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Financial analysis of the implementation of a Drain Water Heat Recovery unit in residential housing

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ABSTRACT

One of the ways of diminishing energy consumption for hot water heating is the use of Drain Water Heat Recovery (DWHR) units. The aim of the use of these devices is thermal energy recovery from warm drain water and transferring it to incoming cold water. This paper presents the calculation model that allows the estimation of the financial efficiency of the project involving the construction of a shower Drain Water Heat Recovery system in a single-family dwelling house. The presented method of investment risk assessment can be used for decision making by individual users, designers and others. The study of the financial performance was carried out for the various parameters of the installation and the different heat recovery system configurations. From investors point of view the most beneficial option of heat recovery system installation is the system in which preheated water is fed to both the hot water heater and shower mixing valve. Additionally, it was proved that obtained financial results are affected by showering time and water consumption. DWHR units will be therefore particularly beneficial to apply in case of swimming pools, sports facilities or fitness clubs, where high rotation of users is observed.

1. Introduction

Energy efficiency has now become one of the indicators of economic development, and the rationalization of its use is the subject of numerous scientific studies [1–5]. Around the world, the aim is to minimize the negative impact of energy on the environment, especially in those industries that contribute most to its degradation. Data from the International Energy Agency [6] show that in 2010 carbon dioxide emissions from the combustion of fuels in the world amounted to 30,326 Mt. It was an increase of almost 94% in comparison to 37 years earlier, that is to 1973, when the emissions were equal to 15,637 Mt. The increase in the amount of greenhouse gases entering the atmosphere is a consequence of the increased energy demand resulting from population growth in the world, as well as the ongoing development of civilization. Environmental pollution caused by excessive CO_2 emissions resulting from the combustion of fossil fuels, raises the need to seek solutions that will contribute to energy saving, and thereby also protect the atmosphere.

According to the Central Statistical Office of Poland [7], households are responsible for about 32% of final energy consumption in Poland. The result is that the interest in using unconventional methods of saving energy is becoming more evident also in the construction sector. The most frequently considered methods are those that allow the reduction of energy consumption for space heating [8–10], but it is also worth considering using methods whose use contributes to reducing the energy demand for hot water which, as Meggers and Leibundgut suggest [11], may in some cases constitute up to 50% of the total demand.

The problem of saving the energy used to heat water for domestic usage has been observed in some countries such as the United Kingdom [12], Ireland [13], Algeria [14], Netherlands [15], Canada [16–18], Australia [19] and Brazil [20], where the effectiveness of the use of different technologies for saving energy used for heating water was analyzed.

Technologies used in order to reduce energy consumption for hot water heating include among others heat recovery from wastewater. Current development of technology makes it possible to recover heat from wastewater on every stage of its formation, transport and utilization. For instance, in works [21,22] installations were described, in which wastewater flowing in collectors is the lower energy source for heat pumps, whereas in publications [23–27] the systems were characterized, in which heat pumps are used in internal building installations. The above examples show that with the use of heat pumps wastewater from various sanitary facilities can be the only source of heat for hot water in the installation as well as used together with renewable sources such as solar energy or outside air. Additionally, the energy recovered from wastewater may be also used for different purposes, for instance for air conditioning or space heating.

Another solution involves the installation of a Drain Water Heat Recovery (DWHR) unit on the shower drain [16,17,28]. With this device there is a transfer of thermal energy contained in the

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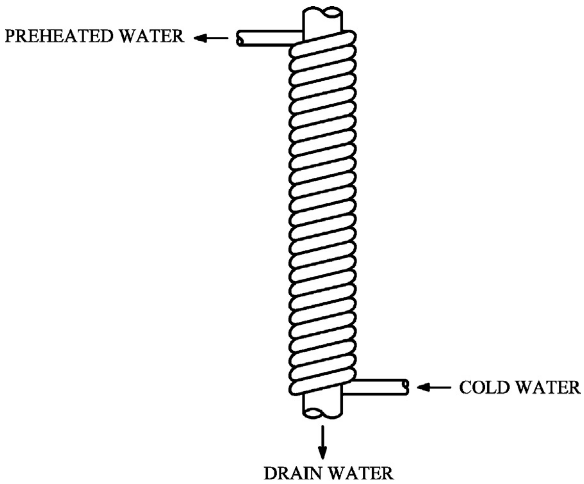

Fig. 1. Diagram of the working of the DWHR unit.

discharged waste water from the shower to the inlet of cold tap water, so that, according to studies carried out in Canada [29,30], Ireland [31] and the United States [32], the required amount of energy used for domestic water heating is significantly reduced. These tests were performed on various models of counterflow heat exchangers constructed of a vertical conduit through which the warm waste water flows, which is wrapped with a vertical coil of copper, inside which the water flows. In such devices, the pipe forming the spiral tube is flattened at the place where it touches the vertical conduit, thus increasing the heat exchange surface, and the formation of a thin layer of biofilms in the waste water pipe enhances the efficiency of heat transfer from the drain water to the heated water. The principle of operation of such a device is shown in Fig. 1, and Fig. 2 shows the heat exchanger of EcoInnovation ThermoDrain TD360, intended for use in residential buildings.

