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Considerations regarding the recovery of residual energy for the heating/cooling of buildings and the preparation of domestic hot water

Considerații privind valorificarea energiei reziduale pentru încălzirea/răcirea clădirilor și prepararea apei calde de consum menajer.

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Abstract. *Currently, many opportunities for real energy and cost savings are missed, primarily due to the perception of quantitative heat recovery. However, in the context of the need for the energy efficiency of buildings and technological processes, the recovery and valorisation of residual energy will be a key element. For this reason, the article analyses the recoverable potential from residual energy from various sources and proposes a way to capitalize on it for heating/cooling buildings and preparing domestic hot water.*

Key words: residual energy, recovery, heating/cooling, domestic hot water

1. Introduction

In order to achieve the EU's energy and climate goals, it is necessary that the existing building stock (75% have poor energy performance [1]), in EU member countries, become decarbonized by 2050. As the high share of energy consumption records for the heating and cooling of buildings, it is obvious that energy efficiency measures are needed in the construction sector, to reduce consumption for these services, but also CO_2 emissions. [2], [3], [4].

In addition, the current, rather outdated technologies equipping buildings with low energy efficiency still rely on conventional fuels generating considerable energy waste. For this reason, in order to participate in the decarbonization of buildings, energy efficiency measures must integrate renewable energy sources (RES) and residual energy recovery methods, both at the local level (micro scale) and at the level of district heating networks (macro scale).

Basically, the waste heat recovery process involves the reuse of thermal energy that would otherwise simply be released into the atmosphere, with negative implications on energy consumption and cost and implicitly on emissions CO_2.

Waste energy recovery systems are designed to capture, store and reuse recovered energy. At the building level, to reduce the total energy demand, in general, the recovery of the exhausted heat through ventilation and air conditioning (HVAC) systems is approached. Energy efficiency directives [1], [4], [5] and specialized literature show that the combination of thermal rehabilitation of buildings (sealing of envelope elements) and the use of ventilation with heat recovery leads to considerable reductions in total energy consumption for space heating/cooling, but also greenhouse gas emissions [6], [7], [8], [9].

Most studies, present in specialized literature, regarding the recovery of residual heat refer to industrial processes, processes that can indeed provide valuable energy sources that contribute substantially to the reduction of total energy consumption. In this regard, studies generally refer to the operation and performance of commonly used technologies, such as [10], [11], [12], [13], [14], [15], [16], [17], [18], [19]: recuperators [14], [15], regenerative and plate heat exchangers [16], [17], furnace regenerators [18], [19], rotary regenerators (rotary air pre-heaters and heat wheels) [11], regenerative and recuperative burners [12], economizers and waste heat boilers and run around coil [13].

A classification of residual energy potential as a function of temperature can be done as follows [10], [20]:

- high temperature - greater than 400 °C - from combustion processes;
- medium temperature - 100–400 °C – combustion gas exhaust;
- low temperature - below 100 °C – hot air discharged from buildings with various destinations (data centers, production spaces, etc.) or wastewater (domestic and industrial sewage installations).

In this context, the article proposes a model of low-temperature waste heat recovery and thermal potential utilization for heating/cooling of buildings. The efficiency of the proposed model is achieved by integrating renewable energy sources (RES) using a photovoltaic system to power the heat pump, the chiller and for own consumption.

3. Low temperature waste heat recovery and utilization system model

The model proposes the valorisation of residual energy from sources that discharge residual energy into the atmosphere. Heat sources whose temperature falls into the low temperature category were considered for the model:

- Data centers (DC);

In Data Center and Server Room spaces the most important parameters that must be controlled and ensured to avoid server failure are temperature and humidity [21], [22], [23]. Inside the rooms, the temperature varies in the range of 35-70°C depending on the number of these equipment's and the height at which they are positioned in the racks (the temperature increases with height) [22], [21], [24]. The usual technologies for recovering energy from hot exhaust air are air-to-water heat recuperators and air-to-water heat pumps.

- Household wastewater sewage systems (SWH);

The temperature of the water discharged through the sewage pipes varies between 37-39°C [25] The heat absorbed by the wastewater is transferred to the cold water through heat exchangers at a temperature of approximately 25-30°C, depending on the material of the pipe SEWAGE.

- Low temperature technological processes (LTTP).

