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ENERGY SELF-SUFFICIENCY OF FARMS IN KOSOVO

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List of Abbreviations

% – Percent

APV – Agrophotovoltaic

BWS – Best-Worst scale

CH₄ – Methane

CHP – Combined heat and power

CO – Carbon monoxide

CO₂ – Carbon dioxide

CO₂eq – Carbon dioxide equivalent

df – Degrees of freedom

DOI – Digital Object Identifier

EID – Electronic Identifier

EJ – Exajoule

ERO – Energy Regulatory Office

EU – European Union

FAO – Food and Agriculture Organization

GDP – Gross Domestic Product

gCO₂eq/kWh – grams of carbon dioxide equivalent per kilowatt-hour

GHG – Greenhouse gas

GJ/ha – Gigajoules per hectare

GJ/year/m² – Gigajoules per square meter per year

GW – Gigawatt

ha – Hectares

IEA – International Energy Agency

KAS – Kosovo Agency of Statistics

Kg – Kilogram

km² – Square kilometer

ktoe – Kilotonne of oil equivalent

kWe – Kilowatt-electric

kWh – Kilowatt-hour

LCA – Life cycle assessment

LSU – Livestock Unit
MJ/kg – Megajoules per kilogram
m³ – Cubic meter
Mm³ yr⁻¹ – Millions of cubic metres per year
Mton/year – Metric tonne per year
MWe – Megawatts electrical
N₂O – Nitrous oxide
NO_x – Nitrogen oxides
p – p-value
PEST – Political, Economic, Social and Technological analysis
PJ – Petajoule
PV – Photovoltaic
PVT – Photovoltaic-thermal
Q1 – Quartile 1
Q2 – Quartile 2
RES – Renewable energy sources
SDGs – Sustainable Development Goals
SO₂ – Sulfur dioxide
SPSS – Statistical Package for the Social Sciences
SWOT – Strengths, Weaknesses, Opportunities and Threats
t/year – tons/year
TWh – Terawatt-hour
UAA – Utilized agricultural area
WBA – World Bioenergy Association
W/m² – Watts per square meter
WPP – Wind power plant
WTP – Willingness to pay
 χ^2 – Chi-square statistic

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INTRODUCTION

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 (Bocean, 2025). 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 (Olabi et al., 2023). 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 (Dogan et al., 2020). Population growth also presents a challenge in itself, so it is important to focus on the efficiency of feeding the population with the lowest possible use of agricultural land. The need for alternative energy sources is increasing every day, the latter as a result of the numerous demands for energy which are increasing simultaneously with the growth of the population (Fitton et al., 2019). This situation is increasing the focus of policymakers to focus on recycling as a genuine method for waste and this method can also be used by agriculture with organic waste. These wastes can be reused to create energy while trying to ensure farm sustainability and self-sufficiency for energy needs (Alao et al., 2022). This direction to achieve self-sufficiency in energy terms from farms has been realized as a result of the continuous need to overcome the energy challenges they face. Solar energy, biomass, wind and hydro energy are alternatives that can be easily included in the agricultural sphere, presenting themselves as a competition to non-renewable resources (Mathur et al., 2022). This sector is considered to be one of the sectors that consumes high amounts of energy in different countries (Sulewski & Wąs, 2024), 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 (Musiał et al., 2021). While this sector uses high amounts of energy, it is also responsible for around 10% of greenhouse gas emissions (mostly N₂O and CH₄) (European Commission, 2023). The latter is a very sensitive issue that is being fought by the European Union, which is showing consistency in achieving climate neutrality by 2050, intending to reduce greenhouse gas emissions from all possible sectors. This imperative extends to agriculture, a sector particularly vulnerable to the impacts of climate change.

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 study 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 in agriculture 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 (Majeed et al., 2023). 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.

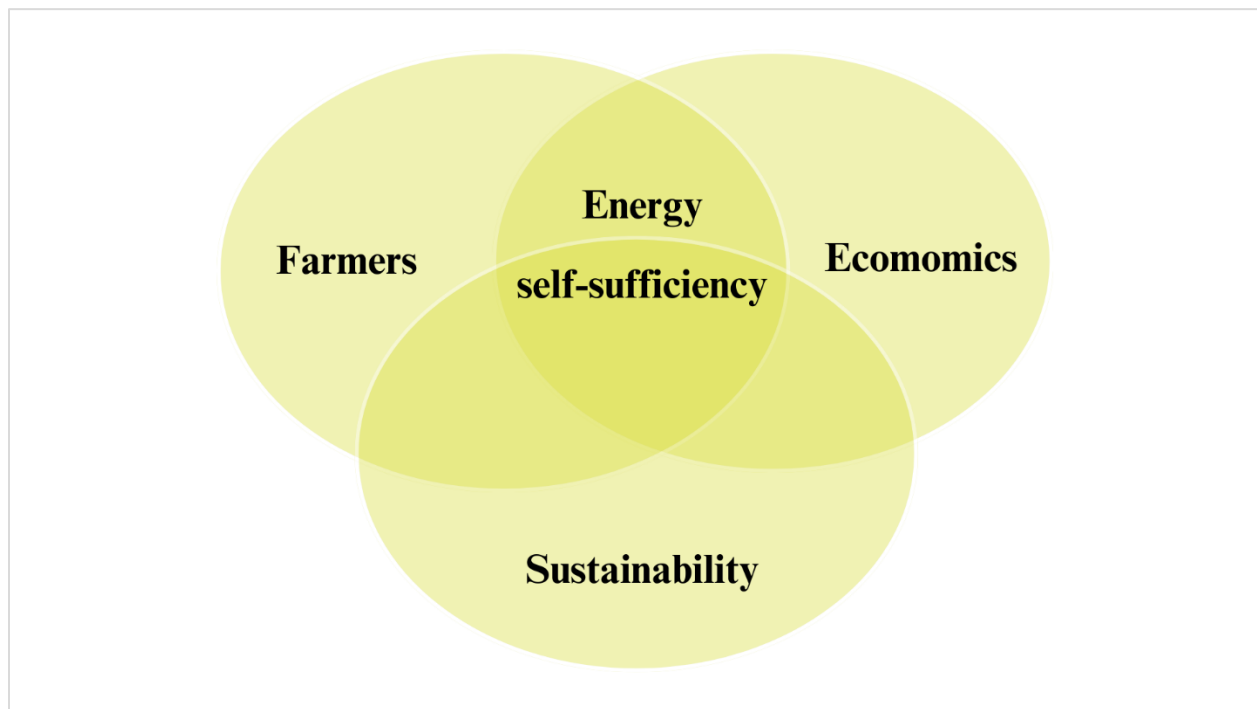


Figure 1. Venn Diagram of the research gap identified in the scope of the research

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. TOPICS AND OBJECTIVES

1.1. The aim and research objectives

The main objective of the topic is to understand the attitudes, perceptions and readiness of Kosovar farmers regarding renewable energy practices in agriculture, and their attitudes towards the use of renewable energy sources, more specifically to have an idea of how things stand in using their potential towards energy self-sufficiency. The thesis also aims to elaborate on the factors that influence the acceptance of such practices, farmers' decisions towards the use of solar energy, biomass and the difficulties they face. Social, environmental, economic and other factors will be taken into account to understand the challenges and potentials in this regard.

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 for the author 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. And 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 answered 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 answered 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 answered 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 answered 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).

1.2. Research approach

The research approach of this research can best be explained through the onion analogy of Saunder et al. (Mark Saunders & Thornhill, 2019). This approach is commonly used in the creation of research methodology and represents the different research stages starting from the initial philosophical principles that build it up to the practices of using data collection and analysis. Each level presented in the onion analogy represents a step in itself that is of great importance in the

creation of data and their clear analysis, thus building a comprehensive framework and spectrum of research strategies. Within the framework of different research philosophies, the positivist one, which includes the inductive and deductive method, is the most appropriate for our research. In order to generalize the attitudes of farmers and to have a clear conclusion of the findings on the preferences of farmers for energy self-sufficiency, qualitative and quantitative data have been used. With field observations and data collection, clear results will be achieved on the elements and factors influencing this process and this transition phase, which is not easy for farmers. A detailed summary of these processes is presented in the Figure 2, which provides an adequate description of the structure used and graphically presents the progress of the research, including the research approach and main concepts.

