Czech-Austrian Winter and Summer School

Implementation potential of photovoltaic in Austria and the Czech Republic

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Content

1 Abstract

Different kind of renewable energy sources will be part of the future energy system. We have to know how much we can use the RES photovoltaic in our energy systems and to identify the problems of integration to establish an adequate policy. The integration of PV is currently a big challenge for energy systems. A big question for policy is how the problems can be managed when PV use increases. This work deals with the problems associated with PV. The paper presents the basic definition of renewable energy sources with a primary focus on photovoltaic. Other chapters focus on the potential energy of photovoltaic power plants in Austria and the Czech Republic. There is also given the current situation and realized capacity for this resource. Following the above and the solution is evaluated in the last chapter, to what extent it is possible to use and fully implement the energy potential of PV in Austria and the Czech Republic.

2 Research questions

Main Research question in this case is, how we can integrate the Renewable Energy Sources, focused on photovoltaic in the future energy system and what the problems are. How much of the PV potential is possible to use. We focus only on technical aspects and the energy system and not on the energy market.

2.1 Renewable Energy Sources

Renewable energy sources in terms of energy conversion are one of the cleanest sources of electricity, because the transformation that do not produce greenhouse gases, especially after the main one, which is carbon dioxide. The exception is biomass. However, in this manufacturing process is produced by only the amount of carbon dioxide, which plants in their lives, take from the atmosphere.

Someone might ask why not use renewable energy to generate electricity more when they are so environmentally friendly than for example thermal power stations that produce large quantities of emissions, but are abundant in the in the production of electricity.

There is another question may arise whether the production of electricity through renewable energy sources is so convenient to be used as a primary energy source. If RES don't cause negative impacts on power system, which is obviously undesirable. If you connect any factory to the distribution system must be satisfied the conditions for connecting to the grid.

2.2 Consumption trends

Development of industry and standard of living goes hand in hand with the development of the energy industry. If not, over time, we suffered from lack of electricity. Industry is increasingly automated and household electrical appliances are added. This growing demand for reliable power supply quality. Therefore, the energy industry must respond to social demands (customers) to ensure supply of electricity to the destination. The graph below in Figure 1 shows that in 20 years, consumption of Small buyers has increased almost twice. On the basis of developments in recent years, we can say that the consumption of electrical energy will rise in coming years. Because power plants, that use for electricity production fossil fuels, are fully dependent on their availability, we must find other sources of electricity. We call them alternative sources. One of these sources may be just the photovoltaic power plants.

Figure 1 Development of electricity consumption

3 The use of PV in electricity production

3.1 PV in the Czech Republic

3.1.1 Sources of electrical energy in the Czech Republic

Czech Republic uses for various power generation sources. The following graph on Figure 2, with detail on Figure 3 shows their individual representation in proportion to their total electricity produced in 2010.

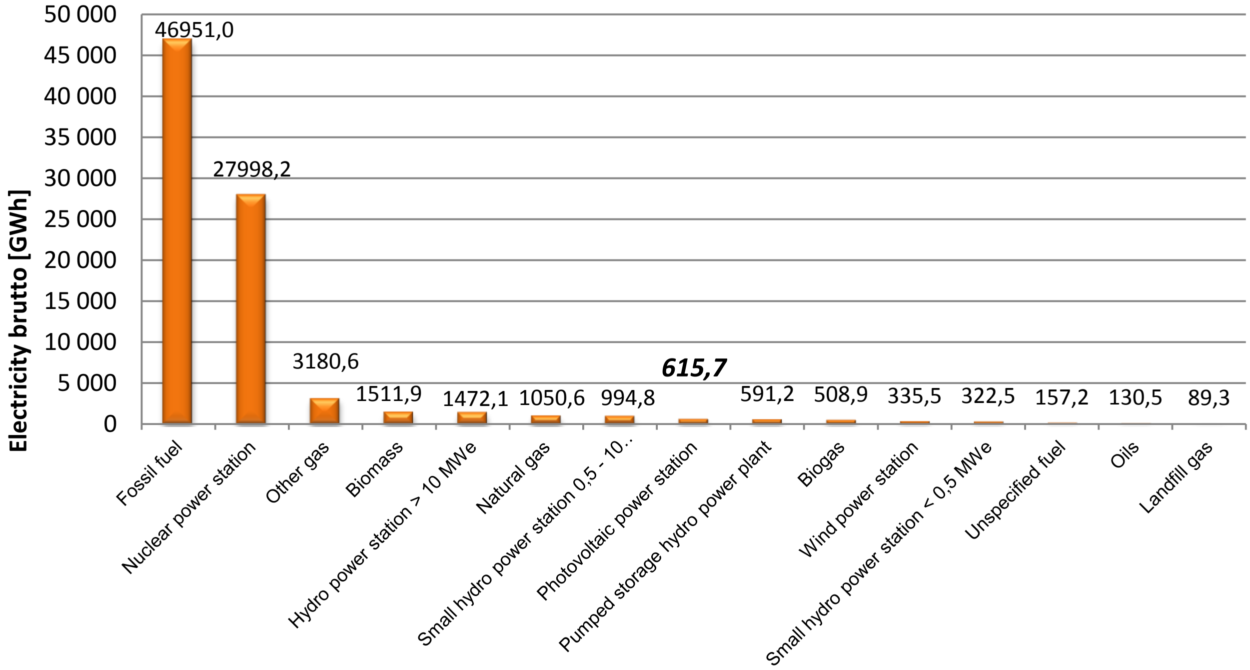


Figure 2 Structure of brutto electricity production in the power system in CR in 2010

