Renewable and Sustainable Energy Reviews 47 (2015) 665–682

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

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

A comprehensive review of heat recovery systems for building applications

Pinar Mert Cuce [a,b,*], Saffa Riffat [a]

[a] Department of Architecture and Built Environment, Faculty of Engineering, University of Nottingham, University Park, NG7 2RD Nottingham, UK
[b] Turkish Ministry of Education, Ankara, Turkey

ARTICLE INFO

Article history:
Received 30 September 2014
Received in revised form
29 December 2014
Accepted 8 March 2015

Keywords:
Heat recovery
Building applications
HVAC
Thermodynamic assessment

ABSTRACT

In this paper, a comprehensive review on building applications of heat recovery systems is presented. The review is given as a clear and understandable summary of the previous works. The review covers detailed description of heat recovery systems with working principle and system components, current typical heat recovery technologies including the building applications, theoretical, experimental and simulation works carried out for different heat recovery technologies and findings from thermodynamic performance assessment. Moreover, environmental impacts of heat recovery systems are evaluated. Future scenarios for heat recovery technologies including some recommendations are also considered in the study. It is concluded from the results that the heat recovery systems are very promising to mitigate the fuel consumption amounts of buildings. Therefore, they can remarkably contribute in reducing greenhouse gas emissions in the atmosphere.

Contents

Abbreviations: DCHEs, direct contact heat exchangers; ICHEs, indirect contact heat exchangers; PV, photovoltaic; PV/T, hybrid photovoltaic and thermal

* Corresponding author. Tel.: +44 7473278285.
E-mail address: ezxapm@nottingham.ac.uk (P.M. Cuce).

http://dx.doi.org/10.1016/j.rser.2015.03.087
1364-0321/

1. Introduction

Carbon dioxide (CO_2) is naturally absorbed by trees and plants. However, the CO_2 is directly released into the atmosphere when fossil fuels such as coal, gas or oil are used. While that is happening quickly, the plants and trees have no enough time to soak up the CO_2 and remove it from the atmosphere. Therefore, the CO_2 emissions notably rise day by day. The continued increase of the CO_2 emissions into the atmosphere is predicted to lead to crucial changes in climate [1]. Three of the well-documented global changes can be ordered as increasing CO_2 concentrations in the atmosphere, alterations in the biogeochemistry of the global nitrogen cycle and on-going land use/cover change [2]. A continuous increase of the CO_2 concentrations affects the Earth's ecosystems. For instance, approximately half of the existing emissions are being absorbed by the ocean and the land ecosystems [1,3]. On the other hand, certain gases in the atmosphere such as CO_2, methane (CH_4) and nitrous oxide (N_2O) absorb some of the energy radiated from the Earth and trap that energy in the atmosphere. Those gases which are commonly called as greenhouse gases make the surface of the Earth warmer because of behaving like a blanket. Since the early 20th century, the surface temperature of the Earth has risen by roughly 0.8 °C, with about two-thirds of that aforementioned rise happening since 1980 [4]. It is a fact that deforestation for agricultural use, directly affects the greenhouse gas concentration in the atmosphere so, it causes rising in the surface temperature of the Earth which is known as global warming. In this respect, stabilization of gas concentrations in the atmosphere is considered as a first goal to achieve in developed and developing countries. Then, broad societal needs have focused attention on technologies that can reduce ozone depletion, greenhouse gas emissions and fossil fuel usage [5]. In other words, it is necessary to incline new alternative energy technologies in order to overcome or mitigate hazardous effects of global warming.

There is a growing concern about energy use and its impacts on the environment [6–14]. The latest reports of the Intergovernmental Panel on Climate Change (IPCC) have enhanced the public awareness of energy use and its environmental impacts [15–17]. Furthermore, intensive efforts have been made in recent years to expand the proportion of alternative energy resources in global energy production. However, fossil fuel based energy consumption still predominate with a lion's share and hence, renewable energy sources are not able to supply the global energy demand. From this point of view, minimization of energy consumption levels in all sectors has become significant in the last decades. In the early 21st century, energy consumption levels were specified by sector and the results interestingly indicated that buildings play an important role on global energy consumption. It was also reported that buildings account for more than 30% greenhouse gas emissions in most of the developed countries. On the other hand, energy consumption levels of buildings increase as a consequence of economic development, growing of building sectors and rising heating, ventilation and air conditioning (HVAC) demand. Buildings have a long life span lasting for 50 years or more and thus, minimization of energy consumption levels of buildings has a notable potential to contribute in mitigating greenhouse gas concentrations for longer periods. Most of the energy losses in buildings occur in heating, ventilation and air conditioning systems. Therefore, recovering the waste heat from HVAC systems may considerably contribute to efficient energy utilization and hence, in degrading gas emissions. Cost-effective heat recovery technologies are therefore significant for both mitigating energy consumed in buildings and halting greenhouse gas emissions worldwide.

Heat recovery system (HRS) provides cost-effective and environmentally friendly energy. Buildings consume energy mainly for cooling, heating and ventilation. In this regard, the aim of heat recovery systems is to mitigate the energy consumption and cost of operating a building by transferring heat between two fluids [10]. Therefore, it saves significant amount of energy while exchanging the exhaust air with fresh air for domestic use. For Sweden and Germany, the first use of heat recovery from ventilation air in dwellings began in 1979 and 1976, respectively [6]. This was due to 1970s energy crisis and new building codes. The rapid climbing in energy costs followed that energy crisis. As a consequence, people developed new and more efficient appliances such as HRSs to reduce the energy consumption of buildings. The buildings were constructed as more tightly and well insulated to help saving energy [13]. The main aim of HVAC design in buildings is to supply comfortable indoor environment and good indoor air quality for occupants during different weather conditions [7,8]. Ventilation air is the major source of moisture load in air conditioning. For instance, ventilation air constitutes approximately 68% of the total moisture load in most commercial buildings as seen in Fig. 1. For this reason, HVAC system is required to remove the moisture from the life space. It is a fact that in most of the countries, the energy consumption by HVAC sectors account for one-third of the total energy consumption of the whole society [7]. Therefore heating, cooling and ventilation of buildings using

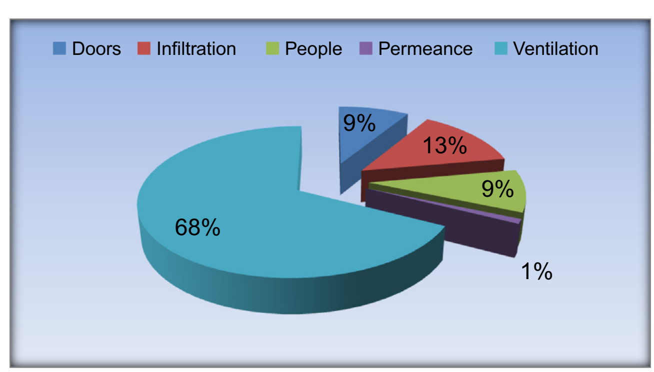

Fig. 1. Sources of moisture loads in a medium size retail store [7].