THESIS OF THE DOCTORAL (PhD) DISSERTATION

ENERGY SELF-SUFFICIENCY OF FARMS IN KOSOVO

Written by

PESTISHA ALBIONA

Supervisor:

Dr. Attila Bai

Full university professor

UNIVERSITY OF DEBRECEN

Doctoral School of Management and Business

Debrecen

2025

Table of Content

1. INTRODUCTION OF THE TOPIC AND THE OBJECTIVES

Modern agriculture is not only a fundamental component of global food security but also a significant contributor to energy consumption and environmental impact. Conventional agricultural methods significantly increase greenhouse gas emissions and environmental deterioration since they rely on fossil fuels for a variety of tasks like irrigation, machinery operation, and transportation. Undoubtedly, this high participation of non-renewable resources also carries other challenges such as environmental degradation and pollution, volatility in electricity prices and major climate changes as a result of carbon emissions. In order to react faster and be stronger in the face of climate change and try to preserve resource reserves, an important pillar is the transition to more sustainable energy practices within the agricultural sector. In addition to minimizing environmental and climate effects, this transition would have a significant effect on economic stability.

Agricultural sector is considered to be one of the sectors that consumes high amounts of energy in different countries, while the sources for the production of this energy are fossil resources such as oil, natural gas and gasoline. It is worth noting that agriculture as a sector is characterized by different intensities of energy use, all of which depend on the different production phases, as well as on the type of crop, different agricultural practices and technological advances. Seeing the difficulties and disadvantages that come as a result of the use of fossil resources, it has highlighted the importance of alternative sources. The latter give farmers access to more stable practices and clean sources of energy. This method of creating energy in agriculture tries to minimize carbon emissions, a target set by various countries in the world, especially in the countries of the European Union, improves energy security, environmental degradation and has a positive impact on economic sustainability.

The agricultural industry is characterized by numerous barriers during production processes, so energy is an essential tool that helps overcome the many obstacles that arise during food production by ensuring a sustainable operation of supply and demand. Every step of the agricultural production process requires energy to operate (Majeed et al., 2023), from planting to pumping water. All equipment (tractors, combine harvesters and functioning irrigation systems) are relevant examples of how energy affects the increase in production efficiency. Furthermore, energy is essential throughout the production cycle, and especially during the growing season of crops by ensuring healthy increases in yield generated through the application of fertilizers and pesticides, weed control and planting. Then even after harvest, the process of transporting and moving products often requires energy for cooling which preserves freshness and prevents spoilage of sensitive products.

Local economy is a strategy that refers to building the economic capacity of a central area in such a way that its economic aspect and well-being of life will be improved. This is a process that in itself includes the involvement of different partners from the public, non-governmental and private sectors who collectively can serve as a bridge to mediate for better conditions of economic well-being and employment (World

Bank, 2006). The local economy is characterized by the activity of farmers and farm economies which play a key role in generating income and creating jobs for the local population through various employment channels (Roberts et al., 2013). Most countries rely on traditional energy sources (fossil fuels) that degrade the environment and contribute to climate change (Wang & Azam, 2024). The transition to alternative energy sources is not only advantageous in reducing carbon emissions but also creates environmental and economic stability. In order to achieve the set objectives for 2030, a radical transformation of the agriculture and food system is needed that takes into account the process of climate change (FAO, 2016). Agriculture is a very important sector in terms of both economic, environmental and social aspects, in terms of the production of raw materials, food, energy and employment (Gokmenoglu et al., 2019).

Therefore, it is important for farms to reduce their dependence on fossil fuels as energy costs are ongoing and environmental impacts are inevitable. Farm self-sufficiency can be achieved through the integration of renewable energy sources such as solar, wind or biomass into agricultural activities (Kiraly et al., 2013). There is a growing trend towards agricultural methods that are more energy-efficient. These methods include the use of precision farming methods of using inputs such as water, fertilizers and machinery that reduce costs and maximize the level of inputs used. By applying renewable energy to farms, the chances of increasing profits over time increase (Majeed et al., 2023). Energy efficiency is associated with lower energy costs, thereby increasing agricultural productivity. Another benefit of using renewable energy is long-term sustainability; water, wind, solar, and biomass resources are characterized by endless use, unlike fossil resources.

Biomass is a concept that represents a variety of organic compounds, especially plants and their byproducts, which are created by the natural process of photosynthesis (Ben-Iwo et al., 2016). This process is achieved through the absorption of sunlight by plants which later convert it into energy. This organic variety includes plants, leaves, stems, roots, agricultural residues, forestry residues, and even organic animal manure. As a result of its regeneration by the continuous growth of plants or various processes that affect the continuous production of organic waste, then in this respect, it is considered a renewable energy source.

According to IEA statistics, bioenergy represents 55% of renewable energy production worldwide, excluding conventional biomass products for heating and cooking (IEA, 2024). As a result of these competitive specifications, bioenergy represents an important resource in the global transition to sustainable practices, especially since it accounts for 6% of the world's energy supply. Agricultural residues and other organic waste are a very important part of bioenergy (Kumar et al., 2023), through which their good management is done, the environmental impact is reduced and the circular economy is developed. This form of energy helps achieve a form of energy security and rural development, reduces dependence on fossil fuels, acts as a stimulant for the local economy, and generates new jobs. Woody biomass is the leading source of solid biomass in the European Union, with a share of 66%. It is followed by organic biomass with a share of 26%, followed by agricultural biomass with a share of 8% (European Union EUR-lex, 2020).

The burning of fossil fuels naturally releases greenhouse gases such as CO, CO_2 and CH_4, which contribute to air pollution and climate change (Filonchyk et al., 2024). The European Union is therefore trying to move towards a low-carbon economic expansion through related policies and indicators (European Commission, 2011). EU countries are very committed to using energy that is sustainable, safe, produced domestically, and an energy that would impact the country's stability towards climate change. Agriculture, as an important food production sector, consumes high amounts of energy and, according to FAO data, was responsible for 9.3 billion tonnes of CO_2 equivalent (CO_2eq) emissions worldwide (FAO, 2021). Arable farms offer materials that are highly recyclable and represent a variety of readily available resources in the form of waste that can be used for energy generation. In recent years, progress has been made in the development of biomass energy production systems. As a result, small-scale and highly suitable on-farm applications have recently been developed for the use of fuels such as straw, which is being used as fuel for heating farm spaces.

Solar energy has numerous applications, one of the least developed being agricultural use (Elahi et al., 2022). According to Pascaris et al. (Pascaris et al., 2021), solar energy can be integrated into the agricultural sector through agrovoltaic projects, which are viewed as an innovative chance to preserve the agricultural function of the land by boosting solar generating capacity. Biofuel usage, namely livestock effluent and urban solid waste, has enormous potential. Combining waste management and alternative energy in one direction appears natural for agriculture, given that the intensive development of animal husbandry and poultry farming necessitates the development of environmental waste disposal technologies (Gál et al., 2013; Popp et al., 2021). RES are successfully employed in animal husbandry, fodder production, peasant (farm) homes, and rural residential areas. They are used to dry agricultural products, heat livestock houses and process water, provide self-sufficient power to farms, and elevate water.

The energy produced by biogas using agricultural waste will help farmers manage waste from livestock and poultry farming, reducing the need for storage space while maintaining environmental safety, lowering GHG emissions charges for farmers, and stimulating the development of local economies (Sobczak et al., 2022). The European Union strongly supports the development of energy from biogas. Germany produces the most energy from biogas, followed by Italy and Austria, and this can serve as a good basis for future development in other countries.

The main challenges that local agricultural energy systems can face can be:

- Although agricultural by-products are in large quantities, they have low economic value. These considerations make marketization difficult (transportation costs may exceed the true value), therefore their local use is feasible; energy methods have a high added (or substitutional) value.
- Photovoltaic panels are becoming increasingly essential on farms, primarily on rooftops but occasionally on the ground. This equipment may take up space (agrophotovoltaic systems could be

a solution), and fluctuations in electricity output and consumption can pose storage issues not only in farms but also in national electrical networks.

- Local renewable energy generation could be far more efficient in complex systems, where sub-systems can reuse each other's byproducts while producing only marketable outputs. These systems could also include the development of specialized energy crops, which are more expensive than by-products but can provide more energy from a smaller area.

The share of renewable energy sources in the energy mix is still low for many countries in the world, but on the other hand, many countries have achieved success in this direction, making some countries face high production and therefore face surpluses of electricity (Punda et al., 2017). Based on the findings of Peng et.al., (Peng et al., 2022) energy consumption from green sources still continues to be inversely proportional to the number of inhabitants, while is in the direct proportion with GDP, and the same situation is present in Kosovo. Energy generation in Kosovo is supported by thermal power plants that use coal as fuel, and the share of energy produced from coal years ago was represented with 97%.

The inclusion of renewable sources and their increased participation in Kosovo’s energy mix is crucial to achieving the country’s green energy recovery. In 2019, only 5.05% of the energy produced was from renewable sources, while the rest was from coal (OECD, 2022). Of these 5.05% of the participation of renewable sources, hydropower leads with 67.7% of energy production, followed by wind with 28.9% and solar energy with a participation of 3.4%. Renewable sources participated with 25.69% of the total energy produced, the bulk of which was used mainly for heating, thus achieving the targeted objective.

Biomass is considered an important asset in Kosovo to achieve the set objectives, which has an extremely significant impact especially in the heating sector. One thing that is very noticeable in Kosovo is the lack of renewable sources used as energy for transport. First, the legal framework lacks regulations governing biofuel sustainability, implying that Directives 2009/28/EC and 2018/2001 are not followed. Households represent the main component of final energy use, contributing to 40% of total energy consumption in 2020. Then there is transport, which consumes approximately 100 to 422 ktoe of energy (Ministry of Economy, 2021).

Energy efficiency in Kosovo faces various barriers. According to the Pestisha & Bai, study, the population is open to installing renewable energy equipment, but a main barrier that is affecting them is the high purchase costs of the equipment and the lack of funds from the state that would facilitate the affordability of these efficient equipment (Pestisha & Bai, 2022).

Kosovo's natural environment is very complex, making it ideal for the development of diverse agricultural. Small family farms are the primary source of production in Kosovo due to present natural conditions and property arrangements. Kosovo is separated into seven distinct zones, each with a neighboring municipality, based on similar qualities such as climate, agricultural production structure, arable land, yield size, livestock and crop density, and so on. The distribution of agricultural economies by kind of output is mostly determined by structural and environmental factors. It should be noted that a large portion of the country has the best conditions for the growth of livestock and agricultural crops; additionally, combining the production of livestock and agricultural crops while taking into account the structure of agricultural land and the surrounding environment. The Republic of Kosovo, located in Southeastern Europe, covers an area of 10,905 km^2 and has 512,000 ha of arable land. According to the Green Report (Ministry of Agriculture, 2020), the total arable land per capita in 2019 was 0.11 hectares, while the average total usable agricultural area per capita was 0.24 hectares. The impact of agriculture on the country's economy is high, contributing 7.4% to GDP in 2022 (MAFRD, 2023c) (Table 1), which represents a satisfactory economic development. In Kosovo, the majority of farms are small and medium-sized farms, with an area of less than 5 ha, unlike the European Union which had two-thirds of farms in this area in 2020 (eurostat, 2022). Small farms affect low productivity and high costs of operationalization and performance of activities.

Table 1. Economic indicators of Kosovo development (2018-2022)

Indicator	2018	2019	2020	2021	2022
Gross domestic product at current prices (million €)	6672	7056	6772	7958	8936
GDP per capita (€)	3715	3959	3772	4486	5037
Unemployment rate (%)	29.6	25.7	25.9	20.7	12.6
Agricultural share in GDP (%)	7.1	7.1	7.1	6.9	7.4

Source: Author's own construction based on (MAFRD, 2023a).

During 2022, utilized agricultural land represented 420,482 hectares, including 44.8% fields (planting vegetables in open fields and in greenhouses), then the rest includes plantations, vineyards, meadows, pastures and so on (MAFRD, 2023c). In 2017, there were a total of 108,803 agricultural properties, of which 64% are properties up to five hectares, with an average farm size of 1.7 hectares (MAFRD, 2018).

According to a study of Sertolli et.al., Kosovo has an annual energy potential of 103,599 t/year in terms of total biomass capacity used for energy, with 345,329 t/year produced from grain residues and 30% of that capacity allotted for energy demands (Sertolli et al., 2023). The most important aspect of this potential is that by-products, unlike major products, can be used locally due to their low value, which prevents long-distance transit. By-products from agricultural activities, such as crop leftovers and animal manure, provide a renewable and readily available source of biomass for energy generation. Agricultural byproducts can be converted into heat, electricity, biogas, and biofuels using a variety of conversion technologies, including anaerobic digestion, biomass combustion, and biofuel production, lowering dependency on fossil fuels and mitigating greenhouse gas emissions. Furthermore, the use of agricultural byproducts to generate electricity advances circular economy principles by closing nutrient loops, reducing waste, and increasing resource efficiency.

According to Sertolli et al. 2023 (Sertolli et al., 2023), the total potential for animal manure production in Kosovo is 3,84 million t/year, of which 76.4% or 142.6 million m3/year can be used for biogas production and the remainder for organic fertilizers, with cattle contributing the most in this regard. Furthermore, a systematic assessment published by Pestisha et al. (Pestisha et al., 2023), revealed that biogas was the most sought-after on-farm renewable energy source between 1988 and 2022 due to its sustainability and environmentally friendly nature. However, taking into account the current state of sustainable agriculture energy use and farm self-sufficiency in Kosovo is necessary given the changing nature of both European and global energy policies for agricultural production, as well as the fact that sustainability has become a critical issue, gaining urgency with climate change and natural resource scarcity.

