ACTA TECHNICA CORVINIENSIS – Bulletin of Engineering
Tome IV (Year 2011). ISSN 2067-3809

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INVESTMENT EFFICIENCY APPRAISAL FOR DIFFERENT SIZES OF THE SOLAR ELECTRICITY PLANTS

ABSTRACT:
Most of the solar electricity plants of different installed power sizes in Slovenia are connected to the electricity supply network. More than one-third of the solar electricity plants are larger than 50 kW. They are often situated on the roofs of different buildings. The sensitivity of the investment economic efficiency appraisals for the solar electricity plants by their four different installed power sizes is investigated. Among important determinants of investment's efficiency are the guaranteed purchase price of electrical energy for micro and small solar electricity plants, investment support measures and technological advancements reducing investment costs for the solar electricity plants.

KEYWORDS:
renewable sources of energy, investment appraisal, solar electricity, purchase price, subsidy, technology management

INTRODUCTION

The development of the solar electricity plants in Slovenia is in an initial, but rapidly growing stage of development [1]. The installed solar electricity plants are often situated on the roofs of business, production, schools, recreation, parking, and larger households' buildings. Similar as water, biomass, biogas and wind energy, also the solar energy is a part of natural renewable sources of energy [2,3]. The European Union (EU) defined within the climatic-energy package support measures for the use of energy from renewable sources of energy. For Slovenia by the year 2020 two objectives are defined: first, 25% share of energy from renewable sources of energy in the final use of energy and second, 10% share of energy from the renewable sources of energy in the final use of energy in transport [4]. To achieve these objectives, EU countries support investments by investment grounds and credit subsidies for the solar electricity plants and with some other measures such as a guaranteed price for the purchase of the electrical energy, which is produced by the solar electricity plants and from the other renewable sources of energy. In a spite of different government support measures to increase energy production from the renewable sources of energy, the results by the EU countries vary. In this respect Slovenia is not any exception.

The paper presents an economic analysis of solar electricity plants of four different power sizes by investment appraisal methods in the case of Slovenia. Economic analysis is conducted on the basis of a plants costs and incomes realized by selling the electricity with subsidized price. We illustrate the dependence of the investment efficiency of the solar electricity plants of four different installed power sizes on the government policy support measures, which are causing the investment costs and revues through electricity prices, and on the technological advancements of the solar electricity plants, which are causing the investment costs. The paper contributes to the literature in three significant directions. First, it provides investment appraisal in the case of the solar electricity plants by using static and dynamic investment appraisal methods and indicators. Second, we conduct the sensitivity analysis of the investment economic efficiency into the solar electricity plants by their four different installed power sizes. Among important determinants of investment's efficiency are the guaranteed purchase prices of electrical energy, which is delivered from the micro and small solar electricity plants on the revenues side, and technological advancements, investment support measures and interest rate subsidy for investments into the solar electricity plants on the investment costs side. Finally, we derive findings for further research and policy relevance, which is important for education, promotion, research and development activities with exchange of good practices from the studied case study for the solar electricity plants' investments.

METHODOLOGY

As the methods of the analysis are used the period of investment return, indicator of economy, indicator of profitability of investment, and indicator of profitability of expenses as the static investment efficiency measures and the net present value and the internal rate of return as the dynamic measures for economic investment efficiency appraisals [5,6]. The period of the investment return is defined as:

$$t = \frac{N}{ar} = \frac{N}{Rr - \mathrm{Re}} \tag{1}$$

where t is the expected period of the investment return in the number of years, which are necessary for the return of the initial capital investment; N is the value of investment, ar = Rr – Re is the annual return or annual profit from the investment, where Re means investment and operational costs, and Rr means revenues from the purchased electrical energy, which is sold from the solar electricity plant.

The indicator of economy (E) of investment is defined as a ratio between total business effects (Rr) and costs (Re) of the solar electricity plant in constant prices:

$$E = \frac{Rr}{\mathrm{Re}} . \tag{2}$$

The indicator of profitability (O) of investment is defined as:

$$O = \frac{Rr - \mathrm{Re}}{N} \cdot 100 , \tag{3}$$

which shows the annual profitability (in %) from invested capital into the solar electricity plant.

The indicator of profitability of expenses (Oe) is defined as:

$$Oo = \frac{Rr - \mathrm{Re}}{\mathrm{Re}} \cdot 100 , \tag{4}$$

which shows the annual profitability (in %) from all expenses of the solar electricity plant.

