ANALYSIS OF GEOTHERMAL ENERGY UTILISATION IN LÉTAVÉRTES

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Abstract – In the European Union buildings are responsible for 40 % of the total energy consumption. To reduce the energy dependency of the member states different Directives were accepted related to buildings energy performance. This paper presents a possibility to use efficiently the geothermal energy for heating at settlement level. The possibilities of public buildings energy refurbishment in Létavértes, reduction of energy need for heating and reduction of CO_2 emissions are shown.

Keywords: geothermal energy, buildings refurbishment, CO_2 emission.

1. INTRODUCTION

In the European Union building sector is responsible for more than 40% from the total energy consumption.

Because no one of the member states is independent from energy point of view, the main goals are the increase of energy efficiency and utilization of renewable energy sources in this sector. This is part of the 20-20-20 EU target. To fulfill the fixed goals several Directives were prepared. One of the Directives is the 2002/90/EC Directive dealing with energy performance of buildings. This Directive last year was revised and adopted as 2010/31/EU Directive. According to this Directive as of 31 December 2020 new buildings in the EU will have to consume 'nearly zero' energy and the energy will be 'to a very large extent' from renewable sources. Public authorities that own or occupy a new building should set an example by building, buying or renting such 'nearly zero energy building' as of 31 December 2018.

In Hungary the operation costs of public buildings are paid by local governments. Most of public buildings were built several decades ago when the energy aspects were not taken into account. Due to the actual economical crisis the payment of high operation cost (heating, ventilation, air conditioning etc.) represents a huge problem for local governments. At the same time there are possibilities to obtain support for buildings thermal refurbishment and integration of renewable energy sources. The energy use of buildings after thermal refurbishment can be reduced by 40-50%, furthermore the energy need of a refurbished building might be covered from renewable energy sources in a share of 70-80%, so taking into account the increasing energy prices important reduction of expenditures may be obtained.

In Hungary there are important reserves of low and medium enthalpy geothermal fluids which might be efficiently used for communal needs.

2. GEOTHERMAL POTENTIAL OF LÉTAVÉRTES REGION

One of the parameters which characterize the geothermal energy is the heat flux. The heat flux value is higher because the thickness of sediments is lower. In Létavértes zone values between 90-100 mW/m^2 are registered. In this area about 20 drillings can be found which gave information about the physical properties of sediments. Part of these drillings attained the basement. Based on measurements the geothermal gradient in this region is 40-50 ^{o}C/km. In hydrocarbon exploratory drilling Álmosd-11 at 2700 m 127 ^{o}C was measured, in Álmosd - 13 well at 2643 m 138 ^{o}C and at 1937 m 146.6 ^{o}C was measured. The temperatures at 1000 m and 2000 m [1] are presented in Fig. 1.

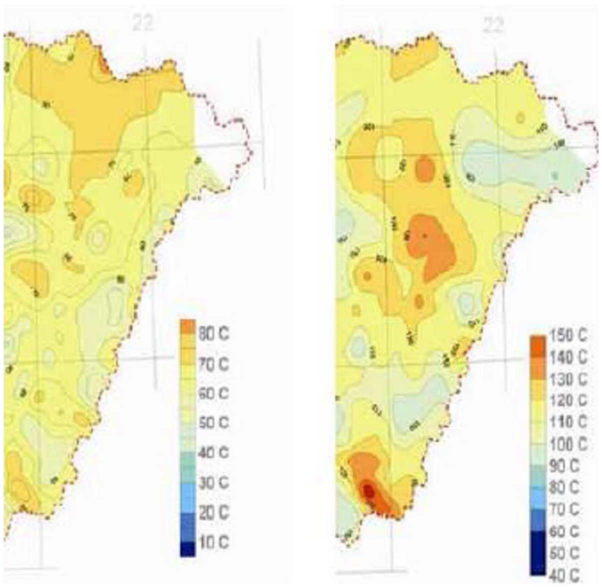

Fig. 1. Expected thermal water temperature at 1000 m and 2000 m

It can be seen that at 1500 m -1800 m the expected value of thermal water is between 60-75 ^{o}C which is enough for hot water preparation and can be used for heating covering partially the energy need. The expected thermal water flow at a thermal well is between 500-600 l/min. Assuming 500 l/min thermal water flow, 60 ^{o}C for supply temperature and 40 ^{o}C return temperature for heating system the output of a thermal well is 696.66 kW.

3. ENERGY ANALYSIS OF PUBLIC BUILDINGS

Létavértes is formed from two main parts Léta and Vértes which were self standing settlements in the past. Several decades ago these two settlements merged in Létavértes. Consequently there are two centres where important public buildings are placed. The distance between centres is about 3.0 km. The type of public buildings is various: schools, kindergartens, cultural stablishments, sport establishment, town hall. The location of above mentioned establishments is presented in Fig. 2.

