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HIERARCHICAL MODELLING OF SUSTAINABLE ENERGY CONSUMPTION PROFILES FOR DEVELOPED AND DEVELOPING COUNTRIES

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Abstract

Purpose: The purpose of this paper is to investigate how energy consumers evaluate economic, social, and environmental factors in developing and developed countries, and to compare developed and developing countries in terms of the impact of these factors on consumer decisions in dimensions of sustainable energy consumption.

Methodology: To achieve this goal, the authors will use data from a survey conducted in five countries representing developing and developed economies, and then use hierarchical modelling to assess consumer preferences regarding sustainable energy consumption. **Findings:** The analysis of the results indicates that economic, social and environmental factors play an important role in shaping consumer decisions on sustainable energy consumption, with their importance varying according to the level of development of the country. The income and energy price are important factors in both developed and

developing countries, but more crucial in developed countries. Social factors are perceived as more important in developing countries. The environmental factors are crucial in developing and developed countries, but this acceptance was higher and more uniform in developed countries.

Originality: This study offers a multidimensional framework for understanding sustainable energy consumption. Besides, the authors assess preferences not only for one group of countries, but also the differences in consumer preferences regarding energy supply between developing and developed countries. This paper provides empirical evidence on why the theory of energy and fuel poverty treats this phenomenon separately in relation to developing and developed countries. Additionally, for the first time during the research process, the hierarchical modeling method.

Keywords: hierarchical modelling, sustainable development, energy, consumption preferences, developed and developing countries

JEL codes: C11, C80, P46, Q01, Q43, H41.

1. Introduction

Sustainable development has emerged as a central paradigm guiding socio-economic policies in the 21st century (Güler & Aydinbaş, 2024). Its ultimate goal is to meet the needs of the present without compromising the ability of future generations to meet their needs. One of the key elements of sustainable development is sustainable consumption, which balances economic, social and ecological goals (Pankov et al., 2021; Saxena, 2024). The literature highlights the importance of sustainable consumption and the role of human behaviour in shaping consumption patterns (Hasbullah et al., 2019; Sesini et al., 2020; Strielkowski et al., 2022; Vargas-Merino et al., 2023). Sustainable consumption is recognized as a complex phenomenon. Previous studies have explored individual motivations and contextual influences on sustainable behaviour (Li et al., 2024), often drawing on theories such as the theory of planned behaviour, norm activation theory, and value-belief-norm theory (Han, 2021). Several conceptual models have also incorporated socio-psychological and structural determinants of sustainability-related decisions (Topal et al., 2021), while technological innovations like virtual reality have been proposed as tools for fostering behavioural change (Zhang & Song, 2022). Due to the growing importance of energy in human life and the economic development of the country, the concept of sustainable consumption has also been applied to energy in the literature, where it is referred to as sustainable energy consumption (Feldhaus et al., 2022; Kumar & Nayak, 2024), which is the consumption of energy that involves consuming the necessary amount of energy but in an environmentally responsible, socially just and economically viable manner. As energy consumption continues to grow worldwide and remains unevenly distributed (Sahu & Mahalik, 2025),

addressing energy-related issues within the framework of sustainable development becomes increasingly urgent.

Despite the growing interest in sustainable development and sustainable consumption in relation to energy, the literature shows significant research gaps. Most of the current work related to sustainable consumption focuses on behaviors in relation to goods or sectors such as tourism, food, and clothing (Sesini et al., 2020; Han, 2021), while energy consumption patterns or determinants of household energy consumption receive less attention. Moreover, although numerous studies have highlighted the importance of structural conditions (Hirth et al., 2023; Vargas-Merino et al., 2023), and there are analyses showing which factors influence energy consumption levels (Dam & Sarkodie, 2023; Johansson & Pirouzfar, 2019; Kuhe & Bisu, 2020; Tsemekidi Tzeiranaki et al., 2023; Zaharia et al., 2019; Zou et al., 2025), there is still a lack of integrated analysis that examines how economic, social, and environmental factors are jointly valued by households, and how these factors influence on consumers‘ choices concerning energy.

Moreover, there are numerous studies on energy poverty in developing countries (Leal Filho et al., 2024; Abdi et al., 2025) and, to a lesser extent, in developed countries (Nagaj, 2022), and numerous studies emphasize the importance of structural conditions (Hirth et al., 2023; Vargas-Merino et al., 2023), or comparative studies between countries with similar levels of development. However, there is still a lack of an integrative comparative analysis that examines how economic, social and environmental factors affect consumers' energy consumption decisions in different regions of the world, i.e., a comparison between developing and developed countries.

The purpose of this paper is to investigate how energy consumers evaluate economic, social, and environmental factors in developing and developed countries, and to compare developed and developing countries in terms of the impact of these factors on consumer decisions in dimensions of sustainable energy consumption. To achieve this goal, the authors will use data from a survey conducted in five countries representing developing and developed economies, and then use hierarchical modeling to assess consumer preferences regarding sustainable energy use.

This study contributes to the literature in three ways. First, by offering a multidimensional framework for understanding sustainable energy consumption. Since the concept of sustainable energy consumption includes three dimensions (economic, social, environmental), the preferences of end consumers in relation to energy will be assessed in relation to economic, social and environmental factors. The authors will propose an assessment model that will allow, on the one hand, to harmonize these three dimensions of the sustainable approach and, additionally, to examine the share of importance of each of these dimensions (factors) in the decision-making process. Second, the authors will analyze and assess whether there are and if so what are the differences in consumer preferences in relation to energy supply in developing and developed countries. Based on these findings, the authors will determine in which dimensions there are differences. This may provide empirical evidence why the theory of energy/fuel poverty treats this phenomenon separately in

relation to developing and developed countries. Third, during the research process and the factor assessment process, the hierarchical modeling method will be applied, which, to the authors' knowledge, has not been used in this research topic so far.

The structure of the paper is as follows. After the introduction, the theoretical background to the study of the issue is presented, followed by the methods and materials used in the research process. The next part of this paper is the results, which is continued by discussions and conclusions that are a collection of the main findings in this paper.

2. Theoretical Background of Analysis

2.1 The concept of sustainable development

According to the concept of sustainable development, development should meet the needs of present generations without compromising the ability of future generations to meet their own needs. The literature clearly indicates the three-dimensional nature of this concept - it includes economic, social and environmental dimensions (Pankov et al., 2021; Vargas-Merino et al., 2023). Sustainable consumption, which is an integral part of the sustainability concept, refers to the responsible use of goods and services in a way that meets basic needs while minimising negative environmental impacts and promoting social justice (Li et al., 2024). Popular and widely implemented technologies, such as monitoring, artificial intelligence or virtual reality, should be tools that support environmentally friendly behaviour (Zhang & Song, 2022; Ramli et al., 2024). It is also pointed out that the integration of environmental issues into science has been somewhat neglected and needs to be more widely integrated into sustainability issues (Nkaizirwa et al., 2021). Environmentally conscious consumers influence not only the level of consumption, but also the development of the closed economy (Corbier et al., 2025). As the theory of sustainable development indicates, contrary to popular opinion, pro-environmental measures such as, for example, increasing renewable energy consumption do not negatively affect economic growth (Bhuiyan et al., 2022). Economic and social factors are also important. As indicated by literature socio-economic factors influence the level of energy consumption (Balsamo et al., 2023), the development of the energy sector (Siksnelyte-Butkiene, 2021). In the context of sustainable development, the attention is paid to the proper implementation of technology, that is, such that it ensures sustainability and does not cause social exclusion. Popular and widely implemented technologies, such as monitoring, artificial intelligence or virtual reality, should be tools that support environmentally friendly behaviour (Zhang & Song, 2022; Ramli et al., 2024).

