*Kurbatova T., Lysenko D., Trypolska G., Prokopenko O., Järvis M., Skibina T. (2022). Solar energy for green university: estimation of economic, environmental and image benefits. International Journal of Global Environmental Issues, 2/3/4, 198-216. https://doi.org/10.1504/IJGENVI.2022.10051037* 

# Solar energy for green university: estimation of economic, environmental and image benefits

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**Abstract:** The paper considers the main components of the green university concept, the foreign experience of environmental transformation of higher education institutions, and the impact of eco-innovations implementation on strengthening universities' position in the UI GreenMetric World University Rankings. The green strategy of Sumy State University, the results of its implementation, and prospects for improvement in terms of increasing renewable energy sources usage through the solar power plant installation are analysed. The effectiveness of the solar power plant investment project and the reduction of carbon dioxide emissions into the atmosphere by replacing conventional electricity with electricity generated by the solar power plant are estimated. It is proved that in addition to economic and environmental benefits, the implementation of the solar energy project will positively impact the university's image at the national and international levels.

***Keywords*:** green university, solar energy, investment project, benefits, Sumy State University, Ukraine

## 1. Introduction

Nowadays, solving global environmental problems is one of the critical challenges facing the world community. The need for transformational changes towards sustainable development has caused the consolidation efforts of governments, organizations, and individuals to implement eco-friendly initiatives at the local, national, and international levels. One of the drivers and catalysts of ecological changes today is universities actively implementing green initiatives in their activities.

The effectiveness of integration into a green university is measured by such criteria as infrastructure and green space on campus, energy consumption and savings, rational use of natural resources, recycling of waste, using environmentally friendly vehicles, training courses on environmental issues, and implementing research projects on sustainable development (IARU, 2014).

In recent years, the green university concept has gained considerable popularity, and nowadays, most universities in the world have been implementing a wide range of green strategies (Geng et al., 2013; Jimenez, 2019; Pereira et al., 2020; Okanović et al., 2021). However, in Ukraine, green university initiatives are only at the stage of their formation and cover only certain areas of their activities. Most attention is paid to implementing educational programs to improve the eco-culture of students and staff, involving students in various environmental projects and actions.

At the same time, Ukrainian higher education institutions have significant potential to implement many other eco-initiatives, particularly in the renewable energy field. Nevertheless, today Ukrainian universities hardly involve renewable energy resources in energy generation processes. The main reason for this is the peculiarities of Ukrainian legislation in managing renewable energy development. Thus, according to current legislation (The Verkhovna, 2017), the feed-in tariff is the primary mechanism for promoting renewable energy development. It applies only to the electricity generated from renewable energy resources not consumed for consumers' purposes. This approach makes it an attractive tool for projects: 1) in the business sector, namely for the construction of large capacity solar power plants to produce and sell green electricity for profit, where the

only source of consumption is the technological needs of power plants); 2) in the households, where the electricity consumption for their purposes is less than the amount of electricity generation by a power plant. However, universities cannot take advantage of the feed-in tariff because, in most cases, they can only place small-capacity power plants. In this case, the amount of generated electricity will not exceed the amount consumed by the higher education institution.

It should be noted that among the range of renewable energy technologies, the most suitable for usage by universities is solar energy, as photovoltaic panels can be placed on the walls and roofs of buildings (Kurbatova et. al., 2020; Sineviciene, et. al., 2021; Melnyk et.al., 2019; 2020). With this in mind, this study will relate to the implementation of the solar energy project and will focus on finding answers to the following questions: 1) Is it economically feasible to implement solar energy projects by higher education institutions in Ukraine, considering the features of state support policy in the renewable energy field?; 2) What environmental and image benefits can bring the implementation of the solar power plant to the university?

The paper is structured as follows. The following section is a literature review of the theoretical foundations of the green university concept, the main university ratings that consider sustainable development issues, and the experience of environmental transformation of the world's universities. Section 3 is devoted to the green strategy of Sumy State University and progress towards its implementation. Section 4 describes the research methodology and data on which the calculations are based. Section 5 discusses the research results, and Section 6 contains conclusions and recommendations for using the study's results.