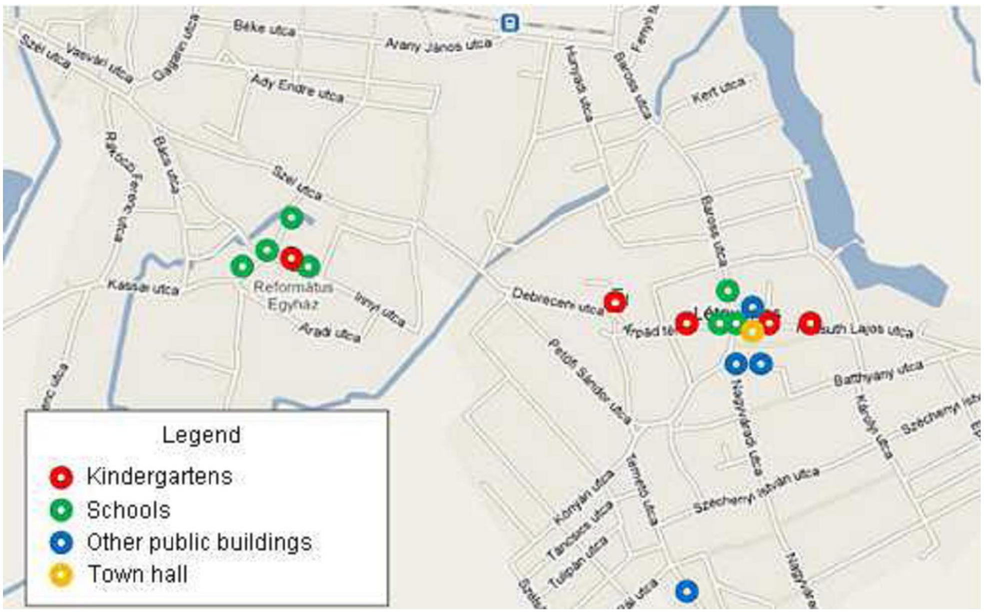

Fig. 2. Location of public building

In the following the analysed buildings are presented [2].

3.1. Town hall of Létavértes

The building of Town Hall was built between 1980 - 1990 using the technology specific to that period (Fig.3). The walls are built using Uniform brick with vertical holes. The roof of the mansard is insulated with mineral wool, the windows were double glazed with a heat transfer coefficient of 2.5 W/(m^{2}K). In 2007 the building was partially refurbished from thermal point of view: the South facade got an additional insulation layer of 5 cm and the windows were replaced with Deceuninck Zendow (D Foris) type having heat transfer coefficient of 1.6 W/(m^{2}K). The net area of the building is 936.80 m^2 and the heated volume is 2797.34 m^3. The total area of the building envelope is 1576.87 m^2.

The heating is realized using a central heating system. The gas boiler of heating system has an output of 120 kW and was built in 1993. The output of the boiler can be controlled in a modular way. The modular step is 20 kW. The circulation of warm water in the double piped heating system is realized with Wilo TOP-S 40/4 circulation pump.

Fig. 3. Town hall in Létavértes

According to Decree 7/2006 TNM the primary energy consumption of the building was calculated. The results are presented in Fig.4.

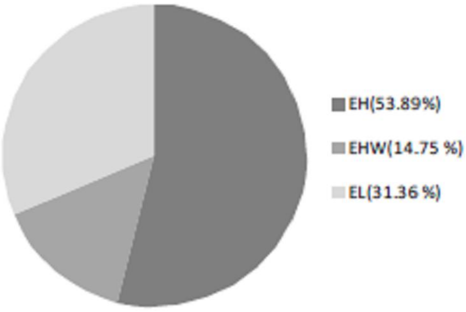

Fig. 4. Primary energy consumption in %, for heating (*EH)*, hot water preparation (*EHW*) and lighting (*EL*)

3.2. Arany János elementary school

The building of Arany János elementary school was enlarged in two steps. The oldest part has walls built from brick with vertical holes (Fig. 5.). The first enlargement had as main purpose the gym containing football field and two swimming pools. In third step the building was enlarged with one floor. This new floor is realized using light sandwich structures with mineral wool. The net area of the building is 7087.4 m^2 and the heated volume is 38809.5 m^3. The total area of the building envelope is 11438.1 m^2. After all enlargements the form of the building is in U. In one wing the 24 classrooms are placed in the other wing the swimming pool and the gym can be found. The heating is realized using a central heating system. There are two VIESSMANN VITOCROSSAL 300 gas boilers installed having an output of 575 kW each. The output of the boiler can be controlled in a modular way. There are radiator, floor and wall heating systems installed. There are thermostatic valves installed and there is a Viessmann central control system which assures the required temperature of the warm water.

There is a ventilation system installed at swimming pools which is used especially to introduce fresh air in order to avoid the fog formation.

Fig. 5. Arany János elementary school

According to Decree 7/2006 TNM the primary energy consumption of the building was calculated. The results are presented in Fig.6.

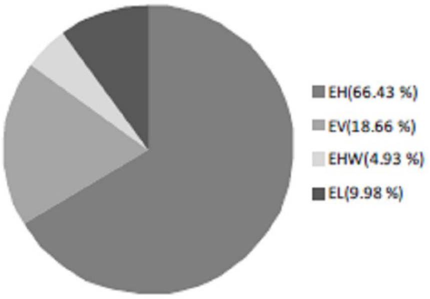

Fig. 6. Primary energy consumption in %, for heating (*EH)*, hot water preparation (*EHW*), ventilation (*EV*) and lighting (*EL*)

3.3. Irinyi János elementary school

The building of Irinyi János elementary school has two levels having a ground floor and a mansard (Fig. 7.). The walls are built from bricks with vertical holes HB30 type. The heat transfer coefficient of the walls is 0.703 $W/(m^2K)$. The roof of the mansard has 14.0 cm thick insulation layer from mineral wool. The heat transfer coefficient of the roof is 0.284 W/(m2K).

There are two different type of windows: the new type with plastic frames has the heat transfer coefficient of 2.0 $W/(m^2K)$, the oldest window type (at ground floor) has metallic frames and a heat transfer coefficient of 3.0 $W/(m^2K)$. There are also two different types of doors. The old type has metallic frames and a heat transfer coefficient of 3.0 $W/(m^2K)$. The new type of door have PVC frames and a heat transfer coefficient of 0.905 $W/(m^2K)$.

The net floor area of the building is 973.9 m^2, the heated volume is 3128.52 m_3. The total area of the building envelope is 1867.38 m^2.

