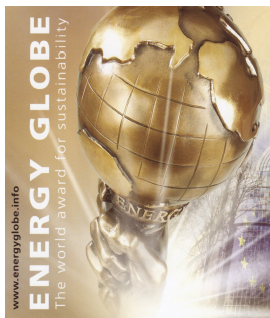


PORSCHE Bucharest West 2

An example of earth energy complex valorization

General data

Country	ROMANIA
City	Bucharest
Client	PORSCHE Romania SRL
Construction type	Showroom and service for AUDI and SEAT cars
Construction year	2006
HVAC system	Heating, ventilation, air conditioning (cooling) and domestic hot water production, provided by heat pumps connected to vertical heat exchangers, built in the ground
Heat pump type	Florida Heat Pump – Water-to-Water & Water-to-Air models, with R410A ecological refrigerant and electric powered compressors
Operation mode	Reversible, heating and cooling
Energy source	100% geothermal
Additional classic fuel	N/A
HVAC designer and entrepreneur	ASA Holding SA - Bucharest
Contact	Alex Aposteanu – President & CEO of ASA Holding SA – ASHRAE Danube Chapter member (alex@asa.ro)
Audited by	Eng. Radu Polizu, Ph.D. – Vicepresident of Romanian Geexchange Society – ASHRAE Danube Chapter member –authorized energy auditor (ipolizu@geoexchange.ro) Assisted by: Prof. Robert Gavriiliuc, Ph.D. T.U. of Civil Engineering Bucharest - Vicepresident of ASHRAE Danube Chapter (rgavriiliuc@instal.utcb.ro)



ROMANIAN GEOEXCHANGE SOCIETY
Energy Globe Award 2006 for the project
"ROMANIA – a clean country for a clean EUROPE"

ENVIRONMENTAL PROTECTION AGENCY EPA – USA
DEPARTMENT OF ENERGY DoE – USA
"Geoexchange is the most energy efficient, environmentally clean, and cost-effective space conditioning systems available".



Summary of the presentation

PORSCHE Bucharest West 2 – Car Showroom and Service (3.507 m²) was achieved in Bucharest in 2006, being commissioned in august.

The HVAC system, designed to cover the heating load (308 kW_t), cooling load (313 kW_t), ventilation load and domestic hot water production (200 kWh_t/day), was designed and executed by ASA Holding SA and is based on reversible heat pumps (heating – cooling) with geothermal source.

The performance of the HVAC system after commissioning was monitored and analyzed, leading to the following conclusions:

(a) 5 times less resource input compared to a classic system, technically equivalent;

(b) 10 times less CO₂ emission compared to the case of a classic HVAC system;

(c) 3 times less heating expenses compared to the case of a classic system.

Data regarding the designer and the entrepreneur of the works

The HVAC system was designed and implemented by ASA Holding SA, as HVAC designer and entrepreneur, in collaboration with IMSAT Muntenia SA, as general building equipment entrepreneur.

ASA Holding SA (www.asa.ro) is a company that develops engineering and consultancy activities. All the running geothermal heat pump applications of wide scope in Romania are linked to the name of ASA Holding SA. The ASA Holding experts are members of ASHRAE – Danube Chapter, IGSHPA, and were trained and certified as specialized Geoexchange designers by AEE – Association of Energy Engineers – USA.

The implemented quality management system is based on standard ISO 9001/2000 and was awarded by SRAC and IQNet in 2004.

Data regarding the construction

The construction, with a total unfolded area of 3.507 m², is metallic, structured in four distinctive parts, namely:

- a SEAT showroom of 360 m², made of steel and glass, with a typical metallic cover, SEAT brand;

- an AUDI showroom of 795 m², from which 650 m² represent the area of car presentation, with glass surfaces on 3 sides and with metallic curved roof, in which is inserted a glass "band" typical for the AUDI brand, and 145 m² represent the office area, on two levels, ground floor and first floor, mainly "open space" type at the ground floor and "light walls separated spaces" at the first floor, with glass frontons and with access to a platform with panoramic view to the showroom at the ground floor;
- a middle section made of metal and glass in area of 421 m², that links the metallic constructions of the two showrooms, with a public destination room, having the role of coffee place, including an auto parts shop, services of invoicing and payments, sanitary and 2 distinctive areas for new car delivery with glass pliable sectional gates;
- an assembly room with wide dimensions, in area of 1931 m², with thermally insulated lateral walls, with concrete struts and ribs, and a "sandwich" roof made of light materials, with the destination of car service, having the following divisions:
 - auto mechanics shop;
 - car washing and cleaning;
 - warehouse for spare parts;
 - car reception and diagnosis depending on the brands, SEAT and respectively AUDI;
 - social area (lockers, dining room, sanitary).