One thing that is very primary is the promotion of sustainability through the inclusion of renewable energy sources, a strategy that would affect the reduction of climate change and improve the energy mix. Based on the findings of Chaikumbung (Chaikumbung, 2021), WTP (willingness to pay) for renewable energy sources varies depending on the type of energy, while residents of more developed countries have a positive approach in this regard. Within the type of energy that has the most perspective for WTP is solar, biomass and wind energy, comparatively the lowest is considered for hydropower. Another article that has dealt with the elaboration of preferences and motives towards electricity (Yang et al., 2016), has concluded that wind energy is an important part of the production of electricity, where in Denmark one third of it is produced in the energy mix. According to this study, an important factor when consumers choose a renewable energy product is its price. Electricity suppliers and contract terms are also important factors. This suggests that consumers who were part of the study have understood the importance of RES and are willing to contribute to increasing their participation.

Meanwhile, another study conducted by a group of Hungarian researchers, investigated the attitudes of the Hungarian people regarding RES practices, and concluded that almost 92% of the population has knowledge about solar, wind and hydropower (Szakály et.al., 2021). These three sources were tested for their importance in terms of attributes which were age, profession, education and environmental awareness, of which the last three appeared to have an impact on the recognition of RES in the Hungarian population. As for the source of biomass, the factors that influenced the recognition and correct understanding of this type of energy were environmental awareness, health awareness and level of education.

A thing in common between Kosovo and Hungary was that the population had a lack of clarity about the type of energy source that is created by the solar collector, and this represented a lack of knowledge between the solar panel and the solar collector. While firewood was considered a conventional and non-renewable resource, and also with a high cost. Another Hungarian study investigated the attitudes of the Hungarian population towards biofuels, and overall their opinion was positive and optimistic (Mizik, 2021; Mizik & Gyarmati, 2021). Another article assesses the preferences of RES in the Hernad Valley in Hungary, an agricultural area that is economically underdeveloped (Bai et al., 2016). In half of the villages, persons who have heard about biomass burning have a knowledge ratio that exceeds 40%. Whereas, the term biomass was not current, only a very small proportion of people associated it with wood or agricultural waste, even though a large part of the population used it for heating as an energy source (approximately 60%).

The impact of citizen participation in climate change mitigation and in the energy evolution phase is also seen as positive by the study by (Fischer et al., 2021). This article also explores the diversity and perception of German individuals about being part of energy cooperatives. His findings show that participation in these cooperatives is low, perhaps as a result of unfamiliarity with the term "energy cooperative", since in Germany out of a total of 10,800 municipalities there are only 900 such cooperatives.

On the other hand, the findings of (Almulhim, 2022) show that a significant portion of Saudi Arabians had average knowledge about renewable energy, and 79.2% were very concerned about the effects of pollution and this pushed them towards alternative energy. While a perceived disadvantage was that 97.2% declared that the prices of renewable energy devices are a factor that led them to consider these devices as ineffective.

In the framework of related research in the Western Balkan countries, a study on attitudes towards RES was conducted in Montenegro (Djurisic et al., 2020). This research demonstrates that when opting to acquire household equipment, energy sufficiency is far less important than price and location. In addition, there was a gap between actual behavior and consumer perceptions, leading to the findings that consumers are informed below average about RES, with more concentration on hydropower and less on geothermal sources. A study in Greece has highlighted that the awareness and appreciation of RES by respondents is very high with a participation of 72%, who think that RES sources are a response to climate change (Kaldellis et al., 2012). On the other hand, regarding the willingness to adapt such a device, only 10% were willing to use such an energy source.

The purpose of this thesis is to investigate the viability and consequences of using renewable energy sources to achieve energy self-sufficiency on farms. Through the analysis of agricultural energy consumption patterns, the identification of obstacles related to the reliance on fossil fuels, and the exploration of renewable energy technologies, this research aims to offer valuable perspectives on how to improve energy self-sufficiency in the farming industry and farmers' intentions towards sustainable energy.

The supply of electricity in Kosovo for farms is characterized by the use of power plants and nearly the whole generation is based on the use of fossil fuels such as coal (lignite), moreover, coal is a source of heat supply. In general, the total energy consumption of the farms is determinately based on fossil energy sources. One of the main important factors toward a stabile development for the whole welfare of society is the security of energy power supply. Renewable energy would be a tremendous instrument for sustainable development in Kosovo. In the current situation, the share of renewable energy is negligible and the information about it is poor, but it is important to have a purpose and to follow the light toward the use of RES.

As a new and developing country, Kosovo needs to have a stable energy supply to provide an adequate infrastructure and a safe environment for the development of all sectors, including agriculture as well. Nonetheless, Kosovo is requesting to join the European family in this order it must meet all the criteria in terms of the environment as well.

Through a combination of literature review, case studies, and analysis, this thesis aims to contribute to the understanding of energy self-sufficiency in agriculture and provide valuable insights for policymakers, researchers, and practitioners working towards a more sustainable future for farming communities. The diagram below (Figure 1) aims to clearly show the research gap among the three primary actors: sustainability, energy self-sufficiency, and farmers. The diagram highlights the need for more research in this area by providing a visual representation of the relationships and connections between these three components. A relationship that needs to be continuously built is that between farmers and energy self-sufficiency, which is constantly influenced by various factors, among which are the different choices of energy practices. By using renewable energy sources, farmers have various benefits starting from climate sustainability, energy and low energy costs. Through important alternative energy methods, farmers have a significant effect on the environment, protecting natural resources, preserving biodiversity and increasing environmental care. This chain of connectivity between these components "farmer", "sustainability" and "self-sufficiency" within the agricultural sector represents a gap in scientific research that must be filled with future research.

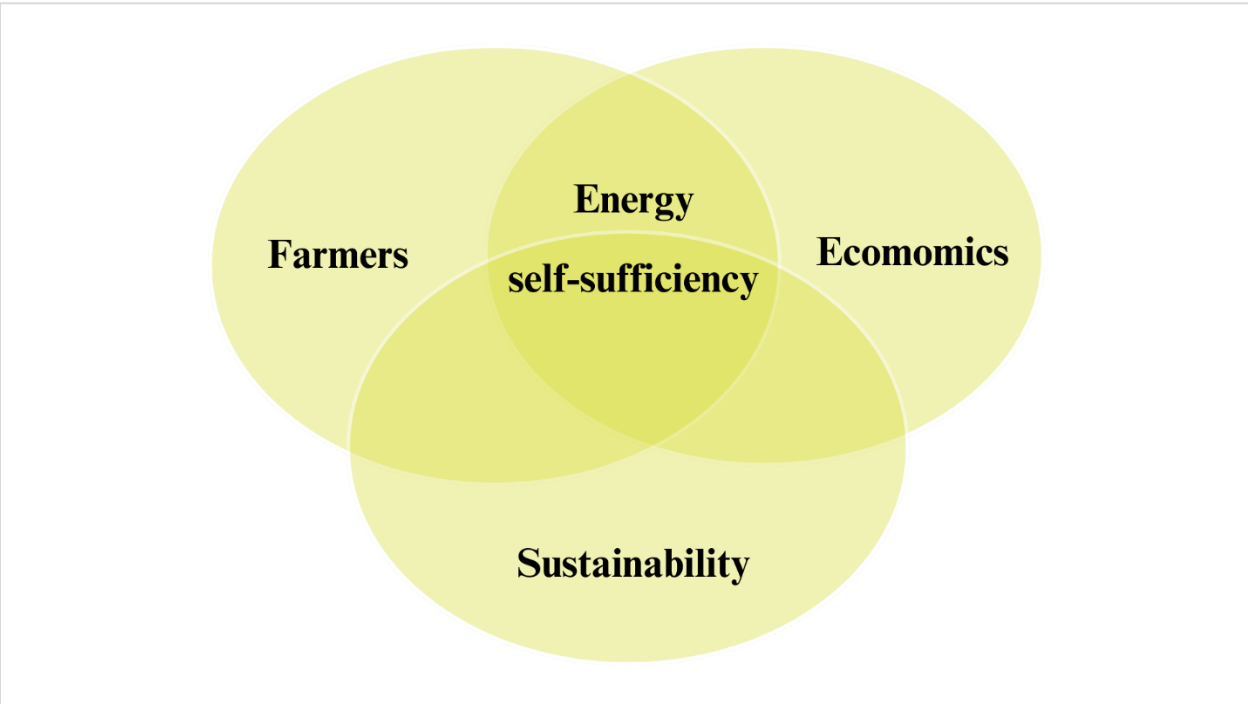

Figure 1. Venn Diagram of the research gap identified in the scope of the research

Source: Created by the author (2024)

The research presents a way of explaining farmers' attitudes towards farm self-sustainability in terms of energy, their approach to alternative forms of energy, deeper integration of ideas on how the application of renewable energy can reduce dependence on other sources and positively impact the farm structure. All findings of this research will serve as a guide for farmers through a clearer understanding of the current situation and the advantages of using these practices. The findings will also serve for various public agencies, universities, agricultural NGOs and not only.

1.1. The objectives and research questions

This section will explain the organization of the research by providing details regarding the objectives, research questions, and goals of the research, delving into the problem and clear objectives that will pave the way in terms of overall structure. The steps that will go through the research process will be elaborated in this section, providing with a precise summary of how the research process will proceed and how the author will arrive at the concise findings of the thesis.

Moreover, the hypotheses presented in this topic have been developed based on prior knowledge and experience. Initially, the idea was formed by the research and experience during the Master's studies of the author, which served as a cornerstone in this field. Also, in addition to the author’s personal academic experience, a literature review has been of great help in shaping the hypotheses presented, thus helping to identify gaps and shape existing models.

To follow a methodology flow for each of the objectives, the author has decided to start with an analytical research on the attitudes and preferences of farmers and the population regarding renewable energy sources through various statistical tests, expanding the research with bibliometric analysis through the R program in a wider spectrum in this field. Another part of the methodology is also the economic calculations through indicators regarding the efficiency of the use of renewable resources on the farm. Finally the methodology concludes with the BWS Scale method which determines two clusters (small and large size farms) through seven attributes and their importance by the farmers.

Objectives 1. What is the importance of self-sufficiency in the farms of Kosovo?

Given that energy stability is an important component of the farm, this objective aims to understand the importance of farm self-sufficiency in Kosovo. It will be possible to understand how this phenomenon will affect daily farm operations, increasing farm safety, reducing energy costs and the perception of using energy sources that are compatible with nature. Given the positive impact on the environment, reducing carbon emissions and preserving the environment, it will be possible to understand the farmer's attitude towards this very important point. The achievement in social and economic aspects will also be analyzed, more specifically how this integration of energy will affect the benefits of farmers in relation to lower energy costs.

H1: Increasing energy self-sufficiency on farms across Kosovo significantly contributes to improving energy access, farm stability and rural diversification.

Hypotheses 1 will be answerd on section 4.4.

Objective 2. What are the reasons to use the renewable energy sources by farmers in Kosovo?

A research towards the attitudes and motivations of Kosovar farmers for renewable energy in agriculture represents another research objective. More specifically, to understand what are the commonalities and preferences between different farmers, and what are the driving factors towards the acceptance of renewable resources.

H2: Kosovar farmers demonstrate a positive level of attitudes and preferences towards on-farm renewable energy, with "Less energy costs" and "Environmental consciousness" as the main driven factor in installing the renewable energy sources in farm.

Hypotheses 2 will be answerd on section 4.2, 4.4 and 4.5.

Objective 3. What is the awareness and attitudes of farmers, regarding renewable energy production in the farm?

Within this objective, the main goal is to research the attitudes and preferences of farmers regarding the production of renewable energy from the farm. More specifically, it attempts to reach the level of awareness of Kosovar farmers regarding renewable energy devices, the factors that push forward and the points that influence the fear of adapting such devices.

Objective 4. What do the farmers think about sustainable agriculture?

This objective aims to understand the attitude of the Kosovar farmer towards a sustainable future and to understand the essence of sustainability and the importance that farmers dedicate to this phenomenon. The perspective that farmers see in relation to the future of energy from sustainable sources is sought. Different research formats, more specifically different questionnaires, will try to bring out the best in the context of stability as an important component in each sector, as well as the impact of energy efficiency on the future of the farm and its operations. The research will also analyze the willingness of farmers to adopt these new methods for a more sustainable agriculture, the advantages that farmers think they will achieve as a result of embracing the idea, as well as determine the obstacles that may appear along this journey.

Objective 5. Which are the most economical bio-energy sources to be produced in the farm for achieving farm self-efficiency compared to the fossil competitive energy sources?

In order to achieve farm energy self-sufficiency, this objective seeks to determine and assess the most economically feasible bio-energy sources that can be produced on farms in Kosovo, as well as how these compare to conventional fossil fuels in terms of costs and advantages. In order to ascertain which bio-energy sources are most cost-effective for farmers given their operational circumstances, the research will concentrate on evaluating various possibilities, including biomass (such as animal waste and agricultural leftovers), biogas, and biofuels.

H3: Biomass (straw) is a more economical source for energy production on the farm compared to wood.

Hypotheses 3 will be answerd on section 4.5.

Objective 6. Does farm size or type of farming influence the way of energy self-sufficiency?

This goal is to investigate how the size of the farm and the kind of farming (crop, livestock, or mixed farming) affect the strategy for reaching energy self-sufficiency. The research will investigate whether the viability, approaches, and efficacy of implementing renewable energy solutions for farm operations are impacted by the size and type of farming operations.

The economic feasibility and usability of different renewable energy systems are significantly influenced by farm size. In order to invest in large-scale renewable energy systems, such solar panel installations or biomass energy production, which could produce enough energy for self-sufficiency, larger farms might have more available area and resources. On the other hand, smaller farms might have difficulties because of the high initial prices and space constraints for these systems, which could make achieving complete energy independence more challenging. This goal will determine whether the flexibility of larger farms to distribute the investment expenses across a larger area or higher production volume makes them more inclined to use renewable energy solutions.

