Utilization of Solar Combisystems in Latvian conditions

Peteris Shipkovs[1], Andrejs Snegirjovs[1], Lana Vasilevska[2] and Martins Vanags[1]

[1] Institute of Physical Energetics, Energy Resources Laboratory,

Aizkraukles Street 21, LV-1006, Riga, Latvia

[2] Riga Technical University, Azenes Street 16/20, LV-1048, Riga, Latvia

[*] Corresponding Author, shipkovs@edi.lv

Abstract

Solar thermal systems in combination with another auxiliary heat resources help to avoid solar thermal systems deficient.

The general aim of the paper is to explore solar systems combination with different secondary fuels – biomass, natural gas, heat pump and electricity. To achieve the objectives are being carried out in a realistic analysis of the objects in the Latvian territory. The measurements and processed data were performed to determine the suitability of the particular combination of Latvian conditions - advantages and disadvantages.

The good example of solar energy use is a heating system of an information building of the North Vidzeme Biosphere Reserve that is combined from solar collectors and heat pump (with 11 holes). Is used solar collectors site at the Institute of Physical Energetics (IPE) solar energy polygon, which gives very accurate data about solar energy using in Latvia. Are used data from a similar pilot projects.

Simulation program for solar combisystems helps to fully capture the data of analysis. Certainly important factors in determining the effectiveness of the combination are their construction and operating value. Solar thermal systems output is affected by solar radiation availability in Latvia environment.

In the paper are given results, various recommendations and few suggestions on effective solar energy use in the high latitudes.

1. Introduction

Latvia is located at the eastern part of the Baltic Sea. Latvia is bordering Estonia to the north, Russia to the East, Belarus and Lithuania to the South and the Baltic Sea to the West.

Latvia is located between the latitudes of 55^0 40´ and 58^0 05´North and the longitudes of 20^0 58´and 28^0 15´East. The area of Latvia is approximately 63,700 km^2. The elevation is up to 200 m above sea level. Along the Baltic Sea the climate is mostly coastal climate with mild winters and chilly summers. In the eastern part the summers are warmer and the winters colder. The relative humidity is rather high and the weather is often clouded.

Fig. 1. Location

Latvia is not rich in natural energy resources. Renewable energy resources (RES) take an important place in Latvian primary resources in the energy balance (Fig.2.).

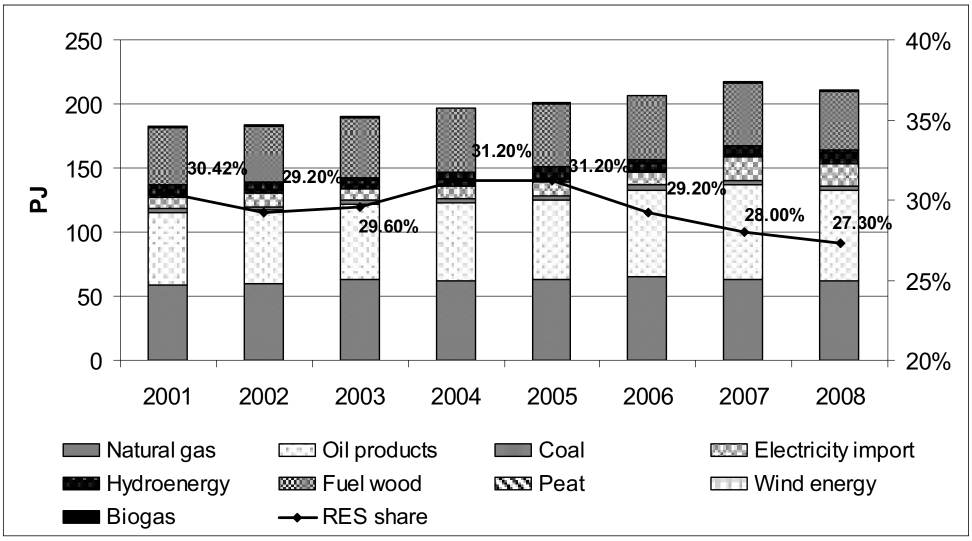

Fig. 2. Dynamic of primary resources consumption and RES share in Latvia

Positive changes are observed in the structure of total consumption of primary energy resources, owing to the increasing consumption of domestic energy resources.

