Czech-Austrian Winter and Summer School
The economics of a small decentralized PV

Miroslav Mengr, Ali Manafi Miralilo

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Content

1. INTRODUCTION AND GENERAL INFORMATION

Is worth to install PV systems with storage of energy in conditions of the Czech Republic and Austria? This is the main question, we would like to answer in our paper. We are going to assume not a business or a factory but just a typical family house PV system installation with energy storage (batteries). The next objective is to prove the importance of location and state policy. We are going to compare two specific regions in both countries with different sun potential and calculate its economic effectives by using net present value.

2. ABSTRACT

Photovoltaics (PV) is the field of technology related to the application of solar cells and can be used for energy production by converting sun energy directly into electricity by using the photovoltaic effect. Solar cells are photovoltaic devices that use semi-conducting materials to convert sunlight directly into electricity. The output of solar cells is direct current (DC) electricity. Solar panels require sunlight to generate energy which causes a problem when it’s dark and cloudy and when we most need light and heat. In recent years we have seen developments in solar battery storage which could smooth out the challenges with solar energy and provide a means to further reduce the cost and reliance on traditional and expensive energy sources. The generated energy during the day can be stored in this battery to use during the night and on cloudy days. This paper is dealing with economic side of this power system in specific conditions of the Czech Republic and Austria.

3. PAPER

Motivation

Photovoltaic (PV) systems and renewable energy sources have increased its number of installation during the last year rapidly. Due to some European directives it is necessary to reduce emission comes from conventional energy sources and that is the reason why we have to shift our electricity production to these "green" sources. On one side, the idea of clean production is clear however on the other hand, the economics of these projects, means new installations, cannot be missed. We feel really passionate about issue of economics or profitability new installed PV systems and its comparison between Czech and Austrian climate and also policy conditions.

Problem statement

What problem are we trying to solve? Why do we care about the problem and the results?

We will try to answer these questions in the following paragraphs. In general, the main problem of PV is that the electricity production does not match a consumption. To be more specific, we have tried to construct a PV production graph, based on a real data. We have obtained some "numbers" from a family house located in the middle Bohemia region. This building has a grid on PV system with 10 kWp install capacity. No more details are, needed because the shape of production curve is the point. Let´s see the following figure.

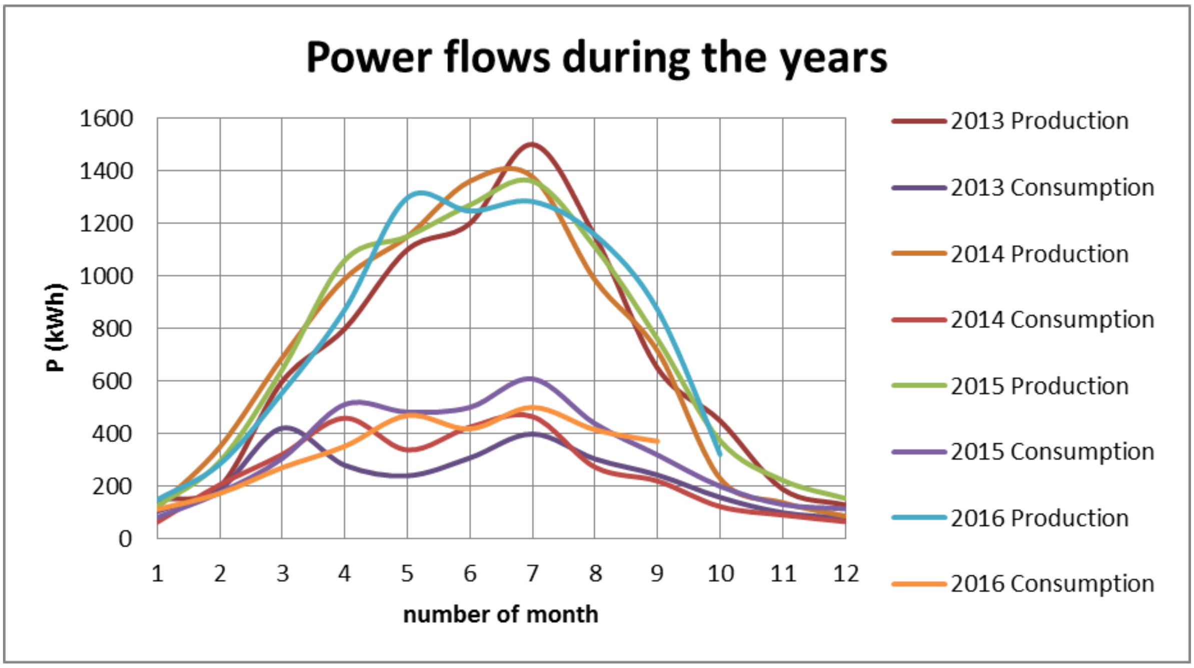

Figure 1 – Electricity production and consumption during the years

It is evident that the biggest electricity production occurs in summers, from this figure. And how does the consumption look like? It is almost just right in the opposite way. The greatest consumption is logically during winters because there is a huge need of lightning and heating. The consumption of electricity in Figure 1 means, how much of PV produced energy was consumed by the household. It is NOT its total consumption. From the huge gap between this consumption and production we can derive that the massive surplus of electricity energy (produced in Summer) could be use during winters or different time period, when the total demand is higher. And here is the “problem”. Electricity is one of typical non-storable commodity. Despite this fact, there are some solutions which can be use for this purpose (like batteries). Our task is to prove the economical effectiveness of accessible technologies in the Czech Republic and Austria.

