EXERGY CONCEPT AND FORMS OF RENEWABLE ENERGY- A REVIEW

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ABSTRACT

Renewable energy has been an important political topic for a long time as there was an increasing realization that the earth's resources are limited and that the world's dependency on fossil fuel must be reduced. Climate scientists generally agree that the Earth's average temperature has risen in the past century. If this trend continues, sea levels will rise, and scientists predict those floods, heat waves, droughts, and other extreme weather conditions could occur more often. Today, climate problems are on the summit of the international political agenda vis-à-vis sustainable development goals. In this paper about the different kind of renewable energy and their application has discussed. Also the concept of exergy, application of exergy in various fields and its characteristic has been as well considered.

Keywords–Renewable Energy, Exergy Analysis, Available Energy, Thermodynamic Analysis

1. INTRODUCTION

Today we primarily use fossil fuels to heat and power our homes and fuel our cars. It's convenient to use coal, oil, and natural gas for meeting our energy needs, but we have a limited supply of these fuels on the Earth. We're using them much more rapidly than they are being created. Eventually, they will run out. And because of safety concerns and waste disposal problems, the United States will retire much of its nuclear capacity by 2020. In the meantime, the nation's energy needs are expected to grow by 33 percent during the next 20 years. Renewable energy can help fill the gap. Even if we had an unlimited supply of fossil fuels, using renewable energy is better for the environment.

We often call renewable energy technologies "clean" or "green" because they produce few if any pollutants. Burning fossil fuels, however, sends greenhouse gases into the atmosphere, trapping the sun's heat and contributing to global warming. Climate scientists generally agree that the Earth's average temperature has risen in the past century. If this trend continues, sea levels will rise, and scientists predict those floods, heat waves, droughts, and other extreme weather conditions could occur more often. Other pollutants are released into the air, soil, and water when fossil fuels are burned. These pollutants take a dramatic toll on the environment and on humans. Air pollution contributes to diseases like asthma. Acid rain from sulfur dioxide and nitrogen oxides harms plants and fish. Nitrogen oxides also contribute to smog. The term Exergy was used for the first time by Rant in 1956, and refers to the Greek words ex (external) and ergos (work). Another term describing the same is Available Energy or simply Availability. The term Exergy also relates

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to Ideal Work as will be explained later, and Exergy Losses relate to lost work. One of the challenges in Thermodynamics compared to Mechanics is the introduction of somewhat abstract entities (or properties) describing PVT systems, such as Internal Energy, Entropy and Exergy. In addition, there are special energy functions such as Enthalpy Helmholtz energy and Gibbs (free) energy that are important in thermodynamic analysis but can be difficult to fully comprehend. While Enthalpy is important for flow processes (open systems) in Mechanical Engineering Thermodynamics, Helmholtz energy (to define equations of state) and Gibbs free energy (for physical and chemical equilibrium) are important in Chemical Engineering Thermodynamics (Gundersen, 2009). Summaries of the evolution of exergy analysis are provided at (Bejan, 1995; Moran and Sciubba, 1994; Madu and Uyaelumuo, 2018).

2. EXERGY CONCEPT

The concept of exergy is stated as the maximum work that can be obtained from an energy flow or produced by a system. The fraction of exergy content expresses the quality of an energy source or flow. This concept can be used to combine and compare all flows of energy according to their quantity and quality. Unlike energy, exergy is always destroyed during conversions because of the irreversible nature of energy conversion process. The exergy concept enables people to articulate what is consumed by all working systems (e.g. man-made systems like thermo-chemical engines and heat pumps, or biological systems including the human body) when energy and/or materials are transformed for human use. Exergy analysis can give insight into the extent to which the quality levels of energy supply (e.g. high-temperature combustion) and energy demand (e.g., low temperature heat) are matched. High-valued energy such as electricity and mechanical work consists of pure exergy. Energy which has a very limited convertible potential, such as heat close to room air temperature, is low-valued energy. Low exergy heating and cooling systems therefore allow the use of low valued energy, which can be delivered by sustainable energy sources, as well. However, in most cases, the low-valued energy demand is met with high quality sources, such as fossil fuels or using electricity. Many researchers and practicing engineers refer to exergy methods as powerful tools for developing and optimizing systems and processes. Exergy losses clearly pinpoint the locations, causes and sources of deviations from ideal circumstances in a system. Exergy efficiencies are measures of the approach to ideal. Nevertheless, exergy analysis is only used by a small group of people, because the analysis method might seem cumbersome or complex (e.g. choosing a suitable reference environment) to some people and the results might seem difficult to interpret and understand.

