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THE ENERGETIC UTILISATION OF CRYSTALLINE SOLAR CELL SYSTEMS, IN THE SIZE OF DOMESTIC SMALL POWER STATIONS IN 2014

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ABSTRACT
Human life is based on energy consumption, and one of the biggest challenges is that the world's demand for energy continues to grow. The aim of present study is to review the world's energy demand and energy supply, the determination of the degradation of solar cells, the characteristics of the Hungarian energy supply, the introduction of renewable energy utilization and the economic determination of the return of crystalline solar systems in Hungary.
The main direction of my recent research is the utilization of photovoltaic solar energy. The studies were performed with crystalline solar systems. The research was carried out in solar-electric power plants extended from 2 kWp to 16.5 kWp.
The study included the investment of crystalline solar cell systems. The calculation of payback time was performed by static and dynamic indices.

Keywords: renewable energy, solar energy utilisation, crystalline solar systems, static and dynamic indices

INTRODUCTION

Sunshine is free and never gets used up. Also, there is a lot of it. The sunlight that hits the Earth in an hour has more energy than the people of the world use in a year. A little device called a solar cell can make electricity right from sunlight. A solar cell doesn’t give off any gases. It doesn’t even make any noise (HANTULA, 2010).
Energy generated by solar cells is free, which reduces the energy dependence on other countries. A system like this spares the supply of raw materials, affects the local economy advantageously and it is not necessary to transport energy on long distances. Unfortunately, solar energy can be planned ahead in a limited way, which is available in the largest quantities in summer. PV systems involve significant investment, but they do not contain moving parts (except for the inverter) and ideally it has to be maintained in every 10 or 15 years.

MATERIAL AND METHOD

The characteristics of the Hungarian energy supply

Hungary's energy consumption was 1162.4 PJ in 2011, 39.17% of which was domestic production and 60.83% of which was import. In our country, the oil and gas consumption is almost 65%. The nuclear energy use is significant and the use of coal shows a slight downward trend. The share of renewable energy in 2011 was more than 7.85% (VER, 2011).

Solar Cells

Solar Cells come in various sizes. Some are tinier than a stamp. Some are 12 centimeters across. The cells are made of a type of material known as a semiconductor. Often, they are made of silicon. Semiconductors can conduct, or carry, electricity. They don't do this as well as metals, however. That is why they are called "semi." Because they only "semi" conduct electricity, they can be used to control electric current. On their top and bottom they typically have metal contacts through which current can flow. A typical simple cell has two layers of silicon. One is known as n-type. The other is p-type. The layers are different from each other. The process of making electricity begins when the silicon atoms absorb some light. The light's energy knocks some electrons out of the atoms. The electrons flow between the two layers. The flow makes an electric current. The current can leave the cell through the metal contacts and be used. When light hits a solar cell, much of its energy is wasted. Some light bounces off or passes through the cell. Some is turned into heat. Only light with the right wavelengths, or colors, is absorbed and then turned into electricity. A single simple solar cell makes only a little electricity. For most purposes more is needed. For this reason, cells are often linked together in groups known as solar modules. A solar module has a frame that holds the cells. Some modules are several feet long and wide. They usually can produce up to a few hundred watts of electricity. If more power is needed, modules can be joined together to form a large solar array (HANTULA, 2010).

Solar Cell degradation

Solar technology is adapting and getting better every day, the leading providers test the product in extreme conditions to ensure that they can provide solar panels that will provide us with the greatest capacity for the longest amount of time. Most warranty conditions declare that their panels are guaranteed to produce around 80% of maximum capacity after 20 years. This falls in line with the UK Government Feed in Tariff that currently are based on 20 years also. This suggests that the majority of solar panel manufacturers' believe that their panels will last a minimum of 20 to 25 years, but in a competitive market manufacturers are always competing to provide the most reliable and efficient product, we hope that this transfers to benefits for the consumer (www.theecoexperts.co.uk). In the research the degradation of solar cells was noted as 0.5% / year.

