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Bibliometric Analysis of Excessive Electricity Consumption in the Context of Economic and Ecological Awareness

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Abstract: Excessive electricity consumption in households is a common phenomenon in taking part of household budgets. In a situation where many countries are facing increase in electricity prices, limiting electricity consumption is an important objective from both the economic and environmental perspectives. The analysis included consumer habits, behaviour and factors related to the exploitation of electrical equipment which may lead to unwanted electrical energy waste in households. Suggestions for examples of solutions to reduce excessive energy consumption were presented in an empirical perspective, based on the bibliometric analysis followed by the literature review. The aim of this study was to examine and map out household electricity consumption patterns, trends and the significant factors contributing to energy wastage. The results of scientific research on the economic and environmental awareness of consumers in the field of excessive energy consumption were also compiled. This paper may become an inspiration for further and more detailed quantitative and qualitative research on electrical energy waste – not only in households but also in public institutions or organisations.

Keywords: economy, electrical energy, environment, household, electricity waste

1. Introduction

The current geopolitical situation is a result of deteriorating growth prospects and inflation, among others due to the price crisis on energy markets. Although this crisis is largely caused by the conflict between Russia and Ukraine, the need to diversify energy sources has been one of the main topics discussed during summits of the world's largest economies for many years. The rising retail energy prices and consequently a growing share of energy and food expenditure in the 'shopping baskets' determine the need for action both at the level of state policy and of households. The policy activity of each country in response to strong energy price dynamics varies from country to country, depending on its impact on macroeconomic indicators. For example, in Germany, cost of energy is a smaller percentage of the average household budget than in Poland (Statistisches Bundesamt, 2020), where it can be observed as being more dynamic than in the last years actions aimed at lowering tax rates on some goods, e.g. food, whose prices are significantly influenced by current energy prices (Bielecki, 2022).

To date, the decisions related to the rational use of energy by households, or, to put it bluntly, minimising wastage, were usually identified with the need to increase social awareness and to shape pro-ecological attitudes and behavior. Currently, the determining factors seem to be the economic considerations resulting from projected increases in energy prices in the nearest future, which is likely related to the Russian-Ukrainian conflict. To conduct a reliable, holistic analysis of the problem of energy wastage in households, it was necessary to consider not only the economic aspect, but also the pro-ecological one, concerning the habits of electricity consumers.

In this century, the increase in the quality of life in highly industrialized countries is directly related to the increase of environmental costs associated with, among others, electricity consumption. Technological progress guaranteeing social and economic development, and consequently the improvement of work and leisure conditions, would have not been possible without electricity. Satisfying energy needs and ensuring the security of energy supplies in the modern world should therefore be accompanied by actions aimed at optimizing the use of energy and limiting its waste (Mrówczyńska et al., 2020). The starting point for such actions taken by households is awareness, which should result from environmental education, economic knowledge, and basic specialist knowledge, e.g. how much energy a single device consumes (Rudnicki, 2013). Ecological awareness is formed under the influence of information from the media, The Internet, obligatory social norms, and activities of the state in the form of programs and initiatives encouraging pro-ecological attitudes. Understanding the motives of one's own behavior and anticipating the impact of everyday decisions on environmental processes can therefore influence the change of consumption habits and make household members pay more attention to the adverse phenomena accompanying electricity consumption (Słupik, 2015).

The objective of this study was to examine household electricity consumption patterns and the significant factors contributing to energy wastage, utilising bibliometric analysis as the principal research tool. By mapping out the research trends, key themes, and influential studies in this field, the study aimed to identify effective strategies for reducing electricity overconsumption. These strategies may include user-education initiatives, restrictive certifications for high-energy appliances, and the use of energy monitoring technologies. The research also sought to uncover gaps in the current body of knowledge and provide a foundation for future inquiries into household energy consumption and wastage.

It should be emphasized that such a multidimensional approach, comprising education, regulation, and technology, may be the basis for further actions to curb household electricity consumption and its wastage.

2. Methodology

The method used in this paper included a literature review based on the queries and bibliometric analysis in the VOSviewer, a software app for producing network diagrams from network data, as well as displaying and understanding these bibliometric maps. The Web of Science, Scopus, Dimensions, and PubMed bibliometric database files are supported by the VOSviewer. The preliminary systematic literature review study concentrated on the Scopus database. The following Scopus database query was created and used: (awareness AND ("electrical consumption")).

The query results indicated a research gap and supported the use of bibliometric analysis in the VOSviewer, providing the outcome as follows. The query was applied with use of the TITLE-ABS-KEY search method in the Scopus database. The TITLE-ABS-KEY search used the TITLE+ABSTRACT+ KEYWORDS fields, combining them into one and then conducting a text search.