In building profession, the exergy concept has been applied to the built environment. Some researchers have also used the exergy concept in a context of sustainable development. In the last few years, a working group of the International Energy Agency has been formed within the Energy Conservation in Buildings and Community Systems programmer: “Low Exergy Systems for Heating and Cooling of Buildings; IEA Annex 37”. The overall objective of the IEA Annex 37 was to promote the rational use of energy by means of low-valued and environmentally sustainable energy sources.

The exergy value of air entails three contributions, a thermal one related to the air temperature, a mechanical one related to the air pressure, and a chemical one related to the humidity ratio of the air. The possibility to calculate the exergy of air in buildings, based on only one or two of these contributions, for example expressed by a characteristic air temperature and/or air as dry air, is explored for three different locations on earth. These values are compared to those calculated using hourly statistical climate data during one year. The results show that it is acceptable in some climates to consider a static reference environment only, instead of a dynamic reference environment, for calculating the exergy value of air in buildings for a year. In a cold climate, the exergy value of the air strongly depends on its thermal contribution.

The analyses are carried out on an instantaneous and a daily basis. The analysis results show that, from the viewpoint of total exergy consumption (which is the summation of thermal exergy by a ventilation airflow and electricity exergy by a ventilation unit) at room level, it could make sense to use heat recovery only when the environmental air temperature is low enough to compensate the additional need for electricity, when the temperature of the environmental air is not too low let ventilation air bypass the heat recovery unit, or if possible by operating the heat recovery unit at low ventilation airflow rate. Nevertheless, the ventilation airflow rate must be qualified to guarantee the indoor occupancy conditions. Lastly, a method for energy and exergy analysis of a building and building services is proposed. The analysis is based on a build-up model from the energy demand of the building side to the energy supply side. This method is intended to enable building designers (and building engineers) to compare, in terms of exergy, the impact of improvements in the building envelope and in building services. In addition, some examples of the energy and exergy analysis of the building and its building services with some changes of their parametric values are studied by using the building simulation tool TRNSYS.

The analysis results show that, in terms of exergy, solar exergy gains in a cold day create the main exergy losses when cooling is needed. These solar exergy gains should be minimized, or better captured to be useful somewhere else e.g. for domestic hot water production or electricity generation. Exergy losses in the building services depend on a temperature level of the thermal energy supply and (electric) auxiliary energy required by the building services, and this is applicable for both heating and cooling cases.

This research provides knowledge that is essential to future development of design instruments and guidelines for exergy efficient building and building services design. Yet, the exergy analyses for the HVAC components and systems and for the building systems are carried out only with outdoor conditions of a cold climate. The exergy analyses for other climates are excluded from this study, since the standard states of environmental air in different climates for the analyses are not similar and should be carefully defined in a proper way. In addition, buildings in different climates are mostly designed in different ways. Exergy in buildings and building services, where they have other different and more complex types, is an interesting topic to study in the near future, and at the same time the knowledge obtained from the research should be disseminated to students and practitioners in a field related to building and HVAC system design.

