# Photovoltaics panels – economic return based on the real effectiveness

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*Abstract:* - This article examines the efficiency of photovoltaic panels in a real environment and their economic returns over their lifetime.

Introductory section describes the general principle of converting sunlight into electricity and judged the system on which measurements were taken. The next part deals with the determination of the efficiency of photovoltaic panels and this issue of conversion of the direction of the solar radiation flow on a horizontal surface of a solarimeter towards the direction normal to the plane surface of the photovoltaic panels is described. On the basis of this transfer can be determined by the total global radiation falling on the surface of the PV panels and determine their true effectiveness. It is described effects of air pollution on the efficiency of PV panels. The last section deals with the economic return assessed system.

*Key-Words:* - photovoltaics, economical evaluation, photodiode, cell, solar radiation, azimuth, pollution, efficiency, invertor.

## 1 Introduction

Nowadays, production of electricity by photovoltaic panels (PV) is very topical, because the solar energy is an environment friendly, maintenance-free and abundant source of energy. Every year in the world increases power consumption and leads to a permanent loss of fossil fuels and one of these options to replace the fuel utilization of solar radiation [1].

Photovoltaics is a technology for the direct conversion of the solar radiation into DC current. The principle has been discovered more than 150 years ago by Alexander Edmond Becquerel. This technology is inexhaustible source of electricity but due to the rate of the solar radiation during the year it is not constant and even depends on weather conditions (clouds, rains, pollution etc.). In recent years, due to the technological development and mass production of the panels, the efficiency of photovoltaics conversion is getting higher and the price is dropping down what gets the photovoltaics utilization more favourable. The spread of photovoltaics thus depends mainly on the electricity price.

## 2 Physical principle of photovoltaics conversion

Photovoltaic is a method for the direct conversion of sunlight into electricity by using the photoelectric effect on large semiconductor photodiodes (photovoltaic cells). The individual photodiodes are called photovoltaic cells and are usually attached into larger units (photovoltaic panels).

The simplest photodiodes consists of two semiconductors with a different type of electrical conductivity. In one of the layers the material of the type N predominate negatively charged electrons, while the second layer of material P predominate "holes" which are essentially blanks which readily accept electrons. At the point where these two layers meet with a P - N junction where there is a pair of electrons with holes, thereby creating an electric field that prevents other electrons move from the N - layer to the P – layer [2]. Normally, the electrons in the semiconductor material are firmly bonded to the atoms of the crystal grid and the material is then nonconductive. By adding a very small amount of an element with a greater number of valence electrons to the crystal creates a region of conductivity of the type N, in which free electrons exist creates electrical charge. Conversely an impurity element with a reduced number of valence electrons creates a region with conductivity of the P type, in which the crystal grid range “hole are as” without electrons. If the semiconductor material capture of a photon of sufficient energy, it results in creation of one electron-hole pair [3]. If the circuit is closed, the wearer's hub starts to move in adverse directions to the negative electrode. A positive hole is shown in Figure 1.

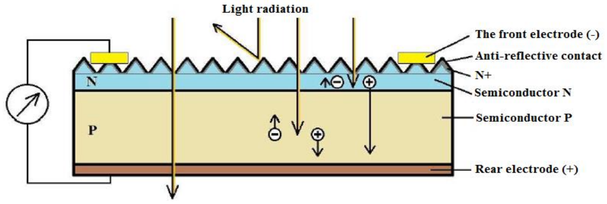


Fig. 1 The structure of the photovoltaic cell [4]

## 2.1 Division of photovoltaics cells

Photovoltaic cells can be divided accordingly to the type of photovoltaic cells into monocrystalline, polycrystalline and amorphous.

Monocrystalline cells are produced by chemical technologies by drawing molten base material in the form of rods which are then cut into slices of the substrate (most often is used material based on silicon). Cell consists of a single quartz crystal and its practical energy efficiency is in the range 13 - 17%. Production of monocrystalline solar cells is expensive as for the large consumption of silicon. However, monocrystalline cells are the largest stake of the market (around 85% of the world production) for the higher efficiency compared with other material of cells [5], [6].

Polycrystalline cells also include a silicon wafer, but unlike monocrystalline cells are formed by the crystal grid. The manufacture of these cells requires significantly less energy consumption than the production of monocrystalline cells, which is reflected in the price. The energy efficiency of these cells is in the range of 12-16 %. These cells use more effectively the diffuse part of the solar radiation then the monocrystalline, and thereby the efficiency of the both types is equivalent. [5], [6].

