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Exergoeconomic Assessment of Coal-Fired Power

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Abstract: *In the present study, a cost analyzed in terms of exergoeconomıc of coal fired power plant. Power plant; It consists of fuel boiler, turbine, electric generator and condensing systems. The total investment rate cost of the plant is consists of fuel boiler* ($\dot{G}_A$)*, turbine* ($\dot{G}_B$)*, electricity generator* ($\dot{G}_C$) *and condensation unit* ($\dot{G}_D$) *systems. The energy unit costs of the plant systems; economic life span* (n_y) *annual working time (t) and interest rate* (I_R) *were examined for different parametric values. Boiler unit cost* (c_2)*, turbine output and generator unit costs* (c_3)*, unit cost per unit energy according to equality method and extraction method were expressed as* $c_{şfeq}$, c_{eleq}, $c_{şfex}$, c_{elex} *respectively. As a result: Per unit costs decrease although economic life and annual working time (t) increase, per unit costs are increasing as interest rate* (I_R) *increases. Knowing the system costs in advance will create more economical facilities. It will provide an increase in economic efficiency.*

***Key words**: Exergy analysis, Rancine cycle, Steam power plant, Exergoeconomıc*

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1 Introduction

Energy is an indispensable source of life for human life in the present century. In despite contrast to the rapidly growing world population, natural energy resources are decreasing in the same ratio. Energy saving does not mean the use of energy less by economically growing and compromising the contemporary living conditions, the realization of energy production and consumption with maximum efficiency, reducing energy losses to a minimum for increasing the efficiency and reducing the cost. When the energy is obtained and used*;* cost, conversion methods of energy, maximum use of energy and energy efficiency are examine becomes important.

Cost of production of electricity in coal-fired power plants is very important in terms of the country's economy. Globally, coal-fired power plants operating at an average net efficiency of approximately 33% provide approximately 40% of the required electricity [1]. There are coal-fired thermal power plant 29522 MW in Turkey and about 21.39% of electric energy to provide from such sources of energy [2].

The generation and the utilization of energy, cost, energy conversion methods, maximum use of energy, energy efficiency are examined under the heading of different analysis techniques based on the second law of thermodynamics. In the literature, there are many studies about energy generation, usage, cost, energy conversion methods, maximum use of energy and energy efficiency analysis for coal-fired power plants.

Exergy and Exergoeconomic analysis in 600 MW Thermal Power Plant they determined that 42% of the total exergy produced was lost in the boiler and 68.79% of the energy loss occurred in the condenser. A general improvement was made in boiler 92% high exergy loss [3].

Applied exergy costing method to cogeneration system of 1000 kW power gas turbine. As a result, while the production process continues, the cost of unit exergy increases and the production cost of electricity increases almost at the same rate as the input cost. The increase in the cost of producing electricity is almost it is the same rate as the increase in input cost [4].

Examined 1000 kW gas turbine cogeneration system components. They applied the pre-determined CGAM program to analyze the exergy-cost relationship of cogeneration systems. They examine the effect of annual cost on production cost with exergy balance and cost balance equations. They stated that the total change in the weighted average cost of the product is proportional to the total change in the annual cost of the system [5].

Examinedthe energy and exergy analysis of the Al-Hussein power plant in Jordan. It has calculated separately the system components that have the greatest energy and exergy losses. It has specify that 134 MW of condenser energy and only 13 MW of boiler system energy is lost to environment. It has specify that 134 MW energy from the condenser and only 13 MW energy from the boiler system was lost to the environment. The rate of exergy destruction in percent, the boiler system (77%), turbine (13%) and condenser fan (9%) specify respectively. The thermal efficiency calculated from the low heating value of the fuel was 26%, while the efficiency of the power cycle was 25%.[6].

Conducted an exergoeconomic analysis of an ultra-supercritical coal-fired power plant in China. To understand the cost-generating process in China, to evaluate the economic performance of each component and to design more cost-effective for purpose possible solutions. As a result the oven, the low temperature heat exchangers, the air preheaters and the low pressure feed water preheaters of the exergoeconomic factors are rather low, the other components are quite large [7].

Comparatively examined the performance of the boiler used in a coal-fired thermal power plant based on coal in terms of the exergoeconomic industry. Design analysis based on criteria as exergetic destruction cost, proportional cost difference and exergoeconomic factor for the boiler used in a power plant with a capacity of 55 MW. As a result they explained that had to be reparation of the boiler [8].

Analysed the relationship between capital costs and thermodynamic losses of electricity generating by coal, oil and nuclear power in plants device. It is structured to achieve an overall optimum design according to the economical characteristics and thermodynamic balancing of electricity generation plant and its devices [9].

In work applied exergoeconomic analysis of CO_2 combustion in chemical combustion cycle at an energy generation plant. They have been compared in terms of exergetic and economical, power generation without CO_2 capture and conventional power generation in The oxy-fuel plant. They stated the overall exergetic efficiency of CLC production was about 5 points lower than the reference plant with the addition of the CO_2 compaction unit. The economic analysis carried out confirms that increase in the investment cost by the addition of the unit for CO_2 compression and CLC. Also explained the cost of electricity for the plant is 24% higher than in comparison to the reference state [10].