The literature emphasizes the role of behavioural factors (Nagaj & Žuromskaitė, 2021), using theories such as the Theory of Planned Behaviour (Cosma, 2024), Norm Activation Theory or Value-Belief-Norm Theory (Han, 2021; Topal et al., 2021). In this way, the role of consumer behaviour and sustainable behaviour is indirectly indicated. Bolis et al. (Bolis

et al., 2023) argue that many human factors contribute to sustainable behaviour, and the interest in sustainable consumption is growing (Hasbullah et al., 2019). An analysis of the theory of sustainable development indicates that an analysis of development or consumer behaviour should be based not only on an analysis of the increase in the amount of goods produced or consumed and economic efficiency, but also on an assessment of the social aspect, or whether social exclusion is taking place, and the environment. The analysis should therefore cover the three dimensions of sustainability together. Despite the growing interest in sustainability theory, there are still significant research gaps in the literature. Most studies on sustainability or sustainable consumption focus only on sectors such as tourism, fashion or food (Sesini et al., 2020; Han, 2021; Nagaj & Žuromskaitė, 2023), and energy consumption issues are analysed less frequently. If the literature analyses the situation in the energy sector or the attitude towards energy consumption, then it focuses only on the economic and environmental aspects (Podesta et al., 2021; Scurati et al., 2021; Misztal et al., 2022; Dam & Sarkodie, 2023) or on a combination of social and economic factors (Kuhe & Danladi, 2019; Makridou et al., 2024). However, there are few multidimensional analyses, and there is a particular lack of analyses that examine the combined impact of economic, social and environmental factors or how they influence energy decisions.

2.2. Sustainable energy consumption

Sustainable energy consumption (SEC) is the application of sustainability principles to the field of energy and the energy sector. As indicated by the literature review on sustainability, three pillars should form the basis for assessing sustainable consumer attitudes and consumption patterns. It includes increasing energy efficiency, reducing greenhouse gas emissions and promoting renewable energy sources in a socially just and economically viable manner (Feldhaus et al., 2022; Łukasiewicz et al., 2022). Technological innovations - such as smart grids or energy-efficient appliances - which are increasingly being implemented, including in urban and academic environments, to optimise energy consumption (Herrera Burstein & Goñi Avila, 2024; Zheng et al., 2024), also fit into the concept of promoting sustainable energy consumption.

However, as the literature indicates, the effectiveness of these solutions largely depends on consumer behaviour and acceptance of such solutions. Both internal motivations (values, emotions, social norms) and contextual conditions (infrastructure, energy prices, energy policy) are important (Elhoushy & Lanzini, 2020; Elhoushy & Jang, 2023; Kumar & Nayak, 2024). Consumer preferences may vary depending on the level of development of a country. Similarly, the development of the energy sector depends on various factors. In developed countries, energy taxes, investment in research and development and trade openness are key, while in developing countries economic growth and access to investment are more important (Dokas et al., 2022; Misztal et al., 2022). SEC correlates strongly with socio-economic development. Yumashev et al. (Yumashev et al., 2020) evaluating the influence of the Human Development Index on the level of energy consumption indicate that a

country's level of development as measured by the HDI depends, among other things, on energy consumption, the level of urbanisation, GDP and the use of clean energy sources. This shows that a country's development is linked not only to economic growth, but also to the use of renewable energy (Bulut & Apergis, 2021; Uwaga & Ogunbiyi, 2024) and the level of energy consumption. Additionally, this indicates that sustainable energy consumption measures are linked to multiple factors, which in the context of our study justifies the need to analyse multidimensionally and the impact of all three factors of sustainable energy consumption.

Despite research advances, there is still a lack of multidimensional analyses integrating behavioural and sustainable energy consumption approaches. Few studies focus on how households assess energy consumption, including no multidimensional studies of assessment in the context of both economic factors, social equity and environmental responsibility. Furthermore, the literature does not provide sufficient comparative data on regional differences, or comparisons between developed and developing countries, which limits understanding of consumer preferences in different parts of the world.

2.3. Determinants of energy consumption

According to the findings in the literature, energy consumption depends on a number of factors. The most important ones identified in the literature are economic growth, population and the level of industrialisation, which increase energy consumption (Rasanga et al., 2024; Zou et al., 2025). In turn, health spending or environmental taxes can reduce it (Zaharia et al., 2019). In developed countries, consumer decisions are influenced by, among other things, lifestyle, access to innovation, the price of energy and the quality of the regulatory system (Nagaj & Žuromskaitė, 2023; Addai et al., 2024). In developing countries, infrastructure constraints (access to the energy grid), dependence on inefficient energy sources, income and institutional barriers play a dominant role (Johansson & Pirouzfar, 2019; Kuhe & Danladi, 2019; Nguyen et al., 2021; Falcone, 2023; Nagaj, 2024).

Unequal access to or limited consumption of energy leads to energy poverty in developing countries or fuel poverty in developed countries. In regions such as sub-Saharan Africa and Latin America, infrastructure constraints, income inequality and poor governance result in limited access to clean and affordable energy (Leal Filho et al., 2024; Soto & Martinez-Cobas, 2025). In developed countries, fuel poverty mainly affects low-income households, for whom high energy prices and low energy efficiency in buildings are major barriers (McCoy & Kotsch, 2021; Nagaj, 2022). This impact is also exacerbated by so-called rebound effects and limited access to energy efficiency programmes (Jin, 2020).

Vulnerable consumers, such as people with disabilities or the poor, may be vulnerable to social benefits or face additional barriers to accessing energy and modern energy sources (Nagaj, 2022; Oteng & Gamette, 2025). Policy tools such as energy vouchers or environmental taxes show varying effectiveness depending on market and regulatory conditions (Podesta et al., 2021; Rabhi et al., 2024).

Concluding, the literature identifies numerous determinants of energy consumption and understands by energy consumption both physical energy consumption and energy services. In general, these can be cumulated into a group of factors related to access to services and related to the financing of energy consumption and energy services. Importantly for energy and fuel poverty theory, however, social factors are highlighted as being significantly able to determine access to energy consumption. There are, however, some research gaps here. These are usually studies on the level of consumption, not on how consumers evaluate those factors that determine their energy consumption choices. The literature review done here, however, shows that consumers' evaluation of energy consumption factors should be carried out taking into account all three dimensions of sustainable energy consumption (economic, social and environmental factors), as they can all determine consumer choices. Without this, there is limited understanding of how consumers make decisions on energy consumption in the context of sustainability. The theoretical background of analysis showed which factors should be taken into account in assessing differences in perceived sustainability factors between developed and developing countries.

2.4. IT aspects of data modelling and data analysis

Advancements in algorithmic techniques and data mining tools remain central to the development of intelligent IT systems. Ana-Maria Ramona et al. (2020) discussed data mining algorithms, highlighting their critical role in knowledge extraction processes. Their exploration offers foundational insights into algorithmic selection in IT systems. Armyanova and Aleksandrova (2023) provided valuable discussions on machine learning design patterns, emphasizing reusable solutions and frameworks that are beneficial for enhancing analytical efficiency. Dogaru et al. (2019) developed an optimization model using big data analytics to measure CO2 sequestration. Their study demonstrates how big data frameworks can support sustainability analytics effectively. Georgescu et al. 2022) analyzed the impact of digital transformation during the COVID-19 pandemic, offering insights into performance management through digital tools, which are critical for strategic IT planning.

Effective IT project management in academic institutions requires flexible delivery models tailored to organizational needs. Kuyumdzhiev 2020) proposed an IT solution delivery model for universities, addressing the challenges of timely deployment and emphasizing efficiency in IT project management and implementation. Mileva 2024) explored big data prediction for seasonal fluctuations in marine traffic, effectively illustrating big data's capability to handle complex temporal analytics. Parusheva & Pencheva (Parusheva & Pencheva, 2020) modelled business intelligence systems using Unified Modelling Language (UML), underscoring the importance of structured modelling techniques in enhancing business operations.

Virtual tools also were applied to analyse the financial and technology sectors. The fintech sector increasingly adopts virtual tools to foster scalability and innovation in digital

financial services. Petrov et al. (Petrov, Stoev, et al., 2021) examined the adoption of virtual tools in fintech startups, demonstrating the integration of digital solutions to enhance the operational scalability of financial technologies. Petrov et al. (Petrov, Radev, et al., 2021) presented a systematic design approach for infrastructure digitalization services, emphasizing the use of structured methodologies for effective data infrastructure management. Petrov et al. (Petrov, Stoev, et al., 2021) further highlighted risk management processes within information systems development, underscoring structured analytical approaches to mitigate potential project risks. Polkowski et al. 2020) evaluated aggregated query plans using heuristic methods, illustrating the optimization of database queries, which is vital to efficient data analysis operations.