Static indicators

Their features is that they do not take the money value of time into account (NÁBRÁDI ET AL., 2008).

Average profitability of the investment

It expresses the efficiency of the investment and the relationship of expenditure and profit in its simplest form (NÁBRÁDI ET AL., 2008).

Br =(E /B)*100

Br the profitability of investment (%)
E the average annual return of investment (HUF)
B one-time investment cost (HUF)

Payback time

It expresses how many years it takes the investment to return from average surplus (NÁBRÁDI ET AL., 2008).

Bm = B/E

Bm the payback period of investment (years)
E the average annual return of investment (HUF)
B a one-time investment cost (HUF)

Dynamic indicators
Dynamic calculation methods take the time factor into account.

Net present value (NPV)
In finance, the Net Present Value (NPV) or Net Present Worth (NPW) of a time series of cash flows, both incoming and outgoing, is defined as the sum of the present values (PVs) of the individual cash flows of the same entity (Net Present Value).

$$\mathbf{NPV} = \sum_{i=1}^{n} \frac{Ri - Ii - Ci}{(1+r)^i}$$

NPV Net Present Value (HUF)
n time of use (years)
Ri receipts in i year (HUF)
Ii investment cost of the i year (HUF)
Ci operating costs in i year (HUF)
r discount rate (%/100)

Internal Rate of Return (IRR)
The internal rate of return on an investment or project is the "annualized effective compounded return rate" or "rate of return" that makes the net present value (NPV as NET*1/(1+IRR)^year) of all cash flows (both positive and negative) from a particular investment equal to zero. It can also be defined as the discount rate at which the present value of all future cash flow is equal to the initial investment or in other words the rate at which an investment breaks even (www.investopedia.com).

Benefit/Cost Ratio, BCR
BCR 1: It shows how many times the discounted sum of the one-time investment and ongoing costs of operation return from the discounted sums of incomes generated during the investment (NÁBRÁDI ET AL., 2008).
BCR 2: It shows how many times the discounted sum of the expenditures of one-time investment returns from the discounted sum of net profit generated during the investment (NÁBRÁDI ET AL., 2008).

$$\mathbf{BCR_1} = \frac{\sum PV(R)}{\sum PV(I) + \sum PV(C)} \qquad \mathbf{BCR_2} = \frac{\sum PV(R) - \sum PV(C)}{\sum PV(I)}$$

PV (R) Present Value of Output (HUF)
PV (I) Present Value of Investment (HUF)
PV (C) Present Value of Costs (HUF)

Profitability index (PI)
Profitability index (PI), also known as profit investment ratio (PIR) and value investment ratio (VIR), is the ratio of payoff to investment of a proposed project. It is a useful tool for ranking projects because it allows you to quantify the amount of value created per unit of investment (www.absoluteastronomy.com).
PI = PV(R)/PV(C)
If PI > 1 then accept the project
If PI < 1 then reject the project

Discounted payback period

It indicates how many years of discounted income is needed to return the sum of the initial investment (NÁBRÁDI ET AL., 2008).

RESULTS

Cost of solar PV systems built in Hungary in 2014

In Hungary it is not cheap to build solar PV systems, but in the last few years prices have fallen dramatically. Price changes in our country are slowly perceptible. The price/Watt relationship of 9 different solar systems of different performance was compared (types produced for network, fixed onto slanted roof, finished systems) (www.bacs-napkollektor.hu).

The type of solar panels is Jüllich and the brands of inverters are EHE and Fronius. The decline in the price of the finished system is not completely in accordance with capacity of the installed power. Upto 5 kWp decrease can be experienced, over 5 kWp there is a smaller price increase. The cheapest system regarding the watt / price connection is the 16,5 kW system (three-phases, one inverter) (*Figure 1*).