In studies submit exergoeconomic analysis of a Kalina cycle combined coal-fired steam power plant utilization specific exergy costing (SPECO) methodology. As a result of capital investment for repair of boiler more efficient boiler will be achieved, also seen that the exergy destroyed is reduced. Evaporator and turbines are the major component of product cost in the facility. They have described exergy will reduce loss cost for improving the productivity of the components [11].

Applied a cost analysis method based on thermoeconomics for a coal-fired power plant with 300 MW installed power. They have developed a simulation for the plant's thermoeconomic analysis. As a result of the simulation, they made analyzes calculating the exergy and negentropyl of the flows for each unit. In theory, three thermo-economic variables have been defined to for improve the of exergy cost equations. These variables is specific exergy destruction, specific irreversibility cost and specific negentropy cost. Provided useful data about on thermodynamic losses and cost of exergy for facility designers and managers [12].

Conducted thermodynamic and economic analyzes on the system based on the concepts of energy and exergy in the power generation of hybrid vehicles [13].

In the studies of Crivellari, et al, [14]. It was tried to determine the economic way by performing performance analysis of the methanol produced by offshore wind-solar energies with exergy and exoeconomic techniques. As a result, they determined that the carbon dioxide-based method is more advantageous than other options.

Conducted a comprehensive research on exoeconomic analysis and optimization of an integrated system for photoelectrochemical hydrogen and electrochemical ammonia production [15].

Wang et al, [16] adopted the life cycle assessment (LCA) and cost accounting theory for evaluate energy production technology by coal-based in China. In the whole process of coal-fired power generation, they included the energy cost as well as environmental emission costs. Coal is used 46.01$ for 1 MWh energy production, whereas the cost of air pollution rate is about 22.90 $. It is explained water pollution and solid waste pollution were 96.42%, 2.12% and 1.46%, respectively.

The coal-fired power generation plant was studied as both dual and traditional rankin cycle. In the cycle of the system, a dual flow of potassium and water is applied as a fluid, compares energy production in terms of cost in both cycles. They also examined in terms of thermoeconomically, including energy production and the cost of capital investment. Exergoeconomic analysis showed that the concept of the dual Rankine cycle is fuel, emission reduction and appropriate in terms of economically [17].

They calculated how much change in energy and exergy values occurred by injecting steam into the turbine combustion chamber in a combined cycle power plant. Additionally, exergyeconomic and environmental analysis was performed. According to the results of the algorithm, they found that steam injection increased the total combined cycle power by 2 MW while significantly reduced design costs to an optimum condition. They stated necessity the restriction of steam injection for some cases. The reason of this; Increased gas turbine loss due to pressure loss; HRSG's production costs grow; The contrast between high and low pressure flow rate changes; NO_X and CO emission costsdependence on ideal circumstances [18].

In ideal condition, exergy and thermal efficiency values of the combined cycle are increased from 42% and 47.6% to 47.28% and 48.94%, respectively.

Mohammadi *at al* [19] examined cooling, heating and power conversion the integration of a complex consisting of units a gas turbine, an organic Rankine cycle, an absorption cooling. Energy and exergy analysis applied to the system. As a result, in design terms, with a round-trip energy efficiency of 53.94 % in the system, showed 33.67 kW of electricity, 2.56 kW of cooling and 1.82 tons of hot water a day.

Wang *et al.*, [20]. examined combined cooling, heating and power systems (CCHP) andmodified from exergoeconomically by them. Consequently, a status study issubmit to analyze the thermodynamic performances of two CCHP desing and the production cost allotment including electricity, frozen water for cooling and domestic hot water in different process modes.

They made a case study the supply of child cooling for water and hot water, the cost of production, including electricity for thermodynamic performance analysis of the two CCHPs. Compared with the previous exergyeconomics consumption, the unit exergy cost of electricity with higher energy level increases 0.09 Yuan/kWh while the cost of other products with lower energy level decrease.

They examined improve performance by fog cooling and steam injection in energy production by gas turbine and steam turbine cycles. Exergoeconomic analyzes show that the cost of electricity and unit components is higher than steam-injected plants in the combined cycle [21].

Elsafi has been explored reviewed parabolic corrugated solar panels providing direct steam production. For each component, exergy and exergy costing level equality have been formulated based on a suitable description of fuel product loss. In the exergoeconomic analysis, steam at the inlet of the low pressure turbine was reheated to increase the temperature by 100 K. As a result, it was shown that the turbine caused an increase of 9,1% in the vapor fraction at the outlet. Studied in terms of exergetic efficiencies and cost of electricity. Reported would be achieved about 2% increase in cost of electricity [22].

Bolattürk *et al,* [23], have been examine from Çayırhan thermal power plant exergy and thermo-economic care in Turke. They have been made each unit of the plant is exergy analyzed. The thermal and second law efficient of the thermal power plant were 38% and 53%, respectively the determined by thermodynamic properties. In addition, units have been examined for exergy cost and the highest exergy loss cost is in the boiler, turbine group and condenser respectively.

