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Investigation of a Geothermal-Based CCHP System from Energetic, Water Usage and CO_2 Emission Viewpoints

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Abstract: Renewable heat sources are a sustainable and clean way to produce power, heating, and cooling. Combined cooling, heat, and power (CCHP) systems are very promising for producing demands simultaneously. In the present study, a CCHP system with the geothermal source has been investigated, and heat loads are designed for the micro-scale application. To determine the feasibility of the system, energy analysis is carried out, and results are reported after optimization. Also, the genetic algorithm method is presented for optimization. The sub-objectives of this study are the calculations of water usage and CO_2 emission in the manufacturing process. For this matter, energy efficiency, water usage, and CO_2 emission after optimization have been examined as three significant parameters. The efficiency of the system, water usage, and CO_2 emission are reported as 46.4%, 688151.2 (lit) and 13439 $\left(kg_{co2,\ eq}\right)$ respectively. The total purchase cost is 43121 \$. Moreover, the results show that between components the maximum water usage in manufacturing and CO_2 emission is belonged to vapor generator with 242010 (lit) and 4701 $\left(kg_{co2,\ eq}\right)$.

keywords: Geothermal, Energy Efficiency, Water Usage, Carbon DIoxide Emission, CCHP, Genetic Algorithm, Optimization

1. Introduction

Energy efficiency has been a great deal of attention because of increased energy prices, shortage of resources, and environmental limitations [1]. International Energy Agency examines different scenarios based on energy technologies, which presented that energy efficiency has a significant role in all choices concerning carbon dioxide reduction [2]. Thus, energy efficiency has an essential part of sustainability development. Multi-generation systems consider as a promising energy-efficient technology; which concludes the simultaneous production of two or more energy agent in a specific integrated process. Combined cooling, heat, and power (CCHP) is one type of multi-generation systems so-called tri-generation. CCHP indicates that power and valuable heat are produced at the same time, along with cooling, which is possible by utilizing the additional surplus heat that would be wasted in conventional technologies.

For this reason, Yi *et al.* [3] suggested a novel polygeneration with dual-gas feed, which utilizes methane and CO_2. Considering CHP as an example into account, which generates applicable heat and power at the same time [4]. The efficiency of a steam turbine is 20-38% in general for stand-alone power generation, but 80-90% when useful heat is additionally produced. The fuel and emission savings fluctuate from 10 to 40 percent reliant on the production technologies used initially by the replaced system [5]. Shariati *et al.* [6] proposed a CHP system consisted of small-scale gasification for industrial purposes. The total energy efficiency of polygeneration can be enhanced further because of the extra useful energy products that can be arisen from the excess heat (e.g., cooling energy).

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Polygeneration has a broader wide range of applications in district heating and cooling, utilities, domestic and commercial buildings and also in different industrial regions, such as paper, plastic, agriculture, chemical, raw materials, and food [7-10]. Several studies have been done to investigate different multi-generation systems [11-15]. Golchoobian *et al.* [12] performed a thermodynamic evaluation for three combined cooling and power (CCP) systems comprised of a micro-gas turbine, steam turbine, and ejector refrigeration technology using R141 as the working fluid. Rostamzadeh *et al.* [13] proposed a novel CCP with three modified combination of the organic Rankine cycle (ORC) and the ejector refrigeration cycle (ERC). This system has been developed from exergoeconomic optimization viewpoint by a combination of ORC and cascade ejector refrigeration system to generate power and cooling at two different adjustable levels by Ebadollahi *et al.* [14]. Wang *et al.* [15] investigated the capability of a CHP with application in building sector driven by solar energy combined with an ORC and ERC systems. Above all, using the geothermal as the reserved heat inside the earth can be a great alternative technology for multi-generation systems. As the Geothermal Energy Association (GEA) reported, the geothermal power industry reached about 3442 MW at the end of 2013 [16]. In recent years, utilizing geothermal energy as the heat source in multigeneration systems has been increased. Several authors have been proposed different multi-generation systems based on a geothermal source. Ratlamwala *et al.* [17] suggested a novel CCHP with hydrogen production based on double flash power generating, ammonia-water absorption, and electrolyzer systems with a geothermal heat source. Akrami *et al.* [18] investigated a geothermal-based multi-generation energy system from energetic and exergoeconomic viewpoints. Ebadollahi *et al.* [19] proposed two CHP systems based on ORC and Kalina cycle which are suitable for the Sabalan geothermal source. In another study, Ebadollahi *et al.* [20] presented a novel CCHP and hydrogen production system using liquefied natural gas (LNG) as a cold energy recovery unit. While the combustion of fossil fuels has been a significant matter of the debate on global warming, when considering power generation, it is essential to acknowledge that all types of energy systems have a CO_2 emission (CE) [21, 22]. Neither any fossil fuel is used nor renewable sources for energy production, the manufacturing process of materials and also the transportation of those to the construction site all releases greenhouse gases [23]. The same argument is propounded when it comes to water footprint (WF), the average WF per unit of electricity, though, might be varies, with respect to the energy and technologies that has been used in the energy system such as the type of cooling technology or the thermal utilities implemented in the system [24]. Cheng *et al.* [25] suggested a new analytical approach for carbon emission flow in energy systems to assess the carbon emission concerning energy production and conversion process.