In Latvia, wide investigations and demonstration projects should be continued concerning all the types of renewable energy resources and solar energy including, since only by this strategy it is possible to put in order the priorities under Latvian economical conditions. So far, solar energy in Latvia has been used for warming water and drying farm products already in 70s. The duration of solar radiation, when the use of solar collectors is maximum profitable in Latvia is 1700 –1900 hours per year. The solar radiation in our latitudes of the northern semi-sphere varies depending on the season: from May till September there can be obtained 700- 740 kWh per 1 m^2 of a solar collector, from October till April – 200 –240 kWh per 1 m^2, while from November till February - 40-50 kWh per 1 m^2 of a solar collector. [2]

Intensive utilization of solar radiation energy in the zones of high latitudes – e.g. the Baltic States - is actually possible only during six months from April to September, while the remaining months of the year are deficient in solar radiation energy (SRE) and its utilization is not so effective. Certain conditions are actually now in Latvia, which make it more suitable to build a solar heating system and certain situations that are especially worth drawing advantage of:

- High hot water consumption during the summer. This means houses and institutions such as hospitals, rest homes, schools are best suited if there are activities during the summer break;
- Expensive heating such as electrical heating, oil or gas;
- New building, where solar heating will be drawn in to the building plans from the beginning.

Taking in account that the solar collectors give the possibilities to cover up to 2/3 of hot water production on a yearly basis for family house and financial aspects of the problem (the payment of hot water preparing in consumer's bills of the total household services takes the rather big part – up to 10 – 20 %) this strategy is very important for Latvia. Using solar heating system in the summer period the oil furnace, gas or electric boiler could be shut down because the solar heating system will produce all necessary hot water. Furthermore the solar heating system could be connected with oil furnace, natural gas, electrical heating, wood boiler and heat pumps. [4]

2. Realized project of the environment-friendly building in the North Vidzeme Biosphere Reserve

The Environmental Education and Information Centre building with an area of 675 m^2 have been renovated in 2009. The Centre serves as a progressive model of environment-friendly renewable energy use. The equipment of heat pumps for geothermal energy use for space heating and cooling, as well as solar energy collectors – for hot water were installed in the frame of project. Such systems have high efficiency and this option was selected with the intention to reduce the environmental impact and to decrease management costs. Energy savings through compression modular equipment using with reverse cycle heating in building and solar collectors for hot water production is 89.9 MWh /year and CO_2 reduction (if taken as the basis of fossil fuel use) - 56.6 tones / year. Number of holes created for space heating and cooling is 11 and solar collectors' area for hot water production is 18 m^2.

It is important in constructing a building to evaluate the solutions that technology to create the smallest possible impact on the environment while providing a needed benefit to the people. Installing additional heat exchanger may use the ground collectors for cooling refrigerant preparation in range 15-20^{0}C. If there is a need for greater cooling capacity or lower refrigerant temperature, then have to choose reverse heat pump, which in ground collector in winter receives heating, but in summer return in cooling process created unnecessary heat.

First saving option is to reduce the rooms' pollution; the second is to understand the air circulation caused by energy consumption determinants. For example, in order to reach 50 kW of heat power would to construct 11 vertical ground holes collectors, each 100 m deep drilling, which would require ground works in area approximately 400 m^2. The same power as horizontal collectors from 1 to 1.5 meters deep, occupy 2000 m^2. With increasing of alternative energy solutions, which are used for geothermal resources, technically economic motivation makes difficulties of information deficiency about thermo physical properties of ground depth deeper than 5-10 m.

