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The Effect of New Method of Drawing Energy and Exergy Flows on the Consequences Calculations Economic and Environmental Aspects

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Abstract

Nowadays, because of the large amount of energy consumption rates in buildings and the excessive use of fossil fuel and their environmental impact on the environment, as well as the rise of energy prices, which prompted the emergence of the concept of reducing energy consumption. Therefore, reducing the consumption of the amount of energy required in buildings has become one of the global requirements to reduce and rationalize the consumption of fossil fuels and the emissions resulting from them. This study concentrate on determining a rigorous way to plot the flows of both energy and exergy that have been drawn by several investigators. Flow reliability is important because of the subsequent calculations that depend on it, such as the analysis of economic. The current method is based on real measured data of each part of the heating system. The study objective is to apply the analyses of energy, exergy, economic availability, and environmental to the heating system of an existing, well-designed building. The flows of both energy and exergy from the generation to the envelope of the building were examined to determine the consumption energy, its cost and the resulting pollution. The calculations were made using the static building analysis method, as the reference temperature for the heating season was taken as -1°C and the temperature inside the building was considered as 23 °C. The analyzes were applied to the SCOLA building located in the Ozeygin University campus in Istanbul with a building volume of 42,000 cubic meter and a 15,093 meter square of floor area. The results assure that there is no difference between the values of input of exergy or energy entering the heating system for both methods 1947 kw and 1901 kw, respectively. Even though there are some differences in losses of both types of energies, efficiencies of distribution and generation, and economic calculations. The exergy losses of the generation stage in both methods are 878 kW and 788 kW, while the distribution phase, 258 kW and 43 kW, respectively. The results also showed that the availability efficiencies and the index of sustainability of both components (the generation and distribution) of the first method were 32%, 37%, 1.47, and 1.59, respectively. While these values in the seconds method were 34%, 78%, 1.52, and 4.55. They also showed that the energy cost, which was calculated by the new method is 62.52$, while its value in the old method is $67. The results also showed that when improving the energy efficiency to 94%, the total energy becomes 1784 kW for the generation and 1837 kW for the distribution. While total exergy and its cost decrease to 1566 kW and 52$, respectively by making the generation exergy efficiency equals to 42%. Moreover, improving the distribution exergy efficiency to 86%, the amount of total exergy and the total cost become 1825 kW and $60.32 respectively.

Keywords: Energy, and Exergy analyses, Exergoeconomic, Low energy buildings, Sustainability.

Introduction:

The concern about the ways of using fossil fuels that can be depleted in close future, the world tended to search for sustainable energy sources to meet the increasing demand for them all over the world, especially industrial ones. The excessive use of these types of fuels has caused many environmental problems such as global warming and the increase in CO2 emissions resulting from the energy production process [1]. In addition to the industrial sector, the amount of energy required in the building sector in the world is now costing the world a lot of money in planning, coordination and design processes to find the best in terms of production, efficiency of consumption, cost of economic consequences and places to land the waste of this fuel. The problems of increasing energy consumption and its negative consequences are no longer a secret to society in the world [2]. Despite the growing interest in these topics, fossil fuels and faint-efficiency tools are widely used in many places around the world [3]. A large amount of world energy demand is consumed in non-industrial buildings such as residential buildings, government departments, hospitals, schools and others [4]. Given the importance of studying the issue of energy consumption in buildings and its impact on reducing global energy demand, many countries have sought ways to reduce this high percentage of consumption in parallel with working to raise the efficiency of power plants. Buildings are identified as one of the most main consumers of energy in the world [5]. For example, in the EU, the building aspect represents 41% of the total energy demand and 35.7% emissions of CO2, and it represents the highest source of buildings emissions in Europe [6], [7]. 50% of the energy demand UK is only for heating [8]. Thus, energy conservation and environmental protection became essential requirements [9]. There is a large consumption of energy in buildings through lighting, heat losses transmitted through walls and windows, ventilation losses, and electrical energy used in cooling and heating systems. Therefore, the whole system, which includes all sub-components, must be studied [10]. Some studies showed that the exergy aspect calculates the dynamic losses that were not determined by using energy [11]. In this regard, the exergy analysis method facilitated the analysis process and gave a well figure out of building energy consumption. According to the initiative of SBCUNE program, which made buildings and construction an opener sector for sustainable development, and this aspect represents a great opportunity to enhance the buildings performance [12]. In addition, exergy plays a key role in enhancement and sustainability, because it is one of the best ways to decrease resource consumption and reduce availability loss by improving this stage exergy efficiency [13]. The objective of the (ECBCS) program is to push the intellectual use of energy by Spreading the culture of low-temperature heating and high-temperature cooling systems use in buildings [14]. Due to the importance of the topic, many researchers, engineers, designers, and energy workers in most countries of the world went to find appropriate solutions and good ways to calculate the energy consumed in buildings in analyzing buildings and charting the energy path through the components of buildings to control the global energy demand[15]. To achieve the aim, we need to analyze the components of buildings and this is done through exergy analysis, which is the best method used because it applies both the first and the second laws of thermodynamics. In order to review what has been done in this field, a group of studies and researches conducted for the purpose of improving and developing the performance of building conditioning components were collected, including among these researchers. Then the researchers [16]conducted a study in which they developed a model of energy work and exergy based on energy use for building and construction service designers. This model provides a simplified description of the energy and exergy required for buildings. Heat transfer and ventilation this module focuses on heating loads for non-industrial building systems. This paper presents a model of building analysis, the model that was selected to be applied on an office building in Germany, which was studied to help building and construction services designers to have an adequate idea to get the best options that can reduce the energy. After a period of time, the researchers [17] offered a paper on the method of space heating analyzes of buildings. The heating load was considered, while the cooling season was not. The study dealt with the energy and exergy analyzes in which three different heating systems were used in the city of Izmir, namely the conventional boiler that runs on liquefied natural gas (LNG), the condensing boiler of liquefied natural gas and the air heat pump. 11.26 kW was the largest power input to the system occurred when a conventional LNG boiler used. While 7.52 kW was the lowest energy demand when using the air heat pump. Also, the lowest losses occurred in primary step when using the condensing boiler. The largest energy loss in the same phase when applying the heat pump. During this period, the two researchers (Zhentao wei, Radu Zmereanu, 2009) [12] conducted a study on the systems used in the adaptation of buildings. In this study, available energy analyzes are used to evaluate two types of (VAV) systems. Two cases of variable Air volume systems are simulated. The first uses the inlet temperature, while the second system uses differential inlet air temperature. The results showed that the annual simulation of the energy used at a site of the first (VAV) system is 133 kwh/m^2, while its value in the second system is around 103 kwh/m^2. At the same time, the two researchers (Jong - Jin Kim and Jin Woo Moon, 2009) [18] conducted a study to determine the effect of insulating different buildings parts on the consumption of energy. A quick power simulation software (EQUEST) was applied to analyze a building. A series of parametric simulations were conducted to obtain energy consumption data for a two-story single-family apartment building with an area of 185.8 m^2 in the United States. The test building simulated two climate zones (Michigan, Detroit, Florida, Miami). Simulations were performed to isolate three different parts of the building envelope: walls, roof, and windows. The study concluded that in cold climates, insulation is useful to reduce heating energy in winter, while the minimum necessary insulation level means any additional insulation will not be useful. At the same stage, the researchers presented (P.Skulpipatsih et al., 2010) [19] a procedure of analyzing buildings and its conditioning systems. This method studies an office of 300 m^2 with high performance conditioning systems. Through the results obtained, the heating loads is greater than cooling. Also during this phase, researchers (M. Tolga Balta et al., 2010) [20] conducted a study of four options for the heating systems used for this building. The researcher compared between the performances of all these options. Also during this period, the researchers (T. M. I. Mahlia et al., 2011) [21] conducted an exergy analysis study for three exergy systems. The aim of work is providing a clear figure out of energy consumption during a day. In the same period of the year, the researchers (Cem

Tahsin Yucer, Arif Hepbasli, 2012) [22] presented a study of the application of the method of residential building analyzing the exergy and Exergoeconomic for heating a dwelling by the traditional boiler. Both flows of all phases are drawn to design a high-performance building. To provide an insight of building performances usefulness, the researchers used (Zygmunt Wiercinski, Aldona Skotonicka, 2012) [23] exergy balance as well as energy balance to evaluate different building types. The study showed that the exergy losses a low-energy house is much less than that of a classic home. It was found that the total energy demand of a conventional house is almost twice higher than that of a low-energy house. After this period, the researchers (Cem Tahsin Yucer, Arif Hepbasli, 2013) [24] conducted a study of the application of the exergy and Exergoeconomic analyzes of the building. In this study, the performance of the building was evaluated. The two researchers (Nurdan Yildirim, Arif Hepbasli, 2014) [25] submitted an inclusive analysis a sustainable buildings. The main objective is to evaluate its performance. Apply Lowex's method. Two cases of heating systems, the first case of a condensing boiler and the second case of a heat pump, were used for comparison purposes. The total energy efficiency of the two cases was calculated and was 49.4% for the condensing boiler and 54.7% for the heat pump. Also, the required exergy rates for heating systems were determined and were 5.33 kW for the first case and 5.35 kW for the second case. The researchers (Raaid Al Doury et al., 2020) [26] conducted a study to find a more precise way to map the flows. Energy and exergy flows are substantial because of the consequences calculations, such as Exergo-economic analysis. The goal of the study is comparing between the classic and the new one. The second way gave more proper results in the calculations of losses, energy efficiency and exergy.

