Project

# Promotion of efficient heat pumps for heating

( ProHeatPump)

EIE/06/072 / S12.444283

## Deliverable N° 32

## Feasibility Studies RES & Heat Pumps in BG and UK

Work Package 5

Heat Pumps and Renewables

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## 1. Methodology description

The technical-feasibility study has been performed for case studies specified by the project partners. For each case study, a complete description file has been documented by the partners to allow the equipment sizing, the energy consumption calculation and the economical analysis.

The table supplied to each partner is hereunder attached as table 1.

On the basis of the case study supplied data, a complete model of the building has been built and dynamical energy consumption simulations have been performed on order to:

- Estimate the **power** of the equipment for heating, air conditioning if necessary, with ENERGY+ software,
- Calculate the **annual energy need** for heating, air conditioning if necessary, with ENERGY+ software,
- Estimate the energy consumption with a solar thermal system with a French dynamic simulation tool SIMSOL, which is running with TRNSYS dynamic simulation software. The meteorological file for each European location has been adapted for the software.

On the basis of the dynamical results, a comparison between, a ground source heat pump coupled with solar panels and standard alternative solutions (electrical boiler, or gas boiler) is performed. Such a system has been chosen for different reasons:

- Micro-turbines for wind mills are on the market but the wind energy potential is very hard to be ensured in an urban area. Moreover, the generation of electricity of such systems is marginal compared to heating and DHW energy consumption.
- Biogas availability is not ensured and depends on infrastructure development in the building project area. At this time, the biogas is mainly generalized in Sweden.
- Photovoltaic solar panels generate electricity, which can be sold at a very good price in most of European countries. It can be considered as a financial operation with a high level of investment (5 €/Wpeak) and an acceptable payback (between 10 and 15 years for Spain, France and Germany). The coupling with heat pump is not industrialized at this time.
- Solar thermal panels have been industrialized for many years and can be easily coupled with heat pumps. Moreover, this kind of coupling is economically reasonable and adapted to exploit solar energy directly for buildings heating and DHW producing.

The technical data for the solar panels and the ground heat pump are from WIESMANN Europe products data files, as this manufacturer proposes the possibility to couple different energy system with flexibility and reliability.

- WIESMANN solar thermal panels references are VitoSol 100 2.5 for any case study.
- WIESMANN heat pumps references depends on the power needed for each case study.

The coupling architecture depends on the size of the building and the power consumption. One storage tank is adapted for a family house with the drawbacks of energy losses, but with a lower investment (see figure 1). The solar panels and the supplement equipment, in our case the Heat Pump, heat the water in the same tank.

The Two storage tank architecture is adapted for large buildings (see figure 2). One tank is dedicated to the solar panels and the other is connected to the tap water and the heat is supplied by the supplement equipment, the heat pump in our case.

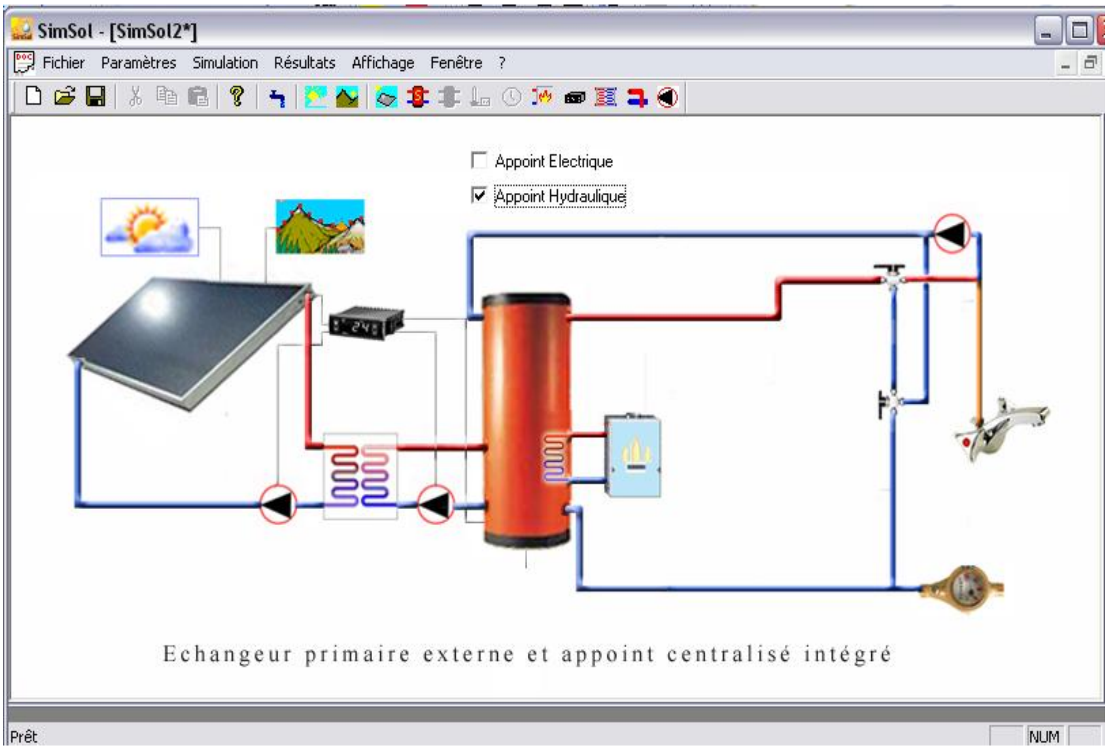


Figure 1 : One storage tank DHW solar system architecture

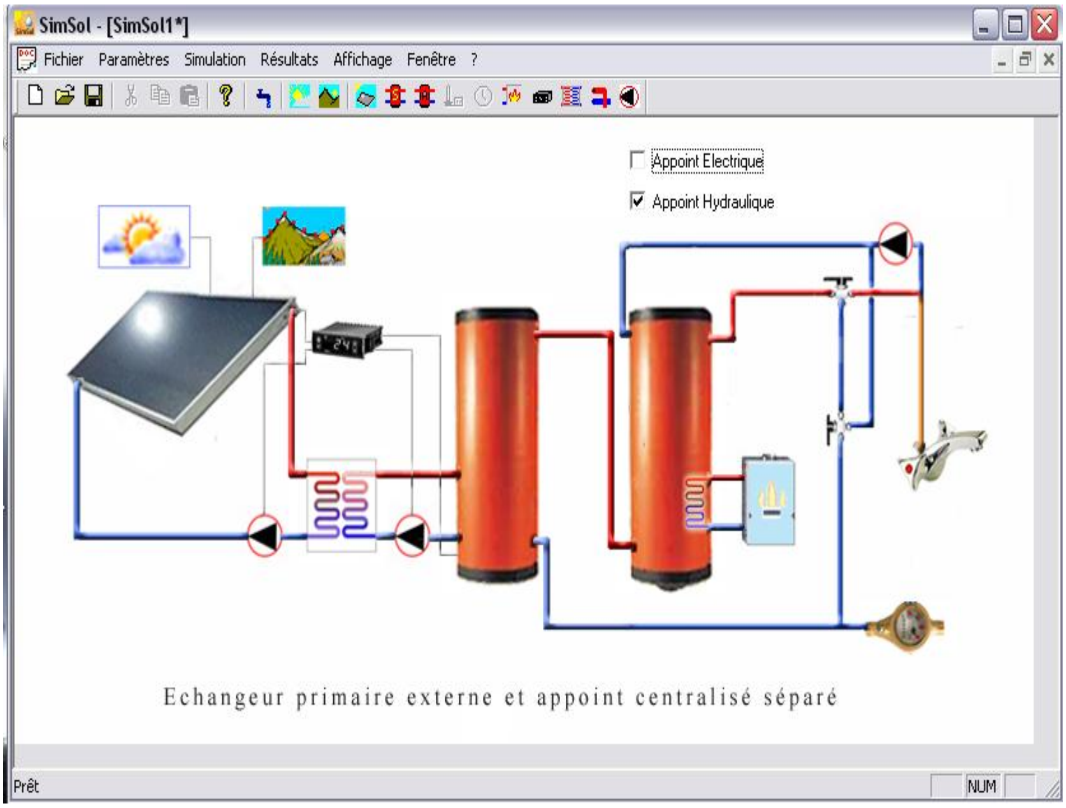

Figure 2 Two storage tank DHW solar system architecture

For each case, the energetic annual cost is evaluated with and annual energy cost increase of +12% /year. The, the Life Cycle Cost of the HVAC system is evaluated taking into account the investment amount and the national subsidies.

Table 1 : Case study characteristics

| ProHeatPump case study characteristics | |
|---|---|
| **Building characteristics** | |
| Surface (m²) | |
| Volume (m3) | |
| Roof structure | |
| Roof orientation | |
| Wall materials | |
| Roof materials | |
| Windows percentage of vertical surfaces | |
| Window materials | |
| Glazes technology | |
| Typical annual heating needs (kWh/m²/year) | |
| **Builing location** | |
| Geographical location | |
| Kind of area : urban, suburban, .. | |
| Shadowing (high, medium, low) | |
| **Building activity** | |
| Activity description (office, dwelling, ..) with schedule | |
| User density (pers/m²) with schedule | |
| DHW consumption (litres/day) | |
| Indoor temperature for heating with schedule | |
| Indoor temperature for air conditionning with schedule | |
| Lighting technology consumption and schedule (W/m²) | |
| Typical annual lighting consumption (kWh/m²/year) | |
| Electrical equipment (computer, ..) W/m² and schedule | |
| **HVAC systems** | |
| Ventilation system : heat recovery, efficiency, .. | |
| Ventilation rate and schedule | |
| Heating device (standart) | |
| Heating terminals | |
| Heating terminals temperature | |
| DHW temperature generation | |
| DHW tap temperature | |
| Typical annual DHW final energy consumption (kWh/m²/year) | |
| Air infiltration level (Volume /h) | |
| **Heat pump technology** | |
| Air / water HP | |
| Water / water HP | |
| Ground source availability | |
| **Renewable energy** | |
| Solar panels : thermal or photovoltaic, supplier, .. | |
| Surface (m²) | |

| | |
|---|---|
| Coupling possibility on the market | |
| **Economic data** | |
| Energy cost (€/kWh) electricity and others | |
| National subsidies | |
| Energy cost (€/kWh) forecast | |
| **System cost (€)** | |
| HP with boreholes | |
| Solar panels | |
| Compared system (boiler) | |