The heat is delivered by a TERMOTEKA 60 ES gas boiler with a nominal output of 70 kW. The radiators connected to double piped central heating system are not equipped with thermostatic valves, so the local control of the delivered heat is not possible. The circulation of heat carrier is realized with Grundfos UPS 25-60 circulation pumps. The control of supply temperature is assured by a two way valve depending on the outdoor temperature. In the building there is no kitchen but a dining room is placed. In the dining room and dishwashing rooms the ventilation is assured by exhausting the air. Because of the vacuum created the fresh air is entering in the building though infiltration.

Fig. 7. Irinyi János elementary school

According to Decree 7/2006 TNM the primary energy consumption of the building was calculated. The results are presented in Fig.10.

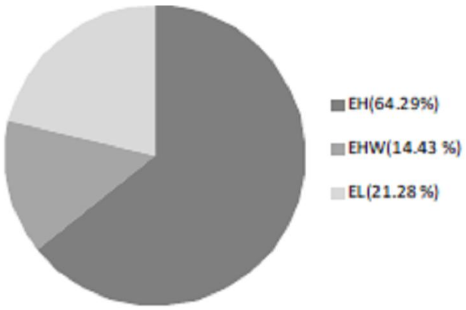

Fig. 10. Primary energy consumption in %, for heating (*E_H*), hot water preparation (*E_{HW}*) and lighting (*E_L*)

3.5. Community Centre of Létavértes

The building of Community Centre was built in ‘60s using the technology specific to that period (Fig. 11.). The 38 cm thick walls are built using traditional brick. The building was enlarged some years ago. The enlargement was built using bricks with vertical holes POROTHERM 38 and contains dressing rooms and new toilets. The old part of the building has large traditional windows having heat transfer coefficient of 3.0 W/(m^{2}K). The new part of the building has windows with plastic frames and well insulating glazing (heat transfer coefficient of 2.5 (W/ m^{2}K)). The net area of the building is 511.4 m^2 and the heated volume is 2552.86 m^3. The total area of the building envelope is 1565.88 m$_2$. Both the new and old parts have flat roof insulated with polystyrene. The heat transfer coefficients are 0,254 (W/ m^{2}K) for new and 0,877 W/(m^{2}K) for old building respectively.

The new and the old part of the building have separately central heating systems. The gas boiler placed in the old part of the building is HİTERM 87 ESB type having an output of 87 kW. The circulation of warm water in the double piped heating system is realized with Wilo TOP S 40/7 circulation pump. There are no thermostatic valves at radiators.

The turbo boiler in the new part of the building is iMMERGAS EOLO STAR type, having an output of 23 kW. The radiators are equipped with thermostatic valves.

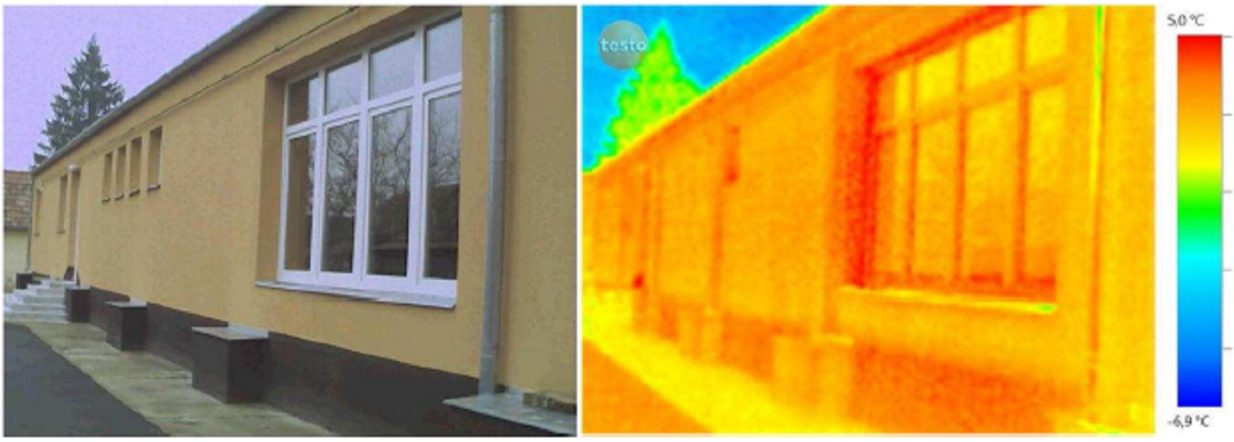

Fig. 11. Community Centre in Létavértes (new part)

According to Decree 7/2006 TNM the primary energy consumption of the building was calculated. The results are presented in Fig.12.

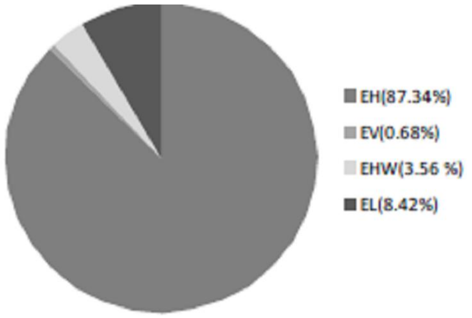

Fig. 12. Primary energy consumption in %, for heating (E_H), hot water preparation (E_{HW}), ventilation (E_V) and lighting (E_L)

3.6. Sport Centre of Létavértes

The building of Sport Centre was built between several years ago using the technology specific to that period (Fig. 13.).