Problem Statement:

Since 2004, the method of determining the efficiencies and loss of the building components have not improved or investigated in different way. The method used by most researchers, which is based on the Schmidt 2004 research method, provides a graph of the energy and availability streams, through which both losses and efficiencies of building vehicles are calculated, and the points before and after the specific part are considered energy and availability in and out of the part of the heating system. The truth is that part of this energy or availability is directly consumed and cannot be considered within the energy entering this particular part, and this results in inaccuracy in the results. Hence, this point has been considered as a problem for research which will be investigated and discussed.

Objectives of the Research:

Determining the real losses of any part of the air-conditioning system, through which its efficiency is determined, leads to more accuracy, because the result of any improvement in the efficiency of this part will be tangible and clear because it will take into account the real entry and exit quantities of energy and availability. Determining these real competencies will lead to accuracy in subsequent calculations of the resulting environmental and economic impact. Therefore, it will be a more accurate method in the calculations of losses and efficiencies for the parts of the buildings and the air-conditioning systems used is the main objective of this research.

Information of Energy flow:

The energy flow that can be seen in Figure (1) explains how the building consumes energy. Seven points of the energy flow path were added one after the other. Where the first point represents the energy of the source, while the second symbolize two types of energy (fuel and electricity). At the second point the electrical is consumed directly by the building purposes lighting, appliances, and ventilation and so on. It is not correct to consider it as a part of the energy input to the second stage (Generation). The second note that should be explained is point (3), hot water represents the output energy of the second stage which is used for two objectives: The first is for warming that inters to the distribution phase and the rest is only for DHW. It does not make a sense considering DHW power as part of the power input to the distribution network. In the rest phases (4), (5), (6) and (7) all output energy enters to the stage so there are not any.

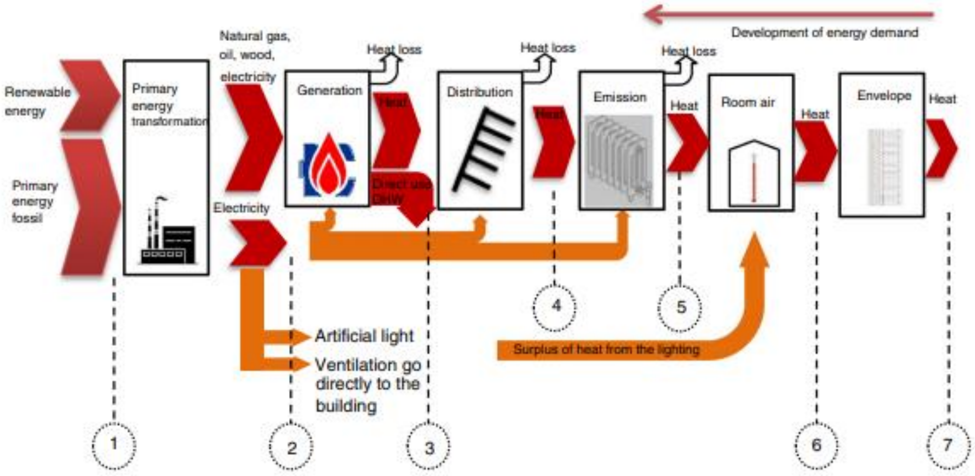

Figure (1). The energy supply chain in buildings.

Methodology:

The simple idea of a new methodology in general is identical, but there is a main variation. This difference is that areal values of input and output energies of all components should be counted carefully. This point specifically and through the previous chapter is absent from the previous studies submitted by all researchers and it is the one that will be focused on in this study. In order to clarify matters in more detail, we include Figure (2), which clears how the real energy passes over the components. Where the first spot represents the source energy, this energy consists of two energies, which are electrical and fuel energies in steps (2) and (2*). Where spot (2) is the sum of these types, while only fuel energy still to enters the generation in spot (2*). The energy that leaves the generation at spots (3) and (3*) is only warm water. The energy at step (3*) is the heating energy that enters to the distribution. DHW is the variation between spots (3) and (3*) that consumed for the only domestic warm water. The rest parts of the building are identical to the previous method, so the article going to focus on distribution and generation stages.

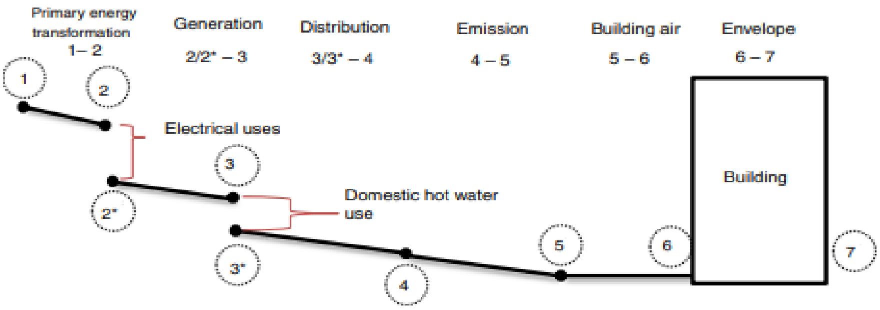

Figure (2) how real energy pass through the buildings parts[26].

Building conditioning system descriptions:

The chosen building has been designed well to be one of the best buildings in Türkiye[27]. The work has an assessment of the energy and availability performance. Where the building area is 17756 m^2, while the net area is 15094 m^2, while the building volume is 42000 m^3. And the area of the external walls is 3788 m^2 of the building the overall heat transfer coefficient of the outer walls (U= 0.6 $W/m^2.k$), the windows consist of double glass and an aluminum frame, and the total area of the windows is 2858 m2 (U=1.3 $w/m^2.k$). 3650 m^2 area of insulated roof (U=0.4 $w/m^2.k$). The floor area is 3650 m^2 the floor heat transfer coefficient (U=0.3 $w/m^2.k$). And the total door area of the building is 80 m^2, and the doors overall heat transfer coefficient (U=2 $w/m^2.k$).

Mathematical analysis:

The following figure shows the energy flow processes resulting from transmission and ventilation through the building envelope to the surrounding environment, indicated in red, and the gains mainly from solar through the glass, and the internal heat gains from the building occupants and devices inside it, indicated in green. The heat source to meet the heating demand is shown in blue. These main processes that occur on the building and represent two types of energies are losses and gains (Schmidt, 2004)[1].

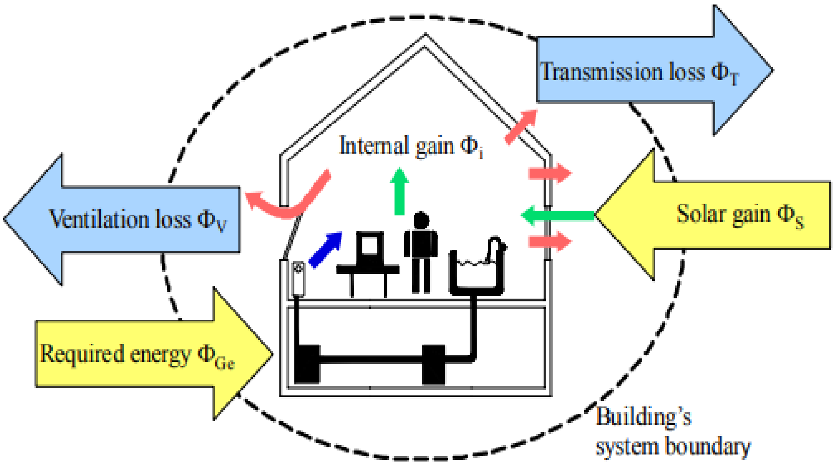

Figure (3) A schematic diagram showing the processes of heat loss and gain in the building [1].

Whereas, the advanced procedure is depended on the energies and availability of the real inputs and outputs for each of the generation and distribution stages. To determine the heat load, the loss must be estimated firstly. Thus, heat losses over the envelope are divided into ventilation, transmission, and leakage losses. It includes heat transfer losses through walls, windows, ceilings, doors and floors, and heat loss is calculated according to German energy conservation regulations [28]. The transfer average of heat loss that can be determined by`d2.

$$\Phi_T = \sum(U_i \, . A_i \, . F_{xi}) \, . (T_R - T_0) \tag{1}$$

Where Φ_T (W) is the thermal losses of the building, U_I ($w/m^2.k$) heat transfer coefficient for any part of the building, A_I (m^2) area of each of the following sections (walls, ceilings, windows, floors, and doors). T_R (k) is the room temperature and T_O (k) temperature of the outside environment, F_{xi} is the temperature correction factor.

The ventilation heat losses are calculated through the following equation:

$$\Phi_V = CP_{air} \, . \rho_{air} \, . V_{build} \, . n_v \, . (1 - \eta_v) \, . (T_R - T_O) \tag{2}$$

Where CP_{air} ($kJ/m^2.C^0$) is the specific temperature, ρ_{air} (m^3/kg) is the air density, V_{build} (m^3) is the building volume, n_v is the rate of Air replacement, η_v represents the heat recovery efficiency.

