*Ринок інсталяцій. – 2003. – № 1. – С. 6–7. 3. Возняк О., Юркевич Ю., Желих В. Теоретичні передумови оптимізації сукупних терморенованій при проведенні енергетичного аудиту будинку // Вісн. НУ "Львівська політехніка" "Теплоенергетика. Інженерія довкілля. Автоматизація". – 2003. – № 476. – С. 140–145. 4. СНиП 2.04.05-91*У. Отопление, вентиляция и кондиционирование. Нормы проектирования. – М.: ЦИТП Госстроя СССР, 1991. 5. Справочник проектировщика. Внутренние санитарно-технические устройства. – Ч. I: Отопление / Под ред. И.Г. Староверова и Ю.И. Шиллера. – М., 1990. 6. ДБН В.2.6-31:2006. Теплова ізоляція будівель // Міністерство будівництва, архітектури та житлово-комунального господарства України. – К., 2006. 7. Наладка и эксплуатация водных тепловых сетей: Справочник / В.И. Манюк, Я.И. Каплинский, Э.Б. Хиж и др. – М.: Стройиздат, 1988. 8. Матвієвський О., Умнякова Н. Утеплення огороджувальних конструкцій // Ринок інсталяцій. – 2003. – № 12. – С. 18–19.*

УДК 624.012:620.193

M. Kušnír, P. Kapalo
University of Košice, Civil Engineering Faculty,
Institute of Building and Environmental Engineering

MODEL EXAMPLE OF PHOTOVOLTAIC SYSTEM APPLICATION

Розглядається питання використання відновлювальних джерел енергії в період фінансової кризи. Наведено результати експериментальних досліджень сонячних панелей для сумісного виробництва теплової та електричної енергії.

In the period of simultaneous energy and financial crises are increasingly coming to the forefront of renewables energy. One of the perspective energy production, is the production of electricity through photovoltaic cells. The article discussed a model example of the application of electricity generation by photovoltaic panels and its use in the administration building. In the contribution is remitted the effectiveness of the current conditions and is outlined anticipated development in the future.

Introduction. The sun is an inevitable part of our everyday life. The sun is the source of all energy on Earth and is a practically inexhaustible source of clean energy. It is assumed that the sun has for burning hydrogen to helium supplies for the following 15 billion years. At the suns core are in progress thermonuclear reactions (fusions). When these processes are releasing huge amounts of energy, which exceeds 11 000 times the current energy needs of mankind. The simplicity may be said, that the sun can emission energy during one hour, that humanity is able to consume over one year.

In the transition of solar radiation the Earth's atmosphere becomes the first obstacle to be overcome on the path to the surface. The amount of solar energy that enters Earth's atmosphere, is largely influenced by several factors: the size and position of the sun, air pollution and clouds.

Solar radiation can be used in several ways. One possibility is passive solar architecture, where the sunlight is used as efficiently as possible, using the actual architectural design of the building. Another of the possibilities of using solar radiation are solar collectors that convert solar energy to thermal energy, and last but not least, is the conversion of solar energy to electrical energy through photovoltaic cells, which will be detailed addressed in this contribution.

Photovoltaic system classification. In terms of application the photovoltaic systems can be divided into autonomous, hybrid and directly connected to the electricity network.

Autonomous System (grid-off) - This application of PV system is used in places where it is not possible or is not appropriate to connect them directly to the electricity network. Autonomous system can be with or without the accumulation of electricity storage (Fig. 1):

- Autonomous system with direct power - system is used in smaller applications, which are not dependent on the constant solar radiation, such as calculators, watches, etc.. Currently there is great demand for small portable charger for mobile phones and computers.
- Autonomous system with storage of electricity – A necessary part of the system is battery, which provides accumulating of electricity produced by solar radiation for use, where is not enough higher sunlight and energy consumption.