## 2. Literature review

Today, the implementation of the green university concept involves integrating the principles of sustainable development in all aspects of higher education institutions. In the education field, it relates to the inclusion of environmental development issues in the curricula of educational disciplines, lectures, seminars, forums, and workshops. In the research area, it concerns simulation of fundamental and applied research in the field of sustainable development and green economy. In terms of infrastructure, the focus is on the formation of the ecologically oriented infrastructure of the university, namely the use of energy-saving equipment and technologies, renewable energy sources, environmentally friendly means for sorting, and disposal of waste, economical use of water, the development of electronic means of communication to minimize paperwork. Much attention is also paid to cooperation (the development of partnership programs and cooperation of the universities with commercial and public organizations that carry out their activities in the sustainable development field; student activity (holding eco-events, eco-festivals, etc.); and employment (assistance to graduates in finding green vacancies and eco-careers) (IARU, 2014; Gomez & Yin, 2019).

Each of the above components is an essential element of sustainable development of higher education and requires a systematic approach and strategic planning while being part of the overall integration strategy into the green university.

Today, many universities worldwide already have successful experience implementing a green university concept in their activities. The effectiveness of its implementation is assessed through several rating systems, which are platforms for communication and exchange of knowledge and best practices. Some ratings are used to assess and rank higher

education institutions solely based on implementing sustainable development measures. In contrast, others consider this indicator as a separate element of the overall assessment of the university. Rating systems vary according to the assessment methodology and priority of indicators. Identifying leading universities at both the global and national levels motivates other educational institutions to implement sustainability measures and join the sustainable development course. Consider some of them.

UI GreenMetric World University Rankings is a global ranking of universities aimed at assessing the commitment of higher education institutions to the ideas of sustainable development and the formation of the green infrastructure of university campuses. It aims to evaluate and compare universities depending on their sustainable development policy implementation. The UI GreenMetric World University Rankings estimates universities' sustainability in six criteria: setting and infrastructure, energy and climate change, waste, water, transportation, education and research. Each of the criteria has its weights and indicators. The tools of the UI GreenMetric World University Rankings include global ranking; regional rating (Europe, Asia, Africa, North America, South America, and Oceania); country ranking; rating by indicators (education and research, environment and infrastructure, energy and climate change, waste and water); ranking by different categories of the university campus ("urban", "in the city center", "high-rise buildings", "suburban" and "rural") (UI GreenMetric, 2020).

The Sustainability Tracking, Assessment and Rating System. It is a voluntary, transparent self-reporting system that evaluates efforts to implement sustainable development initiatives on campuses. The Sustainability, Tracking, Assessment and Rating System is designed to attract and recognize the full range of higher education institutions, from colleges to research universities. It covers the long-term sustainability goals for institutions with some achievements in the sustainable development field and those taking the first steps towards sustainability.

The Sustainability, Tracking, Assessment and Rating System is designed to provide a basis for understanding sustainability in all sectors of higher education; to provide an assessment of educational institutions based on a set of indicators developed with the broad participation of the international community in the sustainable development field; to create incentives for continuous improvement towards sustainable development; to facilitate the exchange of information on the implementation of sustainable development measures, and to create a strong and diverse sustainable development community.

The Sustainability Tracking, Assessment and Rating System measures sustainability in all areas of higher education using five indicators: academics (curricula, research), operations (climate, energy, water, infrastructure, transport, waste), engagement, planning and administration, innovation, and leadership. As a result of ranking, universities and colleges receive bronze, silver, gold, or platinum stars. Each star is an indicator of leadership in the sustainable development field. It allows institutions to compare their results and stimulates change through public recognition (The Sustainability, 2021).

The Times Higher Education University Impact Rankings is one of the most authoritative international rankings of universities. One of its approaches is to assess the success of the world's universities in achieving the goals of the United Nations in the sustainable development field. The Times Higher Education University Impact Rankings evaluates universities based on all seventeen sustainable development goals.