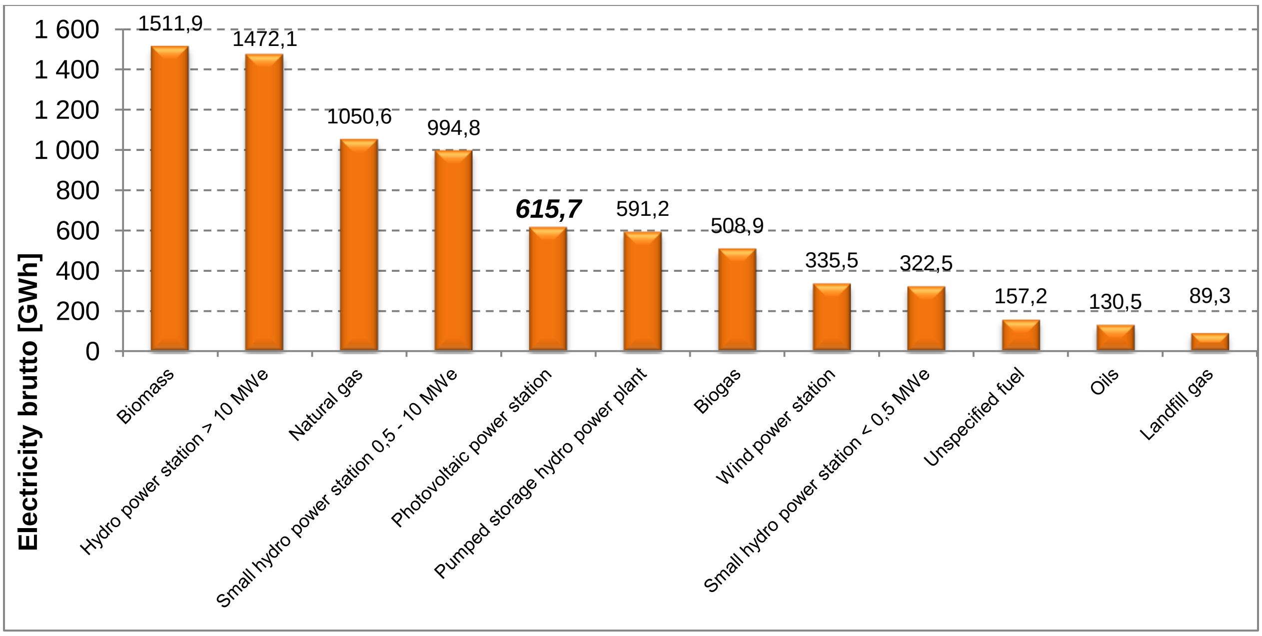


Figure 3 Detail of structure of brutto electricity production in the power system in CR in 2010

Another Figure 4 shows the value of individual sources of electrical energy in the Czech Republic. You can see that the source with the third largest share of installed capacity is currently the photovoltaic power stations. There is installed on 1st February 2012 about 1970 MW in photovoltaic power stations in the Czech Republic. It is about 9,8% of all installed capacity in the Czech Republic. You can also see on the Figure 4 that it is half of installed capacity in nuclear power stations, but the capacity of PV is depending on the radiation and therefore not always available.

