# Investigation of Solar Collector systems use in Latvia

P. Shipkovs[1,*], K. Lebedeva[1], G. Kashkarova[1], L. Migla[2], M. Pankars[2]

[1] Institute of Physical Energetic, Energy Resources Laboratory, Riga, Latvia
[2] Riga Technical University, Riga, Latvia
* Corresponding author: Tel: +371 67553537, Fax: +371 67553537, shipkovs@edi.lv

**Abstract:** Solar energy is the biggest energy resource on the earth. Latvia environment is very potential for solar usage, but there are many reasons why consumers have skepticism and a perception that the environment in this region is not suitable for solar energy usage.
To have broken this stereotype, this study is conducted. The aim of this program is to explore the suitability of Latvian environment with the use of solar collector. For the attainment of objective monotype house will be modeled, the house will be equipped with the combined solar heat system, which will be placed in different regions. There are various amounts of sunny days in different regions, as well as diverse average temperature, wherewith the amount of heat differs. For the modeling of building, modeling program model of solar collectors will be used, which is provided for several solar heat systems, inter alias for the calculation of combined solar heat supply system and for the solving of several relevant tasks. Program is simulation program for the thermal solar energy systems. It suits both for determination of hot water use and heating system use.
There are countries which are located in sunny regions and which history of solar energy usage is very longstanding, wherewith also technological achievements are high. Yet our contemporary rapid technology development enables to use ever more solar energy in the regions which are not so rich with the solar radiance, for example in Latvia. Interest about the usage of solar energy in Latvia increase – partly it is explicable to unpredictable and essential price rise of fossil firing resources and partly to the desire to invest in technologies which could reduce this rise in price in the future.

***Keywords:*** *Modeling, Simulation, Solar Energy, Renewable Sources, Combined systems*

## 1. Introduction

During last few years significance of environmental problems increase. Wherewith, activation of environmental problems increases humans' interest about different environmentally friendly technologies. One of the biggest air polluters are fallouts resulted from burning of fossil firing. That is why urgent becomes utilizations of renewable resources for the energy obtaining, which are less nocuous to environment. Latvia's total final energy consumption is secured from local energy resources and the flow of primary resources from Russia, the CIS countries, the Baltic countries, EU and other countries. Currently, three types of energy resource making up approximately equal proportions dominate in the delivery of Latvia's primary resources – oil products, natural gas and wood-fuel. Like many other European Union countries, Latvia is dependent on i mports of primary resources. The share of RES has traditionally been significant in Latvia's energy supply and in 2008 it comprised 29.9% of the total final energy consumption. Interest about the usage of solar energy in Latvia increase – partly it is explicable to unpredictable and essential price rise of fossil firing resources and partly to the desire to invest in technologies which could reduce this rise in price in the future. That is the reason why is it n ecessary to investigate solar energy potential in Latvian conditions.

Global radiance consists of direct and diffused radiance. Direct radiance is connected with the direction of sunbeams. Diffused radiance develops when molecule and particles in atmosphere disperse sunbeams in all directions. The duration and intensity of solar radiance depends on s eason, climatic conditions and geographical location. Global radiance of the earth on the horizontal area in the regions of solar zone may reach 2200 kWh/m$^2$. Maximal volume of solar radiance in North Europe is 1100 kWh/m$^2$. We can conclude that even in such small country as Latvia are several different solar sliding duration zones. In the zone along the Baltic Sea is the longest solar sliding duration – more than 1900 hours, in its turn in Vidzeme heights it is the least – less than 1700 hours. Volume of Solar radiance is the main factor of solar energy usage in Latvia. [2]

