Photovoltaic Farms – Today Challenge

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Abstract: We have underlined different aspects related to financial trends and the technical and commercial features of the photovoltaic equipment for large photovoltaic farms, in Romanian context. To be more conclusive and strong in our approach, we have simulated the financial cost in the case of a photovoltaic roof (1,35GW) of "Lia Manoliu" arena, in Bucharest.

Keywords: photovoltaic, renewable, energy.

A new opportunity

The electricity generation from photovoltaic systems has change significantly, these days: at the end of 2008 the production capacities of solar photovoltaic panels have been doubled compared with 2007, so this year the prices of the equipment felt down even by 50%. Till now the cost of one watt installed in photovoltaic panels was 2 or 3 times higher as one watt installed in large wind turbines. Now, a photovoltaic farm generates electricity at about 4 Euro/Watt, or even less which is the same price and for one watt installed in wind turbine. And there is no sign that the development of this photovoltaic devices come to an end.

The new 2 axis tracker could rise the energy production at least with 30-36%, but the overall prices grow up with 1 Euro/W.

Figure 1 A photovoltaic pack with fixed orientation

PV type

The power density of crystalline Silicon (Si) panels reaches today 150-160W/mp, and for amorphous Si is only 60-70 W/mp, that mean that for the same installed power we need a double area if we choose amorphous Si. The monocrystalline silicon is the most efficient but both crystalline silicon have strong dependency with the temperature, as it is show below:

PV Module Type	Percent variation of power issue with temperature [%/°C]
Polycrystalline silicon	-0.48
Monocrystalline silicon	-0.46
Thin film amorphous silicon	-0.20

The thin film amorphous silicon has, in spite of its low power density, a very good behavior with temperature. First, overall production is a little bit higher with amorphous Si, because it doesn't sink its power drastically with the higher temperature. And secondly the overall price of the farms built with amorphous Si is a little bit lower.

An advantage of solar photovoltaic farm is the very short set up time - that could be no more than 2 or 3 months. The photovoltaic panels are "one the shelf".

Figure 2. A photovoltaic pack with 2 axis tracker system

Old and overwhelmed procedure

Obviously, our authorities are overwhelmed: the evaluation procedure for incentives for such renewable producer last at least 1 year, if no 2 years!

After some scenarios released by EPIA, (European PhotoVoltaic Industry Association), in 2008, in the next 10 years in Europe should be installed other 12GW photovoltaic farms. But today incentives and in the new prices context it must not surprise that this "optimistic" scenario should be over fulfilled.

A case study – Lia Manoliu arena

The "Lia Manoliu" arena which is now under construction, should have a roof cover of about 35558 m^2, that's mean a capacity of about 20.000 panels with 1.5 m^2, or at least 6GW installed power.

In the figure 3 is presented the possible roof of this arena. As an example, the Bern arena (CH) that was build for the 2008 European Championship has an installed power of 1.35GW on 7930 panels (170W/panel). Let us consider that the "Lia Manoliu" arena should have the same power, 1.35GW. In the below simulation we have not introduced in the overall cost the supplementary cost of the metallic structure to be able to support the weight of these panels. The photovoltaic panel weight is between 12-15Kg/ m^2.

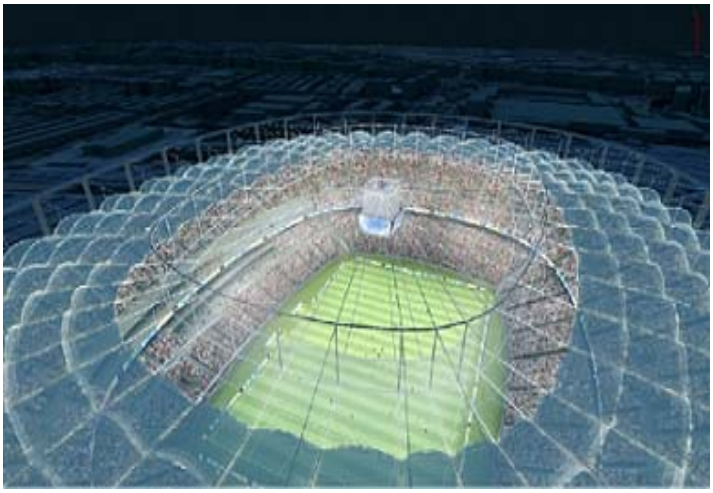

Figure 3 One of the Lia Manoliu stadium roof posibility

If the panels used are with crystalline silicon (Brightwatts BI-156 200W@1,47 m^2), then only 37% of the roof should be covered. On the table below, named "*Photovoltaic Solar Park - Crystalline Si*" (table 1), is summarized a project in terms of components and capital. The capital invested for every installed W is a little bit above 3 Euro (3,03 Euro/W) , which is very low cost effective. A photovoltaic farm built in 2007 (in France Geoffroy park, 216Kw) was at the level of 8,33 Euro/W!

