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Professional paper

THE CONTRIBUTION TO THE DESIGN OF HEATING AND HOT WATER SUPPLY SYSTEM BASED ON LOW TEMPERATURE HEAT PUMP SYSTEM IN COMBINATION WITH SOLAR COLLECTORS

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The low-potential sources in combination with solar devices used in supply heating systems present a perspective alternative to fossil energy in both economic and environmental point of view. The issue of low-temperature heating and renewable energy sources is on the present, when humanity stands on the threshold of fuel-energy sources selection, is extraordinary important. Currently the solar energy, geothermal water energy and environmental energy used in supply heating systems with low-energy potential present a perspective alternative in compare to limited fossil energy. The energy utilization appropriateness is depended by geographic area and climate zone. The article present and solve the design issue of low-temperature heat pump system in combination with solar panels devices.
Key words: heat pump, solar collectors, heating, low temperature heating, hot water.

Doprinos konstrukcijskom rješenju grijanja i pripreme potrošne topple vode temeljenom na nisko-temperaturnom sustavu s toplinskom pompom u kombinaciji sa solarnim kolektorima. Niskopotencijalni izvori u kombinaciji sa solarnim uređajima, koji se koriste u sustavu grijanja, predstavljaju perspektivnu alternativu energiji iz fosilnih goriva i s ekonomskog i ekološkog stajališta. U sadašnje vrijeme, kad je čovječanstvo već limitirano u odabiru izvora energije, pitanje korištenja niskotemperaturnog grijanja i obnovljivih izvora energije je od izuzetne važnosti. Trenutno solarna energija, geotermalna vodna energija i energija okoliša, kao energije s niskim energetskim potencijalom koje se koriste u sustavima grijanja, predstavljaju perspektivnu alternativu u odnosu na ograničenu fosilnu energiju. Povoljnost korištenja navedenih alternativnih oblika energija ovisi o zemljopisnom području i klimatskoj zoni. U radu je prikazano konstrukcijsko rješenje uporabe niskotemperaturnog sustava s toplinskom pumpom u kombinaciji sa solarnim panelnim uređajima.
Ključne riječi: toplinska pumpa, solarni kolektori, grijanje, niskotemperaturno grijanje, topla voda.

INTRODUCTION

Energy is an important condition of satisfying basic human needs. Everyone of us realizes energy need whether in the form of heat, light, fuel or other forms. Actual way of fossil fuels utilization (coal, crude oil, gas and uranium) is time-limited. Presently when mankind is about to choose the fuel-energetic sources the problems of low-temperature heating and renewable sources of energy is extremely important [1]. Just heat supplying systems with low-energetic potential using sun energy, geothermal energy represent perspective alternative in comparison with limited fossil sources of energy. Suitability of their utilization depends on geographical area and climatic conditions in which we live.

In spite of real possibilities of utilization the low-temperature sources of energy in Slovakia. Their utilization is in comparison with states of European Union negligible. Virtue of technologies which use low-potential sources of energy in comparison with traditional sources of energy is not only in energy saving in the heat supplying systems but also relate to ecological cleanness of environment.

APPLICATION OF LOW-TEMPERATURE AND RENEWABLE SOURCES OF ENERGY

Low-temperature heating in conjunction with renewable sources of energy can be used for heat supplying of all spaces where hot water heating of radiant-type heating systems are used.

Requirements for heated object:

Object with low-temperature heating system must meet the requirements:

- ✓ thermal loss of heated objects must be the lowest (15-20 $W.m^{-3}$),
- ✓ heated space must have such thermal loss which can cover heating surface with its output without overpassing hygienically acceptable surface temperature of heating surface (floor, wall, ceiling),
- ✓ when the thermal loss is higher than reachable output of heating surface then thermal resistance of perimeter constructions needs to be increased by additional insulation or cover the shortage output by radiant heating surface in other plane or by heating element [2,3,4].

Object characteristic, its surface and actual way of heating supplying

House with housing area of 117,49 m^2 and floorage of 317,223 m^3 is situated in Borša village (Trebišov district, Slovakia), in row houses at estate of 900 m^2 area. The estate contains of garden of 450 m^2 and un-built area of 70 m^2 .

In present the way of heat supplying and hot water heating is realized in electrical reservoir of 80 l size and heating is secured by gas condensing boiler of A 23 type from Junkers company with continuous equithermal control of heating output from 7 to 28 kW and connecting with solar system option.

For the design of the house heating and HW supplying is necessary to know its thermal loss and day HW consumption for particular 4-memeber family.

