ITU A|Z • Vol 14 No 2 • July 2017 • 119-130

An advanced envelope retrofit option to increase solar gain and ventilation through façade for reducing energy demand of residence buildings

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Received: May 2017 • Final Acceptance: July 2017

Abstract

Researches on reducing building originated yearly energy demand are among the top issues in every country. Nowadays, lots of scientific researches were performed in Mediterranean countries like in others in order to designate different methods to improve the energy performance of the buildings. Turkey is one of the representative countries of Mediterranean climate. Additionally, Turkey follows the developments in EU and EPBD 2010/31/EU became the lead document to direct Turkish building energy policy. National research projects are being done to adopt the methodology in EPBD 2010/31/EU to national conditions. As a finding of the national research project, unlike the standard residential building types, conventional façade retrofit measures doesn't have a considerable effect on energy performance improvement of luxury residential building type. Therefore, an advanced façade retrofit method, which increases solar gain and ventilation rate through the façade depending on the requirement of the season, was suggested for these kinds of buildings in this study and the approach was summarized through the sample case calculations. The approach in this paper offers a different perspective on building envelope retrofits while reaching EU's 2020 target especially to increase renewable energy portion in building construction. Therefore, a new exterior wall component detail was suggested and theoretical investigations were done on an example building to reveal if the façade detail serves for the purpose. Consequently, it was shown that the suggested wall component has big potential to reduce yearly energy demand of luxury residential buildings in comparison to the traditional retrofit actions.

Keywords
Luxury residential buildings, Energy saving, Advanced façade retrofit.

doi: 10.5505/itujfa.2017.16680

1. Introduction

Energy performance improvement studies are one of the crucial subjects in European Union (EU) for its 2020 Strategy of saving 20% of its primary energy consumption and emissions of greenhouse gases and other pollutants. Building sector takes the lead by consuming around 40% of EU's final energy consumption [COM,2011]. For this purpose EPBD 2010/31/EU was published as the amended version of EPBD 2002/91/EC. EPBD 2010/31/EU is a guideline for achieving energy efficiency measures for 2020 target of EU. The methodology in the Directive should require defining reference buildings, defining energy efficiency measures of reference buildings, assess the final and primary energy need of the reference buildings, and calculate the costs of the energy efficiency measures for designating cost-optimal level [EU, 2010]. In order to adapt this methodology, a national project was generated and concluded in Turkey for defining the reference residential buildings, their final and primary energy consumptions and cost efficiency analyses (Project for The Scientific and Technological Research Council of Turkey). In the project Istanbul was selected as the pilot city and four residential building types were designated. Standard and advanced retrofit measures were tested on these buildings [Yılmaz et al, 2015]. For renewable energy, as an additional crucial subject in the Directive the European Council of March 2007 reaffirmed the Union's commitment to the Union-wide development of energy from renewable sources by endorsing a mandatory target of a 20% share of energy from renewable sources by 2020. Directive 2009/28/EC establishes a common framework for the promotion of energy from renewable sources [EU, 2010; EU, 2009]. Thus, studies for 2020 target should consider renewable energy use.

Similar to the developments in EU, the Ministry of Energy and Natural Resources of Turkish Republic published Energy Efficiency National Action Plan in consideration of EU's 2020 target and related directives. Targets of the action plan basically includes the implementation of former related laws and regulations of Turkish Republic, decreasing the energy density 20% until 2023, and decreasing primary energy supply 20% and achieving these goals through EU's legislative framework [Republic of Turkey Ministry of Energy and Natural Resources, 2016]. Specifically for the building sector, Energy Efficiency Strategy Paper 2012-2023 was prepared. According to the paper at least 25% of the building stock in 2010 will be sustainable buildings until 2023, the number of eco-friendly buildings that benefit from renewable energy sources will increase to decrease energy needs and carbon emissions of the buildings, and the use of renewable energy sources will be promoted [Republic of Turkey Ministry of Energy and Natural Resources, 2016].

