# Potential production and development of photovoltaic panels

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**Abstract** – The aim of this article is to compare the changes in performance due to the evolution of technology over the period and to compare the most popular calculators, their advantages and disadvantages. In the first part, there are selected three buildings covering a large part of the types of sites for the construction of PV plants. A potential power calculator is applied to these buildings. In the second part, three calculators that are selected for simulating the performance of a model installation have been selected and described.

**Keywords -** photovoltaic panel, solar energy

## 1. INTRODUCTION

Nowadays, the focus of photovoltaic panels tends to be on a better price/performance ratio, thus the maximum output of the panels sold is not as important as the cost of manufacturing them. Power per unit area has been increasing only slowly since the second decade. The biggest breakthrough in PV panel performance was in the 1990s and eventually at the beginning of the millennium. This article compares the performance of PV panels in the context of the development of PV itself and will also focus on the comparison of different calculators calculating the performance of panels and the advantages or disadvantages of each calculator.

## 2. COMPARISON OF PERFORMANCE IN DEVELOPMENT

In a first step, according to the most suitable scenarios for the PV panels, three specific buildings were selected. The selected buildings belong to the Bánov municipality and were selected for more detailed analyzes for the bachelor thesis. By measuring and calculating the approximate area of roofs that can be used for PV panels, the expected power output on a given area can be determined using calculators based on long-term measurements and observations of ambient conditions such as the ratio of direct and diffuse radiation, the average number of hours the sun shines etc.

For this step, the PVGIS calculator was chosen as it best accounts for ambient conditions from long-term observations in given latitude bands. The input conditions have to include the power installed that is calculated from the average power of the panels and the area where the panels can be installed. Given the objective of comparing PV technology over the last three decades, only the average power of PV panels was changed. The average value of the maximum efficiency of PV panels according to the NREL source was chosen for the calculation. This is the average efficiency of different technologies in a given period. For houses with flat roofs, the south-facing orientation was selected, as it has the best efficiency. For gable roofs, the pitch is determined from maps and then entered into the calculator. The angle of the roof cannot be determined from the maps, so the angle that is common for roof construction is used, which is 35°. In the first case, the value is calculated from today's average PV panel parameters that have been set at 230 Wp/m$^2$. For the model example, a single house with a partly east-facing and partly west-facing orientation was selected. The built-up area of the 1$^{st}$ house is 1 208 m$^2$ and its GPS coordinates are 48.9880136N, 17.7175203E. The other building has a gable roof-oriented half north and half south. The building area is 274 m$^2$ and its GPS coordinates are 48.9897842N, 17.7203292E. In the third case, a building with a flat roof and a built-up area of 339 m$^2$ was selected and its GPS coordinates are 48.9913717N, 17.7185711E. The building areas are not entirely accurate. They have been calculated on the basis of the maps. In this case, the area measurement tool from the mapy.cz website was used [1].

The built-up area of the first building was measured to 1 208 m$^2$ using maps. For houses with a gable roof, it is necessary to consider the increased roof area in relation to the built-up area. This increase in area is given by the roof typification coefficient $T^{st}$. The value of this coefficient shall be considered at 1.5 for all houses with a pitched roof [1].

With a panel area utilization factor for the roof of $K_v = 0.5$, it follows that 906 $m^2$ of PV panels can be fitted on this roof. The total calculated output of this building is 192 467 kWh [2].

