Journal of Environmental Engineering and its Scope
Volume 1 Issue 3

Heating Water by Photovoltaic Panels

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ABSTRACT
The submitted article offers one of the possible options of a usage of photovoltaic panels for a domestic hot water preparation with an option to extra heating a heating system, and following recalculation of a produced electric energy amount in regards of a total return of the assembled system. An electric heating boiler combined with a heating option working on solid propellant was chosen for the experiment. The most frequently used combined electric storage tank was chosen as a classic option to heat a domestic hot water.

Keywords: *electric, assembled,* illustrates

IMPLEMENTATION PHOTOVOTAIC

Solar energy systems include photovoltaic (PV) materials and devices that convert sunlight into electric energy; PV cells are commonly called solar cells [OFFICE OF ENERGY EFFICIENCY AND RENEWABLE ENERGY.: (2013)].

A large study in California completed by Lawrence Berkeley National Laboratory compared sales of homes with PV and without to determine what premium, if any, existed on homes sold with PV systems. Their results indicated that depending on whether the home was new construction, or existing, the price per watt premium varied between $2.30 - $2.60/watt, and $3.90 and $6.40/watt, respectively for homes with PV systems, as compared to comparable homes without PV.

Sample Comparison of Energy Savings Value To better understand some factors that affect energy savings, and therefore value to the consumer, an example follows comparing identical 5 kW PV systems—one in Colorado and one in Louisiana.

This example illustrates the difference in energy savings as a function of production potential, utility electricity rates, and typical electricity consumption patterns. The example uses average conditions and is only intended as an illustration, not a real-world scenario. In Colorado, the typical household uses around 711 kWh of electricity per month, or approximately 8,532 kWh/year, according to 2011 US Energy.

Information Administration (EIA) data.16 Using the typical PV system size of 5 kW, a PV system in Denver will produce approximately 7,594 kilowatt-hours (kWh) in the first year,17 offsetting approximately 89% of the household usage.

Using average electricity rates in Denver of 11.1 cents/kWh,18 the price typically paid by the homeowner is around $947/year, and the value of electricity produced by the PV system is approximately $843 in the first year (11.1 cents/kWh × 7,594 kWh), effectively reducing the amount paid by the homeowner from $947 to $104 in the first year, an 89% reduction. [GEOFFREY T.

KLISE, JAMIE L. JOHNSON, AND SANDRA K. ADOMATIS, *SRA*].

A photovoltaic system by itself and its behavior should be introduced at the beginning. The article will follow the characteristics of the system's equipment. Subsequently, we will evaluate amount of produced electric energy used on a production of domestic hot water and amount of produced electric energy used for additional heating-up the heating system, also with calculation of payback from designed solution for heating.

The photovoltaic is a technical section, which concerns with a process of a direct transformation of light into the electric energy. The term is derived from a word photo (light) and volt (electric current unit). The transformation process runs in a photovoltaic cell. The photovoltaics was discovered by Alexander Edmond Becquerel in 1839. The photovoltaic cells for energy production in cosmic programs were used for the first time in 1958. Since then, it becomes inseparable part of the cosmic program. The article will not analyze a transformation process more deeply.

The bases of the photovoltaic (PV) systems are the photovoltaic (PV) cells merged into the photovoltaic (PV) panels. The most popular photovoltaic panels are made from silicium. The different ways of silicium treatment can create monocrystalline, polycrystalline and amorphous (non crystalline) photovoltaic cells. The monocrystalline cell is black octagon and the polycrystalline cell is a blue square.

The monocrystalline cells are more efficient than polycrystalline, however, the usage of an area in the polycrystalline cells is not so perfect according to its shape, so both types has similar performance in the conclusion.

The polycrystalline cells effectivity is 12-14%. The monocrystalline cells effectivity is 12-16%. Price and durability are the same. The photovoltaic panels are capable to produce an electric energy without a direct sunlight based on a diffuse equipment, which is dominant in the Slovakia.