3. TYPES OF RENEWABLE ENERGY

The United States currently relies heavily on coal, oil, and natural gas for its energy. Fossil fuels are non-renewable, that is, they draw on finite resources that will eventually dwindle, becoming too expensive or too environmentally damaging to retrieve. In contrast, the many types of renewable energy resources such as wind and solar energy-are constantly replenished and will never run out. Most renewable energy comes either directly or indirectly from the sun. Sunlight, or solar energy, can be used directly for heating and lighting homes and other buildings, for generating electricity, and for hot water heating, solar cooling, and a variety of commercial and industrial uses. Solar shingles are installed on a rooftop. Credit: Stellar Sun Shop .The sun's heat also drives the winds, whose energy, is captured with wind turbines. Geothermal energy taps the Earth's internal heat for a variety of uses, including electric power production, and the heating and cooling of buildings. And the energy of the ocean's tides come from the gravitational pull of the moon and the sun upon the Earth. In fact, ocean energy comes from a number of sources. In addition to tidal energy, there's the energy of the ocean's waves, which are driven by both the tides and the winds. The sun also warms the surface of the ocean more than the ocean depths, creating a temperature difference that can be used as an energy source. All these forms of ocean energy can be used to produce electricity.

3.1. SOLAR ENERGY

Solar energy technologies use the sun's energy and light to provide heat, light, hot water, electricity, and even cooling, for homes, businesses, and industry. There are a variety of technologies that have been developed to take advantage of solar energy. These include:

i. Photovoltaic Systems: Producing electricity directly from sunlight.
ii. Solar Hot Water: Heating water with solar energy.
iii. Solar Electricity: Using the sun's heat to produce electricity.
iv. Passive Solar Heating and Day lighting: Using solar energy to heat and light buildings.
v. Solar Process Space Heating and Cooling: Industrial and commercial uses of the sun's heat.

3.2 GEOTHERMAL ENERGY

Geothermal energy is the heat from the Earth. It's clean and sustainable. Resources of geothermal energy range from the shallow ground to hot water and hot rock found a few miles beneath the Earth's surface, and down even deeper to the extremely high temperatures of molten rock called magma. Almost everywhere, the shallow ground or upper 10 feet of the Earth's surface maintains a nearly constant temperature between 50° and 60°F (10°C and 16°C). Geothermal heat pumps can tap into this resource to heat and cool buildings. A geothermal heat pump system consists of a heat pump, an air delivery system (ductwork), and a heat exchanger-a system of pipes buried in the shallow ground near the building. In the wet season, the heat pump removes heat from the heat exchanger and pumps it into the indoor air delivery system.

In the dry season, the process is reversed, and the heat pump moves heat from the indoor air into the heat exchanger. The heat removed from the indoor air during the dry season can also be used to provide a free source of hot water. The Earth's heat, called geothermal energy, escapes as steam at a hot springs in Nevada. Credit: Sierra Pacific in the United States, most geothermal reservoirs of hot water are located in the western states, Alaska, and Hawaii. Wells can be drilled into underground reservoirs for the generation of electricity. Some geothermal power plants use the steam from a reservoir to power a turbine/generator, while others use the hot water to boil a working fluid that vaporizes and then turns a turbine. Hot water near the surface of Earth can be used directly for heat. Direct-use applications include heating buildings, growing plants in greenhouses, drying crops, heating water at fish farms, and several industrial processes such as pasteurizing milk.

Hot dry rock resources occur at depths of 3 to 5 miles everywhere beneath the Earth's surface and at lesser depths in certain areas. Access to these resources involves injecting cold water down one well, circulating it through hot fractured rock, and drawing off the heated water from another well. Currently, there are no commercial applications of this technology. Existing technology also does not yet allow recovery of heat directly from magma, the very deep and most powerful resource of geothermal energy. Many technologies have been developed to take advantage of geothermal energy - the heat from the earth. NREL performs research to develop and advance technologies for the following geothermal applications:

i. Geothermal Electricity Production: Generating electricity from the earth's heat.
ii. Geothermal Direct Use: Producing heat directly from hot water within the earth.
iii. Geothermal Heat Pumps: Using the shallow ground to heat and cool buildings.