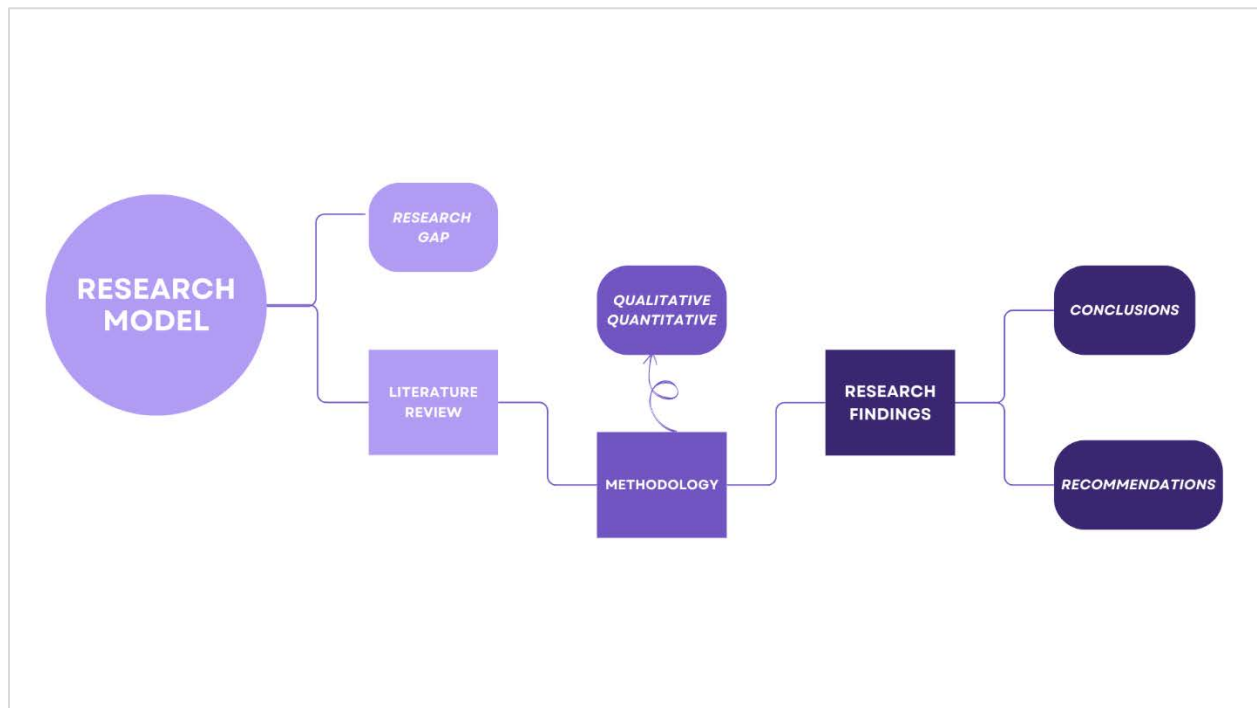


Figure 2. The Research Model of the topic

Source: Author’s own construction

Since the research period and horizon involve data collection over a specific period of time, this research is cross-sectional, based on data on farmers’ current attitudes and preferences. These data will be summarized through descriptive data format, which will easily describe the willingness and attitudes of farmers across this spectrum. Then, to achieve a deeper and more detailed scientific

research, more advanced techniques such as cluster analysis, BWS, correlation and ANOVA, as well as other methods, will be included.

1.3. Structure of dissertation

In terms of the structure of the dissertation, this topic will consist of six main chapters, incorporating subchapters for each. Each of the chapters is elaborated with the sole purpose of reaching the essence of identifying the problem posed, moving from the purpose, findings and recommendations for the future.

In the first chapter, the main research topics are elaborated, including the research objectives and research questions. The summary of the objectives and the elaboration of the research environment are a kind of paving the way for the next steps. The second chapter gives an overview of the content, situation, advantages and disadvantages, definitions and basic concepts for the chosen topic. A general summary of the situation in Kosovo, including publications and the latest data in this regard. Methodology is the third chapter which itself encompasses the research method used, the type of data included in the research and the procedures for their collection. Within the framework of this chapter, the selection of the sample and its size are disclosed, then the selected philosophy, research approach, strategy and time horizon of the research are elaborated. Next comes the chapter of results and discussions, which contains the crucial importance of all the work carried out through certain methods. Initially, the results are presented in the form of descriptive analyses, continuing with more detailed interpretations, comparisons with similar research, evaluations and deeper analyses. This chapter will include two parts, the qualitative and quantitative.

Recommendations and conclusions are presented in the fifth chapter, thus including all the conclusions drawn from the findings and providing with answers to the research objectives and research questions. This chapter provides comprehensive findings on the preferences and attitudes of farmers towards the adoption of renewable energy devices as an adequate form to achieve self-sufficiency by catalyzing the most important findings from the data generated. In addition, this section will also include the limitations that have affected the progress of the research, of whatever nature, which have affected the sample size, the scope of the research, the availability of data, the approach and so on. To continue and close the chapter with recommendations for future focus and

offering ideas for other research in this direction. The most important findings are placed in the sixth chapter, in the form of new knowledge and more specific findings.

2. TECHNICAL LITERATURE REVIEW

2.1. Energy, economy and agriculture

Energy is considered to be a vital factor that covers crucial human requirements for the proper functioning of a wide range of activities in the dynamics of society (Azam et al., 2015). This has to do with ensuring the availability of food to the efficiency of various economic practices. This component is essential for modern life and to power the progress of the food chain within the framework of numerous agricultural processes.

Everyday life requires the use of energy for domestic purposes, including the needs of food preparation, heating and cooling, storage, and so on (Simcock & Mullen, 2016). All of these are activities that increase productivity and improve the quality of life, in turn increasing the comfort and well-being of the family. All of these would be even more challenging without energy that is sustainable and stable, and many activities that are considered to be well-being would not be possible as a result. For the agricultural sector, as for all other sectors, agriculture is of crucial importance as a large range of equipment is put into operation only after contact with energy. Energy is used continuously during planting, fertilizing, harvesting, irrigation, transporting goods and preparing the land, these are activities that require continuous amounts of energy, as energy powers everything from irrigation pumps to tractor engines, increasing their efficiency and effectiveness. Furthermore, crop yields and overall agricultural productivity are also affected by the availability and access to energy, which is a factor in food security, economic sustainability and regional stability (Shi et al., 2022). Energy plays a key role in all sectors, including the commercial and industrial sectors, through the operation of factories, important transportation networks and the continuity of construction projects. Therefore, energy facilitates the daily dynamics of people and products, promotes genuine productivity that affects economic stability.

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.

In addition to the procedures mentioned above, energy is an essential component for post-harvest processing procedures in order to ensure that food items maintain their quality and are distributed in a fresh and predictable state according to the specified conditions. Energy is also important for the drying process, which is considered a process that reduces the moisture content and affects the preservation of crops such as cereals, fruits and vegetables (Saini et al., 2023). Continuing with the process of Food Processing, which through energy enables unprocessed products to be converted into value-added processed products. Such processes add more value to agricultural products, affecting their marketability and demand, in addition to extending their shelf life.

Another process that affects the protection of food from external factors such as infection and spoilage during storage and distribution is packaging, a process that also requires energy to perform. Packaged products must remain safe and fresh until they reach consumers, and this food value chain would collapse if there were a lack of an energy source. And all of this would result in poor quality products, food reserves would be lacking, and there would be a lack of distribution efficiency. Disruptions to the food production cycle would create disruptions in terms of food insecurity and economic instability, directly affecting agricultural development. Energy shortages would have the potential to prevent farmers from optimizing their production to ensure that food is produced through secure mechanisms that meet overall consumer demand.

It is therefore important to maintain a balance between energy and economic sectors to achieve overall sustainability. Population growth is directly linked to increased demand for food products, and in order to meet consumer demands, energy is a necessary factor in fulfilling them (Fukase & Martin, 2020). However, an important component is the good management of the increase in energy demand alongside economic barriers in order to ensure that agricultural production is realized and profitable.

The operationalization of agricultural functions is identified through financial costs (irrigation, cultivation, use of fertilizers and machinery). Over time, costs create instability on the farm, so it is in the interest of the farm to seek strategies that are cost-effective, in the case of alternative energy that is also necessary to reduce environmental impacts.

Innovative interventions, such as the adoption of renewable energy sources that are considered to be resource efficient and improved management practices, can influence farmers to minimize their dependence on traditional energy while also reducing costs. Achieving a balance between energy consumption and the economy is a key point for the long-term sustainability of agriculture and contributes to the larger goal of environmental conservation (Bathaei & Štreimikienė, 2023b). Countries around the world are facing climate change in many ways, such as the need for access to clean water, food security and safety, and energy security from sustainable sources. With the increase in global temperatures, climatic disturbances are becoming more and more evident, thus increasing the vulnerabilities of these countries and exceeding their expectations. Water as an important source of life is also important in agricultural production, its lack is pronounced in many areas that reduce its availability. As a result, farmers often fail to cope with such changes and as a result do not achieve the planned production yields, thus resulting in economic instability due to low incomes. Population growth trends, technological and economic advancements, urbanization and the effects of climate change have contributed to the increase in energy demand at a high rate (Ahmed et al., 2023). This economic growth is being associated with an increase in energy consumption as more people have access to modern technology and is particularly pronounced in developing countries. This energy growth can be met through investment in renewable energy technologies, aiming for sustainability and to respond to the effects of climate change. Climate change and its effects are also increasing the demand for energy. Amid these changes in weather patterns and heat, floods and storms increase the need for energy use for heating and cooling.

Population growth, urbanization and technological developments are expected to contribute to an increase of approximately 27% in energy demand by 2040, with the two superpowers that will be the main consumers being India and China (*BMWK Newsletter Energiewende - IEA, 2018*). This increase in energy demand will lead to higher electricity prices, which will also impact the agricultural sector, creating higher operating costs that lead to lower productivity and will disproportionately affect the operations of smallholder farmers. These cost increases will

significantly impact the entire food production and supply chain. An increase in the prices of agricultural input costs would also be felt by consumers who would pay higher food prices, thereby increasing food insecurity. These increases in agricultural prices will highlight the need for more sustainable agricultural practices, including renewable energy sources that would increase energy efficiency.

2.2. Energy and environment

Global energy consumption is growing rapidly, and fossil fuels such as coal, oil, and natural gas continue to be the primary components of its generation (Holechek et al., 2022). What has contributed to these non-renewable resources being the mainstay of energy production is their relatively low cost and the accompanying infrastructure. Such resources are threatened by their expensiveness, while on the other hand the demand for energy continues to grow. As a result of this imbalance between the supply and demand for energy from traditional sources, unenviable situations are being created with rising energy prices and energy insecurity. While traditional resources and their availability can drive up prices, the consequences can be far-reaching, especially in developing countries that rely on energy imports.

