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SUSTAINABLE ENERGY AND CLIMATE CHANGE UNIVERSITIES: ECONOMIC ANALYSIS AND ORGANIZATIONAL ASPECTS

Alina YAKYMCHUK[1], Iryna BEREZOVSKA[2], Małgorzata RATAJ[3*], Joanna WOJCIK[4], Mariia HOLOVCHAK[5]

[1] University of Information Technology and Management in Rzeszow; ayakymchuk@wsiz.edu.pl, ORCID: 0000-0002-5038-5215
[2] University of Information Technology and Management in Rzeszow; iberezovska@wsiz.edu.pl
[3] University of Information Technology and Management in Rzeszow; mrataj@wsiz.edu.pl, ORCID: 0000-0002-0469-2687
[4] University of Information Technology and Management in Rzeszow; jwojcik@wsiz.edu.pl, ORCID: 0000-0001-7142-1177
[5] Department of Administrative and Financial Management, Lviv Polytechnic National University, Ukraine; golovchak.mariya@gmail.com, ORCID: 0000-0002-9890-6948
* Correspondence author

Purpose: Universities are driving a creative and innovative approach to economic, social, and environmental change in line with the directions set by the Sustainable Development Goals. Green universities are higher education institutions that educate global citizens about the most important environmental challenges and shape their awareness, strive to minimize the environmental footprint of campus activities, and enable students and staff to understand and engage in ongoing research and development to work towards environmental sustainability and make it a priority. The aim of the article is to present the research in terms of the developing the concept of green and sustainable university.
Design/methodology/approach: The research is based on the results of the international UI GreenMetric ranking. The research verifies the regression relationships between the evaluation of the costs of universities for energy conservation and climate change and their overall total evaluation and provides conclusions about the efficiency of sustainable universities.
Findings: The analysis shows that the practices and initiatives at universities have to be accelerated towards sustainable development. In order to support universities in their green transformation, it is, therefore, necessary to create a research program and tools to support them at the national and regional levels.
Research limitations/implications: We used The UI GreenMetric ranking. However, it is worth checking what criteria other such rankings follow and comparing their results.
Social implications There is a weakness in cooperation between universities at sharing knowledge of successful management, implementation, research, and teaching in area of sustainable university change. To improve the situation, it is necessary to create a universal model for the maturity of a green university.
Originality/value: The results of the analysis prove that the concept of green universities, although widely discussed and presented in global politics and rankings, does not find a corresponding level of practical application.

Keywords: sustainable development, green university, green campus, green curriculum, green ranking correlation-regression analysis, statistical significance.

Category of the paper: research paper.

1. Introduction

Implementing the concept of sustainable development at universities (Galleli et al., 2022), which integrates a number of green strategies (Filho, 2021), is among the most important challenges faced by universities in today's world.

The green policies at universities must be developed and implemented within the framework of the 2030 Agenda for Sustainable Development declared by the United Nations (https://sdgs.un.org/2030agenda) and the 17 Sustainable Development Goals indicated in the Agenda (https://www.un.org/sustainabledevelopment/sustainable-development-goals/). As an example, we would like to give a brief overview of the Sustainable Development Strategy for 2022-2024 at the University of Information Technology and Management in Rzeszow, Poland (UITM). The strategy will focus on four key areas:

Education: including the subject of sustainable development at all levels of education; developing new on-line courses and trainings to qualify properly educated staff, application of technologies to increase student involvement, implementation of blended learning, virtual group classes and interactive learning.

Research and development: using information systems/technologies in research that will ensure more efficient use and allocation of existing resources, improve data and information management/sharing, supporting the activities of scientific and student clubs, promoting the principles of sustainable development in lectures, seminars and conferences through environmentally friendly organizational solutions (e.g. electronic conference materials, recycled materials for bags, notebooks, water dispenser, collective transport for conference participants), open-access publications.

Infrastructure and organization: effective water management on both campuses of the University, the use of alternative, renewable energy sources, biodiversity activities in Kielnarowa Campus, reducing the amount of paper/plastic waste and increasing the recycling rate to at least 50% on both university campuses, transformation of research and teaching laboratories towards the so-called green laboratories, consolidation of data centers and data migration to cloud-based systems to reduce energy consumption.

Partnerships: developing an integrated environment (in the form of a system/platform) to support open cooperation, exchange and access to relevant data and information; international cooperation to promote institutional and management decisions and models; intergenerational communicational various levels of education, including the Academy 50+ and the Higher

Academic School (ALO), collaboration with national and international institutions working in the field of sustainable development, including PRME, RESPONSIBLE BUSINESS FORUM and UI GREEN METRIC.

