

# PHOTOVOLTAICS SYSTEMS ON THE TWO BANKS OF DRAVA RIVER

## FOTONAPONSKI SUSTAVI S OBJE STRANE RIJEKE DRAVE

### Henrik ZSIBORÁCS

University of Pannonia  
Georgikon Faculty  
Keszthely, Hungary-8360  
ifj.zsiboracs.henrik@gmail.com

Primljeno / Received: 1. 9. 2014.  
Prihvaćeno / accepted: 2. 11. 2014.  
Izvorni znanstveni rad  
Original scientific paper  
UDK/UDC 342.748.061 (497.5)

### Gábor PINTÉR

University of Pannonia  
Georgikon Faculty  
Hungary-8360  
pg@georgikon.hu

### Béla PÁLYI

University of Pannonia  
Georgikon Faculty  
Keszthely, Hungary-8360  
palyi@georgikon.hu

### Lóránt BALI

University of Pannonia  
Georgikon Faculty  
Keszthely, Hungary-8360  
balilori@georgikon.hu

### ABSTRACT

*The aim of present study is to review the introduction of solar energy utilization, the economic determination of the return of crystalline solar systems in Hungary and in Croatia on the two banks of Drava River. The authors have calculated with the electricity price reductions for individuals in Hungary also, which gives more interest to this article. The study was performed with crystalline solar systems and it was carried out in solar-electric power plants extended from 1.5 kWp to 10 kWp. The study included the investment of crystalline solar cell systems. The calculation of payback time was performed by dynamic indices.*

**Key words:** renewable energy for individuals, solar energy utilisation, dynamic indices

**Ključne riječi:** obnovljivi izvori energije za domaćinstva, korištenje solarne energije, dinamički indeksi

## INTRODUCTION

The photovoltaics technology is involving the direct conversion of solar isolation into electricity using solar cells. The sunshine used by solar panels constitutes an unfailing energy resource but the oil, the uranium and the coal are the most widely used energy resources today. These materials will be to finite in the future. Basic problem at the photovoltaics technology is that the energy production depends on the weather and it is necessary to use energy storages, which considerably drive up the cost of photovoltaics electricity.

This technology is clean and engenders no noise pollution or toxic waste. The silicon (sand) is the main raw material used for solar panels, is one of the most abundant substances on Earth. (Häberlin, 2012). PV systems involve significant investment, but they do not contain moving parts (except for the inverter) and ideally it has to be maintained between 10 and 15 years.

The "Drava region" is a sunny part of both countries. Around the Drava 1280 kWh / m<sup>2</sup> - 1300 kWh / m<sup>2</sup> solar power comes to Hungary and to Croatia. This value is above the average in Hungary and a bit less than the average in Croatia. It shows us that the utilization of solar energy could be viable in that area.

## MATERIALS AND METHODS

### Solar energy and solar cells

1200 kWh / m<sup>2</sup> –1360 kWh / m<sup>2</sup> solar power comes to Hungary every year. These values are in Croatia between 1200 kWh / m<sup>2</sup> and 1600 kWh / m<sup>2</sup>. We calculated with 1280 kWh solar energy / year in the Hungarian Drava area and 1300 kWh solar energy / year in the Croatian Drava area based on Photovoltaic Geographical Information System (including losses) (*Table 2.-3.*). ([www.solar-gis.info](http://www.solar-gis.info), [www.re.jrc.ec.europa.eu](http://www.re.jrc.ec.europa.eu)).

The price / Watt relationship of 3 different Hungary and Croatia solar Pv systems of different performance was compared in 2014 (types produced for network, fixed onto slanted roof, finished systems, without any unexpected network development ([www.napelemdepo.hu](http://www.napelemdepo.hu), [www.bazgin.hr](http://www.bazgin.hr)). The type of solar panels are Renesola, SolarWorld and ET Solar. The brands of inverters are Kaco Powador, SMA and Fronius.

### Indicators

We used dynamic indicators at the calculation as Net present value (NPV), *Internal Rate of Return (IRR)* and *Benefit/Cost Ratio, BCR*:

NPV: this dynamic indicator is well known so we dispense with its explanation.