The leakage losses are calculated by the following equation:

$$\Phi_{inf} = CP_{air} \, . \rho_{air} \, . V_{build} \, . n_{inf} \, . (T_R - T_0) \tag{3}$$

Whereas n_{inf} is the represent the dropout rate.

The acquired solar energy can be estimated through this formula:

$$\Phi_S = \sum(I_{s.j} \, . \left(1 - F_f\right) . A_{w.j} \, . g_j \, . F_{sh} \, . F_{no}) \tag{4}$$

From this equation, $I_{S.J}$ (w/m^2) is the radiation of the sun, F_f is the frame to glass of window fraction, $A_{w.j}$ (m^2) is the area of all windows, g_j is the transmittance of glass, F_{sh} is the shading effects correction factor for surrounding buildings, and F_{no} A radiation correction agent that is not perpendicular to the window glass.

The occupancies load can be estimated by this equation:

$$\Phi_{i.o} = N_{O_{ecc}} \, . \dot{\Phi}_{i.o} \tag{5}$$

Where $\Phi_{i.o}$ (w) are Occupancy loads, NO_{ecc} is the number of people occupying the space, $\dot{\Phi}_{i.o}$ (w) the represent energy per person.

The lighting load is also calculated from the following equation:

$$P_l = p_l \, . A_N \tag{6}$$

Where P_l (w) is the lighting load, p_l (w/m^2) is the specific luminous energy per lamp, A_N (m^2) is the net floor area.

The energy added to the building by the devices used can be estimated through the following equation:

$$\Phi_{i.e} = \dot{\Phi}_{i.e} \,.A_N \tag{7}$$

Whereas $\Phi_{i.e}$ (w) is the appliances load, $\dot{\Phi}_{i.e}$ (w/m^2) is the specific heat energy gained from the device.

Equation 8 can be used to determine the energy load:

$$\Phi_h = \left(\Phi_T + \Phi_V + \Phi_{inf}\right) - (\mathrm{P}_l + \Phi_s + \Phi_{i.o} + \Phi_{i.e}) \tag{8}$$

Where Φ_h (w), is the energy heating load demand

The required heating energy load is equal to the energy at points (7), (6) and (5).

$$E_7 = E_6 = E_5 = \Phi_h \tag{9}$$

Exergy at this spot (7) is zero because of the equilibrium with the ambient.

$$\psi_7 = 0 \tag{10}$$

During the winter season, the acquired internal loads are not added to determine the energy required during design because they are not guaranteed loads.

Using the method presented by (Schmidt, 2009) [29], it is now possible to determine the building exergy demand.

The exergy load for heating the building can be calculated:

$$F_{q.R} = 1 - \frac{T_O}{T_R} \tag{11}$$

$$\psi_R = \psi_6 = \Phi_h \,.F_{q.R} \tag{12}$$

Whereas ($F_{q.R}$) represents room air quality factor,(ψ_R) is the building consumption of exergy .

The equations and calculations will be applied according to a set of assumptions, which are:

1- The overall heat transfer coefficients of all part are assumed to be constants.
2- The temperature of the surrounding is constant.
3- As gains and not fixed, the energies that are internal gains of the heating process will be neglected.
4- For the same reason above, solar energy will be neglected during the winter season.

The temperature at the radiating surface (T_{heat}) is estimated by this formula (Moran and Shapiro 1998) [8].

$$T_{heat} = \left(\frac{T_{in} - T_{ret}}{2\,.\ln\left(\frac{T_{in} - T_R}{T_{ret} - T_R}\right)} + T_R\right) + 273 \tag{13}$$

$$F_{q.heat} = 1 - \frac{T_O}{T_R} \tag{14}$$

Where (T_{in}) represents the entry temperature, (T_{ret}) represent the return temperature, ($F_{q.heat}$) the quality factor is the heater air.

Also, the load of exergy on the surface of emission equals the exergy at point (5):

$$\psi_{heat} = \psi_5 = F_{q.heat} \,.\, \Phi_h \tag{15}$$

The first component that will be studied in the building conditioning system is the fan- coil. A Schematic diagram of the process can be seen in figure (4).

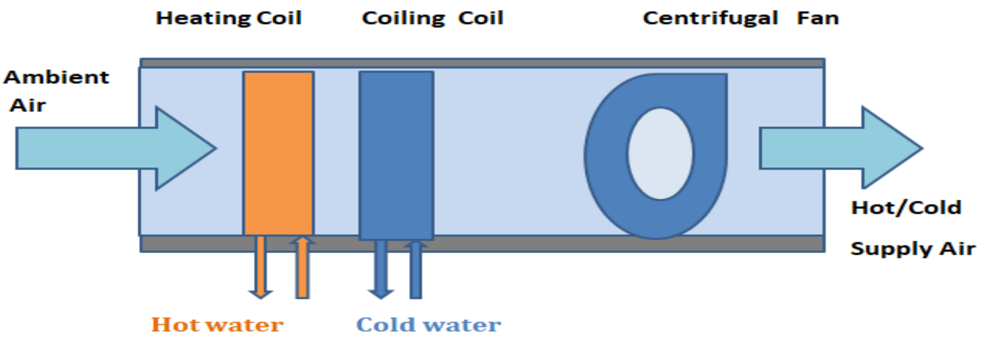

Figure (4) shows a schematic diagram of a four-pipe fan coil.

Because the emission efficiency is not considered 100%, the calculation of the energy load must be done first, and then the calculation of heat losses.

$$\Phi_E = E_4 = \Phi_h \,.\, \frac{1}{\eta_E} \tag{16}$$

Heat losses from emission can be calculated:

$$\Phi_{loss,E} = \Phi_h \,.\, (\frac{1}{\eta_E} - 1) \tag{17}$$

Where (η_E) Represents the efficiency of energy of the emission system.

The auxiliary electrical energy of the emission system is calculated:

$$P_{aux,E} = p_{aux,E} \,.\, \Phi_h \tag{18}$$

Where ($p_{aux,E}$) (w/kw$_{heat}$) Represents the electrical energy of emission.

To determine emission system exergy losses:

$$\Delta\psi_E = \left[\frac{\Phi_h - \Phi_{loss,E}}{T_{in} - T_{ret}}\right]\left[(T_{in} - T_{ret}) - T_O \ln\left(\frac{T_{in}}{T_{ret}}\right)\right] \tag{19}$$

The exergy load of the emission system representing the availability value at point (4) can be calculated:

$$\psi_E = \psi_4 = \psi_{heat} + \Delta\psi_E \tag{20}$$

The energy efficiency of the emission system:

$$\eta_{e,E} = \frac{E_5}{E_4} \tag{21}$$

As for the exergy efficiency of the emission system:

$$\eta_{x,E} = \frac{\psi_5}{\psi_4} \tag{22}$$

The following figure (5) shows the entry and exit points in the distribution pipes. These points represent the energies at inlet and output. The damages in the pipe network represents the difference between the input and output (Bali & Sarac, 2008) [30].

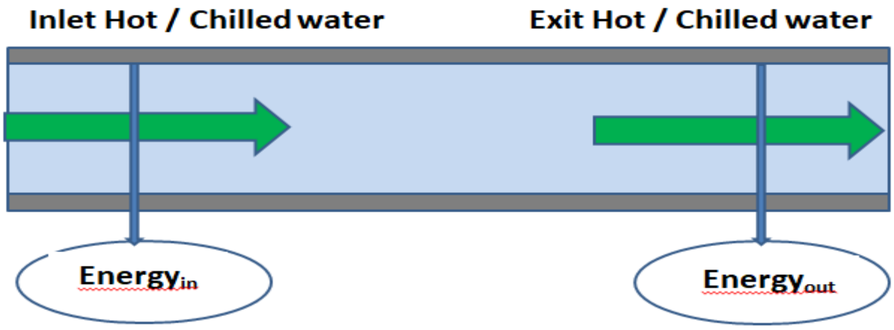

Figure (5) Schematic diagram of distribution pipes.

Distribution network is the second component. Heat losses can be calculated in for the distribution system:

$$\Phi_{loss,D} = (\Phi_h + \Phi_{loss,E})(\frac{1}{\eta_D} - 1) \tag{23}$$

Where (η_D) represents the distribution energy efficiency.

The auxiliary electrical energy of a distribution system can be calculated:

$$P_{aux,D} = p_{aux.D} \cdot (\Phi_h + \Phi_{loss,E}) \tag{24}$$

Where ($p_{aux,D}$) (w/kw$_{heat}$) represents the distribution auxiliary electrical power.