H4: Energy self-sufficiency is perceived differently between farm sizes types, based on different attributes.

Hypotheses 4 will be answerd on section 4.5.

Specific Aims

1. Assess the current energy consumption patterns and sources in farms in Kosovo through surveys and data analysis (quantitative).
2. Identify and analyze the barriers and challenges faced by farms in Kosovo in achieving energy self-sufficiency through literature review and interviews with farmers (qualitative and quantitative).
3. Evaluate the renewable energy self-sufficiency and available resources in farms in Kosovo, including solar and biomass (qualitative).
4. Quantify the economic, environmental and social benefits of energy self-sufficiency in farms in Kosovo through sensitivity analysis, and social impact assessments (qualitative and quantitative).

2. MATERIAL AND METHODS

The methodological process elaborated in this chapter includes discussion of the research design, the rationale for the chosen methodologies, and how these decisions on the selected methods will successfully and accurately address the research questions, which are essential for developing a methodological strategy that shapes the type of research being conducted, whether mixed, qualitative, or quantitative.

The selected research fits into a multidisciplinary framework that, in addition to the selection of environmental research itself, also includes social science premises in order to examine and take into account the attitudes and perceptions of farmers regarding energy self-sufficiency on the farm. Achieving an understanding of the attitudes, preferences, beliefs and choices of farmers based on their decisions regarding energy self-sufficiency is the main goal of the research within the social science elements of the research. Continuing with the examination of the components in turn of the psychological, sociological and economic aspects that may influence their choices within the framework of the research topic. To reach the findings, the research will explore and gain insight into how farmers' perceptions and willingness to adopt efficient renewable energy sources on their farms are influenced by various factors such as social and cultural norms, education level and financial circumstances.

The analysis towards the stability and sustainability of the farm in the framework of agricultural energy self-sufficiency presents an important research framework in the framework of compliance with environmental, social and economic sciences. Furthermore, this component includes the analysis of social and technical attitudes and opportunities for integrating different renewable energy sources into daily farm operations. This focus on the environmental aspect also presents sustainability in the broader context of energy practices, including their ecological impact and role in sustainable agriculture and the degree of eco-friendliness of farmers. As a result of the integration of these two important perspectives, the research provides a comprehensive understanding of the technical (sustainable and energy practices) and social (social attitudes and preferences) aspects of energy self-sufficiency in agriculture. Saunder's definitions help the author understand that the collection of assumptions, beliefs, and guidelines that guide in the process of learning, understanding, and interpreting phenomena under investigation is known as a research philosophy (Saunders & Thornhill, 2019). These premises reflect as a foundation within the research process, greatly influencing the way different researchers conceive of the nature of knowledge, the way research functions, and the accompanying techniques used for data collection and analysis.

As a result, research philosophy is viewed as a roadmap that directs the research. It influences every step of the research process, including the development of research questions, method choices, and data gathering and analysis strategies. In this sense, research philosophy is essential to making sure that the research is carried out carefully, thoroughly, and transparently.

2.1. Bibliometric analysis

A popular and rigorous technique is used in this research, for looking through and evaluating vast amounts of scientific data, and it is called bibliometric analysis (Donthu et al., 2021). In order to generate a proven of information about trends, tendencies, types of patterns, and the impact that research methods on a given topic can have, this method involves the methodical analysis of article publications, citations generated, and other academic metrics. As a result of the variety of computational and statistical tools used, bibliometric analysis helps researchers to draw conclusions about which articles, journals, and authors have had the greatest impact on a given field of research, as well as the connections between different fields of study. The ability of bibliometric analysis to gain detailed insight into the evolution of a chosen topic is a major advantage. This allows researchers to be free to explore how ideas and theories progress over time, distinguishing changes in different time periods as a consequence of the evolution of scientific discourse.

The Bibliometrix R package technique is developed by Aria and Cuccurullo (Aria & Cuccurullo, 2017) and it is the main tool through which the bibliometric analyses for this research study is performed and visualized (Figure 2). The main power of this tool is the performance of complex bibliometric analyses, such as the display of co-authorship networks, co-citations and keyword co-occurrence, which would be prohibitively time-consuming to perform manually, which makes this technique very useful. Furthermore, it gives researchers a complete picture of the current state of science in a given research field, enabling them to accurately identify important areas of study and collaborations with well-known researchers.

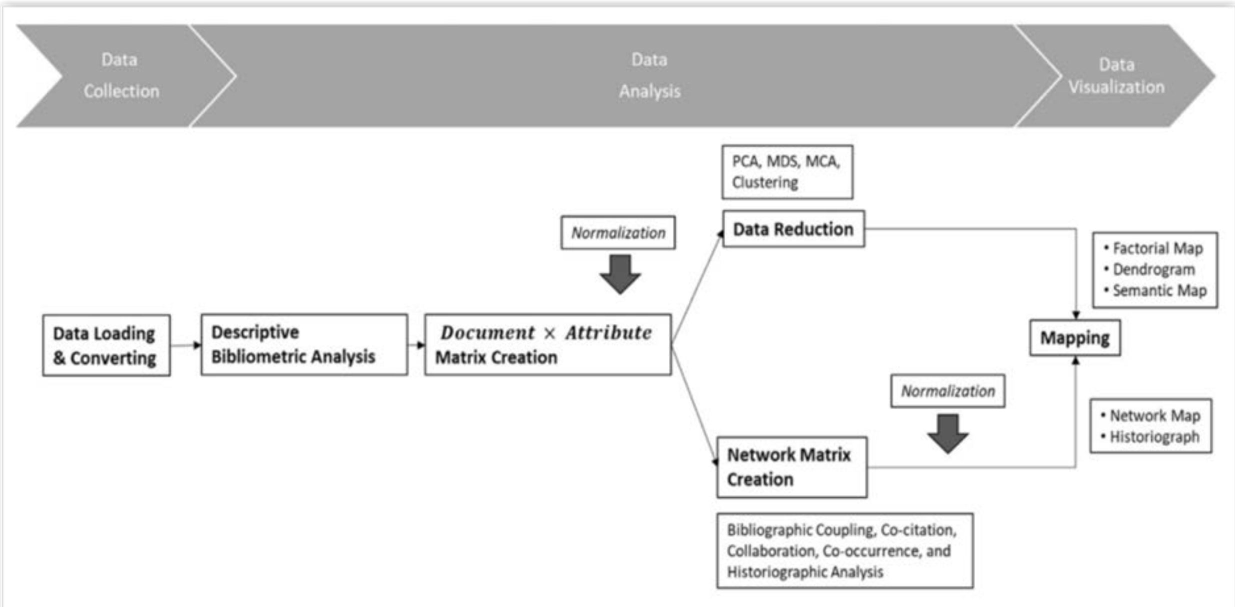

Figure 2. Workflow of the applied science mapping process

Source: (Aria & Cuccurullo, 2017)

This research aimed to investigate the systematic characteristics of publications in the nexus of agriculture, the environment, and renewable energy. In order to drive the investigation, three important terms were used: "*renewable energy*" "*farm*" and "*environment*". These keywords were chosen to guarantee a thorough and targeted approach to the subject.

The *title*, *keywords*, and *abstract* of the pertinent publications were among the search parameters used in our analysis. This helped to focus the research and collect relevant information for additional analysis. However, by showing publication trends and emphasizing the sector's increasing significance over the years, the tables and figures classifying various periods significantly enhance the article and the area. The following was the main query string used in our research: Using TITLE-ABS-KEY ("renewable energy" AND "farm" AND "environment"), to identify articles released from 1988 to 2022. The earliest published study containing all three of these keywords was from 1988, which is the main reason of starting the research that year.

This search produced 925 results in total. After conference reviews, notes, editorials, and letters were eliminated, 894 articles were left for evaluation. After classifying these articles, is discovered that, excluding those that concentrated on wind energy with applications in other domains, there were more than 200 publications about agricultural uses.

2.2. Method of assessing the attitude and preferences of farmers towards renewable energy sources

The path towards a successful integration of renewable energy technologies requires not only high reserves of technological innovation, but an even more important issue is the perception and broad acceptance of these practices and proactive participation by the public. The research in this case aims to gain knowledge about the preferences and attitudes of the Kosovo population regarding the use of renewable energy as an integrated part of the energy mix. The key issue towards this research is, "What are the preferences and attitudes of the population of Kosovo regarding the use of renewable energy?" By addressing this question, it aims to obtain findings on how different groups of the Kosovo population perceive renewable energy, their level of knowledge about efficient devices, and the various factors that influence being for or against their implementation.

All respondents were citizens of Kosovo, selected through simple random sampling to achieve equitable representation of the demographics. Participation was voluntary, ethically compliant, and confidential. The questionnaire was distributed online with a duration of approximately ten minutes to collect demographic information, environmental knowledge and awareness, and attitudes towards renewable energy. Respondents could only complete the survey once and were free to withdraw at any time. In total, 243 completed questionnaires were collected from this survey. As for the farmer questionnaires, their recruitment was more challenging, achieved through snowball sampling, through contacts from the Ministry of Agriculture. This approach helped in reaching different regions and gathering a range of perspectives. Data from farmers was collected between December 2020 and January 2021, with a participation of 30 farmers.

The results from the questionnaires were analyzed with the statistical software SPSS version 26. A variety of statistical techniques were used to investigate the links between demographic and socioeconomic characteristics and preferences for renewable energy sources (RES). The data was initially summarized using descriptive statistics, which provided an overview of important trends and patterns among respondents.

To investigate the significance of connections between different factors, many inferential statistical tests were used, including the chi-square test, independent sample t-test, and one-way ANOVA. The chi-square test of independence was used to analyze categorical data, especially for nominal variables such as gender, income level, education level, age group, occupation, and environmental consciousness. This type of test was performed to assess whether any relationship exists between the variables and the respondents' preferences for alternative energy sources (e.g. whether gender or education level influenced people's willingness to adopt renewable energy technologies).

2.3. SWOT analysis of the energy self-sufficiency in Kosovo

According to the author's reasoning, a significant research gap exists in the field of energy self-sufficiency from biomass sources, as a result of which it is necessary to gather more detailed information on the current situation through a SWOT analysis (Table 2). Through the research methodology, it has been achieved to understand the strengths and weaknesses of the topic and the current situation, trying to turn risks into opportunities for the future. The main research topics are listed as follows, with the main aim of addressing self-sufficiency and its processes:

- What are the challenges and barriers to Kosovo farms using biomass for energy generation?
- What are the advantages, disadvantages, risks, and opportunities of pursuing on-farm energy self-sufficiency as a new strategy?

Table 2. SWOT analysis of renewable energy sources application in Kosovo

Strengths	**Weaknesses**
Geographic location (Ministry of Economy, 2024)	Initial and installation costs (Madurai et al., 2020; Zhang & Xu, 2020)
Targets to increase ambitiously the share of renewables (Ministry of Economy, 2021)	Lack of public financing resources (European Union, 2014)
The development of legal framework (Ministry of Economy, 2021)	Land fragmentation (MAFRD, 2015)
	Insufficient collateral to qualify for farm lending schemes (MAFRD, 2023b)
Opportunities	**Threats**
Availability of resources which guarantee continuous supply of heating and other energy forms (Sertolli et al., 2023)	Inadequate level of knowledge and expertise regarding RE technologies (Szakály et. al., 2021)
Energy and climate change (Ministry of Economy, 2021)	Insufficient local financial schemes to RES projects (MAFRD, 2023b)
Reduction of the farm energy expenses (Bathaei & Štreimikienė, 2023)	Insufficient local financial schemes to RES projects (MAFRD, 2023b)
Environmental eco-friendliness (Botelho et al., 2016; Rath et al., 2021)	RES systems with energy storage can be costly (European Commission, 2021)

Source: Author's own construction (Pestisha & Bai, 2024)

2.4. BWS scale methodology

The Best-Worst scaling method is a tool that can be used to evaluate farmers' opinions about renewable energy approaches. Farmers can use this technique to identify the aspects of renewable energy that they find most and least enticing. Asking farmers to evaluate the best and worst solutions for renewable energy based on a range of statements or qualities, such as equipment cost, ease, or environmental impact, can also yield detailed information about their goals and concerns. This approach helps ascertain how farmers see the potential benefits and challenges of integrating renewable energy into their farming practices. The examination of individual preferences is made possible by the Best-Worst Scaling (BWS) technique, which is based on attributes and is used in the fields of agricultural economics and food demand (Burns et al., 2022; Caputo & Lusk, 2020; De Valck et al., 2022) (Muunda et al., 2021). This approach allows respondents to choose the best and worst alternative, attribute, or attribute level among the alternatives using one of three BWS approaches (object case, profile case, or alternative case) based on expressed preference information (Török et al., 2023a, 2023b).

Based on their applicability and thorough literature review, seven relevant characteristics for farmers' perceptions of renewable energy equipment (Table 3) were taken into account for experimental design. In each BWS choice assignment, the respondents were asked to evaluate the qualities they thought were the most and least important for applications involving renewable energy.

Table 3. The attributes used in the object-case BWS questions

No.	**Attributes**
1	Environmental friendliness
2	Less energy cost
3	Convenience
4	Investment cost
5	Energy cost savings
6	Available products for energy purposes
7	Current energy costs

Source: Author’s own construction (Pestisha et al., 2025)

The following elaborates on the format of the questionnaire's introduction (Table 4): *In the following section, the author wants 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 certain renewable energy source in each of the three scenarios that will be shown to you.* By providing a comprehensive understanding of the relative importance of many components, this approach provides valuable insights into the issues and priorities affecting farmers' attitudes regarding the usage of renewable energy. In the research, 120 farmers were interviewed through a questionnaire from all regions of Kosovo.

