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Farmers' Willingness to Achieve Energy Self-Sufficiency in Kosovo

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Abstract: Agriculture accounts for a significant economic share in less-developed countries, especially Kosovo, where there is a lignite-dominated energy supply. Lignite's partial replacement with locally produced renewable energy sources could play an essential role in reducing farmers' costs and preparing the country for EU accession. Using a sample of 120 farmers, the Best–Worst Scaling (BWS) technique was used to assess farmers' preferences for renewable energy applications and to measure the importance of seven key characteristics associated with the willingness to become energy self-sufficient. The results show a significant preference for "lower energy costs" and "environmental friendliness". Using cluster analysis, it is shown in a statistically reliable way that while the decisions of smaller farms are influenced by economic factors and the role of energy self-sufficiency is negligible, a non-negligible share of larger farms already have already adopted self-sufficiency in energy production (solar panels, byproducts) and also consider the environment and convenience aspects necessary in their decisions. Farmers play an important role in local economic development. Therefore, regulatory schemes with differentiation by farm size may play an important role in promoting local energy management in Kosovo and similar less developed countries.

Keywords: attitude; straw; solar panel; BWS; cluster; local

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1. Introduction

Effective resource use is essential to ensuring sustainable development and avoiding depleting the resource supply for future generations [1]. Rapid increases in the production and use of energy are a side effect of globalization, and they can lead to environmental damage and the depletion of natural resources. In nations with low development, the agriculture sector is essential to long-term growth. Agriculture generates a stable supply of food and thus the population's nutrition, which depend on the sustainable production, distribution, and consumption of agricultural produce.

A structural transition toward an agricultural system that fully integrates climate change considerations is required to meet the 2030 targets of the European Commission [2]. A nation's ability to compete may thus be enhanced through agricultural development, which has the added benefits of improving the supply of food and other essential inputs. By using renewable energy sources in the later stages of production, farmers may lessen the negative impacts of fossil fuels on the environment and their farmland. Despite the undeniable environmental benefits of using renewable energy sources, according to a recent study, the gross final energy consumption of all energy sources worldwide in 2019 was 379 EJ, with renewables accounting for only 17% [3]. Four years later, the final energy consumption rose to 620 EJ in 2023 [4]. The energy potential of biomass from agriculture, forestry, and solid waste will reach around 150 EJ during the next 20 years. Biomass is expected to be essential in creating and operating a new energy system based primarily on renewable energy sources. A total of 1260 EJ/year is considered the biomass on Earth, according to a study by Igbeghe et al. [5], though only 219 EJ/year currently goes toward food, feedstock, fibre, and other industrial uses.

In 2013, biomass emerged as a topic of discussion. A key issue that has been discussed is how the limited land resources available to supply the food needs of an expanding global population severely restrict the potential expansion of biomass for energy production. When 21 EU Member States' gross final energy consumption levels in 2022 were assessed, only 3% of energy on average was produced by agriculture. This ratio differed from nation to nation, ranging from 0.9% in Luxembourg to 7.5% in the Netherlands [6]. Germany is the leading country in terms of renewable energy production from agriculture, with 22% of its renewable energy from this source, or 10,347 ktoe (ktons of oil equivalent). This demonstrates that agriculture is an essential sector for energy generation and consumption.

The current research environment in agricultural renewable energy use and adoption is complex, and our study adds substantial value to this ever-changing industry. The research to date has mostly focused on analyzing the complicated inter-relationships between agriculture, natural resources, renewable energy, and farmers' perspectives on these issues. The purpose of this study is twofold. First, it examines farmers' preferences for renewable energy applications using an object/case Best–Worst Scaling (BWS) technique and cluster analysis. Second, our study quantifies the significance of the seven most relevant factors identified in the current literature, using a sample of 120 farmers. This is the first study to provide a country analysis of RES (renewable energy source) acceptance patterns among farmers using the BWS technique.

1.1. Energy and Its Importance

Conventional utilization of biomass from arable land for food production has exhibited considerable variability in recent decades, primarily attributable to demographic shifts and evolving dietary preferences [7]. It is estimated that the total biomass we can obtain is 1260 EJ/year, and currently, only 219 EJ/year is utilized, leaving vast untapped energy potential [8]. This is of critical value as the rising living standard is typically accompanied by an increasing energy demand, especially in developing countries [9].

Environmentally friendly agriculture offers a renewable energy source, and thus agricultural development may lead to better food security, energy efficiency, and environmental protection [10]. Globally, agriculture's utilization to support energy production differs according to the degree of development, type of agriculture, and agricultural methods used. Developing nations experience greater limitations on their capacity to utilize agriculture for this application because of their underdeveloped infrastructure, restricted access to contemporary technologies, and increased reliance on manual labour [11]. Developed nations, meanwhile, struggle with integrating renewable energy sources, cutting their emissions, and optimizing their energy use. To address the latter challenge, the EU is seeking to boost the proportion of renewable energy used across all economic sectors, which is essential to achieving the targets of cutting net greenhouse gas emissions by at least 55% by 2030 and transforming the continent into a climate-neutral region by 2050 (EU) [12]. This is because the energy sector causes more than 75% of the greenhouse gas emissions in the EU. Modern civilization has raised people's standards of living by decreasing poverty and supplying the growing need for food, but at the expense of the environment, primarily through the release of greenhouse gases like carbon dioxide—greenhouse gas (GHG) emissions contribute to natural climate degradation and constitute a primary global concern. Kosovar farms could lessen their carbon footprint using renewable energy and become more self-sufficient. This may have an indirect impact on the energy markets and supply chains that are linked to the EU. For example, the lower emissions from self-sufficient farms help the overall sustainability of the agricultural supply chain if Kosovo sells agrarian products to the EU. Despite not being a member of the EU, Kosovo's emission reduction initiatives may complement more general regional and international objectives, indirectly assisting the EU's greenhouse gas reduction aims.

Agriculture and forestry use technology (such as tractors to cultivate fields) and energy-intensive processes like heating greenhouses and livestock barns. Indirect energy use occurs in forestry and agriculture when agrochemicals, farm equipment, and structures are made. Inorganic nitrogen fertilizers are made with significant natural gas [12]. Direct energy is used directly in various agricultural processes, such as operating machinery and tools for various farm tasks, vehicles, and drying and refrigeration equipment. In contrast, the energy required to make herbicides, insecticides, and fertilizers for agriculture is called indirect energy usage. Using renewable energy in agriculture will support the separate attention to food, energy, and water, as population growth and climate change are the main drivers of energy and food demand [13]. Food security concerns can be ensured by using renewable energy in agriculture and effective energy management techniques to lessen input costs. According to FAO [14], approximately 30% of the energy used for end-use worldwide is currently consumed by the food industry, and a large portion of this energy is derived from fossil fuels. After production, more than 70% of the energy required in food chains is consumed. To mitigate the effects of climate change, food chain growth needs to break free from its current excessive reliance on fossil fuels. Increasing the size of energy-smart food chains can help reduce this reliance. Better energy efficiency, more excellent production and use of renewable energy, and greater accessibility to contemporary energy services are characteristics of these [13]. Energy requirements for irrigation, heating, cooling, and machinery operation are frequently high on farms. Over time, renewable energy sources like biomass or solar panels can severely lower operating expenses and power bills. By producing renewable energy, farms can become less dependent on erratic energy markets and outside energy sources. Because of its independence, energy costs are stable and predictable, which lessens the impact of price swings. Climate change directly impacts agriculture, and using renewable energy sources lowers greenhouse gas emissions. Solar and biomass energy have less adverse environmental impact than fossil fuels, helping farms achieve their sustainability objectives and reduce their carbon footprint [15]. Farms investing in renewable energy will be better positioned for future compliance and regulatory changes as global energy policies and regulations favour renewable energy sources. This long-term outlook improves the entire viability and resilience of the farm.

Kosovo confronts several energy-related issues, such as outdated infrastructure, inefficient industrial and household energy use, and low understanding and implementation of energy-saving solutions. In addition, farm energy demand is expected to increase significantly with GDP (the standard measure of the value added created through producing goods and services in a country during a specific period) growth, as supported by energy trends in developing countries [9].

Various refrigeration and drying machines, which are frequently used in agriculture to store and extend the shelf life of agricultural produce, can be driven by electricity generated by solar panels [16]. Bioenergy, abundant in agriculture, is another significant renewable energy source [17]. The agricultural sector provides a plentiful and affordable supply of the raw materials required for bioenergy in the form of food crops, animals, and municipal solid waste. Agriculture that uses biowaste can contribute to the production of biogas, which can be used to power generators. Additionally, biowaste can be used as fertilizer to lessen reliance on commercial fertilizers.

1.2. Application of Renewable Energy in Agriculture

Numerous applications of renewable energy in agriculture can improve economic viability, sustainability, and efficiency. The agriculture industry is at a turning point where integrating renewable energy technology has the potential to revolutionize the industry [13]. Agriculture systems face more significant challenges in raising output while reducing environmental effects as the world's population grows and climate change worsens. As a key component of the answer, renewable energy offers sustainable sources that can improve agricultural productivity, save operating costs, and promote environmental stewardship [18]. Utilizing renewable energy sources can result in significant financial savings and environmental advantages in agriculture, where energy-intensive processes—such as heating, irrigation, and gear operation—are crucial. Widespread adoption of renewable energy in agriculture is hampered by issues including initial investment prices, technological complexity, and governmental frameworks, despite their transformative potential [19]. However, these difficulties can be lessened, and the shift to sustainable energy solutions can be accelerated with the help of clever incentives, encouraging laws, and cooperative efforts between stakeholders. In this regard, utilizing renewable energy in agriculture allows for water pumping for irrigation and food drying, extending its shelf life.

Farms employ solar photovoltaic (PV) panels in large quantities to produce electricity. They can power barns, irrigation systems, and other farm infrastructure. In addition to providing heat for room and water heating, solar thermal systems are advantageous for greenhouse operations and animal management. Through anaerobic digestion, agricultural wastes, including crop residues and animal dung, can be transformed into biogas [20]. Biogas is a multipurpose energy source that can be used for cooking, heating, and electricity production.

Furthermore, biofuels from certain crops—such as soybean biodiesel—provide an alternative to diesel fuel for farm equipment. Fusing innovative farming technologies with renewable energy improves operational efficiency and resource management. Precision agricultural methodologies, encompassing sensor networks and data analytics, maximize crop monitoring, irrigation scheduling, and energy efficiency. Automated systems maximize output while reducing resource inputs by adjusting energy use based on crop needs and weather conditions.

Solar thermal and solar photovoltaic (PV) systems are the two leading technologies that produce solar energy. Solar photovoltaic systems use semiconductor materials in photovoltaic cells to directly convert sunlight into electricity [21]. When sunlight strikes them, these cells produce an electric current because it excites the electrons. In contrast, solar thermal systems use solar radiation to heat water or other fluids directly to generate power [22]. Moreover, solar energy has significant positive effects on the environment and is clean and renewable by nature. Firstly, producing solar energy results in lower direct emissions of greenhouse gases, thereby lessening the impact of climate change and enhancing air quality [23]. By achieving this, the farm's carbon footprint is neutralized, and the effects of traditional energy sources on climate change are not increased.

