THE BENEFITS OF ENERGY REFURBISHMENT STRATEGIES ON AN ADAPTIVE REUSED INDUSTRIAL HERITAGE BUILDING

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ABSTRACT

It is possible to compensate the existing city requirements without constructing new buildings and provide a socio-economic contribution to the region by the adaptive reuse of existing structures. The adaptive reuse of non-functional structures that have historic value will not only create a cultural bridge between past and present but also prevent the energy consumption that increases due to the construction processes of new structures. The strategies implemented for these buildings have to provide functional requirements, energy efficiency, optimum climatic, visual, acoustical comfort conditions and minimum environmental effects.

In this study, the effects of energy retrofit strategies on annual energy consumption are investigated through Derince Travers Injection Plant which is an example of an industrial heritage located in Kocaeli-Turkey assumed to be adapted to a social center complex.

The physical conditions of the building are examined by site analysis conducted with infrared thermography (IRT), non destructive test method to determine suitable energy retrofit strategies. Annual energy consumption amounts by implementation of determined strategies on the adaptively reused building are analyzed and compared by the energy analysis program, Design-Builder. The comparison of the result of the total amount of annual energy consumption of the building due to suggested strategies with the limit values defined in national Turkish energy standard showed that its energy class is C which is defined as appropriate range.

INTRODUCTION

Technical developments, diversification of dimensions, process and relations of production equipment stimulated by the increase in production demand have created new spatial requirements in industrial structures. It is observed that some of them can be utilized with their original functions with appropriate interventions; some have not been able to respond to these requirements, have been re-used with new functions or have been abandoned in idle state. Another reason for the industrial structures to remain dysfunctional is the change in raw material supply areas and inefficiency caused by product competition. Generally, the existing industrial structures have failed to meet the requirements of the era. For this reason, the new structures were started to be built to respond to the increase in production, and industrial heritage structures that were abandoned by being deprived of maintenance faced the threat of demolishment. While some of these abandoned structures have been demolished, qualified conservation and adaptive reuse methods for remaining have started to be discussed at the national and international levels.

It is debated to bring the existing structure into use with original or new function after investigations on structural conditions in the context of the adaptive reuse approach as a conservation method. The method of refunctioning is mentioned by “adaptive reuse” concept in ICOMOS (International Council on Monuments and Sites), Turkey Architectural Heritage Conservation Declaration. In this declaration, it is indicated that the new function should respect the originality, integrity and identity of the structure.

Construction is one of the sectors that consume energy the most and pollute the environment dramatically. Therefore, the utilization of existing buildings without constructing a new structure makes a precious contribution to reducing energy consumption and environmental pollution. While the adaptive reused structures in Europe are being designed, active-passive systems are also integrated in the design period in order to increase energy efficiency and reduce CO_2 emissions. When these studies are reviewed, it is observed that the issue of energy efficiency in the reuse of industrial heritage structures has been handled effectively. For example, Becchio et al. (2015) conducted research on methods to reduce energy consumption and cost in adaptive reused historical buildings. He examined an industrial structure in Turin in this context. Giombini et al. (2015) addressed the city of Perugia in Italy and examined the contribution of energy retrofit interventions on existing buildings to increase energy efficiency. Ceroni et al. (2015) performed structural and energy analyzes of the Palazzo Bosco Lucarelli building in Benevento and mentioned practices to increase energy efficiency in line with these analyzes. Lopez et al. (2013) discussed the application methods of active energy systems in adaptive reused historical

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structures, not contrary to the concept of conservation. Therefore, the decisions to increase energy efficiency in the reuse process can be considered as interventions that can be applied in the building envelope, the use of renewable energy sources, and the selection of suitable mechanical and electrical systems. All these approaches provide opportunity for decreasing energy consumption amounts and unwanted environmental effects during operation stages of the adaptive reused building differently.

