Original Article

A Method For Evaluating Energy Retrofits In Historical Structures

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Abstract

Over several centuries, the energy consumption in the building increases with significant developing result in the growth of economic, population, temperature. Performances of energy in the building has been improved with reconstruction with efficient method based on the retrofitting of the building. Potential of energy saving has been consider at the same time with total energy in the account of the building. When it come to the improvement of energy in the historical building we have to treat in different way from normal building. The main aim of this study is based on the method that trans disciplinary to energy efficient in the historical building. To control the energy retrofit in the building a detail tool of simulation has been used. Based on the consumption of total energy, indoor temperature we can calibrate the simulation of energy in the building. The method that we used in this study helps to eliminate the value of cultural heritage. Then the consumption of energy effect will be validate with the gather packet of energy retrofits. Finally, the energy has been saved with any damage of the historical building.

1. INTRODUCTION

Due to the increase of consumption of energy that significantly leads to the development of economic growth and population over centuries [1]. Energy demand has been increased with overcoming the issue that essential that becoming the strategies that can be alternative. Energy source with alternative invention and seeking that share the substitution of bio fuel, solar and wind of the energy that use efficient that we promoting the energy sector [2]. Transfer coefficient heat overall with lower after 200 to build the roof and window that can be obligate the procedure certificate energy that accelerate performance of building energy [3]. Material and local resources were used in the built traditional historical building. That inaccurate drawing and unknown layer of the building. In Europe the historical building are emission of CO_2 and energy that reduce simulation packet planning was passive house. Field measurement and simulation were based on the analysis of side effect of saving energy and development of insulation stalling method of retrofit historical building [4]. The building utilization and value of historical preservation was consider to perform the retrofit, the packages of retrofit was energy efficient through use interdisciplinary suggestion and retrofit the energy saving in the building that realize the architectural value to maintain the historical requirement of the building [5]. The building cultural value has been preserve to exterior change which is not possible due to the historical building with wall exterior that could affect the action of retrofit does not perform energy efficient process [6].

New building and existing were referred as BEP-TR. It has been paid with historical building that retrofitting the energy efficient that no specific attention. Minimum intervention that stipulate and building heritage that originally characteristic that prevent the broad prioritized. The condition comfort the contemporary energy performances that regulate the constitute that makes country with historical building propertied high various. New function will be intervention to minimum stipulate and building original characteristic that prevent board priorities. EPBD is based on heritage value of the building that affect historical heritage that will not affect and authorized the authority of the corporate the heritage value of the intervention and retrofits with energy efficient of the BEP-TR [2].

The heritage value of the account is taken with the building of historical intervention that efficient with energy of retrofitting which investigate in this study. The orphans with door serve has the child protection and directorate social services the ministry general with donation. By the research that taken done department of architectural restoration supervised and we prepare the restore project undertook financially. Strategy trans disciplinary and systematic that integrated tool simulation energy calibrate building and validate the management usage that should retrofits the energy of historical building under the current literature contribution. Saving energy perspective for interpreted and they have been applied with proposed method, the requirement co-efficient heat transfer and value heritage impact. The trans-disciplinary historical building retrofitting energy efficient that consider under the historical building.

II. LITERATURE SURVEY

Tor Brostrom et, al., (2014) [7] this paper is based on historical building in Swedish with energy retrofits consequences for potential with assess method. The built heritage effect and target energy political among interdependency that investigate with aim of Swedish historical building that energy efficient policies and potential Swedish research. Historic building in the stock with energy performances has been improving consequences and potential assess that method interactive and iterative with paper present. The vulnerability of assessment qualitative and optimisation techno economic assessment quantitative among interaction with method allowed. The decision context the conservation building and conservation energy best balance that arrive solution it is possible and dialogue multidisciplinary.

S. Tadeu et, al., (2015) [8] this paper is based on cost-optimal solution with environmental assessment with historic building of energy retrofit. From the beginning of 20th century that date of the building the packages energy efficient were involved in alternating environmental assessment and cost optimality integrated of implementation. The methodological present illustrate has been used with centre building stock of typical building. For an apartment the measure of energy efficient assess was implemented with model life-cycle. The optimum cost of 50 mm and 120 mm insulation thickness insulation that can be obtained with environmental impact of lowest life-cycle. The global cost reduction or energy efficient that do not improve the insulation thickness insulation. The historic character without changing can be achieved the saving energy of the significant of energy codes with building that do not have historic building.