The type of amorphous cells consist of a thin silicon layer, which is applied to a material base formed of glass, plastic or fabric. The energy efficiency of these cells is significantly lower than that on previous mentioned cells and it is in the range of 7-9 %. These cells are suitable to be integrated in building structure surfaces. These type of the cells do not require excessive cooling as the previous mentioned types. [5], [6].

# 3 Description of the system

System described in this chapter is applied in the laboratory of environmental engineering at the FAI UTB in Zlín. The system consists of 9 photovoltaic panels with a total area of 11.25 square meters. The panels used, are of the type of polycrystalline photovoltaic cells. The producer of these panels declared an energy efficiency of 15% (the angle of panels surface inclined from the horizontal one of 45 ° with the southeast azimuth of the normal direction to the panel surface). Installed panels are shown in Figure 2.

Fig. 2 System under consideration

Surface reaches 750 $Wm^{-2}$, the electric power produced by the panels should be **P** = 1265 W, based on the declared efficiency by the producer. The output DC voltage of the panels is converted by the AC voltage inverter in one phase AC current with the 230 V AC. This inverter also displays information about the amount of energy produced by the various operating states of the system (fault, instantaneous power, voltage, total produced energy by the system, etc.) [7].


Fig. 3 Inverter Sunny Boy

Figure 3 shows the inverter Sunny Boy 1700 with defined efficiency by the European standards $\eta_{euro}$ =

91.8%. This value has been measured under varying climatic conditions where maximum efficiency were reached $\eta_{max}$ = 93.5% with the optimal measuring conditions (stable temperature conditions, nominal DC voltage and medium values of AC power). The rest of the converted energy is lost by the electrical conversion in the form of heat [8], [9].

## 4 Methodology validation parameters

To determine the economical evaluation of the investment in photovoltaic systems, which is created by the panels and the electrical conversion facilities, it is crucial to verify energy efficiency of the whole system in the operation conditions. In order to verify the efficiency of the electrical energy production system, it is necessary to compare the total amount of energy produced by photovoltaic panels and total amount of solar radiation energy falling on the surface of the panels in the longer term.

The total amount of solar radiation falling on the photovoltaic panel surfaces can be measured directly by using a solarimeter device, which is inclined in the same angle as the panel surface. In this case, the energy of falling solar radiation to the surface which includes both direct and diffusion parts of the radiation, is compared with the energy produced by the system.

The second option of the evaluation is to measure the solar energy by the solarimeter which is installed horizontally (the particular case). The values of solar radiation measured by solarimeter been converted to the radiation falling on the normal direction of the panels. This equation is given below according to CSN 73 0548 [11]. Solar declination is determined for 21st day of each month according to the formulas (1) to (9):

$$\delta = -23.5\cos\cdot(30\cdot M) \qquad (1)$$

Where $\delta$ is solar declination [°],

number of the month in the year (1– 12).

The solar declination $\delta$ are listed in Table I.

Table 1 Solar declination for each month

| Month | III | IV | V | VI | VII | VIII | IX | X |
|---|---|---|---|---|---|---|---|---|
| $\delta$ [°] | 0 | 12 | 20 | 24 | 20 | 12 | 0 | -12 |

The height of the sun above the horizon, $h$, for 50 ° north latitude is given by the following equation: (2)

$$\sin h = 0.766\sin\delta - 0.643\cos\delta\cdot \cdot\cos(15\tau) \qquad (2)$$

where $h$ is the height of the sun above the horizon [°],
$\tau$ solar time [h].

Solar azimuth, $a$, determine the north in a clockwise direction by the relation: (3)

$$\sin a = \frac{\sin(15\tau)\cdot\cos\delta}{\cos h} \qquad (3)$$

where $a$ is solar azimuth [°].

The angle between the normal of surface and the direction of the rays, $\Theta$, is determined by the relationship: (4)

$$\cos\Theta = \sin\cos h\cdot\cos\alpha + \cos h\cdot\sin\alpha\cdot \cdot\cos(a-\gamma) \qquad (4)$$

where $\Theta$ is the angle between the normal illuminated surface of sun and beam direction [°],
$\alpha$ wall angle with the horizontal plane, taken on the side acing away from the sun [°],
$\gamma$ azimuth angle of the normal wall, taken as solar azimuth [°].

