ENERGY SUPPLY FOR ENVIROMENT- FRIENDLY BUILDINGS

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1. Abstract

The paper describes Latvian experience in the Energy supply for Environment-friendly buildings. The first Environment- friendly project and that successful realization influenced RES policy are analyzed. The administration of the North Vidzeme Biosphere Reserve (NVBR) has completed erection of the Environmental Education and Information Centre with a potential area of 675m^2 in the town of Salacgriva. This centre is expected to provide local residents, businesses, municipalities and state institutions with information about the natural assets of the reserve as well as about protection of natural resources and the use of innovative solutions in the regional development.

By now, a project of the environment-friendly building in the Biosphere Reservation (BR) on the north of Latvia (Vidzeme) has been accomplished. The solar collector is considered in view of using renewable energy for preparation of hot water and smoothing the heat balance of ground by heating it. The total area of solar collectors is: 18 m^2. Solar heat can be received during the daytime, and the greatest amount is receivable in the summer.

The heat of ground, starting with reach of freezing depth, can be used during the whole year. For example to receive 50 kW of heat power, 11 boreholes are to be drilled at depths of up to 100 m forming ground collectors, which would require ground works in the area of about 400 m^2.

The description of the technical solutions and functions of the equipment for heat production and micro-climate control are presented. The paper describes experience and practice of this Policy and Strategy in Latvia. The RES dealt with in the paper relate to the geothermal and solar energy in the Latvian conditions. The use of fossil fuel energy in the country is limited due to changing price policies of foreign providers. At the same time, RES play an ever increasing role in the Latvian energy balance. Nevertheless, besides objective factors, there exist such subjective factors as prejudices of the people who are lacking trust and confidence in new technologies and do not comprehend positive aspects of their use. All this retards more active use of RES in Latvia.

2. Introduction

Biosphere reservations have been established throughout the world, and their goal is to find economic and technological solutions in maintaining the balance between human activities and natural existence. Biosphere reservations are also education, research and scientific centres.

The Environmental Education and Information Centre building with an area of 675 m^2 were completed in 2009. The relevant project was funded by the European Economic Area and Norwegian Government Financial Mechanism. The Centre will serve as a model for the use of environment-friendly renewable energy. According to the project, the heating-and-cooling equipment was installed for geothermal energy use and solar collectors – for preparing hot water. Such systems are highly efficient, therefore they were selected with the aim to reduce the management costs of Environmental, Education and Information Centre.

Wind, solar, hydro energy as well as Latvian context can not be considered as the base capacity, the increase would now be regarded as energy policy priority. However, these resource-based capacity-building can play a positive role in reducing energy consumption of fossil fuels in the power plants, thereby increasing these curity of supply and reducing greenhouse gas (GHG) emissions.

Solar energy production profitability is much more distant in the future. Reliable information is available, that solar energy equipment manufacturers cost approach level that would allow this technology to become profitable. But it will take a long time before lower costs 'reach' equipment customers. Moreover, the same conditions (and, perhaps, that they are progressively closer to Europe), investors will be interested in at first of all to learn the potential of Southern Europe, where in some places every square meter of land during the year to about twice the energy of the sun, than Latvian. If true now as fiction, though seriously discussed projects on the Sahara produced electricity distribution in Europe by high-power direct current electricity, then maybe converted solar energy into electricity in Latvia will be achieved.

2.1. Solar radiation in Latvia

The duration of solar radiation depends on the season, climatic conditions in the region and its geographical position. The annual global radiation may rich 2200 kWh/m^2 on a horizontal surface in solar regions. In North Europe solar radiation is ~1100 kWh/m^2 on the average. Considering the quantity of direct radiation, the efficiency of heating system, losses, etc., Latvia can yearly receive 400 - 450 kWh per 1 m^2.