In the digital era, the green status of a university, similarly to many facets of our life, tend to be measured in figures. Currently several green metrics have been developed and implemented to rank universities worldwide. Additionally, a set of green metrics may serve as a clearinghouse of green best practices to support their implementation and discussion of new ideas about green initiatives. Some ranking systems have taken leading positions in this field. Among them are:

- The Academic Ranking of World Universities (ARWU, https://www.shanghairanking.com/rankings/arwu/2021). It was first published in June 2003 by the Center for World-Class Universities (CWCU), Graduate School of Education (formerly the Institute of Higher Education) of Shanghai Jiao Tong University, China, and updated on an annual basis. Universities are ranked by several academic or research performance indicators, including alumni and staff winning Nobel Prizes and Fields Medals, highly cited researchers, papers published in Nature and Science, papers indexed in major citation indices, and the per capita academic performance of an institution. For each indicator, the highest scoring institution is assigned a score of 100, and other institutions are calculated as a percentage of the top score.
- QS World University Rankings compiled by global higher education analyst Quacquarelli Symonds (QS, https://www.topuniversities.com/about-qs). The rankings are based on a methodology that considers a range of factors, including academic reputation, employer reputation, research impact, and internationalization. The methodology is reviewed annually to ensure that it remains relevant and up-to-date.
- Times Higher Education (THE, https://www.timeshighereducation.com/world-university-rankings). It provides the definitive list of the world's best universities, with an emphasis on the research mission. Other core missions evaluated: teaching (the learning environment); research (volume, income and reputation); citations (research influence); industry income (knowledge transfer) and international outlook (staff, students and research). It uses 13 carefully calibrated performance indicators to provide the most comprehensive and balanced comparisons.
- UI Green Metrics (https://greenmetric.ui.ac.id/). Every year the University of Indonesia (UI) publishes the UI GreenMetric World University Rankings on sustainability. Universities are given a score reflecting their efforts in reducing the ecological footprint of the university and sustainability in education and research.

Lately the UITM was awarded as the 291st World's Most Sustainable University in 2022 UI GreenMetric World University Rankings (https://wsiz.edu.pl/wp-content/uploads/2022/12/WSIiZ-UI-Green-Metric.pdf), and it was #2 in the country ranking.

As is clear from the short list above, most ranking systems focus on education and research missions of universities. The data they contain can help potential students and researchers when choosing a university for study and research work. Only the UI Green Metrics contains data of key interest for the study presented in this article. That is why this ranking system was chosen as the main source of data for subsequent statistical analysis.

2. Search and Method Procedure

The research is based on the results of the international UI GreenMetric ranking (https://greenmetric.ui.ac.id/rankings/ranking-by-category-2021/2). The UI GreenMetric ranking has been assessing university activities related to sustainability and climate protection since 2010 (Atici et al., 2021; Ragazzi et al., 2017; Galleli et al., 2022; Safarkhani et al., 2022). The ranking methodology draws from best practice models including: Times Higher Education, Webometric, HEEACT, QS Ranking, The College Sustainability Report Card.

The UI GreenMetric ranking of the universities taking part in the ranking is based on their self-assessment in relation to 39 indicators divided into 6 categories:

1. environment and infrastructure - weighting 15% (percentage of campus dedicated to green spaces, size of budget for sustainability measures, adaptation of campus for disabled people and mothers with children),
2. energy and climate change - weighting 21% (carbon footprint, renewable energy sources, devices to reduce energy consumption, university climate change programs),
3. waste - weighting 18% (recycling programs, how organic, inorganic and toxic waste is managed and wastewater management),
4. water - weighting 10% (water conservation programs, water recycling programs, use of devices to reduce water intake),
5. transport - weighting 18% (percentage of parking areas in relation to campus area, transport services offered by the university, green transport programs),
6. education and research - weighting 18% (research for sustainability, events promoting sustainability, number of student organizations for sustainability).

For each indicator, the self-assessment must be documented, in the form of photos, videos or calculations based on the formulas indicated.

3. Results

According to the overall final assessment of sustainability of the UI GreenMetric, ten universities of the world are the leaders (Table 1).