For the vertical surface is given by (5),

$$\cos\Theta = \cos h\cdot\cos(a-\gamma) \qquad (5)$$

for the horizontal surface given by (6),

$$\cos\Theta = \sin h \qquad (6)$$

The intensity of direct solar radiation is determined
as follows, (7)

$$\dot{I}_D = 1350\exp\left[-0.1z\left(\frac{16-H}{16+H}/\sin h\right)^{0,8}\right] \qquad (7)$$

where $\dot{I}_D$ is intensity of direct solar radiation [$Wm^{-2}$],
$z$ coefficient of air pollution,
$H$ attitude [km].

For each month is recommended to use these levels of pollution that are listed in Table 2.

Table 2 Values of pollution by month

| Month | III | IV | V | VI | VII | VIII | IX | X |
|---|---|---|---|---|---|---|---|---|
| z [-] | 3.0 | 4.0 | 4.0 | 5.0 | 5.0 | 4.0 | 4.0 | 3.0 |

The intensity of diffuse solar radiation is determined as follows, (8)

$$\dot{I}_d = \left[1350 - I_D - (1080 - 1.4 I_D) \cdot \sin^2 \frac{\alpha}{2}\right] \cdot \frac{\sin h}{3} \quad (8)$$

where $\dot{I}_d$ is intensity of diffuse solar radiation [W m$^{-2}$],
$\boldsymbol{h}$ mentioned in (2).

The total intensity of solar radiation $I_C$ is calculated as (9),

$$I_C = \dot{I}_D + \dot{I}_d \quad (9)$$

where $\dot{I}_D$ is shown in (7),
$\dot{I}_d$ shown in (8).

Using these relations, for every individual day and hour of a year the theoretical intensity of solar radiation falling on both horizontal surface and the panel surfaces is calculated. Based on these calculation, data obtained from the horizontally placed solarimeter are converted to the normal direction of the panel surfaces and in this manner the total energy falling on the panels during evaluated period of year could be achieved. The energy efficiency of a photovoltaic system is calculated according to an equation (10) [11]:

$$\eta = \frac{P_m}{P_{rad}} = \frac{P_m}{E \cdot A_C} \quad (10)$$

Where $P_m$ is performance of a photovoltaic panel [W],
$P_{rad}$ power of the incident radiation, [W],
$E$ total intensity of solar radiation [W m$^{-2}$],
$A_C$ surface of the photovoltaic cell [W m$^2$].

# 5 Methodology validation parameters

In the evaluated period from July to December 2013 was recorded data of generated electricity from photovoltaic panels and the total solar radiation energy measured by the solarimeter.

Measured data of the evaluated period has been summarized in a database and the data of fallen energy measured by the solarimeter in horizontal level were converted from the horizontal surface to the inclined surface of the panels according to (9) in 0.5 hour intervals. From the obtained values of total solar irradiance $I_S$ was subtracted part of diffuse radiation.

Theoretical calculation:

$$q_{s\,skut\,pr} = q_{s\,skut} - q_{s\,skut.dif} \quad (11)$$

where $q_{s\ skut.\ pr}$ is direct radiation incident on solarimeter [W m$^{-2}$],
$q_{s\ skut}$ performance of a photovoltaic panel [W m$^{-2}$],
$q_{s\ skut.dif}$ calculated diffuse radiation [W m$^{-2}$].

$$q_{f\,pr} = q_{s\,skut\,pr} \frac{q_{s\,skut\,pr}}{\sin h} \quad (12)$$

where $q_{f\,pr}$ is direct radiation incident on a vertical surface [W m$^{-2}$],
$g_{s\ skut.pr}$ shown in (11),
sin$h$ shown in (2).

$$q_{n\,pr} = \frac{q_{f\,pr}}{\cos\gamma} \quad (13)$$

where $q_{n\,pr}$ is direct solar radiation incident on photovoltaic panel [W m$^{-2}$],
$q_{f\,pr}$ shown in (12),
cos $\gamma$ shown in (4).

$$q_{n\,celk} = q_{n\,dif} + q_{n\,pr} \quad (14)$$

where $q_{n\ celk}$ is solar radiation incident on the photovoltaic panels [W m$^{-2}$],
$q_{n\ dif}$ radiation diffusion in the direction orientation photovoltaic panels [W m$^{-2}$],
$q_{n\ pr}$ shown in (13).