Even in traditionally analog industries, digitalization efforts are reshaping operational paradigms and introducing new best practices. Stoyanova (Stoyanova, 2020) addressed digitalization practices in construction, identifying best practices critical for effective IT integration into traditionally non-digital sectors. Sulova et al. 2022) proposed a predictive analytics framework tailored to logistics, reinforcing the practical utility of machine learning in enhancing predictive capacities within logistical operations. Sulova & Marinova(Sulova & Marinova, 2024) introduced a metadata management framework for data lakes, crucial for ensuring data quality and integrity in complex analytical environments. The literature review conducted here indicates that these modelling techniques are widely used to analyse phenomena related to IT development, which also confirms the authors' claim that these methods are useful for analysing processes in the energy sector and, in our case, for assessing consumer behaviour in relation to energy. Such method was not used in analysis of the energy sector, so it confirms contribution of this paper to the literature.

3. Methods and Materials

3.1. Survey Design and Data Collection

The aim of this paper is to model sustainable energy consumption profiles, broken down into developed and developing countries. The modelling will be based on evaluation of the importance of three groups of factors of sustainable energy consumption that shape the end-users' decision with regard to energy. Based on the theory of sustainable development and sustainable consumption, a group of economic, social, environmental factors are considered.

Data for modelling were collected using a survey technique, where respondents were asked to rate the importance of factors on a 5-point Likert scale (from 1 - not at all important, to 5 - very important). The sampling method was random, i.e. the questionnaire was distributed to all consumers in the countries surveyed who have access to the Internet, i.e. the CAWI (Computer-Assisted Web Interview) technique was used. However, it should be emphasised that the selection of countries was purposive, i.e. countries were chosen to

represent developing and developed countries. This was important for the purpose of the survey, because according to energy poverty theory, the level of energy poverty, which is determined, among other things, by the level of energy consumption, varies according to its causes. Therefore, it was important that about half of the respondents represented societies that should be in energy poverty due to financial factors (so-called fuel poverty), and the other half of the respondents represented societies where, according to the theory, energy poverty should predominate due to a lack of access to energy due to infrastructure and network factors, i.e. non-financial factors. The survey was distributed in October 2024-January 2025 and April 2025. The number of respondents was 261, of which the number of respondents for the developing countries was 108 and for the developed countries 153. The number of questionnaires used, 261, means that this was the number of fully completed questionnaires by adult respondents. During the survey, data were collected from adult energy consumers who pay their energy bills. This resulted in importance ratings of factors from three dimensions of sustainable energy consumption preferences. The first of these were economic factors, within which respondents rated the following factors:

- income (Q1.1),
- price of energy (Q1.2),
- costs of connecting to the energy grid (Q1.3).

Under social factors, consumers' attitudes towards the following were examined:

- energy subsidies for the poorest (Q2.1),
- providing energy to the poorest for free (Q2.2),
- preference for implementing the ban on disconnecting the poorest from the energy grid (Q2.3).

In terms of environmental factors, respondents assessed the following areas:

- preference for energy consumption from RES over fossil fuels (Q3.1),
- preference for companies with a zero carbon footprint(Q3.2),
- acceptance to pay more for green energy (Q3.3),
- willingness to pay more if the company has no negative environmental effect (Q3.4).

The analysis will be estimated separately for developed countries and developing countries, which will allow for a comparative analysis of consumer profiles from different parts of the world due to their level of development. The division into developed and developing countries was made on the basis of human development index values, where countries with index values of 0.8 and above were classified as developed countries, while countries with index values below 0.8 were classified as developing countries. Thus, respondents from the United Kingdom, United Arab Emirates, and Poland were counted as representing developed countries, while respondents from Bulgaria, Jordan represent developing countries. It was also important to the authors that the countries represent different regions. Poland and Bulgaria represented the EU countries, the UK the non-EU region, while United Arab Emirates and Jordan are located in the Middle East region. As mentioned, due to the purpose of the study, a division according to energy/fuel poverty theory into developing and highly developed countries was most relevant.

3.2. Research process, hierarchical modelling and analytical tools

The research process was a multi-stage process. The literature analysis and critique method was used to identify factors for sustainable energy consumption. This made it possible to identify the key dimensions of sustainable consumption, identify the necessary questions to assess its areas within the survey. In addition, it made it possible to identify which methods had been used in the literature so far and to conclude that the application of hierarchical modelling would be a novelty and a contribution to the literature.

In the next stages of the research process, the importance of factors was assessed using descriptive statistical methods, and hierarchical modelling was applied, the application of which provided answers to the research questions posed in this thesis. Figure 1 shows the methodological development of the research process.

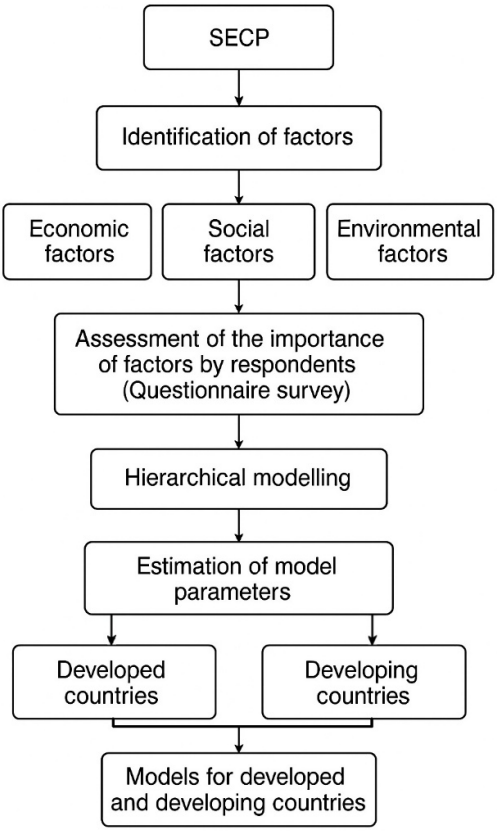

Figure 1. Research model process

Source: Own elaboration.

The use of the hierarchical modelling (or hierarchical linear modelling - HLM or multilevel modelling) method in the analysis of the validity of sustainable energy consumption factors has both theoretical and empirical justification, as it allows us to analyse complex data structures, such as we are dealing with in our study, and multilevel relationships. Thus, this method allows for a better understanding of the complexity of consumption mechanisms. In our study, we assume that sustainable energy consumption is determined by three groups of factors. The applied hierarchical modeling method allows for taking into account the simultaneous influence of factors at different levels of data aggregation in the analysis. This method also allows for controlling estimation errors of the influence of individual factors on sustainable energy consumption. The applied hierarchical modeling method also allows for examining interactions between variables, which creates the possibility of modeling intergroup variability. And the most important issue, the hierarchical modeling method allows for inference with small samples in groups. Hierarchical modeling allows for obtaining better parameter estimates because it takes into account the correlation between observations within samples (Raudenbush & Bryk, 2002; Goldstein, 2011).

As part of the application of hierarchical modeling, ETL procedures are performed to recode from a 5-point Likert scale to a 3-point Likert scale. The responses in the generated data set are coded as follows: „1" not important and not important at all, „3" – neutral, „5" – important and very important. All variables are on a nominal scale. Adequate statistical procedures are carried out in PSPP, JASP and classification techniques in Altair One Studio (the former Rapid Miner).

Using frequency tables and cross-tabulations reveals some aspects of respondents' opinions on energy consumption. But frequency tables give a one-dimensional view and cross-tabulation give a two-dimensional view. Seeking in-depth dependencies 3- and 4-dimensional aspects have to be revealed. These n-dimensional aspects may be visualized and accepted by people using hierarchical visualization.

Many software tools may be used for data visualization. Our previous experience gives us the opportunity to use Altair AI Studio with an academic license. Since our dataset is not so big, Altair AI Studio may be used with the free license. Since the software Altair AI Studio is tested with other datasets and it is stable, it is used for visualization.