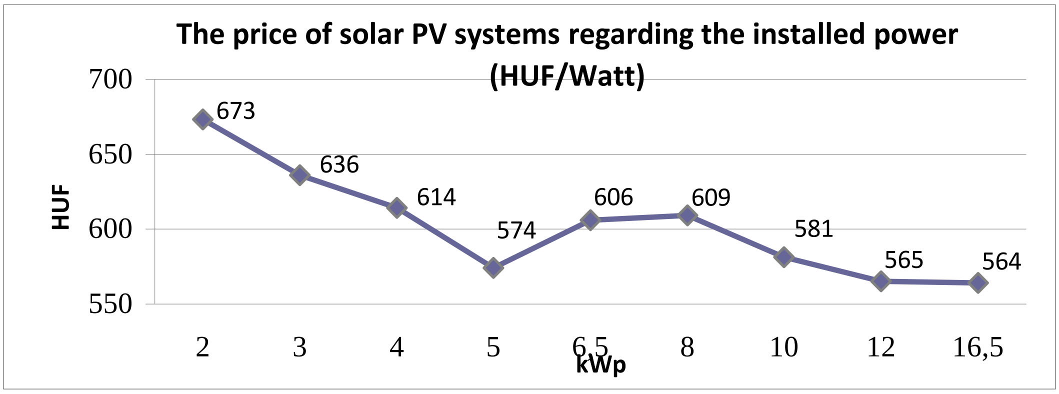

Figure 1. Gross cost of the finished solar PV systems in 2014, depending on the installed capacity (HUF) / Watt)

The examination of the theoretical payback time of crystalline PV systems, in domestic small power station sizes

The payback period was examined by static and dynamic indicators. Planning was helped by SolarGIS data, which provides high-resolution climate data, maps, software and services for on-line access to solar energy. 1200 kWh/m^2 –1360 kWh/m^2 power comes to Hungary every year. In theory a 1kW solar power plant can utilize this energy (20°-25°, including losses).

1 kWh of produced solar energy means a gross 37.47 HUF / kWh savings to private individuals in 2014. Energy measurement is carried out with a two-way measuring device. Excess energy can be sold at 15.44 HUF / kWh, so in the current situation solar power plants should be designed, that they do not produce more energy than we can use in a year (www.solargis.info/,www.eon.hu).

Analyzed systems were of 2 kWp, 5 kWp and 16.5 kWp solar PVs, assuming 100% own capital. These systems include 1 inverter. Characteristics of solar systems is, that they do not require any maintenance for 10-15 years if the instalment is professional. The energy that can be produced in one year: In the case of a 1 kWp nominal power solar system 1280 kWh were taken into account (the average of 1200 kWh and 1360 kWh). The annual

amortization is 0.5% / year, the returns were examined for 15 to 30 years *(*www.solargis.info/, www.bacs-napkollektor.hu*)*.
The life expectancy of inverters is 10-15 years. The replacement is assumed in 15 years' time. Then we calculated operation, maintenance and replacement costs. The price of electricity has been considered with 4% annual price increase (Starting from 2014 / 37.47 HUF / kWh), assuming 100% consumption of energy. Different kinds of natural damage (lightning, hail) were not taken into account. A financial discount rate of 8% was calculated because this value is the applied in the financial sector. On the other hand 8% financial discount rate should be applied to the cash flows discounting (NFÜ, 2008) (*Table 2*).

Table 2. Savings in 1 year in the case of a 1kWh solar PV system in Hungary

1kW solar power plant energy produced, min/max (kWh)	1280
Electricity supply retail selling price of electricity in 2014 (HUF /kWh)	37.47
Overcapacity purchase price in 2014 (HUF/kWh)	15.44
Savings at 100% utilization (HUF)	**47961**
Savings at 80% utilization (HUF)	42321
Savings at 60% utilization (HUF)	36681
Savings at 0% utilization (HUF)	**19763**

The results of static and dynamic indicators

The results of static indicators
The data clearly show that the profitability of a 2 kWp system is 9.2% in the first 15 years, while a 16.5 kWp system is 10.9%, then 10.6 and 12.9%. It can be seen that the profitability of the smallest system is 1.7% lower in 15 years compared to 16.5 kWp system. During 30 years this value goes up to 2.3%. The payback period by solar power plants is can be made among 10 and 14 years (*Table 3*).