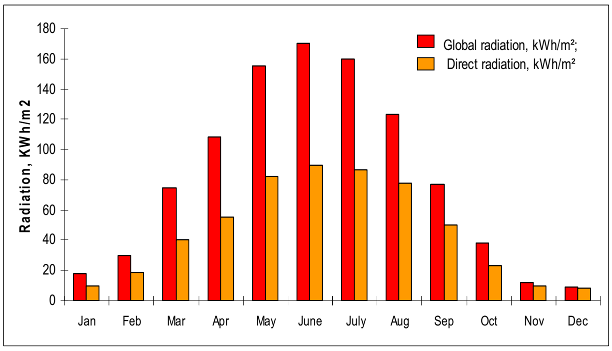

Fig.1. Solar Radiation in Latvia

2.2. Geothermal energy

Latvian territory the main geothermal resources are related to ground water at a temperature above 30 ºC, and the bedrock of hot rocks. The main of geothermal water horizon is the Cambrian sedimentary rocks of different ages, which are circulated throughout the Latvian territory and depth from 350m to2000m. Also, the groundwater temperature varies from 16 ºC to65 ºC

Under Latvian conditions it is possible to use for heat energy production such kinds of RES as biomass, the solar and geothermal energy. Solar heat can be received during the daytime, and the greatest amount is receivable in the summer. The heat of ground, starting with reach of freezing depth, can be used during the whole year. For example to receive 50 kW of heat power, 11 boreholes are to be drilled at depths of up to 100 m forming ground collectors, which would require ground works in the area of about 400 m^2. The same power could be obtained from the area of 2000 m^2 using 1-1.5 m deep horizontal collectors.

A highly important issue is protection of groundwater, since deep drilling of holes for laying pipes can damage the water horizons, city utilities, or soil into which refrigerant is discharged. Therefore, the designing and building works should be managed with much care. Also, attention should be paid to the heat carrier used, harmless substances, water, salts and alcohol liquids.

3. Heating and heat supply system

In creation of such a building it is important to choose among the technological solutions that would cause a lower impact to the environment.

In the project it is important to evaluate the technological solutions that would have the least possible impact on the environment at erection of the environment-friendly building while providing the needed comfort for the people. An additional heat exchanger implies the use of ground collectors for preparation of the refrigerant at temperatures 15-200C°. In the case a greater cooling capacity or lower refrigerant temperature is needed, a reverse heat pump should be used, which in a ground collector in winter receives heat whereas in summer returns the unnecessary heat in a cooling process. The first saving option is to reduce the rooms' pollution, and the second − to gain a more penetrating insight into the air circulation caused by energy consuming equipment. After the preparatory stage, a further logical step is choice of the mechanical ventilation with controlled air exchange, heat and moisture recovery.

With ever increasing number of alternative energy solutions related to the use of geothermal sources, the informational deficiency about thermo-physical properties of ground at a depth more than 5-10 m makes difficult the technically-economic substantiation of some projects. The most popular as to the operational principle of heat pumps is the compression type, because the relevant technologies have sufficiently been tested, so qualitative technical services could be rendered. Therefore it is reasonable to make a test borehole and, based on the results of testing, to determine the heat power to be derived from one hole. For this purpose, special measuring equipment is used, and the temperature variations are measured in series of overnight periods. Such measurements allow identifying more precisely the specific ground conditions and calculating the required number of vertical ground collectors.

The solar collector is considered in view of using renewable energy for preparation of hot water and smoothing the heat balance of ground by heating it. The total area of solar collectors is: 18 m^2.The larger solar collector surface areas provide the possibility to prepare hot water during a year or even during a day when the solar radiation is less than at its maximum.

The heating of buildings with wood seems to be the most economical and environment-friendly solution However, to achieve acceptable working conditions in modern office buildings also air cooling required for several months in summer. The ground provides an excellent opportunity to use the heat potential of both heating and cooling. Employing the heat pump principle, compression type for such a pump was selected, since the relevant technologies have sufficiently been tested, and qualitative technical service of the kind is now available in Latvia. To estimate the useful area around the building, vertical ground collectors have been built up.

