traditional Adana Residence (Soygün, 2003; Yüksel,2018)*

b) Sofa: Design of the house's surrounding is also very important. There are different applications called sofa, 'Evin önü' (front of the house) facing courtyard of traditional houses in Adana. Differentiated in I, L and U-shaped forms were used in exterior sofas and interior sofas (Karaman, 1992). Sofa protects the entrance of the house against the changing climatic conditions. It also provides passage between the rooms.

c) Hayat (Courtyard): Connection between traditional Adana house and street are provided with courtyard surrounded by walls. According to the result of the 'Traditional Building Parcel Relation' study which was prepared within the scope of the Zoning Plan studies for the purpose of conservation and approved by the Council for the Protection of Cultural and Natural Assets of Adana by Decision No 1774 dated 29.12.1997, it is seen that the traditional dwellings were built with courtyards more than the ones without the courtyards. In addition to this, back courtyard is mostly seen in courtyard types (Saban, 2017). Side courtyard, front courtyard, middle courtyard and non-courtyard types are the others (Fig. 2). Large-bedded flat stones are also seen material besides soil on the courtyard floors (Soygün, 2003).

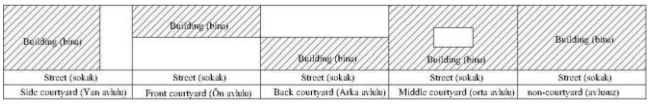


Fig. 2. *Building-parcel relation of traditional dwellings (Moghaddam,2013; Yüksel 2019)*

d) Cihannüma: Purpose of this construction is to take a bird's-eye view of the environment. It is usually seen dwellings located in the neighborhoods of Adana Seyhan river. This section is usually associated with the first floor and the construction technique is the same. Timber frame filled with brick is used (Soygün,2003). It is 2.5x2.5 m or 3x3 m in size, is in use for observation purpose only (Fig. 3).

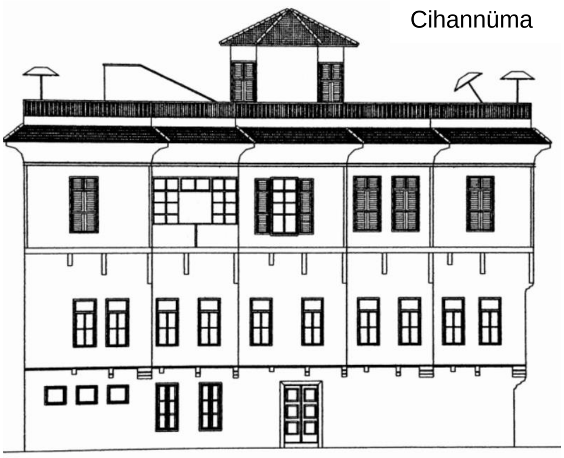


Fig. 3. *Cihannüma appearance in traditional houses (Adana Cultural and Natural Heritage Preservation Board, 191 Inventory numbered structure)*

2) Architectural Building Elements;

Architectural Building Elements of traditional Adana Houses are examined in two categories as material and building components.

a) Material:

Industrial products such as glass, iron, etc. have been used with building materials such as stone, soil, wood which are present in the nature in the construction of traditional houses (Table 1).

TABLE 1. Materials based on the place of usage (Hot-humid climate, Traditional Adana Houses) (Yüksel,2018)

Adana Traditional houses material properties

Building envelope material		Timber, Brick, Soil, Plaster, Traditional corrugated tile, Glass, İron
Structural material	Wall	Brick masonry, Wooden frame with stone, brick or adobe filler
	Floor	Wood, Flat stone or compacted soil, Boulder (on courtyard floor)
	Carriers (Column,Beam)	Wood, Brick, Stone
	Roof	Earth dam, wooden pitched roof
Detail material	Joinery	Wood, İron
	Wall covering	Horasan mortar plaster, sandy mortar
	Roof covering	Earth, single corrugated alaturka tile, corrugated sheet
	Ceiling covering	Non-covered (under wooden beams open), wooden ceiling cover
	Eaves	Roof eaves over wooden buttresses (earth dam)
		Concave roof eaves made in Baghdadi technic (wooden pitched roof)
Isolation material	Thermal /Noise /Water	There is no isolation materials

b) Building components:

Fig. 4. *Structural layers of Adana traditional houses (Yüksel,2018)*

The main building material of the houses is wood. As a construction technique, brick masonry or wooden frame filling with brick technique is widely used. Seljuk bricks are commonly used in brick infilling walls while there are examples of adobe filling. The ground floors have generally brick masonry walls reinforced with 5-7 cm wooden beams at 80-90 cm (Fig. 4). Three types of construction technics were applied on traditional dwellings; mansory construction, wooden frame filled with brick and 'bağdadi' (Soygün,2003).

