Energy and Exergy Analysis of Organic Rankine Cycle (ORC) using Different Eco-Friendly Organic Fluids

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ABSTRACT

In modern days technology, organic Rankine cycle proved as a promising methodology which can provide the effective recovery of waste heat. The main sources of heat for the organic Rankine cycle are mainly medium to low temperature heat sources. The main role performed by ORC is to transform the low-grade energy into its useful form. The present study investigated the performance of various eco-friendly organic liquids-based ORC. Liquids of interest include n-pentane, n-hexane, n-heptane, benzene, and toluene. Thermodynamic analysis of the ORC is carried out by solving the mathematical equations obtained through the energy and exergy balance approach by using Engineering equation solver (EES) software. With increase of vapor generator temperature, energy and exergy efficiencies of organic Rankine cycle also increases. However, the net-work done output decreases. In contrast, with increase in condenser temperature the net-work output, energy efficiency and exergy efficiency they all show declination. Additionally, considering all the five organic working fluids, the value of their net-work done hikes with escalation in mass flow rate of flue gas. Meanwhile, the energy and exergy efficiencies of all these fluids remain constant throughout the process.

Keywords: Organic Rankine cycle (ORC), Eco-friendly, Engineering equation solver (EES), Energy efficiency, Exergy efficiency.

1 Introduction

Every year, a sufficient amount of energy produced worldwide is dumped as waste heat. Most waste heat is classified as low-grade heat or heat below 200 °C. Over 2,500 trillion BTUs in process heating energy are lost annually in highly industrialized nations, including the United States, of which only 10 to 25% can be recovered. Production of greenhouse gases can be drastically reduced by recovering and reutilizing this thermal energy for useful purposes. Although additional methods are now being used to recover this thermal energy, but the organic Rankine cycle considered as the most suitable one. [1].

Beginning in the 19th century, ORC has grown in significance in the power industries of the 21st century. Based on the literature, two solar ORC engines having capacities of 4.5 kW and 11 kW were built in 1904, using sulphur dioxide as the working fluid. In 1940, D'Amelio built a geothermal plant using ethylene as its operating fluid. Until 1950, it was in operation before being shut down. The fields of commercial ORC plants have greatly benefited due to manufacturing over 3000 units up to 4 kW and over 500 units ranging in power from 1 to 25 MW [2]. The primary distinction between ORC and the Rankine cycle is that ORC employs organic fluid instead of water as its working fluid. Compared to typical steam power plants, ORCs operate at lower pressures and temperatures, which results in cheaper installation costs [3]. An ORC is useful for recovering heat from low-temperature sources in an industrial environment. Energy from the sun, thermal energy inside the earth, energy from biomass, automobile exhaust's waste heat, and residual heat from factories and power plants are typical low-temperature sources. ORC is desirable because of its simplicity and accessibility of components [4]. Due to its viability, flexibility, dependability and low maintenance cost, the ORC is becoming the preferred technique to convert low-grade heat into the desired

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high-grade form. [5]. Saini *et al.* [6] proposed three innovative topologies powered by solar energy integrated with heating, cooling, and power systems (CCHP). The CCHP systems include an organic Rankine cycle, a solar thermal evacuated U-tube collector, heat exchanger for heating and an ejector refrigeration cycle for cooling. A thermodynamic analysis of the CCHP system was performed to investigate the performance of all the configurations. All the designs are recommended to identify an environment-favourable method for future human comfort and energy demand. As per 2009 Climate Change Convention, an increase in global temperatures of 2 °C would be catastrophic for individuals and the environment. Therefore, selecting the kind of organic working fluid for ORC must be restricted to environmental factors [7]. Mainly three variety of fluids exist in ORC as working fluids: dry, wet, and isentropic. In the T-s diagram, this division is based on whether the slope of the saturation curve is positive, infinite, or negative. When it comes to avoiding liquid droplets from obstructing the expansion process of the turbine blades, dry and isentropic fluids are more advantageous for ORC.

To increase the output of the turbine, fluids having high density, low liquid-specific heat, and high latent heat are sought. Considering environmental concerns and the increasing rate of global warming, an appropriate working fluid must have less ODP (ozone depletion potential) and less GWP (global warming potential), as well as suitable chemical stability under operating circumstances [8]. Since the working fluid's boiling point in the ORC have a significantly lower value than the steam, there is no need to create steam at a high temperature to run a micro-turbine. That is the primary reason that ORCs can be driven at a lower temperature range than the Rankine cycle, which uses water as a working fuel. The low operating pressure and temperature of ORC also ensure better system safety. Researchers did many studies to find an optimal working fluid for ORC. It was found that none of the particular fluids can fulfil all of the required benchmarks. It completely rely on type of the application in which the functioning fluid is going to use [9]. Wen-quiang *et al.* [10] recovered waste heat from exhaust hot water [EHW] with the help of the organic Rankine cycle. Saini *et al.* [11] developed a solar-powered sustainable and compact combined heating, cooling, and power system to meet the power needs of less storey buildings in far locations. It utilized ORC with thermal energy storage, evacuated tube collectors, ejector refrigeration cycle, and water heater to produce the desired outputs through heating and cooling. Saini *et al.* [12] investigated an innovative solar-driven, small-scale sustainable combined heating, desalination and power system for cold, distant houses using an evacuated tube solar collector integrated with latent heat storage, an active solar still, a water heater, and an ORC system with therminol-66 and n-butane as the working fluid. The primary goal was to simultaneously create power, drinkable water, and hot water. Heberle and Bruggemann [13] examined the concepts of ORC parallel and series circuit combinations. Heat formation for geo-thermal resources carrying temperatures less than 450 K, was investigated using analysis by second-law. In ORC, iso-pentane, iso-butane, R245fa and R227ea were used as working fluids.