Interventions on old building materials or systems cause energy consumption and environmental effects during, material extraction, refinement, processing, manufacture of materials, transportation to the site. Moreover, the replaced items turn back to the recyclers, installation of replacement elements are some of the stages that account for material production for retrofit and maintenance phases that cause energy consumption in the context of recurring embodied energy and carbon (Azari and Abbasabadi 2018).

Generally, the operation stage which comprises energy consumption and environmental effects of heating, cooling, water heating, lighting, and appliances are considered in the studies but all the stages during the lifespan of the building must be considered totally through the determination of realistic energy consumption and environmental effects.

Minimum natural resource extraction, the minimum energy consumption of energy and materials must be the pioneering approach during retrofit and refurbishment processes for adaptively reused heritage buildings in the context of life cycle view of point (Foster 2020). In the retrofit stages, the materials with the lowest life cycle effects must be chosen.

In this study, the importance of material and active-passive system decisions to reduce energy consumption in adaptive reused industrial heritage structures and their contribution to annual energy consumption is investigated through Derince Travers Injection Plant, an industrial heritage located in Kocaeli-Turkey. The result of the total amount of annual energy consumption of the building due to suggested strategies is compared with the limit values defined in the national Turkish energy standard. As the limit values defined in the standard do not consider the embodied energy inputs, the boundary of the study was organized only by consideration of operation phase energy outputs without embodied energy input occurring during the life cycle of the building.

The building is assumed to be adapted to a social center complex. It is also aimed to figure out the contribution of integrations on building envelope; utilization of renewable energy sources and newly proposed mechanical, electrical systems due to new function to increase energy efficiency in the adaptive reuse of the building. The strategies derived for the building envelope are determined due to site analysis conducted by infrared thermography (IRT), diagnosing the existing deteriorations, energy losses, and gains. Annual energy consumption amounts are calculated and analysed by the energy analysis program, Designbuilder in order to observe the effects of the implementation of determined strategies on the adaptively reused building.

Total amount of annual energy consumption of the building after implementation of suggested strategies are compared with the range values of energy class index defined in national Turkish energy standard.

THE ENERGY RETROFIT STRATEGIES

The energy refurbishment process is composed of building performance assessment, measurement of energy savings, economic analysis, risk assessments (Ma et al., 2012). Diagnosis of the physical conditions of the building components, current energy use, climatic, visual, acoustical comfort levels, indoor environmental quality is the first step to determine the appropriate retrofit solutions for the historic buildings (Flourentzou et al., 2002).

The diagnosis of the building elements which is one of the most important steps of building performance assessment provides an opportunity to get information on the existing physical conditions of building elements. The deteriorations, the lack of insulation layers, thermal bridges cause not only mould, efflorescence and/or subflorescence forming, etc. problems but also unwanted heat gain and losses (Franzoni, 2014). The investigation of the problems on building envelope helps to derive the right retrofit scenarios for these building elements to increase building energy performance and comfort conditions.

The data derived from the diagnosis step provide realistic information to energy assessment of the historical building and deciding the best energy approach as it shows the current status of the structure. Annual energy performance of the case study in terms of heating and cooling without energy retrofit applications must be simulated to make the comparison (Pisello et al.2014). Energy retrofit scenarios can be implemented in terms of 3 main approaches.

- Improvement of the building envelope.
- Integration of renewable energy systems
- Increasing the efficiency of heating and cooling equipment (Cabeza et al., 2018).

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Intervention strategies on the adaptive reused building envelope

Exterior walls, windows, doors and roofs are the building elements through which most of the heat losses and gains occur. Technical details and material selections should be made by consideration of the optic and thermophysical characteristics of the materials and the sequence of the layers to prevent humidity problems and reduce the heating load in winter and cooling load in summer. In the reused historical structures, outer insulation is not preferred on the facade to preserve the historical texture.