The Times Higher Education University Impact Rankings methodology is based on the analysis of carefully selected indicators that will ensure a balanced comparison of four areas: 1) research (sustainability research is the most traditional way in which universities

can help achieve sustainable development goals); 2) stewardship (universities have significant physical and intellectual resources, so how they act as stewards is one of the key factors in achieving sustainable development goals); 3) outreach (cooperation with local, regional, national, and international communities is another way in which universities can influence the achievement of sustainable development goals); 4) teaching (it plays a crucial role in training qualified professionals in the sustainable development field and ensuring that all graduates will be promoting key ideas of sustainability in their areas).

The following indicators were used in compiling the rating: 1) research (analyses of publications related to sustainable development; 2) continuous indicators (these indicators are usually reduced to the number of employees or students at university); 3) indicators that require confirmation (initiatives, practices, activities of university in various areas that require confirmation).

Different universities are evaluated based on different sets of sustainable development goals depending on their specialization. The ability of the rating system to reflect the results of the assessment not only as a whole but also in terms of individual indicators allows assessing the contribution of higher education institutions in achieving a specific goal of sustainable development (The Times, 2020).

It is worth noting that, in addition to the above ratings, several other rating systems can be used to assess the sustainability of universities at both international and national levels, namely Auditing Instrument for Sustainability in Higher Education, QS and GAUGE Indian College and University Rating, Green Building Index and more.

However, to date, the most authoritative ranking of universities aimed at assessing the commitment of higher education institutions to the ideas of sustainable development is the UI GreenMetric World University Rankings. The leaders in the implementation of sustainable development values, according to this ranking in 2020, were the universities of the Netherlands, Great Britain, and the United States (Table 1).

**Table 1:** Top-5 green universities according to UI GreenMetric World University Rankings in 2020

| Number in the rating | University's name | Country | Total number of points |
|---|---|---|---|
| 1 | Wageningen University & Research | Netherlands | 9150 |
| 2 | University of Oxford | Great Britain | 8875 |
| 3 | University of Nottingham | Great Britain | 8775 |
| 4 | Nottingham Trent University | Great Britain | 8725 |
| 5 | University of California in Davis | The United States of America | 8725 |

Data source: UI GreenMetric, 2020

Wageningen University & Research is one of the most sustainable universities in the world. It took the 1st position in UI GreenMetric World University Rankings in 2020 and third position in the SustainaBul 2020 ranking – an annual ranking of Dutch educational institutions organized by students. The university's mission is to 'explore the potential of nature to improve the quality of life'. The university actively involves renewable energy resources (sun, wind, biomass, and geothermal) in energy generation processes. It has allowed it to meet its energy needs by 100% and halve carbon dioxide emissions. Most waste on the campus is carefully recycled, and all new buildings meet high standards of sustainability (Wageningen, 2021; Collier, 2021).

The University of Oxford is another well-known green higher educational institution that actively promotes the principles of sustainable development. Environmental sustainability is one of the university's main priorities, and the primary goal of the university's Environmental Sustainability Strategy is to achieve zero carbon emissions by 2035. The university conducts energy audits of its buildings and implements many energy efficiency measures, contributing to energy and financial resources savings. It also pays considerable attention to green transport, encouraging sustainable travel options on the territory of its campus (University, 2021a).

The University of Nottingham contributes to the United Nations Sustainable Development Goals and focuses on working with the University of Nottingham Trent and Nottingham City Council to maximize collective influence and support the city's ambitious goal of becoming carbon neutral by 2028. In recent years, the university has implemented many environmental measures and projects, which have allowed to generate about 950 MWh of electricity from renewable energy sources annually, reduce greenhouse gas emissions by 36% compared to 2010, and provide sustainable transport between campuses. Based on these achievements, the university is stepping up its efforts to implement environmental sustainability in staff and students' education, research, thinking, and behaviour (University, 2021b).