Table 1.
Overall Rankings of sustainability of world's universities, 2021

University	Country	Total Score	Energy and climate change	Education and research	Transportation	Waste	Setting and infrastructure	Water
1	2	3	4	5	6	7	8	9
Overall assessment to the highest number of points								
Wageningen University & Research	Netherlands	**9300**	1825	1800	1550	1800	1325	1000
University of Nottingham	United Kingdom	**8850**	1525	1650	1500	1800	1375	1000
University of Groningen	Netherlands	**8800**	1550	1525	1650	1800	1275	1000
Nottingham Trent University	United Kingdom	**8750**	1750	1750	1450	1800	1200	800
University of California, Davis	USA	**8750**	1650	1675	1450	1725	1300	950
Umwelt-Campus Birkenfeld (Trier University of Applied Sciences)	Germany	**8725**	1950	1600	1650	1500	1025	1000
Leiden University	Netherlands	**8700**	1825	1525	1650	1800	900	1000
University College Cork	Ireland	**8700**	1650	1700	1550	1650	1300	850
University of Connecticut	USA	**8700**	1500	1750	1475	1725	1250	1000
Universidade de Sao Paulo USP	Brazil	**8700**	1475	1600	1675	1650	1350	950

Source: based on the data from the UI GreenMetric ranking.

Wageningen University & Research University of Groningen, Leiden University (Netherlands) are in the first, third and sixth places, the second and fourth ranks are occupied by two UK universities – the University of Nottingham and Nottingham Trent University. According to the world sustainability rating, the University of California, Davis (USA) takes the leading fourth place, and the sixth position is taken by the University of Connecticut. The fifth position is occupied by Umwelt-Campus Birkenfeld (Trier University of Applied Sciences), a German university. Irish (University College Cork) and Brazilian (Universidade de Sao Paulo USP) universities round out the top ten best, sharing the sixth position, respectively.

Table 2 presents the assessment of world universities according to the indicator of sustainable energy use in 2021.

Table 2.
Assessment of world universities according to the indicator of sustainable energy use, 2021

University	Country	Total Score	Energy and climate change	Education and research	Transportation	Waste	Setting and infrastructure	Water
1	2	3	4	5	6	7	8	9
Assessment according to the indicator of sustainable energy use								
Umwelt-Campus Birkenfeld (Trier University of Applied Sciences)	Germany	8725	**1950**	1600	1650	1500	1025	1000
Luiss University	Italy	8475	**1925**	1550	1650	1500	950	900
University of Eastern Finland	Finland	8325	**1875**	1575	1300	1800	775	1000
University of Kashan	Iran	7725	**1875**	1375	1425	1275	875	900
Leuphana Universitat Luneburg	Germany	8525	**1850**	1650	1600	1575	1000	850
Wageningen University & Research	Netherlands	9300	**1825**	1800	1550	1800	1325	1000
Leiden University	Netherlands	8700	**1825**	1525	1650	1800	900	1000
University of Southern Denmark	Denmark	8675	**1825**	1600	1550	1725	975	1000
Universidad de Alcalá	Spain	8200	**1825**	1550	1375	1425	1175	850
Politecnico di Torino	Italy	8500	**1775**	1725	1600	1800	600	1000

Source: based on the data from the UI GreenMetric ranking.

However, according to the indicator of sustainable energy use, which is critical in the modern civilized world, universities have a slightly different distribution: here the leaders are: Germany (Umwelt-Campus Birkenfeld (Trier University of Applied Sciences), Leuphana Universitat Luneburg); Italy (Luiss University, Politecnico di Torino); Finland (University of Eastern Finland); Iran (University of Kashan), Netherlands (Wageningen University & Research, Leiden University); Denmark (University of Southern Denmark), Spain (Universidad de Alcalá). Most of these universities are European ones, except two universities in Iran and Brazil.

Based on the UI GreenMetric Ranking by Category 2021 – Energy and Climate Change this study explores the relationship between indicators regarding energy conservation and climate change estimations for world universities and their overall evaluation. Correlation-regression analysis was performed. The results of mathematical data processing are shown in Table 3. For the clarity of the data, a graph was constructed, and a trend line was drawn between the indicators under consideration, which are presented in Figure 1. The study summarizes the assessment of 956 universities in the world located in different countries.

Mathematical modeling and correlation-regression analysis are used to determine the dependence between the estimation of the universities regarding energy conservation and climate change and their overall evaluation (Table 3).

