*INTERNATIONAL JOURNAL OF ELECTRONICS, MECHANICAL AND MECHATRONICS ENGINEERING*
*Volume 1. Number.1 pp.(56-66)*

# EXAMINATION OF THE THERMODYNAMIC PARAMETERS OF THE RESIDENTIAL - COMMERCIAL SECTOR: AN APPLICATION

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♣Some parts of this article presented by Hepbaslı, A., and Z.Utlu, in *Clima 2007 WellBeing Indoors.*.Paper no. B04F1724, in Helsinki, Finland10-14 June 2007

**ABSTRACT**
*The energy utilization of a country can be evaluated using exergy analysis, which is a way to a sustainable development, to gain insights into its efficiency. The authors have conducted various studies on analyzing the energy utilization efficiencies of Turkey and extend here these studies by dealing with the investigation of the thermodynamic parameters in the Turkish residential-commercial sector (TRCS). The thermodynamic parameters considered are as follows: (i) fuel depletion rate, (ii) relative irreversibility, (iii) productivity lack, and (iv) exergetic factor. These parameters are determined for the components of the TRCS in an attempt to assess their individual performances and are also compared to each other, while the analysis is done based on the actual data. The present study has clearly indicated the necessity of the planned studies towards increasing exergy efficiencies in the sector studied and especially the critical role of policymakers in establishing effective energy-efficiency delivery mechanisms throughout the country. It may be concluded that the current methodology is useful for analyzing the sectoral energy and exergy utilization, giving energy saving opportunities.*

**Key words:** energy, exergy, thermodynamic, residential-commercial, Turkey

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# I. INTRODUCTION

Thermodynamic analysis including exergy analysis method is a powerful tool, which has been successfully and effectively used for estimating energy utilization efficiencies of countries. Based on the earlier studies conducted on the sectoral energy and exergy analysis of countries by many authors, the approaches used to perform the exergy analyses of countries may be grouped into three types, first two approaches ; namely Reistad's approach and Wall's approach, as denoted by Ertesvag [2] and the last one Scuiba's approach [3]. The authors reviewed analyzing and evaluating the energy and exergy utilization of countries [4] .

The concepts of exergy, available energy, and availability are essentially similar. The concepts of exergy destruction, exergy consumption, irreversibility, and lost work are also essentially similar. Exergy is also a measure of the maximum useful work that can be done by a system interacting with an environment which is at a constant pressure P0 and a temperature $T_0$. The simplest case to consider is that of a reservoir with heat source of infinite capacity and invariable temperature $T_0$. It has been considered that maximum efficiency of heat withdrawal from a reservoir that can be converted into work is the Carnot efficiency [5,6]. The primary objective of the present study is to inspect of the effect of thermodynamic parameters on the energy utilization efficiency of the residential-commercial sector; in addition, this case is appraised with an application. In this regard, thermodynamic relations used to perform energy and exergy analyses of reference state changes are given first. Secondly, determined equations for residential- commercial sector (RCS) and its sub sectors such as water heating (WH), spaces heating (SH), cooking and electrical appliances (EA) are presented. In next step, these equations were applied to TRCS. Finally, the results obtained are discussed.

# II. METHODS

## Thermodynamic parameters

A key discussion of the relevant theory of thermodynamic parameters for energy and exergy analyses is stated in this section. Initially, energy, exergy, entropy, reference state, ideal system and real system are expressed in this section.

Dincer et al.[7] reported that, to provide an efficient and effective use of fuels, it is essential to consider the quality and quantity of the energy used to achieve a given objective. In this regard, the first law of thermodynamics deals with the quantity of energy and asserts that energy cannot be created or destroyed, whereas the second law of thermodynamics deals with the quality of energy, i.e., it is concerned with the quality of energy to cause change, degradation of energy during a process, entropy generation and the lost opportunities to do work. More specifically, the first law of thermodynamics is concerned only with the magnitude of energy with no regard to its quality; on the other hand, the second law of thermodynamics asserts that energy has quality as well as quantity. By quality, it means the ability or work potential of a certain energy source having certain amount of energy to cause change, i.e., the amount of energy which can be extracted as useful work which is termed as exergy. First and second law efficiencies are often called energy and exergy efficiencies, respectively. It is expected that exergy efficiencies are usually lower than the energy efficiencies, because the irreversibilities of the process destroy some of the input exergy.