Furthermore, resource conservation is facilitated by solar energy, which lessens dependency on finite fossil fuel supplies and encourages sustainable resource management by utilizing solar or small-capacity wind energy, considering the regionally differential amount of available energy (calculated by Lázár et al., 2020 [24] on solar potential and Lázár et at., 2024 [25] on wind potential) and the challenges in storage. In this regard, the heating use of electricity from solar PV panels, or the heat energy from solar collectors, has less of an adverse effect on natural environments than the use of conventional energy sources does, which has the potential to upset ecosystems. With continuous research and development in energy storage, efficiency enhancements, and innovative grid technologies, the future of solar energy seems bright because grid stability and solar energy integration are improved by developments in energy storage technologies (such as batteries and pumped hydro) by facilitating decentralized energy generation and consumption management. Solar energy is essential to smart city initiatives; the use of solar energy will increase as nations work to fulfil carbon reduction targets outlined in international agreements (such as the Paris Agreement), promoting sustainable development and reducing the dangers associated with climate change [26]. On the other hand, organic elements, including animal dung, crop leftovers, and specially planted energy crops, are sources of biomass [27]. A lot of agricultural biomass is made up of residues that would typically be discarded as waste or in ways that are harmful to the environment, like burning them outside. Agricultural biomass can be turned into valuable energy resources, improving environmental results, as a utilization form for energy. Biomass can be converted into various forms of energy, including electricity, heat, and biofuels, making it versatile for different energy needs and applications [20]. Compared to more conventional fossil fuel energy sources, biomass energy generation on farms frequently has less of an environmental impact. It can lessen greenhouse gas emissions, lessen agricultural-related air and water pollution, and support sustainable land management techniques.

1.3. Farmers' Perceptions of Renewable Energy Application in Agriculture

Research on agri-environmental diversification on farms in Scotland found that younger, better-educated farmers with extra income from outside the farm and subsidies are more likely to be involved in future environmental issues like producing renewable energy [28]. This is consistent with the research article of Pestisha and Bai [29] analyzing the preferences and attitudes of Kosovar farmers for renewable energy practices. The population surveyed showed variation in awareness of RESs across demographic segments, with males exhibiting higher levels of awareness and self-assessed knowledge than females. Those in employment demonstrated higher awareness and self-assessed knowledge in RESs than those in unemployment (most likely for budgetary reasons). Environmentally concerned individuals knew much more about RESs than non-ecologically conscious individuals did. The population surveyed showed variation in awareness of RESs across demographic segments, with males exhibiting higher levels of awareness and self-assessed knowledge than females. Those in employment demonstrated higher awareness and self-assessed knowledge in RES than those in unemployment (most likely for budgetary reasons). Environmentally concerned individuals knew much more about RESs than non-ecologically conscious individuals did. Solar panels are the most appropriate and desirable form of energy for use in the future.

Another study [30] elaborated on adopting renewable energy technology on farms. Regarding agriculture, most farmers thought renewable energy was more beneficial and economical than other forms of energy. Similarly, most of the farmers indicated that renewable energy (RE) is greener than other energy sources currently used on farms. The vast majority of farmers have shown their readiness to take chances by switching from traditional energy sources and increasing their RES investments. Moreover, the factors influencing the adoption of renewable energy sources (RESs) on farms are human capital, farm characteristics, government, perceptions of RESs, and farmer entrepreneurial orientation. In this regard, a study by Wang et al. [31] which researched the willingness of farmers to use agrivoltaics showed that a significant portion of the respondents think it is fair for agrivoltaics to contribute to energy generation. Additionally, some farmers believe installing agrivoltaics systems is beneficial; despite this, a large majority of farmers are generally open to utilizing the technology on their farm. Furthermore, factors identified in the willingness to adopt agrivoltaics on their farm are perceived usefulness, subjective norms such as the same perception from the family or relatives, and innovativeness. Another study by Michels et al. [32] elaborated on the perceptions about farming alternative energy tractors in Germany, showing that larger farms with full-time farmers typically oversee significant acreages and various crop portfolios. Hence, they are the first to adopt new technologies eagerly. Additionally, they constantly show the most incredible enthusiasm for utilizing cutting-edge equipment and technologies in their farming operations. They are naturally early adopters of cutting-edge technologies due to their experience optimizing yield and operational efficiency, which informs their proactive approach. In addition to increasing farm output, their pioneering use of technology makes them stand out in the agricultural world. It inspires others to investigate and adopt game-changing developments in farming methods. Furthermore, alternative fuel tractors are deemed viable mainly for light, non-energy-intensive farm work, and short-distance transport. On the other hand, only a tiny percentage of farmers believe that tractors running on alternative fuels could be helpful for long-distance and energy-intensive field labour. In this regard, the main barriers are lower driving ranges, very high investment costs, and inadequate infrastructure to support alternative fuels. In this regard, an Italian study [33] elaborated on the perceptions of farmers of Pistoia Province towards the willingness to pay for electric tractors, and the findings show that the price, lower-powered engine, and operational costs (due to battery cost and lifespan) are all constraints restricting the potential adoption of electric tractors in the nursery plant industry. In terms of farm features, biofuel tractor preferences rise with farm size, taking into account medium (from 1 to 4 ha) and large farms (>4 ha). According to a study conducted with 1200 Pakistani farmers [34], it was revealed that farmers' socioeconomic factors had a substantial impact on the adoption of PV water pumps, with younger, better-educated, and wealthier farmers ready to pay a premium for green electricity. Furthermore, the data showed that most farmers (72%) were unwilling to pay more for green electricity. The primary reasons for this reluctance were a lack of financial resources, the availability of fossil fuel alternatives, and a lack of knowledge about the new technology.

1.4. Energy Self-Sufficiency in Agriculture

One of the potential rationales for using renewable energy sources is to achieve greater alignment with the legislative framework of the EU. It is acknowledged that decision-makers face complex challenges in this regard, given the multitude of economic growth and environmental protection. These challenges must be addressed promptly and coordinated [35]. Utilizing local resources offers numerous environmental advantages, including decreased energy consumption, enhanced energy efficiency, higher energy supply reliability, decreased transmission losses, and improved energy supply security [36]. It is also possible to generate biogas from biodegradable municipal waste. This trash is a valuable substrate that can produce significant biogas when mixed 1:1 with cattle dung. There is a lot of potential for biogas generated from garbage in rural areas surrounding cities to meet their energy needs. One issue with combined heat and power generation is that biogas plants utilize half of the heat generated, on average, at a relatively moderate level. Just 10% of biogas producers in Germany utilize more than 50% of the heat. The remainder might be used to heat nearby homes and structures that are close to the biogas plant. Despite the considerable potential for biogas production in Kosovo, operational plants are absent in practice [37]. The primary reason is the substantial investment required, which eclipses the advantages of sustainability and local economic development [35].

In Japan, Balda et al. presented a plan for an independent farm that could provide fuel, heat, and electricity to meet its requirements. The study offers a model of an independent farm that maximizes a biogas plant's size based on its unique fuel and food requirements. These farms use crops to produce food or fuel, and cogeneration uses the crop wastes to produce heat and electricity [38].

Due to their suitability in rural areas where electricity access is typically insufficient, agricultural wastes have been suggested to be one of the most dependable raw resources that may be used in Africa to provide universal electricity access and emissions reduction [39]. Numerous methods for producing power from biomass, including agricultural wastes, typically involve two main steps. The first step is turning biomass into intermediate fuels using thermal, chemical, or biological methods. Anaerobic digestion and fermentation are examples of biological processes. Chemical reactions include Fischer–Tropsch and trans-etherification. Gasification, pyrolysis, and combustion are examples of thermal processes. Using an electric generator, the intermediate fuels from the first stage are transformed into electricity in the second stage. Biomass from agriculture could be a prelude to sustainable energy production. Depending on the type of crop species, biomass has varying amounts of energy.

As an illustration, hay straw has roughly 3738 kcal/kg (15.639 MJ/kg) [17]. For cooking, heating, and lighting, more than 30% of home energy worldwide comes from biomass produced in agriculture. Both types of biomass (whether processed or raw) produced during agricultural operations are acceptable for producing heat and power commercially. In Poland, about 25–28 million tonnes of straw were produced annually, according to the Polish database in 2010. About 4.9 million tons of grain and rape straw were utilized to obtain electricity. Biogas may be produced using combustion techniques in an estimated 1.5 billion m^3. In addition to various domestic uses, it is estimated that 37% of China's agricultural biomass is utilized directly as combustible fuel for cooking and heating, meaning that energy self-sufficiency is increased through this material.

Furthermore, in the Latin American population, farm biogas production is sufficient to meet their energy demands; the production capacity reaches 81 TWh/year, covering almost 50% of the energy demand [40]. However, electricity production for small farms (less than 15 cows) is less efficient than for more prominent farm structures. Medium- (50 to 100 cows) and large-size farms (above 100 cows) are considered more self-sufficient and typical for biogas-based types of energy.

A study by Zheng et al. [41] mentioned that the optimized synergetic management strategies indicate that maize and wheat should be prioritized as the primary crops. Additionally, it is recommended that the biomass residues collected from these crops be utilized as a priority for bioethanol production to meet the economic objectives effectively. Moreover, limited water resources are likely to impact crop planting distribution and the availability of agricultural residues. Consequently, this scarcity may alter biomass utilization strategies, shifting the focus from bioethanol production to increased pellet production.

Another form that contributes to energy self-sufficiency is agrivoltaics (AV) systems [42], which are becoming increasingly popular in farming and renewable energy communities. AV systems combine agriculture and electricity production in one area using solar modules placed several metres above the ground. A study by Coşgun et al. [43] researched the nature and application of AV in Turkey. The population's primary traditional activity is agriculture; however, the industrial and service sectors are growing quickly. Turkey has a lot of promise for AV systems because the country has a lot of agricultural areas, lots of sunshine, and a growing energy demand. Using AV systems can help Turkey's energy and agricultural industries.

1.5. Kosovo's Agriculture and Renewable Energy

Kosovo can be described as an essentially agricultural country. Approximately 420,482 ha is designated for agriculture. Within this area, 51.6% is pastureland and meadows, while the remaining 44.8% is arable land, followed by gardens, tree plantations, vineyards, and nurseries with 3.6% [44]. Additionally, 23 acres of agricultural land per capita were represented for 2022. Given these circumstances and the fact that Kosovo's land is highly fertile for farm products, it is evident that Kosovo holds significant agricultural potential. Kosovo's agriculture, however, confronts serious structural difficulties. The division of Kosovo's agricultural land is the main problem. Most farms in Kosovo are small- to medium-sized, with over 90% covering less than 5 hectares [45]. This results in low production and higher production expenses.

