"The role of universities in ensuring energy efficiency and sustainability: Investigating the link between UI GreenMetric ranking and countries' sustainability indicators"

AUTHORS	Denys Smolennikov Alina Raboshuk Oksana Drebot Zhanna Oleksich Liudmyla Huliaieva

ARTICLE INFO	Denys Smolennikov, Alina Raboshuk, Oksana Drebot, Zhanna Oleksich and Liudmyla Huliaieva (2024). The role of universities in ensuring energy efficiency and sustainability: Investigating the link between UI GreenMetric ranking and countries' sustainability indicators. *Knowledge and Performance Management*, *8*(2), 127-143. doi:10.21511/kpm.08(2).2024.10
DOI	http://dx.doi.org/10.21511/kpm.08(2).2024.10
RELEASED ON	Monday, 23 December 2024
RECEIVED ON	Friday, 13 September 2024
ACCEPTED ON	Thursday, 05 December 2024

JOURNAL	"Knowledge and Performance Management"
ISSN PRINT	2543-5507
ISSN ONLINE	2616-3829
PUBLISHER	LLC "Consulting Publishing Company "Business Perspectives"
FOUNDER	Sp. z o.o. Kozmenko Science Publishing

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
55	5	10

BUSINESS PERSPECTIVES

LLC "CPC "Business Perspectives"
Hryhorii Skovoroda lane, 10,
Sumy, 40022, Ukraine
www.businessperspectives.org

Denys Smolennikov (Ukraine), **Alina Raboshuk** (Oman), **Oksana Drebot** (Ukraine), **Zhanna Oleksich** (Ukraine), **Liudmyla Huliaieva** (Ukraine, USA)

THE ROLE OF UNIVERSITIES IN ENSURING ENERGY EFFICIENCY AND SUSTAINABILITY: INVESTIGATING THE LINK BETWEEN UI GREENMETRIC RANKING AND COUNTRIES' SUSTAINABILITY INDICATORS

Received on: 13th of September, 2024
Accepted on: 5th of December, 2024
Published on: 23rd of December, 2024

Denys Smolennikov, Ph.D. in Economics, Associate Professor, Oleg Balatskyi Department of Management, Sumy State University, Ukraine. (Corresponding author)

Alina Raboshuk, Ph.D., Associate Professor, Faculty of Business, Sohar University, Sultanate of Oman.

Oksana Drebot, Doctor of Economics, Professor, Academician of NAAS, Institute of Agroecology and Environmental Management of NAAS, Ukraine.

Zhanna Oleksich, Ph.D. in Economics, Associate Professor, Accounting and Taxation Department, Sumy State University, Ukraine.

Liudmyla Huliaieva, Ph.D. in Economics, Associate Professor, Ph.D., Department of Finance, Academy of Labor, Social Relations and Tourism, Ukraine; Associate of the Global MIT At-Risk Fellows Program, Massachusetts Institute of Technology, USA.

Conflict of interest statement:
Author(s) reported no conflict of interest

Abstract

The article analyzes the role of universities, assessed through the prism of the UI GreenMetric World University Rankings (UI GreenMetric) methodology, in ensuring energy efficiency and sustainability of the national economy. For this purpose, UI GreenMetric results, systematized by country and region, were used, as well as data for 2017–2022 on countries' progress in achieving SDG 7 and the national level of primary energy intensity. The analysis of trends in the development of sustainable universities according to UI GreenMetric shows regional differences: on average, the highest scores in the ranking are given to universities in OECD countries and East and South Asia, and the lowest – to Sub-Saharan Africa and Eastern Europe & Central Asia. A positive correlation (from 13.9% to 18.7% of the variation) was found between the activities of universities and the countries' progress in achieving SDG 7, as well as a negative correlation with the energy intensity of the level of primary energy of these countries; this proves the participation of higher education institutions in ensuring the energy efficiency of national economies (the level of influence is much lower, the explanation of model variations is 2.4%-8.2%). The role of universities is not only to develop green campuses but also to increase research, create new educational programs, develop cross-sectoral cooperation and 'living laboratories' to implement sustainable development practices, and train future leaders capable of overcoming global energy challenges.

Keywords universities, energy efficiency, energy intensity, sustainability, UI GreenMetric World University Rankings

JEL Classification Q01, Q56, P28

INTRODUCTION

The issues of climate change, the efficient use of energy resources, and the search for new energy and climate sustainability models are becoming increasingly relevant in light of new threats. Studies show that if no measures are taken to limit anthropogenic greenhouse gas emissions, the global average temperature will rise by more than 3°C above pre-industrial levels (Alam et al., 2023; Khaustova et al., 2024; Nkwaira & Poll, 2024; Song et al., 2023). This will increase general and food inflation in both high- and low-income countries (Kotz et al., 2023).

Governments, international organizations, businesses, financial institutions, energy companies, educational and research institutions, local authorities, non-governmental organizations, consumers, and other stakeholder groups are all involved in addressing global energy efficiency and sustainability (Boros et al., 2023; Kristianthy & Ekawati, 2024; Soares et al., 2024; Nguyen & Huynh, 2024). However, none of these players can effectively respond to these global challenges alone. Governments make policy decisions (Stefanova & Zhelev, 2022; Danylyshyn & Koval, 2023), businesses and investors finance innovation, universities conduct research, and non-governmental organizations, consumers, and local governments drive action. The cooperation of various stakeholders is crucial to progressing towards a sustainable and energy-efficient future. Universities play a special role in these processes, not only conducting research and developing new technologies, educating future leaders in the field of sustainable development, but also becoming platforms for technological and inter-organizational cooperation (Colombo & Mattarolo, 2017; Haghighi Talab et al., 2020), and fulfilling the so-called "third mission". While many universities are doing important and useful things, the possibility of quantifying their role in improving energy efficiency and achieving sustainable development needs to be studied more, which is essential for making strategic decisions in higher education.

1. LITERATURE REVIEW AND HYPOTHESES

Most scientific publications on the role of universities in ensuring energy efficiency, preventing climate change, and promoting sustainable development are devoted less to quantitative assessment of this role than to qualitative analysis of cases of specific higher education institutions. In particular, the University of Gothenburg (Sweden) significantly reduces carbon dioxide emissions due to a comprehensive climate strategy in which various stakeholder groups cooperate (Omrcen et al., 2018). Indonesian universities are implementing the government's renewable energy goals by developing and implementing special cooperation programs, demonstrating an example of aligning local actions and national targets of the global SDGs (Taqwa, 2019). At the same time, universities, particularly Polish ones, can implement sustainable initiatives without excessive costs, using EU funding and support from industry (Mikulik & Babina, 2009). The case of Bolivia proves the need to strengthen ties between universities and companies operating in the renewable energy market (Gottwald et al., 2012).