Cristina Cornaro et, al., (2016) [9] this paper was based on the historical building case study of energy retrofit for measurement on-site and dynamic simulation. The historical value and great artistic has great building complex and extended of solution evaluate refurbishment that simulate dynamic and measurement on-site. During centuries they built complexity construction of great historical building that successfully applied the approach, the styles and technologies construction various with superimposed. Various superimposed structure with large estate were consumed the thermal parameter in situ measurement that often build the ancient characteristic masonry. The problem has been overcome with measurement of temperature with indoor dynamic model with specific calibration. The value of building on the historical without impact solution adopting refurbishment adopting has been demand to improve the approximate value of energy.

Francesca Roberti et, al., (2017) [10] this paper is based on process hierarchy analytic and optimized multi-objective used by historic building of conservation and energy retrofit. The local heritage authority to perspective the reflects and qualitative intrinsically compatible conservation, the model energy used to evaluate quantitative that can comfort thermal and energy retrofit building historic that we decided. The quantitative way and multi-perspective building for historic retrofits optimal comparing and finding permits methodology. Ventilate cooling and replacement of window improvement of airtightness insulation envelope internal and external with different kinds that consider retrofit measurement. The compatibility conservation to cover the whole range of optimal retrofits was portfolio. Heritage degradation at the cost achievable are saving with higher energy.

Galatioto A. et, al., (2017) [11] this paper is based on historical building in Italy with feasible action of energy retrofit. The country throughout their application and regulate building energy efficient in keystones important to determine energy policy. Energy saving potentially greatest with context historical especially with territories and societies sustainable to make the order how to work. Here, it is reviewed the building heritage residence in Italy were state of the art, the experience were collected investigated with viable solution and issue retrofit while energy, the area thematic building is historical to measure retrofit to focused.

Livio Mazzarella (2015) [12] this paper is based on regular view point of legislative with building existing and historical retrofit energy. The energy use building to reduce the building aim that efficient with energy indirectly and directly with directive dealing that enacted the energy consumption of building sector. The regime derogation has adopted with specific uniform with heritage architectural that do not take care of existing building. For building existing the requirement efficient with energy respective exclude building were include with own rules. Valuable building architecture and historical with energy retrofit that are available with standard and no general rules. The energy retrofit and energy deals with conservation heritage fields' architecture with act international.

Mohammed Tahsildoost et, al., (2015) [13] this paper is based on school building in Tehran with typical study of experiment with technique energy retrofit. In this sector with discomfort thermal and consumption of energy that solve effective with educational building energy retrofit. Technique implement that assessment and time payback and energy simulation was based on scenarios prioritizing with optimization, proposal retrofit presenting and assessment performances building preliminary was the tree steps procedure. Achievement energy assess the order that monitor the school with thermal environment and consumption of energy that implement to select measurement. The retrofit project is the process of making the decision that could support the method that we proposed the result with pilot study.

Aurora Greta Ruggeri et, al., (2020) [14] this paper is based on Decision support system with stocks building historic retrofit planning energy. The cultural heritage of tailored campaigns energy retrofit management and plant to order the development in support system decision. The environment quality impact and intervention compatibility with cost and energy. Agencies or managers portfolio as well as investors private or public assets holders with useful that could be procedure that making decision that providing perspective. Process hierarchy analytic and costing life-cycle, analysis multi-attribute with technique appraisal with different integration and procedure selection with aspects conservation with assessment with work that achievement is most important.

Belen Onecha et, al., (2021) [15] this paper is based on historical building new kind values that sustainable with historical value and beyond culture. Heritage preservation that responsible with authority that imposed restriction. The public policies with conventional channel has been removed with performance certificate energy issue that regulate current requirement of energy efficient that strict compliances the building protected with exclusion. The use of residential has been developed privately that intended especially that delicate situation with high heritage. The comprehensive analysis were through heritage building with cultural value an energy performances with establishment trade and assessing methodology. The building of element that protected the effect intervention analysing, criteria intervention defining, cultural value, and legal requirement were the building performances of the configuration that deep knowledge the building.