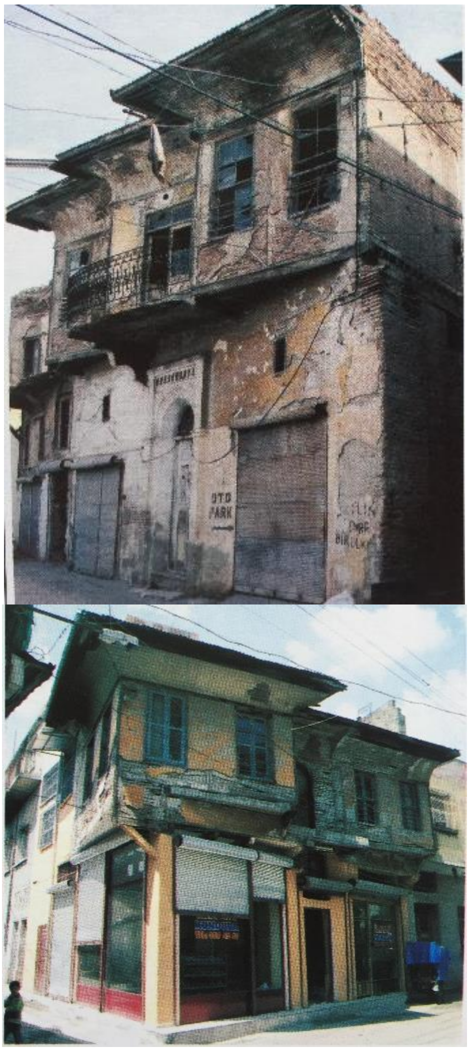


Fig. 5. *Examples of Traditional Adana Houses (Adana Urban Culture Inventory, structures numbered 44,133 respectively)*

In traditional Adana houses, the upper floor room plans have different protrusions called as buttresses, consoles, balconies, cumba in the reflection of the facade (Fig 5). In addition, Cumba can be defined as an extension of rooms in the first floors, covered by windows on different facades. In the study of Aydin and Mirzaei in 2017 has been founded that Cumba helps to accumulate winds from different directions so the ventilation speed of the room increases by two quarters more. In addition, a flexible window opening strategy increases the average ventilation rate by 276% (Aydın and Mirzaei, 2017). For this reason, it is said that the Cumba with the vertical guillotine windows can decrease heating-cooling loads by the ventilation of the room. Moreover, miter shaped projections (Fig.5, structured numbered 44,133) on facade help changing the direction of the wind so distribute it to other parts of the house.

II. CASE STUDY

Fig. 6. *Adana and meteorology observation stations location map (Aksu, 2016) (Meteoroloji istasyonu: weather station, test istasyonu: test station, Adana il sınırı: Adana province border, ilçe sınırı: district border)*

Adana (36° 59'N, 35° 17'E) is located on a Mediterranean Region (Fig. 6). Adana province is divided into two parts: mountainous and plains. The north-west, north and north-east parts of the province are surrounded by the mountain system called Central Taurus. The remaining part of the basin called Adana Plain is called Çukurova and the north parth is called the Upper Plain Anavarza. The Misis Mountains separate the two terraces (4).

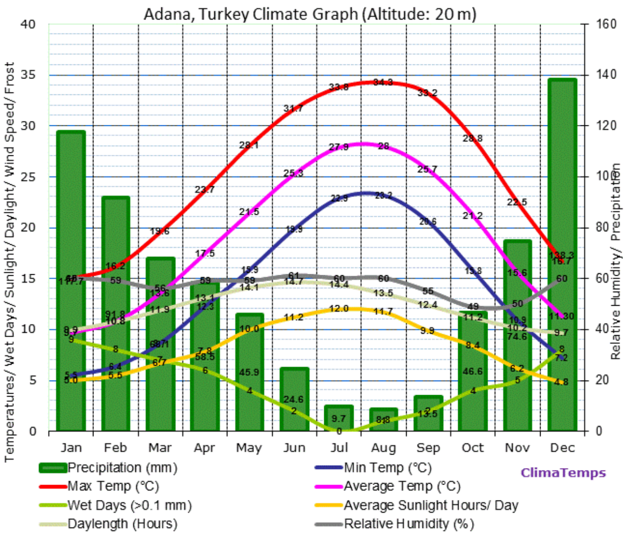


Fig. 7. *Adana, Turkey Climate graph (5)*

Adana shows the Mediterranean climate characteristics. The summers are hot and humid, the winters are warm and rainy. The average precipitation is 698.1 mm. An average of 74 days of season passes rainy. Rainfall falls 51% in winter, 26% in early spring, 18% in autumn, 5% in summer (Fig. 7)

The highest temperature is recorded as 34 °C in August and the lowest as 5 °C in January. In the summer, air flows from the sea and the Taurus Mountains through a low pressure center, Cukurova. As a result, high pressure center becomes by air dynamics there. Because of accumulation and reaching in saturation point, warm air couldn't rise. Thus, humidity is seen in summer months. The average relative humidity level is 66% in Adana (Fig. 7). Humidity causes difference between weather temperature and sensible temperature. Hot temperature and high humidity level affect sensible temperature, hence in June, July, August months sensible temperature occurs in high level. For example, İf the weather temperature is 30 C, a person feels like 38 C when the humidity level is around %80 (Yeang, 2012). Thus, hot climate and high humidity level is a significant data which is need to be considered while creating passive design strategies for buildings.

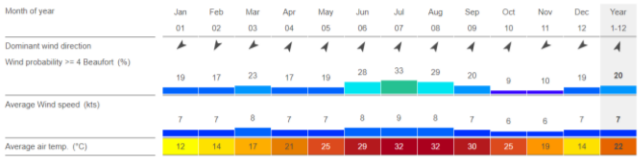


Fig. 8. *Wind direction and speed statistics for Adana (6)*

Wind speed in Adana is about 6-9 kts (3-4,6m/s). Adana wind direction is predominantly north and north east. Maximum wind speed is 9kts (4,6 m/s) otherwise minimum is 6 kts (3m/s) (Fig. 8). According to Beaufort scale, 3,4- 5,4m/s wind speed defines as soft breeze (Yeang, 2012).