The study of these cases reveals significant differences in universities' approaches to sustainable development in different countries and regions. In particular, Saudi Arabia focuses on solar energy, and universities are entrusted with training a skilled workforce for further employment in this area (Alyahya & Irfan, 2016). Chinhoyi University of Technology, a university in Zimbabwe, pays special attention to achieving SDG 13 – "Mitigate the effects of climate change". It integrates climate change awareness into its research and outreach programs, taking into account the local context (Kupika et al., 2020).

Universities in the UK are proactive in their declarations regarding the threatening climate situation in the world. Universities make these statements to demonstrate leadership in sustainable development efforts. In doing so, universities strengthen their institutional reputation and signal a political commitment to specific goals and policies aimed at combating climate change (Latter & Capstick, 2021).

Universities cannot solve global and local sustainability problems alone. Effective regional development requires mechanisms of anti-crisis action and strong cooperation between universities and communities, which involves a bidirectional exchange of knowledge, in contrast to the traditional educational role of universities (Peer & Stoeglehner, 2013; Zavidna et al., 2022). At the same time, different stakeholders should be engaged in cooperation with universities to achieve multiple SDGs simultaneously (Agusdinata, 2022). The interaction of universities with local communities is crucial for the effective response of universities to local needs and the use of their experience for a broader impact on society (Filho et al., 2019). It has been proven that universities should transform from passive observers to active leaders in implementing the SDGs by institutionalizing partnerships with governments and communities (El-Jardali et al., 2018).

Several case studies illustrate successful university initiatives that promote sustainable development

ttp://dx.doi.org/10.21511/kpm.08(2).2024.10

by using higher education institutions as "living laboratories" (Berchin et al., 2018; Horan et al., 2019; Light, 2019). Scholars argue that universities have the potential to test and implement innovative practices before they are adopted by society (Horan et al., 2019). This concept encourages hands-on learning experiences involving students in sustainability projects (Berchin et al., 2018). In this discourse, the role of universities in the development of green entrepreneurship is incredibly important for the formation of students' innovation and leadership skills (Alkhalaileh et al., 2023; O'Leary, 2015; Yi, 2021). At the same time, it has been proven that entrepreneurial universities are more effective in stimulating the transition to sustainable development (Colding & Barthel, 2017). This transition can be ensured by reorienting the main vectors of university activities – education, research, campus management, and community outreach – towards sustainable development (Grundey, 2009; Riccaboni & Trovarelli, 2015). The case of the University of Siena demonstrates that universities play a crucial role in building alliances and promoting the cultural change needed to achieve the SDGs (Riccaboni & Trovarelli, 2015).

Despite the large number of studies on the role of universities in ensuring energy efficiency and sustainability, many of them are qualitative rather than quantitative. At the same time, several researchers have attempted to assess the sustainability of higher education institutions through the results of their participation in international ranking measurements. Most existing university rankings do not consider sustainability indicators (Burmann et al., 2021). At the same time, in recent years, the so-called "green" rankings have been gaining more and more development, the most popular of which are QS World University Rankings: Sustainability, Times Higher Education Impact Rankings, and UI GreenMetric World University Ranking. The latter has the longest retrospective of data collection (since 2010) and a purely environmental focus, while the above-mentioned QS and Times Higher Education rankings methodologically address all 17 SDGs.

Researchers from Indonesia emphasize the significant correlation between a university's position in the UI GreenMetric and the results of its sustainability case studies. Their analysis indicates that higher-ranked institutions are more likely to demonstrate a strong commitment to sustainability, responding effectively to global sustainability challenges. This finding underscores the importance of institutional commitment as a catalyst for sustainability research (Sari et al., 2023). Equally important are the digitalization and alignment of educational programs with the SDGs to increase the relevance of university curricula in promoting sustainable development (Artyukhov et al., 2021; Mobarak Karim et al., 2024; Zhavoronok et al., 2024). Successful integration of sustainable development into university practices requires a combination of information dissemination, mobilization, and structural measures at universities (Filho, 2011). At the same time, the human capital of a higher education institution and sustainable human resource management practices play an important role (Akbar et al., 2024). The experience of the University of Turin and its results in the UI GreenMetric ranking demonstrate the correctness of the administration's decision to create a special monitoring office for sustainable development, which has intensified activities to improve energy efficiency and implement renewable energy projects. As a result, the university has significantly reduced its carbon footprint, demonstrating how proactive measures can increase the sustainability of academic institutions (Baricco et al., 2018).

At the same time, there is very little research to date on analyzing green university rankings by country and region. It has been proven that universities with strong environmental sustainability practices tend to achieve higher results in academic rankings. At the same time, the overall environmental performance of a country has a positive impact on university rankings, which indicates that sustainability is beneficial not only for individual institutions but also for national education systems (Atici et al., 2021). Moreover, countries whose universities are increasingly implementing sustainable practices, as reflected in the results of international rankings, are progressing towards achieving the SDGs.

This article aims to analyze the role of universities, assessed through the prism of the UI GreenMetric methodology, in ensuring energy efficiency and sustainability of the national economy. As part of the study, the following research hypotheses were formulated:

H1: *There is a positive impact of the activities of universities, assessed through the prism of the UI GreenMetric methodology, on the energy efficiency of the countries in which these universities operate, expressed in the country's progress in achieving SDG 7.*

H2: *There is a positive impact of universities' activities, assessed through the prism of the UI GreenMetric methodology, on reducing the energy intensity level of primary energy of the country in which these universities operate.*

2. METHODOLOGY

In this study, "universities" are defined as a set of higher education institutions representing different countries and geographical regions of the world and included in the UI GreenMetric ranking based on the results of their activities in 2017–2022. Thus, the analysis is based not on individual institutions but on clusters of universities whose activities reflect the peculiarities of higher education in the respective countries and regions of the world.