As mentioned before, with increasing number of alternative energy solutions, which were used for geothermal resources, the technical and economic justification makes difficult the there was lack of information on the thermo-physical properties of ground at depths greater than 100 m see above 5-10 m. So it was necessary to make control drill holes and determine heat capacity of one hole. This was done by special measuring equipment. Have been measured changes of temperature in the number of overnight period. Such measurements allow identifying the specific ground conditions and calculate required number of vertical ground collectors.

Changes in the ground heat proceed very smoothly and the depth of 5 m, where sunlight effect is negligible, this implies a much longer time than a couple of months of the heating period. Therefore it is necessary to ensure a constant balance of heat in the winter taking heat from the ground, while in the summer − warming the ground. Otherwise, the layers of ground might be overheated or cooled down, so in a next season the heat pump would not work properly. Even high-capacity facilities require that heat records of ground collector and the temperature records be done in a balance sheet and properly controlled.

3.1 Ventilation system

According to the laws of the Latvian Republic, every person while in the premise has the right to at least 15 m^3/h of outdoor air. The simplest way to achieve this is to open a window; however, the outdoor air temperature and humidity are not always comfortable, so the indoor air should additionally be filtered, heated, cooled, humidified, drained, etc. First saving option is to reduce the area of pollution; the second is to find out the air flow exchange determinants. In this case to mechanical ventilation with air circulation control and heat (moisture) recovery would be the right choice.

Comparing the air-handling units with the equipment used for heat and moisture recovery, the savings in Salacgriva are up to 85% of heat energy.

Taking into account the technical capacity of ground heat pumps and in view of the energy demand for heat carrier transportation, the air handling units of reversal compression type of an air heat pump are now under built. With purified air heat from rooms is used to heat the outdoor air. In this way full autonomy and economy of the air-handling equipment is achieved.

The allowed temperature of coolant in a compression cycle is determined by the type of substance and its contraction rate. Higher temperature in the building engineering systems is needed because the compressor should create more pressure, which, in turn, the amount of heat required to produce electricity in quantities. Therefore, when the needed coolant temperature is to be above 50^{o}C particularly careful consideration should be given to the relevant solutions.

3.2 Description of the technical solutions and functions of the equipment for heat production and micro-climate control

The problem of power supply for the micro-climate control in the building and of the heat removal unit is solved by combining the functions of different thermal devices into a system in which one and the same thermal unit is able to fulfill various functions. The corresponding technical solution includes:

− convert the heat power received from the ground, with using a reversal multi-stage compressor and a vertical double U-like probe system. Eleven vertical thermal probes were drilled – 10 as planned in the project application, and one additional to ensure the capacity incorporated in the design.

− to use the heat-transfer liquids in the process of heat carrier flow power exchange;

− to exert proper control of the heat carrier flow temperature using three-way valves and temperature controllers;

− to use the circulation pumps for maintenance of heat carrier flow, the units ensuring safe operation of the system and hydraulic piping;

− to install the low-temperature re-circulation devices for controlling the micro-climate indoors, with a thermostat built in the air-water exchanger;

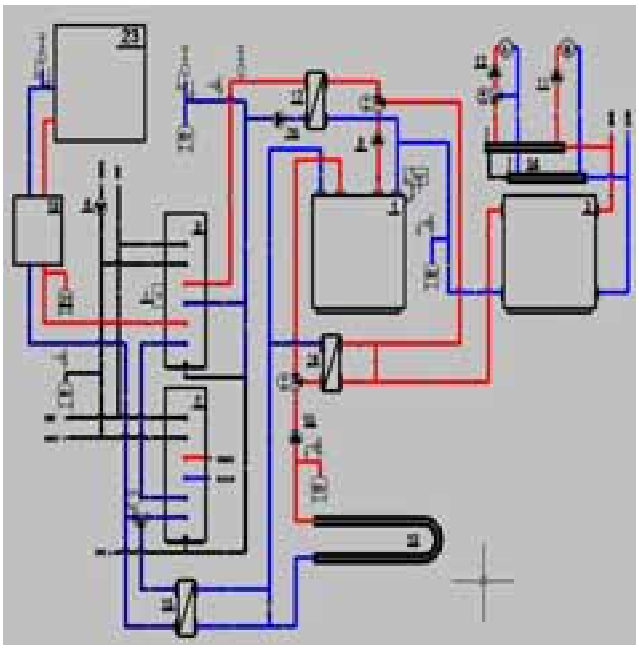

Fig.2. The heat exchange unit. The view of heat carrier flow in the cold period.