On the other hand, only 1.8% of businesses have more than 10 hectares of agricultural farmland. Kosovo thus has a sizable population of part-time agrarian labourers. This shows that family businesses handle a large share of the farming activity in Kosovo, making it challenging to develop a coordinated agricultural policy. Furthermore, farmers must raise the amount of funding for their investments to improve the efficacy of the farm. These investments should be made in increased planted areas, animal farms and stables that meet European standards, and livestock funds. Disadvantages to be mentioned are the inaccessibility of loans and high interest rates of microfinance compared to other sectors [44]. Farmers may boost output by making these improvements to their farms while also getting ready for a new growing season. When considering other significant problems facing Kosovo's agriculture, it is important to highlight that low worker productivity and a dearth of sophisticated agricultural technologies exist. Furthermore, because the sector has not been adequately planned, Kosovo's agriculture has little access to international markets. These problems have led to a declining tendency over time in the added value of agriculture to Kosovo's GDP, with a 12% contribution in 2014 to 7.4% in 2023 [46,47].

Regarding alternative energy, with a potential that is still primarily unrealized, renewable energy sources (RESs) are a significant energy source available in Kosovo. Kosovo exceeded its 25% RES share goal in 2020 [48,49]. With biomass serving as the primary heating source that helped reach the goal, the representation of various RES technologies is uneven, and sectoral RES percentages vary significantly (electricity generation is only 6.3% whereas heating and cooling are 55.9%). Currently, biomass-based energy sources constitute the primary renewable energy source in the energy sector, accounting for the majority of RESs in the electrical industry, at just 6.3%. Furthermore, biomass will be the leading renewable energy source for heating and cooling, with a 92% market share by 2030. Kosovo's theoretical potential for renewable energy is 6.13 million tons per year, according to the study of Sertolli et al. [50], while its potential for biomass energy is estimated to be 4.57 million tons per year, of which 74.6% can be used for energy demands (heating and electricity). The statistics and computations indicate that biomass has significant potential as an energy source in Kosovo despite its relatively small share. It makes sense to increase it for both economic and environmental grounds. Using forestry wastes, agricultural residues, and specially cultivated energy crops that may be grown on marginal sites, biomass energy encourages resource efficiency.

Notwithstanding the numerous advantages inherent in the operation of biogas plants in agriculture, the high financial outlay required to establish such facilities renders them a missing component of Kosovo's agricultural sector [37]. In addition to supporting sustainable farming practices, this lowers the costs of the disposal of trash and lessens the environmental impact of waste management. Nevertheless, there is still a lack of enthusiasm among farmers to use biomass for energy production on their farms [51]. Small farm sizes, a lack of facilities, and mechanization are just a few of the serious issues facing the industry that must be addressed to maintain agricultural economic growth. In contrast, a study by Pestisha and Bai [29] researched the farmers' perceptions and attitudes towards renewable energy sources. It concluded that farmers were interested in innovative renewable solutions like solar panels because of their environmental eco-friendliness. Contrarily, it was revealed that the main deterrent to deploying any RES technology is the high cost of equipment purchases. Furthermore, almost all farmers who were asked if they would be interested in selling the extra and leftover straw from their farms said that they would.

The comparatively low rates of alternative energy farming in Kosovo are caused by several issues, including the following:

- Economic constraint: One major obstacle to farmers accessing alternative energy forms is the high cost of equipment [29]. RESs are no longer affordable for many farmers due to this financial load. Given the high initial investment cost and the disparity in purchasing power among them, many of the farmers are unable to access electricity sources that use renewable energy.
- Insufficient funding: the availability of cost-effective financing alternatives for renewable energy applications in agriculture initiatives is limited, posing challenges for farmers [47].
- Reliability and maintenance: The existing conditions for adopting alternative energy in agriculture are frequently vulnerable to poor maintenance skills, and they might not have the resources and knowledge necessary to support and maintain renewable energy systems for the duration of their useful lives. This includes having access to replacement parts, skilled technicians, and technical assistance for repairs and troubleshooting.

To address these infrastructure constraints, a comprehensive strategy considers legislative assistance, financial incentives, technological innovation, and cooperation between government agencies, energy providers, farmers, and other stakeholders. Overcoming these obstacles will enable agricultural renewable energy to provide significant advantages, including lower energy costs, less of an impact on the environment, and more energy independence for rural areas.

2. Materials and Methods

Through an approach that focuses on comprehending the growing awareness of sustainable agriculture practices, the opinions of Kosovo's farmers on renewable energy are investigated. This study intends to explore how Kosovo's farmers rate the significance of renewable energy sources and view their incorporation into local agricultural systems, considering the global debates surrounding climate change. This study uses questionnaires to collect data to determine farmers' knowledge and attitudes regarding renewable energy solutions, including different attributes for them. Assessing the level of familiarity regarding renewable energy technologies, their existing application in farming methods, and any obstacles or difficulties farmers may encounter in implementing these technologies are further components of the process. This strategy will shed light on how renewable energy is perceived in the context of Kosovo's agriculture industry and how it might affect rural development and sustainable farming methods.

It is essential to comprehend farmers' perspectives on renewable energy to promote a sustainable culture in the agriculture industry. Farmers will be crucial in influencing agricultural practices that encourage sustainable energy technologies because they are major participants in the sector. Their opinions can offer essential insights into the possible obstacles and advantages of incorporating renewable energy into farming systems, eventually affecting sustainable agricultural development in their area. Additionally, integrating renewable energy into farming methods can make farms more resilient to climate change and growing energy prices. For instance, farmers can lessen their dependency on costly electricity or fuel-powered generators by using solar energy to power irrigation equipment. Similarly, using biogas made from organic waste can offer a sustainable energy source for powering, lighting, and heating farm equipment. By reducing greenhouse gas emissions, these technologies increase energy independence and give farmers the chance to moderate their environmental impact. In Kosovo's rural areas, where access to dependable energy sources may be restricted, and energy prices might account for a sizable portion of operating expenses, such techniques can be especially crucial.

To effectively assess farmers' attitudes toward renewable energy methodologies such as the Best–Worst Scaling method can be employed. This method can determine which features of renewable energy farmers find most appealing and which they find least attractive. Furthermore, detailed information on farmers' objectives and concerns can be obtained by asking them to rank the best and worst options for renewable energy based on various statements or features, such as equipment price, convenience, or environmental impact. This method assists in determining how farmers view the possible advantages and difficulties of incorporating renewable energy into their farming operations. The more detailed process that led the authors to choose this method is presented in Figure 1.

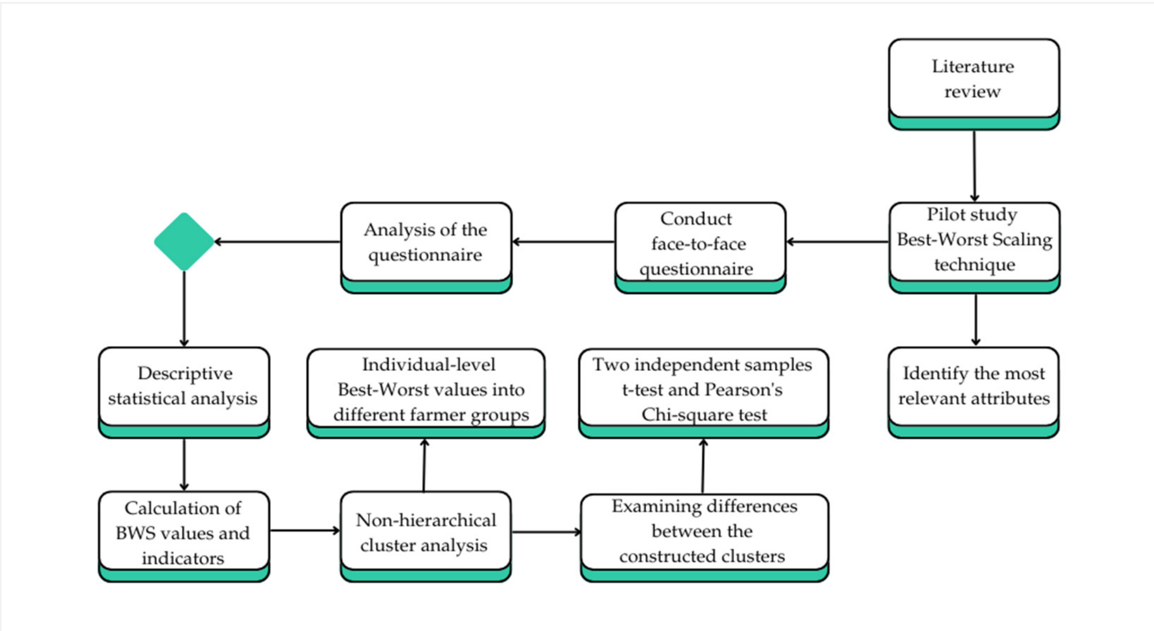

Figure 1. Flowchart describing the detailed process leading to method selection. Source: author's own construction.

The Best–Worst Scaling (BWS) technique allows the study of personal preferences based on attributes applied to food demand and agricultural economics [52–55]. Based on stated preference information, this method asks respondents to use one of three BWS methodologies (object case, profile case, or alternative case) to select the best and worst alternative, attribute, or attribute level among the other options [56,57].

Based on their relevance and extensive literature research, seven pertinent attributes for farmers' opinions of renewable energy equipment (Table 1) were considered for the experimental design. The respondents were asked to rank the attributes that they believe are most and least significant for renewable energy applications in each BWS choice assignment.

Table 1. Attributes used in the object case BWS questions.

No.	Attributes
1	Eco-friendliness
2	Less energy cost
3	Convenience
4	Investment cost
5	Energy cost savings
6	Available products for energy purpose
7	Current energy costs

Source: author's own construction.

The questionnaire's introduction was structured as follows (Table 2): "In the following section, the author wanted to examine the elements that affect your choice to use renewable energy sources in the next part. You will be asked to rank the most and least significant characteristics that influence your decision to choose a renewable energy source in each of the three scenarios shown to you". This method enables a thorough comprehension of the relative significance of different elements, offering insightful information on the priorities and issues influencing farmers' attitudes toward the use of renewable energy.

Table 2. Example of the BWS decision situation.

What Factors Do You Consider Most Important and Least Important Regarding the Use of Renewable Resources?		
Feature	The most important	The least important
Eco-friendliness		
Availability		
Investment costs		

Source: author's own construction.

The primary data analysis stage is determining the Best–Worst Scaling (BWS) values. The authors determined the difference between each feature's "most important" and "least important" elements to accomplish this. This technique allowed the authors to examine how each attribute was regarded compared to the others. The study discovered that four of the seven qualities obtained good ratings, with only three having negative BWS levels. These four features were consistently rated as "most important" by participants, emphasizing their relative importance in comparison to the other attributes. In the second phase of the analysis, the BWS values were normalized to account for the sample size (120 participants) and the frequency with which each attribute featured in the experimental design. The authors calculated standardized BWS values by dividing the BWS values by the number of participants and the frequency with which each attribute was presented. These standardized values were then ranked to provide a more accurate view of the relative relevance of each element. This ranking process enabled the identification of the most to least significant elements based on farmers' perceptions. In the third phase of the analysis, the Best Ratio Scale was created by taking the square root of the ratio between the "most important" and "least important" cumulative data, $\sqrt{\frac{\text{Best}}{\text{Worst}}}$. This step standardized the data, allowing for more accurate comparisons across the various properties. The attribute that received the highest score based on this formula was "Less energy costs", which had the highest cumulative value of 100%. As a result, it was placed at the top of the scale. All other attributes were then measured relative to it. This approach allowed identifying which attributes were perceived as more or less important when considered in the context of the most highly ranked factor.