The establishment is formed from two parts: the sports-court built from sandwich panels and the service part which includes dressing rooms, toilets, administrative rooms, store rooms etc. The net floor area of the sports-court is 412.0 m^2, its internal height is variable between 6.0-10.0 m. The internal height of the service building is 2.7 m, its net floor area is 271.57 m^2. The sandwich panels are zincked and contain 14 cm mineral wool. The roof of the sport-court is built from the same panels. The heat transfer coefficient of these panels is 0.327 W/(m^2K). The ventilation of the sports court is realized with eight axial-fans placed in the walls. Windows are placed on the each facade of the sport court. The wood framed windows have high heat transfer coefficient (4.0 W/(m^2K)) but their radiation transmittance coefficient is also higher.

The heating of the sport court is realized using eight gas radiators. The length of these radiators covers the width of the court. In such a case the utilization of gas radiators is the optimal solution since the convective heating systems may lead to a stratification of the air temperature with negative influence on the thermal comfort. The gas radiators assure the best comfort in the occupation zone.

The attached service building has its walls from 38 cm traditional brick. This part of the establishment was additionally insulated with 5.0 cm expanded polystyrene. The old windows were replaced with new plastic framed windows. The service building has its own central heating system. The Saunier Duval SD 50 KLO gas boiler supplies the double piped heating system. The radiators have no thermostatic valves, so the local control of the delivered heat is not possible. The circulation of heat carrier is assured by Grundfos circulation pump.

Fig. 13. Sport Centre in Létavértes

According to Decree 7/2006 TNM the primary energy consumption of the building was calculated. The results are presented in Fig.14.

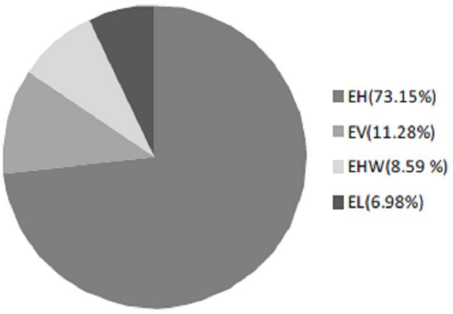

Fig. 14. Primary energy consumption in %, for heating (E_H), hot water preparation (E_{HW}), ventilation (E_V) and lighting (E_L)

3.7. Energy class of analysed buildings

The building and its elements must satisfy the three levels requirement group. The basic requirement is related to external building elements (opaque and transparent). Practically the maximal values of heat transfer coefficient U [W/m^2K] are limited. Several values are presented in Table 1.

Table 1. Admissible values for heat transfer coefficient

Building element	Heat transfer coefficient, U [W/m^{2}K]
External walls	0,45
Flat roofs	0,25
Ceiling on the cellar	0,50
Walls between heated and unheated rooms	0,50
Attic ceiling	0,30
Floor on the soil	0,50
Windows with wood or PVC frames	1,60
Windows with Al frames	2,00
Roof windows	1,70
Entrance doors, or doors between heated and unheated rooms	1,80

The second level of requirements is concerned to whole building. This is the maximal value of specific heat losses q_m [W/m^{3}K], which depends only by the area of external elements and heated volume ratio ($\Sigma A/V$). The q_m value may be determined using one of the following relations:

$$\begin{aligned} &\Sigma A/V \leq 0{,}3 && q_m = 0{,}2\ \mathrm{W/m^3K} \\ &0{,}3 \leq \Sigma A/V \leq 1{,}3 && qm = 0{,}086 + 0{,}38(\Sigma A/V)\ \mathrm{W/m^3K} \qquad (1) \\ &\Sigma A/V \leq 1{,}3 && q_m = 0{,}58\ \mathrm{W/m^3K} \end{aligned}$$

or using the diagram from Fig.15.

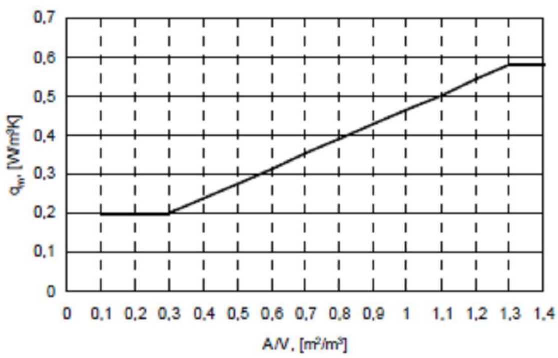

Fig. 15. Requirement for specific heat losses

This value is independent by the building function. This requirement level should be used in order to avoid situations when the uppermost requirement level is satisfied for a building with low thermal characteristics of the envelope assuming high-tech building service systems. The elements of heating or air conditioning systems may be replaced during the construction with others having lower efficiency or the function of building may be changed in time. Even in these situations the building must fulfil the second level of requirements. At the same time there are buildings where the third level of requirements concerned to primary energy consumption is impossible to be stated. In these buildings usually with a complex function (e.g. sport, therapy and hotel) the standard consumer is practically impossible to be defined.

The uppermost level of requirements is related to primary energy consumption of buildings. So that, at this level both the building and its service systems are included. The maximal admitted values of primary energy consumption E_P [kWh/m2a] depend on the building function and the ΣA/V ratio, and express the yearly primary energy consumption per net floor area. For residential buildings the requirement could be determined using the following diagram (Fig. 16.). If in the building there are spaces with different functions, the designer can choose as requirement the value corresponding to the main function, but in this case the requirement may be determined as an average value of requirements for different destinations weighted by their volumes. When there are no requirements for the analyzed buildings only the basic and second levels have to be fulfilled [3].

