COMPARISON OF SOLAR COLLECTORS AND CONVENTIONAL TECHNOLOGIES USED FOR WATER HEATING IN LATVIA

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Abstract. The article deals with comparison of such energy sources as fossil fuel and solar radiation. Contamination of the atmosphere, shortage of electric energy and running out of fossil fuel stimulates to look for alternative energy sources for the production of electricity. This searching is contributed by the legislations of the European Commission, the European Union and the protocol of Kyoto. In the climatic conditions of Latvia as energy sources for production of electricity it is possible to use almost all alternative fuels. Our calculations have shown that the prime cost of 1 kWh heat energy produced by the flat plate solar collector placed on the roof of a house at Ulbroka, is about 0.077 € and that is more that produced by combustion of fossil fuel. Solar radiation makes no hazardous emissions, and for Latvia it is absolutely for free, but the use of it demands rather expensive equipment, as the intensity of solar radiation is low. Production of electricity from other sources of energy also demands certain capital investments as well as the purchase of fuel, maintenance of equipment and presence of different manipulators. Introduction of up-to-dated equipment for the use of alternative energy is long–term investment in the national economics.

Key words: energy, fossil fuel, solar radiation.

Introduction

According to the prognosis of World Energy Council outspoken in the year 1994, in the year 2020 there will live about 8 billion people on the Earth [1]. Thereby, considering the technical progress, the whole world consumption of energy resources will increase by 60% in the nearest 20 years [2]. The consumption of energy in maximal variant may reach 17.2 Gtoe (giga ton of crude oil equivalent), but in minimal variant 11.3 Gtoe. In order to satisfy this lack of energy (allowing for common consumption of energy 16 Gtoe), it is envisaged to consume coal at an average 3.8 Gtoe (23.7%), crude oil 4.5 Gtoe (28.1%), natural gas 3.6 Gtoe (22.5%), large hydro-power stations 1.0 Gtoe (6.3%), and renewable energy sources 3.1 Gtoe (13.1%) [1]. At present the combustion of coal, natural gas and crude oil gives about 90% of the total amount of energy consumption [3]. Calculations have shown that resources of coal will be enough for 250 years, crude oil for 40 years and natural gas for 65 years (after [4] for 200 years) [1, 3].

The European Commission (EK) has ratified the "Green Paper Towards a European Strategy for Security of Energy Supply", which appeals to discuss the strategy of the future of the European Union (EU) to its safety supply with energy, including all energy sources accordingly to the classification of the EK: fossil sources or energy – coal (including coal, brown coal and turf), crude oil, natural gas, nuclear power and renewable sources or energy – biomass, biogas, waterpower, wind energy, geothermal heat and solar radiation [5].

The Republic of Latvia is not rich in natural sources of energy – about 70% of energy sources have to be imported [6]. That is why the promotion of the use of local and renewable sources of energy has particular importance for the conditions of Latvia.

Both electric and thermal energy demands in Latvia are met by the use of various sources of energy, like natural gas, crude oil products, coal, local and renewable sources of energy. The cost of corresponding energy sources, available technologies and developmental tendencies of national economy determine the demand for each of mentioned source of energy [3]. However, each kind of energy resource has their specific feature, which separates it from another energy resource and affects its market cost.

Considering energetic, economical, ecological, social and other factors in the assessment of technically economical potential of energy resources, it is stated that local and renewable sources of energy substantially enlarge competitiveness among the sources of energy in comparison with traditional fossil energy sources used until now [3].

The consumption of energy increases with every year. As told, the combustion of fossil fuels nowadays provides approximately 90% of energy consumption in the world. The usage of fossil energy is the main pollutant of the atmosphere which in last decades contributes irreversible global heat. The resources of fossil fuels in the near future will run away.

