[8] Grishnova, O., Dmitruk, S. (2015). Human capital under crisis: evaluation and preservation opportunities search. Bulletin of Taras Shevchenko National University of Kyiv Economics, 5 (170), 11–16. doi: 10.17721/1728-2667.2015/170-5/2

[9] Azmuk, N. (2014). The factors of formation and development of human capital innovative forms. Ukraine: aspects of labor, 3, 47–51.

[10] Kovalchuk, V., Shakhno, A. (2016). Investing in human capital as a factor of innovation development of Ukrainian economy. Socio-economic problems and the state, 2 (15), 33–40.

[11] Mazina, O. (2012). Estimation and factors of human capital development. State and economy. KNUTE Bulletin, 6, 16–26.

[12] Levchenko, O. M., Plynokos, D. D., Tkachuk, O. V. (2015). Human capital as a factor for the innovative development of the national economy of Ukraine. State and Regions, 5 (86), 3–9.

[13] Osiichuk, O. A. (2013). Human capital theory development. Bulletin of Khmelnytskyi National University, 3 (3), 138–142.

[14] The Global Human Capital Report 2017. (2017). World economic forum. Available at: https://www.weforum.org/reports/the-global-human-capital-report-2017

[15] Official site of the National Bank of Ukraine. Available at: https://www.bank.gov.ua/

[16] Official site of the Transparency International (the global coalition against corruption). Available at: www.transparency.org/

[17] Mykhailova, L. I. (2008). Human Capital: Formation and Development in Rural Regions. Kyiv: Center for Educational Literature, 388.

ECONOMIC EFFICIENCY OF USING SOLAR ENERGY IN THE AGROINDUSTRIAL BUSINESS

Liudmyla Uniiat
Department of Accounting and Economics-Legal Providing of Agroindustrial Business
Ternopil National Economic University
11 Lvivska str., Ternopil, Ukraine, 46020
luda@uniyat.in.ua

Abstract

Under conditions of limited organic resources, polluted external environment, excessive emission of carbon in the atmosphere and as a result of global warming the use of renewed energy sources may become one of ways of solving problems of energy saving, energy efficiency, environment protection, energy independence from import raw materials. The active use of renewed energy sources will favor the increase of economic efficiency and competitiveness of components of the national AIC.

The article indicates that during the last 20 years the world underwent worsening of natural-climatic and living conditions, climate change, strengthening of negative natural phenomena and so on. The aforesaid problems of the world scale were discussed at the international climatic conferences (Brazil – 1992; Japan – 1997; SAR – 2002; Paris – 2015; Germany – 2017), while considering the complex of questions as to improving the natural-climatic and living environment in the world, saving use of natural resources, acceleration of using renewable energy sources (RES), especially solar one.

It was elucidated, that during the last years the power of solar energy stations (SPS) grew essentially. For the end of 2015 the leaders if setting SPS were the following countries: China, Germany, Japan, USA. In Ukraine the plan of development of the Combined energetic system for 2016–2025 years of SE «NEC «Ukrenergo»» provided the association of SPS power with electric nets of energy system with volume 1641.2 MW.

There was realized the grouping of Ukrainian regions by the level of the technically achievable potential of solar energy.

There was realized the assessment of the economic efficiency of products at using solar energy in the agroindustrial business in different regional conditions of Ukraine.

Keywords: solar energy, efficiency of projects, cash receipts, cash expenses, payback period, return on investments.

DOI: 10.21303/2504-5571.2018.00609

1. Introduction

The world community considers the use of renewable energy sources (RES) as one of most prospective ways of solving increasing problems of energy saving. The presence of inexhaustible resource base and ecological pureness of RES are determining advantages under conditions of using non-renewable resources of organic fuel and increasing terms of pollution of the natural environment. At the same time the growth of the population number in the world, reduction of world reserves of many dug out types of fuel, increase of prices for petroleum and gas, striving to decrease the energy dependence on import raw materials condition the increase of countries' motivation as to the development and use of renewable energy sources.

Questions of the development of solar energy in the world practice were considered in many scientific works of researchers throughout the world [1, 2]. Problems of expedience of using renewable energy sources are considered in scientific sources [3, 4], and their dynamics – in literature [5, 6]. Modern aspects of using solar energy in Ukraine are elucidated in literature [7, 8]. Prospects of using renewable energy sources in Ukraine – in literature [9, 10]. But problems of using renewable sources of energy remain urgent and need a scientific solution of a series of concrete questions, especially determination of the economic efficiency of projects for using solar energy in the agroindustrial business under concrete production conditions, taking into account regional peculiarities of solar insolation in Ukraine.