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).

$$\overline{BCR}_1 = 829$$

$$\overline{BCR}_2 = \frac{\sum PV(R) - \sum PV(C)}{\sum PV(I)}$$

PV (R) Present Value of Output (EUR)

PV (I) Present Value of Investment (EUR)

PV (C) Present Value of Costs (EUR)

*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](http://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).

**RENEWABLE ENERGY REGULATION***Hungary*

In line with the EU's requirement, Hungary also prepared its National Renewable Action Plan ("Nemzeti Megújuló Cselekvési Terv – hereinafter also NMCST) outlining the steps planned and the path to be covered in order to meet the 2020 renewable goals, pledging to achieve a renewable share of 14.65% by 2020 (Fodor, 2012).

In Hungary, there are four different plant categories, defined on the basis of Electricity Law LXXXVI / 2007 and governmental regulation 273 / 2007 (Bozsoki ET AL., 2011).

1. *Household-sized or domestic small power plants (HMKE) (up to 50kVA)*: In general, a normal household needs less than 10kVA to cover its electricity demand, which means that the capacity of this power plant type fits the needs of small- and medium-sized companies and publicly owned buildings (Bozsoki ET AL., 2011).

2. *Licence-free small-scale power plants (between 50kVA and 500kW)*: In this category, licence-free means that it is not mandatory to receive an authorisation for production from the regulator. All other authorisations, like construction or environmental protection authorisations are still needed. Most biomass plants fit into this category, with some exceptions of around 1 MW counted as small-scale power plants. (Bozsoki ET AL., 2011).

3. *Small-scale power plants (between 500kW and 50MW)*: The most important technology in this category is wind power, as wind power plants have in general a capacity between 600kW to 3MW installed capacity. The accumulated installed capacity sums up to nearly 400MW (Bozsoki ET AL., 2011).

4. *Power plants (more than 50MW)*: For these plants, the TSO must also be included in the process; however no new RES-E plant in Hungary reaches this size (Bozsoki ET AL., 2011).

*Croatia*

In accordance with Article 26 of Energy Act (NN 68/2001) a tariff system for promotion of electricity production from renewables and combined heat and power (CHP) plants has been prescribed in Tariff System for electricity production from renewable energy sources and co-generation power plants (NN 33/2007). Renewable energy and CHP power plants are entitled to preferential price for electricity delivered to grid. There are two major categories of renewable energy power plants, those with installed capacity of less than 1 MW and those with installed capacity above 1 MW. There are four major categories of CHP plants:

1. Micro cogeneration – installations with installed capacity of 50 kW or less and all installations which use hydrogen fuel cells

2. Small cogeneration - installations with installed capacity of 1 MW or less and more than 50 kW.
3. Medium cogeneration - installations with installed capacity 1 – 35 MW (35 MW included) which are connected to distribution grid.
4. Large cogeneration - installations with installed capacity of more than 35 MW, and all CHP plants connected to transmission grid.

Tariffs prescribed in this regulation are fixed and are determined by in the beginning of each year. Tariffs for electricity from renewable energy sources are directly correlated with retail price index for previous fiscal year. Tariffs for electricity from CHP plants are determined each month. They are subject to change according to change in natural gas price and change in price for production of electricity. Funding for this tariff system is collected from additional price on electricity consumption for all consumers in Republic of Croatia. In 2012 Government of Republic of Croatia has adopted new Tariff system for production of electricity from renewable energy sources and cogeneration (Official Gazette No. 63/12) (*Table 1.*) (Vuk ET AL., 2012). We worked with the Household-sized (HMKE) and with the Micro cogeneration category because these categories were the most profitable in Hungary and in Croatia.