This study is organized in three stages:

1) analysis of global trends in the development of sustainable universities according to UI GreenMetric;
2) assessing the role of higher education institutions in achieving the SDGs in 7 countries where these universities operate;
3) formalizing the role of universities in ensuring the energy efficiency of the respective national economies.

The input data collected were indicators characterizing a country's place in the annual UI GreenMetric ranking, which evaluates universities by their level of environmental sustainability and implementation of green practices. The ranking methodology involves analyzing the activities of universities by six broad indicators: "Setting & Infrastructure", "Energy & Climate Change", "Waste", "Water", "Transportation", and "Education & Research" (UI GreenMetric, 2024a), which are additionally taken for further analysis in the form of relevant sub-indices. The values used for the analysis are aggregate indicators representing the average scores of all universities in the country included in the annual ranking.

The second stage of the study collected data from the Sustainable Development Report (Sachs et al., 2024) on countries' progress in achieving SDG 7, expressed as an index that focuses on ensuring access to modern, reliable, sustainable, and affordable energy sources for all. The third stage of the study used the values of the energy intensity level of primary energy published annually by the country (World Bank, 2024). The summarized information on all input data is presented in Table 1.

Table 1. Input data characteristics

Indicators	Symbol	Data Source
UI GreenMetric	grmetric	UI GreenMetric data (UI GreenMetric, 2024a)
- Setting & Infrastructure	setinfr	
- Energy & Climate Change	enclchange	
- Waste	waste	
- Water	water	
- Transportation	transp	
- Education & Research	edres	
UN SDG 7 score	unsdg7sc	Sustainable Development Report (Sachs et al., 2024)
Energy intensity level of primary energy (MJ/USD 2017 PPP GDP)	energint	DataBank World Development Indicators (World Bank, 2024)

ttp://dx.doi.org/10.21511/kpm.08(2).2024.10

Table 2. Breakdown of sample countries by period and geographic region

Countries	2017	2018	2019	2020	2021	2022
General sample countries	76	79	79	75	78	79
E. Europe & C. Asia	11	12	12	13	12	13
East & South Asia	11	11	10	9	9	10
LAC	10	11	11	10	10	7
MENA	11	10	11	10	12	13
Oceania	–	1	1	1	1	1
OECD	30	31	31	29	29	29
Sub-Saharan Africa	3	3	3	3	5	6

The study period covers 2017–2022, for which the necessary statistical information was available and comparable. The distribution of the sample countries by geographical regions and by years is shown in Table 2, which allows us to identify regional differences and patterns in the environmental sustainability indicators of universities. However, it is worth noting that there are significant differences between countries within individual regions, which can significantly affect the overall results of the analysis. Aggregating data at the level of large geographic regions smooths out these differences, which is a significant limitation of the study. The results of the UI GreenMetric ranking are usually published annually in December based on the previous year's statistical data of universities collected from May to October. Therefore, for this study, the data of the UI GreenMetric ranking for 2018–2023 reflecting the activities of universities in 2017–2022 were used.

Scatter plots were used to assess the data distribution visually, and the Shapiro-Wilk test was used for formal statistical analysis to check the normality of the data. Causal patterns were identified using correlation and regression analysis. All calculations and visual representations of the data in this paper were performed using the STATA SE18.0 software package.

3. RESULTS AND DISCUSSION

3.1. Global trends in sustainable universities according to UI GreenMetric

The UI GreenMetric indicator system allows us to determine the level of sustainability efforts of universities that are directly related to their environmental responsibility and green transformation. Figure 1 demonstrates significant regional

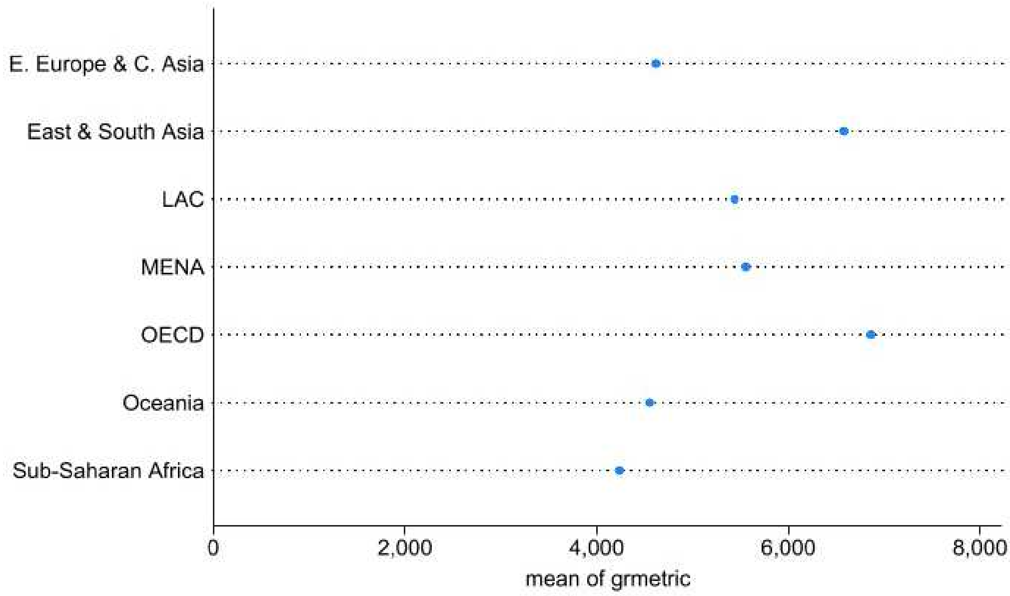

Figure 1. Average value of the overall score in the UI GreenMetric ranking by geographic region in 2022

differences in the sustainability performance of universities (based on 2022 data used in the UI GreenMetric rankings), given the different resources available and the policies and priorities in place in the respective countries and geographical regions.

In particular, OECD countries and East & South Asia have the highest values. OECD countries typically have robust environmental policies and strong regulatory frameworks that promote sustainable development across all sectors, including higher education. These frameworks encourage universities to adopt sustainable practices, such as energy efficiency measures, waste reduction strategies, and green transportation initiatives. For example, Sweden has a strict climate policy (UNESCO, 2021) that universities must adhere to, which leads to higher rankings for their sustainability performance. Also, universities in these regions often receive significant funds for sustainability projects from the government and the private sector. This financial support allows higher education institutions to invest in renewable energy sources, sustainable infrastructure, and research initiatives that address environmental issues. For example, many East Asian universities, particularly South Korea (Jung et al., 2022), have made significant investments in green technologies and campus sustainability programs, contributing to their high scores in the UI GreenMetric rankings.