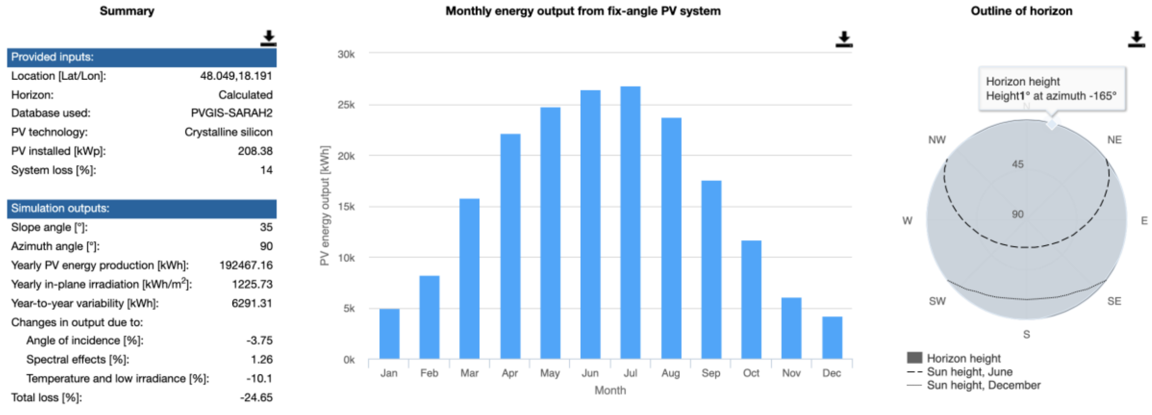


**Figure 1:** Results from the calculator for a given building [2].

The same calculation has to be made for the other selected years. For a flat roof, the calculation of the usable area differs only in the coefficient $T_{st}$, which in this case is equal to 1. The total power calculated by the calculator is equal to 273 624 kWh [5].

In the 1990s, the average efficiency of a monocrystalline panel was 10-12%. Thus, the known performance is around 100 Wp/$m^2$. As for the theoretical power calculated by the PVGIS calculator, the power is equal to 118 967 kWh. The amount of electricity produced in the 1990s would be less than half of what it is today [5].

At the beginning of the millennium, the efficiency increased dramatically and was around 16% that means that the output was around 160 Wp. The total value of the energy produced would be 190 347 kWh according to the calculator [5].

In the last case in the 2010s, the efficiency of commercial panels was around 20%. The panel output was therefore 200 Wp per square meter. The value of the model buildings would be equal to 237,933 kWh [5].

**Table I:** Evolution of the performance of the buildings in relation to the efficiency of the panels (E…electricity generated) [2].

| *t* | *E* |
|---|---|
| year | MWh |
| 1990 | 118,967 |
| 2000 | 190,347 |
| 2010 | 237,933 |
| 2020 | 273,624 |

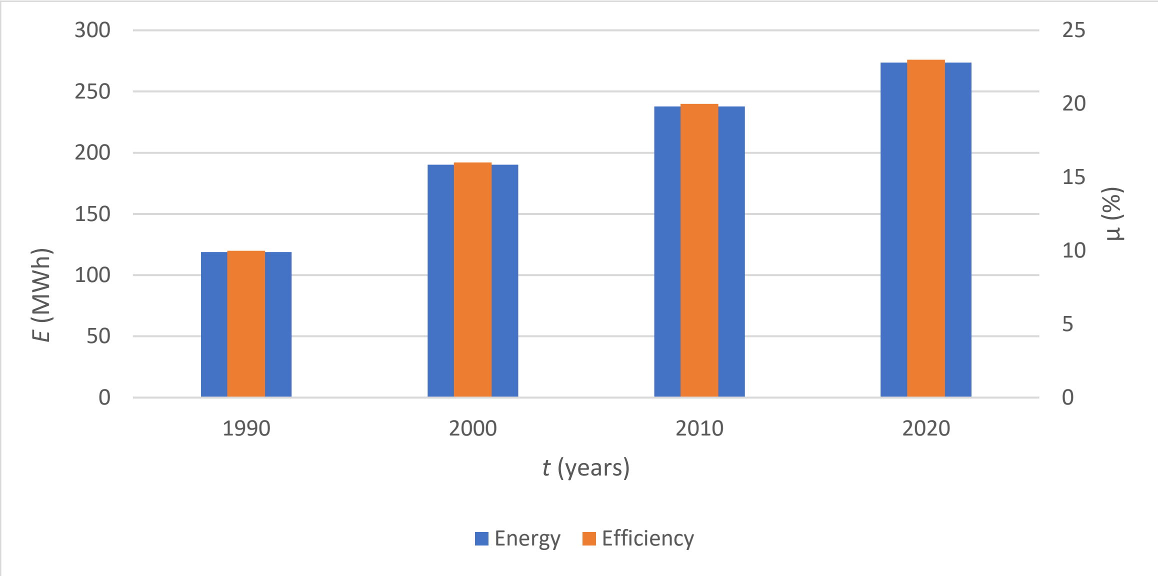


**Figure 2:** Evolution of the performance of the buildings in relation to the efficiency of the panels [2].

## 3. COMPARISON OF CALCULATORS

This chapter compares three different types of calculators, each with its advantages and disadvantages and each suitable for a different type of use.