In Altair AI Studio the following process is created. This process is shown in Figure 2.

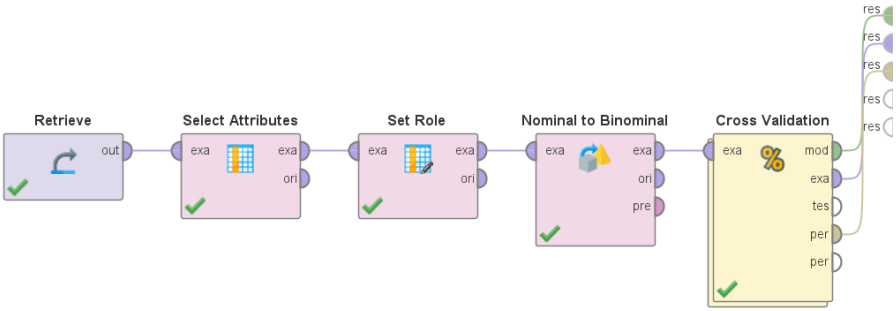

Figure 2. The main process in Altair AI Studio
Source: Own elaboration.

The Retrieve operator is used to load the dataset. The Select Attributes operator is used to select some of the columns of the dataset. The „Set Role" operator and the „Nominal to Binominal" operators are used for the variable "country". The Cross Validation is used to make hierarchical clustering. Figure 3 shows how the operator cross validation is carried out.

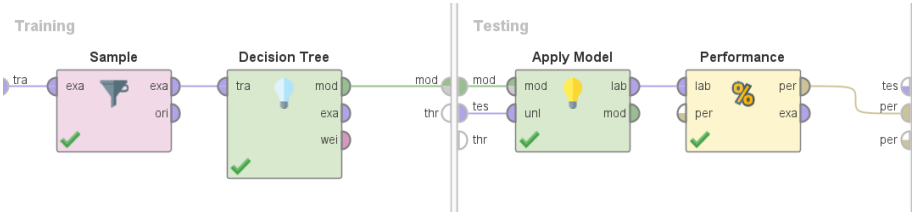

Figure 3. The Cross Validation operator in details.
Source: Own elaboration.

The dataset is balanced with sample ratio of 0.1. The Decision Tree parameters are the following – Criterion: gain ratio; maximal depth: 10; applied pruning, confidence: 0.25; applied prepruning; minimal gain: 0.01; minimal leaf size: 2; minimal size for split: 4, number of prepruning alternatives: 3. We give the parameters of the Decision Tree operator because if other researchers want to make a replication of the research, it is important to fine-tune the Decision Tree. The Performance operator is with the following setup – main criteria: first; accuracy is checked.

4. Results

First, the assessment of influencing factors by country was carried out. The first of the assessed economic factors was income, for which the relationship with the country was

assessed (Table 1). The nominal by nominal contingency coefficient between Q1.1"income" and country is statistically significant (r=0.18, n=261, p<0.05).

Table 1. Cross-tabulation between economic factor Q1.1 „income" and type of country – developed or developing (% by columns)

Q1.1 "income"	Country	
	Developing	Developed
1 – not important	17.6	20.9
3 – neutral	18.5	6.5
5 – very important	63.9	72.5
Total	100.0	100.0

Source: Own contribution.

The results show that the income is a very important economic factor for developing and developed countries. The analysis also showed that income is an important decision-making factor for about two-thirds of respondents in developing countries and three-quarters in developed countries, so it is stated as more important for developed countries.

The next factor assessed was the energy price (Table 2). The nominal by nominal contingency coefficient between Q1.2 „energy price" and country is statistically significant (r=0.21, n=261, p<0.05).

Table 2. Cross-tabulation between economic factor Q1.2 „energy price" and type of country – developed or developing (% by columns)

Q1.2 "energy price"	Country	
	Developing	Developed
1 – not important	23.1	13.1
3 – neutral	17.6	7.8
5 – very important	59.3	79.1
Total	100.0	100.0

Source: Own contribution.

Results show that the energy price is a very important economic factor for developing and developed countries, but it is stated as more important for developed countries.

For the last economic factor Q1.3 „costs of connecting to the energy grid" the relationship with the country's level of development is statistically insignificant. The analysis therefore indicated that the energy price is the factor that shows the greatest relationship with the country (the country's level of development).

Questions Q2.1, Q2.2 and Q2.3 are focused on the social factors. The analysis showed that for two of the 3 social factors, i.e. Q2.1 „energy subsidies for the poorest" and Q2.3

„preference for implementing the ban on disconnecting the poorest from the energy grid", the relationship with the country (level of country development) is statistically insignificant. Whereas, the nominal by nominal contingency coefficient between Q2.2 „providing energy to the poorest for free" and country is statistically significant (r=0.21, n=261, p<0.05). The evaluation results for factor Q2.2 are shown in Table 3.

Table 3. Cross-tabulation between economic factor Q2.2 „providing energy to the poorest for free" and type of country (developed or developing)

Q2.2 "providing energy to the poorest for free"	Country	
	Developing	Developed
1 – not important	34.3	55.6
3 – neutral	17.6	15.0
5 – very important	48.1	29.4
Total	100.0	100.0

Source: Own contribution.

Here one of the greatest differences are identified. For developing countries providing energy to the poorest for free is very important. For developing countries providing energy to the poorest for free is not very important.

The questions Q3.1, Q3.2, Q3.3 and Q3.4 are oriented to the environmental factor. Only the results for statistically significant relationships are shown below. The nominal by nominal contingency coefficient between Q3.3 „acceptance to pay more for green energy" and country is statistically significant (r=0.18, n=261, p<0.05).

Table 4. Cross-tabulation between economic factor Q3.3 „acceptance to pay more for green energy" and type of country (developed or developing)

Q3.3 "acceptance to pay more for green energy"	Country	
	Developing	Developed
1 – not important	39.8	47.1
3 – neutral	22.2	24.5
5 – very important	38.0	28.4
Total	100.0	100.0

Source: Own contribution.

For developing countries there is polarization of opinions on acceptance to pay more for green energy. Almost 2/5 of the people in these countries accept that to pay more for green energy is very important and almost 2/5 of the people in these countries accept that to pay more for green energy is not very important. 1/5 of the people in developing countries are neutral on the statement. For developed countries almost ½ of the people think

that to pay more for green energy is not important.

The results of the analysis show that the nominal by nominal contingency coefficient between each of the variables Q1.3, Q2.1, Q2.3, Q3.1, Q3.2, Q3.4 and „country" are not statistically significant (n=261, p>0.05).

The analysis continues with hierarchical modeling in Altair AI Studio using just all variables for the three factors: economic, social and environmental. Figure 4 shows the hierarchical modeling process in our analysis.

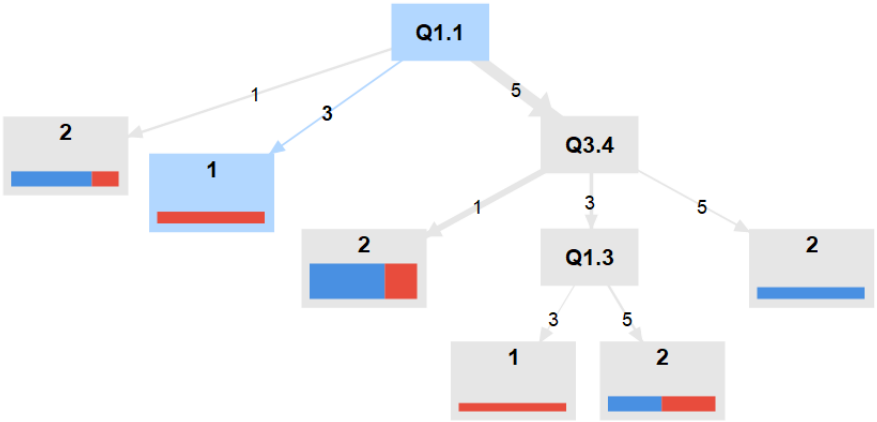

Figure 4. Hierarchical modeling with Altair AI studio – tree 1*

*** Legend**:

Number on the arrows: 1 – not important 3 – neutral 5 – important	Numbers in the boxes (leaves): 1 – developing countries 2 – developed countries	Colors of the boxes (leaves): Red – developing countries Blue – developed countries

Source: Own elaboration

The interpretation of the tree is the following. 6 leaves are identified. Starting from left to right. The first one, the income as an economic factor (Q1.1) is not important („1" on the arrow) for developed countries („2" in the leaf and blue color).