This method of conversion, however is questionable during the occurrence of strong clouding. Water vapour density of the atmosphere does not correspond to the coefficient of air pollution in equation [11]. Hence, for the conversion mentioned above, the percentual way of calculation for separation of diffusion radiation intensity from solarimeter data was used.

Theoretical calculation:

$$\frac{\boldsymbol{I}_{d\ vod}}{\boldsymbol{I}_{D\ vod}} = \boldsymbol{p} \tag{15}$$

where $\boldsymbol{I}_{d\ vod}$ is intensity of diffuse radiation incident on a horizontal surface [W m$^{-2}$],
$\boldsymbol{I}_{D\ vod}$ intensity of direct solar radiation horizontal surface [W m$^{-2}$],
$\boldsymbol{p}$ proportion of intensity.

$$\frac{\boldsymbol{I}_{d\ sik}}{\boldsymbol{I}_{D\ sik}} = \boldsymbol{p}_1 \tag{16}$$

where $\boldsymbol{I}_{d\ sik}$, is intensity of the diffuse radiation incident direction panel orientation [W m$^{-2}$],
$\boldsymbol{I}_{D\ sik}$ intensity of direct solar radiation in the direction of orientation of the panels [W m$^{-2}$],
$\boldsymbol{p}_1$ proportion of intensity.

$$\boldsymbol{I}_d = \boldsymbol{I}_c \cdot \boldsymbol{p} \tag{17}$$

where $\boldsymbol{I}_d$ is intensity of diffuse radiation incident on solarimeter in [W m$^{-2}$],
$\boldsymbol{I}_c$ measured data solarimeter [W m$^{-2}$],
$\boldsymbol{p}$ proportion of intensity.

$$\boldsymbol{I}_D = \boldsymbol{I}_c - \boldsymbol{I}_d \tag{18}$$

where $\boldsymbol{I}_D$ is intensity of direct solar radiation incident solarimeter [W m$^{-2}$],
$\boldsymbol{I}_c$ measured data solarimeter [W m$^{-2}$],
$\boldsymbol{I}_d$ diffuse radiation incident on solarimetr [W m$^{-2}$].

Conversion to the orientation angle of photovoltaic panels is given by formulas (19) (20),

$$\boldsymbol{I}_c = \boldsymbol{I}_d + \boldsymbol{p}_1 \cdot \boldsymbol{I}_c \tag{19}$$

$$\boldsymbol{I}_c = \frac{\boldsymbol{I}_D}{1 - \boldsymbol{p}_1} \tag{20}$$

where $\boldsymbol{I}_c$ is total intensity of solar radiation incident panel [W m$^{-2}$],
$\boldsymbol{I}_d$ shown in (18),
$\boldsymbol{p}_1$ shown in (16).

The measured values were calculated for every individual month for an average intensity of solar radiation per hour and then were multiplied by the daily lighting time and the number of days in the month. Panel lighting time was different for individual months, which are reflected in the calculations. In the following example is presented a sample calculation for the September 2013 (21):

$$\begin{aligned}\boldsymbol{\eta} &= \frac{\boldsymbol{P}_m}{\boldsymbol{P}_{rad}} = \frac{\boldsymbol{P}_m}{\boldsymbol{E} \cdot \boldsymbol{A}_C} = \\ &= \left(\frac{143267}{((378.98 \cdot 11.25) \cdot 12) \cdot 30}\right) \cdot 100 = \\ &= 9.34\%\end{aligned} \tag{21}$$

where the values are used:

$P_m$ = 143267 [W]
E = 378,98 [W m$^{-2}$]
$A_C$ = 11.25 [m$^2$]
Time = 12 [h]
Days = 30

Similarly, the calculations for the other months were performed, following table.

Table 3 Calculated values

| Month | Total global solar radiation[kW] | Power PV panel[kW] | Efficiency [%] |
|---|---|---|---|
| July | 1096.9 | 105.2 | 9.59 |
| August | 2159.1 | 213.7 | 9.90 |
| September | 1532.8 | 143.3 | 9.35 |
| October | 761.7 | 142.4 | 9.68 |
| November | 317.3 | 52.8 | 9.58 |
| December | 237.6 | 39.9 | 9.56 |

### 5.1.1 Measured values

Table 4 compares theoretical and measured values of the supply of electricity by photovoltaic panels on the first day of the month of September.

