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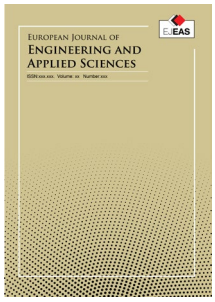

Research Article

Actual Scientific Research Directions On Smart Villages In the Web of Science Database Publications

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Abstract: In Azerbaijan, large-scale works are currently underway to restore the once-destroyed Karabakh region through the implementation of the popular trend of the current century, the "smart" village concept, which implies the most efficient applience of the available resources of a region through the use of innovative construction technologies and materials, "green" energy, and digitalization of all spheres of human life. The first smart village in Azerbaijan is Agali village. The purpose of this study is to review scientific publications, abstracted in the Web of Science database in the category "Green sustainable scientific technologies" on the subject of smart village and identify areas of current scientific research using the VOSviewer program, which allows to group keywords by frequency of their occurrence in articles and determine the most refereed articles. The program grouped scientific publications into 6 clusters: applying the circular economy to smart villages; the use of renewable energy technologies for energy supply; the impact of innovation on the quality of population life; the environmental impact of smart villages in the Chinese context; the application of efficient management methods; and strategies for ensuring sustainable development. The identified trends in scientific research on the development of smart villages are relevant to Azerbaijan. Some measures to achieve sustainable development of the village indicated in the articles studied have already been implemented, and some are planned to be applied. This study's results will help specify further necessary research on the development of smart villages in Azerbaijan.

Keywords: *Sustainable development, Renewable energy sources, Circular economy, Efficient management methods, Cluster.*

Web of Science Veritabanı Yayınlarındaki Akıllı Köylere İlişkin Güncel Bilimsel Araştırma Yönergeleri

Öz. Azerbaycan'da, bir zamanlar harap olan Karabağ bölgesinin, içinde bulunduğumuz yüzyılın popüler trendi olan ve mevcut kaynakların en verimli şekilde kullanılmasını ifade eden "akıllı" köy konseptinin hayata geçirilmesi yoluyla yeniden ayağa kaldırılmasına yönelik geniş çaplı çalışmalar sürdürülmektedir. Yenilikçi inşaat teknolojileri ve malzemelerinin kullanıldığı, "yeşil" enerjinin kullanıldığı ve insan yaşamının tüm alanlarının dijitalleştirildiği bir bölge. Azerbaycan'ın ilk akıllı köyü Agali köyüdür. Bu çalışmanın amacı Web of Science veritabanında yer alan "Yeşil Sürdürülebilir Bilimsel Teknolojiler" kategorisinde "akıllı" köy konu alanına ilişkin bilimsel yayınları incelemek ve güncel bilimsel araştırma alanlarını VOSviewer programı kullanarak tespit etmektir. anahtar kelimeleri makalelerde bulunma sıklıklarına göre gruplandırmak ve en soyut makaleleri belirlemek. Program bilimsel yayınları 6 kümede gruplandırdı: döngüsel ekonominin akıllı köylere uygulanması; enerji tedariği için yenilenebilir enerji teknolojilerinin kullanılması; yeniliğin nüfusun yaşam kalitesi üzerindeki etkisi; Çin bağlamında akıllı köylerin çevresel etkisi; verimli yönetim yöntemlerinin uygulanması; akıllı köylerin sürdürülebilir kalkınmasını sağlamaya yönelik stratejiler ve stratejiler. Akıllı köylerin geliştirilmesine yönelik bilimsel araştırmalarda belirlenen eğilimler Azerbaycan'daki akıllı köylerle ilgilidir. İncelenen maddelerde belirtilen köyün sürdürülebilir kalkınmasını sağlamaya yönelik bazı önlemler halihazırda uygulamaya konmuş olup, bazılarının da uygulanması planlanmaktadır. Bu çalışmanın sonuçları, Azerbaycan'da "akıllı" köylerin geliştirilmesine yönelik gerekli araştırmaların belirlenmesine yardımcı olacaktır.