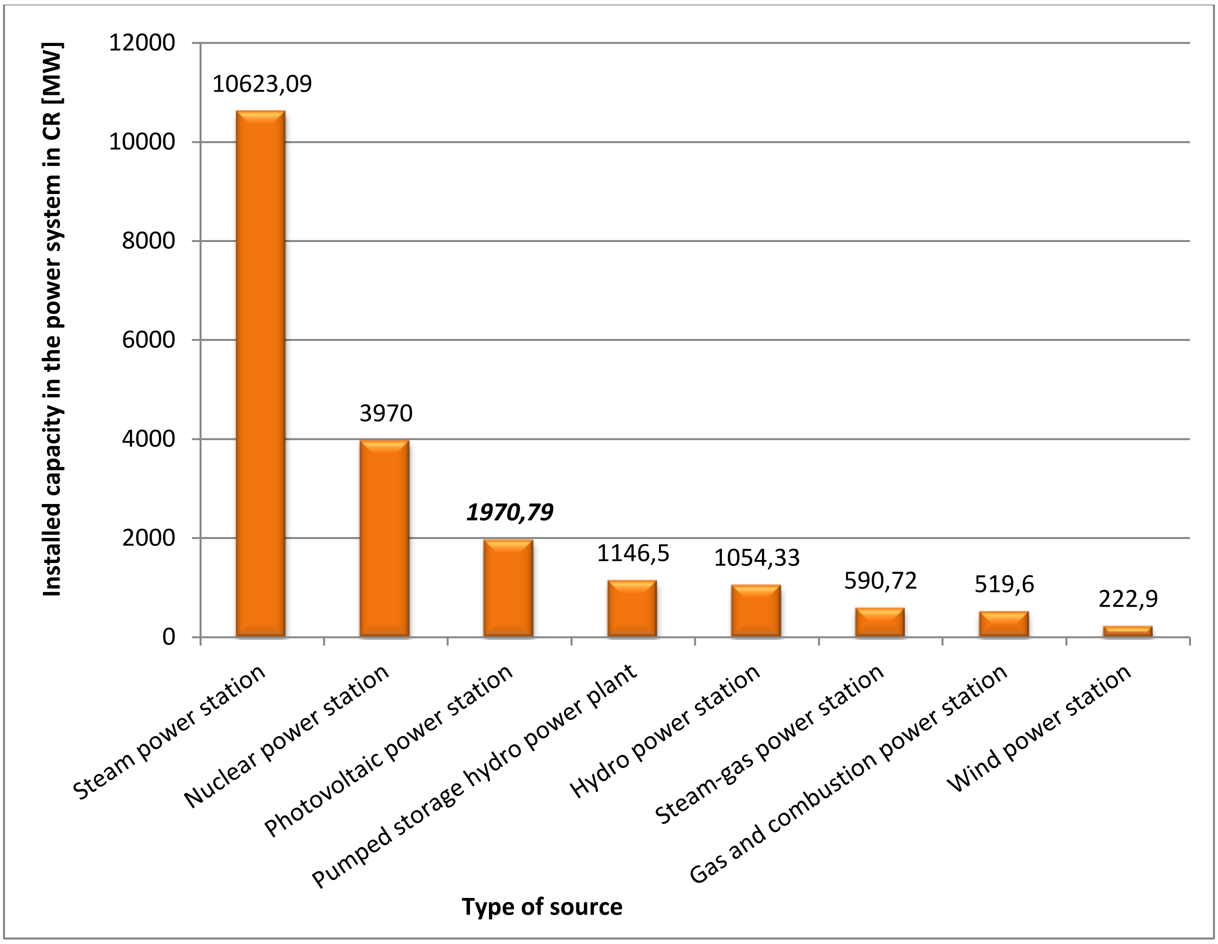


Figure 4 Installed capacity in the power system in CR 2012

3.1.2 Comparison of pricing decisions of the Energy Regulatory Office

Support for a higher share of electricity production from renewable energy sources was introduced in 2002 and was given a minimum purchase price of electricity from different types of RES. From the beginning it was only a basic breakdown of the various RES, but over the years with different types of RES they got further divided according to the date of commissioning and were attributed to different amounts of evaluation in the form of minimum purchase prices. Since 2006 has been introduced another form of RES support in the form of green bonus.

The purchase price shall apply to electricity has been supplied and measured at the delivery of factory and grid operator for the distribution system or transmission system operator, which enters the imbalance settlement clearing agency responsible for losses in the regional distribution system or clearing agency responsible for losses in the transmission system . They are set as the minimum purchase price under a special legal regulation. Green bonus shall apply to electricity supplied and metered at the delivery point of factory and grid distribution system operator or regional transmission system supplied by the manufacturer and retailer of electricity or eligible customer and the other for their own consumption of electricity under a special legal regulation. They are set as fixed prices under a special legal regulation. In one production is not possible that these two modes of of purchase prices combined with each other.

As is seen from the graph on Figure 5, the first increase in the minimum purchase price for electricity supplied to the grid from RES could be observed in 2005, which was due to the fact that the Republic is committed to the Treaty of Accession to the European Union to increase the share of RES to 8 %.