The energy value at point (3*) in Fig. (2) is equal to the energy input of the phase of the distribution network with respect to the developed method.

$$E_{3^*} = \Phi_D = (\Phi_h + \Phi_{loss,E} + \Phi_{loss,D}) \tag{25}$$

Exergy losses for the distribution phase can be estimated:

$$\Delta\psi_D = (\frac{\Phi_{loss,D}}{\Delta T_D})(\Delta T_D - T_o \ln(\frac{T_D}{T_D - \Delta T_D}) \tag{26}$$

Also, it is possible to calculate the distribution exergy inlet, which represents the spot (3 *) as in Figure (2) for the developed method.

$$\psi_{3^*} = \psi_D = \psi_E + \Delta\psi_D \tag{27}$$

The energy efficiency and exergy of the distribution phase is calculated in the traditional method:

$$\eta_{e,D} = \frac{E_4}{E_3} \tag{28}$$

$$\eta_{x,D} = \frac{\psi_4}{\psi_3} \tag{29}$$

As for the energy efficiency and exergy of the distribution phase in the developed method:

$$\eta_{e,D} = \frac{E_4}{E_{3^*}} \tag{30}$$

$$\eta_{x,D} = \frac{\psi_4}{\psi_{3^*}} \tag{31}$$

Gas is the fuel of the Boiler

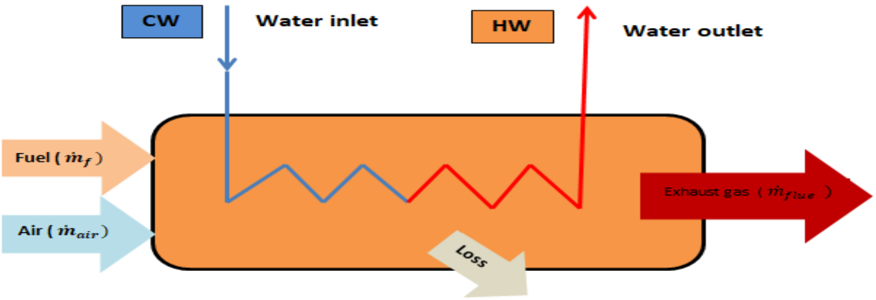

Figure (6) the inlet and outlet energies from the boiler.

The energy required for the generation stage is calculated:

$$\Phi_G = (\Phi_h + \Phi_{loss,E} + \Phi_{loss,D})(1 - F_s)/\eta_B \tag{32}$$

Where (F_s) represents the solar fraction, (η_B) is the boiler efficiency.

The auxiliary electric energy of the generation phase can be calculated:

$$P_{aux,G} = p_{aux,G} \cdot \left(\Phi_h + \Phi_{loss,E} + \Phi_{loss,D}\right) + p_{aux,G,con} \tag{33}$$

($P_{aux,G}$) (W/kwheat) Auxiliary electric energy for the generation stage, ($P_{aux,G,con}$)(w) constant auxiliary electric energy for generation stage.

After that, the exergy load is calculated for the generation stage:

$$\psi_G = \Phi_G \cdot F_{q,s} \tag{34}$$

Where ($F_{q,s}$) is the availability factor of the source.

The DHW can be calculated, and it is calculated according to the system configuration and the people number occupying the space.

$$\Phi_{DHW} = V_w \, . CP_w \, . \rho_w \, . \Delta T_{DHW} \, . NO_{occc} / \, \eta_{G,DHW} \tag{35}$$

The DHW exergy Load is calculated:

$$\psi_{DHW} = \Phi_{DHW} \, . F_{q,s,DHW} \tag{36}$$

To estimate the energy at spot (3) in figure (2), DHW energy must be added to the energy of the distribution network, which can be calculated:

$$E_3 = \Phi_D + \Phi_{DHW} \tag{37}$$

The value of exergy can also be calculated at point (3):

$$\psi_3 = \psi_D + \psi_{DHW} \tag{38}$$

The value of the energy at the point (2 *) in figure (2) represents the real energy that enters this stage:

$$E_{2^*} = \Phi_G \tag{39}$$

The exergy at point (2*):

$$\psi_{2^*} = \psi_G \tag{40}$$

Considered as (E_{2^*}) and (ψ_{2^*}) the real energy and exergy enters to the stage, respectively, for the developed method.

The total auxiliary electrical energy can be calculated:

$$\Phi_{elec} = (P_l + P_v + P_{aux,G} + P_{aux,D} + P_{aux,E}) \tag{41}$$

$$\psi_{elec} = \Phi_{elec} \tag{42}$$

In the classical method, energy and exergy at spot (2) are counted as energy and exergy inputs for the generation stage. that usually calculated by adding electrical energy to the generation capacity.

$$E_2 = \Phi_G + \Phi_{elec} \tag{43}$$

Also, the exergy at point (2) can be estimated by gathering the exergy of electricity to the generation exergy.

$$\psi_2 = \psi_G + \psi_{elec} \tag{44}$$

The energy efficiency and exergy in the generation stage is calculated in the traditional method:

$$\eta_{e,G} = \frac{E_3}{E_2} \tag{45}$$

$$\eta_{x,G} = \frac{\psi_3}{\psi_2} \tag{46}$$

As for the developed method, energy efficiency and exergy are calculated as follows:

$$\eta_{e,G} = \frac{E_3}{E_{2^*}} \tag{47}$$

$$\eta_{x,G} = \frac{\psi_3}{\psi_{2^*}} \tag{48}$$

The main assumptions for the boiler unit calculations were made as follows:

1- The fuel flow rate and water are constant and stable.
2- The temperature at inlet and outlet are constant.
3- The exergy factor for natural gas is 0.9 [29].
4- Energy and air exergy are not taken into consideration.

To estimate the total energy demand, the energies of lighting, ventilation, domestic hot water and auxiliary electric energy must be considered. The total energy and exergy requirements are calculated as follows:

The exergy load of the station can be calculated:

$$\psi_{x,plant} = (P_l + P_v).F_{q,elec} + \Phi_{DHW} .F_{q,s,DHW} \tag{49}$$

Where ($F_{q,elec}$) , ($F_{q,s,DHW}$) DHW source quality factor.

The total energy required for the building can be calculated:

$$ED = \Phi_G .F_p + \left(P_l + P_v + P_{aux,G} + P_{aux,D} + P_{aux,E}\right) .F_{p,elec} + \Phi_{DHW} .F_{p,DHW} \tag{50}$$

The total exergy demand can also be calculated:

$$XD = \Phi_G .F_p .F_q + \left(P_l + P_v + P_{aux,G} + P_{aux,D} + P_{aux,E}\right) .F_{p,elec} .F_{q,elec} + \Phi_{DHW} .F_{P.DHW} .F_{q,DHW} \tag{51}$$

The values of the factors listed below are taken as suggested by (Schmidt, 2004a).

The values of $F_{p,DHW}$, F_p , $F_{p,elec}$, $F_{q,DHW}$, F_q , and $F_{q,elec}$ are taken to be 1.1, 1.1, 3, 0.9, 0.9, 1 respectively [11].

$F_q = F_{q,DHW}$, $F_p = F_{p,DHW}$ because there is only one boiler for both uses.

<u>Exergoeconomic analysis</u>:

Improvements depending on exergy analysis is not sufficient because absence of economic and environmental aspects will not provide a comprehensive image about the improvements. The economic exergy approach is the best method used in this aspect, which combines cost, energy inputs, fund investment, and exergy rates for all components [31]. Exergoeconomic can be defined as a department of engineering that well links system components grade and thermodynamic assessments according to exergy results with considering the economic aspect to provide the investors and the owners a clear figure out of comprehensive information about the energy conversion system for the purpose of designing a cost-effective system, which does not It can be obtained by analyzing energy and exergy [32]. Appreciates of all components of the air conditioning system in the building includes many economic aspects that include purchase, installation, operation and maintenance work. In addition, the costs of electrical energy are considered one of the important factors that affect the total cost. Depending on the theory that presented by many researchers, the equilibrium equation for exergoeconomic can be written for each part of the cycle. Figure 8.3 shows a schematic diagram of the basic concepts of exergoeconomic analysis [33], [34].

$$\dot{cost}_{in} + \dot{Z}_j = \dot{cost}_{out} \tag{52}$$

Where $(\dot{cost}_{in})$ represent entry costs, $(\dot{cost}_{out})$ represent exit costs, $(\dot{Z}_j)$ represents capital, working and servicing costs.

It can be calculated by the mathematical formula provided by (Yücer & Hepbasli, 2014) [35].

$$\dot{z}_j = \frac{cost_{inv} \,.\, CRF \,.\, \lambda}{NH \,.\, 3600} \tag{53}$$

Where $(cost_{inv})$ represents the cost of capital, (CRF) It represents the capital recovery factor, and it can be estimated from the next mathematical form:

$$CRF = \frac{i \,.\, (1+i)^{ny}}{(1+i)^{ny} - 1} \tag{54}$$

Whereas (i) represents the advantage rate, (ny) represents the working period during the years.

Thus, through the mathematical relationship between the exergy and its costs of any equipment of the whole system depends on the exergy cost factor (C_j) (the coefficient of Exergy cost) (\$/kWh) as shown in the following equations below:

$$\dot{cost}_{j.in} = c_{j.input} \cdot \dot{\psi}_{j.in} \tag{55}$$

$$\dot{cost}_{j.out} = c_{j.product} \cdot \dot{\psi}_{j.out} \tag{56}$$

Where (C_j) represents the specific cost (\$/kWh).