Exergy is the expression for loss of available energy due to the creation of entropy in irreversible systems or processes[8]. The exergy loss in a system or component is determined by multiplying the absolute temperature of the surroundings by the entropy increase. Entropy is the ratio of the heat absorbed by a substance to the absolute temperature at which it was added. While energy is conserved, exergy is accumulated.

Exergy analysis provides a method to evaluate the maximum work extractable from a substance relative to a reference state (i.e., dead state). This reference state is arbitrary, but for terrestrial energy conversion the concept of exergy is most effective if it is chosen to reflect the environment on the surface of the Earth. The various forms of exergy are due to random thermal motion, kinetic energy, potential energy associated with a restoring force, or the concentration of species relative to a reference state.

In order to establish how much work potential a resource contains, it is necessary to compare it against a state defined to have zero work potential. An equilibrium environment which cannot undergo an energy conversion process to produce work is the technically correct candidate for a reference state [9].

It should be noticed that exergy is always evaluated with respect to a reference environment (i.e. dead state). When a system is in equilibrium with the environment, the state of the system is called the dead state due to the fact that the exergy is zero.

At the dead state, the conditions of mechanical, thermal, and chemical equilibrium between the system and the environment are satisfied: the pressure, temperature, and chemical potentials of the system equal those of the environment, respectively.

Table 1. Some of the key aspects of thermodynamics in terms of energy and exergy used in the modeling [1]

| Process | Energy efficiency | Exergy efficiency |
|---|---|---|
| System Balance | $\dot{Q} + \sum \dot{m}_{in} h_{in} = \dot{W} + \sum \dot{m}_{out} h_{out}$ | $\sum_{in} m_{in} ex_{in} - \sum_{out} m_{out} ex_{out} + \sum_{r} Ex^{Q} - Ex$ |
| Specific exergy | | $ex^{PH} = (h - h_0) - T_0 (s - s_0)$ |
| General Efficiency | *$\varepsilon_1$=(Energy in products/Total energy input) * 100* | *$\varepsilon_2$=(Exergy in products/ Total exergy input)* 100* |
| Electrical heating | $\varepsilon_{1e,h} = Q_p / W_e$ | $\varepsilon_{2e,h} = Ex^{Qp} / Ex^{We}$ $\varepsilon_{2e,h} = [\, 1 - (T_0 / T_p)]\, Q_p / W_e$<br>$\varepsilon_{2e,h} = [(\, 1 - (\, T_0 / T_p\, )]\, \varepsilon_{1e,h}$ |
| Fuel heating | $\varepsilon_{1f,h} = Q_p / m_f H_f$ | $\varepsilon_{2f,h} = Ex^{Qp} / m_f \varepsilon_f$ $\varepsilon_{2f,h} = [(\, 1 - (\, T_0 / T_p)]\, Q_p / (m_f \gamma_f H_f)$<br>$\varepsilon_{2f,h} = [\, 1 - (T_0 / T_p)]\, \varepsilon_{1f,h}$ |
| Electrical cooling | $\varepsilon_{1c,e} = Q_p / W_e$ | $\varepsilon_{2c,eh} = Ex^{Qp} / Ex^{We}$ $\varepsilon_{2c,eh} = [(\, 1 - (T_0 / T_p\, )] Q_p / W_e$<br>$\varepsilon_{2c,eh} = [\, 1 - (T_0 / T_p\, )]\, \varepsilon_{1c,eh}$ |
| Shaft work production via electricity | $\varepsilon_{1e,w} = W / W_e$ | $\varepsilon_{2e,w} = Ex^{W} / Ex^{We} = W / W_e = \varepsilon_{1e,w}$ |
| Shaft work production via fuel | $\varepsilon_{1f,w} = W / m_f H_f$ | $\varepsilon_{2f,w} = Ex^{W} / m_f H_f = W / (m_f \gamma_f H_f) = \varepsilon_{1f,w} / \gamma_f$ |
| Fuel driven kinetic energy production | $\varepsilon_{1f,ke} = m_s \Delta ke_s / m_f H_f$ | $\varepsilon_{2f,ke} = m_s \Delta ke_s / m_f \varepsilon_f = m_s \Delta ke_s / (m_f \gamma_f H_f) = \varepsilon_{1f,ke} / \gamma_{f,ke}$ |
| Improvement potential | $IP = (1 - \varepsilon_2)(Ex_{in} - Ex_{out})$ | |
| Carnot factor | $Q_{carnot} = 1 - (\, T_0 /\, Tp\, )$ | |
| Space/Water heating | $\varepsilon_2 = \left(\frac{\varepsilon_1}{q_{fuel}}\right)\left\{1 - \left[\frac{T_o}{T_2 - T_0}\right]\ln\left(\frac{T_2}{T_0}\right)\right\}$ | |
| Overall SH,WH,EA, | $\varepsilon_{1osh} = [(a_1 * \varepsilon_{1,1c}) + (a_2 * \varepsilon_{1,2c}) + (a_3 * \varepsilon_{1,3c}) + \ldots\ldots + (\, a_9 * \varepsilon_{1,9c})]/100$ | |
| Overall SH,WH,EA, | $\varepsilon_{2osh} = [(a_1 * \varepsilon_{2,1c}) + (a_2 * \varepsilon_{2,2c}) + a_3 * \varepsilon_{2,3c}) + \ldots + (\, a_9 * \varepsilon_{2,9c})]/100$ | |
| Overall fuel | $\varepsilon_{1of} = [(f_{sh} * \varepsilon_{1osh}) + (f_{wh} * \varepsilon_{1owh}) + (f_c * \varepsilon_{1oc}]/100$ | $\varepsilon_{2of} = [(f_{sh} * \varepsilon_{2osh}) + (f_{wh} * \varepsilon_{2owh}) + (f_c * \varepsilon_{2oc})]/\, 100$ |
| Cooking / Cooling | $\varepsilon_2 = \varepsilon_1 \left[1 - \left(\frac{T_0}{T_2}\right)\right]$ | $\varepsilon_2 = \varepsilon_1 \left[\left(\frac{T_o}{T_3}\right) - 1\right]$ |
| All sector | $\varepsilon_{1,orc} = \frac{(\varepsilon_{1e} * e_{rc} + \varepsilon_{1of} * f_{erc})}{(e_{rc} + f_{erc})}$ | $\varepsilon_{2,orc} = \frac{(\varepsilon_{2e} * e_{rc} + \varepsilon_{2of} * f_{exrc})}{(e_{rc} + f_{exrc})}$ |

