RENEWABLE ENERGY RESOURCES EFFECTIVE USE FOR RURAL DEVELOPMENT

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Abstract. During the last few years significance of environmental problems increases and activation of environmental problems enlarges humans' interest about different environmentally friendly technologies. One of the biggest air polluters are fallouts resulted from burning of fossil fuel. That is why urgent becomes utilization of renewable energy resources (RES) for the energy production obtaining, which are more environmentally friendly. The paper presents investigations on the possible RES use in rural area of Latvia and especially about solar energy use taking in account availability of good developed solar energy testing park in the Institute of Physical Energetics. The main results will apply evaluation of RES potential and RES place in energy consumption; innovative technologies for different types of RES use; possibilities of solar energy use for heating and cooling. The progress in developing energy production technologies of using renewable energy resources has been made in many countries, but there is a need to make the results widely known, to transfer and exchange technologies and practices. Recent development of solar collector's technology opens new possibilities for solar energy use. The main aspects of RES use also include dynamic of energy and renewable energy consumption including determination of renewable energy resources theoretical and technically useable potential; the main policy and legislative documents describing and relating to the use of renewable energy resources.

Keywords: RES, rural development, solar energy, environment protection.

Introduction

The main goal of the Latvian energy policy is to reduce dependence of energy sector on imported primary energy markets. Latvia, like other EU Member States, has committed to achieving the quantitative targets set in the Directive 2009/28/EC on the promotion of the use of renewable energy resources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC, and in the National Reform Program of Latvia for the Implementation of the "Europe 2020" Strategy – to achieve a 40 % share of renewable energy in the gross final energy consumption, as well as a 10 % share of renewable energy in the gross final energy consumption in the transport sector in 2020. Cost-efficient use of local energy resources and safe energy supply are among the main conditions of national economic independence and energy supply safety. Therefore, it is even more important to improve the efficiency of the existing heat supply systems and use energy resources more efficiently, thus contributing greatly to the reduction of greenhouse gas emissions. In the world, a tendency is developing step-by-step with replacement of the traditionally employed energy carriers by those of higher quality, with inclusion of renewable energy resources – biomass, solar and wind energy. The slow introduction of new technology in energy has resulted in ad hoc national or regional efforts to make the energy system more sustainable. This would undeniably lead to the cost reduction for the RES – technologies, which, in turn, would mean their increased competitiveness and wider utilization. Accordingly policy makers continue to deploy targeted approaches such as subsidies and favourable tax treatment of specific technologies also in Latvia – feed-in-tariffs for cogeneration.

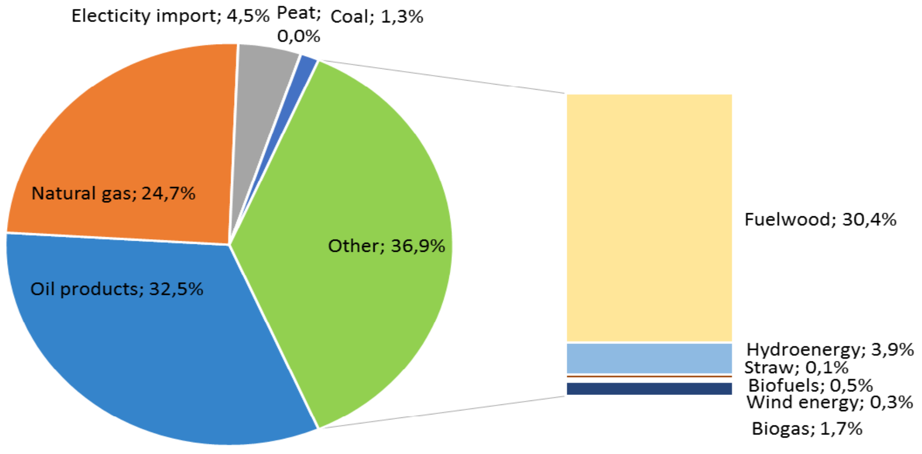


Fig. 1. **Primary energy consumption structure in 2014 (by energy types), %**

According to Latvian Central Statistical Bureau the share of RES share of 36.9 % in the primary energy consumption was achieved in the year 2014 (Fig. 1). 54.5 % (2803 GWh) of the total gross electricity volume produced was generated from RES (HPPs, wind, biogas, biomass, etc.). In 2014, the total installed capacity for electricity production from RE increased by 16 MW, as compared to 2013, constituting 1780 MW in total.