In the present paper, the optimization of a CCHP with the combination of ORC, ERC, and geothermal heat source has been studied. In literature, the lack of research on the relations between the water and CO_2 emission with energy analysis has been found. Due to the importance of this matter, this research aims to improve the cogeneration efficiency of the presented CCHP concerning the water usage of the components in the manufacturing process and the CO_2 emission of them. The combined effect between the optimal operation of the system, water used in manufacturing and CO_2 emission has been investigated.

2. System Description

The CCHP system with R134a as its working fluid driven by the geothermal source has consisted of two subsystems: (i) the heat source and (ii) the CCHP subsystem. The schematic illustration of the integrated system is demonstrated in Fig. 1. In the heat source subsystem, the LTW (Low-Temperature Well) of Sabalan geothermal has been used as the primary heat source for the vapor generator. The inlet temperature and pressure of this stream are 438 K and 700 kPa respectively [26].

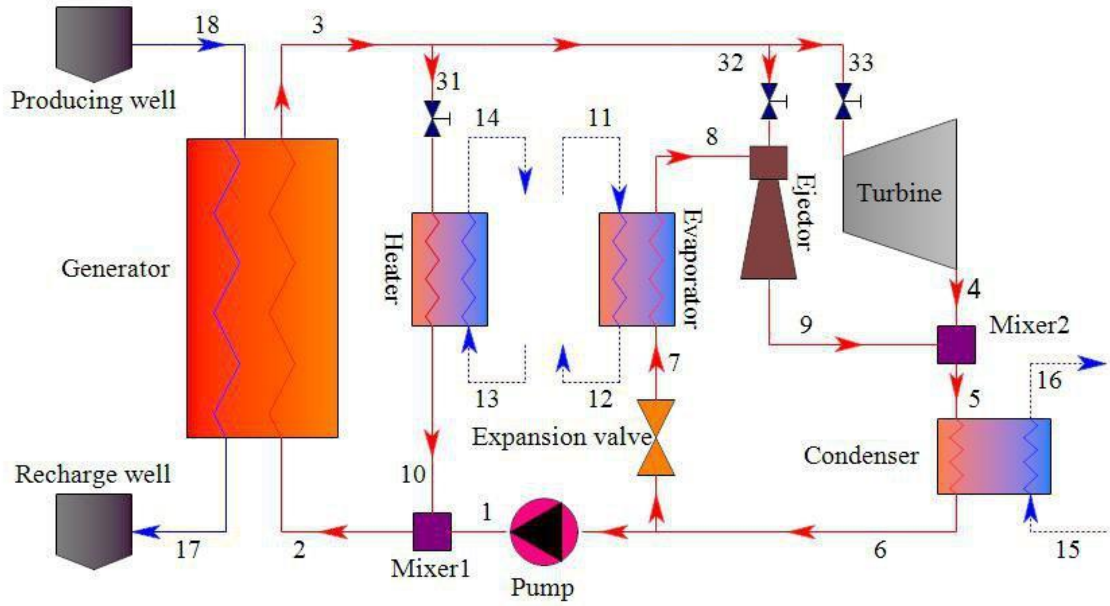

Figure 1. Schematic diagram of the CCHP with geothermal source

The CCHP consists of these components: vapor generator, turbine, evaporator, heater, regenerator, condenser, ejector, feed pump, and throttling valve. In the vapor generator, the working fluid at the liquid phase is evaporated to super-heated vapor via absorbing heat from the geothermal source. Then, it divides to three streams: one outlet enters the heater for the heating purpose, other flows through the supersonic nozzle of the ejector while the other expands by the turbine for generating power. A high vacuum can be formed by the rapid flow at the nozzle terminal while taking a secondary flow from the evaporator into the chamber. Two streams are mixed in the chamber then flow throughout the diffuser of the ejector. Then, Exhaust of the turbine and Outlet stream of the ejector are combined into the mixer (2) before flowing through the condenser. In the condenser, the fluid is condensed to a saturated liquid by rejecting heat into the ambient. One branch of the exit condenser flows throughout a throttle valve and inserts to the evaporator, while the other one flows across the mixer (1) after being pumped. Afterward, the liquid is pumped to the vapor generator to complete a whole cycle.

Generally, the present CCHP system could be operated under three different conditions. In a warm climate like summer, when the need for cooling and power are presented, the heating branch is not operating, and the system works as a combined cooling and power (CCP). In winter, the system can be switched to the combined heating and power (CHP) mode, which cuts off the cooling branch. In some applications, when neither heating nor cooling needed, the system could produce only power.

3. Mathematical Representation