## 2. Methodology

In order to define, how great volume of heat from building total use of the heat is possible to secure using solar heat energy, the model of the building will be created using modeling program. With the help of this program it is possible to carry out research, the modeling, the calculation of heat supply solar systems. Simulation of all type heating supply solar system is based on independent meteorological data. Time step of simulation is possible starting with one second even until one hour, it depends on situation, in its turn, there are a lot of versions of model simulation time periods – starting from one day until several years. The calculation basis in program has been integrated from subprogram Meteonorm. Using preferences of simulation program have been cleared up most effective location for solar collector in Latvian conditions. Comparatively, effective solar radiation may catch solar collector that is placed 55° anent to horizon or slope and 0° anent to the South or orientation and which has clean horizon, nothing puts a slur and otherwise do not affect the activity of collector, that is why received amount of solar heat takes as average from all models that are placed in corresponding place and location. However first of all foreseeable tables has been made. Data about the volume of receivable heat from 1 $m^2$ solar collector that depends from location, to be more precise in what angle as to the ground it has been put and in what orientation as to the South solar collector will catch the greatest volume of heat, has been put in the table.

*Table 1. Percipient heat volume from 1 $m^2$ of solar collector in Riga dependence of location, $kWh/m^2$.*

| Orient. \slope | 0° | 15° | 30° | 45° | 55° | 60° | 75° | 90° |
|---|---|---|---|---|---|---|---|---|
| 0° | 259 | 325 | 382 | 417 | **426** | 425 | 401 | 348 |
| 15° | 259 | 320 | 376 | 412 | 422 | 423 | 406 | 359 |
| 30° | 259 | 325 | 380 | 412 | 417 | 414 | 385 | 324 |
| 45° | 259 | 310 | 362 | 396 | 407 | 408 | 395 | 357 |
| 60° | 259 | 322 | 370 | 396 | 397 | 393 | 358 | 294 |
| 75° | 259 | 297 | 341 | 370 | 380 | 381 | 370 | 335 |
| 90° | 259 | 314 | 355 | 373 | 369 | 363 | 325 | 262 |

Such location is the most effective and in the table 1 there are the same data, then we can conclude that program is comparatively precise for the calculation in the Latvia conditions. The least received heat volume is when the solar collector is located 0° anent to the Earth horizon. This location is the most inappropriate for the detection of solar radiance. To 0° anent to horizon at any orientation, the volume of received heat is constant, because ray angle falling form the Sun anent to the area is constant at any orientation of solar collector. In the Table 1 it is clearly seen how volume of received heat change and its changes are twice as much bigger. Therefore the precise setting up of solar collector has significant meaning. Although this calculation was done only for one type collectors, though the calculation corresponds to previously defined, we can conclude that in wholesale it is similar to all collectors.

The collector efficiency mainly depends on the difference between the mean collector temperature and the ambient temperature *Tm - Ta*. If this difference is high then the heat radiation and the convection losses are high. At small temperature differences the efficiency can reach 90%. If the mean collector temperature drops below ambient temperature because of a cold heat transfer medium then the efficiency can exceed even 100%. In this case the heat transfer medium is not only heated by the sun, it's also heated by the ambient air. [1] The efficiency is described by the efficiency curve. The temperature difference (*Tm - Ta*) divided by the irradiation normal to the collector (*Gk*) is the variable (*x*).

$$x = \frac{Tm - Ta}{Gk} \quad (1.)$$

Following a typical efficiency curve of a regular glazed flat collector:

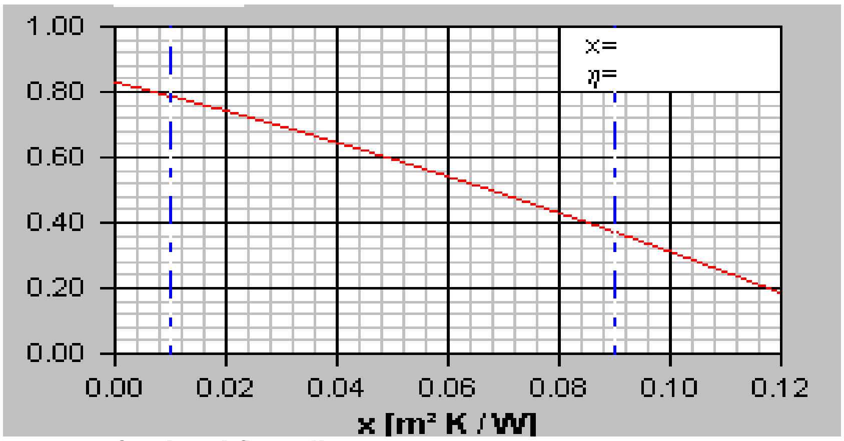


*Fig. 1. Efficiency curve of a glazed flat collector.*

The higher the mean collector temperature lowers the efficiency. The irradiation is 800 W·m$^{-2}$. This curve is described by a 2nd order Polynom with sufficient accuracy. This Polynom is clearly defined by three parameters, $c_0$, $c_1$, $c_2$ (or $a_0$, $a_1$, $a_2$; values measured under wind speed of 2-4 m·s$^{-1}$):

$$\eta = c_0 - c_1 x - c_2 G_k x^2 \quad (2.)$$

where $\eta$ – efficiency of collector; $c_0$, $c_1$, $c_2$ – coefficient of polynomial set in model; $G_k$ – tightness of solar radiation, that falls athwart to the surface of collector,

The efficiency value amounts to $c_0$, if the mean collector temperature and the ambient temperature are equal. This value should be high. $c_1$ and $c_2$ describe a combination of different loss factors. These values are low if a collector is well insulated. It is worth to mention that such polynomial is used in modeling program for the calculation of efficiency. [1]

## 3. Results

Since program isn't potted to the conditions of Latvia, there isn't meteorological data, which are necessary for activity simulating of the combined heat supply of solar system in the Latvian conditions in its data basis. Since this program contains meteorological data from all world, in order to get this necessary information, accurate coordinates from different towns of Latvia, which are located in different zones of sun shining: Riga, Liepaja, Daugavpils has been entered. For the more visible efficiency determination of heat supply solar system, also coordinates of typical sunny south city Bremen (Germany) and cool northern city Boden (Sweden). Wherewith, computer models will be created for different climatic zones and conditions in the European Union countries.

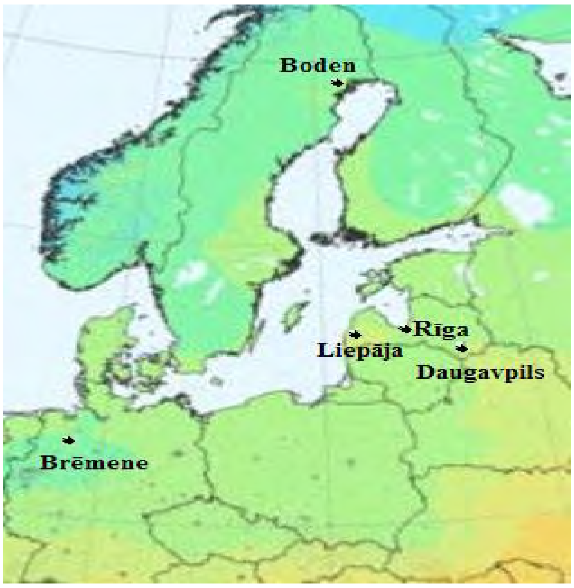


*Fig. 2. Locations of cities that are used for modeling*

Those data of communities that are used for the modeling of combined solar heat supply system are shown in table 2.

*Table 2. Meteorological data for Meteonorm*

| Place of location | Latitude | Degrees of longitude | Elevation above sea level, m |
|---|---|---|---|
| Riga, Latvia | 56,88° | 24,13° | 14 |
| Liepaja, Latvia | 56,49° | 21,02° | 1 |
| Daugavpils, Latvia | 55,87° | 26,52° | 105 |
| Boden, Sweden | 72,80° | 12,58° | 121 |
| Bremen, Germany | 65,78° | 21,67° | 31 |

Initially model one family building with the floor space 150 m$^2$, 4 persons will live in that building. Heat loss through demarcation constructions of building (external walls, roof, windows etc.) makes essential part form total use of heat energy. Power efficiency of demarcation constructions is able to evaluate when thermal coefficient of given construction is U (W/m$^2$·K). Because in Latvia there is relatively cool climatic conditions, than building must be well isolated with heavy constructions. Walls are made from bricks and from outside they have 0.2 m heavy insulation. Air exchange 0.6 l/h, and radiant 400W. Require heating capacity 6.1 kW at -8°C. Looking closely at balance sheet of used and acquired heat of each place we can conclude that in all chosen places development of heat use during year is similar, only volume of heat differs.