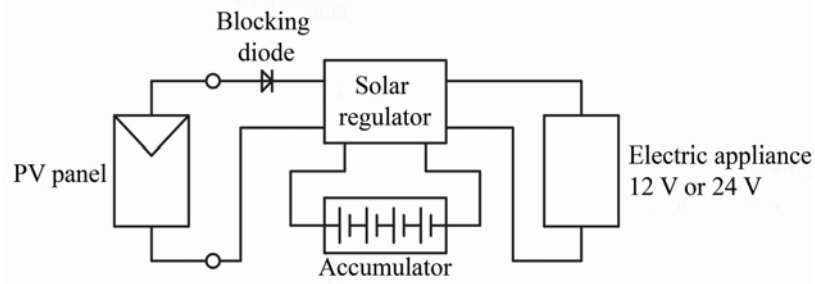

Fig. 1 Autonomous system (grid-off)

Direct connection to the electricity grid (grid-on) - Most widely used system connections of photovoltaics panels. The wide application of PV system is in the areas, where there is sufficient cover of electricity grid. The system does not need any accumulator, because produced electricity is either consumed by appliances in the building or spare electric energy is supplied to the electricity grid. By this connection it is expected economic return of the system (Fig.2).

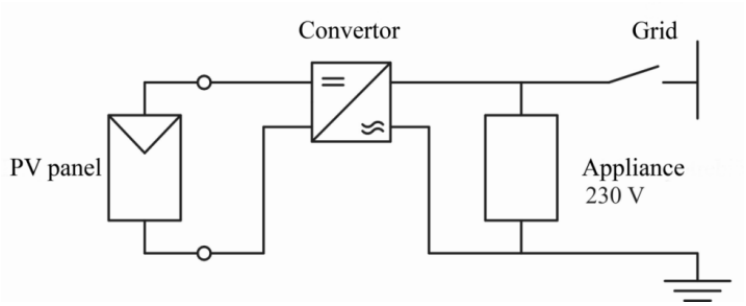

Fig. 2 Direct connection to the electricity grid

Hybrid system - It is an autonomous system connections, which includes the auxiliary generator. For example, consider the generator dieselagregat, water or wind power plant. The system is characterized by a complex regulation, which is caused optimization of all energy sources.

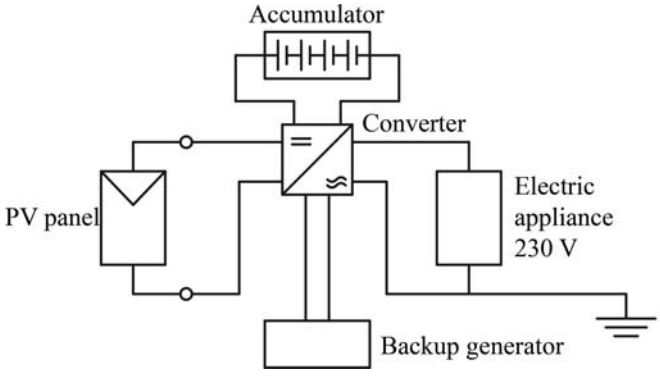

Fig. 3 Hybrid system

Current situation in Slovakia. In our geographical latitudes, the solar energy has the largest potential of renewable energy sources (RES) in Slovakia, which corresponds to 54 038 TWh. Of this total share is technically exploitable potential 9 450 GWh, from that electricity is 1 540 GWh/year. In Slovakia, the potential use of solar energy is higher than for countries (Czech Republic, Germany, the Netherlands), where the potential is lower but the number of installations of PV systems far exceeds Slovakia. Photovoltaic systems are working well despite the adverse weather conditions (clouds), which uses the diffusive solar radiation. Also, the system is characterized by year-round and daily variability of the solar radiation intensity. Most favorable inclination to install PV systems for Slovakia is approximately 35°, with South orientation to make the most of the radiation potential. Besides the optimal inclination, PV systems could be also installed in the horizontal and vertical position. To maximize the energy input are installed tracking systems, which are rotating throughout the day on the sun (Table 1)[5].

Important role in the field of photovoltaic in Slovakia plays a forthcoming law on the promotion of RES. Other important standards include the legal strategy of higher utilization of RES and energy security of the Slovak Republic. Price regulation performs the Regulatory Office for Network Department (ÚRSO). Regulation of prices in the electric-power sector provides EDICT ÚRSO No. 2/2008 on the energy prices in 2009.