This paper focuses on developing an advanced façade retrofit in accordance with the results of national project. In residential building typology definitions, there is luxury residential building, which is called as "residence" in Turkey which varies from other countries. In accordance with the rapid rise of the land prices in city center this building typology was developed. Residence buildings are usually high-rise buildings and hosts residential and social areas all together in the same building. Their energy demand level is higher than the other standard residential building types due to their high-level characteristic features. Thermo-physical properties of the building façade of residence residential buildings are very convenient to energy efficient levels and more efficient than the requirements in national heat insulation standard (TS 825) [TSE, 1999]. Therefore, standard retrofit measures that are very effective for other residential building typologies are not efficient enough for residence buildings and advanced retrofit measures are required for this building typology. So, in order to reach 2020 target of EU and 2023 target of Turkey, advanced façade retrofits that benefit from renewable energy will be convenient to propose for "residence" buildings.

There are various research studies on developing advanced façade technologies to improve the energy efficiency and for reaching EU's 2020 target. Fong

Table 1. *Comparison between the façades of case study building and suggested advanced component applied façade.*

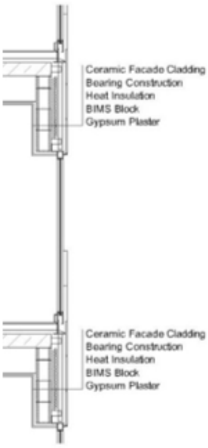
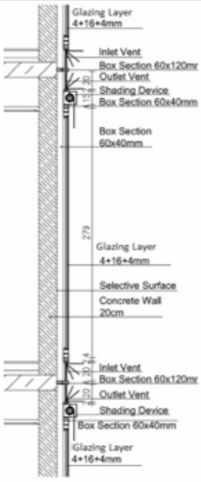
<table>
<tr><th>Case Study Building</th><th>Suggested Advanced Façade Component</th></tr>
<tr><td>
</td><td>
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Table 2. *Thermo-physical and optical properties of the glazing of the suggested advanced façade component.*

	U Value (W/m²K)	SHGC (%)	T_{vis} (%)
Glazing	1.1	60	78
Frame	1.8	-	-

et al. presented using building integrated solar collectors and PV panels on an office building for solar cooling with Hong Kong climate [Fong et al, 2012]. Sun et al. presented the effects of shading type building integrated photovoltaic claddings on energy saving and the effect of surface azimuth angles on this systems efficiency [Sun et al, 2012]. Li et al. explored building integrated wind turbines on a high-rise building for power generation [Li et al, 2016]. Favoino et al. investigated adaptive transparent building façades on an office building case to achieve nZEB objectives [Favoino et al, 2015]. Connelly et al. presented building integrated concentrating PV, smart window system consisting of a thermo-tropic layer with integrated PVs was treated as an electricity-generating smart window or glazed façade as a new concept. The system automatically responded to climatic conditions by varying the balance of solar energy reflected to the PV for electricity generation and transmitted through the system into the building for provision of light and heat [Connelly et al, 2016].

This paper presents a theoretical approach to design an advanced façade component that provides more benefit from solar radiation by increasing solar gain by a component application that contains selective surface layer increasing ventilation rate through vents on the component to cool down the façade in accordance with the climatic conditions. Therefore, the aim of the paper is reaching EU's 2020 and Turkish Republic's 2023 renewable energy targets through an alternative suggestion. So as to analyze the suggested advanced façade component a theoretical case study building was generated in accordance with the information data in the name of building envelope and boundary conditions that was designated in Turkish national project [Yılmaz et al, 2015]. Cost calculations were done under Turkish national market conditions.

2. Materials and methods

The first step of the research is introducing the suggested advanced façade component since it is the main focus of this research and then explanation of the simulation components that were used investigate the suggested component. After that, presenting the case study building; defining the façade retrofit scenarios; designating yearly heating, cooling and lighting energy demands of the case study building; applying standard façade retrofits to the case study building; applying the advanced façade retrofits with the suggested new façade component to the case study building; defining primary energy demands of the case study building and scenarios; generating global cost – primary energy demand comparison graphs; analyzing the results.

The building model with all geometric features and thermo-physical properties of the envelope was generated by DesignBuilder interface of simulation tool called EnergyPlus, other data input and simulations was done by EnergyPlus building simulation tool. Both software are under the license of

US Department of Energy (DOE) and scientifically proven by lots of research studies several times.

2.1. The constructional details of the suggested component

In order to explain the suggested façade component it is important to investigate the façade sections of the base case and the base case with the suggested component applied on. Architectural vertical section of base scenario façade and suggested advanced component are shown in Table 1. The parts of the suggested façade component are a selective surface applied aluminum layer on BIMS block (20 cm or 40 cm depends on the scenario), then 10 cm air gap and a glazing layer in front of the gap. There are air inlet and outlet vents on the glazing for each floor and there is shading device in front of the glazing layer according to the climatic conditions.