It can be noticed that the exergy cost factor at the output from any component of the system is equal to the exergy cost factor at the entrance to the following component. When applying these equations, we will know the cost of producing the exergy in all parts of the system, and the required exergy cost for the building will also be determined.

The cost of natural gas is supposed to be 24.5 (1000\$/kwh)[18].

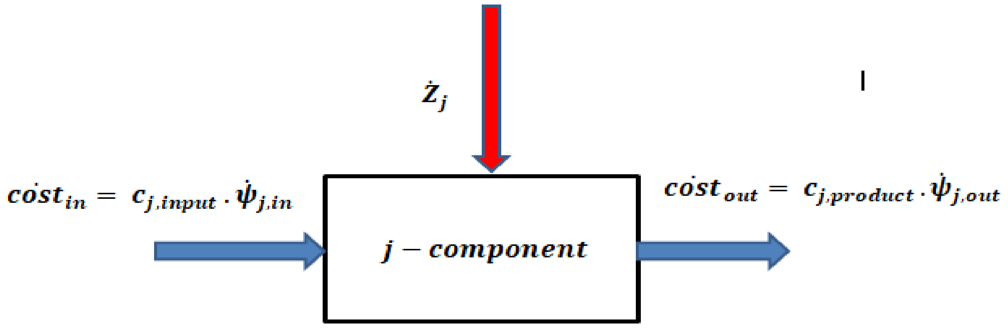

Figure (7) a schematic diagram illustrating the exergoeconomic analysis idea [36].

Where (j) It represents a component which can be a coolant, boiler, distribution piping and fan coil.

Environmental analysis:

Environmental analysis is a source of great concern to the global community because of the negative effects of the increasing consumption of energy that results from climate changes. The high rate of greenhouse gas emissions and Co_2 emissions, which has become a serious problem, causes the retention of radioactive energy in the atmosphere and most of the environmental effects resulting from it [19]. Emissions also constitute other negative effects because of this growing that guides to a growth in environmental pollution that increases the risks of global climate change. Energy effects can be minimized by reducing the energy use by controlling building modifications and user behavior, and buildings can be rated based on potential energy demand and emissions. The mathematical formula by (Caliskan et al,2012), through which it is possible to determine of gas emissions [37].

$$Y_{co_2} = AN_{co_2} . WY_p . NH \tag{57}$$

Where (Y_{co_2}) represent gas emissions CO_2 generated during the year (tCo2/year), (AN_{co2}) represent gas emissions CO_2 resulting from the process of burning fuel for natural gas (0.19 kgco2/kwh), (Cervigni et al,2013) [20], the greenhouse gas reporting program (GHGRP) 2017 [21], (WY_p) represents the annual energy produced using annual fuel consumption (Y_{co2}) of fuel, (NH) represents the loop operative time(hours) (Yucer & Hepbasli, 2013)[24].

Exergy efficiency and Sustainability index:

Human comfort has been considered as a most important aspect of sustainable development [23]. Sustainable development does not require the use of clean, cheap and available sustainable resources of energy, but also requires the use of resources with high efficiency. Exergy analysis methods are very important tools in improving efficiency and sustainability, which allow society to maximize the benefits of resource use while minimizing negative side effects. A sustainability indicator that is directly related to the exergy qualification, which is a powerful tool for assessing sustainability. The sustainability index (SI) can be calculated by applying the following mathematical formulas[38].

$$\eta_{x,sys,heating} = \frac{\dot{\psi}_{heating}}{XD_{heating}} \qquad (58)$$

$$\eta_{x,sys,heating} = 1 - \frac{1}{SI} \qquad (59)$$

$$SI = \frac{1}{1 - \eta_{x,sys,heating}} \qquad (60)$$

Results and discussion:

For the purpose of comparison and calculating the difference between the two methods, the first and second methods, the calculations were made for the two methods, and the energy and exergy pathways for them were drawn, as well as the related calculations, such as pollution and the economic aspect. The results obtained for the two methods will be reviewed and the difference between them is indicated. Figure (8) explains the results of the static analysis. It was found that the rates of energy loss and exergy to be (444.0 kW) and (36.0 kW), respectively.

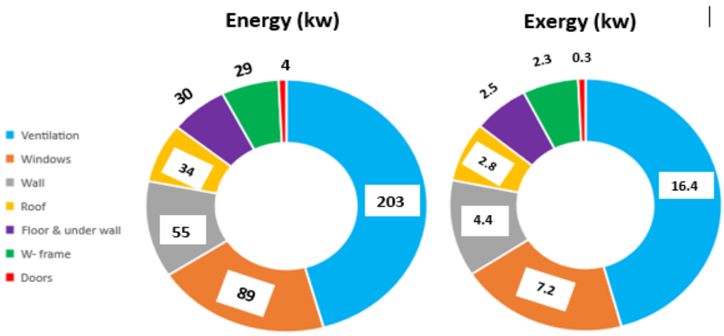

Figure (8) shows the rates of energy loss and exergy of the building components for the heating system.

After calculating the required energy and exergy to carry the heating, it is the initial move in conducting the exergy analysis. Where the rates of energy and exergy entering the system amounted to (1947 kW), (1901 kW), respectively, which is the energy that was supplied from the source. We note that there is a decrease in the rates of energy and exergy over its path in the ingredients of the system until it reaches the building envelope. This decline in energy and exergy rates occurs due to losses in the building components. In order to give a clear figure out of the difference between the methods and to compare the results, figure (9) explains the main difference between the energy paths of methods. From figure (9) it can be noticed that the energy conversion stage at spot (1) to the generation stage at spot (2) the difference cannot be found between the energies at this stage between the methods. The energies at inlet point of generation are two types, the electricity that be consumed directly by the building, and the fuel energy that represents the input energy to the generation. It makes no sense to consider these two types of energies as input energy. The electricity is difference between spots (2) and (2*), which was determined to be (91 kW). The rest which is the fuel is the input energy of the boiler at spot (2*). The output energy is the hot water at point (3). In the classic method, the input and output energies of the generation stage at points (2) and (3) was (948 kW) and (736 kW), respectively, while the energy efficiency was 78%. Whereas, in the second method, the energy entering and leaving the generation phase between the points (2 *) and (3) was found and it was (857 kW) and (736 kW), respectively, and the energy efficiency was 86%. Determining the actual input energy to the boiler stage guides to a more reliability losses and efficiency and the consequences. After that, the output energy of the generation stage enters the distribution stage. In the traditional method, the energy enters and exits the distribution network at points (3) and (4), and its value at this stage was (736 kW) and (450 kW), respectively. The energy was 61%. In the method developed at this stage, energy is used to heat the structure and DHW. The hot water energy enters and exits to the distribution network at points (3 *) and (4), where the values of these energies (509 kW) and (450 kW), respectively, were found. The energy efficiency at this stage was 88%, and the difference between these two spots (3) and (3*) is the energy of DHW and its value was equal to (227 KW), which directs to the structure to be used. Therefore, it is not rational to count it as an input energy to the stage. The traditional method combines heating energy and DHW as an input energy to the same stage. From this point and on, all the energy enters and exits the building components, so there is no difference between these two methods. The difference occurs only in the two stage (generation and distribution), so the work going to converges on these stages.

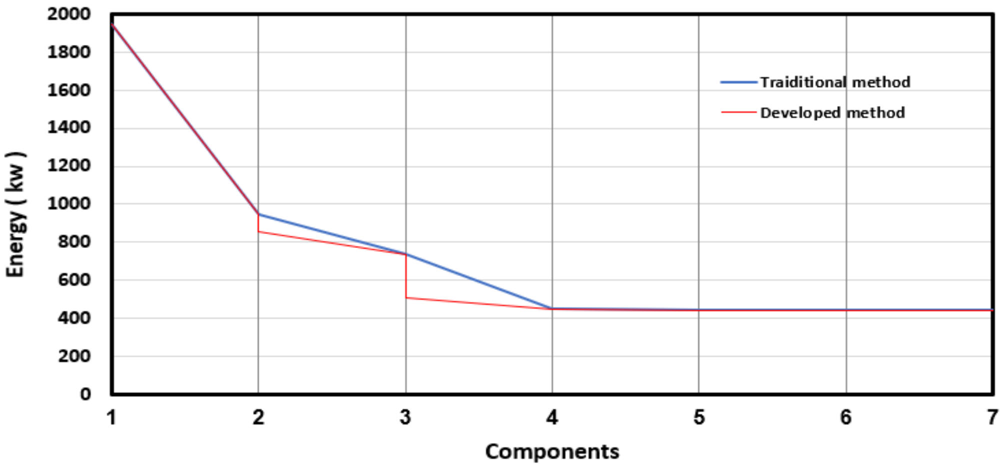

Figure (9) energy flow through the parts of the heating system for both methods.