Table 1

Inclination of PV systems [5]

	PV system installation							
	Horizontal		Vertical		Optimal inclination		Tracking system	
	G	E	G	E	G	E	G	E
Minimum	1015	760	780	585	1160	870	1450	1090
Average	1120	840	880	660	1280	960	1615	1210
Maximum	1205	905	940	705	1370	1030	1760	1320

G – Annual global energy radiation (kWh.m^2); E – Production potential of solar electricity (kWh/1kWp).

The price of electricity produced from renewable energy sources is determined as a fixed price in Euros (Slovak crowns) for mega-watt-hour for the period of 12 years, since the introduction of assembly devices into service as follows:

From solar energy for:

1. Equipment put into service until 31st December 2004: 390 €/MWh (12 000 Sk/MWh);
2. Equipment put into service from 1st January 2005 to 31st December 2008: 425 €/MWh (12 800 Sk/MWh);
3. Equipment put into service from 1st January 2009: 448 €/MWh (13 500 Sk/MWh).

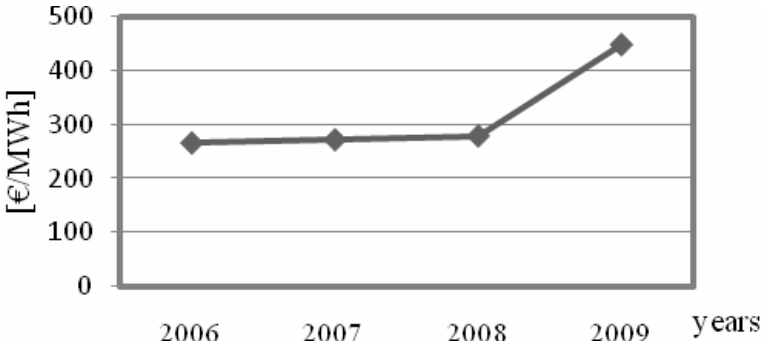

Fig. 4 Graph Diagram of purchasing prices [€/MWh]

Compared to last years, it is a significant move forward, because in the last year was the price set at 279 €/MWh (8 410 Sk/MWh) in 2007 it was 272 €/MWh (8 200 Sk/MWh) and in 2006 it was 266 €/MWh (8 000 Sk/MWh). From these numerical statements is evident more than 60% price increase for the repurchase of electric power produced by photovoltaic cells as compared to last year (Fig. 4) [4].

By the year 2015, the aim is to produce from RES 7% of the total electricity consumption. Estimated production of various forms of RES in 2015 compared to 2010 is shown in the table (Table 2) [1].

Table 2

Production of electricity in 2015 [1]

Source / Year	2010 [GWh]	2015 [GWh]	Difference [GWh]
Small water power plants	350	400	100
Biomass	410	650	340
Wind power plants	300	900	350
Biofuel	180	300	220
Geothermal energy	0	40	40
Photovoltaic cells	0	10	10
Sum	949	2 300	1060

Application of photovoltaic system in model condition. Proposal of photovoltaic system is transferred to the model administration building in which they were applied theoretical knowledges and the various calculations necessary to design the system.

Input parameters:

Q_{max} = 130 kW – maximum heat power input of the building

θ_i = 20 °C - required computing design/calculation temperature (average)

θ_e = -13 °C - required computing temperature (average)

$\theta_{e,pr}$ = 4 °C – average external air temperature

d = 223 – length of the heating period (days)

Period of service in the summer - 1 830 hours (cooling)

When the total consumption of electricity in the administration building played one of the most important tasks, are electrical appliances. The daily need of electricity for appliances in the building is constructed around the value of 300 kWh/day. Considering 250 working days, the total annual need for electricity is 75 000 kWh/year. In the table (Table 3) is daily energy needs for electric appliances in evaluated building.