The net present value (NPV) is defined as the difference between the present value of revenues (PRr) and the present value of expenses (PRe):

$$NPV = \sum_{i=1}^{i=n=30} (Rr - \mathrm{Re}) \cdot \frac{1}{(1+r)^i} = \sum_{i=1}^{i=n=30} Rr \cdot \frac{1}{(1+r)^i} - \sum_{i=1}^{i=n=30} \mathrm{Re} \cdot \frac{1}{(1+r)^i} , \tag{5}$$

where NPV should be positive: PRr > PRe, r is a discount rate (derived from the average market interest rate for long-term deposits) and i is the time period of investment.

The internal rate of return (IRR) is defined as:

$$IRR = r_p + (r_n - r_p) \cdot \frac{NPV_p}{NPV_p - NPV_n} , \tag{6}$$

where r_p is a discount rate for a positive NPV_p and r_n is a discount rate for a negative NPV_p.

Iteratively, it should hold:

$$0 = \sum_{t=0}^{n} \frac{(Rr - \mathrm{Re})^i}{(1+r)^i} , \tag{7}$$

where Rr is total revenue of the solar electricity plant project in year i and Re is total expense of the solar electricity plant project in year i, r is a discount rate when holds NPV = 0 and r = IRR, n is the project life time period in years, and i is the current index of time periods i = 1, 2, …, n.

EMPIRICAL RESULTS. SOLAR ELECTRICITY PLANT INSTALLED POWER SIZE AND INVESTMENT COSTS

We present the size of investment costs for four investment alternatives by the size of the installed power of the solar electricity plant (Table 1). Total investment costs for the four investments alternatives are increasing with the size of the installed power of the solar electricity plant from 10 to 100 kW, and vice versa holds for the price per installed power unit, which declines by 21.1%. This decline in per unit of the installed power price by the increased size of the solar electricity plant is caused by the decline in per unit fixed costs as a result of utilisation of economies of the solar electricity plant size. On long-term, the technological advancements and progress in production of photovoltaic modules, which is the most important in the investment structure of the solar electricity plant, also causes declining patterns in investments costs per installed kW. The price per installed power from 2.81 to 3.56 Euro per Wp is for photovoltaic modules, which are produced from monocrystalline or multicrystalline silicon. It is worth mentioning because prices for thin-film cells such as a-Si, CIS, CdTe or similar are much lower, but they require much bigger installing surface on the roofs of the buildings.

Table 1 – Investment costs alternatives by the size of the installed power of the solar electricity plant (in Euro)

Investment cost structure	10 kW	20 kW	50 kW	100 kW
Photovoltaic modules	23,500.00	46,000.00	112,500.00	210,000.00
Network trafficator	5,100.00	8,150.00	16,200.00	31,300.00
Installation material and assembling	4,500.00	8,500.00	20,000.00	35,000.00
Electro projects	500.00	700.00	900.00	1,200.00
Connection on the network	1,200.00	1,200.00	1,500.00	2,000.00
System control	750.00	1,000.00	1,250.00	1,500.00
Total	35,550.00	65,550.00	152,350.00	281,000.00
Price per installed power (Euro per Wp)	3.56	3.28	3.05	2.81

Source: Kon Tiki Solar Kamnik (2010).

SOLAR ELECTRICITY PLANT PRODUCTION AND GUARANTEED PRICE FOR ELECTRICITY

Sunray in Gorenjska region in Slovenia is estimated at 1,050.0 operational hours per installed kWh/kW. We assume that solar electricity production declines by 1% per year during the life period of the solar electricity plant and after 30 years the achieved conversion factor is at 0.71. Moreover, the methodology for the reference costs of electrical energy produced from renewable sources of energy in Slovenia assures the guaranteed price for electrical energy, which is produced and sold by the solar electricity plants for the 15 years since the start of the solar electricity plant operation. This guaranteed subsidized price is set at 0.41546 Euro per kWh for the solar electricity plant of the installed power up to 50 kW and 0.38002 Euro per kWh for the solar electricity plant of the installed power from 50 kW to 1 MW (Table 2).