Thermal and optical properties of the glazing of suggested advanced façade component is shown in Table 2. These data were provided by a well-known national glazing brand [Şişecam, 2015]. The glazing was chosen by considering solar heat gain amount and maximum benefit from solar radiation on selective surface.

Within the scope of the analyses, exterior shading devices were on from 1st of April until 1st of November, between the hours of 06.00 and 20.00 and except this period the devices were off Working schedule of air inlet and outlet vents were defined as open from 1st of May until 1st of October and except this period the vents were off in order to benefit from solar radiation. These operation schedules were determined as a result of background simulation analyses in order to designate the most effective periods of shading devices and air inlet-outlet vents.

Exterior shading device helps alone during transition seasons, while according to the conducted simulation tests; faster air circulation is an obligation during summer period vents need to be operated. Shading devices behave as obstacles for solar radiation to enter inside to the wall cavity (air gap) and heat the air inside of the gap. They are off between the hours of 20.00 and 06.00, as during these hours site outdoor air temperature is lower than air gap temperature. Therefore, exterior shading devices help on transition and cooling periods. During summer period, shading devices alone are not enough because of the high solar radiation intensity. When air inlet and outlet vents are open during that period, air circulation occurs and cools the air inside of the gap together with the wall surface that has selective surface layer on it. After a while, air gap temperature becomes lower than zone mean air temperature, therefore zones start to cool down by losing heat to the air gap. At the same time, walls are continuously cooled down by air circulation.

As a result of all simulation tests, suggested façade component not only provides reduction on yearly heating energy demand, but also provides reduction on yearly cooling energy demand.

The comparison of the base scenario façade and partial application of suggested façade component in architectural elevation drawings is shown in Table 3.

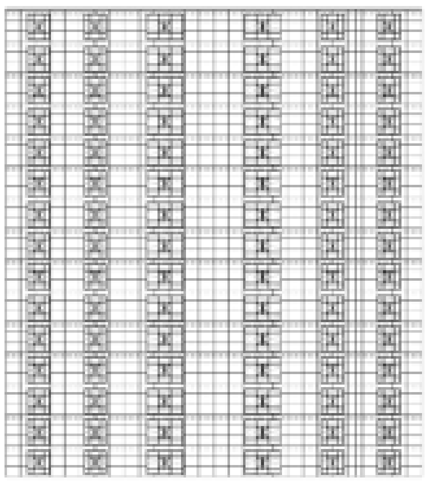
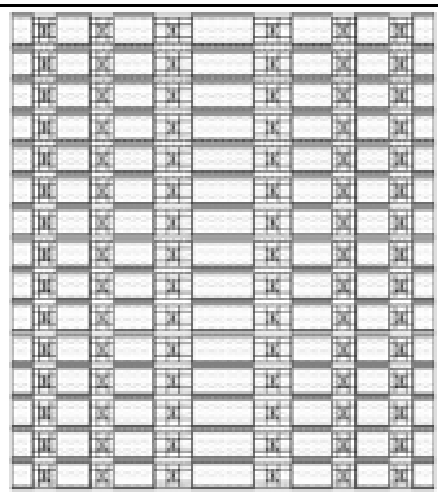
2.2. Applied simulation model components

The suggested advanced façade component was modelled by internationally well-known and scientifically proven building simulation tools that are developed by US Department of Energy.

Material layers of the proposed façade component were defined similar to defining other material layers in EnergyPlus. For inside surface convection TARP algorithm and for outside surface convection DOE-2 algorithm were selected. Conduction transfer function algorithm was selected as heat balance algorithm. In the simulation calculations full interior and exterior solar distribution was considered [US Department of Energy, 2015].