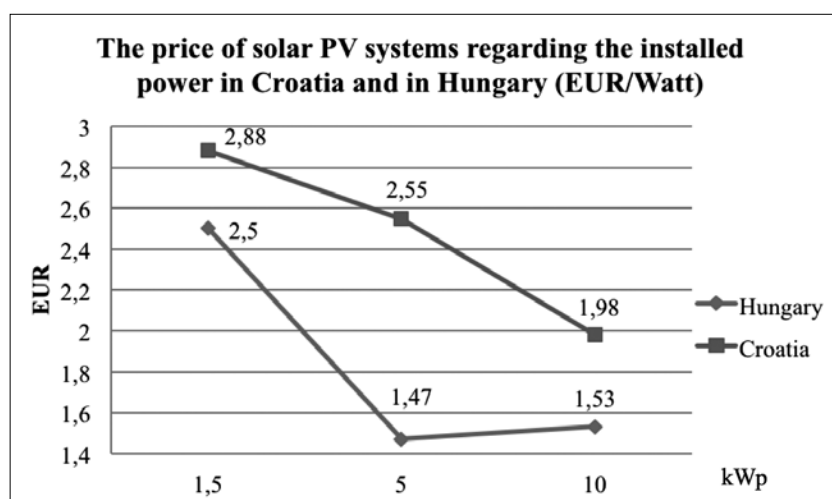
## RESULTS

### Cost of solar PV systems built in Croatia and in Hungary in 2014

The decline in the price of the finished system is not completely in accordance with capacity of the installed power. Up to 5 kWp decrease can be experienced in Hungary, over 5 kWp there is a smaller price increase. The cheapest system regarding the watt / price connection was the 5 kWp Hungary in 2014 (three-phases, one inverter) (Figure 1). In Croatia was continuous price decrease and the 10 kWp system was 0.45 EUR more expensive than in Hungary ) (Figure 1).

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

The payback period was examined by dynamic indicator. We calculated with 305 HUF / 1 EUR and 7.6 HRK / 1 EUR exchange rate. 1 kWh of produced solar energy means a gross 11.58 EUR cent / kWh savings for individuals and 15.8 EUR cent / kWh for business customer in Hungary in 2014. This value was in Croatia 35 EUR cent / kWh savings to 0-10 kWp systems for individuals and for business customer in 2014.



**Figure 1.** Gross cost of the finished solar PV systems in 2014 summer, depending on the installed capacity in Hungary and in Croatia (EUR / Watt)

**Source:** the authors own work based of [www.napelemdepo.hu](http://www.napelemdepo.hu), [www.bazgin.hr](http://www.bazgin.hr), 2014

We used these values to the comparison. We can see in *table 1* the economic categories of solar energies of Hungary and in *table 2* of Croatia.

Economic category in Hungary / Croatia	*Prices in 2014 (EUR cent / kWh / peak period)
Small power plant, Hungary, from 50 kW to 2MW, E.ON contract	1.6
HMKE, Hungary, max 50 kW, individuals, sold energy	5
HMKE, Hungary, max 50 kW, business customer, sold energy	7.2
KÁT, Hungary, from 20 to 50MW	9.5
KÁT, Hungary, to 20MW	10.6
HMKE, Hungary, max 50 kW, individuals, own use	11.58
HMKE, Hungary, max 50 kW, business customer, own use	15.8

\*Peak period in Hungary: in winter: 06:00 – 22:00, in summer: 07:00 – 23:00

**Table 1.** Economic categories of solar PV energies in Hungary

**Source:** the authors own work

Economic category in Croatia	*Prices in 2014 (EUR cent / kWh / peak period)
Ground-mounted power plants, Croatia, 10 kW – 1 MW	15
Roof-mounted power plants, Croatia, 30 – 300 kW	22
Ground-mounted power plants, Croatia, 0 – 10 kW	26
Roof-mounted power plants, Croatia, 10- 30 kW	30
Roof-mounted power plants, Croatia, 0- 10 kW	35

\*The prices are in Croatia fixed

**Table 2.** Economic categories of solar PV energies in Croatia

**Source:** the authors own work

Analyzed systems were 5 kWp and 10 kWp solar PV's (also in Hungary and in Croatia), assuming 100% own capital on the Hungarian side because in the current situation solar PV plants should be designed, that they do not produce more energy than we can use in a year in Hungary ([www.eon.hu](http://www.eon.hu)) (Table 1.). These systems include 1 inverter.