In order to react to the adjustments of humanity activities, in year 2001 there had been signed the Kyoto protocol, which predicts reduction of emissions of greenhouse gases during the period of the years 2008 – 2012 in comparison with the year 1990 by 5.2%. The aim is to decrease the density of fossil fuel and thus to decrease hazardous emission in the atmosphere. When Latvia joined the EU, it signed the EU directive 2001/77/EC about the increasing use of renewable energy for the generation of energy. In accordance with these regulations in Latvia in the year 2010 the energy generated from renewable energy sources have to make 49.3% of the total amount of energy consumed in the year 2000.

As renewable energy sources in Latvia it is possible to use water-power, wind energy, geothermal heat, biomass, biogas, geothermal heat and solar radiation. Alternative energy sources are becoming increasingly important, both because they are renewable and because their use generally has less environmental impact that the use of fossil fuels or nuclear power [7].

As known, the traditional technologies of water heating are relatively expensive. In order to clear up what kind of benefit gives the solar energy in comparison with one or another energy source, the research has been carried out.

The aim of our research was to give a small insight in the table of energy sources used at present in Latvia, as well as to have a look at the role of solar energy in the spectrum of more widely used sources of energy.

Materials and methods

There several primary sources of energy exist in the nature (electric energy, heat energy and mechanical energy). The way, how energy is delivered to its consumer and how it is transformed, in Fig. 1 is presented.

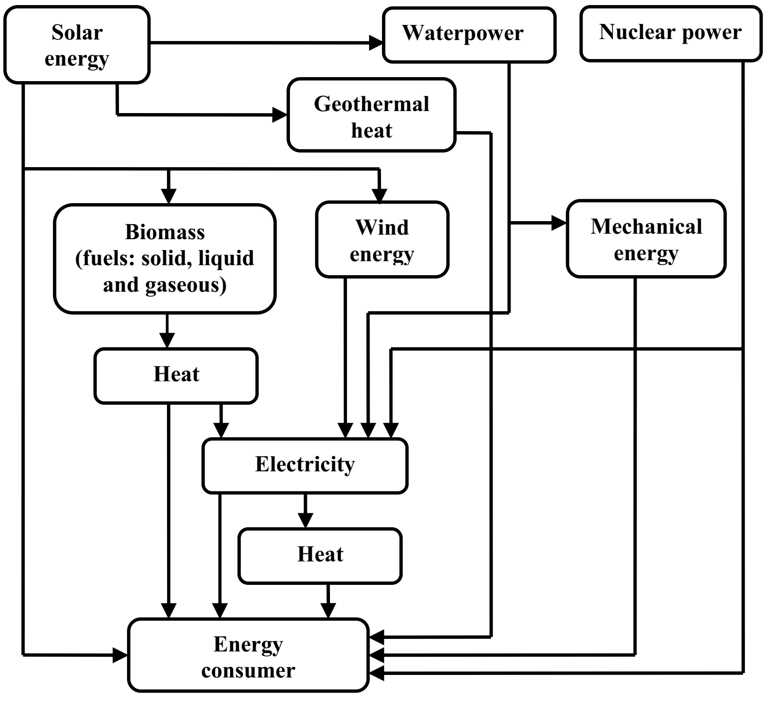

Fig. 1. **Transformation of some energy sources** [8, 9]

At present the most popular way, how a consumer gets heat energy is combustion of several kinds of organic matter, thus obtaining mainly heat energy. By the discharge of fuels chemical energy, it is converted into heat energy, and directly or stepped up any more processes of transformation (for example, heat – electric energy – heat) delivered to a consumer [8].

The Sun is the central energy producer of solar system. Only a small fraction of the energy produced in the sun hits the Earth and makes life on our planet possible. Solar radiation drives all natural cycles and processes such as rain, wind, photosynthesis, ocean currents and several other which are important for life. The whole world energy need has been based from the very beginning on solar energy. All fossil fuels (oil, gas, coal) are converted solar energy [10]. The Sun is practically inexhaustible resource of energy and, what is important; the solar energy is absolutely for free.