Fossil-based energy production is a contributing factor to environmental pollution, worsening the environmental situation (Hou et al., 2023). Global warming is a phenomenon that is being caused by several pollutants, especially carbon dioxide (CO₂) and other greenhouse gases that are emitted by the burning of fossil fuels (Florides & Christodoulides, 2009). As a result, as global temperatures rise, climate change (unstable weather, rising sea levels, and lack of ecosystem biodiversity) also increases. As a result of the burning of fossil fuels, the negative environmental effects not only endanger the diversity of flora and fauna but are also closely linked to the sustainability of food production, clean water and serious problems with the health of the population. For this reason, the transition from fossil fuels to alternative sources that are cleaner is being preferred every day. Alternative sources such as solar, biomass, wind, and hydropower are known for reducing carbon emissions (Liu & Han, 2024), which help slow global warming and stabilize energy prices.

A study of Turconi et. al. took into account the analysis of 79 articles by different researchers who examined the life cycle assessment (LCA) of the generation of electricity and heat from the most important forms of renewable energy (solar, wind, hydroelectric, biomass, geothermal, waste, heat

pumps, marine technologies). From this study, the findings showed that greenhouse gas emissions are much higher for energy produced from fossil sources (around 500 – 1100 gCO₂eq/kWh, from natural gas to lignite) than from renewable sources (Turconi et al., 2013).

2.3. Local economy

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). A local economy can be successful depending on the ability of the community to adapt to the change that continuously appears as a result of various market variables (local, national and international). The dynamics of development are fluid; therefore, this is measured by the consistency of individuals in how agile they are in dealing with the changes that have occurred and the competition. Therefore, local economy plays an important role in the framework of community inclusiveness and overcoming the challenges that threaten these societies, through building and strengthening the economic capacity of the region. This process aims to create a favorable investment climate, providing opportunities for diverse businesses and promoting long-term growth and sustainability, through which productivity and competitiveness among local entrepreneurs and workers are also increased.

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). These farm activities provide support through production to the food supply chain. By growing productive crops, raising livestock, and practicing sustainable agricultural practices, these farms influence demand for maintenance, animal care, veterinary care, and processing assistance. In turn, businesses and the workforce benefit from these demands, as a result of the diverse supplies of seeds, fertilizers, and agricultural machinery, as well as integrated food processors, retailers, wholesalers, and distributors. All of these processes highlight the importance of the local agricultural economy as an economic driver not only in rural areas but also in generating employment and adding value to the food and production chain.

Most countries in the world have large and persistent geographical differences, especially in wages, incomes or even unemployment rates. A growing trend is towards country-based policies, which

try to address these differences, especially through public investment and subsidies in order to help disadvantaged regions. These direct policies are based specifically on a particular country and have defined goals. Of course, before going ahead with the design and implementation of such policies, policymakers take into account all the positive effects or even the various challenges that those policies may face (Kline & Moretti, 2014).

Local authorities are the ones who are most knowledgeable about the challenges and trends of their local areas. They can therefore take a more holistic approach to the development of their area: for example, some local authorities invest in public transport schemes in order to promote, help a specific local area. In this way they are able to balance social, economic and environmental considerations for the area in question. Local authorities are increasingly trying to design plans that are appropriate to the circumstances of their area and to be accountable to local residents for their achievement. It has also been appreciated that the local economy would foster diversity and innovation, creating evidence of what works and what does not (Hildreth, 2011).

Another definition relates to the local economy, where, among other things, economic power and sustainability are redistributed, thereby reducing disconnection and inequality in the community. Also in the local economy there is usually a greater number of small businesses and local ownership, which usually perform better in a number of economic areas, compared to centralized economic actors. Various cases from practice have suggested that the notions of localism that underpin current local government economic development policy can only succeed if they are closely linked to a decentralization of capital and power held within the economy (Leach, 2013).

2.4. Renewable energy and agriculture

Along with food, water and air, the demand for alternative energy sources is becoming increasingly necessary. 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. Agriculture is considered a sector that has untapped potential and capacities that positively impact the Sustainable Development Goals, but on the other hand, is also characterized by negative environmental risks and threats. To address these risks and challenges, a sustainable chain of production, processing, consumption, and distribution must be

developed in order to increase agricultural productivity, and to enable food security and the highest quality of food, in addition to the predetermined predispositions in the framework of energy production and climate (Z. Yu et al., 2022). 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). Although it has many aspects of importance, this sector also contributes to the increase in carbon footprints. This sector accounts for 70% of water use for irrigation of crops and livestock (Pellegrini et al., 2016). Also, carbon emissions and other greenhouse gases increase during production (livestock, input use, planting). In the case of food production, there is a continuous increase in land footprints (Van Eck & Puchta, 2019). Since most farms use outdated technologies and are based on the use of fossil fuel inputs, they cause environmental damage that is an obstacle to achieving the Sustainable Development Goals (SDGs). About 20% of global CO₂ emissions come from agricultural activity (FAO, 2020), so this is a crucial issue that must be considered for sustainable development (Gokmenoglu & Taspinar, 2018), (Ridzuan et al., 2020). Agriculture is also a sector that needs to use energy and also contributes to global warming as a result of its activity and use of traditional energy sources, so implementing alternative independent systems would reduce concerns about farm sustainability (Ma et al., 2024). 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). Wind turbines can generate sufficient energy for various agricultural activities, while solar panels can produce energy for farm lighting, machinery and irrigation systems. Also, biogas production from organic farm waste represents an energy source that can create energy self-sufficiency of farm (Calbry-Muzyka et al., 2022). Agriculture according to OECD (OECD & FAO, 2022), is among the three sectors that affect climate change, with an energy consumption of about one third and with a participation in anthropogenic GHG almost the same as emissions from industry with a share of 22%. As agriculture is contributing to climate change, it is important that agricultural practices based on renewable energy are put into operation and farmers "compensate" for their losses from an economic and environmental perspective (Ben & Youssef, 2017). These energy sources can be used to operate many agricultural activities such

as heating, irrigation, drying of products, cooling and soil maintenance (Mehdi & Slim, 2017). UN statistics (2021) also show the agricultural sector as a high energy user, which in 2019 negatively contributed 16.5 billion tons of GHG emissions, of which 7.2 billion tons were from farm gate activities, 5.8 billion tons from supply chain activities, and 3.5 billion tons from land use change (UN, 2021).

The involvement of these energy sources can reduce operational energy costs (IRENA, 2022) and in addition would affect the carbon footprint of agriculture which would have an impact on reducing climate change. In order to achieve farm self-reliance, in addition to alternative energy practices, effective recycling of agricultural fertilizers is also an important element that must be considered (Panuccio et al., 2022). Composting and enriching the soil with organic fertilizers would have positive advantages (Culas et al., 2025) in the flow of nutrients to the soil. Improving soil health enables the farm to produce with fewer inputs and promote ecosystem diversity and reduce greenhouse gas emissions.

The agricultural sector exhibits a high value of energy requirements for operational farm management processes on production and forecast activities. In this context, fertilization is a process that consumes high amounts of energy to produce and apply fertilizers (Paris et al., 2022). On the other hand, irrigation is one of the most important activities in agriculture (Ingrao et al., 2023) for the proper functioning of the operation, but this activity also has high energy requirements. The irrigation systems used by farmers are realized by pumping water, a process that requires energy. These formats require different levels of energy, which can be reduced through the use of more advanced irrigation systems such as sprinkler irrigation or drip irrigation. Furthermore, a significant portion of farm energy is used to operate agricultural machinery, including transportation, planting, harvesting, and other activities that require fuel for operation. Then, in the case of the final production of the agricultural product, it is necessary to transport the products to the intended markets (Arete, 2017), which is done by vehicles that use fuel, which increases costs and carbon emissions.

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.

2.4.1. Solar energy

The sun is the primary source of energy that enables life on Earth and the realization of many natural processes (Franjić, 2020). Through sunlight, humans use most of the energy to carry out their daily activities, a clean and renewable source. This solar energy is transformed into other forms of energy through a variety of technologies such as solar and thermal systems, solar panels. Solar energy is often referred to as eco-friendly energy, sustainable energy, and green energy, highlighting its renewability and the advantages of the proper functioning of the ecosystem and natural resources.

The sun is a great source of energy, but the energy emitted decreases until it reaches the earth's surface, then the environment has a part of the energy while the rest is scattered into space. Although the amount emitted reaching the earth has an intensity many times lower than the beginning, it is still good for energy use and the environment.

From research conducted by NASA, it has been concluded that about 342 watts of solar energy falls on each square meter of the Earth's surface within a year (Nasa, 2009). All of this radiation yields about 44 quadrillion watts (4.4×10^{16} watts), which is a significant amount of energy. This means that the amount coming to Earth is relatively significantly higher than its capacity that people currently use, and represents a huge potential for its production as a form of renewable energy. This capacity could reduce our need for fossil fuels and promote energy sustainability as technology advances.

Among the technologies for generating energy from the sun, solar photovoltaic (PV) systems are considered an important component of the renewable energy framework, with high capacity for generating energy worldwide. A whopping 80% of the increase in renewable energy capacity between now and 2030 will come as a result of these practices (IEA, 2024b).