Table 2 – Electricity production and guaranteed electricity price by the alternative sizes of the installed power of the solar electricity plants

	10 kW	20 kW	50 kW	100 kW
Electricity production in the first year (kWh)	10,500.0	21,000.0	52,500.0	105,000.0
Cumulative electricity production during the life period of the solar electricity plant (30 years)	275,100.0	550,200.0	1,375.500.0	2,751.000.0
Guaranteed price of electricity (Euro per kWh) for the first 15 years of the solar electricity plant operation	0.41546	0.41546	0.41546	0.38002

Source: Compiled by the authors

FINANCIAL FLOWS FOR ALTERNATIVE INVESTMENTS BY THE INSTALLED POWER OF THE SOLAR ELECTRICITY PLANT

We assume that the investment project into the solar electricity plant is financed by own resources. The depreciation period for the network trafficator is taken 15 years, which means 6.67% annual linear depreciation rate, while for the photovoltaic modules and other equipment parts of the solar electricity plant the depreciation period is taken 30 years, which means 3.3% annual linear depreciation rate. Net present value of investment captures all revenues and expenses for own and borrowed sources during the life period of the solar electricity plant investment. The economic analysis is conducted only on the basis of a plants costs and incomes realised by selling the electricity with subsidised price. In our calculations we do not consider some other positive externalities from solar power plants, which on indirect way contribute to environment, economy, and society such as reducing carbon dioxide emissions. The sum of revenues and expenses should be positive or at least equal zero for an acceptable investment project (Figure 1).

Real money flows of investment means all revenues and expenses for the investor during the life period of the investment into the solar electricity plant. The static investment indicators give us approximate investment appraisal, but often they do not give us satisfactory and accurate evidence on economic efficiency of a certain investment project. Among the static investment indicators, we include here the period of the investment return, which tell us the expected number of years, which are necessary for the return of the initial investment capital/expenses. From Figure 2, which presents real money flows and the expected period of the investment return, can be seen that cumulative total revenue changed from the negative to the positive value by 8.32 years for the installed power size of 50 kW per the solar electricity plant, by 8.36 years for the installed power size of 100 kW per the solar electricity plant, by 9.06 for the installed power size of 20kW per the solar electricity plant, and by 10.12 years for the installed power size of 10 kW per the solar electricity plant.

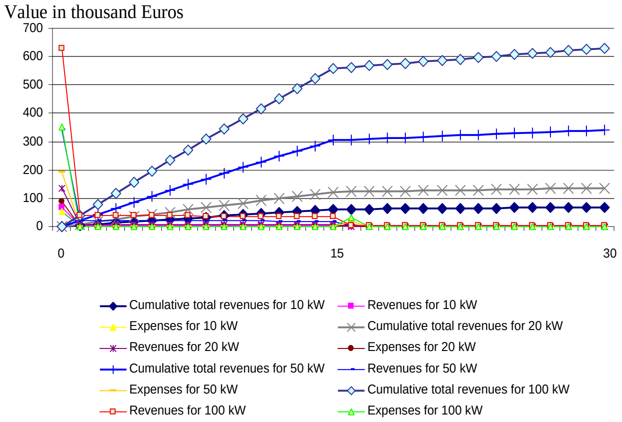

Figure 1 – Total monetary flows for an investment into the solar electricity plant by the installed power 10, 20, 50, and 100 kW
Source: Own calculations.

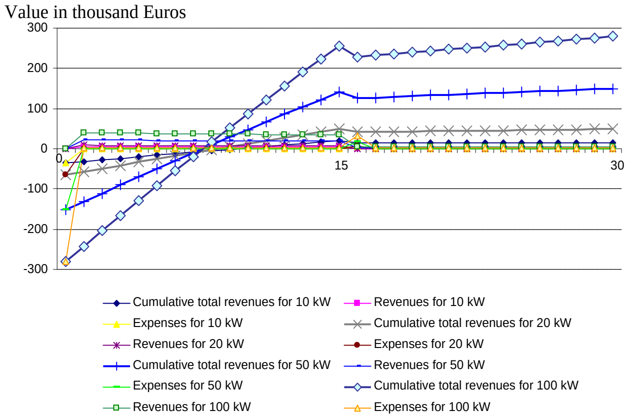

Figure 2 – Real monetary flow and the period of the investment return for the solar electricity plant of the installed power 10, 20, 50, and 100 kW
Source: Own calculations.