Therefore internal insulation can be applied in buildings where the transmission coefficient of the wall material is low. However, there are disadvantages such as the formation of thermal bridges, the reduction of the interior area, additional manufacturing and cost increase. On the other hand, since the roofs are in direct contact with the external weather conditions, especially in abandoned historic structures, insulation problems may occur when maintenance and repair are not performed. This causes rotting on roofs with wooden beams, corrosion on roofs with steel girders, effloresces and molds on the walls. Strengthening studies are needed in structures where the existing construction is in bad condition. In addition, since the roofs of some neglected industrial heritage buildings are covered with materials that are considered hazardous to health today, these materials may mix with nature and damage human health. In such cases, the roof material covered with a substance harmful to health is replaced with a material suitable for the original appearance of the structure. Preserving the original material in reuse is also of great importance in the usage process.

Suitable insulation material should be selected by considering the fire, heat and water factors in both the original structure and the additional structure roofs required by the new function, in the reused structures. Openings in industrial heritage buildings are of great importance in reflecting the historical value of the building. It is preferred that the original dimensions of the windows do not change and if possible, the original material is used when these structures are re-functioned. But usually wood joints rot by taking water over time. The joinery, which cannot be used, is replaced and multi glazing is preferred in order to provide heat insulation during the reuse process of the glasses (Köksal, 2005). Using double glass instead of a single glass to increase energy performance may cause visual differences in the elevations. In cases where the existing window casing can be used, the second layer of glass can be added to the structure with a new casing and wing to prevent this difference and not increase the load on the window casing (Abusamhadana et al., 2018).

The low thermal transmittance, U-value of the filling material to be used between the glasses also reduces the thermal transmission of the glasses. Energy performance can be increased by using gases like argon, krypton, etc. instead of the dry air gap between glasses. Designs with low-E coating of glass and U value below 1.8 W / m^2K are recommended to be selected in TS 825.

Integration of renewable energy systems to adaptive reused building

The integration of renewable energy sources with active-passive energy systems will contribute to increase energy efficiency and decrease carbon dioxide emission also in the adaptive reused buildings. However, the utilization of these systems in historical buildings requires a meticulous study. Transformation or updating these systems as required by the new function, have to be made carefully not to ruin the historical value and architectural fiction of the building. Increasing natural ventilating and lighting performances have to be given importance. When the refunctioning examples are analyzed across buildings of historical value, it is observed that the most common approach is saving energy in terms of electricity and mechanics by using solar panels. Integration of PV modules, tiles texture on building roof systems compatible with the building in terms of color and which also decrease carbon emissions; providing heating and cooling demands by renewable energy sources as biomass wood pellets, geothermal heating, solar thermal heating, and absorption cooling are the other attempts that provide energy efficiency (Cabeza, 2018).

Increasing the efficiency of heating and cooling equipment of adaptive reused building

In cases where natural ventilation and lighting are insufficient, the selection of mechanical and electrical systems should be made in a way that does not contradict the architectural value of the building and minimize energy consumption.

The choice of mechanical systems in historical re-used buildings may differ depending on the new function and the type of intervention to be performed. In these buildings, the interventions that require major renovation are avoided with the concern of preserving the historical value. Air-conditioning systems are preferred, which provide design flexibility with higher energy efficiency compared to conventional systems, with narrow and easy application in different areas. The control of indoor climate conditions is another reason for the use of air conditioners in the adaptive re-used buildings not to damage the equipment of the original function. Heating and cooling operations can be provided with duct type split air conditioners with external air connection. Often the high wall thickness is a factor that makes the passage of the channels

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difficult. VRF systems are suitable options due to the insufficient space to position the outdoor unit for each zone. Automation systems have special importance in buildings with historical value. When these systems are used without damaging the historical texture of the building, they benefit in terms of air conditioning, security and fire safety. The utilization of Building Energy Management Systems (BEMS) dramatically reduces energy consumption by controlling the amount of heating/cooling and ventilation according to the activity and intensity of use in each location. With the integration of the automation system, efficient operation of the chiller system with suitable capacity, mixed air handling unit, fancoils, condensing boilers can be provided. Unnecessary energy consumption can be prevented to a great extent in heating, cooling, ventilation and lighting system by human sensitive sensors. Energy efficiency can be increased by choosing lighting elements with high lumen/watt ratio.