The lowest values are for Sub-Saharan Africa and Eastern Europe & Central Asia. Many countries in Sub-Saharan Africa and Eastern Europe face significant economic challenges that limit their ability to invest in sustainability initiatives. According to the Times Higher Education Sub-Saharan Africa University Rankings (Times Higher Education, 2023), the financial resources available to higher education institutions in these regions are often insufficient to support comprehensive sustainability programs. Research also shows that universities with lower UI GreenMetric rankings often have fewer publications thematically related to the SDGs. While some East Asian universities have thousands of publications on sustainable development, institutions in sub-Saharan Africa and Eastern Europe typically publish significantly fewer papers on the topic (Sari et al., 2023).

3.2. The role of higher education institutions in achieving SDG 7

A correlation analysis was conducted to identify possible relationships between the results of universities in the respective countries in the UI GreenMetric and the progress towards achieving the SDG 7 of these countries for 2017–2022, presented in Table 3.

Thus, there is a stable direct positive correlation between the results of universities in the UI GreenMetric and the progress of the respective countries in achieving the SDGs, with a slight decrease in recent years. Moreover, among the ranking indicators, the “Setting and Infrastructure” indicators had the lowest correlation coefficients ranging from 0.183 to 0.276. This may be explained by the fact that universities prioritize other aspects of sustainability over infrastructure improvements due to pressing needs or available funding. For example, institutions may focus on improving energy efficiency or waste management practices rather than investing heavily in physical infrastructure upgrades (Sari et al., 2023). Moreover, in the UI GreenMetric methodology (UI GreenMetric,

Table 3. Correlations between university scores in UI GreenMetric and national progress on SDG 7

Variables	unsdg7sc					
	2017	2018	2019	2020	2021	2022
grmetric	0.421***	0.433***	0.410***	0.377***	0.373***	0.379***
setinfr	0.276**	0.186**	0.183**	0.198*	0.210**	0.266**
enclchange	0.315**	0.289**	0.247**	0.277**	0.296**	0.426***
waste	0.499***	0.471***	0.438***	0.364***	0.460***	0.367***
water	0.126**	0.304**	0.297**	0.267**	0.304***	0.262**
transp	0.370**	0.310**	0.321**	0.268**	0.192**	0.308***
edres	0.419***	0.485***	0.462***	0.481***	0.412***	0.331**

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

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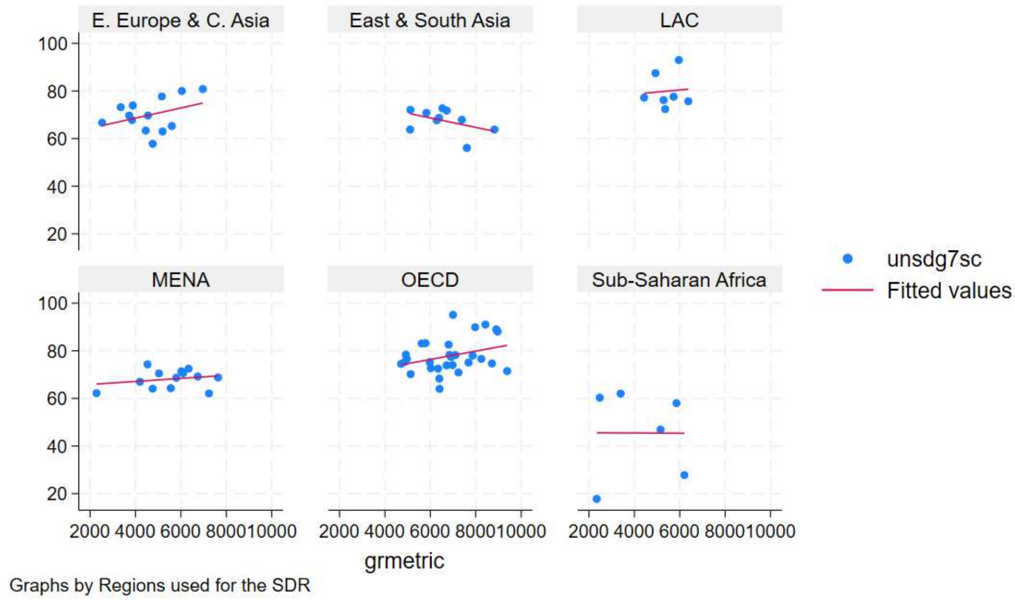

Figure 2. Scatter plots of UI GreenMetric university scores and national progress on SDG 7 by geographical regions in 2022

2024b), when determining the total number of points for the "Setting and Infrastructure" indicator, many indicators practically do not change over time and do not depend on the university administration's policies. We are talking, for example, about the percentage of undeveloped campus territory or territory covered by forests. Also, infrastructure projects are usually long-term and require significant investments for their implementation. Accordingly, the effects of these projects become noticeable only after a long period, while other short-term measures can ensure rapid progress on certain SDGs, particularly SDG 7.

Waste management indicators had the highest correlation coefficients (from 0.364 to 0.499) for the years under analysis. Moreover, these indicators fluctuated insignificantly, as such measures directly impact environmental sustainability. The correlation coefficients for the rest of the indicators were moderate, with minor fluctuations. The highest value of the correlation coefficient (0.426) in 2022 was obtained for the "Energy & Climate Change" indicator, whose components are most relevant to SDG 7, the country progress under which it is being studied.

In the regional context, there are certain differences in the direction of correlations (Figure 2). The relationship is positive for the 2022 data for Eastern Europe and Central Asia and OECD countries, but for East & South Asia, it is negative. For LAC, MENA, and Sub-Saharan Africa, the existence of a relationship is generally debatable. The correlation coefficients by region as of 2022 are shown in Table 4, which allows us to trace not only the relationship between the results of the respective countries' universities in UI GreenMetric and the progress of these countries in achieving SDG 7 but also individual ranking indicators. This allows us to identify the following patterns. For Eastern Europe & Central Asia, the strongest positive correlation with the achievement of SDG 7 is observed for the indicator "Waste", for LAC countries - with the indicator "Water", and for OECD countries – with the indicator "Energy & Climate Change". Instead, in East & South Asia, there is an inverse relationship with "Energy & Climate Change" and "Transportation". For Sub-Saharan Africa, there are mixed results, including a negative correlation between the achievement of SDG 7 and the indicator "Waste".