Analyzing the Latvian energy balance by energy consumption sectors the most energy-consuming sector is the household sector, where final energy consumption was – 31.1 %, transport sector – 27.8 %, industry and construction sector – 21.9 %, the service sector – 15.4 %, and the agricultural sector – 3.9 % in 2014 (Table 1). About 70 % (in 2014) of the total centralized heat energy final consumption has been distributed to households, the consumption structure of centralized heat supply has remained unchanged over the past years, with central heating comprising 65-70 % , hot water supply 30-35 %.

Latvia by the territorial division consists of 9 cities of national importance, with the population approximately 51 %, and 110 rural districts. In urban areas with developed infrastructure RES potential is explored as well as potential of cogeneration and energy efficiency steps. Taking into account the specificities of rural areas related to dispersive energy consumption structure of the territory and the agricultural process performance, increased attention should be paid to the small-scale local power plants development – wind, solar thermal and electrical energy, small biomass boiler houses, biogas plants, waste disposal plants, etc., including microgeneration.

Table 1

Energy final consumption by energy consumption sectors (PJ)

Energy Sectors	2010	2011	2012	2013	2014
Transport	50.9	46.0	44.7	45.3	46.3
Industry and construction	34.9	34.6	37.9	35.8	36.4
Services	25.2	23.4	26.1	25.3	25.6
Households	58.2	55.5	57.6	53.1	51.8
Agricultural	6.5	6.5	6.3	6.5	6.5
Final consumption	175.6	166.1	172.7	165.9	166.6

Heat supply is an important Latvian citizens' life quality component, taking into account the climatic conditions. Centralized district heating produced 7.21 TWh of heat for sale by 631 boiler houses and 175 cogeneration stations in 2014. Consequently, according to Latvian Central Statistical Bureau, approximately 34 % of the required heat is provided by centralized district heating (CDH) and trends of recent year's show that the share of RES in heat production process is increasing and reached 33 % in 2014. Latvia not rich variety of local resources, and fossil fuels are imported, so, given the extensive natural gas infrastructure coverage, heat production is dominated by natural gas and fuel wood. Fuels such as diesel and liquefied petroleum gas (LPG), are mainly used to cover peak loads. Renewable energy plays an important role in electricity generation in Latvia. Their share of gross electricity consumption in the past 10 years has fluctuated from 30 % to 37 % (Fig. 2).

The total electricity production from RES in 2013 was 3534 GWh, while in 2014-2803 GWh. Around 90 % (the average for the last 10 years), provided by large hydro power plants and the remaining part – small hydro power plants (HPP), wind power plants (WPP) and RES use cogeneration plants (CHP). In recent years, power production from renewables is very variable because it is highly dependent on hydroelectric power station generations capacities. HPP production largely depends on the water inflow in rivers, so the amount of electricity generated fluctuates from year to year. WPP generated electricity since 2004, almost three-times increased, while electricity volume generated by biogas plants are gradually increasing - particularly increase was observed in the last four years, as well as very rapidly (53 times out of 2004) power production volumes by cogeneration plants using biomass. Biomass for energy production is already widely using, of course there is still the potential for it use and with each passing year technology develops and evolves, but in Latvia there are good gas infrastructure and it is no need to acquire further potential biomass. According to the EU Directive 2012/27/EU requirements Latvian has almost reached the high-efficiency cogeneration and efficient district heating potential. As well as power generation HPP potential is almost exhausted, almost certainly still not acquired the wind, biogas and solar potential.