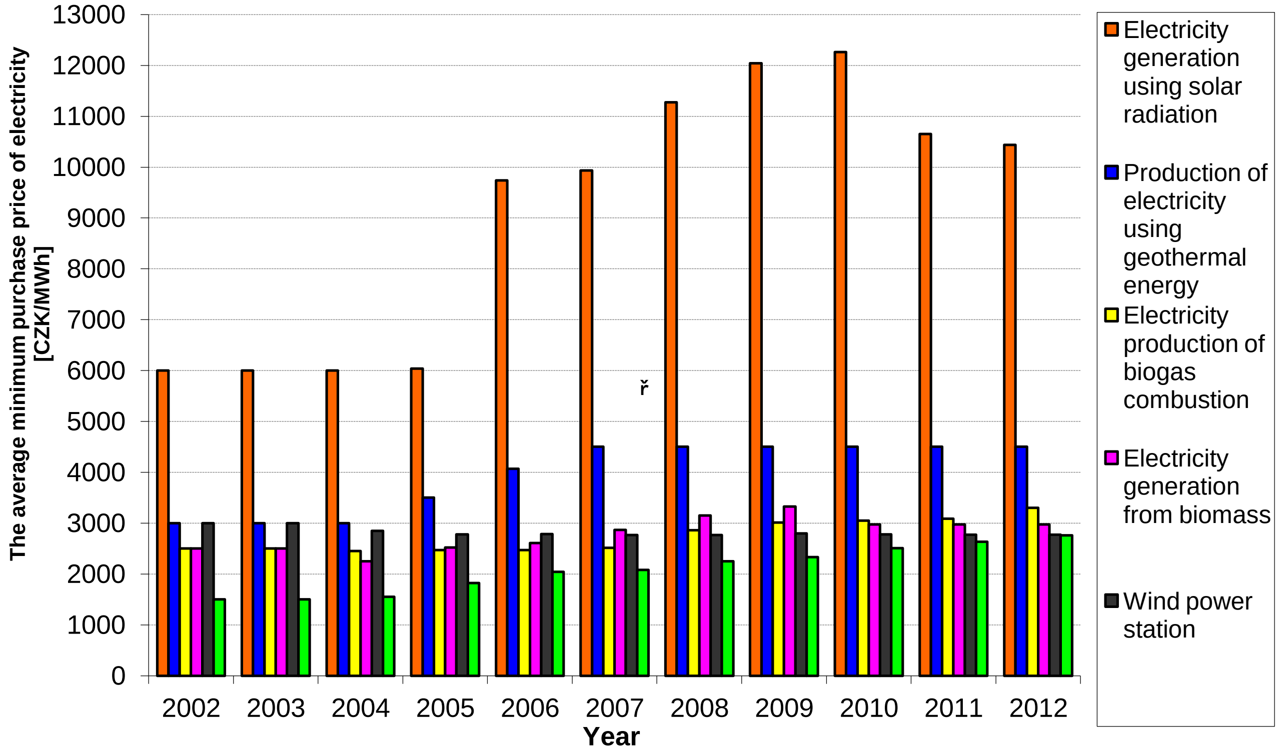
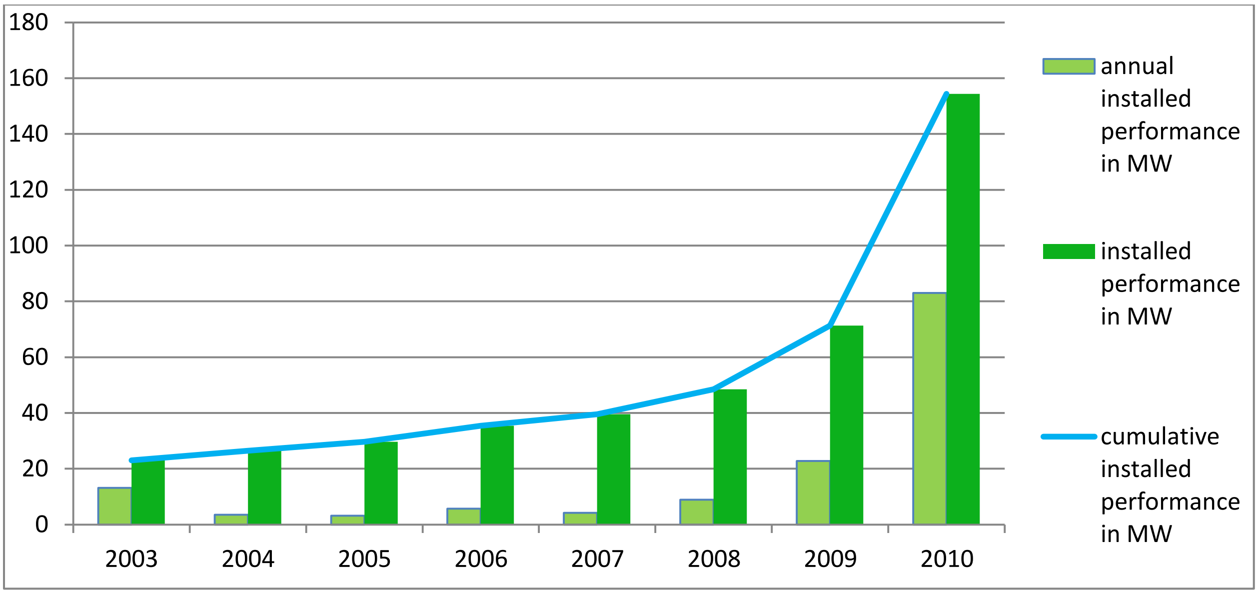


Figure 5 The average minimum purchase price of electricity in CR 2002 – 2012

As shown in these graphs, so the initial introduction of green bonus has been taken in 2006. However, the first signs were already in 2005 the electricity generation fuel mix combustion of biomass and fossil fuels, which this year was the establishment of a fixed purchase price in the industry. In 2010, shows a significant increase in the value of green bonus from the previous year (2009). For example, small hydro power stations are to increase by 72% of the average green bonus. In contrast, the lowest increase in average bonus for green electricity generation using solar radiation, which amounts to approximately 11%. But at first sight it is obvious that the value of green bonus is the highest for PV.

