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# The influence of ventilation with heat recovery, and solar energy in the sizing of soil collectors

## Influența ventilației cu recuperarea căldurii și a energiei solare în dimensionarea captatorilor de sol

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**Abstract.** *The European Green Pact aims to make Europe neutral in terms of climate and CO2 emissions by 2050. The residential sector contributes to the emission of greenhouse gases in a proportion of over 39%, of which 28% represent emissions generated by energy consumption to ensure climatic conditions (heating, cooling), 11% are emissions resulting from technological manufacturing processes of construction materials, and an undefined percentage represents energy consumption for the thermal preparation of food. Actions aimed at reducing greenhouse gas emissions go in the direction of replacing building materials with a high CO2 footprint with traditional materials and with a low degree of processing, and replacing large greenhouse gas-generating heating and cooling sources with alternative, renewable sources without reducing or compromising comfort. The use of heat pumps, and especially those that use geothermal resources, for heating and domestic hot water preparation is becoming an attractive and decisive solution in the effort to reduce greenhouse gas emissions. In order to set a budget for the investment and to make a decision, it is necessary to dimension the equipment and implicitly the soil collectors (the length and quantity of boreholes needed for operation).*

**Key words:** heat pump, renewable resources, geothermal resource, energy efficiency, traditional solutions

**Rezumat.** *Prin pactul verde European se are în vedere ca până în anul 2050 Europa să devina neutră din punct de vedere climatic și al emisiilor de $CO_2$. Sectorul rezidențial contribuie la emiterea gazelor cu efect de seră în proporție de peste 39%, dintre acestea 28% reprezintă emisiile generate de consumul de energie pentru asigurarea condițiilor climatice ( încălzire, răcire), iar 11% sunt emisii rezultate în urma proceselor tehnologice de fabricare a materialelor pentru construcții, un procent nedefinit îl reprezintă consumul de energie pentru prepararea termică a hranei. Acțiuni menite să reducă emisiile gazelor cu efect de seră se duc în direcția înlocuirii materialelor de construcții cu amprentă ridicată de $CO_2$ cu materiale tradiționale și cu un grad scăzut de procesare, înlocuirea surselor de încălzire și răcire mari generatoare de gaze cu efect de seră cu surse alternative, regenerabile, fără reducerea sau compromiterea confortului. Utilizarea pompelor de căldură, și în special a celor ce folosesc resursa geotermală, pentru încălzire și preparare apă caldă menajeră devine o soluție atractivă și determinantă în efortul de reducere a emisiilor gazelor cu efect de seră. Dimensionarea echipamentelor și implicit a captatorilor de sol, ( lungimea și numărul de foraje necesar* *funcționării) este o etapă preliminară stabilirii unui buget pentru realizarea investiției și tot o dată un factor decisiv în luarea unei decizii.*

**Cuvinte cheie:** pompă de căldură, resurse regenerabile,resursă geotermală, eficiență energetică, soluții tradiționale

## 1. Introduction

In light of the current energy crisis and Europe's goal to become the first continent with net CO2 emissions neutrality by 2050, [5] solutions are being sought to reduce the consumption of fossil fuels and to find new solutions and technologies that are environmentally friendly and do not produce greenhouse gases..

A sector with a consistent contribution of greenhouse gas emissions is the residential sector, which produces more than 39% of greenhouse gas emissions, of which 28% are emissions resulting from energy consumption to ensure comfort thermal (heating/cooling) and 11% are generated by the building materials manufacturing industry.

The use of renewable energy sources represents a viable solution for reducing greenhouse gas emissions resulting from the burning of fossil fuels. The seasonal nature of solar energy (1) makes the heat pump a concrete alternative for replacing equipment that uses fossil fuels.

Depending on the environment from which the heat is extracted, heat pumps are classified into air-water, water-water, soil-water heat pumps. If for air-to-water heat pumps they have the evaporator predefined by the manufacturer and subject to limiting conditions the minimum outside air temperature for heat extraction and variable COP, with temperature, known; instead for heat pumps, water-water and soil-water, additional works are required consisting of drilling for water or geothermal, works that impose additional costs, mostly unknown at the time of system design.