Calculation of object total thermal loss

Total thermal Total thermal loss of the object (in this case) is sum of particular room thermal losses and it is determined according to the equation:

$$Q_{t,h} = \sum_{i=1}^{n} Q_{t_i} \qquad \text{(W)} \quad (1)$$

where:

$Q_{t,h}$ – total thermal loss of the house, (W),

Q_{ti} – total thermal loss of particular rooms, (W).

Calculation leads to the total thermal loss of the house that is 13,806 kW.

Calculation of heat and HW heating year consumption

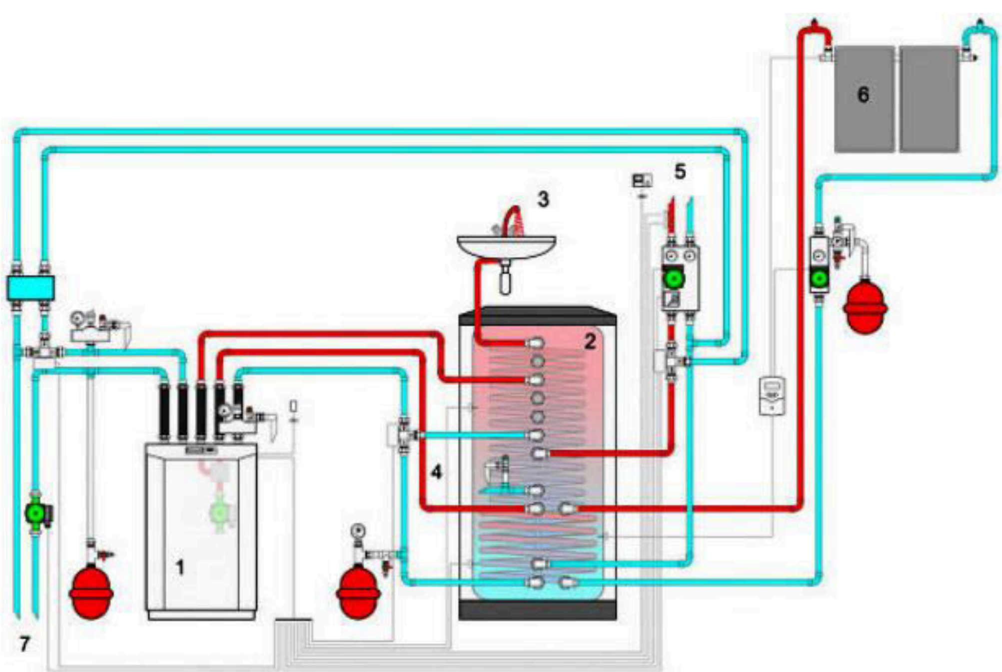
In calculation of year heat consumption for heating it comes out from thermal loss of the object $Q_{t,h}$ for uninterrupted heating according to the standard EN 12 831. Total heat and hot water (HW) heating year consumption - Q_{total} = 31 295 (kWh.y^{-1}).

Calculation of heat and HW heating year consumption

The goal while designing the heat supply for heating and HW heating of the house was to create the system which would effectively utilize excessive solar energy for heat pump (HP) support and as backup facility heat source - gas condensing boiler.

Mentioned interconnection of old and new way of heat supply has advantage in the gas boiler being able to ensure the total heat need for space heating and HW heating in case of problems with heat pumps or solar collectors.

There was designed bivalent operation mode in combination with solar collectors where heat pump will work separately until so-called point of bivalence at which peak source starts to heat i.e. gas condensing boiler.



1 – heat pump, 2 – heat exchanger, 3 – hot water, 4 – cold water , 5 – space heating, 6 –solar installation, 7 – heat source

Figure 1. Scheme of heat supplying system
Slika 1. Shema sustava za grijanje i pripremu potrošne tople vode

Required number of solar collectors determination

All elements of solar system were chosen the same as storage reservoir from product offer of Regulus company.

For choosing the solar collectors is necessary to know operation conditions. Collectors will be situated at flat roof of additional building oriented on south. As it is considered all year service so the angle of inclination will be 45°. Specifically they will be vacuum tube solar collectors with more effective reflective KTU R2 metal sheet KTU 9R2 type of 2,15 m^2 aperture area.

Required number of collectors calculation is realized according to the equation from [5, 6, 7]:

$$n_{sc} = \frac{A_c}{A_{ef}} \quad (-) \qquad (2)$$

where:

n_{sc} – required number of solar collectors, (-),
A_c – calculating absorption area of solar, (m^2),
A_{ef} – effective area of absorber , (m^2), A_k = 2,15 m^2.