The progress of solar PV is a testament to the fact that they are adaptable and scalable systems (Tyagi et al., 2013). The practicality of installation, from rooftop installations to large, commercial farms, is also a significant advantage. It is estimated that this type of energy will reach a significant amount by 2030, being an important factor in the production of low-carbon energy. The phenomenon is also observed in the countries of the European Union, where there is an increase in electricity production capacities in the maximum electric grid capacity. Furthermore, global solar capacity has experienced an increase with a participation of 120,000 MWe in 2019 compared to 176 MWe in 2000, an increase of 700 times (eurostat, 2021). This extraordinary growth trend means that solar technology is developing at a high rate, as a result of efficiency, clean energy sources, falling costs compared to previous years and the need for eco-friendly energy alternatives. In this regard, the integration of government initiatives for lower taxation and subsidies in various countries for sustainable practices have also been key incentives in promoting investment in this area (OECD, 2007). Therefore, solar energy has gained momentum at a rapid pace, making a particular contribution to the energy mix and the reduction of environmental impacts such as carbon emissions (Nijse et al., 2023).

Today's agricultural farms are more modern and use more advanced technologies compared to the past, achieving improvements in sustainability and efficiency. These technologies have also had a positive impact on maximizing productivity, improving crop yields, and reducing negative effects on the environment. These technological advances in modern farms have to do with automated machinery and sophisticated systems such as irrigation and precision agricultural equipment. Agriculture consists of operational activities that require a continuous and sustainable supply of energy (farm trucks, harvesters, water pumps, and processing equipment). The continuous supply of energy for these activities has been achieved by fuels such as gasoline and oil, which at the same time have caused disturbing effects on the environment (air pollution and greenhouse gas emissions).

Since solar energy is abundant, this makes it a promising option for power generation and an important component in the transition to sustainable energy. Agricultural activities contribute to climate change through greenhouse gas (GHG) emissions (Xing & Wang, 2024). Carbon dioxide (CO₂) and other toxic gases are released through the use of agricultural equipment, while methane and nitrous oxide emissions are a result of the active use of fertilizers and the process of raising

livestock (Balogh, 2022). These emissions affect human health, global warming and endanger agricultural production and activities related to food security. In this context, the production of energy from solar energy could reduce dependence and the need for fossil fuels and at the same time would affect the mitigation of environmental problems.

In the context of generating energy from the sun, two main methods are most often used; photovoltaic (PV) systems and solar thermal heating systems (Hasan et al., 2023). Depending on the different factors of the energy application and requirements, both methods have high benefits and special characteristics. In the case of solar thermal heating, the energy generated is used to produce heat, which can then be used for water heating or other practices (Ismail et al., 2021). These systems are characterized by solar collectors that use the sun's energy to heat a fluid, which produces steam and activates a turbine connected to a generator. The use of this technology is effective for heating homes and businesses and can be very suitable in places with a lot of insolation. As for the structure of photovoltaic (PV) systems, they are characterized by semiconductor components to convert sunlight into electricity. These systems are very affordable to deploy in a variety of sizes (from rooftops to large solar farms).

Other technologies such as Photovoltaic-thermal (PVT) systems incorporate the characteristics of conventional solar photovoltaic panels and solar thermal collectors, which use sunlight to produce both heat and electricity at the same time. In this case, electricity is produced by photovoltaic cells that use sunlight to power farm equipment, lighting, and so on. Thermal collectors absorb excess solar heat, which can be used to heat greenhouses, heat water, and dry crops (Amiche et al., 2020). Distributed photovoltaic (PV) systems are becoming increasingly popular in agricultural contexts, as a result of their adaptability for use on smaller-scale farms and production systems (greenhouses) (Asa'a et al., 2024). Moreover, distributed PV systems also offer a degree of convenience and energy security in more remote and isolated areas, which are therefore less susceptible to power outages from centralized sources. In general, solar energy and the agricultural production system are closely linked to each other, thus influencing the implementation of more environmentally friendly practices, thereby increasing their resilience through empowerment within the framework of sustainable practices of distributed photovoltaic systems.

2.4.2. Biomass energy potential

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. Therefore, special importance should be given to a component such as bioenergy that is considered to be an accessible form that contributes to the sustainability of energy (IEA BIOENERGY, 2022). A distinctive feature of this form of energy is its convertibility into different forms of energy (heat, electricity and biofuels from organic waste such as wood, agricultural residues). Bioenergy currently exceeds the share of wind and solar energy production. Specifically, it contributes four times more to the fulfillment of heat and electricity than wind and solar photovoltaic (PV) systems combined. These aspects highlight the value of bioenergy for its positive impacts towards cleaner energy practices, as a reliable source that fills the gaps that solar and wind energy have in the event of weather changes. Bioenergy consists of advanced technologies such as biomass power plants, biogas production and waste-to-energy. It is of great importance in electricity generation, and not only that, it is very important in the heating industry, especially for district heating systems. The advantage of bioenergy is its carbon neutrality, which contributes to the decarbonization of heat and electricity markets.

According to IEA statistics, bioenergy represents 55% of renewable energy production worldwide, excluding conventional biomass products for heating and cooking (IEA, 2024a). 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, 2020). In the ranking of countries characterized by high biomass production, Germany leads, with a volume of 137,675 thousand m³ of biomass from organic waste. Moreover, Germany leads the way in the amount of forest biomass produced, with a share of 66,658 thousand m³, followed by Sweden with 20,844 thousand m³. Meanwhile, in the context of biomass from agriculture, Spain ranks first. These figures imply that the EU makes a high contribution to the total amount of biomass produced and is a group of countries that attaches high importance to environmentally sustainable practices.

A study was conducted in India, which investigated the use of agricultural waste in India and its use in energy generation, thus affecting self-sufficiency in the context of energy production on farms (Vijay et al., 2021). Biomass is an important source of energy production and its participation in primary energy production according to WBA statistics (2021) is 11.8% or 55.6 EJ (World Bioenergy Association, 2021). In the context of the Indian study, it is emphasized that this energy source is in high quantities of availability due to the participation of the agricultural sector, which contributes 17% to GDP. From the findings of the study, it was concluded that the plant biomass potential is between 450 to 686 million tons, while of them 150-213 million tons is the surplus that can be used to achieve energy self-sufficiency (Vijay et al., 2021).

The deployment of renewable sources can be driven by the continued demand for energy (Pintér, 2022), with a significant participation also from the agricultural sector (T. Liu et al., 2014). Within the framework of the forms of biomass that contribute most to energy purposes, forest biomass has the highest participation (World Bioenergy Association, 2021). As a result of innovations in agriculture and the simultaneous increase in crop yields, this could reduce the desire for energy production alongside food. It has also been estimated that through adequate agricultural policies, approximately 240 million ha of arable land, representing 5% of current arable land, could be designated for energy crops by 2035. Therefore, through incentive factors, agriculture can be involved in energy production, which helps in saving income, local development, climate change and, above all, farm self-sufficiency.

2.5. Energy self-sufficiency and agriculture

The burning of fossil fuels naturally releases greenhouse gases such as CO, CO₂ and CH₄, which contribute to air pollution and climate change (Filonchuk 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 CO₂ equivalent (CO₂eq) 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. The number of agricultural farms in the European Union in 2020 was 9.1 million (eurostat, 2022). Family farms (farms where at least 50% of the workforce is family-owned) made up the majority of this structure, with a share of 94.8% in 2020. Over two-thirds of farms in the EU were smaller than 5-hectare, as shown in the Figure 3. As a result of their activity and the potential they have, these farms can provide additional income that reduces vulnerability to rural poverty. The remaining 7.5% of the productive farm structure is represented by farms with more than 50-hectare.

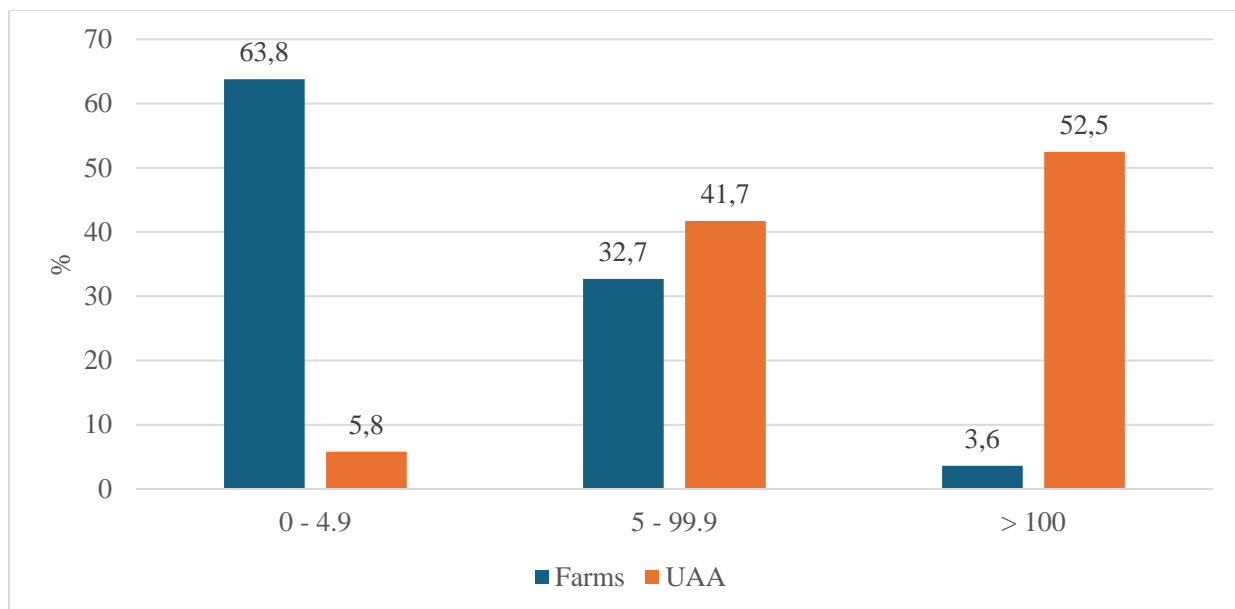


Figure 3. EU farms distribution level and utilized agricultural area (UAA) according to farm size 2020