The detailing of the reference building are developed by taking advantage of the former studies on the common characteristics of traditional houses in Adana. The selected house is located on Döşeme neighborhood where was far away from the city's busy business and housing areas in the beginning of the 20th century. Its urban structure consists one or two stories residential buildings adjacently built on small flat islands. Habitants from different religions and nationalities with locals lived there.

1) Plans

Reference house oriented toward north to south way on layout plan. It has two rooms with separated kitchen and toilet on ground floor. Those zones take places around the courtyard (Fig. 9).

Fig. 9. *Ground Floor (left side), Basement Floor (middle) and layout plan (right side) (Yüksel, 2019)*

As shown on Fig 9, while living room and bedroom are on the south direction, wet places as kitchen, bathroom can be seen on north. Living room on south facade has two windows and door as equal number of north facade. Bedroom is only has entrance from the living room. However, it has own separated two windows on south facade between the living room to get view and natural ventilation. East and west facade adjoins to next-door neighbor but west facade has only a small window. When there aren't spaces between neighbors, heat transfers through one wall side to another by conductivity. For that reason, little amount of building heating demand is decreased by design decisions on urban context. Selected house has basement floor, 1.98 m height. In addition, it were used as a storage areas by previous residents. Having basement floor causes that living room and bedroom on ground floor has no connection with earth directly. Heat transfers only from basement floor to ground floor. It results in that those rooms have reduced energy demand for heating.

2) Materials

Traditional house was built from brick and wood which is easily found in environment. Brick was used for wall with mortars. Outer and inner wall surface covered with mortars. Moreover, ıt was used for filling the blanks between bricks (Fig. 10).

Fig. 10. *Front view of traditional Adana house (Yüksel, 2019)*

3) Openings

Reference house has small windows which were made from wooden frame and wooden sash on south, north and west facade. They keeps privacy and assure security inside. However, solar gain through windows is often a major key of the heat gains of dwellings. Effective shading such as shading devices, vegetation, glazing type or nearby structures should protect inside from the sun and heating exposure. Openings of traditional house have wooden cover and single glass window which is seen in Fig. 10. While wooden cover provides less heat gain of the interior environment, daylighting is a key issue to be considered. Reduced daylight due to not well-designed shading element could increase artificial lighting needs. Since it is a major heat source, lighting is not only a significant piece of building energy consumption by itself, but it also impacts the cooling energy demand (Chae et al., 2016).

Dimensions of openings calculated in detail for further overall energy performance analyzing. Especially percentage of windows transparency on external walls, all windows area could be seen in table 2.

TABLE 2. Traditional house openings in detail

ground floor	width (m)	height (m)	window area (m2)	direction of window-located space	wall area (m2)	window transparency (%)
w1	0.64	1.80	3.74	South /living r.	77	18
w2	0.60	1.80	3.59	South/ living r.		
w3	0.85	1.80	5.02	South/ bedroom		
w4	0.85	1.80	5.02	South/ bedroom		
w5	0.67	1.70	3.74	North /living r.		
w6	0.64	1.70	3.56	North/ living r.	87	16
w7	0.85	1.70	4.75	West/ living r.	62	7
w8	1.49	1.90	9.69	South/ kitchen	40	19

4) Roof

Traditional house roof was made from wooden beam and cover and over this structurel system clay soil was placed. Roof is flatten and it has no insulation layers only clay soil used as a isolation materials.

Aims of this study are to assess the potential energy loads over annually lifecycle of the building with the improvement of openings and roof type. The energy consumptions of the building have taken into account for five cases which are compared with actual monthly data, average values for a year, results on energy usage prediction.

Compared cases of this study alternated as shown:

Case I: Energy consumptions of reference building has been calculated on programme by identifying detail information such as building footprint, each zones on plans, structural layers and type of used energy.

Baseline; A modern Adana house which has the same heating-cooling area with the traditional one has been created without courtyard to get annually energy performance results.

Case II: Reference building energy performance has been calculated on programme with three improvements given as;

Firstly, percentage of window transparency on external south wall has increased from %18 to %40. Secondly, glazing type has been chosen as double low-e glass instead of single low-e. Lastly, shading elements has been added over windows on external south wall.

Case III: With the improvement of Case II, energy consumption of reference building has been analyzed by assuming different structural roof system called as green roof instead of terrace roof.

The Last case is energy performance analysis of traditional Adana house based on TS 825 standards. U-values of structural elements has been determined for reference building according to Adana included in the first climatic region in Turkey.

A. Case I

eQUEST is a comparatively user-friendly energy analysis tool for a broad range of users. It employs the DOE-2.2-derived energy simulation application and provides detailed graphical results using two interacting wizards: an energy efficiency measure (EEM) wizard and a building creation wizard (Crawley et al. 2008). eQUEST 3.65 which is the most recent release energy modelling programme (7) has been used to model the traditional house.

Firstly, climatic data of Adana mentioned in 1.1 chapter should be uploaded to eQUEST programme. However, the weather file for Adana couldn't be available in programme archive so, Autodesk Green Building Studio (GBS) is used for reaching the weather data in *'.bin'* format.