*Table 3. Heat energy consumption for space heating depending from location, kWh/m² per year.*

| Place of location | Common use of heat energy for room heating (kWh per year) | Use of heat energy for room heating on 1 $m^2$ (kWh/$m^2$ per year) |
|---|---|---|
| Riga, Latvia | 12 650 | 85 |
| Liepaja, Latvia | 12 500 | 80 |
| Daugavpils, Latvia | 13 615 | 92 |
| Bremen, Germany | 9 652 | 65 |
| Boden, Sweden | 27 342 | 182 |

In warmer climatic zone use of thermal energy reduces. Because Bremen is located closer to equator and its average temperature is superlative for all viewed cities, for that reason required volume of thermal energy is the least. Yet looking closely at Boden, which is located close to the North, it is contrary. Distinction among Riga, Liepaja and Daugavpils brings about location of those towns' towards the sea. Temperature at the sea in winter is warmer wherewith volume of thermal energy for room heating is different, yet towns are located relatively close to each other, wherewith volume of thermal energy is not very different. As in the building lives 4 persons and it is known that on one person provides 2 $m^2$ solar collectors, than for the building model use 8 $m^2$ flat area collectors. Previously we found out that solar collector works most effective when its slope angle is 55°C anent to horizon and 0°C anent to the South. We estimate position along vertical of solar collector modules. Wherewith, we can define thermal conductivity and thermal capacity of pipes, as well as the stream speed in pipes. Pump and system described values are calculated automatic after input of necessary data. In this case inputted values are the following: flow of pump, flow speed of their process 120 $l \cdot h^{-1}$ and back process 0, 06 $m \cdot s^{-1}$. Also one more important parameter of efficiency determination of combined solar heat supply system is heat carrier data of used solar collector. Usually water is used like heat carrier, due to its availability, low price and suitable physical qualities. In combined heat supply solar systems, water can be used only in the inner supply of heat and water. For the very reason in Latvia conditions pipes are excluded as heat carrier in exterior contour. Therefore glycol solutions must be chosen as the heat carrier in pretence model. Necessary volume of heat for the preparation of hot water in all climatic conditions is nearly identical 4069 kWh in a year. In some places suspended volume of solar heat is different.

*Table 5. Perceptive solar heat volume, kWh/in a year.*

| Place of location | Common use of heat energy for room heating (kWh per year) | Use of heat energy for room heating on 1 $m^2$ ($kWh \cdot m^{-2}$ per year) |
|---|---|---|
| Riga, Latvia | 3 200 | 400 |
| Liepaja, Latvia | 3 345 | 418 |
| Daugavpils, Latvia | 3165 | 395 |
| Bremen, Germany | 2930 | 366 |
| Boden, Sweden | 2890 | 360 |

It is not possible to unequivocal assert that solar collectors works more effective closer to the South and to the North they do not work effective. The most effective works solar collector that is located in Riga and not the solar collector in Bremen that is closer to the South. It is explained by the less requirement of system for heating, because during the year in all models the volume of warm water for the preparation of hot water and containers heat loss is equal. In a period when heating is necessary but available volume of solar heat energy is sufficient not only for the preparation of hot water but also for the room heating, combined solar system has been used valuable. In the Northern models such periods are longer, wherewith the volume of used solar energy is greater. Riga's model in comparison with Bremen model volume of used solar energy is greater, because the air temperature in Bremen at the beginning and at the end of the year is a bit lower, but available solar heat is greater, wherewith the volume of used solar thermal energy increase. In all versions the volume of produced heat in auxiliary boiler is greater than necessary for the building. It is explained by the extra load of auxiliary boiler for the production of hot water. Because several simulations with different combinations has been carried out with different capacity auxiliary boilers and electricity, then average result has been accepted as the volume of produced heat of auxiliary boiler.