In the countries of the EU with climatic conditions similar to Latvia, in the development and installation of solar collectors remarkable results are achieved. The areas of solar collector installed in some countries in Table 1 are seen.

Table 1. **Areas of solar collectors installed in some countries of Europe [11]**

Country	Total areas of installed collectors, $\cdot 10^6$ m^2	Areas of collectors, m^2 per 1000 inhabitants
Germany	2.6	33
Austria	2.0	about 250
Greece	2.8	268
Switzerland	1.05	160
Sweden	0.2	22
Denmark	0.3	55

In Latvia installed solar collector areas are not statistically counted. We have gathered information about the solar collectors in Latvia and their areas are following.

Table 2. **Solar collectors in Latvia**

Place of location	Area of collectors, m^2
Research Institute of Agricultural Machinery, Ulbroka, Riga region	1.4
Research Institute of Agricultural Machinery, Ulbroka, Riga region	3.8
Boarding school of Iecava, Bauska region	9.2
Children village of Islice, Bauska region	90
Aizkraukle regional gymnasium	33
Aizkraukle city boiler house	120

The situation that in Latvia there are so small number of solar collectors, have developed historically because of existing low price of fossil fuel. Considering the solar collectors, made by farmers and private house owners by their selves, there are about 300 m^2 of solar collector installed in Latvia. The possible reason of such a situation is too high price of solar devices offered by the companies of foreign countries, and the lack of production of solar collectors in Latvia. Further the results of our investigation of the distribution of solar collectors, ecological and economical comparison of solar collectors, and conventional technologies used for water heating in Latvia are presented.

Results and discussion

The prime cost of heat energy produced by solar collectors in some countries of the EU and Latvia has been analyzed. The solar devices of high quality produced in countries of the EU for inhabitants of Latvia are expensive, because there are cheaper sources of energy. Considerably cheaper are in Latvia built ones, but their quality and service time may be shorter.

Table 3. **Price of solar collectors, €·m^{-2}* [11]**

Country	Characteristic of device	Area of collector, m^2	
		up to 10	up to 500
Sweden	Complete set	500	250
	Including water tank	100	50
Germany	Complete set	750 – 900	up to 375
Latvia	“Viessmann” equipment	up to 750	–
	Collectors made in Latvia	150 – 200	–

* 1 € = 0.7 Ls

The cost of heat energy obtained by solar collectors consists of amortization and exploitation expenses, attributed to the quantity of obtained heat.

Prices, shown in Table 4, are approximate and for each of devices they can be different. It is possible to reduce the cost of heat energy produced by solar collectors, if the device is own made.

Table 4. **Price of heat energy produced by small collector devices**

No.	Indices	Derivation of collector	
		Made in EU	**Made in Latvia**
1	Amortization, €·m^{-2}	32.1 (in 20 years)	21.4 (in 10 years)
2	Exploitation, €·m^{-2}, including	3.21	3.21
	a) operation of pump (10 W/2500 h)	0.36	0.36
	b) technical service	2.86	2.86
3	Total expenses, €·m^{-2}	38.53	24.64
4	Heat yield per year, kWh·m^{-2}	400	320
5	Price of heat energy, €·kWh^{-1}	**0.096**	**0.077**

In order to establish the efficiency of the use of solar energy for water heating, the following calculations were made. For example, the necessary quantity of peat brick Q_{fuel} for production of 1 kWh of heat energy is calculable as following [8, 12]

$$Q_{fuel} = \frac{3600}{Q_z^d \cdot \eta} = \frac{3600}{16000 \cdot 0.84} = 0.268 \text{ kg}, \quad (1)$$

where Q_z^d – lower heat capacity of peat, kJ·kg^{-1} (kJ·m^{-3});
η – coefficient of efficiency of the combustion device, %.

Comment: 1 kWh = 3600 kJ.