In this section, the mathematical modeling of the examined CCHP is described with details. The energy balances in the components, the mass flow rate balances, and the outputs definitions are specified. Furthermore, all the assumptions are clarified to model the proposed system from thermodynamics viewpoint in a convenient way. Following considerations have been made in this investigation to simulate the cycle appropriately:

- All components operate at a steady-state condition.
- The ambient temperature and pressure have been considered at 298.15 K and 1.01 bar, respectively.
- Isentropic efficiency of the turbine and pump are assumed to be 95% and 90% respectively.
- The thermal efficiency of the heat exchanger is presumed to be 80%, and terminal temperature difference in heat exchangers is presumed 10 K.
- The kinetic energy in the inlet and outlet of the control volumes are neglected.
- The ideal gas model with constant properties has been used inside the ejector in an adiabatic process.

• Outlet streams of the evaporator, heat exchangers and condenser are taken into account as saturated fluids.

• Inlet water enters the condenser assumed to be in ambient condition.

3.1. Energy and Mass Flow Rate Balances

A control volume for each component is taken into consideration, and the first law of thermodynamics applied to assure the mass and energy conservation laws. For this matter, mass and energy balance relations can be stated as follows:

$$\sum \dot{m}_{in} = \sum \dot{m}_{out} \quad (1)$$

$$\sum (\dot{m}h)_{in} - \sum (\dot{m}h)_{out} + \sum \dot{Q} - \sum \dot{W} = 0 \quad (2)$$

The following equations give the energy balances in the heater, condenser, and evaporator:

$$\dot{Q}_h = (\dot{m}_{31})(h_{31} - h_{10}) \quad (3)$$

$$\dot{Q}_c = (\dot{m}_6)(h_5 - h_6) \quad (4)$$

$$\dot{Q}_e = (\dot{m}_7)(h_8 - h_6) \quad (5)$$

3.2. Vapor generator calculation

The following equation explains the heat exchanger operation:

$$\dot{m}_{12}h_{12} + \dot{m}_{16}h_{16} = \dot{m}_{13}h_{13} + \dot{m}_{14}h_{14} \quad (6)$$

3.3. Turbine Calculations

The turbine is responsible for power generation. This power is taken from the generator for electricity production. Eq. (7) describes the isentropic efficiency definition of the turbine, while Eq. (7) presents the work produced by the turbine.

$$\eta_{is,t} = \frac{h_{33} - h_4}{h_{33} - h_{is,4}} \quad (7)$$

$$\dot{W}_t = (\dot{m}_{33})(h_{33} - h_4) \quad (8)$$

3.4. Pump Calculations

Pump expands energy in order to compress and pressurize fluids. Eq. (9) describes the isentropic efficiency definition of the turbine, while Eq. (10) presents the work produced by the turbine.

$$\eta_{is,p} = \frac{h_{is,1} - h_6}{h_1 - h_6} \quad (9)$$

$$\dot{W}_p = (\dot{m}_1)(h_1 - h_6) \quad (10)$$

3.5. Ejector Calculations

The ejector has the capability of transportation and compressing a bulk of induced fluid from the suction pressure to the exit pressure. Liu *et al.* [27] have been indicated the full mathematical relations of the ejector. In table 1, all the parameters and relations of the ejector have been defined.