To identify the specifics of the relationship between the results of universities in UI GreenMetric and the progress of the respective countries in achieving SDG 7, elements of regression analysis were used (Table 5), as well as a scatter plot (Figure 3). The results are statistically significant and indicate

Table 4. Correlations between university scores in UI GreenMetric and national progress on SDG 7 by geographical regions in 2022

Variables	Eastern Europe & Central Asia	East & South Asia	LAC	MENA	OECD	Sub-Saharan Africa
grmetric	0.366*	−0.444*	0.077	0.232	0.320*	−0.005
setinfr	0.183	−0.250	0.048	0.206	0.166	0.017
enclchange	0.297	−0.558*	0.246	0.176	0.415*	0.336
waste	0.518*	−0.238	0.217	0.162	0.198	−0.634*
water	0.018	−0.377	0.636*	0.249	0.325*	−0.274
transp	0.413*	−0.574*	−0.436	0.063	0.313*	0.471
edres	0.120	−0.386	−0.273	0.393	0.303*	0.051

Note: *** p < 0.01, ** p < 0.05, * p < 0.1.

Table 5. Regression analysis of universities' contribution (measured by UI GreenMetric) to national progress on SDG 7

Variables	unsdg7sc					
	2017	2018	2019	2020	2021	2022
grmetric	0.004***	0.003***	0.003***	0.003**	0.003***	0.003***
	(0.001)	(0.0001)	(0.001)	(0.001)	(0.001)	(0.001)
Constant	65.14***	65.09***	74.32***	71.18***	68.89***	54.78***
	(5.222)	(3.819)	(3.493)	(6.796)	(6.479)	(6.199)
R-squared	0.177	0.187	0.168	0.142	0.139	0.143

Note: Robust standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

that the models explain between 13.9% and 18.7% of the variation in progress towards achieving SDG 7. In particular, a one-unit increase in the UI GreenMetric score of universities positively impacts progress toward SDG 7 (an average increase of 0.003 units).

The construction of regression models for each UI GreenMetric indicator allows us to trace the following patterns (Table 6).

The introduction of effective waste management systems in universities is the most significant fac-

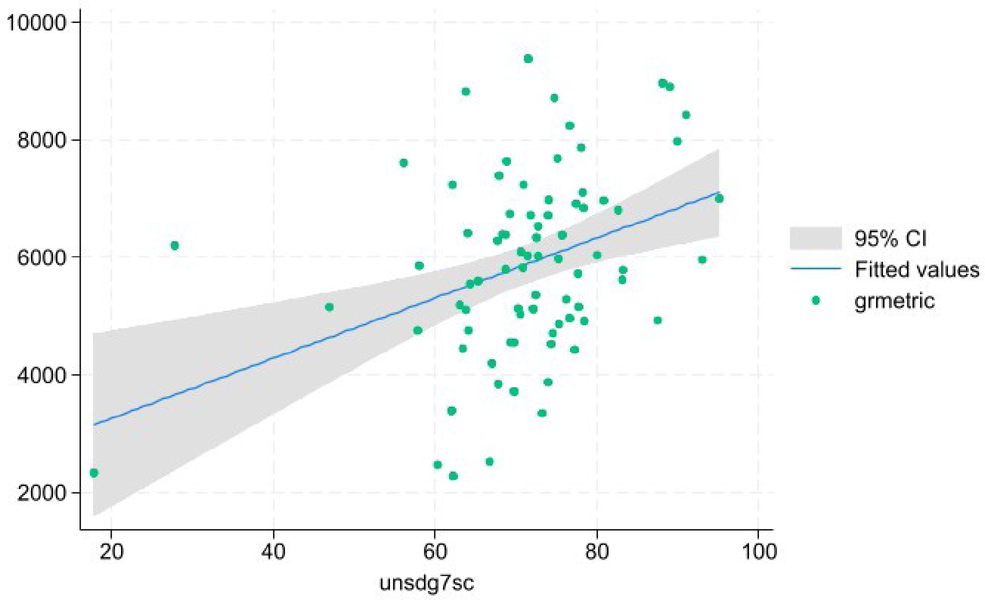

Figure 3. Scatter plot of UI GreenMetric university scores and national progress on SDG 7 in 2022

ttp://dx.doi.org/10.21511/kpm.08(2).2024.10

Table 6. Regression analysis of different vectors of universities' contribution (measured by UI GreenMetric) to national progress on SDG 7

Variables	unsdg7sc					
	2017	**2018**	**2019**	**2020**	**2021**	**2022**
setinfr	0.017***	0.010	0.009	0.010*	0.013*	0.016**
	(0.007)	(0.006)	(0.005)	(0.006)	(0.007)	(0.007)
R-squared	0.076	0.035	0.033	0.039	0.044	0.071
enclchange	0.012***	0.009***	0.007**	0.009**	0.011***	0.015***
	(0.004)	(0.0001)	(0.003)	(0.004)	(0.004)	(0.004)
R-squared	0.099	0.084	0.061	0.077	0.088	0.181
waste	0.015***	0.013***	0.010***	0.012***	0.014***	0.010***
	(0.003)	(0.003)	(0.002)	(0.003)	(0.003)	(0.003)
R-squared	0.249	0.222	0.192	0.133	0.211	0.135
water	0.007	0.016***	0.0129***	0.015**	0.018***	0.014**
	(0.007)	(0.006)	(0.005)	(0.006)	(0.006)	(0.006)
R-squared	0.016	0.092	0.088	0.071	0.092	0.069
transp	0.016***	0.013***	0.011***	0.010**	0.009*	0.012***
	(0.005)	(0.004)	(0.004)	(0.004)	(0.005)	(0.004)
R-squared	0.137	0.096	0.103	0.072	0.037	0.095
edres	0.018***	0.017***	0.0137***	0.016***	0.017***	0.012***
	(0.004)	(0.003)	(0.003)	(0.003)	(0.004)	(0.004)
R-squared	0.176	0.236	0.213	0.231	0.170	0.109

Note: Robust standard errors in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

tor affecting progress towards SDG 7, with model variability ranging from 0.133 to 0.249, the highest among all indicators. Effective waste management practices like recycling and composting can lead to resource recovery and energy production. For example, universities that implement comprehensive waste management systems can convert organic waste into biogas that can be used for energy production. Also, proper waste management reduces environmental pollution, including harmful air emissions, which is crucial for achieving SDG 7.