Where as the equation for calculating absorption area of solar collectors is:

$$A_{ef} = \frac{P_u}{P_s \cdot \eta} \quad (\mathrm{m}^2) \qquad (3)$$

where :
P_u – heat need for HW heating, (kWh.day^{-1}),
P_{avg} – average useable solar energy, (see table. 1),
P_{avg} = 4,7 kWh.m^{-2}.day^{-1} – summer half-year (IV. – IX. month),
P_{avg} = 2,2 kWh.m^{-2}.day^{-1} – temperate season (autumn, spring),
η – average efficiency of solar system, (-).

Table 1. Average amount of solar energy per south oriented area [8]
Tablica 1. Prosječna dozračena sunčeva energija po južno orijentiranoj površini [8]

	Amount of incident solar energy per area unit in Trebišov - Slovakia (kWh.m^{-2})												
Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Average
Daily	1,36	2,33	3,58	4,36	5,03	4,85	5,21	4,78	3,98	3,22	1,59	1,09	3,45

Heat need P_u *is based on equation*:

$$P_u = m \cdot c \cdot (t_{hw} - t_{sw}) \quad (\mathrm{kWh.day^{-1}}) \qquad (4)$$

where:
m – day hot water consumption, (l.day^{-1})
m = number of person. 50 l.day^{-1} = 4·50 = 200 l.day^{-1}
c – specific heat capacity of water, c = 1,16.10^{-3} kWh.kg^{-1}.K^{-1},
t_{tw} – temperature of taken water, t_{tw} = 45 °C,
t_{sw} – temperature of supplied water, t_{sw} = 10 °C.

$$P_u = 200 \cdot 1{,}16.10^{-3}.(45-10) = 8{,}12 \ \mathrm{kWh.day^{-1}}$$

a) system sizing for summer season:

$$A_c = \frac{P_u}{P_{avg} \cdot \eta} = \frac{8,12}{4,7.0,5} = 3,46 \text{ m}^2$$

$$n_k = \frac{A_c}{A_{ef}} = \frac{3,46}{2,15} = 1,61 \approx 2 \text{ collectors}$$

b) system sizing for temperate season:

$$A_c = \frac{P_u}{P_{avg} \cdot \eta} = \frac{8,12}{2,2.0,5} = 7,38 \text{ m}^2$$

$$n_{sc} = \frac{A_c}{A_{ef}} = \frac{7,38}{2,15} = 3,43 \approx 3 \text{ collectors}$$

There were designed three solar collectors of KTU 9R2 type based on the calculations and with knowing the solar energy accumulation demand.

What concerns reservoir heater whereas there are 4 persons with daily hot water consumption of 50 litres. It is enough to choose storage reservoir with reservoir of DUOV 750/200 type with total value of 750 litres and heat water reservoir of 200 litres. Inner surface of reservoir is enamelled and is equipped with magnesium anode.

Storage reservoir for storing solar energy excess will be PS2F 300 type of 300 litres volume and 2 tube exchangers which size will be customized according to the chosen application and needed performance.

Option of suitable heat pump type

As indicated by principal scheme on Figure 1 heat supply for heating and HW (through period of need) will be ensured by heat pump earth-water. Because mentioned heat pump type can easily and effectively interconnected through salt brine circuit with storage reservoir of solar system. As central heating of the house is solved by using hot-water heating system 90/70 °C. It was necessary to choose heat pump type which is able to operate at these conditions in order to heating elements not to have to be changed.

Compressor heat pump earth-water with electric drive from Viessman company marked as VITOCAL 350 with outlet temperature 65°C meets those conditions.

That was specially developed for modernization with radiator circuit left.
Particular type VITOCAL 350 HP depends on required heat need.

Because thermal losses of object are calculated at lowest outer temperature of surroundings which in reality introduces little number of hours needed HP output will be designed to ensure 75 - 95 % of heat need for heating and HW and addition will be ensured by additional source. What concerns HW at present demand for comfort day energy need for preparing HW is about 17 kWh or average energy input for water heating about 0,7 kW per 4 persons [9, 10, 11].