Many companies use combined power plants for electricity generation. For this reason, the cost analysis of the combined power plants as an exergy economy has been made. In the energy production system examined, the prices of the plant units invested have been determined. The production cost per unit energy of the thermal power plantin the process was determined. In order to be able to calculate the for production cost of the energy generation systems, the total cost to the plant must be known. Usually these costs are determined as major costs such as feasibility studies, project, land, construction installation, unit installation of the plant, then operation and maintenance repair. In the study, the unit cost in electricity energy production facility was emphasized. Annual interest rate (I_R) of the facility and annual electricity generation amount and economic life of the plant (n_y), on the effect of the turbine and generator outputs of the power plant on cost per unit energy (c_3) was analyzed in terms of exergy economics.

2 System Descriptions

As shown in Fig. 1 high pressure steam from boiler is given to the turbine. The working fluid in the turbine is supplied to the condenser as low pressure steam. Condensed by decrease vapor temperature in condenser and given to the boiler as feed water.

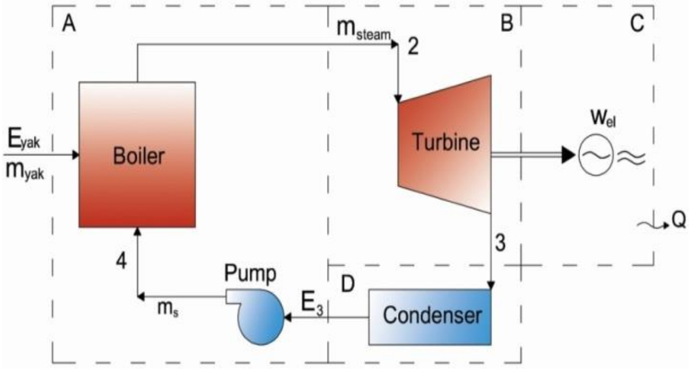

Figure1
Counter-pressure combined heat power plant

Acceptances made for a thermal power plant. Electric power of the generator $\dot{W}_{el}$ = 5 000 kW, boiler pressure, P_2 =4 MPa, superheated steam temperature T_2 = 400 °C, turbine back pressure P_3 = 400 kPa, ambient temperature T_o = 20 °C, The net heat value of coal used in the unit is $H_u^v = 14644\ \mathrm{kJ/kg}$ [24], the price of the kilogram of the coal is accepted as c_k= 0.2 $ / kg. In addition, the investment costs of the main equipment of the plant constituent during the installation phase; the cost of the boiler C_A^C= 3.5 x10^6 $, turbine cost C_B^C= 0.32x10^6 $, electricity generator cost C_C^C= 0.11x10^6 $, the cost of the cooling system is C_D^C= 0.1x10^6 $ dir. The investment interest rate is $0.05 \ll I_R \ll 0.25$, repayment period $10 \ll n_Y \ll 20$ years, The annual operating time of the plant is in discussion at 6 000 «t« 8 760 hours the range.

All pressure losses have been neglected in the systems. Except for electrical and mechanical energy losses in the generator area, all heat transfer losses have been neglected. The power and energy consumed have been neglected at feed pump and other auxiliary equipment.

During interaction between the system and the environment, the energy gained by the system, the energy lost by the environment must be equal [25]. In the case of multiple products, a single cost equation is not enough. Additional criteria are needed to decide the relationship between the unit costs of different products. These are mainly as the use of exergy in costing products. In thermal analysis, the flow and transformation of the energy, in economic analysis, only the cost is examined. At the cost of exergy, both the interaction with environment of the system and the financial effect of the irreversibilities in the system are examined [26].

3 Theoretical Concepts

Turbine shaft power, taking into account the efficiency of the electricity generator and the mechanical efficiency of the turbine

$$\dot{W}_{şf} = \frac{\dot{W}_{el}}{\eta_m \eta_{el}} \qquad (1)$$

Determined by equality (1) [23].

The massive flow of the work that circulates through the system and completes the cycle

$$\dot{m}_s = \frac{\dot{W}_{şf}}{h_2 - h_3} \qquad (2)$$

The amount ($\dot{m}_k$) of fuel used for generate thermal energy in the system is determined from the energy equation (3) of the fuel boiler.

$$\dot{m}_k (H_u^v)\, \eta_{yan} = \dot{m}_s (h_2 - h_4) \qquad (3)$$

In general, the main cost of the fuel boiler is C_A^c, the thermal capacity ratio of the boiler is determined as a linear function of ($\dot{Q}_A$). In this case, the main cost of the fuel boiler is determined by equation (4).

$$C_A^c = a_A + b_A \dot{Q}_A \qquad (4)$$

Here, there are two constant values a_A and b_A for the boiler type and size. The thermal capacity ratio of the boiler is $\dot{Q}_A$, it depends on the combustion efficiency and the fuel coefficient (φ_{dry}) [25].

$$\dot{Q}_A = \dot{E}_{yak} + \frac{\eta_{yan}}{\varphi} \qquad (5)$$

Exergy entering to the fuel boiler is determined by multiplying the specific exergy of fuel with fuel quantity,

$$\dot{E}_{yak} = \dot{m}_k \, \varepsilon_k \qquad (6)$$

The exergy or usable energy is when coming into equilibrium with a system environment indicates the most useful work it can do. Therefore exergy is a measure of the potential ability to work of the system for a specific environment state. Exergy analysis is increasingly used in the evaluation and design of thermal systems. Specific exergy of steam at the turbine entrance treated as [25].

