

**Economic viability of small PV installations on family houses – the Czech and Austrian case**

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# Abstract

The cost of generating electricity can be derived for a photovoltaic system and can be regarded as a key parameter for evaluating the economic viability of a PV installation for a small household. The costs are divided into investment costs and operation costs. To determine the investment cost factors like grid connection, installation costs and the cost of capital must be investigated. For the operation costs besides maintenance, insurance must also be included. Legislation has also a profound effect on these costs. For PV installations in Austria and the Czech Republic they are not uniform. Moreover it can vary for different households in one country. Therefore an in detail evaluation of these factors for a particular installation site is indispensable. When the cost of electricity generation is lower as the price of energy purchased from the gird, grid parity is achieved. For the model example in Austria and Czech this is the case. The economic viability is then dependent on how much energy is used for consumption and what the income for selling energy is. If the price for selling energy on the market is too low, feed-in tariffs can support the viability for the household. Alternatively power accumulation can be used to increase self-consumption but should be considered in the costs of generating the electricity.

# 1. Motivation

While we can see more and more government targets to increase the share of renewable energy in lots of countries in the world, it is recognized that acceptance in society is the crucial factor in the whole process. We would like to focus on market acceptance because we share the opinion that the best way to motivate society is to make renewable economically viable. We can say about every situation in society that they are somehow connected and it is crucial that we follow more goals by increasing the share of renewable energy sources. For example the goal of reducing greenhouse gas emissions is connected with the effort of reducing environment pollution and developing renewable resources. We have the biggest chance to succeed if these efforts contribute to other societal and economic objectives. Government planning should be designed to create synergies between various topics of social situations.

Another alarming fact is that energy consumption is rising rapidly. Consumption rises as societies industrialize. Between 1840 and 2010 energy use grew more than 100 times on per capita basis. As societies industrialized they began to use new forms of energy sources such as electricity, oil, coal, natural gas and propane. Non renewable fossil fuel is now supplying around 80 percent of the world energy demand. We can expect that energy consumption will triple by 2050. Current trends show us that there is a huge possibility that fossil fuels will still remain dominant. All the people in the world will have to join the effort to avoid this scenario. Dealing with this multigenerational problem is a huge challenge for the world.

Climate change is one the greatest threats that the world is facing. The impacts of climate change leads to events such as sea level rise. Kyoto protocol has an impact on reduction of greenhouse gas emission. Some experts say that we need to reduce carbon emission by more than 60%. The question is how? Renewable energy provides one among many answers to this question. We are talking about carbon free economy achieved by usage of renewable. It is slowly happening across Europe and it is mostly a success. We can see its potential to be a solution to climate change problems.

# 2. PV Technology Overview

A photovoltaic system, also solar PV power system is a power system designed to supply usable solar power by means of photovoltaics. It consists of an arrangement of several components, including solar panels to absorb and convert sunlight into electricity, a solar inverter to change the electric current from DC to AC, as well as mounting, cabling and other electrical accessories to set up a working system. A rooftop PV system has its solar panels mounted on the rooftop of a building. Positioning PV plant on rooftop is a great idea since we have lots of free space on the roofs in our urban environment. We will focus on roof-top systems for small households in this paper.

There are various aspects that affect effectivity of installed PV. These aspects are for example: time of the year, weather conditions, roof slope, shading from other objects. It is desirable to avoid these aspects to achieve maximal output. PV energy is an established and rapidly expanding energy sector. PV technology is among the renewable energy technologies that experts are predicting that they will help the European Union achieve its 2020 goals of obtaining 20% of the energy from renewable sources. Recent advancements in the technology have led to substantial increase in their efficiency and reliability as well as decrease in price.

# 3. Problem Statement

When talking about supporting renewable energy it is often said, that when levelized cost of generating photovoltaic energy is lower than purchasing energy form the gird, PV systems for small household are economically viable.

A household faces different aspects when calculating the costs, which can be separated in investment and operational costs. The investment costs include not only the PV modules, but also the other parts of a full functioning system often called the balance of system (BOS) and the installation it. Also the cost of capital must be taken into considerations. The operation costs of the PV modules are minor, but still some maintenance and cleaning must be taken into consideration and other costs, like insurance.

When summing up all those costs and arriving to a value which is cheaper than the price of energy form the gird, the retail price, this still does not guarantee economic viability of the photovoltaic plant. Since the supply of PV energy goes in hand with solar radiation, the supply and load may not coincide. Therefore, when demand is higher than the current supply of PV power, additional power must be purchased from the grid. Furthermore, when PV supply is higher than the current load it cannot be used for consumption, but will be sold. This all leads to reduced profits and can undermine the viability of the PV installation.

