RIGA TECHNICAL UNIVERSITY
Heat, Gas un Water Technology institute

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SOLAR COMBINED HEATSUPPLY SYSTEMS IN LATVIA

Doctoral Thesis

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CONFIRMATION STATEMENT

Hereby I confirm that I have worked out the dissertation, which is submitted for acquisition the degree of Doctor of Engineering Sciences at Riga Technicsl University. The dissertation has not been submitted in any other university for acquisition of scientific degree.

Lana Migla …………………………….

Date: ………………………

The Dissertation has been written in Latvian: it contains Annotation, Introduction, five Chapters, Conclusions, References. It consist of 47 figures and 15 tabeles. It composes 118 pages with 89 reference sources.

SYMBOLS USED IN WORK

α	surface heat transfer coefficient, W/m^2K,
ak	auxilary heater,
ap	heating,
b	the distance between the tube axis, m,
Bi	bionumber, W/K,
c	heat capacity of the substance, J/kg K,
cirk	water cirkulation,
CS	Solar Combined heatsupply system,
D_1, D_2, D_3	solar absorber areas,
h_0	collector plate thickness, m,
I_{BT}	theoretical direct daily solar radiation, MJ/m^2 day,
I_s	intensity of solar radiation, J/m^2,
IPE	Institute of Physical Energetics
ku	domestic hot water
m	substance mass, kg,
P	atmosferic opcity, radiation units,
q	solar radiation density, W/m^2;
Q	heat release period, kWh/time,
$Q_{zud.sk}$	heat loses in solar collector's, kWh/day,
$Q_{zud.c}$	heat loses in pipelines, kWh/day,
S_0	solar constante,
SC	solar colectors,
t	time, s,
V	flow, m^3/s,
δ	height of yhe Sun, grades,
η	system efficiency, %,
η_c	solar absorption efficiency,%,
λ	collector plate thermal conductivity, W/m K.
φ	lenght, radians,
Φ	dimensionless size,
ξ	dimensionless size,
μ	eigenvalues, dimensionless size,
Θ	dimensionless size,
Ψ	dimensionless size.

ANNOTATION

Dissertation investigated the combined solar heating system efficiency aspects as a prerequisite for the efficient operation of Latvia's climatic conditions, thus increasing energy independence, reducing heat production's negative impact on the environment, and promoting consumer comfort and quality of life.

The goal is to develop a methodology for a combined efficient solar heating system for Latvia's energy production.

To implement this goal, the following objectives have been advanced: to explore the functional arrangements, to identify the factors that affect high energy efficiency rate of change, and the combined heating system efficiency to cover the heat demand of consumers, taking into account the development of the energy system, and to define a variety of other factors on the optimal heating scheme selection and methodology. To develop and experimentally verify Latvia's conditions for a suitable combination of solar energy systems, analyze its performance in simulation and economic optimization of the system defining the various measures and technical solution application.

In this thesis studies are based on the author's practical, experimental research experience working with the Institute of Physical Energetics Solar Energy Resources Research Laboratory site. For studies, the voluminous data accumulated in IPE material on the actual climate data and solar panels indicators was used. The author carried out the experimental measurements and theoretical summary of the results of the single methodology for structuring the flow diagram with a mathematical model. Thus, the thesis of a scientific innovation of a complex system of mathematical modeling using the experimental data obtained, thus making the calculation methodology most accurate and close to real conditions. The thesis, the developed methodology and conclusions of a practical application for engineering work in the design and implementation of the modernization of existing combined systems.

The research results have been reported 13 times in international scientific conferences and are reflected in 27 publications. The doctoral thesis consists of 5 chapters and its volume is 118 pages, which contain 47 images, 15 tables. The study uses 89 literature sources.

CONTENTS

INTRODUCTION

The topicality:

Energy imports are an important aspect of Latvia's energy sector. Latvia's government's target for the year 2020 is to reach 40% of renewable energy in total gross final energy consumption. This can be achieved by increasing the renewable energy, mostly heat and transport sectors, the introduction of sustainable support mechanisms for renewable energy resources, as well as providing state support for cost-effective technical solutions and the promotion of renewable energy and related technological development to economic investment.

It is the combined use of solar energy systems that have the potential to increase Latvia's energy independence. As well as promoting environmentally friendly technologies in energy generation process, thus reducing environmentally harmful emissions. Ever since the eighties, a stable solar collector area of growth around the world in hot water and space heating needs is evidence of solar heating systems technical safety and reliability. The combined system has the advantage of technological solutions, diversity and environmental protection, which increases the energy independence of the major suppliers of energy, and promotes the use of environmentally friendly equipment. The work will describe and define ergo economic factors leading to the combination of solar heating systems and efficient use of Latvia's heat energy demand. Based on the analysis of climate data, the optimum heating systems main components optimal parameters will be determined in order to promote effectiveness of the combined solar heating systems.

The aim of the work:

Develop a methodology to set efficiency of solar combined heatsupply system in the Latvian energy consumption.

The main tasks of the study:

To study the functional arrangements, to identify the factors that affect high energy efficiency, rate of change, and the combined heating system efficiency to cover the heat demand of consumers, taking into account the development of the energy systems, and to define a variety of other factors on the optimal choice for heating circuit and methodology. To develop and experimentally verify for Latvia's conditions a suitable combination of solar energy systems, analyze its performance in simulation and economic optimization of the system.

The research methodology:

Dissertation investigated the combined solar heating system efficiency aspects as a prerequisite for the efficient operation of Latvia's climatic conditions, thus increasing energy independence, reducing heat production negative impact on the environment, promotion of consumer comfort and quality of life. To develop and optimum system selection methodology, taking into account the combined heating systems of work are used in a number of methods. Mathematical method, the optimal parameters (using mathematical modeling and numerical simulation programs-PolySun, Transys), optimal technical equipment selection according to cutting-edge technology, cost-effective and appropriate to the situation in Latvia's energy combined system parameters, and climatic factors on the analysis of the system.

Scientific novelty:

In this thesis studies are based on the author's practical, experimental research experience working at the Institute of Physical Energetics Solar Energy Resources Research Laboratory site. Studies used the large volumes of data of accumulated material on the actual climate data and solar panels indicators. The author carried out the experimental measurements and theoretical summary of the results of the single methodology. Thus, the thesis of scientific innovation of a complex system of mathematical modeling using the experimental data obtained, thus making the calculation methodology most accurate and close to real conditions.