As well as from Figure (10), it is possible to observe the exergy path rates over the parts. The input and outlet values of exergy of the generation phase were (1287 kW), and (409 kW), whereas the same vales of the distribution phase were (409 kW) and (151 kW). The exergy efficiency and sustainability index for the generation and distribution phases were 32%, 37%, 1.47 and 1.59, respectively, this is relative to the traditional method. While for the developed method, it was found that the interning and output exergy values for the generation phase were (1197 kW) and (409 kW) and for the distribution phase were (194 kW) and (151 kW), respectively, while the efficiency of exergy and index of sustainability of the generation and distribution phases were 34% ,78%, 1.52, and 4.55, respectively. The reason for the high percentage of losses in the generation stage is due to the fuel combustion process and the accompanying energy transformation processes, as well as the high percentage of energy and exergy offered with the exhaust gases. We note that whenever the exergy efficiency is high for the stage, the sustainability index is also high, because the sustainable index is linked to the exergy capacity, which is a powerful instrument. The low exergy efficiencies of the heating system reveal that it is necessary to develop its performance to minimize the exergy destructions and increase the demand for it. The efficiencies must be taken into account when designing the building.

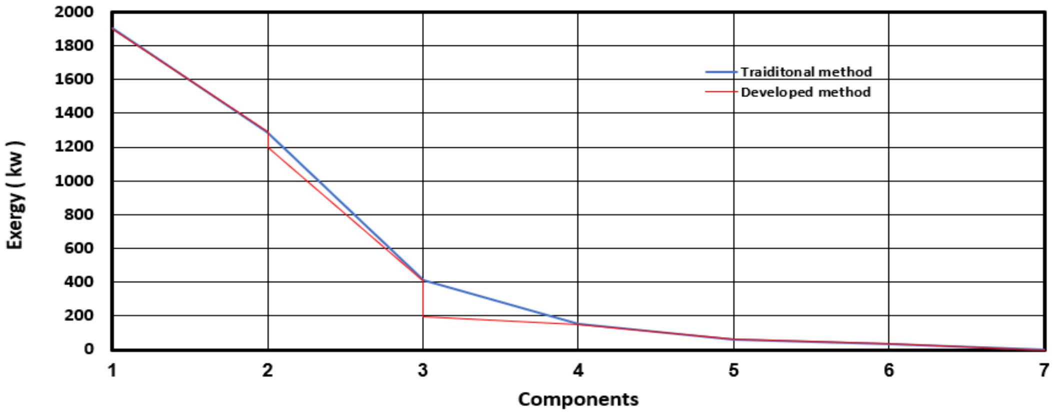

Figure (10) exergy flow over the system parts for both methods.

Figures (11) and (12) show the energy and exergy losses for parts of the system. Because of these casualties, irreversible system and inefficiencies during heat transfer processes through building components, energy and exergy vanish into the environment. The energy then flows out of the building through the building envelope to the ocean and there is still a noticeable amount of energy remaining, but the same does not apply to the exergy, as it will reach zero value as it has reached a state of thermal and mechanical equilibrium with the surroundings. Determining the losses and caused parts will be helpful for decision makers to decide which part should be developed first. From figure (11) and according to the outcomes, it can be seen that the highest energy losses occurred in the initial energy conversion stage, at which the energy source (natural gas) is converted, in addition to the losses of energy transfers from the station to the end, where the energy losses amounted to (999 kW). In the traditional method, energy losses are not calculated correctly, and the electrical energy that goes to the building is not a part of input energy that enters this phase (212 kW) and this happened between points (2) and (3). While the value of the energy losses in the developed method in the generation stage was between the points (2 *) and (3) it was (121 kW). The same can be observed in the distribution stage, the energy losses in the traditional method at this stage occurred between points (3) and (4), which amounted to (286 kW). While in the developed method, if we subtract the power (DHW) whose value was (227 kW), which represents the difference between the points (3 *) and (4), the value of the losses is (59 kW).

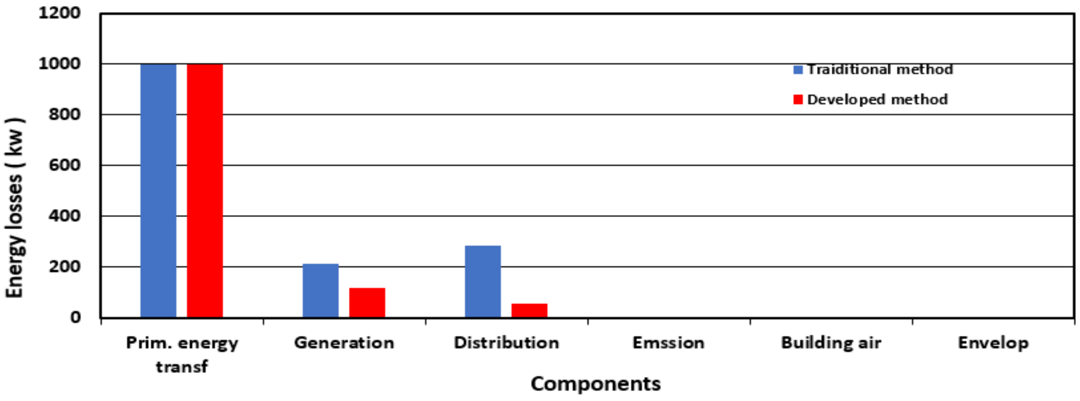

Figure (11) energy flow losses through the components of the heating system for both methods.

The differences of exergy losses can be remarked here, where the highest losses occurred in the generation and distribution phases of the two methods in figure (12). The exergy losses in the generation stage by the traditional method (878 kw) occurred between points (2) and (3), while its value is in the developed method (788 kw) and it occurred between points (2 *) and (3). As well as the exergy losses for the distribution phase in the traditional method was (258 kW) between points (3) and (4), while its value in the developed method is (43 kW) and was between points (2 *) and (3). We note that there is a high percentage of losses that occurred in the stages of primary energy conversion and generation, due to the combustion processes that result in large losses, in addition to the high-temperature exhaust gases presented to the surrounding environment, which are considered wasted energies that reduce the efficiency of these stages. The results show that the improvement and development of boiler performance will lead to better results than any other component improvement operations due to the high percentage of losses at this stage. Determining the main component that causes the largest energy losses is necessary in diagnosing any proposal that leads to an improvement in the performance of the building, and this in turn leads to a reduction in cost and the resulting pollution.

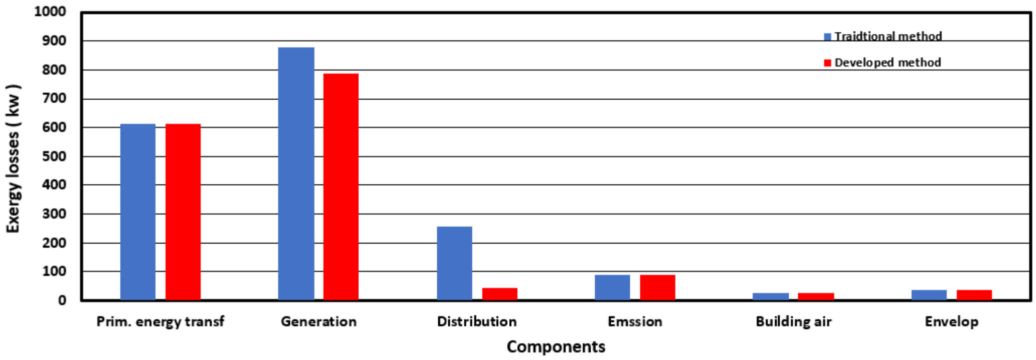

Figure (12) the exergy losses in both methods

The exergy and its losses can be clarified by redrawing the system and components by (Sankey) diagram for the two methods to make it clearer as in Figures (13) and (14).

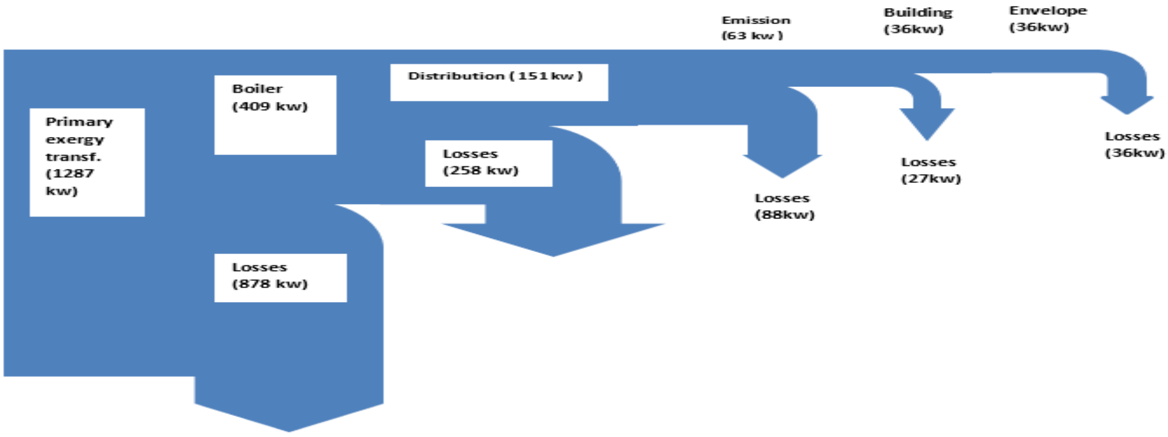

Figure (13) the exergy flow Sankey diagram and its losses in the traditional method.