An exception would be net-metering, because than every unit energy produced would mean reduction in purchased energy. When net-metering is not available, power accumulation systems, like batteries can increase the share of self consumption, but at the same time it adds additional costs to the generation.

The focus of this paper is to assess the cost of a PV system for a small household. Therefore we investigate what is needed for a functioning PV system and what the costs are. We will also compare these factors in Austria and the Czech Republic. After presenting our findings we will assess what the average cost of one unit energy is for this installation, the levelized cost of generating energy. This will be used to judge the economic viability of PV systems in Austria and Czech for an example calculation.

# 4. Results

## Investment Costs

The investment costs are the main expenditure and are due on the beginning of the photovoltaic investment. Besides the total costs of all components of the PV System also the montage has to be paid.

According to (Biermayr, et al., 2015) the cost of complete 5kWp roof-top PV system, including installation, in Austria was on average 1.752€ per kilowatt peak.

The investments costs for PV in Czech Republic are 217700 CZK for a 5kWp system, based on a model project, including the installation.

When talking about high expenditures the cost of capital cannot be neglected. Because, on the one hand, when not enough capital is available to purchase the PV system it is possible to take a credit, but the interest must be paid. When the household has enough equity, the money could have been used otherwise which are called opportunity costs.

On the other hand, when the PV system comes into operation and from the generation income is obtained it must be respected that money obtained at a later time is less worth (time preference of money).

Above discussion leads to the application of the discount rate to quantify this issues. It can vary from household to household. It depends on what interest rate can be obtained from alternative investments. For example it could be set as the interest rate from safe bonds plus a premium.

When a bank load is taken for the installation costs it should be at least as high as the interest rate on the loan. When both own equity and debt is used the method of weighted capital costs (WACC) can be used.

In the course of projecting the PV system it is essential to consider that saving in expenses on the PV installation can have effect on the yields. For example a more efficient inverter will cost more, but will lead to a higher yield. Also a professional installation can decrease later expenses on operational costs. Therefore there is possible trade-off between non-recurring investment cost and future effects on the operation costs.

## Operation Costs

**Electricity generation with photovoltaic does not include any moving mechanical parts. Therefore there should be no wear out and running expenses for maintenance. This is true for the silicon modules itself but not for the electronics.**

**This leads to the peculiarity, that although the PV modules have a lifetime of 25 years or more, current inverters have an expected lifetime of 15 years. This means that in the minimal lifetime of the PV installation at least once the inverter needs to be replaced. This can be considered in the operation costs.**

**Additionally it’s indispensable that the PV systems are regularly checked for functioning optimally. Any malfunctions of one part of the system, for example a module, can decrease the whole PV system performance.**

**Furthermore, cleaning of the PV modules can also be important, but depends on where the PV modules are installed. For example next to a busy street dust is collected on the modules and requires cleaning, but in other cases rainfall is enough.**

## Legislative

When looking at economic viability, legislative regulations have also to be kept in mind. Module costs are for example fairly homogenous across Europe, because it is one market, but legislative can be quite heterogeneous. Some aspects are mandated by the EU, but there is still variation in detail between countries. This can have severe economic impacts on the calculations and also adds risk for the household when they change abruptly.

This can be exemplified on the VAT regime in connection with private photovoltaic power supply. Value added tax (VAT) is paid for any economic activity by the consumer. When buying the photovoltaic system, VAT makes it more expensive.

Therefore an Austrian operator of a household 20 kW photovoltaic system argued that by selling the PV energy he actually has a business and should not pay the tax. This led to a court case at the European Court of Justice, who ruled in favour of the operator (Gregori & Komarek, 2013).

Before this decision, in Austria the argument was made that when most electricity is consumed by the household itself, the operation of the photovoltaic system is not an enterprise. The second argument was that because the selling of photovoltaic energy is hardly viable, it is like a hobby and those kinds of enterprises do not get a tax exemption.

The ECJ ruled that it does not matter how much is self-consumed. When the photovoltaic energy is sold with a sustainable aim to make profit, it is a business and VAT is not applicable to investment costs (Press Release No 75/13, 2013).

The problems are how to deal with households where not all of the generated energy is sold, but when possible also used for self-consumption (excess feed-in). In this case, when the PV system is bought as an investment, VAT should be paid for energy that is consumed in the household. As calculation price for the energy that is obtained from the PV system, the cost of electricity generation is taken (Bundesministerium für Finanzen, 2014).