The second one, the income as an economic factor (Q1.1) is stated as neutral opinion („3" on the arrow) mainly for developing countries („1" in the leaf and red color). People who think that the income as economic factor (Q1.1) is important („5" on the arrow) have 4 subcategories:

a) the willingness to pay more (Q3.4) is not important („1" on the arrow) are mainly from developed countries („2" in the leaf with blue color, but a small share with red color for developing countries).
b) the willingness to pay more (Q3.4) are neutral („3" on the arrow) also neutral on costs to connecting to energy grid (Q1.3) are mainly from developing countries („1" in the leaf, red color)
c) the willingness to pay more (Q3.4) are neutral („3" on the arrow); important („5" on the arrow) to connecting to energy grid (Q1.3) are from developing and developed countries (blue and red color)
d) the willingness to pay more (Q3.4) is important („5" on the arrow) are mainly from developed countries („2" in the leaf; blue color).

If the minimal leaf size of the Decision tree is changed to „3", a more compact tree (hierarchy) is visualized.

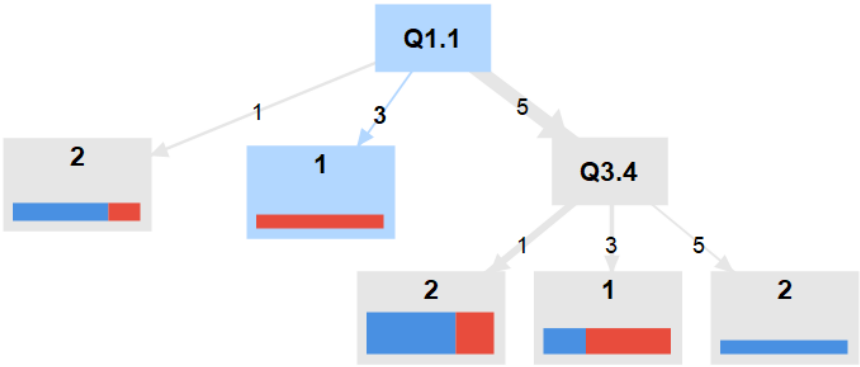

Figure 5. Hierarchical modeling with Altair AI studio – tree 2*

* **Legend**:

Number on the arrows: 1 – not important 3 – neutral 5 – important	Numbers in the boxes (leaves): 1 – developing countries 2 – developed countries	Colors of the boxes (leaves): Red – developing countries Blue – developed countries

Source: Own elaboration

These results showed the relationships in consumers' assessment of the individual dimensions of sustainable energy consumption. The results showed that such relationships exist especially between economic and environmental factors. It was found that such connections are mainly for developed countries. Consumers from these countries, as people

who pay more attention to income or energy prices, are more differentiated due to their willingness to bear higher costs related to environmental protection and consuming green energy. The results of the analysis indicated that the identified hierarchical model may be useful for formulating government policy on the energy sector.

5. Discussion

The analysis of the results indicates that economic, social and environmental factors play an important role in shaping consumer decisions on sustainable energy consumption, with their importance varying according to the level of development of the country. The finding on income as an economic factor confirms that it is important in both developed and developing countries, but it is seen as even more crucial in developed countries. This finding confirms previous findings in the literature, which argued that income level influences energy-related decisions (Han, 2021; Vargas-Merino et al., 2023). Similarly, the price of energy was found to be an important factor in both groups, but its role is more pronounced in developed countries, confirming earlier studies that highlighted the importance of energy prices in shaping consumer behaviour (Addai et al., 2024). Interestingly, the cost of connecting to the electricity grid was not found to be a statistically significant differentiating factor between consumers living in countries with different levels of development, suggesting that this factor is perceived as less decisive, which may be due to other economic factors being more important and is consistent in this area of research with the findings of Dokas et al. (Dokas et al., 2022) and Misztal et al. (Misztal et al., 2022). This is probably due to the fact that income and the price of energy refer to the monthly expenditure on energy carriers, whereas the cost of connecting to the energy grid is seen as a one-off cost and thus less perceived by consumers regardless of the level of development of the economy.

In terms of social factors, the biggest difference between consumers from developing countries and those from developed countries was observed in the assessment of the importance of providing free energy to the poorest. In developing countries this aspect is rated as very important, while in developed countries it is perceived as less important. These findings may indicate confirmation of findings in the literature (Nagaj, 2022; Leal Filho et al., 2024), that there are major challenges related to energy access and energy poverty in developing countries. In addition, the high energy price sensitivity of consumers in developed countries may indicate that consumers in richer economies are for this reason not interested in financing poor consumers, as free energy for the poorest means a higher price for other energy consumers. These findings therefore coincide with energy poverty theory, which differentiates types of energy poverty by level of economic development and identifies financial factors as the main criterion for advanced economies, and access to grid and energy as a criterion for emerging markets (Al Kez et al., 2024; Nagaj, 2022). Other social factors, such as subsidies for the poorest or a ban on cutting them off the grid, did

not show significant differences, which may indicate similar perceptions of these solutions or their lesser impact on consumer decisions.

In the area of environmental factors, it was statistically significant to agree to pay a higher price for being able to consume green energy. In developing countries, opinions on this topic were polarised, with around 40% of respondents accepting a higher price, which may reflect differences in environmental awareness and financial capability and is in line with the literature (Elhoushy & Jang, 2023; Kumar & Nayak, 2024). This acceptance was higher and more uniform in developed countries, in line with previous studies that highlight a greater willingness to pay environmental costs in these countries (Feldhaus et al., 2022; Łukasiewicz et al., 2022). Additionally, the analysis showed that opinions are polarised in developing countries, which in turn confirms earlier research of Yumashev et al. (Yumashev et al., 2020) indicating differences in environmental attitudes depending on the level of development. The results of the analysis showed that assessing consumer preferences in the context of sustainable energy consumption theory makes sense, as there are differences in all dimensions between consumers from developing and developed countries, even though energy is a basic good and it seems that preferences should be the same everywhere.

6. Conclusion

The aim of the paper was to investigate how energy consumers evaluate economic, social, and environmental factors in developing and developed countries, and to compare developed and developing countries in terms of the impact of these factors on consumer decisions in dimensions of sustainable energy consumption.

The findings confirmed the basic rights deriving from the theory of sustainable development and the theory of fuel poverty that the assessment of consumer preferences should not only take place from an economic perspective, but also from a social and environmental perspective. In addition to this, the findings confirmed that fuel poverty can result from different factors depending on the level of development of a given economy. In this case, it can be argued that the types of fuel poverty and the distinction between fuel poverty resulting from difficulties in accessing access to energy (and identified with developing economies) and fuel poverty resulting from financial factors (identified with advanced economies), and resulting mainly from supply-side factors, also overlap with consumer preferences, i.e. demand-side factors.

Findings of this paper also showed that in developed countries there is a greater emphasis on economic and environmental factors, while in developing countries there is a greater emphasis on social issues, particularly related to energy access for the poorest. In summary, the results confirm that energy decisions are shaped by complex interactions of economic, social and environmental factors, the importance of which varies according to a country's level of development.

This study fills two significant gaps. The first one relates to the limited attention given to energy-related consumption in sustainability studies. The second gap pertains to the absence of integrated cross-country comparisons that differentiate between developed and developing economies. This study provides comparative data between countries with different levels of development, which is in line with previous indications that comprehensive analyses taking into account all three dimensions of sustainable energy have so far been lacking . The main contribution of this study is its comparative, multidimensional approach to sustainable energy consumption, along with the innovative use of hierarchical modelling, which is quite fresh in this research area. The use of hierarchical modelling represents an innovative approach that has provided a deeper understanding of how individual factors influence consumer decisions in different development contexts.