Figure 4 plots the comparison of the actual panel performance with data given by the producer of the panels.

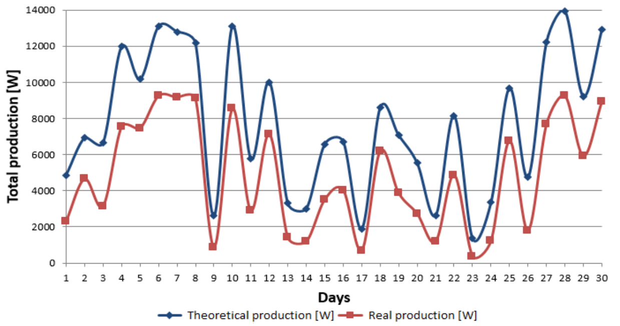


Fig. 4 Comparison of theoretical and real efficiency panels

Table 4 Measured values September

| Day | Theoretical production [kW] | Theoretical production PV [kW] | Real production [kW] |
|---|---|---|---|
| 1 | 32.4 | 4.9 | 2.3 |
| 2 | 46.2 | 6.9 | 4.6 |
| 3 | 44.3 | 6.6 | 3.1 |
| 4 | 79.8 | 11.9 | 7.5 |
| 5 | 67.8 | 10.1 | 7.4 |
| 6 | 87.3 | 13.0 | 9.2 |
| 7 | 85.3 | 12.8 | 9.2 |
| 8 | 81.1 | 12.1 | 9.1 |
| 9 | 17.4 | 2.6 | 0.8 |
| 10 | 87.3 | 13.1 | 8.5 |
| 11 | 38.4 | 5.6 | 2.8 |
| 12 | 66.7 | 10.0 | 7.1 |
| 13 | 21.9 | 3.3 | 1.4 |
| 14 | 20.0 | 3.0 | 1.1 |
| 15 | 43.9 | 6.6 | 3.5 |
| 16 | 44.8 | 6.7 | 4.0 |
| 17 | 12.6 | 1.9 | 0.6 |
| 18 | 57.3 | 8.6 | 6.2 |
| 19 | 47.1 | 7.0 | 3.8 |
| 20 | 36.9 | 5.5 | 2.7 |
| 21 | 17.6 | 2.6 | 1.2 |
| 22 | 54.2 | 8.1 | 4.9 |
| 23 | 9.0 | 1.3 | 0.4 |
| 24 | 22.4 | 3.3 | 1.2 |
| 25 | 64.6 | 9.7 | 6.8 |
| 26 | 31.6 | 4.7 | 1.8 |
| 27 | 81.4 | 12.2 | 7.7 |
| 28 | 92.9 | 13.9 | 9.2 |
| 29 | 61.4 | 9.2 | 5.9 |
| 30 | 86.0 | 12.9 | 8.9 |

## 6 Influence of air pollution panels on their power

A necessary part of the use of photovoltaic panels is also their maintenance, which consists mainly of removing the dirt from the surface of the panels. These impurities have a negative impact on the effectiveness of photovoltaic panels. Another factor which affects the efficiency of the photovoltaic panels is aging these panels. Aging process itself depends on various factors such as the amount of impurities contained in the material or chemical composition and structure of the material. Aging material is defined as the irreversible changes properties of the material under given conditions. These changes occur due to light, heat, weather conditions and atmospheric gases. These changes are essential affect the efficiency of solar panels. Manufacturers, therefore, for the parameters panels also report their lifetime, aging manifests especially a decrease in their effectiveness.