According to the destination of the various areas of the construction, a choice was made for the thermal and technical characteristics of the construction materials used in the buildings covers, as following:

- the concrete plates for the ground setting of the SEAT showroom, for the AUDI showroom, of the ground floor offices and of the middle section of the building, in total area of 1460 sqm, are thermally insulated at the bottom part with extruded polystyrene, which offers a high thermal resistance, with the value of 3,19 (m²K)/W;
- the aluminum carpentry of the screen walls is "shucco" type, and the thermally insulated window is pressurized with a 16 mm thick argon bed, providing to the assembly a total thermal resistance of 0,8 (m²K)/W;
- the curved covers of the two showrooms and the roof of the middle section from these two are metallic, manufactured of aluminum with semi-rigid mineral wool in several beds with a total thickness of 12 cm, with a thermal resistance of the assembly of more than 3,1 (m²K)/W;
- the clerestory "band" type of the AUDI showroom has a thermal resistance of 0,33 (m²K)/W;



- the opaque light outer walls of the showrooms and of the assembly room are metallic, prefabricated, with expanded polyurethane "sandwich" type and having a thermal resistance of 4 (m²K)/W, the thermal resistance being identical to that of the prefabricated roof of the assembly room;
- the 12 sectional gates of the construction, are air-proof and have a minimal thermal resistance of 0,28 (m²K)/W.

The data presented above lead to a **medium thermal resistance of the building** of 2,13 (m²K)/W and to a specific thermal loss of 0,209 W/(m³K) that, according to the A/V [m⁻¹] proportion (where "A" is the area of the building's shell, with the value of 7448 m², and "V" is the conditioned volume of the building, with the value of 17.114 m³), places the building under the maximum accepted value of the thermal loss of 0,257 W/(m³K), value recommended in the EU countries for the new mechanically ventilated buildings, with a low energy consumption.

According to the specific climatic conditions of the capital of Romania and to the imposed indoor temperatures for the cold season and the hot season of the year, the following calculation data was established:

Winter situation:

- | | |
|--|-------|
| ▪ outdoor air temperature: | -15°C |
| ▪ outdoor air relative humidity: | 80% |
| ▪ indoor air temperature for public areas, showrooms, offices and sanitary facilities: | 20°C |
| ▪ indoor air temperature for production areas: | 18°C |

Summer situation:

- | | |
|---|--------|
| ▪ outdoor air temperature: | 34,5°C |
| ▪ outdoor air relative humidity: | 11,95% |
| ▪ insurance degree: | 98% |
| ▪ indoor air temperature for public spaces, showrooms, offices and sanitary facilities: | 26°C |
| ▪ indoor air temperature in production spaces and in the warehouse: | 27°C |

Based on the thermal characteristics of the construction and on the indoor microclimate data, the thermal loss of the building during the winter season and the heat gains in the summer season were calculated. Between the thermal calculation for the public area, the showrooms and the offices, on the one side, and the social area on the other side, the elements that were taken into consideration for the heat gains were: the heat release from the inner sources (people, electric light, office electronic devices, kitchen devices and refrigerating cabinets), heat releases that have a very important role in the calculation of the total cooling load of the building during summer time. Both during winter and summer time, the mechanical ventilation installations are dimensioned for an hourly maximum fresh air flow of approximately 3.000 m³/h, which represents approximately 0,5 exchanges per hour of the 6.000 m³ volume of the areas intensely populated of the building.

The thermal loads resulted from the calculation are as follows:

- 308 kW_t heating load during winter time;
- 313 kW_t cooling load during summer time;
- 200 kWh_t/day domestic hot water preparation.

The concept of building air conditioning system

In the three distinctive parts of the construction, heavily populated, having large glass surfaces, serving as SEAT and AUDI showrooms, and for the public area for clients, were created over 750 m² of special surfaces of underfloor piping systems, regularly placed near the glass walls. These underfloor piping systems were made

of high density polyethylene, buried in cement capping. These special underfloor piping systems are fed with heating thermal agent during winter and cooling thermal agent during summer - the thermal agent is produced by the Water-to-Water Heat Pumps. Thus, an important part of the public areas floors are thermally radiant in winter and thermally absorbent in summer.

In these areas of the building several ventilation channels are installed, some visible, some hidden, connected to several Water-to-Air Heat Pumps, located mainly in the false ceilings of the building. They are mixing the fresh air with the re-circulated air and function on the "auto change over" principle, meaning they switch automatically from heating mode to cooling mode, as a reaction to "building overheating".