Methodology & major data

Our chosen approach is following. We are going to use solar maps for description of climate and especially sun conditions in each country, than choose two locations in each. One with average solar radiation or the capitals and one with the best sun conditions. Afterwards we are going to do a prediction of electricity production and match it with typical or average household electricity demand (consumption). Thanks to this we will be able to calculate electricity consumption comes from PV and theoretical potential for energy storage. In the next part we would like to calculate profitability of investments into several PV systems with a different type of energy storing like water boilers or batteries. These economic calculation are going to be based on the net present value and cash flow projections. The important part is including of national supporting programs like subsidies or feed in tariffs.

CZECH PART OF PAPER

I would like to start this chapter with a small description. The Czech Republic is located in middle part of Europe and the sun conditions during the years are let´s say average. To project a PV system it is necessary to know the annual production or potential per install capacity (per each kWp). There are lots of sources on the internet with solar radiation maps with these crucial information thus we can use one of them. I used on from SOLARGIS.COM.

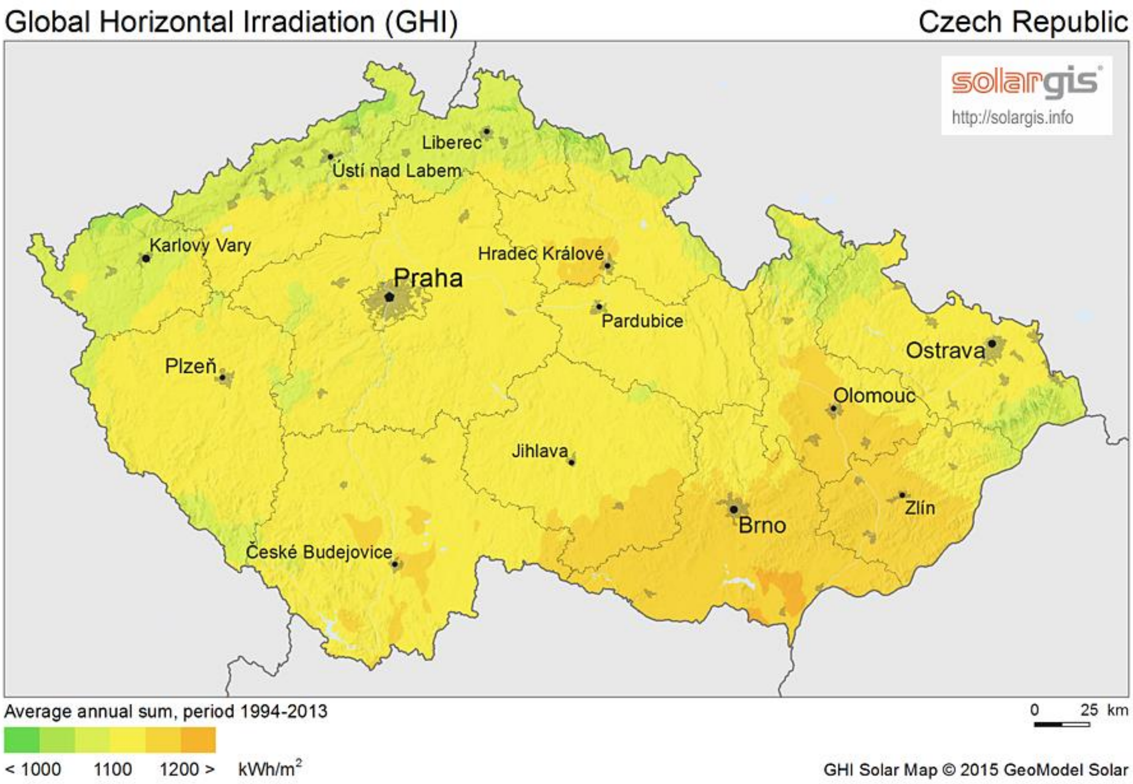

Figure 2 – Solar map of the Czech Republic – Retrieved from (SOLARGIS n.d.)

Now when the PV potential production is known, we can choose a specific places for assessment. The first one will be Prague (Praha) as a region with the average annual sum around 1150 kWh/m2 and the second area to the south from Brno with the maximum sun potential in this country (around 1250 kWh/m2).

State support

Before we choose a specific PV system, we must check all legislative requirements and possible support. Nowadays there is the only one possible financial support from state side and it is investment subsidy. There were some feed-in tariff and obligatory purchase strategies in recent years, but it is already gone.

If an investor wants to reach to this subsidy, he must meet some requirements. The first thing is that at least 70 % of electricity produced from PV must be consumed in the place of origin (of its production). The next thing is maximum install capacity 10 kWp. Furthemore if the PV system has a battery storage, then there must be passed a minimum specific ratio for install capacity of batteries 1.75 kWh/kWp. The maximum amount of money (105 000 CZK) is connected with system over 3 kWp.

The next thing is that basically no electricity distributor respective trader does not buy electricity from new PV installations anymore. Because of these facts, I decided to model a system with install capacity of 3.12 kWp with 6 kWh battery storage included. This system is able to meet all mentioned requirements and reach to the highest level of subsidy at the same time.

Technology and economy of chosen PV system

The PV system mentioned in the previous paragraph, we can buy as all in one solution from various companies. For purpose of this case, I have chosen one from with average price. PV system contains panels BenQ and converter Kostal Piko. This PV system with battery storage is suitable for a typical family house with annual electricity consumption over 4.9 MWh. So let´s assume this case. The final price for the whole system (PV panels, convertor, cabels, parts for fastening, assembly, project, handling of subsidy etc.) is around 344 thousands CZK which is approximately 12 741 €. (Anon n.d.)