Anahtar kelimeler: *Sürdürülebilir kalkınma, Yenilenebilir enerji kaynakları, Döngüsel ekonomi, Etkin yönetim yöntemleri, Kümelenme.*

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1. Introduction

In recent decades, global urbanization has reached unprecedented proportions, challenging modern society regarding energy consumption, environmental sustainability, and quality of life. In response to these challenges, smart cities emerged, focused on using information and communication technologies to optimize infrastructure, management, and consumption of resources [1, 2]. However, in parallel with this development, a smart village has become relevant, as a sustainable settlement that integrates modern technologies with the natural environment [3]. In Azerbaijan, large-scale work is currently underway to restore the once-destroyed Karabakh region through the implementation of the smart village concept, the popular trend of the current century [4], which means the most efficient use of the available resources of a particular region through the use of innovative construction technologies, materials, “green energy", and the digitalization of all spheres of human life and infrastructure [5]. The first pilot smart village project implemented in Azerbaijan was Agali village (Fig. 1), rightfully considered as the Azerbaijani analog of the global trend, and that is the first in the post-Soviet space. The key point of the strategy for its creation is self-sufficiency using local resources and innovative technologies in four development areas: green energy; energy efficiency of construction projects; intellectual infrastructure and social services; and full employment of residents [6].

The purpose of this study is to review scientific articles on the “smart village” subject topic, abstracted in Web of Science (WoS) Core Collection database and to identify current scientific research areas using the tools of VOSviewer 1.6.20.

Figure 1. *Smart Agali village, Azerbaijan, 2023, (https://caliber.az/ print/179595)*

2. Materials and Methods

To select the metadata of scientific articles from the database WoS, the query “smart” village was used with the keyword-sustainability [7, 8]. As a result, 319 518 documents were received for the period 1982-2024. Fig. 2 shows a histogram of publications over the past 10 years; the largest number of articles were published in 2023- 38 421, and 8 736- in 2024.

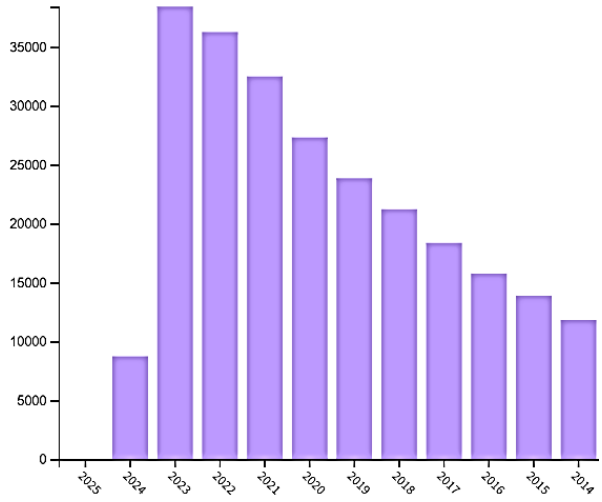

Figure 2. *Distribution of the publications` number of by subject area “smart village” in WoS (2014-2024)*

Fig. 3 shows publications by WoS`s categories. The maximum number of articles falls in the Environmental Science category- 76,111. The second category is Green sustainable scientific technologies, and the number of publications is 52 640.