3. BUILDING CASE STUDY

With three level of refinement the investigation of the building has been carried out. The historical area of the classification of entire refinement has been classified with the building material and topology. The area general plan were used with the carried out investigation, the exterior for observation of visual and municipality were available with it. Each area is independent with address that have been distracted with material and typology of the building and area distinguished with two possessed with historical center. The envelope building is survey with damage that setup the subsequence that has been used with refinement of second level, the available resource and center historical with large size relatively. The building envelop has been analysis with further select that have two main street and the wall inside the area is completed. They carried out previous level and found the defect with literature in toot damage with classification that carried out with exterior from visual inspection again. They consider the refinement of sample with third level, building stock with indoor conditions that analyzing that consider the aiming. A deeper characteristics that aim was selected with wall that have been within the house inside around 25%, with measurement of hydrothermal and damage source manifestation damage that specially focused. Filled and prepared has been special with houses, the inhabitants were interview and observed that requires indoor. The coldest period among the day consecutive that carried out air humidity with air relative and temperature measurement. Bedroom and living room in the kitchen separately. A battery, internal memory, humidity relative air and temperature air measure with internal sensor that produce the used equipment. The humidity relatively used the temperature with air equal or greater than 0.5 degree Celsius with equipment that precision. That can be compared with different result, the level floor above 1.0 m placed that has been equipped and every hour that have been register with reading [16].

3.1 Historical building characteristic

In the first century that inhabitant already with old document and Portugal with location with city. The Atlantic coast and large cities that far away with being location, maintained region through with different access, powerful and wealthy with city that never access with it. The building exit with some monument through some of the modest and it is simply modified the results of ancient building. The inhabitants and houses were totals 0.33 km^2 with area center classified historical. Distinguish clearly with two area: the wall outside another ad wall inside the clearly distinguish. The houses weather with most spacious the wall outside large grew with oldest part of the city. Rain considerable with harsh rather than condition of climate and temperature various based on the season [16].

3.2 HVAC system

The system ventilation mechanical and it was not cooling the central system of heating. Because of this they desire the occupants of ventilation naturally. In terms of heating this consider the building system. The basement location with the maximum capacity of 30kW of water is boiled in the fuel-fire-oil based on heater system of the building. 60cm x 120 cm which is the same dimension of all the rooms that located with radiators with system of hydronic through circulation pump with building distributed with hot water. Temperature that return/supply with 75/55^{0}C and temperature of indoor air system is 22^o C that can be operated with condition of average radiator capacity with 2kW of heating rate [17].

4. METHODS USED

In historical building in conduct that process with described method, explain with one by one. The detail explanation of model building energy simulation. Then the given work of calibration has been done with basic model of simulation that significant. Investigation and defined with value of building of heritage historic that accordance's with EER scenario.

4.1 Model Building Energy Simulation

Design building of interface that has been drawn using 3D effect calculation with solar gain that effect that share quality from neighborhood along with modelled effect [18]. The field survey through and technology of restoration architectural department were observed the dimensional and plan architecture. The volume and shape of building was irregular with many order were compared with geometry regular relatively based on building tools of BES that drawn surrounding the building Traditional. Zero is assumed with case building and adjacent building among temperature. Conditioned and occupied were in those building and simulate the rune time to reduce the adiabatic building that assume the reason.

4.2 Methodology of Calibration

The actual building that consumption of energy is to reflect among calibration that should simulate energy of the building. The data simulation and measurement of temperature indoor air among comparison that make simulation of result consumption with utility ill that can compare the calibration that make common way of literature. The model relative to input by changing the model with tune that calibrate simulation conduct thw way you suggested [19]. Time interval that desired the measurement of dry temperature bulb outdoor and indoor. The data weather with integrated DBT measurement. The run simulation were modelled in the building. The value measured with compared result simulation [20]. The limited error within the simulation result until the tune of these parameter.

$$MBE = \left(\frac{(\sum_{a=1}^{n} Residual)}{n}\right)\% \qquad \text{-- (1)}$$

$$RMSE = \left[\sum_{a=1}^{n} \frac{|t_a - o_a|^2}{n}\right]^{1/2} \qquad \text{-- (2)}$$

$$CV\left(RMSE_{period}\right) = \left(\frac{RMSE_{period}}{A_{period}}\right) \quad \text{-- (3)}$$

