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Electrical Power Generation from Industrial Waste Heat Sources According to the Iraqi Environment

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Abstract

There are a wide range of temperatures wasted in some Iraqi factories ranging from low to medium to high grades, offset by a wide variety of generation techniques and liquids that can be used, this diversity allows us to choose the appropriate generation techniques (and fluids type) with the available waste heat in our factories, allowing us to make the maximum benefit of this wasted thermal energy in accordance with the recommendations of the International Energy Conference. All over Iraq, thermal waste is an abundant source of emission-free power that is frequently overlooked. It is a byproduct of industrial processes that could lower energy costs and reduce overall emissions from electric generation. The thermal waste is produced as long as the operation running. Producing electrical power from thermal waste would help to reduce energy costs. This research paper will explain and discuss choosing the appropriate technology between the three suggested technologies. In addition, the paper will discuss choosing the appropriate organic liquid for (Organic Rankine Cycle) ORC to recover the heat and transform it into an energy based on the waste temperature of some Iraqi industries. Also, it will discuss the choice of appropriate technology for the quantity and quality of this heat. That would help to reduce the waste of energy and air pollution.

1. Introduction

With the recent increase in atmospheric temperatures as a result of pollution caused by polluting gas emissions from factories and power generation, leading to an increase of greenhouse gases on the planet, solutions must be sought to reduce the amount of these emissions and compensate for polluting energy sources as much as possible to reduce the deterioration of the planet's condition. Industrial thermal waste is an energy source generated in the industrial process and is not put to any practical use during the production line and is wasted into the environment and it is associated with gases contaminating the environment. Waste heat sources include hot combustion gases emitted from chimneys, hot products and hot equipment surfaces. Consequently, research has focused on techniques for investing this waste heat energy and reducing associated pollution. However, adopting such techniques can be costly but can be recovered in the long run. In this research, a set of steps are suggested to support the decision making of choosing appropriate generation technology according to the type and amount of waste heat source. Waste heat temperatures can be classified as high temperature (over 400℃), medium temperature (400℃ to 100℃) and low temperatures (less than 100℃) [1-6].

In general, there are a large amount of heat losses in the Iraqi factories. Most of these losses are attributed to the obsolescence in the age of the factory, the Country situation and the lack of keeping pace with modern environmentally friendly technology. Some of the waste heat source is not only a heat emission, but it may be accompanied by several polluting or toxic gases like CO_2, lead oxides and sulfur.

2. Experimental Procedure

Waste Heat Recovery Systems

Waste heat recovery systems include capturing and transferring waste heat from industrial processes using gas or liquid (heat transfer medium) to the system as an additional source of power generation. This power source can be used to generate additional heat or to generate electrical and mechanical power, Figure (1) shows the waste heat capture system in factories. In general, the higher the temperature, the more quality it will be and the easier it will be to recover it [7-9].

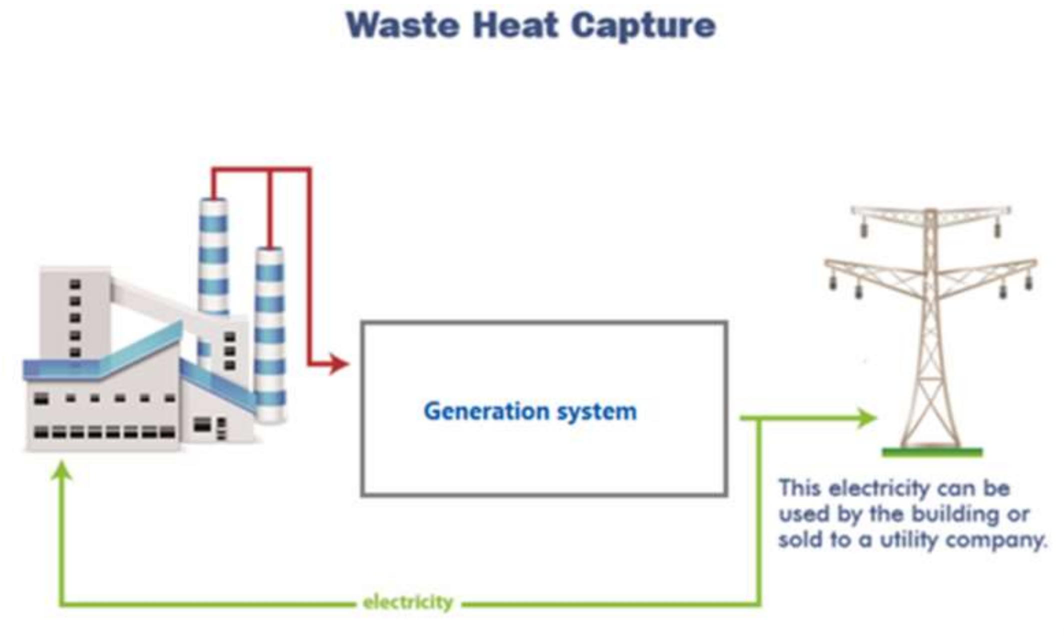

Figure (1). Capture waste heat in factories.