Finding the best and worst values for each criterion is the first stage in data analysis using this method. To accomplish this, the 'best' and 'worst' values are subtracted. Remembering that this procedure can be performed at both the individual and aggregate levels (Equations (1) and (2)) is crucial.

$$\textit{Best–Worst}\ \text{Score}_{\text{n,k}} = \textit{Best}\ \text{score}_{\text{n,k}} - \textit{Worst}\ \text{score}_{\text{n,k}} \quad (1)$$

where k is the evaluated factor taken into account and n is the respondent.

$$\textit{Best–Worst}\ \text{Score}_{\text{k}} = \textit{Best}\ \text{score}_{\text{k}} - \textit{Worst}\ \text{score}_{\text{k}} \quad (2)$$

The significance of the factors under consideration is ranked using the final level (aggregate) Best–Worst Scores. The average Best–Worst values and the standard deviations of the criteria can be found in the next step. The standardized Best–Worst values of Cohen (2009) can then be computed and plotted, both individually (Equation (3)) and aggregated (Equation (4)).

$$\text{Standardized}\ \textit{Best–Worst}\ \text{score}_{\text{n,k}} = \frac{Best\text{–}Worst\ scoren,k}{f}, \quad (3)$$

where f is the frequency of occurrence of the aspects taken into consideration.

$$\text{Standardized}\ \textit{Best–Worst}\ \text{Score}_{\text{k}} = \frac{Best\text{–}Worst\ scorek}{Nf}, \quad (4)$$

When N is the number of respondents.

The square root of the Best–Worst ratio (Equation (5)) and its standardized form (Equation (6)) are calculated in order to analyze the factors.

$$\text{sqrt.}\ \textit{Best–Worst}\ \text{score}_{\text{k}} = \frac{Best - scorek}{Worst - scorek}, \quad (5)$$

$$\text{sqrt.}\ \textit{Best–Worst}\ \text{score}_{\text{k}} = \frac{\text{sqrt.Best–Worst scorek}}{\text{max.(Best–Worst score)}} \quad (6)$$

where max. (Best–Worst Score) is considered to be the highest value of sqrt. Best–Worst score_{k} [58].

Individual-level Best–Worst values are used for additional statistical analyses because of preference heterogeneity investigation. This method enabled the authors to investigate how respondents' preferences and attributes differed. To further understand these differences, the non-hierarchical (K-Means) cluster analysis is used to discern different respondent groups according to their attribute preferences for using renewable energy. This method made it possible to find hidden patterns in the data that would not have been immediately obvious.

Additional statistical tests were conducted to investigate variations across the identified clusters. To determine significant differences between clusters, the Mann–Whitney test was used on ordinal measurement variables such as gender, age, type of agricultural sector, location, residence, and occupation. IBM SPSS Statistics 29 was used to perform two-step clustering, which increased the analysis's robustness. Two independent samples, *t*-tests and Pearson's Chi-square test, were conducted to examine the clusters further and determine how the detected groups differed in demographic and socioeconomic features. The combination of approaches enabled a thorough examination of preference heterogeneity and its ramifications.

Data Sampling

In the study, 120 farmers from all regions of Kosovo were interviewed through a questionnaire. To ensure representativeness, the authors considered the number of active agricultural households per region based on the data of KAS (Kosovo Agency of Statistics) [59] and then conducted the sampling per region. The total number was 129,220, with Prishtina leading with 31,966 agricultural enterprises. Then, based on the number of interviews generated, the authors applied the analysis of collected data through the quantitative research of the BWS methodology. Based on the results in Table 3, 0.8% of the interviewees are from Prishtina, the capital city, whereas the Ferizaj region was represented less, with just 9.2% of the interviewees participating in our study.

Regarding farm production, the majority were combined farms, producing both livestock and plant production. Farm size varied on different scales, but mainly in terms of the minor categories, with 73.3% being less than 5 hectares. The farms were primarily headed by males (94.2%), which is typical in farms globally. However, the average age of 43 years (with a high standard deviation) is significantly lower than the age of farmers in the EU, which is 57 years old [60]. The figure of 76.7% of farmers having high school degrees is a positive factor.

Regarding crop planting, 77.5% of the farmers cultivated maize and grain, while 92.5% used straw for farm bedding. These products are essential for self-sufficiency in foddering and bedding; however, straws also have great potential for energy self-sufficiency. The 10% of solar panel owners in farms are noteworthy in terms of electricity self-sufficiency; however, practical usage and storage are problems that need to be solved.

The main sample characteristics are reported in Table 3.

It is worth mentioning that the agriculture sector in Kosovo continues to use data from the 2014 agricultural census, since this outdated database does not represent current advancements and changes in this sector. Moreover, the currently available data are not disaggregated at many levels, including those for agricultural farmer categories based on age, education, energy in farms, and production levels. Due to the information void this has caused, it is challenging to gather precise and comprehensive data for upcoming agricultural analyses. The authors have, therefore, looked for alternatives to offer more current and accurate data. One of the possibilities for more updated data was the Kosovo Association of Milk Producers, which has a membership database with 1250 farmers [61]. This information makes conducting analysis and better comprehending the dynamics of Kosovo's agriculture industry possible. In this way, the Kosovo Association of Milk Producers has given the authors a better picture of the current circumstances of member farmers in addition to the inaccurate and out-of-date information provided by the 2014 census data.

Due to the lack of an up-to-date and detailed official national agricultural database, every effort has been made to ensure that the distribution of our sample of 120 farmers is by the estimated national figures based on experts' opinions. This factor further underpins the novelty of our research and, to a certain extent, supports their representativeness.

Table 3. The main characteristics of the farms and the farmers.

Denomination	Categories	Percentage
Gender	Male	94.2
	Female	5.8
Education	Primary school	5.8
	High school	76.7
	University	17.5
Municipality	Ferizaj	9.2
	Gjakovë	12.5
	Gjilan	14.2
	Mitrovicë	14.2
	Pejë	13.3
	Prishtinë	20.8
	Prizren	15.8
Type of the farm	Cattle or crop farm	7.5
	Combined production	92.5
Farm size	Lower than 5 hectares	73.3
	Between 5 and 10 hectares	10.0
	Above 10 hectares	16.7
Production of maize	Yes	77.5
	No	22.5
Bedding	Yes	92.5
	No	7.5
Solar panel in the farm	Yes	10.0
	No	90.0
Age (year)	Mean	43.78
	SD	9.27
Solar panel capacity (kW)	Mean	0.52
	SD	1.89
Electricity consumed (EUR/month)	Mean	46.88
	SD	118.61
Number of cows	Mean	19.89
	SD	30.76
Wheat production (ha) (n = 112)	Mean	4.81
	SD	14.67
Maize production (ha) (n = 97)	Mean	7.21
	SD	16.49

Source: author's own results.

3. Results and Discussion

The attitudes and perceptions among farmers of the seven main regions in Kosovo show increased awareness of including sustainable practices in farms driven by an eco-friendliness motivation. The environmental and sustainable perceptions are found in Table 4.

Table 4. Farmers' opinions towards sustainable practices in agriculture.

Denomination	Categories	Percentage
How much do you prefer solar cells?	Moderately	5.8
	Very	9.2
	Very much	85.0
How much do you prefer by-product use for energy purposes (e.g., straw firing)?	Not at all	18.3
	Slightly	17.5
	Moderately	25.0
	Very	7.5
	Very much	31.7
How much do you prefer main-product use for energy purposes (e.g., short-rotation coppice for heat production)?	Not at all	5.0
	Slightly	15.8
	Moderately	27.5
	Very	13.3
	Very much	38.3
In comparison with traditional energy, clean energy can improve quality of life.	Likely	3.3
	Most likely	7.5
	Definitely	89.2
To what extent do you believe that improving energy efficiency practices (e.g., better insulation, energy-efficient equipment) can contribute to energy self-sufficiency on farms?	Slightly	1.7
	Moderately	4.2
	Very	8.3
	Extremely	85.8
Government incentives and subsidies play a significant role in promoting the adoption of energy self-sufficient practices on farms.	Not Strongly Agree	8.3
	Strongly agree	91.7

Source: author's own results.

As global consciousness is increasing, the attitude of farmers is following the same direction. Growing environmental awareness has affected farmers' perspectives on farming methods. Many farmers have started to switch to more sustainable agricultural practices as awareness of climate change increases. Farmers are being prompted to re-evaluate conventional farming methods that may have been more detrimental to the environment in favour of methods that promote ecological balance due to increased environmental consciousness. Based on farmers' perspectives, this positive shift can be seen in Table 5.

Table 5. Farmers' perspectives towards sustainable practices in agriculture.

Denomination	Categories	Percentage
The importance of community collaboration and knowledge-sharing in promoting energy self-sufficiency initiatives among farmers.	Not extremely important	5.0
	Extremely important	95.0
Investing in energy self-sufficiency measures enhances the overall competitiveness and viability of farms.	Neutral	5.0
	Agree	11.7
	Strongly agree	83.3

Table 5. *Cont.*

Denomination	Categories	Percentage
Utilizing renewable energy sources such as solar and wind power is an effective way to reduce greenhouse gas emissions on farms.	Neutral	8.3
	Agree	15.0
	Strongly agree	76.7
Indicate your perception of technical challenges, such as lack of expertise or knowledge, as barriers to the adoption of renewable energy technologies in agricultural operations.	Important	6.7
	Extremely Important	93.3
	Mean	Standard Deviation
BWS—Energy cost savings	1.24	0.73
BWS—Available byproducts for energy purposes	−0.39	0.93
BWS—Less energy costs	2.31	1.13
BWS—Environmental friendliness	1.88	0.98
BWS—Convenience	−2.14	1.02
BWS—Investment cost	−1.27	1.17
BWS—Current energy costs	−1.63	0.83

Source: author's own results.

The following sections will detail the descriptives and the statistics performed to better understand how farmers act towards new energy practices, sustainable practices, and care for the environment. The main goal was to understand the effect of sustainable farming and the importance that farmers attach to the sustainability goals.