$$\varepsilon_2 = (h_2 - h_o) - T_o (s_2 - s_o) \qquad (7)$$

The fluid from the feed line or condenser is assumed to be at the same temperature as the ambient conditions and the exergy value is considered zero. $\dot{E}_4$=0 in this case exergy efficiency of boiler,

$$\psi_A = \frac{\dot{E}_2}{\dot{E}_{yak}} \quad (8)$$

Determined by equality

Turbine exergy and power output are expressed by $\dot{E}_3$ and $\dot{W}_{şf}$ respective. The exergy efficiency of the turbine is determined by two different methods. This data is first expressed as the equality method (eq) and the extraction method (ex). According to the equilibrium method of the turbine, exergy efficiency (ψ_B^{eq}) is determined by the equation (9) [23].

$$\psi_B^{eq} = \frac{\dot{W}_{şf} + \dot{E}_3}{\dot{E}_2} \quad (9)$$

According to the extraction method, when the output of the turbine is considered only as $\dot{W}şf$, the best exergy efficiency of the turbine is determined by ψ_B^{ex}. The following equation is written for ψ_B^{ex}.

$$\psi_B^{ex} = \frac{\dot{W}_{şf}}{\dot{E}_2 - \dot{E}_3} \quad (10)$$

The exergy efficiency of the electricity generator is (11) from equation

$$\psi_C = \frac{\dot{W}_{el}}{\dot{W}_{şf}} \quad (11)$$

When accepted condensation unit adiabatic exergy efficiency [25].

$$\psi_D = \frac{\dot{E}_4}{\dot{E}_3} \quad (12)$$

3.1 Financial Regulations

The annual cost of the investment should be determined previously. Annual cost of investment, capital and repayment installments in certain years determined beforehand should be determined. In addition, the capital recovery factor (a^c) multiplier is determined according to years [17, 25]. The capital recovery factor is calculated as in equation

$$a^c = \frac{I_R\,(1+I_R)^{ny}}{(1+I_R)^{ny}-1} \quad (13)$$

3.2 Investment Life of the Facility

One of the required data to (for) make an investment decision is the economic life of the investment. Economic life (n_y) is defined as the period during which a business or system can be economically beneficial. Investment life is very important in determining the exergy economy of the facility.

3.3 Discount Rate (I_R)

Discount Rate: It is the minimum efficiency rate that the investor is expected to achieve due to his investment. In other words, in discounted cash flow analysis, it is the interest rate used to determine the value of cash flows in one period in another period.

3.4 Unit Costs for Exergy Input

Contained within carbon (C), hydrogen (H), oxygen (O) and nitrogen (N), provided that the mass ratio of oxygen to carbon in solid fossil fuels (o / c) is less than 0.667, the default value of φ_{dry} is determined by (14) [25]. With a mass ratio of oxygen to carbon less than 0.667,

$$\varphi_{dry} = 1.0437 + 0.1885\,\frac{h}{c} + 0.0610\,\frac{o}{c} + 0.0404\,\frac{n}{c} \quad (14)$$

Here, the mass fractions of C, H, O, and N are c, h, o, n, respectively [25]. Coal of specific exergy

$$\varepsilon_k=[(H_u^v) + w\ h_{fg}]\varphi_{dry}+ [\varepsilon_s^v - H_s^v] \quad (15)$$

Expressed by the equation (15) [25]. If the ambient temperature To = 298.15 K, the moisture mass share in the fuel is w = 0.080, the amount of sulphide mass fraction in the fuel is s = 0.01, evaporation enthalpy of water at standard atmospheric temperature h_{fg} = 2 442 kJ/kg, the net heat value of the fuel is $H_u^v = 14\,644$ kJ/kg. Cost of kilograms of coal c_k= 0.2 \$/kg. The standard sulfur energy in the fuel [ε_s^v - H_s^v] =9417 kJ/kg accept as. As a result of these acceptances the specific exergy of the fuel is calculated from the equation (15) εk = 16091 kJ/kg. Thus, with respect to the net calorific value, the unit cost of the input exergy of the unit would is $c_{yak}^{\varepsilon} = 1.2429x10^{-5}$ \$/kJ. Capital investment rate required for fuel boiler ($\dot{G}_A$)

$$\dot{G}_A = \left(\frac{a^C}{t_{op}}\right) C_A^C \quad (16)$$

Similarly, the $\dot{G}_B$, $\dot{G}_C$, $\dot{G}_D$, values, which are the necessary capital investment rates for the turbine, generator and condensation unit, are determined by the same equation. Unit cost of entering exergy

$$c_{yak}^{\varepsilon} = \frac{c_k}{\varepsilon_k} \quad (17)$$

Determined by equality [23].