1. Heat pump, Q - 50 kW; 2. Accumulation tank, V-2000 L; 3. Hot water tank, V-300 l; 4. Hot water boiler with integrate electric heater, N-6kW; 8. Hot water arc circulating pump; 9. Primary arc heat circulation pump; 10. Secondary arc heat circulation pump; 11. Booster pump of building's heat supply system; 12. Circulating pump of floor heating system; 13. Ground probe collectors of heat pump secondary arc; 14. Primary arc heat distribution manifold; 15. Sensor of an outdoor air temperature; 16. Heat draining system's exchanger for unused heat accumulated by vacuum solar collector; 17. Hydraulic separator for hot water exchange systems; 18. Heat exchanger of "Passive cooling" heat draining systems; 19. Circulating pump station for solar collector system; 20. Hot water circulation pump; 21. Volume of expansion vessel (EV), 23. Vacuum solar collectors, 6 pieces, 3m^2. 24. CW - cold water; 25. HW - Hot Water; 26. HWC – Hot water circulation; 27. SDHC – Diesel Heating supply, 28. RDHC –Return diesel heating supply; 29. EHS - Existing heating and air-flow cooling systems' supply; 30. EHR - Existing heating and air-cooling systems' return supply.

3.3 Description of heat conversion and distribution process

In the cold season of a year as a heat source the heat power accumulated by the ground can be utilized. To collect this power a vertical probe system is constructed which, using the capability of heat carriers to transfer the geowarmth to a multi-stage compression station – to the heat pump. The temperature schedule of the fed heat carrier is not used for the building's heat supply since this temperature varies from -5ºC to +5ºC. Employing the unique properties of the cooling agent (Freon) in the ''Carnot cycle'' the temperature schedule at a direct pass of the heat carrier is extended up to 35 ºC - 50 ºC.

Using the building's heat distributing and transferring hydraulic system the indoor air temperature indicated in the normative acts. The main problem in this heat distribution and transfer process is comparatively small difference between the direct-pass and indoor air temperatures: from 15ºC to 30ºC. Based on estimation of various aspects of the system's operation the following has been established:

− a lower temperature difference between a heated surface and indoor temperatures seriously affects the quality of room climate control, while the process with changeable heat carrier possesses much higher inertia;

− the heat losses in the system decrease, since the temperature difference between the heat carrier and the indoor space is small;

As inference, the decision has been made to utilize air as the liquidation for heat exchangers. To speed-up the process of heat convective heat transfer the exchangers fitted with re-circulation flow fans were chosen.

In the calculations it has been revealed that the system's heat power consumption is non-uniform. Therefore in its working cycle an accumulation tank was added. Such a tank allows the multi-stage compression unit to be employed more rationally. The operational efficiency is increased owing to reduced number of switching on/off and working with constant consumption.

Under temperate climate conditions the heated area can be increased by 700 m^2. In the process of project realisation to the heat generating unit of the new building the existing building was connected. This made it possible to use the multi-stage compression unit more rationally; replacing the heat potentially generated by the diesel-fuelled boiler house by the heat power converted using the mentioned compression unit. Such a process is economically substantiated, since the results of calculation and comparison are in favour of the multi-stage compression unit.

3.4 Description of the building's ''passive'' cooling solution

After the first successful experimental session of heating the experiments were not stopped, since the system's configuration was to be performed that would allow using this system both for heating the air and for cooling it.

