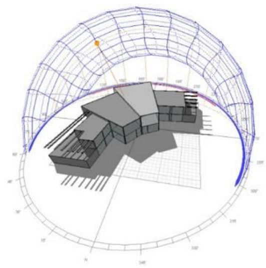

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EXAMINATION OF SAMPLES PUBLIC BUILDINGS ACCORDING TO ENERGY EFFICIENT

BADANIE OBIEKTÓW UŻYTECZNOŚCI PUBLICZNEJ W ASPEKCIE ICH SPRAWNOŚCI ENERGETYCZNEJ

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ABSTRACT

Public utility buildings are formal, structurally and functionally complex entities. In order to demonstrate energy-related defects of building designs developed by students, the conduct of analyses was proposed. The completed designs of public utility buildings were examined with regard to the energy efficiency of the solutions they feature through the application of the following program: *Ecotect* software was sufficient. Thus, it has been reached that how can be designed public utility buildings according to energy efficiency. Paying more attention to the energy aspect must change the previously designed architectural design of buildings.

Key words: Energy efficiency, *Ecotect* software, building design, public buildings.

1. INTRODUCTION

Contemporary buildings design incorporates sustainable features to create friendly public spaces and green areas with easy access to local amenities and workplaces. With their growing functional and structural complexity, public utility buildings now play an increasingly important role in shaping the fabric of the urban environment. Modern construction methods and materials, as well as technological advances, have enabled developers to vary the internal structure of buildings and adapt them to serve various functions. Around 75% of Europe's buildings are not energy efficient. Therefore, increasing the quality and energy efficiency of refurbishments offers a huge energy-saving and cost-saving opportunity [1]. From this point of view, buildings should have designed with energy efficiency principles from the beginning of the design process to end.

Public utility buildings have some kind of functions and according to these functions, every building has to have a different level of sunlight (daylight) and energy. So, the public buildings have to be designed in terms of these necessities. In the study, two examples of public utility buildings are examined. These buildings were designed by students in the project class on master studies. Typically, these are a library building and a culture and tourism additional building to a city hall. It is not easy for students to design these buildings with functional, construction and material aspects as well as aesthetic point of view during the one semester. Because of this, generally, projects have some defensives about related to energy efficient solutions. In this study, firstly the students' projects are chosen and after examining the original students' projects by *Ecotect* from the energy point of view, every building is changed as forms for gaining much more sunlight and less shadow for inner spaces. These changes are arranged according to the buildings' functions. For example, the library building has to have more windows and sunlight for inner spaces but not legibly and magazines of books, of course. In contrast, another building which is additional tourism and culture building to the city hall, has to have not much sunlight for inner spaces. In addition, owing to take correct comparison results, it is important that two designs (new and old) should have to have the same parameters (coefficient- U) during the analyses with *Ecotect.* Because if we have the same parameters of thermal conductivity of external building elements, the energy balance of both buildings will document the benefits of designing a new architectural form.

1.1. Problem

In the study, a library building and a culture-tourism building have examined by *Ecotect* software. The study's main problem is how can this different kind of buildings redesign for evolving more energy efficient buildings according to the *Ecotect* analyses' results which are related to energy balance, radiation-lighting, sun shadow analyses, etc.

1.2. Objective

The study aims that changing the buildings' forms and re-design the public utility buildings according to an energy point of view. And also, the original buildings become more sufficient, sustainable and ecologic.

1.3. Scope

Architecture students design public utility buildings in the Architectural Design Studio course are just focus on functional, aesthetic, construction and material issues. In this context, two public utility designs are selected and examined in terms of energy efficiency.

1.4. Method

In the method, firstly students' projects are assessed by energy efficiency software which is the name of *Ecotect*. In terms of energy efficiency, buildings' shadow analyses, thermal analyses, and annual sun-path diagram etc. are done by the software. And then, according to the results of the program's report, buildings are redesigned for more energy efficiency, sustainable and ecologic purposes. And finally, redesigned buildings are examined by the *Ecotect* again because of testing the energy efficiency for comparing results to the origin and new design.