3.1. Farmers' Attitude Towards Renewable Energy

The data generated from the questionnaires showed an excellent level of enthusiasm for the practice of solar panels, with 85% of the respondents indicating that they prefer solar panels very much, showing an outstanding level of support towards sustainable energy sources, as shown in Figure 2. The other 9% showed a "very" preference, with a positive view of this equipment. Overall, the results indicate a favourable preference from the farmers towards the practices of solar energy, showing a tremendous shift in farmers' opinions and an increase in awareness of the benefits of this form of energy. The positive shift is similar to the findings of a German study, where 74.8% of respondents believed that agrivoltaics may help energy production in Germany [31]. This shows increasing agreement on agrivoltaics' potential to provide sustainable energy solutions. The encouraging prognoses in both nations emphasize the growing acceptance of cutting-edge, dual-purpose land use technology that boosts agricultural output and supports renewable energy ambitions. On the other hand, 72.4% of respondents are generally open to implementing the technology on their farms. This implies that even while the potential of agrivoltaics is highly believed in, the personal adoption of technology still needs careful consideration, most likely because of implementation and cost issues.

Even though the farmers preferred solar panels, their applications on the farm were not very high in actual conditions. The results in Figure 3 show that 90% of the farms had not yet adopted solar panels in their farms. This considerable difference shows that despite the increasing awareness of the benefit of alternative energy sources, farmers are still facing different barriers to adopting solar energy in their farms. The initial cost of installing the solar panels is the main factor that impacts this situation. Even though solar energy lowers the costs in the long term, the upfront installation and purchase costs are a determinant factor in the first steps of adaptation.

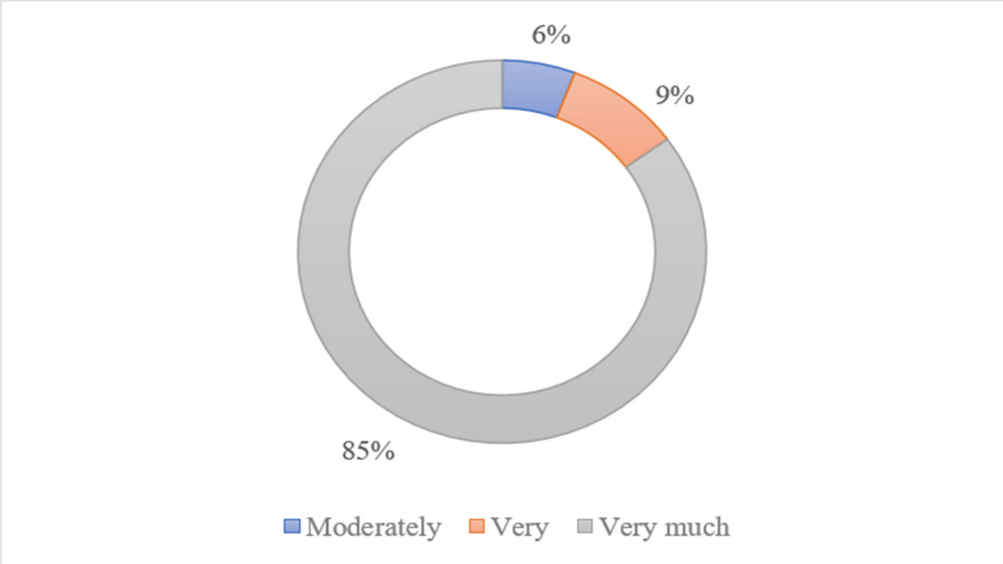

Figure 2. The opinion of farmers for the following question: how much do you prefer solar panels? Source: author's own results.

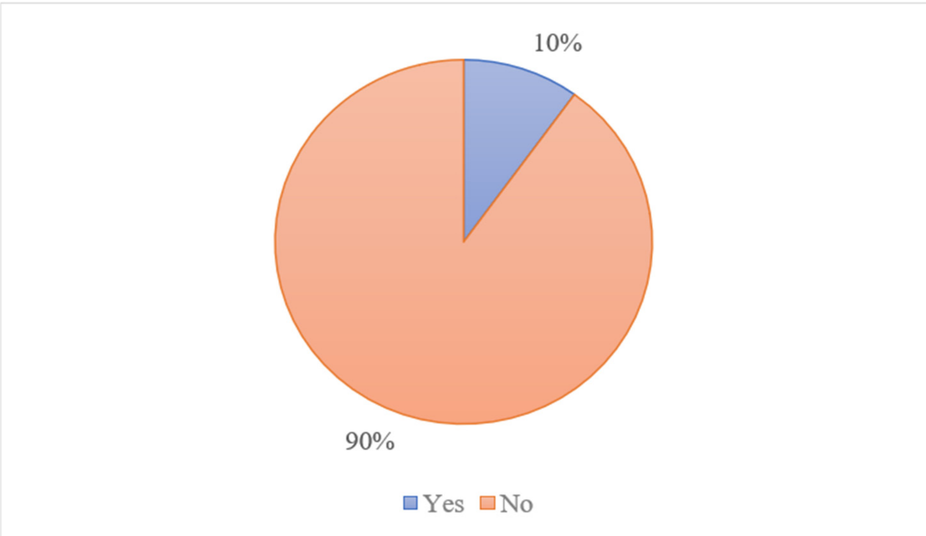

Figure 3. The level of solar panel application in the farm. Source: author's own results.

However, government incentives, educational background, and several equipment advancements can help improve farms' positions in terms of eco-friendliness, cost, and sufficiency.

In terms of preferences for using byproducts for energy purposes, there are a range of perspectives, showing that 31.7% of farmers have a significant preference for this practice, as a group that also wants to lower the leftovers in farms and contribute to sustainability in terms of energy, as shown in Figure 4. A positive response came from 64.2% of the farmers, who rated "very much", "very", and "moderately", showing a great trend toward energy efficiency, cost reductions, and environmental impact. However, a little scepticism was found, as 18.3% of the respondents showed hesitancy and concern regarding the practicality of using and underestimating the value of byproducts (straw and stalks). A study elaborated on the barriers that affect farmers' biomass cultivation for energy purposes [62]. Two categories of factors influence farmers' willingness to start or expand biomass production for bioenergy: situational (such as market conditions, infrastructure, environmental conditions, institutional frameworks, and legal settings) and personal (such as attitudes, values, habits, and needs).

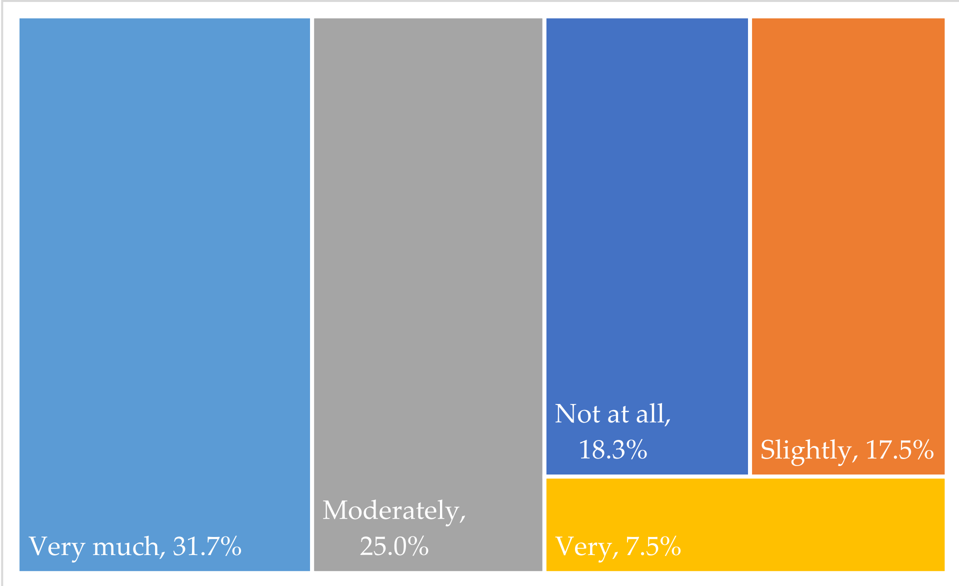

Figure 4. How much do you prefer byproducts to be used for energy purposes (e.g., straw firing)? Source: author's own results.

This cheerful outlook of farmers reflects a clear perception of the importance of renewable energy in combatting climate change. Farmers are vital in working towards best practices that contribute to lowering global effects on the climate. This utilization of byproducts helps to reduce leftovers on farms, lower air pollution due to burning straw, reduce carbon footprint, and help farmers to meet their sustainability goals.

Moreover, there is strong knowledge and opinion regarding the notion that clean energy can improve quality of life compared to traditional sources. This is documented by the 100% positive opinions from the respondents, of which 89.2% mentioned that clean energy "definitely" improves quality of life, leading to environmental advantages and health prosperity (Figure 5). Only 10.8% of the respondents had a little reservation with regard to this factor; 7.5% chose "most likely", whereas 3.3% chose "likely", showing little uncertainty in the benefits of clean energy compared to traditional sources. Participants support cleaner energy practices and see this transition as being necessary for a more sustainable and economically stable future. The adoption of renewable energy solutions by farmers is significantly influenced by both environmental regulation and value perception. Government mandates, incentives, and environmental restrictions establish a framework that encourages farms to transition to more sustainable energy techniques. To meet environmental requirements and stay out of trouble, farmers are frequently pushed toward cleaner choices by these rules, which include financial incentives or penalties [63]. However, farmers' decisions are also influenced by their perception of value. Farmers are more inclined to adopt sustainable energy technologies as they become aware of the long-term advantages, such as lower energy costs and improved environmental stewardship. Farmers are more likely to incorporate renewable energy into their business if they believe it will be a profitable and environmentally beneficial investment. The combination of regulatory pressure and a favourable change in the perception of clean energy significantly increases farmers' adoption.

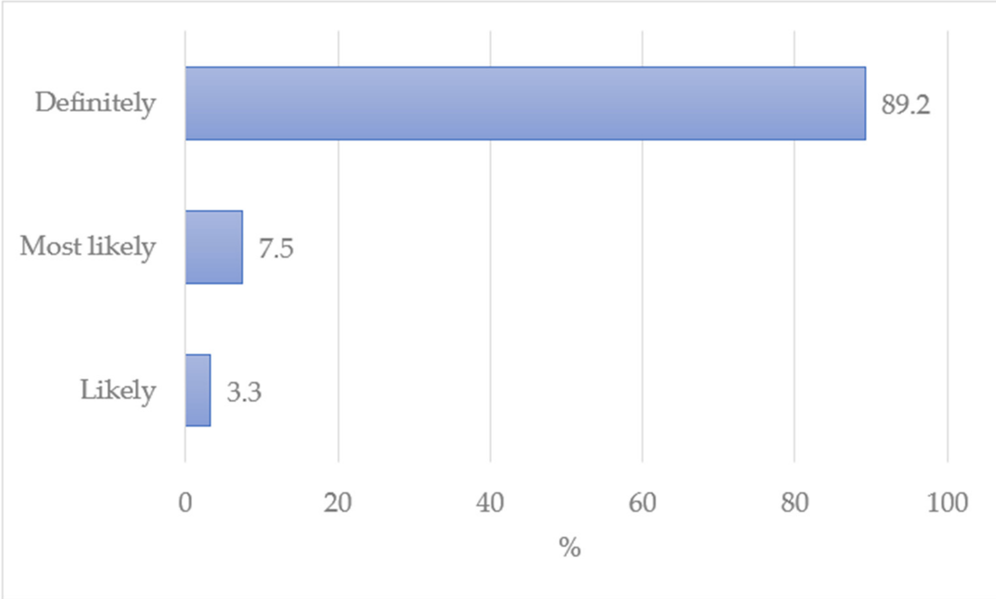

Figure 5. Farmers' opinion about the following statement: in comparison to traditional energy, clean energy can improve quality of life. Source: author's own results.