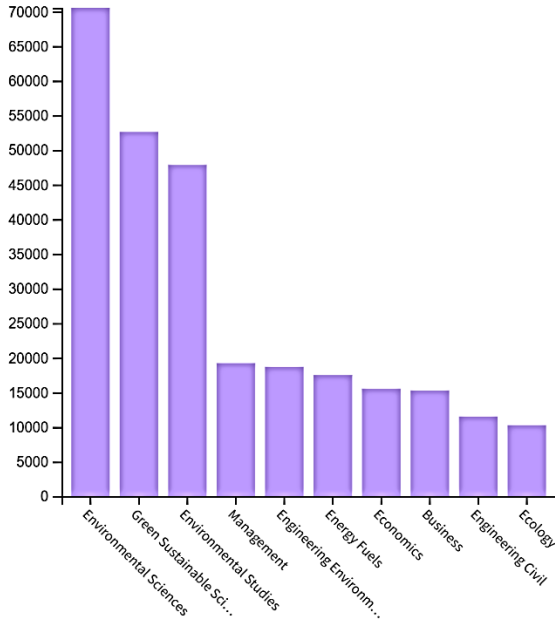

Figure 3. *Distribution of the publications` number of by categories of WoS (1982-2025)*

To narrow the scope of research, scientific articles for the year 2024 were identified from the total number of 319 518, and the category Green Sustainable Scientific Technologies was selected from the WoS Categories section. As a result, 933 publications remained. The found publications were uploaded as a delimited file tabulation in Full record format [9]. Next, in VOSviewer, the data type was selected- Creating a map using bibliographic data. Then the program read the data from the downloaded WoS file. As a type of keyword analysis, the function of their co-occurrences in publications was chosen; the calculation method is “Complete” [10].

From the metadata of the downloaded 933 publications

VOSviewer identified 5717 keywords. With a minimum number of co-occurences keywords of 12, 64 words were involved in constructing the bibliographic map. The 20 most frequently used keywords with the frequency of their co-occurences and the full degree of connections are shown in Table 1, they are mainly the terms and phrases of the authors themselves [11]. The most frequently used terms in the 933 publications reviewed are smart village, sustainability, circular economy, productivity, renewable energy, impact, governance, carbon emissions, innovation, sustainable development, life cycle assessment, economic growth, energy consumption, system, etc.

Table 1. The most frequently occurring top 20 keywords for the subject area "smart village" in WoS (2024), program fragment

Create Map

Verify selected keywords

Selected	Keyword	Occurrences	Total link strength
☑	sustainability	220	396
☑	performance	72	159
☑	impact	66	147
☑	management	75	144
☑	renewable energy	60	130
☑	co2 emissions	29	102
☑	model	51	93
☑	circular economy	42	88
☑	energy	38	86
☑	innovation	34	84
☑	design	33	83
☑	china	32	82
☑	economic-growth	27	82
☑	consumption	26	80
☑	sustainable development	46	80
☑	efficiency	29	76
☑	framework	28	76
☑	impacts	29	71
☑	life cycle assessment	26	66
☑	system	24	58

Based on the density of keywords and their occurrence in publications, it can be judged that the main direction of research is related to the sustainability of the development of smart villages [12]. The keyword "sustainability" stands out as the most frequently used keyword (Fig. 4).

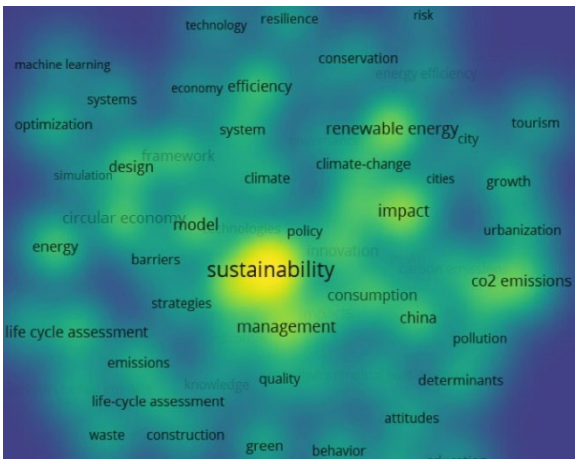

Figure 4. *Graphical representation of the density of keywords according to their occurrence in publications*

3. Results and Discussion

64 keywords from selected publications were grouped by VOSviewer into 6 clusters and marked in different colors (Fig. 5):

1st cluster- red - 13 terms on adapting the principles of the circular economy for a smart village (Fig. 6, a);

2nd cluster- green - 11 terms regarding the use of renewable energy technologies (Fig. 6, b);

3rd cluster- blue - 10 terms on the impact of innovation on the quality of people life (Fig. 6, c);

4th cluster- yellow - 10 terms on the environmental impact of smart villages in the context of China (Fig. 6, d);

5th cluster- purple - 10 terms on the use of efficient management methods (Fig. 6, e);

6th cluster- blue - 10 terms on strategies for ensuring sustainable development of smart villages (Fig. 6, f).