This solution was substantiated by a potential 200% improvement of the cooling/heating system's efficiency in the warm period. For this purpose a building structure was erected, with possibility to produce the amount of heat sufficient for warming water, which would allow interruption in the heat pump's operation in the warm season of a year.

When doing calculations and estimating the possibilities, it was decided to give up the idea of using the heat from the cooling process for preparation of hot water, because:

- owing to variable hot water consumption the air cooling system cannot be continuously cooled in the reverse motion;
- the payback possibilities for capital investments are estimated to be too slim.

In the warm period it is possible to equally well remove heat from the building using the vertical probe system designed for heat power collection. The temperature amplitude of the heat carrier in the direct pass is from +5 ºC to +10 ºC. The basically devised solutions of the heating system were supplemented by:

- one heat exchange unit, which separates hydraulically the ground loop from the heating/cooling system of the building;
- enhanced flow circulation owing to a circulation pump installed in the primary cycle of the heat pump;
- separation of the heat carrier flow from the hot water preparation system. This function in a warm season is fulfilled by the collectors accumulating the solar heat;
- replaced control and handling system.

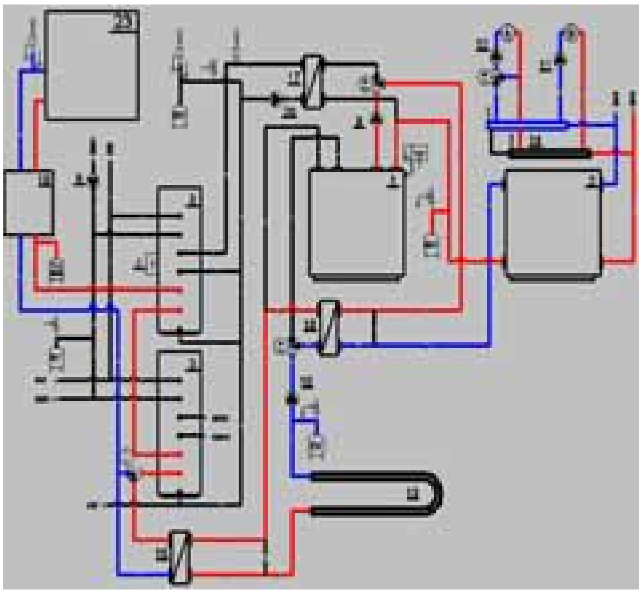

Fig.3. The heat exchange unit. The View of heat carrier flow in the warm period.

The devices for the building's micro-climate control (re-circulation air heaters) can equally well fulfill the functions of air cooling in the warm period of a year.
The heat carrier temperature graph varies from +7 ºC to +12 ºC, and in the reverse motion – depending on the accumulated heat power (while not exceeding +18 ºC.) The necessary air temperature in the rooms can be achieved by raising the efficiency of re-circulation airflow fans of the devices for the building's micro-climate control. In so doing, the noise produced by these control devices has been estimated. The noise measurements were performed using the chosen portative measuring apparatuses. The results obtained confirm that the LVS CR 1752 requirements are met. The noise measurements were preventive measures of informative character.

In 2010, the new building's cooling system preserving at the same time the multi-stage compressor ''Carrier'' installed in the 90-ies. In that season it was not necessary to use the existing compression equipment. The COP (coefficient of performance) was improved from ~2.7 up to ~ 9.9. The necessary calculations have been performed and the electricity consumption by the air cooling system compared for two seasons. The proposed technical solution considerably reduced the electricity consumption for the micro-climate control in the building.

Energy savings through compression modular equipment were used in the reverse cycle heating of the building and solar collectors − for hot water production up to 90 MWh/ year. As a result, the following was achieved:

- CO_2 reduction (taking fossil fuel use as the basis) − 56.6 tonnes / year.
- Number of holes drilled for space heating and cooling − 11;
- Solar collector's area for production of 500 l hot water − 18 m^2.

4. Calculation

According to the laws and regulations of Republic of Latvia LBN 003-01 „Construction climatology", the solar radiation on various oriented surfaces in the clear weather in July was estimated per hour for a solar collector to be ~550 W/m^2.