Types of Used Photovoltaic (PV) System
It is necessary to describe a division of the photovoltaic systems and its functioning before we describe the actually used and tested system.
Photovoltaic system:

Stand-Alone Systems: It is used when costs on connection and its operation are higher than a single photovoltaic system. An exemplary case is when a distance from the connection point is longer than 500-1000 m.
Stand-alone systems are divided:

Direct Connection: It is a simple reconnection of a photovoltaic panel and a device. The device works only when there is a sufficient intensity of sunlight. The usage of this type is mostly for charging small devices, pumping water for irrigation, powering ventilating fans.

Hybrid Systems: It is used when a yearlong operation is necessary, and sometimes a device with a high input power is used. It is possible to create a lot less energy from the photovoltaic panels in a winter than in a summer. It is necessary to design the systems for a winter operation, which has an effect on a higher production power, and essentially higher costs at the beginning. The preferable choice is to extend the system with an additional source of electricity, which covers a need of an electric energy during months with an insufficient sunlight and during operation of devices with a higher input power. The additional source for example can be a wind generator, a generator, a cogeneration machine, and so on.

Storage System: It is used when there is a need of electricity, though there is no sunlight. The stand-alone systems have special storage batteries made for slow charging and discharging due to reasons mentioned above. Optimal charging and discharging of batteries is ensured by a regulator. It is possible to connect devices powered by a direct current (system current is usually 12 or 24 V alternately 48V) and common network devices (230V/~50Hz) connected by an inverter.

Systems connected to the network: It is performing automatically thanks to a microprocessor, which is running an inverter, and transforms a direct current from the panels to an alternating current powering devices. The connection to the network is subjected to an authorization approval of energy distributions. It is necessary to comply with given technical parameters.
[BUILDING INTEGRATED PHOTOVOLTAICS., (2013)].

DESIGNED SYSTEM

The designed system is with a direct connection. This system was chosen due to its quick payback, what was the initiative though of a system design.

- Used system elements: Photovoltaic (PV) panels Kyoto 275kwp – 16 pieces
- MPPT regulators DC/AC designed for PV system – 2 pieces
- Combined boiler Mora k 120L 2x1000W or 2x1800W
- Storage tank Regulus 200L
- Electric heating spirals 2x 2000W

Existing heating system combining electric boiler and heating by a solid propellant

It is necessary to mention, that the photovoltaic system was installed into the existing fully functional system of domestic water heating. It was ensured by an electric energy from the network in a summer and the heat exchanger connected to the heating system in a winter.

The combined boiler was used MORA K 120L by reason of having dry spirals installed in the flange with changeable input power 2 x 1000W or 2 x 1800W /LD TOPTEL/. The combination of the spirals settings 2 x 1000W was used during connection to the network 230V/ ~50 Hz, combination 2 x1800W was used during connection of the MPPT regulators DC/AC determined for medium solar PV system in a number of 2 pieces. They are connected to the photovoltaic panels in number of 8 pieces with a performance 275Wp by piece on every regulator, what gives together approximately 4,4kWp.

Measurement of the Consumption of an Electric Energy Taken from the Network

I did not measure the real consumption of an electric energy from the network, I keep up to the information from manufacturer, who officially indicate 7,64kWh with input power 2 x 1000W and temperature up to 65°C from initial entry temperature of water 15°C /figure no. 1/. This information is sufficient for a functionality demonstration and a payback of the whole system. It is possible to measure the real consumption of an electric energy with given type of the boiler and boundary conditions in a case of deeper examination.