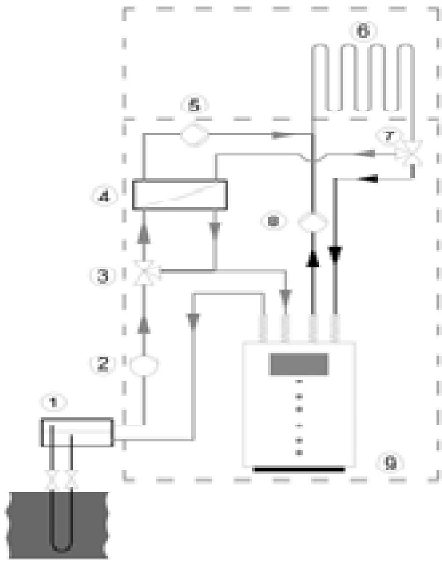

Fig. 3. Simplified scheme

1.A ground heat probe and collector well; 2.Primary circulator pump; 3.Three-way valve switching arrangement, heating / cooling; 4.The cooling heat exchanger; 5.Cooling circulation pump; 6.Heating circuit of the building; 7.Three-way valve switching arrangement, heating / cooling; 8.The secondary circulations pump; 9.Heat pump.

In the scheme are not shown heating accumulation tank, solar collectors and hot water heating tank, reserved connection to existing heating boilers

Very important issue is protection of groundwater, because by the deep drilling of holes for pipe lying can be damaged water horizons, drilled city utilities, or damage to soil can be discharged refrigerant. Therefore, with special care must be managed design and built works. Accountable in situations as a heat carrier used for human maintenance, harmless substances, water, salt and alcohol liquids.

This system is very effective. It has minimal CO_2 emissions. Independents of others energy providers (except electricity) make this system more prepossessing. In the end this system is environmentally friendly.

But it has several cons: System is very expensive and too difficult and complicated from engineering and usage aspect. Nature around deep drilling place will be damaged. Problem is that Latvia has not enough possibility to use ground heat.

3. Project of Aizkraukle Secondary school

As an integrated part of the project “Thermal Solar collectors at Aizkraukle Secondary School No.2” a general feasibility study for the possibilities of using thermal solar energy in Latvia were worked up by the IPE.

