Applied Thermal Engineering 39 (2012) 53–62

Contents lists available at SciVerse ScienceDirect

Applied Thermal Engineering

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

Feasibility study of a localized residential grey water energy-recovery system

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ARTICLE INFO

Article history:
Received 15 October 2011
Accepted 12 January 2012
Available online 20 January 2012

Keywords:
Energy management systems
Energy-recovery
Heat pumps
Heat recovery units
Water heaters
Grey water

ABSTRACT

In order to improve the overall efficiency of building energy usage, a grey water energy-recovery system, which adopted a multiple-function heat pump system, was proposed for domestic water heating, and space heating and cooling of buildings. A numerical model has been developed for investigation of annual energy and water consumptions of the proposed system and the conventional building energy system with gas furnace space heating, package air-conditioning, and electricity water heater for hot water heating. Based on a case study of a typical residential house with four family members and three bedrooms in New York, NY, results show that the overall source energy consumption with the proposed system decreases 33.9% for space heating and cooling and hot water heating, and also the potable water consumption reduces 27.2% compared with those of the conventional system. An extended study with fourteen other cities was performed in various climate zones in the U.S. Among these 15 cities, the savings in source energy and potable water consumption have ranges of 17%–57.9% and 15%–34.1%, respectively. The results also show the proposed system can provide substantial energy and potable water savings, particularly with moderate outdoor temperature.

1. Introduction

In the U.S., the residential building sector represented 20% of primary energy and 20% of carbon dioxide emissions in 2006 [1]. The major components dominated the energy consumption in residential buildings are space heating, space cooling, and water heating systems. Statistical results show that the space heating and cooling, and water heating systems consume 51.9% of energy, cost 55.7% of expenditures, and emit 50.4% of carbon dioxide in residential building [1].

Most existing households in the U.S. are designed to use a boiler, a furnace, and an air-conditioner individually and independently to serve the water heating, space heating, and space cooling. The utilization of a heat pump for the space heating and cooling only accounts for 8.3% of total number of households [2]. In addition, use of electric and natural gas boilers for hot water heating dominates the market of residential buildings (38.8% and 52.8%, respectively [2]). Although a great deal of effort has been done to enhance the efficiencies of individual systems and significant progresses have been achieved in the past decade [3–6], it is still challenging to achieve the aggressive, multi-year goal of 40–70% whole-house energy savings by 2020 set by the U.S. Department of Energy's (DOE's) Buildings Technology Program [7].

Residential buildings not only consume energy, but also potable water. A typical residential building with a four-member family consumes about 1300 L/d (i.e. liters/day) of fresh water and generates 800 L/d of wastewater [8]. A huge amount of energy existing in wastewater is discharged to the environment without being properly reclaimed. Some tentative attempts have proposed to utilize the heat of residential wastewater, such as shower-water heat recovery using a simple single-pass counter-flow heat exchanger in high-rise residential buildings [9] and dishwasher waste-heat reuse through a spiral heat exchanger [10]. Some researchers have focused on the energy reclamation from the municipal wastewater [11–13] and wastewater of commercial buildings [14,15]. However, from the best knowledge of the authors, there is no previous research on the recovery of heat from residential wastewater.

Condenser heat recovery is an energy saving technology that reclaims condenser heat from air-conditioners for other heat demands in residential buildings. There are numerous theoretical and experimental studies on this technology found in existing publications. Most of those studies utilized condenser heat for generating domestic hot water from a split type air-cooled, water-

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doi:10.1016/j.applthermaleng.2012.01.031