Source: Author's own construction based on (eurostat, 2022)

Larger agricultural holdings, defined as 50-hectare or more, were discovered to be more common in various European nations. Significant percentage of these larger farms were discovered in Luxembourg, France, Finland, Germany, and Denmark, accounting for 52.7%, 46.0%, 33.3%, 31.5%, and 30.9% of all farms, respectively, when compared to the total number of farms at the national level. Furthermore, in most Member States, these larger-scale agricultural activities, which are specified by a minimum size threshold of 50-hectare, constituted the majority of the Utilized Agricultural Area (UAA). According to European Commission statistics, the average farm size is 17.4 ha; however, this is not a typical average because there are farms in Europe with sizes ranging from less than five hectares to more than 100 ha (eurostat, 2022). Crop specialists account for roughly six out of ten farms in the EU (58.3%). Furthermore, organic waste from these farms can be turned into biogas, which can then be used in gas engines to generate combined heat and power (CHP) or upgraded to vehicle fuel quality and used in tractors. In this regard, specialized livestock farms accounted for another fifth (21.6%) of all farms in the EU; the most common categories of these farms were specialized dairy farms (5.1%) and specialized farms raising and fattening cattle (4.2%). However, because biomass is a limited resource that takes energy to grow, collect, and convert into usable energy carriers, the development of biomass-based energy carriers may have implications. Furthermore, biomass is a heavy material, limiting its economic transport distance. These disadvantages can be avoided by using biomass just on the farm of origin and using the residual (inedible) products as energy sources.

According to a 2014 research by Popp et al, by 2050, 1500 EJ of biomass will be available globally, with 200-500 EJ potentially meeting 40-50% of the predicted primary energy demand (Popp et al., 2014). Overall, the EU's primary supply of solid biomass increased by 33.5%, from 3.3 EJ in 2008 to 4.5 EJ in 2021 (European Commission, 2023a). The majority of biomass comes from forests or woods (66%), followed by organic waste (26%), with three-quarters coming from Germany, and agricultural biomass (8%), primarily from Sweden and Finland. During this period, the usage of wood pellets (413%) and animal waste (351.9%) led to the greatest increase in household solid biomass output.

In 2022, renewables accounted for 23% of the EU's total final energy consumption. Sweden topped the EU in 2022, with renewable sources accounting for more than two-thirds (66.0%) of gross final energy consumption (eurostat, 2024). According to the analysis (Paris et al., 2022), open-field

agriculture in the EU consumes at least 1431 PJ of energy per year, accounting for approximately 3.7% of the EU's total annual energy consumption; thus, most crops require energy inputs. From 15 to 25 GJ/ha, the majority of energy comes from nonrenewable sources. This energy is mostly used in the production of fertilizers, oil, insecticides, and seeds, among other applications. This energy is mostly used in the production of fertilizers, oil, insecticides, and seeds, among other applications. In 2021, the European Union produced 159 TWh of solar PV (photovoltaic) electricity. Biogas produced 92 TWh of energy globally in 2021.

2.5.1. Energy self-sufficiency

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. Furthermore, (Elahi et al., 2022) examined farmers' attitudes toward green energy and discovered a negative association between the expenses of green energy technologies and their readiness to install a PV water pump and pay more for electricity generated from green sources. Young educated farmers with higher incomes were expected to pay more for green energy. Solar technology not only promotes economic activity and agricultural output, but it also improves the quality of life for rural populations (Feuerbacher et al., 2021; Schepens et al., 1987) . Farmers' roles, access to land, and education in farm-generated renewable energy all have an impact on energy sustainability. Farmers do not believe that age affects their ability to pursue innovative and sustainable precision farming practices. It is often assumed that successful implementation of sustainable precision and organic farming necessitates more experience and a large network of contacts (Kováč et al., 2022).

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. Furthermore, the energy derived from RES can be used for a variety of purposes (Popp et al., 2016). For example,

using energy from a wind power plant (WPP) can ensure the operation of a pumping station that supplies water for land irrigation, settlement water supply, and cattle watering. In addition to wind turbines, photovoltaics can generate electricity by converting solar energy (thermodynamic approach) or by using biogas to power gas generators, among other things.

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.

Agrophotovoltaic (APV), or solar panels for agriculture, involves the cultivation of diverse crops using ground-based photovoltaic panels. Although this notion has been offered for a long time, APV received little attention until lately. Many scientists have proven the benefits of its application, including increased electricity generation, improved yields, and reduced water consumption (Fraunhofer ISE, 2024).

There are numerous regulations to ensure that the building of solar systems does not reduce agricultural land or harm the ecosystem. For example, ground-mounted solar systems can only be installed in "disadvantaged areas". These are regions where land management may be abandoned due to location or adverse production conditions (Feuerbacher et al., 2021). The agro-photovoltaic system is one technique to integrate renewable energy expansion with nature and species conservation. This approach attempts to enable the production of food and feed while also producing electricity on the same place. Solar systems are developed on agricultural land specifically for this reason (Trommsdorff et al., 2021).

Especially in the European Union, solar energy is considered an important resource, which has been growing in recent years, especially with the type of photovoltaics that are considered very important in the EU energy mix, led by Germany with a total of 50 GW of capacity. This photovoltaic market is experiencing a positive trend of rapid development in Poland and the Baltic countries. Solar energy can be utilized in agriculture to dry grass, heat water, and make more efficient greenhouses, as well as to provide energy for buildings and equipment that are away from

residential building electricity connections. The role of renewable energy sources (RES) will grow when energy supply policies are made mandatory in all locations. The depletion theory presents its main focus on achieving energy demands that can be provided through renewable energy, and not on the focus on how to meet current energy demands with new technologies (Tsagkari et al., 2021). Based on the article Sertolli et al. (2022) (Sertolli et al., 2022) the focus on renewable energy is not only related to the increase in demand for it, but to achieving self-sufficiency today.

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.

A study in Latin America demonstrates the relevance of energy self-sufficiency and reducing GHG emissions in dairy farms where cow manure is employed as a source of biogas production, which does have an impact. According to Villarroel-Schneider et al. (Villarroel-Schneider et al., 2022), Latin American dairy farms' biogas production potential is sufficient to meet their energy needs (50% of the energy service demand could be met by the biogas production capacity of 81 TWh/year). Dairy farms are quite important in Latin American countries, particularly Brazil, Colombia, Mexico, and Argentina. Brazil is the largest producer of milk, accounting for 45% of total production each year, with Argentina, Colombia, and Mexico accounting for the remaining 85%. Based on the same study (Villarroel-Schneider et al., 2022), it was discovered that the production of biogas and electricity is technically and economically possible in all types of dairy

farms, allowing for energy self-sufficiency using organic waste. Although it is considered to be less attractive for farms under 15 cows, because the use of biogas can only be for cooking and heating water. On the other hand, this technology is a solution for reducing CH₄ and N₂O emissions from dairy farm manure. It was found that 19.6 Mton/year is the reduction in eq. CO₂, for all of Latin America. Regarding the implementation of the biogas solution for dairy waste management, this would allow a 60% reduction in GHG emissions currently generated by manure management, energy and land application (fertilizers) in the countries mentioned above. In general, the solutions promoted seem to be attractive for Latin America to achieve energy self-sufficiency in agriculture which constitutes an advantage at the farm level.

In addition, another study was undertaken on biogas production from dairy waste in the Canary Islands. The total manure production in these islands is 495,622 tonnes per year, primarily from Gran Canaria and Tenerife, with contributions from goats, cows, poultry, and pigs (Ramos-Suárez et al., 2019). The biogas potential from manure on a dairy farm is projected to be 44.7 Mm³ yr⁻¹, or 27.1 Mm³ yr⁻¹, after considering the restrictions (manure availability and farm size), with a comparable installed capacity of 6.8 MWe. This is equivalent to 0.22% of the total power share. Biogas production has been widely dispersed across seven islands, with around 546 farms having the possibility to establish their own plant for power or heat generating with capacities ranging from 3 to 185 kWe. Furthermore, the study forecasts a reduction in GHG emissions because biogas outperforms other renewable sources in this area and is more environmentally friendly.

Two studies (Ramos-Suárez et al., 2019; Villarroel-Schneider et al., 2022), demonstrate the many approaches to farm self-sufficiency and its value at the farm level. Agriculture offers prospects for farm energy generation since biomass produced on the farm is used as an efficient fuel in thermal power plants to produce energy that is fed into the regional electricity supply grid. In this context, it is also possible to argue that the ideal approach or tool, or their combination, for assessing and planning agricultural energy production and self-sufficiency, or even at the farm level, is determined by a variety of criteria.

2.6. Renewable energy situation in Kosovo and the self-sufficiency in agriculture

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%. Despite all this, energy production from lignite is considered to be the main source to achieve the realization of people's daily activities. When it comes to energy prices in Kosovo, they are considered to be lower than in the countries of the region (World Bank Group, 2017), but still high for the standard of the country's residents. In 2012, the average tariff for electricity for individual consumers was €0.0688 per kilowatt-hour (kWh) after taxes, significantly cheaper compared to the average of countries in the region of €0.0797. As a result of the extremely high growth in demand for gas, there have also been consequences in the increase in the global level of energy prices. This situation has also affected Kosovo since there is present the import of electricity due to the negative balance (production and consumption) (Balkan Green Energy, 2022). Therefore, the Energy Regulator of Kosovo has imposed new electricity tariffs from April 2025 with an increase of 16.1% of the energy price (Energy Regulatory Office, 2025).