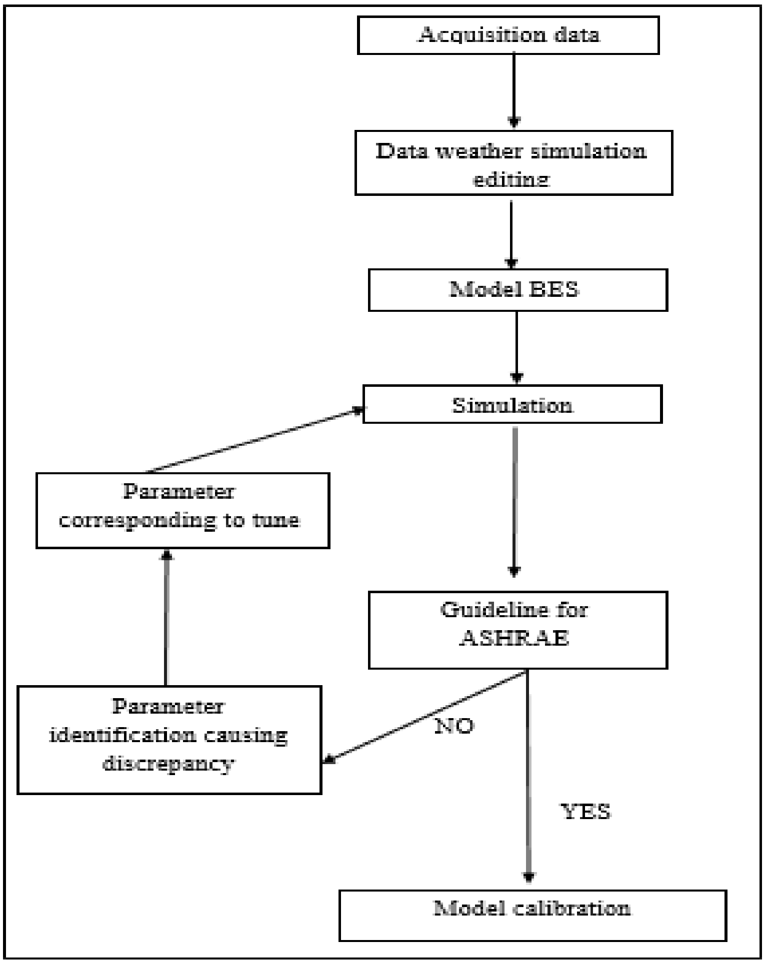

Figure 1: Methodology of Calibration

4.3 Methodology of Retrofitting

Characteristic should be investigating the building based on methodology. We should be characterized with priorities and targets. The assessment criteria were due to inappropriate elimination to assess and introduce the retrofits the long list benefit assessment and risk it. The target multiple due to meet mainly ackage into the gatheres with retrofit with appropriate short list. It is terminate the assessment with target based on the acknowledgement. They can be obtained with required result with sequence iterated and adjusted with previous step.

4.3.1 Characteristic of Building

Building case use heritage value that define characteristic purpose. The building envelope is regarding especially with related component that focus on energy of the characteristic like door, wall, shutter, and floor.

4.3.2 Targets

Building conservation and energy were implicit or explicit the object of EER. The following are the target that selected for the case study.

1. Energy saving target:

- primary energy consumption is total with 20% reduction
- primary energy consumption is total with 40% reduction

2. U value requirement:

- Wall: 0.70 < W/m^2mK,
- Floor: 0.70 < W/m^2 K,
- Roof: 0.45 < W/m^2 K,
- Windows: 2.40 < W/M^2 K.