Table 3

Electric energy need

Daily energy demand					
number	appliance	amount	service hours [h/d]	input power [W]	energy need [kWh/d]
1	computer	100	10	150	150
2	printer	40	2	50	4
3	lamp	550	12	15	99
4	refrigerator	5	24	200	24
5	cooling box	2	24	200	9,6
6	television	5	10	50	2,5
7	microwave	10	1	1000	10
8	projector	1	1	100	0,1
9	cashier	4	10	20	0,8

In the next table (Table 4) is annual consumption of energy need for every type of energy consumption in the office building.

Table 4

Annual electricity consumption

Type of energy consumption	kWh/year
electric appliances	75 000
heating	206 389
cooling	95 160

Photovoltaic system design. For a model office building is designed photovoltaic system with a direct connection to the electricity grid (grid-on)(Fig.1). This is the most widely used system of connected photovoltaic panels. The wide application of the PV system is in areas where there is sufficient coverage of electricity distribution network. The system does not need any battery because of the electricity produced is either consumed by appliances in the building or the excess electric energy is supplied to the electricity grid. When this involvement is expected to return earlier system.

In the design of photovoltaic system was used 203 pc. of photovoltaic panels Solartec SG 72-175/24 oriented on the south with 45° slope and 61 pc. of the same photovoltaic panels. These panels have south orientation and the slope is 90°. Photovoltaic panels Solartec SG 72-175/24 are composed of 72 pieces monocrystaline 5" silicon Si.

Next two tables (Table 5 and 6) shows the yearly production of electricity by photovoltaic panels which have different slopes. Panels with 45° slope are freestanding panels and panels with 90° slope are integrated on the building façade.

Table 5

Production of electricity by PV panels (90°)

Month	Ed	Em	Hd	Hm
January	12,50	387	1,38	42,9
February	18,70	523	2,12	59,3
March	24,10	747	2,82	87,6
April	23,00	690	2,83	85,0
May	21,70	672	2,78	86,0
June	19,30	580	2,54	76,1
July	21,10	654	2,78	86,3
August	22,60	700	2,91	90,2
September	23,50	705	2,91	87,2
October	23,80	737	2,84	87,9
November	13,50	404	1,55	46,6
December	10,30	320	1,15	35,6
Year	19,50	593	2,39	72,6
Total for year		7120		871

Table 6

Production of electricity by PV panels (45°)

Month	Ed	Em	Hd	Hm
January	45,40	1410	1,45	45,0
February	72,90	2040	2,39	66,8
March	106,00	3290	3,61	112
April	120,00	3600	4,27	128
May	132,00	4090	4,82	149
June	126,00	3770	4,66	140
July	135,00	4190	5,05	157
August	125,00	3880	4,65	144
September	110,00	3290	3,94	118
October	95,00	2950	3,28	102
November	50,10	1500	1,67	50,0
December	36,90	1150	1,18	36,7
Year	96,30	2930	3,42	104
Total for year		35100		1250

Ed – Average daily electricity production from the given system (kWh)

Em – Average monthly electricity production from the given system (kWh)

Hd – Average daily sum of global irradiation per square meter received by the modules of the given system (kWh/m^2)

Hm – Average sum of global irradiation per square meter received by the modules of the given system (kWh/m^2)

In the next table (Table 7) is calculated percentage coverage of electric power made by photovoltaic system for each type of energy consumption in the model office building.

Table 7

Percentage electric power coverage

Energy need coverage	[%]
heating	20,46
cooling	44,37
electric appliances	56,27

Economic return of photovoltaic system. Price of one piece of the PV panel is 830 € (25.000 Sk). The investment in the purchase of 264 pieces of PV panels at a price of 830 € (25.000 Sk) will be 219.120 € (6.600.000 Sk). Total investment of the photovoltaic system is about 233.333 € (7.000.000 Sk) (including transport, installation, frame, etc.). The Slovak Republic is obligated to buy electricity produced using renewable energy sources. Price for photovoltaic energy is set to 0,488 €/kWh (13,5 Sk/kWh). The price of electricity from the power plants is fixed at 0,11 €/kWh (3,32 Sk/kWh). This implies a profit 0,338 €/kWh (10,18 Sk/kWh). With the produced electricity 42.220 kWh/year, it is saved 14.270,4 € (429.908,87 Sk). Financial return of the PV system is calculated for 16¼ years.