## 2. Presentation of the work

In this paper, an analysis is made of the dimensioning of the soil collector for soil-water heat pumps, as well as the influences of the energy balance and the energy performance of the building equipped with such a pump in the dimensioning of the soil collectors.

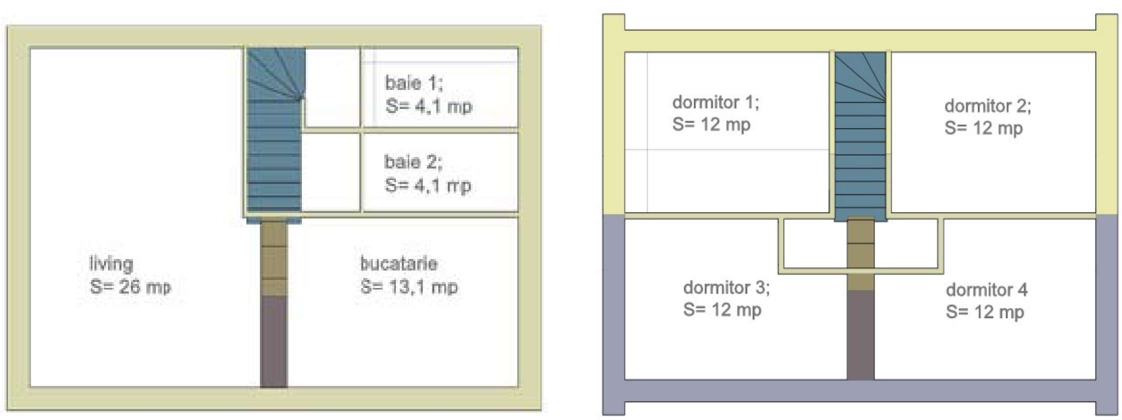
The subject of the analysis is a building, Fig. 1, to be built, predominantly made of ecological materials (wood, reeds, and straw bales), using traditional constructive solutions subject to modern technological updates.

The building, with a footprint of 70 sq m, is to be used as an agro-tourism accommodation unit and has on the ground floor a living room of 26 sq m, a technical space/kitchen of 13 sq m, two bathrooms of 4 sq m each, the staircase and access hall, and in the attic there are 4 bedrooms of 12 sq m each (Fig.2).

Figure.1 Ecological construction will be built according to the building regulations in the Danube Delta.

The energy analysis will follow the determination of the calculation heat requirement determined according to SR 1907-1 and the establishment of the annual energy requirement for heating according to C107. The calculation will be made for the minimum standardized resistances according to MC 001 and for the resistances determined by the chosen constructive solution.

The obtained results will be analyzed from the perspective of the parameters necessary for the operation of soil-water heat pumps in optimal conditions and the requirements for geothermal drilling.




(a) (b)

Figure. 2. Ground floor plan (a), Attic plan (b)

## 3. Technical parameters

The composition of the tire and the thermotechnical characteristics [4] of the constructive elements are presented in Table (1), compared to the solution of the resistances of the tire components according to the constructive solution, Table (2), an increase in the average corrected resistance of the tire, Table (3).

*Table 1*

| Thermotechnical characteristics of tire elements - minimum requirements | | | | | | |
|---|---|---|---|---|---|---|
| Nr.crt | The Construction Element | A | R'm | τ | (A·τ)/R'm | percentage of the building envelope |
| | | $m^2$ | $m^2K/W$ | -- | W/K | % |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | Flooring | 57.33 | 5.00 | 1 | 11.47 | 23.25 |
| 2 | Exterior walls | 109.17 | 4.00 | 1 | 27.29 | 44.26 |
| 3 | Exterior carpentry | 17.55 | 1.11 | 1 | 15.80 | 7.12 |
| 4 | Sarpannta | 57.33 | 6.67 | 1 | 8.60 | 23.25 |
| 5 | Outer door | 5.25 | 0.77 | 1 | 6.82 | 2.13 |
| | | | | | | |
| T O T A L | Suprafață anvelopă | 246.63 | **3.525** | -- | 69.97 | |
| VOLUM | $m^3$ | 303.85 | | | | |