2. WHAT ASPECTS ARE ANALYSED?

A Library Building in Konya-Turkey and Culture and Tourism Additional Building to Trabzon City Hall in Trabzon-Turkey were analyzed. The completed designs of public utility buildings were examined with regard to the energy efficiency of the solutions they feature through the application of the following software's: *Ecotect,* and in case of simpler analyses (shading, insolation of building planes) *Archicad* extensions were sufficient. The following aspects are examined:

- **Location:** Is a building properly positioned relative to the direction of the world? Does the southern façade receive sufficient amount of insolation? Isn't the building shaded with other structures – chiefly at the time of equinox – 21.03 and 23.09 in times 10 -14.

- **The shape of the building body:** Is it shaped in such a way that its own shadow interferes with room light? Which building body planes receive the most solar energy? Are internal patios and breaks in the body of the building properly shaped?

- **Amount of daylight and of solar radiation in particular rooms:** How much light do the provided window openings allow into the rooms? How do they function in intense insolation? Is the body of the building sufficiently "open" to southern insolation?

- **Annual thermal balance**, itemized into individual months: What is the demand for heat at specific, constant coefficient value of external envelopes insulating power (solid walls U=0.15 W/m2K, roofs and flat roofs U=0.1 W/m2K, ground slab U=0.15 W/m2K, windows U=0.7 W/m2K, glass curtain walls, doors U=1.2 W/m2K). It was calculated what proportion of thermal energy demand is covered by solar radiation gains, what proportion is obtained from gains generated by people and devices, and how much needs to be supplied from conventional sources of heating. For the summertime, the question is: how much energy will be consumed by air conditioning that cools the buildings?

2.1. Re-examination of samples according to energy efficient application methods

2.1.1. Library in Konya, Turkey

- Location: When selecting the project land, an intensive area of the city was preferred and in this way, the land is taken care of the agricultural area, in the special area that needs to be protected or close to any water source.

The project has been designed to be within walking distance to public transport stops, and so users are encouraged to use public transport (Figure 2.1).

In addition, the building was designed in a land which has no context buildings and so there is no problem of shadowing from neighboring buildings. Due to the environmental analysis carried out and the form of the land, the design was shaped „ L" and the courtyard was formed to the North-West direction. Besides, glass material was used on the most part of the Northwest facade.

The shape of the building body: Building form is compact, not partial designed. And also, terracing is made on both sides of the design form and using shading elements for balanced daylight.

Amount of daylight and of solar radiation in particular rooms: The courtyard of the building is on the Northwest direction. So, the enter part of the building has not enough sunlight. In addition, Northwest façade of the building has full of the windows. So, this situation is undesirable in terms of solar radiation. By the way, there are not enough windows on the southern facade of the design for daylight because the library function does not need daylight much. However, solar energy saving has been minimized.

Annual thermal balance, itemized into individual months: The use of materials and insulation elements has not been paid much attention in the design period. Used materials which are solid walls (U=0.15 W/m2K), roofs and flat roofs (U=0.1 W/m2K), ground slab (U=0.15 W/m2K), windows (U=0.7 W/m2K), glass curtain walls and doors (U=1.2 W/m2K) are analyzed for annual thermal balance. The energy gain was increased by using more windows from the south and less from the north and a Trombe wall in addition to these materials with a new design (Figure 2.2).

Fig. 2.1. Location of the design building. Source: personal archive.

This Trombe wall is composed of some different layers. These layers comprise an transparent insulation layer, a ventilated air cavity, a mass heating wall, a closed air cavity, and a glass plate [3]. And, according to the used materials and methods, Table 2.1 shows us to design and analysis of the library – A summary analysis of the object before and after the changes.