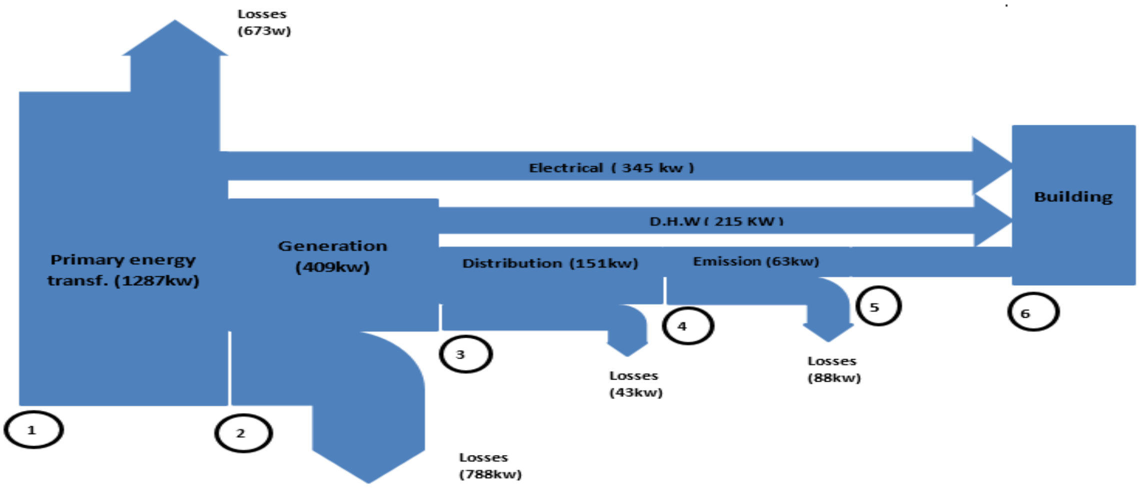

Figure (14) the exergy flow Sankey diagram and its losses in developed method.

After completing the exergy analysis procedures and determining its value and losses over the parts of the system. Only exergy test does not provide a clear and accurate picture for designers and researchers in this field without economic studies when conducting any improvement operations on buildings and the air conditioning systems used in them. Therefore, it represents an onset point for exergo-economic analysis. The application of SPECO is used to make components of a building's heating system. According to the cost equilibrium equation that equals the interning and exiting exergy of all components, the cost of capital investment in units $/h of the component is added to the interning exergy. The calculations of the investment factors and the exergy cost factors for the building components were carried out using the traditional and the developed methods, and they were included in tables (1) and (2), respectively.

Table (1) shows the analysis of the exergoeconomic of the building using the traditional method.

Components	Entering exergetic cost	Hourly investment	Exiting exergetic cost
Generation	C_{gf} = 13 \$/GJ	$\dot{Z}_g$ = 3.1 \$/h	C_{gp} = 43.01 \$/GJ
Distribution	C_{df} = 43.01 \$/GJ	$\dot{Z}_d$ = 0.5 \$/h	C_{dp} = 117.42 \$/GJ
Emission	C_{ef} = 117.42 \$/GJ	$\dot{Z}_e$ = 2.9 \$/h	C_{ep} = 294.22 \$/ GJ

Table (2) shows the analysis of the exergoeconomic of the building by the developed method.

Components	Entering exergetic cost	Hourly investment	Exiting exergetic cost
Generation	C_{gf} = 13 \$/GJ	$\dot{Z}_g$ = 3.1 \$/h	C_{gp} = 40.15 \$/GJ
Distribution	C_{df} = 40.15 \$/GJ	$\dot{Z}_d$ = 0.5 \$/h	C_{dp} = 52.5 \$/GJ
Emission	C_{ef} = 52.5 \$/GJ	$\dot{Z}_e$ = 2.9 \$/h	C_{ep} = 138.62 \$/GJ

The highest value of the exergy cost was found in the emission stage and its value was by the traditional method (294.22 \$/GJ), while its value by the developed method was (138.62 \$/GJ). Where the cost factor increases from generation to emission. Where the exergy cost factor for generation (C_{gp}) in the traditional method was found in the range of (43.01 \$/GJ), while its value in the developed method was (40.02 \$/GJ) from the exergy outside the generation stage and this value gives a perception of the energy cost of this component of the heating system for this stage. In the same case, the parameters (C_{dp}) and (C_{ep}) give the values of exergy costs (\$/GJ) for both the distribution network and the emission. Determining the values of these parameters allows researchers and designers to estimate the cost of consuming energy. Then the cost was calculated of both the classic and the enhanced methods were (67\$) and (62.52\$), respectively. Figure (15) shows the total cost of both methods. according to the exergoeconomic outcomes the difference between the two methods was found to be 10%, which indicates that the benefit of searching for a new methodology may achieve more accuracy and this value can causes more relibility results. The amount of CO_2 emitted annually from heating systems was also calculated and it was (370 kg CO_2).

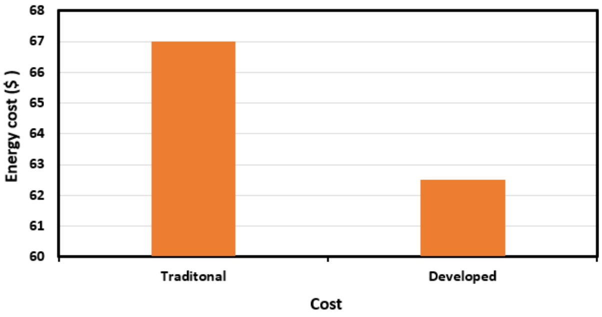

Figure (15) energy cost of both methods.

By comparing the results obtained from the two methods, it was found that the results are different between the two methods. The second method shows more precise results because its values represent the real energy input values for each component. Therefore, the outcomes of the impact of changing energy efficiency and exergy for the generation and distribution stages will be discussed in relation to the developed method. Therefore, we will first change the energy efficiency of the generation and distribution stages, and discuss the changes that occur in the values of energy inputs and the resulting rebirth. Figure (16) represents the energy efficiency effects of each of the distribution network and generation (the boiler), as the enhancement of the two efficiencies guides to a reduction in the values of energy inputs for both stages. When improving the energy efficiency to 94% for the two phases, the energy demands reduces to (1784 kw) for the case of generation and (1837 kw) for the case of distribution. The reason is due to less losses due to improved efficiency, which leads to lower total power. It can be seen that the decrease in the generation stage is greater at the same improvement in efficiency, because the energy entering in this stage is greater than the distribution stage.

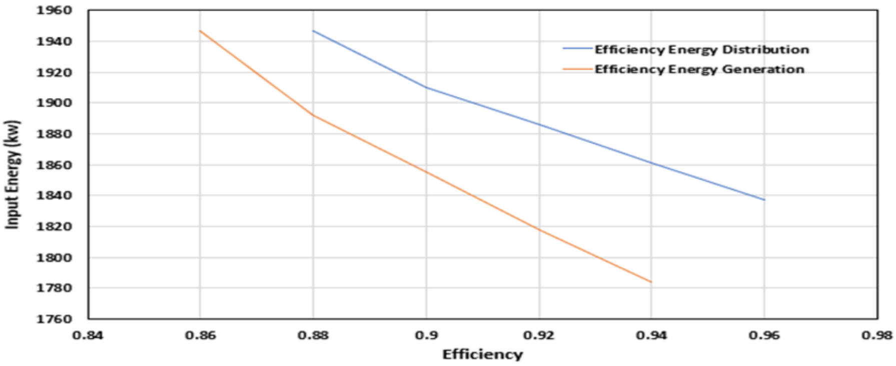

Figure (16) the effect of generation energy efficiency on the total energy.

In addition to the decrease in energy, the improvement in efficiencies leads to a reduction in energy consumption and the resulting emissions, which reduces the release of harmful pollutants to the environment, as CO_2 emissions are considered the most responsible for climate changes and the occurrence of global warming. The effect of improving efficiencies on pollution can be remarked in Figure (17), which displays the effect of energy efficiency of both the generation and distribution stages on the CO_2 emissions. When improving the energy efficiency to 94% for the previous two stages, this leads to a decrease in CO_2 emissions to (339 kg co_2) for the generation stage and (354 kg co_2) for the distribution case. Through the results obtained, it was found that the best percentage of reduction in the energy entering the system and the emissions resulting from it was 8.4% when improving the energy efficiency to 94%.

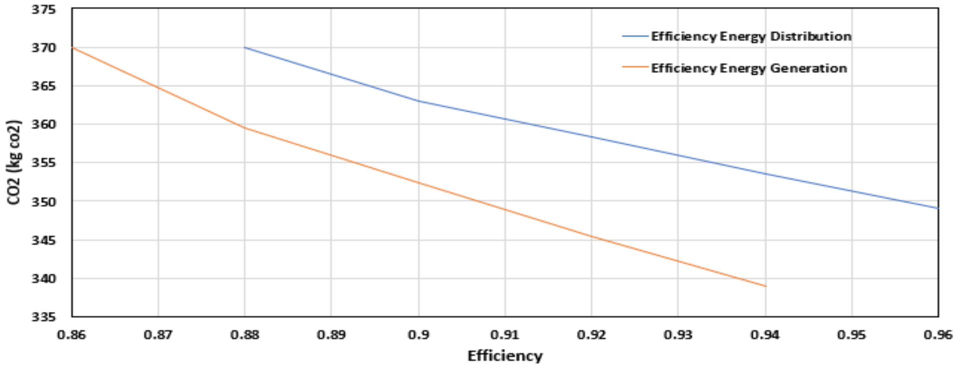

Figure (17) The effects of both the energy generation and distribution efficiencies on the CO_2 emissions.

