Journal of Cleaner Production 82 (2014) 58–69

Contents lists available at ScienceDirect

Journal of Cleaner Production

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

Rationalization of water and energy consumption in shower systems of single-family dwelling houses

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ARTICLE INFO

Article history:
Received 13 March 2014
Received in revised form
25 June 2014
Accepted 26 June 2014
Available online 5 July 2014

Keywords:
Drain water heat recovery system
Financial performance evaluation
Hot water heater
Shower flow limiter

ABSTRACT

Reduction of costs incurred for supplying water and heating it for household purposes is possible by means of an application of systems recovering heat from drain water in combination with water flow limiters. Then, not only advantageous financial results can be obtained, but also positive effects in the form of reduced use of fossil fuels, improved air quality, and limited water consumption. This paper presents a calculation model that allows to assess the synergy of financial effects for different variants of an investment project consisting in mounting a water flow limiter and a DWHR unit in a shower system of a single-family building. This model has a large application potential that can be used as a tool facilitating the decision-making process both in the system design and modernization stage. A simulation test carried out for the case study involving different variants of modernization of a household shower system shows that profitability of such investment depends on the adopted modernization variant and system usage parameters. The best financial performance characterizes variants involving the use of a water flow limiter or both devices. The mounting of both devices becomes the most advantageous when the shower taking time is long. The obtained results additionally show that the most favorable financial effects can be achieved in buildings in which the total time of using shower facilities is the longest. The application of the presented solutions will be, therefore, particularly profitable in case of buildings characterized with significant water consumption and high rotation of users.

1. Introduction

Human life depends to a large extent on accessibility to sources of water and energy. The short-sighted approach of several generations of consumers to the issue resulted in the situation where each single liter of water and each kilowatt-hour of energy must be taken care of. The inevitable consequence of running out of drinking water and conventional fuel resources are rapidly rising prices.

From the data present in the paper (GWI, 2013) it follows that in the period from July 2012 to July 2013 the average increase in the rates for water and sewage amounted to 3.7% in the world. The currently observed annual increase in prices is, albeit, decidedly lower than just several years ago (GWI, 2011), yet in many cities in Europe and the world it still exceeds 20% (GWI, 2013). The increasing tendency is also observed in cities located in Poland. For example in Rzeszów, a city possessing one of the lowest rates for water and sewage in Poland, the fees incurred for supplying water and sewage removal were subject to increase within the past 5 years by 46.0% in comparison with 2008 (City Council of Rzeszów, 2012, 2007).

A significant increase is reported also in the case of electric energy prices (AEMC, 2013; Eurelectric, 2013). The Polish Ministry of Economy (2009) claims in its forecasts that such trend will prevail in future. Particularly severe price rises are planned in the year 2020 when, as a result of the energy-climatic package being accessed by Poland, this very energy carrier is expected to go up in price at a highest rate.

The statistical values of the indicators for unit water use are different depending on the region, climatic zone in which the given country is located as well as the available water resources. At present the average daily use of water in households located in the European Union amounts to 160 dm^3 per person (BIO Intelligence Service, 2012). Meanwhile, from data quoted in paper (Chudzicki and Sosnowski, 2009) it follows that in Poland water consumption in apartments characterized with high technical level of equipment varies in the range 100–150 dm^3 per person per day. On the other hand, Chudzicki (2008) reports that in dwelling houses in which none of the devices allowing to reduce water consumption

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http://dx.doi.org/10.1016/j.jclepro.2014.06.078
0959-6526/

was installed, it amounts to about 125 dm^3 per person per day. These are means values, and the actual water consumption figure in individual households differs from the statistical average depending on the region, applicable tariffs for water supply and wastewater collection, habits of the residents, sanitary equipment standard, and above all, on the type of the installed draw-off fittings and reliability of the water supply system (Beal et al., 2013; Maaki et al., 2013). In conditions prevailing in Poland, the quantity of tap water used in dwelling houses can exceed 200 dm^3 per person per day (Bugajski and Satora, 2009; Satora and Milijanović, 2007). In view of currently occurring climate changes and rapidly progressing urbanization it should be however expected that, in the longer perspective, maintaining the current water accessibility level may prove difficult or simply impossible.

The problem of insufficient water presently touches every third inhabitant of our planet (Lambooy, 2011). This results not only from the fact of the lack of available fresh water resources, but also from their significant pollution (Máñez et al., 2012; Zeng et al., 2013). From among the reasons of the exhaustion of water resources, the following should be differentiated: first and foremost the progressing urbanization as well as the development of industry, an example of which is the Huanghe River, which is the second largest river in China (Wang et al., 2006). This results in the need to search for solutions enabling the limiting of water use as well as their implementation in all sectors of the economy, in industry (Alkaya and Demirer, 2014; Enderle et al., 2012) as well as in residential buildings (Maaki et al., 2013).