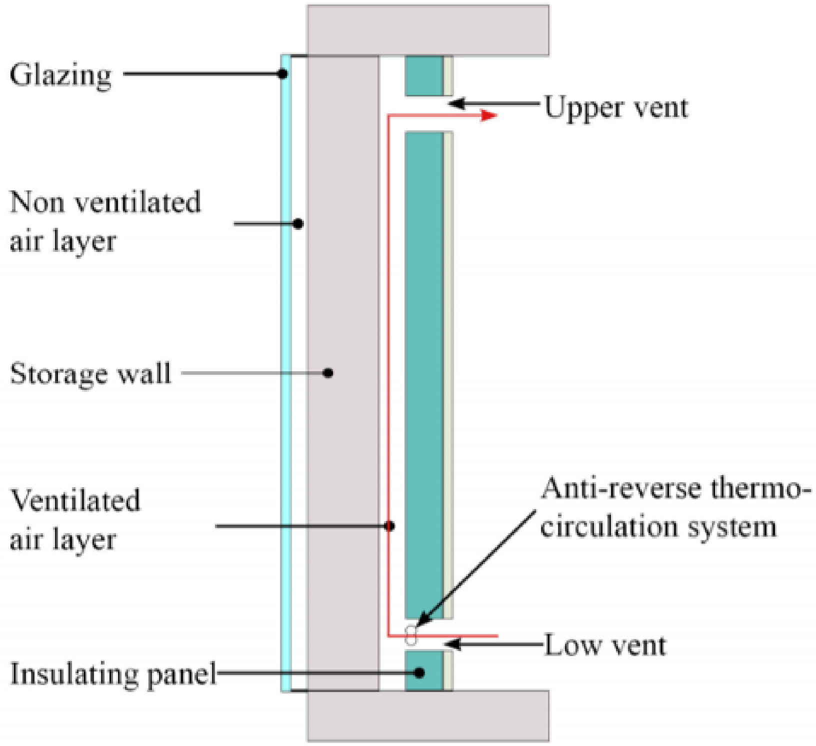
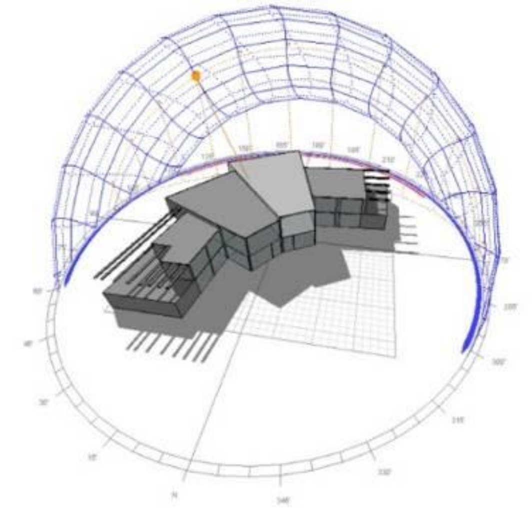
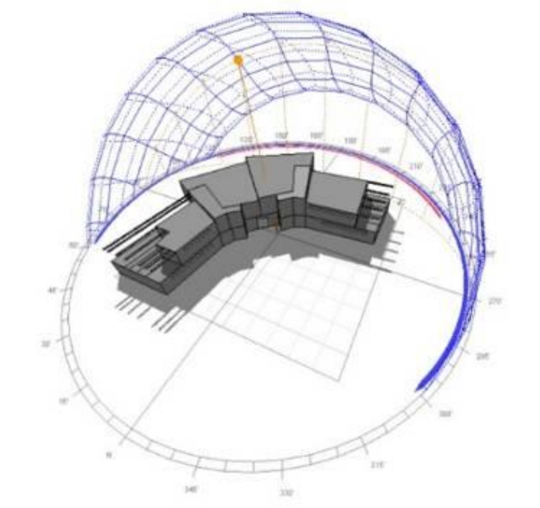
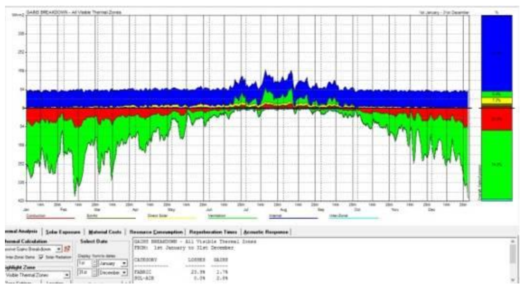
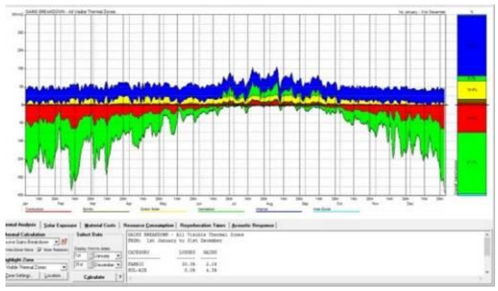
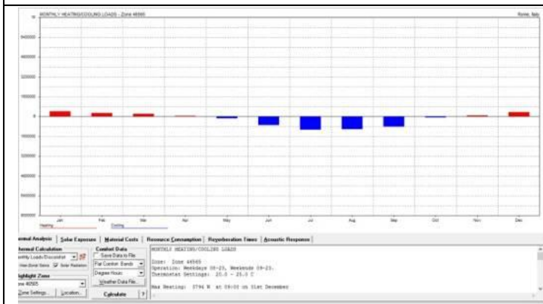
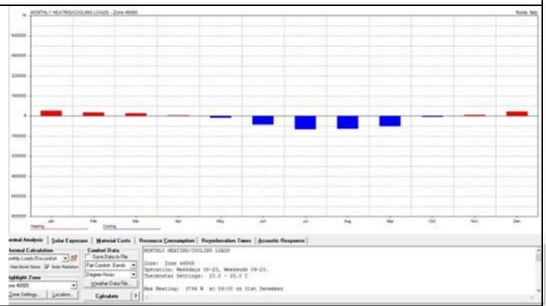