Case study: Derince Travers Injection Plant

Derince Travers Injection Factory functioned as wooden traverse creosote injection factory until 2001 in a single block is located in Kocaeli province, Derince Port Area district. The construction of the factory was started in 1930 by a German company called Borsig. The factory started its operations in 1931 and was operated by German masters until its final acceptance (Berkel, 1954). Although the structure is subjected to deformations, it is still standing with its external and internal equipment (Figure 1) (Qi, 2016). There is a wagon maintenance workshop in the south of the building, a registered transformer structure in the east, Demirspor facilities with a single-story in the north, and open storage areas in the west (Bozdağ, 2013). Derince Travers Injectable Factory has been registered as an industrial heritage with the decision of Kocaeli Cultural Heritage Preservation Board of the Ministry of Culture and Tourism on 14.05.2013, due to its technical and historical features, as reflecting the industrial movements of the 20th century in the region, modernist facade layout, steel-wooden truss roof system, original site equipment and details, architecture. Although there are re-use planning and attempts, the structure is still obsolete.

Figure 1: The non-functional Derince Travers Injection Factory

Proposal: New function

International research was prepared under the project, named as BOOSTHER submitted to H2020 calls. In the project, the main local partner was TCDD (Turkish State Railways), Derince Municipality and Kocaeli University, and the Kocaeli Metropolitan Municipality was the supporting partner. The building was proposed to be reused adaptively as a social center after physical and social analyzes for the region, structural evaluation of the structure by considering the needs of their community and aim to provide an economic contribution to the district (Kavuru, 2017). According to the project, there were restaurant, dance, workshop and bar spaces in the building, assumed to serve as a social center for Safiport employees and Derince people. In the place where the mezzanine is located, the chemical tanks left from the original function have been fully preserved, and this place has been used as an surveillance area. In addition, kitchen, open area in front of the restaurant and main entrance sections were added to the building for the new function.

Diagnosis process

Diagnosis of the physical condition of Derince Travers Injection Factory was conducted by on-site observation and imaging studies with thermal cameras. Heat leakages from the cracks and thermal bridges at the junction points of the building elements have been identified on the building envelope (Figure 2). On the facade, there are efflorescences, cracks and salts caused by moisture. Although there is no serious structural damage, there are some deteriorations as plaster cracks, material loss and color changes in the plaster. All window glazings are broken on the facade of the building, and there are spatial cracks and spills (Figure 3). Wooden forehead boards of the structure without rain gutter are rotten in a structure which also increases the mould problems. Asbestos is used as the roofing material. The odor of creosote (tar oil), which was used to tighten wooden sleepers and to protect it from external conditions, still exists in the building. There is no mechanical-electrical system available in the building currently.

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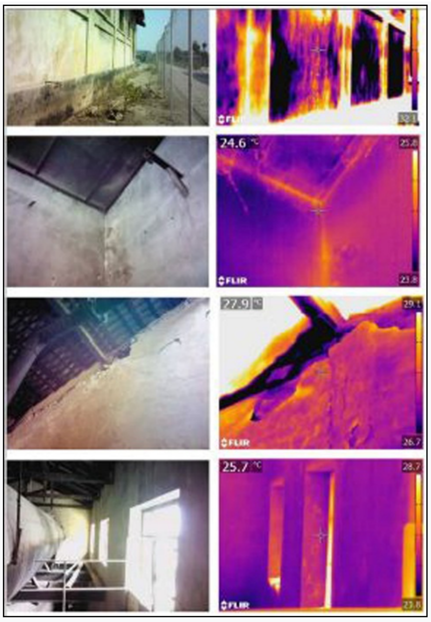

Figure 2: Derince Travers Injection Factory thermal camera images

Figure 3: Derince Travers Injection Factory deformation on the facade

Energy retrofit strategies proposed for Derince Travers Injection Plant

Intervention suggestions for energy retrofit of the building were made in the context of assumptions for the new function of the structure Strategies have been developed for the building are; Strategies for the building envelope, integration of renewable energy sources, the suggestion of HVAC and lighting systems.