The prime price of 1 kWh heat energy is calculable as following

$$P = Q_{fuel} \cdot P_f = 0.268 \cdot 10^{-3} \cdot 45 = 0.012 \text{ €·kWh}^{-1}, \quad (2)$$

where P_f – price of peat, €·t^{-1} (€·m^{-3}).

The results of calculation are shown in Table 5 [12, 13, 14].

Table 5. **Price of heat energy obtained by combustion of several sources of energy**

Source of heat	Lower heat capacity Q_z^d, kJ·kg^{-1} (kJ·m^{-3})	Price P, €·t^{-1} (€·m^{-3})	An average efficiency of device η, %	Necessary quantity of fuel for production of 1 kWh of heat, kg (m^3)	Price of heat energy P, €·MWh^{-1}
Firewood	14000 (1)	(40)	80	0.321	0.013
Wood brick	16800	210	80	0.268	0.056
Wood granule	16800	180	80	0.268	0.048
Coal	23500	90	84	0.192	0.017
Peat	12000	35	84	0.375	0.013
Peat brick	16000	45	84	0.268	0.012
Natural gas	(33600)	(240) (2)	92	(0.117)	0.028
Liquefied gas of propane-butane	46000	(485)	92	(0.085)	0.041
Derv	42500	(800)	92	(0.092)	0.074
Heavy fuel oil	40000	(215)	92	(0.098)	0.021
Heat pump	–	0.018 (3)	400 (4)	–	0.018
Electric energy	–	0.073 (5)	100	–	0.073

(1) *humidity of 25%;* (2) *price for 1000 m^3 of natural gas with yearly consumption of 500 – 25000 m^3;* (3) *price of heat energy if the coefficient of heat pump transformation is 400% (consumption of 1 unit electric energy gives 4 units of heat energy). Price is given in €·kWh^{-1};* (4) *coefficient of transformation;* (5) *price is given in €·kWh^{-1}*

As shown in Table 5, the cheaper heat energy may be obtained from combustion of peat brick. But there in case of the use of fossil fuel a storehouse is needed where to preserve resources of the fuel. Such a solution is not always profitable because of additional cost or lack of the space for preservation. Beside to this fossil fuel have another negative factor. Combustion of it makes hazardous emission what is dangerous for surrounding environment and people. To ascertain what kind of substances originate at the combustion of fossil fuel, the following table was formed [8, 15, 16, 17].

Table 6. **Pollution generated from sources of energy**

Resource of energy	**Quantity of emissions, grown out of combustion of several sources of fuel**						
	CO_2, %	H_2O, %	H_2S, %	NH_3, %	NO_x, %	sulphur, %	ash, %
Coal	×	×	×	×	×	0.3 – 7.6	10 – 40
Peat	-	×	×	×	×	min 0.5	15
Natural gas	max 12	×	up to 0.002	×	×	–	–
Petroleum products	×	×	×	×	×	0.15 – 3.5	up to 0.3
Nuclear power	General danger of radiation						
Firewood	–	×	–	–	–	–	up to 1
Biomass	–	×	–	–	–	–	4
Biogas	30 – 40	1					
Geothermal heat	Boring wells are in train for access of geothermal water						
Small hydropower stations	Water dams, fish pass discomfiture, river drainage and inundation						
Wind energy	Collisions with birds, occupation of ground territory						
Sun energy	Aesthetic devices, zero harm to the environment						
Electrical energy	Like end-product does not make pollution, but is dangerous for people health in contact with it						

From Table 6 it is seen that alternative energy resources make no hazardous emissions. It means that the use of renewable energy sources in the nearest future must be regarded as priority number one.

Conclusions

1. Combustion of fossil fuels nowadays provides approximately 90% of energy consumption in the world.
2. When fossil fuel is used, the store-houses are needed.
3. A unit of heat obtained from solar radiation is more expensive than obtained from fossil fuel, because the intensity of solar radiation is low.
4. The solar energy in comparison with traditional fossil fuel makes no hazardous emissions.
5. The use of alternative sources of energy in the nearest future must be regarded as priority number one.

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