Nottingham Trent University is also one of the leaders in the environmental transformation of higher education institutions. In 2020, in addition the fourth position in the UI GreenMetric World University Rankings, it took 3rd in the People and Planet University League in the United Kingdom. The university has implemented about 107,000 sustainable development measures, namely planted about 18,000 trees on the campus and beyond them, installed 300 solar panels and solar water heaters, organized sustainable transport, and more.) It allowed reducing carbon dioxide emissions by 51% compared to 2005. Due to Nottingham Trent University's strong position in UI GreenMetric World University Rankings in recent years, delegates from international universities of South Korea, Australia, Austria, and others visited the university to extrapolate the experience of how to be more sustainable (Nottingham, 2021).

The University of California, Davis is widely known for its commitment to sustainable development. It has a gold award under the STARS system, which assesses the level of sustainable development in US higher education institutions. University campuses are equipped with energy-efficient technologies and electric car charging points. In 2020, the university reduced greenhouse gas emissions by 50% in comparison with 1990. In the future, the university has more ambitious goals, namely to become carbon neutral by 2025. In addition, the university launched the 'sustainable 2nd-century' movement, which aims to make every aspect of the campus sustainable. Therefore, all the new university's buildings will be eco-friendly (UC Davis, 2021).

Thus, the world's leading universities understand that sustainable development is possible only with the economical use of natural resources, maintenance, and improvement of the quality of the environment. Implementing a wide range of sustainable development strategies allows them to be examples of green development centres and drivers of environmental growth in their countries.

## 3. Green strategy of Sumy State University and the results of its implementation

Recognizing the role of higher education institutions in forming national and regional policies considering sustainable development goals, Sumy State University also declares the priority of considering environmental aspects in its activities.

The environmental activity of the university is ensured through compulsory and voluntary activities. Mandatory activities are regulated by the requirements of current legislation and regulations of the university, voluntary – by taking and fulfilling additional environmental commitments.

The main directions of ecological activity of Sumy State University are approved by the order № 0912-I of December 13, 2019, according to which the university undertakes to implement a set of environmental measures in general organizational, administrative, educational, scientific, and extracurricular activities (SSU, 2019).

In the general organizational and administrative-economic sphere, the ecological activity of the university has three main directions: 1) implementation and continuous improvement of environmental management systems and integration of ecological aspects in the activities of all departments; 2) reducing the burden on the environment by increasing the efficient use of electricity and heat, the use of renewable energy resources, increasing the volume of reuse water, reducing the use of paper, plastic, disposable items, etc.; 3) reducing the environmental impact of vehicles by optimizing the planning of the educational process to the needs on journeys of staff and students, use of ecological services (ensuring conditions for bicycles, electric vehicles, etc.); 4) cooperation on environmental issues with the authorities, scientific, educational, and other institutions at the local, regional, national, and international levels.

Implementation of environmental policy in the university's educational activities, first of all, relates to exercising training specialists with higher education, post-graduate and doctoral students in the field of ecology, environment, and sustainable development. Another activity in this field concerns increasing students' understanding of the environmental aspects of their future professional activities by including ecological issues in the curriculum of compulsory and elective courses.

Greening of scientific activity primarily aims to develop existing and introduce new directions of scientific research and developments of ecological orientation. It also includes preventing research and development, which may lead to adverse environmental consequences. In addition, considerable attention is being paid to cooperation with state and local authorities in providing consulting and research services in ecology, environmental protection, and sustainable development.

In extracurricular activities, the university's environmental policy is aimed at considering ecological aspects in the organization of extracurricular activities and carry out actions to popularize ecological knowledge and support volunteer initiatives in an environmental field.

At present, Sumy State University has implemented many environmental measures. The most significant results of implementing the green strategy can be observed in energy efficiency, waste management fields, and research on sustainable development issues.

Thus, today the university implements the Comprehensive Target Program "Energy Efficient Sumy State University". Under this program, heat and waterproofing of campuses, replacing windows were made. It allowed to reduce heat consumption by 20%. At the same time, the university implements its energy-efficient developments and technologies, particularly a system for monitoring the heat consumption in buildings, which allows using mobile communications and Internet technologies to automatically collect information on coolant parameters and ambient temperature with a forecast for the next

day. The university also has a system for monitoring the electricity consumption of buildings. Measures are being taken to set up energy-efficient computer equipment, limit the operating time of multimedia equipment to reduce electricity consumption. (Scientific, 2021a).