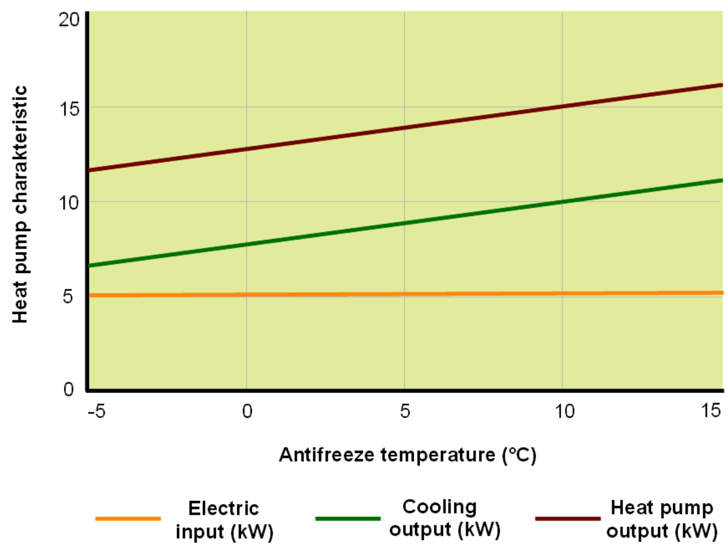


Figure 2. HP VITOCAL 350 characteristics
Slika 2. Karakteristike toplinske pumpe HP Vitocal 350

Next, it is necessary to consider everyday heat pump lay off for certain number of hours in order to ensure its trouble-free operation. What is related to temperature regeneration inside the earth. This means that daily the heat pump will be blocked for 4 hours in two two-hour intervals and heat will be removed from DUOV storage reservoir. What is taken into account by increasing the total required HP output by 1,2 times. In consequence total required HP output will be: *(13,738 kW + 0,7 kW) . 1,2 = 17,326 kW.* After taking the required output into account heat pump type was selected VITOCAL 350 type. Heat pump characteristics are taken from technical materials from Viessmann company are shown in fig. 2 and fig. 3.

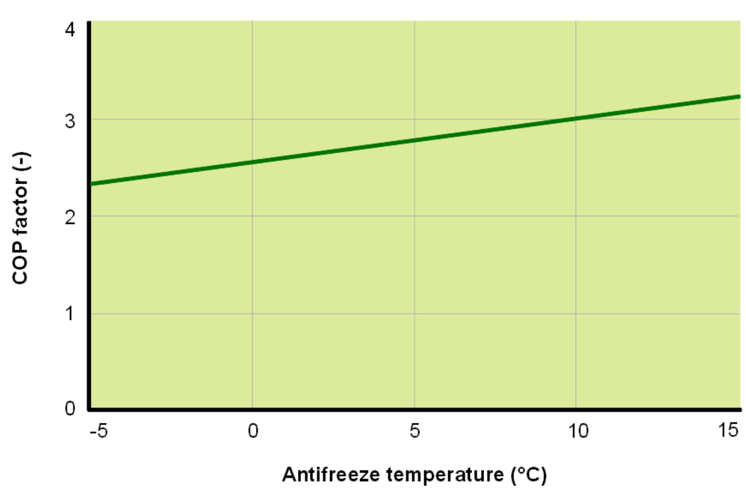


Figure 3. Heating factor of HP VITOCAL 350 process
Slika 3. Faktor grijanja toplinske pumpe HP Vitocal 350

The most important characteristic of the heat pumps is the COP facto (Coefficient of Performance), which is the ratio between heat pump output and heat pump input, or ratio between heat transferred to the heat transfer medium and consumed work (workload). The Coefficient o Performance is influenced by the increasing temperature of the heat source. The energy and the economic efficiency of the heat pump system and the achievable quantity of energy is affected by the parameters o low-potential heat source, by heat level, by available energy of the heat source and so on.

Point of bivalence determination

Point of bivalence was defined according to (see fig. 4) for salt brine temperature of 2°C what corresponds to 13,2 kW heating output of heat pump. If temperature of salt brine is under 2°C gas condensing boiler will work as help out.