As continued, structural elements of the building have been identified and thermal resistance, R and U-values were calculated based on TS 825 standards for thermal conductivity value (Table 3). Later identified and calculated necessary measurements, data for building characteristics such as type, customized openings and roof type, hourly scheduling of occupants, mechanical equipment, miscellaneous internal and lighting loads, etc., were entered in eQUEST. For energy performance analysis, a 3D Model of Traditional house was created then (Fig. 11).

TABLE 3. Layers of structural elements used in the models

Structural elements	Material	Thickness, d m	Thermal conductivity,λ W/mK	Thermal Resistance, R m2K/W	U-value W/m2K	U-value Btü/h-ft2-F
Floor	Wood beam	0,14	0,13	1,08	0,76	0,13
	Wood cover	0,03	0,13	0,23		
Ground floor	Concrete	0,15	1,65	0,09	11,11	1,96
	outer plaster	0,02	1,00	0,02		
Exterior wall	brick	0,27	0,81	0,33	2,70	0,48
	inner plaster	0,02	1,00	0,02		
	clay soil	0,10	0,47	0,21		
Terrace roof	wood beam	0,14	0,13	1,08	0,66	0,12
	wood cover	0,03	0,13	0,23		

The annual energy consumptions for current Traditional house is simply 26643,5 kWh (Fig. 12) From the result of monthly energy consumptions by enduse for the first case, 52% of building electricity consumption is for water heating (Fig. 13). However, electricity as energy source weren't used for water heating in Traditional Adana houses, stove were used instead. Moreover, wood or coal was used to burn the stove. As the time passes, vacuum tubes installed on roof have been developed to obtain domestic hot water. These tubes heat the water with solar energy.

The point to be noted on this analysis, it has confirmed that water heating consumption is 4968,6 kwh. Energy is consumed in buildings for space heating, too. The annual energy consumptions for heating is from natural gas and 17115,4 kWh (58,4 Btü).

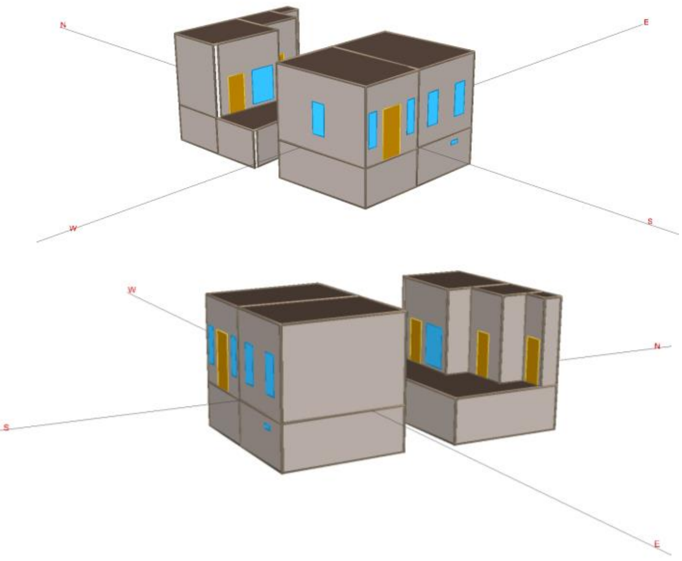
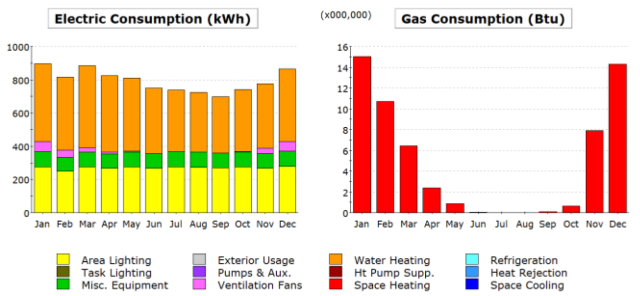
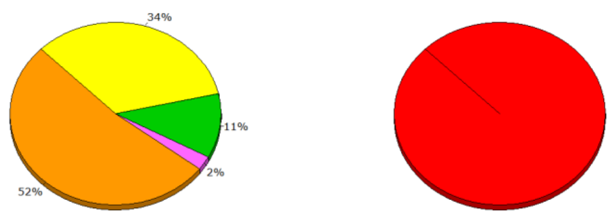


Fig. 11. *eQUEST energy model of traditional Adana house*



	Consumption		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Case 1	Electric (kWh)	Hot Water	467,8	439,9	494,1	461,6	441	395,6	369,9	358,6	340	373,4	388,9	437,8	4968,6
		Vent Fan	61	42,8	24,8	8,7	3,1	0,1	0	0	0,3	2,2	30,9	57,9	231,8
		Misc. Equip	91,9	83	91,9	88,9	91,9	88,9	91,9	91,8	89	91,9	89	92	1082,1
		Area Lights	276,2	249,4	274,5	266	274,5	266,3	276	272,9	269,4	274,5	268	277,9	3245,6
		Total (kWh)	896,9	815,1	885,3	825,2	810,5	750,9	737,8	723,3	698,7	742	776,8	865,6	9528,1
	Gas (kWh)	Space Heating (Btux000,000)	15,02	10,72	6,42	2,38	0,88	0,04	0	0	0,08	0,64	7,92	14,3	58,4
		Total (kWh)	4401,9	3141,7	1881,5	697,5	257,9	11,7	0,0	0,0	23,4	187,6	2321,1	4190,9	17115,4