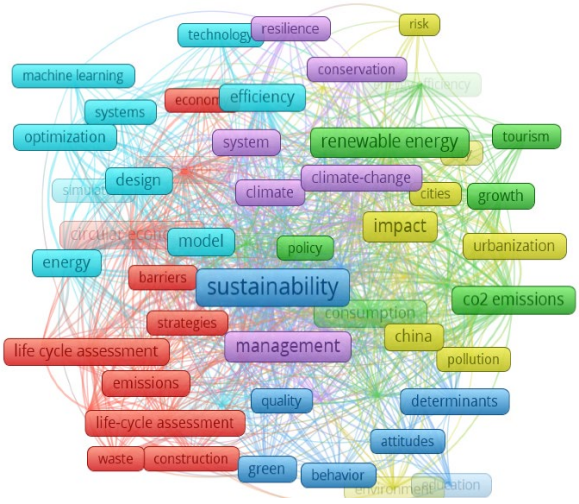

Fig. 5. *Clustering of keywords according to their co-occurrence in the WoS database for the "smart village" subject area*

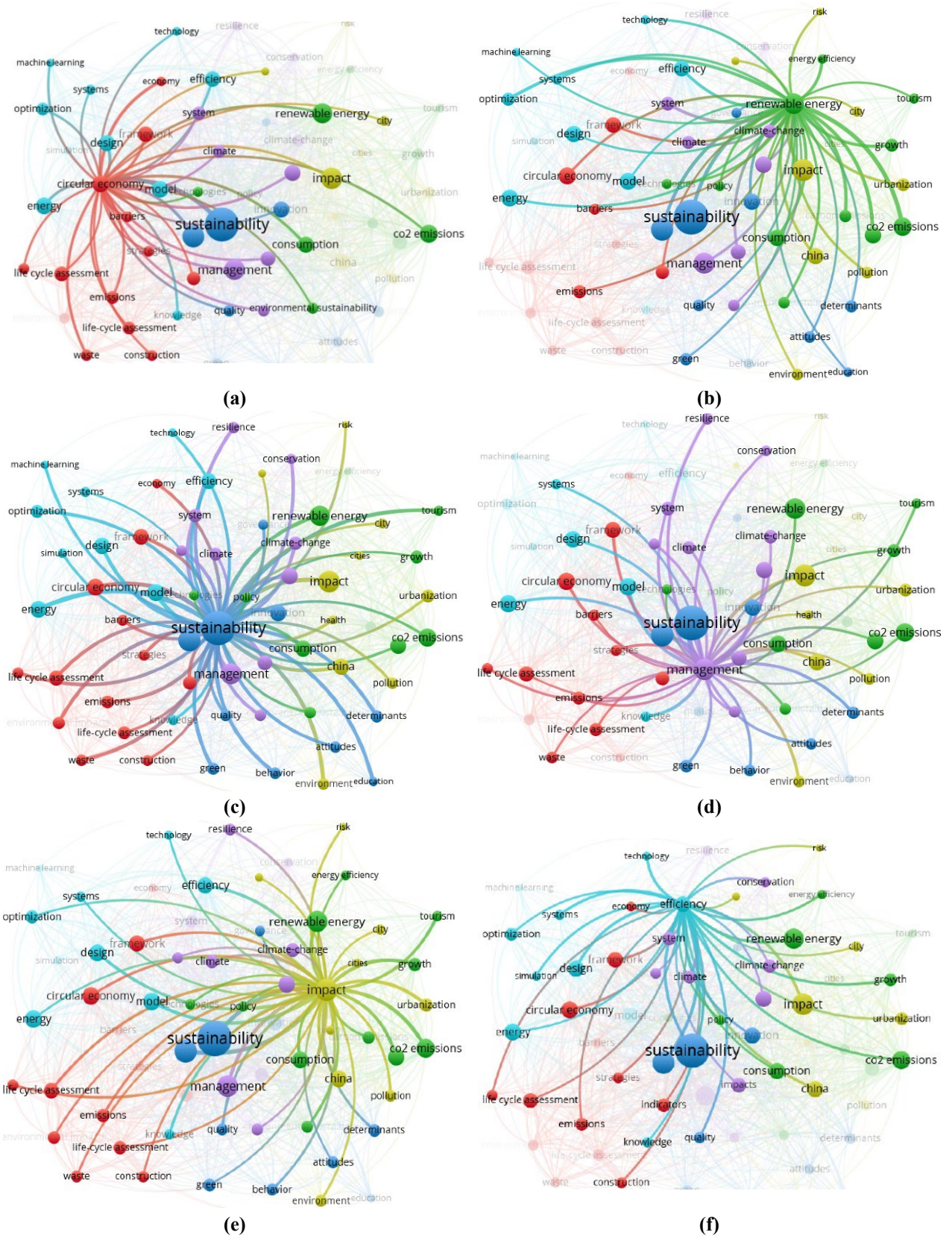

Fig. 6. *Bibliographic mapping for "smart village" scientific area:* ***(a)*** *Cluster 1,* ***(b)*** *Cluster 2,* ***(c)*** *Cluster 3,* ***(d)*** *Cluster 4,* ***(e)*** *Cluster 5,* ***(f)*** *Cluster 6*

As a result of the analysis of scientific articles abstracted in the WoS database in the subject area of smart village, the following actively developing areas of scientific research were identified.

1. The economic structure of a smart village should promote maximum resource efficiency and waste minimization [13]. According to the publications generated in the first cluster, it can be concluded that the village is an integrated environment where it is recommended to adapt circular economy strategies [14]. The circular economy is characterized by: minimizing the consumption of primary raw materials and the volume of

processed resources; reducing waste sent to landfills; and reducing the area of landfills and landfills [15]. A circular economy involves sharing, renting, reusing, repairing, upgrading, and recycling existing materials and products. The application of this concept helps to solve problems such as loss of biodiversity, generation and accumulation of waste, and environmental pollution [16].

