Renewable and Sustainable Energy Reviews 43 (2015) 1016–1034

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

Thermodynamic and environmental analyses of biomass, solar and electrical energy options based building heating applications

Hakan Caliskan [1]

Department of Mechanical Engineering, Faculty of Engineering, Usak University, 64200 Usak, Turkey

A R T I C L E I N F O

Article history:
Received 24 February 2014
Received in revised form
29 October 2014
Accepted 25 November 2014

Keywords:
Energy
Enviroeconomic
Environmental
Exergy
Exergoenviroeconomic
Exergoenvironmental
Heating

A B S T R A C T

In this study, the biomass, solar, and electrical energy options based building heating are investigated and compared along with energy, exergy, sustainability, environmental, exergoenvironmental, enviroeconomic and exergoenviroeconomic analyses. All of the analyses are presented gradually to show the complete energy and exergy based advanced analyses. Eight different reference temperatures are considered which are varying from 4 °C to 7.5 °C with a temperature interval of 0.5 °C. The most efficient and sustainable energy option of the building is found to be solar energy, while biomass energy is the second one. Furthermore, according to environmental analysis, maximum 0.1599 kg-CO_2 is released in a day for the solar energy option, while this value is 0.6082 kg-CO_2 for the biomass energy, and 29.614 kg-CO_2 for the natural gas fired electrical energy 4 °C reference temperature. In addition, among the energy options, solar and biomass energies have the best exergoenvironmental results in which exergetic results are taken into account. Finally, the maximum released CO_2 prices in a day are determined at 4 °C reference temperature to be 0.0088 $, 0.0023 $, and 0.4294 $, while the corresponding exergoenviroeconomic results are found as 0.0040 $, 0.000933 $, and 0.4294 $ for the biomass, solar, and electrical energy options, respectively.

© 2014 Elsevier Ltd. All rights reserved.

Contents

1. Introduction

Energy consumption and demand of the world have been rising year after year. According to U.S. Energy Information Administration, energy consumption of the world increases by 53% from 2008 to 2035. Energy demand also grows 0.6% and 2.3% per year for

E-mail addresses: hakan.caliskan@usak.edu.tr, hakanc85@gmail.com
[1] Tel.: +90 276 221 21 21x2756; fax: +90 276 221 21 37.

http://dx.doi.org/10.1016/j.rser.2014.11.094
1364-0321/© 2014 Elsevier Ltd. All rights reserved.

Organization for Economic Co-operation and Development (OECD) and non-OECD countries, respectively [1]. In the last decades, most of the energy is produced by non-renewable traditional energy sources, such as coal, natural gas, oil, etc., that crate a risk for environment and human life [2]. On the other hand, 10% of energy consumption is from environmentally friendly renewable energy sources like solar, wind, biomass, etc. Furthermore, 19% of world electricity generation is from renewable energy [3].

Most of total primary energy is utilized in buildings. It may be reduced by using renewable sources and applying energy/exergy efficiency strategies [4]. 40% of total energy use occurs in buildings which also causes 36% of European Union's total CO_2 emissions. The utilization of renewable energy sources in the buildings causes reduction in energy imports and greenhouse gases [5]. The renewable energy capacity increases globally. Most of the countries (more than 85) adapt their policies basing on renewable energy sources (such as biomass, solar, etc.) [6].

One of the most important renewable energy sources is biomass which includes some primary materials and can be used directly or be converted into secondary fuels. So, the biomass based heating systems (e.g. biomass boiler) are considered as efficient energy systems [7]. The biomass for energy can be classified as residual and purpose grown biomasses. The residual biomass is a product of the industry (e.g. forest timber and waste wood). The purpose grown biomass is especially produced crop that only used for energy production [8,9]. The benefits of biomass are discovered throughout the 20th century. Some advantages of biomass can be thought such as additional economic, environmental and social benefits. Biomass energy sources decrease the level of atmospheric hazardous gases (e.g. SO_2). Also, biomass causes no net release of CO_2 when sustainable purpose grown biomass is supplied [10,11].

Alongside of biomass, solar energy counts for 13% of the energy consumption in buildings [12]. The utilization of solar thermal energy has grown in recent years. There are solar collectors with the area of 19 million m^2 in Europe. Solar thermal energy is generally used for low heat requirements such as space (floor) heating in buildings. Solar thermal energy can supply heat to the buildings for summer, late spring and early autumn seasons. It is also useful as a product for energy suppliers. Solar collectors can be installed on factory and residential roofs to generate heat for consumers [13].