Interventions for building envelope

In order to avoid thermal bridges and to benefit from the heat storage feature of the building elements, external thermal insulation was proposed for the outer walls of the kitchen, which were added to the original structure in line with the new function.

Insulation was proposed to the roof of the same zone. Since PV panel systems are suggested for this area, protection concrete on insulation is recommended in order not to damage the waterproofing during maintenance processes. As the roofing material of the original structure is asbestos, which is a substance harmful to health and the environment, self-mineral mineral insulated metal panel was suggested due to its maintenance, repair, easy and fast assembly advantages. The corrugated metal panel is considered as the panel type in order to be compatible with the original appearance of the building.

In the study of Kavuru (2017), a new glazing type with a low thermal transmission coefficient for broken and unusable glasses across the structure is recommended. This suggestion was developed to increase the temperature control, daylight transmission and thermal comfort and “Low-e double glass with argon infilled, low iron additives” was used in all windows due to TS 825 values. It is aimed that maximum amount of the daylight would enter the interior space with the selection of low iron added glass.

Integration of renewable energy sources

PV panels on the roof have been proposed in order to contribute to electricity consumption in heating and cooling. Considering the structural behavior of the existing building, it is assumed that 80 PV panels of a polycrystalline cell type with a size of 0.6 m x 1.00 m and 15% energy efficiency have been located on the roof of the kitchen zone.

Effective criteria in the selection of cell types were adequate application area, energy efficiency and cost factors. Shade length between panels, walking areas left for maintenance and cleaning requirements became the determining factors in deciding the number of PV panels. Terrace roof offers the opportunity to easily adjust the periodic angles of the panels. Thus, it is aimed to provide optimum benefit from daylight during the year.

The suggestion of HVAC and lighting systems

The building does not have any available mechanical-electrical systems so the equipment belonging to these systems has been converted into an exhibition element. In order not to damage the historical texture of the building, a split HVAC (Heating, Ventilating and Air Conditioning) system has been proposed as a split air conditioner and independent ventilation system.

The wall thickness of the historical building, the number of zones in the building and the noise limitation of the area have greatly influenced the selection of the mechanical system. For this reason, air conditioning systems that require a minimum level of intervention were preferred for the reuse of Derince Travers Injection Factory as a social center. The split air conditioner has been proposed as a simpler solution instead of VRF system due to its low space requirement. In addition, the intensity and usage time of each department are different, it is aimed to save energy with automation systems. Artificial lighting appliances with high energy efficiency have been selected to support natural lighting. The illumination level appropriate for the function of each zone has been determined.

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Annual energy consumption of Derince Travers Injection Plant with new function

Ensuring energy efficiency in the adaptive reused buildings is one of the issues to be considered. The energy consumption amounts should be calculated by the simulation period and the operating period and decisions should be taken to increase energy efficiency during selection of retrofit strategies. In this context, annual energy consumption amounts were calculated with the energy analysis program Designbuilder in order to evaluate the contribution of heating, cooling, ventilation systems, materials, lighting, PV panels propose in order to re-adapt the structure as a social center. The parts where different activities are performed are modeled as separate thermal zones (Figure 4, Figure 5). Climate data named "TUR_Kocaeli_MN6" was used for the calculations.