Photovoltaic system design. The following graph (Fig. 5) shows the evolution of the price of photovoltaic cells in recent years. This indicates a price reduction of photovoltaic panels but also increasing its performance. From this graph it is clear that this continuing trend, the price will decline and performance rise, is the prospect of using the system in the future.

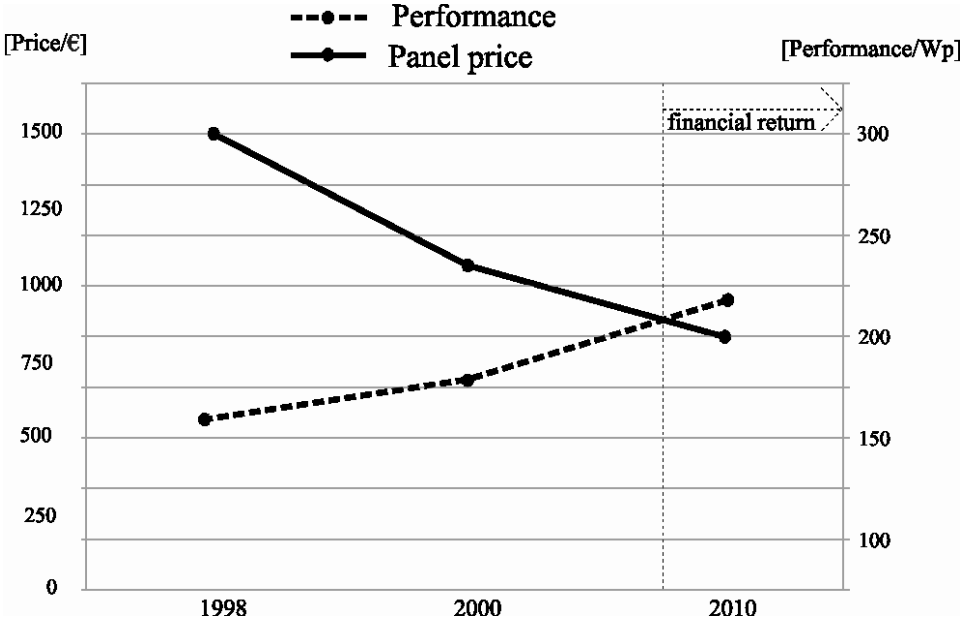

Fig. 5 Capitalizing of PV system

Conclusion. In this paper are presented legislative standards and decrees - rules, that are in force valid in Slovakia. the calculation version of the photovoltaic system is also described there with the economic return and its perspective capitalizing.

Acknowledgements. The authors are especially grateful to NATO - scientific committee and Slovak Scientific grant agency for supporting of project ESP.NUKR.CLG 982978 The paper was created in connection with research center of excellence within the project ITMS “26220120018”.

1. Výnos Úradu pre reguláciu sieťových odvetví z 28. júla 2008 č. 2/2008, ktorým sa ustanovuje regulácia cien v elektroenergetike. http://www.skrea.sk/fileadmin/skrea/user_upload/dokumenty/vynos_02-2008_sk.pdf. 2. Photovoltaic energy barometer – Total UE installed capacity in 2007: 4689.5 MWP. http://www.eurobserv-er.org/pdf/baro184.pdf. 3. Rozhodnutie Úradu pre reguláciu sieťových odvetví č. 0028/2009/E. 4. Sluka Ľ. Skúsenosti s projektovaním fotovoltaických elektrární, In: 2.celoslovenská konferencia – Mesto, obec, efektívna energia. – Bratislava, 2008. – P. 53 – 65, ISBN 978-80-228-1945-9. 5. Slovak Renewable Energy Agency. http://www.skrea.sk/index.php?id=17.7. 6. Photovoltaic Geographical Information System – Interactive Maps. http://re.jrc.ec.europa.eu/pvgis/apps3/pvest.php.