## 2. Bulgarian case studies

### a. Multi playhouse in Varna

The building description is summarized by the table 2:

Table 2 : Multi playhouse VARNA

| **ProHeatPump case study characteristics** | |
|---|---|
| **Building characteristics** | |
| Surface (m²) | 1791 |
| Volume (m3) | 4959 |
| Roof structure | Flat roof |
| Roof orientation | |
| Wall materials | fig. 1 |
| Roof materials | Fig. 2 |

| N | | S | W |
|---|---|---|---|
| 12<br>3,8<br>6 | | 14<br>3,2<br>3 | 26<br>7,0<br>8 |

| | |
|---|---|
| Windows percentage of vertical surfaces | 28% |
| Window materials | Will be change with new windows |
| Glazes technology | Normal |
| Typical annual heating needs (kWh/m²/year) | 104,7 |
| **Builing location** | |
| Geographical location | Varna, Bulgaria,<br>Heat season - 180 days (21 October – 20 April)<br>It need 2400 DD (19°C indoor temperature) |
| Kind of area : urban, suburban, .. | Urban |
| Shadowing (high, medium, low) | Low |
| **Building activity** | |
| Activity description (office, dwelling, ..) with schedule | Dwelling, in use all time |
| User density (pers/m²) with schedule | 0,022 (There is 40 people) |

| | |
|---|---|
| DHW consumption (litres/day) | 32 292 kWh/year |
| Indoor temperature for heating with schedule | 19°C |
| Indoor temperature for air conditionning with schedule | |
| Lighting technology consumption and schedule (W/m²) | Simple electrical lamp<br>4,46 W/m² |
| Typical annual lighting consumption (kWh/m²/year) | 1,129 kWh/m²/year , (2022 kWh/year) |
| Electrical equipment (computer, ..) W/m² and schedule | |
| **HVAC systems** | Fig 3 |
| Ventilation system : heat recovery, efficiency, .. | It has ventilation system only in bathroom. |
| Ventilation rate and schedule | |
| Heating device (standart) | split system, electric stove or virgin woods stove (fig.3) |
| Heating terminals | |
| Heating terminals temperature | |
| DHW temperature generation | By electric boilers |
| DHW tap temperature | 65°C |
| Typical annual DHW final energy consumption (kWh/m²/year) | 18.03 |
| Air infiltration level (Volume /h) | After retrofitting we expect 0,5 Volume /h |
| **Heat pump technology** | |
| Air / water HP | |
| Water / water HP | |
| Ground source availability | Yes |
| **Renewable energy** | |
| Solar panels : thermal or photovoltaic, supplier, .. | Both |
| Surface (m²) | 200 |
| Coupling possibility on the market | |
| **Economic data** | |
| Energy cost (€/kWh) electricity and others | 0.11 |
| National subsidies | up to 600 euro per household |
| Energy cost (€/kWh) forecast | increase |
| **System cost (€)** | |
| HP with boreholes | about 700 euro/kW electric power |
| Solar panels | 550 euro |
| Compared system (boiler) | |

Figure 3 : Varna multi playhouse picture

**Building modeling:**

The building model has been done and parameters were checked to reach the annual energy consumption specified as target by the Bulgarian specification (final energy consumption: 105 kWh/m².year) with the specified envelop characteristics.

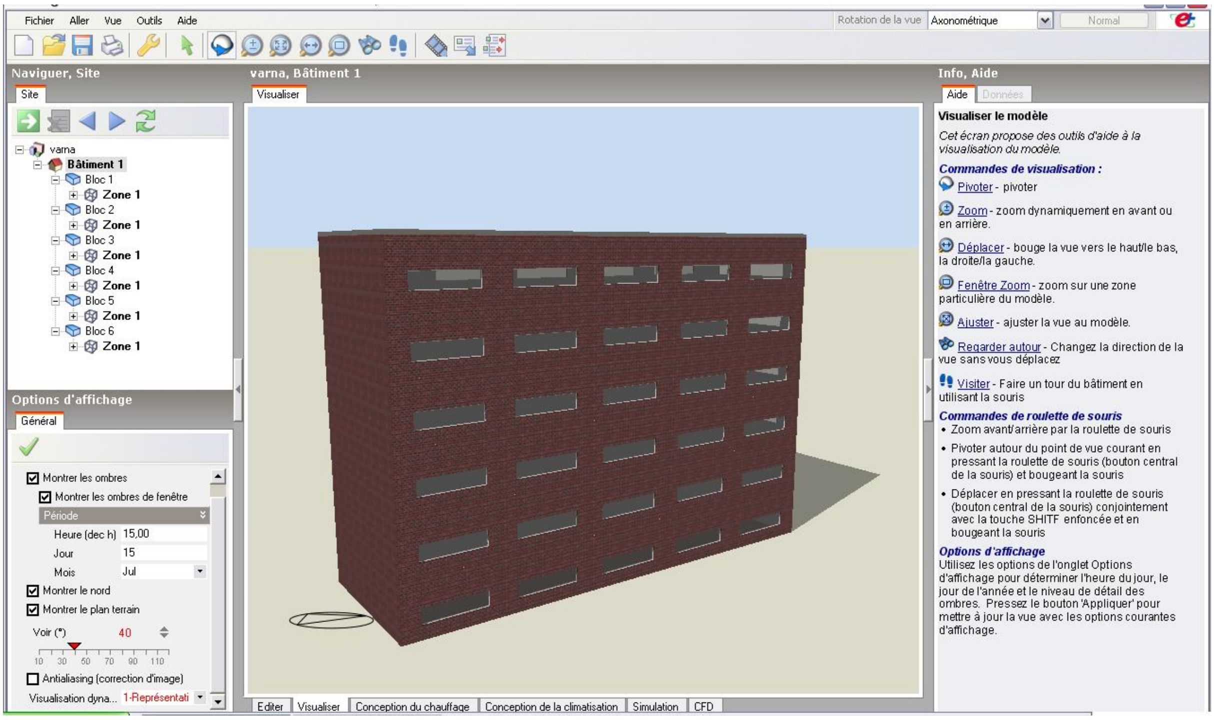


Figure 4 : Building model made with ENERGY+ software

**Energy and power analysis:**

Thanks to the ENERGY+ model and the SIMSOL solar system simulation software, the equipments have been characterized (rated power, surface of panels, etc…) with the annual energy demand for heating and annual DHW consumption.

| System spécifications | | |
|---|---|---|
| | | |
| Heating Power | 97 | kW |
| Air conditionning power | 0 | kW |
| DHW power (supplement) | 10 | kW |
| Solar panels surface | 28 | m² |
| | | |
| Heating Energy demand | 122 573 | kW.h |
| Air Conditionning demand | 0 | kW.h |
| DHW energy demand | 32 292 | kW.h |

Table 3 : Equipment characteristics and energy demand

**Technical and economical study:**

The data generated by the building model made with ENERGY+ software, and the DHW solar system simulated thanks to SIMSOL software are used to perform a comparison with an electrical heating system and with a gas boiler.

Main results are shown in the table 4 hereunder.

The electric heating system are far less expensive compare to HP & solar and gas boiler solution, as electric heaters and individual electric DHW system are very cheap.
The gas boiler needs a storage tank for DHW water tank, which increases the investment.
The HP & solar system is the highest investment solution even with 600 € subsidies per householder.

Exploitation cost is significantly higher for the electrical system.
Gas boiler and heat pump & solar annual energy cost are at the same level with a slight difference for HP & solar. This advantage can be easily cancelled because of the ancillaries' energy consumption of the ground source heat pumps coupled with solar panels. Actually, the ground heat exchanger is permanently fed with water + glycol mixture, and the solar panels is also fed by fluids, then and the pump consumptions can a slight disadvantage if low efficiency electrical motors are used (roughly from 5% to 10 of heat energy consumption).

The feasibility depends on the choice of low consumption ancillaries with efficient heat pump system.

| HEAT PUMP PERFORMANCES | | ELECTRICAL HEATER & BOILER PERFORMANCES | | GAS BOILER & AIR CONDINNING PERFORMANCES | |
|---|---|---|---|---|---|
| Heat Pump COP (heating at 55°C) | 2,9 | Electrical Heating COP (heating at 55°C) | 0,95 | Gaz boiler efficiency (heating at 55°C) | 0,95 |
| Heat Pump EER | - | Air conditionning EER | - | Air conditionning EER | - |
| Heat pump COP (DHW) at 65°C | 2,6 | DHW electrical heating at 65°C | 0,90 | Gas boiler heating at 65°C | 0,90 |
| Heating energy consumption | 42 267 kW.h | Electrical heating energy consumption | 129 024 kW.h | Gas boiler heating energy consumption | 129 024 |
| Air Conditionning energy consumption | 0 kW.h | Air Conditionning energy consumption | 0 kW.h | Air Conditionning energy consumption | 0 |
| Thermal Solar system energy consumption | 4 375 kW.h | DHW electrical boiler energy consumption | 35 880 kW.h | DHW gas boiler energy consumption | 35 880 |
| Ancillaries energy consumption | 12 257 kW.h | Ancillaries energy consumption | 0 kW.h | Ancillaries energy consumption | 6 451 |
| Total electrical energy consumption | 58 899 kW.h | Total electrical energy consumption | 164 904 kW.h | **Total energy consumption** | **171 356** |
| Investisment cost | | Investisment cost | | Investisment cost | |
| Heat pump and boreholes | 23 420,01 € | Electrical heater | 950,00 € | Gas Boiler | 8 026,93 € |
| Solar panels | 15 400,00 € | DHW system | 6 300,00 € | DHW system | 1 500,00 € |
| Heating storage | 1 500,00 € | | | Air conditionning system | 0,00 € |
| National subsidies | 10 800,00 € | National subsidies | 0,00 € | National subsidies | 0,00 € |
| Total investment | 28 020,01 € | Total investment | 7 250,00 € | Total investment | 9 526,93 € |
| Energy cost (1 kWh) | 0,11 € | Energy cost (1 kWh) | 0,11 € | Energy cost (1 kWh) Gas | 0,04 € |
| Annual Energy cost | 6 478,84 € | Annual Energy cost | 18 139,47 € | Annual Energy cost | 7 305,81 € |

Table 4 : Comparison of system performances and annual energy cost

The annual energy costs have been calculated for the systems over 20 years, as shown by the figure 5.