By using panels with amorphous Si (Sun Gen NH100 100W@1,54 m^2), then at least 77% of the roof is covered. On the table below, named "*Photovoltaic Solar Park Amorphous Si*" (table 2), is summarized a project in terms of components and capital. The capital invested for every installed W is a little bit under the cost with Crystalline Si, but not far (2,95 Euro/W). The estimated production rises from 1550GWh/year, in the case of photovoltaic panels with crystalline Si, to 1580GWh/year, in the case of photovoltaic panels with amorphous Si, a very insignificant difference!

To decide which the best is solution from the two above presented, it must be put into the balance all: the prices, the energy produced with the occupied surface and the supplementary weight.

A 3GW farm for large electrical energy consumers

Taking into account some big companies like: Radiocom, CFR, Metroul Bucharest, Urban Transport Companies, Alro Slatina (aluminum plant), etc., have a very large budget for energy consumptions, we will simulate the case of a bigger farm with 2 axis tracking systems (table 3). Of course, at such efficiency a photovoltaic farms will be more expensive. A 3GW photovoltaic park with crystalline Si and 2 axis tracker systems need an area of about 3ha. This new case was simulated for Bucharest too, and the estimated year production should be of about 4,54GWh.

In the conditions of the Incentive Law for renewable energy (Law 220/2008), that provides: i) a bonus of 4 Green Certificates, GC, for 1MWh produced through photovoltaic means, and ii) every GC could be sold on the market between 27÷55 Euro, the revenue per year for the energy delivered to national grid are in the margins presented here:

1,35GW crystalline Si	1,35GW Si amorf	3GW crystalline Si with 2 axes monitoring system
1,55 GWh/year	1,58 GWh/year	4,54 GWh/year
218.000-376.000 Euro	222.000-383.000 Euro	640.000-1.103.220 Euro

The tables below are intended to give a more accurate imagine of what could mean today a photovoltaic park, in terms of production yield, capital costs, specific costs, area needed, etc. All what is needed for decision bodies to think further this opportunity.

Table nr 1. A 1,35Mw photovoltaic park with crystalline Si for "Lia Manoliu" stadium

Lia Manoliu Arena

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Photovoltaic Solar Park Crystalline Si

power		kw	1350	installed power	1350	Kw
park surface		mp		surface with access avenue	13.006	mp
location	Bucuresti	44,15 N	26,15 E	annual energy	1.550	Mwh
iradiation		kwh/mp/day	3,18	average energy/day	4.247	Kwh
clarity coefficient			0,46	capacity factor	0,13	%

photovoltaic panels

brand		*brightwatts*	total no. recalc	pieces	6753
crystalline type		*BI-156*	aprox no	pieces	6751
power	W	200	price per watt	Euro	2,00
length x width mm	1482	992	panel surface	mp	1,47
unit price	Euro	400	surface of the panels	mp	9.927

fixed orientation

brand		*genyal*	surface of the panels	mp	9927
optimum angle	°	*35*	surface per phase	mp	3.309
no of rows per structure		5	power per phase	kw	450,2
unit price/panels	Euro	5	fixing system price/ phase	Euro	16545

inverters

brand, type	*sunny mini c 11000TL*	*ok*	requested power pe phase	W	450.200
power	w	11000	no. of inverters per phase		41,00
unit price	Euro	2600			

Park structure			F1	F2	F3	Total
solar panels		BI-156	2251	2251	2251	6753
inverters	sunny mini c 11000TL		41	41	41	123
optimum angle	°	35				

Cost per components		PU	quantity	PT
solar panels	BI-156	400	6753	2.701.200
inverters	sunny mini c 11000TL	2600	123	319.800
fix orientation support systems		5	9927	49.635
		Equipment cost without VAT	**Euro**	**3.070.635**

Cost per installed W	**Euro/W**	**3,03**		
Total price per Mwh produced in 25 years	**Euro/Mwh**	**105,39**	**Total cost**	**4.083.945**