Today Sumy State University is implementing the most potent energy-efficient infrastructure project in recent years under the program "Higher Education. Energy Efficiency and Sustainable Development" from the European Investment Bank. The project concerns the construction and reconstruction of educational, research and support facilities of seven universities of Ukraine, one of which is Sumy State University. The focus will be on energy efficiency and energy-saving measures to reduce the operational costs of universities while improving the quality of educational space and academic research opportunities (European, 2014).

Sumy State University has a Waste Management Program. The program's strategic goal is to minimize the impact on the environment caused by waste generation and management. Within the framework of this program, a system of separate waste collection has been introduced, in particular: resource-intensive waste (paper, plastic); hazardous waste (fluorescent lamps); specific wastes that require special treatment (wastes of electrical and electronic equipment, medical wastes); other non-hazardous waste. The separately collected waste is transferred for further utilization or disposal to specialized organizations that provide services in waste management.

In addition, since 2018, the library of Sumy State University with the Goethe Institute (Germany) support is implementing the project "Green Library". The project's primary goal is to promote the implementation of the United Nations Sustainable Development Goals through information, training, and own example of responsible consumption, waste sorting, and recycling.

The university has introduced and is actively developing electronic document management, widely used distance and mixed forms of education, involving transferring a certain amount of learning tasks in electronic form. Each employee and student has a personal account, which is part of the overall information system of the university and allows to work with electronic documents in all areas conveniently. Introduction and development of internal digital document management in the university allowed to reduce paper consumption for the corresponding purposes by 30% (Scientific, 2021b).

In addition, the university participates in international and national projects and programs on sustainable development issues. The university conducts many scientific studies in energy efficiency, renewable energy, climate actions, particularly on the development of mechanisms to promote renewable energy and innovative growth (Sotnyk et al. 2018; Kurbatova et al., 2020; Prokopenko et al., 2021; Klymchuk et al., 2020; Benetyte et al., 2021), the synthesis and optimization of the characteristics of third-generation solar cells for solar energy (Diachenko et al., 2017; Diachenko et al., 2018; Yeromenko et al., 2018), carbon footprints and carbon efficiency (Rui et al., 2020; Voronenko et al., 2017), energy-efficient transformation (Karintseva, et al., 2021; Melnyk, et al., 2013; Hens, et al., 2018), ecological modernization of the transport system (Shkarupa, et al., 2017; Hens, et al., 2019), assessment and compensation of environmental damage (Tarkhov, 2012; Marekha, 2016; Veklych, et al., 2017;), socio-natural antientropic potential (Melnyk, 2013; 2021), the impact of developing human capital on the quality of the environment (Sineviciene, et al., 2020), improving the quality control of energy resources of industrial enterprises to increase their energy efficiency (Matsenko & Ovcharenko, 2013) and more.

Sumy State University's presentation in the UI GreenMetric World Environmental Rating resulted from declarative environmental policy provisions and their strict implementation. Thus, in 2020 the university took 409th place among 912 educational institutions from 83 countries. Sumy State University was highly estimated for more than 40 criteria on energy efficiency, responses to climate change, waste disposal, the level of environmental research, the implementation of environmental measures and sustainable development issues in educational programs, and more.

Sumy State University took the third position among the ten best Ukrainian higher education institutions included in the UI GreenMetric in 2020 (Table 2) (UI GreenMetric, 2020).