Chowdhury and Mokheimer [14] conducted a comparative energy and exergy performance inspection of a solar powered organic Rankine cycle using several organic fluids. They discovered that n-pentane could perform at peak temperatures up to 480 K compared to R245fa and R134a. Toluene operated best at higher turbine inlet temperatures of up to 550 K. Li [15] discovered that ORC paired with an internal heat exchanger (IHX) attended better thermal efficiency and less energy destruction than baseline ORC. Abam *et al.* [16] adapted the ORC for cooling and power generation by including turbine bleeding and regeneration (ORCTBR). Lee and Kim [17] conducted an energetic and energetic study of the combined LNG Rankine and organic Rankine cycles. They discovered that the volume of power produced in the ORC and LNG cycles is the same, highlighting the importance of the cold energy of LNG. Razmi *et al.* [18] presents an innovative cogeneration system revolve around the hybrid compression-absorption refrigeration cycle, ORC, and the compressed air energy storage. It was attempted to improve the efficiency of the CAES by using cooling capacity from the remaining hot gases in the exhaust of the turbine by operating an ORC-driven refrigeration system.

Zarei *et al.* [19] built a system with an ejector-compression refrigeration cycle for chilling above and below zero and a recuperative ORC. This system provides cooling and heating as well as power for home purposes. Rosyid [20] discovered that by employing n-pentane as an eco-friendly, organic working fluid in ORC, the total efficiency of the system improves and can be larger than 25%. Tashtoush *et al.* [21] developed a method in which solar energy is integrated with ORC to generate cooling and electric power in a combined ejector refrigeration system. According to Dai *et al.* [22], hydrocarbons (HCs) are promising working fluids for ORC with exceptionally low global warming potential (GWP). Koc *et al.* [23] established a subcritical and supercritical regenerative ORC (rORC). It turned out that subcritical rORC provides the best performance. By incorporating it into the system, the disadvantages of ORC (poor performance) and the supercritical cycle can be eliminated. The scope for improvement in overall performance of the system exists. Yuan *et al.* [24] used ORC to generate power from a hot, dry rock geothermal resource. To assess the performance of the system, the related thermal calculation model was produced. Acar and Arslan [25] reported that when geothermal-powered ORC is combined with solar energy, the energy and exergy efficiencies decline, but there is improvement in total power-output of the system. By minimizing the solar collector area, the exergy and energy efficiency of the geothermal-powered, solar energy-aided ORC improves. Guanglin *et al.* [26] observed that many driving fluids are suited for various temperature of heat source. Depending on heat source characteristics, the appropriate working fluid and split ratio must be calculated.

2 System Description

The configuration of the proposed ORC system is shown in Figure 1 and Figure 2. show the temperature-entropy diagram for the system. The driving fluids of ORCs are crucial to the functioning of the system. Five different types of organic driving fluids are used in this investigation to assess the thermodynamic performance of the ORC system. The organic fluids are n-heptane, toluene, benzene, n-hexane, and n-pentane. The important properties of ORCs chosen organic working fluids are given in Table 1 and the input parameters used in this study of ORC are given in Table 2. Working fluids are chosen solely based on their low global warming potential (GWP) and ozone depletion potential (ODP), which are considered when selecting a fluid. Except for using organic fluids with low boiling temperatures as the working fluid in place of water, constructing an ORC is alike a conventional steam cycle.

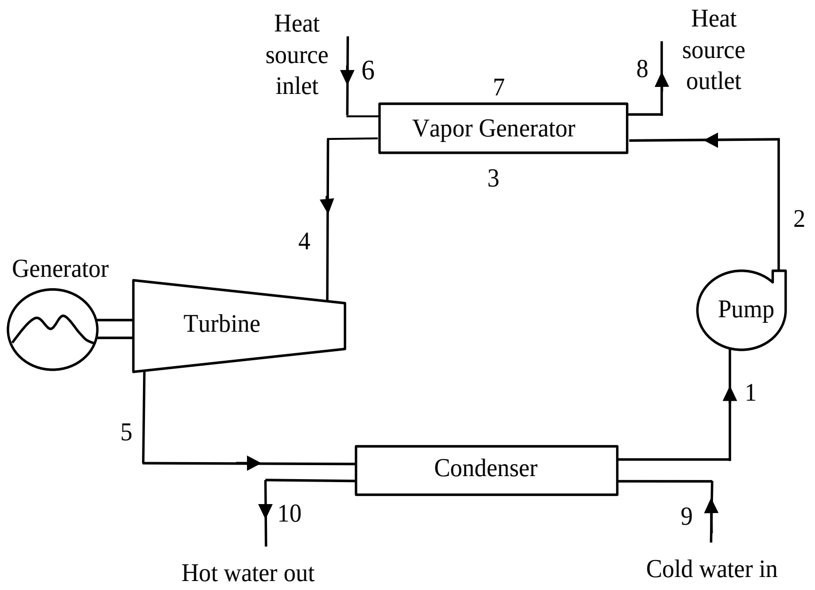

Figure 1: *Organic Rankine Cycle*

The four main parts of an ORC are the turbine, condenser, vapor generator and feed pump.

Table 1: *Important properties of selected working fluids [27], [28]*

Organic Fluids	Type of Fluid	Critical Temp. (K)	Critical Pressure (MPa)	Molecular Mass (kg/K mol)	Latent Heat of Vaporization At 0.1 MPa. (kJ/kg)	ODP	GWP (100 Yr)
n-pentane	Dry	469.7	3.37	72.149	357.89	0	0
n- hexane	Dry	507.82	3.03	86.175	335.24	0	0
n-heptane	Dry	540.13	2.73	100.2	317.20	0	0
Benzene	Dry	562.02	4.89	78.112	394.96	0	0
Toluene	Dry	591.75	4.12	92.138	361.00	0	0

The vapor generator (2-4) conducts the working fluid by extracting heat generated from the heat source (HS). Getting superheated steam is the primary objective. The heat source transmitted the heat to the organic working fluid (WF) and causes it to vaporize into a saturated or superheated state. The superheated vapour that enters the turbine is used up and produces useful work that powers the generator to produce energy.