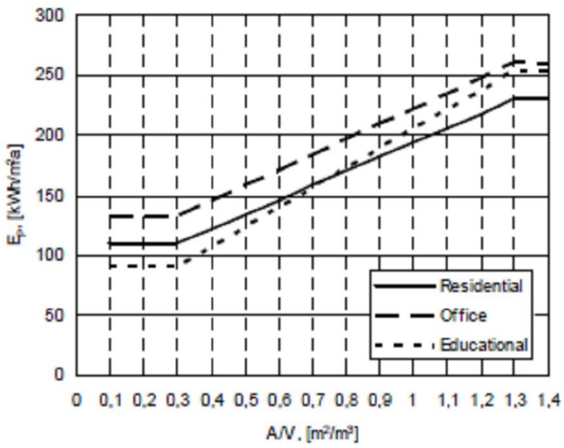

Fig. 16. Primary energy consumption for residential buildings

The specific heat loss q [W/(m^3·K)] is the difference between heat losses by transmission and passive solar gains when the indoor-outdoor temperature difference is 1 K, divided by heated volume.

Using the detailed calculation method:

$$q = \frac{1}{V}\left(\sum AU + \sum \Psi l - \frac{Q_{sd} + Q_{sid}}{72}\right) \qquad W/m^3K \quad (2)$$

where: V – is the heated volume, [m3]; A – surface of the external building element (opaque or transparent), [m2]; U – heat transfer coefficient of the external element [W/(m^2·K)]; Ψ - heat transfer coefficient along thermal bridges, [W/(m·K)]; l – length of thermal bridges, [m]; Q_{sd} – direct solar gains (through glazed elements), [kWh/a]; Q_{sid} – indirect solar gains (through Trombe walls, transparent insulation, solar spaces), [kWh/a]; 72 – specific degree-day value for Hungary (20 ^{o}C indoor emperature, 12 ^{o}C balance point temperature), divided by 1000 (because of kWh unit at solar gains), [h·K]. The primary energy consumption for heating is calculated using the following relation:

$$E_H = \left(q_H - q_{LT\Rightarrow H} + q_{H,h} + q_{H,v} + q_{H,t}\right)\cdot \sum\left(C_k \cdot \alpha_k \cdot e_H\right) + \\ +\left(E_{FSz} + E_{FT} + E_{FK}\right)e_v \qquad (3)$$

in which q_H is the net value of the specific heat demand of the building, [kWh/m2a]; q_{LT}□H – part of heat demand covered by ventilation system, [kWh/m2a];

$q_{H,h}$ – heat losses caused by control system, [kWh/m^{2}a]; $q_{H,v}$ – heat losses of distribution pipes, [kWh/m^{2}a]; $q_{H,t}$ – heat losses of heat storage if any, [kWh/m^{2}a]; C_k – reciprocal of boilers efficiency; a_k – part of heat demand covered by analysed heating system; e_H – transforming factor of used energy type into primary energy; E_{FSz} – electric energy need of circulation pumps, [kWh/m^{2}a]; E_{FT} – electric energy need of heat storage if any, [kWh/m^{2}a]; E_{FK} – electric energy need of the boiler; e_v - transforming factor of electrical energy into primary energy.

The primary energy consumption for hot water preparation is calculated using the following relation:

$$E_{HW} = (q_{HW} + q_{HW,v} + q_{HW,t}) \cdot \sum (C_k \cdot \alpha_k \cdot e_{HW}) + + (E_c + E_k) e_v \quad (4)$$

in which q_{HW} is the net value of the specific heat demand hot water preparation, [kWh/m^{2}a]; $q_{HW,v}$ – heat losses of distribution pipes, [kWh/m^{2}a]; $q_{HW,t}$ – heat losses of heat storage if any, [kWh/m$_2$a]; C_k – reciprocal of boilers efficiency; α_k – part of heat demand for hot water preparation covered by analysed system; e_{HW} - transforming factor of used energy type into primary energy; E_c – electric energy need of circulation pumps, [kWh/m$_2$a]; E_K – electric energy need of the boiler; e_v - transforming factor of electrical energy into primary energy.

The primary energy need for ventilation is calculated using the following relation:

$$E_V = \{(Q_{V,n}(1 + f_{V,sz}) + Q_{V,v})C_k e_V + + (E_{FAN} + E_{V,s}) e_v\} \frac{1}{A_N} \quad (5)$$

where $Q_{V,n}$ – is the net heat demand covered by ventilation, [kWh/a]; $f_{V,sz}$ – heat losses of ventilation system caused by control system in percent; $Q_{V,v}$ – heat losses of air ducts, [kWh/a], C_k – reciprocal of boiler efficiency; e_V – transforming factor of used energy type into primary energy; E_{FAN} – electrical energy used by fans; $E_{V,s}$ – electrical energy used for control of air flow; A_N – net floor area of the building, [m$_2$].

The energy consumption for lighting can be calculated using the following equation:

$$E_L = E_{L,n} e_L \upsilon \quad (6)$$

where $E_{L,n}$ – the specific yearly energy need of installed lighting system, [kWh/m^{2}a]; e_L - transforming factor of used energy type into primary energy; u – correction factor which takes into account the control of the lighting system.

The primary energy transforming factors are presented in table 2.

Table 2. Primary energy transforming factors

Energy type	*e*
Electrical energy	2.50
Electrical energy out of the peak consumption	1.80
Natural gas	1.00
Oil for heating	1.00
Coal	0.95
District heating (heat plant)	1.20
District heating (combined heat-power plant)	1.12
Wood, biomass	0.60
Renewable energy sources	0.00

It can be seen that in case of renewable energy sources using the primary energy transforming factor zero in relation (3), (4), (5), or (6) the primary energy consumption can be even zero.

The energy class of buildings is given depending on the calculated and reference values ratio (table 3).

Table 3. Energy class

Energy class	Ratio of calculated and reference value of primary energy consumption in [%]
A+	<55
A	56-75
B	76-95
C	96-100
D	101-120
E	121-150
F	151-190
G	191-250
H	251-340
I	341<

For analysed buildings, using the above mentioned relations the energy characteristics have been established (table 4).