The productive industrial sector has a considerable residual heat potential, and for its valorisation a diversity of technologically mature technologies is available, technologies that are presented in Fig.2.

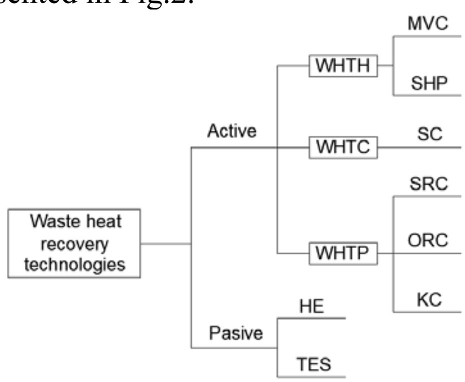

Fig. 2 Types of waste heat recovery technologies
WHTH-Waste heat to heat, WHTC-Waste heat to cold, WHTP-Waste heat to power, MVC-Mechanical vapour compressor, SHP-Sorption heat pump, SC-Sorption chiller, SRC-Steam Rankine Cycle, ORC- Organic Rankine Cycle, KC- Kalina Cycle, HE- Heat exchangers, TES-Thermal Energy

Research attention in the field of heat recovery has been drawn to the high or medium temperature recoverable potential (contained in flue gases), while the low temperature recoverable potential is often neglected. Even though it is possible that the residual potential of the processes that exhaust air or water of lower temperature does not constitute a significant source of residual heat that can be used directly, nevertheless by means of some equipment this potential can be harnessed.

Also, the residual low temperature potential is present in many sectors of activity, such as flat glass melting, food and beverages, chemical, textile, pulp and paper industry, non-metallic mineral processes, wood, other (metal cleaning, painting drying). The low-temperature residual potential is found in considerable quantities, as can be seen in Fig. 3 [20].

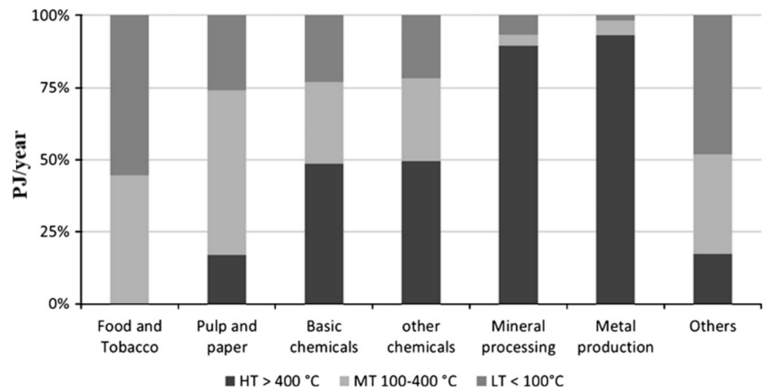

Fig. 3. The temperatures of processes from industry [20]

Thus, in the first stage, by implementing the proposed system model (Fig. 4), the residual potential is recovered from data centers/server room (CD), domestic sewage systems (SWH) and low-temperature technological processes (LTTP), the recovered heat being stored in thermal energy storage tanks (TES 1).