Table 5 Intensity of solar radiation

| Time [h] | Solar radiation, $I_c$ [W/m$^2$] |
|---|---|
| 10:42 | 331.8 |
| 10:57 | 33.91 |
| 11:07 | 354.61 |
| 11:13 | 354.62 |
| 11:28 | 354.63 |
| 11:43 | 354.63 |
| 11:58 | 354.62 |
| 12:00 | 334.71 |
| 12:15 | 334.08 |

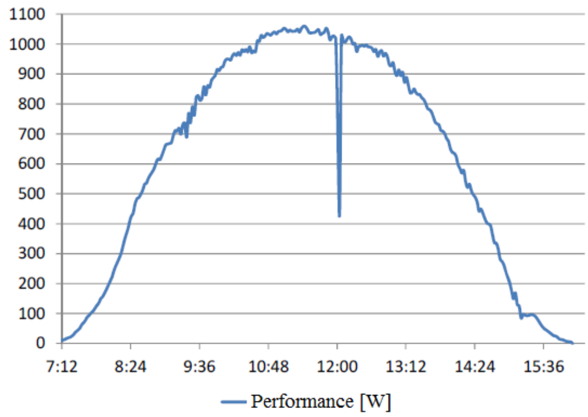


Fig. 5 Performance increase after maintenance

The overall efficiency of photovoltaic panels is increased to about 11.5% (1% of the before maintenance).

## 7 Return on investment

Based on these parameters (measured efficiency of a photovoltaic panel, panel purchase price, guaranted purchase price of electric energy) the economical evaluation can be determined. The following figure 5 shows the payback period of 1 m$^2$ photovoltaic panel in one year, under the conditions of Table 5 and assuming 15% efficiency, actually measured 10.5% and 11.5% for maintenance.

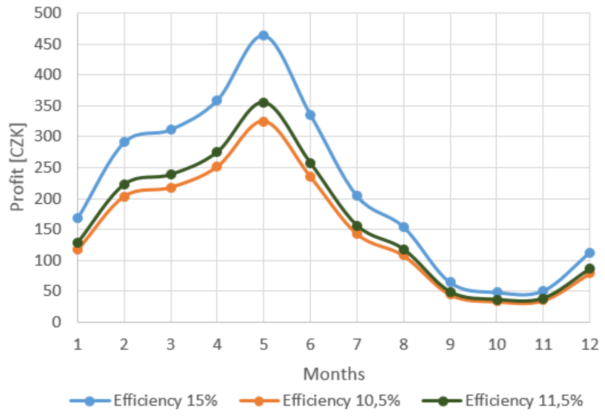


Fig. 6 Comparison of return 1m² photovoltaic panel

Table 5 shows, at which time it returns 1 m² of photovoltaic panels.

Table 6 Time of return of photovoltaic panel

| | | Year profit [CZK] | Return of investment [years] |
|---|---|---|---|
| Date of commissioning PV power plant | 1.1.2008 – 31.12.2008 | - | - |
| The redemption [CZK/kWh] | 15180 | - | - |
| The average amount of solar radiation [kWh/m² year] | 950 - 1250 | - | - |
| The price of PV modules [CZK/1m²] | 18102.4 | - | - |
| The efficiency of PV panels | 15% | 2563 | 7 |
| The actual efficiency | 10.50% | 1794 | 10 |
| Efficiency after cleaning | 11.5% | 1965 | 9.2 |

The price of photovoltaic power systems is not only containing the panel itself but also the other components. Among which include cabling, inverter, control devices work professional firms and maintenance over their lifetime [14]. All of these costs are therefore necessary to consider before deciding to invest funds into such a volatile renewable energy sources such as photovoltaic panels. The calculation can be carried out in accordance with act no. 318/2012 call [15]. “Energy audits and energy assessment”.

Calculation of economic evaluation is given by equation (22) to (25):

The simple payback period of the investment is given by the following equation: (22)

$$T_S = \frac{IN}{CF}, \qquad (22)$$

where **IN** is capital expenditure of the project,
**CF** annual benefits of the project.

The real payback period $T_{sd}$ including the discount rate, r is given by the following equation: (23)

$$\sum_{t=1}^{T_s} CF_t.(1+r)^{-t} - IN = 0, \qquad (23)$$

where $CF_t$ is annual cash flow of the project,
$r$ discount,
$(1+r)^{-t}$ discount factor.

Net present value *NPV* is given by the following equation: (24)

$$NPV = \sum_{t=1}^{T_z} CF_t.(1+r)^{-t} - IN = 0, \qquad (24)$$

where $T_z$ is lifetime (evaluation) project,
$CF_t$ annual benefits of the project,
$r$ discount,
$(1+r)^{-t}$ discount factor
$t$ number of returns.