In terms of the question related to the help of government in forms of subsidies and grants (Figure 6), most of the farmers strongly agree with a percentage of approximately 92%, indicating that there is a critical role of support in these instances that plays a great role in the transition to renewable energy and environmentally friendly agriculture practices. This could help them deal with the high upfront costs of purchasing this equipment, leading to more accessible adoption of energy-efficient practices. The high costs of installing energy-efficient equipment are considered a barrier, as shown by a two-year study by the authors [29], making it a reason for low investment in alternative energy sources. The opinion on subsidies is also shown in the article of Ek et al., 2024 [62], which clarified how substantial subsidies may be in boosting demand and helping farmers as they switch to a market that includes these alternative energy products. Subsidies reduce the expenses of implementing new crops or technologies by offering financial support, which makes it easier for farmers to diversify their businesses. These subsidies can also help fund the purchase of equipment and facilities needed to install energy systems or other cutting-edge farming techniques. Many farmers may be reluctant to make the first investments required for such transformations without this financial support. Subsidies impact farmers' attitudes and desire to embrace new crops or methods in addition to their economic implications.

The lower rate or absence of government incentives has a high rate of difficulties in energy-related farm operations. Unlike in resource-rich nations where consumers can afford expensive green energy, governments in resource-poor nations must currently subsidize the grander cost of green energy technology [34]. The support would positively impact the farm's management of energy production, self-sufficiency, and reliance on external sources. Moreover, a significant percentage of respondents see this support as a key pillar to encourage farmers to accept clean energy for their farm purposes. The government can foster a more sustainable environment in the agricultural industry by continuing to support energy alternative practices in terms of energy self-sufficiency.

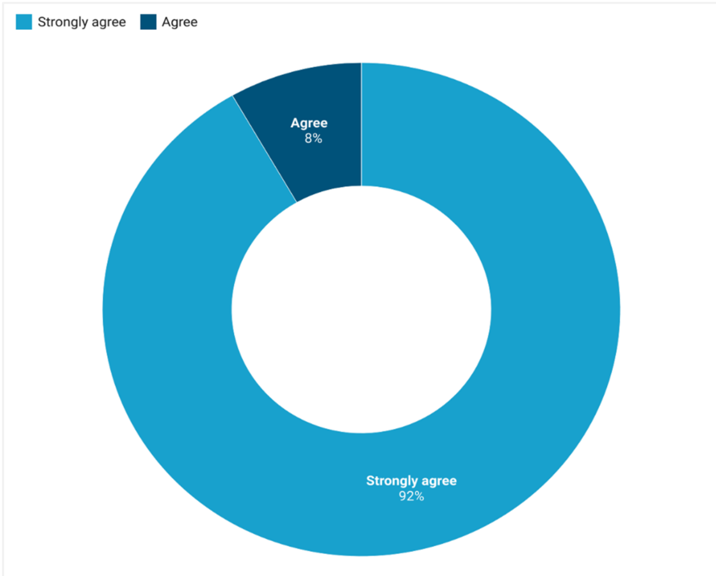

Figure 6. Farmers' opinion about the following statement: government incentives and subsidies play a significant role in promoting the adoption of sufficient energy practices on farms. Source: author's own results.

3.2. Best–Worst Scale Results

This section summarizes the data from farmers' impressions of renewable energy, which were assessed using Best–Worst Scaling (BWS). The findings demonstrate the relative relevance of several renewable energy qualities based on the frequency with which participants assigned the best and worst results.

Table 6 shows the frequency distribution of each attribute's best and worst results. According to the data, "less energy costs" and "eco-friendliness" were the most highly desired aspects of renewable energy, with farmers rating them first and second, respectively. Farmers prioritize cost-effectiveness and environmental sustainability while choosing renewable energy alternatives. In contrast, the attribute "convenience" was rated as the least important, indicating a lower focus on the ease of use or accessibility of renewable energy sources. This suggests that, while convenience is vital, farmers are more interested in renewable energy sources' financial and environmental benefits.

Table 6. Best–Worst Scores for RES attribute importance from the view of farmers.

Designation	Energy Cost Savings	Less Energy Costs	Environmental Friendliness	Available Byproducts	Investment Costs	Convenience	Current Energy Costs
The most important	18.10	34.17	28.69	12.26	2.86	2.74	1.19
The least important	0.36	1.19	1.79	17.86	20.95	33.33	24.52
BWS value	149.00	277.00	226.00	−47.00	−152.00	−257.00	−196.00
Standard value	0.41	0.77	0.63	−0.13	−0.42	−0.71	−0.54
Rank order	3	1	2	4	5	7	6
Square root [a]	7.12	5.36	4.01	0.83	0.37	0.29	0.22
Relative [b] %	100.00	75.26	56.31	11.64	5.19	4.03	3.10
Rank order	1	2	3	4	5	6	7

[a] "The most important/the least important" results after the square root. [b] Relative values of "the most important/the least important" results after the square root %. Source: author's own results.

Based on the information in Table 6, the authors can conclude that respondents chose "Less Energy Costs" as the most critical factor. This attribute was preferred over others. The second and third most important features followed closely behind: "environmental friendliness" and "energy cost savings". These findings indicate that respondents rated environmental impact and financial savings as highly significant, with only a minor difference. "Available Byproducts" landed in second place, with a significantly lower BWS score of 12.26, indicating a lesser level of importance than the top three criteria. This implies that, while byproducts are essential, they pale compared to cost savings and environmental considerations in the context of renewable energy preferences.

The final three components (investment costs, convenience, and current energy costs) received negative BWS scores, indicating a lesser relevance to respondents. The negative BWS scores suggest that many respondents selected these attributes as being the least important. Only 2.86%, 2.74%, and 1.19% of respondents ranked Investment Costs, Convenience, and Current Energy Costs as the most important, indicating their relative importance compared to the other variables.

The graphic below depicts the standardized BWS values for the various elements, as defined by Cohen (2009), simplifying the interpretation of feature rankings. These standardized values allow for a better understanding of how each factor is evaluated in terms of relative importance.

Figure 7 clearly shows that "Less Energy Costs" is the most essential characteristic, with a standardized value of 0.77, showing that respondents place a high value on this. This implies that farmers prioritize lowering energy expenses when exploring renewable energy sources. "Environmental Friendliness" comes next, with a standardized value of 0.63, highlighting the importance of environmental sustainability. This is a crucial attribute for production farmers as sustainable farming is essential to producers' operationalization, highest yields, and financial success [64].

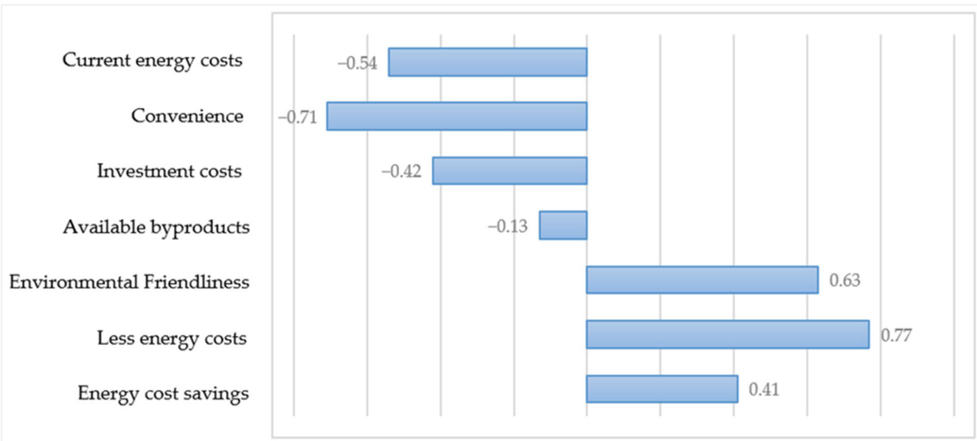

Figure 7. The standardized BWS values of the renewable energy aspects. Source: author's own results.

While it is slightly less essential than energy savings, it is still a significant concern for responders. "Energy Cost Savings" ranks third with a standardized value of 0.41, indicating that financial savings are still relevant but slightly less critical than the first two criteria. The least popular aspects are "Investment Costs" (−0.42), "Current Energy Costs" (−0.54), and "Convenience" (−0.71), all with negative standardized values. This reflects their lower importance in farmers' decision-making processes, with respondents indicating that these traits have less influence than the more integral factors of cost savings and eco-friendliness.

Figure 8 illustrates the diverse priority levels provided by respondents to various qualities of renewable energy, ranging from 3.1% to 100%. These disparities show that respondents value certain variables more when considering renewable energy sources. The significant disparities in these values provide vital insights into what motivates farmers' preference for renewable energy. For instance, the attribute with the highest value, "Energy Cost Savings", has a significant value of 100%, indicating that respondents believe this feature is the most important. This emphasizes the importance of lowering energy prices in altering attitudes toward renewable energy, as cost savings are a primary driver for adoption.

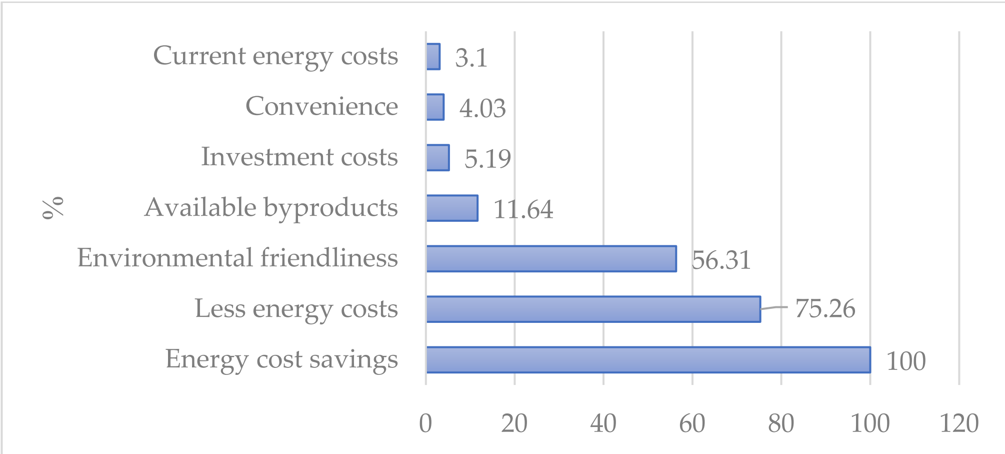

Figure 8. The relative best values of the renewable energy aspects (%). Source: author's own results.

On the other hand, "Current Energy Costs" has a rating of only 3.1%, indicating that this feature is relatively less relevant than other aspects. Despite having a role in the more considerable discussion about energy usage, respondents prefer other factors, such as energy savings and environmental effects, over the current state of energy prices.