As it could be seen the Arany János elementary school got the worst energy category. This does not mean that the other buildings are at higher technical level from energy point of view. First of all the higher energy consumption of this building is caused by the swimming pool and its ventilation system.

Table 4. Energy characteristics of analysed buildings

	Function of building	A [m^2]	ΣA/V	q [W/m^{3}K] reference	q [W/m^{3}K]	Ep [kWh/m^{2}a] reference	Ep [kWh/m^{2}a]	Energy class
1	Town hall	936.80	0.563	0.300	0.319	166.15	175.39	D
2	Arany János elementary school	7087.40	0.295	0.200	0.206	90.00	180.35	G
3	Irinyi János elementary school	973.90	0.596	0.312	0.324	138.69	143.61	D
4	Library	868.62	0.647	0.331	0.404	176.82	180.88	D
5	Community Centre	511.40	0.613	0.319	0.399	69.93	83.14	D
6	Sport Centre	683.57	0.547	0.293	0.356	146.35	183.59	E

4. REFURBISHMENT OF ANALYSED BUILDINGS

We assumed that all analysed buildings were refurbished according to the new requirements given in table 1. Because the insulation material layer is standardized there were buildings where the new heat transfer coefficient is a little bit lower than the admissible value. In the followings the new thermal characteristics of the envelope of analysed buildings are presented.

At Town Hall the additional insulation of external walls with 8.0 cm expanded polystyrene and 20.0 cm mineral wool at opaque elements of the mansard. The heat transfer coefficients of new windows is 1.5 W/(m2×K).

At Arany János elementary school the external brick walls were additionally insulated with 8.0 cm expanded polystyrene. The heat transfer coefficient of new windows and doors is 1.3 W/(m^2×K). The roof and floor are assumed to be additionally insulated with 8.0 cm respectively 12.0 cm thick polyurethane based panels.

At Irinyi János elementary school the external walls were additionally insulated with 8.0 cm thick expanded polystyrene. The heat transfer coefficient of the new windows is 1.3 W/(m^2×K).

The roof and floor are assumed to be additionally insulated with 8.0 cm respectively 12.0 cm thick polyurethane based panels.

At the Library the external walls were insulated with 8.0 cm expanded polystyrene. The ceiling of attic is supposed to be insulated with 5.0 cm expanded polystyrene. The heat transfer coefficient of the new windows is 1.37 W/(m^2×K).

At the Community Centre the external walls were insulated with 8.0 cm expanded polystyrene. The heat transfer coefficient of the new windows is 1.3 W/(m2×K). The roof and floor are assumed to be additionally insulated with 8.0 cm respectively 12.0 cm thick polyurethane based panels.

At the Sport Centre the external walls of service building were insulated with 8.0 cm expanded polystyrene. The heat transfer coefficient of the new windows at sports-court is 1.3 W/(m^2×K). The roof and floor of service building are assumed to be additionally insulated with 8.0 cm respectively 12.0 cm thick polyurethane based panels. The floor of sports-court is assumed to be additionally insulated with 8.0 cm polyurethane based panels.

The new energy characteristics of the refurbished buildings are presented in table 5.

Table 5. Energy characteristics of thermally refurbished buildings

	Function of building	q [W/m^{3}K] before refurbishment	q [W/m^{3}K] after refurbishment	Ep [kWh/m^{2}a] before refurbishment	Ep [kWh/m^{2}a] after refurbishment	New energy class
1	Town hall	0.319	0.220	175.39	156.66	B
2	Arany János elementary school	0.206	0.126	180.35	154.89	F
3	Irinyi János elementary school	0.324	0.245	143.61	129.08	B
4	Library	0.404	0.237	180.88	147.39	B
5	Community Centre	0.399	0.172	83.14	57.77	B
6	Sport Centre	0.356	0.203	183.59	157.07	D

It can be seen that thermal refurbishment of buildings envelope will assure one class better energy quality. The refurbishment of building elements is necessary since renewable energy sources may be efficiently used in buildings with low energy demand.

After thermal refurbishment of building elements we assumed that the central heating system is refurbished too and geothermal energy is used for heating. Because of lower temperature of the warm water in case of very low outdoor temperatures the geothermal energy will not cover the heat demand. In this case peak gas boilers deliver the necessary heat quantity. We suppose that the peak gas boilers will be condensation boilers.

Taking into account the degree day curve and the heat demand variation, geothermal energy will cover the heat demand in 84% of the heating season. We supposed that the control of the heating systems is assured locally (thermostatic valves) and centralized. In case of ventilation system heat recovery elements were supposed to be installed. The new energy characteristics of the refurbished buildings supplied with geothermal energy are presented in table 6.

It can be seen that some of building get the best energy quality class A+.

Table 6. Energy characteristics of analysed refurbished buildings using geothermal energy

	Function of building	Ep [kWh/m^{2}a] reference	Ep [kWh/m^{2}a] refurbished+geothermal	New energy class
1	Town hall	166.15	94.325	A
2	Arany János elementary school	90.00	74.477	B
3	Irinyi János elementary school	138.69	57.083	A+
4	Library	176.82	63.964	A+
5	Community Centre	69.93	23.702	A+
6	Sport Centre	146.35	55.380	A+

In Fig. 17. the schema of heating plant connection is presented taking into account that a new geothermal heating system will be realized. The main elements of the new heating system are: special heat exchanger usable for thermal water, two way valves which assure the switch from traditional heat source to geothermal energy, filter for thermal water placed before the heat exchanger. The supply temperature of the building heating system is 65 °C, the return temperature is 45 °C. The control of the heat exchanger output should be realized using a two way valve and a bypass pipe between supply and return branch.