Table nr 2. A 1,35Mw photovoltaic park with amorphous Si for “Lia Manoliu” stadium

Lia Manoliu Arena

Octavian Capatina

Photovoltaic Solar Park Amorphous Si

power		kw	1350	installed power	1350	Kw
park surface				surface with access avenue	27.241	mp
location	Bucuresti	44,15 N	26,15 E	annual energy	1.580	Mwh
iradiation		kwh/mp/day	3,18	average energy/day	4.329	Kwh
clarity coefficient			0,46	capacity factor	0,07	%

photovoltaic panels

brand			*Sun Gen*	total no. recalc	pieces	13503
crystalline type			*NH100*	aprox no	pieces	13501
power		w	100	price per watt	euro	1,90
length x width	mm	1400	1100	panel surface	mp	1,54
unit price		euro	190	surface of the panels	mp	20.794

fixed orientation

brand			*genyal*	surface of the panels	mp	20794
optimum angle		°	*35*	surface per phase	mp	6.931
no of rows per structure			5	power per phase	kw	450,1
unit price/panels		Euro	5	fixing system price/ phase	Euro	34657

inverters

brand, type		*sunny mini c 11000TL*	*ok*	requested power pe phase	W	450.100
power		W	11000	no. of inverters per phase		41,00
unit price		Euro	2600			

Park structure				F1	F2	F3	Total
solar panels		solar panels	NH100	4501	4501	4501	13503
inverters	inverters	sunny mini c 11000TL		41	41	41	123
optimum angle	optimum angle	°	35				

Cost per components			PU	quantity	PT
solar panels		NH100	190	13503	2.565.570
inverters	sunny mini c 11000TL		2600	123	319.800
fix orientation support systems			5	20794	103.970
		Equipment cost without VAT		**Euro**	**2.989.340**

Cost de capital per w instalat	**Euro/W**	**2,95**		
Total price per Mwh produced in 25 years	**Euro/Mwh**	**100,65**	**Total cost**	**3.975.822**

Table nr 3. A 3 Mw photovoltaic park with crystalline Si and 2 axis tracking system

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Photovoltaic Solar Park

power		kw	3000	installed power	3016	Kw
park surface				surface with access avenue	25.129	mp
location	Bucuresti	44,15 N	26,15 E	annual energy	4.540	Mwh
iradiation		kwh/mp/day	3,18	average energy/day	12.438	Kwh
clarity coefficient			0,46	capacity factor	0,20	%

photovoltaic panels

brand			silikem	total no. recalc	pieces	12312
type			SLK60	aprox no	pieces	12245
power	W		245	price per watt	Euro	2,20
LxI	mm	1640	950	panel surface	mp	1,56
unit price	Euro		540	surface of the panels	mp	19.182

2 axis tracking system

brand		sonnen	no. of panels per tracking syst		38,00
type		3_60	Installed power per tracking syst		9.310
surface	mp	60	no. of tracking systems /phase		108
unit price	Euro	9450	total no. of tracking systems		324

inverters

brand, type	sunny mini central 8000TL	ok	requested power pe phase	W	9.310
power	W	10000	no. of inverters per phase		1,00
unit price	Euro	2500			

Park structure		F1	F2	F3	Total
solar panels	SLK60	4104	4104	4104	12312
inverters	sunny mini central 8000TL	108	108	108	324
monitoring systems	3_60	108	108	108	324

Cost per components		PU	quantity	PT
solar panels	SLK60	540	12312	6.648.480
inverters	sunny mini central 8000TL	2500	324	810.000
monitoring systems	3_60	9450	324	3.061.800

		Equipment cost without VAT	Euro	10.520.280
Cost per installed W	**Euro/W**	**4,46**	Total cost	13.465.958
Total price per Mwh produced in 25 years	**Euro/Mwh**	**118,64**		

In stead of conclusion

In the case of the electricity generation from 1,35Gw Silicon amorphous photovoltaic park and in Romanian incentives law (the 220/2008 law) - the capital cost is about 4 billions euro and the annual revenue should be in a very good position in Romania (Galati, Braila, Tulcea, Contanta) at about 400.000 euro. That's mean about 10 years period for capital replacement. But with the EU funds the invested capital needed should sink to half for the big companies, and sink to 30% for small companies. In other words a capital replacement period of 5 years (the case of big companies) or a capital replacement period of 3 years (the case of small companies) are very good in the energy industry. A year before this replacement period was double!

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