Although the price of electricity in Kosovo is lower than in surrounding countries, the cost of electricity is still out of proportion to household income, consuming a high amount of expenses within a month. In comparison to European countries that rarely paid more than 6 percent of their income on electricity, in Kosovo the opposite is true, with an average share of 9.6 percent of the total amount spent on electricity in 2015 (Schlissel, 2016). This high production from coal has many consequences as a result of its low quality. In addition, the two current power plants in Kosovo are also high contributors to pollution as a result of outdated operation. As a result of this and various environmental factors, during 2021, 129 people lost their lives with an affected cost of 209 million euros (Bankwatch, 2021), while due to their limited activities and low productivity

(absence at the workplace) the value reached 6.4 million euros. However, coal is important in Kosovo as it provides employment for people involved in the coal mining industry and those who work in the energy production sites.

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. Table 1 presents the values of the energy participation from renewable sources, as a kind of comparison between the EU, Kosovo and other countries in the region, including thus the gross consumption of electricity, heating and cooling, as well as transport. The reason behind the inclusion of Balkan countries is justified by the geographical aspect of Kosovo, as it is part of the Balkan region. This relative comparison would enable a clearer understanding of the regional dynamics in the energy aspect. While comparisons with the European Union countries are relevant in terms of Kosovo's ongoing aspirations and efforts towards EU membership. Both comparisons would help in understanding the gap between current local practices and EU standards, thus assessing progress and identifying areas for improvement. The table shows that the Scandinavian countries lead in this aspect with the highest participation in the development of renewable energy, followed by Central European and the Balkan countries.

In the Balkan region, the share of renewable energy varies by country and sector of use. Kosovo shows a modest share of 19%, with a 9% share in electricity and no contribution to transport. On the other hand, Albania and Montenegro fare much better with a share of 46% and 40%, respectively. In terms of electricity generation, Albania leads the Balkans due to its strong hydropower capacity, but the opposite is true in terms of transport, the participation of renewable energy is extremely insignificant.

Table 1. A comparison of renewable energy indicators in European and Balkan countries in 2023

Countries	Share of energy from renewable sources (%)	Share of energy from renewable sources in gross electricity consumption (%)	Share of energy from renewable sources in heating and cooling (%)	Share of energy from renewable sources in transport (%)
EU	24	45	26	11
Kosovo	19	9	44	0
Norway	76	116	33	28
Sweden	66	87	67	33
Denmark	44	79	54	11
Austria	40	87	39	13
Germany	21	52	17	12
Croatia	28	58	36	1
Hungary	17	19	22	8
Albania	46	105	22	0.4
Montenegro	40	67	66	0.3
Macedonia	20	32	37	0

Source: (eurostat, 2024).

Kosovo's energy system will be more efficient as the economy becomes less energy-intensive and moves toward more energy-efficient development. This has a number of benefits, including reducing the need for energy sources, which in turn reduces the need for costly energy expenditures and the related greenhouse gas emissions and pollution, reducing reliance on imports, and lowering the financial burden on individuals and businesses. This strategic goal is approached through two specific objectives: improving building energy efficiency and fostering effective district heating and cogeneration systems (Ministry of Economy, 2021). In Kosovo's energy production, the share of renewable sources has been progressive in recent years. In 2020, Kosovo managed to exceed its target of 25% of the share of energy production from renewable sources.

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 2023 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 km² 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 hectare.

The impact of agriculture on the country's economy is high, contributing 7.4% to GDP in 2022 (MAFRD, 2023c) (Table 2), 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 2. 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: Authors 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 (Figure 4) (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).

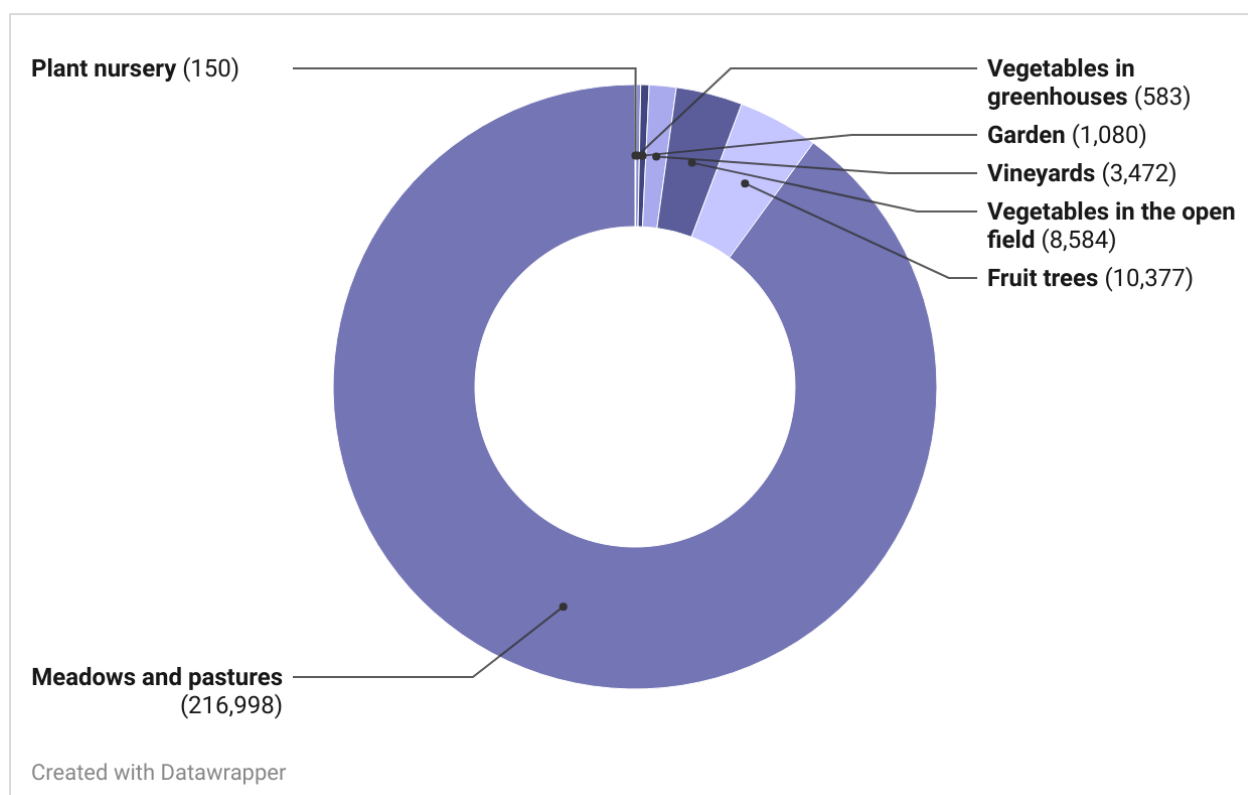


Figure 4. Agricultural land use classification in Kosovo (hectare)

Source: (MAFRD, 2023c).

Kosovo's most recent agricultural census was done in 2014, therefore the data is somewhat dated. Nonetheless, considering the region's agricultural practices and climate, current estimates are likely to be similar to those from the previous census, with a slight increase. Table data are largely the same in the Western Balkan regions typified by small-scale agriculture, with 1.2 hectares in Albania (European Commission, 2024), 1.9 hectares in Macedonia (FAO, 2023), and 4.6 hectares in Montenegro (Monstat, 2017). Table 3 shows the main characteristics of Kosovar farm based on the surface and the number of the agricultural holdings.

Table 3. Agricultural holdings' size by surface of arable land and number of holdings

Farm size (ha)	Surface (ha)	%	No. of Agricultural holdings	%
0>5	118537	64	102530	94.2
5>10	29498	16	4531	4.2
10>20	16258	9	1253	1.2
20>30	5300	3	226	0.2
30<	16109	9	263	0.2
Total	185702	100	108803	1

Source: (MAFRD, 2017)

The number of agricultural holdings by region in Kosovo is shown in the Figure 5. The Pristina region leads with the highest number of farms, followed by Prizren, Peja, Mitrovica, Ferizaj, Gjakova and lastly the Gjilan region. Through the figure can be seen the distribution of farms by region, where the largest number of farms is attributed to Prishtina as a result of the highest number of residents and supporting infrastructure, while Gjilan as a less developed region includes a lower number of agricultural economies, all of which are attributed to economic conditions, access to resources and the desire to carry out agricultural activities.