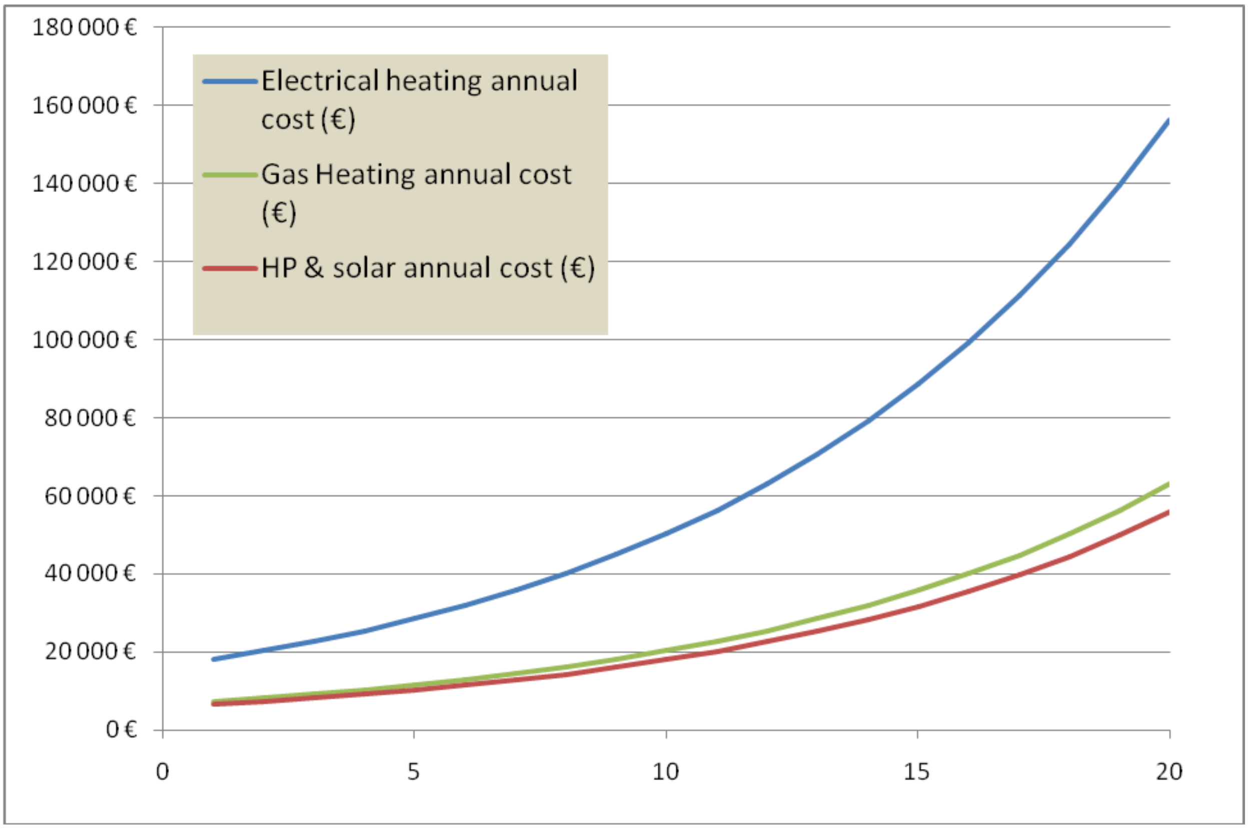


Figure 5 : Annual energy cost for the 3 systems

Electrical heating solution is dramatically more expensive than the 2 other solutions.

Then, on the basis of investment evaluation made by the Bulgarian partner and the financial subsidies that could be onbtained if Renewables Energy are used for building application, a Life Cycle Cost evaluation of HVAC equipments has been realised.

The obtained curves shown by the figure 4 are used for evaluating the feasibility of Renewables Energy system with a payback of investment obtained after 3 years of buiding exploitation compare to electrical heating solution.

On the other side, the over-investment of the HP and the solar panels is not paid back before 13 years in comparison with the gas boiler solution, with the hypothesis of the same cost increase for gas and electricity.

The economical feasibility of the HP & solar system is easily proved if the alternative is only electrical heating.
The gas boiler is still the more competitive altenative system with drawbacks :

- Gas supplying continuity to be ensured during the next 20 years,
- Greenhouse gases emissions of natural gas combustion,

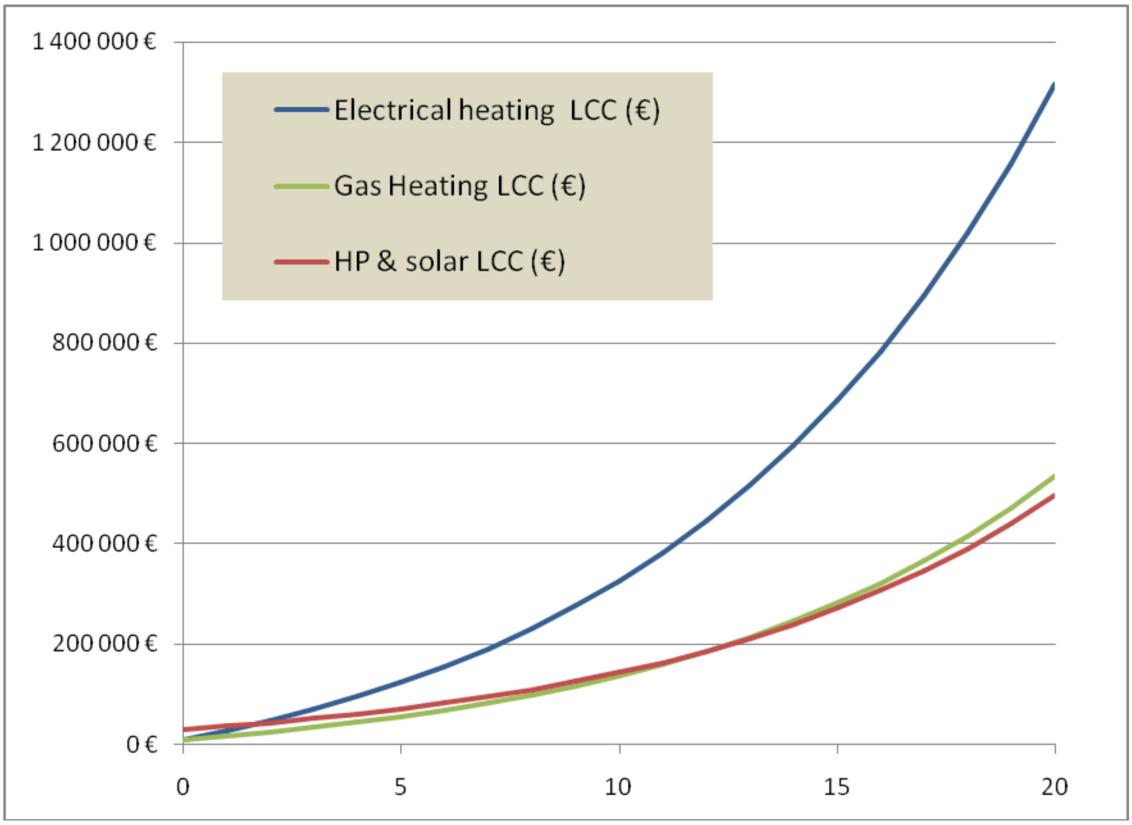

Figure 6 : Life Cycle Cost evaluation of HVAC equipments

### b. Family house in Varna

The building description is summarized by the table 5:

Table 5 : Family House VARNA

| ProHeatPump case study characteristics | |
|---|---|
| **Building characteristics** | |
| Surface (m²) | 560 residential area (1,2 and 3 floor) + 325 service space ( fittnes hall, Pub with kitchen, technical and service rooms and garage) |
| Volume (m3) | 1512 + 845 |
| Roof structure | Flat roof |
| Roof orientation | |
| Wall materials | fig. 1 |
| Roof materials | Fig. 2 |
| Windows percentage of vertical surfaces | ˜ 35%, architecture plan of the building will be attached on Wednesday ( May 13) |
| Window materials | PVC |
| Glazes technology | Double glass packages with argon |
| Typical annual heating needs (kWh/m²/year) | It is a new building |
| **Builing location** | |
| Geographical location | Varna, Bulgaria,<br>Heat season - 180 days (21 October – 20 April)<br>It need 2400 DD (19°C indoor temperature) |
| Kind of area : urban, suburban, .. | Suburban |
| Shadowing (high, medium, low) | Low |
| **Building activity** | |
| Activity description (office, dwelling, ..) with schedule | Family house, in use all time, all year round |
| User density (pers/m²) with schedule | There is 4 people |
| DHW consumption (litres/day) | |
| Indoor temperature for heating with schedule | 23°C |
| Indoor temperature for air conditioning with schedule | |
| Lighting technology consumption and schedule (W/m²) | Halogen lamps<br>19 W/m² |
| Typical annual lighting consumption (kWh/m²/year) | new building |
| Electrical equipment (computer, ..) W/m² and schedule | 20W/ m², |
| **HVAC systems** | Fig 3 |
| Ventilation system: heat recovery, efficiency, .. | Possibility to be installed in the two parts of the basement, on the 1st and on the top ( 3rd) floor.<br>It has ventilation system only in the bathrooms. |
| Ventilation rate and schedule | |
| Heating device (standart) | Installed only on the 2nd floor, air conditioning multi split system (fig.3), with inside unit in each of the rooms. Separately it is installed water heating system with radiators in each of the 4 bedrooms, ventilation convectors in the 2 living rooms. Radiators are installed in the 4 bathrooms, at the floor entrance and |

| | |
|---|---|
| | in the kitchen box |
| Heating terminals | |
| Heating terminals temperature | |
| DHW temperature generation | Central system with circulation pipe and pump, by water heater 300 liters ( to 95°C), with one serpentine for heating with gas or other source, second serpentine for solar system heating and additional electric heater 3 x 2 KW. |
| DHW tap temperature | 65°C |
| Typical annual DHW final energy consumption (kWh/m²/year) | Data n/a |
| Air infiltration level (Volume /h) | 0,5 Volume /h |
| **Heat pump technology** | |
| Air / water HP | |
| Water / water HP | |
| Ground source availability | Yes, combination ground source and water / water |
| **Renewable energy** | |
| Solar panels: thermal or photovoltaic, supplier, .. | Both |
| Surface (m²) | 40 ( 100) |
| Coupling possibility on the market | |
| **Economic data** | |
| Energy cost (€/kWh) electricity and others | 0.11 |
| National subsidies | up to 600 euro per household |
| Energy cost (€/kWh) forecast | increase |
| **System cost (€)** | |
| HP with boreholes | about 700 euro/kW electric power |
| Solar panels | 550 euro |
| Compared system (boiler) | |