According to the characteristics of solar systems they do not require any maintenance for 10-15 years if the instalment is professional. The average annual amortization was 0.3% / year based on practical experience, the returns were examined for 15 years ([www.solargis.info/](http://www.solargis.info/), [www.napelemdepo.hu](http://www.napelemdepo.hu), Dirk C. Jordan and Sarah R. Kurtz, 2012).

The life expectancy of inverters is between 10-15 years. The replacement is assumed in 15 years' time. The electricity price increased about 7% / year between 2000 and 2010 in Hungary but from 2010 the increase of the price has stopped and the level has stayed at the same place till 2013. In 2013 and in 2014 the electricity price for individual customer has slinked 3 times with total 24.55%. We calculated that the reduction of the electricity price has stopped in 2014 in Hungary.

We have thought it will have no increase or decrease of the electric Price in the next 15 years in Croatia and in Hungary. The prices are fixed in the contracts for 14 years in Croatia. The Hungarian

prices can sink a bit in the next years but later they have to rise, so all together they will stay at the same lever.

We calculated with assuming 100% consumption of energy because so can a PV system for individuals quickly return and we used stable feed prices on the Croatia side (35 EUR cent / kWh). A financial discount rate of 2.1% was calculated in Hungary because the base interest rate was 2.1% since 23.07.2014. This value was 5% since 01.01.2014. in Croatia. We used this interest rate. (www.tradingeconomics.com). Different kinds of natural damage (lightning, hail) were not taken into account.

Year	1. 9. 2014.	
Economic category (HMKE)	Retail selling	Business selling
1kW solar power plant energy produced (kWh)	1280	
Electricity selling price in 2014 (Euro Cent / kWh)	11.58	15.8
Overcapacity purchase price in 2014 (Euro Cent / kWh)	4.49	7.2
100% own utilization (EUR)	148.2	202
Delivery price (EUR)	57.5	92

**Table 3.** Savings in 1 year in the case of a 1kWh solar PV system with HMKE category in Hungary in 2014

**Source:** the authors own work

Year	2014
1kW solar power plant energy produced (kWh)	1 300
Electricity selling price from 0 kWp to 10 kWp system's in 2014 (Euro Cent / kWh)	35
Delivery price (EUR)	455

**Table 4.** Savings in 1 year in the case of a 1kWh solar PV system with Roof-mounted power plants, (0- 10 kW) in Croatia in 2014

**Source:** the authors own work

As the 3. and the 4. table show us, the price of 1 kWh was 11.58 Euro Cent for individuals and 15.8 Euro Cent for business customer in Hungary. The Croatia value was 125% better than the business Hungary's value.

## THE RESULTS OF DYNAMIC INDICATORS

*The results of dynamic indicators for individuals in Hungary*

We can see on the tables 5. - 6. that the discounted payback period were about 120-150% better with 100% own utilization than the energy is sold. In the current situation solar PV plants should be designed, that they do not produce more energy than we can use in a year in Hungary.

Years	15			
Economic category	Sold energy	100% own utilization	Sold energy	100% own utilization
System size (kWp)	5		10	
Investment costs (EUR)	7 370	7 370	14 990	14 990
Maintenance costs (EUR)	0			
Electricity charge savings, at the same price (EUR)	4 226	10 890	8 452	21 779
r = interest (%)	2.1			
Present value savings (EUR)	3 597	9 270	7 194	18 539
NPV (EUR)	-3 772	1 900	-7 795	3 549
IRR (%)	- 6.3	5.37	-6.47	5.12
BCR1	0.49	1.26	0.48	1.24
BCR2	0.49	1.26	0.48	1.24
PI	0.49	1.26	0.48	1.24
Discounted payback period (Year)	(30.7)	11.9	(31.3)	12.1