When improving the exergy efficiency of the generation stage to 42%, this guide to a reduction in exergy demand to be (1566 kw), as well as a decrease in the total cost (52$). This can be seen in the following figures (18) and (19).

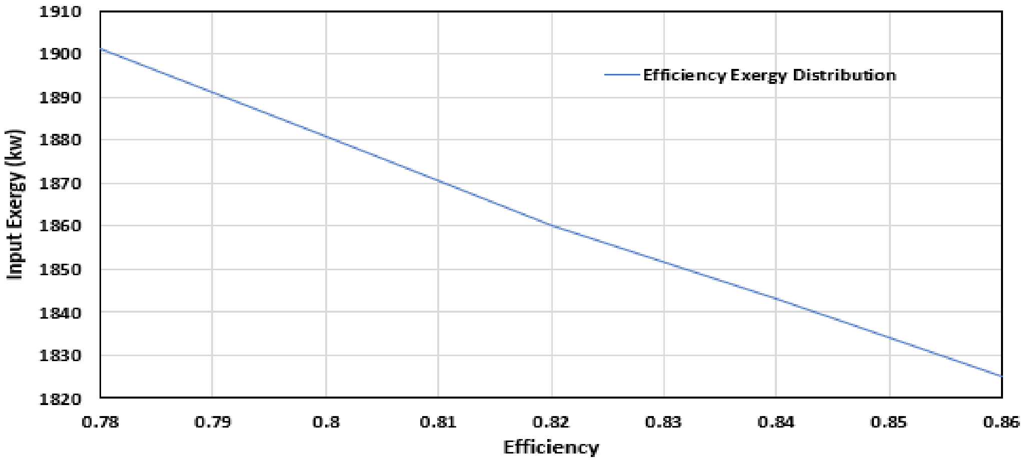

Figure (18) the generation phase exergy efficiency effect on the exergy demand.

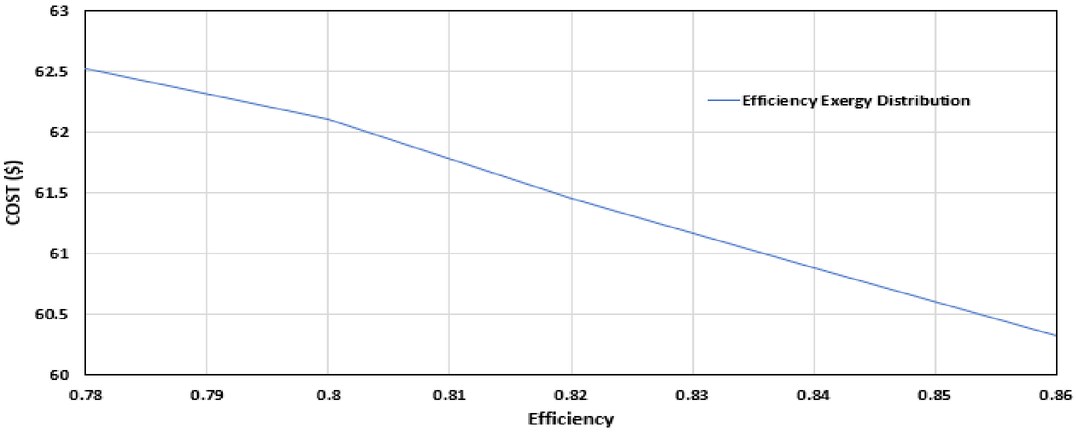

Figure (19) the generation phase exergy efficiency effect on the total cost.

As for improving the exergy efficiency of the distribution stage to 86%, we notice that the amount of exergy entering the system is (1825 kw) and the total cost of the system is (60.32 $), this can be seen through Figures (20) and (21). The calculation of costs depends entirely on the exergy according to the method used (SPECO), so any improvement in exergy efficiency lead to reduction in the.

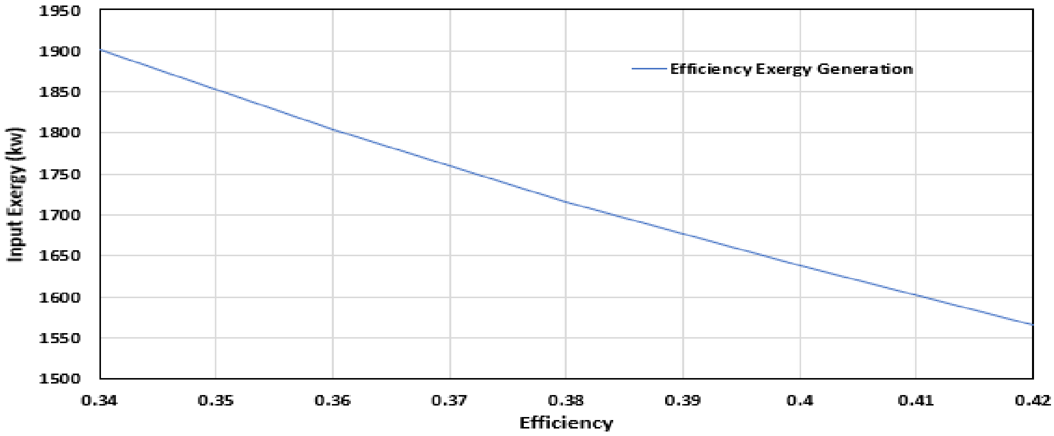

Figure (20) the distribution phase exergy efficiency effect on the exergy demand.

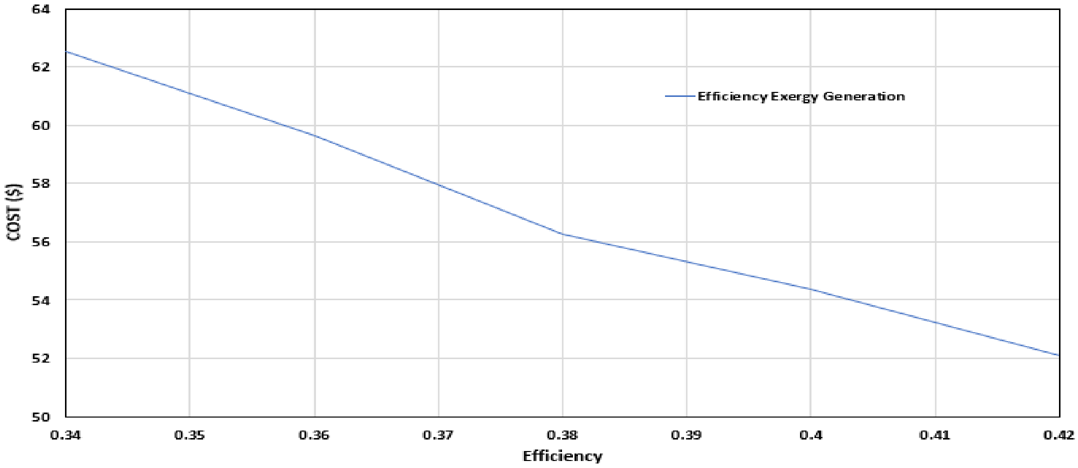

Figure (21) the distribution phase exergy efficiency effect on the total cost.

Whereas, the best percentage reduction in system exergy and total cost was 17.6% and 16.7%, respectively, when the exergy efficiency changed to 42%. Maximum improvement in system exergy efficiency is achieved when the loss of exergy in non-reversible operations is minimized.

Conclusions:

By comparing the two methods and the results that have been reached, it is possible to refer to some conclusions that can be mentioned in this part.

1. The need to continue studying and developing new methods for calculating energy and exergy analysis and consequences calculations.

2. Exergy analysis can become a strong tool to help implement energy analysis projects for buildings and prioritize changing some of their components such as walls, ceilings, windows or the air conditioning system itself.

3. The potential method results is more reliable in the calculations of losses, energy efficiency and exergy because the real input values of the components are considered.

4. It can me concluded that the best percentage of reduction in the energy entering the system and the emissions resulting from it was 8.4% when improving energy efficiency to 94% for the generation stage because the energy entering in this stage is greater than the distribution stage. Whereas, the best percentage reduction in the exergy of the system and the total cost was 17.6% and 16.7%, respectively, when the exergy efficiency was improved to 42% for this generation stage for the developed method.

5. The results proved that the best improvement in building performance was when applying the third case, as the percentage of heat load, system exergy and total cost were reduced to 8.6%, 6% and 7.2%, respectively. This proves the impotency of insulation in this field.

Recommendations:

- Studying the building of a comprehensive study that is dynamic and not static to obtain more accurate results in addition to the inclusion of the cooling period as it is the most important in Iraq.

- Inclusion of advanced systems in the adaptation of buildings to show the extent of their environmental and economic impact.

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