Shading devices were modeled in "window material", "shade" object which is common for window shading device definition. Reflectance and emissivity properties are assumed to be the same on both sides of the shade. Shades are considered to be perfect diffusers (all transmitted and reflected

Table 3. *Comparison between the elevations of case study building and suggested advanced component applied façade.*

Case Study Building Facade	Façade with Suggested Advanced Façade Component
	

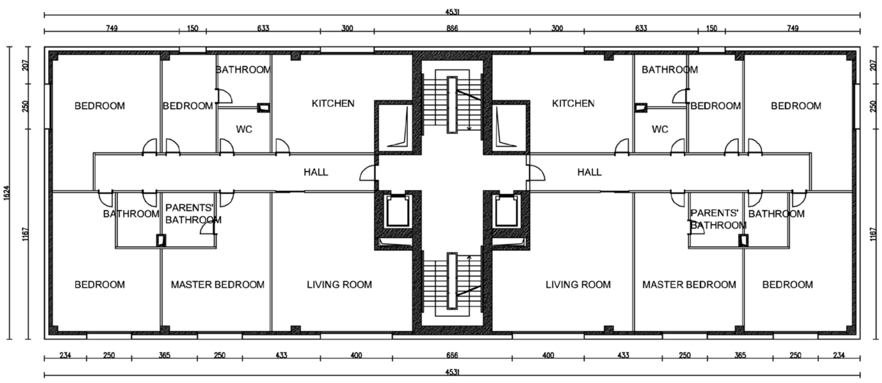


Figure 1. *Architectural plan of case study building.*

radiation is hemispherically-diffuse) with transmittance and reflectance independent of angle of incidence [US Department of Energy, 2015]. Thermo-physical and optical properties of shading device was provided from an internationally known window treatment firm's extension tool [Hunter Douglas, Software version: 1.0.0.129].

Air circulation between bottom and top vents was modeled by "wind and stack open area" object in the simulation tool. For this object, the ventilation air flow rate is a function of wind speed and thermal stack effect, along with the area of the opening being modeled. The total ventilation rate calculated by this model is the quadrature sum of the wind and stack air flow components [US Department of Energy, 2014].

2.3. Case study building

A theoretical residence building was generated to perform the analyses. In order to focus the effects of suggested advanced façade component the building was designed in convenient to the passive solar design parameters, therefore the effects of passive solar parameters on results were kept out.

The case study building locates in Istanbul, Turkey. Istanbul is in the warm-humid climatic region of Turkey located in Mediterranean Climate. The weather data for simulations was obtained from weather data source of EnergyPlus [EnergyPlus, 2012].

The building form and envelope thermo-physical properties were determined as they will represent the characteristics of these kinds of buildings. According to the investigations the building form and apartment unit types are not limited; therefore the building form was generated by a general perspective.

According to Turkish Statistical Institute (TUIK) the average household member rate in Turkey is 3.7 so, most common family consists of parents and 2 children. Therefore, the apartment unit layouts were generated convenient for parents and 2 children family together with a housekeeper room since the occupant profile of residence buildings is high income group.

There are fifteen residential floors and two apartment unit in each floor. Architectural floor plan of the case study building is shown in Figure 1. Floor area of the building is 618.32 m².

Façade components were defined in accordance with the residence reference building investigations in national project and thermal transmittance (U-value) of the façade components were designated in respect to the component selection. The most common opaque façade components for these kinds of buildings are ceramic or aluminum curtain walls. Additionally, thermo-physical properties of the building envelope should be convenient to the minimum values that are defined in Turkish Heat Insulation Standard (TS 825). The building was assumed to be constructed in between 2000-2006 period and at this time TS 825 1999 was in force [TSE, 1999]. In Table 4, the comparison between the required minimum U-values in the standard and values of the case study building façade was shown.

Boundary conditions data were defined in accordance with the residence reference building investigations in Turkish national project [Yılmaz et al, 2015]. As explained above, four-person families were considered for the calculations. The operational scenario was defined according to the published research by Ministry of Family and Social Policies in 2011 and 2013 [Republic of Turkey Ministry of Family and Social Policies, 2011-2013]. Activity levels of the occupants were specified in accordance with ASHRAE 55 – Thermal Environmental Conditions for Human Occupancy standard [ANSI/ASHRAE, 2013]. Operation schedule of occupancy is shown in Table 5.

Average power values of household electrical equipment were designated by investigating the existing household electrical equipment in the market [Arçelik, 2015; Vestel, 2015; Bosch, 2015]. Determined equipment powers and operating times per each apartment unit were defined in Table 6.