Table 4. 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 (Pestisha et al., 2025)

Individual-level best-worst values were employed for additional analysis in order to investigate the heterogeneity of preferences. This made it possible for the author to evaluate how respondent characteristics affected choices. K-Means cluster analysis uncovered hidden patterns by identifying discrete groups according to preferences for renewable energy. Additional tests were employed to investigate demographic and socioeconomic variations between clusters, such as the T-test, Chi-square, and Mann-Whitney test. IBM SPSS Statistics 29's two-step clustering improved the analysis and allowed for a more thorough comprehension of the preference variance and its implications.

2.5. Economic calculations

The method performed includes calculations of straw use and its efficiency compared to the wood source. In Kosovo, wood is a common source of energy and serves in our case as a good reference point to assess the sufficiency and sustainability of the use of biomass for heating, thus comparing the energy costs and benefits of the use of both sources. The method of this research is based on secondary data collected at national and international levels in order to have a more comprehensive picture of the research. A broader perspective is achieved by drawing on existing studies, reports and statistics. National data provide with general knowledge of the local situation regarding the heating sector in Kosovo and the existing resources used in this regard. The main goal of this research is to fully analyze the different heating sources and their effectiveness for the farm economy, by examining factors such as cost, resource availability and overall sustainability. Through this analysis, the current dynamics of heating in Kosovo and the possibilities of using renewable sources in the energy mix of the farm and the household economy are understood.

The calculations were carried out at two levels of farmers, small-sized and medium-sized ones, in situations that the author thought were similar to the conditions of Kosovar agriculture. In most cases of the small farm, the number of cows used is from one to five, as small farms are of this size, with cow heads stated also in the questionnaires performed for our studies. The sensitivity analysis included three straw consumption scenarios based on farm sizes of zero, 20 and 270 breeding cows, in order to reflect the degree of variability in straw demand. In this regard, zero cows on a farm have no demand for straw. The reason for selecting twenty cows is that this was the average herd size of cows based on the questionnaire conducted with farmers in Kosovo, categorized as medium-sized farms. While the maximum value of 270 cows represents the farm with the largest herd size reported in the questionnaire, thus positioning it as a large-sized farm. This analysis highlights the aspect of straw demand based on herd size. Whereas related to greenhouse size, both farm sizes use 0.5-hectare, which can be considered realistic in the Kosovar agriculture situation.

The energy demand of farms is significantly influenced by the type of the farm activity, in this regard the activities of cow breeding and greenhouse cultivations are taken into consideration for straw calculations. For livestock sector the amount of straw needed is very high due to bedding needs, whereas for greenhouse the straw is mostly needed for heating issues. To understand the each sector needs the sensitivity analysis is carried out. The results are organized in the tables in different scenarios.

3. MAIN FINDINGS OF THE DISSERTATION

3.1. Bibliometrics analysis results

An important indicator and element in the process of research and investigation is the total number of publications in a country for a certain period which represents a bibliometric indicator. The number of publications within the selected topic, which represents the annual scientific output of academic research that has been carried out in the thirty-four years set within the research framework, is graphically presented in Figure 3. Visualizing these data provides with the variations and trends in scientific output through the data that provide with an evaluation of the research field. Based on the figure, in the period between 1988 and 2008 a small amount of scientific output was produced, in the maximum with four articles produced per year, but hopefully this production began to gradually improve over time, especially after 2008 with a noticeable increase. However, even for the period under review, the total number of publications never exceeded 22 per year, despite a noticeable upward trend after 2008. As the Figure 3 explains, during the COVID-19 pandemic period a noticeable drop in publication output and productivity was observed, as a result of the shutdown and interruption of general activity. Extreme global events like the Russian-Ukrainian war and the COVID-19 epidemic, however, have caused major supply chain instability and fluctuating energy prices in Europe and around the world. Author believes that energy self-sufficiency will continue to acquire relevance in the long run, even though the rising trend in publications has changed into swings during the last three years, mostly because of the everyday financial difficulties experienced by farmers.

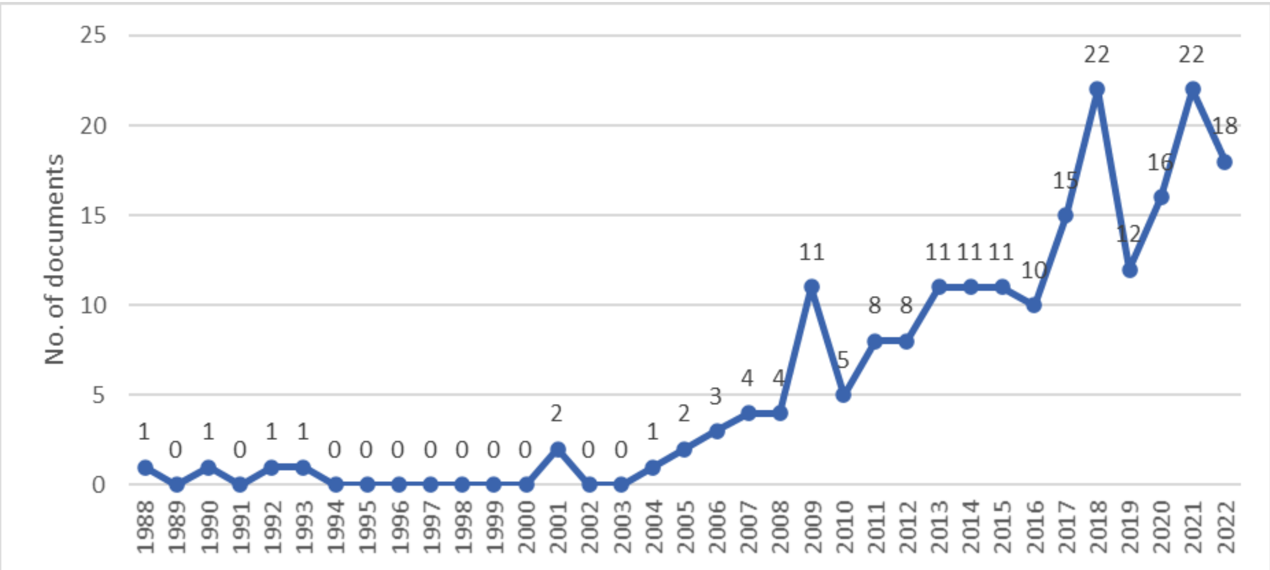

Figure 3. Annual scientific production of the chosen topic
Source: created by the authors (Pestisha et al., 2023)

China and the United States are the two countries that lead the table and attach great importance to scientific research in the context of RES application in agriculture. Both of these developed countries have made large investments in building capacities for renewable energy production. The frequency of keywords used has also been elaborated, which can be seen grouped in Figure 4. These clusters represent 26 keywords out of a total of 715, with “renewable energy” as the most frequently used keyword, followed by “biogas”, “sustainability”, followed by “biomass” and the term “environment”. Based on the Figure 4, the cluster with the most progress in terms of keywords is the red cluster, thus generating the highest number of keywords from the database. This cluster is led by the "renewable energy" keyword, which is a factor that has been widely used and is the most important within the dataset. Above all, this group represents a radical research focus highlighting the importance of including renewable energy in scientific research.

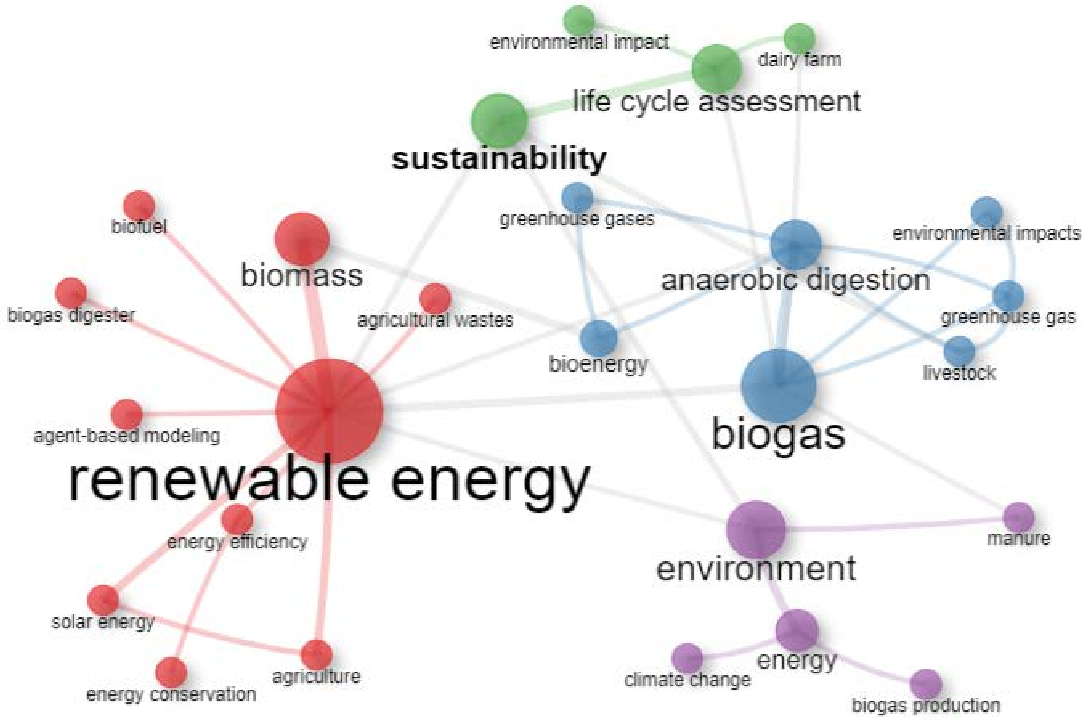

Figure 4. The keyword co-occurrence visualization network (1988-2022)
Source: created by the author (Pestisha et al., 2023)

To gain insight into the concentration of keywords for the near term, a co-occurrence keyword network visualization is generated for the research areas that have gained the highest importance and the greatest growth spurt during the 2019 to 2022 time period, as shown in Figure 5. Among the twenty most used keywords in this time period were "renewable energy resources", "sustainable development", "greenhouse gases", “energy efficiency” and "fertilizers", which attracted the attention of researchers in the focus of their research. the red cluster contains the majority of keywords, similar to the one shown in Figure 4, a connection between the research areas over the years. The blue cluster has also experienced an increase in the scope of research, reflecting the research on advanced RES practices. In this group, the most prominent keywords are "biomass", followed by "biogas" and "fertilizers", highlighting the growing agricultural sustainability practices within this sector. This is also supported by the findings of the research by Sertolli et al., (Sertolli et al., 2022) revealing the importance of biomass, with a high-scale annual production of 1260 EJ/year, estimated from the entire Earth's surface, thus with satisfactory availability.

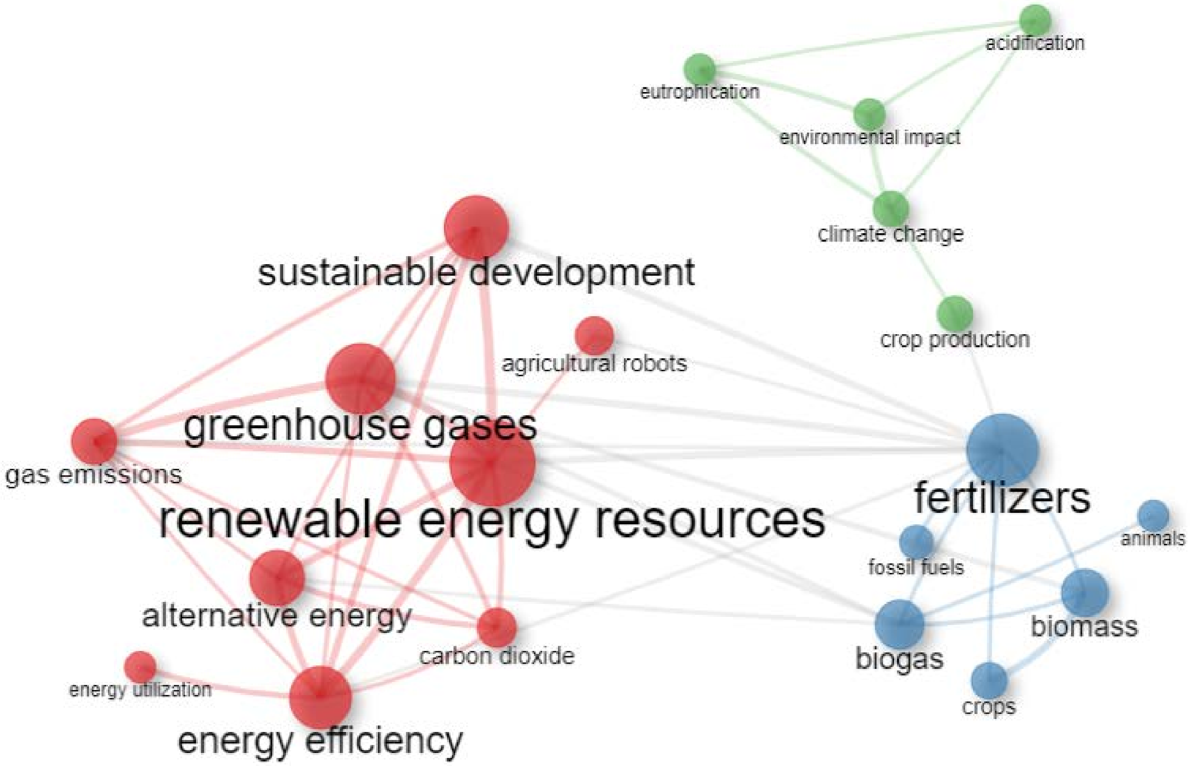

Figure 5. Keyword co-occurrence network (2019-2022)

Source: created by the author (Pestisha et al., 2023)

3.2. Attitude of farmers towards renewable energy sources

The research results reflect an increase in awareness of renewable energy sources such as solar, wind and hydropower, for both groups included in the research, with a range of 80% to 100% for each energy source. Factors that may have had an impact are continuous education, various trainings and the influence of promotion through the media. Among the sources listed, solar energy has presented a reflection of recognition by both groups included in the research, but it is obvious that farmers seem to be richer in knowledge in the field of solar energy. This phenomenon may be related to the farmers' conceptions of solar energy as a concrete way towards reducing energy costs on the farm. However, knowledge about this type of energy source has been correctly understood by both groups, which is confirmed by the value of the standard deviation, as in Table 5.