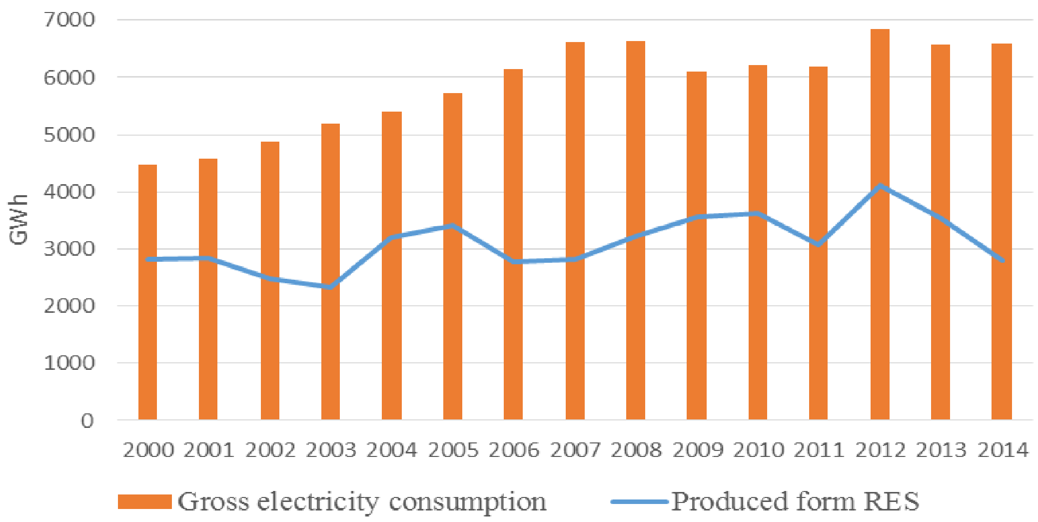


Fig. 2. **Gross electricity consumption**

In 2004 the electricity production volumes form RES was 3040 GWh from Large scale HPP, 70 GWh from small scale HPP, 49 GWh – WPP, 6 GWh – Biomass CHP and 32 GWh – Biogas CHP, but in 2014 the volumes changed as follows 1925 GWh – Large scale HPP, 68 GWh – small scale HPP, 141 GWh – WPP, 319 GWh – biomass CHP, 350 GWh – biogass CHP, that shows that resource structure are significantly changed due technological development.

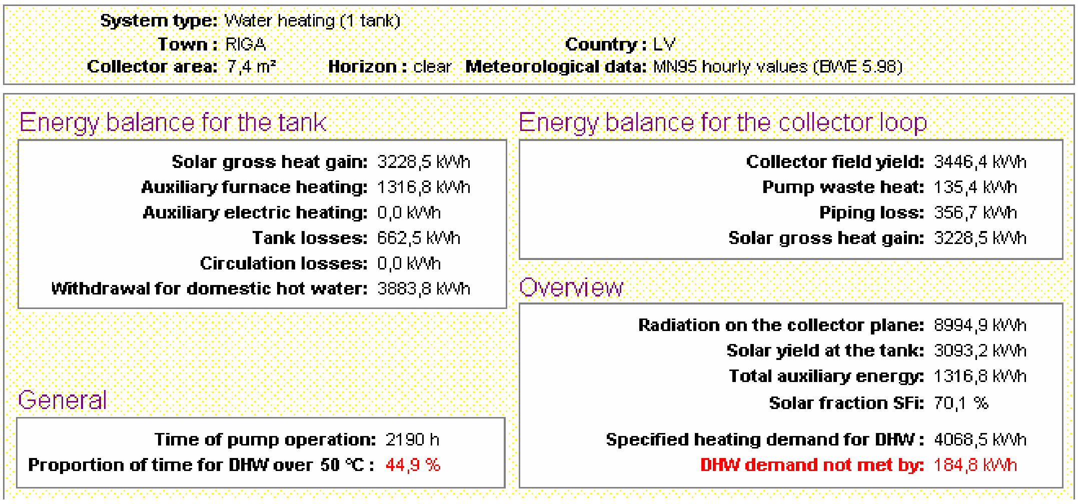
Sustainable Energy Action Plans (SEAP) were worked up in 19 municipalities of Latvia for the rational and effective RES use in rural areas especially. Successful strategies mean jobs, reduced CO_2 emissions and competitive advantage for the regions. These plans help regional and local authorities to specify what they can do to use bioenergy, for example, what ideas are at hand, what policy measures can support RES use for energy production and how to handle the decision processes. In the countryside especially, there are many private and public buildings with old wood burning heating systems. SEAPS helps to learn how to use bioenergy and other RES efficiently as well as about the best technologies for these needs. They also gain information on the experience in other regions and how to obtain funding from variety of financial instruments. The financial instruments provided by the state allow for replacement of out-of-date technologies with new and more efficient ones.