Practical application

As a result, the worked out combination of solar heating systems and the adaptation to Latvia's energy needs through a number of variously built collection methods, making their adaptation to climatic conditions, taking into account the current economic situation, and achieved through modern technology solutions. The thesis, the developed methodology and conclusions of a practical application for engineering work in the design of new or upgrading existing implementation of the combined systems. The Institute of Physical Energetics Energy Resources Laboratory carried out not only research but also informative activities and communication with engineers, designers and potential users. The author’s methodology is used for the optimal combination of solar heating systems and selection according to customer requirements.

1. THEORETICAL BACKGRAOUND FOR INVESTIGATION OF SOLAR COMBINED HEATSUPPLY SYSTEMS

The main problem, which is not conducive to combined solar heating systems in Latvia, in the study of this kind of system, is the use of a negative experience.

It is believed that Latvia's climatic conditions are unsuitable for solar energy use in heating use, but optimizing the combined system using the design methodology can achieve maximum efficiency. The combined system has the advantage of a combination of factors that contribute to high potential applications of such systems usage in Latvia.

The world's solar energy success is due to a successful solar equipment market, which is the result of several factors: the legislative provisions, stable and well-designed financial incentives for investors, standard products and equipment for the existence of high-efficiency equipment, and, in particular, explains the success of solar collectors for use in single-family homes. Part of such a system for effective implementation of Latvia's energy factors have already been achieved or are in the process. In order for Latvia to be able to successfully introduce new alternative technologies research was required. In order to facilitate the implementation of solar energy in the economy, state and support tools can be used in the legislation, as well as project financing and support for science, solar energy research, and providing discounts for those who use solar energy and other renewable energy sources.

The paper describes and defines electro energy factors leading to the combination of solar heating systems and efficient use of Latvia's heat energy demand. Based on several years of climate data analysis, certain key components of heating system optimal parameters were determined which increase efficiency. A combined solar thermal heating system depends on the amount of solar radiation received at the various latitudes which are different. Also, there are different types of consumer-heat required for space heating and hot water supply required quantity of water proportions. It is also observed in the combination of different heating solar system design and operational characteristics. For example, in southern latitudes is much less demand for space heating, while the north more, even though the hot water demand is not very different in different latitudes of the globe. The biggest difference between the different kinds of combined systems are most commonly associated with currently used solutions by engineers for heat-storage tank and heat delivery method, and applied control algorithm differences between system components, dimensions, etc.

The rapid growth in demand of a combined system contributed to the need to analyze and organize the growing market through a structured system, creating standards, so in 1998 International Energy Agency (IEA) Solar Heating and Cooling (SHC) Programs inclusion created

TASK26 '-optimal solar combined systems for single-family, several multi-family and multi-family homes, in addition to the standardized classification and development process. Since Latvia was not a member of the European Union when TASK26' was drawn up in 1999 by the European Union, and did not participate in the International Energy Agency (IEA), unfortunately, Latvia's conditions for suitable combination have not been established. As work progressed on all available systems, combining the three were selected, which can be suitable to Latvia's conditions, taking into account the experience of neighboring countries, climatic characteristics and heat demand, which have been analyzed.

One of the combined solar heating system efficiency factors is heat loss; the largest loss is in solar collector systems. Collector efficiency in Latvia's climatic conditions is analyzed and a maximum of improved results, this can be done through a series of measurements as a result of determining the optimum parameters for solar collectors, which are influenced by climatic characteristics of each region of the world and is different. When analyzing the literature and based on the experiences at the solar research site, collectors are analyzed under real conditions, which provides more accurate results and a picture of solar thermal systems, which affects not only the efficiency of solar radiation, but also the outdoor air temperature, air humidity, wind speed and direction, cloudiness and other factors, which makes Latvia's climatic conditions unique. It is important to pinpoint the characteristics of solar collectors in Latvia's conditions affecting the solar collector efficiency, eliminate or improve them, thus optimizing the total system. In the theoretical mathematical modeling it is possible to describe the ongoing processes in the solar collector, which solves the problems associated with solar activity analysis and the development of new interceptor necessary conditions. Solar System combined difference from other heating systems have high operating temperature and heat fluctuations, which depends on many external factors. It is important to find a balance between the heat loss decreasing operations and economic performance of the system, the combined system more attractive to a maximum of Latvia's consumers. The research carried out and the simulation methodology described in the flowcharts help.

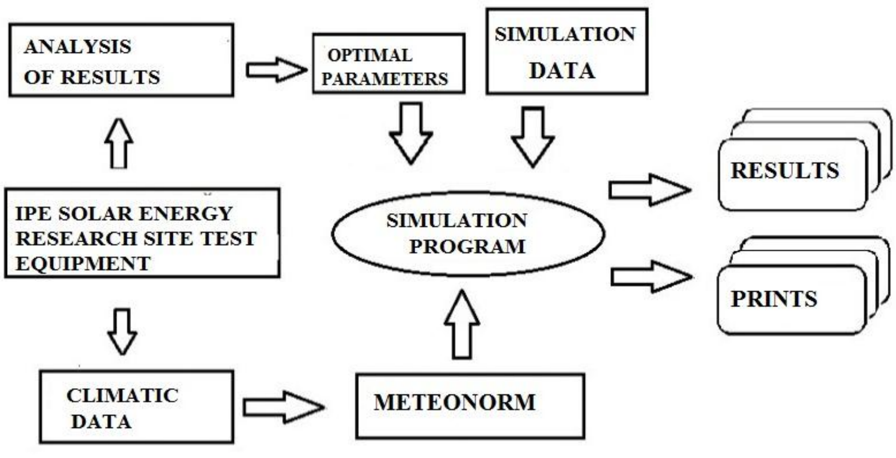

Fig. 1.1 The work of the methodologies used by block diagram

By optimizing the combination of solar heating systems on the methodology developed by and with the aid of government contribution, significant results can be achieved that contribute to the heating systems in Latvia's energy usage, thus increasing energy independence and promoting green energy heating use.

Use of solar energy in Latvia's conditions, combined heat-producing systems as well as system optimization previously studied such scholars as LAS Academic P.Šipkovs (since 1980), Prof., Dr.habil.sc.ing. E.Dzelzītis, as well as Prof., Dr.habil.sc.ing. V.Zēbergs, Scientific Doctors K. Lebedeva (since 2008) and I.Pelēce (since 2010). In turn, studied in depth the combined solar heating systems in the European Union Solar Energy Association president W.Weiss engineer (since 1997) and Dr.sc.ing. C.Roshas (since 2010), Prof., Dr.habil.sc.ing. D. Blumberga. Mathematical models describing the process of heat conduction studied by Prof., Dr.habil.sc.ing. V.Barkāns.

