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Analysis of Economical Efficiency of Low-Temperature Heating Utilization and HW Supply in Combination with Solar Collectors in Housing and Municipal Sphere

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BIOGRAPHICAL NOTES

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KEY WORDS

Energy utilization, economical efficiency, low-temperature heating utilization, solar collector, municipal sphere

ABSTRACT

Economical system application of heat supply with using solar collectors in combination with heat pump is not only a question of return of investment. It is also the question of priorities, life style and ecology.
Many methods, studies and tables with presented data about energy consumptions for various ways of heating to determinate return of investment.
Basic condition of economical advantageousness of heat pump utilization instead of classic way of heat production in term of total year costs is that those are lower than total year costs for comparative classic way of heat production. Because difference in investment costs of comparative heating systems and heat pumps is almost always in the disadvantage of heat pump system.

INTRODUCTION

Application of efficient system of heat supply using the solar collectors in combination

with the heat pump is not only a question of return of investment. It is also the question of priorities, life style and ecology. There are several methods, studies and tables with presented data about energy consumptions for various ways of heating to determine the return of investment.
The basic condition of economical efficiency of heat pump utilization instead of classic way of heat production in terms of total annual costs is the fact that these are lower than total annual costs for the classic way of heat production. Because the difference in investment costs of compared heating systems and heat pumps is almost always in the disadvantage of heat pump system [1].

DETERMINATION OF SIMPLE RETURN OF INVESTMENT

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

$$N = \frac{N_{inv}}{N_{pr}} \quad year \qquad (1)$$

where: N - *return of investment in years,* **(y), N_{inv}** - *total investment costs, (€.y^{-1}),* **N_{pr}** - *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 1.

Name of item	Number of pieces	Price without VAT (€)/pc	VAT 19% (€)	Price with VAT (€)
Solar collectors KTU 9R2	3	975,323	185,31	3481,9
Accumulation reservoir DUOV 750/200	1	1719,546	326,71	2046,3
Storage reservoir PS2F 300	1	792,106	150,50	942,6
HP VITOCAL 350 BWH 110	1	9827,922	1867,305	11695,2
Sum				***18166,0***

Tab. 1 *List of investment costs for alternative system of heat production*

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_{inv} = 31 603,6 €.y^{-1}.**
The operational costs are defined as follows:

$$N_{pr} = N_{pe}^{TC} + N_{pe}^{X} \quad (€.r^{-1}) \qquad (2)$$

where: N_{pe}^{TC} - *annual energy costs for compressor HP cycle, (€.y^{-1}),* **N_{pe}^{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 [3], [4]:

$$N_{pe}^{TC} = c_e \left(\frac{Q_r^{TC}}{\varepsilon} \right) \quad (€.r^{-1}) \qquad (3)$$

where: N_{pe}^{TC}- *annual energy costs for compressor HP cycle , (€.y-1),* **c_e** - *price of electric energy, c_e = 0,0853 €.kWh^{-1}, valid since 1.1.2010,* **Q_r^{TC}** - *annual heat supply by heat pump, (kWh.y^{-1}), ε - heating factor, ε = 2,59.*

Mentioned price of electric energy (c_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.

$$N_{pe}^{X} = \frac{c_p}{\eta_k . Q_n} . Q_r^{X} \quad (€.r^{-1}) \qquad (4)$$

where: c_p - *NG price, cp = 0,0422 €/kWh (VAT included), valid since 1.1.2010,* **Q_r^{X}** - **a***nnual heat supply by gas heating, (kWh.y^{-1}),* **η_k** - *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 [5],[7].
Qsk - annual profit of vacuum tube solar collectors,
Qsk = 611 kWh.m^{-2}.y^{-1}
After that for the 3 above-mentioned collectors is:
Qsk = 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 [6]. Its value is determined as follows:

$\mathbf{Q_{cel,r} = 112{,}622\ GJ.y^{-1} = 31\,293{,}792\ kWh.y^{-1}}$

From that:

$\mathbf{Q_{r,vyk} = 99{,}372\ GJ.y^{-1} = 27\,603{,}33\ kWh.y^{-1}}$

$\mathbf{Q_{TV,r} = 13{,}29 GJ.y^{-1} = 3\,690{,}462\ kWh.y^{-1}}$

$$Q_{cel,r} = Q_r^{TC} + QSk + Q_r^X \ \left(kWh.y^{-1}\right) \qquad (5)$$

where: $\mathbf{Q_{cel,r}}$ – *annual heat need, (kWh.y⁻¹),* $\mathbf{Q_r^{TC}}$ – *annual heat supply by heat pump, (kWh.y⁻¹),* $\mathbf{Q_{sk}}$ – *annual probit of vacuum tube solar collectors,* Q_{sk} *= 3 940,95 kWh.y⁻¹,* $\mathbf{Q_r^X}$ *– annual heat supply by gas heating, (kWh.y⁻¹).*

Then

$$Q_r^X = Q_{cel,r} - \left(Q_{Sk} + Q_r^{TC}\right) \ \left(kWh.y^{-1}\right) \qquad (6)$$

$$Q_r^{TC} = \varepsilon_0.Q_v.24.n\frac{t_i - t_{es}}{t_i - t_e} =$$

$$= 0{,}765.\left(13{,}2.1{,}2\right)20.212\left(\frac{20 - 2{,}9}{22 + 15}\right) =$$

$$= 26522{,}5\ kWh.y^{-1} \qquad (7)$$

$$Q_r^X = 31293{,}792 - \left(3940{,}95 + 26522{,}5\right) =$$

$$= 830{,}342\ kWh.y^{-1}$$

Then annual energy costs for compressor HP cycle are:

$$N_{pe}^{TC} = 0{,}0853\left(\frac{26522{,}5}{2{,}59}\right) = 873{,}50€.y^{-1} \qquad (8)$$

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:

$$N_{pe}^x = \frac{0{,}0422.10{,}550}{1{,}09.9{,}52}830{,}342 = 35{,}63€.y^{-1} \qquad (9)$$

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:

$\mathbf{N_{pr} = 1\,085{,}35\ €.y^{-1}}$.

$$N_{pr} = 990{,}62 + 94{,}73 = 1085{,}35\ €.y^{-1} \qquad (10)$$

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

$$N = \frac{31603{,}6}{1085{,}35} = 29{,}12\ years \qquad (12)$$

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. Fuel costs for heat supplying by gas condensing boiler are:

$$N_{pe}^x = \frac{c_p}{\eta_{Pk}.Q_n}.Q_r^x \ \left(€.r^{-1}\right) \qquad (12)$$

where: $\mathbf{c_p}$ *- NG price, cp = 0,0403 €/kWh (VAT included), valid since 1.1.2010,* $\mathbf{Q_r^X}$ *- annual heat supply by gas heating, (kWh.y⁻¹),* η_{Pk} *- boiler efficiency,* η_{Pk} *= 1,09,* $\mathbf{Q_n}$ *- fuel net caloric value (natural gas),* Q_n *= 34,259 MJ.m⁻³ (9,52 kWh.m⁻³),* $\mathbf{N_{pe}^{El}}$ *- annual NG costs at heat supply by gas condensing boiler, (€.y⁻¹).*

$$N_{pe}^x = \frac{0{,}0403.10{,}550}{1{,}09.9{,}52}27603{,}33 = 1130{,}98\ €.y^{-1}$$

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 [9]:

$$N_{pe}^{El} = c_e\left(\frac{Qr^{El}}{\eta_{El}}\right) \qquad (13)$$

where: $\mathbf{N_{pe}^{El}}$*- annual energy costs for HW heating by using electric energy, (€.y⁻¹),* $\mathbf{c_e}$ *- price of electric current,* c_e *= 0,1126 €.kWh⁻¹, valid since 1.1.2010,* $\mathbf{Q_r^{El}}$ *- annual heat supply for HW heating, (kWh.y⁻¹),* η_{El} *- efficiency of HW heating appliance,* η_{El} *= 0,99.*

$$N_{pe}^{El} = 0,1126\left(\frac{3690,462}{0,99}\right) = 419,74\ €.y^{-1}$$

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:

$$N_{pe}^{S} = N_{pe}^{x} + N_{pe}^{El} \quad \left(Sk.y^{-1}\right) \tag{14}$$

$$N_{pe}^{S} = 1222,98 + 501,1 = 1724,08\ Sk.y^{-1}$$

Fuel and energy costs saving is determined as follows:

$$u = N_{pe}^{S} - Npr \quad \left(Sk.y^{-1}\right) \tag{15}$$

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

$$u = 1724,08 - 1085,35 = 638,72\ €.y^{-1}$$

CONCLUSION

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 [10].

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 [11].

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 [12].

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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