This capability of switching allows that during winter - when, for example, during daytime, the indoor temperature rises from the setpoint of 20°C to the value of 27°C, due, mainly, to the direct and diffuse solar radiation combined with the specific illumination of the showrooms - to recover important quantities of exceeding heat. This is accumulated in the external circuit of the heat exchanger and has an important contribution in keeping a

high performance coefficient of the HVAC system during winter time.

For the time period under survey, the performance coefficient of the HVAC system was always placed at a higher value than $COP=4,8$. This value means that, during the cold season, for each 1 electrical kW introduced in the HVAC system at least 4,8 thermal useful kW are obtained in the building. The key to a successful geothermal HVAC project is represented by keeping the temperature of the water in the heat pumps' main circuit, be the Water-to-Water and Water-to-Air, at a high value (10.5÷13°C) during the entire cold season of the year, by a proper dimensioning of the heat exchanger and by important recoveries of secondary energies.

For example, the performance of the thermal equipment in various cases of use is shown in Figure 1, in the diagrams Pressure-Enthalpy specific for the refrigerants R410A and R22 (used by the Florida brand Water-to-Water heat pumps).

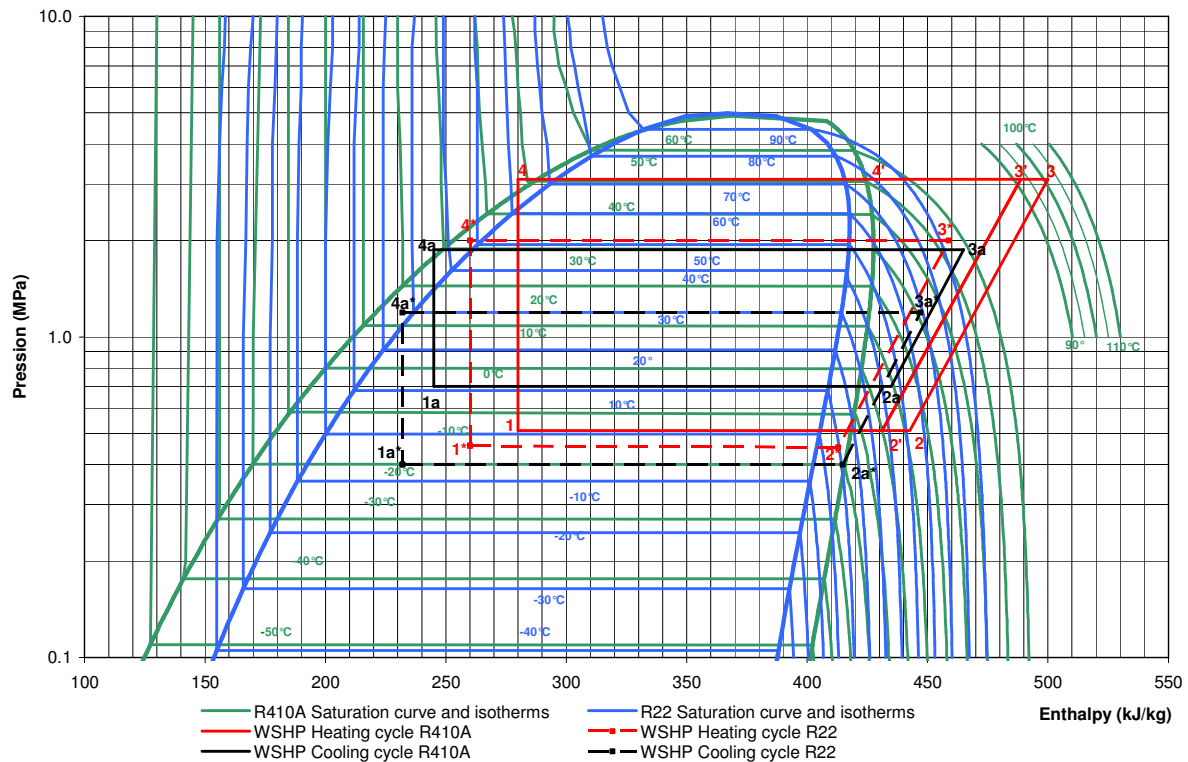


Figure 1. Comparative analysis of the thermodynamic cycles for the Florida Water-to-Water Heat Pumps, using the refrigerants R410A and R22