Fig. 2.2. The Trombe wall which used in redesign. Source: [2]

The plan schema of the building has not changed much. So, ensure the comparability of results, the Trombe wall is used in the new design. Although, all the designed buildings featured the same insulating power properties of external envelopes as specified above. As a result of the conducted analyses, solutions are recognized as significant defects. The most frequent defects included:

– Not considering sunshine rates on the north and south facades of the building;
– The inappropriately shaped body of the building breaks causing high shading, excessively shaded patios;
– Incorrectly designed window openings;
– Lack of solutions related to the operation of the building in the cold and hot seasons.

Table 2.1. Design and analysis of a Library Building in Konyal;– A summary analysis of the object before and after the changes (shading, lighting sunlight envelope planes of the building, interior lighting by daylight, the annual heat balance) Source: creating by the authors.

CURRENT DESİGN	REDESİGN
	
21 March, 10:00 Shadow analyse	21 March, 10:00 Shadow analyse
	
Passive gains breakdown analyse	Passive gains breakdown analyse
	
Monthly heating and cooling loads	Monthly heating and cooling loads

2.1.2. Culture and Tourism Additional Building to Trabzon City Hall

Location: It is positioned as environmentally sensitive in the historical area. Southern façade of the building is restricted by other historical buildings and so the building has not enough sunlight. But, the building has enough insolation at the part of southern façade. According to the time of equinox (21.03 and 23.09), the building is shaded with other buildings (Table 2.2)