Figure 7 : Varna multi playhouse picture

**Building modeling:**

The building model has been done and parameters were checked respect specification with the specified envelop characteristics.

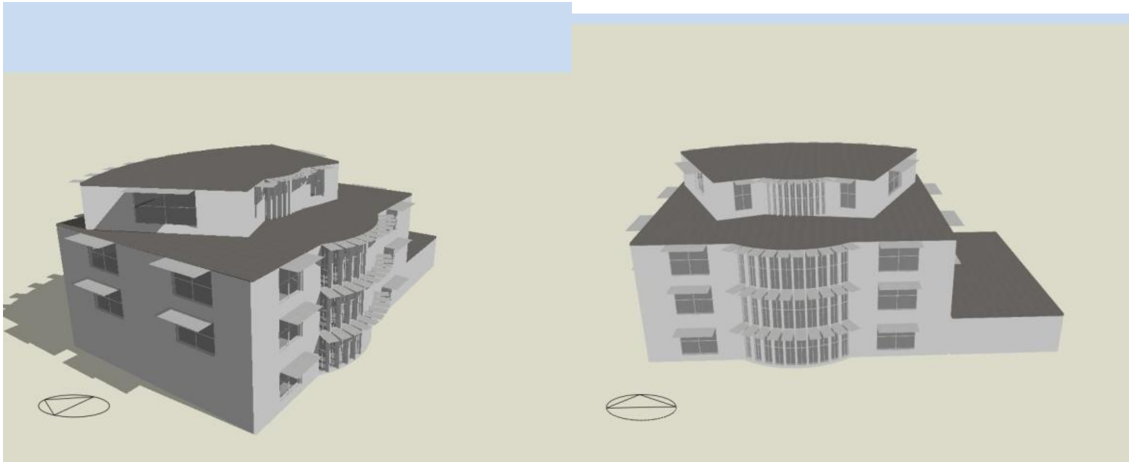

Figure 8 : Varna family house ENERGY+ model

**Energy and power analysis:**

Thanks to the ENERGY+ model and the SIMSOL solar system simulation software, the equipments have been characterized (rated power, surface of panels, etc…) with the annual energy demand for heating and annual DHW consumption.

| System spécifications | | |
|---|---|---|
| | | |
| Heating Power | 50 | kW |
| Air conditionning power | 13 | kW |
| DHW power | 10 | kW |
| Solar panels surface | 5 | m² |
| | | |
| Heating Energy demand | 35 254 | kW.h |
| Air Conditionning demand | 5 009 | kW.h |
| DHW energy demand | 3 179 | kW.h |

Table 6: Equipment characteristics and energy demand

**Technical and economical study:**

The data generated by the building model made with ENERGY+ software, and the DHW solar system simulated thanks to SIMSOL software are used to perform a comparison with an electrical heating system and with a gas boiler.

Main results are shown in the table 7 hereunder.

| HEAT PUMP PERFORMANCES | | ELECTRICAL HEATER & BOILER PERFORMANCES | | GAS BOILER & AIR CONDINNING PERFORMANCES | |
|---|---|---|---|---|---|
| Heat Pump COP (heating at 55°C) | 2,9 | Electrical Heating COP (heating at 55°C) | 0,95 | Gaz boiler efficiency (heating at 55°C) | 0,95 |
| Heat Pump EER | 2,5 | Air conditionning EER | 2,00 | Air conditionning EER | 2,00 |
| Heat pump COP (DHW) at 65°C | 2,6 | DHW electrical heating at 65°C | 0,90 | Gas boiler heating at 65°C | 0,90 |
| Heating energy consumption | 12 157 kW.h | Electrical heating energy consumption | 37 110 kW.h | Gas boiler heating energy consumption | 35 254 kW.h |
| Air Conditionning energy consumption | 2 004 kW.h | Air Conditionning energy consumption | 2 505 kW.h | Air Conditionning energy consumption | 5 009 kW.h |
| Thermal Solar system energy consumption | 290 kW.h | DHW electrical boiler energy consumption | 3 532 kW.h | DHW gas boiler energy consumption | 3 179 kW.h |
| Ancillaries energy consumption | 3 525 kW.h | Ancillaries energy consumption | 0 kW.h | Ancillaries energy consumption | 0 kW.h |
| **Total electrical energy consumption** | **17 975,4 kW.h** | **Total electrical energy consumption** | **43 147 kW.h** | **Total energy consumption** | **64 733 kW.h** |
| Investisment cost | | Investisment cost | | Investisment cost | |
| Heat pump and boreholes | 12 099 € | Electrical heater | 1 055 € | Gas Boiler | 4 509 € |
| Solar panels | 2 750 € | DHW system | 1 500 € | DHW system | 0 € |
| Heating storage | 1 500 € | Air conditionning system | 3 000 € | Air conditionning system | 3 000 € |
| National subsidies | 600 € | National subsidies | 0 € | National subsidies | 0 € |
| **Total investment** | **15 749 €** | **Total investment** | **5 555 €** | **Total investment** | **7 509 €** |
| Energy cost (1 kWh) | 0,11 € | Energy cost (1 kWh) | 0,11 € | Energy costs (1 kWh) | 0,11 & 0,04 |
| **Annual Energy cost** | **1 977 €** | **Annual Energy cost** | **4 746 €** | **Annual Energy cost** | **1 975 €** |

Table 7 : Comparison of system performances and annual energy cost

The electric heating system are far less expensive compare to HP & solar and gas boiler solution, as electric heaters, air conditioning systems (split system) and individual electric DHW system are very cheap.
The HP & solar system is the highest investment solution with 600 € subsidies.

Exploitation cost is significantly higher for the electrical system.
Gas boiler and heat pump & solar annual energy cost are exactly at the same level.
As for the case 1, this equality can be easily cancelled because of the ancillaries' energy consumption of the ground source heat pumps coupled with solar panels. Actually, the ground heat exchanger is permanently fed with water + glycol mixture, and the solar panels is also fed by fluids, then and the pump consumptions can a slight disadvantage if low efficiency electrical motors are used (roughly from 5% to 10 of heat energy consumption).

The annual energy costs have been calculated for the systems over 20 years, as shown by the figure 9.

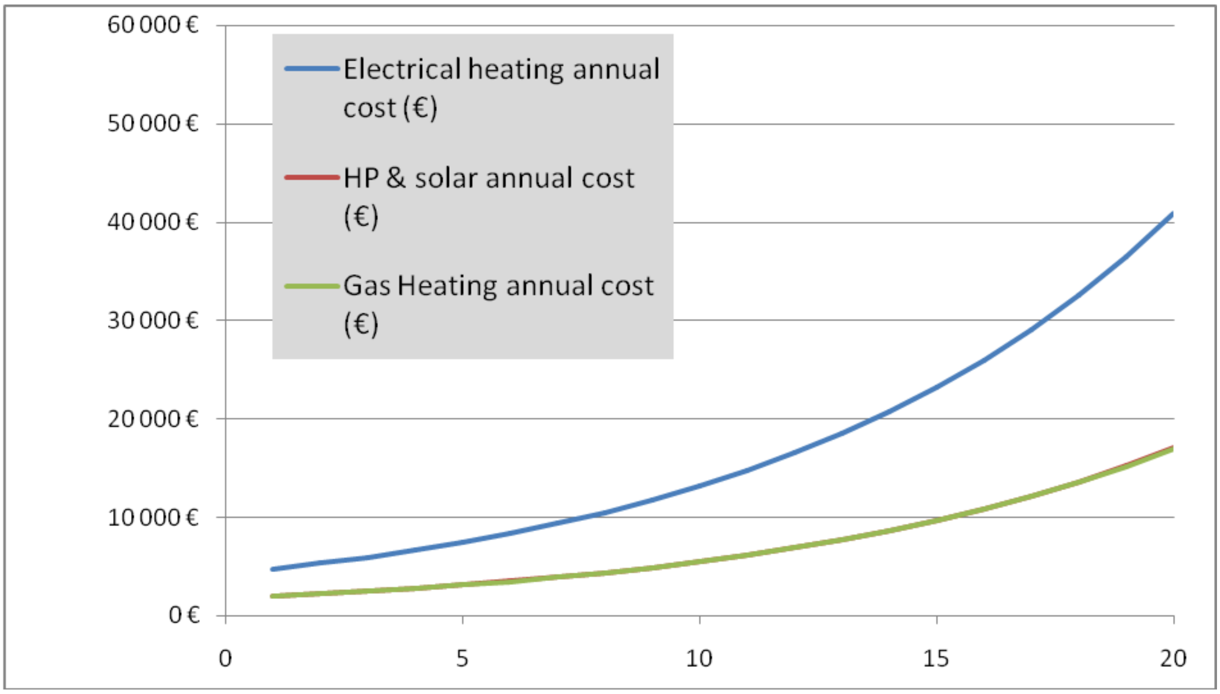


Figure 9 : Annual energy cost for the 3 systems

Gas and HP & Solar are exactly the same. Electricity is far more expensive.