*Table 2*

| Thermotechnical characteristics of tire elements - constructive solution | | | | | | |
|---|---|---|---|---|---|---|
| Nr.crt | The Construction Element | A | R'm | τ | (A·τ)/R'm | percentage of the building envelope |
| | | $m^2$ | $m^2K/W$ | -- | W/K | % |
| 0 | 1 | 2 | 3 | 4 | 5 | 6 |
| 1 | Flooring | 57.33 | 5.69 | 1 | 10.08 | 23.25 |
| 2 | Exterior walls | 109.17 | 5.58 | 1 | 19.57 | 44.26 |
| 3 | Exterior carpentry | 17.55 | 1.77 | 1 | 9.93 | 7.12 |
| 4 | Sarpannta | 57.33 | 6.97 | 1 | 8.22 | 23.25 |
| 5 | Outer door | 5.25 | 0.77 | 1 | 6.82 | 2.13 |
| | | | | | | |
| T O T A L | | 246.63 | **4.516** | -- | 54.62 | |
| VOLUME | $m^3$ | 303.85 | | | | |

*Table 3*

| | | S1 | S2 | GROWTH |
|---|---|---|---|---|
| | | R'm | R'm | |
| | | $m^2K/W$ | $m^2K/W$ | % |
| | | 3 | 3 | |
| Flooring | | 5.00 | 5.69 | 13.76 |
| Exterior walls | | 4.00 | 5.58 | 39.47 |
| Exterior carpentry | | 1.11 | 1.77 | 59.05 |
| Sarpannta | | 6.67 | 6.97 | 4.57 |
| Outer door | | 0.77 | 0.77 | 0.00 |
| Medium resistance | | 3.52 | 4.52 | 28.10 |

### 3.1 Determination of the calculation heat requirement SR1907-1

The calculation of heat requirement Q0 expressed in watts, determined by formula (1) represents the parameter that establishes the technical characteristics of the heating equipment: radiators, heat generators, radiant surfaces, etc. It depends on the degree of insulation, respectively, on the thermal resistance of the tire elements and on the supply of fresh air for ventilation.

$$Q^{NEC}_{tot} = Q^{NEC}_{tra} + Q^{NEC}_{aer} \quad (W) \qquad (1)$$

- $Q^{NEC}_{tot}$ = total heat flow (W)
- $Q^{NEC}_{tra}$ = the heat flow lost through transmission; formula (2) (W)
- $Q^{NEC}_{aer}$ = thermal flow for heating fresh air; formula (3) (W)

$$Q^{NEC}_{tra} = c_m * \sum \frac{A_j}{R_j} * \left(\theta_i - \theta_{e_j}\right) + Q_S \quad (W) \qquad (2)$$

$$Q^{NEC}_{Aer} = 0{,}334 * n_a * C_m * V_i * (\theta_i - \theta_e) + Q_u \quad (W) \qquad (3)$$

The calculation was performed in 3 (three) scenarios;

- Scenario 1: The tire elements have the minimum standardized resistances; the number of air exchanges is 0.5; without ventilation with heat recovery, the calculation of the external temperature is -15°C.
- Scenario 2: The tire elements have the resistances determined in the laboratory for the constructive solution; the number of air exchanges is 0.5 [$h^{-1}$] without ventilation with heat recovery.
- Scenario 3: The tire elements have the resistances determined in the laboratory for the constructive solution; the number of air exchanges is 0.053 []. calculated for a requirement of 25 $m^3h$ for one user, the

calculated outdoor temperature was corrected to 17.8°C, ventilation with recovery heat, and the recovery efficiency was 92% [2].