The performance during the cold season is given by the configuration of the refrigeration cycle that determines the value of the useful heat, and it is maximum for the cycle 1-2-3-4, where point 2 represents an overheating of R410A vapors from approximately -13°C up to $+10^{\circ}\text{C}$ obtained in the main heat exchanger of the heat pump by feeding the device with water from the heat exchanger at the temperature of $+12^{\circ}\text{C}$. The useful heat, obtained from this refrigeration cycle and represented by the segment 3-4, is - in this case - by 10-20% bigger than the heat produced by the same heat pump used in a HVAC system in which the heat exchanger delivers to the heat pump a water temperature of only $2-3^{\circ}\text{C}$ (cycle 1-2'-3'-4). The vapors' temperature at the end of the compression process (temperature of state point 3) is also important - it establishes the value of the fluid's enthalpy when it enters the secondary heat exchangers of the heat pump and its availability to produce domestic hot water in a "desuperheater" powered by refrigerant vapors at 103°C (process 3-4'), simultaneously with the production of domestic hot water with a temperature of 49°C obtained in the condenser of the thermal machine powered by refrigerant vapors at 52°C (process 4'-4).

The thermal agent, respectively the 49°C water, is used in winter not only for feeding the radiant floors, but also for feeding several "cassette" type convectors installed in the offices, and for several „assembly room" type convectors, with a high dynamic pressure, installed on the perimeter of the production room and of the warehouse.

On the same water circuits, during summer time, circulates a 7°C cooled thermal agent, delivered by the Water-to-Water Heat Pumps, according to the processes from the cooling cycle 1a-2a-3a-4a of the R410A refrigerant presented in Figure 1.



It is very important to notice two main aspects for this cycle, mainly:

- (a) The diagram shows that far less energy is consumed during compression (process 2a-3a) than during the similar compression (process 2-3) of the heating cycle;
- (b) The relative low condensation temperature for this cycle, around 34°C, generated by the temperature of the water feeding the ground heat exchanger, which is maintained at around 27°C during summer time.

Obviously the air cooled chillers installed in hypermarkets equipped with water loop heat pumps are much less efficient because, in summer time, the condensation temperature rises up to 40°C, thus having a negative effect on the compression energy and on the energy consumed in the cooling

cycle. In Figure 1 the thermodynamic heating cycle 1*-2*-3*-4* of the Florida brand heat pumps, using R22 as refrigerant, is drawn on purpose superposed on the actual cycle, in order to underline the significant technical progress achieved by the geothermal heat pumps alongside the alignment to the demands of the Kyoto Treaty (this one restrains the use of refrigerants with negative effect on the ozone layer in the atmosphere). R410A is a high performance and ecological refrigerant.

The ground heat exchanger

The ground source heat pumps use the solar energy accumulated in the ground surface. This represents over 60% of the energy received by the Earth from the



Sun. It represents low enthalpy energy, it is regenerative and must not be mistaken to the geothermal energy of medium enthalpy, which is exhaustible, has limited dissemination, and has as source the hot magma from the center of the earth.

For the reason of avoiding confusions, the ground energy originating from the sun and used with the aid of the heat pumps (of the above described type) is called **geothermal** energy, or, in other words, **geosolar** energy. It can be obtained in three distinctive ways, namely:

- from the underground waters, the drilling going usually until 200 m depth, where the water has a constant temperature of up to 20°C;
- from a horizontal heat exchanger, installed at a depth limit of 2 m from the ground surface, that uses a mixture of water and glycol, whose temperature, during winter time, is below 0°C ;
- from a vertical heat exchanger, installed in special boreholes with depths of around 150 m, connected to each other through a system of high density

polyethylene pipes buried at 2m depth, system that allows the use of non-glycol water as a heat thermal agent in the ground heat exchanger at quasi constant positive temperature values all the winter through.