For maximizing self-consumption and using power accumulation this creates a conflict. All in all this measure reduces the financial burden form the investment, but makes self-consumption more expensive, because, like from energy purchased from the grid, VAT has to be paid. There is also a certain threshold that has to be kept in mind. When Self-consumption increases to the level, where only 10% of PV power is fed into the grid and sold, there is no indication anymore, that the operation of the PV system is a business. The VAT can retrospectively be collected.

Any income made from the operation of a PV plant is also subject to income tax. The income is the revenue made from selling PV energy minus the cost of the enterprise. But when the PV system is also used for producing energy for self-consumption, the operating and investment costs can only partially be assigning to the business of selling PV energy. Therefore the investment costs and the operation costs are assigning to the business in proportion to the energy that what was fed-in.

All in all the transition from the time, where PV systems for household where not generally regarded as enterprise in Austria to a regulation where they can also operate as an enterprise has gone forward with a slow pace and there are a lot of open questions. This causes of course unsettledness private household who would like to install profitable PV systems.

Problem with the PV in the Czech Republic is that you need a licence to sell your extra energy. Most of the companies instaling PVs deal with the administration connected to the licence for you. It is part of the investment cost. This licence is similar to bussines licence which means that the person with the licence has to contribute to social and health security system and to pay taxes for the energy you sold. There is also no claim on unemployment compensation after you lose your job because you are considered as an entrepreneur. The other thing is that this licence can not be interrupted to get unemployment compensation, it can only be terminated. This is strange because regural entrepreneur can interrupt his licence as he sees fit.

## Grid Connection

In Austria, the montage of the PV has to be done by certified professionals in order that the PV plant gets recognized as a green electricity plant („Ökostromanlage“), which is not only important to qualify for support, but can also be a prerequisite for a grid connection.

Additionally, the possibility feed in (partially or fully) the PV energy generated an already installed grid connection is in most cases not sufficient anymore and the connection must be upgraded. This depends on the current workload of the gird in that particular area and therefore has to be considered independently for every household.

The grid operator is responsible for an efficiently working grid. He is allowed to charge the PV operator for any upgrades that have to be undertaken. But because the grid operator is monopolistic a regulatory body needs to overlook that the fees are fair. In Austria this is done by the E-Control.

If more and more households want to generate PV energy and feed it in, the burden on the gird rises and the grid operator may therefore not want to process the upgrade. But any delay in installing the grid connection and for the household not having the possibility to feed-in are losses and will reduce the viability of the PV installation.

An example list how much the costs can be in a municipality in Austria see (Voralberger Energienetze GmbH, 2015).

## Storing Energy

With cost of PV generation reaching grid-parity and decreasing feed-in tariffs, self-consumption becomes more and more beneficial.

Two factors can increase self-consumption. Firstly, to let load times coincide with PV power supply time (demand management). This can be achieved by changing the consumption behaviour, for example making household works with high power usage when a high gain from the PV system is expected. This can also be automated with smart home systems. Secondly power accumulation is a solution. When more power is produced by the PV system then consumed by the user, the surplus power will be used to charge a battery. When PV energy is not enough to power the house, instead of purchasing energy form the grid, the energy form the battery can be used.

Now the optimal design of the storage capacity is an important but difficult question. The larger the storage the more it increases self-consumption, but also makes the PV installation more expensive. Should the capacity be large enough that any excess energy generated from the PV system will be stored and used for later consumption? Then the household has 100% self-consumption and saves the same amount in purchasing from the grid and also has the option not to install the PV system to the grid. When the PV installation is large enough to provide any energy needed by the household the household becomes autofocus, which maybe also be favourable. But then the battery system must additionally provide enough power output.

In total those additional features add to the cost of the PV system and even when self-consumption in combination with storage is viable compared to purchasing from the gird, it can still reduce the long-term viability of the installation.

Therefore, when calculating if power accumulation pays off, following has to be considered: The price of electricity from the grid, the income from selling PV energy and the cost of electricity from the storage. The cost of electricity from the storage is the cost of generating electricity with the standalone PV system plus the costs that arise from the storage system (Poonpun & Jewell, 2008).

Finally, for a depth analysis of the viability of PV Systems with Battery Storage the individual load of the household compared to the supply of PV energy must be examined (Hoppmann, et al., 2014).

In further developments, when the price for feed-in is volatile, for example when facing the wholesale market price, smart-systems can be used which observe this price and determine if its better at the moment to sell the energy or to accumulate it for later use.