Figure 1 presents an overlay visualization of the proposed query used in the Scopus database between 2010-2020. During the creation of the map, the minimum number of occurrences of a keyword was 1. This shows that 272 keywords were used to draw the map.

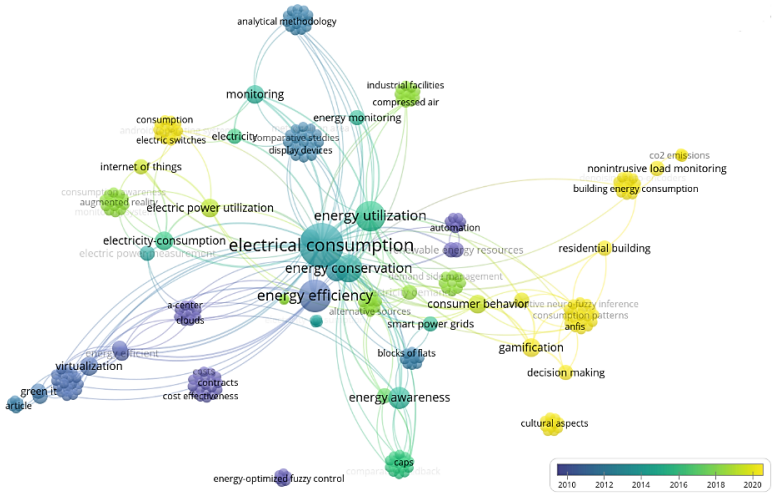

Figure 1. Overlay visualisation map of Scopus query

Source: own elaboration.

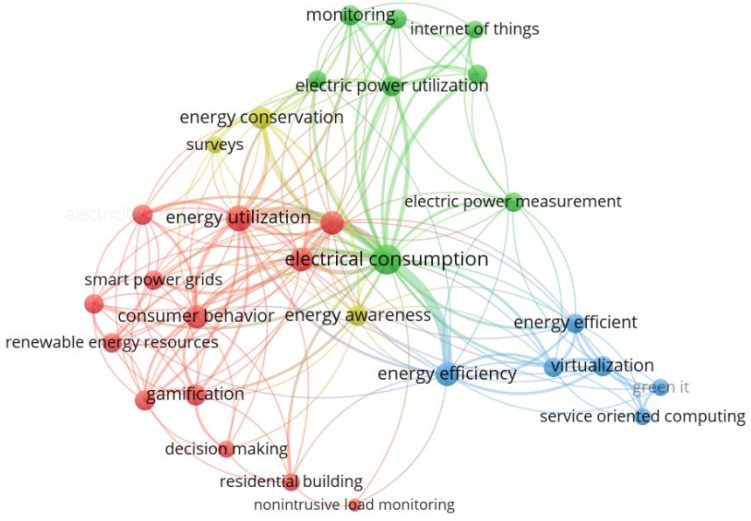

Figure 2. Electricity consumption awareness bibliometric map

Source: own elaboration.

Figure 2 shows the co-occurrence map. The VOSviewer tool can be used to illustrate various correlations between awareness and electrical consumption. These dependencies are evident in the examination of the title, keywords, and abstracts with the set co-occurrences = 2. The purpose of this study was to explore the literature regarding awareness and electrical consumption in the context of economic and ecological aspects.

The above map of the queries can be split into two different areas. The left side of the figure (red cluster) describes consumer behavior versus economic awareness. The right side (blue and green clusters) can be analyzed as consumer actions, the technological aspects of energy versus ecological awareness. There is a key expression that connects two aspects of economic and ecological issues: energy awareness (yellow cluster).

3. Results and Discussion

In order to identify the causes of excessive household electricity consumption, it was necessary to consider a number of perspectives related to the areas referred to by the keywords shown in Figures 1 and 2. Due to the complexity of the issue and its breadth, the authors chose to highlight the following areas: economic development and technological advances (Pelau & Acatrinei, 2019), consumer awareness and behavior, and climate conditions and ecology. These areas can be directly interlinked, resulting in a gradual increase in household demand for electricity (Tzeiranaki et al., 2019), whose consumption is increasingly dependent on, among others, the level of affluence, the composition and size of the family (Brounen et al., 2012). Whatever the reasons, there has been a slow increase in electricity consumption in the European Union area since 2014 (Tzeiranaki et al., 2019), therefore implying the need to control its consumption more effectively and, in some cases, even implement new automation and computer-based technological solutions to optimize the operation of electrical appliances (Kott & Kott, 2019). However, to achieve this goal, it is essential to have the right knowledge and information that underpins any transformation – both technological and process. Referring to the bibliometric analysis and the literature, the following factors were highlighted:

1. Economic development and technological progress. As in the case of industry, where the increasing demand for electricity is linked to the intensity of manufacturing processes (Doyle & Cosgrove, 2018), households are also influenced by technological change, leading to an increase in demand for electricity (Tzeiranaki et al., 2019). Cosgrove and Doyle note that if it is difficult to estimate its consumption at the level of individual processes, this can make it difficult to implement measures to reduce overconsumption (Doyle & Cosgrove, 2018). With technological developments, the number of electrical appliances and their functions in households is gradually increasing (Alahmad et al., 2012). It is worth noting that these devices – e.g. microwave ovens, computers, phone chargers, coffee machines, and televisions – individually do not consume a large amount of energy, whereas together they can generate significant costs. Even so-called 'smart devices' using IoT, which aim to save energy or, in some cases, monitor energy consumption, also consume a certain amount of energy while constantly in standby mode (McMahon, 2018). A not insignificant role is also played by the increase in energy consumption in the tertiary sector (e.g. passenger and freight transport), linked directly to consumer-oriented industry and transport (Thomas & Rosenow, 2020).
2. Consumer awareness and behavior. Consumers are often unaware of exactly how much electricity is consumed by everyday appliances (e.g. white goods), particularly in standby mode, although it is estimated that this can be a huge amount (Liu et al., 2012). They are also often unaware of how much energy is used during daily activities (e.g. laundry, cooking, and cleaning), usually knowing only the overall energy consumption (Pompermayer et al., 2017). The growing human population and the expansion of residential locations is undoubtedly contributing to an increase in electricity consumption (Thomas & Rosenow, 2020), leading more and more researchers to highlight the need to change consumer habits to reduce electricity waste (Caroll et al., 2009). Intense demographic changes and consumer lifestyles are cited as some of the main factors influencing the level of its

consumption in households (Doyle & Cosgrove, 2018). It is worth mentioning that household electricity consumption is expected to increase in the coming years due to an increase in the number of low-power devices (consumer electronics, computers, televisions). This implies the need for systemic solutions aimed at educating consumers in more efficient and rational use of electricity, as well as regulations encouraging good practices in this area, e.g. by subsidizing energy efficiency improvement projects (Kott, 2015).

3. Climate conditions and ecology. Although changes are being observed in the electricity production and distribution system to reduce CO2 emissions, conserve the resources used to produce electricity and to plan for a more sustainable energy future (Alahmad et al., 2012), much of this energy has been wasted by consumers, and significant resources are used to produce it. As an example, American households consumed one-fifth of the energy produced in the USA in 2007, 60% of which was electricity. Studies indicate that as much as 41% of the energy supplied to them is wasted (Williams & Matthews, 2007), although its production involves not only strictly economic costs (inputs), but also environmental costs (e.g. environmental contamination). Note that electricity demand and consumption can also be related to geographical location, urban sprawl and density, quality and lifestyle, and climate. For example, Belussi and Danza observed that when the outdoor air temperature drops, energy consumption proportionally raises (Belussi & Danza, 2012). The aspect of climatic conditions and the associated intensity of use of equipment such as air conditioners, for example, is therefore important from the perspective of not only economics, but also ecology, as the production and transmission of electricity involves resources that have an impact (often negative) on the environment – e.g. the extraction of fossil fuels and their subsequent processing. In a situation where European countries are also facing a gigantic increase in the price of electricity, the rational use of household appliances seems to be an important element of a pro-environmental policy aimed not only at reducing the waste of electricity but, above all, of the resources necessary for its production.

To implement this method, one can utilize common software tools such as MS Excel or MS Word to develop a detailed table, which should include a list of all electrical appliances within the household, noting their specific power consumption, the duration of use measured in kilowatt-hours (kWh), and the applicable electricity rate. By organizing this information, consumers can effectively track and estimate their energy usage over various periods – weekly, monthly, or even annually. This systematic tracking not only fosters awareness but also encourages more responsible energy usage. To better understand the practical application of this method, the following example was outlined in Table 1.

Table 1. An example of monthly power consumption

Electrical device	Power (W)	kW	Monthly operation time (h)	kW x h	Cost per 1 kWh*	Monthly cost (PLN)
Refrigerator	90	0.09	30 days x 24 h = 720 h	0.09 kW x 720h = 64,8 kWh	0.34 PLN	64.8 kWh x 0.34 PLN = 22 PLN

* Based on Tauron's G11 exemplary tariff in Poland (Tauron, 2022).

Source: own elaboration.

Another practical example was monitoring the energy consumption of household appliances using relatively simple and widespread technologies based on so-called 'smart sensors'. The data acquired in real time can then be visualized (e.g. via tablets or smartphones) and analyses and forecasts can be made to identify different patterns of energy use (Angrisani et al., 2018). Detailed real-time energy consumption data can stimulate energy-saving measures (Doyle & Cosgrove, 2018) and helps to understand consumer habits to become more aware of the real impact, both economically and environmentally.