Energy analysis is generally not fully sufficient to evaluate systems. So, an analysis based on both of first and second laws of thermodynamics may be necessary. This analysis is named as exergy or availability analysis. Exergy is a potential or quality of energy and it is possible to make sustainable quality assessment of energy. This analysis is useful tool to compare different types of energy carriers on the equivalent basis [14,15].

Open literature has been searched for background studies of biomass, solar or electrical energy based building heating. Stritih and Butala [7] illustrated the performance of a biomass boiler with thermal storage for buildings. The TRNSYS program package was used to make system and mathematical models. As a result efficiency was calculated. Also, it is found that the heat was stored at the best exergy degree, and water mixing was a condition for optimizing the thermal storage. Jablonski et al. [16] designed a framework using market segmentation techniques for biomass heat demand in UK residential sector. It was found that the demand for bio-heat in the UK residents was between 3% and 31% of the total energy consumed in the heat market. Vallios et al. [8] presented a method for design of biomass district heating systems considering building structure and urban settlement around the plant. Biomass burning-district heating system was investigated along with energy, environmental and economic evaluations. Verma et al. [17] studied on comparative evaluation of several existing quality labels and standards for small scale biomass heating systems and the biomass fuels. It was determined that, quality labeling of both biomass heating systems and fuels leads to stricter emissions, efficiency and safety requirements as compared to European Union standards. Some measures supporting green energy market in the several countries in Europe were searched. As a result, the policies and incentives in France and Germany were the best. Meehan and McDonnell [18] identified potential sources of biomass within the catchment zone with different cases (case I: 10% biomass, case II: 50–100% biomass, and case III: environmental). The results showed that maximum energy production was obtained from case II in which generated within the catchment zone using 50–100% of biomass. Huang et al. [11] designed a system to meet the energy requirements of buildings and district heating/cooling applications. The biomass downdraft gasifier was used for the simulated trigeneration plant (commercial building). A simulation package was considered to use energy resources efficiently. Also, effects of biomass, such as rice husk, willow, etc., on the performance of the system were investigated. Fraisse et al. [19] studied on a combination of solar collector and direct solar floor heating system. It was found that the annual photovoltaic cell efficiency was 6.8% which represented a decrease of 28% in comparison with a conventional non-integrated PV module of 9.4% annual efficiency. Also, without a glass cover, the efficiency was 10%. Zhai et al. [20] worked on heating of the 460 m^2 building using the solar collectors with an area of 150 m^2. It is determined that the solar-powered floor heating system had a good potential in energy conservation in winter. The solar fraction was 56% for heating period, and the performance could be enhanced with the solar insolation increasing. Balta et al. [21] studied on seven heating applications for a building of 392 m^3. Low exergy (LowEx) analysis and sustainability index were performed and it was calculated that overall exergy efficiencies of heating systems were range from 2.8% to 25.3%. Hepbasli [22] reviewed the studies conducted on LowEx heating and cooling systems for buildings. Some of them included biomass, electrical or solar collector heating systems. It was found that the exergy efficiency rates of the LowEx heating and cooling systems for buildings were calculated to range from 0.40% to 25.3%.

The objectives of this study are to apply the energy, exergy, sustainability, environmental, exergoenvironmental, enviroeconomic, and exergoenviroeconomic analyses to various energy options for building floor heating, and to compare them. In this regard, this study differs from the previously conducted ones as follows: (i) biomass, solar and electrical energy options are considered for building heating, (ii) various reference (dead state) temperatures are taken into account, (iii) sustainability indexes are determined, (iv) environmental and enviroeconomic effects are presented, and (v) new analysis methods with different new formulations, which are named as "exergoenvironmental analysis" and "exergoenviroeconomic analysis", are applied to the systems.

2. System description

The building considered here has 120 m^2 floor areas and 360 m^3 volumes, while its indoor temperature is 21 °C and outdoor temperature is changing from 4 °C to 7.5 °C. Some specification of the building are listed in Table 1, while some necessary data for the analysis are given in Table 2. There is a floor heating system to heat the building. Also, the energy options are considered as biomass, solar and electrical energy. The natural gas fired electrical energy option and biomass energy option are commonly used for building heating. So, the solar energy option is considered for alternative option to see the advantages and disadvantages of the heating systems. The general schematic

Download English Version:

https://daneshyari.com/en/article/8118118

Download Persian Version:

https://daneshyari.com/article/8118118

Daneshyari.com