The next issue is a lifespan of system. It is already known that lifespan of a PV panel might be over 20 years, while lifespan of a convertor is only about one half of it (10 years). Unfortunately lifespan goes hand in hand with degradation of a materials or efficiency of products. In this case we can observe this decrease not only on PV panels but especially on capacity of batteries. The following figures show more to this issue.

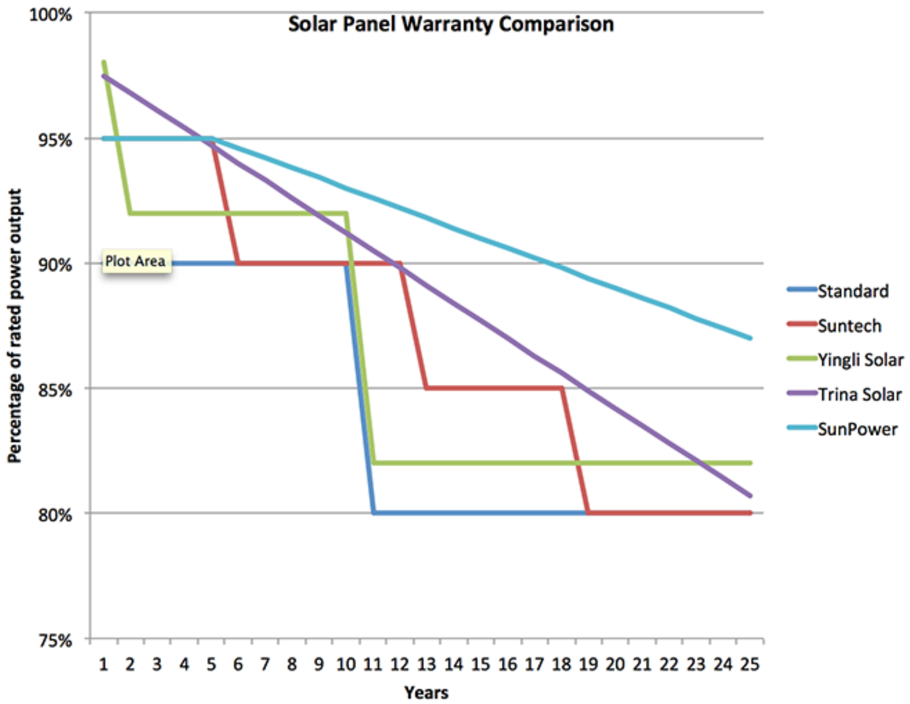

Figure 3 – Comparison of decrease in power of PV panels of various producers (Mathias Aarre Maehlum 2014)

From the previous figure we can see that the percentage of rated power output during the year may vary a lot. However, there is for every producer common limitation of decline in rated power to the level of 80 % guaranteed. This efficiency level after 20 years is not so bad. However the situation of nowadays batteries is much worse. The following figure shows analogous progress for commonly use type of gel accumulators.

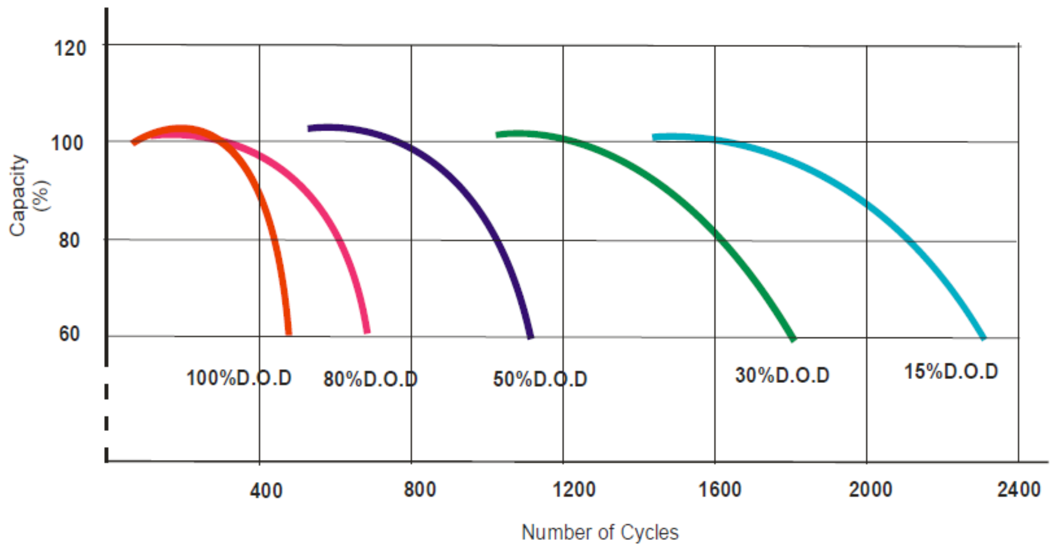

Figure 4 – Dependency of a common accumulator lifespan (Anon n.d.)

As we can see, the huge impact on a battery or accumulator lifespan has so called D.O.D which means depth of discharge. Numbers are not so important as the occurrence in this case. According to this observation, we have to calculate with lifespan on a maximum level 10 years for accumulator. Afterwards there is a reinvestment needed parallel as the convertor. The extra price of accumulator for our PV system is settled to 70 000 CZK (2 592 €) (Anon n.d.) and for convertor 32 000 CZK (1 185 €) (Anon n.d.) which I consider to be quite lot.