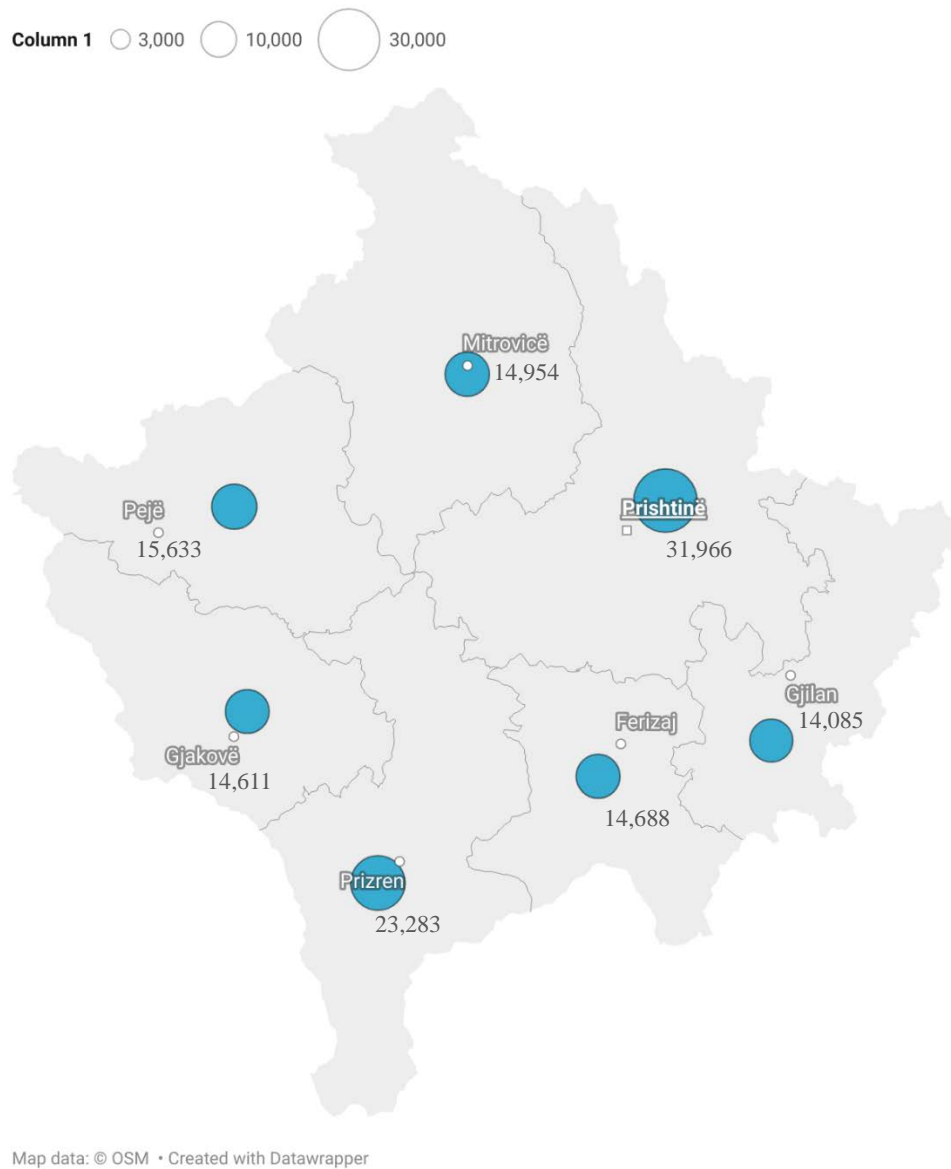


Figure 5. Thematic map of 129,220 agricultural farms per the regions of Kosovo

Source: Author's own construction through Datawrapper tool, (ASK, 2024)

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. Table 4 shows that cattle, sheep, goats, and poultry account for 98% of the country's livestock production.

Table 4. Livestock categorization by units in livestock structure of Kosovo, 2023

Livestock	Thousand LSU (Livestock Unit)	Share (%)
Cattle	213	72
Sheep and goats	24	8
Pigs	23	8
Poultry	37	12
Total	297	100

Source: (MAFRD, 2023c)

Table 4 demonstrates that animals in Kosovo create a significant amount of waste (manure), which can be utilized to generate biogas, another form of renewable energy. 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. In light of this, it is critical to examine the elements that influence farms' proclivity to engage in energy-efficient activities. This study looks into the various factors that influence farmers' agricultural activities and their willingness to explore new energy sources for their farms.

2.7. Attitude towards renewable energy sources

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. Furthermore, an Hungarian study (Bujdosó et al., 2012) elaborated the public acceptance of renewable energy sources in Hungary and showed that the people have heard and have general knowledge of solar energy, wind energy and hydropower with a participation of 90% while the share of those who had not heard of any of these technologies is only 1.4%. As for the farmers interviewed, most of them have heard of solar energy and wind energy, with over 80% of them being familiar with it (Bujdosó et al., 2013). Among the benefits that were valued by Hungarian residents in relation to the use of renewable energy sources were environmental aspects (87.7%) and cheaper energy compared to fossil energy sources (60.8%) (Bujdosó et al., 2012). 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. The study conducted by Bai et al., (Bai et al., 2023) presents the situation of Hungarians' attitudes towards the monetary value of convenience and environmental features for heating energy consumption.

This study shows that environmental friendliness is higher than the convenience factor in the evaluation of energy sources. This attitude was especially prevalent among educated people and those with high financial income, suggesting that environmental values in terms of energy use depend on the level of monetary capital.

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.

3. METHODOLOGY

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.

In essence, it outlines how knowledge is created and developed in a certain topic. Clarifying your research philosophy is crucial because it enables other researchers to comprehend the underlying presumptions that inform your methodology as well as how you interpret and communicate your findings (O'gorman & Macintosh, 2014). By being clear about your research perspective, you make it possible for others to assess the trustworthiness and validity of your assertions and the supporting data. This clarity also aids in defending the research's methodology and data collection strategies. Although several philosophical views or procedures may be used to solve the same research subject, it is important to show that the chosen approach has a well-thought-out and justified strategy. It must be able to explain the rationale behind the choice of a specific philosophy, how it supports the research's overall design and results, and how it fits with the goals of the investigation. By guaranteeing that the methodology is not only acceptable but also logical and consistent with the conceptual presumptions that underpin it, this justification enhances the research.

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.

Given the situation in Kosovo, there were some limitations that affected the development of the research, such as limited access to national data and inappropriate local agricultural statistics. Despite these limitations, the sample was carefully selected to include a significant number of different farm sizes, geographical locations and production diversity, which helps to understand the general attitudes and preferences of farmers towards renewable energy and its application on the farm. However, the results were interpreted with caution in cases of generalization to the entire agricultural population, in order to provide a meaningful representation of the main trends from the perspectives of farmers in the agricultural sector of Kosovo.

Future research in this direction, with institutional support and improved access to national data, could further strengthen the generalizability of the findings.

3.1. 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.

Investigating new trends in the performance of publishing articles and journals, collaboration patterns between different authors, research formats, and examining the research framework of a given field within the framework of existing literature are the main goals of bibliometric analysis. Bibliometric analysis assists in identifying important contributors, significant publications, and changes in scholarly focus by methodically looking at citation networks, publication numbers, and authorship trends (Verma & Gustafsson, 2020). This can show which study areas are growing more diversified or interwoven over time, as well as which themes are gaining traction.

The use of quantitative methods on bibliometric data to evaluate and analyze different facets of scientific study is known as bibliometric methodology (Broadus, 1987). In order to find patterns, trends, and connections within the research landscape, this methodology entails methodically gathering and examining data from scholarly publications, including books, journals, conference proceedings, and articles. Bibliometric analysis provides a means of quantifying variables including publication volume, citation impact, author productivity, and the influence of certain journals or institutions through the use of statistical and computer methods.

What is more important and functional is that large amounts of bibliometric data can now be obtained much more easily thanks to the development of scientific databases such as Scopus. Easy access to a large number of publications produced over the years, journals, conference proceedings from various fields is enabled through these databases which provide data security. The inclusion of high-impact journals in Scopus is one of the most advantageous aspects of this aspect; this database provides researchers with useful citation data for bibliometric analysis. Then, this data can be analyzed in a general way by researchers using bibliometric tools such as Bibliometrix. Data processing techniques such as citation analysis, co-citation analysis and search trend visualization are enabled by the widely used Bibliometrix technique, through an open source R application that uses data from trusted databases such as Scopus, which was used in this research. For disciplines in important sectors such as energy, agriculture and environmental science, where specialized knowledge on scientific contributions is provided, Scopus is an exceptionally important resource. Furthermore, researchers researching these fields can use Scopus to monitor and compare the progress of knowledge, to identify important articles and writers of a higher order, and to investigate new developments within their subjects of interest. Considering all of the above, the Scopus database and technical resources such as Bibliometrix offer a powerful combination for understanding the state of research in research environments and assessing the impact of academic work in specific areas defined by researchers.

In fact, the bibliometric approach has been used in many scientific research domains, from examining publications and citation patterns to examining collaboration patterns and the conceptual framework of a field of study (Ellegaard & Wallin, 2015; Kumar et al., 2021; Xu et al., 2018). From recognizing important studies and new subjects to comprehending how knowledge is shared among many communities, this adaptable method enables researchers to acquire insights into a variety of aspects of academic work. When it comes to publication analysis, bibliometric techniques can monitor patterns in author productivity, citation impact, and publication volume. This makes it possible to evaluate objectively how study topics change over time, which authors and organizations are at the forefront of the field, and how particular concepts or inventions become more well-known.

In addition, the Bibliometric technique also includes other analyses such as network and descriptive analysis as well as the collection of metadata from various scientific literature. It is

very important because in some form it evaluates many aspects of academic research. In particular, this technique deals with the annual pace of publications, analyzes the volume of citations, evaluates the findings of authors using established scientific criteria and provides other useful data in the context of academic achievements. These research techniques help in understanding the types of the research models, the importance behind the teamwork effects and the impact that the publications in specific research areas do have.

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 6). 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.

What makes this tool so widely used and widespread in application is that R is an object-oriented and multifunctional programming language, covering a wide range of applications. This data-friendliness makes it easy to generate analyses and develop specific visualizations suited to unique research requirements. As an open source program, R also has the advantages of a rich database and enjoys a large user base, which consists mainly of statisticians and data scientists. Due to its open nature, users have easier access to a variety of resources, can exchange information with each other and obtain important information, enabling them to perform challenging analytical tasks generated in a short period of time.