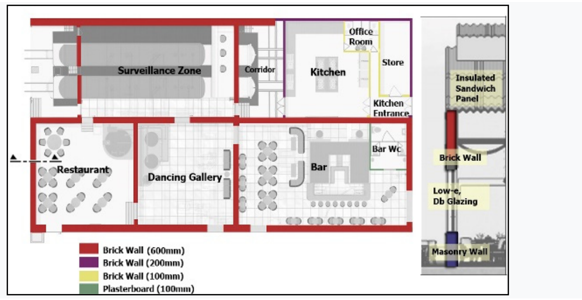

Figure 4: Schematic representation of Design Builder material inputs, (Kavuru, 2017), (Eres, 2019)

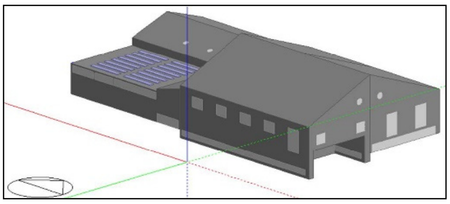

Figure 5: Design Builder model

The construction system of the wall is either stone masonry or concrete plastered in both faces (65 cm). The material of the slab is cast concrete covered by ceramic tiles (28 cm) Building occupancy hours are between 17:00 - 23:00 for restaurant and dance gallery; 08:00 - 00:00 for the bar, kitchen and surveillance room. Lighting intensities were selected from lighting data defined by DesignBuilder for specific activities in the zones.

The types of internal gains by occupancy and lighting are also defined. The daily operating time of every specific zone in terms of occupancy and lighting is determined due to activities performed. Infiltration, natural ventilation, and lighting information are also specified for every specific zone. A simple HVAC data template was used to calculate cooling and heating requirements. The simulation was carried out by HVAC models generated for split HVAC systems.

The results of the energy analysis of the strategies suggested to increase the energy efficiency of building assumed to be reused are presented. Annual energy consumption spent in the building with a total area of 846 m^2 has been calculated as 413.227,11 kWh (Table 1).

The PV panels used provided a 13.25% gain and reduced the total annual energy consumption to 401,764.03 kWh (Table 2). The total amount of energy per square meter is 494.95 kWh. The distribution of this amount is 103.73 kWh / m^2 for electricity consumption, 58.51 kWh/m^2 for cooling load and 332.71 kWh/m^2 for heating load (Table 3). It is seen that electricity consumption is the most in the building after heating. It is observed that the mean temperature variation is above 20 °C in summer and 0-10 °C in the winter period in Kocaeli. The set point temperature is 20 ° C for winter and 25 °C for winter conditions. In the facility where cooling energy is required in summer and heating energy requirement in winter, the monthly average of operative temperature is mostly around 19.7- 22.06 ° C in dining and bar areas. This amount corresponds to the restaurant ambient temperature in TS 825 standard. (TS825, 2008). The temperature and humidity level are consistent and maintained considerably within the comfort level. The discomfort hours are zero in summer and almost negligible in winter.

Table 1:
Annual energy consumption amount

	TOTAL ENERGY	ENERGY PER TOTAL BUILDING AREA	ENERGY PER CONDITIONED BUILDING AREA
	[kWh]	[kWh/m^2]	[kWh/m^2]
Total Annual Energy Consumption	413227,11	494,95	494,95
Net Annual Energy Consumption	401764,03	481,22	481,22

Table 2:
Electricity generation

	ELECTRICITY	PERCENT ELECTRICITY
	[kWh]	[%]
Photovoltaic Power (Total On-Site Electric Sources)	11463.08	13.24
Electricity Coming from Utility	75139.18	86.76
Surplus Electricity Going to Utility	0.71	0.00
Total On-Site and Utility Electric Sources	86601.54	100.00

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Table 3:
Energy consumption per unit area for heating, cooling and lighting

	ELECTRICITY INTENSITY	DISTRICT COOLING INTENSITY	DISTRICT HEATING INTENSITY
	[kWh/m^2]	[kWh/m^2]	[kWh/m^2]
Lighting	41,72	0	0
HVAC	0	58,51	332,71
Other	62,01	0	0
Total	103,73	58,51	332,71

Especially the amount of solar radiation acting from the southern façade with greater window wall ratio compared to the other facades, is higher in summer. It was observed that the utilization of mechanical ventilation increased in the summer months. Mechanical and natural ventilation systems operate during the active period of the business. For summer days, the calculation was made according to the time when the cooling load was maximum in each thermal zone. Total consumption amount, indoor temperatures, sensible and non-sensible heat loss gains and cooling loads were calculated. The kitchen and surveillance zone seem to create the highest monthly cooling and heating loads (Figure 6). Although it orients to the south, it was observed that the cooling load was mostly in the surveillance room due to the large size of the space, the glass/wall ratio, and the number of doors. The amount of energy spent for heating and cooling is very low compared to the surveillance room, due to the low opening and floor height in the kitchen space added to the original structure in the southern facade in line with the new function (Figure 7, Table 4).