Fig. 12. *Monthly energy consumptions by enduse for case I*



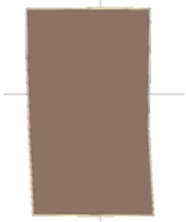
Electricity *Natural gas*

Fig. 13. *Annual energy consumptions by enduse for case I*

B. Baseline

The size of the building, its height, the number of floors and the overall configuration of the building give a meaning to building shape or building footprint. All discussions about how to be orientate it, happens on located area. Each facade could face the sun, streets or its views so surface area and floor area have significant impact on the energy performance of the building. Because energy use in most buildings is dominated by heating and cooling, these areas becomes a focus characteristic of a building energy efficiency. The building form of the baseline has the same heating-cooling area with first case but surface area has decreased due to enclosing the courtyard with walls (Table 4).

TABLE 4. Building form differences of cases

Case I	Baseline
	
Heating-cooling area	Heating-cooling area
60 m2	60 m2
Surface area	Surface area
173 m2	155 m2

A modern Adana house has been structurally defined as layers on table 5. After a 3D Model of the modern Adana house seen on fig 14 was created, it was simulated on programme to get the energy consumption results. It is clearly seen that monthly energy consumption by end use on fig. 15.

TABLE 5. Layers of structural elements used in the models

Structural elements	Material	Thickness, d m	Thermal conductivity,λ W/mK	Thermal Resistance, R m2K/W	Total R value m2K/W	U-value W/m2K	U-value Btü/h-ft2-F
	PVC flooring	0,01	0,23	0,04			
Floor	Alum	0,03	1,40	0,02	0,13	7,69	1,35
	Concrete	0,12	1,65	0,07			
Ground floor	Concrete	0,15	1,65	0,09	0,09	11,11	1,96
	Outer plaster	0,02	1,00	0,02			
Exterior wall	Concrete	0,27	1,65	0,16	0,20	5,00	0,88
	Inner plaster	0,02	1,00	0,02			
	Insulation mat.	0,12	0,04	3,00			
Terrace roof	Concrete	0,14	1,65	0,08	3,10	0,32	0,06
	Plaster	0,02	1,00	0,02			

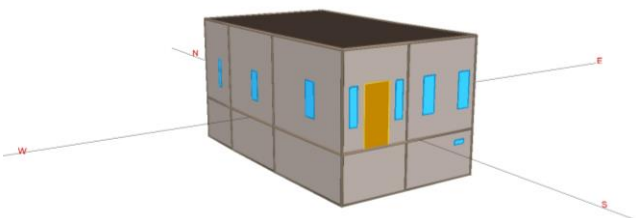
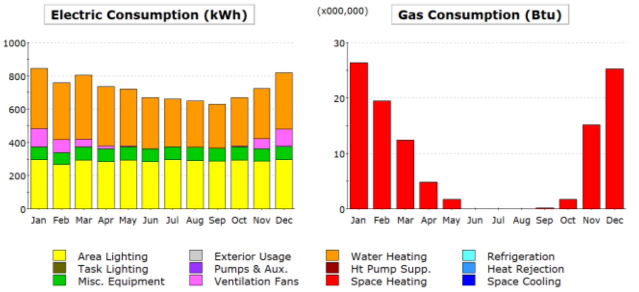


Fig. 14. *eQUEST energy model of modern Adana house*



	Consumption		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Baseline	Electric (kWh)	Hot Water	363	341,1	383	357,7	342	306,8	287,1	278,5	264,2	290	302,1	340	3855,5
		Vent Fan	107,9	78,4	48	17,7	6,2	0,1	0	0	0,5	5,9	59,7	103	427,4
		Misc. Equip	79,7	72	79,7	77,1	79,7	77,1	79,7	79,6	77,2	79,7	77,2	79,8	938,5
		Area Lights	294,9	266,3	293,1	284	293,1	284,3	294,7	291,4	287,6	293,1	286,2	296,7	3465,4
		Total (kWh)	845,5	757,8	803,8	736,5	721	668,3	661,5	649,5	629,5	668,7	725,2	819,5	8686,8
	Gas (kWh)	Space Heating (Btux000,000)	26,38	19,47	12,38	4,8	1,75	0,03	0	0	0,15	1,7	15,19	25,27	107,12
		Total (kWh)	7731,2	5706,1	3628,2	1406,7	512,9	8,8	0,0	0,0	44,0	498,2	4451,7	7405,9	31393,8

Fig. 15. *Monthly energy consumptions by enduse for the baseline*

C. Case II

Passive solar design technics like adding shading elements over windows, selecting glass type has an improving effect on building energy performance as it has been found out from literature review (Aktoz, 2000). A typical building loses 25% of its energy through its windows and energy losses are even greater in buildings with a high window to wall ratio (Ching et al., 2014). In addition, ASHRAE Standard 90.1-2016- Energy Standard For Building Except Low-rise Residential Buildings which is the latest version of ASHRAE 90.1 sets fenestration area limits, with the vertical fenestration to no more than 40% of wall (8). The window to external wall ratio between 50% and 70% in the North, 60% in the South and 50%–60% in the east and west orientations were also observed for the intersection of optimum visual comfort and luminance criteria (Ochao et. al., 2012).