Table 4. *Thermal transmittance coefficient (U-value) comparison of TS825 1999 and case study building.*

	Case Study Building U-Value (W/m²·K)	TS825 1999 U-Value [6] (W/m²·K)
External Wall	0.296	0.6
Window	1.65	2.8

Table 5. *Operational schedule of occupancy.*

	Hours	Number of People	Acitivity	Space
Weekdays	00:00 - 07:00	5	Sleeping	Bedrooms
	07:00 – 08:00	2	Meal Preparation	Kitchen
	08:00 -17:00	1 (housekeeper)	Home works	Whole Spaces
	17:00 – 18:00	2	1 person: Meal Preparation 1 person: Reclining	Whole Spaces
	18:00 -24:00	5	Dining, Watching TV, Doing homeworks, Surfing on Internet	Whole Spaces
Saturday	00:00 – 08:00	5	Sleeping	Bedrooms
	08:00 – 12:00	3/2	Sleeping/Homeworks	Bedrooms/Other Spaces
	12:00 – 18:00	3	Homeworks, Reclinig, Sitting	Whole Spaces/Living Room, Bedroom
	18:00 – 20:00	4	Meal Preparation, Dinner, Reclining	Kitchen, Living Room
	20:00 – 23:00	2	Watching TV, Surfing on Internet, etc	Living Room, Bedroom
	23:00 – 24:00	5	Sleeping	Bedrooms
Sunday	00:00 – 12:00	5	Sleeping	Bedrooms
	12:00 – 15:00	2	Meal Preparation, Breakfast, Homeworks	Kitchen, Whole Spaces
	15:00 – 24:00	5	Dinner, Watching TV, etc	Whole Spaces

Table 6. Power values and operational schedules of household electrical appliances.

Household Electrical Equipment	Power (W)	Operating Time
Refrigerator	54.3	All day (24 h)
Oven	3100	6 hours / week
Electrical Stove	7200	Weekdays: 2 hours / day Saturday: 2 hours / day Sunday: 1.5 hours / day
Range Hood	290	Weekdays: 2 hours / day Saturday: 2 hours / day Sunday: 1.5 hours / day
Dishwasher	1399	4 hours / week
Washing Machine	718.2	4 hours / week
Tea Maker	1650	Weekdays: 2 hours / day Weekends: 2 hours / day
Iron	2600	6 hours / week
Vacuum Cleaner	1450	4.5 hours / week
TV	128	Weekdays: 3 hours / day Weekends: 5 hours / day
Laptop	88	Weekdays: 3 hours / day Weekends: 5 hours / day

According to the residence residential building investigations there is not any specific lighting system limitation. Therefore, a lighting and electricity project of an existing residence building was taken into account as example and similar lighting power density was applied to the case study building. Lighting power density of each apartment unit was calculated as 6.9 W/m^2 according to the projects.

Heating and cooling thermostat setpoint values were determined in accordance with the investigations and information gathered from multiple "residence" buildings. Thus, thermostat value for heating period was designated as 22 °C and for cooling period 24 °C. In this research study, HVAC system was modeled as Ideal Loads System. This component can be thought of as an ideal unit that mixes air at the zone exhaust condition with the specified amount of outdoor air and then adds or removes heat and moisture at 100% efficiency in order to produce a supply air stream at the specified conditions [US Department of Energy, 2014]. This method provides a model for an ideal HVAC system without any loss and will allow seeing the effect of suggested advanced façade component on building energy performance without any intervention by HVAC systems.

2.4. Façade retrofit scenarios

Retrofit scenarios that were investigated in this research are shown in Table 7. The "S" mark indicates the scenarios and the number next to the mark shows the number of the scenario. S0 represents the base scenario. Scenarios from S1 to S4 are standard façade improvement scenarios that are very effective on standard residential buildings. S1 indicates adding heat insulation layer to the existing building façade. S2, S3 and S4 show various glazing type applications instead of the existing glazing for the whole building façade. Cases from S5 to S10 are advanced façade improvement scenarios with suggested façade component That has selective surface and air vent applications to increase solar gain and façade surface ventilation through the air gap.

The façade views of the cases are shown in Table 8. The images of all cases were generated by DesignBuilder simulation tool.

In S5 and S8, suggested advanced façade component was applied on opaque surfaces of South façade. In S6 and S9, suggested component was applied on opaque surfaces of South, East and West façades. In S7 and S10, suggested component was applied on opaque surfaces of South, East, West and North façades. In S5, S6 and S7 the component was applied on mass wall of 20 cm and in S8, S9 and S10 the component was applied on mass wall of 40 cm.