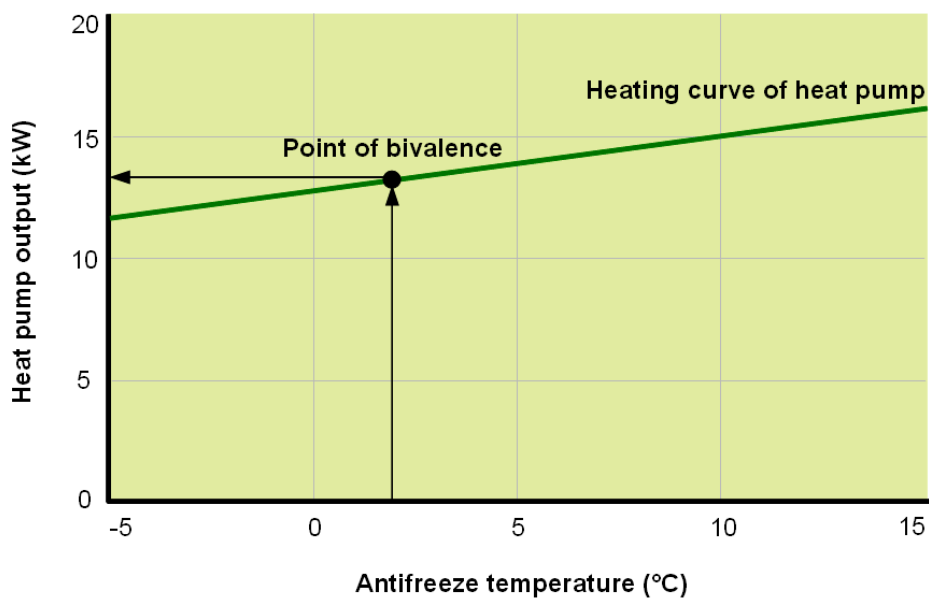


Figure 4. Point of bivalence determination diagram
Slika 4. Dijagram za određivanje bivalentne točke

Drill hole depth determination for heat pump

Drill holes depth for HP ground probes is affected by the type of foot wall, amount of underground water and other factors.

Table 2 was important for determination of vertical collectors depths for selected HP. This contains informative values of needed collectors length in dependence on required output and foot wall composition.

Table 2. Informative ground collectors depth in dependence on HP output
Tablica 2. Učinak grijanja toplinske pumpe u ovisnosti o vrsti i dubini tla

Type of foot wall	Heating output (W) per 1m of collector length	Depth (m) per 1kW of heating output
Dry soil	30	33
Continual solid soil	55	18
Rock with big thermal conductivity, clay	80	13
Rock with underground water	100	10

Since un-built area of 70 m^2 is made by clay rock with big thermal conductivity. Two drill holes of 88 m depth and 5 m spacing (because of little interaction and ensuring regeneration in summer) were designed based on heating output of 13,2 kW.

Despite of the earth temperature in our climatic conditions in the depth of 10 m is already steady around 10 – 12 °C. As shown in fig. 5 it is obvious that at constant taking off from drill hole the temperature will progressively decrease in its environment certain temperature cone. The level will be balanced again after stopping heat taking off. Thermal flows will become constant even if the temperature can slowly decrease. This problem is analysed in detail in source [10].

According to that it is valid that if output of 75 W/m is not overpassed system works without problems. For this case is valid that output per 1m of drill hole depth the presented limit does not overpass: *13 200 W: (2.88 m) = 75 (W.m^{-1}).*

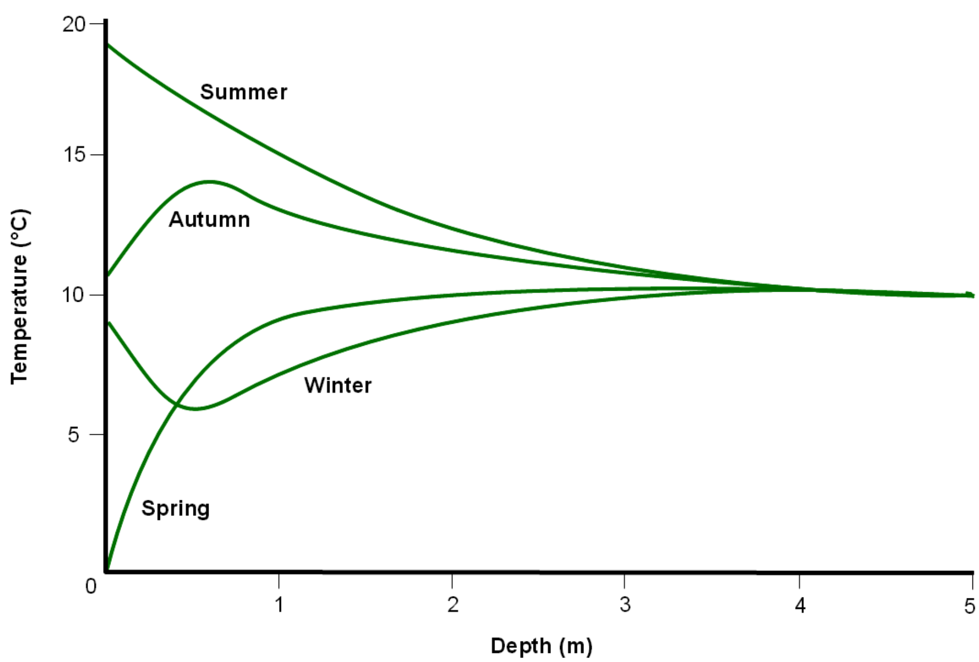


Figure 5. Earth temperature process in dependence on year season
Slika 5. Temperatura po dubini tla u ovisnosti o godišnjem dobu