The performance of the ORC mainly rely on the turbine, which is one the fundamental components of the complete ORC power plant. It causes the working fluid (4-5) to expand, generating mechanical energy that is then transformed into electricity by a generator connected to the turbine shaft. The condenser cools the expelled vapour, which then passes through it to become a saturated liquid. After that, this saturated organic working fluid entered the vapour-generating section straight from the pumping unit (5-1). An electric motor

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with a variable rotational speed powers the pumping unit. The primary function of this unit is to raise the organic working fluid from the condensation pressure to the maximal pressure of the organic Rankine cycle before supplying it to the vapour-generating unit (1-2). The turbine and pump utilized in this organic Rankine cycle are regarded as adiabatic devices, and the action inside them is considered entirely isentropic. The heat exchange is thought to occur at constant pressure in the vapour generator and condenser.

The T-S diagram represents the cycle route of this cycle as 1-2-3-4-5-1. The evaporator (6-7-8) receives heat in an isobaric state. The reversible adiabatic pumping process (1-2) and the reversible adiabatic expansion process (4-5) are isentropic. A constant pressure heat rejection process is shown in the procedure (5-1). Because ORC operates at its peak pressure, it is advantageous for applications with minimal power requirements. The pressure at which the pump is operating is practically lower than the critical pressure of working fluid. Inlet conditions of the turbine are ensured to be at a superheated state for maximum output.

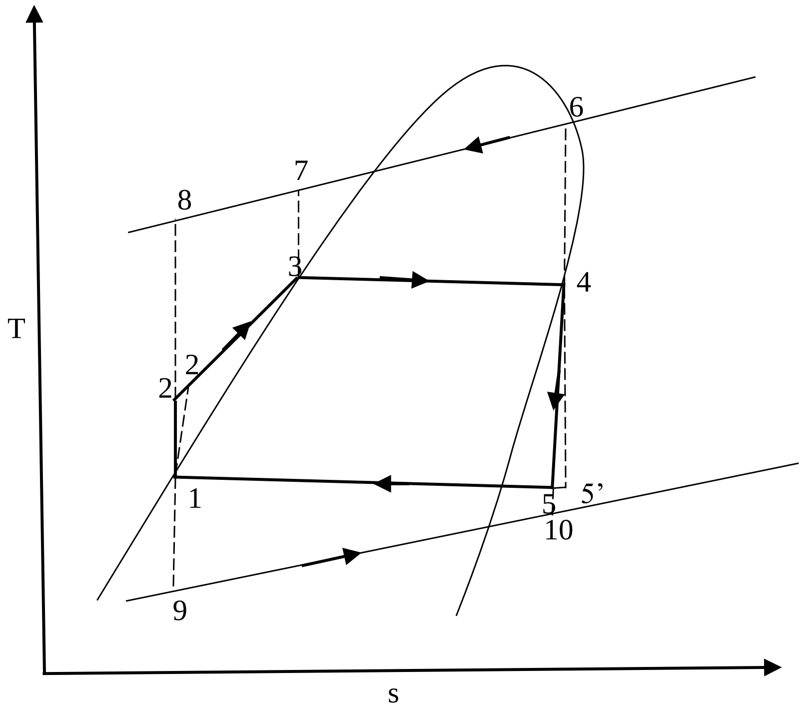

Figure 2: *Temperature Entropy diagram of ORC*

The cycle includes reversible adiabatic (isentropic) pumping of the working organic fluid, heat supply at constant pressure to the organic working fluid, isentropic expansion of the working fluid carrying the two-phase mixture, heat rejection at constant pressure in the condenser, and finally, return with the mixture of two phase in the saturated liquid state. The code developed by the Engineering Equation Solver (EES) programme simulates the system. Before the examination of the ORC system and its supporting systems, the following assumptions are made:

- All the processes and sub-systems are in a steady state.
- Turbine and pump are taken as adiabatic devices.
- No significant heat or pressure losses exist in any ORC equipment.
- The working fluid exits the condenser in a state of saturated liquid, while it exits the vapour generator in a saturated vapour condition.
- The vapour generator and condenser unit consider constant pressure heat exchange.

Table 2: *The input parameters used in this study of ORC*

Input parameter	**Range/Value (unit)**
Vapor generator temperature	363-403 (K)
Condenser temperature	305-313 (K)
Mass flow rate of flue gas	0.01-0.03 (kg/s)
Heat source inlet temperature	423 (K)
Turbine isentropic efficiency	87 (%)
Cold water inlet temperature	303 (K)
Pump isentropic efficiency	85%
Pinch point temperature difference (vapor generator)	5

3 Thermodynamic Analysis

Exergy and energy analysis of the cycle for all five organic working fluids is done to determine the thermodynamic behavior of the system.

3.1 Energy Analysis

The first law of thermodynamics, which specifies how much energy a system can create or carry, in terms of energy it guides to evaluate the performance of the system. The general energy equations for the organic Rankine cycle can be expressed as follows when performing energy analysis:

Work consumed by pump:

$$\dot{W}_P = \dot{m}_{WF} \times (h_2 - h_1) \tag{1}$$

Work done by turbine:

$$\dot{W}_T = \dot{m}_{WF} \times (h_4 - h_5) \tag{2}$$

Heat supplied to vapor generator:

$$\dot{Q}_{in} = \dot{m}_{WF} \times (h_4 - h_2) \tag{3}$$

Energy efficiency of ORC:

$$\eta_I = \frac{\dot{W}_T - \dot{W}_P}{\dot{Q}_{in}} = \frac{(h_4 - h_5) - (h_2 - h_1)}{(h_4 - h_2)} \tag{4}$$