Also wood pellets are a generally known source which is used for heating in Kosovo, while biogas is another source about which the farmers group has heard much less compared to the internet-oriented population, perhaps as a result of the fact that there is no such agricultural plant in Kosovo and this affects the lack of knowledge in this aspect. Also in this case, financial resources are not considered as a fully determining factor, but the level of knowledge about resources is an important factor. In the context of biofuels for use in transport, knowledge is low, as a result of their insignificance in daily activities.

Table 5. Types of renewable energy sources and heard rate by the population (N=243, N=30)

Types of RES	Internet-oriented population %			Farmers %		
	Have heard about it	Mean	Standard deviation	Have heard about it	Mean	Standard deviation
Solar	89.7	0.9	0.3	100	1	0
Wind	85.6	0.86	0.35	90	0.9	0.3
Hydro	83.5	0.84	0.37	80	0.8	0.4
Geothermal	37.4	0.37	0.48	30	0.3	0.46
Heat pumps	28	0.28	0.45	30	0.3	0.46
Bio-briquette	23	0.23	0.42	66.7	0.67	0.47
Wood pellet	68.3	0.68	0.46	86.7	0.87	0.34
Biogas	27.2	0.27	0.44	16.7	0.17	0.37
Biodiesel	22.2	0.22	0.41	33.3	0.33	0.47
Bioethanol	16	0.16	0.36	13.3	0.13	0.34

Source: Own results based on the responses from the questionnaires (Pestisha & Bai, 2022)

Pearson correlation was performed to see if there was a significant relationship between the sources, and based on the results, relationships were found between solar and wind energy ($r=0.51$, $p<0.001$), hydro ($r=0.47$, $p=0.00$), wood pellets ($r=0.23$, $p=0.00$) and geothermal energy ($r=0.23$, $p=0.00$). This means that people who have heard of solar energy are more likely to have heard of these four other renewable energy sources.

After the survey regarding awareness in the context of biomass, the results turned out to be very high, with farmers having a much better position compared to the other group, as a result of daily dealing with biomass at the farm level (agricultural waste).

In light of the research on the attitudes and preferences of the internet-oriented population and farmers, the author was able to understand the level of suitability and acceptability of RES. Over 70% of respondents from the internet-oriented group and of farmers admitted that they would easily accept and use RES in their households and businesses (Table 6). Of both groups, the most used source of RES was wood, followed by wood pellets. This source is easily accessible and a cheap source that is used extremely widely for heating which was considered to be a non-renewable source by respondents. Also in the case of farmers, wood was the most used source among RES, as a result of easy access to it as a result of living in rural areas and access to forests. In the case of wood pellets, the percentage of use by farmers was almost the same as that of the general population, as a result of the awareness that the raw material for pellets comes from agriculture. Regarding awareness of the positive aspects of RES, almost every farmer was aware, and they admitted that these devices have high and unaffordable costs for installation on farms.

Table 6. The use of RES and their desired types for future use (N=243, N=30)

Type of sources	Distribution of Responses for Internet-oriented population				Distribution of Responses for Farmers			
	Use of Res		Would like to use it in future		Use of RES		Would like to use it in future	
	N	%	N	%	N	%	N	%
Solar panel	7	2.9	180	74.1	4	13.3	23	76.7
Wind energy	1	0.4	84	34.6			3	10
Firewood	74	30.5	40	16.5	29	96.7		
Bio-briquette	3	1.2	18	7.4			4	13.3
Wood pellet	42	17.3	41	16.9	5	16.7	9	30
Heat pumps			35	14.4			2	6.7
Other	30	12.3	8	3.3			1	3.3
Don't know			7	2.9				
None			9	3.7				

Source: Own results based on the responses from the questionnaires (Pestisha & Bai, 2022)

3.3. SWOT analysis results

Agriculture as a sector in Kosovo faces major challenges, which follow farmers in their production process, thus realizing a lack of efficient sources in the context of renewable energy, problems with financial resources, high initial investments, lack of government support, and inadequate education on more coherent practices related to sustainable agriculture. All these barriers are highlighted and identified by the SWOT technique which was used to determine the possibility of energy self-sufficiency in agriculture. By evaluating and examining the strengths/weaknesses and opportunities/threats (SWOT) framework, a strategic overview and portfolio of actions is created, enabling to make efforts to exploit the strengths and opportunities created, along with premises and initiatives that aim to reduce and mitigate weaknesses and threats within the context of the national energy sector. Table 7 provides a summary of the primary obstacles preventing the local renewable energy sector from growing.

Table 7. Problems of renewable energy utilization in Kosovo and the actions needed to be taken

Problems	Actions
Insufficient support for RES projects from financial institutions and banks	Bank financial schemes with government assistance (grants and subsidies)
Inadequate use of biomass in stock breeding, industry, and agriculture	Establish biomass supply chains
Inadequate level of familiarity with RES technologies.	Seminars and different trainings for interested people
A lack of practical research and inadequate study and training programs on RES sources and technologies.	Mobilization of young researcher's support

Source: Author's own construction (Pestisha & Bai, 2024)

A multifaceted strategy that incorporates policy interventions, technological advancements, capacity building initiatives, and stakeholder engagement strategies is required to strengthen the energy self-sufficiency of farms in Kosovo, which is experiencing similar factors and effects as other developing nations. In the context of its emerging economy, Kosovo is working to establish its local RES market.

A national energy plan with clear targets for the use of renewable energy sources must be the focus of the authorized mechanism to address the aforementioned problems. The most important areas are as follows:

- The removal of present barriers prevents the execution of the RES project.
- Capacity to strengthen and expand governmental institutions in order to implement RES
- Develop a national RES master plan with the involved stakeholders, emphasizing the importance of rural community involvement as a cornerstone of the renewable energy project.
- Develop training and awareness initiatives on relevant RES technologies to enhance the local capabilities of engineers, technicians, operators, and users of such systems.

Unless indigenous energy sources, such as renewable energy, are developed, Kosovo will continue to produce fossil fuels to meet its growing energy needs, which may increase annually. According to the findings of the SWOT analysis of Kosovo's RES utilization, there are encouraging opportunities that merit further investigation. However, there are still some serious risks and vulnerabilities that must be addressed to ensure the efficient usage of RES systems. Two of the biggest obstacles that could obstruct Kosovo's efforts to develop renewable energy sources are the availability of financing schemes and the possible future costs of power produced by renewable sources. In Kosovo, there are presently few commercial banks with financial schemes specifically designed to support the expansion of RES.

3.4. BWS Scale of sustainability practices in Kosovar agriculture

The data gathered from the questionnaires demonstrated a high degree of enthusiasm for the use of solar panels, with 85% of the respondents saying that they favor solar panels very much. This indicates that there is widespread support for sustainable energy sources. Although solar panels are preferred by farmers, their use on farms is actually very limited. Ninety percent of the farms have not yet installed solar panels. This significant disparity demonstrates that farmers continue to face many obstacles to implementing solar energy on their farms, despite growing awareness of the advantages of alternative energy sources. The initial cost of installing the solar panels is the primary factor influencing this predicament. The initial expenses of installation and purchase are a determining factor in the adaptation process, even if solar energy reduces costs over the long run. Regarding the topic of government support in the form of grants and subsidies, the majority of farmers (roughly 92%) strongly concur, suggesting that these cases are crucial in facilitating the shift to renewable energy and ecologically sustainable farming methods. This could make it easier for them to handle the extremely high upfront expenditures of buying this technology, which would make energy-efficient techniques more widely available.

The data from farmers' perceptions of renewable energy, which were evaluated using Best-Worst Scaling (BWS), is compiled in this section. Based on how frequently participants were assigned the best and worst outcomes, the results show the relative importance of several renewable energy attributes. The frequency distribution of the best and worst outcomes for each attribute is displayed in Table 8. The research showed that farmers ranked "less energy costs" and "eco-friendliness" as the two most rated features of renewable energy, ranking them first and second, respectively. This demonstrates that while selecting renewable energy options, farmers give cost-effectiveness and environmental sustainability top priority. On the other hand, the attribute "convenience" received the lowest rating, suggesting that people place less emphasis on how simple or accessible renewable energy sources are. This implies that farmers are more interested in the economic and environmental advantages of renewable energy sources than in convenience.

Table 8. Best-Worst results for RES attribute importance in 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: Constructed by author (Pestisha et al., 2025)

The BWS statistical analysis is carried out in terms of cluster evaluation in order to determine the preference heterogeneity (Table 9). The results are crucial for comprehending the choices and obstacles farmers have when implementing energy self-sufficiency options. The two-cluster technique was the most professionally explicable after several cluster-matching procedures. This approach produced a consistent and comprehensible preference segmentation, highlighting groups of individuals with different priorities and perspectives toward energy-related equipment and habits.

Table 9. Description of clusters according to different factors

Denomination*		Cluster 1 Small farmers	Cluster 2 Medium to large farmers	Levene's test value	Significance value	Test-value	Significance value
Respondent number (120)		106	14				
BWS Energy cost savings		**1.30a**	0.79b	F=0.25	p=0.617	t=2.53	p=0.013
BWS Available byproducts for energy purpose		-0.54b	**0.71a**	F=1.93	p=0.167	t=5.24	p<0.001
BWS Less energy costs*		**2.62a**	-0.07b	F=51.41	p<0.001	t=6.48	p<0.001
BWS Environmental friendliness*		1.75b	**2.93a**	F=6.79	p<0.001	t=10.09	p<0.001
BWS Convenience		-2.41b	**-0.14a**	F=0.02	p=0.965	t=11.04	p<0.001
BWS Investment cost		**-1.14a**	-2.21b	F=2.22	p=0.139	t=3.37	p=0.001
BWS Current energy costs*		**-1.58a**	-2.00b	F=13.43	p<0.001	t=2.45	p=0.023
Age (year)	Mean: 43.78	43.63	44.93	F=0.88	p=0.351	t=0.49	p=0.625
Solar panel capacity (kW)*	Mean: 5.2	3.7	16.4	F=10.03	p=0.002	t=1.81	p=0.091
Electricity consume (€/month)*	Mean: 46.88	33.47	148.43	F=21.08	p<0.001	t=1.40	p=0.184
Number of cows*	Mean: 19.89	16.39	46.11	F=10.45	p=0.002	t=1.68	p=0.117
Wheat (ha)	Mean: 4.81	4.11	10.71	F=0.43	p=0.512	t=1.48	p=0.141
Maize (ha)*	Mean: 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 represent the Welch test results
**Different letters show significant differences ('a' represents significantly larger value)

Source: Author's own results (Pestisha et al., 2025)

There are two groupings in the statistical results: "Small farmers" (Cluster 1) and "Medium to larger farmers" (Cluster 2). The two groups' primary conclusion is that energy cost savings are the most crucial component, particularly for "small farmers" who place a high value on it because these savings have a greater impact on their financing and means of subsistence, including expenses for their families and farms. The t-test results (t=2.53, p=0.013), which demonstrate that energy cost savings are a significant factor in lowering operating expenses, support this. On the other hand, "Medium to larger farmers" place more value on the "availability of the byproducts" with a positive score of 0.71 compared to "Small farmers" who have a negative score of -0.54, this difference is statistically significant (t=5.24, p<0.001). "Environmental friendliness" is another crucial quality, scoring higher (2.93) for "Medium to large farmers" than for "Small farmers" (1.75). The value of the t-test results (t=10.09, p<0.001) further supports this, indicating that larger-scale farmers place a higher value on this trait. This set of farmers benefits from clean techniques that affect the environment and is more concerned with sustainability. With 106 respondents classified as "small farmers" and 14 in the "medium to larger farmers" category, the sample distribution was unbalanced, highlighting the fact that the majority of farms in Kosovo are small. Last but not least, both groups demonstrated a substantial consensus regarding the significance of government incentives. To attain energy self-sufficiency in agricultural operations, the majority of Small Farmers (97 out of 106) and Medium to Larger Farmers (13 out of 14) in both groups strongly believed that government assistance in the form of financial resources or equipment was necessary. Despite this widespread belief, there was no significant difference between the clusters in this region ($\chi 2=0.029$, $p=0.864$), indicating that both groups recognize the subsidies and incentives in the energy transition.

3.5. Economic calculations

The calculations in this research are focused only on heat production, excluding transport fuel and electricity production. Therefore, in this case there is only evaluated the calculations for straw use, while solar panels and other energy crops are not included in the analysis. Based on a survey conducted in Kosovo, higher energy consumption is expressed in rural areas, this is probably due to the easier access of residents in urban areas to various energy sources such as electricity, central heating and renewable sources (Krajnc et al., 2015). The demand for wood as fuel is also influenced by the country's temperatures during the winter season, geographical and social factors.

Table 10. Annual thermal energy demand of a family house and its cost covered by wood-fired boiler

Denomination	Indicators	Unit
Thermal energy demand	0.86	GJ/year/m2
Wood stove efficiency	82	%
Average area	120	m2
Net price of wood	7.2	Euro/GJ
Energy input	125.9	GJ/year
Cost of thermal energy	899.9	euro/year

Source: Author's own calculations

Overall, the Table 10 presents calculations regarding the use of wood and a stove to heat a family home. The high efficiency of the boiler helps to reduce running costs and also to moderate the amount of wood used. An important factor when considering the use of this energy source for heating is the price of wood. The information in the table may be useful for energy users seeking alternative heating methods to achieve energy and financial sustainability. If this demand would be considered to be met by biomass, an alternative method of providing thermal energy is the use of agricultural straw, as an abundant resource (Table 11). In the boiler, for this purpose, a straw bale of 20kg is needed for efficient operation depending on the moisture rate and density. The current price in the region is 0.50 € for 20kg ball, while the price per kg is 0.025€.