*Note: Electric and fossil fuel heating processes are taken to generate product heat $Q_p$ at a constant temperature $T_p$, either from electrical energy $W_e$ or fuel mass $m_f$. Double subscripts indicate the processes in which the quantity represented by the first subscript is produced by the quantity represented by the second; e.g., the double subscript h,e heating with electricity.$E_{in}$ is the rate of net energy transfer in, $E_{out}$ is the rate of net energy transfer out by heat, work and mass, where ex denotes specific exergy, $Ex^Q$ and $Ex^W$ are the exergy transfers associated where h and s specific enthalpy and entropy, while the subscript "0" denotes conditions of the references envirovement with Qr and Wr and I is the sistem exergy consumption, $\varepsilon_1$ and $\varepsilon_2$ is first and second law efficiencies, a denote the share of the relevant utilization component in the total for electrical*

In addition, the system has no motion or elevation relative to coordinates in the environment. Under these conditions, there is neither possibility of a spontaneous change within the system or the environment nor an interaction between them. The value of exergy is zero. Another type of equilibrium between the system and environment can be identified. This is a restricted form of equilibrium, where only the conditions of mechanical and thermal equilibrium (thermomechanical equilibrium) must be satisfied. Such state is called the restricted dead state. At the restricted dead state, the fixed quantity of matter under consideration is imagined to be sealed in an envelope impervious to mass flow, at zero velocity and elevation relative to coordinates in the environment, and at the temperature $T_0$ and pressure $P_0$ taken often as 25 1C and 1 atm [6]. The reference state is a state of a system in which it is at equilibrium with its surroundings. When a system is at the same Some of the key aspects of thermodynamics in terms of energy and exergy used in the modeling are taken in Table 1 [1, 10,11].

**Energy and Exergy Efficiency Calculations in Residential-Commercial Sector**

Residential-Commercial sector includes space heating SH, water heating WH, cooking and electrical appliances EA. In all activities in this sector, based on electricity, heat is produced. Quality of heat is Carnot factor that is strongly depend on temperature. Quality factors for some energy carriers and forms are 1.00, 0.60, 0.2-0.3,0-0.2, 0 for mechanical energy, steam ($600^0$C),district heating ($90^0$C), space heating ($20^0$C), and earth respectively [12,13] .

Energy efficiency is simple comparison of energy content of input and output energy carrier or flow. However, energy efficiency is defined as a function of requirement temperatures in system. Exergy efficiency is simple comparison of exergy content of input and output energy carrier or flow. Energy and exergy efficiencies values of these categories are determined separately as present above.