3.2 Exergy Analysis

The energy efficiency of the ORC is merely a measure of the quantity of energy present in the system. The amount of useful work that this energy might provide must be explained. Therefore, more than energy analysis is required to identify the quality of energy that a system is carrying. The second law of thermodynamics provides guidelines for assessing the effectiveness of systems based on exergy, which constantly declines due to irreversibility and is crucial in examining energy quality. In simple terms, exergy can be used to measure quality, usefulness, or potential of the stream to bring change. The Overall exergy efficiency for ORC is calculated by:

$$X_{in,ORC} = \dot{m}_{HS}\, C_{p,HS} \left[(T_6 - T_8) - T_a \ln\left(\frac{T_6}{T_8}\right)\right] \quad (5)$$

Irreversibility of Vapour Generator:

$$\mathrm{I_{vg}} = \mathrm{X_6} - \mathrm{X_8} + \mathrm{X_2} - \mathrm{X_4} \quad (6)$$

Irreversibility of Turbine:

$$\mathrm{I_t} = \mathrm{X_4} - \mathrm{X_5} - \mathrm{W_t} \quad (7)$$

Irreversibility of Condenser:

$$\mathrm{I_{cr}} = \mathrm{X_5} - \mathrm{X_1} + \mathrm{X_9} - \mathrm{X_{10}} \quad (8)$$

Irreversibility of Pump:

$$\mathrm{I_p} = \mathrm{X_1} - \mathrm{X_2} + \mathrm{W_p} \quad (9)$$

Total Irreversibility of the ORC system:

$$\Sigma \mathrm{I} = \mathrm{I_{vg}} + \mathrm{I_t} + \mathrm{I_{cr}} + \mathrm{I_p} \quad (10)$$

Total exergy destroyed or irreversibility of the system:

$$X_{in,ORC} - W_{net} = \Sigma I = \mathrm{I_{vg}} + \mathrm{I_t} + \mathrm{I_{cr}} + \mathrm{I_p} \quad (11)$$

Exergy efficiency would be:

$$\eta_{II} = \frac{\mathrm{W_{net}}}{\mathrm{X_{in,ORC}}} \quad (12)$$

4 Results and Discussion

Engineering Equation Solver (EES) software code serves to model the overall investigation of the Organic Rankine Cycle (Figure 1). The impact of changing the vapour generation temperature (T_{vg}), condenser temperature (T_{cr}), and flue gas mass flow rate ($\dot{m}_{gas}$) for n-pentane, n-hexane, n-heptane, benzene, and toluene was investigated. Moreover, the values of net-work done (W_{net}), energy efficiency (η_I), and exergy efficiency (η_{II}) of the concerning working fluids were also simulated. This analysis examines the impact of various entities on the amount of net-work done, exergy efficiency, and energy efficiency of the organic Rankine cycle. The mean values taken for the vapour generator temperature (T_{vg}) is 383 K, condenser temperature (T_{cr}) is 309 K, and for the mass flow rate of flue gas ($\dot{m}_{gas}$) it is 0.02 kg/s.

4.1 Effect of Vapor Generator Temperature

Among the five organic working fluids (n-pentane, n-hexane, n-heptane, benzene, and toluene) for the increasing vapour generator temperature (T_{vg}), n-pentane carries the highest value of the net-work, which is 184.7 kW. However, benzene shows the lowest value, 174 kW, at the common vapour generator temperature of 363 K. The benzene, which exhibits an overall net-work value of 83.3 kW and a vapour generator temperature of 403 K, is the lowest in the range of vapour generator temperatures from 363 K to 403 K. However, n-Pentane displays the highest net-work value at this time, 97.07 kW. For all five organic working fluids, it has been found that the quantity of net-work declines as the vapour generator increases its temperature, as shown in Figure 3.

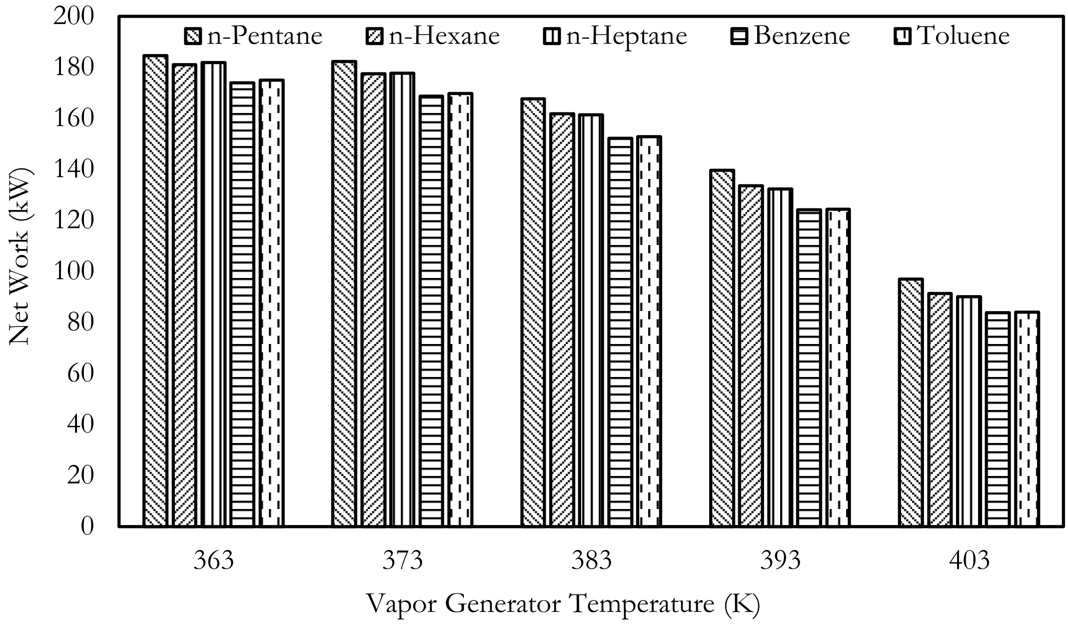

Figure 3: *Variation of net-work output with vapour generator temperature*

At a T_{vg} value of 403 K, benzene demonstrated the highest 16.85% energy efficiency compared to other fluids. Regarding energy efficiency, n-pentane obtains a minimum value of 15%. However, n-Hexane exhibits an overall minimum energy efficiency value of 10.6% at a T_{vg} value of 363 K as well as toluene possesses a maximum energy efficiency of 11.44% at this stage, as shown in Figure 4.