On the other hand, there are not only costs connected with PV project. In this case, I assume that the lifespan of PV panels is approximately 20 years, of convertor and battery 10 years. All energy comes from PV panels I am able consume (model family house is a consumer) so there is no need to buy this electricity from a trader. This will be the project revenue. Detail of all calculations is attached in Excel file.

The last but not least thing which I have to mention is annual PV system production. There are many options how to calculate this value but maybe the easiest way, how to do it, is use one of free online tool like PVGis(Anon n.d.). By using this tool I obtained estimated **annual production of 2950 kWh for Prague and 3240 kWh for South Moravia region**. Both numbers are based on these assumptions: optimal azimuth – to the South, optimal slope 35 degrees, system losses of 14 % and average PV technology. Production during the year, by using the tool, looks like this:

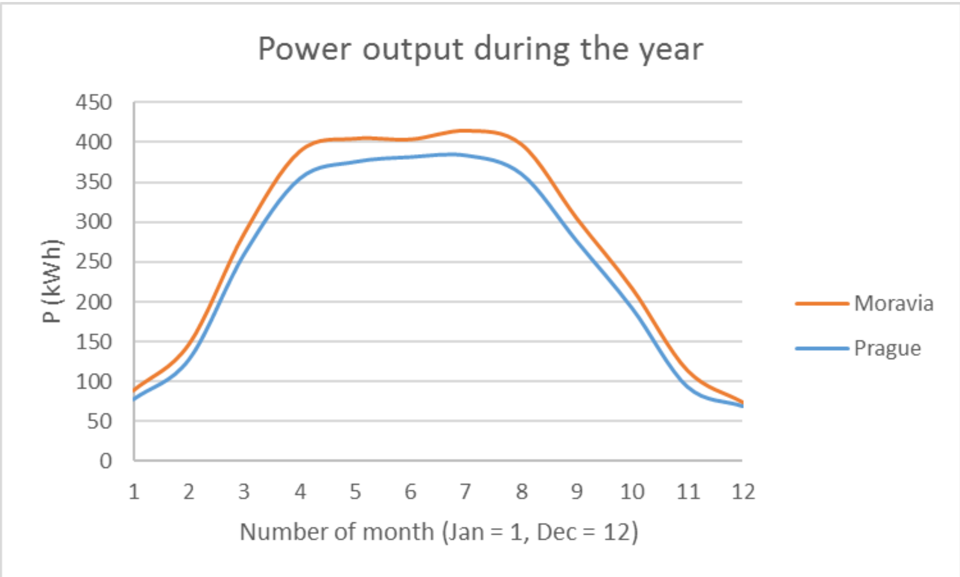

Figure 5 – Power output of the 3 kWp PV system

The following table shows initial conditions and assumptions of economic calculation model.

Investment to PV system (all included)	344 000	CZK	12 741	€
Converter Kostal Piko	32 000	CZK	1 185	€
Solar accumulator	70 000	CZK	2 593	€
Electricity price growth	2,0%			
Discount rate	2,0%			
Average pice per kWh	3,5	CZK	0.1296	€
Subsidy	105 000	CZK	3 889	€
Annual maintenance	1 000	CZK	37	€
Annual production (kWh):				
Prague	2 950			
South Moravia	3 240			
PV efficiency decrease in 20 years	20%			
CZK/€	27			

Table 1 – Initial assumptions of economic model

I would like to put some more comments to this table. Electricity price growth is taken from long term prices of one specific household. The discount rate is at the same level as a long term aim value of inflation by Czech central bank. The next important thing is average price per kWh for households. My source for this value was Eurostat (Link), where the average price was amounted to 0.129 €/kWh for the year 2015 (the last published).

Results

By using these previous data, I calculated the net present value for project of PV system in Prague and in Moravia region. The results looks like this:

NPV Prague	**-155 177 Kč**	**-5 747 €**
NPV Moravia	**-136 907 Kč**	**-5 071 €**

Both negative NPV values mean only losses due to investment to the project. However it is clear that the price of electricity and discount rate have a significant impact on the final NPV values. Due to this, I have decided to do a sensitivity analysis to these two factors. Let´s see the output.

NPV (€)		Price of electricity						
Prague	**0,1111**	**0,1296**	**0,1481**	**0,1667**	**0,1852**	**0,2037**	**0,2222**	**€/kWh**
-5747	3	3,5	4	4,5	5	5,5	6	CZK/kWh
0,0%	-6 258	-5 072	-3 887	-2 701	-1 516	-330	855	
0,5%	-6 393	-5 264	-4 134	-3 005	-1 875	-746	384	
1,0%	-6 517	-5 439	-4 362	-3 284	-2 207	-1 129	-52	
Discount rate **1,5%**	-6 629	-5 600	-4 571	-3 542	-2 514	-1 485	-456	
2,0%	-6 731	-5 747	-4 764	-3 781	-2 797	-1 814	-831	
2,5%	-6 823	-5 883	-4 942	-4 001	-3 060	-2 119	-1 178	
3,0%	-6 908	-6 007	-5 106	-4 205	-3 304	-2 403	-1 501	
3,5%	-6 985	-6 121	-5 257	-4 393	-3 530	-2 666	-1 802	
4,0%	-7 055	-6 226	-5 397	-4 568	-3 739	-2 910	-2 081	