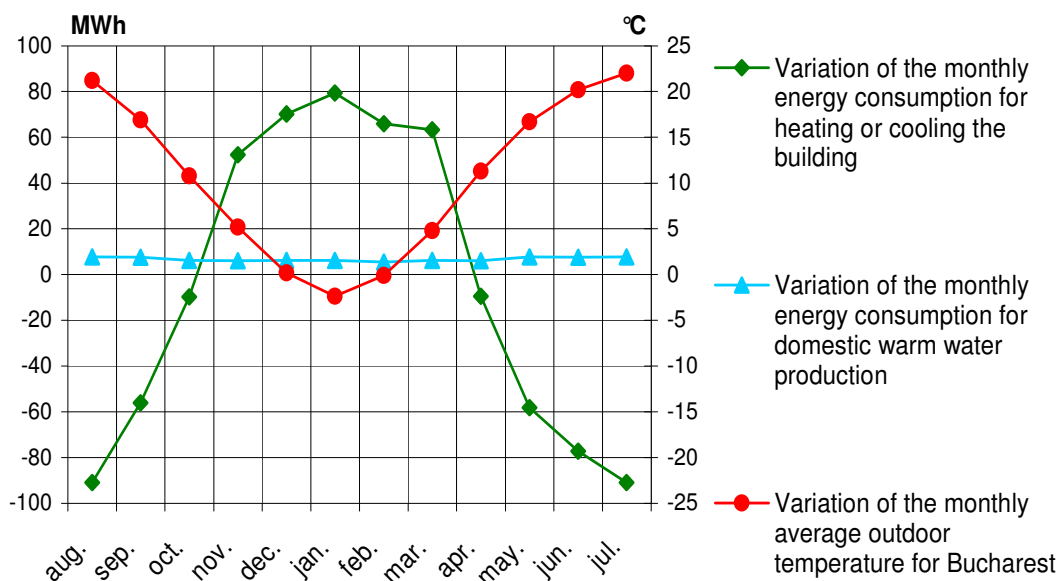


Figure 2. The theoretical variation of the monthly thermal energy consumption for heating, cooling and domestic hot water production of PBW2 depending on the monthly average temperatures in Bucharest (Simulation of the building behavior and of the geothermal HVAC installations)

In the case of higher thermal energy capacities installed in the geothermal HVAC systems, the most efficient technical solution is a vertical ground heat exchanger. This solution was adopted also in the case of Porsche Bucharest West 2, where a number of 128 vertical boreholes of 70 m depth each were installed on a 3.500 m² field in order to ensure a total 475 MWh of thermal energy exchange with the earth, necessary for heating (including the domestic hot water), and of 393 MWh thermal energy necessary for cooling, with the monthly variations theoretically established in standard conditions, according to the Chart from Figure 2.

Results obtained in practice

For monitoring the main real practice data obtained by using the HVAC geothermal system from Porsche Bucharest West 2, all the electric panels that supply electricity to the HVAC system components (namely Water-to-Water and Water-to-Air Heat Pumps, ventilators for introducing and extracting the air, fancoils, etc.) were surveyed.

Figure 3 presents the real results from the winter period 2006-2007 (obtained from the financial invoices put at our disposal by PORSCHE Romania – the owner and user of the building). The energy consumptions were reported to the air-conditioned surface of 3.507 m² and are compared to the theoretical values anticipated through the project, resulting from the values shown in Figure 2.