## Insurance

Because of the high expenditure of the photovoltaic system, insurance should not be neglected. The insurance should include on the one hand any possible damages caused by the PV installation, which could be easily incorporated in an existing household and liability insurance. Secondly, to minimize the risk and ensure viability the PV installation should have insurance for malfunctions, because any failure of the PV system leads to losses of earnings. An optimal insurance would compensate any projected revenue from power generation.

In Austria the premiums for insurances which offer complete protection are in the range of 60€ per year.

## Energy Yield

Calculating the cost of PV electricity generation the costs is one side but the total amount of generated energy must also be projected. A 5kW PV system does not equal 5kWh energy generation each hour in a year. This is because the power specification of a module is only valid for the Standard Test Condition (STC, defined by the IEC), which are not the conditions the PV modules are likely to face in actual operation.

Following two aspects alter the yield of a PV module compared to the STC. First, the amount of solar irradiance depends on the location of the modules, there angle and orientation. Secondly, the STC is determined for a constant temperature. In actual operation the PV modules heat up, which has a significant impact on efficiency. With higher temperature they generate less energy. At the same time, when in winter the outside temperature is low the efficiency increases. This has the interesting effect that in countries in the northern part of the globe the lower solar irradiance is compensated by lower mean temperatures.

To cope with these amount with these uncertainties the Joint Research Centre of the EU provides the tool PVGIS (Šúri, et al., 2005). With average information gathered about the trend of ambient temperatures in a year and the trend of solar irradiance taking into consideration the location and angle of the PV System and using a formula which estimates the effect of temperature on PV modules, the average annual possible electricity production for a PV System can obtained.

Last but not least the losses in the balance of system must be considered. This includes losses from the cables and the inverter. With this we get the annual yield. In the lifetime of the PV installation it will not be constant, because of degradation due to various reasons (Ndiaye, et al., 2013).

# 5. Discussion

After analysing all the costs in connection with PV installations or households we would like to calculate the cost of generating electricity.

$$LCOE =\frac{I+\sum\_{t=1}^{T}\frac{c\_{t}}{(1+r)^{t}}}{\sum\_{t=1}^{T}\frac{E\_{t}}{(1+r)^{t}}}$$

Here $C\_{t} $and $E\_{t}$ are the operation cost and energy yield for each year, respectively, and they are discounted with the factor $r$. The investment costs are denoted by $I$ for the PV system with a lifetime of $T$ years. It equals the minimum production price for which the NPV would be zero.

$$NPV = -I+\sum\_{t=0}^{T}\frac{(LCOE\*E\_{t}-C\_{t})}{(1+r)^{t}}=0$$

This means, if for every unit of energy generated income in the extent of the LCOE can be made (from saving purchased energy or from selling it), the return of the investment is favourable and the PV installation is economically viable.

For an exemplary PV installation in Austria and in the Czech Republic the average results obtained from the research where used, see Table 1 and Table 2.

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Lifetime [years] | Invest. costs [EUR/kWh] | Diskont-factor[%] | Operation costs [EUR/year] | Nominal Peak Power [kWp] | Yield before losses [kWh/kWp] | System Efficiency [%] | Degeneration [%] |
| 25 | 8700 | 5 | 90 | 5 | 1220 | 85 | 0.71 |

Table 1: Example input data for calculating the cost of electricity generation for Austria

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Lifetime [years] | Invest. costs [CZK/kWh] | Diskont-factor[%] | Operation costs [CZK/year] | Nominal Peak Power [kWp] | Yield before losses [kWh/kWp] | System Efficiency [%] | Degeneration [%] |
| 25 | 217700 | 5 | 2180 | 5 | 1130 | 85 | 0.71 |

Table 2: Example input data for calculating the cost of electricity generation for the Czech Republic

The calculation in detail is showed for Austria in Table 3. The result for the LCOE is
14.6 cent/kWh. For the Czech Republic the calculation were carried out similarly and the computed LCOE is 3.92 CZK/kWh.