**Space Heating;** Heating options specified for heating systems are district heating, central heating, individual heating and stove. Firstly energy and exergy efficiencies of each other temperature, pressure, elevation, velocity and chemical composition as its surroundings, there is no opportunity to construct a heat engine or other device to extract work, to operate a piston, to raise a weight or turn a turbine. No potential differences exist in such instances that would allow the extraction of useful work.

Ideal system is a reversible cycle that is one consisting of reversible processes only. The efficiency of an engine operating on a reversible cycle can be shown to be at the maximum, i.e., greater than that of any engine operation on an irreversible cycle can be shown to be at the maximum, i.e., greater than that of any refrigeration system operating on an irreversible cycle. It follows that the efficiencies of all reversible engine cycles are equal and are the maximum possible, and the COP' s of all reversible-cycle refrigeration systems are equal and are the maximum possible[4].

Energy carriers considered for all systems efficiencies are determined than heating system and fuel preference of dwelling units are determined according to their utilization ratios.

43-52% of all direct fuel use was for space heating, which is done entirely by home heaters having the same first law efficiencies of home stoves. Energy and exergy efficiency values of these categories are determined separately as presented above.

Energy and exergy efficiencies of each other energy carriers considered for all systems efficiencies are determined and heating system and fuel preference of dwelling units are determined according to their utilization ratios. Quality factors of energy carriers are obtained from ref [14]. Reference state temperatures are from $0^0$C(273K) to $25^0$C(298K), SH here needs a temperature of $50^0$C (323K) Achieved energy and exergy efficiency values are illustrated in Table 2.

**Water Heating;** In WH activities, various energy carriers are used that are natural gas, LPG, wood, dried dung, solar and electricity.First law efficiencies of energy carriers in water heating are determined by producer using temperatures $25^0$C (298) and $60^0$C (333K) for instance electric water resistant energy efficiencies is 98%, home gas water heater 60% Energy efficiencies of direct fuel use for water heating are assumed to be 27-80% [14,15].

The second law efficiency of water heating are calculated from Eqs. Substituting the relevant numerical values into Eq. in Table 1, we obtained the figures ranging from 3.10% to 10.80% for all energy carriers, as indicated in Table 2.

Overall first and second law efficiencies of WH are calculated using Eqs. in Table 1.

**Cooking;** In cooking activities, various energy carriers are used that are natural gas, city gas, LPG, electricity, wood and dried dung.

Energy efficiencies used in the previous study, dead state (ambient) and process temperatures used in calculations are for cooking applications $20^0$C and $120^0$C respectively cooking efficiencies are assumed as, 50% for gas cooking stove, LPG, natural gas, 80% for electric cooking stove, 22% for wood, 20% for dried dung.The second law efficiencies are calculated by the using Eqs. in Table 1.These assumptions yield second law efficiencies of fuel use ranging from 4.1% to17.2% for the years studied, as indicated in Table 2.Overall efficiencies are calculated as stated above.

**Electrical Appliances;** Electrical appliances includes, lighting, refrigerator, air condition, dish washer, washing machine, iron, television, computer and others appliances, as hair dryer, mechanical drive. In RCS, electricity is primarily consumed for refrigeration, lighting, air conditioning and other activities.

For electrical appliances, input exergy is equal to input energy.However, In refrigeration and air conditioning applications, purpose is extracting heat instead of producing heat. It is assumed that the temperatures inside freezers and refrigerators are approximately –8$^o$ C, the room temperature near the refrigerator coil is 20$^o$ C and the coefficient of performance (COP) is calculated. It is assumed that the temperatures for air conditioning 33$^o$C and13$^o$C the COP is 2.0.

Elsewhere, output is mechanical or electrical energy that its exergy content is equal to energy content Approximately 35-38% of all electrical use was for lighting [1]. Lighting is assumed to be 80% incandescent and 20% fluorescent with first and second law efficiencies of about 5% and 4.5%, and 20% and 18.5%, respectively [14]. Combining the relevant first and second law efficiencies for lighting, we calculated $\varepsilon_1$ =9.5-15.5% and $\varepsilon_2$ = 8.70-14.3% for the years considered.

6-7% of all electrical use was for television and computer. First and second law efficiencies are assumed to be 80%.

Dish washer, iron, are heat-producing appliances that they are evaluated according to following equations in Table 1. If electrical or mechanical energy is output, since quality factor of both energy forms are 1 the following equation is valid.