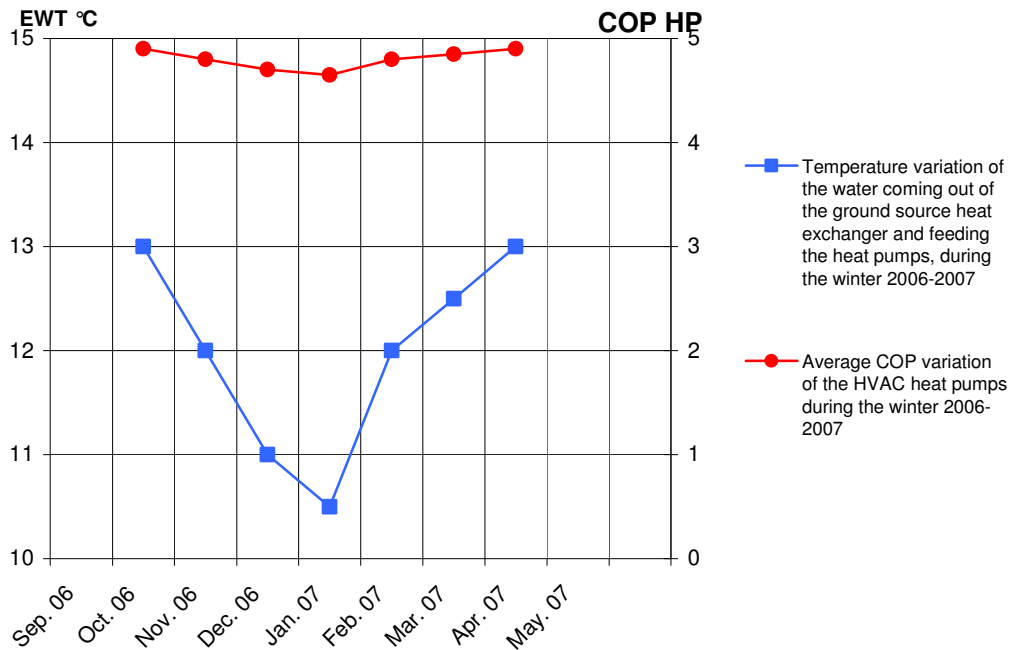
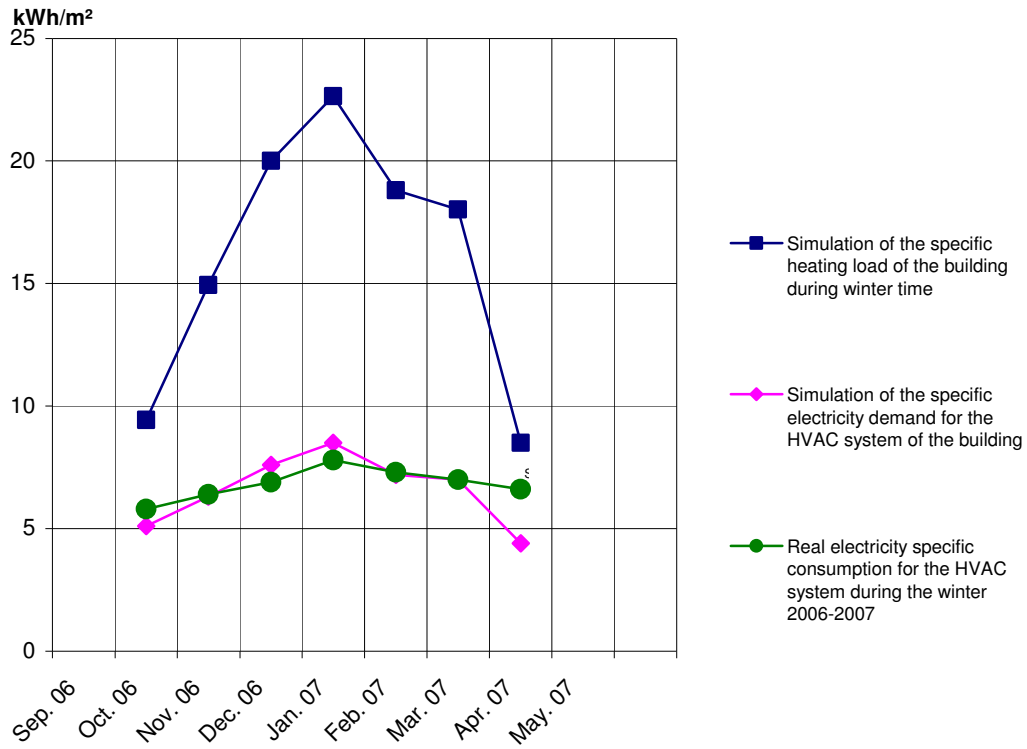


Figure 3. The performances of the PBW2 geothermal HVAC system during the winter 2006-2007 compared to the results of the buildings and equipment simulation

The real practice data presented in Figure 3 certify the following:

- The specific electric energy consumption of the HVAC system.

The average value of the specific effective electric energy consumption for the winter period (October 2006 – April 2007) was 6.83 kWh/(m² x month). For an average price of the electric energy of 72.86 Euro/MWh (exclusive VAT and excises) the operating cost of the geothermal system during winter for a total of 47.8 kWh/(m² x year) is 3.48 Euro/(m² x year).

- The specific energy consumption for heating and preparing domestic hot water.

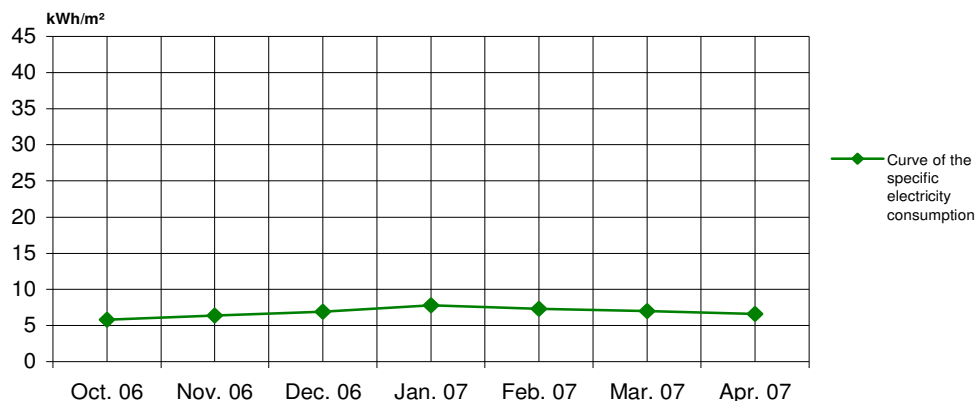
The sum of the values of the monthly specific thermal energy consumption during winter, mentioned in Figure 3, represents 112.32 kWh/(m² x year). According to law 372/2005 regarding the energy performance of the buildings (Directive 91/2002/CE), the value of 112.32 kWh/(m² x year) corresponds to class B on the energy classification scale of the buildings in Romania, was correctly anticipated by the calculation of the global coefficient of thermal insulation and corresponds to the present demands imposed to the new and mechanically ventilated industrial buildings.