2. DEFINITION OF SOLAR COLLECTOR OPTIMIZATION PARAMETERS

Cost-effective and appropriate to the situation in Latvia's energy of combined solar heating system parameters is an optimization process, and a key factor in the implementation of Latvia's heat power consumption in energy balance. All the processes in the system affect the climatic characteristics of Latvia's territory as part of the Northern Region, where the biggest heat consumption is for space heating, and not hot water, as most of the solar heating system is designed. Solar thermal system performance and efficiency is affected by climatic characteristics, not only the outdoor air temperature, wind and solar radiation, but also the transparency of the air in each region is different, because it depends on many environmental factors.

Fig. 2.1. Solar Energy Research polygon

Working in solar energy research polygon since 2009 and preparating obtained data base was used both- the existing meter and installed new high-precision measuring instruments. Climatic data was gathered by the following devices - Piranometr, Pirheliometr, Pirgeometr, Solar Tracker, NetRadiometrs, etc. The data contains not only meteorological data, but also the specific data that are important to analysed solar collector activity for the optimization and upgrading, improving their efficiency, such as certain intensity of solar radiation, depending on the inclination of the surface on which it falls. The work supported long-term measurements, it was found that the deviation between the radiation intensity in different years, dropping on plane on 60 ° position can reach 37%. Fluctuations in the quantity of radiation in different years may differ by 7%. In the following calculations it is taken into account.

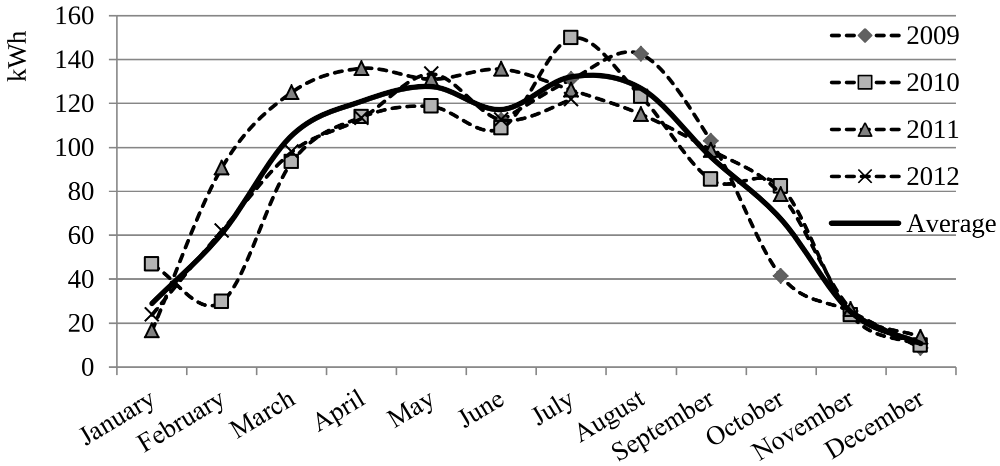

Fig. 2.2. Solar radiation in different years

In long-term observations of solar radiation at the plane on position on 60 ° during the period from 2009 to August 2012, the data was analyzed and displayed graphically in Figure 2.3.

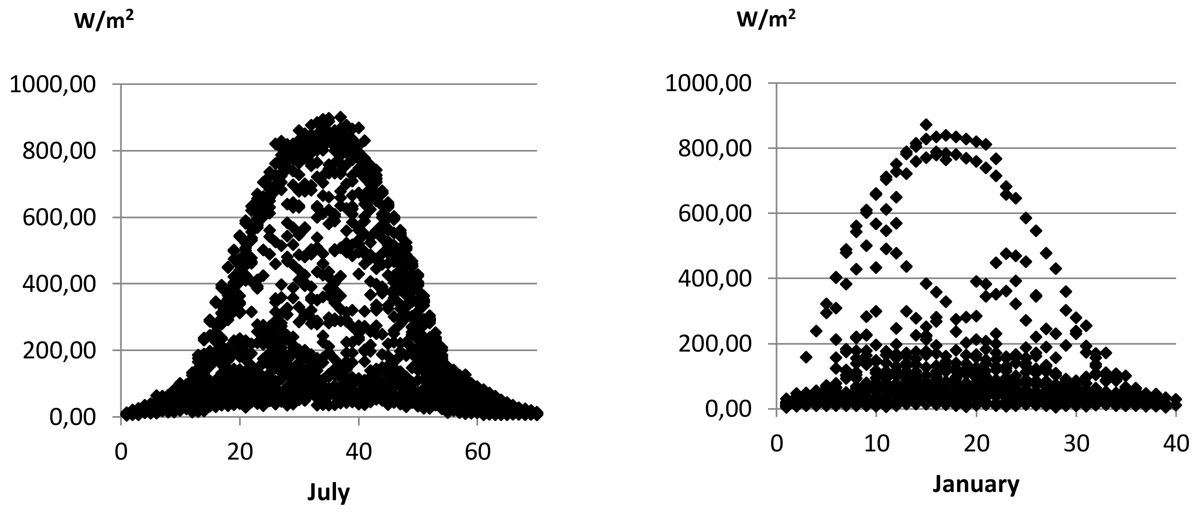

Fig. 2.3. The frequency of solar radiation in different times of the year

Chart depicts the size of the solar radiation frequency in July and January. It was found that the maximum of solar radiation in both periods is similar- to above 800 W/m^2, but the frequency is higher in July. In January frequency achieve 200 W/m^2. This study is based on the fact that in winter months efficientive solar energy are available, which can be used for the production of heat in solar panels, but the current collector design does not allow fully use available solar energy. In-depth research into a new type of solar collector design can minimize the heat loss from solar collectors.

To determine the atmospheric transparency and diffuse radiation on solar collector exact calculations were used, because of the need to know basis for direct and diffuse solar radiation values. The calculation covers the atmospheric clarity evaluation, measurement and diffuse radiation.

$$I_{BT} = S_0 \cdot P^m \cdot \sin\delta \qquad (2.1.)$$

This type of calculation is necessary to develop the design of solar collectors applied to the local conditions in Latvia and other northern European countries.