The supposed geothermal district heating system is presented in Fig. 18.

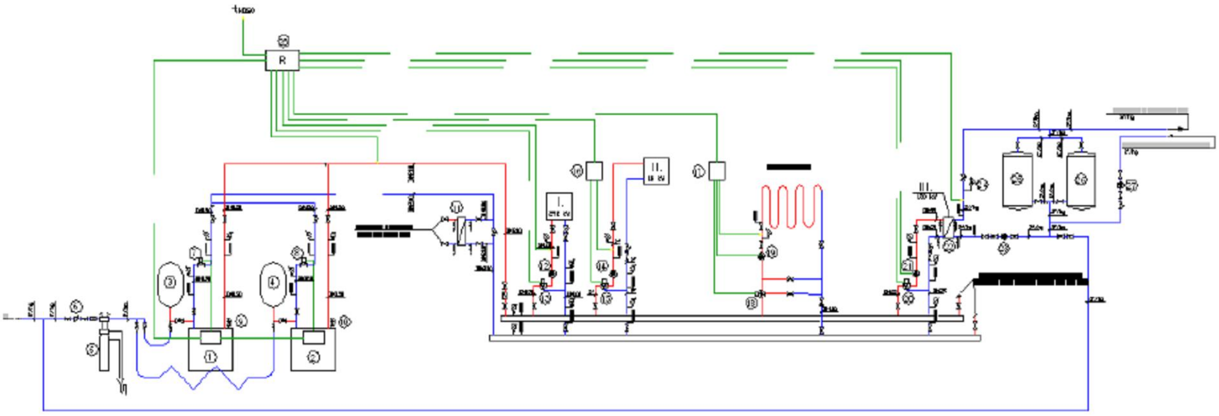

Fig. 17. Connection of building to geothermal district heating system

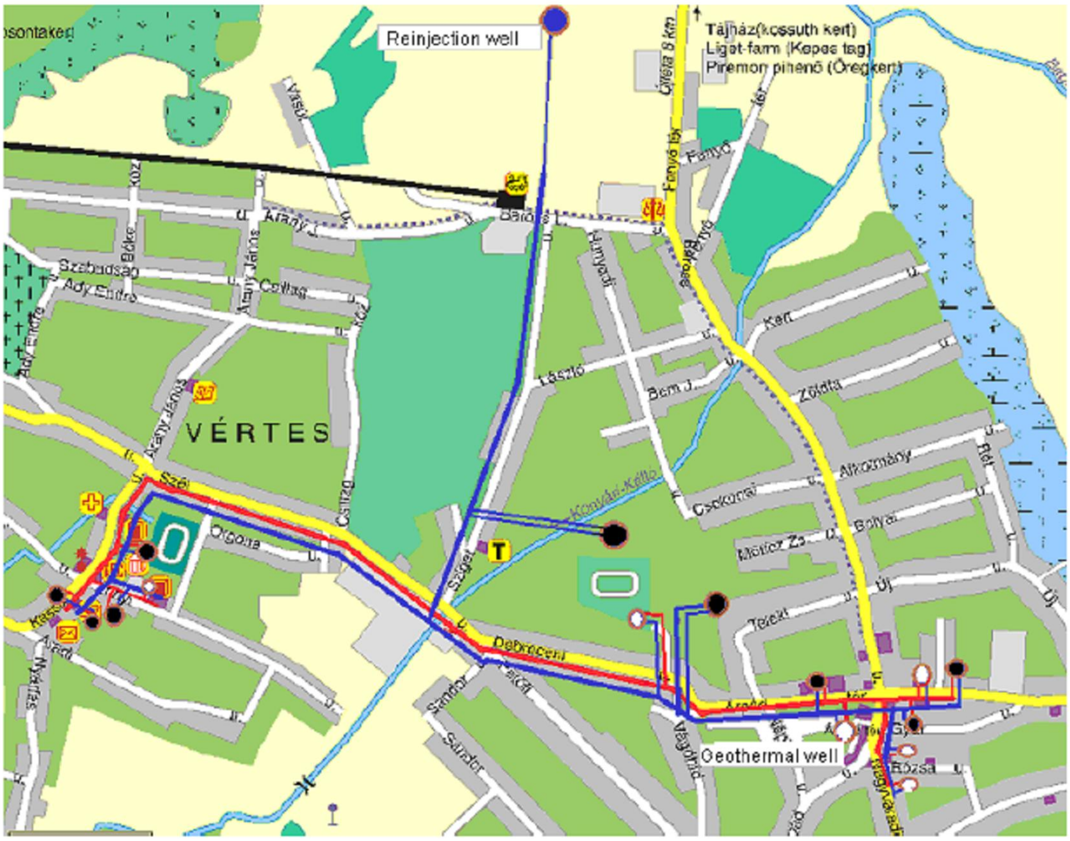

Fig. 18. Possible trace of geothermal district heating system in Létavértes

It can be observed that on Fig. 18 there are 15 establishments supplied with thermal water. We have analysed in detail only six buildings (white coloured), but their heat demand is lower than the output of the geothermal well (table 7). As a consequence new public buildings can be taken into account as consumers (black coloured).