3.2 PV in Austria



Figurem 6: Development of the grid connected PV-electricity production in Austria (Faninger 2007, BMVIT 2009, 2009) (E-control, 2011)

In 2010 in Austria the whole grid-connected performance of PV-plants was 154,41 MW. The supplied volume of the government-funded power in 2010 was 26 GWh. Therefore there is a high potential for the development of PV. (E-control, 2011)

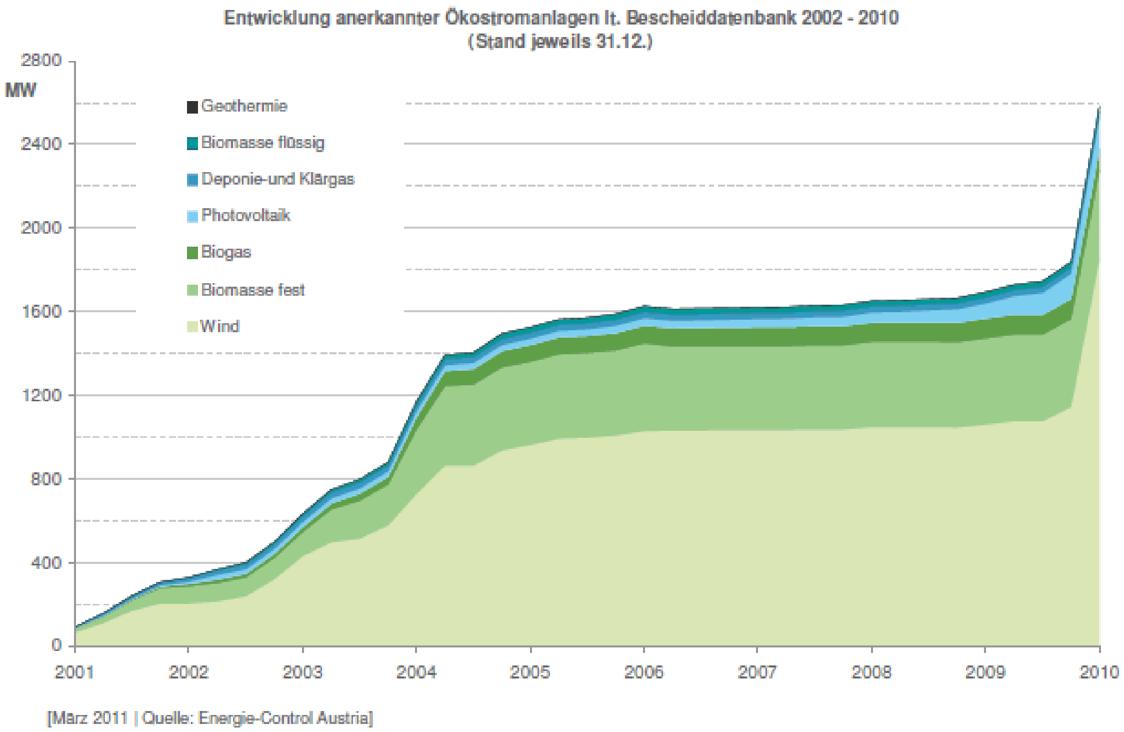


Figure 7: Plant development of green electricity 2002-2010. (E-control, 2011)

roof		
position on the waiting list	**PV < 20 kWp**	**PV > 20 kWp**
	c/kWh	c/kWh
2011	38	33
2012	35,15	31,55
2013	33,25	29,70
2014	31,35	28,05
2015	29,45	26,40

surface		
position on the waiting list	**PV < 20 kWp**	**PV > 20 kWp**
	c/kWh	c/kWh
2011	35	25
2012	32,90	24,38
2013	31,15	23,13
2014	29,40	21,88
2015	27,65	20,63

Table 1: Development of PV subsidies in Austria (Tarifabschläge)

Table 1 shows the development of the subsidies for PV. The so called „reduction“ is a flexible mechanism to react perfectly to the changes of the module price. The subsidies are as high as they have to be to guarantee a amortisation of 13 years.

4 Energy potential of PV

In this chapter we approached, as it is with the energy potential of PV in the Czech Republic and Austria in terms of transferability. Whether this potential Czech Republic and Austria all use and whether it is ever such a thing in terms of stability of the power system of the Czech Republic and Austria possible.

Energy potential we can divide into 4 categories [25] :

1. **Technical potential**, which is given by the presence of source and by conditions of energy transformation. Technical potential has only theoretical significance.

2. **Usable potential**, which is the *technical potential* that can be used in currently available technical resources and its use is limited by legislative, environmental or other similar constraints.

3. **Available potential**, which is defined as that part of the *usable potential*, which can be used for energy purposes.

4. **Economic potential**, which is characterized as the *available potential*, which can be under current conditions affecting the economics of specific projects used commercially.