Zaloum at al. [29] showed that the use of a vertical heat exchanger is justified in situations where there is a simultaneous movement of the two media, that is the drain water and the heated water, as is the case when showering. Research carried out in the Canadian Centre for Housing Technology [29] has also shown that the system has a higher efficiency when the water heated in the DWHR heat exchanger flows only to the hot water tank than when it is fed to both the tank and the inlets supplying the shower in cold water. This is due to the fact that a smaller amount of flowing water can be heated to a higher temperature. It was also shown that, despite that, a larger gas savings can be achieved thanks to the second set-up, due to the possibility of increasing the temperature of a greater amount of water.

Study [30] continued the assessment of the financial performance of the technology described in study [29]. Zaloum at al. [30] presented the results of the analysis of the impact of water flow, the temperature and the configuration of the system on the efficiency of the set-up. The authors' experiment has shown that the flow rate carries the greatest importance for the efficiency of heat recovery from the waste water.

An analysis carried out on behalf of the United States Department of Energy [32] confirmed that the use of a vertical counterflow heat exchanger is indicated only for devices such as a shower,

Fig. 2. The EcoInnovation ThermoDrain TD360B heat exchanger (used with permission).

and the greatest energy savings can be achieved when the two media flow is balanced. Study [32] also points out that the cost-effectiveness of the use of such devices increases with the number of showers taken during the day. For this reason, the greatest benefit of heat recovery from waste water discharged from the shower can be obtained in large family homes, multi-family buildings or other buildings that share a common drain from a larger number of showers.

Research which was carried out in Northern Ireland [31] indicated the possibility of recovery of up to 75% of the heat energy contained in the waste water. It was noted, however, that in reality the operation of the device may be affected by additional factors, such as the presence of contaminants in the waste water, for example, fragments of soap, as well as air temperature inside the heat exchanger, which can result in loss of efficiency in comparison with the results obtained in the laboratory.

An alternative solution to heat exchangers made of coil wound around the drainage pipe are “tube in tube” exchangers. The principle of operation is based on the exchange of heat between the warm waste water flowing in the inner conduit and the cold water flowing in the space between the waste water pipe and the external pipe forming the housing of the device [33].

In addition to vertical countercurrent heat exchangers there are also solutions allowing horizontal mounting of the heat exchanger, examples of which are shown in [34,35]. The inflow and drainage pipes are set up in a counter-current in this heat exchanger. There are also solutions in the market in which the heat exchanger is installed directly in the linear shower drainage. Than the warm drainage water that is discharged flows into a small chamber with a height of several centimeters in which a coil is located. Through this coil flows heated tap water. Another heat exchanger solution, which can be used to recover heat from the gray water discharged from the shower, is a device built into the shower basin. This flat exchanger is located under the perforated plate constituting the bottom of the basin.

When wastewater from sanitary facilities is used as a heat source, which makes use of periodic discharges, heat recovery systems with retention can be used. An example of such a heat exchanger solution is described in [36].

In Poland, despite the fact that the costs incurred in the preparation of water at the right temperature is relatively high, the use in residential buildings of heat recovery from wastewater still raises a lot of controversy, and DWHR heat exchangers are not generally available for sale. This state of affairs may be due to lack of data on the financial performance of the presented investments, as information on cost-effectiveness of a heat recovery system from wastewater discharged from sanitary facilities usually comes from the materials from manufacturers. As a result they are not very believable for potential users. It raises the need for an independent analysis of the profitability of Drain Water Heat Recovery units.

2. Device mounting options

In traditional plumbing installations (option 0) the cold water incoming to the building is fed both to the shower mixing valve and the hot water heater, where its temperature is raised to the required level. Fig. 3 shows the working of such a system.

The use of a Drain Water Heat Recovery unit requires modifying the routing of water pipes, which is possible according to three main configurations. Choosing the right option for mounting the device for the recovery of heat from gray water is essential for the operation, and therefore also for the financial efficiency of the investment.