3.5 Regional Cost of Exergy

In order to clearly determine the cost of total exergy of the plant it would be more accurate to examination separately the plant sites. The general cost calculation for any x region of the facility is determined by equation (18) [25].

$$\sum_{out.x}(\dot{E}_o c_o^{\varepsilon}) = \sum_{in.x}(\dot{E}_i c_i^{\varepsilon}) + \dot{G}_x \quad (18)$$

Here, c_i^{ε}, c_o^{ε}, is the average exergy cost of each unit, $\dot{E}_i$, $\dot{E}_o$, is the exergy flow. According to Figure 1, region (A) is taken as basis. The unit cost of the thermal energy using the (produce) exergy generated for the fuel boiler is obtained by the equation (19) [25]. In order to determine the total exergy cost of the facility clearly, determining the exergy cost of the facility units separately will give more accurate results.

$$c_2^{\varepsilon} = \frac{\dot{E}_{yak} c_{yak}^{\varepsilon}}{\dot{E}_2} + \frac{\dot{G}_A}{\dot{E}_2} \quad (19)$$

$$c_2^{\varepsilon} = \frac{c_{yak}^{\varepsilon}}{\dot{\psi}_A} + \frac{\dot{G}_A}{\dot{E}_2} \quad (20)$$

In the same way, the unit cost of the high-pressure steam turbine in zone B is determined from the general equality expression.

$$\dot{W}_{şf} c_{şf}^{\varepsilon} + \dot{E}_3 c_3^{\varepsilon} = \dot{E}_2 c_2^{\varepsilon} + \dot{G}_B \quad (21)$$

In this equation, There are two unknown parameters such as $c_{şf}^{\varepsilon}$ and c_3^{ε} in this equation. These parameters are related to two important turbine outputs such as $\dot{W}_{şf}$ and $\dot{E}_3$. Two different methods are used to determine for high vapor pressure cost and turbine investment capital. These methods include.

3.5.1 Equality method

With this method, primarily two separate energy production outputs as $\dot{W}_{şf}$ and $\dot{E}_3$ energy production output is taken into account in determining the capital. High vapor pressure cost and turbine investment capital, shaft unit cost when evaluated according to equality method

$$c_{şfeq}^{\varepsilon} = c_3^{\varepsilon} = \frac{c_2^{\varepsilon}}{\psi_B^{eq}} + \frac{\dot{G}_B}{\dot{W}_{şf}+\dot{E}_3} \tag{22}$$

Again, Same way the based on main formula, the electricity generator cost is determined by unit cost.

$$c_{eleq}^{\varepsilon} = \frac{c_{şfeq}^{\varepsilon}}{\dot{\psi}_C} + \frac{\dot{G}_C}{\dot{W}_{el}} \tag{23}$$

3.5.2 Extraction method

The main purpose of the turbine is to produce power in the system. Thus, including formation occurring to irreversibility in turbine, obtained all cost is made for the power. Here the unit costs of the exergy of the steam entering and leaving the turbine it is assumed to be the same. For this reason, calculations $\dot{E}_3$ are not included. According to extraction method, the unit cost for the shaft power generated in the facility is

$$c_{şfex}^{\varepsilon} = \frac{c_2^{\varepsilon}}{\psi_B^{ex}} + \frac{\dot{G}_B}{\dot{W}_{şf}} \tag{24}$$

Thus, according to the output method result in different acceptance the unit exergy cost of the steam c_3^{ε} is higher than the equality method. In the cost analysis of the plant, some costs such as construction, maintenance and repair, labor cost are not included in the cost analysis.
Again, Same way the based on main formula, the electricity generator cost is determined by unit cost

$$c_{elex}^{\varepsilon} = \frac{c_{şfex}^{\varepsilon}}{\dot{\psi}_C} + \frac{\dot{G}_C}{\dot{W}_{şf}} \tag{25}$$

The unit cost of the condensation unit is determined from (26) [25].

$$c_D^{\varepsilon} = \frac{c_3^{\varepsilon}}{\dot{\psi}_D} + \frac{\dot{G}_D}{\dot{E}_3} \tag{26}$$

Another method is without electricity energy production, only the production of steam in the system. The cost of steam production at the low pressure and temperature of the fuel boiler is calculated. The unit cost of the turbine steam c_3^{ε} is calculated. Decision to increase or decrease steam production capacity in the facility, the correct cost analysis is performed with the extraction method. It is also, whether more economical of combined systems, better decide with this method. But it is seen that using the equality or the extraction method gives the more accurate results in determining the actual cost of $\dot{W}_{şf}$ and $\dot{E}_3$.

The investment cost can be more than one unit cost. Exergy losses can take different values in each unit. However, it is not the right approach to do separately cost analysis of the different units of the plant. The equation showing the total cost of the plant is as follows. [25].

$$\dot{E}_{yak}\, c_{yak}^{\varepsilon} + (\dot{G}_A + \dot{G}_B + \dot{G}_C + \dot{G}_D) = \dot{E}_3\ c_3^{\varepsilon} + \dot{W}_{el}\, c_{el}^{\varepsilon} \tag{27}$$

The output energy cost of both turbines is assumed to be of equal importance.

$$c_3^{\varepsilon} = c_{el}^{\varepsilon} = \frac{\dot{E}_{yak}\, c_{yak}^{\varepsilon}}{\dot{W}_{el}+\dot{E}_3} \tag{28}$$

Thermal cost value of turbine unit output

$$\dot{C}_3 = \dot{E}_3 \; c_3^{\varepsilon} = \dot{m}_s \; \varepsilon_3 c_3^{\varepsilon} \tag{29}$$

is found by (28)

4 Conclusions

Shown the different I_R values for the fixed n_y = 20 years, t = 7 000 (hours / year) at during study in Fig. 2, Fig. 3, and Fig. 4. c_{sfeq}^{ε}, c_{sfex}^{ε}, c_{eleq}^{ε}, c_{elex}^{ε}, c_2, c_3 unit energy cost changes are observed depending on the systems A, B, C, D in Figure 2. As the interest rate (I_R) increases, the unit energy cost also increases and at most c_2 and at least c_{elex} increases.