### PVGIS

The already mentioned calculator used for the first part of the work is the PVGIS calculator, which is suitable for measuring larger sites. The calculator works on a simplified and less accurate principle where an average value of the area that can be used for PV panels is calculated. It evaluates the average annual output divided into individual months. Also, it takes into account the ambient conditions that have been observed for a certain period of time in a given location. From the input data it is then necessary to know the installed capacity, the system losses, the tilt and rotation of the area on which the panels are installed [2].

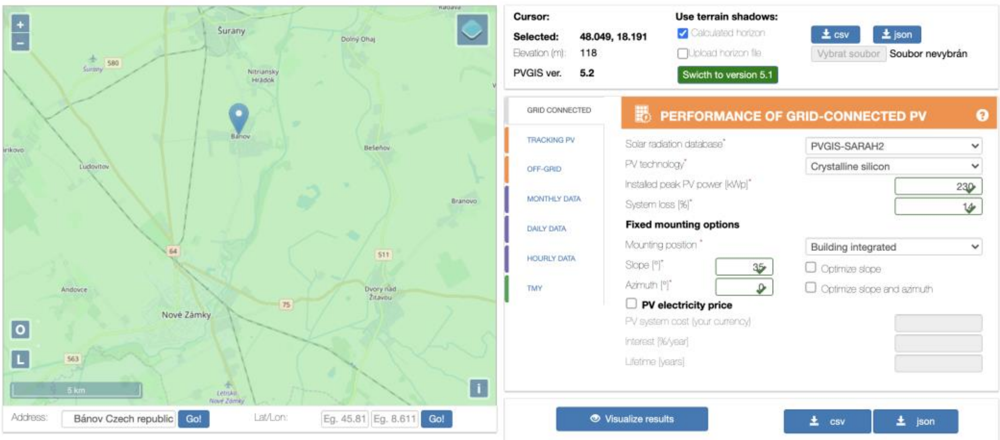


**Figure 3:** PVGIS calculator [2].

### EASY-PV

The EASY-PV calculator is more suitable for individual buildings, where you can select the panel and the roof on which the system is to be installed based on the specified parameters. The calculator can also be used for other areas. Once the area has been generated, the panels can be directly modelled and stacked. The advantage of the calculator is its accuracy. The disadvantage is the long modelling processand also unsuitability for modelling larger areas [3].

## PROJECT SUNROOF

The calculator was created by Google that uses data directly from its maps. It works on a similar principle to the PVGIS calculator. It can directly calculate the area available for the installation of panels and clearly calculates the electricity generated and the payback based on the data filled in. The calculator is only available in the US for now, but it is expected to be launched in Europe in the longer term [4].

## COMPARISON OF CALCULATORS

Each mentioned calculator offers different types of functions. The PVGIS calculator offers potential electricity production in the output data, taking into account the already measured data on ambient conditions. In the output data, the production is modelled on a month-by-month basis based on the ambient conditions during the period. The PV-CASE calculator offers the modelling of a custom PV plant on configured roof and can calculate the installed capacity value of the modelled installation based on the input data. The last calculator, Project Sunroof, combines the functions of the previous calculators and can calculate the possible installed capacity on a given roof using artificial intelligence and then calculate the theoretical value of the electricity produced from the map data.

## 4. CONCLUSION

Photovoltaic technology is constantly evolving and increasing in efficiency. The aim of this work was to compare the theoretical outputs that the panels could produce as the technology evolves. The calculators can be used for future area evaluations in case that lidar data is not available. They can serve as a general assessment of the magnitude of performance that could be achieved in a given area. Panel efficiency has not radically increased by over the last 20 years. Rather, the priority is to reduce the cost of production and improve the price/performance ratio of PV panels. Over the period studied, average panel efficiencies have increased by 5% per decade. The second part was focused on calculators that calculate the theoretical output and the electricity produced. The calculators account for ambient effects and have made great strides in this direction. Three types of calculators have been selected in this article. Each calculator has a specific purpose according to what the customer needs. The first calculator, PVGIS, is best used as a tool for a year-long theoretical overview of the energy produced relative to the specified output of the installation. The EASY-PV calculator is suitable for determining the installed power from a user-modelled installation. Google's latest calculator called Project Sunroof combines both functions of the previous calculators. The calculator uses input directly from maps and uses artificial intelligence to evaluate how much installed power can fit on a given roof and how much total energy the installation can generate.

The work seeks to gain insight into the future development of photovoltaic technology and how the electricity potential of a given area can be calculated. The values can be used to calculate how much electricity can be produced from renewable sources, which are essential for future electricity production.

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