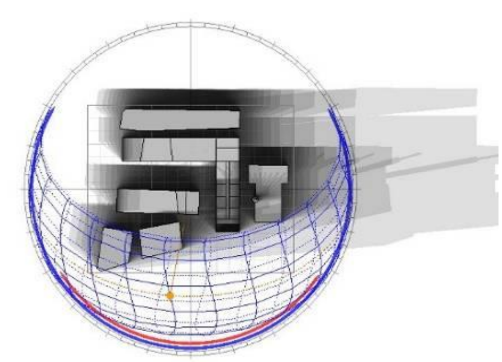
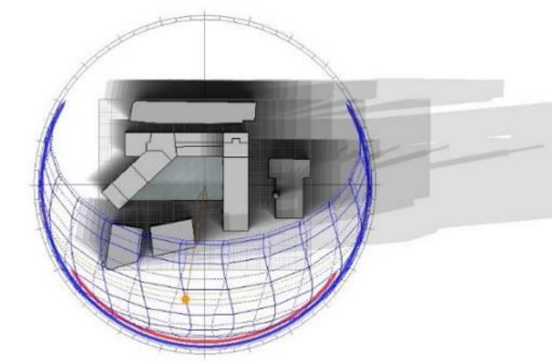
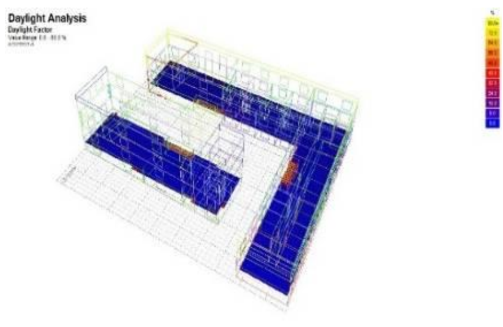
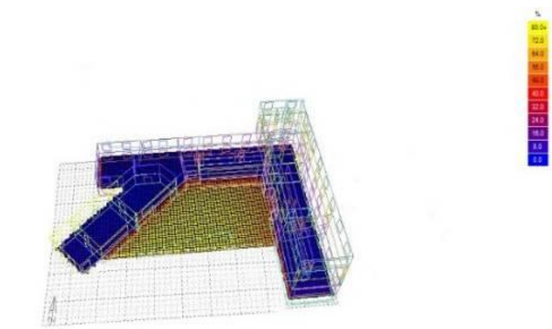
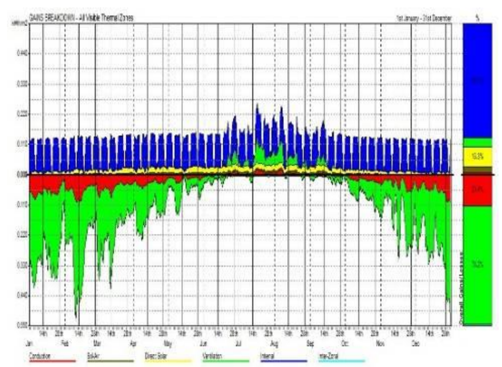
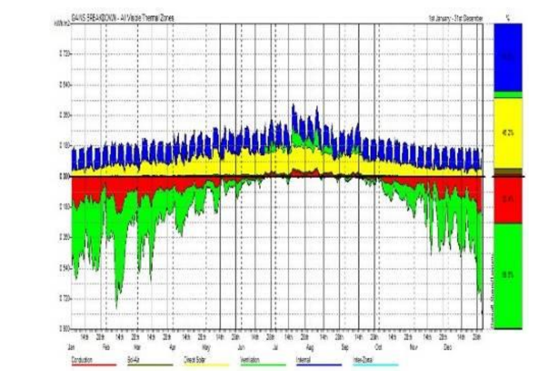
The shape of the building body: The building is shaped in such a way that its own shadow interferes with room light. According to the equinox time (21.st March, 10.00 – 14.00 p.m), the building's southern parts which no restricted by other buildings have much more solar energy than the other part of a building. But, the building's courtyard has much more shadow because of its shape. Moreover, the internal patios and breaks are not shaped according to sunlight.

Amount of daylight and of solar radiation in particular rooms: The building has a lot of windows but because of the building shapes and orientation towards the sun, rooms have not enough sunlight. Some part of the buildings is open to the southern insolation.

Annual thermal balance, itemized into individual months: In the all designs which are new and redesigned are used the materials what is the demand for heat at specific, constant coefficient value of external envelopes insulating power (solid walls U=0.15 W/m2K, roofs and flat roofs U=0.1 W/m2K, ground slab U=0.15 W/m2K, windows U=0.7 W/m2K, glass curtain walls, doors U=1.2 W/m2K). It was calculated what proportion of thermal energy demand is covered by solar radiation gains, what proportion is obtained from gains generated by people and devices, and how much needs to be supplied from conventional sources of heating. For the summertime, the question is: how much energy will be consumed by air conditioning that cools the buildings?

The current building design and the redesigned building has the same insulating power properties parameters which are related to about walls, ceiling, doors, windows, floors and roofs energy balance U-value to ensure the correct results.
As a result, according to these analyses (Table 2.2.) the building deficiencies are identified. These deficiencies should be resolved by the new building design. The list below shows that the most frequent defects included:
– inappropriately shaped body of the building (high value of the ratio defining the relation of external planes to cubature), breaks causing high shading, excessively shaded patios;
– the rooms which are located wrongly according to directions of the world;
– the windows and curtain walls which are designed inappropriately e.g. current model has a lot of windows but not correct size;
– lack of solutions related to the operation of the building in the cold and hot seasons;
– failure to take into account the differences in insolation of the body of the building on southern and northern facades and also building's southern and northern facades have the same amount of windows.

Table 2.2. Design and analysis of the Culture and Tourism Additional Building to Trabzon City Hall;– A summary analysis of the object before and after the changes (shading, lighting sunlight envelope planes of the building, interior lighting by daylight, the annual heat balance) Source: creating by the authors.