Universities' education and research activities also significantly impact SDG 7, with coefficients of determination ranging from 0.109 to 0.236. Universities integrating sustainability into their curricula equip students with the knowledge and skills to address energy challenges.

Other indicators also show a positive impact, albeit less pronounced. Thus, all UI GreenMetric indicators, and thus all aspects of sustainable university operations, are important for ensuring progress towards achieving SDG 7.

In general, the first hypothesis of this study, according to which the activities of universities have a positive impact on the energy efficiency of countries, as reflected in their progress towards achieving SDG 7, was confirmed. The analysis shows that universities with higher rankings tend to implement effective waste management systems and invest heavily in education and research related to sustainable development. This aligns with previous findings that emphasize the importance of institutional commitment to sustainability as a driving force for energy efficiency.

The strong correlation between university activities, particularly in waste management, and progress towards SDG 7 highlights the potential of universities as living laboratories for emulating best practices in their communities. By adopting innovative waste management practices, universities reduce their environmental footprint and contribute to national efforts to reduce energy intensity. This conclusion is in line with research showing that effective waste management can lead to resource recovery and energy production, thus supporting the achievement of SDG 7 (Maçin, 2021).

3.3. Energy efficiency as a key aspect of sustainable development of universities

The analysis of the relationship between UI GreenMetric and the energy intensity level of

Table 7. Correlations between university scores in UI GreenMetric and national energy intensity level of primary energy

Variables	energint					
	2017	2018	2019	2020	2021	2022
grmetric	−0.156*	−0.165*	−0.142	−0.197*	−0.236**	−0.286**
setinfr	−0.139	−0.007	−0.035	−0.057	−0.147	−0.181*
enclchange	−0.229**	−0.252**	−0.221	−0.153	−0.175	−0.299**
waste	−0.156	−0.231**	−0.254	−0.289*	−0.290**	−0.201*
water	−0.097	−0.120	−0.109	−0.036	−0.186*	−0.156*
transp	−0.069	−0.008	−0.012	−0.175	−0.122	−0.279**
edres	−0.077	−0.105	−0.121	−0.181	−0.271***	−0.371***

Note: *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

primary energy, an important indicator of energy efficiency in the country's economy and helps to understand how efficiently a country converts energy resources into economic products, is presented below. Table 7 shows the correlation analysis results between the universities' results in the UI GreenMetric and the energy intensity level of primary energy in the countries in which these universities operate.

The obtained values of the indicators indicate an inverse relationship (negative correlation coefficients). This indicates that a higher university score on the UI GreenMetric is associated with lower energy intensity. The densest among the analyzed indicators was the growing dependence on "Education & Research" (from −0.077 in 2017 to −0.371 in 2022), emphasizing the importance of developing educational programs and research in sustainable development to improve energy efficiency. The significant impact of university activities in energy and climate change on national energy efficiency has also been proven, as the correlation coefficients for "Energy & Climate Change" ranged from −0.2 to −0.3 units. Universities that favor sustainable development often implement energy-saving practices on their campuses. This includes using renewable energy sources, optimizing energy consumption, and reducing waste. Many countries with lower energy intensities have introduced strong regulatory frameworks that promote energy efficiency and sustainabil-

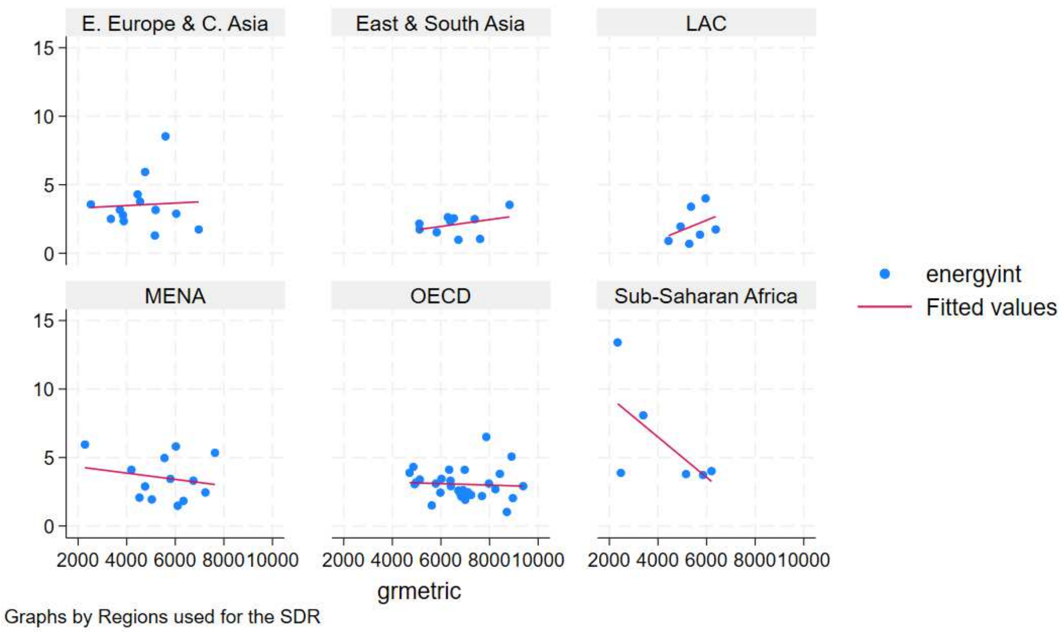

Figure 4. Scatter plots of UI GreenMetric university scores and national energy intensity level of primary energy by geographical regions in 2022

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Table 8. Correlations between university scores in UI GreenMetric and national energy intensity level of primary energy by geographical regions in 2022

Variables	E. Europe & C. Asia	East & South Asia	LAC	MENA	OECD	Sub-Saharan Africa
grmetric	0.057	0.361	0.375	-0.206	-0.064	-0.641*
setinfr	0.234	0.723**	0.532	-0.175	-0.022	-0.373
enclchange	-0.135	0.216	0.398	-0.436	-0.162	-0.412
waste	-0.061	0.558*	0.323	-0.114	-0.116	-0.081
water	0.179	0.378	0.062	-0.058	0.058	-0.489
transp	0.004	0.259	0.288	-0.112	-0.072	-0.767*
edres	0.275	-0.145	-0.206	-0.229	0.031	-0.780*

Note: *** p < 0.01, ** p < 0.05, * p < 0.1.

ity (European Commission, 2012). Universities in these countries and regions will likely align their activities with national targets, thereby implementing sustainable practices on campus. This alignment can lead to better performance in the UI GreenMetric rankings and, at the same time, contribute to the country's overall energy-efficient development.