Table 7. Buildings connected to geothermal system

Building	Heat demand, [kW]
Irinyi János Elementary School	35.47
Community Centre	35.65
Sport Centre	50.20
Arany János Elementary School	279.81
Town Hall	34.86
Létavértes Library	36.77
Total:	472.76

It can be seen that connecting the analysed public buildings to the geothermal district heating system 480,73 kW output can be used and sold for residential buildings or companies. Assuming the consumers mentioned in table 7 the hot water preparation is assured using the geothermal system. In table 8 is presented the primary energy consumed before and after thermal rehabilitation of buildings, the gas consumption, the costs for heating and the CO_2 emission caused by heating systems. In table 9 the energy consumption is presented for hot water preparation in case of buildings where hot water is prepared using natural gas. Furthermore the costs and CO_2 emission is shown for these buildings. In table 10 there are presented data about buildings where hot water is prepared using electricity. In these cases the costs and CO_2 emissions were calculated too. It can be seen that after thermal refurbishment of buildings 22.6% energy and costs savings are obtained, also the CO_2 emissions will be lower with 22.6%. Using geothermal energy for heating, covering 84% of the energy demand there are obtain a reduction of energy consumption, costs and CO_2 emissions of 87.6%. Taking into account that for hot water preparation 100% of the energy demand can be covered by geothermal energy the savings in a year will be: 126783.38 m^3 natural gas, 46910.68 kWh electricity, 22339281.3 HUF (82740 euro). The yearly CO_2 emissions decrease with 280 tonnes. Taking into account that 1tonne of CO_2 can be sold on the CO_2 quota market for 17.76 euro, the reduction of CO_2 emissions will assure another 5000 euro income.

Table 8. Energy and costs characteristics of analysed refurbished buildings using geothermal energy - heating

	Building	E_H [kWh/a] before	E_H [kWh/a] after	Gas consumption before [m^3/a]	Gas consumption after [m^3/a]	Cost before [HUF/a]	Cost after [HUF/a]	CO_2 emission before [kg/a]	CO_2 emission after [kg/a]
1	Town hall	88546.336	71000.072	9379.908	7521.194	1444505.905	1158263.886	18412.760	14764.104
2	Arany János elementary school	849297.317	668674.928	89967.936	70834.208	13855062.160	10908468.102	176607.059	139047.551
3	Irinyi János elementary school	99516.998	70955.432	10542.055	7516.465	1623476.444	1157535.654	20694.054	14754.821
4	Library	101002.265	71904.364	10699.392	7616.988	1647706.441	1173016.101	21002.907	14952.147
5	Community Centre	37259.070	24236.269	3946.935	2567.401	607828.045	395379.809	7747.834	5039.809
6	Sport Centre	91804.818	73677.909	9725.087	7804.863	1497663.347	1201948.937	19090.345	15320.947

Table 9. Energy and costs characteristics of analysed buildings using geothermal energy – hot water preparation

	Building	E_{HW} [kWh/a]	Gas consumption [m^3/a]	Cost [HUF/a]	CO_2 emission [kg/a]
1	Arany János elementary school	63077.860	6681.977	1029024.411	13116.720
2	Irinyi János elementary school	10905.732	1155.268	177911.309	2267.792
3	Community Centre	1517.324	160.733	24752.952	315.520
4	Sport Centre	10779.215	1141.866	175847.369	2241.483

Table 10. Energy and costs characteristics of analysed buildings using geothermal energy – hot water preparation using initially electrical energy

	Building	E_{HW} [kWh/a]	Cost [HUF/a]	CO_2 emission [kg/a]
1	Town hall	24239.700	1454382.000	16240.599
2	Library	22670.982	1360258.920	15189.558

5. CONCLUSION

According to research results obtained it have to be stated that the maximal energy savings can be reached only in case of buildings refurbishment and integration of renewable energy sources. Separately these two solutions will not give the expected results. This was demonstrated by other cases too, [4], [5], [6], [7]. In case of Létavértes the energy demand of analysed buildings decreases only with 22.6% after a thermal refurbishment according to the present requirements. Integrating geothermal energy sources the fossil fuels utilization decreases with more than 85%. In this case the CO_2 emission decreases with 80 tonnes/year. According to our assumption 84% of energy need for heating and 100% of energy need for hot water preparation will be covered by geothermal energy.

If the heat demand of hot water preparation is integrated in the heat demand of buildings important geothermal energy reserves remains available, since the output of the analysed thermal well is 696.66 kW. As a consequence this energy quantity might be sold to population or agricultural or industrial establishments leading to other incomes for local government. Taking into account that only six buildings were analysed it can be stated that refurbishment of existing buildings and utilisation of available renewable energy sources is a possibility to step forward for local governments.

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REFERENCES

[1]. Dövényi, P., Drahos, D., Lenkey, L. – Magyarország geotermikus energiapotenciáljának feltérképezése a felhasználás növelése érdekében. Hımérsékleti viszonyok. Jelentés a Környezetvédelmi Alap Célelıirányzat részére. – kézirat ELTE, Geofizikai Tanszék 10 p., 2001.
[2]. Kalmár, F., Csáki, I. – Középületek energetikai vizsgálata Létavértesen, 16th Building Services, Mechanical and Building Industry days, Debrecen, p. 168-180, 2010.
[3]. Zöld, A., Baumann, M., Csoknyai, T., Kalmár, F., Magyar, Z., Majoros, A., Osztroluczki, M., Szalay, Zs. – Az új épületenergetikai szabályozás, Bausoft Pécsvárad Kft. Pécs, 2006.
[4]. Kalmár,F. – Energy conscious heating, Akadémiai Kiadó, 2011.
[5]. Kalmár, F. – Geotermikus rendszerek fenntarthatóságának integrált modellezése. Geotermikus rendszerek hidraulikai és energetikai vizsgálata, Debreceni Egyetem, Műszaki Kar, 2011.
[6]. Kalmár, F. – Energiafelhasználás csökkentése lakóépületekben, Debreceni Egyetem, 2009.
[7]. Bartha, I., Tóth, J., Husi, G., Effect of four-way rotating device to the electric energy production with solar cell, Annals of the Oradea University, Fascicle of management and Technological Engineering, Volume X (XX), No. 1, 2011.