2. Aim of research

To determine the economic efficiency of products for using solar energy in the agroindustrial business under different conditions of solar insolation in Ukraine.

3. Materials and methods of research

At preparing the scientific article, there were used the data of statistic yearbooks, reports, projects of SE "NEC"Ukrenergo"", Scientific-project center of the development of the combined energetic system of Ukraine, National institute of strategic studies, State energy efficiency.

The following methods were used in the work: monographic, economic-statistic (statistic observation, grouping, comparison), method of analysis and synthesis, calculating-constructive, financial planning and prognostication, abstract-logic.

4. Research results

The worsening of conditions of the natural-climatic environment, living conditions in many world countries, climate change, caused by acceleration of the world economy globalization, condition the urgent problem – activation of using RES.

Problems of worsening the natural-climatic conditions, living environment, change of climate with negative consequences in the world was discussed at the international climatic conferences [1, 2]: in Brazil («Rio - 92», 1992); «Rio + 5» (New-York, 1997); (signing of «Kioto protocol») in Japan, 1997; «Rio + 10» (Johannesburg, 2002); (COP 21 «Parisian agreement» in France, 2015); in FRG (Bonn, 2017).

At the climatic conference in Bonn the main cause of the global warming was named – the increase of emissions of carbon dioxide in the atmosphere, resulted in worsening climatic conditions, natural cataclysms with great negative and destructive results in the world. There was considered the complex of questions as to improving the natural-climatic and world environment in the world, rational use of natural resources, activation of using RES and so on.

Practice testifies that the method of direct transformation of solar radiation in electric energy is most comfortable for a consumer. Such method is considered as eco-friendly way of getting electric energy as opposite to other ones (thermo-, hydro-, nuclear electric stations) [3, 4].

The report of the international conference REN 21 («GLOBAL STATUS REPORT 2016») [5, 6] about the state of world alternative energetics indicates that during the last years the power of solar power stations (SPS) grew essentially. Thus, in 2000 the world power of solar energy stations was only 1.29 GW, in 2005 – 5.1 GW; in 2008 – 15.84 GW ; in 2009 – 23.18 GW. The abrupt growth of solar energy stations in the world was observed since 2010, where set power of solar stations

reached 40.33 GW, in 2011– grew to 70.47 GW, in 2012 – to 100.5 GW, in 2013 – to138.86 GW, in 2014 – to 178.99 GW, in 2015– to 237.12 GW.

As it is testified by literature [7] for the end of 2015 the leaders of set power of solar photoelectric systems (stations) were the following countries: China (43 GW), Germany (39.6 GW), Japan (33.3 GW), USA (25.5 GW) and Italy (18.9 GW). In 2015 China became the absolute leader in the development of renewable solar energetics. There were set 14.8 GW of photoelectric systems (stations). China with the total power of solar energetic more than 43 GW occupies the leading place in the world. Such progress is stimulated by the necessity to decrease pollution of the external environment as a result of burning dug out fuel under conditions of growing needs in energy.

Japan occupies the second place in the rating for 2015, according to the report of REN 21. In 2015 near 10 GW of power were set there. USA is at the third place with 7.3 GW of set power of SPS, at that the total set power of all types of SPS in the country is near 25.5 GW than15 times exceeds the level of 2005. The list of 10 most acting or built photoelectric SPS includes 4 American ones with the power from 290 MW to 580 MW.

EU countries in 2015 set near 7.2 GW, and the total set power of SPS for the end of 2015 reached 98.66 GW, or increased since 2005 more than 30 times.

It must be noted that the positive dynamics of growing solar energetics will be kept further. The essential activation of the development of solar energetic was favored by signing the agreement by most countries at the climatic conference COP21 in Paris about counteraction to climatic changes by intensifying the development of renewable energetic for decreasing emission volumes of greenhouse gases. The Parisian conference accepted (2015) the international act about reduction of emissions and keeping global warming at the level less than 2 C of the pre-industrial level. For industrially developed countries volumes of decreasing emissions must be 80–95 % of 1990 to 2050, and for developing countries – to 50 % of the level of 1990.

It must be noted that the use of the solar energy potential in Ukraine is conditioned by climatic peculiarities of its territory. Thus, the average annual potential of solar energy in Ukraine (1235 kW hour/m^2) is rather high and much higher than in Germany – 1000 kW hour/m^2, or Poland – 1080 kW hour/m^2 [8]. These indices indicate that Ukraine has good possibilities for the effective use of the thermoenergetic equipment at its territory.