Mechanical drive requirements in RCS meet to by small electric motors and both energy and exergy efficiencies of about 70%.

Table 2.Energy and exergy efficiencies of residential-commercial sector at reference state temperature changes[1,14]

| | | Temperatures $^0$C | | | | | | Temperatures $^0$C | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Energy carriers | 0 | 5 | 10 | 15 | 20 | 25 | 0 | 5 | 10 | 15 | 20 | 25 |
| | | Energy efficiencies (%) | | | | | | Exergy efficiencies (%) | | | | | |
| Space heating | Coal stove | 90 | 81 | 72 | 63 | 54 | 45 | 7.14 | 5.75 | 4.52 | 3.44 | 2.51 | 1.74 |
| | Coal district | 84.21 | 77.19 | 70.18 | 63.16 | 56.1 | 49.12 | 7.85 | 6.56 | 5.39 | 4.34 | 3.41 | 2.60 |
| | Fuel-oil | 100 | 90 | 80 | 70 | 60 | 50 | 8.26 | 6.65 | 5.23 | 3.98 | 2.9 | 2.01 |
| | Natural gas | 99 | 96.95 | 92.9 | 86.54 | 80 | 70 | 10.33 | 9.22 | 7.99 | 6.66 | 5.44 | 4.15 |
| | Wood | 80 | 72 | 64 | 56 | 48 | 40 | 6.35 | 5.11 | 4.02 | 3.06 | 2.23 | 1.55 |
| | Electricity | 100 | 95 | 90 | 85 | 80 | 75 | 13.55 | 12.09 | 10.72 | 9.44 | 8.24 | 7.14 |
| | Geothermal | 100 | 88.89 | 77.78 | 66.67 | 55.6 | 44.44 | 29.03 | 22.45 | 16.74 | 11.89 | 7.88 | 4.71 |
| | LPG | 99 | 96.95 | 94.74 | 92.1 | 86.7 | 75.83 | 9.6 | 8.57 | 7.57 | 6.59 | 5.48 | 4.18 |
| Water heating | Natural gas | 100 | 91.67 | 83.33 | 75 | 66.7 | 58.33 | 10.44 | 8.72 | 7.17 | 5.78 | 4.54 | 3.46 |
| | Wood | 100 | 86.12 | 72.22 | 58.33 | 44.4 | 30.56 | 9.33 | 7.32 | 5.55 | 4.01 | 2.7 | 1.62 |
| | LPG | 100 | 93.24 | 85.47 | 77.7 | 69.9 | 62.16 | 9.67 | 8.16 | 6.77 | 5.51 | 4.38 | 3.39 |
| | Electricity | 100 | 96.25 | 94.17 | 92.25 | 89.3 | 79.33 | 14.77 | 13.43 | 12.38 | 11.39 | 10.3 | 8.56 |
| | Fuel-oil | 100 | 91.67 | 83.34 | 75 | 66.7 | 79.33 | 9.6 | 8.11 | 6.66 | 5.37 | 4.21 | 3.21 |
| | Geothermal | 100 | 87.5 | 75 | 62.5 | 50 | 37.5 | 23.03 | 17.53 | 12.8 | 8.85 | 5.63 | 3.15 |
| | Solar | 100 | 91.67 | 83.34 | 75 | 66.7 | 58.33 | 10.3 | 8.61 | 7.07 | 5.70 | 4.47 | 3.41 |
| Cooking | LPG | 51.43 | 48.91 | 46.51 | 44.23 | 42.1 | 40 | 15.86 | 14.45 | 13.14 | 11.93 | 10.8 | 9.77 |
| | Natural gas | 51.43 | 48.91 | 46.52 | 44.23 | 42.1 | 40 | 17.62 | 15.55 | 14.14 | 12.84 | 11.6 | 10.51 |
| | Wood | 29.64 | 28.40 | 27.17 | 25.93 | 24.7 | 23.95 | 7.99 | 7.23 | 6.56 | 5.91 | 5.29 | 4.72 |
| | Electricity | 94.95 | 90.29 | 85.87 | 81.66 | 77.7 | 73.85 | 28.98 | 26.41 | 24.02 | 21.81 | 19.8 | 17.84 |
| Elecrical appliances | Refrigeration | 1.03 | 1.05 | 1.07 | 1.09 | 1.11 | 1.13 | 3.02 | 4.91 | 6.79 | 8.68 | 10.6 | 12.45 |
| | Air condition | 1.98 | 2 | 2.02 | 2.024 | 2.05 | 2.07 | -3.46 | 0 | 3.53 | 7.111 | 10.8 | 14.47 |
| | Clothes Dry | 100 | 93.34 | 86.67 | 80 | 73.3 | 66.67 | 21.54 | 18.77 | 16.18 | 13.79 | 11.6 | 9.58 |
| | Dishes Machine | 100 | 90 | 80 | 70 | 60 | 50 | 14.71 | 13.24 | 11.76 | 10.29 | 8.82 | 7.36 |
| | Iron | 100 | 96.67 | 93.34 | 90 | 86.7 | 83.33 | 34.75 | 33.59 | 32.43 | 31.28 | 30.1 | 28.96 |