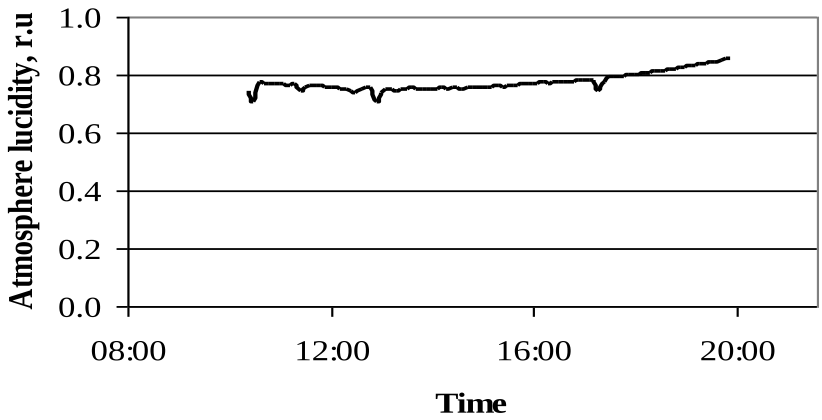

Fig. 2.4. Atmospheric opacity in Riga (IPE Solar Energy Research site)

During the measurements it was found that the atmospheric opacity is 0,77 ± 0,05 units. Not only cloud cover, but the clarity of the atmosphere affects solar radiation intensity.

Solar facility research work was carried out in the course of the experiment, during which the results were compared from the vacuum tube solar collectors and flat surface of solar collectors, the facility is equipped with measuring equipment and information management. Graphically depicted different types of solar collectors, solar radiation captured in annual terms, four of them are flat surface collectors and three vacuum tube collectors. Where presented, each collector displays and an average value of the results shown in Fig. 2.5.

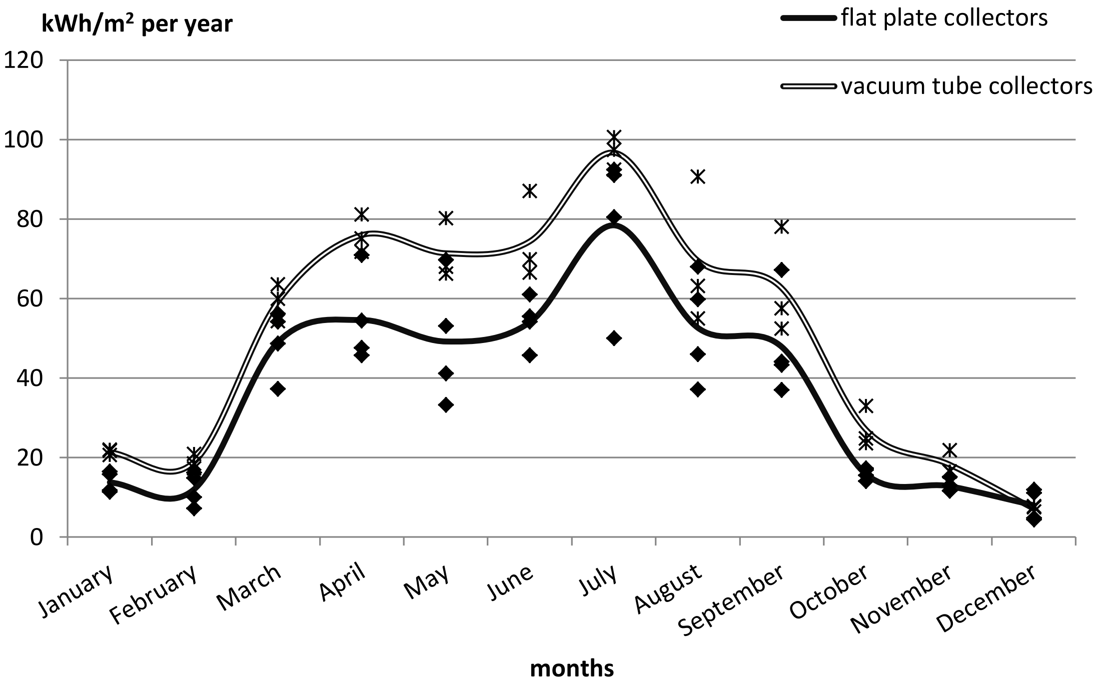

Fig. 2.5. Amount of energy produced by different types of collectors

Vacuum tube collectors under Latvia's conditions operate more efficiently than the flat surface of the solar collector, this is due to different principles. Vacuum tube collectors are less susceptible to rapid temperature fluctuations that are characteristic of Latvia's latitude. Carried out during the experiment, showed that the flat surface of the collector is compared with several different brands of collectors, depending on its structure capable of receiving up to 20% margin, which is a very significant fact optimizing the combined system. Vacuum tube collector solar radiation quantity produced in 2009, the most effective collector reaches up to 610 kWh/m^2 per year. It was established that vacuum tube collectors placed at the solar research site and analyzed showed between a 25% difference in perceived levels of energy. Vacuum tube collectors in 2009. were 10% more efficient than the flat surface of the collector. It is related to the fact that 2009. was sunny, but the air cool and windy. Outside air temperature falls significantly reduces the yield of flat collectors, due to the increased heat loss.

On the global optimum radiation, angle selection reduces the risk of too much energy in the production of the hot summer months, leading to energy overproduction and can cause equipment overheating and system failure. Experimental and modeling simulation program was set on solar energy resources by months on the slopes of the horizontal position to the vertical position of 0 ° to 90 °. The results were presented in Figure 2.6.

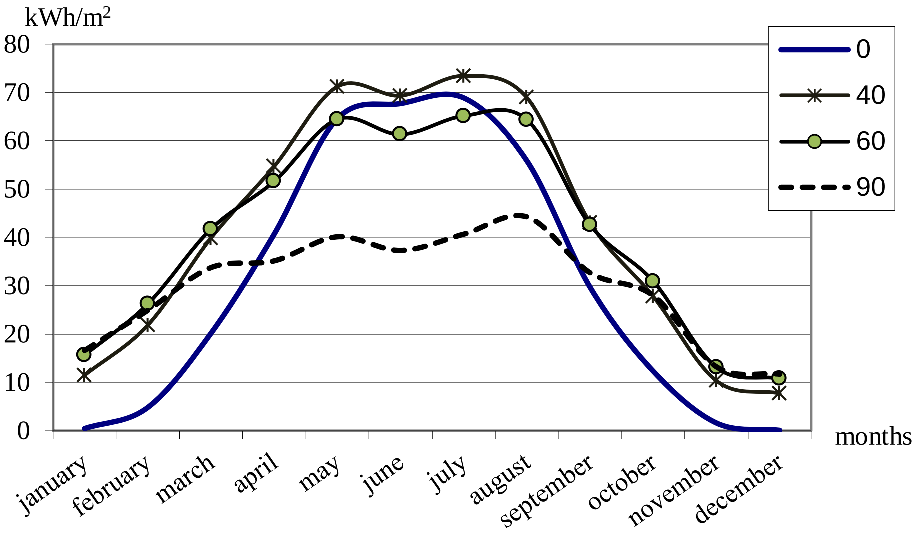

Fig. 2.6. The amount of solar energy, depending on the angular position of the collector