Table 3.
Regression statistics and model values dependence between the evaluation of the world universities regarding energy conservation and climate change and their overall estimation

Indicators	Results of modeling				
	df	**SS**	**MS**	**Fisher's Cr. (F)**	**Significance F**
Regression	1	2049810174	2135342.413	1960,570418	1,1064E-233
The rest	955	998468965,2	2408.077733	F_{cr}	3,851214
Total	956	3048279139		t_{cr}	1,962451136
Standard Error	t-Statistics		P-value	Coefficients	Upper 95%
6.936926579	22,82739144		2,17448E-92	b_0 = 1980,969492	2151,272
0.186223649	44,27832899		1,1064E-233	b_1 = 3,646988304	3,808626
Regression Statistics					
Multiple Correlation coefficient R			0,82002946		
Coefficient of determination R-square			0,672448316		
Adjusted R-square			0,67210533		
Standard error			1022,505375		
Cases			956		

Source: the authors' own calculation.

The choice of the analytical form of the model, which describes the dependence between the university indicators on energy conservation and climate change and their overall evaluation, is based on the constructed scattering diagram, which is a graphical representation of the selected statistical sample. This relationship is close to linear, so in this case, as a relationship between variables, it is advisable to choose a linear function. The linear regression function, in this case, will look as follows:

$$\hat{y} = b_0 + b_1 x \tag{1}$$

where $\hat{y}$ – an estimate of mathematical expectation of the dependent model variable (overall evaluation of a university); x – independent model variable (evaluation of the costs of universities for energy conservation and climate change); b_0, b_1 – selective regression parameters.

Accordingly, the model describing the dependence between indicators of universities regarding energy conservation and climate change and their overall evaluation is:

$$Y = 1980 + 3{,}65x \tag{2}$$

The indicators of universities on energy conservation and climate change and their overall total evaluation were used to determine estimates of the b_0, b_1 model parameters (Table 2).

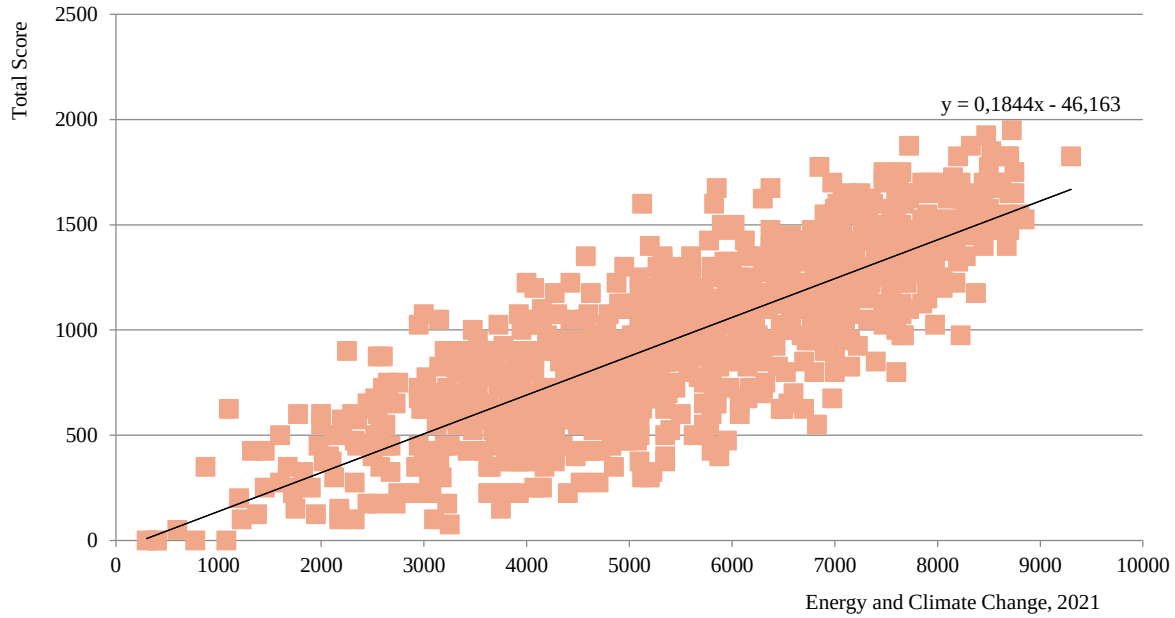

Figure 1. The trend line for evaluating the university rankings regarding energy conservation and climate change in the overall system of the university sustainable development.

Source: calculated based on the data from the UI GreenMetric Ranking.

As it can be seen in the Figure, there is a linear relationship describing the data on energy conservation and climate change in the overall system of university sustainable development. A trend line between the investigated indicators is a linear function of the following form:

$$Y = 0{,}1844x - 46{,}163 \tag{3}$$

The verification of the model for adequacy, quality, and significance was carried out to check if the choice of the structure of the model to explore the link between evaluating universities based on indicators of energy conservation and climate change and their overall evaluation in the form of linear regression is correct. The determination and correlation coefficients are used to assess the quality of this model. The model statistical significance has been tested on the basis of Student and Fisher criteria.