This paper also provides policy implications. The main stakeholders in both developed and developing economies of this paper are politicians, but also companies in the broader energy sector. The political implications indicate that energy policy related to regulating sustainable energy consumption and limiting energy consumption cannot be applied uniformly to all countries. Findings indicated that although incomes reduce energy poverty everywhere, they are also a key factor stimulating energy consumption. It was therefore stated that in order to create sustainable energy consumption, policy makers in developed countries should put the main emphasis on macroeconomic policy, because incomes are the most important for consumers. In developed countries, however, policy makers should also take care of energy prices, and therefore economic regulation of energy prices should be considered, and not only ensuring an increase in consumer incomes. Another implication for policy makers is the importance of social policy, which has proven to be important in the context of sustainable energy consumption in developing countries. Finding that the cost of connecting to the power grid is perceived as a one-time cost and therefore less felt by consumers means that in these countries, policymakers should implement social mechanisms that are aimed at consumers permanently, not just once. It was also found that it is not true that in developing countries consumers do not care about the environment and are not interested in renewable energy or products that are related to the consumption of green energy. This is also important for consumers, but the promotion of sustainable energy consumption should first be preceded by reducing energy poverty. Stakeholders for the implications of the findings of this work are also companies. The basic implication is that in developed countries consumers are increasingly paying attention to climate issues, so companies in promotional campaigns should pay attention not only to the issue of energy prices, but also to climate protection and show consumers what the carbon footprint of energy production is. Moreover, they are willing to accept a higher energy price if the energy is produced from renewable sources. In developed countries, another important implication for entrepreneurs from the energy sector is not to emphasize the use of social tariffs for the poorest, because most consumers treat it as a negative factor. In developing countries, on the other hand, consumers will pay attention to the use of social tariffs as a positive factor, a factor stimulating sustainable energy consumption, and that ecology is important to them

but on condition that it is not associated with higher energy prices.

This work also has research limitations. The primary one is the need to conduct research on a larger group of respondents. A larger population of respondents would make the findings more credible and allow the conclusions to be generalised. In this case, the findings are only related to the responded research group. As an excuse for this research limitation, it should be pointed out that the literature indicates that it is also possible to generalise findings with a lower sample size. For example, Lopez (2019) indicates that sample size requirements for hierarchical linear models (HLMs) may be smaller. The literature on the 10-times rule method for minimum sample size estimation or the minimum R-squared method (Hair et al., 2014; Kock & Hadaya, 2018; Ranatunga et al., 2020). Additionally, as indicated in the literature (Jenkins & Quintana-Ascencio, 2020), in studies on economics, the median for the sample size is 218, which therefore indicates that this study (here the sample size is 261) does not differ from other studies in the literature and is in line with the standards used in the study of economic phenomena. In an attempt to address this shortcoming, it was the HLM method that was applied, as this method allows for inference with small samples in groups and inference in the case of unequal samples. However, this does not change the fact that a higher sample size would increase the precision of the results and allow the findings to be generalised. There is also scope for further research to assess whether there are differences between societies within different regions of the world.

References

1. Abdi, A., Siyad, S., Okash, M., & Mohamed, O. (2025). Approaches to ecological sustainability in sub-Saharan Africa: Evaluating the role of globalization, renewable energy, economic growth, and population density. *Research in Globalization*, *10*, 100273. https://doi.org/10.1016/j.resglo.2025.100273
2. Addai, G., Suh, J., Bardsley, D., Robinson, G., & Guodaar, L. (2024). Exploring sustainable development within rural regions in Ghana: A rural web approach. *Sustainable Development*, *32*(4), 3890-3907. https://doi.org/10.1002/sd.2887
3. Al Kez, D., Foley, A., Lowans, C., & Del Rio, D. F. (2024). Energy poverty assessment: Indicators and implications for developing and developed countries. *Energy Conversion and Management*, *307*, 118324. https://doi.org/10.1016/j.enconman.2024.118324
4. Ana-Maria Ramona, S., Marian Pompiliu, C., Stoyanova, M. (2020). *Data Mining Algorithms for Knowledge Extraction*. In: Fotea, S., Fotea, I., Văduva, S. (eds) Challenges and Opportunities to Develop Organizations Through Creativity, Technology and Ethics. GSMAC 2019. Springer Proceedings in Business and Economics. Springer, Cham, pp. 349–357. https://doi.org/10.1007/978-3-030-43449-6_20
5. Armyanova, M., & Aleksandrova, Y. (2023). Design patterns in machine learning. In *AIP Conference Proceedings*, 2938, 03010. https://doi.org/10.1063/5.0182552
6. Balsamo, M., Montagnaro, F., & Anthony, E. J. (2023). Socio-economic parameters affect CO2 emissions and energy consumption – An analysis over the United Nations Countries.

Current Opinion in Green and Sustainable Chemistry, *40*, 100740. https://doi.org/10.1016/j.cogsc.2022.100740

7. Bhuiyan, M., Zhang, Q., Khare, V., Mikhaylov, A., Pintér, G., & Huang, X. (2022). Renewable Energy Consumption and Economic Growth Nexus—A Systematic Literature Review. *Frontiers in Environmental Science*, *10*, 878394. https://doi.org/10.3389/fenvs.2022.878394
8. Bolis, I., F. A. C. Sigahi, T., Thatcher, A., Saltorato, P., & Morioka, S. (2023). Contribution of Ergonomics and Human Factors to Sustainable Development: A systematic literature review. *Ergonomics*, *66*, 303–321. https://doi.org/10.1080/00140139.2022.2079729
9. Bulut, U., & Apergis, N. (2021). A new methodological perspective on the impact of energy consumption on economic growth: Time series evidence based on the Fourier approximation for solar energy in the USA. *GeoJournal*, *86*, 1969-1980. https://doi.org/10.1007/s10708-020-10171-x
10. Corbier, D., Pettifor, H., Agnew, M., & Nagashima, M. (2025). Shaping sustainable consumption practices: Changing consumers' habits through lifestyle changes and Extended Producer Responsibility schemes. *Resources, Conservation and Recycling*, *217*, 108214. https://doi.org/10.1016/j.resconrec.2025.108214
11. Cosma, A (2024). Understanding Post-covid-19 Consumer Purchase intention for sustainable clothing: Insights from Romania. *Intellectual Economics*, *18*(2), 384-405. https://doi.org/10.13165/IE-24-18-2-07
12. Dam, M. M., & Sarkodie, S. A. (2023). Renewable energy consumption, real income, trade openness, and inverted load capacity factor nexus in Turkiye: Revisiting the EKC hypothesis with environmental sustainability. *Sustainable Horizons*, *8*, 100063. https://doi.org/10.1016/j.horiz.2023.100063
13. Dogaru, V., Brandas, C., & Cristescu, M. (2019). An Urban System Optimization Model Based on CO2 Sequestration Index: A Big Data Analytics Approach. *Sustainability*, *11*(18). https://doi.org/10.3390/su11184821
14. Dokas, I., Panagiotidis, M., Papadamou, S., & Spyromitros, E. (2022). The Determinants of Energy and Electricity Consumption in Developed and Developing Countries: International Evidence. *Energies*, *15*(7), 2558. https://doi.org/10.3390/en15072558
15. Elhoushy, S., & Jang, S. (2023). How to Maintain Sustainable Consumer Behaviors: A Systematic Review and Future Research Agenda. *International Journal of Consumer Studies*, *47*(6), 2181-2211. https://doi.org/10.1111/ijcs.12905
16. Elhoushy, S., & Lanzini, P. (2020). Factors Affecting Sustainable Consumer Behavior in the MENA Region: A Systematic Review. *Journal of International Consumer Marketing*, *33*, 1–24. https://doi.org/10.1080/08961530.2020.1781735
17. Falcone, P. M. (2023). Sustainable Energy Policies in Developing Sustainable Energy Policies in Developing Countries: A Review of Challenges and Opportunities. *Energies*, *16*(18), 6682. https://doi.org/10.3390/en16186682
18. Feldhaus, C., Gleue, M., Löschel, A., & Weidenbörner, V. (2022). On the determinants of regional sustainable electricity consumption: Individual preferences and regional co-benefits. *Die Unternehmung*, *76*, 338–359. https://doi.org/10.5771/0042-059X-2022-3-338
19. Georgescu, M. R., Stoica, E. A., Bogoslov, I. A., & Lungu, A. E. (2022). Managing Efficiency in Digital Transformation – EU Member States Performance during the COVID-19 Pan-