Depending on the type of heat source wasted, its quantity and temperature recoverable from the process can determine which recovery systems are appropriate for application. Accordingly, there are several technologies to recover waste heat energy [8-10]:

Steam Rankine Cycle Technology (Steam Turbines)

Steam turbines are one of the most famous and oldest technologies used to generate electricity by converting water into steam at high pressure, and are considered an effective and environmentally friendly technique because the liquid used in this technology is water, but it needs to be heated to a high temperature for the purpose of generating water steam at high pressure suitable for recycling these turbines. This technique is ineffective if the waste heat temperature is within the medium or low limits. [11-13]. Figure (2) presents a scheme of Rankine Cycle Technology [8].

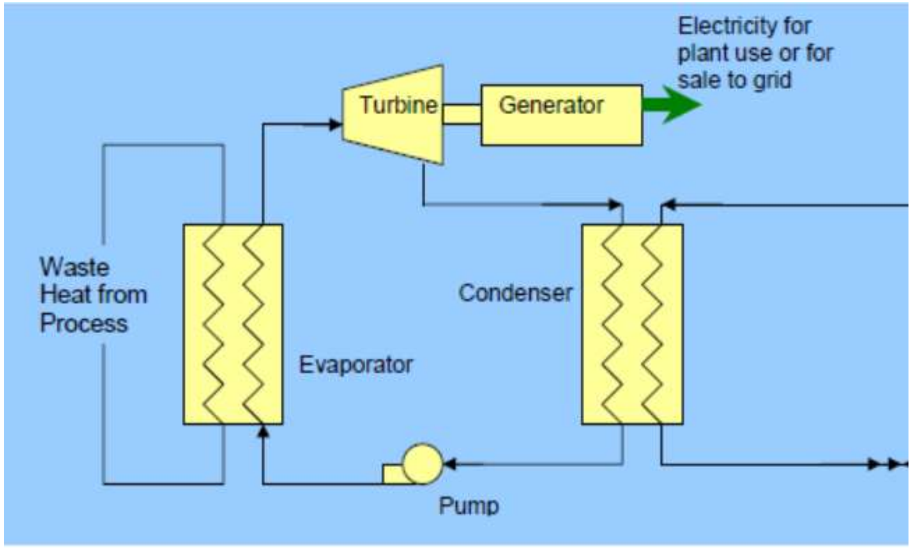

Figure (2) Rankine Cycle Technology [8].

Organic Rankine Cycle

The Organic Rankine Cycle follows the same principle as the Rankine Steam Cycle, but with a different working liquid. The organic fluids used to generate electricity must have a low-boiling point that generates high steam pressure with a higher mass. This fluid makes the system able to recover energy from medium to low-temperature waste heat. The waste heat is delivered to the evaporator and is used to heat the special working fluids that are suitable for the heat available to generate steam. This steam is then directed to the turbine to generate power and then passes through the condenser, after that returns to the organic Rankine Cycle. This technology is characterized by the availability of a number of working fluids types that can be used in the process of generation. As shown in Figure (3) the ratio between the cost of generation through the Organic Rankine Cycle and the amount of electrical capacity produced for several factories and several organic working liquids, as published in previous research, which shows that the cost of using this technique is inversely proportional to the amount of electric power produced, where the cost decreases the greater the amount of capacity produced. [14-19].