Table 1. Parameters and relations of the ejector [27]

Relation	Parameter	Eq.
$a_1 = \frac{\sqrt{\eta_s}}{\sqrt{\eta_p}} \emptyset_m$	Constant Factor	(11)
$a_2 = -\frac{\sqrt{\eta_s}}{\sqrt{\eta_p}} \emptyset_p$	Constant Factor	(12)
$x_1 = \frac{P_{s\sqrt{T_p}}}{P_{p\sqrt{T_s}}} \frac{A_3}{A_t}$	-	(13)
$x_2 = \frac{P_{s\sqrt{T_p}}}{P_{p\sqrt{T_s}}} \frac{A_{py}}{A_t}$	-	(14)
$b_1 = \frac{\sqrt{\eta_p \eta_d}}{\emptyset_d}$	Constant Factor	(15)
$b_2 = \frac{\emptyset_m}{\emptyset_d}$	Constant Factor	(16)
$x_3 = (V_{py} + \omega V_{sy}) \frac{P_p}{\sqrt{T_p}} \sqrt{\frac{\gamma}{R}\left(\frac{2}{\gamma+1}\right)^{\frac{\gamma+1}{\gamma-1}}}$	-	(17)
$x_4 = P_{sy}\frac{A_3}{A_t}$	-	(18)
$\omega = a_1 x_1 + a_2 x_2$	Entrainment Ratio	(19)
$P_C^* = b_1 x_3 + b_2 x_4$	Critical Back Pressure	(20)

η_s: Suction efficiency, η_p: Primary nozzle efficiency η_d = Diffuser efficiency, P_s: Secondary flow pressure, P_p: Primary flow pressure, T_s: Secondary flow Temperature, T_p: Primary flow Temperature $\emptyset_m$, $\emptyset_p$, $\emptyset_d$: ejector geometrical parameters

In order to assess the validity of the ejector's simulation, the experimental data extracted from Ref. [28] for ejector parameters using R134a as working fluid is performed on the constructed mathematical representation and results are compared in Table 2. Eqs. (21) and (22) have been employed to calculate the relative error and Root Mean Square (RMS) error.

Based on Table 2, the ARD errors are under 8%, which shows a good agreement with the experimental results.

$$E_R = \left|\frac{V_{Ref} - V_{model}}{V_{Ref}}\right| \tag{21}$$

$$E_{RMS} = \sqrt{\frac{\sum_{i=1}^{N}\left(\frac{V_{Ref}-V_{model}}{V_{Ref}}\right)^2}{N}} \tag{22}$$

Where V_{Ref} and V_{model} denote for the values of the selected parameter obtained at the chosen reference and present research, respectively.

3.6. Other Components and Definitions

The throttling valve is assumed as ideal, which means that the enthalpy is constant. Eq. (23) describe this assumption:

$$h_7 = h_6 \tag{23}$$

The overall efficiency of the trigeneration system is as explained in Eq. (24):

$$\eta_{CCHP} = \frac{\dot{W} + \dot{Q}_H + \dot{Q}_e}{\dot{Q}_{V.G}} \tag{24}$$

The logarithmic mean temperature difference (LMTD), and the overall heat transfer coefficient (U_i), the heat transfer equation can be expressed as follows:

$$\dot{Q}_i = U_i\, A_i\, LMTD_i \tag{25}$$

The overall heat transfer coefficient for heat exchangers has been reported in Table 3.

3.7. Cost Evaluation

In order to assess the component costs, the cost functions for each - are extracted from literature (see Table 4).