4.1 Energy potential of PV in the Czech Republic

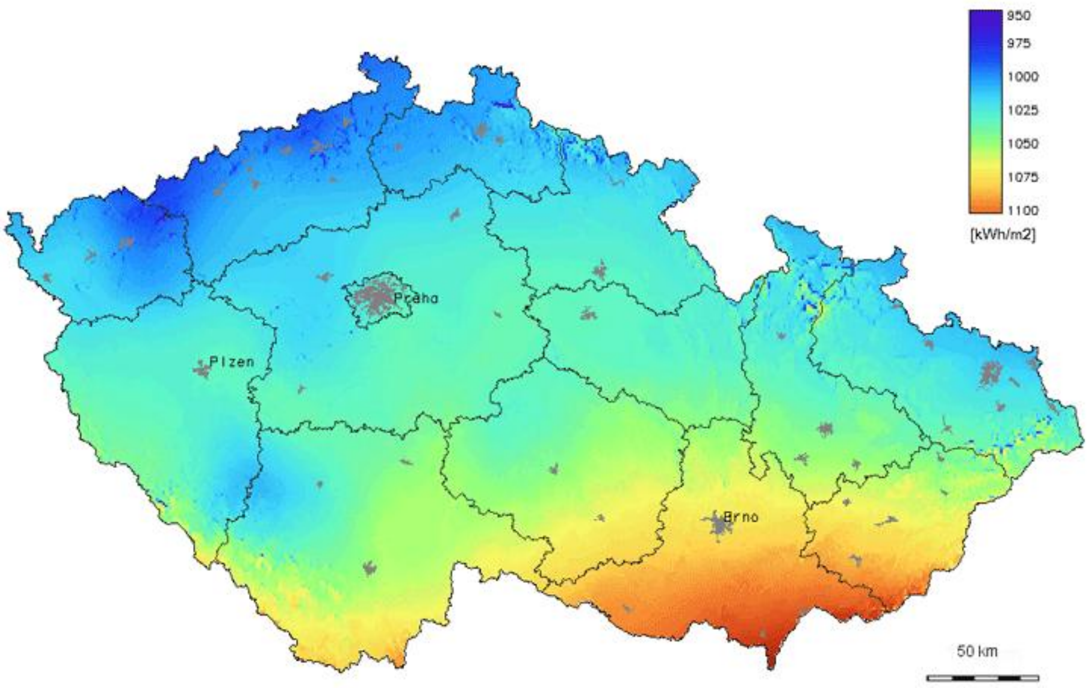


Figure 8 Yearly sum of global irradiation on horizontal surface – CR [26]

The largest photovoltaic power development started in 2006, a radical increase in the minimum purchase price for electricity supplied to the network of photovoltaic power plants. The gradual increase in minimum prices for electricity from photovoltaic power subchapter deals with 3.1.2. Most of these solar power plants were built thanks to subsidy titles. Without these subsidies would a return could not reach the border 15 years repayment. The estimated energy potential of solar power plants in the Czech Republic is 5 500GWh/rok. This value also includes the built up area of space, which means the roof of each building. There is seen solar map of the Czech Republic on the Figure .