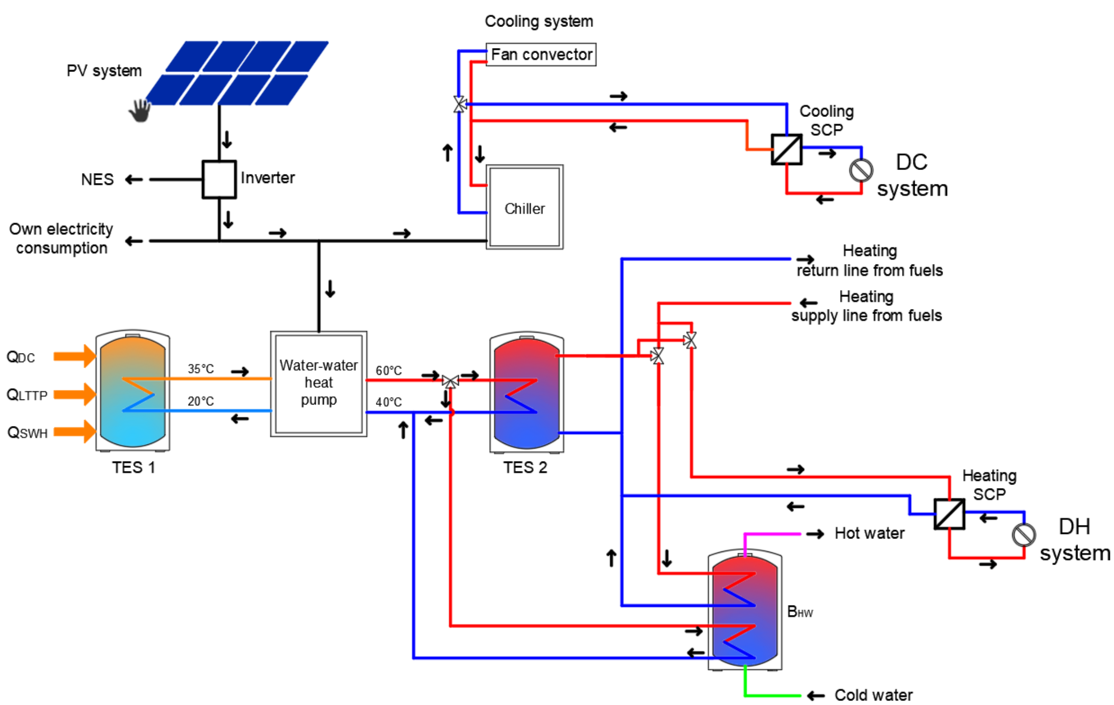

Fig. 4. The proposed model for heating/cooling buildings

In the second stage, by means of water-to-water heat pumps, supplied at a temperature of 35°C, the temperature of the water is raised to a temperature of 60°C and stored in thermal energy storage tanks (TES 2).

The thermal agent produced by the water-to-water heat pumps is transferred either to the boiler related to the internal sanitary installation for the preparation of domestic hot water (B_{DHW}), or to the thermal energy storage tank (TES 2) so that it can be used again for the preparation of hot water later domestic or to feed the central heating system by means of plate heat exchangers (SCP).

For the efficiency of the proposed model, for the electricity supply of the heat pump, the chiller and the system's own consumption, a photovoltaic system is provided.

The photovoltaic system will be dimensioned in such a way as to ensure during the hot season the electricity needed to power the chiller from the cooling system component and the heat pump from the residual thermal energy recovery system component for the preparation of domestic hot water.

During the cold season, the photovoltaic system will feed the heat pump from the residual thermal energy recovery system component to prepare domestic hot water and to provide renewable energy in the centralized heating system.

The thermal energy surplus of the recovery system can be delivered to the centralized thermal energy supply system of the locality and during the warm season, the possible surplus of electricity from the photovoltaic panels can be delivered to the National Energy System (NES).

Therefore, compared to classical heating/cooling systems that usually have a single heat source providing heat/cooling in heating/cooling installations or heat in district heating systems, the proposed system model is a multi-source system of heat that could effectively solve the problem of heating systems.

3. Conclusions

Heating/cooling of buildings with multiple heat sources enables the large-scale use of waste energy from various applications as well as photovoltaic energy. The proposed system model addresses the integration of several heat sources that together can constitute the main source to feed either directly buildings or a centralized heating/cooling system or can constitute auxiliary heat sources in a system that includes a main source of heat which throughout the heating period maintains the operation at full load, while the auxiliary heat sources are adjusted to meet the different thermal load requirements of the users. These types of systems will improve the average efficiency of all heat sources.

Another advantage of this system model, compared to classic heating systems, is the fact that when a failure occurs in the main heat source, the auxiliary sources remain in operation, thus increasing the reliability of the system. This aspect is also an advantage for the stages of modernization or expansion of the system capacity.

An effective method of capitalizing on the high and medium temperature residual potential, already applicable, is the transfer of residual thermal energy in heating systems, in an energy-efficient manner, by using heat exchangers or heat pumps that prepare thermal agent for heating buildings.

The proposed heating/cooling model can integrate into the concept of smart thermal grids, a concept that can be seen as parallel to smart electrical grids and which focuses on the integration and efficient use of potential energy resources (renewable and waste), as well as the operation of a structural network that enables distributed generation that may involve interaction with consumers. Through the information network, different parts (heat source, pipeline network, substations, heat/cold user) are connected with each other and integrated into a controlled and intelligent long-distance management system, namely intelligent heating system.

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