Table 2. Ejector result comparison between present research and Del Valle *et al.* [28]

T_{pf}(°C)	T_{sf}(°C)	$\omega = \dot{m}_{sf}/\dot{m}_{pf}$		$T_{sat,cri}(K)$		ARD₁* (%)	ARD₂** (%)
		Del Valle *et al.* [28]	**Present work**	**Del Valle *et al.* [28]**	**Present work**		
89.37	17	0.422	0.4138	28.95	30.48	1.94	0.55
89.37	20	0.494	0.474	29.41	32.01	4.04	0.9
94.39	17	0.342	0.3596	31.68	32.72	5.14	0.39
94.39	20	0.398	0.4138	32.47	34.17	3.97	0.6
99.15	15	0.273	0.2838	32.02	34.07	3.95	0.72
99.15	17	0.297	0.3144	34.11	34.94	5.85	0.32
99.15	20	0.339	0.3635	35.41	36.3	7.22	0.33

*Absolute relative difference for ω

**Absolute relative difference for critical temperature

Table 3. Overall heat transfer coefficient for heat exchangers [29]

Component	The overall heat transfer coefficient $(kW.m^{-2}.K^{-1})$
Vapor generator	1.6
Evaporator	0.9
Condenser	1.1
Heater	0.9

Table 4. Function costs for each component [20, 30, 31]

Component	Cost function	Reference year	Eq.
Turbine	$Z_t = 3880 \dot{W}_t^{0.7}\left(1+\left(\frac{0.05}{1-\eta_{is,t}}\right)^3\right)\left(1+5\times 2.71^{\frac{T_{vg}-866}{10.42}}\right)$	2000	(26)
Pump	$Z_{pu} = Z_{R,pu}\left(\frac{\dot{W}_{pu}}{\dot{W}_{R,pu}}\right)^{m_p}\left(\frac{1-\eta_{is,pu}}{\eta_{is,pu}}\right)^{n_p}$	2000	(27)
Ejector	$Z_{ej} = A'B'M\left(\frac{T_{in}}{P_{in}}\right)^{0.05} P_{out}^{-0.75}$	2000	(28)
Expansion Valve	$Z_{ev} = 114.5\, \dot{m}_{ev}$	2000	(29)
Heat exchanger	$Z_{HE} = 2143 \times A_{HE}{}^{0.514}$	2006	(30)
Working Fluid	$Z_{wf} = 25\dot{m}_{fluid}$	2012	(31)
Mixer	$Z_{mix} = 280.3\, \dot{m}_{exit}^{0.67}$	2000	(32)

4. Methods

A proper mathematical code is written in the engineering equation solver (EES) software in order to simulate the examined system regarding the assumptions that had been described earlier. The energy analysis with the aim of the first law of thermodynamics has been examined. Genetic algorithm has been widely implemented for optimizing energy systems [32]. Thus, the genetic algorithm has been employed in this study for finding the optimum state. The parameters of the genetic algorithm method are shown in Table 5. The thermal efficiency of the system is considered as the objective function. While vapor generator pressure $(P_{v.g})$, evaporator pressure (P_e), heater pressure (P_h), a thermal temperature difference of vapor generator $(TTD_{v.g})$, condenser (TTD_c), heater (TTD_h), and evaporator (TTD_e) are specified as the decision variables as described in Table 6, respectively. It has to be noted, the main goal of this optimization is the maximization of the thermal efficiency by considering a single parameter as an objective function [30].

$$\text{Optimize: } \eta_{th}\,(P_{v.g}, P_e, P_h, TTD_{v.g}, TTD_c, TTD_h, TTD_e) \tag{33}$$

Table 5. Optimization assumptions and outcomes

Parameter	Value
Individual number in the population	32
Number of generations	64
Maximum mutation rate	0.25
Minimum mutation rate	0.0005
Initial mutation rate	0.25
Crossover probability	0.85

To calculate the water usage and CO_2 emission of the presented CCHP system, the required quantity of materials for each component has been estimated. For this matter, the amount of the selected heat exchangers has been evaluated with the help of Aspen EDR. The most responsible components for water usage and CO_2 emissions are turbine and heat exchangers. Because of this, a correction factor is considered for considering other components with lower impacts on water usage and CO_2 emission. Details of the calculations are described in the next section.