Washing machine, vacuum cleaner, television and others are assumed as electricity or mechanical work producers and evaluated according to equations in Table 1.Electricity consumption values of other electrical appliances, for instance, computer and hair drying were selected estimated as given in Table 3, while the first and second law efficiencies of these appliances are listed in Table 2.

In this sector, overall first and second law efficiencies for the entire RCS are calculated by aggregating both purchased electrical energy and direct fuel use. Using the numerical values obtained using in these models, the weighted mean overall energy and exergy efficiencies for the entire RCS were found.

## III. RESULTS AND DISCUSSION

***An application for Turkey Residential and Commercial Sector***

The present application analyzes of the energy and exergy uses of the TRCS are based on thermodynamic parameters of process. This analysis is also based on the actual data for 2004, and it is used in the calculations.

Total energy and exergy inputs for the same period according to energy carriers are obtained from ref[15]. By 2004, Turkey's population and dwelling unit are determined to be 71332000 and 16487640, respectively. Total energy and exergy inputs to the Turkish sector were 3758.23 and 3710.24 PJ in 2004, respectively. In addition per/capita for total energy consumption and for RCS were determined as 48.08 GJ/capita and 10.78 GJ/capita in studied year.

In 2004, of Turkey's total end-use energy, 42% was used by the industrial sector, followed by the residential-commercial sector at 30%, the transportation sector at 20%, the agricultural sector at 5%, and the non energy (out of energy) use at 3% [16].

***Energy and exergy utilization in the Turkish residential-commercial sector***

According to ref [14], energy and exergy utilization values for the year studied in the TRCS.The highest contributions came from fuel with 38.45 %, renewable resources (includes wood) with 38.20% and electric with 23.31% in 2004. In 2004, the highest contributions came from wood with 192.20 PJ[16].However, natural gas usage has continuously increased in the TRCS for space heating, water heating and cooking purposes in several cities. Share of the energy utilization in the residential-commercial modes is as follows: space heating with 41%, water heating with 25%, cooking with 11% and electrical appliances with 23% in the year studied.These values are determined for 2004 achieved from Refs. [1,17,18].

***Estimation of component and overall efficiencies for SH ,WH and cooking***

Various fuels given in Table 3 are used for the purposes of WH, SH and cooking activities in this sector. Energy utilization values for the TRCS are also indicated in Table 3. SH requires the largest fraction of fuel with about 44%, while WH and cooking are responsible for 35%, and 21% of the total fuel inputs in this year, respectively. Based on the values obtained from Turkey's population census, the fuel preferences of dwelling units in the year of 1998 in Turkey [15].Considering the reference listed in Table3 for the year of 2004.

The first and second law efficiency of space heating was calculated below steps.

44% of all direct fuel use was for space heating, The needed temperature for the SH equipment is $50^oC$ and the ambient temperature is from $25^oC$ to $0^0C$. Heating system and fuel preferences must be considered for calculating. Those preferences are given in Table 3 for the year of 2004. Overall energy and exergy efficiencies of SH were calculated as follows: Substituting the relevant numerical values into equations at state temperatures from 25 $^0C$ to $0^0C$, we obtained $\varepsilon_{1sh}$= 48.74% to 90.02%, $\varepsilon_2$sh= 2.25 % to 7.18% in 2004 for SH.