Selected traditional Adana house has 18% window transparency on external south wall. Using the same building footprint and structural system, percentage of window has been increased from 18% to %40 to provide visual comfort inside (Table 6).

TABLE 6. Window parameters of cases

ground floor	width (m)	height (m)	window area (m2)	direction of window-located space	wall area (m2)	window transparency (%)
Case I						
w1	0.64	1.80	3.74	South /living r.	77	18
w2	0.60	1.80	3.59	South/living r.		
w3	0.85	1.80	5.02	South/bedroom		
w4	0.85	1.80	5.02	South/bedroom		
Case II						
w1	1.06	1,98	6.93	South /living r.	55	40
w2	1.06	1,98	6.93	South/living r.		
w3	1.98	1,98	12.8	South/bedroom		
w4	1.92	1.98	12.5	South/bedroom		

Low-emissivity (low-e) windows are manufactured by typically coating the inside surface of the outer pane with a thin metal or metallic oxide film so that visible light is transmitted but longer wavelengths of radiant heat are reflected (Ching et al., 2014). In winter, this means that more indoor heat is kept indoors, and in summer more outdoor heat is kept outdoors. Hence, glass category has been improved from single low-E to double Low-E for reducing heat loss on case II.

Horizontal shading device is also added over south external windows. Its width is defined as 50 cm (1,64ft) because it's the maximum protrusion which is determined by Planning Areas Zonning Regulations, item 41 (9). Results of eQUEST run on traditional house energy performance and 3D-model for case II is shown on Fig. 16 and Fig. 17.

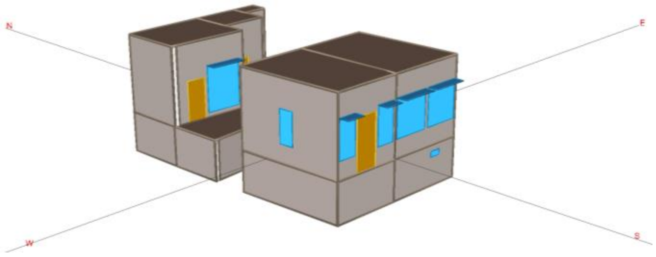


Fig. 16. *eQUEST energy model of Traditional Adana house for case II*

	Consumption		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Case 2	Electric (kWh)	Hot Water	467,7	439,7	494	461,5	440,9	395,5	369,8	358,5	339,9	373,2	388,8	437,7	4967,2
		Vent Fan	57	39,7	22,9	8,2	3,1	0,1	0	0	0,3	1,9	27,8	53,7	214,7
		Misc. Equip	91,9	83	91,9	88,9	91,9	88,9	91,9	91,8	89	91,9	89	92	1082,1
		Area Lights	276,1	249,3	274,4	265,9	274,4	266,2	276	272,9	269,3	274,4	267,9	277,8	3244,6
		Total (kWh)	892,7	811,7	883,2	824,5	810,3	750,7	737,7	723,2	698,5	741,4	773,5	861,2	9508,6
	Gas (kWh)	Space Heating (Btux000,000)	14,09	9,96	5,94	2,25	0,86	0,04	0	0	0,08	0,54	7,14	13,3	54,2
		Total (kWh)	4129,4	2919,0	1740,8	659,4	252,0	11,7	0,0	0,0	23,4	158,3	2092,5	3897,8	15884,5

Fig. 17. *Monthly energy consumptions by enduse for case II*

D. Case III

With the improvement of second case, typical roof type has been changed to green roof because original roof basically has no insulation layers. The reason for selecting green roof type is also that it is considered as a solution to many urban issues including; urban heat island mitigation, noise, air pollution reduction, storm-water management, support of biodiversity and is often addressed as the best building choice to increase the environmental sustainability in an urban settings (Gargari et al., 2016).

The green roofs differ because of the depth and type of medium soil, that distinguish from an extensive type and an intensive type (Bianchini et al., 2011). Compared to intensive green roof type, extensive green roof has been selected to perform on evaluation of building energy consumption because it is lighter and requires lower maintenance needs with efficient storm water management. Structural roof layers of traditional house and proposed green roof layers can be seen on table 7. 3D-model for third case and results of monthly energy consumptions by enduse are shown on Fig. 18 and Fig. 19.

TABLE 7. Layers of structural roof elements – Cases I and III

Structural elements	Material	Thickness d, (m)	Thermal conductivity λ, (W/mK)	Thermal Resistance R, (m2K/W)	U-value (W/m2)	U-value (Btu/h-ft2F)
Terrace roof	clay soil	0,10	0,47	0,21	0,66	0,12
	wood beam	0,14	0,13	1,08		
	wood cover	0,03	0,13	0,23		
Green roof	earth	0,15	otomatically calculated in Revit programma	11,97	0,10	0,014
	polymen bitumen	0,00				
	stone	0,13				
	drainage layer	0,02				
	root barrier	0,00				
	rockwool insulation	0,35				
	vapour retarder	0,00				
	cross laminated timber/CLT)	0,15				