5. Results and Discussion

The present study aims to investigate the energy analysis of the present CCHP system with the geothermal source by EES software. The assumptions have been made as described in Section (3) for modeling the system more accurately. For a cold environment, the demand for heat and cooling set to be 150 and 15 kW, respectively. After executing the results, a genetic algorithm has been indicated for optimizing the thermal efficiency, as explained in the previous section. The thermal efficiency of the CCHP system before and after optimization is 42.1% and 46.4% respectively. The results of the energy simulation have been reported in Table 7. With the optimized written code, the thermodynamic and mass flow rates of each state have been derived (see Table 8).

The specifications of each component were calculated from modeling and energy analysis of this system. The size and material of each component are required for finding the weight of constructions. For the water usage (WU) and CO_2 emission (CE) calculations; after specifying the types and specifications of each component, the amount of materials used in each component is estimated. Based on these compositions, the WU and CE of the turbine and heat exchangers have been calculated. For calculating the weight of the heat exchangers, the Aspen EDR has been used. All heat exchangers are shell-and-tube type and made of chromium-nickel. The selected turbine consists of 52% steel, 41% iron, and 6.6% copper. The values of carbon and water used in the manufacturing process of steel, iron, and chromium-nickel has been obtained from Ashby *et al.* [33]. The main components responsible for water usage and CO_2 emission are heat exchangers and turbine. Due to this fact, a correction factor of 1.1 values has been applied because of other components, i.e., ejector, mixers, throttling valve, and piping.

Table 6. Genetic algorithm parameters

Decision variables	Range of difference	Optimization results
Vapor Generator pressure $P_{v.g}$ (kPa)	2000-3500	3497
Evaporator pressure P_e (kPa)	400-500	497
Heater temperature P_h (K)	325-345	339.2
Terminal temperature difference of generator $TTD_{v.g}$ (K)	5-15	14.94
Terminal temperature difference of condenser TTD_c (K)	5-15	14.83
Terminal temperature difference of heater TTD_h (K)	5-15	14.49
Terminal temperature difference of evaporator TTD_e (K)	5-15	9.802

The results of the WU and CE indicate the vapor generator as the maximum WU and CE of the system and the evaporator as the minimum. The reported WU and CE for vapor generator are 24210 litter and 4701 $kg_{co2,eq}$. While this amounts for the evaporator are 16990 litter and 330.1 $kg_{co2,eq}$ respectively (Table 9).

Cost evaluation is applied for different components of this system (see Table 10). According to the results, the turbine has the highest purchase cost. The system purchase cost is 43121.65 $.

Table 7. The results of energy simulation

Results	Value
Cogeneration efficiency (%)	46.4
Heating load (kW)	150
Cooling load (kW)	15
Vapor generator load (kW)	376.5
Condenser load (kW)	192.7
Turbine power (kW)	9.69

Table 8. Thermodynamic properties at each stage of the system

Point	T (K)	P (kPa)	s $\left(kJ.kg^{-1}.K^{-1}\right)$	h $\left(kJ.kg^{-1}\right)$	$\dot{m}$ $(kg.s^{-1})$
1	342.5	3497	0.5255	153.4	0.8884
2	340.9	3497	0.5176	150.7	1.748
3	423.1	3497	1.095	366.1	1.748
31	423.1	3497	1.095	366.1	0.8593
32	423.1	3497	1.095	366.1	0.2196
33	423.1	3497	1.095	366.1	0.6687
4	398.3	1999	1.096	351.6	0.6687
4s	397.7	1999	1.095	350.9	0.6687
5	392.1	1999	1.078	344.5	1
6	340.6	1999	0.525	151.7	1
7	288.7	497	0.5518	151.7	0.1116
8	288.7	497	0.9241	259.2	0.1116
9	379.7	1999	1.041	330.1	0.3313
10	339.2	3497	0.5095	147.9	0.8593

Table 9. Results of water usage and CO2 emission in the manufacturing process

Components	Heat capacity (kW)	Microturbine power (kW)	Weight (kg)	Heat transfer area (m^2)	WU in manufacturing (lit)	CE $\left(kg_{co2,eq}\right)$
Vapor generator	376.5	-	408.8	12.86	242010	4701
Evaporator	15	-	28.7	1.817	16990	330.1
Heater	150	-	308	7.939	182336	3542
Condenser	192.8	-	284.9	2.615	168661	3276
Turbine	-	9.687	105.9	-	15595	368.81