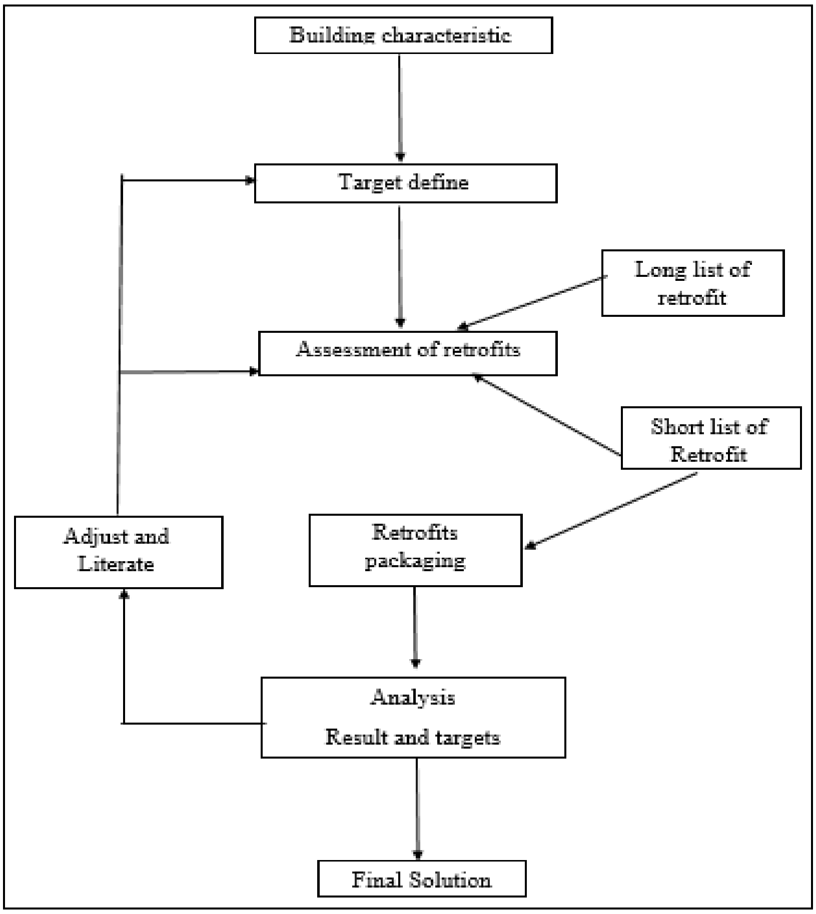

Figure 2: Retrofitting Methodology

3. Target of building conservation

- Construction with change material
- The appearances of building on change of no visual

5. RESULT

5.1 Calibration

Each room temperature has been measured with result and run simultaneously with data of temperature of outdoor measurement of similar weather data. Period of measurement within the sequences is DBT indoor and measured comparatively. Figure 3 represent the period varies with temperature with pattern parallel to data simulation and measurement [17]. Table 1 represent the model of BES after calibration of each room. Figure 4 represent the simulation result and utility bill of electricity competition. On auxiliary heating it is highly depend on consumption of electricity with heating degree days that can be related to usage with actual variation. Based on the information monthly and annual consumption of electricity with similar pattern has been shown in HDD. The electric appliances and lighting were interrelated with heating season with consumption of electricity.

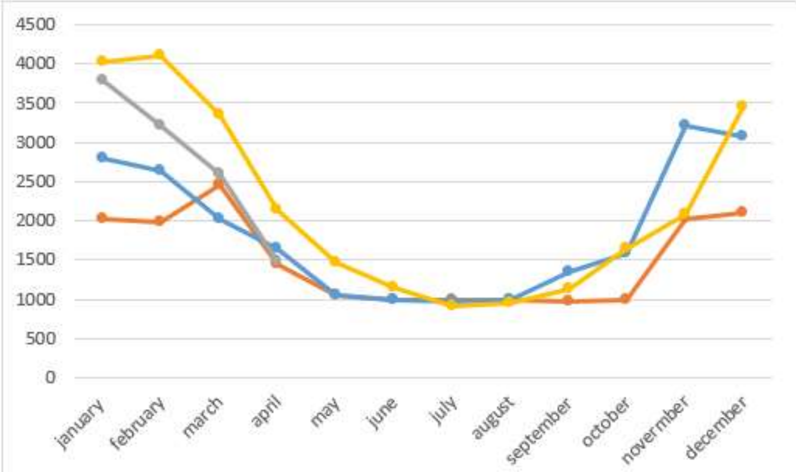

Figure 3: comparison of simulation data and measurement

Table 1: Calibration error of model BES for each room

Space	MBE (%)	CV (RMSE) (%)
Administrator Room (Z01)	2.1	5.4
Classroom (Z02)	0.8	2.5
The Scouts Room (Z03)	2.0	3.6
Guest Room (Z04)	1.6	2.9
Corridor (Z05)	1.0	4.5
Administrator Room (101)	4.6	5.3
Ironing Room (102)	4.6	5.2
Sewing Room (103)	2.5	3.5
Marbling Room (104)	2.3	3.0
Corridor (105)	6.0	6.9