Comparing the LCOE with the average price of purchasing energy from the grid in Austria, 20.0 cent/kWh (EUROSTAT), shows that grid parity is reached in this example. Also in the Czech Republic there is grid parity for an average retail price of 4.75 CZK/kWh in Prague.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Year | Power [kW] | Production [kWh] |  Production discounted [kWh] | Operation costs discoutned [EUR] |
| 1 | 5.00 | 5185 | 4938 | 86 |
| 2 | 4.96 | 5148 | 4670 | 82 |
| 3 | 4.93 | 5112 | 4416 | 78 |
| 4 | 4.89 | 5075 | 4175 | 74 |
| 5 | 4.86 | 5039 | 3948 | 71 |
| 6 | 4.83 | 5004 | 3734 | 67 |
| 7 | 4.79 | 4968 | 3531 | 64 |
| 8 | 4.76 | 4933 | 3339 | 61 |
| 9 | 4.72 | 4898 | 3157 | 58 |
| 10 | 4.69 | 4863 | 2985 | 55 |
| 11 | 4.66 | 4828 | 2823 | 53 |
| 12 | 4.62 | 4794 | 2670 | 50 |
| 13 | 4.59 | 4760 | 2524 | 48 |
| 14 | 4.56 | 4726 | 2387 | 45 |
| 15 | 4.53 | 4693 | 2257 | 43 |
| 16 | 4.49 | 4659 | 2135 | 41 |
| 17 | 4.46 | 4626 | 2018 | 39 |
| 18 | 4.43 | 4593 | 1909 | 37 |
| 19 | 4.40 | 4561 | 1805 | 36 |
| 20 | 4.37 | 4528 | 1707 | 34 |
| 21 | 4.34 | 4496 | 1614 | 32 |
| 22 | 4.31 | 4464 | 1526 | 31 |
| 23 | 4.27 | 4433 | 1443 | 29 |
| 24 | 4.24 | 4401 | 1365 | 28 |
| 25 | 4.21 | 4370 | 1290 | 27 |
|  |  |  |  |  |
|  |  | SUM | 68366 | 1268 |
|  |  |  |  |  |
|  |  | LCOE | **14.6** | cent/kWh |

Table 3: Calculation and Result of the LCOE for the Austrian case

Additionally there is a difference between the grid price of 5.6 cent and 0.83 CZK per kWh in Austria and the Czech Republic, respectively. Therefore, when we calculate the NPV for theses PV installations, it would be higher than zero implying a higher rate of return than requested with the discounting rate for the capital.

Without power accumulation this is unlikely for a normal household, readily identifiable when comparing the trend of PV energy supply in a day and the normal household demand. Therefore when judging the economic viability it must be taken into consideration what can be gained from selling unconsumed energy. To elaborate on this we assume that in one year 40% of the energy is self-consumed and the rest is fed in. For covering the cost the PV electricity generation the average revenue for selling PV energy

 $R\_{avg} = ^{(LCOE-P\_{E}\*40\%)}/\_{60\%}$

must be 11 cent/kWh in Austria and 3.53 CZK/kWh in the Czech Republic, for a price of purchased energy $P\_{E}$ as before. The result is lower than the LCOE for both cases, because of the additional earnings due to the difference in the LCOE and the price of purchased energy. In Austria the price offered by electricity utility companies is between 6 and 9 cents per kWh (PV Austria).

For the Czech Republic market prices between 0.3 – 0.6 CZK/kWh are reported. To balance the difference between the minimum market price and the actual there was a green bonus. In the Czech Republic the green bonus is not set for new PVs since 2014. Ofcourse PVs instaled before 2014 still get the green bonus. This means that for now PVs are not as good investment as they were with the green bonus. But still there are model situations where you can save money by instaling PV for your personal usage.

What the average income is when selling PV energy in the market is difficult to predict, but there exist methods to derive it (Benes & Knápek, 2007). But because the market price volatile, the viability for a household depends not only how much they use for self-consumption but also when they do it. The amount of self-consumption will also vary in the year and maybe rise if taking the degradation into account.

Feed-in tariffs exist as a support mechanism to cope with this uncertainty and provide the household more assurance for the viability of a PV installation. The current feed-in tariff in Austria, for PV-System with a peak power between 5kWp and 200kWp starting operations in 2015 is 11.5 cent/kWh (OeMAG), therefore a little above the calculated minimal value. The PV installation for the household in Austria in this example would be therefore economically viable.

# 6. Conclusion

While the calculation for the cost was a simplified, we showed what aspects must be taken into account when determining the costs of PV installations for small household and how the economic viability can be assed preliminary. Nonetheless, for a comprehensive judgment a household must take into consideration all cash-flows to ensure liquidity and a financially sound investment. The regulation concerning private PV installation turned out to be problematic both in Austria and in the Czech Republic problematic. Therefore we recommend for households to secure legal advice. In addition, power accumulation was discussed, as a means to maximize self-consumption, which is becoming more and more important and considered since PV energy has reached grid parity.

It is important to state the fact that we are talking about economic costs and we are looking for the viability of the system from the view of economic costs. In the case of social costs and benefits there are many opinions regarding green energy. The difference is in apprehension of importance of preserving the environment. Consuming energy from rooftop PV panels has impact on reducing fossil fuels consumption and that can be considered as a step towards preservation of environment. It is hard to quantify these benefits therefore we did not calculate them into our cost analysis.

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