Table 10. Equipment purchase costs

Component	Cost ($)
Turbine	21395.22
Pump 1	384.68
Ejector	10.24
Expansion Valve	12.78
Vapor Generator	7964.75
Heater	6215.87
Evaporator	2912.93
Condenser	3512.39
Working Fluid	25.00
Mixer 1	280.30
Mixer 2	407.50
Total	43121.65

5.1. Parametric study

A parametric study is applied to investigate the impact of $TTD_{v.g}$, heat source temperature, and evaporator and vapor generator pressures. With increasing $TTD_{v.g}$, the heat recovery of the vapor generator decreases, therefore, $\dot{Q}_{v.g}$ will be decreased which has a greater impact on η_{th} than $\dot{W}_{net}$ (Fig. 2). Similarly in case of heat source temperature, since the turbine inlet stream has more thermal energy, turbine power will be increased while heat source temperature arises. But as is shown in Fig. 3, η_{th} decreased for the same reason. With increasing P_{vg}, $\dot{Q}_{v.g}$ decreases while $\dot{W}_{net}$ is increasing. Since the rate of increase in $\dot{W}_{net}$ is more than $\dot{Q}_{v.g}$, η_{th} will be increased (Fig. 4). With increasing P_e, the mass flow rate of the evaporator ($\dot{m}_6$) increases because of the constant cooling load ($\dot{Q}_e$). Based on mass balances the flow rate of vapor generator has decreased. $\dot{W}_t$ decreases since the mass flow rate of turbine inlet is decreased. Eventually, $\dot{W}_{net}$ is decreased but the rate of decrease in $\dot{Q}_{v.g}$ is more than $\dot{W}_{net}$, η_{th} will be increased (Fig. 5).

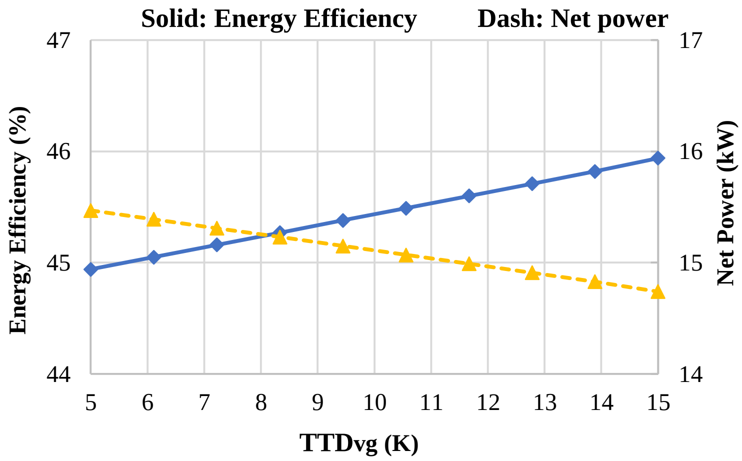

Figure 2. Impact of TTD_{vg} on the energetic efficiency and net power

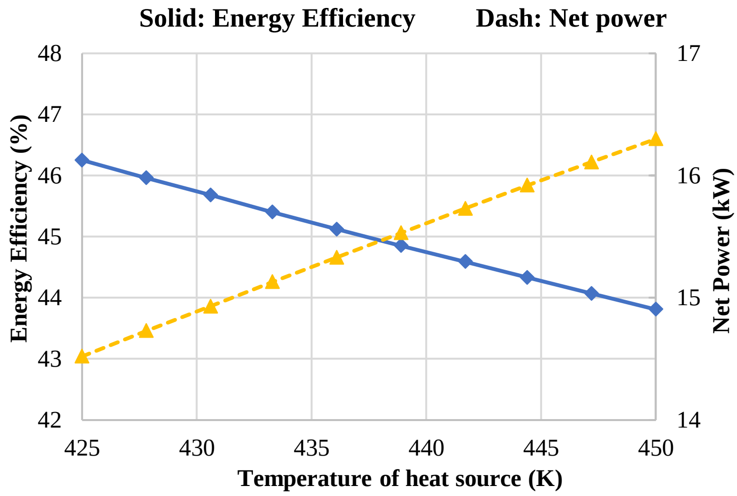

Figure 3. Impact of heat source temperature on the energetic efficiency and net power