Table 3. Distribution of residences according to fuel types and components of fuel uses and values for energy and exergy utilization of electric and saturation values of EA in 2004(%)[1]

| Space heating | | | | | Water heating | Cooking | Electrical appliances | | |
|---|---|---|---|---|---|---|---|---|---|
| | Ratio of residence | | | | Ratio of residenc | Ratio of residenc | | Ratio of saturatio | Utilization of electric |
| Energy carriers | District | Central | Individual | Stove | | | Component | (%) | (%) |
| Coal (stove) | | | | 72.5 | | | Lighting | 100 | 36 |
| Coal | 58 | 39 | | | | | *(Incandescent)* | *75* | *75* |
| Fuel-oil | 21 | 24 | 6 | 0.8 | 2.04 | | *(Fluorescent)* | *25* | *25* |
| Natural gas | 18 | 37 | 94 | 3.9 | 2.10 | 9.5 | Refrigeration | 99 | 42 |
| LPG | | | | 1 | 42.5 | 90 | Washing machine | 87.1 | 3 |
| Electricity | | | | 3.7 | 7.8 | 0.3 | Dishes machine | 32.5 | 1 |
| Wood | | | | 18 | 32 | 0.1 | Vacuum cleaner | 89.4 | 2 |
| Geothermal | 3 | | | | 0.3 | | Air conditioning | 2.5 | 3 |
| Solar | | | | | 13.16 | | Television+Computer | 99 | 8 |
| Dried dung | | | | 0.1 | 0.1 | 0.1 | Iron | 96 | 1 |
| **Total** | **100** | **100** | **100** | **100** | **100** | **100** | Clothes drying | 82 | 1 |
| **Ratio of residences** | **4** | **6** | **6** | **84** | **100** | **100** | Other | 3.2 | 3 |
| | | | | | | | **Overall electrical utilization** | | 100 |

[a]The values for 2004 are obtained from Ref.[1, 14].

Based on the values achieved from Turkey's population census, the fuel preferences of dwelling units for wafer heating were determined for each province in 2004, 35% of all energy carrier use was for WH. The efficiencies of WH is calculated below.

Fuel preferences must be considered for calculating that are given in Table 3 for the year of 2004. Overall first $_{and}$ second law efficiencies of WH are calculated; Using Eqs. and the numerical values assumed, we found $\varepsilon_{1wh,f}$= 52.43% and 100%,and $\varepsilon_{2wh,f}$=3.22% and10.10% in 2004 for WH.The first and second law efficiencies of cooking are calculated as in water and space heating.

Overall first and second law efficiencies are calculated from equations in a similar way and are found from 9.85% to16.05% and from 40.06% to 51.51% at reference state temperature changes for cooking in 2004, respectively.

## *Estimation of overall efficiency and effectiveness values for electric utilization*

Energy utilization values and the saturation values of EA for the TRCS are indicated in Table 3. Refrigeration requires the largest fraction of electricity with 42% in the year studied, followed by lighting with 36%. The overall efficiency and effectiveness values for electric utilization are estimated as follows:

Lighting is assumed to be 75% incandescent and 25% fluorescent with first and second law efficiencies of about 5% and 4.5%, and 20% and 18.5%, in 2004, respectively [13,14].Combining the relevant first and second law efficiencies for lighting, we calculated $\varepsilon_{1,l}$ =8.75-15.5% and $\varepsilon_{2,l}$ = 8.0-14.3% for the year considered.

Refrigerators are consumed huge share of electricity. 40% of all electrical use was for refrigeration [14]. It is assumed that the temperatures inside freezers and refrigerators are approximately $-8^{o}$ C, the coefficient of performance (COP) is 1.0 and the room temperature near the refrigerator coil is from 25 to $0^{o}$ C. Using equations, these assumptions yield second law efficiencies from 3.44 to 12.44% in 2004.

Assuming that the COP value of the electric air conditioning unit is 2, this unit extracts heat from air at $14^{o}$ C and the outside temperature is from $33^{o}$ C to 8 $^{0}$C and using equations in a similar manner, we found $\varepsilon_{2,a}$=14.46 and -3.46% in the year studied.

8%of all electrical use was for television and computer. Annual electricity consumption of television and computer has increased compared to previous years due to an increase in the number of TV channels, and usage of computer spread in daily life as at school and work in Turkey.Energy and exergy efficiencies are assumed to be 75%.

Dish washer, iron, are heat-producing appliances that Using Eqs. and the numerical values assumed, we found first and second law efficiencies $\varepsilon_{1dw}$= 50% and 83%, and $\varepsilon_{2dw}$= 7.35% and 28.95% for 25$^0$C,and $\varepsilon_{1I}$= 100% and 100%, and $\varepsilon_{2I}$= 14.70% and 34.75% for 0$^0$C in the year studied for dishes washing and iron, respectively.