Internal return rate *IRR* is calculated from the condition according to the following equation: (25)

$$\sum_{t=1}^{T_z} CF_t.(1+IRR)^{-t} - IN = 0. \qquad (25)$$

The following Table 7 shows the time after which the entire investment in photovoltaic power returns.

Table 7 Time of return of photovoltaic panel

| Measure/variant | | Efficiency [15%] | Efficiency [11.5%] | Efficiency [10.5%] |
|---|---|---|---|---|
| The investment cost of the project | [CZK] | 447748 | 447748 | 447748 |
| Investments cost for the life of the project | [CZK] | 490161 | 490161 | 490161 |
| Change in energy costs | [CZK/ year] | 28833 | 22106 | 20182 |
| Change in other operating expenses | | | | |
| Change in personnel costs | [CZK/ year] | 0 | 0 | 0 |
| Change in other operating expenses | [CZK/ year] | 0 | 0 | 0 |
| Change in sales | [CZK/ year] | 0 | 0 | 0 |
| The benefits of the projects total | [CZK/ year] | 28833 | 22106 | 20182 |
| Measure/variant | [CZK] | 447748 | 447748 | 447748 |

| Economic evaluation | | | | |
|---|---|---|---|---|
| Investment costs for the life of the project N1 | [CZK] | 490161 | 490161 | 490161 |
| The benefits of the projects total P | [CZK/year] | 28833 | 22106 | 20182 |
| Evaluation period z | [year] | 25 | 25 | 25 |
| Discount r | [-] | 0.03 | 0.03 | 0.03 |
| Inflation p | [-] | 0.02 | 0.02 | 0.02 |
| The simple payback period $T_s$ | [year] | 17.00 | 22.17 | 24.29 |
| Disc. Paybackperiod $T_{sd}$ | [year] | 19.10 | 25.69 | 28.52 |
| NPV | [CZK] | 144833 | -3317 | -45000 |
| IRR | [-] | 0.052 | 0.067 | 0.022 |

The following Figure 7 shows the return on investment in photovoltaic panels depending on their effectiveness.

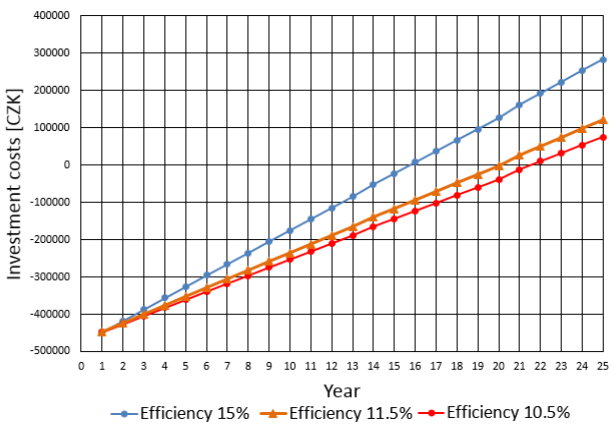


Fig. 7 Simple payback period

From the Figure 7 it follows that the entire investment in a photovoltaic power plant at 15% efficiency photovoltaic panels throughout their lifetime (25 years) should return for 17 years. Measurements showed that if solar panels are not regularly deprived of the dust and other contaminants will be the entire investment back at least 24 years of age. Assuming of the regular cleaning (1 month) will slightly increase the efficiency of photovoltaic panels and shortening the payback period to 22 years.

## 8 Conclusion

The aim of this experiment is to economical evaluation in photovoltaic panels for educational purposes. The panels are designed to power the experimental heating and cooling equipment in the laboratory of environmental engineering FAI UTB in Zlin. From the economical evaluation results the fact that based on the conditions of panels efficiency of electrical conversion of 15 % and conditions given by Table 4 is the investment in photovoltaics system on edge of the economical effectiveness. During the measurements it was found that the panels are substantially less efficient than in the manufacturer after offsetting the influence of aging on the panels and 10.5%. After maintenance, which consisted mainly of removing impurities from the surface of the photovoltaic panels there was only a slight increasing of efficiency by about 1%. The efficiency level of 11.5% of the photovoltaic system is inefficient.

The subject of our further research will deal to determine real efficiency of the photovoltaics system including real weather conditions and its influence on the effectiveness and utilization of produced energy by the panels for direct cooling and heating via thermal accumulative panels installed in the laboratory of environmental engineering

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