DESIGN OF SALT BRINE FLOW THROUGH SOLAR SYSTEM STORAGE RESERVOIR

Utilization of solar system summer excess stored in storage reservoir will take place in the period when HP will not be able to ensure necessary heat as result of salt brine temperature fall from ground collector under the point of bivalence. In that case the salt brine circuit would be closed and this would flow through storage reservoir of solar system and take off its accumulated heat from summer.

Temperature of water in storage reservoir would be kept at 60°C in the time of charging from solar system and heat would be taken from it until the temperature of 2°C. This circuit would be closed after decreasing of water temperature on 2°C and salt brine would flow back to the ground. It would ensure required heat in bivalent mode with gas condensing boiler on the basis of automatic regulation by equithermal system.
Salt brine is demanded to warm up about 3 °C while flowing through reservoir because during ground probe flowing it is warmed up about this temperature difference. Determination of salt brine temperature increase during ground probe flowing:
It is necessary to know output of low-potential heat source for making calculation which is defined as:

$$Q_O = \frac{Q_{HP}.(\varepsilon - 1)}{\varepsilon} \quad \text{(kW)} \quad (5)$$

where:
Q_{HP} – heating output of heat pump (kW),
Q_0 – energy from low-temperature source of heat (kW),
ε – work supplied to the heat pump (kW).

$$Q_{HP} = \frac{13{,}2 \cdot (2{,}59 - 1)}{2{,}59} = \underline{\underline{8{,}1}} \text{ kW}$$

Then on basis of this output with knowing salt brine flow salt brine warming up is determined as:

$$Q_{HP} = m_{salt} \cdot c_{salt} \cdot dt \quad \text{(kW)} \quad (6)$$

where:
Q_{HP} – energy from low-temperature heat source (kW),
m_{salt} – minimal flow of salt brine through vertical collector ($m^3.h^{-1}$),
$m_{salt} = 2{,}7\ m^3.h^{-1}$,
c_{salt} – specific heat capacity of salt brine,
$c_{salt} = 1{,}1875\ kW.t^{-1}.K^{-1}$,
dt – warming up of salt brine (°C).

Diameter of tube heat exchanger for salt brine flowing will be designed on basis of this minimal flow and circulating pump will be selected.

DETERMINATION OF SIMPLE RETURN OF INVESTMENT

Simplified return of investment without using loan can be calculated as follows:

$$N = \frac{N_{ic}}{N_{oc}} \quad \text{(y)} \quad (7)$$

where:
N - return of investment in years, (y),
N_{ic} - total investment costs, (€.y^{-1}),
N_{oc} - total operation costs, (€.y^{-1}).

Investment costs for solar collector system and earth-water heat pump system without accessories and montage are shown in Table 3.

Table 3. List of investment costs for alternative system of heat production
Tablica 3. Popis investicijskih troškova za alternativni sustav proizvodnje topline

Name of item	Number of pieces	Price without VAT (€)/pc	VAT 19% (€)	Price with VAT (€)
Solar collectors KTU 9R2	3	975,323	185,31	3 481,9
Accumulation reservoir DUOV 750/200	1	1 719,546	326,71	2 046,3
Storage reservoir PS2F 300	1	792,106	150,50	942,6
HP VITOCAL 350	1	9 827,922	1 867,305	11 695,2
Sum				**18 166,0**

If we add to the price of drilled holes in the compact soil which is from 66 €/m to 100 €/m in dependence on applied drilling set to the mentioned costs, so at price of 76,35 €/m for two 88 m deep drilled holes we will get the total sum of investment costs: **N_{ic} = 31 603,6 €.**

The operational costs are defined as follows:

$$N_{oc} = N_{oc}^{HP} + N_{oc}^{X} \quad (€.r^{-1}) \qquad (8)$$

where:

N_{oc}^{HP} - annual energy costs for compressor HP cycle (€.y^{-1}),

N_{oc}^{X} - annual fuel costs of gas condensing boiler (€.y^{-1}).