The need to reduce the amount of water used is also observed on the territory of Poland. Poland's current water resources are estimated on the level of 1600 m^3 per person per year which categorizes the country as having at its disposal one of the poorest water reserves both in Europe, with its annual 4500 m^3 of water per capita, and in the world, as the statistical inhabitant of the Earth has an access to about 6500 m^3 each year (Hotloś, 2008). Larger water resources are available even in such countries as India, Nigeria, Ethiopia, or Syria (FAO, 2003). Currently the problem of water shortage in Poland is not discernible yet, however the occurring climate changes manifesting themselves not only with higher intensity of precipitation (Kotowski et al., 2013), but also with increasing duration of rainless periods (Szwed et al., 2010), can result in significant decrease of this index in the perspective of incoming years.

The concern for Poland's water resources should be accompanied by monitoring of the condition of natural environment, including atmosphere. The considerable source of pollution in this part of our planet is greenhouse gases emitted as the result of the combustion of fossil fuels. In the year 2011 alone, the emission of CO_2 equivalent greenhouse gases in Poland, without emission related to land usage, its changes, and the forestry, amounted to 401.47 Tg (Bebkiewicz et al., 2013). This gives rise to search for rational solutions, such as those proposed in the paper (Lu et al., 2013), application of which will contribute to the reduction of the use of fossil fuels and thus allow to limit the destructive effect wielded by the power industry on the natural environment.

It follows from data published by the Central Statistical Office (2013) that in Poland about 30% of energy in its final form is consumed by households, of which nearly 15% of energy consumed by apartments occupants is used for heating hot utility water. On the other hand, Meggers and Leibundgut (2011) report that in some cases, demand for energy related to heating water may represent as much as 50% of the total demand. It is therefore worthwhile to examine this type of energy saving opportunities more carefully. Such approach can contribute significantly to the reduction of the use of fossil fuels on one hand and cutting costs incurred for final energy in individual households.

The problem of saving water and the energy used for heating it in residential houses has been already noticed in many countries.

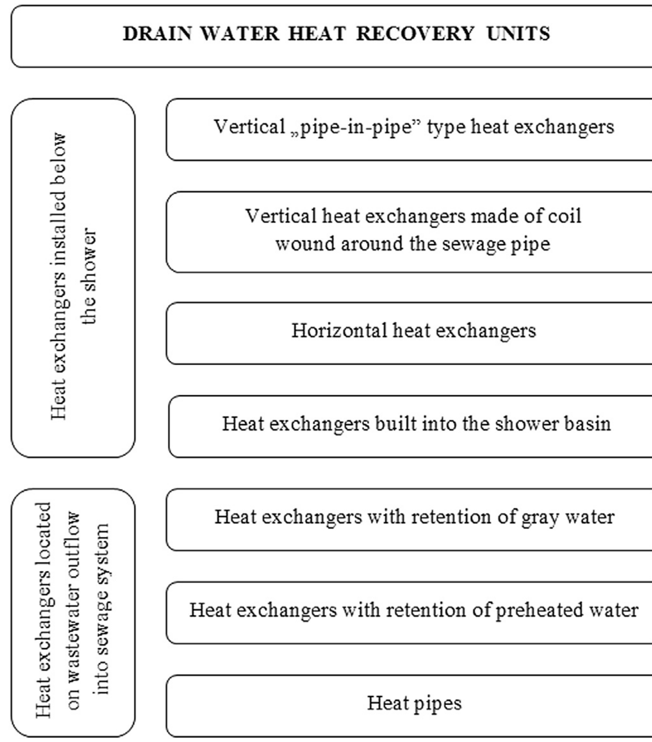

Fig. 1. Systemic classification of Drain Water Heat Recovery units.

For example, the papers (Boait et al., 2012; Chow et al., 2011; Naspolini et al., 2010) analyze the efficiency of various domestic hot water heating systems. Chang et al. (2011), Doménech and Sauri (2011), and Ghisi (2006) in turn pay attention to the need of water savings. These problems have been recognized also in Poland (Chudzicki, 2008; Słyś and Kordana, 2013, 2014), however, in an average household the issue of the implementation of sustainable development principles is still associated with high capital investments that will be impossible to generate any net profit in the course of the anticipated service life of the utility water system. To dispel such doubts, authors of the present paper have carried out a complete financial analysis aimed at the determination of profitability related to the application of selected utility water system configurations allowing to reduce water and energy consumption in shower appliances of single-family dwelling houses.

2. Opportunities to save water and energy in dwelling house shower systems

Application of non-conventional methods for hot water heating allows to reduce the consumption of fossil energy resources resulting in turn in the reduction of the quantity of greenhouse gases emitted to and polluting the atmosphere (Beal et al., 2012; Huang et al., 2012; Ibrahim et al., 2014). The most common methods of saving energy used for the purpose of preparation of hot utility water include: solar radiation energy acquisition (Koroneos and Nanaki, 2012; Koroneos and Tsarouhis, 2012), hot water consumption reduction (Clarke et al., 2009; Plappally and Lienhard, 2012), and the improvement of the efficiency of water heating systems (Ho et al., 2010; Tajwar et al., 2011). In turn, this paper presents a method that can be used for the financial assessment of projects involving the recovery of waste energy carried by warm wastewater in shower systems.

In conventional solutions of water supply/sewage disposal systems, the cold tap water supplied to the building is connected both