To assess the adequacy of the model with statistical data, the value of this determination coefficient R^2 is calculated (0,672). Since the value of the coefficient of determination $R^2 = 0{,}672$, the impact of evaluating the universities by indicators of energy conservation and climate change is quite significant. The strength of the linear relationship between the model variables is estimated using the correlation coefficient. Based on the value of R = 0,82, the close linear relationship between the indicators of the model is detected. The following F-statistics (Fisher's *F*-criteria) are used for verification:

$$F = \frac{R^2}{1 - R^2} \cdot \frac{n - k}{m} \tag{4}$$

which has a Fisher distribution with degrees of freedom $v_1 = m$ i $v_2 = n - k$.

According to the statistical tables of Fisher's F-distribution at a given level of significance $\alpha = 0.05$, the critical value of Fisher's criterion $F_{cr} = 3{,}851214$. Since Fisher's criterion is $F = 1960{,}570418$, which is more than its critical value, the model is adequate and statistically significant. To determine the significance of the model parameters contributing to the overall statistical significance, t-statistics was used (Student's criterion):

$$t_{b_j} = \frac{b_j}{\hat{\sigma}_{b_j}},\ j = \overline{0,m} \tag{5}$$

where:

b_j – estimation of the parameter β_j of the theoretical regression,

$\hat{\sigma}_{b_j}$ – standard error of the *j* parameter of the model.

According to the selected significance level of $\alpha = 0.05$ and freedom degrees available in the statistical tables of the Student's *t*-distribution, the Student's criterion critical value $t_{cr} = 1{,}962451136$ was found. The values of $b_0 = 1980{,}969492$ and $b_1 = 3{,}646988304$ exceed the critical value $t_{cr} = 1{,}962451136$, which also confirms the adequacy and significance of this regression model (Table 3).

The verification of the model of dependence between evaluating universities by energy conservation and climate change and their overall evaluation indicates the adequacy of the model and the existence of a close linear relationship between its variables, as well as the significance of the model as a whole and its parameters.

It is worth noting that the parameters of maintaining sustainability in the use and conservation of energy in order to reduce the negative effects of climate change reflect the general economic and social influence of universities on the regions where these universities are located, forming a positive image of the respectable area and its capacity for sustainable development. Availability of sufficient resources in the budgets of universities gives them the opportunity to develop their local community, to provide their residents with more diverse and quality services, not only educational, but also research, consulting, transport, information-structural, etc. In addition, the advantage of such sustainable universities is the ability to implement large infrastructure projects with significant investments and substantial social benefits, create conditions to attract investment capital and business development, form partnerships between the government, business and science, support other types of activities, research, economic development.

4. Discussion and Conclusions

The work summarizes the assessment of 956 universities in the world located in different countries. The authors conclude that sustainable universities are the "business card" of local communities, and in the future, they will become the ground for the marketing strategy of their development and positive territorial image promotion.

The research determines an interrelation between the evaluation of universities by energy conservation and climate change and their overall total evaluation. The verification of modeling results indicated the adequacy of the model in terms of statistics and the existence of a close linear relationship between its variables, as well as the significance of the model as a whole and its parameters. The correlation coefficient is close to 1,0 and is 0,82. This means that 82% of the change in the annual evaluation of universities regarding energy conservation and climate change rate depends on their overall evaluation.

The value of the research lies in a multidisciplinary approach to substantiating the indicators of sustainable development of universities for the effective future socio-economic development of the regions where these universities are located. Such universities become centers of socio-economic and cultural development, allow to attract significant investments, create clusters and incubators of science, develop cooperation between business and government on legal grounds. In addition to the educational function, a modern university has many tasks and areas of activity – it takes care of the preservation of the environment and energy, is able to provide transport and consulting services for the population, build infrastructure facilities, form the foundations of ecological and economic security, and contribute to the formation of information environment.

The value of the research results is the improvement of the concept of sustainable development and the application of the tools of green economy at modern universities, which is the basis for the new global strategy of sustainable development of universities, increasing the level of socio-ecological and economic security of local communities, and revitalizing local economies.

Further research will deal with theories of university management known in world science, which will be supplemented by new concepts and approaches taking into account sustainable energy conservation and prevention of climate change in the world, formation of the economic value of a modern university as a cultural, educational, scientific and economic center.

We used the UI GreenMetric ranking, this presents a limitation. It is worth checking what criteria other rankings follow and comparing their results.

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