**In Figure 1a and 1b for 2002 in TRCS.**

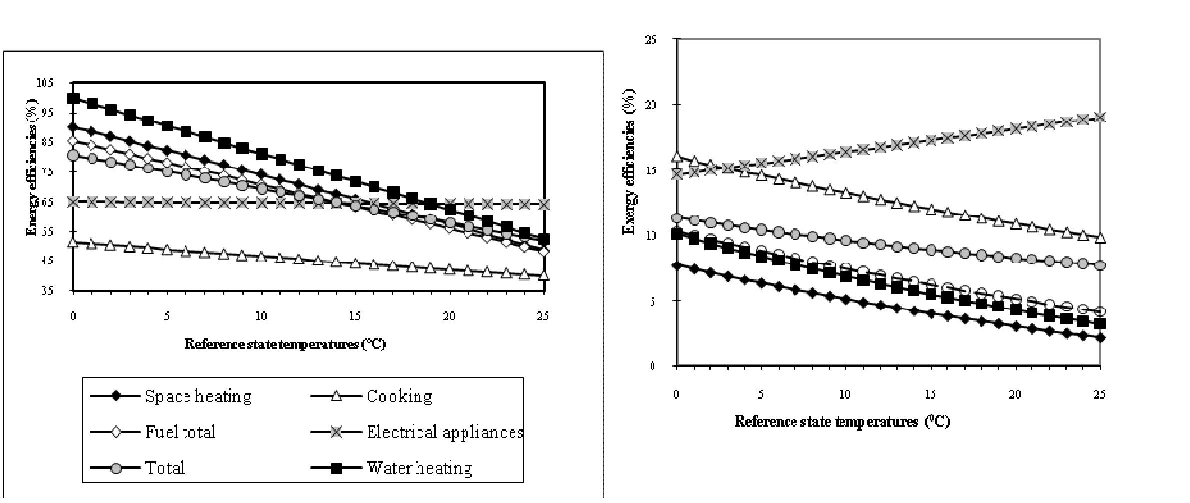


**Fig. 1.** Energy (a) and exergy (b) efficiencies of residential-commercial sector in Turkey reference state temperature changes for the year of 2004.[1]

Mechanical drive requirements in RCS meet to by small electric motors and both energy and exergy efficiencies of about 70%. We found energy efficiencies from 64.19 to 65.09% and exergy efficiencies from 14.65% and 19.02% for electrical use in 2004. This changes of efficiencies are illustrated in Figure1 a and b.

***Energy and Exergy Utilization Efficiencies all TRC***

Overall, first and second law efficiencies for the entire RCS were calculated by aggregating both purchased electrical energy and direct fuel use using equations. The weighted mean overall energy efficiencies for the entire residential-commercial sector were found to be from 51.89% to 80.75% in 2004 for reference state temperatures changes. There is major differently energy efficiencies for reference state temperatures changes in TRCS as shown in Figure 1a and 1b. In terms of energy loses this sector rank rather differently for about 19-38%. Overall exergy efficiencies in the year studied for the entire RCS were found to be from 7.74% to 11.16% in 2004 for reference state temperatures changes. This sector shows considerably important and comparable losses of energy and exergy. In the regard of exergy loses, this sector grades very differently, accounting for about 88-92% of all exergy loses.

## IV. CONCLUSIONS

In this study ınvestigated the thermodynamic parameters of energy and exergy usage in RCS. The main results derived from the present study may be summarized as follows:

- This very useful knowledge is also needed for identifying energy efficiency and/or energy conservation opportunities, as well as for dictating the right energy and exergy management strategies of a country.
- Changes of the reference state temperatures don't have an important impact on exergy

efficiencies. Besides, this changes are displayed considerably effect on energy efficiencies because of energy efficiencies is defined as a function of requirement temperatures in system.

- A case study presented the analysis of the energy and exergy utilization of the TRCS in the year of 2004.
- This analysis is done based on the actual data for the year of 2004.
- The energy efficiency value for the TRCS is found to be from 51.89% to 80.75% and the exergy efficiency value for that is obtained to be 7.74% to 11.16% for reference state temperature changes in 2004.
- This study indicated that exergy utilization in Turkey was even worse than energy utilization. Turkey represents a big potential for increasing the exergy efficiency. It is clear that a conscious and planned effort is needed to improve exergy utilization in Turkey.
- As a conclusion, the author expects that the analyses reported here will provide the investigators with knowledge about how effective and efficient a country uses its RESs.

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EXAMINATION OF THE THERMODYNAMIC PARAMETERS OF THE RESIDENTIAL - COMMERCIAL SECTOR: AN APPLICATION

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