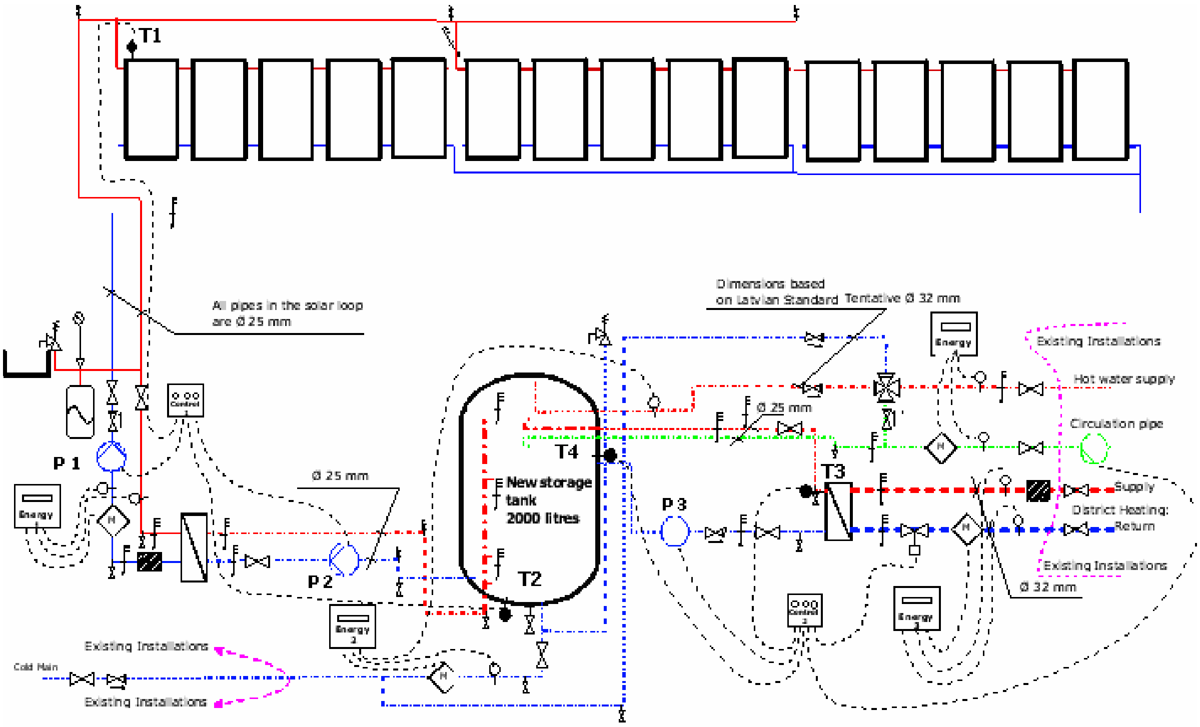

Fig. 4. Principle scheme of heat supply system at Aizkraukle Secondary School

Solar collectors deployed at Aizkraukle Gymnasium and at the boiler house roof, with an area -153 m² of solar collectors: 33 m² on the gymnasium roof and 120 m² of the boiler house roof is the largest in the Baltic States. On the school roof placed 15 collectors in the same row, oblique (45 °) to the south facing, so they are able to perceive the sun's rays from sunrise to sunset. In optimum meteorological weather, both collectors of Aizkraukle district heating system produce heat up to 70 kilowatts, which is 3% of the total urban heat load during summer. It's enough to supply hot water for a five-story apartment house, but the benefits of solar energy heat production are highly dependent on weather conditions.

CO_2 emission reduction and school student’s environment friendly thinking are the biggest advantages of this system. While solar collectors area is large scale (certainly accordingly heat loses), due to type of scheme this project is the most effective thermal Solar system in the Baltic States.

3.1. Capital costs

A large part of the total costs of an active solar system consists of marketing expenses, as the systems will be sold one by one and also because the market is so little. The costs of solar water heating systems are often considered to be the major barrier to the development of the solar heating market. However it has been found that this barrier can be reduced through bulk purchasing. In addition, two recent market studies have shown that there are other barriers, which have to be recognized, and which can be turned into market opportunities. Collectors' costs today are partially influenced by manufacturing techniques that are often small-scale and can benefit from automated production. The life-cycle of currently available solar systems approach 25 years. Even at lower life-cycles of 10 years, today's solar heating costs in some markets are already comparable with fossil fuels, whereas in other countries the costs are up to twice as expensive, depending on the climate, market structure, and taxes on fossil fuels. One important condition for lowering solar energy use equipment costs is international trading. Market barriers need to be removed and international standards and codes developed, helping to internationalize and rationalize the trade in solar equipment. [3]

Table 1. Initial costs expressed in percentages and estimated life of solar heating system. [3]

Equipment	Estimated life	Initial costs
Solar collector	20 years	30-50%
Piping and insulation	More than 20 years	25-30%
Storage tank	10-20 years	20-25%
Auxiliary equipment	10-20 years	5-10%

In accordance with the variable parts in Tariff structure it will be calculated the new heat tariff for consumers. In Latvian climate conditions the energy savings of each m^2 of solar collector could be 360 - 400 $kWh/m^2/year$. [3]

4. Modelling of Solar combisystems in Latvian conditions

In order to determine the share of heat derived from solar energy in the total consumption in a house, a building model has been designed using the modeling program Polysun 3.3. The combisystem – solar system and auxiliary (electricity and biomass) has been modeled. The calculation basis in Polysun 3.3 program has been formed using Meteonorm 95 subprograms. In this subprogram was introduced data about weather, wind and solar radiation from Institute of Physical Energetics. [1] This allowed the computer modeling of buildings located in different climatic zones thus making it possible to compare the specific weight of solar energy for different climatic zones and conditions in the EU/EC countries.

One-family building was initially modeled with a floor space of 150 m^2 for 4 persons. The heat losses through the bounding structures of a building (external walls, roof, windows, etc.) make up a considerable share/part in its total heat energy balance.

Table 2. Heat energy consumption for space heating depending on the location, kWh/m2 per year and The amounts of solar heat

Location	Total heat energy use for space heating (kWh/year)	Heat energy use per (1) m^2 (kWh/m^2 /year)	Solar heat received from one m^2 of collector (kWh/year)
Riga	12650	85	400
Liepaja	12500	80	418
Daugavpils	13615	92	395
Bremen	9652	65	366
Boden	27342	182	360

As in the building four persons are living and it is known that energy supply for one person is provided by 2 m^2 solar collector, then for the building 8 m^2 area of flat-plate collectors are needed.