Then, on the basis of investment evaluation made by the Bulgarian partner and the financial subsidies that could be onbtained if Renewables Energy are used for building application, a Life Cycle Cost evaluation of HVAC equipments has been realised.

The obtained curves shown by the figure 10 are used for evaluating the feasibility of Renewables Energy system with a payback of investment obtained after 3 years of buiding exploitation compare to electrical heating solution.

On the other side, the over-investment of the HP and the solar panels is never paid back in comparison with the gas boiler solution, with the hypothesis of the same cost increase for gas and electricity.

The economical feasibility of the HP & solar system is easily proved if the alternative is only electrical heating. The gas boiler is still the more competitive altenative system with drawbacks :

- Gas supplying continuity to be ensured during the next 20 years,
- Greenhouse gases emissions of natural gas combustion,

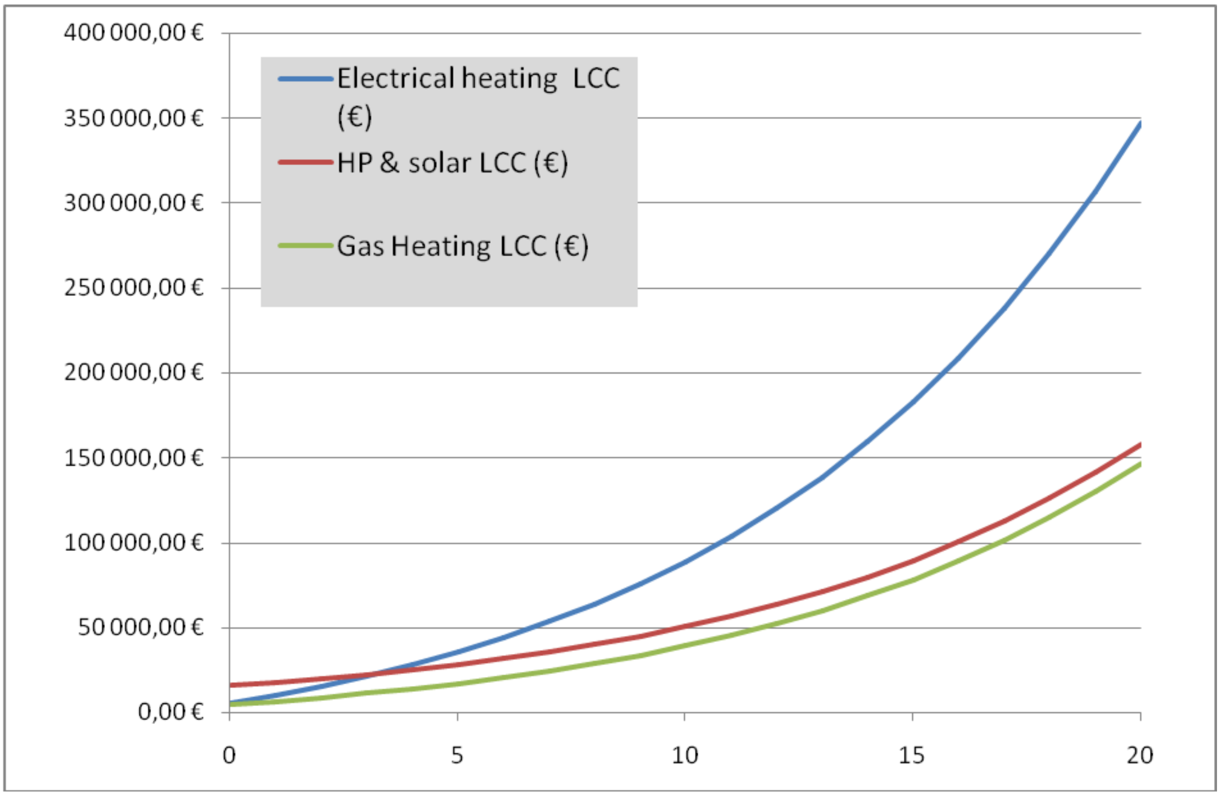


Figure 10 : Life Cycle Cost evaluation of HVAC equipments

It can be underlined that HP and solar cannot be paid back when building envelop is not performant enough to limit over investment.

### c. Kindergarten in Varna

The building description is summarized by the table 8.

Table 8 : Kindergarten VARNA

| ProHeatPump case study characteristics | |
|---|---|
| **Building characteristics** | |
| Surface (m²) | 1974 |
| Volume (m3) | 6992 |
| Roof structure | Flat roof |
| Roof orientation | It is flat roof |
| Wall materials | Fig.1. |
| Roof materials | Fig.2. |
| Windows percentage of vertical surfaces | NW: 94,6; SW: 97,50; SE: 101,10; NE: 108,90; 25% |
| Window materials | Now the window materials are woodwork, but it have plan for change with PVC windows. |
| Glazes technology | K - windows |
| Typical annual heating needs (kWh/m²/year) | 219,5 |
| **Builing location** | |
| Geographical location | Varna, Bulgaria,<br>Heat season - 180 days (21 October – 20 April)<br>It need 2400 DD (19°C indoor temperature) |
| Kind of area : urban, suburban, .. | Urban |
| Shadowing (high, medium, low) | low |
| **Building activity** | |
| Activity description (office, dwelling, ..) with schedule | Kindergarten – 171 Childs and 34 staff<br>8 hours – Monday - Friday |
| User density (pers/m²) with schedule | 0,10 |
| DHW consumption (litres/day) | 14,9 kWh/m²/year |
| Indoor temperature for heating with schedule | 20 °C |
| Indoor temperature for air conditionning with schedule | |
| Lighting technology consumption and schedule (W/m²) | Simple electrical lamp<br>8,35 W/m² |
| Typical annual lighting consumption (kWh/m²/year) | 2 kWh/m²/year |
| Electrical equipment (computer, ..) W/m² and schedule | 25,80 W/m² |
| **HVAC systems** | |
| Ventilation system : heat recovery, efficiency, .. | There is no ventilation system in the building. |
| Ventilation rate and schedule | |
| Heating device (standart) | There are installed 2 hot water boilers - 150 kW and 250 kW power. The boilers use naphtha for fuel. It has planned to change the fuel base to natural gas. The rooms are heating by cast iron radiators. |

| | |
|---|---|
| Heating terminals | Hot water pipelines |
| Heating terminals temperature | 90 °C |
| DHW temperature generation | By boilers, in summer they have electric boiler. |
| DHW tap temperature | 65 °C |
| Typical annual DHW final energy consumption (kWh/m²/year) | 14,9 kWh/m²/year |
| Air infiltration level (Volume /h) | After retrofitting we expect 0,5 Volume /h |
| **Heat pump technology** | |
| Air / water HP | |
| Water / water HP | |
| Ground source availability | Yes |
| **Renewable energy** | |
| Solar panels : thermal or photovoltaic, supplier, .. | Thermal panels |
| Surface (m²) | 1000 m2 |
| Coupling possibility on the market | Yes |
| **Economic data** | |
| Energy cost (€/kWh) electricity and others | 0.11 |
| National subsidies | up to 600 euro per household |
| Energy cost (€/kWh) forecast | increase |
| **System cost (€)** | |
| HP with boreholes | about 700 euro/kWelectric power |
| Solar panels | 550 euro |
| Compared system (boiler) | |

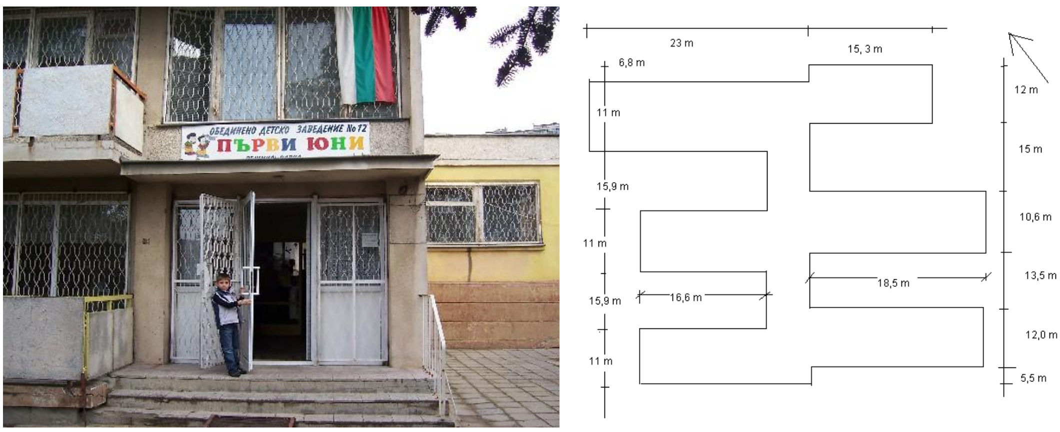


Figure 11: Varna Kindergarten picture and drawings

**Building modeling:**

The building model has been done and parameters were checked respect specification with the specified envelop characteristics.