40 ° and 60 ° degree Slanted collectors perceive similar amounts of radiation, but you can see how the spring and autumn months, the most energy to surfaces, which are positioned at an angle of 60 degrees. But the greatest power in the summer months can be seen on the surface of 40 degrees to the horizon. In this case, the difference did not exceed 3%. So depending on the application required an optimum angle can vary. If the Solar System combined for higher heat demand during the summer months when optimizing solar peak is close to 40 °, for example, summer houses, camps and other places where heat demand is seasonal, while individual homeowners, the optimum temperatures of 60 ° to the sun radiation contribution to the spring, autumn and winter months should be utilized. Comparing the horizontal and vertical position can be observed solar angle to capture the impact of seasonal variations related to changes in the sun's path during the year. According to my research, the June-August months' periods of solar radiation intensity decrease can be explained by the reduction in atmospheric transparency.

In order to make solar panel development, using theoretical studies, a mathematical model was developed. Using mathematical modeling methodology to characterize the flat side of the collector, a mathematical model of a new type of flat surface of the collector where the two metal sheets, one of which is flat, while the other punched and piling them one on the other, there is a solar collector absorber suitable for construction, with cross section shown in Figure 2.3. By perforated volumes of fluid, heat can circulate in liquid form. Mathematically, the temperature field is found in the absorber, which consists of a single flat sheet of metal, which superimposed metal sheet with extruded square terrain.

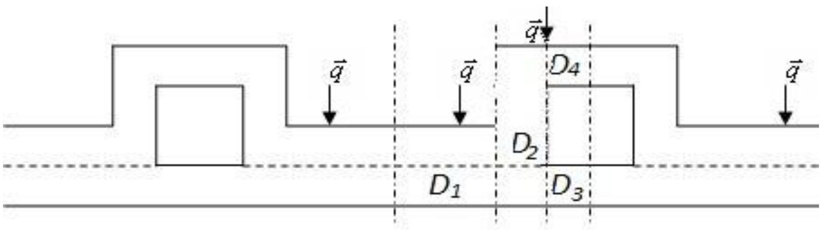

Fig. 2.7. Absorber plate cross section

Intersection part conditionally divided into four parts D_1,D_2,D_3,D_4.

$$\Theta(\xi,\eta)=\begin{cases}\Theta_1(\xi,\eta), \; kur \; (\xi,\eta)\in D_1\begin{cases}0\le\xi\le\xi_1;\\0\le\eta\le 2\eta_0;\end{cases}\\ \Theta_2(\xi,\eta), \; kur \; (\xi,\eta)\in D_2\begin{cases}\xi_1\le\xi\le\xi_2;\\0\le\eta\le\eta_2;\end{cases}\\ \Theta_3(\xi,\eta), \; kur \; (\xi,\eta)\in D_3\begin{cases}\xi_2\le\xi\le 1;\\0\le\eta\le\eta_0;\end{cases}\\ \Theta_4(\xi,\eta), \; kur \; (\xi,\eta)\in D_4\begin{cases}\xi_2\le\xi\le 1;\\\eta_1\le\eta\le\eta_2.\end{cases}\end{cases} \quad (2.2.)$$

Using the boundary conditions, we obtain dimensionless temperature in rural area D_1:

$$\Theta_1(\xi,\eta)=\frac{Q}{4\eta_0}\left(\xi^2-\eta^2\right)+F \quad (2.3)$$

where

$$F=1+Q\cdot\eta_0, \quad (2.4)$$

To solve the temperature field Θ_2 mathematical physics techniques were used. The Fourier method of separation of variables obtained temperature field in the D_2 area:

$$\Theta_2(\xi,\eta)=\frac{1}{2}\left(a_{2,0}+a_{2,1}\xi\right)+\sum_{k=1}^{\infty}\left(a_{2,k}ch\lambda_{2,k}\xi+b_{2,k}sh\lambda_{2,k}\xi\right)\cdot\cos\lambda_{2,k}\eta+$$
$$+\frac{2\cdot Q}{\xi_2-\xi_1}\sum_{k=1}^{\infty}\frac{1-(-1)^k}{\mu_{2,k}^2}\cdot\frac{ch\mu_{2,k}\eta}{sh\mu_{2,k}\eta_2}\cdot\cos\mu_{2,k}(\xi-\xi_2), \quad (2.5)$$

with eigenvalues given by the formulas:

$$\lambda_{2,k}=\frac{k\cdot\pi}{\eta_2}; \qquad \mu_{2,k}=\frac{k\cdot\pi}{\xi_2-\xi_1}; \qquad k=1,2,3,... \quad (2.6)$$

Like the D_2 region, the temperature field is located in the D_3 and D_4 regions. Here just write a temperature fields in the area without the need for progress in solving. Thus, the area D_3 temperature field is:

$$\Theta_3(\xi,\eta)=\frac{a_{3,0}}{2}+\sum_{k=1}^{\infty}a_{3,k}ch\lambda_{3,k}(\xi-1)\cdot\cos\lambda_{3,k}\eta+\sum_{k=1}^{\infty}c_{3,k}ch\mu_{3,k}\eta\cdot\cos\mu_{3,k}(\xi-1), \quad (2.7)$$

with eigenvalues:

$$\lambda_{3,k} = \frac{k \cdot \pi}{\eta_0}; \qquad \mu_{3,k} = \frac{k \cdot \pi}{1-\xi_2}; \qquad k = 1,2,3,... \tag{2.8}$$