The development of solar energetic in Ukraine is related to priority national projects, the first solar power station was put into operation in 2010. In 2011 the set power of power stations on RES in Ukraine grew from 152 Mw to 397 MW. In 2012 the power of built solar power stations in Ukraine increased to 230 MW.

At the beginning of 2016 112 objects of solar energetics with the set power almost 838.83 MW functioned in Ukraine by the "green" tariff for electric energy production. These objects produced more than 475.1 mln kW·hour of electric energy in 2015.

The decree of the President of Ukraine of 12.01.2015 No.5/2015 approved the development strategy «Ukraine – 2020». The main aims of the state policy in the sphere of energetic independence is, according to statements of the Strategy, the reduction of energy consumption of GDP by 20 % till 2020 by beginning to use energy effective technologies and equipment, realization of projects using alternative energy sources, provision of 100 % of the obligatory commercial accounting of energy resources consumption (energy, fuel) and so on.

It must be noted, that activation of RES development at the state level motivated the Institute of renewable energetic of NAS of Ukraine to create the Atlas of the energetic potential of renewable energy sources of Ukraine that presented the annual technically achievable potential of renewed energetics of the country. The order of NCRECS of 30.06.2016 No.1187 about fixing "green" tariffs for electric energy for economic subjects and bonuses to green tariffs for observing the level of using the equipment of Ukrainian production (with changes) fixed the following "green" tariffs for electric energy producers (cop/kW·hour, without VAT): wind energy – 317.93; biomass and biogas – 348.21; micro- ,mini- and small HPS – from 327.02 to 545.03; from energy of solar radiation: land objects – from 449.65 to 1308.06; SPS which set power exceeds 10 MW – 726.70; SPS, fixed on roofs and/or facades of houses, buildings and facilities, which set power exceeds 100 kW – from

981.05 to 1253.56; SPS, CEC, fixed on roofs and/or facades of houses, buildings and facilities, which set power doesn't exceed 100 kW – from 906.86 to 1199.06 and so on [9].

The further development of RES is realized by VR of Ukraine that adopted the Law of Ukraine of 04.06.2015 No. 514-VIII «About introduction of changes to some laws of Ukraine as to providing competitive conditions of production of electric energy of alternative energy sources". It must be noted that SE «NEC «Urenego» elaborated the Plan of development of the Combined Energetic System (CES) of Ukraine for 2016–2025 years (farther – Plan of development of CES of Ukraine for 2016–2025), which statements determined the main directions of the development of alternative energetics (WPS, SPS, BPS) till 2025 as electric energy sources.

For accelerating realization of projects on renewable energy sources, there is the program of financing alternative energetic in Ukraine (USELF), supported by the European Bank for reconstruction and development (EBRD) and Fund of clean technologies of the World bank.

According to the National plan of actions on renewable energetics for the period till 2020, the set power of SPS in 2020 must reach 2300 MW, raising production of electric energy to 2420 GW·hour [9].

For realizing the National plan of actions on renewable energetic for the period till 2020 The State energy efficiency together with the Institute of renewable energetic of NAS of Ukraine elaborated the project of a Road map of the development of solar energetics in Ukraine till 2020 and posted it on the site of State energy efficiency for discussing. The main aim of elaboration and realization of the Road map is favoring investments in the development of the sphere of renewable energetic of the country. For raising the efficiency of using energy resources in Ukraine, the National institute of strategic studies elaborated the "Project of energetic strategy of Ukraine till 2035" for the Ministry of enegetics and coal industry [10].

It must be indicated, that essential reserves of raw materials, industrial and scientific-technical base for producing photoelectric devices for SPS can not only completely satisfy needs of domestic consumers, but to create conditions for beginning export supplies of more than two thirds of products.

The potential of solar energy and calculation of theoretically possible and technically available solar energy in regions of Ukraine is elucidated in the Road map of the development of renewable energetics of Ukraine till 2020.

Based on this Road map, we divided territories of the regions of Ukraine in four groups by the level of the technically achievable potential of solar energy in the regions of Ukraine (**Table 1**).

As it is seen on the table, the highest level of the technically achievable potential of solar energy is inherent to the regions of IV group (AR Crimea, Odessa region), and the least one – Western regions of Ukraine (I group of regions).

Let's note, that such division of regions by the level of the technically achievable potential of solar energy, is very important as to the effective placing, functioning and using solar power stations.