Notably, many households have decided to take more decisive measures, ranging from sensitizing household members to the issue of simply switching off electrical devices or lights while they are not

in use, through the purchase of energy-saving devices that produce electrical energy using photovoltaic panels. It should be also noted that measuring is usually the first step towards the changes for good and becoming aware of electricity consumption and to make efforts to reduce it.

4. Conclusion

The bibliometric analysis demonstrated an evolving emphasis on these areas within the body of research over the years. The author suggests that as awareness of the environmental implications of energy use has grown, so has the research focused on strategies to enhance consumer knowledge, implement stricter energy use regulations, and leverage modern technologies for energy monitoring. It is expected that by studying the trajectory of research in this area, one can predict finding a shift towards these strategies and a consequent reduction in household energy wastage.

The problem of increasing electricity consumption, especially caused by the consumption of fossil fuels, also requires the application of countermeasures due to the harmful effects on the environment. The primary issue of preventing energy wastage begins with user education. The basic and also the simplest solution that can have a direct impact on consumer awareness may be an information campaign – advertisements and graphic instructions at points of sale, and information on the amount of energy consumed by a household appliance over its lifetime. Another, and even more radical yet controversial solution, is the restrictive certification for appliances with high energy consumption and, in economic terms, the introduction of additional charges or taxes.

The real impact of households on energy consumption is inextricably linked to the use of various types of control and measurement devices, such as thermostats interlinked with electric heating or air--conditioning systems. It should be emphasized that measures related to thermo-modernization of residential buildings also have a significant impact on household energy consumption. The authors also pointed out that awareness of increasing the efficiency of energy consumption may lead to energy saving and provide households with lower expenditures on energy carriers.

Regardless of the choice, method, or tools – all the mentioned solutions can offer tangible results if they result in a reduction of electricity consumption. One should also note that the future of households' economic awareness against energy waste is also determined by the energy audit. Understanding its purpose and the information potential it holds will allow to raise the existing energy efficiency and energy waste prevention measures to a higher level. It is especially important nowadays when the world’s economy is being affected by events leading to increase of energy prices, and many consumers still waste energy (both deliberately and being unaware) because of a combination of environmental and economic unawareness (Figure 2). These are not alternatives to each other, and both determine non-price changes in demand.

The complexity of the presented issue of overconsumption of electricity means that this paper can initiate further research and discussion including:

- creating more accurate queries on issues interlinked with energy consumption and carrying out a comparative analysis based on the Scopus and Web of Science databases. The research may contribute to designing further hypotheses for testing in quantitative research which may be an interesting and relatively rare approach,
- qualitative research on the analysis of the cultural determinants associated with energy wastage,
- quantitative studies on the extent of energy wastage in large public institutions, e.g. schools, universities, hospitals, non-governmental and governmental organizations,
- the development of electricity production biased towards (or focused on) renewable energy sources,
- long-term energy perspectives i.e. energy price as a trade-off between security of energy supply and transportation and environmental costs.

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Analiza bibliometryczna nadmiernego zużycia energii elektrycznej w kontekście świadomości ekonomicznej i ekologicznej

Streszczenie: Nadmierne zużycie energii elektrycznej w gospodarstwach domowych wiąże się z dodatkowymi kosztami obciążającymi budżety domowe. Ograniczenie jej zużycia jest celem z perspektywy zarówno ekonomicznej, jak i środowiskowej. Analizie poddano nawyki i zachowania konsumentów oraz czynniki związane z eksploatacją urządzeń elektrycznych, które mogą prowadzić do

marnotrawstwa energii elektrycznej. Propozycje przykładowych rozwiązań mających na celu ograniczenie nadmiernego zużycia energii zostały przedstawione w perspektywie empirycznej, w oparciu o analizę bibliometryczną oraz przegląd literatury. Celem artykułu jest rozpoznanie i mapowanie wzorców zużycia energii elektrycznej w gospodarstwach domowych, a także trendów i ważnych elementów przyczyniających się do marnotrawstwa energii. Zestawiono wybrane wyniki badań naukowych dotyczących świadomości ekonomicznej i ekologicznej konsumentów w zakresie nadmiernego zużycia energii elektrycznej. Niniejszy artykuł może być również inspiracją do dalszych badań ilościowych i jakościowych nad zjawiskiem marnotrawstwa energii elektrycznej – nie tylko w gospodarstwach domowych, ale także w instytucjach publicznych lub organizacji.

Słowa kluczowe: gospodarka, energia elektryczna, środowisko, gospodarstwo domowe, odpady