Table 11. Annual thermal energy demand of a family house and its cost covered by straw

Denomination	Indicators	Unit
Straw price	0.025	euro/kg
Energy content of straw	12	MJ/kg
Straw yield from 1-hectare	2	tonnes/hectare
Efficiency of straw stove	82	%
Energy from straw price	0.0021	euro/MJ

Energy input	125.9	GJ
Cost of thermal energy	262.20	euro/year

Source: Author's own calculations

The table shows that the total amount needed for straw heating yearly is 10.5 tonnes (125.9 GJ/12MJ/kg). This quantity is dependent on weather conditions from year to year. The correlation between the average yield of grain and straw can vary from weak to medium because their ratio depends on the cereal species.

Intensive greenhouse production technologies have high energy requirements to maintain optimal conditions for plant growth according to the intended conditions. Not only intensive greenhouses but also farmers' home greenhouses (small scale) require heat energy, and biomass can be considered as a source for their purposes. When determining the annual heating of the equipment, a value of 150-200 W/m^2 is usually used, while in the case, it was calculated with a heating capacity of 175 W/m^2 (TÉGLA, 2015). Table 12 shows the differences in costs for the predetermined sizes of greenhouses when using wood and straw heating. Based on the parameters set already, it can be seen that in each case, a cost saving of 73% can be achieved by replacing wood with straw. Greenhouses of 0.5-1 ha can be heated using a small-scale boiler, but larger greenhouses must be heated with an industrial boiler. The prices of wood and straw boilers are approximately the same, depending on the performance, so the use of straw boilers does not require additional investments. However, one feature that makes the difference between one and the other is automation, which is not possible with straw boilers.

Table 12. Comparison of wood and straw costs for heating a greenhouse

Size of operation (ha)	Annual heating power demand (kWh)	Annual wood consumption (m3)	Heating costs with wood (euro/year)	Annual straw consumption tonne	Heating costs with straw (euro/year)	Savings with straw firing (euro/year)
0.5	8750	4.09	225.0	2.43	60.76	164.24
1	17500	8.18	450.0	4.86	121.53	328.47
3	52500	24.55	1350.0	14.58	364.58	985.42
5	87500	40.91	2250.0	24.31	607.64	1642.36
10	175000	81.82	4500.0	48.61	1215.28	3284.72

Source: Author's own calculations

Another aspect considered in the context of straw use is animal bedding in the livestock sector, as a good by-product due to its comfort and availability. In Kosovo, the livestock fund has higher participation of cows at 250,899 heads compared to sheep, goats and horses (MAFRD, 2023c). Based on the literature, an average cow has a demand of about 1.3 tons per year per litter. Farms in Kosovo are of the small, medium and large types, therefore in the Table 13, calculations have been made for some structures of dairy cows. The reason why the number 20 cows were taken is that in the research carried out by us, the average number of dairy cows from 120 farmers was 20.

Table 13. Straw calculations for bedding in livestock production

Size (cow)	Annual straw consumption (tons/cow)	Area (ha)	In case of crop rotation (ha)	In the case of greenhouse usage (ha)	Considering crop rotation for both aspects (ha)
1	1.3	0.65	1.30	1.87	3.73
5	6.5	3.25	6.50	4.47	8.93
10	13	6.50	13.00	7.72	15.43
20	26	13.00	26.00	14.22	28.43

Source: Author's own calculations

In the context of using straw for bedding, the author must keep in mind that there is a need for large amounts of the generated straw, to use it for greenhouse heating, animal bedding, and also taking into account the crop rotation process. In this case, for one cow, the amount of straw needed is 1.3 tons, which requires a planned area of 0.65 ha of cultivation, while if there is also taken into account the amount of straw for heating a 0.5 ha greenhouse and the amount of straw for crop rotation, then the total amount needed to meet the straw needs will be 3.73 tons.

A purpose of the sensitivity analysis is to compare the impact of different price levels of the two sources selected for comparison, straw and wood. Table 14 presents the heating costs and potential savings by using straw as a heating source compared to wood. The reason for selecting these three straw price values is as a result of data from the current situation on the ground in Kosovo, where the price of straw per ton of straw ranges from 20 to 30 euros, therefore in all calculations the authors have used the average price value for straw of 25 euros/ton.

Table 14. Best scenarios for straw price

Straw Price (€/kg)	Heating Cost with Straw (€)	Savings with Straw (€)	Wood Price (€/m³)	Heating Cost with Wood (€)	Savings with Straw (€)
0.02	64.02	210.4	45	224.5	144.47
0.025	80.03	194.4	55	274.4	194.36
0.03	96.04	178.4	65	324.3	244.25

Source: Author's own calculations

With the increase in the price of straw, the cost of heating with straw also increases, but indirectly the savings compared to the use of wood also decrease. The table enables a deeper understanding of how the fluctuation in the price of straw will also have an impact on heating costs and the advantages of using it over wood.

4. CONCLUSION AND NOVEL FINDING

The limitations, potential, and current uses of several renewable energy sources, including biomass and solar energy sources were taken into consideration for agricultural purposes, to assess the preferences and attitudes of farmers in this field.

Eighty to one hundred percent of farmers and internet-oriented people know about renewable energy sources (RES) such as solar, wind, and hydro. However, compared to the average person, farmers have heard more about solar and wind energy and less about hydro energy. Furthermore, men were more familiar with those three energy sources than women, and educated people were more familiar with them than uneducated people. Due to a lack of knowledge and their limited application in daily life, biodiesel and bioethanol are generally unknown.

Because firewood is less expensive, the majority of responders with lower incomes heat their homes using it. Furthermore, like in Hungary and the USA, firewood is typically seen as a non-renewable energy source. Additionally, because wood pellets are convenient, those with greater salaries prefer them for heating. The population has a comparatively high level of environmental consciousness, which is cited as the primary justification for the future deployment of RES technologies. However, the respondents stated that the main deterrent to installing any RES technology is the high cost of purchasing the necessary equipment.

Males reported higher levels of awareness and self-assessed knowledge than females, and awareness of RES varied among demographic divisions of the population studied. Compared to unemployed people, employed people demonstrated higher awareness and self-assessed expertise in RES (perhaps for financial reasons). RES knowledge was substantially higher among individuals who cared about the environment than among those who didn't. The results show that although people are receptive to other possibilities, they are kept away from potential new solutions by outdated customs, false information, and a lack of funds.

Most farmers and internet-oriented participants (74.1% and 76.7%, respectively) intend to employ renewable energy sources (RES) in the future, particularly solar panels. Farmers are interested in using wood pellets and solar panels in the future because they will lower production costs, increase their level of independence, and protect the environment. Solar collectors can power the irrigation system, dry crops, warm greenhouses, animal facilities, and dwellings. The economics of employing RES in agriculture is unclear and will be the subject of future research, but the municipality's available funds are limited. Good informational efforts and appropriate agricultural policy can help close the gap between the level of RES utilization in Kosovo and the willingness to use it. Comparing the Kosovar and Hungarian circumstances was simple because the questionnaire's structure was based on a prior Hungarian study. In the future, it might be helpful for other foreign polls. Our findings might also provide a solid foundation for cross-border comparisons because they are generally valid for the small nations of South-East Europe.

With the exception of the years of severe crisis (Covid19), the number of published papers for the pertinent literature in the field of renewable energy with application in agriculture shows a growing trend year by year when viewed from the perspective of the variation trend of the number of published papers. In particular, the number of published papers has increased since the 2008 recension. While the number of publications in scientific journals is highest in Elsevier journals (with more articles published in Q1 and Q2) and the MDPI journals of Energies and Sustainability have published a number of articles, scientific outputs from China and the USA exhibit a high trend and have the most accomplishments in this research field. . Nonetheless, researchers from the US, UK, and India are the authors of the top ten most cited papers. High-level keywords in the literature are mostly related to renewable energy, the environment, energy, anaerobic digestion, biogas, sustainability, and biomass, according to cluster mapping and keyword co-occurrence. The environment and energy sustainability are the main topics, including greenhouse gas emissions, livestock, climate change, biofuels, agricultural wastes, and environmental effects. Attention is becoming more and more focused on using RES in agriculture.

According to the statistical analysis, the two groups of the cluster "Small farmers" and "Medium to larger farmers" have varied definitions of energy self-sufficiency, placing varying values and characteristics on energy efficiency. While the other group is more ecologically conscious and places a higher value on the availability of byproducts, small farmers in this context place a higher value on energy cost reductions. Since farmers' objectives are influenced by factors such as farm size, energy usage, and livestock numbers, farm scale can play a significant role in integrating these alternative technologies. The unique requirements of any group can be met in the direction of sustainable agricultural practices with the aid of laws, incentives, and education.

Hence, the cluster analysis results show that there are significant differences between the two groups. "Small farmers" are more likely to be concerned with energy cost savings because they have a practical need to lower farm operating energy costs, even though their adoption of solar panels is low because of the high upfront costs. In contrast, "Medium to larger farmers" exhibit favorable attributes toward sustainability and environmental goals, have a fantastic viewpoint on incorporating byproducts into the energy transition, and have a favorable opinion of renewable energy as a crucial element for long-term success. Because of their superior position in the agricultural chain, large-scale farms are more likely to adopt renewable energy technology, indicating a relationship between farmers' energy needs and the size of their operational farms. To increase energy self-sufficiency in farms across both groups, a great deal of weight is placed on government incentives, community cooperation, and awareness raised by educational sources. Supportive policies and public acceptance of the shift to alternative energy are particularly crucial.

Based on the heating performance of two sources (wood and straw), the use of biomass raw material (straw) for energy needs is suggested as a result of the lower operating cost, especially for agricultural needs. Based on the tabular data extracted from the sensitivity analysis, it can be concluded that there is a significant relationship between the number of livestock, its use for heating the greenhouse, straw consumption, heating costs and the necessary area of land for straw cultivation. From the analyses carried out, it is clear that the presence of livestock on the farm increases the demand for straw for internal use. Also, with the increase in the number of livestock, straw consumption and the area cultivated with winter wheat increase proportionally, emphasizing the intensive use of resources for livestock, especially when the presence of the greenhouse significantly increases the amount needed for a more complex and costly operation.

Furthermore, the price of straw plays an important role in the cost-effectiveness of using straw for heating and animal bedding. As its price increases, the cost of heating with straw also increases, thus affecting the competitiveness of the straw source with wood and narrowing the gap between them. Although higher straw prices affect the farmer's profits, straw still remains an economically favorable option compared to wood, as long as the price of straw does not exceed the price of wood. Therefore, continuous monitoring of the price of these two sources by farmers affects the cost-effectiveness of using heating sources.

The research aimed to assess the attitudes and preferences of Kosovar farmers regarding renewable energy and energy self-sufficiency on the farm. The findings of this research have a degree of consistency with the established hypotheses, thus providing insights into the attitudes and approaches of farmers towards sustainable practices and environmentally friendly choices. The assessment of the hypothesis is as follows:

H1: Increasing energy self-sufficiency on farms across Kosovo significantly contributes to improving energy access, farm stability, and rural diversification.

Based on the findings and farmers' perceptions, energy self-sufficiency leads to greater economic stability, access to reliable energy sources, and diversification of energy options. This hypothesis is accepted since farmers have acknowledged that self-sufficiency is an important factor that increases farm productivity.

H2: Kosovar farmers demonstrate a positive level of attitudes and preferences towards on-farm renewable energy, with "Less energy costs" and "Environmental consciousness" as the main driven factor in installing the renewable energy sources in farm.

Farmers have a motive and preference to adopt renewable technologies that affect self-sufficiency, as it affects the sustainability of agricultural operations, offering an answer to farm energy costs, as an efficient solution in managing energy resources in agriculture. On the other hand, an important factor in the adoption of self-sufficiency resources on the farm is also the environmental issue known as environmental friendliness. The research supports this hypothesis by the fact that Kosovar farmers have presented positive attitudes towards renewable energy production on their farms, and especially for the use of solar panels with a 100% positive attitude, while in terms of by-products 81.7% have expressed a positive attitude towards their use. Moreover, BWS results show the highest score for "less energy costs" 34.17 and "environmental friendliness" with a BWS score 28.69.

Kosovar farmers display a positive perception of agricultural sustainability, thus influencing farm well-being and productivity. This is supported by a high percentage of 100% positive sentiments, of which 89.2% stated that clean energy "definitely" improves the quality of life, resulting in health and environmental benefits.

H3: Biomass (straw) is a more economical source for energy production on the farm than wood.

The price of straw is an influencing factor in the cost-effectiveness of this resource, according to calculations made, straw is a more efficient source compared to wood and is a more productive source in farm self-sufficiency as long as its price does not exceed the price of wood, therefore this hypothesis is accepted.

H4: Energy self-sufficiency is perceived differently between farm sizes, based on different attributes.

Motivations and perceptions regarding on-farm self-sufficiency vary among different groups of farmers based on farm size (small and medium-sized farmers). This hypothesis is accepted as there are different conceptions of factors and motives among different types of farmers, small farmers see energy self-sufficiency as a factor that reduces energy costs, while medium-sized farmers see it as a response to environmental friendliness.

Moreover, this thesis had some limitations:

This thesis is characterized by limited access to secondary data, which impacts the depth of the analysis. The research also does not include longitudinal analyses of attitudes and preferences towards energy self-sufficiency as these are continuously evaluated.

A good recommendation from the thesis would be to incorporate and develop renewable energy training from the Ministry of Agriculture, Forestry and Rural Development as an important process that would provide farmers with new and adequate knowledge, particularly given the close relationship between agricultural practices and renewable energy. Policymakers should focus on the appropriate next steps to achieve effective results for practical achievements in terms of energy self-sufficiency in farms.