Table 1

Level of the technically achievable potential of solar energy at the territory of Ukraine

Groups of regions by the level of technically achievable potential, Bil kW·hour/year			
I – >1.00	**II – 1.01–1.50**	**III – 1.51–2.00**	**IV – 2.01 and more**
Rivne (0.96)	Poltava (1.5)	Kherson (1.84)	AR Crimea (2.2)
Ternopil (0.81)	Kiev (1.45)	Dnipropetrovsk (1.76)	Odessa (2.09)
Ivano-Frankivsk (0.70)	Cherkasy (1.4)	Zaporizhzhya (1.66)	
Transcarpathian (0.62)	Vinnitsia (1.29)	Kharkiv (1.62)	
Chernivtsy (0.46)	Kirovograd (1.26)	Chernihiv (1.6)	
	Sumy (1.21)	Lugansk (1.56)	
	Lviv (1.12)	Donetsk (1.54)	
	Khmelnitsky (1.08)	Zhytomyr (1.52)	
	Volyn (1.04)	Mykolaiv (1.52)	

Source: made by the author, based on [7]

Detail studies of the problem of production and use of solar energy by existent projects were realized on the example of agroindustrial enterprise InSC "Dobra Voda' of Zboriv district of Ternopil region. This enterprise extracts, processes and realizes drinking water for consumers.

For saving energy, decreasing production and administrative expenditures and possibly getting additional profits for energy, sold by the "green" tariff, several projects as to setting up a solar power station on roofs of own lodgings and also at the territory of the enterprise were offered for InSC "Dobra Voda". The general technological scheme of a solar power station is presented in literature [11]. The review of the market of solar panels is elucidated on sites [12, 13]. Commercial offers on problems of realization of projects for setting solar power stations are considered in literature [14–17].

The studies of the economic efficiency of using solar energy under conditions of InSC "Dorba voda" were realized by the realistic production scenario (5285.1 thousand bottles of water in a year) by existent projects with power: 585 kW; 700 kW; 850 kW; 1 MW.

It was established, that the most amount of electric energy by all analyzed projects will be produced during the spring-summer period (April – August). The least amount of electric energy will be produced by all projects in the following months: January, February, October, November, December. Just for this period the enterprise must buy the necessary amount of energy from energy sources.

At the realistic production scenario at the analyzed enterprise, energy consumption in a year were 712.7 thousand kW·hour, and average month consumption of electric energy – 59.4 thousand kW·hour. It conditions the need in buying electric energy in Autumn-winter months: 206.4 thousand kW·hour for the project of 585 kW; 169.5 thousand kW·hour – project of 700 kW; 142.2 thousand kW·hour – project of 850 kW and 119.1 thousand kW·hour – project 1MW. At the same time the excess of electric energy in spring-summer periods will be: 53.2 thousand kW·hour for the project of 585 kW; 126.3 thousand kW·hour – project of 700 KW; 242.5thousand kW·hour – project of 850 kW; 362.8 thousand kW·hour – project of 1MW.

The studies demonstrated that the use of projects with the higher power favors the increase of solar energy for possible sale by the "green" tariff.

The expected results of the economic efficiency of using solar energy by projects at the realistic production scenario (5285.1 thousand bottles of drinking water) at actual tariffs till 2020 are presented in **Table 2**.

As it can be seen from the table, the most effective project of InSC "Dobra Voda" is the project with power 1 MW. It allows the enterprise to get net receipts (cash flow) in a year as 2820.23 thousand hrn. The payback period is 11.4 years, and return on investments – 8,78 %.

The second place by the analyzed efficiency parameters belongs to the project of 850 kW. Its net receipts are 2213,09 thousand hrn in a year, payback period – 12,5 years, return on investments – 8 %.

Let's note, that the calculation of static indices of the investment efficiency (return on investments and payback period), was realized by actual tariffs till 2020. For specifying the calculations of net receipts (cash flow) from realization of the project and also static indices of the investment efficiency, the projects must be analyzed in dynamics. For the complex assessment of their efficiency, taking into account cost of moneys in time, it is necessary to calculate discount indices of the investment efficiency (there are present value of net receipts (cash flow) , net present value of project, profitability index of the investment project, discount payback period, internal rate of return).