Possibilities of solar energy use for rural development

The potential for solar energy use for heating and cooling in Latvian climate conditions is under development, but there are many reasons why consumers have skepticism and a perception that the climate conditions in this region is not suitable for solar energy use. There are many countries which are located in the 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 Latvia. But in the same time in countries like Germany, Czech Republic, Sweden, where the solar radiation level is nearly similar as in Latvia, solar energy is actively used for heat and electricity production. Interest about the usage of solar energy in Latvia increases – partly it is explicable to unpredictable and essential price rise of fossil fuel and partly to the desire to invest in technologies which could reduce this rise in price in the future.

Variability of Solar energy is a main deficiency of this resource; hence, it can be used as an auxiliary resource in combination with other resources, in such a way will be reduced resource consumption and environmental impact. Especial area for solar energy use is a rural area neither because it is profitable to use solar collectors not only for heating and hot water preparing for household but also for agricultural requirements for greenhouses, farms, grain, and hay drying, etc.

Investigations into the possibilities of solar collectors use have been carried out applying the PolySun model, where solar collectors are combined with other energy sources. PolySun model has been adopted for the correct results adding with long term climate date (diffused, direct radiation, wind parametrs, nebulosity etc.). With the help of PolySun program diversified solar energy use systems in different combinations were modeled and analyzed; the results have been obtained on the heat energy produced, on the share covered by solar collectors in the total heat production; the data on the temperatures of a collector, of a heat carrier, of hot water, etc. Adopted values correspond to average size rural estate consumption. In the promotion work the possibilities are analyzed as to the connection of solar collectors with boilers operating on solid fuel (biomass). The results are exemplified in the scheme of Fig. 3, where the total energy balance is shown comparatively for a boiler and solar collectors. In the bottom right window it could be seen that the solar collectors produce 3093.2 kWh of warm water, while the solid-fuel-operated boiler – 1316.8 kWh (total production 4410 kWh), which means that the Sun energy gives 70.1 % to the warm water preparation. The results of analysis are presented in Fig. 4.


System type: Water heating (1 tank)
Town : RIGA **Country :** LV
Collector area: 7,4 m² **Horizon :** clear **Meteorological data:** MN95 hourly values (BWE 5.98)

Energy balance for the tank

Solar gross heat gain:	3228,5 kWh
Auxiliary furnace heating:	1316,8 kWh
Auxiliary electric heating:	0,0 kWh
Tank losses:	662,5 kWh
Circulation losses:	0,0 kWh
Withdrawal for domestic hot water:	3883,8 kWh

Energy balance for the collector loop

Collector field yield:	3446,4 kWh
Pump waste heat:	135,4 kWh
Piping loss:	356,7 kWh
Solar gross heat gain:	3228,5 kWh

General

Time of pump operation:	2190 h
Proportion of time for DHW over 50 °C :	44,9 %

Overview

Radiation on the collector plane:	8994,9 kWh
Solar yield at the tank:	3093,2 kWh
Total auxiliary energy:	1316,8 kWh
Solar fraction SFi:	70,1 %
Specified heating demand for DHW :	4068,5 kWh
DHW demand not met by:	184,8 kWh