Energy and resource savings

In order to precisely establish the level of performance obtained by applying the geothermal HVAC system in PORSCHE BUCURESTI VEST 2, the Austrian Group PORSCHE IMMOBILIER, representing the investor, and PORSCHE Romania, user of the construction, initiated the monitoring process of the PORSCHE Bucharest West 2 (PBW2) in parallel and compared it to an absolutely similar construction, achieved in a very close area, identical in its solar orientation, named PORSCHE Bucharest West 1 (PBW1). Commissioned in January 2006, the PBW1 HVAC system is a classical one, using natural gas to produce heat and domestic hot water, and using the last generation of Air-to-Air VRV (Variable Refrigerant Volume) multisplit systems for ventilating and conditioning the building during winter and summer.

The activities developed in PBW1 are identical to those developed in PBW2 building, namely showroom, offices and car service. The brands specific to PBW1 are SKODA and VOLKSWAGEN. The total analyzed surface for the winter time in the case of PBW1 is of 5,231 m². Based on the financial invoices for the natural gas and electric energy consumptions paid by the user of PBW1, and by reporting the amount to the total conditioned surface, during October 2006 – April 2007, the specific values of energy consumption were determined. These values are graphically presented in Figure 4, and compared to the specific values of electric energy consumption determined in the case of the geothermal HVAC system from PBW2. In the calculation of the specific figures, the energetic equivalent of the methane gas from the invoices was considered the one officially written on the invoices, respectively 10,725 kWh/m³_N.

**SPECIFIC ELECTRICITY CONSUMPTION OF THE GEOTHERMAL HVAC SYSTEM
PORSCHÉ BUCHAREST WEST 2 DURING OCTOBER 2006 – APRIL 2007**



**SPECIFIC ELECTRICITY AND NATURAL GAS CONSUMPTION FOR THE
CLASSICAL HVAC SYSTEM IN THE CASE OF PORSCHÉ BUCHAREST WEST 1
DURING OCT. 2006 - APR. 2007**

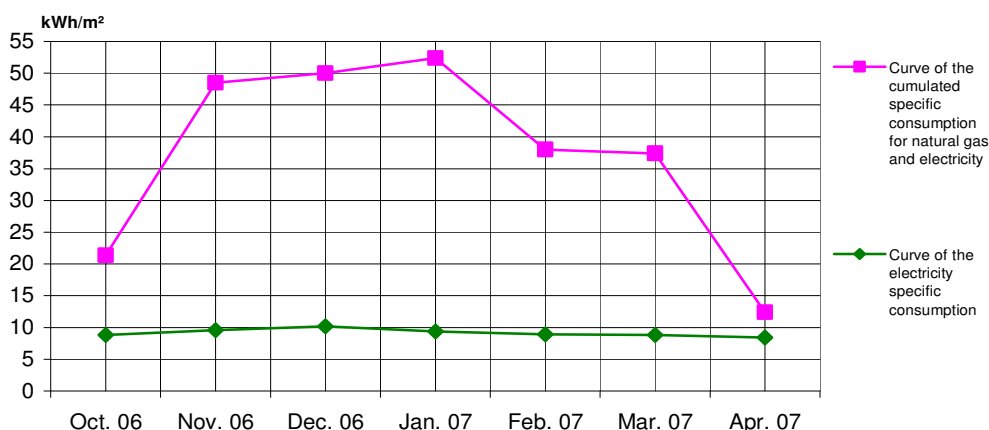


Figure 4. Comparative analysis of the energetic behaviour of the buildings and HVAC equipments from PBW1 and PBW2 during the cold period between October 2006 – April 2007

The following conclusions can be drawn from Figure 4:

- The specific electric energy consumption of the HVAC VRV ventilation system from PBW1 has the value of 641 kWh/(m² x year) for the period analyzed, and it is by approximately 34% bigger than the value registered by the geothermal HVAC system from PBW2, thus leading to a specific consumption value of 4.67 Euro/(m² x year).
- The specific natural gas consumption of the HVAC system at PBW1 has the value of 196 kWh/(m² x year), **representing practically the replacement of the geothermal input used in the HVAC case at PBW2** and reaches the value

of $18,275 \text{ m}^3_{\text{N}}/(\text{m}^2 \times \text{year})$, which, for an average price considered in calculations of 316.8 Euro/1000 m^3_{N} (exclusive VAT), means an expense of 5.79 Euro/ $(\text{m}^2 \times \text{year})$.