It must be said, that the operation term of projects on setting solar power stations is 25years. That is why at assessing the efficiency of innovative projects using discount methods, there were taken into account cash receipts and cash expenses for projects till 2042. Let's note that from 2018 to 2019 the sale of electric energy by "green" tariff is set at the level of 16.37 eurocents/kW hour for power stations on roofs; for the period 2020–2024 tariffs will decrease to 14.76 eurocents/kW hour for power stations on roofs and13.52 eurocents/kW hour for surface power stations. During 2025–2029 tariffs will decrease again to 13.09 eurocents/kW hour for power stations on roofs and 12.01 eurocents/kW hour for surface power stations. The state has not legally determined a pay-

ment for energy of RES Starting from 2030. That is why calculations for the period 2030–2042 are based on the tariff of buying energy from electric nets, namely 153,92 cop without VAT for 1 kW.

Table 2

Economic efficiency of projects on using solar energy at the enterprise InSC "Dobra voda" by the realistic scenario at actual tariffs till 2020

Parameters	Use of projects by power:			
	585 kW	700 kW	850 kW	1 MW
Need of electric energy in a year, kW·hour	712744.0	712744.0	712744.0	712744.0
Expenditures for used energy in a year, thousand hrn	1316.47	1316.47	1316.47	1316.47
Produced electric energy in a year, kW·hour	559552.5	669550.0	813025.0	956500.0
Energy, must be bought for autumn-winter months in a year, kW·hour	206438.7	169494.3	142176.7	119071.0
Expenditures for bought electric energy in a year, thousand hrn	381.30	313.06	262.61	219.93
Possible realization of the excess of electric energy in a year (by the "green" tariff), kW·hour	53247.3	126300.4	242457.7	362827.0
Cash receipts for sold energy by the "green" tariff in a year (for power stations on roofs)*, thousand hrn	271.96	271.96	271.96	271.96
Cash receipts for sold energy by the "green" tariff in a year (for power stations on land surface)*, thousand hrn	–	342.57	887.28	1451.73
Cash receipts from the project for electric energy, consumed by an enterprise, thousand hrn	1316.47	1316.47	1316.47	1316.47
Cash receipts from realization of the project totally in a year, thousand hrn	1588.42	1931.00	2475.70	3040.16
Money expenditures for buying electric energy in a year by the project, thousand hrn	381.30	313.06	262.61	219.93
Net receipts (cash flow) for the project in a year, thousand hrn	1207.12	1617.93	2213.09	2820.23
Cost of the project, thousand hrn	19693.81	22674.12	27665.14	32109.84
Payback period of the project, years	16.31	14.01	12.50	11.39
Return on investments, %	6.13	7.14	8.00	8.78

Note: exchange rate of euro for 1.10.2017 was 31.2 hrn. Source: author's calculations based on [15, 16, 18]

The economic efficiency of innovative projects of using solar energy taking into account the conception of discounting by the realistic scenario of agroindustrial production under conditions of InSC "Dobra voda" is presented in **Table 3**.

Table 3

Economic efficiency of innovative projects of using solar energy taking into account the conception of discounting by the realistic scenario of agroindustrial production under conditions of InSC "Dobra voda"

Parameters	Projects by power:			
	585 kW	700 kW	850 kW	1 MW
Production volume by the realistic scenario, thousand bottles of water	5285.1	5285.1	5285.1	5285.1
Net receipts (cash flow) for the project totally, thousand hrn	27514.99	34569.67	44335.79	54215.80
Cost of the project thousand hrn	19693.81	22674.12	27665.14	32109.84
Effect (benefit) from realization of the project, thousand hrn	7821.18	11895.55	16670.65	22105.96
Average annual return on investments, %	5.59	6.10	6.41	6.75
Payback period, years	17.89	16.40	15.59	14.80
Discount rate, %	4.50	4.50	4.50	4.50
Present value of net receipts (cash flow) thousand hrn	16624.94	21170.56	27537.59	33993.01
Net present value of the project, thousand hrn	–3068.88	–1503.56	–127.54	1883.17
Discount payback period, years	29.61	26.78	25.12	23.62
Profitability index	0.84	0.93	0.99	1.06
Internal rate of return, %	2.80	3.80	4.40	5.10

Source: author's calculations, based on [15, 16, 18]

The study of the economic efficiency of investment projects in the dynamics for 25 years, taking into account the conception of discounting, demonstrated that among four offered projects, the most effective is the one with power 1 MW. The efficiency indices for this project are: effect (benefit) from its realization – 22105.96 thousand hrn; average annual return on investments – 6.75 %; payback period – 14.8 years, net present value at discount rate 4.5 % is 1883.17 thousand hrn, discount payback period – 23.62 years; profitability index – 1.06, and internal rate on return that indicates the maximal permissible discount rate value is 5.1 %.