STATIC AND DYNAMIC ECONOMIC EFFICIENCY APPRAISAL FOR THE ALTERNATIVE INSTALLED POWER SIZES FOR THE SOLAR ELECTRICITY PLANTS

Our special focus is on the indicators of economic investment efficiency appraisal for the analyzed four sizes of the installed power of the solar electricity plants. As can be seen from Table 3 the static indicators of economic efficiency of investment (indicator of economy, indicator of profitability, and indicator of profitability of expenses) are increasing by the installed power of the solar electricity plant. The greater the installed power of the solar electricity plant from 10 kW to 100 kW, the greater is the static economic efficiency of investment. However, the increase is not linear after the installed power size over 50 kW. The reason in behind are government support measures, particularly lower guaranteed price for sold electricity for the solar electricity plants above the 50 kW. The shortcoming of the static indicators of economic efficiency of investment is that they do not consider investment time dimension in a proper way. This is the reason to consider more in detail the dynamic economic investment efficiency appraisal by the net present value and the internal rate of return by the size of the installed power of the solar electricity plants. The calculated net present value is found to be negative for the smallest installed power size of the solar electricity plant of less than 10 kW. The calculated internal rate of return is found to be the highest (9.82%) for the size of the installed power 50 kW per solar electricity plant, because only up to this size the government guarantees the highest guaranteed price for the purchased electricity. In a spite of the lower guaranteed price for larger installed power sizes of the solar electricity plants, the relatively high internal rate of return (9.77%) for the largest installed power of 100 kW per solar electricity plant is achieved due to the relatively lower fixed costs per unit of the greater electricity production. Therefore, the investment efficiency appraisal confirms that the investment efficiency for the solar electricity plants up to 50 kW is determined significantly by the guaranteed price for the purchased electricity during the first 15 years of the operational period. On the other hand, the investment efficiency for the solar electricity plants greater than 50 kW in addition to government policy is determined by the technological advancements and the utilization of the economies of scale of the larger installed power of the solar electricity plants, which is likely to reduce fixed operational costs per unit of the electricity production and sale.

Table 3 – Indicators of economic investment efficiency appraisal by the size of the installed power of the solar electricity plant

	10 kW	20 kW	50 kW	100 kW
Indicator of economy (E)	1.31	1.56	1.78	1.79
Indicator of profitability (O)(%)	45.1	74.6	97.9	99.3
Indicator of profitability of expenses (Oe) (%)	30.7	55.9	77.8	79.4
Net present value (NPV) (in Euro)	-1,057.00	7,724.00	36,132.00	66,939.00
Internal rate of return (IRR) (in %)	5.53	8.01	9.82	9.77

Note: Discount rate is taken at 4.375% for profitability of government bonds. Source: Own calculations

CONCLUSION

The development of the solar electricity plants in Slovenia is in an initial, but rapidly growing stage of development. Most of the installed solar electricity plants of different sizes are connected to the electricity supply network. The sensitivity of the economic efficiency of investments for the solar electricity plants by their four different installed power sizes confirms that among the important determinants of investment's efficiency are the government policies, particularly the guaranteed purchase price of electrical energy, which is found to be relatively more significant for the economic efficiency of the solar electricity plants up to 50 kW, as well as other investment supports and interest rate subsidies for investment into the solar electricity plants. The free installing surface on the buildings roofs of different purposes is a limitation factor for the installed power size of the solar electricity plants. The installed power size of the solar electricity plant improves the economic investment efficiency positively due to the reduction of the fixed costs per unit of electricity production and sale. Therefore, the government support measures can encourage new investments for smaller and medium installed power size solar electricity plants, which can be situated on the roofs of different households' buildings.

The paper stresses importance of governmental influence in mitigating the risks in the solar electricity plants development in Slovenia. The reduction in governmental support measures and more free market conditions are likely to increase competition in wider (non-Slovenian) European neighborhood with a greater investment risks into the solar electricity plants development. This can cause possible instabilities on the solar electricity market. On the other hand, the technological advancements and progress in photovoltaic modules production is likely to further strengthen economic efficiency of the largest installed power sizes of the solar electricity plants, which can be situated on the roofs of the largest buildings such as schools, hospitals, factories, stadiums, and similar as a challenging issues for future research with managerial and policy implications. Among issues for future research is also the analysis of the other factors, in addition to a plants costs and incomes realized by selling the electricity with subsidized price, which on indirect way contribute to positive externalities improving the economy of solar power plants, such as reducing carbon dioxide emissions.

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