3.3. BIOENERGY

We have used biomass energy or bioenergy - the energy from organic matter - for thousands of years, ever since people started burning wood to cook food or to keep warm. And today, wood is still our largest biomass energy resource. But many other sources of biomass can now be used, including plants, residues from agriculture or forestry, and the organic component of municipal and industrial wastes. Even the fumes from landfills can be used as a biomass energy source. Switch grass crops can be harvested to make biofuels. Credit: Warren Gretz. The use of biomass energy has the potential to greatly reduce our greenhouse gas emissions. Biomass generates about the same amount of carbon dioxide as fossil fuels, but every time a new plant grows, carbon dioxide is actually removed from the atmosphere. The net emission of carbon-dioxide will be zero as long as plants continue to be replenished for biomass energy purposes. These energy crops, such as fast growing trees and grasses, are called biomass feedstocks. The use of biomass feedstock can also help increase profits for the agricultural industry.

There are three major biomass energy technology applications:

i. Biofuels: Converting biomass into liquid fuels for transportation.
ii. Biopower: Burning biomass directly, or converting it into a gaseous fuel or oil, to generate electricity.
iii. Bioproducts: Converting biomass into chemicals for making products that typically are made from petroleum.

3.4 HYDROPOWER

Flowing water creates energy that can be captured and turned into electricity. This is called hydroelectric power or hydropower. The most common type of hydroelectric power plant uses a dam on a river to store water in a reservoir. Water released from the reservoir flows through a turbine, spinning it, which in turn activates a generator to produce electricity. But hydroelectric power doesn't necessarily require a large dam. Some hydroelectric power plants just use a small canal to channel the river water through a turbine. Hydroelectric power generates about 10% of the nation's energy. Credit: US Army Corps of Engineers. Another type of hydroelectric power plant, called a pumped storage plant can even store power. The power is sent from a power grid into the electric generators.

The generators then spin the turbines backward, which causes the turbines to pump water from a river or lower reservoir to an upper reservoir, where the power is stored. To use the power, the water is released from the upper reservoir back down into the river or lower reservoir. This spins the turbines forward, activating the generators to produce electricity. A small or micro-hydroelectric power system can produce enough electricity for a home, farm, or ranch.

4. DIFFERENT FORMS OF EXERGY

A Work Exergy

Because exergy is defined as the maximum work potential, the work transfer rate, W equivalent to the exergy transfer rate, $\dot{E}_{x,w}$ in every respect

$$\dot{E}_{x,w} = \dot{W} - P_0 \frac{dv}{dt} \qquad (1)$$

B Heat Transfer Exergy

Assuming a uniform temperature distribution in a thermal energy reservoir, the exergy transfer rate, $\dot{E}_x$ connected with the heat transfer rate, Q, can be calculated by the following formula:

$$\dot{E}_{x,Q} = \dot{Q}\,(1 - \frac{T_0}{T}) \qquad (2)$$

Where T_0 is the ambient temperature, which is set to 298 K (Szargut *et al*, 1988) and T is the heat source temperature.

C Stream Flow in Steady State Exergy

Exergy transfer rate associated with material streams can be calculated with the following formula (Moran and Shapiro, 1994):

$$E_x = E_x^{tm} + E_x^{ch} \quad (3)$$

$$\dot{E}_x^{tm} = \dot{E}_x^{ke} + \dot{E}_x^{p} + \dot{E}_x^{pe} \quad (4)$$

Where

$\dot{E}_x^{ke} = \frac{1}{2} m V_0^2$ represents the kinetic exergy rate, V_0 is the speed of the stream.

$\dot{E}_x^{p}$ = Flow relative to the earth surface

$\dot{m} g Z_0$ presents the potential exergy rate, where g is the earth gravity and $Z_0$the stream altitude above the sea level.

$\dot{E}_x^{pe}$ represents the thermo mechanical exergy based on the temperature and the pressure of the stream.

$\dot{E}_x^{ch}$ represents the chemical exergy based on the chemical potentials of the components in the stream. The specific exergy is written as:

$$e_x = e_x^{k} + e_x^{p} + e_x^{pe} + e^{ch} \quad (5)$$

Where

$$e_x = \frac{\dot{E}_x}{\dot{m}} \quad (6)$$

$\dot{m}$ is the mass flow rate of the stream.