It is necessary to take into account, that the economic profit from realization of the projects with less power is: for the project of 850 kW only at discount rate 4.4 %; for the project of 700 kW – at discount rate 3.8 %; for project of 585 kW – only at discount rate from 2.8 %.

Let's note, that under conditions of Ternopil region and also Rivne, Ivano-Frankivsk, Transcarpathian, Chernivtsy) projects of setting solar power stations are less effective than in other regions of Ukraine, that is conditioned by the technically achievable potential of solar energy (**Table 1**).

The analyzed projects of using solar energy under conditions of Eastern and Southern regions of Ukraine may have much more successful indices of the economic efficiency. This fact motivated us to determine the economic efficiency of the analyzed projects on using solar energy taking into account the level of the technically achievable potential of solar energy in all groups of regions of Ukraine. For that, based on table 1, where was determined the average technically achievable potential of solar energy in each group of regions. Taking into account that the studied enterprise InSC "Dobra voda" is almost on the boundary of Lviv and Ternopil regions, the calculated average level of the technically achievable potential is 0.956.

Taking into account text limitations for elucidating results of the studies of the economic efficiency of all projects on using solar energy under different regional conditions of Ukraine, we considered detail the efficiency results of only two projects – power 700 kW (**Table 4**) and 1 MW (**Table 5**).

As we can see on **Table 4**, electric energy production by the project with power 700 kW will increase from 669550 kW hour/year (first group) to 1407000 kW hour/year (fourth group) or in 2.1 times. The need in buying electric energy in autumn-winter months will change essentially: from 169494.3 kW hour/year in the first group to 68158.59 kW hour/year in the fourth group. Expenditures for buying electric energy for year will decrease too. At that the sale of excesses of electric energy by the "green" tariff will essentially grow from 126300.4 kW hour/year in the first group to 762414.63 kW hour/year in the fourth one. These factors provide the increase of net receipts (cash flows) of the analyzed project: 34569.67 thousand hrn in the first group to 88058.84 thousand hrn in the fourth one or in 2.5 times and effect (benefit) correspondingly from 11895.55 thousand hrn to 65384.72 thousand hrn or in 5.5 times. Efficiency indices of the project essentially were improved by groups of solar insolation: average annual return on investments will grow from 6.1 % (first group) to 15.53 % (fourth group), or in 2.5 times; payback period will decrease correspondingly – from 26.78 to 10.04 years or in 2.6 times. It must be noted that the net present value of the project will increase from (–1503.56 thousand hrn) in the first group to 33761.05 thousand hrn in the fourth one. At that the investment profitability index that indicates the current cost of incomes in the calculation for each hryvnia of pure investments, will increase from 0.93 (first group) to 2.49 (fourth group).

The internal rate of return that indicates the maximal permissible value of the discount rate or capital cost will grow from 3.8 % (first group) to19.3 % (fourth), or in five times. It testifies that enterprises of the first group of solar insolation can involve assets only for 3.8 % per annum, second group – 8.7 %, third group – 12.1 %, and the forth group – 19.3 %.

The studies demonstrated that the comparatively highest economic efficiency of using solar energy by analogous parameters in all regional conditions with different levels of solar insolation is provided by the project with power 1 MW (**Table 5**). As we can see from the table, main economic indices are essentially improved: net present value of the project may increase from 1883.2 thousand hrn (first insolation group) to 52504.6 thousand hrn (fourth group); the discount payback period may be decreased, correspondingly from 23.62 to 9.49 years; investment profitability index may be increased from 1.06 to 2.64, the internal internal rate of return may be raised from 5.1 % (first group) to 21.1 % (fourth insolation group).

Table 4

Economic efficiency of the innovative project of using solar energy with power 700 kW, taking into account the discounting conception, by the realistic production scenario at enterprises of the agroindustrial business under regional conditions of different levels of solar insolation in Ukraine

Parameters	Groups of regions by the average level of the technically achievable potential of solar energy, bil kW ·hour/year			
	I gr. (0.956)	II gr. (1.290)	III gr. (1.520)	IV gr. (2.01)
Electric energy production in a year, kW·hour	669550.0	903000	1064000	1407000
Electric energy, must be bought in autumn-winter months for year, kW·hour	169494.3	125699.62	105751.72	68158.59
Sale of excesses of electric energy for year (by the "green" tariff), kW·hour	126300.4	315955.66	457007.76	762414.63
Net receipts (cash flow) for the project totally, thousand hrn	34569.67	51110.37	62844.24	88058.84
Cost of the project, thousand hrn	22674.12	22674.12	22674.12	22674.12
Effect (benefit) from realization of the project, thousand hrn	11895.55	28436.26	40170.12	65384.72
Average annual return on investments, %	6.10	9.02	11.09	15.53
Payback period, years	16.40	11.09	9.02	6.44
Discount rate, %	4.50	4.50	4.50	4.50
Present value of net receipts (cash flow), thousand hrn	21170.56	32030.38	39772.90	56435.16
Net present value of the project, thousand hrn	–1503.56	9356.26	17098.79	33761.05
Discount payback period, years	26.78	17.7	14.25	10.04
Investment profitability index	0.93	1.41	1.75	2.49
Internal rate of return (IRR), %	3.80	8.7	12.1	19.3