4.2 Energy potential of PV in Austria

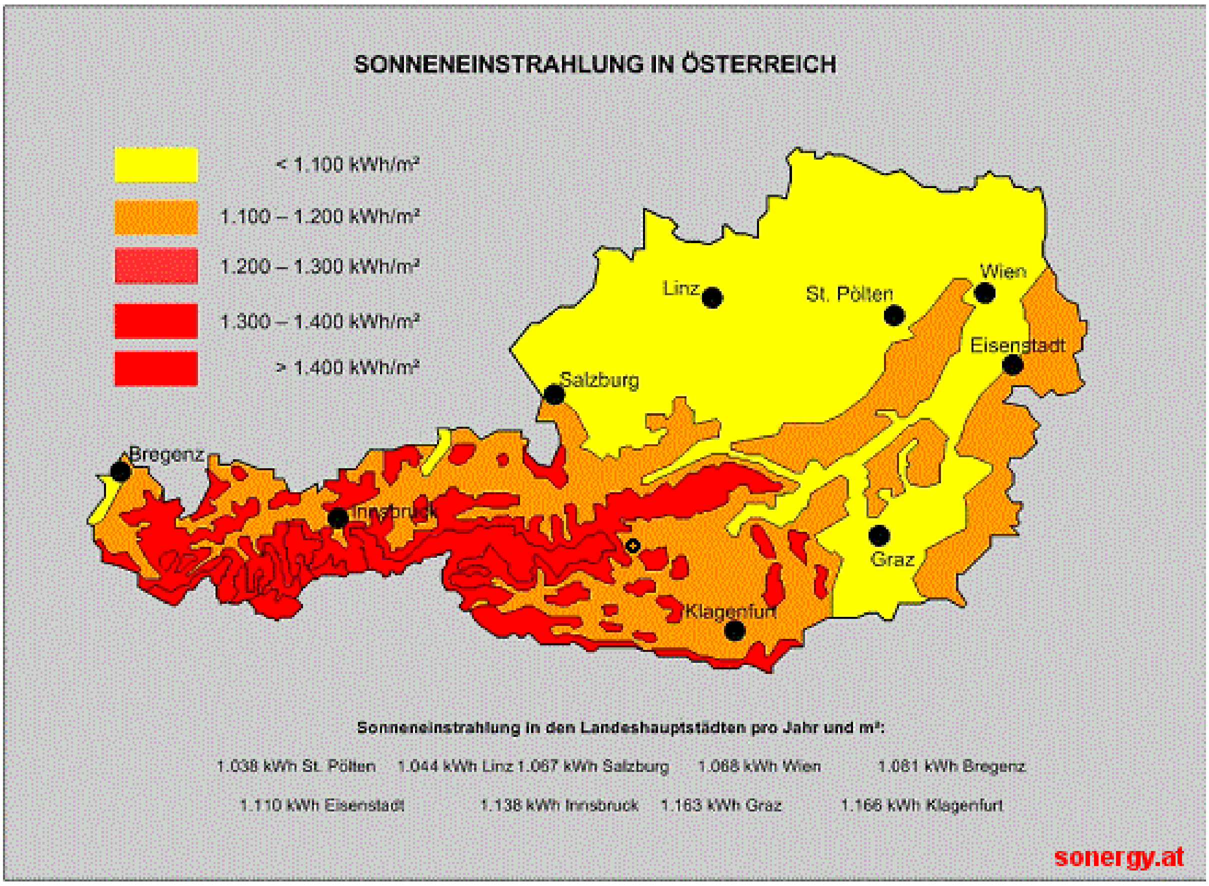


Figure 11: Allocation of longtherm averages of total radiation in Austria (Sonergy, 2011)

The average solar radiation is in Austria at 1100 kWh/m2 per year. This radiation is enough to operate a PV-plant cost effective with adequate funding. The highest regions of Austria (Grossglockner) reach values over 1400 kWh/m^{2}a (Sonergy, 2011).

4.2.1 Theoretical and technical potential

The representation of the potential of a photovoltaic power generation to meet demand for electricity in Austria is on the current state of the art. The discussion is restricted to a grid-connected photovoltaic power generation scale.

The Austrian surface area has a theoretical supply of solar radiation range of about 332.2 EJ / a (92.3 PWh / a). For this radiation offers results at current efficiency of 18% for PV systems a theoretical potential of 16.61 PWh / a. Referring to the potential surfaces for photovoltaic use results in a total technical potential-current-generating from 18.8 to 42.9 TWh / yr This is between 30 and 70% of net electricity generation in Austria in relation to 2006. (Kaltschmitt Martin, 2009)

Table 2: Potential of electricity from PV in Austria (Kaltschmitt M. , Regenerative Energien in Österreich, 2009)

		Roofs		building facades	surface	noise protection walls	total
		flat roof	sloping roof				
theoretical potential	PWh/a						92
Theoretical potential of produced electricity	PWh/a						26
Theoretical surface potential	km^2	155	479	809	983	1,53	2427
Technical surface potential	km^2	35	79	52	136	0,46	303
Istalled capacity	GW	2,4 – 5,5	5,6 – 12,7	3,6 – 8,3	9,5 – 21,8	0,03 – 0,07	21,2 – 48,5
annual yield	kWh/kW	950	900	650	950	650	
Technical supply potential	TWh/a	2,3 – 5,3	5 – 11,4	2,4 – 5,4	9,1 – 20,7	0,02 – 0,05	18,8 – 42,9

4.2.2 Technical potential

If all of the technical offer potential for use in Austria, the daily sum of a summer day of the current technically deployable in comparison to the demand of electric energy throughout the day for a Sunday or weekday is considered a factor of 2.6 - 3.4 above.

In order to use the full technical offer potential, appropriate Memories are integrated into the power generation system (pump storage power plants).There is no provision that may occur in this scenario to undesirably large load variations or control problems in the existing power generating system.

5 Simulation - Replacement of steam power block by PV

This part is simulating the situation, when we take a block of steam power station with level of nominal power 200MW. This kind of block you can for example see in Dětmarovice (4x200MW), Počerady (5x200MW), etc. The steam power station use for electricity generation non-renewable energy resources. There is installed capacity in the steam power stations about 10 623 MW in CR in 2012.

For calculations of installed capacities of different types of power stations, we need to use coefficient of annual utilization, which is for every type of power stations different. It shows that the power station had given continuously throughout the work on a percentage (calculated) of its nominal power to produce the same quantity of electricity. It can be calculated by the formula:

$$k = \frac{W_t}{P_i * 8760}$$

W_t… quantity of electricity produced per year (brutto)
P_i… installed capacity
8760…sum of hours per year

Then we have to calculate with own power plants consumption. For this we use coefficient of own consumption (υ) by which we hate to multiply installed capacity of chosen type of power plant. We have to use that to calculate with own power plants consumption, which is in the case of steam power station higher than in case PV. Using this factor causes a reduction in the required installed capacity of replacement PV. For calculation there were used data of annual report on the operation of power system in year 2011. Formula for calculation of real installed capacity is:

$$P_i = \frac{k_{PE}}{k_{PV}} * P_{iPE} * \upsilon$$

$$\upsilon = \frac{\frac{Netto_{PE}}{Brutto_{PE}}}{\frac{Netto_x}{Brutto_x}}$$, $\frac{Netto_x}{Brutto_x}$ ...of the type of power station