Fig. 3. **Total energy balance for boiler and solar collectors**

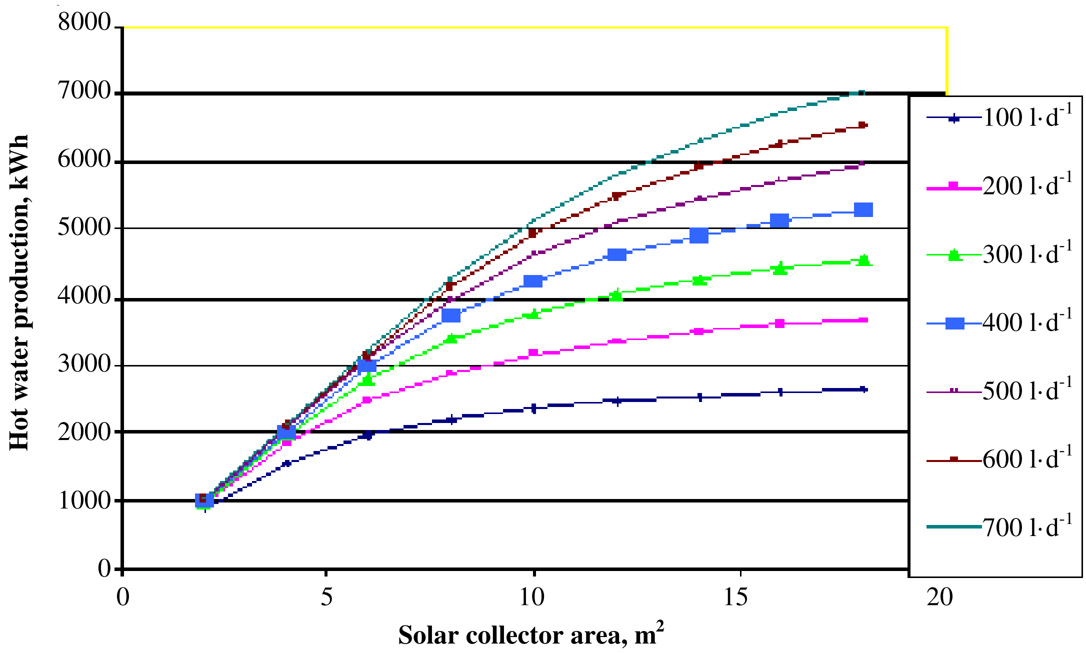


Fig. 4. **Diagrams of hot water production depending on solar collectors area**

It is estimated mathematically what area of solar collectors should be for a definite consumption level. Fig. 3 shows a plot in which on the abscissa axis the solar collector's area is laid off, and on the ordinate axis – the produced hot water in kWh. For different needed quantities of hot water the corresponding curves have been obtained, and the kilowatt –hours necessary for hot water preparation are given. Each curve initially has a steep rise, which in the end tends asymptotically to a definite value. From these curves it follows that it is profitable to increase the area of solar collectors taking their steeply growing part (i.e. steep rise in energy production), and after that, when the curve asymptotically approaches a constant value corresponding to the necessary volume of hot water the enlargement of solar collectors is unprofitable, since the energy obtained does not compensate in this case the cost of their installation [1].

Economic indices of a heat supply system with solar collectors have been calculated. To impartially judge the efficiency of a combined heat supply solar system at least 12 months should be taken, since the system's operation depends on the amount of incident radiation and a consumer's demand, which vary with season.

In order to calculate the amount of solar thermal energy accumulated by the system during its operation or the savings of other energy resources, as well as the efficiency of the system's operation and heat energy consumption load per 1 m^2 of a solar collector's area, one should take into account the heat obtained from the solar collectors and the secondary boiler, the amount of heat needed for hot water preparation and indoor heating, losses in the storage tank, as well as the set solar collector areas and characteristic parameters of the system's operation [2]. From the previously modeled energy balance variant one can see that a solar collector with the area of 7.4 m^2 and a 450 slope is capable of producing 3233 kWh annually. With due consideration for the losses in the pipes and pump, we obtain 3093 kWh per year.

Having estimated in the beginning the yield from 1 m^2 of solar collectors it is possible to determine the saving as compared with electric energy (1-2).

$$Q_{efe.kop./m^2} = \frac{Q_{efe.kop.}}{m^2} \tag{1}$$

Therefore, in this situation 1 m^2 of solar collectors can yield 418 kWh·m^{-2} annually.

Now, it is known that 1 kWh of electric energy costs 0.165 EUR (with VAT).

$$A = \frac{TQ_{efe.kop.}}{m^2}, \tag{2}$$

where A – monetary amount savings, EUR;
T – electric energy cost for kWh.

This means that 1 m^2 of solar collectors saves 69 EUR per year. Therefore for the 7.4 m^2 area of the model under consideration the yearly saving is 510 EUR. Given the solar collector system's s expenses to be approximately 1200 EUR, such a combined heat supply solar system has a payback projected in 2-3 years. Its installation in a private house could be done approximately within a month. The maintenance costs in the first five years are 0.5- 1% of the total expenses.