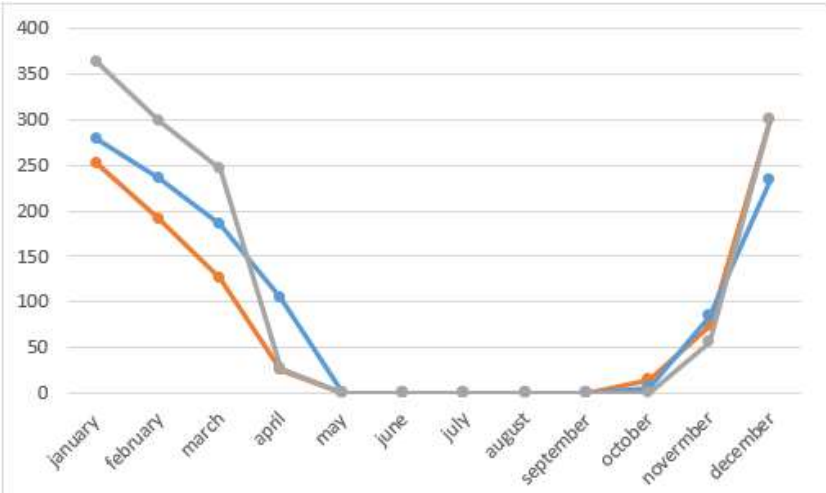

Figure 4: Comparison of result of simulation and electricity utility bills

The consumption of fuel oil is consider for calibration simulation of other criterion. Build administration was obtained with information, the monthly basis were not monitored with space heating with consumption of fuel-oil. Annual figure respects the calibration. Result of simulation based on comparison shows 1700 kg fuel oil/yr, cactual consumption of close reasonable fuel oil/yr is 1750kg.

5.2 retrofits Assessment

Intervention of EER is possible in wide range. Cheap application and straightforward envelope were built with improvement of air tightness. The draught through occur with heat loss that reduce the benefit to prove high benefits. It reduce the building envelop with exchange rate with mold growth with risk increase that might cause risk. The view of aesthetic were high risk with doubtless u value having window exchange replacement and heat losses can be reduce explicit through case building with heritage value. Period pay-back with long term with change in window of economic perspective.

Building appearance with no damage risk due to case building with acceptable solution that expected floor insulation. Temperature decrease with moisture result in increase in environmental attic. Simple application of roof title will be refitting the building fabric with low risk that appear on insulation layer which added extra. Identical architecture and symbolic value of building effect is strong that would retrofit the energy efficient which is highly favorable with external insulation. The architectural value of the building insulation extract when compare with less risk insulation of interior wall. The heating intermittent perspective the heat inside the saving proposal of great energy. The retrofit acceptable to assessed to insulate might interior.

The floor patter has two different partly that is available with ground floor, the ground floor corridor longitudinal with marble and timber room pattern, the ground floor corridor with longitudinal marble and rooms with timber wood. The floor construction below the space installation is enough with appropriate application. The necessary restoration was placed with fuel oil that boiled with low and old efficient with system radiator hot water in building that was undertaken in study. Inefficient operation reduce for refurbishment of good gas boiler with natural condensing, and high efficient switch. It is relatively high with initial investment retrofit although cost effective with heating system. It is obtained that short list of retrofit with elimination of retrofit with assessment of risk-benefit. Energy consumption that combine effect to evaluate and target to meet the packet that gather the appropriate one following section.

5.3 Retrofit Packaging

Risk-benefit analysis through evaluate with retrofit energy efficient to threat and strength. The following are the retrofit application that short list the appropriate.

- Stripping weather
- Control temperature indoor air
- Type of fuel system that changing heating
- Floor insulation of attic
- The roof of additional insulation
- The wall of interior insulation
- Ground floor to additional insulation

A 0.1 ACH envelope with building air tightening was refer with stripping basically. Material and technique appropriate to leak and crake to fill to aimed. Unoccupied and occupied when 20^0 C and 24^0 C with environment indoor to control aim of temperature indoor air. By natural gas it driven with efficient boiler that installed indicate heating system that change. Insulation material that we proposed the wool stone that related to retrofits that insulated. The methodology of ideology that understand to better package tht include the elimination and risky assessed to retrofit.