Table 1: *Technical parameters of energy consumption*

TYPE	K 120 L
Volume (l)	120
Pressure (MPa)	0,6
Weight / filled with water (kg)	62/66
Anticorrosive protection	Enamel / Mg anode
Input power (W)	2x1000
Voltage	230 V ~
Protection class	I.
Protection level	IP25
Time to heat water to 65°C (h)	3.82
Energy consumption to temperature 65°C (kWh)	***7,64***
Quantity of water with 40°C (l)	228
Heat loss (kWh / 24h)	1,77

It is required to mention the spirals connection to the boiler 2x 1000W was changed to 2x1800W to use the most input power from the photovoltaic panels in the shortest time. We watched it as an advantage during winter, when there is a less sunlight.

Display of the System Connection

The domestic hot water heating system is solved by 16 pieces of the photovoltaic panels FV Kyoto 275kwp, which are connected by 8 pieces in a series with 2 pieces of regulators MPPT OPLOCKY. The panels are directly connected into to the regulators, where a switch is designed by a capillary thermometer in a case of overheating the combined boiler. An excessive energy after overheating of the combined boiler goes straight to the heating system via resisting heating spirals assembled to the storage tank connected to the existing heating system. The excessive energy after overheating the combined boiler will be discussed some other time. The combined boiler is directly connected to the MPPT OPLOCKY regulators with classic 16A plug box, although, there is a change against the classical electric energy network. The dry spirals with a performance 2x 1000W were changed for the heating device for contact heating LD-TOPTEL, cartridge heater with caliber 12.5 mm, L = 400 mm, and outlet length Lv = 250 mm, U = 230 V and performance 1800W for one piece.

Measurement Methodology

The basis of my research is the question: "Will the given photovoltaic system fulfill needs of a domestic hot water with correct operation and without any feeling of missing comfort due to lack of hot water, or any necessary physical switching to a classical electric network?". The measurement was designed for reading the values based on a boiler's water temperature, which was set on a maximum operational temperature. The reading was always at 5 pm. The measurement of the really produced electric energy was made similarly, however, we will not represent it in this article. [http://www.energybulletin.net, (2010)].

Payback of Domestic Water Heating

It is necessary to bring up, that particular photovoltaic system would also run with a half number of panels and one regulator MPPT OPLOCKY for a half price of photovoltaic panels with accessories. However, my though was to design a heating system, which will still work during winter months – December, January. It could not be done with a system of 8 pieces of panels and only one regulator MPPT OPLOCKY. / The measurement implemented in 2016 and 2017.

Fig 1. *Designed system*

Table 2: *Input costs*

Photovoltaic panels	140 € x 16	2 240 €
Connection accessories + cables		387€
regulator MPPT OPLOCKY	2	300€
Cartridge heater	2	105€
Assembly material on the roof		274€
		3285€

Table 3: *Consumption of the Combined Boiler*

Real consumption of an electric energy reported by a manufacturer multiplied by ratio 1.5, because of need of hot water was mostly more than 1 heat up of the combined boiler in a day	7,64kW/h x 1,5	11,46kW/h	365 day	4182 kW/h

Table 4: *Calculation of a Total Electricity Price*

Distributive area	**Product**	**Amount of energy import in kW/h**
East Slovakia	DD2	1T/VT - 4 182,00

Invoicing items	Yearly [€]	Monthly [€]
Payment for electricity	186,68	15,56
Fixed monthly payment – keeper	7,80	0,65
Fixed payment for distribution (breaker, emergency capacity)	50,83	4,24
Variable payment for distribution	105,80	8,82
Loss	25,05	2,09
System services	28,82	2,40
System operation	109,57	9,13
Nuclear fund	13,42	1,12
DPH	105,60	8,80
Total	**633,59**	**52,80**

The payback of the whole system after total calculation of all costs is 5.18 year. However, with half number of the panels and only one regulator is payback 2.59 year.

CONCLUSION

The photovoltaic system for a hot water heating was design with a thought to speed up money payback from initial capital. The time of 5.18 year might look long, yet, we did not focus on an excessive energy after overheating the combined boiler. This energy could be used to heat water in a heating system, though this topic will be discussed in some other article.

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