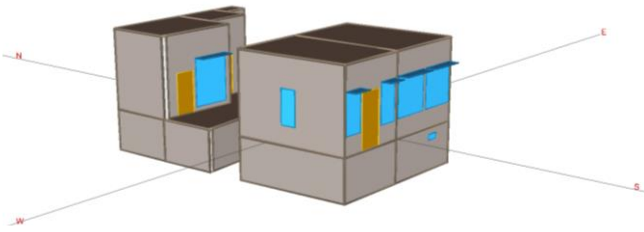
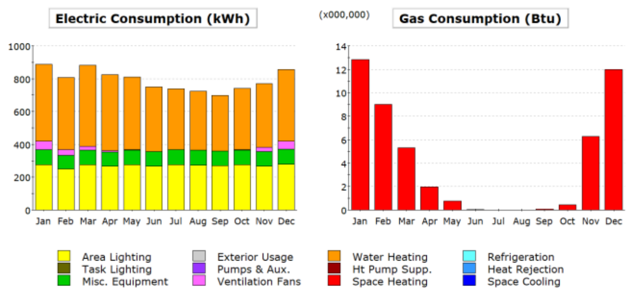


Fig. 18. *eQUEST energy model of Traditional Adana house for case III*



	Consumption		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Case 3	Electric (kWh)	Hot Water	467,7	439,8	494,1	461,6	441	395,6	369,9	358,6	339,9	373,2	388,8	437,7	4967,9
		Vent Fan	51,9	35,9	20,5	7,2	2,6	0,1	0	0	0,2	1,5	24,4	48,3	192,6
		Misc. Equip	91,9	83	91,9	88,9	91,9	88,9	91,9	91,8	89	91,9	89	92	1082,1
		Area Lights	276,2	249,4	274,5	266	274,5	266,3	276	273	269,4	274,5	268	277,9	3245,7
		Total (kWh)	887,7	808,1	881	823,7	810	750,9	737,8	723,4	698,5	741,1	770,2	855,9	9488,3
	Gas (kWh)	Space Heating (Btux000,000)	12,83	9,01	5,31	1,98	0,75	0,04	0	0	0,06	0,43	6,27	11,98	48,66
		Total (kWh)	3760,1	2640,6	1556,2	580,3	219,8	11,7	0,0	0,0	17,6	126,0	1837,6	3511,0	14260,8

Fig. 19. *Monthly energy consumptions by enduse for case III*

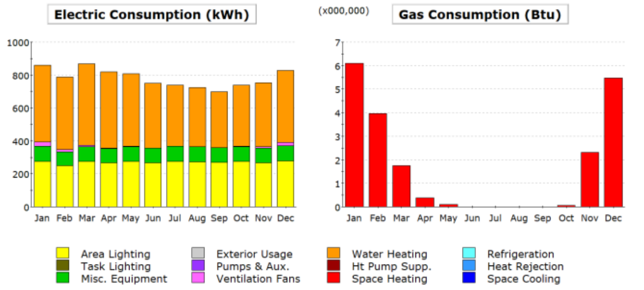
E. Energy Performance Analysis Of Traditional Adana House Based On TS 825 Standard

TS825 is Turkish standard which setting rules thermal insulation requirements for buildings. Turkey is divided to five heating centigrade and day zones based on iı. For cities on every region have been determined U-values which is advised as the maximum accepted value. Adana is placed in the first climatic zone (Table 8). With Case I based on TS 825 recommended u-values simulated energy performance on E-quest. Fig. 20 shows E-quest results of energy performance traditional Adana house as known Base Case with inputs of TS 825 u-values.

TABLE 8. Recommended u-values to be accepted as maximum value according to regions (TS 825, December 2013)

(Ud: Thermal conductivity of wall, UT: Thermal conductivity of ceiling, Ut: Thermal conductivity of floor which is connected with earth, Up: Thermal conductivity of windows)

Region of Turkey	Ud (W/m2K)	UT (W/m2K)	Ut (W/m2K)	Up (W/m2K)
1. Region	0,66	0,43	0,66	1,80
2. Region	0,57	0,38	0,57	1,80
3. Region	0,48	0,28	0,43	1,80
4. Region	0,38	0,23	0,38	1,80
5. Region	0,36	0,21	0,36	1,80



		Consumption	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Case TS 825	Electric (kWh)	Hot Water	466,6	439,3	494	461,8	441,4	396	370,3	358,8	339,7	372,6	387,8	436,5	4964,8
		Vent Fan	24,4	15,6	6,6	1,4	0,3	0	0	0	0	0,2	8,9	21,9	79,3
		Misc Equip	91,9	83	91,9	88,9	91,9	88,9	91,9	91,8	89	91,9	89	92	1082,1
		Area Lights	276,2	249,4	274,5	266	274,5	266,3	276	273	269,4	274,5	268	277,9	3245,7
		Total (kWh)	859,1	787,3	867	818,1	808,1	751,2	738,2	723,6	698,1	739,2	753,7	828,3	9371,9
	Gas (kWh)	Space Heating (Btux000,000)	6,09	3,96	1,75	0,39	0,1	0	0	0	0,01	0,07	2,31	5,47	20,15
		Total (kWh)	1784,8	1160,6	512,9	114,3	29,3	0,0	0,0	0,0	2,9	20,5	677,0	1603,1	5905,4

Fig. 20. *Monthly energy consumptions by enduse based on TS 825 standards*

III. COMPARISON OF RESEARCH RESULTS

TABLE 9. Energy usage of compared cases – results summary (excluded domestic hot water usage from electric consumption)