*Table 6. Heat volume from auxiliary boiler, kWh/year.*

| Place of location | Heat volume from auxiliary boiler (kWh in a year) |
|---|---|
| Riga | 15 400 |
| Liepaja | 14 800 |
| Daugavpils | 16 080 |
| Boden | 11980 |
| Bremen | 27120 |

In existing versions of auxiliary boilers more to the North, the volume of produced heat increase on the count of necessary volume of the heat for the production of hot water. At the beginning of colder season auxiliary boiler has been started later, because sufficient volume of the heat is stocked up in the container, which ensures room heating and preparation of hot water for the short period. In that way heat has been stocked up for the later use, which is one of the formation preconditions of the combined heat supply solar system. It is not important to evaluate the productivity of solar collector but the relations of produced capacity in the power balance of the building. As models of Riga, Daugavpils and Liepajas is relatively similar and let the chart is more obvious only Riga, Bremen and Boden will be compared.

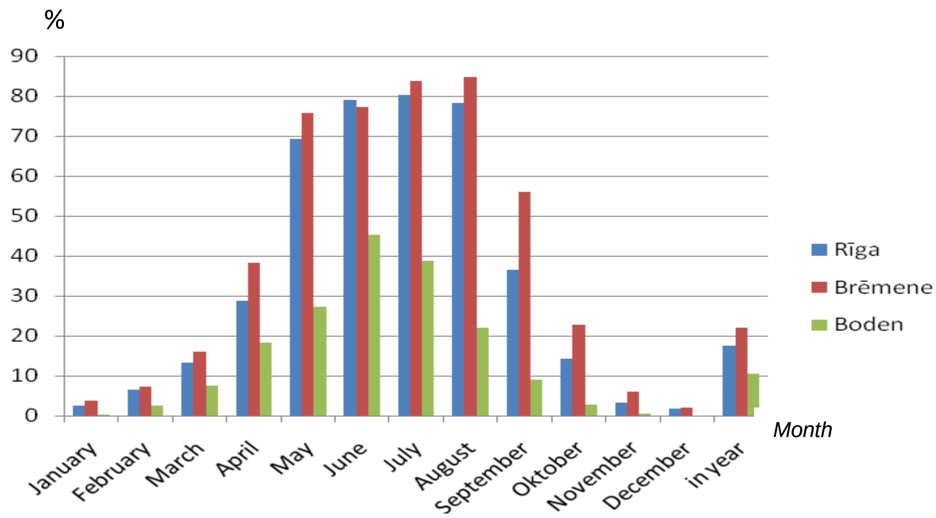


*Fig.3. Percentage of produced heat from solar collector, %*

Solar collectors may cover the necessary volume of heat during the summer month. Capacity of heat is not necessary for the room heating during the summer month, capacity of heat is necessary only for the preparation of hot water. It is important that solar collectors of Riga's model produce practically the same volume of heat energy from building heat balance as it is in Bremen. To be more precise solar collectors in Riga's model produce more heat energy than Bremen model but heat loss of building is greater in Riga. The decrease of heat volume necessary for room heating reflects not only in the volume of used heat but also partly in not received volume of solar heat. In its turn, the volume of solar heat that is used in the preparation of hot water is growing, because the volume of solar heat is available. For that reason the bigger part of the solar heat energy is observed in used volume of heat. Important conclusion in that during the winter month volume of received heat is minimal and very similar to all viewed models. Consequently during those months combined solar heat supply system has reduction of usefulness. Probable it is worth to consider on solar collector unlock during the cooler season, in such a way raising its usefulness. Though already in early spring solar collectors may provide 30% from the use of building heat for the room heating and hot water. The volume of suspended solar heat do not show real possible volume of solar heat energy that may be used, because conveying of solar heat energy to the storing container happens during almost all light period of day, only disconnecting circulation pumps of model in short periods.