Area D_4 temperature field is as follows:

$$\Theta_4(\xi,\eta) = \frac{a_{4,0}}{2} - Q\cdot\eta + \sum_{k=1}^{\infty} a_{4,k} ch\lambda_{4,k}(\xi-1)\cdot\cos\lambda_{4,k}(\eta-\eta_2) +$$

$$+\sum_{k=1}^{\infty} b_{4,k} ch\mu_{4,k}(\eta-\eta_2)\cdot\cos\mu_{4,k}(\xi-1) \quad , \tag{2.9}$$

ar īpašvērtībām:

$$\lambda_{4,k} = \frac{k\cdot\pi}{\eta_2-\eta_1}; \qquad \mu_{4,k} = \mu_{3,k} = \frac{k\cdot\pi}{1-\xi_2}; \qquad k = 1,2,3,... \tag{2.10}$$

Using the equation of heat flow and temperature uniformity in the area of D_1 and D_2 of the shared border, $\xi = \xi_1$ we obtain the equations for the unknown coefficients for calculations. Deleted were expressions, where each expression contains collector absorber parameters and changing these parameters, you can get the optimum collector performance. Finding the temperature gradient field can define the nature of the temperature distribution. The resulting temperature field is found in each area separately. Heat conduction process of a characteristic mathematical model solves the problems of conducting studies under realistic conditions. Mostly, they are the high costs of: purchase of solar collectors, equipment and measuring devices, the area corresponding to the collector deployment requirements, workload and time. Using theoretical calculations it is possible to describe the ongoing processes of solar collectors, which promote solar collector development.

3. SIMULATION MODELS USE TO INCREASE THE CS EFFICIENCY

Using mathematical modeling program, CS model simulations were used. The program adapted to Latvia's climatic conditions, using the data from trials of solar radiation (global, diffuse), wind strength and direction, outside temperature, air turbidity, and other information relevant to the combined system. In the combined system simulation with PolySun several variants were calculated which determined that the average heat produced by the system covers 12.4% of the heating demand of the system of consumption and 40% of the hot water in annual terms. Data may vary under real conditions, because consumers have access to individual heat consumption and comfort level.

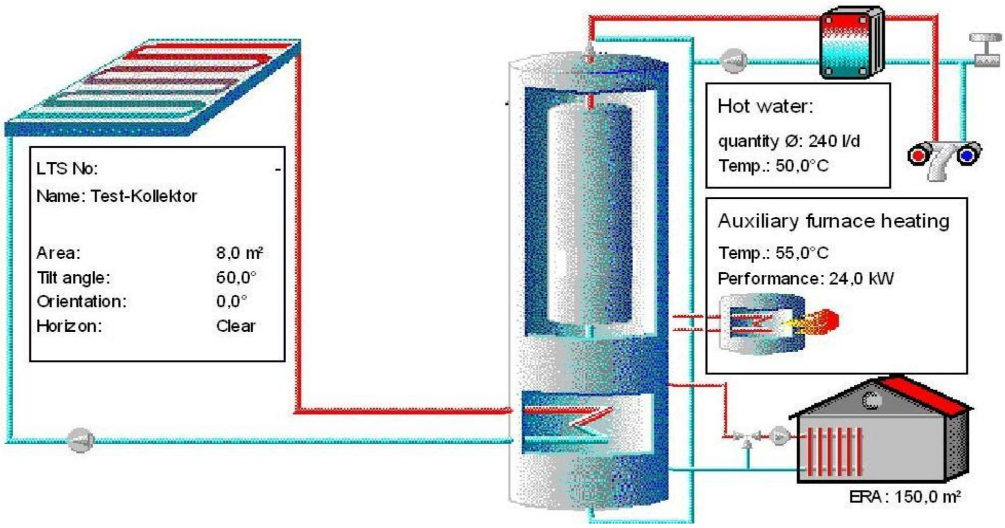

Fig.3.1. Simulation variant pricipial scheme of Solar combined system

In total, the combined systems, solar collectors provide 18% energy savings on energy consumption. Was calculated with the simulation model of heat loss in combined systems, which are located in different climatic zones, it allows to describe the impact of climate on heat consumption and solar collector output amount of heat in combined systems.

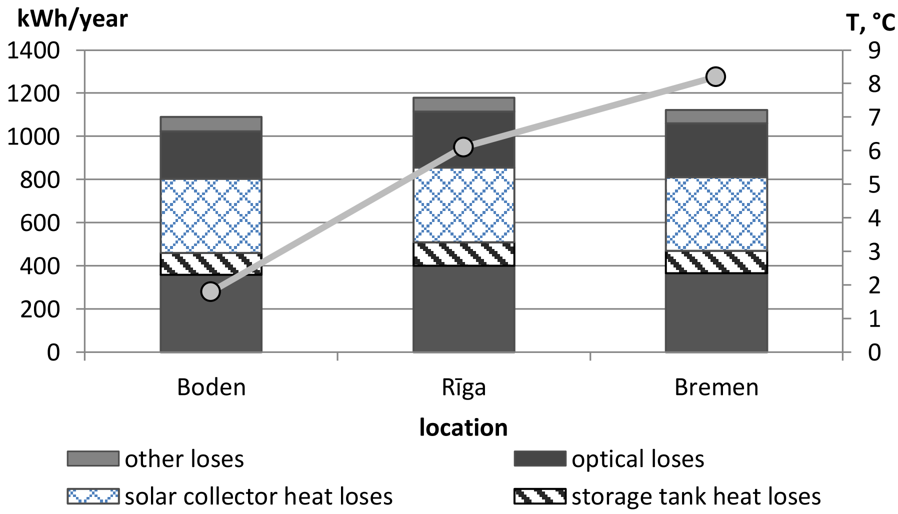

Fig.3.2. Heat loses volume depending on simulation variant location

Although with Latvia's conditions the optimum angle of solar collectors produce a considerable amount of heat when compared to other regions, there is more to the south, but the biggest problem is heat loss, which is the largest in solar collectors and heat transfer process, which raises awareness about the system optimization. Therefore, when simulation was calculated that the heat loss is the smallest of the optimum tank capacity of 1 square meter of solar collector is 0.1

cubic meter. Solar collector productivity is significantly lower at the relationship of less than 0.1m3/m2. Heat losses in the storage tank are growing faster than solar thermal energy production in the relationship over the 0.1m3/m2. Analyzing CS heat exchanger types of storage tank of the solar collectors, the most effective is the case when the system is combined with a small water tank, which is inserted into the storage tank; it is related to the heat exchange surface area size. This system uses natural stratification, which reduces heat loss and energy inputs, making it the most optimal. Heat transfer can influence the type of heat loss by at least 4%.