These findings highlight that farmers are more concerned with the long-term benefits of renewable energy, notably its ability to cut costs and environmental impact, than with current energy prices. The wide range of the most and least essential variables indicates the various degrees of value assigned to each trait, providing a more nuanced picture of farmer choices for renewable energy options.

It is worth noting that the highly emphasized attribute "Eco-friendliness" carries over five times the weight of the fourth-ranked component "Available Byproducts" (11.64%). This substantial disparity highlights the high value that respondents placed on environmental sustainability when evaluating renewable energy options. The preference for eco-friendliness above other criteria demonstrates that environmental impact is the most essential concern, considerably outweighing considerations such as the availability of byproducts, which is much lower in comparison. This is supported by the findings of the study of Batool et al. [65]; several important aspects affect consumers' propensity to embrace renewable energy technology, especially those that are reasonably priced and dependable. Adoption was discovered to be very positively impacted by a strong belief system. Renewable energy solutions are more likely to be adopted by consumers who believe in the value of sustainability and environmental responsibility. Adopting such technology is frequently seen by these people as an ethical commitment to the environment as much as a practical one.

Additionally, the study revealed that environmental concerns were one of the main factors influencing adoption. Customers are more inclined to look for renewable energy solutions to lower their carbon footprint and support international sustainability initiatives as knowledge of climate change and environmental deterioration grows. Due to increased environmental consciousness, renewable energy is now more widely accepted as a necessary and sustainable substitute for conventional energy sources.

The significant difference between the most incredible and lowest priority highlights how diverse factors influence decision-making. For example, "Current Energy Costs" is the least relevant element, being rated more than 32 times lower than "Energy Cost Savings". This gap implies that respondents are more concerned with future renewable energy savings than current prices. It may also indicate an underestimation of the logistical and accessibility constraints associated with renewable energy sources.

The authors calculated the average of the Best–Worst (BWS) values and their standard deviation to understand the examined features' significance better. The average BWS value is a key measure of the overall importance attributed to each feature. In contrast, the standard deviation reveals the variability or consistency of respondents' opinions across the sample. The results show that "Less Energy Costs" has the highest average value, indicating that this characteristic is the most important to the respondents. The high average score reflects the growing global concern about financial savings and the need for cost-effective energy solutions. As global energy prices continue to increase, lowering energy costs has become a top concern for many, making it a critical aspect of the decision-making process for renewable energy solutions. On the other hand, "Eco-friendliness" appears to be a paramount component; however, it does not exceed "Less energy costs" in terms of overall value (Figure 9). Eco-friendliness's importance reflects a growing knowledge of environmental issues and a desire for sustainable energy sources.

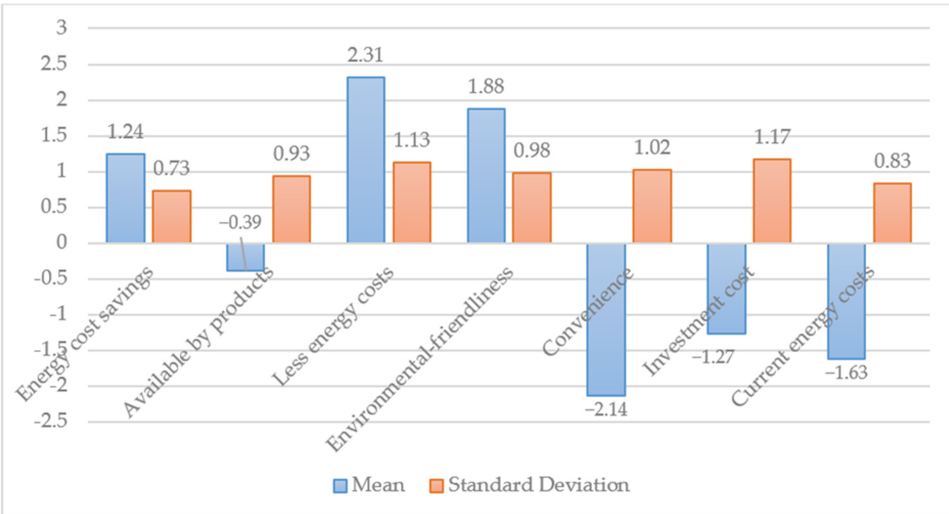

Figure 9. Two-dimensional plot of means and standard deviation of BWS values. Source: author's own results.

"Energy cost savings" has a medium average (1.24) and a moderate standard deviation (0.73), indicating that respondents consider it as a moderately essential feature, playing a significant role in the farmers' decision-making in terms of energy. On the other hand, "availability of byproducts", "investment costs", "current energy costs", and "convenience" remain at a low level of average values, appearing to be far less influential than the factors mentioned earlier. The expressed reluctance to pay more for green energy was in line with the findings of Elahi [34]. A lack of financial resources mainly caused it, as did the availability of fossil fuels and a lack of knowledge about green energy technology. The attribute of "Convenience", which is the lowest on average, is related to the ease of maintenance, operation, and implementation, and the low rating attributed to this is connected with the fact that farmers attach more importance to energy cost reduction, viewing it as a long-term energy solution.

3.3. Evaluation of Cluster Analysis Results

To identify the preference heterogeneity, BWS statistical analysis is performed in terms of cluster evaluation (Table 7). The findings are noteworthy in understanding farmers' preferences and barriers while adopting energy self-sufficiency solutions. These elements can be reached by analyzing the statistical data through Levene's test and *t*-tests, which help to determine the differences between groups and understand the factors that influence the decision-making process. The authors used non-hierarchical clustering with Best–Worst values for the seven parameters under consideration. The experiment with several cluster solutions achieved the optimal number of clusters to capture the underlying patterns in the data. After different cluster-matching processes, the two-cluster technique proved to be the most professionally explainable. This strategy resulted in a consistent and interpretable segmentation of preferences, indicating groups of people with varying priorities and attitudes toward energy practices and equipment.

Table 7. Description of clusters according to different factors.

Denomination **	Mean	Cluster 1: Small-Sized Farms	Cluster 2: Medium- to Large-Sized Farms	Levene's Test Value	Significance Value	Test Value	Significance Value
Respondent number ($n = 120$)		106	14				
Energy cost savings		**1.30a**	0.79b	F = 0.25	$p = 0.617$	t = 2.53	$p = 0.013$
Available byproducts for energy purposes		−0.54b	**0.71a**	F = 1.93	$p = 0.167$	t = 5.24	$p < 0.001$
Less energy costs *		**2.62a**	−0.07b	F = 51.41	$p < 0.001$	t = 6.48	$p < 0.001$
Environmental friendliness *		1.75b	**2.93a**	F = 6.79	$p < 0.001$	t = 10.09	$p < 0.001$
Convenience		−2.41b	**−0.14a**	F = 0.02	$p = 0.965$	t = 11.04	$p < 0.001$
Investment cost		**−1.14a**	−2.21b	F = 2.22	$p = 0.139$	t = 3.37	$p = 0.001$
Current energy costs *		**−1.58a**	−2.00b	F = 13.43	$p < 0.001$	t = 2.45	$p = 0.023$
Age (year)	43.78	43.63	44.93	F = 0.88	$p = 0.351$	t = 0.49	$p = 0.625$
Solar panel capacity (kW) *	5.2	3.7	16.4	F = 10.03	$p = 0.002$	t = 1.81	$p = 0.091$
Electricity consumed (EUR/month) *	46.88	33.47	148.43	F = 21.08	$p < 0.001$	t = 1.40	$p = 0.184$
Number of cows *	19.89	16.39	46.11	F = 10.45	$p = 0.002$	t = 1.68	$p = 0.117$
Wheat (ha)	4.81	4.11	10.71	F = 0.43	$p = 0.512$	t = 1.48	$p = 0.141$
Maize (ha) *	7.21	4.58b	**27.79a**	F = 26.03	$p < 0.001$	t = 2.43	$p = 0.036$

* Levene's test was significant ($p < 0.05$); therefore, t-value represents the Welch test results. ** Different letters (a, b) indicate significant differences between the clusters. Source: own results.

In the statistical results, there are two groups: "Small-sized farms" (Cluster 1) and "Medium- to large-sized farms" (Cluster 2). The main finding of the two groups is that energy cost savings are the most critical factor, especially for the "Small-sized farms" who attached high importance, because savings in energy cost play a higher role in their financing and livelihood, including farm and family costs. This is proved by the *t*-test results (t = 2.53, $p = 0.013$), which show that energy cost savings are an important issue in reducing operational costs. However, the moderate score of the average unit (1.30) indicates that it is not considered a crucial feature, but it is still considered one. On the contrary, "Medium- to large-sized farms" show higher importance for the "availability of the byproducts", with a positive score of 0.71 in comparison with a negative output of "Small-sized farms", with a score of −0.54 and this difference showing statistical significance (t = 5.24, $p < 0.001$). Larger farmers are seen as more interested in using agricultural byproducts, such as straw and biomass from leftovers, since they operate on a large scale and generate more byproducts, which are mostly enough for feeding a farm-size straw boiler. This is particularly true for farmers with fewer cattle. This positive attitude towards byproducts reflects a strong awareness of environmentally friendly farm techniques. Another vital attribute is "Environmental friendliness", with a higher rate (2.93) for "medium- to large-sized farms" in comparison with "Small-sized farms" (1.75). This is also confirmed by the value of the *t*-test results (t = 10.09, $p < 0.001$), showing that larger-scale farmers value this attribute more. This group of farmers is more interested in sustainability and benefiting from clean practices that impact the environment. In contrast, with regard to the attributes of "convenience" and "investment costs", both groups ranked this as having less importance, and their negative values for convenience (−2.41 for small-sized farms and −0.14 for medium- to large-sized farms) and investment costs (−1.14 for small-sized farms and −2.21 for medium- to large-sized farms) show that these attributes impact decisions in terms of the process of energy very little. Still, the *t*-test results suggest that while these attributes are considered relevant due to their statistical significance (convenience t = 11.04, $p < 0.001$; investment costs t = 3.37, $p = 0.001$), they are not a high factor in terms of decision-making when it comes to energy cost savings and environmental friendliness. This indicates that farmers, especially the "Medium- to large-sized farms" group, are considering opportunities for using alternative energy to achieve cost reduction and contribute to the environment.

Regarding the capacity for the solar panels used in farms, "Medium- to large-sized farms" show a significantly higher average capacity of 16.4 kW compared to the other group, characterized by a rate of 3.2 kWh. Analyzing the *t*-test results (t = 1.81, $p = 0.091$) does not show statistical significance at the level of 0.05, but it still shows a trend that larger-sized farms have more probability of investing in solar panels for energy generation. This is because large-sized farms have more financial resources and consume more energy, making solar energy a solution for them. There is a difference between the two groups regarding electricity consumption, which is not statistically representative ($p = 0.184$). Small-sized farms consume and spend more electricity (46.88 EUR/month), indicating greater resilience to traditional energy sources.