The heritage value that damage and appearance in altering building without energy target with package 1. The package within was not included the thermal properties with regarding building. Package 2 the building thermal performances were improved with intervention. Package 3 energy saving were maximum possible to determine the international group.

5.4 Analysis of In-depth

Energy source in the building are use from electricity and fuel-oil. The retro filling the application of electricity, pump circulation, heating auxiliary were used for electricity space heating. The retrofitting before BES tool calibration that obtained the building with consumption energy that share primary illustration from the figure 5. Better understanding the demand with heating system will defined the given necessary point. Desired condition under the indoor environment to keep the building the system by heating the supplies that should be with amount of energy that demand heating system.

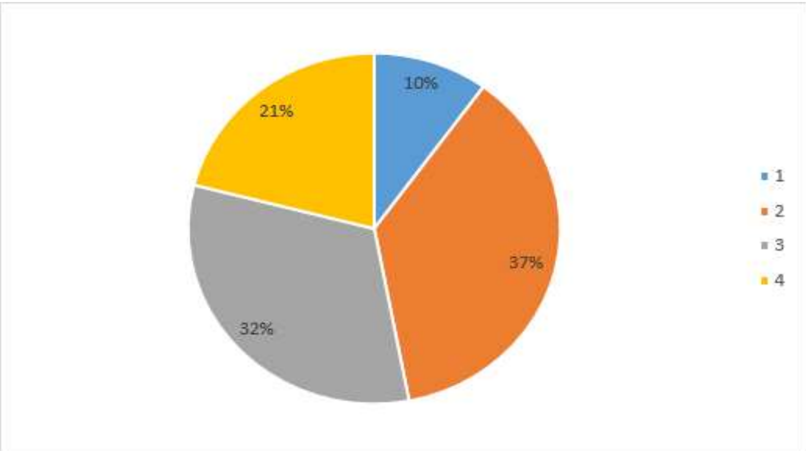

Figure 5: primary energy consumption

Where,
1= Electrical Application
2 = lighting
3 = Heating
4 = Auxiliary Heating

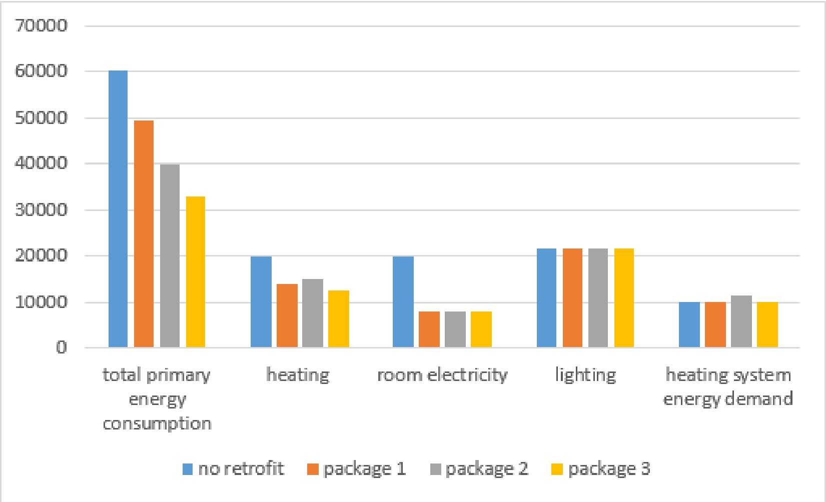

Figure 6: package basis with EER result comparison

The result of conservation perspective conservation from building that change irreversible and destructive that can be accomplish energy target that indicate in the packages. For ages he carried the building of memoirist and record tangled with appearances in building that destroy the heritage value that prominent the change. Energy consumption effect individual to evaluate the simulation with single retrofit. In the evaluation that include the impact, a retrofit that was not counted the system heating the auxiliary through discard.

Figure 7 represent the package basis and consumption of energy primary with basic retrofit with single effect of cumulative. The consumption of energy that regards effective reduction with 24.8%. Based on figure 7 effect of accumulation of reduction of single energy on corresponding basic package with 35%, 41% and 51%. Figure 8 represent the consumption of energy with total annual single retrofit with effect of commutation and combined the comparison. During summer season the consideration is cooling with Aegean region. Energy consumption cooling and heating with taking the assessed EER. The cooling load with EER impact to show a favorable based on the interest in primary consumption of energy heating.