Considering the heating load distribution of the building, the highest heating load is observed in the surveillance room again due to the space volume. Under the comfort conditions suitable for the activity to be performed in each thermal zone, the heat loss occurs mostly in the circulation areas and in the places where the floor height is high. It was observed that the heating load calculated for the restaurant section was higher than the dance gallery with the size of the nearby space due to the type of activity performed.

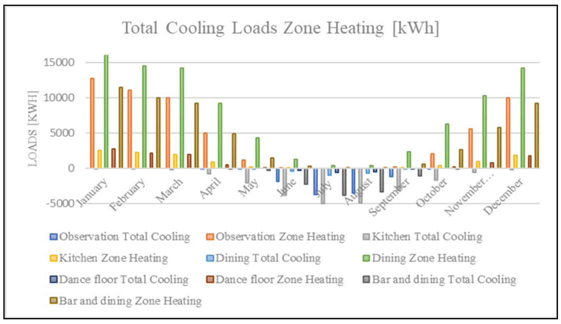

Figure 6: Comparison of zonal monthly cooling and heating loads

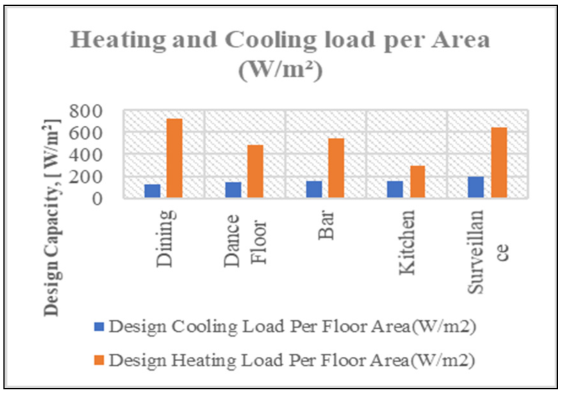

Figure 7: Cooling-heating design capacity distribution (W/m^2)

Within the scope of the Energy Performance Regulation in Buildings, Primary energy reference indicator, (RG) value as 540 kWh/m^2-year defined for "commercial building (restaurant, hotel and motel etc.) can be used for comparison as the functions are similar to a social center with calculated energy performance indicator in terms of primary energy (EP), the value of 481.22 kWh / m^2. When put in place in the table, the energy performance class is determined as C (Table 5). Although there is no specifically defined limit value on the energy class of existing structures in the regulation, Class C energy performance is a threshold but enough result for an existing structure to be adaptive reused.

Table 4:
Cooling-heating design capacity distribution (W)

Block	Design Capacity (W) (cooling)	Design Capacity (W) (heating)
Block 1-Dining	16.530,00	92.160,00
Block 2-Dance Floor Gallery	17.400,00	57.860,00
Block 3-Bar	32.600,00	115.780,00
Block 4-Kitchen	23.640,00	46.650,00
Block 5-Surveillance	43.450,00	140.570,00
Total	**133.620,00**	**453.020,00**

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Table 5:
Energy performance class calculation table:

Building Energy Class	Energy Class Index by Primary Energy Consumption (EP)	Calculation
A	EP<0.4*RG	481.22<216
B	0.4*RG≤EP<0.8*RG	216 ≤ 481.22< 432
C	**0.8*RG≤EP<RG**	**432 ≤ 481.22 < 540**
D	RG≤EP<1.2*RG	540 ≤ 481.22< 648
E	1.2*RG≤EP<1.4*RG	648 ≤ 481.22< 756
F	1.4*RG≤EP<1.75*RG	756 ≤ 481.22< 945
G	1.75*RG≤EP	945 ≤ 481.22

EP:	Energy Performance Indicator in Primary Energy (kWh/m^2-year)	481.22 kWh/m^2-year
RG:	Primary Energy Reference Indicator (kWh/m^2-yıl)	540 kWh/m^2-year Commercial Buildings (Hotel, Motel, Restaurant etc.)