Annual energy costs for compressor HP cycle with compressor driven by electromotor is defined as follows :

$$N_{\mathrm{oc}}^{HP} = p_e \cdot \left(\frac{Q_{\mathrm{y}}^{HP}}{COP} \right) \quad (€.y^{-1}) \qquad (9)$$

where:

$N_{ce}^{TČ}$ - annual energy costs for compressor HP cycle , (€.y^{-1})

p_e - price of electric energy, c_e = 0,0853 €.kWh^{-1},

$Q_{y}^{TČ}$ - annual heat supply by heat pump, (kWh.y^{-1}),

COP - heating factor, ε = 2,59.

Mentioned price of electric energy (p_e) per 1 kWh for heat pump operating 20 hours a day but supplying the heat for 24 hours at low tariff of 0,0853 € (VAT included).

Another item for annual costs calculation is the fuel costs of gas condensing boiler.

$$N_{\mathrm{oc}}^{\mathrm{X}} = \frac{c_p}{\eta_b \cdot Q_n} \cdot Q_y^X \quad (€.y^{-1}) \qquad (10)$$

where :

p_p - NG price, p_p = 0,0422 €/kWh (VAT included),

Q_{y}^{X} - annual heat supply by gas heating, (kWh.y^{-1}),

η_b - boiler efficiency, η_k = 1,09,

Q_n - fuel net caloric value (natural gas), Q_n= 34,259 MJ.m^{-3} (9,52 kWh.m^{-3}).

Since from major part HW heating is realized by solar collectors it is necessary to add also the heat produced by solar system to the total heat supply.

Q_{sc} – annual profit of vacuum tube solar collectors, Q_{sc} = 611 kWh.m^{-2}.y^{-1}

After that for the 3 above-mentioned collectors is: Q_{sc} = 3 940,95 kWh.y^{-1}

Heating and HW supply costs can be determined from year heat consumption which includes heat need for heating and HW preparation. Its value is determined as follows:

$$Q_{total,,y} = 112{,}622 \text{ GJ.y}^{-1} = 31\,293 \text{ kWh.y}^{-1}$$

$$Q_{total,y} = Q_y^{HP} + Q_{sc} + Q_y^X \quad (\text{kWh.y}^{-1}) \tag{11}$$

where:

$Q_{total,\,y}$ – annual heat need, (kWh.y^{-1}),
Q_y^{HP} – annual heat supply by heat pump, (kWh.y^{-1}),
Q_{sc} – annual probit of vacuum tube solar collectors,
Q_{sc} = 3 940,95 kWh.y^{-1}
Q_y^X – annual heat supply by gas heating, (kWh.y^{-1}).

Then

$$Q_y^X = Q_{total,y} - \left(Q_{sc} + Q_y^{HP}\right) \quad (\text{kWh.y}^{-1}) \tag{12}$$

$$Q_y^{HP} = 26522{,}5 \text{ kWh.y}^{-1}$$

$$Q_y^X = 31293{,}792 - (3940{,}95 + 26522{,}5) = 830{,}342 \text{ kWh.y}^{-1}$$

Then annual energy costs for compressor HP cycle are:

$$N_{oc}^{HP} = 0{,}0853 \cdot \left(\frac{26522{,}5}{2{,}59}\right) = \underline{\underline{873{,}50}} \text{ €.y}^{-1}$$

To obtain final heat pump energy costs is necessary to add fixed rate in the amount of 9,76 € per month, i.e. 117,12 € per year (VAT included) to the year HP costs. With this final costs for heat pump will increase to **990,62 €.y^{-1}**.

Fuel costs for heat supply with the gas condensing boiler are:

$$N_{oc}^X = \frac{0{,}0422.10{,}550}{1{,}09.9{,}52} \cdot 830{,}342 = \underline{\underline{35{,}63}} \text{ .y}^{-1}$$

Fixed rate (which is 4,925 € per month (VAT included) what is 59,1 € per year) is necessary to be added to these costs. Then final fuel costs are in the amount of **94,73 €.y^{-1}**.
Total operational costs are defined as follows:

$$N_{oc} = 990{,}62 + 94{,}73 = \underline{\underline{1\,085{,}35}} \text{ €.y}^{-1}$$

Using cost values determined above can be the return of investments calculated with the following equation:

$$N = \frac{31\,603{,}6}{1085{,}35} = \underline{\underline{29{,}12}} \text{ years}$$

Fuel saving calculation can be performed by the comparison of recently used heat production form i.e. gas boiler providing heating and electrically heated water for HW preparation and a new alternative - combination of heat pump, solar collectors and back-up gas condensing boiler [12]. Fuel costs for heat supplying by gas condensing boiler are:

$$N_{oc}^X = \frac{p_p}{\eta_b \cdot Q_n} \cdot Q_y^X \qquad (\text{€.y}^{-1})$$

where:

N_{oc}^X - annual NG costs at heat supply by gas condensing boiler, (€.y^{-1}),
p_p - natural gas price, c_p = 0,0403 €/kWh (VAT included), valid since 1.1. 2010,

Q_y^X - annual heat supply by gas heating, (kWh.y^{-1}),
η_b - boiler efficiency, η_k = 1,09,
Q_n - fuel net caloric value (natural gas), Q_n= 34,259 MJ.m^{-3} (9,52 kWh.m^{-3}).

$$N_{oc}^X = \frac{0{,}0403.10{,}550}{1{,}09.9{,}52} \cdot 27603{,}33 = \underline{\underline{1\ 130{,}98}}$$

€.y^{-1}

After adding the fixed rate of 7,667 € (VAT included) i.e. 92 €.y^{-1} the annual fuel costs will increase to **1 222,98 €.y^{-1}**.

Energy costs for HW heating by using electric energy [13]:

$$N_{\mathrm{oc}}^E = p_e \cdot \left(\frac{Q_{\mathrm{y}}^{\mathrm{E}}}{\eta_E} \right) \quad (€.\mathrm{y}^{-1}) \qquad (13)$$

where:

N_{oc}^E - annual energy costs for HW heating by using electric energy (€.y^{-1}),
p_e - price of electric current, c_e = 0,1126 €.kWh^{-1},
Q_y^E - annual heat supply for HW heating (kWh.y^{-1}),
η_E - efficiency of HW heating appliance, η_E = 0,99.

$$N_{oc}^E = 0{,}1126 \cdot \left(\frac{3690{,}462}{0{,}99} \right) = \underline{\underline{419{,}74}}\ €.\mathrm{y}^{-1}$$

Fixed rate in this case is 6,78 € (VAT included) i.e. 83,36 €.y^{-1}. Annual costs of electric energy will be **501,1 €.y^{-1}**.

Final operational costs for resently used system:

$$N_{oc}^F = N_{oc}^X + N_{oc}^E \quad (€.\mathrm{y}^{-1}) \qquad (14)$$

$$N_{oc}^F = 1222{,}98 + 501{,}1 = \underline{\underline{1\ 724{,}08}}\ €.\mathrm{y}^{-1}$$

Fuel and energy costs saving is determined as follows:

$$u = N_{oc}^F - N_{oc} \quad (€.\mathrm{y}^{-1}) \qquad (15)$$

where:
u - annual saving of operational costs with using new heat production alternative in comparison with resently used system, (€.y^{-1}),
N_{oc}^F - final operational costs for presently used system of heat production, (€.y^{-1}),
N_{oc} - final operational costs of new heat production alternative, (€.y^{-1}).

$$u = 1724{,}08 - 1085{,}35 = \mathbf{\underline{\underline{638{,}73}}\ €.y^{-1}}$$

CONCLUSION

Possibility of effective solar energy utilization for low-temperature heating systems depends on solar equipment efficiency as from technical as economical aspect so with the highest possible efficiency at the lowest investment costs.

There are real possibilities of improving technical-economical parameters for solar collectors in the systems of heat pumps from point of view of significant investment demandingness decrease by removing the clear casing of collector and thermal insulating layers. As an result of low temperature of working medium in the collector -what increases collector efficiency. At low temperature in the collector the diffusion radiation can be used in early morning and late evening hours.

The collector in the system of heat pump should be designed not only for solar radiation utilization but also for heat gaining from environment (air, rain, wind). One of serious problems of solar energy utilization for heat pumps systems is unpredictable periods without solar shine which can be in the winter season in our geographical area even more than 7 days. Therefore for solar energy utilization in winter season for heat pump systems it is necessary to install alternative source of thermal output or use relatively big and capital-intensive heat reservoirs.

From above-mentioned calculations can be shown that in consequence of high investment costs the return of investment of designed heat supply alternative is relatively high.

It is necessary to take into account also fuel and energy savings per year with the systems what in conversion means the value of 38 %.

Next, with taking into account always increasing prices of input energies it can be stated that economical benefit from using RSE will constantly raise and fuel and energy savings will proportionally raise.
Slovakia has great potential for alternative sources of energy utilization such as solar collectors and heat pumps. Thereby can be saved the primary energy sources and related economical savings and at the same time can be decreased of ecologically adverse effects in comparison with other ways of heat production.

However, finally there is a fact that the height of investment costs does not permit the application of above-mentioned systems for most of users.

The solution for this problem can come from the site of the state by supporting the investment projects focusing on RSE utilisation.

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