2.5. Primary energy demand and global cost

Yearly energy demand of each façade retrofit scenario was designated by EnergyPlus dynamic building energy simulation tool. In order to develop cost optimal analysis, primary energy demand of each case scenario was specified. The calculations were performed under ideal load conditions in order to focus the effect of suggested façade component. Primary energy conversion factors revealed by Turkish Ministry of Environment and Urbanization are 1 and 2.36 for natural gas and electricity respectively.

Global cost is the sum of the present value of the initial investment costs, sum of running costs, and replacement costs (referred to the starting year), as well as disposal costs if applicable. Therefore, in order to calculate the global cost in terms of net present value, separate cost categories should be defined. In this research initial investment costs, replacement costs, energy costs are considered. Net present value represents the current worth of a cash flow over time [Olson, 2003]. According to EU Regulation supplementing Directive 2010/31/EU the calculation period was fixed equal to 30 years and cost calculations consider only costs of elements which are effective on building energy performance and are different for the various cases [EU, 2012].

The inflation rate was taken as 8.05%, according to the statistics of Turkish Republic Central Bank's last 5 years' average value. Market rate of interest rate was 14.3% [TCMB, 2015]. In order to calculate energy costs, natural gas unit price was taken 0.18800 TL/kWh, electricity unit price was taken 0.36637 TL/kWh considering 2015 values [İGDAŞ, 2015; TEDAŞ 2015]. The increase in energy costs was assumed as equal to the inflation rate.

Lifespan of the building elements were collected from national data. The cost of the building façade was calculated for each retrofit scenario. In order to calculate initial investment costs of each building element that are effective on energy performance improvement, costs were gathered from the market in Turkey.

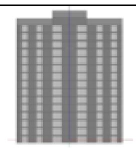
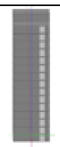
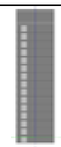
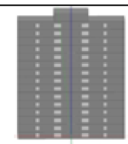
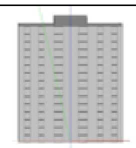
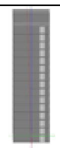
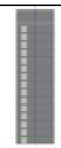
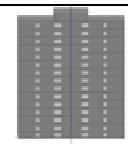
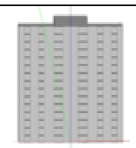
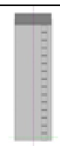
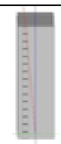
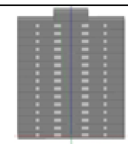
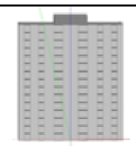
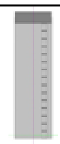
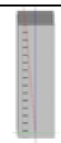
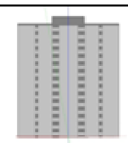
3. Results

This part reveals heating, cooling and lighting primary energy demand results of each façade retrofit scenario. Calculated result of each scenario was compared to the base scenario. Yearly primary energy demand results of the retrofit scenarios are shown in Figure 2.

Table 7. *Description of the retrofit scenarios.*

SCENARIO	DESCRIPTION
S0	Base case
S1	2 cm extra heat insulation to the exterior walls
S2	Glazing replacement; U:1.4W/m²·K SHGC:0.34 Tvis:0.49 (S0 U:1.56W/m².K SHGC:0.45 Tvis:0.51)
S3	Glazing replacement; U:1.3W/m²K SHGC:0.54 Tvis:0.77 (S0 U:1.56W/m².K SHGC:0.45 Tvis:0.51)
S4	Glazing Replacement; U:0.9W/m²K SHGC:0.37 Tvis:0.61 (S0 U:1.56W/m².K SHGC:0.45 Tvis:0.51)
S5	Suggested façade component application on South façade of 20cm mass wall
S6	Suggested façade component application on South, East and West façades of 20cm mass wall
S7	Suggested façade component application on South, East, West and North façades of 20cm mass wall
S8	Suggested façade component application on South façade of 40cm mass wall
S9	Suggested façade component application on South, East and West façades of 40cm mass wall
S10	Suggested façade component application on South, East, West and North façades of 40cm mass wall

Table 8. *Façade elevations of advanced façade retrofit scenarios.*

	South Facade	East Facade	West Facade	North Facade
S0				
S5/S8				
S6/S9				
S7/S10				