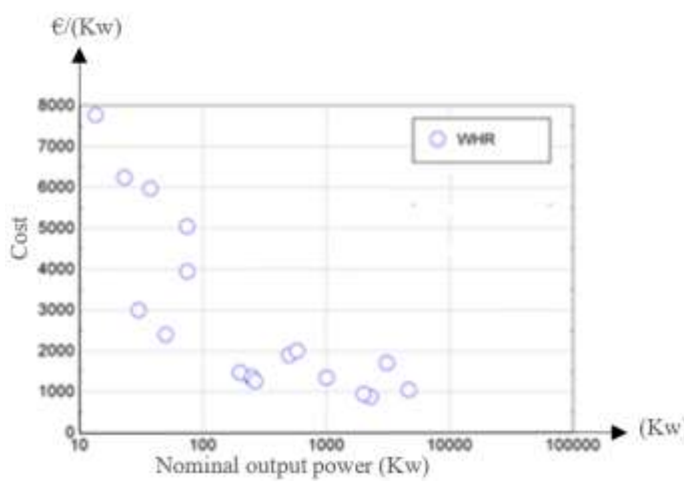

Figure (3). The relationship between the cost of generation and the nominal output power [11].

To choose the most appropriate organic work fluids, some recommendation must be taken into account:

- Thermal dynamic performance (critical point and density) for the purpose of producing as much energy as possible from the available temperature [14].
- High steam density and this characteristic is important for liquids with low condensation pressure where low density is reduced to a larger size in the heat exchanger for the purpose of reducing pressure loss [14].
- Low viscosity of steam and fluids used is a good characteristic that reduces friction losses [14, 15].

- High heat conductivity [16].
- Acceptable steam pressure [16].
- Organic fluids must be stable at high temperatures so temperatures determine the chemical stability of the liquid [17, 18].
- Provides a high degree of safety because some organic fluids are toxic or flammable [18, 19].
- Consider the availability and low cost of organic fluids [19].

Table (1) shows some types of organic fluids (used in the commercial sector) with their own evaporation and condensation temperature based on previous studies in this area.

Table (1). Some types of organic fluids with their own evaporation and condensation temperature.

organic working fluids	evaporator T_{ev} (°C)	condenser T_{cd} (°C)	Ref.
pentane, Toluene, HCFC-123	150-200	20	[20]
HFC-245fa,Toluene,HCFC-123	120	40	[21]
R245a	100-210	25	[22]
HFC-245fa, R245a	327	27-87	[23]

Emerging Technology (Thermos-Photovoltaic TPV)

New emerging technologies are being used to convert heat directly into electric power, such as photovoltaic thermal power generation techniques.

Photovoltaic thermal generator is an innovative system for converting radiation from an artificial heat source using PV cells into electric power through a special filter that allows radiation waves to pass along a wavelength suitable for PV cells for the purpose of converting it into electric energy as shown in Figure (4). Generally similar to solar cells and radioactive is made from heat-resistant materials, the TPV system operates within a wide temperature range of 300-1500°C [24-26].

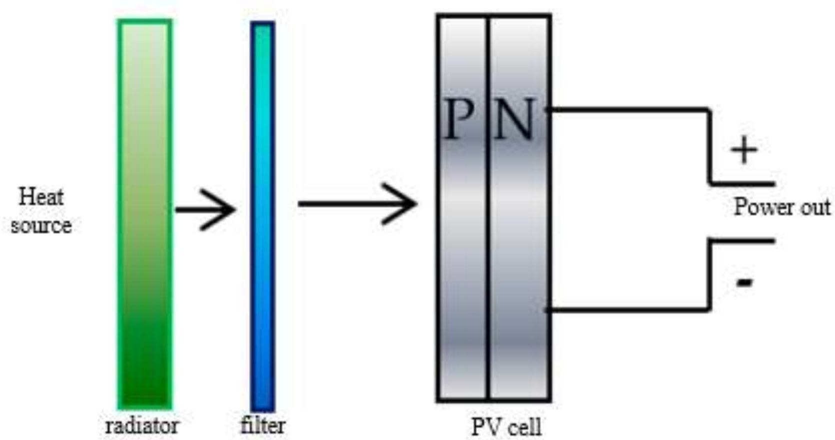

Figure (4). Schematic diagram of an overall TPV system [26].

Comparison of Waste Heat Recovery Methods and Electricity Generation

In general, the use of steam turbines is very effective in the case of high temperatures. Water as working fluid characterized by low-cost, environmentally friendly, non-flammable and non-toxic work fluids, as well as high chemical stability. This technology needs a high thermal source and a water source for steam turbine work [11].

In the case of lower temperatures, the use of the organic Rankine Cycle is more effective. You don't need high temperatures, it works with less steaming pressure, produces more condensation pressure, and no water treatment system is needed. This technology needs to provide organic fluids suitable for the waste heat temperature available (chemical stability of the organic fluids is important), in addition to the advantage of providing a large number of types of organic fluids used in this technology, offering multiple options according to the requirements of the place of use.