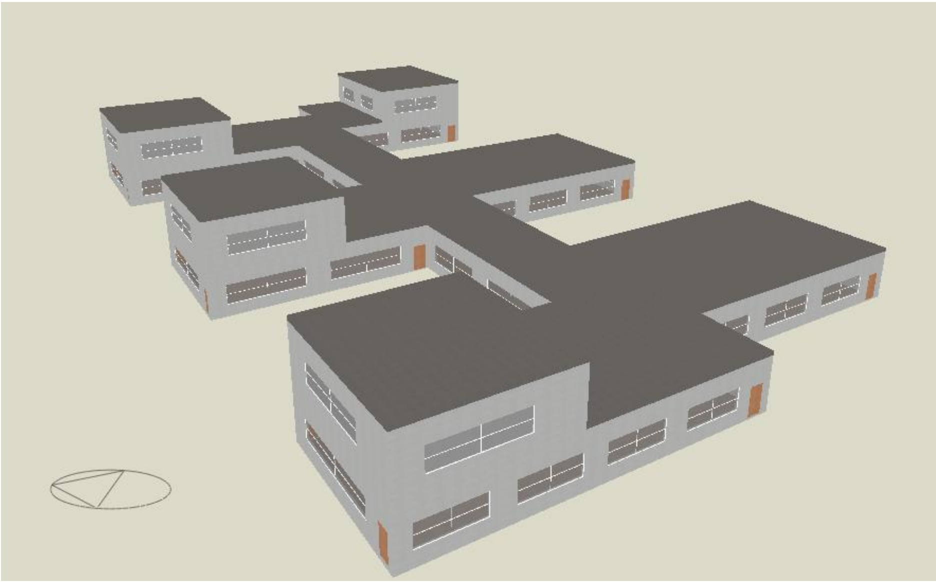

Figure 12: Varna Kindergarten ENERGY+ model

**Energy and power analysis:**

Thanks to the ENERGY+ model and the SIMSOL solar system simulation software, the equipments have been characterized (rated power, surface of panels, etc…) with the annual energy demand for heating and annual DHW consumption.

Table 9: Equipment characteristics and energy demand

| System spécifications | | |
|---|---|---|
| | | |
| Heating Power | 144 | kW |
| Air conditionning power | 0 | kW |
| DHW power | 10 | kW |
| Solar panels surface | 25 | m² |
| | | |
| Heating Energy demand | 95 968 | kW.h |
| Air Conditionning demand | 0 | kW.h |
| DHW energy demand | 27 942 | kW.h |

**Technical and economical study:**

The data generated by the building model made with ENERGY+ software, and the DHW solar system simulated thanks to SIMSOL software are used for performing a comparison with an electrical heating system and with a gas boiler.

| HEAT PUMP PERFORMANCES | | | ELECTRICAL HEATER & BOILER PERFORMANCES | | GAS BOILER & AIR CONDINNING PERFORMANCES | |
|---|---|---|---|---|---|---|
| Heat Pump COP (heating at 55°C) | 2,9 | | Electrical Heating COP (heating at 55°C) | 1,00 | Gaz boiler efficiency (heating at 55°C) | 0,95 |
| Heat Pump EER | - | | Air conditionning EER | - | Air conditionning EER | 2,00 |
| Heat pump COP (DHW) at 65°C | 2,6 | | DHW electrical heating at 65°C | 1,00 | Gas boiler heating at 65°C | 0,90 |
| Heating energy consumption | 33 092 | kW.h | Electrical heating energy consumption | 95 968 kW.h | Gas boiler heating energy consumption | 101 019 kW.h |
| Air Conditionning energy consumption | 0 | kW.h | Air Conditionning energy consumption | 0 kW.h | Air Conditionning energy consumption | 0 kW.h |
| Thermal Solar system energy consumption | 10 747 | kW.h | DHW electrical boiler energy consumption | 27 942 kW.h | DHW gas boiler energy consumption | 31 047 kW.h |
| Ancillaries energy consumption | 10 994 | kW.h | Ancillaries energy consumption | 0 kW.h | Ancillaries energy consumption | 5 051 kW.h |
| **Total electrical energy consumption** | **54 833** | **kW.h** | **Total electrical energy consumption** | **123 910 kW.h** | **Total energy consumption** | **64 733 kW.h** |
| Investisment cost | | | Investisment cost | | Investisment cost | |
| Heat pump and boreholes | 34 844 € | | Electrical heater | 2 887 € | Gas Boiler | 11 577 € |
| Solar panels | 13 750 € | | DHW system | 1 500 € | DHW system | 0 € |
| Heating storage | 3 000 € | | | | | |
| National subsidies | 0 € | | National subsidies | 0,00 € | National subsidies | 0 € |
| **Total investment** | **51 594 €** | | **Total investment** | **4 387 €** | **Total investment** | **11 577 €** |
| Energy cost (1 kWh) | 0,11 € | | Energy cost (1 kWh) | 0,11 € | Energy costs (1 kWh) | 0,11 & 0,04 |
| **Annual Energy cost** | **5 385 €** | | **Annual Energy cost** | **13 630 €** | **Annual Energy cost** | **5 485 €** |

Table 10: Comparison of system performances and annual energy cost

The electric heating system are far less expensive compare to HP & solar and gas boiler solution, as electric heaters, and electric DHW system are very cheap.
The HP & solar system is the highest investment solution with no subsidies known at that time.

Exploitation cost is significantly higher for the electrical system.
Gas boiler and heat pump & solar annual energy cost are almost at the same level.
As for the case 1 and 2, this equality can be easily cancelled because of the ancillaries' energy consumption of the ground source heat pumps coupled with solar panels. Actually, the ground heat exchanger is permanently fed with water + glycol mixture, and the solar panels is also fed by fluids, then and the pump consumptions can a slight disadvantage if low efficiency electrical motors are used (roughly from 5% to 10 of heat energy consumption).

The annual energy costs have been calculated for the systems over 20 years, as shown by the figure 13.

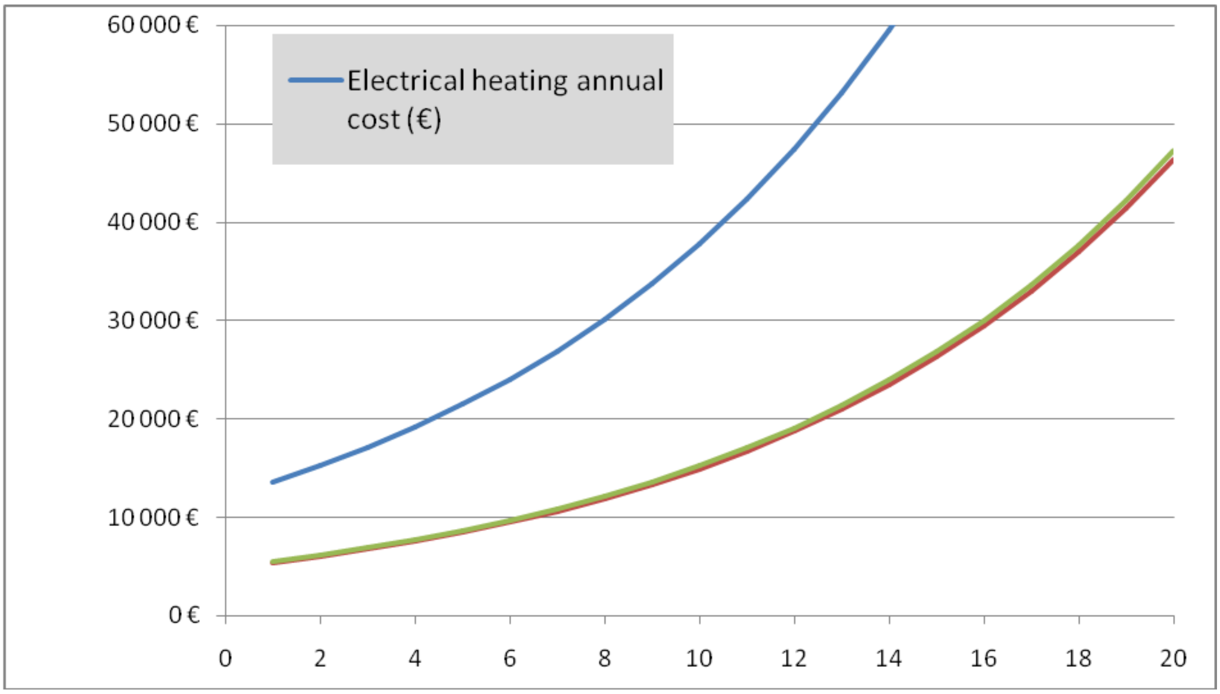


Figure 13: Annual energy cost for the 3 systems

Gas and HP & Solar are exactly the same. Electricity is far more expensive.

Then, on the basis of investment evaluation made by the Bulgarian partner and the financial subsidies that could be onbtained if Renewables Energy are used for building application, a Life Cycle Cost evaluation of HVAC equipments has been realised.

The obtained curves shown by the figure 14 are used for evaluating the feasibility of Renewables Energy system with a payback of investment obtained after 5 years of buiding exploitation compare to electrical heating solution.

On the other side, the over-investment of the HP and the solar panels is never paid back in comparison with the gas boiler solution, with the hypothesis of the same cost increase for gas and electricity. It should be notify that ther is no subsidies known at that time of the project.