Using mathematical modeling a relationship was established between heat loss and heat conductivity coefficient values for indoor and outdoor pipes and depicted graphically. It was made of various kinds of insulation and operating cost calculation period. As a result, the 60mm stone wool insulation type is the smallest energy cost over 20 years, which is close to the working life of insulation. This type of insulation is the most cost-efficient outdoor and indoor copper tube of 18 mm diameter.

4. AUTOMATIC MANAGEMENT ANALYSIS

The paper studies the various types of automation control effects of the combined systems. IPE solar research site carried out a series of experiments which considered automatic solar activity according to different parameters: the weather, the temperature difference between the solar collectors, the heat flow rate and solar radiation intensity, given the nature and management deficiencies. Since the solar system activity is directly exposed to external weather conditions, the time variable, it is essential to maximize the effective regulation of the system. Identify the most effective procedure for the automatic control of several sets of parameters, where the pump is regulated according to the intensity of solar radiation, the lower storage tank temperature and the outside air temperature.

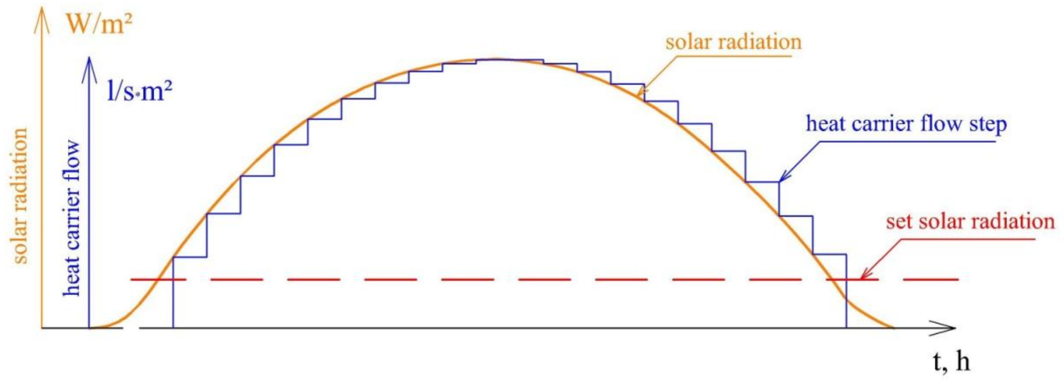

Fig. 4.1. Flow depending on the intensity of solar radiation

Automatic control according to the intensity of solar radiation, flow is described by the following expression:

$$V = \frac{I \cdot \eta_{sk} - Q_{zud.sk} - Q_c}{c \cdot \Delta t} \quad , \qquad (4.1.)$$

In the calculation automation control deficiencies associated with additional loss in test mode can be avoided. Experimental data shows that the total solar thermal systems increase productivity by 7% on a sunny day compared with control by temperature differences.

5. COMBINED SYSTEM EFFECTIVENESS ASSESSMENT

For the evaluation of the effectiveness of the combined system, system performance evaluation method is used in the work. This method allows the comparison of very different systems, which contain a variety of parameters, such as the different detection sites, solar fields and important system differences, and heat consumption patterns, space heating or hot water delivery, or a combination thereof. To combine the above clarifies the combined system parameters and the system optimization, a modeling program created several set of options, which simulated the three theoretical systems, where I variant contained migration, which can be characterized as economic. Option II - to determine the optimal parameters, and Option III parameters were maximum comfort.

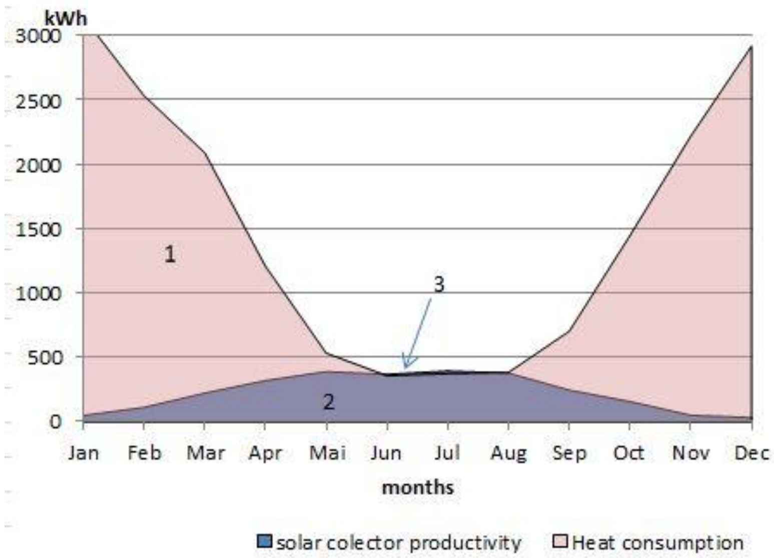

Fig. 5.1. Evaluation of the effectiveness of the combined system

Studies and analysis processes, assessment of results showed the benefits of each system and operational risks.

$$\eta = \frac{\left(\sum_{i=1}^{12} Q_{ap} + \sum_{i=1}^{12} Q_{ku} + Qcirk\right)}{\left(Q_{sk} + \sum_{i=1}^{12} Q_{ak}\right)} \tag{5.1}$$

The percentage contribution of the combined solar system is energy balance of solar heat production in relation to the demand for energy. Expected solar fraction of the system I variant is 14.3% for Option II is 21.7%, while the Option III due to large solar collector area reached 25.5%, but as shown CS Assessment Option III, there is a risk of overheating. This shows that the work of the methodology examines several aspects of CS, with the utmost accuracy CS provides performance assessment.

In order to determine the source of heat in addition to the impact on the combined efficiency of the system, the methodology was chosen in advance to determine the optimal system Nr.II. Option, as well as possible modifications:

1) Combined system with a gas boiler (assumed efficiency of 90%)
2) Combined system with a granular boiler (assumed efficiency of 80%)
3) Combined system with ground source heat pumps (assumed transformation ratio 4.0),
4) The system only with a gas boiler (assumed efficiency of 90%)
5) The system only a granular boiler (assumed efficiency of 80%).

Calculated financial profitability results shown in the graph.