Table 2 – Sensitivity analysis of NPV Prague PV system

NPV (€)			Price of electricity					
Moravia	**0,1111**	**0,1296**	**0,1481**	**0,1667**	**0,1852**	**0,2037**	**0,2222**	**€/kWh**
-5071	3	3,5	4	4,5	5	5,5	6	CZK/kWh
0,0%	-5 558	-4 257	-2 955	-1 653	-351	951	2 253	
0,5%	-5 727	-4 486	-3 246	-2 005	-765	476	1 716	
1,0%	-5 881	-4 698	-3 514	-2 331	-1 148	36	1 219	
Discount rate **1,5%**	-6 022	-4 892	-3 762	-2 632	-1 502	-372	758	
2,0%	-6 151	-5 071	-3 991	-2 911	-1 831	-751	329	
2,5%	-6 269	-5 235	-4 202	-3 169	-2 135	-1 102	-68	
3,0%	-6 377	-5 387	-4 397	-3 407	-2 418	-1 428	-438	
3,5%	-6 476	-5 527	-4 578	-3 629	-2 680	-1 731	-783	
4,0%	-6 566	-5 656	-4 745	-3 835	-2 924	-2 014	-1 103	

Table 3 – Sensitivity analysis of NPV Moravia PV system

From these tables we can see that mainly negative values of NPV are shown. For different final result, the electricity price must be almost twice higher than it is now or there must be I bigger gap between electricity growth (higher) and discount rate (lower).

AUSTRIAN PART

Renewable energies in Austria

Renewable energies play an important role in Austria and will be also more important in the future. Photovoltaics are especially growing in the private area and more people are taking power into their hands and wanting to achieve a certain degree of energy autonomy. The commercial segment also achieved the profitability of photovoltaic systems. But in comparison with other countries the Austrian photovoltaic market is still small of and has not yet been exhausted to its full potential. After the record in year 2013 that the PV expansion was above 260 MWp , it was due to decreasing subsidies in 2014 and 2015 that caused annual growth rate to be at around 150 MWp and it was stabilized at this range.

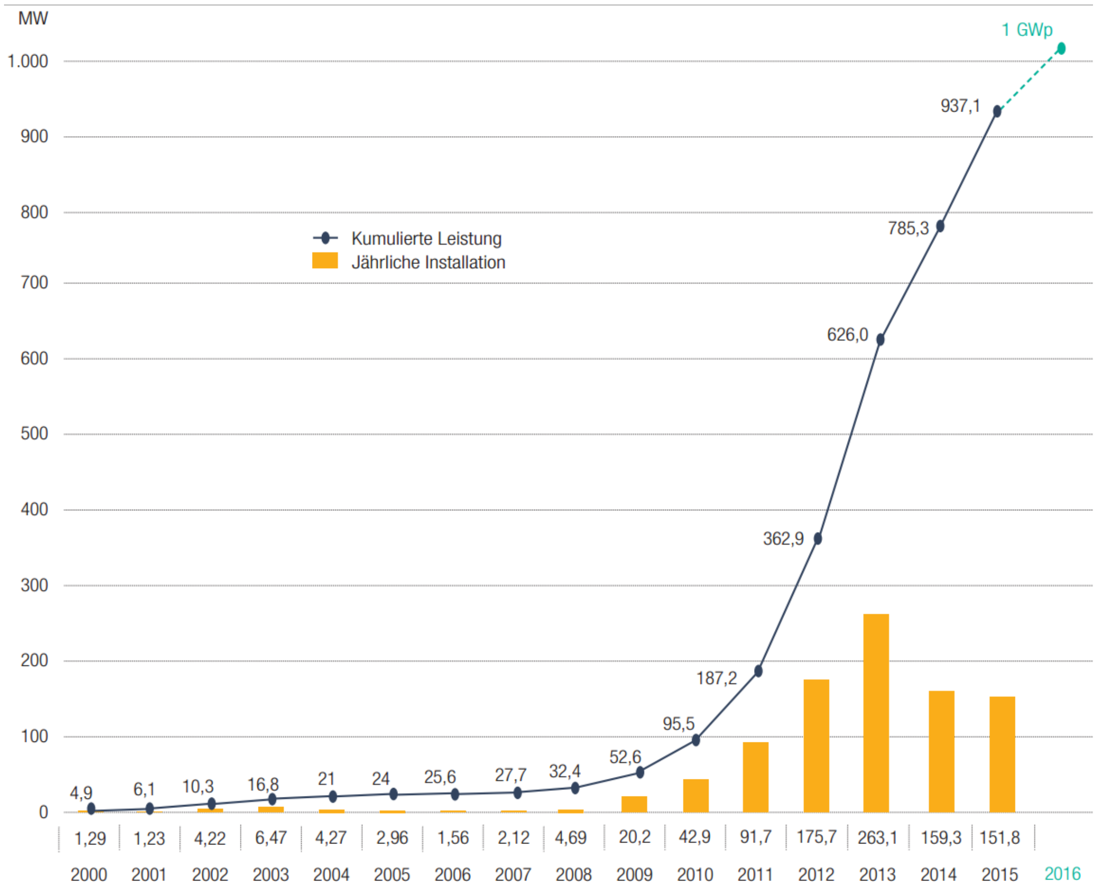

Fig. 6 : Development of photovoltaics in Austria - Source: PV market statistics bmvit (Prof. Faninger bis 2006, 2007–2015 Technikum Wien); Grafk: © PV Austria

Solar irradiation values for Austria :

The sun is a virtually inexhaustible , free source of energy . In approximately 20 minutes , the sun provides the same amount of energy that is consumed by the world's entire population in a year. Photovoltaics convert sunlight directly into electricity – silently and without creating exhaust, noise pollution or odour emissions. It is shown in Figure 7 , that the Austria is a sunny country and this possibility can very well be used for photovoltaic power generation especially in the west regions of Austria.