2. Based on the publications classified in the second cluster, it can be concluded that a smart village, to save energy, should actively use renewable energy sources, such as solar energy, wind energy, biomass energy, and hydropower with the integration of advanced technologies. Biofuels for transportation, including biodiesel, are increasingly being used to reduce greenhouse gas emissions from transport [17]. Due to anaerobic fermentation, wastewater can serve as a source of renewable energy. The use of renewable energy will reduce carbon dioxide emissions and ensure environmental sustainability [18]. Policies to support such initiatives will promote economic growth.

3. In the publications of the third cluster, the smart village is considered based on the principles of sustainability, innovation and ensuring a high quality of population life, and preserving cultural heritage [19]. Innovations in the field of social systems and infrastructure provision shape new relationships and behavior of people[6]. Digitalization and robotization of labor-intensive processes are catalysts for sustainable rural development. The task of digitalization of rural infrastructure is to improve the standard of population live through accessible and high-quality education, medical care, transport connections. In addition that, the transition to smart farming helps to increase production efficiency [20]. Smart farming technologies operate based on Internet of Things technologies and are applied in all aspects of agriculture. In particular, the use of drones simplifies the processes of applying fertilizers and insecticides, irrigation mapping, monitoring the condition of fields, monitoring and managing livestock complexes, and ensuring the protection of territories in hard-to-reach places [21].