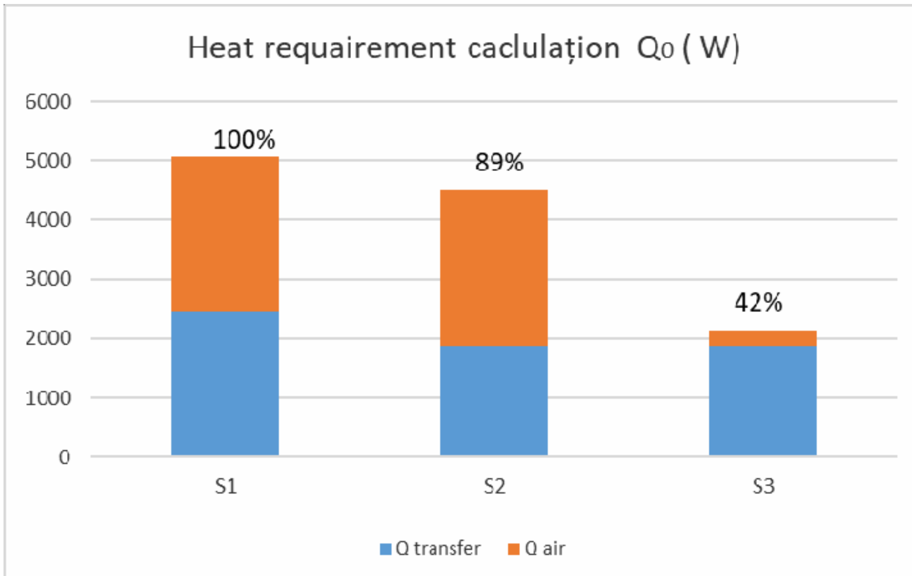



Figure. 3 Calculation of heat requirement

To compensate for heat losses, equipment with a minimum thermal power of 6 kW in scenario 1, 5.5 kW in scenario 2, and 2.6 kW in scenario 3 is required.

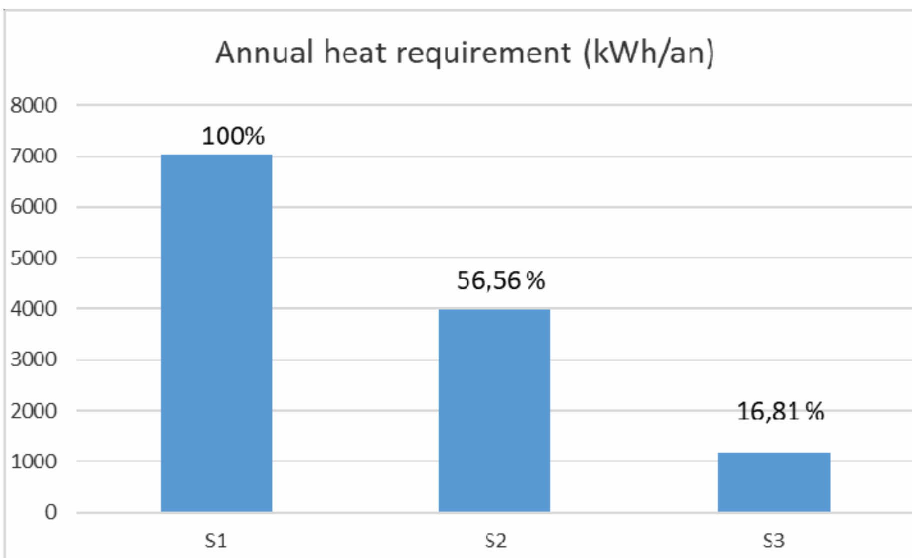



Figure. 4 The annual heat requirement

1. Increasing the corrected average resistance by 28% generates a reduction in the calculation heat requirement by 11% and a reduction in the annual heat requirement by 43.44%.

2. Increasing the corrected average resistance by 28% and using ventilation with heat recovery with an efficiency of 92% generates a reduction in the calculation heat requirement by 58% and a reduction in the annual heat requirement by 83.19%.

### 3.2 Establishing the annual energy requirement for domestic hot water preparation

According to I9/2022, Annex 1.2, the specific water requirement, V _(s,day) and the specific hot water requirement, V _(s,day,ac) for buildings (except residential buildings) for accommodation units of 2 stars, without laundry, is 190 liters/person.day cold water and 76 liters/person.day. The volume of daily hot water consumption is calculated with formula (4).

$$V_{ac,zi} = V_{s,zi,ac} * N_p \tag{4}$$

Table 4 shows the calculation of the hot water and thermal energy requirements to bring the cold water from 10 °C to a temperature of 60 °C, including the annual energy requirement.