However, since the prices of gas and electricity are instable and are rising fast every year, it would be more reliable to take a secondary boiler that operates on biomass: the wood fuel costs 0.046 EUR·kWh^{-1}, while electricity – 0.165 EUR·kWh^{-1} and natural gas – 0.054 EUR·kWh^{-1} (these latter are imported energy resources, and, the price on natural gas is instable and ever rising; moreover, natural gas is not available in the entire Latvian rural territory). In view of the above, with the proper system operation, the system has great potential for use in agriculture and for rural development. The combined use of solar collectors and solar batteries has been also investigated. In the experiment, as the feeding source for the circulation pump a solar PV battery was employed, whose size was calculated following from the chosen pump capacity. Under laboratory conditions experimental examination of this system was made; it was established that such a heating system can be used in non-electrified private houses (or when it is necessary to save electricity), with PV serving as the pump feeding source as well as using PV for cooling in summer time. The total capacity of currently installed PV is up to 1300 kWel grid-connected and up 250 kW off-grid in Latvia up to now. Forecast for total contribution of electricity expected the share from solar energy – SolarPV as 4 GWh·yr^{-1} for the year 2020. PV batteries are used in different appliances, on lighthouses and buoys in the Baltic Sea, PV are used for autonomous systems (autonomous systems usually complement a diesel generator or wind power plants generate electricity that can be important in rural areas, for summer cottages) and in the last years also PV batteries are used by connecting to the grid and deliver the energy to electricity grid, according to Latvian law. So the possibilities of solar energy use for electricity production are wide, and the market is rather big.

Till year 2011 PV batteries in Latvia was used only in the households and for offices of small private companies, but now for the first time in Latvia in the companies for industrial process. The company's goal was to limit the pollutions to the environment and to support environmentally friendly technologies. Average per year generated CO_2 emissions are 3867 tons. The company planning gradually replaces activities to ensure the implementation of clean technologies in all stages of the process. The main a project result – replaced energy from boiler and, respectively, the amount of emissions with energy from solar energy technologies: PV batteries and solar collectors with a total yearly production output of around 157 500 kWh per year.

The aim of this study is to explore the suitability of Latvian climate conditions with the use of solar collectors for cooling. In Latvian conditions cooling is required about 5000 degree hours per year (at an indoor temperature of 21 ºC), but the importance of outdoor air relative humidity ranging from 70-90 %. Optimal relative humidity for human body is from 45-55 %, if the moisture levels in the air are lower or higher, it would adversely affect the health, so it is important that humidity level is optimal in areas with a high human concentration. Solar energy is available at the same time when is need to cool rooms, so Solar Cooling are suitable also in Latvia. In Latvia such a system is not used, so it is important to assess the potential of this system. In the Institute of Physical Energetic Solar Energy Testing polygon the Solar Cooling system was installed with the cooling capacity 8 kW in the facility, measuring equipment was connected and operating data have been monitored and technical equipment performance were improved. As in Latvian climatic conditions in the summer period (May -September) the average outside air temperature is about 15 ºC (max temperature of summer season average value + 26.38 ºC) and solar radiation – 1100 $kWh \cdot year^{-1}$, than the experimental equipment has operation temperature range of 55-95 ºC in the driving circuit [3]. An, evaluation of possible use, the advantages and disadvantages of the system, taking into account the reduction of fossil fuel use for cooling will be provided. It is possible to define of cooling demand influence on solar collector part, through simulation of solar cooling system without additional heat demand. Solar collectors can almost totally provide heat requirement for chilling process, by producing about 4.2 MWh per year. Such small scale installation can be used in both rural municipal buildings and other buildings where in the summer months there are people, as well as in industrial processes, where high energy consumption for indoor temperature behavior are.

Conclusions

The specific of Latvian rural areas contributes use of small scale installations for energy production. The investigations that have been done prove that in Latvian climate conditions is advantageous to use RES for energy production in rural area and the solar systems also (solar collectors and PV) for extra heat and electricity supply due to the reduction of energy impacts on the environment or for non-electrified summer cottages. It was established that the use of such solar heating system during the summer allows saving up to 30 kg of fossil fuel per 1 m^2 of solar collectors.

As shown by experimental studies, the application of solar collectors in Latvia can give good results. Solar energy could be used for hot water preparation in summer, because hot water is needed throughout the year to ensure that it is necessary to combine the traditional energy sources and renewable energy sources, and this increases the capital and operating costs. Solar energy use equipment has a relatively long service life – 25-30 years (to deteriorate automatics, pumps) and low operating costs.

Acknowledgment

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