Within the framework of the thematic and its future development direction, studies can evaluate and compare the technical and economic aspects of different types of renewable energy sources (solar, biogas, wind, biomass) across different types of farms in Kosovo (e.g., dairy farms versus crop farms). Also, a very important aspect of the research can be related to international energy policies, subsidies and harmonization of EU practices with local ones in investments in renewable energy systems. Although Kosovo is a small country, farms are of different sizes, so socio-economic barriers and incentives should also be taken into account. Therefore, the exploration of social, financial barriers and institutional incentives in the context of energy self-sufficiency and their effective assessment can positively impact the research spectrum.

The following may be significant novelties in this dissertation:

1. The author confirmed that this dissertation has managed to combine a series of methods that have managed to successfully research the issue and perception of farmers for energy self-sufficiency at the farm level. As a result of this research through different research models, the author conclude that farmers have shown a positive attitude towards renewable energy sources that find application on the farm.
2. Based on the bibliometric analysis conducted from 1988 to 2022, the network of keywords related to renewable energy has undergone a change compared to the focus of academics during the period 2019 to 2022, and especially the red network which has grown extremely much, also having "energy efficiency" as a keyword with a very high concentration, which is in the same category as "sustainable development", "renewable energy resources" and "greenhouse gases". This is as a result of the global climate agenda which is under the Paris Agreement and also the European Union's Green Deal, influencing the focus on greenhouse gas management and alternative energy practices. On the other hand, COVID 19 also influences the reshaping of economic practices and the prioritization of practices that affect the well-being of individuals and the fight against climate change.
3. The fact that 72.4% of farmers expressed willingness to apply solar panels on their farms represents a preference and positive attitude of Kosovar farmers towards renewable equipment and energy self-sufficiency on farms. Despite the fact that attitudes are positive, adoption still remains skeptical due to the fact that there are various barriers that hinder this process starting from installation challenges and high initial costs, the need for financial support from the government and various trainings that would facilitate the perception of these practices.
4. It is concluded that with increasing market prices, between straw and wood as heating sources, straw remains the more cost-effective option compared to wood. With the price of straw at €0.025/kg, the cost of heating amounts to €80.03, while the cost of wood at €55/m^3 is €274.4, the savings still remain significant compared to the €194.4 cost of wood for heating. Therefore, straw as a biomass source represents an important part of energy self-sufficiency on the farm.

5. SUMMARY

The topic explores farmers' attitudes and preferences regarding renewable energy and their desires to achieve energy self-sufficiency on the farm. Given the use and reliance on fossil fuels for energy generation, as well as the potential for integrating renewable energy on farms, this thesis focuses on how businesses view energy independence and the factors that influence the use of efficient and environmentally friendly assets.

In terms of research, the research objectives are presented as follows:

- The importance of self-sufficiency in the farms of Kosovo;
- The reasons to use the renewable energy sources by farmers in Kosovo;
- The awareness and attitudes of farmers regarding renewable energy production on the farm;
- What do the farmers think about sustainable agriculture?
- The most economical bio-energy sources to be produced in the farm for achieving farm self-efficiency compared to the fossil competitive energy sources;
- Does farm size or type of farming influence the way of energy self-sufficiency?

To reach these objectives, the research is based on primary and secondary data, through surveys and interviews conducted with farmers in different regions of Kosovo, exploring energy use patterns, energy technologies, factors influencing the integration of these assets on farms and farmers' attitudes towards energy sustainability.

As a result of this research, the author reached the following results:

- The findings show that interest among farmers in renewable energy is growing, leading to higher energy self-sufficiency on farms. Of course, major challenges remain the difficult access to finance, lack of information, and low institutional support through various financial mechanisms. However, farmers are open to adopting renewable energy on farms, especially if the government facilitates some integration measures through various incentives.
- In terms of global comparison, China and the USA are two countries that attach high importance to scientific research and investments in the application of renewable energy sources in agriculture. Both countries are major investors in building capacities in the realization of production from renewable sources in the agricultural sector.
- Among the renewable energy sources, solar energy remains one of the most popular sources among the surveyed farmers, thus demonstrating a higher level of knowledge in this type of energy technology.

- Different perspectives related to the use of by-products for energy production in agriculture show that 81.7% of farmers expressed a positive attitude, indicating a trend towards the acceptance of the benefits of energy self-sufficiency in farms.
- From the research, it can be concluded that there is a high level of awareness regarding the fact that clean energy can improve living standards compared to traditional energy. As 89.2% of respondents affirmed and ranked it as “definitely improves quality of life”. Respondents link this to environmental sustainability and the positive impact on health.
- Government influence through support in the form of grants and subsidies is a welcome issue for farmers, with approximately 92% expressing strong agreement on the importance of such decisions. These positions emphasize the role of financial incentives to switch from traditional energy to more efficient and friendly energy, which would also ease the burden of investment costs and increase the adoption of best energy practices on farms.
- The research highlights that farms prioritize “lower energy costs” and “eco-friendliness” as the two most valued attributes in relation to the application of renewable energy, highlighting cost-effectiveness and the importance of environmental sustainability as principles that influence farm and agricultural practices.
- Based on the size of the farms, there are two groups of farmers "small farmers" and medium-sized farmers. The first group places a high value on “energy cost savings” it because these savings have a greater impact on their financing and means of subsistence, including expenses for their families and farms, whereas the second group in “environmental eco-friendliness”.
- In order to heat a 0.5-hectare greenhouse, 1.22 hectares of winter wheat must be cultivated, while if there is taken into account crop rotation, it must be cultivated 2.43 hectares as a result of ensuring the quantity for two years. In the case of a 10-hectare greenhouse, an amount of 48.61 tons/year is needed to provide heating, and for this, 24.31 hectares of winter wheat must be cultivated.
- The sensitivity analysis shows that the relationship for any decrease or increase in the price of straw and costs is proportional; as the price of straw increases, the savings benefits decrease, however straw still provides savings compared to wood. This analysis shows that straw remains a more effective option while having a lower price than wood.

As a result of the findings of this research, it is proposed that Kosovo should develop a comprehensive strategy in order to harmonize its policies with those of the European Union, towards advancing self-sufficiency through a more efficient use of renewable energy sources.

The thesis recommends government interventions in various information and educational policies and campaigns, as well as subsidy programs to promote energy self-sufficiency on farms, thus contributing to improving farmers' position in energy access and environmental sustainability.

6. LIST OF PUBLICATIONS RELATED TO THE DISSERTATION

Articles, studies

1. **Pestisha, A.,** Bai, A., Sertolli, A., Bytyqi, N., Balogh, P.: Farmers' Willingness to Achieve Energy Self-Sufficiency in Kosovo.
   Energies. 18 (6), 1-32, (article identifier: 1332), 2025.
   DOI: https://doi.org/10.3390/en18061332
   IF: 3.2
   Quartiles: Q1
   Quartiles: N/A
   Citations: 1

2. **Pestisha, A.**, Bai, A.: Energy self-sufficiency of farms in Kosovo: an application of SWOT and PEST methodology.
   Acta Carolus Robertus. 14 (Klsz.), 139-160, 2024.
   DOI: https://doi.org/10.33032/acr.5546
   IF: N/A
   Citations: 0

3. **Pestisha, A.**, Gabnai, Z., Chalgynbayeva, A., Lengyel, P., Bai, A.: On-Farm renewable energy systems: A systematic review.
   Energies. 16 (2), 1-25, (article identifier: 862), 2023.
   DOI: https://doi.org/10.3390/en16020862
   IF: 3.2
   Quartiles: Q1
   Citations: 29

4. **Pestisha, A.**, Bai, A.: Preferences and knowledge of farmers and internet-orientated population about renewable energy sources in Kosovo.
   Int. rev. appl. sci. eng. 1-11, 2023.
   IF: 0.261
   Quartiles: Q2
   Citations: 5

Conference papers

1. "INTERNATIONAL SCIENTIFIC DAYS", PhD Conference 2025 – Farmers' willingness towards energy self-sufficiency in Kosovo", Pestisha, A., Sertolli, A., Bytyci, N., & Bai, A.
2. "SUSTAINABLE ECONOMY –SUSTAINABLE SOCIETY" International Scientific Conference 2024 – Biomass heat energy and competitive products in Kosovo, its environmental effects and usage barriers: Applying BWS method", Sertolli, A., **Pestisha, A.**, Bytyci, N., & Bai, A.
3. "SUSTAINABLE ECONOMY –SUSTAINABLE SOCIETY", International Scientific Conference 2024 – "Towards Energy Self-Sufficiency of Agricultural Sector in Kosovo and a Hungarian Comparison: Applying a SWOT Analysis", **Pestisha, A.**, Sertolli, A., & Bai, A.
4. 18th Annual Meeting Opportunities of Core and Peripheral Regions for their Sustainable Future (2020) – "Opportunities of wastewater heat utilization for heating and cooling of urban buildings", Gabnai, Z., Sertolli, A., **Pestisha, A.**, Bai, A., Németh, K., Péter, E., & Mező, N.

7. LIST OF OTHER PUBLICATIONS

Articles, studies

1. Sertolli, A., Bai, A., **Pestisha, A.**, Balogh, P.: Prospects for Biomass Heat Energy in Kosovo: Environmental Considerations and Usage Limitations.
   Biomass. 5 (1), 1-29, (article identifier: 14), 2025.
   DOI: https://doi.org/10.3390/biomass5010014
   IF: N/A
   Quartiles: N/A
   Citations: 0

2. Sertolli, A., Bai, A., Gabnai, Z., Mizik, T., **Pestisha, A.**: Theoretical and energy biomass potential of heat and electricity production in Kosovo.
   Energies. 16 (20), 1-23, (article identifier: 7209), 2023.
   DOI: https://doi.org/10.3390/en16207209
   IF: 3.2
   Quartiles: Q1
   Citations: 5

3. Chalgynbayeva, A., Gabnai, Z., Lengyel, P., **Pestisha, A.**, Bai, A.: Worldwide research trends in agrivoltaic systems: a bibliometric review.
   Energies. 16 (2), 1-25, (article identifier: 611), 2023.
   DOI: https://doi.org/10.3390/en16020611
   IF: 3.2
   Quartiles: Q1
   Citations: 61

4. Gabnai, Z., Németh, K., Péter, E., Sertolli, A., **Pestisha, A.**, Mezőfi, N., Bai, A.: Opportunities for wastewater heat recovery in Hungary and its role in the circular economy.
   Apstract. 15 (3-4), 81-90, 2021.
   DOI: https://doi.org/10.19041/APSTRACT/2021/3-4/10
   IF: N/A
   Quartiles: 0
   Citations: 0

Total IF of journals (all publications): 13.061

Total IF of journals (publications related to the dissertation): 6.661

Scopus/WoS ranking: 5 (100%)

7. REFERENCES

1. Agriculture, Ministry. of Forestry and Rural Development (2018). *Kosovo Green Report 2018*.
2. Almulhim, A. I. (2022). Understanding public awareness and attitudes toward renewable energy resources in Saudi Arabia. *Renewable Energy*, *192*, 572–582. https://doi.org/10.1016/j.renene.2022.04.122
3. Aria, M., & Cuccurullo, C. (2017). bibliometrix: An R-tool for comprehensive science mapping analysis. *Journal of Informetrics*, *11*(4), 959–975. https://doi.org/10.1016/J.JOI.2017.08.007
4. Bai, A. (2005). *Domestic perspectives on biomass production*.
5. Bai, A., Durkó, E., Tar, K., Tóth, J. B., Lázár, I., Kapocska, L., Kircsi, A., Bartók, B., Vass, R., Pénzes, J., & Tóth, T. (2016). Social and economic possibilities for the energy utilization of fitomass in the valley of the river Hernád. *Renewable Energy*, *85*, 777–789. https://doi.org/10.1016/j.renene.2015.06.069
6. Bathaei, A., & Štreimikienė, D. (2023). A Systematic Review of Agricultural Sustainability Indicators. *Agriculture (Switzerland)*, *13*(2). https://doi.org/10.3390/agriculture13020241
7. Ben-Iwo, J., Manovic, V., & Longhurst, P. (2016). Biomass resources and biofuels potential for the production of transportation fuels in Nigeria. *Renewable and Sustainable Energy Reviews*, *63*, 172–192. https://doi.org/10.1016/J.RSER.2016.05.050
8. Botelho, A., Pinto, L. M. C., Lourenço-Gomes, L., Valente, M., & Sousa, S. (2016). Public Perceptions of Environmental Friendliness of Renewable Energy Power Plants. *Energy Procedia*, *106*, 73–86. https://doi.org/10.1016/J.EGYPRO.2016.12.106
9. Burns, J. G., Glenk, K., Eory, V., Simm, G., & Wall, E. (2022). Preferences of European dairy stakeholders in breeding for resilient and efficient cattle: A best-worst scaling approach. *Journal of Dairy Science*, *105*(2), 1265–1280. https://doi.org/10.3168/JDS.2021-20316
10. Caputo, V., & Lusk, J. L. (2020). What agricultural and food policies do U.S. consumer prefer? A best–worst scaling approach. *Agricultural Economics (United Kingdom)*, *51*(1), 75–93. https://doi.org/10.1111/agec.12542
11. Chaikumbung, M. (2021). Institutions and consumer preferences for renewable energy: A meta-regression analysis. *Renewable and Sustainable Energy Reviews*, *146*, 111143. https://doi.org/10.1016/J.RSER.2021.111143
12. De Valck, J., Rolfe, J., Rajapaksa, D., & Star, M. (2022). Consumers' preferences and willingness to pay for improved environmental standards: insights from cane sugar in the Great Barrier Reef region*. *Australian Journal of Agricultural and Resource Economics*, *66*(3), 505–531. https://doi.org/10.1111/1467-8489.12484
13. Djurisic, V., Smolovic, J. C., Misnic, N., & Rogic, S. (2020). Analysis of public attitudes and perceptions towards renewable energy sources in Montenegro. *Energy Reports*, *6*, 395–403. https://doi.org/10.1016/J.EGYR.2020.08.059
14. Donthu, N., Kumar, S., Mukherjee, D., Pandey, N., & Lim, W. M. (2021). How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, *133*, 285–296. https://doi.org/10.1016/J.JBUSRES.2021.04.070
15. Elahi, E., Khalid, Z., & Zhang, Z. (2022). Understanding farmers' intention and willingness to install renewable energy technology: A solution to reduce the environmental emissions of agriculture. *Applied Energy*, *309*, 118459. https://doi.org/10.1016/J.APENERGY.2021.118459
16. European Commission. (2011). *The roadmap for transforming the EU into a competitive, low-carbon economy by 2050*. 1–4. https://ec.europa.eu/clima/sites/clima/files/2050_roadmap_en.pdf
17. European Union. (2014). *IPA II: the EU's Instrument for Pre-accession Assistance 2014-2020 | EUR-Lex*. European Union. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=legissum:2603_2
18. European Union EUR-lex. (2020, November 3). *EUR-Lex - 52020DC0098 - EN - EUR-Lex*. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52020DC0098
19. eurostat. (2022). *Farms and farmland in the European Union - statistics - Statistics Explained*. Eurostat. https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Farms_and_farmland_in_the_European_Union_-_statistics
20. FAO. (2016). The state of food and agriculture, 2016. In *The Eugenics review* (Vol. 59, Issue 2).
21. FAO. (2021). Emissions due to agriculture. Global, regional and country trends 2000–2018. *FAOStat Analytical Brief 18*, *7*(1), 87–98.