The economical feasibility of the HP & solar system is easily proved if the alternative is only electrical heating. The gas boiler is still the more competitive altenative system with drawbacks :

- Gas supplying continuity to be ensured during the next 20 years,
- Greenhouse gases emissions of natural gas combustion,

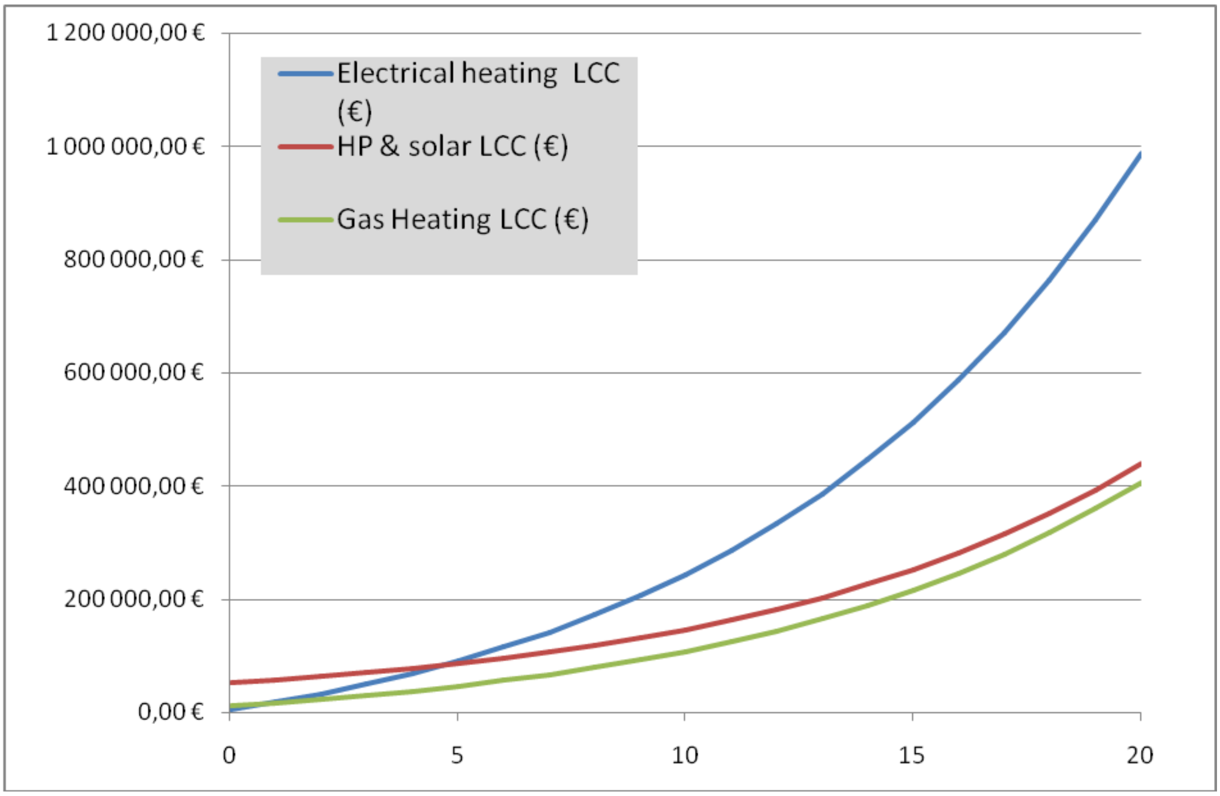


Figure 14: Life Cycle Cost evaluation of HVAC equipments

It can be underlined that HP and solar cannot be paid back when building envelop is not performant enough to limit over investment. An over insulation of the building could be a solution to obtain acceptable pay back period.

## 3. UK case studies

### a. Small family house in Edinburgh

The building description is summarized by the table 11:

Table 11: Small suburban house UK

| ProHeatPump case study : UK 1 – small suburban house retrofit | |
|---|---|
| **Building characteristics** | |
| Surface (m²) | 56m² (external) / 48m² (internal) each of two storeys; |
| Volume (m³) | 290m³ (external) / 220m³ (internal) |
| Roof structure | ceramic tile and caps, some metal flashing at joins (photos); over wood rafters |
| Roof orientation | 35º sloping roof, facing NE and SW; gable end SE & NW; projection to NE over garage (photos) |
| Wall materials | outer layer 10cm brick, 6cm rockwool insulated cavity, inner 10 cm concrete breeze block, 3 cm batons; 1 cm plasterboard; plaster skim; total wall thickness 30cm; no external render; likely (ideal) U value 0.45 w/m²/C ? |
| Roof materials | reflective sarking under tiles, otherwise no insulation under roof (photo); 10cm rockwool between horizontal joists at ceiling level in roofspace, over ~90% of area, plasterboard ceiling, plaster skim; insulation poor condition and compressed to <10cm in places; vents in eaves, venting into roofspace |
| Windows percentage of vertical surfaces | 7.6m² - 4% |
| Window materials | PVC covered aluminium frames, reasonably well-sealed when closed |
| Glazes technology | Double-glazed with 14mm gap; no selective coatings |
| Typical annual heating needs (kWh/m²/year) | Typical total annual gas use 6400 kWh; i.e. kWh/m², but not separable into heating, cooker hob and DHW, other than by typical ratios: 25% used for DHW?<br>Heating season: typically Oct - May<br>Degree days (2008) on 15.5C base (standard UK basis): 2520<br>Typical specific heat loss: 60W/m²? |
| **Building location** | |
| Geographical location | Musselburgh, Midlothian<br>UK postcode : EH21 6TT<br>coordinates: N 55º 56.138' ; N 55º 56.138'<br>(aerial views attached) |
| Kind of area : urban, suburban, .. | Suburban 1980s private housing estate |
| Shadowing (high, medium, low) | Low; adjacent houses shelter NW & SE ends of house but no significant shading from south (aerial views attached) |
| **Building activity** | |
| Activity description (office, dwelling, ..) with schedule | family dwelling, between 2 and 4 occupants |

| | |
|---|---|
| User density (pers/m²) with schedule | |
| DHW consumption (litres/day) | not available ; estimate 45L/day |
| Indoor temperature for heating with schedule | thermostat set at 20C; heating in season typically 0600-0800 and 1700-2200; drops to ambient slowly when not heated |
| Indoor temperature for air conditioning with schedule | no AC |
| Lighting technology consumption and schedule (W/m²) | mix of incandescent (total 200W); LED downlight (total 18W); halogen downlight (total 400W); compact fluorescent (total 50W); intermittent use only |
| Typical annual lighting consumption (kWh/m²/year) | total annual electricity consumption for all purposes: 2000 kWh; not separable into lighting, equipment, cooking (oven), DHW immersion top-up, etc. |
| Electrical equipment (computer, ..) W/m² and schedule | not separable from total above |
| **HVAC systems** | |
| Ventilation system : heat recovery, efficiency, .. | None; only natural ventilation from leaky building envelope and opening windows! |
| Ventilation rate and schedule | None |
| Heating device (standard) | Non-condensing gas boiler; max output 12kW; theoretical efficiency 80%; maintained annually but probably operating at much lower efficiency; DHW tank (117L) has top-up electric immersion heating element, but contribution not known |
| Heating terminals | Water radiators in all rooms (total 6) plus 2 heated towel rails on same circuit |
| Heating terminals temperature | 60C ? |
| DHW temperature generation | 60C ? |
| DHW tap temperature | 50C ? |
| Typical annual DHW final energy consumption (kWh/m²/year) | not separable from total gas and electricity consumption |
| Air infiltration level (Volume /h) | Not known |
| **Heat pump technology** | |
| Air / water HP | |
| Water / water HP | |
| Ground source availability | 66m² rear garden |
| **Renewable energy** | |
| Solar panels: thermal or photovoltaic, supplier, .. | not fitted |
| Surface (m²) | not fitted |
| Coupling possibility on the market | |
| **Economic data** | |
| Energy cost (€/kWh) electricity and others | electricity 0.13: gas: 0.038 (incl VAT) |
| National subsidies | 30 % of costs up to €4500, per household for GSHP or solar or wind, under SCHRI scheme or combined RE/HP installation |
| Energy cost (€/kWh) forecast | unpredictable; recent 10% drop |
| **System cost (€)** | |
| HP with boreholes | €12000 system and installation; grant available (see above) |
| Solar panels | flat plate €3-5000; evacuated tube €4-7000; grant available – typically €450 (see above) |
| Compared system (boiler) | €1600 boiler and installation |

Figure 15: UK small suburban house picture

**Building modeling:**

The building model has been done and parameters were checked respect specification with the specified envelop characteristics.

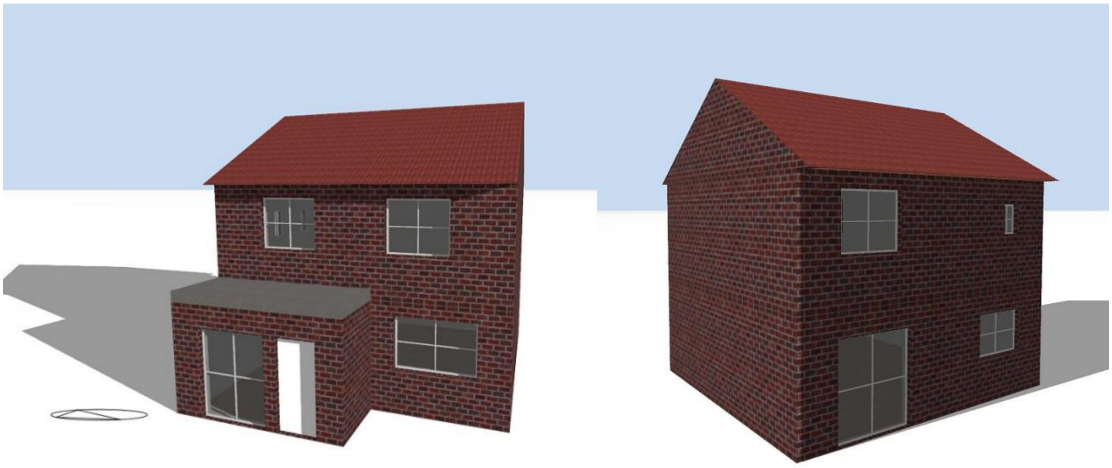

Figure 16: UK small suburban house ENERGY+ model

**Energy and power analysis:**

Thanks to the ENERGY+ model and the SIMSOL solar system simulation software, the equipments have been characterized (rated power, surface of panels, etc…) with the annual energy demand for heating and annual DHW consumption.