*Table 4*

| necesarul maxim anual de energie pentru preparare apă caldă | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ian | feb | mar | apr | mai | iun | iul | aug | sep | oct | nov | dec |
| nr persoane | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| litri/pers,zi | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 | 76 |
| litri/zi | 608 | 608 | 608 | 608 | 608 | 608 | 608 | 608 | 608 | 608 | 608 | 608 |
| kwh/zi | 34.7 | 34.7 | 34.7 | 34.7 | 34.7 | 34.7 | 34.7 | 34.7 | 34.7 | 34.7 | 34.7 | 34.7 |
| nr zile, lună | 31 | 28 | 31 | 30 | 31 | 30 | 31 | 31 | 30 | 31 | 30 | 31 |
| litri/lună | 18848 | 17024 | 18848 | 18240 | 18848 | 18240 | 18848 | 18848 | 18240 | 18848 | 18240 | 18848 |
| kwh/lună | 1075.63 | 971.54 | 1075.63 | 1040.94 | 1075.63 | 1040.94 | 1075.63 | 1075.63 | 1040.94 | 1075.63 | 1040.94 | 1075.63 |
| kwh/an | 12664.71 | | | | | | | | | | | |

### 3.3 The annual energy requirement for domestic hot water preparation and heating

The cumulative annual energy requirement for the production of domestic hot water and heat was determined for the three calculation scenarios represented in Fig. 5.

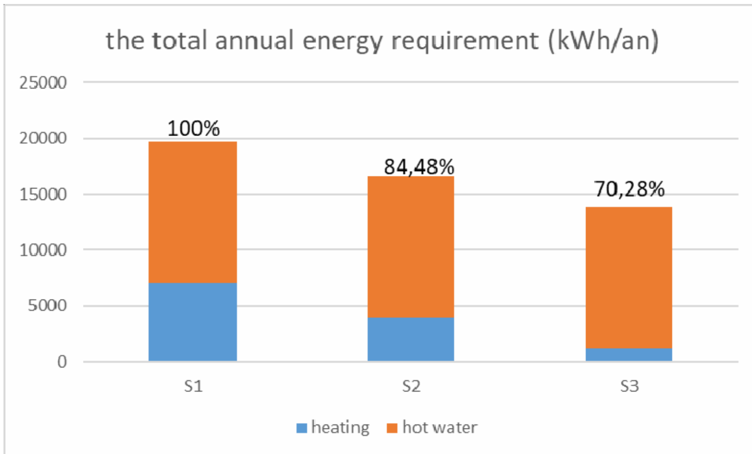



Figure. 5 Total annual heat requirement: hot water + heating

## 4. Solar thermal energy available

Solar energy has a seasonal character [3], in which the available energy is influenced by the calendar period of the year [7], by the latitude at which the equipment is installed, by the mounting angle of the solar energy capture elements, and the efficiency of the equipment to capture solar energy. Fig. 6 shows the average monthly energy available in the place. Zimnicea per square meter in the case of installation angles of 0°, 45°, and 90°.

For the analyzed building, it was decided to mount a solar system with vacuumed thermal tubes in a closed loop, which has 60 tubes. The net capture area is 7.8 $m^2$. Hot water is stored in two boilers connected in series, with a total capacity of 620 liters (120 liters + 500 liters).

The solar thermal system dimensioned in this way fully covers the hot water requirement for the months of March–October [6] and has input for preparing hot water in the months of November–February. Fig 7.

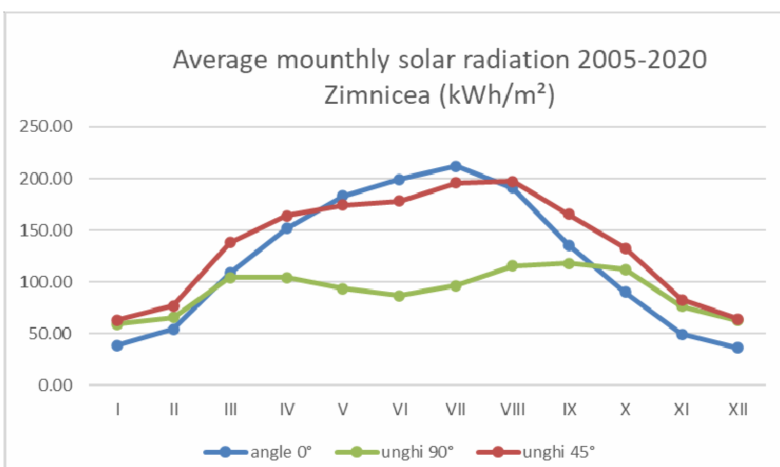



Figure. 6, Average monthly radiation for the period 2005–2020 for different montaj angles