CURRENT DESİGN	REDESİGN
	
21 March 12.00 Shadow analysis	21 March 12.00 Shadow analysis
	
Room sunlight analysis	Room sunlight analysis
	
The annual heat balance	The annual heat balance

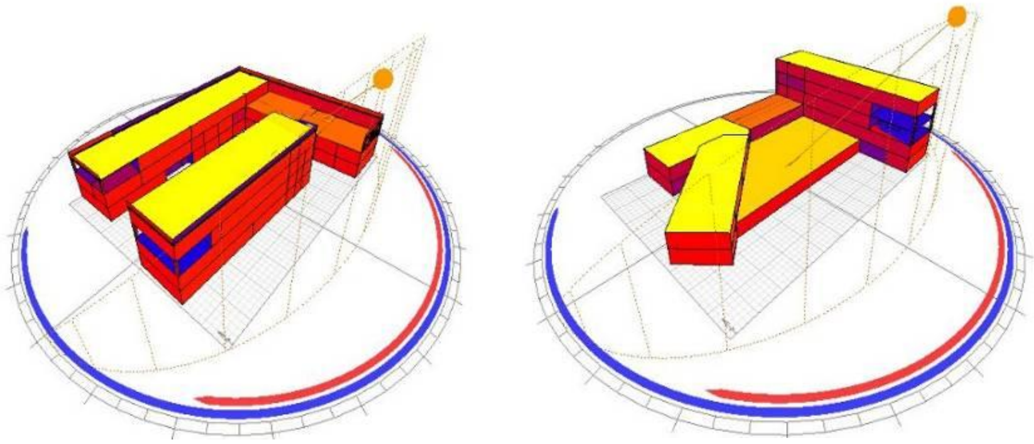


Fig. 2.3. Solar access analysis of current model and redesigned model. Source: creating by the authors.

3. CORRECTIONS OR COMPLETE CHANGE OF ORIGINAL DESIGNS?

The flaws found in analysed designs had to be corrected. Additionally, designers were provided with extensive information on simple and efficient passive systems of using solar energy. Design corrections eventually became substantial redesigns. Knowing the functional diagrams of previously designed buildings, designers found it easy to incorporate changes and supplementations of new solutions increasing energy efficiency. Consequently, the architecture of the facilities became different from the original one. The changes involved:

– remodelling the form of a building, in order to decrease building's own shadow, e.g. softening breaks or reforming them in such a way so as to prevent them from shading adjacent parts of the building;
– shaping the form of the building in such a way that a longer facade has been created on the southern side;
– redesigning a room layout so as to enable temperature zoning of building rooms (warm from the south or the centre of the layout, cold from the north or as an external buffer from the windward side);
– addition of a greenhouse / conservatory as an integral structural element;
– incorporation of other passive systems of acquiring thermal energy from solar radiation;
– a conceptual solution of air circulation in winter and summer time;
– proposal of a system of heat recuperation from ventilated air and a way of preliminary heating of air introduced into the ventilation system;
– to gaining much more solar energy, enhancing the southern facade of the building's windows size and amount.

According to the design of the library, the building plan schemes have not changed much. This schema is already designed compactly. However, an introverted design is created on the North-West façade in order to reduce the coldness effect of the courtyard. The current and redesign models have the same form but different parameters. The Trombe wall is used in the new design. Also, there is no changing about the functional program of the building (Table 2.1 and Fig.2.2).

And finally, in consequence of the Culture and Tourism Additional Building, its shape has a different form. Before the changes, the building has 3 main parts and not compact shape as a form but after that on the southern part of the building is rotated 45 angles to northern façade and integrated the northern part of the building. As a result, it is more compact and located according to the direction of the world. The current and redesign models have the same parameters but different form. Also, there is no changing about the functional program of the building. A conservatory (greenhouse) is now one of the fundamental elements integrally connected with the building and also has glass material. It is also an element of improving the building's energy balance (Table 2.2 and Fig.2.3).

4. ENERGY ANALYSIS OF THE REDESIGNED BUILDING

New building designs were subjected to similar examinations as the original designs, whose focus was on: - location, - shading, - a shape of the form of the building, - daylight amount and amount of insolation in individual rooms, - annual thermal balance including an itemization of individual months.