demic. *International Conference on Industry Sciences and Computer Science Innovation*, *204*, 432–439. https://doi.org/10.1016/j.procs.2022.08.053
20. Goldstein, H. (2011). *Multilevel Statistical Models*. Wiley. https://doi.org/10.1002/9780470973394
21. Güler, İ., & Aydinbaş, Y. E. (2024). Proposing Sustainable Development and Growth Strategies for CIS-7 Countries by Investigating the Persistence of Consumption-Based and Production-Based CO2 Emissions. *Regional Science Policy & Practice*, *16*(10), 100114. https://doi.org/10.1016/j.rspp.2024.100114
22. Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2014). A primer on partial Least Squares Structural Equation Modeling (PLS-SEM). Thousand Oaks, California: SAGE Publications.
23. Han, H. (2021). *Consumer behavior and environmental sustainability in tourism and hospitality: A review of theories, concepts, and latest research*. *Journal of Sustainable Tourism*, *29*(7), 1021–1042. https://doi.org/10.1080/09669582.2021.1903019.
24. Hasbullah, N. N., Sulaiman, Z., & Mas'od, A. (2019). Factors Affecting Sustainable Apparel Consumption in Emerging Countries: A Systematic Literature Review. *Preprints*. https://doi.org/10.20944/preprints201908.0015.v1
25. Herrera Burstein, Y. E., & Goñi Avila, N. M. (2024). Promoting sustainable consumption among university students: A systematic literature review. *International Journal of Sustainability in Higher Education*, *25*(2), 265–288. https://doi.org/10.1108/IJSHE-09-2022-0298
26. Hirth, S., Kreinin, H., Fuchs, D., Blossey, N., Mamut, P., Philipp, J., Radovan, I., & the EU-1.5°Lifestyles Consortium. (2023). Barriers and enablers of 1.5° lifestyles: Shallow and deep structural factors shaping the potential for sustainable consumption. *Frontiers in Sustainability*, *4*, 1014662. https://doi.org/10.3389/frsus.2023.1014662
27. Jenkins, D. G., & Quintana-Ascencio, P. F. (2020). A solution to minimum sample size for regressions. *PLoS ONE*, *15*(2): e0229345. https:// doi.org/10.1371/journal.pone.0229345
28. Jin, S.-H. (2020). Fuel poverty and rebound effect in South Korea: An estimation for home appliances using the modified regression model. *Energy & Environment*, *31*(7), 1147–1166. https://www.jstor.org/stable/26960853
29. Johansson, T., & Pirouzfar, P. (2019). Sustainability challenges in energy use behaviour in households: Comparative review of selected survey-based publications from developed and developing countries. *Problemy Ekorozwoju–Problems of Sustainable Development*, *14*(2), 33–44.
30. Kock, N., & Hadaya, P. (2018). Minimum sample size estimation in PLS-SEM: The inverse square root and gamma-exponential methods. *Information Systems Journal*, *28*(1), 227–261.
31. Kuhe, A., & Bisu, D.Y. (2020). Influence of situational factors on household's energy consumption behaviour: Towards an effective energy policy. *International Journal of Energy Sector Management*, *14*(2), 389-407. https://doi.org/10.1108/IJESM-03-2019-0017
32. Kumar, G., & Nayak, J. K. (2024). Consumers' Green Energy Buying Behaviour and Intention: A Literature Review. *Vision*, *0*(0). https://doi.org/10.1177/09722629241281613
33. Kuyumdzhiev, I. (2020). *A model for timely delivery of IT solutioms Bulgarian Universities* (p. 10). SGEM 2020 Conf Proc. https://doi.org/10.5593/sgem2020/2.1/s07.001
34. Leal Filho, W., Gatto, A., Sharifi, A., Salvia, A. L., Guevara, Z., Awoniyi, S., Mang-Benza, C., Nwedu, C. N., Surroop, D., Teddy, K. O., Muhammad, U., Nalule, V. R., & da Silva, I. (2024).

Energy poverty in African countries: An assessment of trends and policies. *Energy Research & Social Science*, *117*, 103664. https://doi.org/10.1016/j.erss.2024.103664

35. Li, H., Appel-Meulenbroek, R., Arentze, T. A., & Hoes, P.-J. (2024). Conceptualizing sustainable occupant behaviour in offices from an interdisciplinary point of view: A systematic review. *Energy and Built Environment*, *15*(3). https://doi.org/10.1016/j.enbenv.2024.08.004
36. Lopez, J. S. G. (2019). *Sample Size Requirements and Considerations for Models to Assess Human-Machine System Performance*. https://apps.dtic.mil/sti/citations/AD1084395
37. Łukasiewicz, K., Pietrzak, P., Kraciuk, J., Kacperska, E., & Cieciora, M. (2022). Sustainable Energy Development—A Systematic Literature Review. *Energies*, *15*(21), 8224. https://doi.org/10.3390/en15218284
38. Makridou, G., Matsumoto, K., & Doumpos, M. (2024). Evaluating the energy poverty in the EU countries. *Energy Economics*, *140*, 108020. https://doi.org/10.1016/j.eneco.2024.108020
39. McCoy, D., & Kotsch, R. A. (2021). Quantifying the Distributional Impact of Energy Efficiency Measures. *The Energy Journal*, *42*(6), 121–144. https://doi.org/10.5547/01956574.42.6.dmcc
40. Mileva, L. (2024). Big data predictions of Seasonal Fluctuations in Marine Traffic (using AIS data) by monitoring idle ships. *Business & Management Compass*, *68*, 5–22. https://doi.org/10.56065/f0wzb375
41. Misztal, A., Kowalska, M., & Fajczak-Kowalska, A. (2022). The Impact of Economic Factors on the Sustainable Development of Energy Enterprises: The Case of Bulgaria, Czechia, Estonia and Poland. *Energies*, *15*(18), 6842. https://doi.org/10.3390/en15186842
42. Nagaj, R. (2022). Macroeconomic Policy versus Fuel Poverty in Poland - Support or Barrier. *Energies*, *15*(13), 4710. https://doi.org/10.3390/en15134710
43. Nagaj, R. (2024). Green Deal as one of the determinants of energy poverty. *Scientific Papers of Silesian University of Technology Organization and Management Series*, *208*, 420–434. https://doi.org/10.29119/1641-3466.2024.208.24
44. Nagaj, R., & Žuromskaitė, B. (2021). CEE Millenial Travellers' Attitude Towards Security Measures Applied in Tourism Infrastructure. *Ourism: An International Interdisciplinary Journal*, *69*(1), 140–155. https://doi.org/10.37741/t.69.1.10
45. Nagaj, R., & Žuromskaitė, B. (2023). Young Travellers and Green Travel in the Post-COVID Era. *Sustainability*, *15*(18), 13822. https://doi.org/10.3390/su151813822
46. Nguyen, M., Quach, S., & Thaichon, P. (2021). The effect of AI quality on customer experience and brand relationship. *Journal of Consumer Behaviour*, *21*. https://doi.org/10.1002/cb.1974
47. Nkaizirwa, J. P., Nsanganwimana, F., & Aurah, C. M. (2021). Reexamining the measurement of pro-environmental attitudes and behaviors to promote sustainable development: A systematic review. *Eurasia Journal of Mathematics, Science & Technology Education*, *17*(9), em2001. https://doi.org/10.29333/ejmste/11138
48. Oteng, C., & Gamette, P. (2025). Intersectionality of access and use of clean energy consumption among persons with disability in Ghana. *Regional Science Policy & Practice*, *17*(4), 100175. https://doi.org/10.1016/j.rspp.2025.100175
49. Pankov, S., Velamuri, V. K., & Schneckenberg, D. (2021). Towards sustainable entrepreneurial ecosystems. *Small Business Economics*, *56*(3), 1073–1095. JSTOR.
50. Parusheva, S., & Pencheva, D. (2020). *Modeling a Business Intelligent System for Managing Orders to Supplier in the Retail Chain with Unified Model Language*. In: Magdi, D.A.,