22. Filonchyk, M., Peterson, M. P., Zhang, L., Hurynovich, V., & He, Y. (2024). Greenhouse gases emissions and global climate change: Examining the influence of CO_2, CH_4, and N_2O. *Science of The Total Environment*, *935*, 173359. https://doi.org/10.1016/J.SCITOTENV.2024.173359
23. Fischer, B., Gutsche, G., & Wetzel, H. (2021). Who wants to get involved? Determining citizen willingness to participate in German renewable energy cooperatives. *Energy Research & Social Science*, *76*, 102013. https://doi.org/10.1016/J.ERSS.2021.102013
24. Gál, T., Nagy, L., Dávid, L., Vasa, L., & Balogh, P. (2013). Technology planning system as a decision support tool for dairy farms in Hungary. *Acta Polytechnica Hungarica*, *10*(8), 231–244. https://doi.org/10.12700/aph.10.08.2013.8.15
25. Gokmenoglu, K. K., Taspinar, N., & Kaakeh, M. (2019). Agriculture-induced environmental Kuznets curve: the case of China. *Environmental Science and Pollution Research*, *26*(36), 37137–37151. https://doi.org/10.1007/s11356-019-06685-8
26. IEA. (2024). *Bioenergy - IEA*. IEA. https://www.iea.org/energy-system/renewables/bioenergy
27. Kaldellis, J. K., Kapsali, M., & Katsanou, E. (2012). Renewable energy applications in Greece—What is the public attitude? *Energy Policy*, *42*, 37–48. https://doi.org/10.1016/J.ENPOL.2011.11.017
28. Kiraly, A., Pahor, B., & Kravanja, Z. (2013). Achieving energy self-sufficiency by integrating renewables into companies' supply networks. *Energy*, *55*, 46–57. https://doi.org/10.1016/J.ENERGY.2013.03.001
29. Krajnc, D. N., Rok Pisek, M. S., Michael R. Waschak, P. D., & Alicia English, P. D. (2015). *Wood biomass sector in kosovo*. http://www.fao.org/3/a-i4968e.pdf
30. Kumar, J. A., Sathish, S., Prabu, D., Renita, A. A., Saravanan, A., Deivayanai, V. C., Anish, M., Jayaprabakar, J., Baigenzhenov, O., & Hosseini-Bandegharaei, A. (2023). Agricultural waste biomass for sustainable bioenergy production: Feedstock, characterization and pre-treatment methodologies. *Chemosphere*, *331*, 138680. https://doi.org/10.1016/J.CHEMOSPHERE.2023.138680
31. Madurai Elavarasan, R., Afridhis, S., Vijayaraghavan, R. R., Subramaniam, U., & Nurunnabi, M. (2020). SWOT analysis: A framework for comprehensive evaluation of drivers and barriers for renewable energy development in significant countries. *Energy Reports*, *6*, 1838–1864. https://doi.org/10.1016/J.EGYR.2020.07.007
32. MAFRD. (2015). *Green book 2014*. https://www.mbpzhr-ks.net/repository/docs/56917_161214_GR_2014_ENG_Final_Printed_Version.pdf
33. MAFRD. (2023a). *Bujqësia e Kosovës në Numra*. https://www.mbpzhr-ks.net/repository/docs/Bujqesia_e_Kosoves_ne_Numra_2023.pdf
34. MAFRD. (2023b). *G R E E N R E P O R T 2 0 2 2*. https://www.mbpzhr-ks.net/repository/docs/Kosovo__Green_Report_2022.pdf
35. MAFRD. (2023c). *Green report 2 0 2 3*. https://enact.info/wp-content/uploads/2024/07/Green_Report_2023.pdf
36. Majeed, Y., Khan, M. U., Waseem, M., Zahid, U., Mahmood, F., Majeed, F., Sultan, M., & Raza, A. (2023). Renewable energy as an alternative source for energy management in agriculture. *Energy Reports*, *10*, 344–359. https://doi.org/10.1016/J.EGYR.2023.06.032
37. Mark Saunders, P. L., & Thornhill, A. (2019). Research Methods for Business Students. In *Synthese* (Vol. 195, Issue 5). https://www.amazon.com/Research-Methods-for-Business-Students/dp/1292208783/ref=sr_1_2?dchild=1&qid=1614706531&refinements=p_27%3AAdrian+Thornhill+%2F+Philip+Lewis+%2F+Mark+N.+K.+Saunders&s=books&sr=1-2&text=Adrian+Thornhill+%2F+Philip+Lewis+%2F+Mark+N.+K
38. Ministry of Agriculture, F. and R. D. (2020). *Green Report 2020*. https://www.mbpzhr-ks.net/repository/docs/Green_Report_2020r.pdf
39. Ministry of economy. (2021). Energy Strategy of the Republic of Kosovo 2022-2031. In *Ministry of economy*. https://me.rks-gov.net/wp-content/uploads/2023/04/Energy-Strategy-of-the-Republic-of-Kosovo-2022-2031-1-1.pdf
40. Ministry of Economy. (2024). *Ministry of Economy opens the Call for Subsidy of Efficient Heating Equipment for Households*. https://me.rks-gov.net/en/blog/ministry-of-economy-opens-the-call-for-subsidy-of-efficient-heating-equipment-for-households/
41. Mizik, T. (2021). Economic aspects and sustainability of ethanol production—a systematic

literature review. *Energies*, *14*(19). https://doi.org/10.3390/en14196137
42. Muunda, E., Mtimet, N., Schneider, F., Wanyoike, F., Dominguez-Salas, P., & Alonso, S. (2021). Could the new dairy policy affect milk allocation to infants in Kenya? A best-worst scaling approach. *Food Policy*, *101*, 102043. https://doi.org/10.1016/J.FOODPOL.2021.102043
43. OECD. (2022). *Multi-dimensional Review of the Western Balkans*. https://www.oecd-ilibrary.org/development/multi-dimensional-review-of-the-western-balkans_8824c5db-en
44. Pascaris, A. S., Schelly, C., Burnham, L., & Pearce, J. M. (2021). Integrating solar energy with agriculture: Industry perspectives on the market, community, and socio-political dimensions of agrivoltaics. *Energy Research & Social Science*, *75*, 102023. https://doi.org/10.1016/J.ERSS.2021.102023
45. Peng, G., Meng, F., Ahmed, Z., Oláh, J., & Harsányi, E. (2022). A Path Towards Green Revolution: How do Environmental Technologies, Political Risk, and Environmental Taxes Influence Green Energy Consumption? *Frontiers in Environmental Science*, *10*(May), 1–8. https://doi.org/10.3389/fenvs.2022.927333
46. Pestisha, A., & Bai, A. (2022). *Preferences and knowledge of farmers and internet-orientated population about renewable energy sources in Kosovo*. https://doi.org/10.1556/1848.2022.00516
47. Pestisha, A., Bai, A., Sertolli, A., & Bytyqi, N. (2025). *Farmers ' Willingness to Achieve Energy Self-Sufficiency in Kosovo*. 1–32.
48. Pestisha, A., Gabnai, Z., Chalgynbayeva, A., Lengyel, P., & Bai, A. (2023). On-Farm Renewable Energy Systems: A Systematic Review. *Energies*, *16*(2), 1–25. https://doi.org/10.3390/en16020862
49. Pestisha Albiona –BaiAttila. (2024). Energy Self-sufficiency of Farms in Kosovo: An Application of SWOT and PEST Methodology megtekintése. *Acta Carolus Robertus*, *14*, 139–160. https://journal.uni-mate.hu/index.php/acr/article/view/5546/6477
50. Popp, J., Kovács, S., Oláh, J., Divéki, Z., & Balázs, E. (2021). Bioeconomy: Biomass and biomass-based energy supply and demand. *New Biotechnology*, *60*, 76–84. https://doi.org/10.1016/J.NBT.2020.10.004
51. Punda, L., Capuder, T., Pandžić, H., & Delimar, M. (2017). Integration of renewable energy sources in southeast Europe: A review of incentive mechanisms and feasibility of investments. *Renewable and Sustainable Energy Reviews*, *71*, 77–88. https://doi.org/10.1016/J.RSER.2017.01.008
52. Rath, P., Jindal, M., & Jindal, T. (2021). A review on economically-feasible and environmental-friendly technologies promising a sustainable environment. *Cleaner Engineering and Technology*, *5*, 100318. https://doi.org/10.1016/J.CLET.2021.100318
53. Renewable Energy and Agri-food Systems: Advancing Energy and Food Security towards Sustainable Development Goals. (2021). *Renewable Energy and Agri-Food Systems: Advancing Energy and Food Security towards Sustainable Development Goals*. https://doi.org/10.4060/CB7433EN
54. Roberts, D., Majewski, E., & Sulewski, P. (2013). Farm household interactions with local economies: A comparison of two EU case study areas. *Land Use Policy*, *31*, 156–165. https://doi.org/10.1016/J.LANDUSEPOL.2011.09.012
55. Sertolli, A., Bai, A., Gabnai, Z., Mizik, T., & Pestisha, A. (2023). Theoretical and Energy Biomass Potential of Heat and Electricity Production in Kosovo. *Energies*, *16*(20), 1–23. https://doi.org/10.3390/en16207209
56. Sertolli, A., Gabnai, Z., Lengyel, P., & Bai, A. (2022). Biomass Potential and Utilization in Worldwide Research Trends—A Bibliometric Analysis. *Sustainability (Switzerland)*, *14*(9). https://doi.org/10.3390/su14095515
57. Sobczak, A., Chomać-Pierzecka, E., Kokiel, A., Różycka, M., Stasiak, J., & Soboń, D. (2022). Economic Conditions of Using Biodegradable Waste for Biogas Production, Using the Example of Poland and Germany. *Energies*, *15*(14). https://doi.org/10.3390/en15145239
58. Tamás Mizik, & Gábor Gyarmati. (2021). clean technologies Economic and Sustainability of Biodiesel Production — A Systematic Literature Review. *Economic and Sustainability of Biodiesel Production—A Systematic Literature Review*, *3*, 19–36.
59. TÉGLA, Z. (2015). ECONOMIES OF SCALE VEGETABLE FORCING THE UTILIZATION OF GEOTHERMAL ENERGY. *AgEcon Search*, *3*, 143–155. file:///F:/Spec 2/Traffic Delay

Model.pdf
60. Török, Á., Yeh, C. H., Menozzi, D., Balogh, P., & Czine, P. (2023a). Consumers ' preferences for processed meat : a best – worst scaling approach in three European countries. *Agricultural and Food Economics*, *4*. https://doi.org/10.1186/s40100-023-00277-4
61. Török, Á., Yeh, C. H., Menozzi, D., Balogh, P., & Czine, P. (2023b). European consumers' preferences for fresh fruit and vegetables – A cross-country analysis. *Journal of Agriculture and Food Research*, *14*, 100883. https://doi.org/10.1016/J.JAFR.2023.100883
62. Wang, J., & Azam, W. (2024). Natural resource scarcity, fossil fuel energy consumption, and total greenhouse gas emissions in top emitting countries. *Geoscience Frontiers*, *15*(2), 101757. https://doi.org/10.1016/J.GSF.2023.101757
63. World Bank. (2006). Local economic development: a primer developing and implementing local economic development strategies and action plans. In *Local Economic Development Primer*. http://documents1.worldbank.org/curated/en/763491468313739403/pdf/337690REVISED0ENGLISH0led1primer.pdf
64. Yang, Y., Solgaard, H. S., & Haider, W. (2016). Wind, hydro or mixed renewable energy source: Preference for electricity products when the share of renewable energy increases. *Energy Policy*, *97*, 521–531. https://doi.org/10.1016/J.ENPOL.2016.07.030
65. Zhang, C., & Xu, Y. (2020). Economic analysis of large-scale farm biogas power generation system considering environmental benefits based on LCA: A case study in China. *Journal of Cleaner Production*, *258*, 120985. https://doi.org/10.1016/J.JCLEPRO.2020.120985
66. Zoltán Szakály, Péter Balogh, Enikő Kontor, Z. G. and A. B. (2021). *Attitude toward and Awareness of Renewable Energy Sources :* 1–25. https://www.mdpi.com/1996-1073/14/1/22