The maximum heat power per hour, which results from the use of the solar collector, is 18 m^2 x 0.9 (η) x 550 W/m^2 ~ 8.9 kWh, with η (the solar collector efficiency) reaching up to 90%.

Heat losses in the heat transfer system are negligible and not taken into account in the calculation.

The capacity of tanks for hot water preparation tanks is

$$2 \times 300l = 600l \text{ (eq. 1)}$$

It turned out that the 200 l hot water tank is not sufficient for the staff. It is agreed to increase its capacity by 100 l for the needs of existing building. The new task for a designer of the new building implied that it is necessary to set the water consumption up to 0.6 m^3/h.

The cold water temperature is assumed to be 10 °C, which is to be raised to 55°C for the needs of hot water use. The temperature difference is thus Δt = 45 °C.

According to the regulatory act LBN 221-98 "Building internal water-supply and sewerage" of the Latvian Republic (item 34), the heat for warming 600 l of water to 55 °C is

$$1.16 \times 600\mathrm{l} \times 45\,^{\circ}\mathrm{C} + 0 = 31.32\ \mathrm{kW} \text{ (eq. 2)}$$

Lastly, the time required to warm this amount of water to 55 °C is

$$31.32\ \mathrm{kW} \div 8.9\ \mathrm{kWh} = 3.5\ \mathrm{h} \text{ (eq. 3)}$$

The calculation does not imply to raise the hot water consumption.

Heating:

$$\sum \mathrm{T} = 205\mathrm{d} \times 24\ \mathrm{h} = 4920\ \mathrm{h} \text{ (eq. 4)}$$

$$\mathrm{Q}_{\text{heating/hour}} = 23.5\ \mathrm{kW} \text{ (eq. 5)}$$

$$\mathrm{Q}_{\text{heating/year}} = 115\,620\ \mathrm{kW} \text{ (eq. 6)}$$

The annual electric energy consumption for heating and ventilation compression cycles (heating pumps).

$$\sum N_{year} = Q_{heating/year} : COP = 36\,135 \text{ kWh} \text{ (eq. 7)}$$

Heat supply system devices using electricity:

$$N_{total\ annual} = \sum N_{yearly\ for\ ventilation} \text{ kWh} + \sum N_{yearly\ for\ heating} \text{ (eq. 8)}$$

Electric energy price= 3692.35 € per year.

Diesel fuel heat supply system devices:

$$\sum Q_{year} \times x1000 \div \eta_{efficiency\ of\ heating\ boiler} \times \mu \times 1.163_{\ annual\ costs\ of\ diesel\ heating\ capacity} = 16.8 \text{ m}^3$$

$$N_{total\ per\ year} = 10039.78 \text{ EUR per year} \text{ (eq. 10)}$$

To avoid overheating of the system, a heat exchanger has been designed for extra heat removal, which is connected to the ground manifold. The heat exchanger has a power exceeding 10% of the solar heat capacity. Using a hot water tank and heat extraction system it is possible to balance the system.

This system functioning also provides the possibility, to return the soil part of the thermal power, which is consumed in the cold period.

5. Conclusion

As a result of the work the recommendations for the effective and rational use of RES have been prepared.

The realized project made it possible to clarify the main important aspects of heat pump use, such as:

- protection of groundwater and communications,
- ground heat energy balance over the years,
- efficiency of a compression cycle,
- prospects of heat pumps in view of technological development .

The Environmental Education and Information Centre fulfilled its function as to promoting the state's comprehension of the importance of the RES use. Investments involved in the project were an economically viable option; besides, the realized project helps to reduce the yearly maintenance costs.

As a result of the project it has become clear that the energy independence of Salacgriva from imported energy resources is an invaluable and nationally important issue, which could be as a model to several European Union countries.

The project also includes informational events that promote the advantages of using renewable energy for heating; this especially concerns heat pumps in combination with solar collectors.

6. References

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