At the same time, there are clear differences in the regional focus. In particular, the correlations are positive for East & South Asia and LAC, and for MENA and Sub-Saharan Africa, they are negative (Figure 4). For other regions, the relationship needs to be clarified.

The obtained correlation coefficients allow us to identify the dependencies between the analyzed indicators by geographical region (Table 8). Although the correlation between the overall UI GreenMetric score and the studied indicator was insignificant for East & South Asia, a positive correlation was confirmed for the "Setting & Infrastructure" and "Waste" indicators. In contrast, for Sub-Saharan Africa, there is a clear negative correlation between the energy intensity level of primary energy and the "Transportation" and "Education & Research" indicators.

The results of the regression analysis of the impact of universities' activities, assessed by UI GreenMetric, on the energy intensity level of primary energy in the respective countries are shown in Table 9 and Figure 5.

The results show that the impact of university activities on reducing the energy intensity level of primary energy of the respective countries is rather small, with the explanation of variation in the models ranging from 2.4% to 8.2%, with a tendency to increase in recent years. This is because many factors other than university activities influence the reduction of energy intensity: national energy policy, the use of energy-saving technologies in industry, economic conditions, etc. For example, countries with lower energy intensity often have comprehensive policies promoting renewable energy and efficiency in all sectors, not just education. At the same time, universities are contributing to SDG 7 through research and sustainability initiatives, and this impact is more systemic and comprehensive across different stakeholder groups. University actions such as implementing renewable energy projects or improv-

Table 9. Regression analysis of universities' contribution (measured by UI GreenMetric) to national energy intensity level of primary energy

Variables	energint					
	2017	2018	2019	2020	2021	2022
grmetric	−0.001	−0.001	−0.001	−0.001*	−0.001**	−0.001**
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Constant	4.980***	5.006***	3.781***	5.693***	5.665***	5.232***
	(0.726)	(0.730)	(1.206)	(0.976)	(0.920)	(0.797)
R-squared	0.024	0.027	0.006	0.039	0.056	0.082

Note: Robust standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

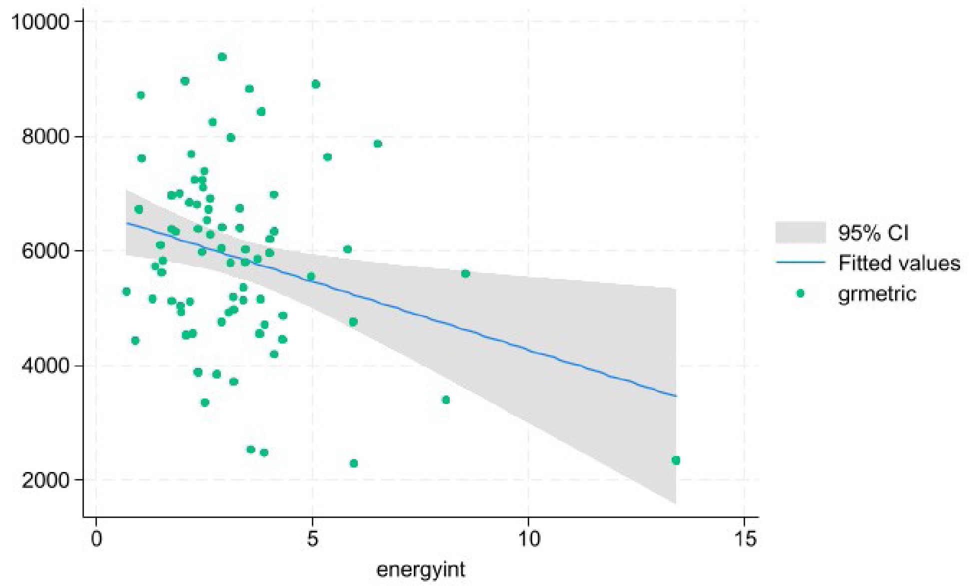

Figure 5. Scatter plot of UI GreenMetric university scores and national energy intensity level of primary energy in 2022

ing energy efficiency on campus are important. Still, they cannot lead to a significant reduction in energy intensity at the national level.

The results of the regression analysis on the impact of different vectors of university activities, assessed through individual UI GreenMetric indicators, on the energy intensity level of primary energy in the respective countries confirm the previous results and show a statistically insignificant relationship for most combinations (Table 10).

However, it is worth noting that waste management, despite the low explanatory power of the model, has an inverse effect on the country's energy intensity, and in 2012, transportation management and university education and research activities also had a significant impact.

Table 10. Regression analysis of different vectors of universities' contribution (measured by UI GreenMetric) to national energy intensity level of primary energy

Variables	energint					
	2017	2018	2019	2020	2021	2022
setinfr	–0.001	–0.001	–0.001	–0.001	–0.001	–0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
R-squared	0.019	0.000	0.004	0.003	0.021	0.033
enclchange	–0.001	–0.001	–0.001	–0.001	–0.001	–0.002*
	(0.001)	(0.000)	(0.001)	(0.001)	(0.001)	(0.001)
R-squared	0.053	0.063	0.005	0.002	0.018	0.089
waste	–0.001	–0.001*	–0.001	–0.001*	–0.001*	–0.001*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
R-squared	0.024	0.053	0.000	0.084	0.084	0.040
water	–0.001	–0.001	–0.001	–0.001	–0.001	–0.002
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
R-squared	0.009	0.014	0.008	0.001	0.021	0.024
transp	–0.001	–0.000	–0.001	–0.001	–0.001	–0.002*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
R-squared	0.006	0.000	0.002	0.031	0.015	0.078
edres	–0.001	–0.000	–0.001	–0.001	–0.001*	–0.002**
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
R-squared	0.006	0.011	0.001	0.033	0.073	0.137

Note: Robust standard errors in parentheses. *** p < 0.01, ** p < 0.05, * p < 0.1.

ttp://dx.doi.org/10.21511/kpm.08(2).2024.10

To summarize, the second hypothesis stated that universities' activities positively impact reducing energy intensity in the countries where these institutions operate. The correlation analysis revealed an inverse relationship between the UI GreenMetric ranking and national energy intensity levels, indicating that higher-ranked universities are usually located in countries with lower energy intensity. This finding suggests that universities contribute to lowering energy intensity by committing to sustainability practices and research initiatives focused on energy efficiency.