**Table 5.** Dynamic indicators analysis in 15 years for individuals, in Hungary

**Source:** the authors own work

*The results of dynamic indicators for business customer in Hungary*

Years	15			
Economic category	Sold energy	100% own utilization	Sold energy	100% own utilization
System size (kWp)	5		10	
Investment costs (EUR)	7 370		14 990	
Maintenance costs (EUR)	0			
Electricity charge savings, at the same price (EUR)	6 787	14 900	13 574	29 800
r = interest (%)	2.1			
Present value savings (EUR)	5 778	12 683	11 555	25 336
NPV (EUR)	-1 592	5 313	-3 435	10 376
IRR (%)	-1.02	10.53	-1.22	10.23
BCR1	0.78	1.72	0.77	1.69
BCR2	0.78	1.72	0.77	1.69
PI	0.78	1.72	0.77	1.69
Discounted payback period (Year)	(19.1)	8.7	(19.5)	8.9

**Table 6.** Dynamic indicators analysis in 15 years for business customer, in Hungary,

**Source:** the authors own work

*The results of dynamic indicators in Croatia*

In Croatia we can make a contract with the energy service for **14 years** with fixed prices. There is no difference between individuals and business customers. This system is missing from Hungary therefore the payback period is change from year to year and therefore is the Croatian system more safe and clear for the PV electricity producers.

Years	15	
System size (kWp)	5	10
Investment costs (EUR)	12 750	19 800
Maintenance costs (EUR)	0	
Electricity charge savings, at the same price (EUR)	31 508	63 016
r = interest (%)	5	
Present value savings (EUR)	21 862	43 724
NPV (EUR)	9 112	23 924
IRR (%)	14.38	20.03
BCR1	1.71	2.21
BCR2	1.71	2.21
PI	1.71	2.21
Discounted payback period (Year)	8.7	6.8

**Table 7.** Dynamic indicators analysis in 15 years in Croatia

**Source:** the authors own work

We can see that the discounted payback period were about 7-9 years which is much better than the Hungarian one but the investment cost for the same system is higher in Croatian than in Hungary (see the 8-9. table).

Nations	Hungary (Individuals, 100% own utilization)	Hungary (business customer, 100% own utilization)	Croatia
Years	15		
System size (kWp)	5		
Investment costs (EUR)	7 370		12 750
IRR (%)	5.37	10.53	14.38
Discounted payback period (Year)	11.9	8.7	8.7

**Table 8** Summary table about the 5 kWp systems

**Source:** the authors own work

Nations	Hungary (Individuals, 100% own utilization)	Hungary (business customer, 100% own utilization)	Croatia
Years	15		
System size (kWp)	10		
Investment costs (EUR)	14 990		19 800
IRR (%)	5.12	10.23	20.03
Discounted payback period (Year)	12.1	8.9	6.8

**Table 8.** Summary table about the 10 kWp systems

**Source:** the authors own work



We can see on the tables 3-9. that the bank rate were 2.9% lower in Hungary than in Croatia. This phenomena had a positive impact to the Hungary's payback period because this nation can save about 3 years with the 5 kW system and about 2 years with the 10 kW system. As the 3-9. tables show us that the sunshine hours and the feed prices were better in Croatia, which is a huge competitive advantage but the 5 kW system was about 74 % more expensive than in Hungary and this value was about 42% better with the bigger system. In Croatia could a smaller (5kWp) system 3.2 years faster return (Hungary, individuals) and the payback period was equal at the Hungarian business customer and in Croatia. In the bigger system were these values 5.3 and 2.1 years better in Croatia because the bigger system was cheaper.

## CONCLUSIONS

The energetic utilisation of solar PV systems, in the size of domestic small power stations (HMKE, 0 kWp – 49.9 kWp) and the Roof-mounted power plants are increasingly popular in Hungary and in Croatia, because these categories were the most profitable. This helps a lot in the spread.

In Croatia the tariff system is very advantageous because of the contract are valid for 14 year despite than Hungary. In Hungary the HMKE system's energy prices have changed, as the current electricity prices for individuals (the price of 1 kWh changed about 27% from 01.01.2012. to 01.09.2014). This change has not affected the business customers, therefore better for them the payback period. In Croatia are these incentive fees (table 1.) with contracts valid for **14 years** and this situation made it clear and calculable. The authors think this is the most important advantage of the Croatian bank of the Drava River compared with the Hungarian bank.