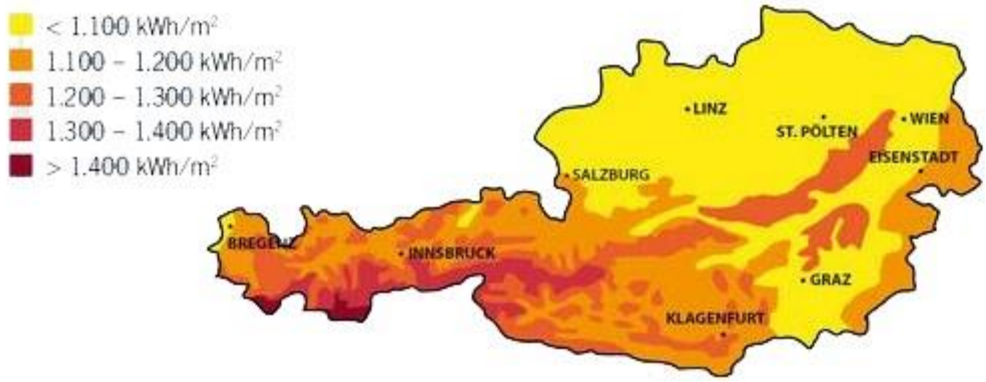

Fig. 7 : Solar irradiation values for Austria - Source (http://www.pv-schule.at/startseite)

Technical potential of photovoltaics :

Figure 8 shows the technical potentials of photovoltaics in the Austrian districts in GWh per year. It is clearly indicated that Vienna is the strongest area to install photovoltaic panels on the roofs . From the technical point of view , on the one hand building areas (roofs and facades) and on the other hand , small portions of public areas, agricultural land and areas of the wasteland are used to calculate the technical potentials of the of photovoltaics panels . The geographic distribution of the technical potentials are directly related to the permanent settlement area .

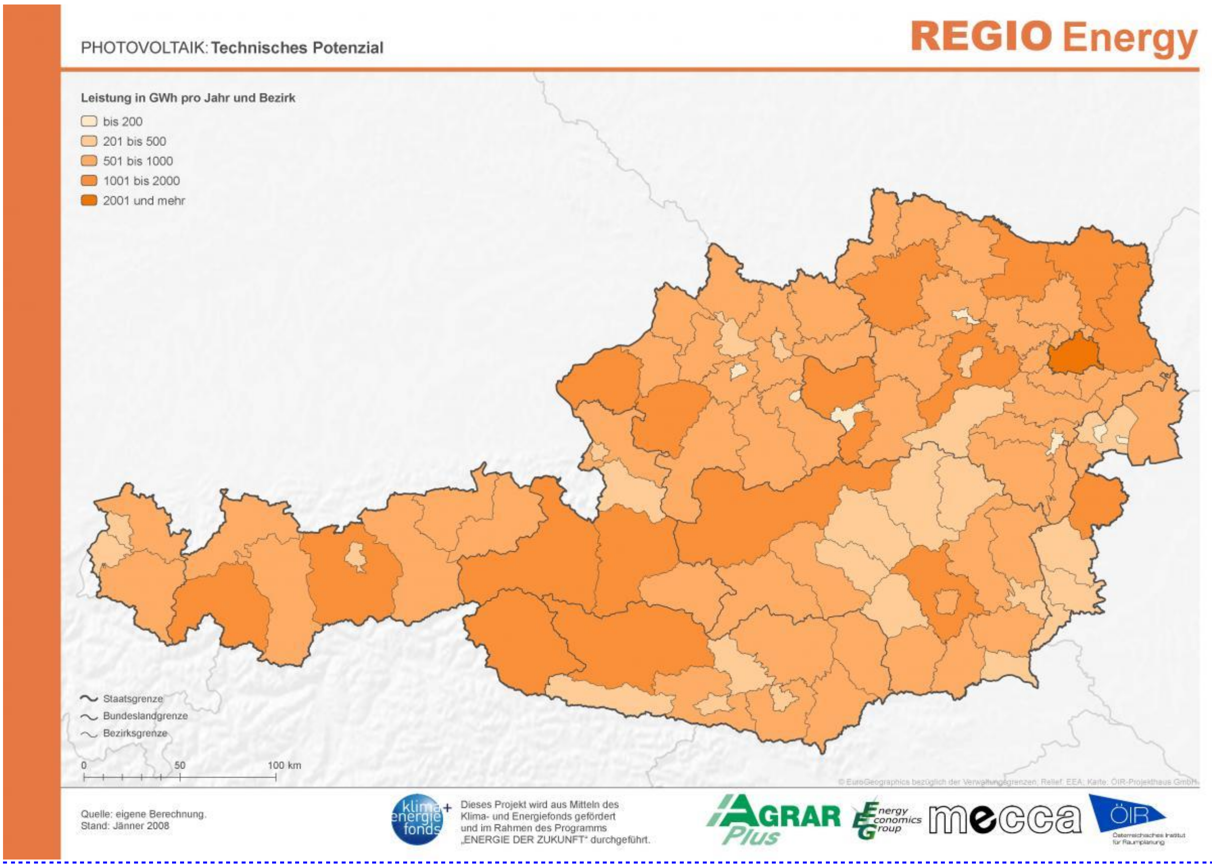

Fig 8. The technical potentials of photovoltaics in the Austrian districts in GWh / year - Source (http://regioenergy.oir.at/photovoltaik/technisches-potenzial)