Source: author's calculations, based on [7, 15, 16, 18]

It was established, that the lowest level of economic efficiency of using solar energy in all regions of Ukraine is provided by the project with power 585kW that can be used at small and middle enterprises of the agroindustrial business.

The project with power 850 kW occupied the second place after the project of 1 MW by the economic efficiency of using solar energy. It is expedient to use it at enterprises of agroindustrial business with different sizes.

The presented results of the economic efficiency of innovative projects with using solar energy demonstrate that central and regional authorities must differentially support and motivate consumers of solar energy by: giving concessional loans with the minimal lending rate (2.0–3.0 %) especially for enterprises of the agroindustrial business and also smoothing conditions and taxation requirements for all enterprises of the agroindustrial business for the period of developing projects of renewable energy sources. .

6. Conclusions

1. Thus, most countries of the world support activation of the development of solar energy, stimulate its wide use, increase of efficiency and economic profit, aim at 50 % and more use of RES in the energetic sector. Each country elaborated its own way of achieving this aim that takes into account implementation term, volumes and target directions as to increasing the level of energetic safety, preventing global climatic changes and widely implementing energy effective directions of using energetic resources, especially with RES.

Table 5

Economic efficiency of the innovative project of using solar energy with power 1 MW, taking into account the discounting conception, by the realistic production scenario at enterprises of the agroindustrial business under regional conditions of different levels of solar insolation in Ukraine

Parameters	Groups of regions by the average level of the technically achievable potential of solar energy, bil kW·hour/year			
	I gr. (0.956)	II gr. (1.290)	III gr. (1.520)	IV gr. (2.01)
Electric energy production in a year, kW·hour	956500.0	1290000	1520000	2010000
Electric energy, must be bought in autumn-winter months for year, kW·hour	119071.0	77750.32	59321.99	21003.99
Sale of excesses of electric energy for year (by the "green" tariff), kW·hour	362827.0	655006.36	866578.03	1318260.03
Net receipts (cash flow) for the project totally, thousand hrn	54215.80	78148.77	94975.70	130933.61
Cost of the project, thousand hrn	32109.84	32109.84	32109.84	32109.84
Effect (benefit) from realization of the project, thousand hrn	22105.96	46038.93	62865.86	98823.77
Average annual return on investments, %	6.75	9.73	11.83	16.31
Payback period, years	14.80	10.27	8.45	6.13
Discount rate, %	4.50	4.50	4.50	4.50
Present value of net receipts (cash flow), thousand hrn	33993.01	49744.44	60856.57	84614.42
Net present value of the project, thousand hrn	1883.17	17634.60	28746.73	52504.58
Discount payback period, years	23.62	16.14	13.19	9.49
Investment profitability index	1.06	1.55	1.895	2.64
Internal rate of return (IRR), %	5.10	10.2	13.7	21.1

Source: author's calculations based on [7, 15, 16, 18]

2. According to the National plan of actions on renewable energetics for the period till 2020, the set power of SPS in Ukraine must reach 2300 MW with increasing electric power production to 2420 GW·hour.

3. Activation of using RES in the agroindustrial business allows to accelerate the efficiency of enterprises' functioning, to raise the competitiveness of domestic products at internal and external markets.

The studies demonstrated that among four offered projects of using solar energy the most effective for all four groups of regions with different levels of solar insolation is one of 1 MW taking into account the discounting conception: discount payback period – 23.62 (I group of regions) –9.49 years (IV group of regions); profitability index is correspondingly – 1.06–2.64, internal rate of return that indicates the maximal permissible discount rate value is 5.1–21.1 %.

The offered projects of using solar energy reach the comparatively highest efficiency of functioning in regions of the fourth and third groups with the highest level of technically achievable potential of solar energy that testifies the expedience of building solar power stations in the aforesaid regions, in first turn.