Table 3. Analysis of the profitability of investment and the investment payback

Years	**15**	**30**	**15**	**30**	**15**	**30**
The size of the system (kWp)	2		5		16.5	
E (HUF)	123 212	164 518	308 029	411 296	1 016 495	1 357 275
B (HUF)	1 346 200	1 546 200	2 870 200	3 258 820	9 311 640	10 488 930
Br=E/B*100 (%)	9.2	10.6	10.7	12.6	10.9	12.9
Bm=B/E (Years)	10.93	9.40	9.32	7.92	9.16	7.73

The results of dinamic indicators
NPV, PI, BCR1, BCR2: The examined plants are not recommended to be implemented in 15 years (*Table 4*).
IRR: The investment proposals will not be accepted.

Table 4. Dynamic indicators analysis in 15 years

Years	15		
System size (kWp)	**2**	**5**	**16.5**
Investment costs (HUF)	1 346 200	2 870 200	9 311 640
Maintenance costs (HUF)	0		
Electricity charge savings, at the same price (HUF)	1 848 173	4 620 433	15 247 431
r = interest (%)	**8**		
Present value savings (HUF)	1 004 623	2 511 558	8 288 144
NPV (HUF)	- 341 576	-358 641	-1 023 496
IRR (%)	**3.90**	**6.06**	**6.30**
BCR1	0.75	0.88	0.89
BCR2	0.75	0.88	0.89
PI	0.74	0.87	0.89
Discounted savings time (Year)	-	-	-

Table 5. Dynamic indicators analysis in 30 year

Years	30		
System size (kWp)	**2**	**5**	**16.5**
Investment costs (HUF)	1 546 200	3 258 820	10 488 930
Maintenance costs (HUF)	200 000	388 620	1 177 290
Saving Electricity charge, the same price (HUF)	4 935 546	12 338 865	40 718 256
r = interest (%)	**8**		
Present value savings (HUF)	1 533 669	3 834 173	12 652 772
NPV (HUF)	187 469	963 973	3 341 132
IRR (%)	**9.09**	**10.68**	**10.87**
BCR1	1.09	1.29	1.31
BCR2	1.09	1.30	1.32
PI	1.13	1.33	1.35
Discounted savings time (Year)	**26.33**	**22.45**	**22.08**

NPV, PI, BCR1, BCR2, IRR: The examined systems are recommended to be realized, but the payback period is very long, about 26 years (*Table 5*).

CONCLUSIONS

An average Hungarian family needs 2500-5000 kWh of electricity / year. This demand can be reduced significantly by the 2 kWp or the 5 kWp photovoltaic system. The cost of a 5 kWp system is slightly more expensive regarding watts / price (maintenance and replacement costs), than the 16.5 kWp solar power plant, but it is much cheaper. The investment cost of the 2 kWp system was the worst regarding watts / price (also in payback time). In this case the cost of the inverter is the most expensive.

Licensing, design, construction costs are not negligible, which are also more expensive in the case of a low capacity system compared to the total costs. Unfortunately it is difficult to model the future. An unexpected factor is for example, the reduction of electricity prices introduced in 2014. Unfortunately, a solar system becomes recoverable later. In Hungary a solar power plant based on the applied models at 100% of personal funds returns in a long time. It would be appropriate to support not only companies in a project like this, but also individuals. It would be important to rationalize the transfer price of the extra energy. In households this amount is 15.44 HUF net. The price of the solar energy under 20 MW or in the case of smaller solar PV power plants is 32.49 HUF net in 2014 (www.eh.gov.hu).

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