CONCLUSION

This paper showed a method for an industrial heritage building how the application of specific action for the energy retrofit of existing buildings could decrease the annual energy requirement for heating and cooling in the pre-design phase of adaptive reuse actions.

The historic and listed factory carries multi-dimensional values as an industrial heritage asset in Kocaeli. The building was an issue of an international project and all the actors (the owner, municipalities and the experts) were convinced to involve a sustainable project for the neighborhood and the people working in the port close to the area. The building was proposed as a social hub and reuse strategies were sought. In this study, energy retrofit actions are applied to the building in the adaptive reuse design stage. The strategies which do not change the historic value of the façade were selected and the ultimate monthly and annual energy consumption values were obtained.

Structural analysis of the re-functional industrial heritage structures should be done first to determine physical conditions, it is necessary to determine the deteriorations and heat bridges that cause energy losses by means of undamaged tests such as IRT imaging methods and to perform energy analyzes with different scenarios in order to reduce these losses. Decision steps to improve energy efficiency regarding reuse of buildings; The choice of function suitable for the architectural setup of the historic building can be listed as material, mechanical- electrical equipment decisions and integration of active-passive energy systems without effecting the original appearance and the value of the building.

As a strategy of a passive approach, the integration of PV panels proposed for the reuse of Derince Travers Injection Factory contributed 13.24% to annual energy consumption. It has been shown that these systems can be applied in areas added to the building in line with the new function and without disturbing the architectural integrity.

Intervention suggestions to increase the energy efficiency of Derince Travers Injection Factory have been made and the net annual energy consumption per conditioned building area is calculated as 481.22 kWh/m^2. Although there are no specifically defined energy consumption limit values defined for historic buildings in Turkish energy regulation, in the study limit values for energy identity documentation of buildings which is obligatory for new and existing buildings after 2017 are used for the comparison of calculated values. According to the results, energy performance of the Derince traverse injection factory seem to provide threshold values of energy consumption with energy retrofit strategies. The energy class of the heritage building can be increased with other strategies to A or B class. Although this standard provide opportunity for calculation of carbon emission and energy consumption amounts, life cycle approach which include embodied energy and carbon defined as cumulative energy and carbon inputs occurring during construction, renovation-maintenance and demolition period in the life span of a building is not considered.

The building displays a unique value in terms of the urban context as it is located in the private port area where the manufacturing and process activities are high. The building was endangered to be demolished despite being listed as cultural heritage. Retrofitting and refurbishment activities conducted for the industrial structure to be adaptively reused with consideration of embodied energy and carbon through life cycle approach would be an operative tool for sustainable development by establishing a minimum increase in energy, carbon emissions and a maximum advancement of habitability. Particularly, the retrofit approaches proposed for the building would help to reduce the energy consumed during the operation phase. Acquisition of local raw materials causing a small amount of resource consumption and environmental effects, local manufacturing, processing, domestic workmanship along with the living knowledge on construction skills and the durability of the construction materials, decreasing the requirement of new materials and system are highly suggested in order to obtain the benefits not only through operation phase but also through all stages of life cycle of the building.

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Energy consumption is an important issue in the use process for these structures that have been re-functioned by preventing the loss of energy resulting from the construction of a new building. An arrangement should also be made for existing buildings in the Energy Performance Regulation in Buildings, where only a limit value is given for new buildings. In the structures to be re-functioned, simulation studies should be carried out with different scenarios based on the limit value specified in the regulation, and according to the results of these studies, decisions should be made to improve the energy performance in the reuse of the structure.

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