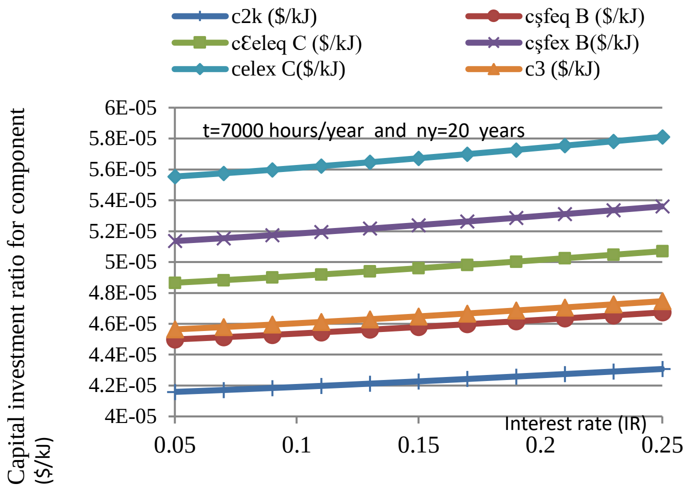

Figure 2

Exergoeconomıc Assessment Of Coal Fıred Power Plants

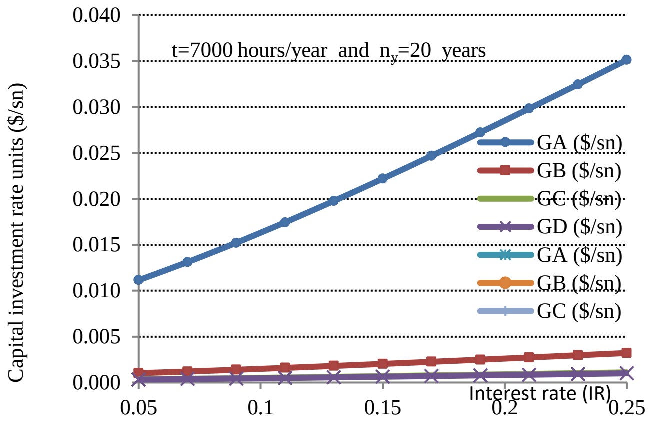

Figure 3

The unit cost of the installation units in the annual interest rate change

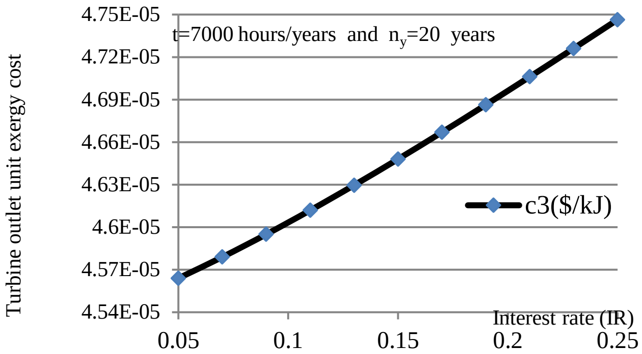

Figure 4
Total unit cost in annual interest rate change

In Fig. 3, from facility systems, the unit cost of A is $\dot{G}_A$, the unit cost of B is $\dot{G}_B$, the unit cost of C is $\dot{G}_C$, the unit cost of D is $\dot{G}_D$, the unit cost increases with the increase of the investment interest rate (I_R), especially the increase of the $\dot{G}_A$ is quite high.

In Fig. 4, as the investment interest rate (I_R) increases, unit cost per unit energy (c_3) also increases.

In Fig. 5, Fig 6, Fig. 7, t = 7 000 (hours / year) and I_R = 0.18 were examined at constant values. The economic life (n_y) of the plant is between 10 and 30 years. In this condition, as shown in Fig. 5, as the economic life increases, the unit energy costs of c^{ε}_{sfeq}, c^{ε}_{sfex}, c^{ε}_{eleq}, c^{ε}_{elex}, c_2, c_3, decreases. The generator unit cost is seen at the lowest c_2 and the maximum at c_{celex}.

In Fig. 6, the plant constituents are the cost of unit A is $\dot{G}_A$, the cost of unit B is $\dot{G}_B$, the cost of the C unit is $\dot{G}_C$. As the economic life increases, the unit cost decreases. But, unit energy cost is more than other B, C units in the boiler thermal energy production system.

Fig. 7 shows it is seen that as the economic lifetime increases, the cost per unit total energy of the plant, C_3, decreases.