Therefore, the exploitation expenses, during the cold season of the year, for the classic HVAC system used in PBW1, rises to an amount of 10.46 Euro/ $\text{m}^2 \times \text{year}$ ($4.67 \text{ Euro}/(\text{m}^2 \times \text{year}) + 5.79 \text{ Euro}/(\text{m}^2 \times \text{year})$) and is 3 times bigger than the one registered by the geothermal HVAC system from PBW2 ($10,46 / 3,48 = 3$). The same proportion is kept in the cost of the Gcal which - in the geothermal HVAC system - is 31 Euro/Gcal, and in the classic system, based on the use of the natural gas, it is 92 Euro/Gcal.

Under the energy aspect, the value of the specific resources consumption registered by the classical energy source system from PBW1 is $260.1 \text{ kWh}/(\text{m}^2 \times \text{year})$, and it is more than 5 times higher than the one registered by the geothermal HVAC system from PBW2 ($260.1 / 47.8 = 5.44$).

It has to be noticed that the value of this fraction represents the COP of the geothermal HVAC system during winter, and it is similar to the COP of the heat pumps which is close to 5. This idea is useful in the technical-economical studies requested by the Romanian Law no. 372/2005 regarding the replacement of classical HVAC solutions by renewable solutions for heating, ventilating and domestic hot water in the case of new buildings with a built area higher than 1000 m².

Environment protection

In Romania, according to the calculation methodology of the energy performance of the buildings – Code Me 001-2006 – the CO₂ emission during the natural gas burning is $0.205 \text{ kg CO}_2/\text{kWh}$ (the value in the United Kingdom is 0.194), and the CO₂ emission during the electricity production, considering an average of primary sources accepted (for instance, in France this value is $0.09 \text{ kg CO}_2/\text{kWh}$).

Applying these values to the comparative analysis of the two HVAC systems in PBW1 and PBW2, the following conclusions result:

- The thermal energy produced during the cold period (October 13, 2006 – April 10, 2007) by PBW2 needed a total electricity consumption of $47.8 \text{ kWh}/ \text{m}^2$, equivalent to $4,3 \text{ kg CO}_2/ \text{m}^2$ pollutants delivered to the atmosphere;
- The thermal energy produced in the same cold period 2006-2007 by PBW1 needed $196 \text{ kWh}/ \text{m}^2$ natural gas and $64.1 \text{ kWh}/ \text{m}^2$ electricity, equivalent to $40.18 \text{ kg CO}_2/ \text{m}^2$ for natural gas consumption and respectively $5.77 \text{ kg CO}_2/ \text{m}^2$ for electricity, leading together to a total consumption of $45.95 \text{ kg CO}_2/(\text{m}^2 \times \text{year})$ gas with greenhouse effect, that is 10 times more per year and per 1 m^2 of air-conditioned surface than PBW2.

Conclusions

The technical investigations based on real consumptions resulted from the invoices for the geothermal HVAC system used at PBW2 and the comparison to the results obtained with the classic system from PBW1 (which uses natural gas, thermal cast iron boilers and a VRV Air-to-Air ventilation and air conditioning system), represent the first work of this type in Romania. The results obtained by using the two systems during the cold season between October 13, 2006 – April 10, 2007, allow us to establish a truth (only assumed until now), namely:

- ***The thermal ground source Heat Pumps used properly in the geothermal HVAC systems bring important economical and ecological advantages, compared to the classic HVAC technique;***
- ***The consumption of resources for heating, ventilation and preparing the domestic hot water on the winter season in a geothermal HVAC system is 5 times smaller than in a technically equivalent classic system;***
- ***The CO₂ pollution - in the case of using a geothermal HVAC system - is 10 times smaller than in the case of using a classic system, based on natural gas;***
- ***The expenses for the cold season of the year in the case of using a geothermal HVAC system are 3 times smaller than in the case of using a classical system, no matter how performant the latter would be. The situation will become even more favorable for using the ground source in the near future due to the predictable increase of the natural gas price.***