Table 10: Equipment characteristics and energy demand

| | | |
|---|---|---|
| System spécifications | | |
| | | |
| Heating Power | 5 | kW |
| Air conditionning power | 0 | kW |
| DHW power | 7 | kW |
| Solar panels surface | 4 | m² |
| | | |
| Heating Energy demand | 7 634 | kW.h |
| Air Conditionning demand | 0 | kW.h |
| DHW energy demand | 2 800 | kW.h |

**Technical and economical study:**

The data generated by the building model made with ENERGY+ software, and the DHW solar system simulated thanks to SIMSOL software are used for performing a comparison with an electrical heating system and with a gas boiler.

| HEAT PUMP PERFORMANCES | | ELECTRICAL HEATER & BOILER PERFORMANCES | | GAS BOILER & AIR CONDINNING PERFORMANCES | |
|---|---|---|---|---|---|
| Heat Pump COP (heating at 55°C) | 2,9 | Electrical Heating COP (heating at 55°C) | 1,00 | Gaz boiler efficiency (heating at 55°C) | 0,95 |
| Heat Pump EER | - | Air conditionning EER | - | Air conditionning EER | 2,00 |
| Heat pump COP (DHW) at 65°C | 2,6 | DHW electrical heating at 65°C | 1,00 | Gas boiler heating at 65°C | 0,90 |
| Heating energy consumption | 2 633 kW.h | Electrical heating energy consumption | 7 634 kW.h | Gas boiler heating energy consumption | 8 036 kW.h |
| Air Conditionning energy consumption | 0 kW.h | Air Conditionning energy consumption | 0 kW.h | Air Conditionning energy consumption | 0 kW.h |
| Thermal Solar system energy consumption | 742 kW.h | DHW electrical boiler energy consumption | 2 800 kW.h | DHW gas boiler energy consumption | 3 111 kW.h |
| Ancillaries energy consumption | 903 kW.h | Ancillaries energy consumption | 0 kW.h | Ancillaries energy consumption | 402 kW.h |
| **Total electrical energy consumption** | **4 277 kW.h** | **Total electrical energy consumption** | **10 434 kW.h** | **Total energy consumption** | **11 549 kW.h** |
| Investisment cost | | Investisment cost | | Investisment cost | |
| Heat pump and boreholes | 1 294 € | Electrical heater | 107 € | Gas Boiler | 1 600 € |
| Solar panels | 2 200 € | DHW system | 500 € | DHW system | 500 € |
| Heating storage | 800 € | | | Air conditionning system | 0 € |
| National subsidies | 1 288,14 € | National subsidies | 0,00 € | National subsidies | 0,00 € |
| **Total investment** | **3 006 €** | **Total investment** | **607 €** | **Total investment** | **2 100 €** |
| Energy cost (1 kWh) | 0,13 € | Energy cost (1 kWh) | 0,13 € | Energy costs (1 kWh) | 0,13 & 0,038 |
| **Annual Energy cost** | **556 €** | **Annual Energy cost** | **1 356 €** | **Annual Energy cost** | **439 €** |

Table 11 : Comparison of system performances and annual energy cost

The electric heating system are far less expensive compare to HP & solar and gas boiler solution, as electric heaters, and electric DHW system are very cheap.
The HP & solar system is the highest investment solution with 30% of investment subsidies.

Exploitation cost is significantly higher for the electrical system.
Gas boiler is cheaper than the heat pump & solar panels because of low price of natural gas.

The annual energy costs have been calculated for the systems over 20 years, as shown by the figure 9.

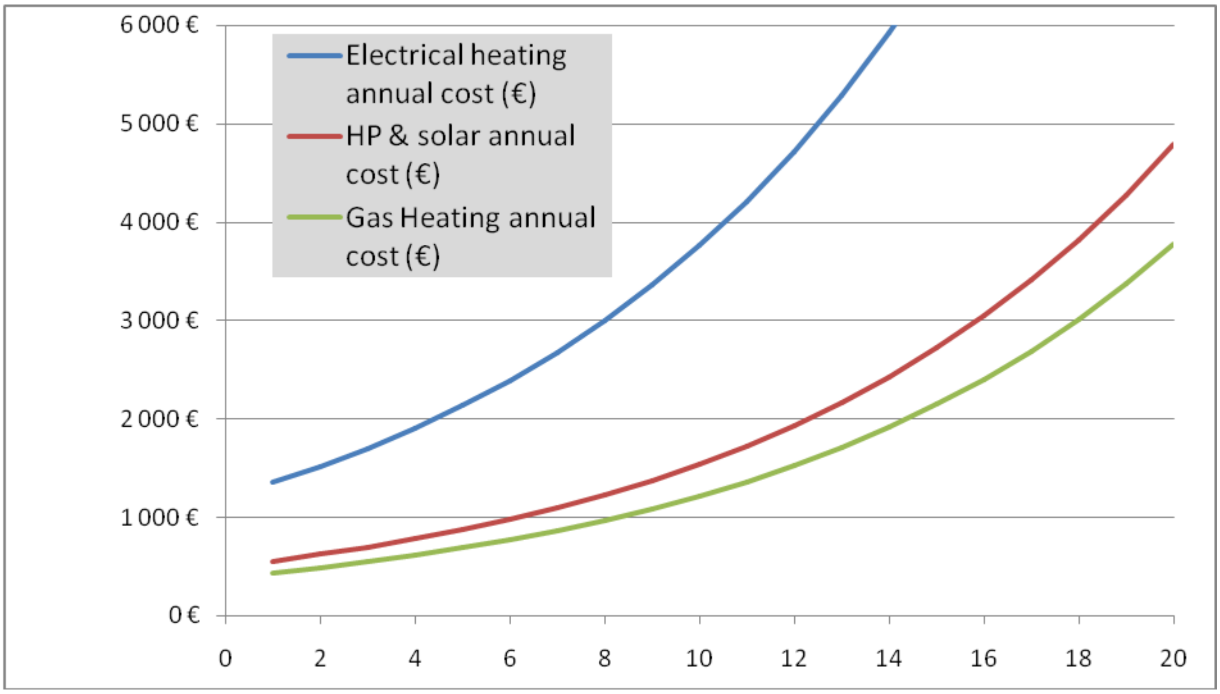


Figure 11 : Annual energy cost for the 2 systems

Gas is cheaper than HP & Solar and Electrical heater is far more expensive.

Then, on the basis of investment evaluation made by the UK partner and the financial subsidies that could be onbtained if Renewables Energy are used for building application, a Life Cycle Cost evaluation of HVAC equipments has been realised.

The obtained curves shown by the figure 18 are used for evaluating the feasibility of Renewables Energy system with a payback of investment obtained after 3 years of buiding exploitation compare to electrical heating solution.
Because of the low cost of natural gas, the investment of HP and solar panels is never paid back.

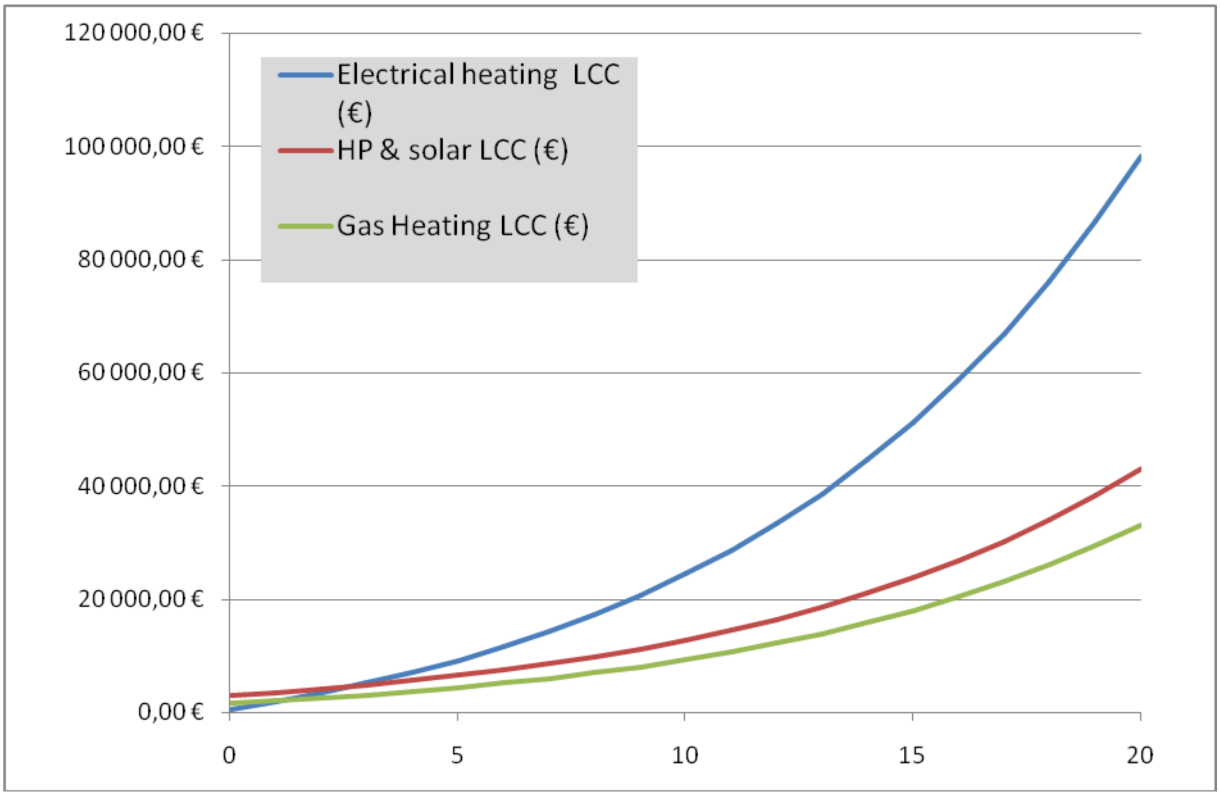


Figure 18: Life Cycle Cost evaluation of HVAC equipments

## 4. Conclusion

Ground force Heat Pump and solar panels technical feasibility is difficult to prove for building project when it is possible to install natural gas boiler.
It can be underlined that it is, in the studied cases, always easy when it is competition with electrical heating system.

The drawback of heat pump remains the high investment level and the electricity cost that are hardly compensated by the system efficiency.
The unknown parameter is the increase rate of energy, and the similarity between gas and electricity in the near future.

The only case where the feasibility is possible, under condition of installing efficient ancillaries, the building envelop has been totally retrofitted to reduce power demands for heating. In that case, the over investment is dramatically decreased, and the economical feasibility can be shown thanks to national subsidies.

Generally, **at the European scale**, as the ground heat pump cost depends mainly on the borehole drilling, it is economically interesting to reduce as much as possible the equipment power. Consequently, **the building envelop performances should be designed to reduce building power heating demands to reduce investment and obtain profitabilit**y.

It another proof that a global energy approach is needed to ensure renewable energy system application in building field.