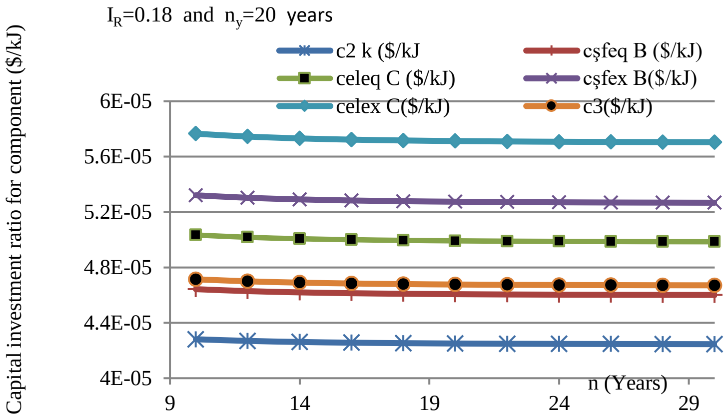

Figure 5

The unit exergy cost of each unit depending on the economic lifecycle

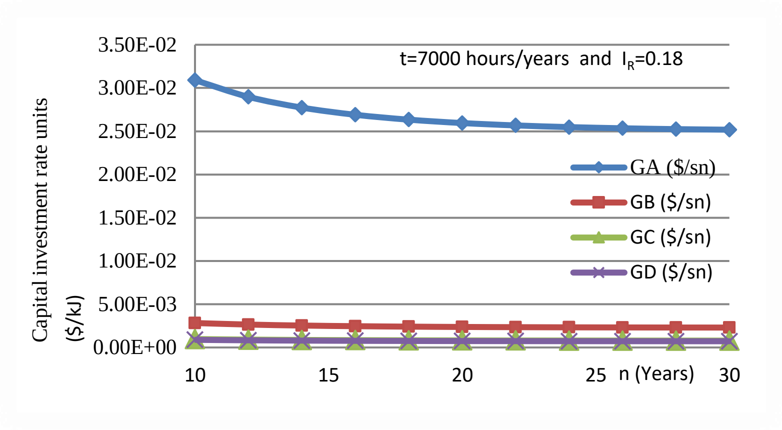

Figure 6

Depending on the economic life cycle the unit costs of installation units

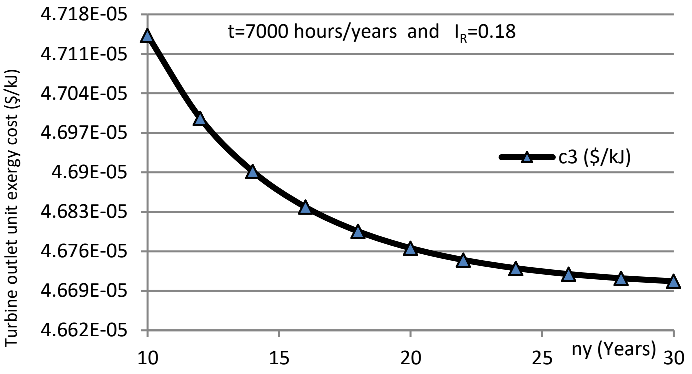

Figure 7

Depending on the economic life cycle total unit energy cost

Fig. 8, Fig. 9, Fig. 10 show that I_R = 0.18, ny = 20 years must be constant, (t) economic effect has been emphasized of the annual electricity generation period of the plant. In Fig. 6, the plant constituents examined are the cost of unit A is $\dot{G}_A$, The cost of unit B is $\dot{G}_B$, the cost of the C unit is $\dot{G}_C$. Here, unit cost is decreasing as the annual working time (t) increases. But, unit energy cost is more than other B, C, units in the boiler thermal energy production system. In Fig. 9, the unit energy costs. c^{ε}_{sfeq}, c^{ε}_{sfex}, c^{ε}_{eleq}, c^{ε}_{elex}, c_2, c_3 of the units decrease as the annual operating time (t) increases and it is seen that the lowest value c_2 at least decrease. c^{ε}_{elex}. Fig.10. shows that turbine output of the plant, cost per unit energy c_3 is decrease in as annual working time (t) increases.