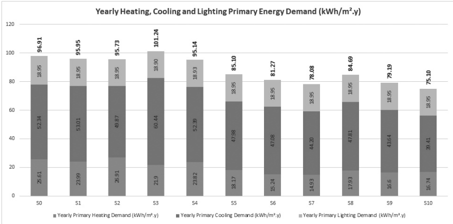


Figure 2. *Yearly heating, cooling and lighting primary energy demands of scenarios.*

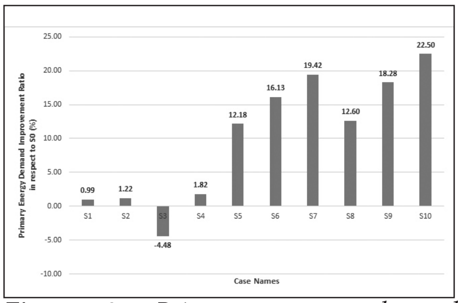


Figure 3. *Primary energy demand improvement ratios of the scenarios in comparison to the base scenario.*

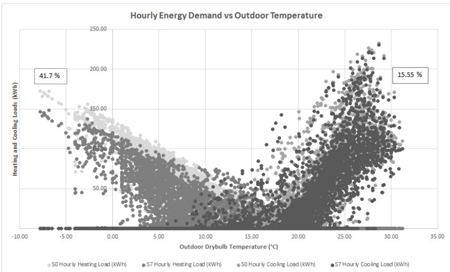


Figure 4. *Hourly heating and cooling energy demands of S7 through the year.*

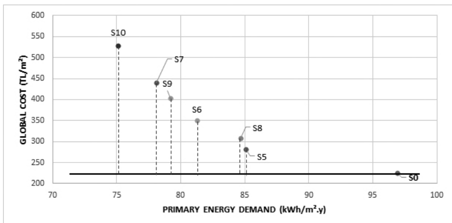


Figure 5. *Global cost - primary energy demand comparison.*

In respect to the results, primary energy demand of S0 is 96.91 kWh/m².y. According to the results the effects of standard façade retrofits on energy saving is very few, moreover as in S3 yearly primary energy demand of the building was increased to 101.24 kWh/m².y with the recommended glazing application in this scenario. Whereas; as expected, all advanced façade retrofits are very effective on the primary energy demand results. In compliance with the results, advanced façade retrofits with suggested component application on 40 cm mass wall (S8, S9, S10) were resulted with lower primary energy demand than the retrofits with suggested component application on 20 cm mass wall.

Primary energy performance improvement ratio in comparison to the base scenario is shown in Figure 3.

According to Figure 3, primary energy performance improvement ratios of standard façade retrofits are so low that cannot be considered as energy performance improvement scenarios. The primary energy improvement ratios of S1, S2 and S4 in comparison to the base scenario are around 1-2% while in S3 the ratio is around 4% on the negative side. The reason of that results is opaque and transparent components of case study building façade have better thermal transmittance coefficients than TS825 1999 is required. Thus, increasing the façade heat insulation thickness as in S1 could only decrease the primary energy demand from 96.91 kWh/m².y to 95.95 kWh/m².y and in the scenarios with glazing type change the results are very similar to S1. So, on the contrary of the general aspect in the building sector, standard façade retrofits as adding heat insulation layers or using glazing with lower U-value are not effective every time as shown in this case study. Therefore, it is very important to decide the convenient retrofit applications according to the conditions. Primary energy performance improvement ratios of advanced façade retrofits are very high in comparison to the standard retrofits.

In Figure 4, hourly heating and cooling energy loads of S0 and S7 were compared.

According to Figure 4, in the graph, the light grey dots on the left side represent hourly heating load of S0 through the year and the dark grey dots on the left side represent the same parameter for S7. Also, the light grey dots on the right side in the graph represent hourly cooling load of S0 through the year and the dark grey dots on the right side represent the same parameter for S7. Dots representing heating and cooling loads of S7 are below the dots representing heating and cooling loads of S0 in every hour through the year. Therefore, with hourly sensitive analysis heating and cooling loads of S7 are less than S0 in each hour. The reduction in yearly heating demand of S7 in comparison to S0 is 41.7% and the reduction in cooling demand is 15.55%. In respect to this graphical result, suggested component is very effective to reduce the heating and cooling energy demands.

Global cost – primary energy demand comparison graph is shown in Figure 5. Since, standard façade retrofits are not convenient to be evaluated as applicable scenarios, the research was continued with advanced façade retrofits from this part.