The observed negative correlation between the UI GreenMetric ranking and the energy intensity level of primary energy indicates that higher-ranked universities are usually located in countries with more efficient energy systems. This relationship can be explained by countries with lower energy intensity often establishing regulatory frameworks promoting energy efficiency and sustainability. Consequently, universities working within these frameworks are more likely to align their activities with national goals, improving sustainability practices.

However, it is important to recognize that while universities are making positive contributions in this area, their efforts are insufficient to reduce energy intensity significantly. Furthermore, it is unlikely that immediate effects can be expected from the time-consuming training of new energy leaders and research in this area.

The regression analysis results in this study indicate that the models explaining variations in energy intensity levels account for smaller percentages (from 2.4% to 8.2%) compared to the models assessing the university's activities related to SDG 7. In the context of individual UI GreenMetric indicators, the results were generally statistically insignificant for most indicators, except for waste management, transportation management, and educational and research activities in 2022, which indicates the presence of other factors that reduce the energy intensity level of primary energy. These facts indicate the need for further research into the factors influencing energy intensity and the contribution of higher education institutions. Future research should examine how external variables, such as economic conditions, technological advances, and policy changes, interact with university initiatives to ensure energy efficiency and sustainability of the national economy.

Although this study provides valuable insights into the role of universities in promoting sustainable development and their relationship to national energy efficiency, several limitations should be recognized. One of the challenges is the diversity of sustainable university practices, which are difficult to assess with a single tool. Differences in institutional capacity, cultural context, and available resources can affect how universities approach sustainability initiatives (Boiocchi et al., 2023). Also, the effectiveness of sustainability practices at universities is often affected by regulatory and legal restrictions, as well as the climatic conditions of the respective countries.

In addition, a significant limitation of this study is the limitations directly related to the UI GreenMetric ranking methodology. As with other ranking measurements, there is always a non-zero probability of incomplete or inaccurate data being submitted by participating universities. As noted in previous studies, universities may leave fields blank, provide zero values, or report illogical numbers due to outliers or errors in the data collection process (Presekal et al., 2018). Also, this ranking requires several methodological improvements to increase its rigor and specificity (Galleli et al., 2022).

Also, one of the main methodological limitations of the study is the grouping of universities and relevant countries by enlarged world regions, which can significantly level the intra-regional variability of sustainability indicators. For example, the East & South Asia region includes both highly developed economies of East Asia (Japan, South Korea) and developing countries with different technological and infrastructural progress levels. This aggregated approach can lead to a significant statistical error and mask significant differences in the performance of universities and countries within the regions. In the future, a more detailed analysis should be conducted at the level of individual countries or regions.

CONCLUSIONS

This article aimed to analyze the role of universities, assessed through the prism of the UI GreenMetric methodology, in ensuring energy efficiency and sustainability of the national economy.

The study revealed significant regional differences in implementing sustainable development principles at universities directly related to the available resources, environmental policies, and countries' priorities. Higher education institutions in OECD countries and East and South Asia demonstrate the highest sustainability scores, as they have strong regulatory frameworks, significant funding, and consistent government policies in sustainability. Instead, universities in Sub-Saharan Africa and Eastern Europe face economic constraints, which complicate their green transformation.

The hypothesis that universities positively impact the progress towards achieving SDG 7 by the respective countries was confirmed. The most significant factor was waste management, with correlation coefficients ranging from 0.364 to 0.499, demonstrating higher education institutions' potential as "living laboratories" for sustainable development. At the same time, the regional analysis revealed significant differences in correlations: from clearly positive in Eastern Europe & Central Asia and OECD countries to negative in East and South Asia.

Correlation and regression analyses showed a limited but important contribution of universities to reducing countries' energy intensity. A negative correlation was found between the scores of universities in the UI GreenMetric ranking and the energy intensity level of the primary energy indicator, which indicates a relationship between institutional sustainability of higher education and national energy efficiency. Educational and research initiatives and energy and climate change activities were the most influential. At the same time, the study confirmed that the explanatory power of the built models is insignificant (2.4-8.2%), as a set of external factors, including national energy policy, economic conditions, and technological progress, influences the level of energy intensity.

At the same time, the study has several limitations and prospects for further research. The main challenges are the variability of sustainable practices of universities, the complexity of their unified assessment, and the risks of inaccurate data in the UI GreenMetric ranking. Grouping universities into aggregated global regions can lead to significant statistical error due to the concealment of significant intra-regional differences. These limitations underscore the need for more disaggregated research, focusing on country and region-specific analysis and considering their unique institutional, economic, and cultural characteristics.

AUTHOR CONTRIBUTIONS

Conceptualization: Denys Smolennikov, Alina Raboshuk, Oksana Drebot, Zhanna Oleksich.
Data curation: Oksana Drebot, Zhanna Oleksich, Liudmyla Huliaieva.
Formal analysis: Alina Raboshuk, Liudmyla Huliaieva.
Funding acquisition: Denys Smolennikov.
Investigation: Alina Raboshuk.
Methodology: Denys Smolennikov, Alina Raboshuk, Liudmyla Huliaieva.
Project administration: Denys Smolennikov, Alina Raboshuk.
Resources: Oksana Drebot, Zhanna Oleksich.
Supervision: Denys Smolennikov, Alina Raboshuk.
Validation: Oksana Drebot, Zhanna Oleksich.
Visualization: Oksana Drebot, Zhanna Oleksich.
Writing – original draft: Denys Smolennikov, Alina Raboshuk, Liudmyla Huliaieva.
Writing – review & editing: Alina Raboshuk.

ttp://dx.doi.org/10.21511/kpm.08(2).2024.10

FUNDING

Denys Smolennikov gratefully acknowledges support from the Jean Monet module project "Transparency. Accountability. Responsibility. Governance. Europe. Trust. Sustainability" financed by the Erasmus+ program (101085395 – TARGETS – ERASMUS-JMO-2022-HEI-TCH-RSCH).

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