Helmy, Y.K., Mamdouh, M., Joshi, A. (eds) Digital Transformation Technology. Lecture Notes in Networks and Systems, vol 224. Springer, Singapore, pp. 375-393. https://doi.org/10.1007/978-981-16-2275-5_23

51. Petrov, P., Radev, M., Dimitrov, G., Pasat, A., & Buevich, A. (2021). A Systematic Design Approach in Building Digitalization Services Supporting Infrastructure. *TEM Journal*, 31–37. https://doi.org/10.18421/TEM101-04
52. Petrov, P., Stoev, S., Radev, M., Sergeev, A., & Dimitrov, G. (2021). *Risk management processes in information systems development*. In: 21st International Multidisciplinary Scientific GeoConference SGEM 2021, 467-473. https://doi.org/10.5593/sgem2021/2.1/s07.18
53. Podesta, M., Poudou, J.-C., & Roland, M. (2021). The Price Impact of Energy Vouchers. *The Energy Journal*, *42*(3), 27–54. https://doi.org/10.5547/01956574.42.3.mpod
54. Polkowski, Z., Mishra, J. P., Prasad, S. S., & Mishra, S. K. (2020). Evaluation of aggregated query plans using heuristic approach. *2020 12th International Conference on Electronics, Computers and Artificial Intelligence (ECAI)*, Bucharest, Romania, 1-4, https://doi.org/10.1109/ECAI50035.2020.9223222
55. Rabhi, A., Soujaa, I., & Parsons, B. (2024). Do environmental taxes and renewable energy consumption play a role in climate change mitigation? International evidence from developing economies. *Research in Globalization*, *9*, 100266. https://doi.org/10.1016/j.resglo.2024.100266
56. Ramli, H., Azizi, Z. M., & Thurairajah, N. (2024). Sustainable Smart City Technologies and Their Impact on Users' Energy Consumption Behaviour. *Energies*, *17*(4), 771. https://doi.org/10.3390/en17040771
57. Ranatunga, R.V.S.P.K., Priyanath, H. M. S., & Megama. R.G.N,. (2020). Methods and Rule-of-Thumbs in The Determination of Minimum Sample Size When Appling Structural Equation Modelling: A Review. *Journal of Social Science Research*, *15*, 102–109. https://doi.org/10.24297/jssr.v15i.8670
58. Rasanga, F., Harrison, T., & Calabrese, R. (2024). Measuring the energy poverty premium in Great Britain and identifying its main drivers based on longitudinal household survey data. *Energy Economics*, *136*, 107726. https://doi.org/10.1016/j.eneco.2024.107726
59. Raudenbush, S. W., & Bryk, A. S. (2002). *Hierarchical Linear Models: Applications and Data Analysis Methods*. Sage.
60. Sahu, A. K., & Mahalik, M. K. (2025). The linkage between income inequality, opportunity and renewable energy demand: Panel evidence from OECD economies. *Renewable Energy*, *243*, 122588. https://doi.org/10.1016/j.renene.2025.122588
61. Saxena, A. K. (2024). Impact of industry 4.0 on green intellectual capital and sustainable development: The moderating role of managerial emotional intelligence (EI). *Intellectual Economics*, *18*(1), 7-33. https://doi.org/10.13165/IE-24-18-1-01
62. Scurati, G. W., Bertoni, M., Graziosi, S., & Ferrise, F. (2021). Exploring the Use of Virtual Reality to Support Environmentally Sustainable Behavior: A Framework to Design Experiences. *Sustainability*, *13*(2), 943. https://doi.org/10.3390/su13020943
63. Sesini, G., Castiglioni, C., & Lozza, E. (2020). New Trends and Patterns in Sustainable Consumption: A Systematic Review and Research Agenda. *Sustainability*, *12*(15), 5935. https://doi.org/10.3390/su12155935

64. Siksnelyte-Butkiene, I. (2021). Impact of the COVID-19 Pandemic to the Sustainability of the Energy Sector. *Sustainability*, *13*(23), 12973. https://doi.org/10.3390/su132312973
65. Soto, G. H., & Martinez-Cobas, X. (2025). Energy poverty and the green energy transition's impact upon income inequality in Latin America. *Structural Change and Economic Dynamics*, *72*, 220–232. https://doi.org/10.1016/j.strueco.2024.09.015
66. Stoyanova, M. (2020). Good Practices and Recommendations for Success in Construction Digitalization. *TEM Journal*. https://doi.org/10.18421/TEM91-07
67. Strielkowski, W., Korneeva, E., Gorina, L. (2022). Sustainable development and the digital transformation of educational systems. *Intellectual Economics*, *16*(1), 134-150.
68. Sulova, S., Aleksandrova, Y., Stoyanova, M., & Radev, M. (2022). *A Predictive Analytics Framework Using Machine Learning for the Logistics Industry*. In: CompSysTech ,22: Proceedings of the 23rd International Conference on Computer Systems and Technologies, pp. 39-44. https://doi.org/10.1145/3546118.3546130
69. Sulova, S., & Marinova, O. (2024). Metadata management framework for business intelligence driven data lakes. *Business management*, 2, 22–42. https://doi.org/10.58861/tae.bm.2024.2.02
70. Topal, H. F., Hunt, D. V. L., & Rogers, C. D. F. (2021). Exploring Urban Sustainability Understanding and Behaviour: A Systematic Review towards a Conceptual Framework. *Sustainability*, *13*(3), 1139. https://doi.org/10.3390/su13031139
71. Tsemekidi Tzeiranaki, S., Bertoldi, P., Economidou, M., Clementi, E. L., & Gonzalez-Torres, M. (2023). Determinants of energy consumption in the tertiary sector: Evidence at European level. *Energy Reports*, *9*, 5125–5143. https://doi.org/10.1016/j.egyr.2023.03.122
72. Uwaga, M., & Ogunbiyi, E. (2024). Assessing the economic and environmental impacts of renewable energy adoption across different global regions. *Engineering Science & Technology Journal*, *5*, 1767–1793. https://doi.org/10.51594/estj.v5i5.1154
73. Vargas-Merino, J. A., Rios-Lama, C. A., & Panez-Bendezú, M. H. (2023). Sustainable Consumption: Conceptualization and Characterization of the Complexity of "Being" a Sustainable Consumer—A Systematic Review of the Scientific Literature. *Sustainability*, *15*(10), 8401. https://doi.org/10.3390/su15108401
74. Yumashev, A., Ślusarczyk, B., Kondrashev, S., & Mikhaylov, A. (2020). Global Indicators of Sustainable Development: Evaluation of the Influence of the Human Development Index on Consumption and Quality of Energy. *Energies*, *13*(11), 2768. https://doi.org/10.3390/en13112768
75. Zaharia, A., Diaconeasa, M. C., Brad, L., Lădaru, G.-R., & Ioanăș, C. (2019). Factors Influencing Energy Consumption in the Context of Sustainable Development. *Sustainability*, *11*(15), 4147. https://doi.org/10.3390/su11154147
76. Zhang, Y., & Song, Y. (2022). The Effects of Sensory Cues on Immersive Experiences for Fostering Technology-Assisted Sustainable Behavior: A Systematic Review. *Behavioral Sciences*, *12*, 361. https://doi.org/10.3390/bs12100361
77. Zheng, Z., Shafique, M., Luo, X., & Wang, S. (2024). A systematic review towards integrative energy management of smart grids and urban energy systems. *Renewable and Sustainable Energy Reviews*, *189*, 114023. https://doi.org/10.1016/j.rser.2023.114023
78. Zou, Y., Wang, C., Najam, H., Nassani, A. A., Djuraeva, G., & Oscar, D. (2025). Energy con-

sumption prediction for households in a society with an ageing population. *Energy Strategy Reviews*, *57*, 101622. https://doi.org/10.1016/j.esr.2024.101622