## REFERENCES

- Bea Emőke Fodor (2012): Promoting the Use of Renewable Energies An Evaluation of the Hungarian Feed-in Tariff System PhD Dissertation - Corvinus University of Budapest Doctoral School of Management and Business Administration - Budapest 2012, p.14
- Branko Vuk, Alenka Kinderman Lončarević, Damir Pešut (2012): Energy Efficiency Policies and Measures in Croatia - ODYSSEE- MURE 2010 - Monitoring of EU and national energy efficiency targets - Energy Institute Hrvoje Pozar, Pdf, p.p. 50-51
- Dirk C. Jordan and Sarah R. Kurtz (2012): Photovoltaic Degradation Rates - An Analytical Review - NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, operated by the Alliance for Sustainable Energy, LLC, p.16
- Domestic small power stations delivery prices  
[http://www.eon.hu/Aram\\_informaciok\\_arak](http://www.eon.hu/Aram_informaciok_arak)  
[http://www.eon.hu/Uzleti\\_aram\\_egyetemes\\_szolgaltatoi\\_arak](http://www.eon.hu/Uzleti_aram_egyetemes_szolgaltatoi_arak)
- Domestic small power stations information from Hungary  
<http://www.eon.hu/eon.php?id=290>
- Feed-in tariffs (FIT) in Croatia  
<http://mobis-solar.hr/en/photovoltaic/feed-in-tariffs/>
- Global horizontal irradiation in Hungary  
[http://www.solargis.info/doc/\\_pics/freemaps/1000px/ghi/SolarGIS-Solar-map-Hungary-en.png](http://www.solargis.info/doc/_pics/freemaps/1000px/ghi/SolarGIS-Solar-map-Hungary-en.png)
- Heinrich Häberlin, Herbert Eppel (2012): PHOTOVOLTAICS SYSTEM DESIGN AND PRACTICE - John Wiley & Sons, Ltd, WILEY, p.28
- Ingrid Bozsoki, Edoardo Binda Zane, Anna Pobłocka, Rebekka Frank, Dierk Bauknecht (2011) - Integration of electricity from renewables to the electricity grid and to the electricity market INTEGRATION - National report: Hungary, Berlin, 20 December 2011, p.p. 17-18
- Interest rate in Hungary and in Croatia  
<http://www.tradingeconomics.com/croatia/interest-rate>
- Internal Rate Of Return – IRR  
<http://www.investopedia.com/terms/i/irr.asp>

Nábrándi András. Pupos Tibor. Tanácsné György Katalin. 2008. Üzemtan I. Szaktudás Kiadó Ház, Budapest.

Net Present Value (NPV). Calculating net present value a retailers perspective. Pdf. Zumo retail

[http://zumocalculators.com/retail/corporate\\_responsibility.php](http://zumocalculators.com/retail/corporate_responsibility.php)

Photovoltaic Geographical Information System - Interactive Maps

<http://re.jrc.ec.europa.eu/pvgis/apps4/pvest.php>

Profitability index

[http://www.absoluteastronomy.com/topics/Profitability\\_index](http://www.absoluteastronomy.com/topics/Profitability_index)

PV prices in Croatia

[http://www.bazgin.hr/proizvodi/solarni\\_fotonaponski\\_sistemi\\_oprema\\_elektrane\\_pula\\_istra\\_akcija.html](http://www.bazgin.hr/proizvodi/solarni_fotonaponski_sistemi_oprema_elektrane_pula_istra_akcija.html)

PV prices in Hungary

<http://napelemdepo.hu/>

## SAŽETAK

Cilj je sadašnje studije razmotriti postojeće stanje iskorištenja sunčeve energije i gospodarske razloge za povratak solarnih panela u Mađarskoj i Hrvatskoj na obje obale rijeke Drave. Autori su računali i na smanjenje cijene struje u Mađarskoj za domaćinstva, što povećava interes za ovaj rad. Studija je provedena na energanama sa solarnim panelima, snage od 1.5 - 10 kWp. U istraživanje je uključena vrijednost investicije nabave solarnih sustava. Izračun povrata uložениh sredstava proveden je korištenjem dinamičkih indeksa.