4. Publications in the fourth cluster consider the smart village in the context of the modern world, where special attention is paid to the impact of smart villages on the environment [22]. An example is China, where smart villages play a key role in achieving sustainable development goals, and combating pollution and people health risks. The introduction of environmentally friendly and resource-saving technologies for the sustainable use of the environment is necessary to preserve and restore the village ecosystem through a careful study of the specifics of a particular area [23, 24].

5. According to publications highlighted in the fifth cluster, an important aspect of a smart village is a management method using information and communication technologies that can solve problems related to climate change, conservation of natural resources, and sustainable development [25]. The management system of a smart village must be flexible, adaptive, and based on up-to-date data to ensure the efficient functioning of the infrastructure, optimization of resource use, and minimization of negative impacts on the environment [26].

6. According to publications generated in the sixth cluster, it can conclude that a smart village is a model of rural development that uses information and communication technologies, taking into account local resource capabilities [27]. The concept of sustainable village development is associated with intensive economic development and is based on the rational and efficient use of resources, taking into account the needs of future generations. The basis of sustainable development is the balance of economic growth, social and environmental responsibility of the village leadership [28]. An imbalance can lead to negative consequences, for example, extensive development of a territory by covering large areas can disrupt the ecosystem, provoke pollution of water resources, and threaten food security. The essence of the problem of sustainable rural development is to achieve production efficiency in conditions of limited and exhaustible natural and energy resources [29].

4. Conclusions

The topic of smart villages has been reseached extensively from 1982 to the present. This article evaluates scientific publications in the subject area of “smart villages” for 2024. Based on the analysis of keywords, the main research areas are identified: adaptation of the principles of the circular economy for a smart village; application of renewable energy technologies; the impact of innovation on the quality of people life; the environmental impact of smart villages in the Chinese context; use of effective management methods; strategies to ensure sustainable development of smart villages.

A smart village is a concept for a sustainable rural community that integrates advanced information and communication technologies and circular economy principles to ensure the minimization of environmental impact and improved quality of life [30]. The goal of a smart village is to create a sustainable innovative environment where renewable energy sources are actively used to supply the population with electricity and heat, and energy consumption itself is optimized using efficient technologies and remote control. One of the key aspects of a smart village is its sustainability through the use of a circular economy, where resources are maximized and waste is minimized through recycling and reuse [31]. Life cycle assessment of materials and products plays an important role in this process, identifying the best ways to manage resources and reduce negative environmental impacts. The economic growth of a smart village is driven not only by increased productivity and resource efficiency but also by stimulating innovation [32]. Innovation plays a key role in the development of smart technologies that improve the quality of life and ensure sustainable development. Incorporating renewable energy into a smart village reduces dependence on fossil fuels and reduces carbon emissions, which is beneficial to the environment and promotes sustainable development. However, to ensure sustainability, it is also necessary to focus on managing energy consumption, introducing innovative technologies, and developing an effective management system that ensures optimal use of resources.

The identified trends in scientific research on the development of smart villages are also relevant to the conditions of Azerbaijan [33]. Some measures to achieve sustainable development indicated in the studied articles have already

been implemented, and some are planned to be applied. This study will help to clarify further directions for the development of smart villages in Azerbaijan and it can be used by researchers to study research trends on this topic [34]. The fact that the keywords- sustainability, circular economy, renewable energy sources, quality of life of the population, effective management methods, carbon dioxide emissions- are most often used in the considered research field, shows its interdisciplinary, therefore interdisciplinary scientific research in this direction is necessary [35].

Author Contribution

Data curation – Samira Akbarova (SA); Formal analysis - (SA); investigation - (SA); Experimental Performance - (SA); Data Collection - (SA); Processing - (SA); Literature review - (SA); Writing - (SA); Review and editing - (SA)

Declaration of Competing Interest

The authors declared no conflicts of interest with respect to the research, authorship, and/or publication of this article.

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