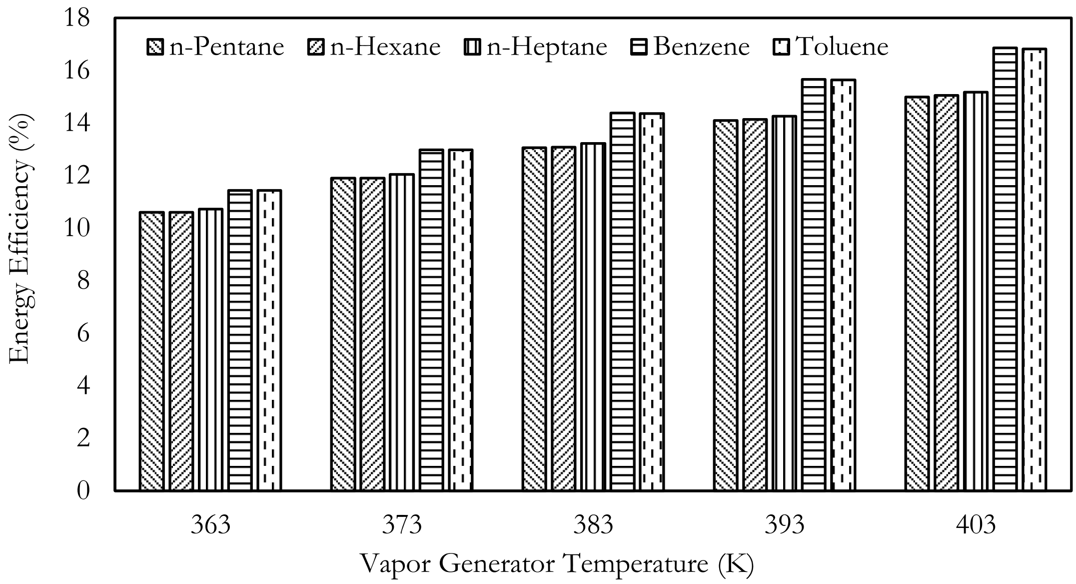

Figure 4: *Variation of energy efficiency with vapour generator temperature*

At a T_{vg} value of 403 K, benzene achieved the highest 63.88% exergy efficiency of all the fluids. In addition, n-hexane yields a minimum exergy efficiency of 58.08% at the comparable T_{vg} value. Meanwhile, n-hexane attains an overall minimum value of exergy efficiency of 50.81% at a T_{vg} value of 363 K. However, toluene gained a maximum exergy efficiency of 52.61%. It is noticed that with an increase in the temperature of the vapour generator, both exergy and energy efficiency increase for all of the five organic working fluids, as shown in Figure 4 and Figure 5.

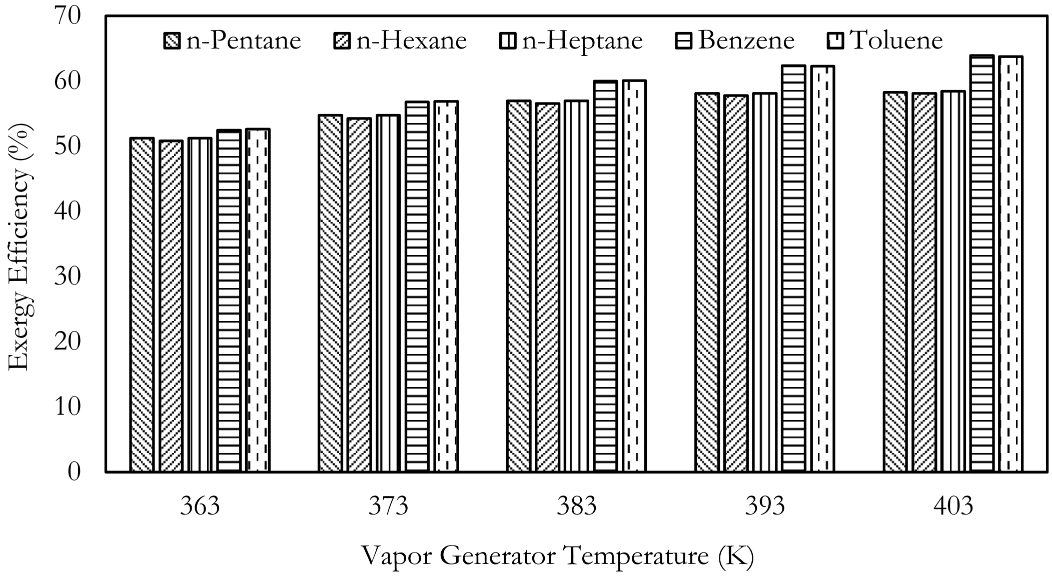

Figure 5: *Variation of exergy efficiency with vapor generator temperature*

4.2 Effect of Condenser Temperature

Among the five fluids (n-pentane, n-hexane, n-heptane, benzene, and toluene), for the increasing condenser temperature (T_{cr}), n-pentane carries the maximum value of the net-work, 179.4 kW. In contrast, benzene shows the lowest value, 162 kW, at a T_{cr} value of 305 K. The condenser temperature range from 305 K to 313 K is represented by benzene, while its lowest net-work value is 142.7 kW at a T_{cr} value of 313 K. However, n-pentane gained the highest net-work value, which is 156.3 kW, at a T_{cr} value of 313 K. For all five fluids used, it was found that the quantity of net-work reduced with an increase in condenser temperature which is shown in Figure 6. Meanwhile, benzene and toluene attended the highest 15.09% energy efficiency compared to other fluids at a T_{cr} value of 305 K when the effect of change in condenser temperature on energy efficiency and exergy efficiency of all five organic working fluids was evaluated. In addition, n-pentane shows a minimum energy efficiency of 13.71% at the same T_{cr} (305 K) value, as shown in Figure 7.