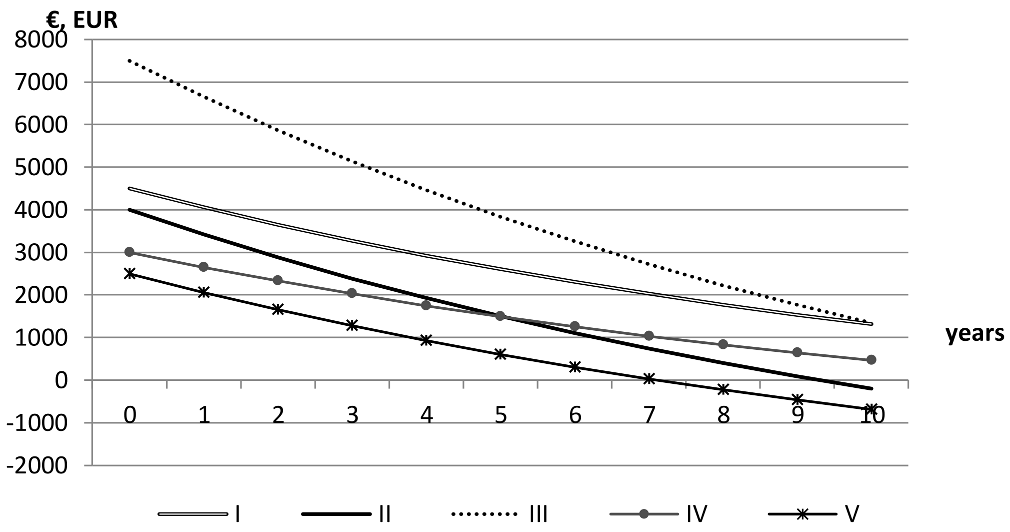

Fig. 5.2. The financial evaluation of the various systems

I-compound system with a natural gas boiler, II - a combined system with a wood pellet boiler, III - a combined system with a heat pump, IV-system with gas boiler, V - with granular chisel.

When analyzing the graphics and looking at all the systems, it was concluded that the most efficient system is considered in combination with granular boilers. The curves show the rapid decrease how quickly the system self-released, despite the large capital investment and start earning compared to the rest of the systems. It should be noted that the curve system with a granular boiler, showing the shortest payback period, but it only shows that the system has lower cost than other systems.

If you look at the combined system with a granular boiler and wood pellet system with a granular over a longer period, such as 15-20 year period, which is the operating system of the time, the combined system curve for cross-system with granular pellets, which shows that the combined system with a granular boiler and solar collectors are more cost effective. Combined with the heat pump system curve decline, despite the particularly high initial cost, reflecting the efficiency of the system. Looking at it over a longer period, it is clear that the efficiency is higher than for systems with natural gas, but it should be noted that the heat pump efficiency is affected by many factors, including the price of electricity.

As a result, concluded that the combined system optimization increases the efficiency of the system and this way, they become more cost-effective than a simple heating systems without solar collectors.

Energy extraction and conversion always involves environmental factors. Therefore, the importance of the combined system of environmentally friendly energy acquisition. One of the parameters used in the environmental impact of technology assessment is the reduction of CO_2, which is characterized by plants evaluated CO_2 reduction potential, taking into account the replaced energy CO_2 emissions factor. Since solar energy does not cause pollution of CO_2, but the combined system in addition to other heat sources in the energy conversion process uses combustion, which includes the release of CO_2, the reduction resulting from additional heat source to heat the replacement of the solar energy produced. Thus, the combined solar system is able to effectively reduce CO_2 emissions without compromising customer convenience. In this way, not only improving air quality, but also contributing to the EU directives.

CONCLUSIONS

1. The work accomplished the methodology for the combined system energy consumption minimization, based on climatology data in-depth research and analysis – solar radiaton, the outdoor parameters repetition rate and energy consumption in various combination system installations. Following the methodology developed comparison of the energy consumption of different CS work schemes. The method usd consists of the calculation models adapted to the modified aggregated climatic data and other additional indicators.

2. Climate data in an in-depth study and analysis was conducted at the IPE Solar Energy Research site, creating a new platform for renewable energy technologies and their optimal parameter choices, including combinations of fossil fuel energy sources.
3. By analyzing years of climatic data, it was evident that the radiation intensity variation from selected years can decrease by 37% on the 60^o positioned collectors. The difference between the cumulative amount of radiation in different years may reach 7%. This was taken into account when working out the calculations. The atmospheric opacity in Riga is $0,77 \pm 0,05$ entities, as well as that not only clouds, but also the atmospheric turbidity scattered radiation intensity, which in turn, affects the efficiency of solar collectors, creating an environment for new research.
4. Investigated the combined system functioning order and identified factors that affect the high energy efficiency, performance changes. Optimizing CS Latvia's conditions, the effectiveness rises above 44%, which is a high figure for such a system to operate in the northern region. The measurement result, certain vacuum tube solar collector design principal advantages Latvia's conditions, reaching 10% of the heat output edge over the flat surface of the collectors. Solar collectors optimal position angle to the horizon may vary depending on the heat demand characteristics, however, CS for use all year round, is close to the optimum angle of 60° relative to the horizon.
5. By optimizing the heat transfer process, a certain storage tank and heat transfer effects on the type of heat loss in the system, the CS energy balance can range from 10-22%. Solar collector CS productivity is significantly below the storage tank and the solar ratio of less than $0.1 m^3/m^2$. Heat losses in the storage tank is growing faster than the solar thermal energy produced in the growth of the relationship over the $0.1 m^3/m^2$.
6. Analytically resolved temperature field in solar absorber using a new type of mathematical model, the absorber plate consisting of two plates, one of which is perforated with square bumps. The temperature field is calculated in four areas of the Laplace equation in stationary conditions. Written the boundary terms in each collector area, resulting in left expression, where changing the expression collector absorber parameters, can describe the optimum collector performance. A temperature gradient field, specify the difference of the temperature distribution. Not integrated gradient found by cross-sectional area, find the amount of heat that passed through the cross-sectional area.
7. Identified the most effective procedure for the automatic control of several sets of parameters where adjusted by the solar control of the intensity of solar radiation, the lower storage tank temperature and the outdoor temperature, the total capacity of a sunny day can be increased by about 9% compared to the management of certain parameters.

8. Analysis of several Latvian regions of heat recovery solutions for residential sector with a financial viability analysis, showed that the heating system, modeled after the established methodology based on optimal parameters, despite the fact that CS investment is by 37.5% higher, it is a more efficient system than the heating system using only a granular boiler. As a result, states that the optimized CS Latvia's climatic conditions effectively act as a heat source for private sector and CO_2 emissions are lowering agent.

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