As was revealed earlier, a solar collector is operating most efficiently when the slope/inclination to the horizon is 55° and to the south − 0°. We therefore placed the solar collector modules vertically. We estimated the position of solar collector modules along the vertical, with the horizon assumed to be clean, without shadows cast on the absorber area of collector. After that we were able to define the thermal conductivity and thermal capacity of the collector pipes, as well as the velocity of the air/heat carrier flow value in them. At determination of a combined solar heat supply system's efficiency of importance is the heat carrier data of the solar collector used. In combined heat supply solar systems water are excluded as heat carrier in the external circuit and glycol to be used instead.

The amount of heat needed for preparing hot water (which in all climatic conditions is nearly identical) is 4069 kWh per year. It follows that it is impossible to unambiguously state that solar collectors work more efficiently closer to the south and less efficiently towards the North. As it seen, the most efficient collector is located in Riga but not in more southern Bremen, as could have been suggested previously. This is explainable with a smaller demand of the system for space heating, since within a year's time for all models the amount of heat for hot water is equal to the heat losses in the tank capacity. In the year period when the heating of a house is required while the available amount of solar energy is sufficient not only for hot water but also for space heating, a full-value use of the combined system can be observed; such periods are longer for the northern models, therefore the amounts of the solar energy used are greater.

Solar collectors can provide the necessary heat during the summer months, since the space heating is not needed in summer, and is needed only for warming water. It is important that solar collectors of the Riga's model produce practically the same thermal energy in a building heat balance as those in Bremen. To be more precise, solar collectors in the former model produce more heat energy than in the latter, while heat losses of a building are greater in Riga. The decrease in the amount of heat necessary for space heating reflects not only the amount of the total heat used but also partly the not received amount of solar heat. In turn, the amount of solar heat used for warming water is growing, because a greater amount of solar heat is available, and, therefore, the share of the solar heat energy in the total balance is also greater. The important conclusion is that during the cooler months (November, December, January, and February) the amount of received heat is minimal and very similar in all the considered models. Consequently, during those months a combined solar heat supply system is less useful.

5. IPE Solar Energy Testing Polygon

The Institute of Physical Energetics is the leading institute for solar energy research and development in Latvia.

A testing polygon has been created n the roof of IPE for the investigations of solar energy use, which consists of the following four large parts:

- A system for solar collectors testing;
- An autonomous system for testing solar photo-voltaic (PV) elements;

- Quasi-autonomous system for testing PV elements;
- Measuring equipment for solar radiation parameters and weather conditions.

5.1. Solar collectors testing system

The system for testing solar collectors consists of seven solar collectors, accessories, monitoring devices, control system's devices, and a heat accumulator. Each solar collector possesses its own separate frame capable of changing its slope to the horizon. The installed collectors are: five collectors of the popular producers and two self-made collectors. From each collector a pair of tubes is extended, which forms for it a separate heat carrying loop. A collector's loop contains a circulating pump, a heat meter, a bidirectional valve with drive, and a balance valve. For automatic pump operation, in the forward and backward directions of each collector's loop temperature sensors are arranged. Similar arrangement is provided for the meters and driven valves. At the heat accumulator the forward tubes of all the loops meet in one tube. The same occurs with the backward tubes. Near the heat accumulator a common heat meter is installed. The monitoring and control of the solar collector system is performed automatically with the help of controller.

Solar collectors testing system gives possibilities to determine the better technical solutions for solar energy use for heating in real weather conditions and to provide different kind of investigations associated with the solar energy use.

6. Conclusions

The realised Latvian pilot projects and simulation data show that Latvia is a very suitable environment for the solar system operation. The Solar energy use could give in energy balance of household up to 17 % of the total heat energy consumption.

Latvia is an opportune country for varies environmentally friendly projects taking in account deficiency of own fossil fuels. Good experience of RES use shows that Latvia has a lot of potential for the realisation of the new projects especially using combined systems – RES and fossil fuels.

The life cycle of currently available solar systems approach is up to 25 years. Even at lower life-cycles of 10 years, today's solar heating costs in some markets are already comparable with fossil fuels.

The efficient solar thermal technologies that are on today's market highly reliable should be used for the new projects in high latitudes weather conditions.

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