The total technical potential of photovoltaics in Austria is 71,244 GWh per year. The values per district are different , for example : Vienna has a potential about 3.474 GWh per year . The top 5 districts with regard to the technical potential of photovoltaics are :

City	potential of photovoltaics(GWh / year)
Vienna	3,474
Spittal a.d. Drau	1,834
Zell am See	1,655
Gänserndorf	1,646
Mistelbach	1,564

Table 4 – technical potential of photovoltaics

Photovoltaic energy in Austria :

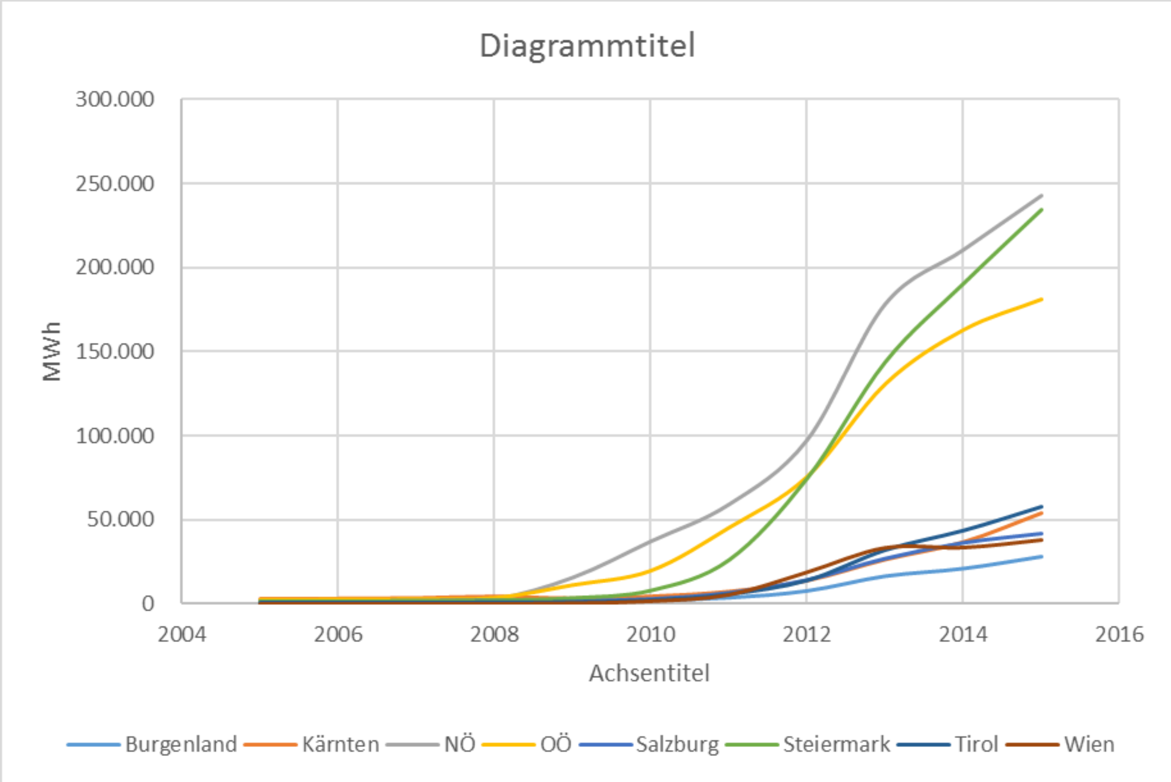

Fig 9 . The chart of generated photovoltaic energy in Austria between 2005 and 2015 .

The chart in figure 9 shows photovoltaic energy generation in Austrian districts . As it can be seen , three Austrian districts generated more photovoltaic energy than other districts. The difference was huge between 2012 and 2015 . In figure 7 and 8 it can be seen that the southwest of Austria has a good potential of photovoltaic energy generation because in this area both of the solar irradiation values and the technical potentials of photovoltaics have a high amount in the maps.

Even though the cities that are located in the southwest of Austria where the conditions are more suitable of photovoltaic energy generation could not achieve the full potential of their conditions . On the other hand regions in the east part of Austria that the conditions are not as good as the west part could generate a higher photovoltaic energy .

For example the solar irradiation values in the southwest area (Tirol , Salzburg , Kärnten) is almost higher than 1300 kWh/m^2 and also a good technical potential of photovoltaics . however the figure 9 shows that these districts did not generate enough photovoltaic energy in comparison with the other districts .

Battery and solar system size

It is important to get a system that is optimally sized for your usage and solar generation because a unsuitable size of the PV-system will never pay your investment . Many modelling systems can be used to estimate the battery and PV-system size , for example : for a 4kW solar system, the 4kWh battery is almost always more cost efficient than the 7kWh battery. This is because the larger battery capacity is less likely to be fully used each day.

The using time of the power

If the PV- system generating power at home is used during the day, the PV-system payback time, even without a battery, will be shorter. This is because self-consumption of solar power is much higher. In fact, many modelling systems indicate, that you can potentially halve the payback time if you're using a lot of your solar power during the day.

Tariff arbitrage and time-of-use billing

There are two main methods, that a battery can save you money. One is by storing excess daytime solar to use during the night, and the other is through tariff arbitrage. Doing both of these, in a household that has some daytime usage, can be financially beneficial.

Tariff arbitrage involves charging the battery with energy from the grid when it is cheap (off peak, usually around 10pm-6am) and using the power from the battery in the morning in the peak period when tariffs are expensive (usually after 6am).

"Tariff arbitrage makes a big difference for battery system value, significantly reducing payback times in many scenarios.