According to Figure 5 none of the retrofit scenarios are cost optimum. In the scope of cost-optimal level, advanced retrofit actions would increase the initial investment cost as expected. However, the income of the occupants is comparatively higher than the standard building occupants. Considering higher income level of building owners and higher energy demand of the building, advanced façade retrofits are applicable since they are reducing the yearly energy demand with an important ratio. Additionally, global cost of S5 and S8 are not so higher than S0 and both scenarios reduce the primary energy demand with an important ratio around 12%.

4. Discussion

The aim of this research is to suggest an alternative façade component in order to decrease the primary energy demand of "residence" named residential buildings and increase the renewable energy portion within this building type for approaching EU's 2020 and Turkey's 2023 target. Suggested advanced façade component targets to increase the solar energy gain portion during heating period and increase the façade ventilation portion during the cooling period. Building integrated renewable energy systems in the market are usually separate systems than the building, this study tries to show developing the building integrated renewable energy systems as construction components.

According to the results standard façade retrofits are not effective on building energy performance of "residence" residential buildings. The reason of this result is residence residential buildings are high-quality constructed buildings in the scope of façade characteristics. Therefore, advanced façade retrofits are necessary for this building type even if they increase the global cost.

All advanced façade scenarios resulted with high improvement ratios the best resulted scenarios are S7 and S10. Primary energy performance improvement ratio of S7 is 19.42% while the improvement ratio of S10 is 22.5%. Suggested advanced façade component was applied on all façade directions in these scenarios. The only difference between them is suggested component was applied on a mass wall of 20 cm in S7 and on a mass wall of 40 cm in S10. Therefore, in the scope of primary energy demand performance improvement scenarios with mass wall of 40 cm resulted better but not so different than the scenarios with mass wall of 20 cm. Additionally, mass wall of 20 cm scenarios (S5, S6, S7) increase the global cost less than mass wall of 40 cm scenarios (S8, S9, S10). Therefore, scenarios with mass wall thickness of 20 cm are more likely to be evaluated for EU's 2020 and Turkey's 2023 targets.

Moreover, this study shows that suggested advanced façade component is effective both on heating and cooling periods. This is very important for mixed-climatic conditions while reaching renewable energy targets of EU and Turkey.

5. Conclusion and further studies

This research study is based on a national project that aims to adopt the methodology in EPBD 2010/31/EU. According to the results of the project, standard façade retrofits are not effective to improve the energy performance of "residence" residential buildings since thermo-physical properties of these building façades are high-quality. Therefore, advanced façade retrofits are considered. In order to analyze the effects of advanced façade retrofits and suggesting an alternative façade component a theoretical case study building was designed. Firstly, standard façade retrofits were tested and then advanced façade retrofits with suggested façade component were tested.

As in this scope, building integrated renewable energy systems are very suitable for considering EU's 2020 target especially for the articles related with renewable energy. Existing renewable energy systems are improvable and also, the market is open for new suggestions. Architects design the façade of the buildings; at this point it is an important chance for architects to develop the building façade construction as a renewable energy system itself. This research study aims to suggest a new façade component that increases the solar gain and façade ventilation rate in accordance with the climatic conditions. According to the test results, the suggested component is very effective on reducing yearly heating and cooling energy demands of "residence" type residential buildings. Additionally, the component is not cost-optimum. However, the occupant profile of residence residential buildings is high-income group and reducing the monthly energy costs is more important than reducing the initial apartment unit costs for this group. Thus, with the application of the suggested component yearly energy demand of the case study building reduces around 12-22% in accordance with the application area on the façade (only on one direction or more). Accordingly, applying standard façade retrofits didn't result with considerable primary energy performance improvement ratios. On the contrary to the most common knowledge in the sector, decreasing the U-value of the façade opaque and transparent component is not always the solution for reducing yearly energy demands.

So, the suggested component is considerable for EU's 2020 and Turkey's 2023 targets for renewable energy use. Since Turkey is one of the representative Mediterranean climate country, the applications in Turkey could be example and applicable in other Mediterranean countries.

In order to improve this research, the component should be tested on another and more complex residence residential buildings. Location, direction, surroundings of the building could affect the results. It is important to analyze the change of these parameters too.

Acknowledgement

The baseline of this study was supported by Scientific and Technological Research Council of Turkey (TUBITAK) with a PhD researcher grant.

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