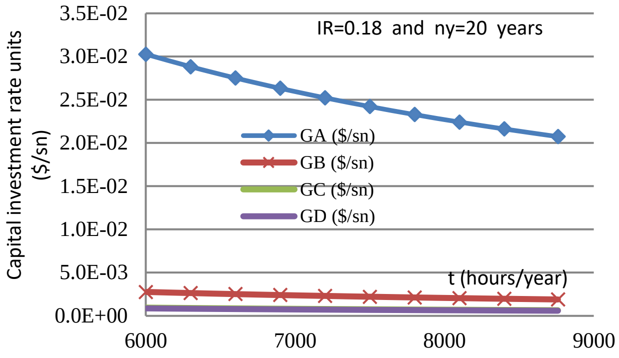

Figure 8

Unit investment cost of the units within the annual study period

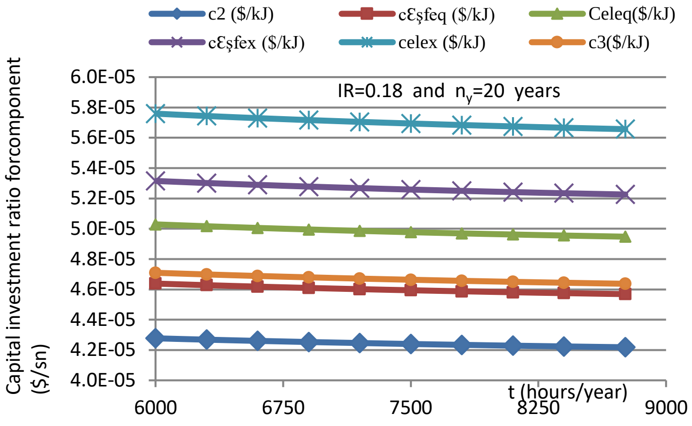

Figure 9

Unit exergy cost of each unit within the annual study period

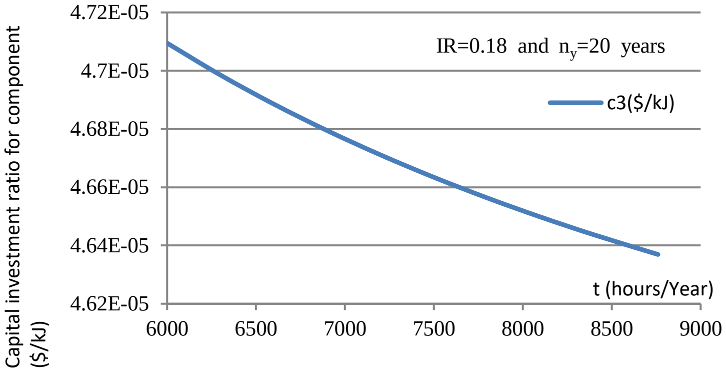

Figure 10

Turbine output unit exergy cost within annual operating period

5. Result

As a result, exergy analysis was applied to combined power plants. Plant forming systems; fuel boiler ($\dot{G}_A$), turbine ($\dot{G}_B$), electric generator ($\dot{G}_C$), condensing unit ($\dot{G}_D$). Unit costs of these systems are; as the economic life (n_y) and annual working time (t) increase, unit costs decrease, and interest rates (I_R) increase so the unit costs increase.

As the economic life (n_y) increases, costs c_{sfeq}^{ε}, c_{sfex}^{ε}, c_{eleq}^{ε}, c_{elex}^{ε}, c_2, c_3 which have the unit exergy costs of the units decreased.

As the economic life (n_y) of $\dot{G}_A$, $\dot{G}_B$, $\dot{G}_C$, units increases, unit costs decrease. Interest rate $I_R = 0.18$ economic life $n_y = 20$ about to be fixed, as the annual operating time (t) increases, the unit energy cost c_{sf}, c_{el}, c_2, c_3 decreases and consequently the lowest value is c_2 and the least decrease is c_{elex}.

As the annual operating time (t) decreases, the unit costs of $\dot{G}_A$, $\dot{G}_B$, and $\dot{G}_C$ and of the units increase. The unit energy cost in the fuel boiler B thermal power generation system was found to be higher than the C units. As the annual working time (t) increases, turbine output and unit exergy cost of generator (c_3) of the plant is understood be reduced.

Symbol	Nomenclature	SI Units
a_A	Boiler cost	$
a^c	Capital recovery factor	
b_A	Size of boiler cost	$/kW
C_A^C	Boiler cost	$
C_B^C	Türbine cost	$
C_C^C	Electric generator cost	$
C_D^C	Condenser cost	$
C_2	Boiler unit cost	$/kJ
C_3	Turbine out unit cost	$/kJ
c_k	Coal unit cost	$/kg
$c_{şfeq}$	Capital cost of türbine	$/kJ
c_{eleq}	Capital cost of electric	$/kJ
$c_{şfex}$	Capital cost of saft power	$/kJ
c_{elex}	Cost equation for electric generator	$/kJ
$\dot{E}$	Exergy flow rate	kW
$\dot{G}_A$	İnvestment cost rate for the boiler	$/s
$\dot{G}_B$	İnvestment cost rate for the turbine	$/s
$\dot{G}_C$	İnvestment cost rate for the generator	$/s
$\dot{G}_D$	İnvestment cost rate for the condensation	$/s
H_u^v	Calorific value of the coal	kJ/kg
H_s^v	Calorific value of the sulphur	kJ/kg
A	Boiler	
B	Turbine	
C	Generator	
D	Condenser	
Eq	Equality method	
Ex	Extraction method	

Symbol	Nomenclature	SI Units
h	Specific enthalpy of the stream	kJ/kg
h_{fg}	Enthalpy of evaporation of water	kJ/kg
I_R	Rate of the capital	
$\dot{m}_s$	Mass flow rate	kg/s
$\dot{m}_k$	Mass coal	kg
n_y	Period of repayment	years
$\dot{P}$	Pressure	kPa
$\dot{Q}_A$	Boiler thermal capacity	kW
s	Specific entropy	kJ/kg
s	The mass fraction of sulphur	kg
T	Temperature	C, K
t	Annual working time	7000 h/year
w	Mass franction of moisture in the fuel	
$\dot{W}_{el}$	Electric power output	kW
W_{sf}	Turbine shaft power	kW
ε	Specific exergy	kJ/kg
ψ	Exergy efficiency	
φ_{dry}	Fuel coefficient	
η	Thermic efficiency	
η_{el}	Electrical efficiency	
η_m	Mechanical efficiency	
Indices		
el	Electric power	
in	Into	
k	Coal	
o	Out	
s	Sulphur	
sp	Pesific cost	
şf	Shaft power	
yak	fuel	

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