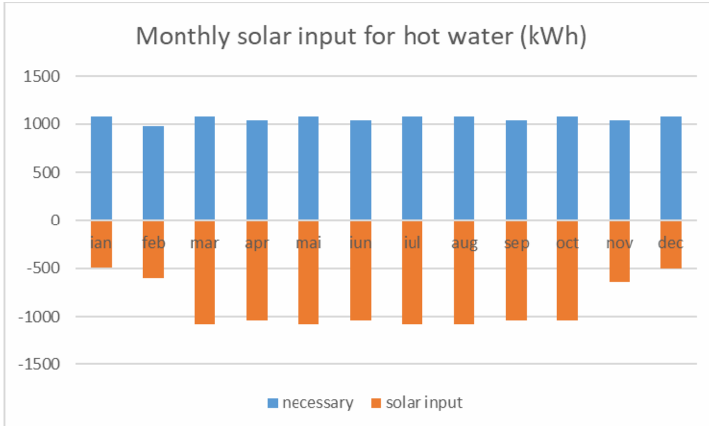



Figure. 7. Solar input for hot water preparation.

The introduction of solar energy into the energy balance reduces the annual energy requirement in scenario 1 by 54.3%, in scenario 2 by 64.29% and in scenario 3 by 77.28%.Fig. 8

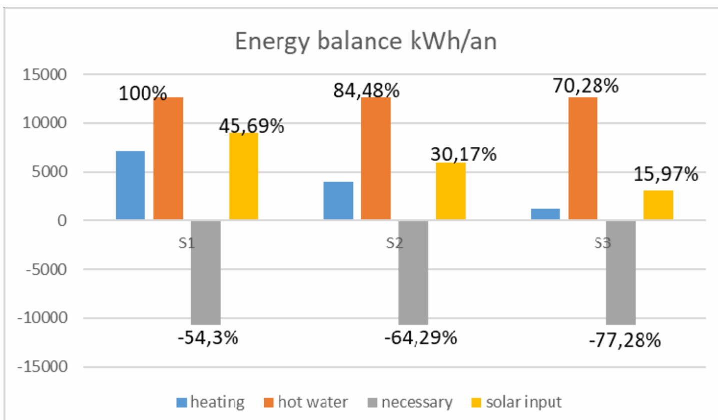



Figure. 8. Bilanțul energetic.

## 4. Results analysis

For the building under analysis, in the three working scenarios, the thermal powers were determined (Table 5), based on which possible options for choosing the heat pump were identified.

*Table 5*

| scenario | **Q nec** | Qheat | Qhw | **Qtotal1** | Qsolar | **Qtotal2** |
|---|---|---|---|---|---|---|
| | **W** | kWh/an | kWh/an | **kWh/an** | kWh/an | **kWh/an** |
| S1 | **5067** | 7039 | 12664,71 | **19703,71** | -10701 | **9002,66** |
| S2 | **4498** | 3981 | 12664,71 | **16645,71** | -10701 | **5944,66** |
| S3 | **2143** | 1183 | 12664,71 | **13847,71** | -10701 | **3146,66** |

Following the market study, the following equipment was identified as being able to satisfy the comfort requirement: Table 6

*Table 6*

| technical specifications | Flow | Qheat | Δt |
|---|---|---|---|
| tip pompă căldură | $m^3/h$ | kWh | °C |
| TMC 22 hyper-jet | 1.20 | 8 | 3 |
| NIBE S1155 | 1.08 | 8 | 3 |
| ecoGEO B/C 1-9 | 1.32 | 9 | 3 |

Heat transfer in the soil collector is of the conductive convective type in the stationary regime in the cylindrical wall.

Convective components, respectively, the hydraulic component of the soil collectors, must be sized in such a way as to ensure the minimum temperature difference to ensure vaporization of the refrigerant at the nominal flow indicated by the heat pump manufacturer.