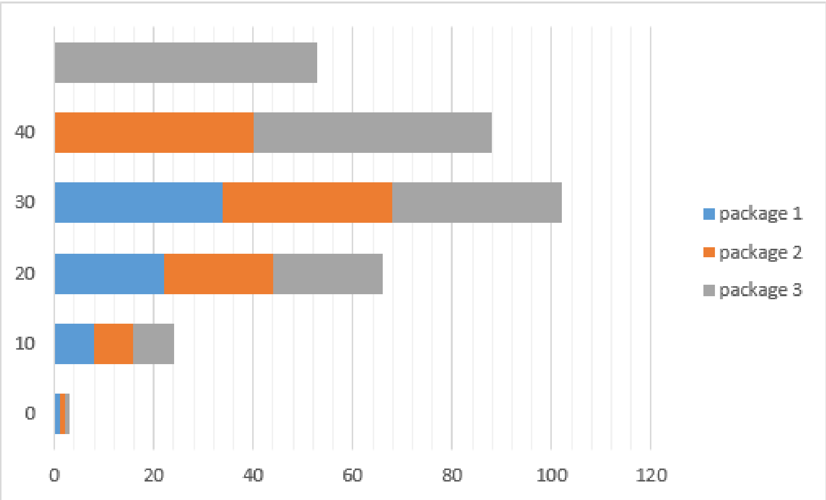

Figure 7: package basic with single retrofit in cumulative effect

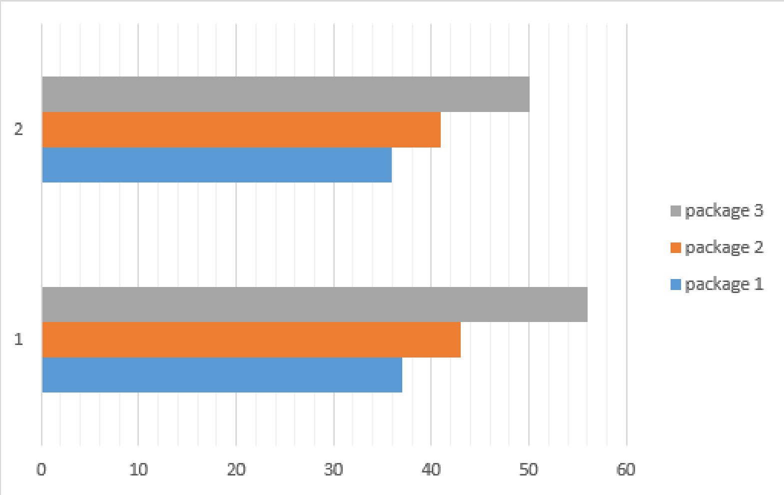

Figure 8: comparison of retrofit that effect cumulative and combination

For each EER they calculated the comfort zone within the each point rate with no case retrofit of 47%, the result of 1st packet is 57%, 2nd packet 52%, 3rd packet is 54%. The EER package has been improved with heating season that conform thermal within it. The comfort zone that dropped out based on two circle, that indicate with some point that can seen anywhere. Regime intermittent heating with the building based on big circle highlighted point is the reason behind it. Control humidity with relative that can acceptable temperature with condition that can be with indoor air that indicate small circle point.

6. CONCLUSION

In the recent past, the one built that can be compared with more energy that generate historical building. With modern life that reintegrate the great awareness and deliberate treated with value heritage carrying the building, unattended, undisturbed to leave with one conclusion. The heritage value with impact historical without unacceptable in season heating with building energy consumption to reduce methodology Trans disciplinary with investigated the building. The methodology about understanding good establishment with application that inappropriate that eliminated. This was selected with retrofits energy efficient with most common intervention based on literature collection. In the basement insulation heat and window improved, stripped weather like cheap one, non-destruction, simple impact detrimental exterior appearances affect measures indicate result. In thermal comfort improvement with measures retrofitting is recommended and case building analyzed that should comfort thermal with effect retrofitting. Laws and directives emphasized and historic building approach trans-disciplinary. Historic building improved efficient energy regarding no clear remembering.

Conflict of interest:
There is no conflict of interest.

Data availability statement:
The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

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