D Physical Exergy

Physical exergy, known also as thermo mechanical exergy, is the work obtainable by taking the substance through reversible process from its initial state (T, P) to the state of the environment (T_0, P_0). The specific physical exergy is written as:

$$e_x = h - h_0 - T_0(s - s_0) \quad (7)$$

For a perfect gas with a constant

$$e_{x,flow,g} = C_p T_0\left(\frac{T_1}{T_0} - 1 - \ln\frac{T_1}{T_0}\right) + R T_0 \ln\frac{P_1}{P_0} \quad (8)$$

For solids and liquids when assuming a constant specific c:

$$e_x^{ph} = c\left[(T - T_0) - T_0 \ln\left(\frac{T}{T_0}\right)\right] - \upsilon_m (p - p_0) \quad (9)$$

Where υ_m is the specific volume, determined at temperature T_0 .

E Chemical Exergy

Chemical exergy is equal to the maximum amount of work obtainable when the' substance under consideration is brought from the environmental state (T_0, P_0) to the dead state (T_0, P_0, μ_{i0}) by processes involving heat transfer and exchange of substances only with the environment The specific chemical exergy e_x^{ch} at P_0 can be calculated by bringing the pure component in chemical equilibrium with the environment. For pure reference components, which also exist in the environment, the chemical exergy consist of the exergy, which can be obtained by diffusing the components. to their reference concentration P00. The specific molar chemical exergy of a reference component i is:

$$\dot{E}_x^{ch} = \sum n_i(\mu_{io} - \mu_i^e) \quad (10)$$

When a substance does not exist in the reference environment, it must first react to reference substances in order to get in equilibrium with the environment. The reaction exergy at reference conditions equals the standard Gibbs energy change. So the overall specific chemical exergy term becomes:

$$\mu_{i0} = \bar{g}_i(T_0, p_0) + \bar{R} T_0 \ln y_i j \quad (11)$$

$$\mu_i^e = \bar{g}_i(T_0, p_0) + \bar{R}T_0 \ln y_i^e \quad (12)$$

The chemical exergy of a gaseous mixture or a mixture of ideal liquids is given by:

$$\bar{e}_x^{\ ch} = \bar{R}T_0 \sum_{i=1}^{j} y_i \ln \frac{y_i}{y_i^e} \quad (13)$$

The chemical exergy of real solutions can be computed from:

$$\bar{e}_x^{\ ch} = \sum_{i=1}^{j} y_i \bar{e}_i^{ch} + \bar{R}T_0 \sum_{i=1}^{j} y_i \ln y_i \, I \quad (14)$$

The chemical exergies of gaseous fuels are computed from the stoichiometric combustion chemical reactions. For many fuels, the chemical exergy can be estimated on the basis of the Lower Heating value LHV. The relation between the LHV and the chemical exergy is where can be calculated with Formulas CaHb based on the atomic composition.

When CaHb is gas

$$\frac{\bar{e}_x^{\ ch}}{LHV} \cong 1.033 + 0.0169\frac{b}{a} - \frac{0.0698}{a} \quad (15)$$

When CaHb is liquid

$$\frac{\bar{e}_x^{\ ch}}{LHV} \cong 1.033 + 0.0169\frac{b}{a} - \frac{0.0698}{a} \quad (16)$$

5. CONCLUSION

Climate change concerns, coupled with high oil prices, peak oil, and increasing government support, are driving increasing renewable energy legislation, incentives and commercialization.

New government spending, regulation and policies helped the industry weather the global financial crisis better than many other sectors. According to a 2011 projection by the International Energy Agency, solar power generators may produce most of the world's electricity within 50 years, dramatically reducing the emissions of greenhouse gases that harm the environment.

In this paper about the different kind of renewable energy and their application has discussed and about the concept of exergy and its characteristic and application in various fields has been discussed. And different forms of exergy have been derived. Also a brief comparison between energy and exergy analysis has been done.

The search shows that Exergy get us better understanding of energy availability for doing work. Exergy is a useful concept that could use for analysis different kind of industry. For optimization and improvement industries efficiency exergy analysis has more effort than energy analysis.

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