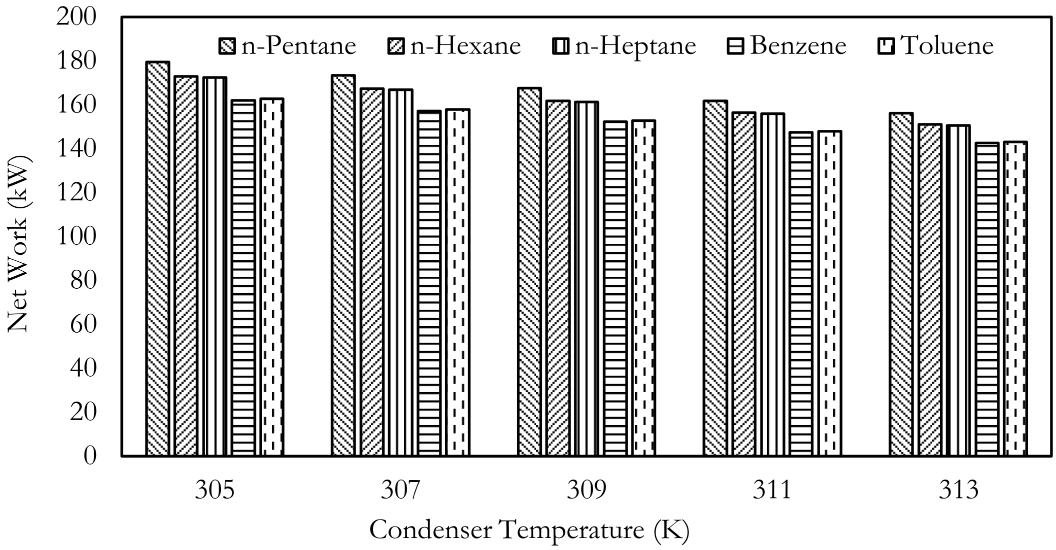

Figure 6: *Variation of net-work output with condenser temperature*

At a T_{cr} value of 313 K, n-Pentane achieves an overall minimum energy efficiency of 12.43%. However, benzene reaches a maximum energy efficiency of 13.66% for the same value of T_{cr} (313 K). Meanwhile, at a T_{cr} value of 305 K, toluene showed the highest 63.23% exergy efficiency compared to other fluids. In contrast, n-hexane gained a minimum exergy efficiency of 59.57% at the same T_{cr} (305 K) value, as shown in Figure 8.

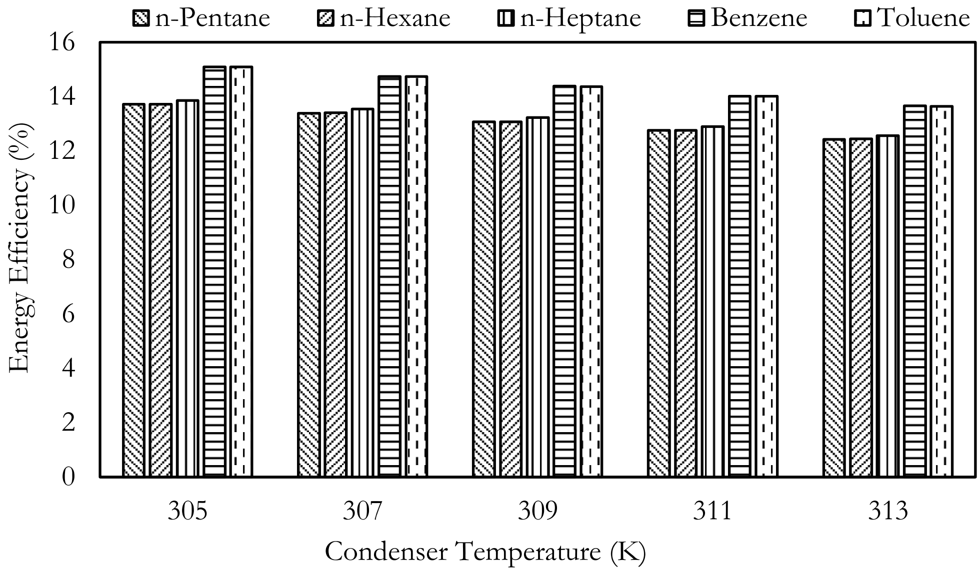

Figure 7: *Variation of energy efficiency with condenser temperature*

The minimum exergy efficiency which is 53.54%, is gained by n-hexane at a T_{cr} value of 313 K. At the same value of T_{cr}, benzene and toluene both obtained maximum (56.87%) exergy efficiency. It is observed that with an increase in condenser temperature value, both energy and exergy efficiency increase for all the organic working fluids, as shown in Figures 7 and Figure 8.

4.3 Effect of Variation in mass flow rate of flue gas

Among the five fluids (n-pentane, n-hexane, n-heptane, benzene, and toluene), for the increased mass flow rate of flue gas ($\dot{m}_{gas}$), n-pentane carries the highest value of the net-work, which is 251.5 kW. In contrast, benzene exhibits the lowest net-work, 228.4 kW at $\dot{m}_{gas}$ value of 0.03 kg/s. The overall lowest net-work

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value in $\dot{m}_{gas}$ range from 0.01 kg/s to 0.03 kg/s is shown by benzene, which is 76.13 kW at $\dot{m}_{gas}$ value of 0.01 kg/s. However, n-pentane shows the highest value of the net-work, 83.83 kW, for the same mass flow rate of flue gas ($\dot{m}_{gas}$ = 0.01 kg/s). It was observed in Figure 9 that with an increase in flue gas mass flow rate, the amount of net-work increases for all five organic working fluids. However, toluene showed the highest 14.37% energy efficiency than other fluids at all the increasing flue gas mass flow rate values, as shown in Figure 10.