**Table 2:** Top-10 universities of Ukraine in UI GreenMetric World University Rankings in 2020

| Name of the university | Place in the ranking in 2020 | The number of points by indicators: | | | | | |
|---|---|---|---|---|---|---|---|
| | | Infrastructure | Energy and climate change | Waste | Water use | Transportation | Education and research |
| Ukrainian National Forestry University | 1 | 1075 | 1050 | 1275 | 650 | 1325 | 1800 |
| Uman National University of Horticulture | 2 | 1150 | 1325 | 1050 | 550 | 1075 | 1000 |
| **Sumy State University** | **3** | **900** | **1325** | **675** | **525** | **1000** | **1125** |
| Western Ukrainian National University Ukraine | 4 | 500 | 1000 | 675 | 525 | 1175 | 1225 |
| VN Kharkiv National University Karazina | 5 | 775 | 875 | 675 | 625 | 975 | 1025 |
| National University of Ostroh Academy of Ukraine | 6 | 800 | 750 | 825 | 500 | 1075 | 775 |
| Lviv Polytechnic National University | 7 | 525 | 950 | 675 | 250 | 950 | 1025 |
| Sumy National Agrarian University | 8 | 1025 | 700 | 375 | 250 | 800 | 1175 |
| National University of Life and Environmental Sciences | 9 | 775 | 700 | 450 | 250 | 775 | 1300 |
| Mykolayiv National Agrarian University | 10 | 1000 | 625 | 300 | 550 | 775 | 975 |

Data source: UI GreenMetric, 2020

Thus, it can be argued that today Sumy State University is one of the leaders in the green development among education institutions in Ukraine. However, at the same time, the university has significant potential to improve its position in UI GreenMetric World University Rankings and other ratings that consider the implementation of sustainable development measures. First of all, this is possible by attracting renewable energy resources

to energy generation processes. The above analysis shows that one of the main criteria for different ratings is implementing measures in the energy sector aimed at reducing carbon dioxide emissions. That is why further research will focus on the environmental and economic justification of the solar energy project implementation by Sumy State University, its impact on the university's image, achieving the goals of the national and international policy of Ukraine in the energy and environmental fields.

## 4. Methods and Data

A wide range of methods estimate green projects' efficiency and justify their feasibility (Shkola et al., 2021). Nevertheless, one of the most convenient is the Levelized Cost of Electricity (LCOE) method (Ouyang & Lin, 2014). Nowadays, LCOE is widely used by a number of international organizations in the energy field to compare electricity generation cost based on various energy technologies, particularly International Renewable Energy Agency (IRENA, 2020), International Energy Agency (IEA, 2020), and others.

The LCOE reflects a fixed tariff for electricity throughout the lifecycle of a power plant that equates the total discounted costs of its construction and operation to the total discounted revenue from selling electricity (IRENA, 2020).

To calculate the cost of generating electricity by the solar power plant, we will consider the following components: investment and operating costs, the amount of generated electricity, the decommissioning cost, and the discount rate.

Thus, the formula for calculating the LCOE will be as follows:

$$LCOE = \frac{\sum_{t=0}^{n} ((I_t + Q_t + D_t) \cdot (1+r)^{-t})}{\sum_{t=0}^{n} (E_t \cdot (1+r)^{-t})}, \quad (1)$$

where *LCOE* is fixed cost of electricity generation during the lifecycle of the solar plants, UAH/kWh; $E_t$ is the amount of electricity generated by the solar power plants in the *t* year, kWh/year; $I_t$ is investment costs in the t year, UAH; $Q_t$ is operating expenses in the *t* year, UAH; $D_t$ is costs for decommissioning of the solar palnt in *t* year, UAH; *n* is the duration of the life cycle of the solar power plant, years; *r* is the discount rate; *t* is year of investment project implementation.

The discount rate is calculated based on Weight Average Cost of Capital (WACC) (Finswin, 2021). For this study, the formula will look like this:

$$WACC = K_s \cdot W_s + K_d \cdot W_d \quad (2)$$

where *Ks* is the cost of equity for investment project implementation; *Ws* is the part of equity by balance; *Kd* is the cost of debt for the investment project implementation; $W_d$ is the part of the debt by balance.