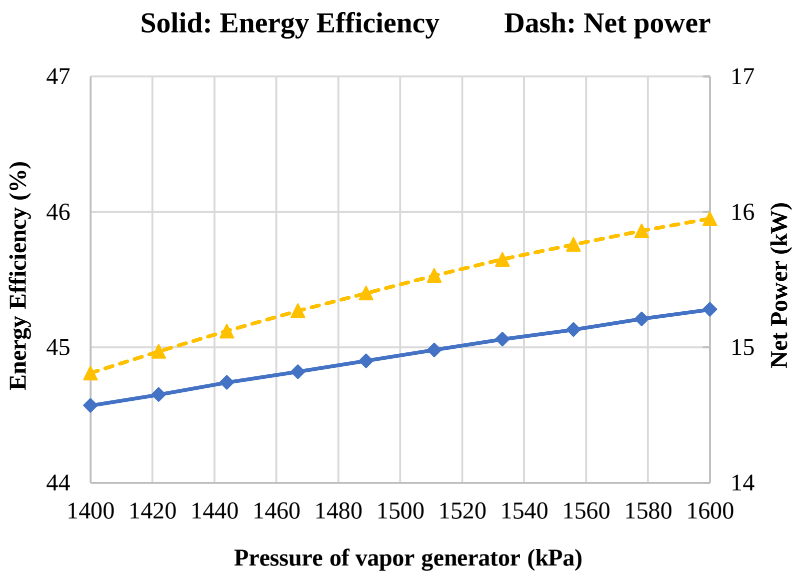

Figure 4. Impact of P_{vg} on the energetic efficiency and net power

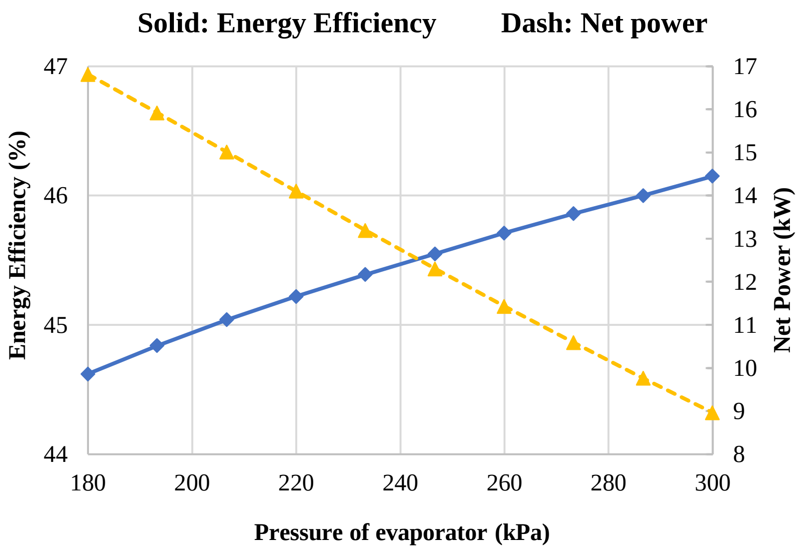

Figure 5. Impact of Pe on the energetic efficiency and net power

6. Conclusion

Energy efficiency depicts a significant role in the growth of sustainability. Polygeneration is a promising energy-efficient technology; the basic form of polygeneration is CHP and CCHP systems. In this paper, a CCHP system with the geothermal source has been investigated. To determine the feasibility of the system, according to energy assessment outcomes, the efficiency of the system is increased from 42.1% to 46.4% after optimization. The whole purchase cost of the system is 43121.65 $. One of the sub-purposes of this research is the calculations of water usage and CO_2 emission in the manufacturing process. For this matter, water usage, and CO_2 emission after optimization have been examined as two significant parameters. Therefore, the results for water usage and CO2 emission are reported as 688151.2 (lit) and 13439.8 $\left(kg_{co2,eq}\right)$, respectively. Furthermore, the results indicate that between components, the maximum water usage in manufacturing and CO2 emission are belonged to vapor generator with 242010 (lit) and 4701 $\left(kg_{co2,eq}\right)$.

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