On the other hand, farm characteristics show that medium- to large-sized farms are large in operation, with 46 cows on average, an average of 27.79 hectares of land being used for maize cultivation, and 10.17 hectares being used for wheat. On the contrary, small-sized farms have an average of 16 cows with an average of 4.58 hectares of land for maize cultivation and 4.11 hectares for wheat. These results suggest that these two indicators may play a role in the consumption of energy in farms and the level of investment in renewable energy equipment, with "Medium- to large-sized farms" in a better position when it comes to efficient energy practices. Lastly, maize cultivation shows a significant difference ($p = 0.036$) between the two groups in terms of the land used for maize production. This suggests that land use influences the adoption of renewable energy solutions, with larger farms showing high potential when it comes to this implementation.

Table 8 shows different statistical analyses of the farmers' responses from the two clusters generated, "Small-sized farms" and "Medium- to large-sized farms", in terms of various indicators such as age, gender, farming practices, government incentives, and energy usage. The sample distribution was imbalanced, with 106 respondents in the "Small-sized farms" group, whereas 14 were categorized as being in the "Medium- to large-sized farms" group, reinforcing that most farms in Kosovo are small.

Table 8. Description of clusters according to different factors—second part.

Denomination *		Cluster 1: Small-Sized Farms	Cluster 2: Medium- to Large-Sized Farms	Test Value	Significance Value
Respondent number (n = 120)		106	14		
Gender	Female (n = 7)	7	0	$\chi^2 = 0.98$	$p = 0.322$
	Male (n = 113)	99	14		
Solar panel in farm	No (n = 108)	99	*9*	$\chi^2 = 11.64$	$p = 0.001$
	Yes (n = 12)	*7*	**5**		
Government incentives and subsidies	Not Strongly Agree (n = 10)	9	1	$\chi^2 = 0.029$	$p = 0.864$
	Strongly agree (n = 110)	97	13		
Importance of community collaboration	Not extremely important (n = 6)	6	0	$\chi^2 = 0.834$	$p = 0.361$
	Extremely important (n = 114)	100	14		
Perception of technical challenges	Important (n = 8)	6	2	$\chi^2 = 1.479$	$p = 0.224$
	Extremely Important (n = 112)	100	12		
Maize cultivators	Maize (n = 93)	82	11	$\chi^2 = 0.01$	$p = 0.919$
	Non-maize (n = 27)	24	3		
Using byproducts for bedding purposes	Bedding (n = 111)	99	12	$\chi^2 = 1.05$	$p = 0.305$
	No bedding (n = 9)	7	2		
Education (rank means)		61.36	54.00	Mann–Whitney U value: 651	$p = 0.313$
Preferences for solar cells (rank means)		61.61	52.07	Mann–Whitney U value: 624	$p = 0.120$
Preferences for by-product use for energy purposes (e.g., straw firing) (rank means)		59.33	69.36	Mann–Whitney U value: 618	$p = 0.296$
Preferences for main-product use for energy purposes (e.g., short-rotation coppice)		59.63	67.07	Mann–Whitney U value: 650	$p = 0.432$
Clean energy improves the quality of life in comparison with traditional energy		60.74	58.71	Mann–Whitney U value: 717	$p = 0.705$
Improving energy efficiency can contribute to energy self-sufficiency on farms		61.65	58.29	Mann–Whitney U value: 620	$p = 0.100$
Investing in energy self-sufficiency measures enhances the competitiveness in farms		60.79	58.29	Mann–Whitney U value: 711	$p = 0.696$
Utilizing RES is an effective way to reduce GHG emissions on farms (rank means)		**62.55a**	45.00b	Mann–Whitney U value: 525	$p = 0.016$
Farm size (rank means)		57.01b	**86.93a**	Mann–Whitney U value: 372	$p < 0.001$

* Different letters (a, b) indicate significant differences between clusters. Source: author's own result.

The "Small-sized farms" group strongly emphasized energy cost savings as a preference for reducing operational costs. However, "Small-sized farms" were keener to prioritize energy cost savings than other attributes, highlighting that the willingness to cut the energy expenses scored higher (t = 2.53, $p = 0.013$); as mentioned before, regarding environmental friendliness, medium- to large-sized farms preferred this attribute and the use of byproducts for energy production. Medium- to large-sized farms, with an average score of 2.93 for environmental friendliness, prioritized sustainable practices and saw renewable energy as a significant tool for decreasing their carbon footprint. Moreover, they also ranked byproducts for energy purposes significantly higher than other groups, showing an openness for the integration of agricultural waste, leftovers, straw, and biomass into energy production (t = 5.24, $p < 0.001$), suggesting that this group is looking for long-term sustainability goals. Regarding solar energy adoption, "Small-sized farms" (99 out of 108) did not use solar panels. In contrast, medium- to large-sized farms (5 out of 7) use solar panels, showing more interest in incorporating this equipment in their farms with a Chi-square test ($\chi^2 = 11.64$, $p = 0.001$), being more likely to adopt solar panels and showing a great capacity for this.

Furthermore, "Medium- to large-sized farms" were more optimistic about reducing greenhouse gas emissions due to renewable energy, which is a factor in lessening environmental damage (U = 525, $p = 0.016$). However, in terms of farm size, "Medium- to large-sized farms" operated significantly larger farms (mean rank of 86.93 compared to 57.01 for small-sized farms), according to the Mann–Whitney U test (U = 372, $p < 0.001$). This indicates that "Small-sized farms" are impacted by different limitations in terms of land size and financial resources, while other groups are in a better position in this regard. An article by Frantal and Prousek [66] concluded that business size and cultivated land area were favourably correlated with adopting energy-related activities. More excellent financial resources enable larger farms to invest in energy technologies, covering startup expenses and enabling them to take advantage of economic incentives. Larger land enterprises also increase the likelihood that businesses will embrace renewable energy solutions since they may integrate energy production into agricultural activities and use their size for commercial viability.

Interestingly, both clusters strongly agreed that community collaboration is crucial to the energy transition when questioned about it; 94% of small-sized farms and 100% of medium- to large-sized farms rated it as extremely important ($\chi^2 = 0.834$, $p = 0.361$). This alignment emphasizes the shared knowledge that successful implementation of energy-efficient practices and renewable energy systems requires teamwork. Lastly, concerning government incentives, both clusters strongly agreed on the importance of such incentives. The majority of both groups, small-sized farms (97 out of 106) and medium- to large-sized farms (13 out of 14), showed a strong belief in the need for government support in the form of equipment or financial sources to achieve energy self-sufficiency in terms of farm operation. Notwithstanding this common opinion, there was no discernible difference between the clusters in this area ($\chi^2 = 0.029$, $p = 0.864$), suggesting that both groups acknowledge the contribution of incentives and subsidies to the energy transition.

4. Conclusions

The impact of social and cultural elements on farmers' views on renewable energy is a significant factor towards farm energy self-sufficiency. There can be a lack of knowledge about the advantages of newer renewable technology in an area where conventional energy sources, like wood and fossil fuels, have historically predominated [67]. Cultural beliefs and pragmatic worries about cost, dependability, and unfamiliarity with new technologies might influence farmers' intentions to embrace renewable energy solutions. Engaging farmers in educational initiatives highlighting the energy transition's social and community aspects is essential to overcoming these obstacles. These courses ought to concentrate on how public policy, community involvement, and local stakeholders promote renewable energy projects. By encouraging dialogue on these subjects, farmers can better understand their shared accountability for advancing sustainable energy practices, enabling them to actively participate in determining the energy future of their communities and promoting the broader adoption of renewable technologies in the agriculture industry.

In summary, the outputs of this study provide a strong foundation for a comparative analysis of the importance of farm size in the context of locally available energy management. Our survey's findings show that farmers' preferences are influenced by "less energy costs", which stands out as the most highly regarded quality, followed by environmental concerns, showing a moderated balance between sustainability and economic performance. People are becoming more aware of how their choices impact the environment and profitability, and they are willing to make concessions in other areas, such as energy cost savings, to support the best practices in farm operation, as evidenced by the overwhelming emphasis on sustainability and lower energy costs. Farmers reflected positively on the attitude towards solar panels, the preferences for byproducts in agricultural use, the importance of government incentives, and the consideration of alternative energy sources as a clean practice.

In conclusion, based on the statistical analysis performed, energy self-sufficiency is perceived differently between two groups in the cluster, "Small-sized farms" and "Medium- to large-sized farms", having different priorities and attributes related to energy efficiency. In this context, small-sized farms give a high value to energy cost savings, whereas the other group is more environmentally friendly, giving great importance to the availability of byproducts. The priorities reflected by farmers are shaped by the farm size, consumption of energy in farms, and the number of livestock, leading to the great importance that farm scale can have in integrating these alternative technologies. Through the help of policies, incentives, and education, the specific needs of each group can be supported in order to achieve sustainable practice in agriculture.

The results of cluster analysis hence indicate that there are key differences between both groups. "Small-sized farms" tend to be more focused on energy cost savings, having a practical need to reduce the energy expenses for farm operation; even though they have a low rate of adopting solar panels in farms, this is due to the high level of initial costs. Meanwhile, "Medium- to large-sized farms" show positive attitudes towards sustainability and environmental objectives, with a great perspective on including byproducts in energy transition and reflecting a positive view of renewable energy as an important component for long-term success. This finding demonstrates that farmers' energy needs are linked with the size of the operational farms, with large-scale farms being more likely to accept renewable energy technologies due to their better position in the agricultural chain. Considerable importance is attached to the extent of government incentives, community collaboration, and awareness from educational sources in expanding energy self-sufficiency in farms across both groups, with the paramount importance of supportive policies and public embracement in a transition towards alternative energy.

In terms of the future applicability of the results obtained, it is believed that they could be helpful for an international study on the role of farm size in energy self-sufficiency, taking into account the development of the country (GDP per capita), the importance of agriculture, the existing energy structure, and possibly other country-specific factors (e.g., EU accession, age of farmers, education).

In global terms, the survey can be helpful in the study of the following strategic issues:

- What are the specificities of farmers' decisions regarding renewable energy compared to other population groups?
- What are the perspectives for energy self-sufficiency in agriculture and local economic development?
- In which areas is it more appropriate to apply a more favourable efficiency or sustainability-based support system resulting from economies of scale or to apply social aspects in supporting energy modernization on farms?

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Abbreviations

The following abbreviations are used in this manuscript:

AV	Agrivoltaics
BWS	Best–Worst Scale
χ^2	Chi-square
EJ	Exajoule
EU	European Union
GDP	Gross Domestic Production
GHGs	Greenhouse Gases
ha	Hectares
KAS	Kosovo Agency of Statistics
kcal/kg	Kilocalories per kilogram
ktonnes	Kilotonnes
ktoe	Kilotonnes of oil equivalent
kW	Kilowatt
m^3	Cubic metre
MJ/kg	Megajoules per kilogram
PV	Photovoltaics
RE	Renewable energy
RES	Renewable energy sources
SPSS	Statistical Package for the Social Sciences
TWh	Terawatt hour

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