The discounted payback period of the investment project is calculated as follows:

$$DPP = \sum_{t=1}^{n} \frac{CF_t}{(1+r)^t} \geq I_{0,} \quad (3)$$

where *DPP* is the discounted payback period of the investment project; $I_0$ is the initial investment during year zero of the project, UAH; $CF_t$ is the net cash flow in *t-year*, UAH; *r* is the discount rate*; n* is the project lifetime, years; *t* is the year of the project implementation.

To assess the reduction of emissions from implementing the solar power plant project, we use the Large-scale consolidated methodology for grid-connected renewable power plants" (UN, 2012).

According to the above method, the reduction of carbon dioxide emissions is calculated by the formula:

$$ER_t = BE_t - PE_t , \quad (4)$$

where $ER_t$ is the emissions reduction in period *t*, t $CO_2$-eq.; $BE_t$ is baseline emissions in the period *t*, t $CO_2$-eq.; $PE_t$ is projected emissions in the period *t*, t $CO_2$-eq.

Thus, according to (UN, 2012) baseline emissions of carbon dioxide during electricity generation by solar power plants are calculated as follows:

$$BE_t = QE_t \cdot EF_t , \quad (5)$$

where $BE_t$ – baseline emissions in the period *t*, t $CO_2$-eq.; $QE_t$ – the amount of electricity generation by the solar power plant in the period *t*, MWh; $EF_t$ – specific carbon dioxide emissions during electricity generation by thermal power plants included in the United Energy System of Ukraine in the period *t*, t $CO_2$-eq.

According to the above methodology, the project emissions ($PE_t$) during electricity generation by the solar power plants are zero. Specific emissions of carbon dioxide during electricity generation by the thermal power plants are 1.063 tons of $CO_2$-eq./MWh.

## 5. Results and Discussion

To calculate the electricity generation cost according to the LCOE method, we will consider the technical and economic data of the solar power plant. To collect them, statistical data on solar energy projects implementation in Ukraine and recommendations of international organizations in the energy field were used (Engineering, 2021a, Engineering, 2021b, IEA, 2010):

- installed capacity – 50 kW;
- projected electricity generation in the first year of the solar power plant operation – 48595,45 kWh (coefficient of reduction of electricity generation – 0,8% annually (Jordan et al., 2012);
- life cycle duration – 25 years;
- projected investment costs – 867,180 UAH;
- projected operating costs – 21,000 UAH/year.
- projected costs for decommissioning of the solar power plant – 43,359 UAH (5% of investment costs, according to recommendations of the International Energy Agency).

The discount rate calculated by the formula (2) is 8%. Its calculation assumed that the university would not attract credit resources for the project implementation. Accordingly, the cost of debt capital and its share in the balance in this study is zero. The cost of equity

was defined as the sum of alternative investments in deposit accounts in state-owned banks (PrivatBank, 2021; Ukrgasbank, 2021; Oschadbank, 2021). As of May 1, 2021, Ukrgasbank offers the highest rate on hryvnia deposits – 8%. It will be taken for calculating the discount rate.

Based on the above data, the cost of electricity generation by the solar power plants, calculated by the formula (1), is 2,12 UAH/kWh.

The results of calculating the payback period of the investment project by formula (3) show that at the current level of the electricity tariff, the university will reimburse the initial investment for 17,1 years.

Note that the payback period of the investment project was calculated at the tariff for the university as of 01.05.2021 – 2,56 UAH/kWh). Given that electricity tariffs are periodically increasing, the payback period, considering their growth, will decrease.

Thus, the obtained results allow us to state that implementing the solar power plant project by Sumy State University is expedient, as the project's payback period does not exceed the power plant's life cycle and the projected increase in electricity tariffs will positively impact its reduction.

It should be noted that economic feasibility is not the only motive for implementing the solar energy project (Prokopenko et al., 2015; Domashenko et al., 2017). One of the main advantages of generating electricity based on the solar power plant is the absence of carbon dioxide emissions. Thus, installing a solar power plant will positively influence reducing the technogenic load on the environment.

Based on formulas (4, 5) and actual data on the amount of generated electricity by the solar power plant, we have calculated the reduction of carbon dioxide emissions during the life cycle of the solar power plant (Table 3).