Figure 9 shows the principle diagram of heat exchange in an environment with a constant temperature (soil temperature).

In this case

- $t_1' = t_1'' = t_{sol}$
- $t_2'' = t_1'' - 2°C$
- $t_2' = t_2'' - \Delta t$ minimum required

The minimum required Δt represents the minimum required temperature difference in the evaporator.

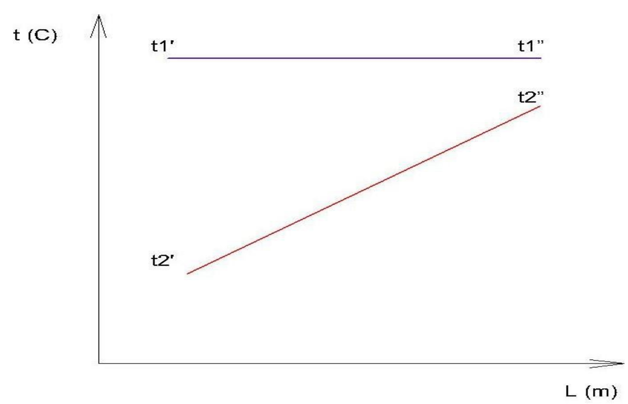



Figure. 9. Diagram of heat transfer in a medium with a constant temperature

The analysis of soil collectors will be carried out on two levels;

1. Hydraulic (convective) analysis of the solution adopted for the realization of soil collectors; pipe diameter, material conductivity, heat exchange surface, economic speeds.

2. Analysis of the environment (conductive transfer through the cylindrical wall) from which heat is extracted; specific heat of the soil (unit/average); density; initial temperature (at the entrance to the heating season); final temperature (at the exit from the heating season); regeneration capacity so that the soil temperature escapes to the initial temperature upon entering the heating season.

Hydraulic analysis of the soil collector, determination of the heat exchange surface, maintaining a minimum temperature difference Δt in the vaporizer, determining the length and number of boreholes.

The LMTD method for a two-fluid heat exchanger uses relations (5), (6), and (7)

$$Q_1 = \dot{m}_1 * c_1 * (t_1' - t_1'') = \dot{C}_1 * (t_1' - t_1'') \quad (5)$$
$$Q_2 = \dot{m}_2 * c_2 * (t_2'' - t_2') = \dot{C}_2 * (t_2'' - t_2') \quad (6)$$
$$Q_{tr} = K * A * \Delta t_m \quad (7)$$

Considering that the heat transfer from the hot source is exclusively conductive in a cylindrical wall, then formula (5) turns into formula (5').

$$Q_1 = \frac{2\pi\lambda l}{ln\frac{r_2}{r_1}} * (t_1 - t_2) = \frac{\pi l}{\frac{1}{2\lambda} ln\frac{d_2}{d_1}} (t_1 - t_2) \quad (5')$$

In which case

- $t_1$= soil temperature
- $t_2 = \frac{t_2' + t_2''}{2}$ (8)

Q1=Q2=Qtr

Calculation parameters:

- The density of the working fluid, ρ=kg/m³
- The specific heat of the working fluid c=J/kgxK
- The diameter of the soil trap d=m
- Flow section A=m²
- Primary circuit fluid flow Q=m/s, m³/h

**5. Conclusions**

The use of ventilation with heat recovery and solar energy generates significant reductions in the realization of soil traps of up to 87%.

The thermal requirement for heating of 25% of the thermal capacity of the equipment has the effect of a reduced operating time and, implicitly, a reduction in wear and savings on energy consumption.

The reduction of investment costs generated by the realization of geothermal wells adapted to the corrected energy requirement makes the solution of using geothermal heat pumps attractive..

It is important once again to continue the study by analyzing the heat transfer in the soil between the thermal agent that circulates through the pipes of the collector and the energy stored in the soil, determining the amount of heat extracted, and evaluating the resilience time between two seasons.

A solution to encourage the adoption of solutions with geothermal heat pumps is subsidizing, with up to 100% of the drilling.

For the purchase of heating equipment with zero CO2 emissions, access to loans with subsidized interest up to 0% must be ensured.

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