4. At the macroeconomic level state authorities must realize the differentiated approach (by coefficients, set in regions) as to the state assistance and support of building and development of solar power stations by: giving concessional loans with the minimal lending rate (2.0–3.0 %), smoothing conditions and taxation requirements for all enterprises of the agroindustrial business for the period of developing projects and so on.

References

[1] Timmons, D., Harris, J. M., Roach, B. (2014). The Economics of Renewable Energy. Global Development And Environment Institute. Tufts University Medford. Available at: http://www.ase.tufts.edu/gdae/education_materials/modules/RenewableEnergyEcon.pdf

[2] Timilsina, G. R., Kurdgelashvili, L., Narbel, P. A. (2011). A Review of Solar Energy: Markets, Economics and Policies. World Bank Policy Research Working Paper No. 5845. Washington, 51. Available at: http://documents.worldbank.org/curated/en/546091468178728029/A-review-of-solar-energy-markets-economics-and-policies

[3] Halkos, G. E., Tzeremes, N. G. (2013). Renewable energy consumption and economic efficiency: Evidence from European countries. Journal of Renewable and Sustainable Energy, 5 (4), 041803. doi: 10.1063/1.4812995

[4] Perpina Castillo, C., Batista e Silva, F., Lavalle, C. (2016). An assessment of the regional potential for solar power generation in EU-28. Energy Policy, 88, 86–99. doi: 10.1016/j.enpol.2015.10.004

[5] REN 21 "Renewables 2016 Global Status Report". National Technical University of Athens, 272. Available at: http://www.ren21.net/wp-content/uploads/2016/06/GSR_2016_Full_Report.pdf

[6] Energy efficiency indicators (2016). Highlights: Statistical report. International Energy Agency, 154.

[7] Proekt Dorozhnia karta rozvytku vidnovliuvanoi enerhetyky Ukrainy na period do 2020 roku. Derzhavne ahenstvo z enerhoefektyvnosti ta enerhozberezhennia Ukrainy. Available at: http://saee.gov.ua/uk/pressroom/1133

[8] Nosenko, Yu. (2012). Suchasni soniachni tekhnolohii. Available at: http://agro-business.com.ua/agro/zhyttieve-seredovyshche/item/8292-suchasni-soniachni-tekhnolohii.html

[9] Stan i perspektyvy rozvytku maloi hidroenerhetyky, soniachnoi, vitrovoi ta inshykh dzherel ponovliuvanoi enerhii zarubizhnykh krain ta Ukrainy (2016). Viddil z informatsiino-analitychnoi roboty departamentu mizhnarodnoho spivrobitnytstva ta yevrointehratsii. Kyiv, 104. Available at: https://ua.energy/wp-content/uploads/2018/01/4.-Stan-i-perspektyvy-rozvytku-PDE.pdf

[10] Enerhetychna stratehiia Ukrainy na period do 2035 roku (2014). Natsionalnyi instytut stratehichnykh doslidzhen na zamovlennia Ministerstva enerhetyky ta vuhilnoi promyslovosti Ukrainy. Kyiv, 40. Available at: http://www.niss.gov.ua/public/File/2014_nauk_an_rozrobku/Energy %20Strategy %202035.pdf

[11] Promyslovi merezhevi soniachni elektrostantsii pid kliuch. Available at: https://rentechno.ua/ua/solar/utility-scale.html

[12] Prodazh obladnannia dlia soniachnykh elektrostantsii. Available at: https://rentechno.ua/ua/services/procurement.html

[13] Typovi komertsiini propozytsii. Available at: http://gravicappa.com.ua/ua/solar-power-stations/

[14] Promyshlennaia solnechnaia elektrostantsyia 1 MVt. Available at: http://alteco.in.ua/solution/solnechnaya-energetika/solar-plant-1mw

[15] Enerhiia sontsia | Derzhenerhoefektyvnosti Ukrainy (Finansova model soniachnoi elektrostantsii potuzhnistiu 1 MVt). Available at: http://saee.gov.ua/uk/ae/sunenergy

[16] Komertsiini propozytsii z fotoelektryky. Available at: https://www.atmosfera.ua/uk/sonyachni-elektrostancii/komercijni-propozicii/

[17] Typovi komertsiini propozytsii. Available at: http://gravicappa.com.ua/ua/solar-power-stations/

[18] Parkhomets, M. K., Uniiat, L. M.; Parkhomets, M. K. (Ed.) (2006). Analiz efektyvnosti investytsii na pidpryiemsvakh molochnoi promyslovosti: orhanizatsiia ta metodyka. Ternopil: Ekonomichna dumka, 223.