**Table 3:** Reduction of carbon dioxide emissions when replacing conventional electricity with electricity generated by the solar power plant, t $CO_2$-eq.

| Amount of electricity generation during the life cycle of the solar power plant $QE_t$ (MWh/year) | Specific $CO_2$ emissions from electricity generation by the thermal power plants, $EF_t$ (t $CO_2$-eq.) | Baseline emissions, $BE_t$ (t $CO_2$-eq.) | Project emissions, $PE_t$ (t $CO_2$-eq.) | Emission reductions, $ER_t$ (t $CO_2$-eq.) |
|---|---|---|---|---|
| 1108,37 | 1,063 | 1178,2 | 0 | 1178,2 |

Data source: calculated by the authors

Thus, the replacement of conventional electricity by electricity generated by the solar power plant will help reduce emissions in 1178,2 tons of $CO_2$-eq. throughout the life cycle of the solar power plant. It will positively impact preventing global warming and climate change.

The implementation of the solar energy project can bring the university economic and environmental benefits and help improve its image at the national and international levels.

First of all, increasing the share of green electricity in final energy consumption will allow the university to improve its position in the UI Green Metric World University Rankings and other ratings that consider implementing sustainable development measures (Kaminov et al., 2012).

The solar power plant installation will help raise awareness and accumulate theoretical and practical knowledge in the renewable energy field, positively impacting the training of highly qualified specialists in this sphere, particularly at the Faculty of Technical Systems and Energy Efficient Technologies. It will help raise the university's image among higher education institutions in Ukraine that train students of related specialties. The solar power plant will provide students and graduate students with research work within the university, having access to the latest technological and metrological equipment. It will allow the university to increase its competitiveness in the research field and significantly improve the visibility and recognition of its brand in the scientific area.

In addition, the implementation of the solar power plant will contribute to achieving the strategic goals of the state energy policy to increase the share of green electricity in the countries' energy mix. Thus, according to the Energy Strategy of Ukraine for the period up to 2035, its growth in the country's final energy consumption is projected to 12% and 25% in 2025 and 2035, respectively (CMU, 2017). At the same time, the replacement of conventional electricity with electricity generated by the solar power plant will help meet commitments under the Paris Climate Agreement, where Ukraine aims to reduce carbon dioxide emissions by 40% from 1990 to 2030 and by 70% to 2050 (Dombrovsky & Geletukha, 2016). It, in turn, will strengthen the image of the university as a higher education institution that contributes to achieving the goals of the national and international policy of Ukraine.

## 6. Conclusions

Today, one of the promising ways of environmental transformations of higher education institutions of Ukraine is the solar energy projects implementation. Most Ukrainian universities do not implement such projects due to the lack of opportunity to sell electricity at the feed-in tariff, which guarantees their quick payback. However, the implementation of such projects by the universities to partially cover their own electricity needs is also appropriate, as the electricity generation cost based on the solar power plant is lower than the tariff at which universities purchase electricity. The study results show that at the current level of the electricity tariff, higher education institutions will return the initial investment for 17,1 years, while the solar power plant life cycle is 25 years. In addition, given the increase in electricity tariffs, which is quite likely, the payback period will be reduced. In addition to economic efficiency, the implementation of solar energy projects can bring many other benefits. Thus, replacing conventional electricity with electricity generated by the solar power plant, installed capacity of 50 kW, will reduce carbon dioxide emissions in the amount of 1178,2 tons of $CO_2$-eq. for the entire period of the solar power plant operation. In this way, the university will contribute to fulfilling Ukraine's obligations under the Paris Climate Agreement. Increasing the share of green electricity in the university's final energy consumption will strengthen its position in the UI Green Metric World University and other world rankings. In addition, by implementing the solar energy project, the university will contribute to achieving indicative national targets for renewable energy development specified in the Energy Strategy of Ukraine until 2035.

**Acknowledgment**

The study was carried out within the project "Solar energy for green universities: estimation of economic, environmental and image benefits". We are thankful to the Czech Development Cooperation support, which allowed this scientific cooperation to start.

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