As a result, firstly all the designs which are the original and redesigned building have the same parameters of insulating power. Because of this, all the results which are related to thermal balance can be compared in a correct way. The differences in thermal balance are related to changing the building shape and not about adding or extracting mechanical elements or anything.

Table 2.1 shows us that the original and redesign building has the same shadow because plan scheme does not change much. However, the thermal balance analysis is the most substantial difference between the original and redesign building (Table 2.1) because of the using the Trombe wall, increasing the size of windows on the south facade, less window use on the northwest facade and an inward facing facade solution in the redesign. And, as a result of the analysis, the new design has approximately 75% energy gain compared to the original design (Table 2.1., yellow colour in the diagram).

Besides that, according to the monthly thermal balance analyse (Table 2.1), redesigned building gain related to solar energy substantially. When we compared to the redesign and original design, the new design suffers 15% less energy loss.

As it is seen in Table 2.2, according to the shadow analysis the original design of the building has much more shadow in the courtyard. Moreover, the internal patios and breaks are not shaped according to sunlight. But, after changing the building's courtyard has almost no shadow. And also, the correct positioning of the redesigned window numbers and dimensions resulted in more daylight and less shadow (Table 2.2, the room sunlight analysis).

Secondly, it can be seen in Table 2.2 (thermal balance analysis), the most significant difference between the original design and the redesigned building is about thermal balance. According to the result of the analysis, the new design has much more solar energy approximately 50% gain than the original design. But, it is also based on the new shaping of the building and function not about insulating power parameters. In addition, this case shows to architects that a building's correct form plays a most important role in energy efficiency. Moreover, this situation can be seen in the (Fig.2.2, solar radiation analysis), according to this analysis, the new design gains on the all facades much more sunlight than the old one. This is a result of the new shaping of the building.

In accordance with monthly thermal balance can see in Table 2.2, because of the shaping changes of the building the redesigned building higher gains related to passive systems of solar energy use (yellow colour in the diagram). And also, when we compare the original design and redesigned building by the losses of ventilation point of view (Table 2.2, green colour in the diagram), the original design has fewer losses approximately 11%. The thermal balance of the buildings does not precisely account for the use of warm air from a conservatory in the ventilation system.

5. CONCLUSIONS

The 21st-century designs of public utility buildings should always be energy efficient and feature other pro-environmental solutions. Energy efficiency must not be an element supplemented in a technical design through an increase of thermal insulation layers and the application of glazed surfaces of higher thermal transmittance. Addition of liquid or photovoltaic collector to a building becomes a newsworthy event. In the study, the analysis by *Ecotect* which are related to energy efficiency, find out the buildings' deficiencies from the energy point of view. According to these analyses, one of the main results is that the form and internal space layout have a significant impact on the energy efficiency of a building. Moreover, it is obvious that the buildings which have the same function but different form gain solar energy approximately higher 50% than original design (Table 2.1 and Table 2.2). Therefore, from the beginning of the design process of a building should be used in the passive solar system because of the getting energy efficient building. Energy efficiency further entails the right form and space layout of a building, and even function solutions, not merely insulation elements of external envelopes and some technical gadgets.

In addition, the special forms are used in the design to control the air ventilation and creating a courtyard which an intersection with indoor and outdoor so as to getting energy efficient building. According to this, in the study, the new design (Culture and Tourism Additional Building to Trabzon City Hall) has a conservatory to ensure good ventilation and gain much more solar energy. Also, on the conservatory's roof are used photovoltaic PV modules to producing electricity for the building's light and energy system. And secondly, the library building has a greenhouse too. But, it's located in the North-West direction. So, the new design of the north-west facade is formed an introverted design, not many windows in order to gain daylight. In addition, the southern facade is used Trombe wall. It is separated from the outdoors by glazing and air space, and absorbs solar energy and slowly releases it toward the building's interior at night.

As a main result of the study, architects act the most significant role in the design of the buildings' process to get energy efficient building. But, it must be thought from the beginning of the design building's concept. In the future, it can be said that the software's which are used in the design process of a building from the energy point of view such as *Ecotect* etc., is considered as a necessity in the design process.

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