The Developed models were viewed on the other side. Heat exchanger effect on System efficiency was determinate. The system affects the handling characteristics, such as heat exchangers. They fulfill the important function as a heat-transfer. The resulting solar collector heat storage tank is given by the mixing of heat already is there or whether the fluid is more effective when the heat from the solar collector storage tank into the system through a heat exchanger. The heat storage tank heat loss is smallest when the system has been equipped with heat exchanger for Domestic hot water. Previously was found how to place the solar collectors to receive the maximum amount of solar radiation.

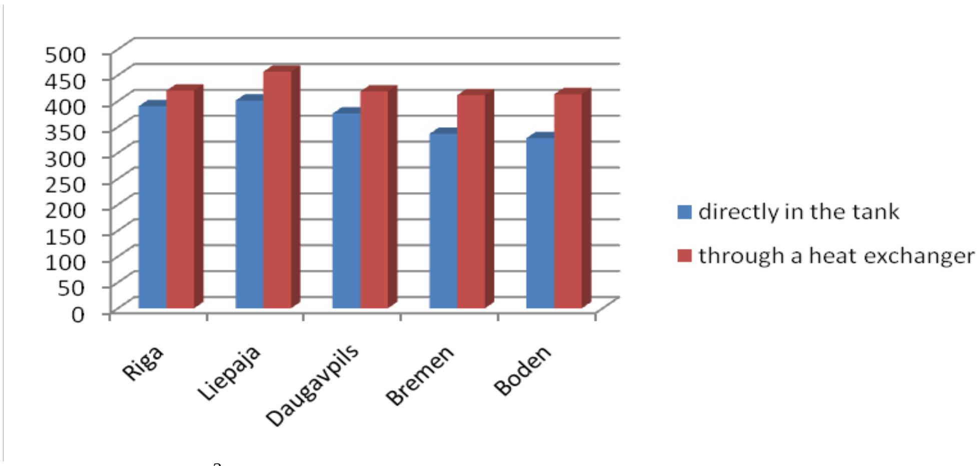


*Fig. 4. Heat quantity W/m$^2$ depending of heat transforms type in system*

The heat transfer from the solar collector system to the heat storage tank through a heat exchanger is about 14% efficiently than in cases where heat transfer occurs mixing of solar collector fluid transforms the heat in the tank. This is explained by the fact that the liquid flowing through the heat exchanger is less than the local losses. As well as more efficient heat exchange takes place.

## 4. Conclusions

The activity of the system depends on the weather conditions of particular place, which have an impact of the geographical fix, available volume of solar heat. It depends also on the individualities of particular place: the hills, the sea, the wind direction etc. In addition, the great importance has the users of combined solar heat supply system, their way of life. Wherewith, comparing of simulation models located in different places is conventional.

The greatest volume of perceived solar heat in Riga is in the situation when solar collector is placed 55° against horizon and 0° orientation against the South

The combined solar heating system provides for constant domestic hot water and seasonally variable space heating demand ensuring in annual terms. As well as changing hot water and constant heating demand ensuring in daily. Combined solar heating system operation depends on various technical specifications and performance characteristics of system components, such as the installed area of solar collectors, size of thermal storage tank, heat conductivity, as well as other parameters of system. During the winter months such a system is not useful, but it pays off in the summer months, producing enough heat for domestic hot water and pre warming for space heating. Effect on system's efficiency gives availability and location of heat exchanger. The heat transfer from the solar collector system to the heat storage tank through a heat exchanger is about 14% efficiently than in cases where heat transfer occurs mixing of solar collector fluid transforms the heat in the tank.

Difference between accumulated solar collector's heat of the Latvian, Sweden (Boden) and Germany (Bremen) models are not significant. But Consumed heat for space heating and domestic hot water is drastically different. Hence contribution varies of solar thermal system in consumer balance sheets. As the building model of Boden has the highest heat consumption, than solar collector contribution in balance sheet are relative the smallest.

## References

[1] Polysun 3.3. Documentation 2003. Solar Energy Laboratory SPF;

[2] P. Shipkovs, Atjaunojamo energoresursu izmantošana Latvijas apstākļos, RTU, Rīga, P. 2007, pp. 67;