The photoelectric thermal generator contains no fluid in the generation process, making it suitable for use in the absence of a water source close to the plant. In addition to being stable and containing no moving parts, it is considered a silent generating device (does not make noise). Figure (5) shows the diversity of the water-saturated curve and some organic fluids used in the Organic Rankine Cycle. And how each one behaves according to temperature.

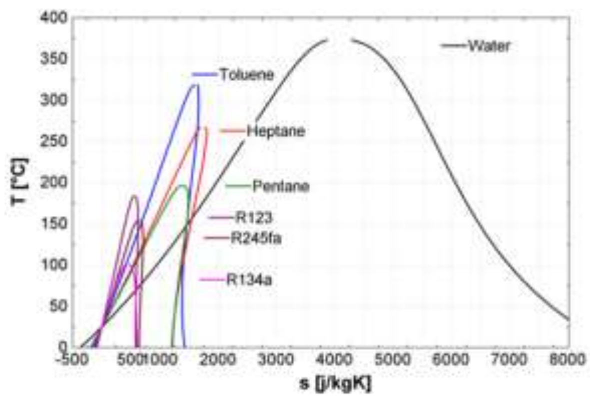

Figure (5). T-s diagram (saturation-curve) of water and various typical Organic Rankine Cycle [14].

Choosing the Right Technology to Recover Wasted Thermal Energy in Factories

For the purpose of determining which recovery systems are optimal for the application, the following steps must be taken:

1. Specify waste heat sources: Conduct a survey of the factory environment to identify waste heat sources (gases, hot fluids or hot equipment surfaces) [27].
2. Quantitative and qualitative assessment of the waste heat: This assessment is carried out by determining the extent of the temperatures offered and the type of transport media and how much energy can be recovered from this heat in addition to determining the timetable for the availability of this heat taking into account the availability of a place where heat recovery equipment can be placed with the importance of measuring the amount of pollution associated with this heat [26, 28].
3. Choose the appropriate technology: There are many ways to recover waste heat and the appropriate method is determined according to the quantity and quality of this heat to ensure maximum energy recovery [27,29]
4. Things to support the decision: There are several important recommendations to consider when determining the type of technology used to recover waste heat and convert it into electrical energy to ensure the maximum benefit, a data model taken from the plant in previous steps is created with the calculation of cost, recovery period (years) and the amount of CO_2 reduction (ton/year) presented in the environment.

Applying the Method of Choosing the Appropriate Technology to Recover Waste Heat from Iraqi Factories

For the purpose of taking advantage of waste heat, it is necessary to analyse industrial processes and investigate the possibility of utilizing this thermal waste heat by applying appropriate heat recovery methods.

Through readings obtained from Iraqi factories (by Emailing each factory) energy recovery techniques can be classified according to temperatures wasted in various industrial processes to ensure that as much energy as possible is recovered as shown in Table (2).

Table (2). Classification of technologies by temperature emanating from each industrial process.

factory name	Industrial process	Wasted temperature (°C)	proposed technology	suggested working fluids
1- State Company for Phosphate				
Sulfur factory	Burning and absorbing sulfur	82	Organic Rankine	HFC-245fa HFC-134a n-pentane
Service boilers	Burning gas and heavy fuel	350	Organic Rankine TPV	HFC-245fa R245a
2- UR state company				
Aluminum factory	Production of aluminum section of different shaps which presents exhaust gas mixture of CO_2	(450-350)	Steam Turbines Organic Rankine TPV	water HFC-245fa R245a
Rolling Mill	Aluminum ovens release CO_2 gas	600	Steam Turbines TPV	water
Bullion factory	Smelting aluminum scrap in oven and subtracting CO_2 gas with lead oxides and sulfur	700	Steam Turbines TPV	water
3- State co. for steel industries				
Steel foundry	The production process releases CO_2 gas and sulfur	200	Organic Rankine	n-pentane Toluene HCFC-123 R245a
Heavy foundry	The production process releases the residues of oxides	(100-75)	Organic Rankine	HFC-245fa HFC-134a n-pentane

3. Conclusions

It can be concluded from the foregoing that there is a flexible diversity in energy production technologies from heat that can be invested for the purpose of taking advantage of the waste heat in Iraqi factories significantly and according to the type of waste heat source and the amount and time range of its availability and thus will provide a source of electricity energy that is considered economically and investment of wasted heat. In addition, this energy will reduce the cost of purchasing electricity from the national grid and their impact on reducing the amount of greenhouse gas emissions associated with traditional generation methods as well as reducing pressure on the national grid.

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