The location of cities

Let's take a look at cities around Austria. According to figure 7, Vienna and Klagenfurt are chosen for comparison of PV–energy generating. The online tool PVGis (Anon n.d.) can be used to calculate the annual production for these cities and the result are 5377 kWh for Vienna and 5851 kWh for Klagenfurt. The results are based on these assumptions: optimal azimuth – to the South, optimal slope 35 degrees, system losses of 14 % and average PV technology. Figure 10 shows the PV-energy generating during the one year in Vienna and Klagenfurt. The difference between east and south can be seen in this figure.

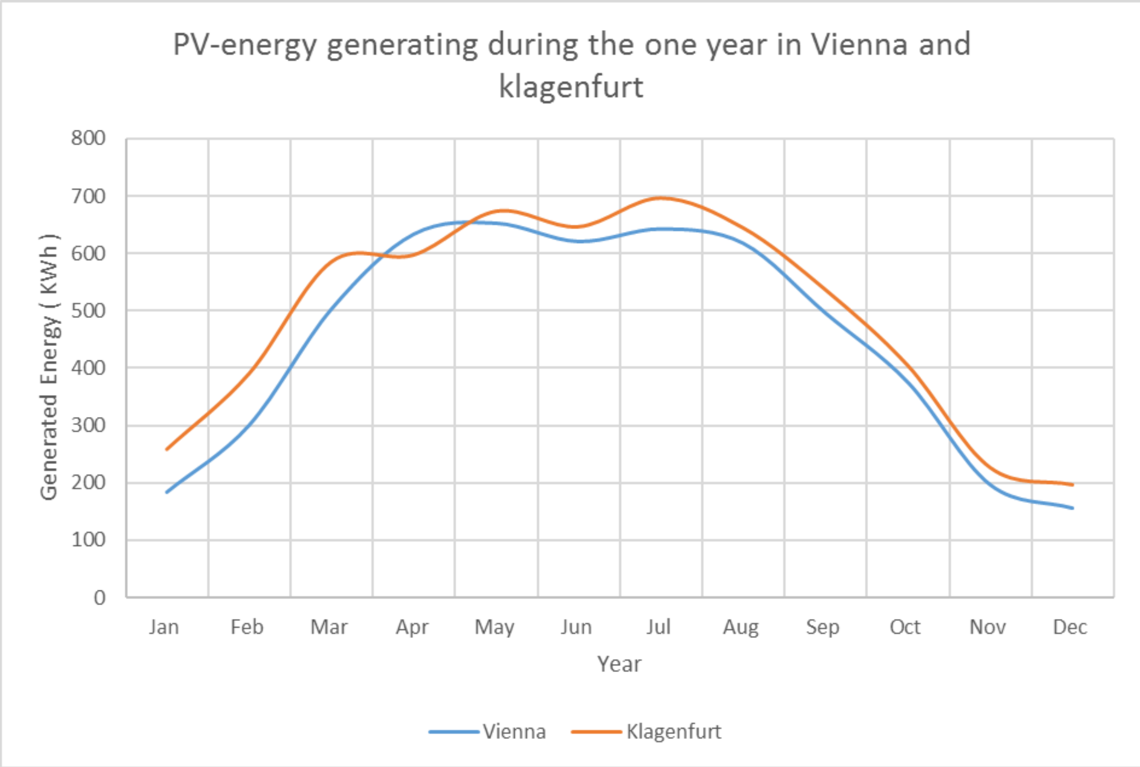

Fig 10 . The PV-energy generating in a year in Vienna and Klagenfurt .

It was explained that Battery and solar system size is important but the price of them is also very important. There are many factories to produce the PV-system with many different prices and also different qualities. On the one hand the price for investment must be reasonable and on the other hand the quality must be suitable. A favorable and good variant for 4kWh can be cost almost 16000 € (The solar system with battery) .

Investment to PV system (all included)	16000 €
Average price per kWh	0.2 €
Subsidy	4000 €
Annual maintenance	50 €
Annual production (kWh):	
Vienna	5377
Klagenfurt	5851
PV efficiency decrease in 20 years	20%

Table 5 – Initial assumptions of economic model

With assuming that the electrical energy price is constant, the total result for 10 years can be calculated :

Vienna	-2821 €
Klagenfurt	-1968 €

They are several researches , that battery storage would not deliver savings and in some cases it would only add to costs.

CONCLUSIONS

The storage of PV energy is of key importance to arrive at a very high share of renewable energy consumption mix , especially for generated PV energy during the day , that will be storaged to consume during the night .But they are very important problems which prevent speed of growing the PV energy generating . One of them is the cost of batteries and even worse that the batteries are destroyed after a certain time . A possibility to avoid this problem is the changing of energy . The surplus energy during the day can be sell by network to the consumers who they need it at day and the required energy during the night can be buy network .

To sum up, by writing this paper we obtained one common verdict for both countries. It is not feasible to install PV panels in economic effective way in Czech Republic even in Austria. We have to say that our economic models include some assumptions and simplifications, however this is an obvious way how to solve these tasks. Both countries have some regions with different sun potential, however even the best (“sunnest”) one is not acceptable in terms of NPV of PV projects. State policy (subsidies, taxes) is more important in final assessment than climate conditions.

If the price of electricity would be higher than the results could also differ. For example in conditions of the Czech Republic, this increase must be very significant, which means that the price of electricity must almost doubled itself. This change in prices is highly improbable in the few next years. Because of these facts, we do not recommend to invest in PV systems with battery storage for those, who seek for real payback period (economic effectiveness).

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