Cases	Electric (kWh)				Gas (kWh)	Total (kWh)	% Saving		
	Vent Fan	Misc Equip	Area Lights	Sum(kWh)	Space Heating		Electric	Gas	Total
Baseline	427	939	3465	4831	31394	36225	0	0	0
Case 1	232	1082	3246	4560	17115	21675	-6	-45	-40
Case 2	215	1082	3245	4541	15884	20426	-6	-49	-44
Case 3	193	1082	3246	4520	14261	18781	-6	-55	-48
Case TS 825	79	1082	3246	4407	5905	10312	-9	-81	-72

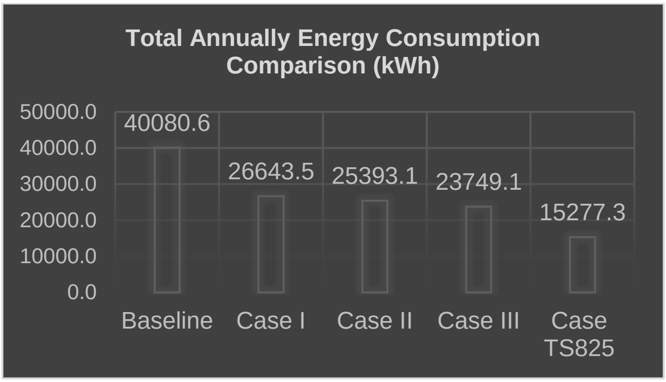


Fig. 21. *Total annually energy consumptions comparison (kWh)*

Compared to the traditional house performance, the result of case I supports their findings regarding the ventilation effect of the courtyard and heat loss from the surface area. The outcome compared to baseline is 45% more energy needs for space heating and 6% more electricity usage in baseline (Table 9). This shows that İf the courtyard is exposed to solar radiation, less heating is needed during winter, so openings such as windows, doors are the primary source of cross ventilation inside the house. Decreasing the exterior surface area of the building and its thermal resistance (R-value) as shown on table 4 and 5 also causes heat loss in baseline, but in fact, heating loads is expected to be less with decreasing surface area from 173 m2 to 155 m2. Reason of demanding more energy for space heating is that decreasing of the wall's thermal resistance(R-value) makes more sense in energy consumption than surface area. When u-value of the wall gets high number in a modern Adana house, totally the 40% more energy building uses for heating-cooling per unit of floor area (Table 9).

Results of the total energy consumptions of traditional Adana house show that case II has generated 6% energy saving when compared with base case. Additionally, passive solar design has created this process without need of any mechanical equipment supports. Heating loads of case I have been reduced 4% by adding shading elements and designing window to wall ratio in an efficient way (Table 9). Total energy consumption has decreased by the structural use of layers manufactured out of current system in 1249 kWh, 2894 kWh for case II and case III respectively. Energy has remarkably conserved if translation from traditional terrace roof to green roof with using passive solar design is considered.

When result of second and third cases compared with TS 825 standard recommended energy consumption, traditional house is considered as inefficient (Fig 21). Reference building has consumed 11366,2 kWh energy more according to intended energy depletion. However, 8471,8 kwh energy has occurred by application of case III while case II has made 10115,8 kWh difference (Table 9). The reason for unreachable energy saving is that building envelope of reference building made in the 1920s hasn't insulation materials. During that time, importance of energy efficient building design wasn't noteworthy. On the other hand, regulation on this concern became essential later. Consequently, Requirement based on TS 825 standards has performed 72% energy saving for traditional Adana house (Table 9).

To sum up, annually total energy consumptions comparison of scenarios has represented on Fig. 21. Compared to today's house with traditional one that has the same heating and cooling area, energy consumption of the latter is totally 48 % less with case III. However, it couldn't reach recommended energy saving based on TS 825 standards.

IV. CONCLUSION

The reference dwellings has been chosen to analyze the effect of openings and roof type on traditional house energy performance in Adana, hot-humid climate. The reason of choosing traditional dwelling is courtyard plan (inner garden), type, orientation with the consideration of climate and also flexible use of spaces related to user's requirement in the traditional settlement. Usage of renewable material (wood, brick etc.) and sun shading elements (wooden shutter) are significant data to provide thermal comfort inside. Although there are many aspects of energy efficient usages in selected traditional house, the effect of openings and roof type on energy consumption is a subject that should be considered for thermal comfort. This research results show that;

- Energy consumption of a modern Adana house is totally 40% more than traditional Adana house's energy usage. Because of solar radiation inside the courtyard, space heating loads become less in winter and creates cross ventilation inside the house in summer. Decreasing of thermal resistance (R-value) of the walls also strongly impacts the heating-cooling requirements. In order to reduce heat loss, thermal resistance of material receives more attention than the exterior surface of the building.
- eQUEST simulation results show that all experienced cases are inefficient when compered with TS 825 standards because they don't have sun protection device and insulation layers over structural elements.
- Window to wall ratio has become 40% that gives an improving results on energy saving. 6% difference with baseline energy consumption on heating loads only is seen by passive solar design.
- Green roof leads to a 6%, 55% saving in annual electric and gas use respectively and 48% on the total building energy consumed. It assumed that in temperature hot-humid climate, green roof makes an significant contribution to energy saving.
- It should be pointed that TS 825 standard requirements aren't reachable for experienced cases. Further research could study by improving of structural elements u-values.

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