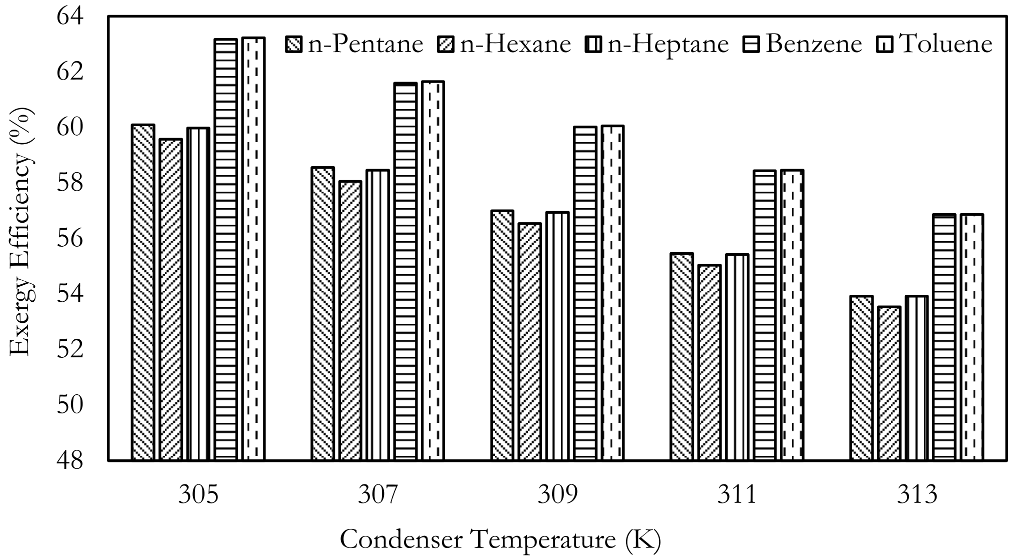

Figure 8: *Variation of exergy efficiency with condenser temperature*

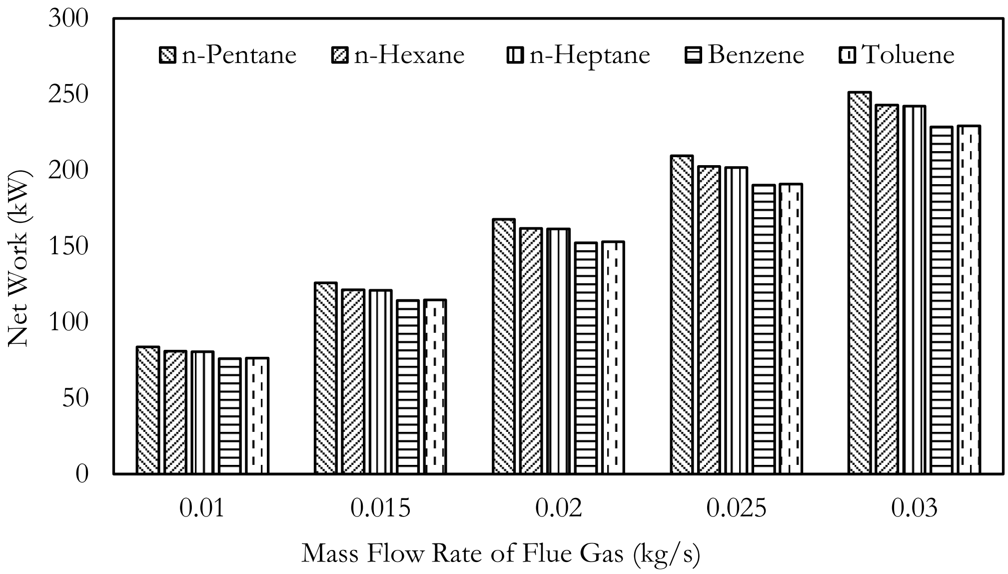

Figure 9: *Variation of net-work done with mass flow rate of flue gas*

Toluene gained a higher energy efficiency value than other organic working fluids at all values of increasing flue gas mass flow rate. In contrast, n-pentane obtained the lowest value at all values of increasing mass flow rate of flue gas, or 13.07%. At all rising flue gas mass flow rate values, n-hexane achieves an overall minimum energy efficiency of 53.54%. The energy and exergy efficiency of all five fluids remain constant and exhibit no variation as the mass flow rate of flue gas increases, as shown in Figure 10 and Figure 11.