	Brutto production [GWh]	Netto production [GWh]	$\frac{Netto}{Brutto}$	Coefficient of own consumption
Steam power station	49 973,0	45 183,7	0,9042	1,000
PV	2 118,0	2104,8	0,9938	0,946

Coefficient of annual utilization

1. Steam power station

$$k = \frac{W_t}{P_i * 8760} = \frac{49\,973 \cdot 10^6}{10\,787{,}5 \cdot 10^3 * 8760} = 0{,}529$$

2. PV

Coefficient of annual utilization of PV we can calculate of averaging Coefficient of annual utilization of some PV.

Photovoltaic power station	P_i [MW]	W_r [MWh]	k
Ševětín	29,9	32 533	0,124208
Mimoň Ra 3	17,5	17 629	0,114997
Solar Stříbro s.r.o.	13,6	15 629	0,131186

$k_{PV} = 0{,}123464$

$$P_i = \frac{k_{PE}}{k_{PV}} * P_{iPE} * \upsilon = \frac{0{,}529}{0{,}123464} * 200 * 0{,}946 = 811\ MW$$

Evaluation of sources substitution

It means that for replacement of 200 MW block of steam power station by PV, we should need about 811 MW of installed capacities. Price of 1W of installed capacities of PV panel is about 90 CZK /W (ca 3,6 €/W). Also for replacement of 200 MW block of steam power station we should need minimum 72 990 000 000 CZK (2 919 600 000 €) just for PV panels. Then also we need to think about built-up area. For example we can take PV panel Avancis PowerMax 130 (capacity 130W), which has size about 1,1 m^2. The size just of area with PV panel, without space between panels, we can calculate by formula:

$$S = \frac{P_i}{P_{panel}} * S_{panel} = \frac{811 \cdot 10^6}{130} * 1{,}1 = 6{,}862\ km^2$$ (area about *2,62 x 2,62* km)

6 Influence of PV to power system

One of the main problems that affect to power system in terms of instability of RES production plants for some types of RES. The biggest influence is seen just after the photovoltaic power plants and wind power plants. This is due to the fact that they are fully dependent on the strength and regularity of solar radiation or wind power required. Thanks the availability of instability source of electricity generation from PV is necessary to ensure their installed capacity in other power stations to ensure stability of the grid in case of impossibility to produce electricity using PV.

One of negative influence of PV to power system could be phase voltage asymmetry. Ideally, single-phase load is divided between three phases, but in everyday situations is almost impossible. To alleviate the asymmetry we used three-phase generator, but at the expense of heating, which is caused it is installed protection against unbalance the network, which may cause loss of energy in rural networks. For example, if we take home PV and single phase generators can greatly increase the phase voltage unbalance. This solves a symmetric distribution of the three phases as well as loads.

Next problem could be harmonics. Harmonics can be defined as integral multiples of the fundamental curve. To compensate harmonics there are used harmonic filters. But if the harmonics are too large can cause overheating in the worst case ignite the harmonic filters. Current from PV is usually DC. This means the inverter is converted to alternating current. New models of these devices do not cause harmonious, but the older models of converters, which are not so good; they can generate higher harmonic iff converts direct current into alternating. The system called PWM, or if the pulse width modulation helps us prevent the creation of higher harmonics. Most computer equipment nowadays has a harmonic filter, which removes most of us already in the harmonic output of PV. Today the equipment is given by the value of the total harmonic distortion factor. This value will never exceed 5%. This is set so as to avoid undue influence of other devices that are connected to the distribution network.

Other negative influences that are causing problems in the electricity system could include unintentional islanding, jumps and drops in voltage and power in the point of common coupling to the distribution network, etc.

7 Analysis and discussion of results

As we can see in the paper, there is a huge potential both in Austria and the Czech Republic to increase the photovoltaic use. The potential has been differentiated into technical potential, usable potential, available potential and economic potential to see how much we can use the hypothetical potential for practical use.

Because of further degression of the module prices, we will reach grid parity in the next 2 years. That means that the price of electricity of PV costs as much as the price the customers have to pay. If we have grid parity PV production will be independent of subsidies, hence then the PV-produced electricity will raise amazingly.

We have to prepare our energy systems for this huge energy supply of PV. As previously mentioned the PV has a lot of impacts to our energy systems. A large PV capicity needs a lot of control energy, to be able to compensate the variations of supply and demand. In Austria there can be used the existing pumped storage power plants to generate the needed control energy. In the Czech Republic is the use of gas-fired power plants necessary. But energy systems are not confined to individual countries.

Due to the liberalization of European energy markets and the import and export of electrical energy with the corresponding transmission capacity and new power plants for balancing power and storage options, the volatility of the photovoltaic will be compensated.

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