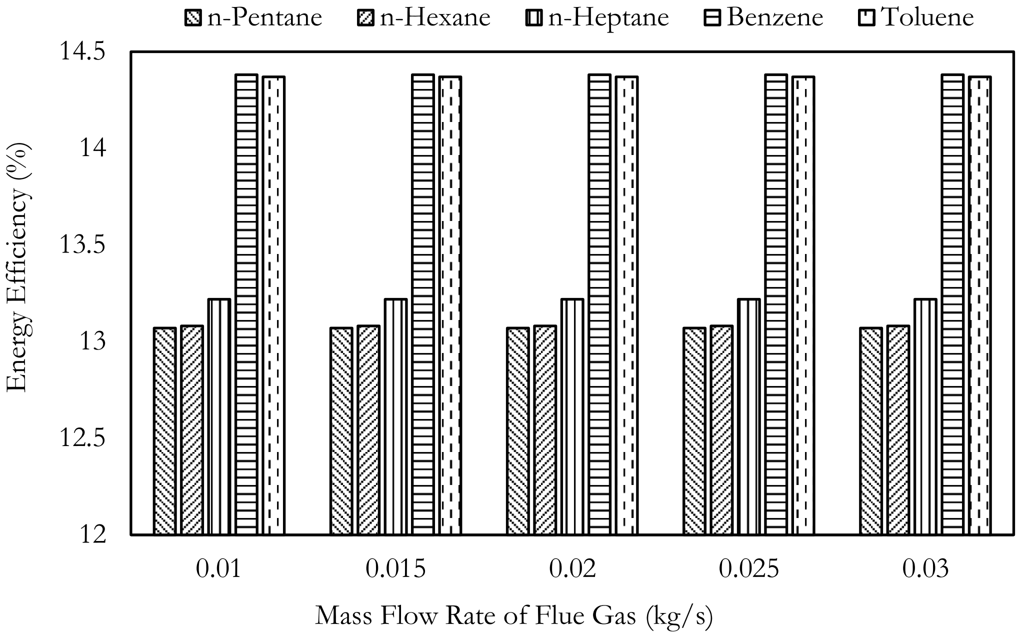

Figure 10: *Variation of energy efficiency with mass flow rate of flue gas*

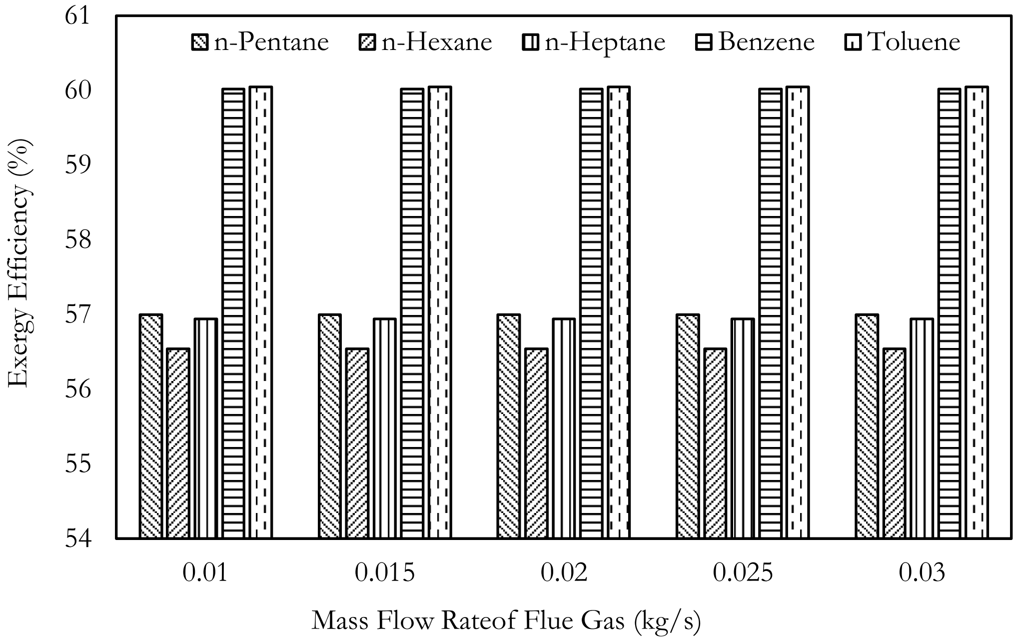

Figure 11: *Variation of exergy efficiency with mass flow rate of flue gas*

5 Conclusions

The fundamental ORC is examined using several environmentally acceptable organic fluids chosen by stringent environmental standards, including n-pentane, n-hexane, n-heptane, benzene, and toluene. Engineering Equation Solver (EES) software simulates a mathematical algorithm that completes the thermodynamic analysis of the ORC system. From the analysis, it was observed that keeping other parameters held fixed at their mean values, with an increase in vapour generator temperature, the net-work output decreased for all selected working fluids. The net-work output is found to be minimum and maximum as 83.87 kW and 97.07 kW for benzene and n-pentane, respectively, at higher generator temperatures. Meanwhile, the energy efficiency is increasing for all the selected working fluids with increased generator temperature. Energy efficiency is found to be minimum and maximum, 15.0% and 16.85% for n-pentane and benzene, respectively, at T_{vg} 403 K of generator temperature. The energy efficiency value of all these fluids shows an increase with the increase in vapour generator temperature.

In exergy efficiency values, the highest value carried by benzene is 63.88%, where n-hexane carries a minimum value that is 58.08%; both are at 403 K. Similarly, again keeping other parameters held fixed at their mean values, with an increase in condenser temperature the net-work output is decreasing for all selected working fluids. At the highest condenser temperature (T_{cr} = 313 K), benzene and n-pentane obtained minimum and maximum net-work output, 142.7 kW and 156.3 kW, respectively, at the highest condenser temperature. Meanwhile, the energy efficiency decreases for all the selected working fluids with increased condenser temperature. However, at the same condenser temperature (T_{cr} = 313 K), n-pentane and benzene achieved minimum and maximum energy efficiency, 12.43% and 13.66%, respectively. Exergy efficiency value of all these fluids shows a decrease with increased condenser temperature. In exergy efficiency values, the highest value carried by toluene is 63.23%, whereas n-hexane carries a minimum value of 59.57%, both at 305 K.

In the same scenario, it was observed that the net-work output increased for all the selected organic working fluids with an increase in flue gas mass flow rate. The net-work output is found to be maximum and minimum as 251.5 kW and 228.4 kW for n-pentane and benzene, respectively, at higher flue gas mass flow rates. Meanwhile, the exergy and energy efficiency of all the selected working fluids shows no change in their respective values with a change in the mass flow rate of flue gas. Based on the above parametric analysis, benzene and toluene showed the best energy and exergy efficiency values among the five chosen organic fluids.

6 Declarations

6.1 Competing Interests

No conflict of interest exists.

6.2 Publisher's Note

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