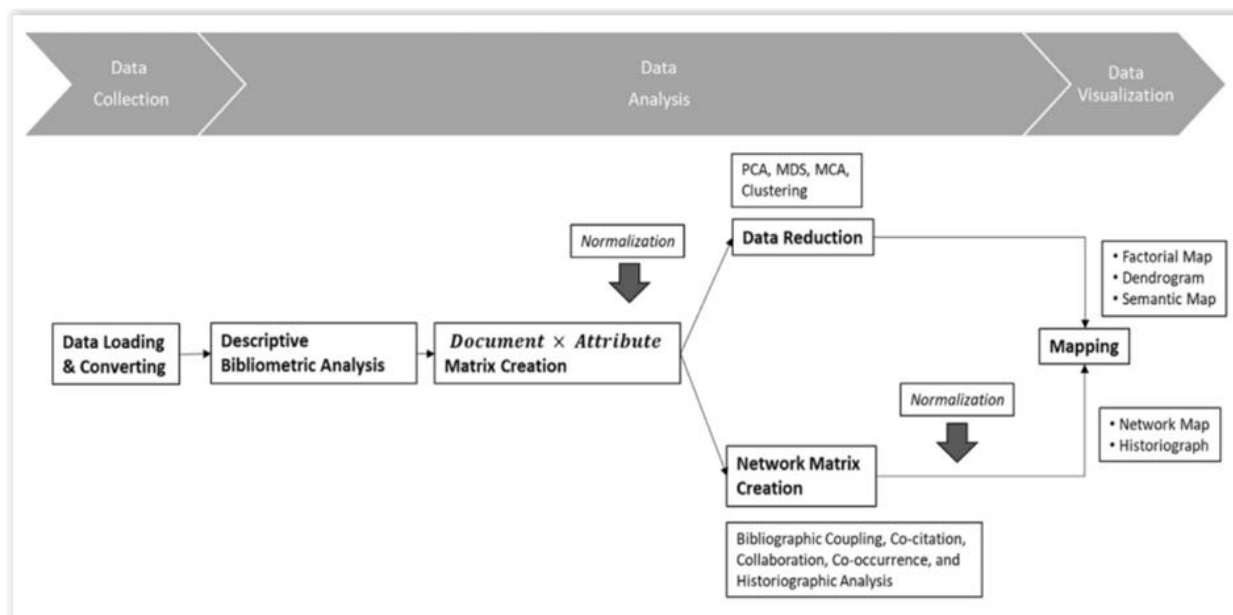


Figure 6. Workflow of the applied science mapping process

Source: (Aria & Cuccurullo, 2017)

3.1.1. Data collection and management in bibliometrics analysis

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, as can be shown in Table 5.

Table 5. Main information regarding the collection of articles

Description	Results
Period	1988 – 2022
Documents	200
References	8982
Author's Keywords	715
Authors	788
DOCUMENT TYPES	No.
Article	142
Book	1
Book chapter	7
Conference paper	33
Review	17

Source: Created by the authors (Pestisha et al., 2023)

3.1.2. Interpretation

To cover the whole field of research on the use of renewable energy in agricultural fields, a thorough search of journal publications was carried out. Four crucial steps were engaged in this process:

- First, the author used Scopus, one of the most dependable databases for scholarly research, to collect data from all over the world. This guaranteed the precision and thoroughness of our data gathering.
- Examined each article's title, abstract, literature review, and keywords. Detailed citation information, including authors, author IDs, article titles, publication years, source titles, volume, issue, article numbers, pages, citation counts, DOI, links, abstracts, author keywords, document types, open access status, and the EID (Electronic Identifier), was included in the search results, which were downloaded as.csv files.
- To glean valuable insights, each of these data elements was methodically examined. The author was able to pinpoint important trends and patterns in the literature on the use of renewable energy in agricultural settings thanks to this in-depth analysis.

- Finally, relationships were sought between countries that prioritized research on this topic, authors, journals with the highest publications at this level, annual scientific outputs, and collaborative networks; hence, were displayed through different data visualizations to make it easier and convenient to understand trends and connections in the field.

The information that was generated as a result of easy access to the required data through the selected technique was more easily organized by processing the data into common groups of information and into specific categories using the cluster analysis approach. Furthermore, the placement of keywords into different categories (close in importance to each other) is a distinctive feature of the use of this technique, which helps researchers find thematic trends within a piece of text. This type of clustering technique is particularly useful for organizing large sets of data, the monitoring of which can be challenging, and identifying new research topics for the future. Furthermore, by analyzing the frequency and manner in which particular terms appear in the literature of researchers who have focused on this topic, a keyword analysis allows to highlight the main directions and trends of this research topic. The relationships and connections between different concepts in a subject can be learned by examining the association of keywords. This method helps to understand the main terms that dominate the topic and, above all, to understand how the focus of research has changed over time in different research periods.

Each term presented in the visualization framework is represented as a node in a network of keyword connections and whenever two words occur together, it represents a connection created between them. The frequency and intensity with which two keywords appear linked together in several articles shows how strong the relationship is between them. The stronger the connection between two keywords, the more often they occur together. Using this method of creating networks, it can be seen how different ideas in the field of agriculture and renewable energy are connected to each other, exposing the level of knowledge and development of the area through new practices. Furthermore, the author's choice of keywords is of great importance as it significantly influences the way in which a generated value is portrayed, shared and discussed in the scientific community. These keywords determine the visibility of the research output in search databases and citation networks and furthermore provide an overview of its main points, with an impact of the research on upcoming studies.

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

The current focus on sustainability and progress on this issue in global aspects, as well as preferences towards renewable energy sources, are the reasons that highlight and underline the importance of research to identify consumer attitudes and preferences towards alternative energy options. Kosovo, although a country that has faced numerous problems and emerged from war, is trying like many other countries, to increasingly involve renewable energy sources (RES) in the energy mix as a solution solve issues of environmental sustainability, to reduce the dependence of energy generation on fossil fuels and to promote long-term economic growth.

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.

To reach the findings relevant to this research question, a comprehensive survey was conducted using structured questionnaires with two population groups: the general residential population and farmers (on their farm applications). The reasons that led to focus on these groups are based on the fact that these groups are continuous energy consumers and to understand how different bi-energy policies would affect the decisions they would make for their energy future. The general public represents broader social perspectives (attitudes and preferences), while farmers, who are often directly affected by environmental policies for their activities and energy consumption, serve as premises that provide with insights into the current state of perceptions and the opportunities that would be created for a sustainable future.

3.2.1. Data collection

In the next step, data collection, all respondents were citizens of Kosovo, their recruitment method was carried out through random sampling which allowed each individual to have equal chances to be part of the research, regardless of their gender, age, race or nationality. In this research, simple random sampling was used which includes the likelihood of including the entire demographic composition of the country. Above all, participation in the research was completely voluntary and participants were informed that their data would be kept confidential. This research adhered to ethical issues and the interviewees were informed that their data would be used only for research reasons and all their responses would be analyzed and performed in a group manner and not individually.

The questionnaire to collect the data was divided online and consisted of two parts (Annex 2). The first part collected demographic data as well as the knowledge that individuals had about the environment and issues related to it. While the second part was fully concerned with the level of understanding of renewable energy and the views that the interviewees had in this regard. This data allowed the author to gain information on environmental awareness and how they view the integration of renewable energy into energy production. The questioning was logical, clear and easy to understand, and the maximum time it would take to complete it was ten minutes, making this an easy way of collecting data. It is worth noting that respondents were free to withdraw at the moment they did not find themselves in this type of topic, all this so that they would not feel forced to continue if they were not interested in the topic. Furthermore, the questionnaire could only be completed once by the same person, so that the data would be as real as possible, their integrity would be preserved, and would not be faced possible biases from multiple completions by the same person.

In terms of involving farmers in the research, this was more difficult and their recruitment was done through a snowball sampling strategy, all as a result of the difficulties in reaching this community. Since farmers work on the farm all the time and reaching them through online means is very difficult, the first contact for their selection was received from the Ministry of Agriculture in Kosovo, which served as a bridge by facilitating communication with them. The snowball sampling method, on the other hand, allowed to identify and include respondents through referrals, ensuring that farmers came from different regions of Kosovo. This method will help to generalize

knowledge and perceptions as a result of their representation across the country, gathering a diverse range of perspectives. Data from farmers were collected between December 2020 and January 2021.

The research continues with the analysis of the attitudes and preferences of the first group (internet-oriented), who completed the online survey. The reason why the form of conducting the surveys was online is based on the fact that according to KAS, approximately 98.6% of households in Kosovo are connected to an internet connection, which makes me understand that this method is an appropriate approach to achieve the distribution of the survey to the target individuals (ASK, 2023). Furthermore, the high level of internet usage gives the green light for the online survey approach, which thus enables to diversify the sample and ensures that the population can be inclusive and representative of the demographic structure of the general population. In total, 243 completed questionnaires were collected from this survey. Other reasons for using online questionnaires were also driven by practical reasons such as logistical barriers (lack of access such as face-to-face interviews or telephone surveys) that hinder the development of research on the selected topic. In this case, online access has been a much lower cost and efficient means of collecting data that eliminates the barriers mentioned above. As a result of all these reasons, the choice of using online surveys in this context was not only practical and easier, but also necessary to ensure that the research could encompass a wide scale and provide important insights into the population's attitudes towards renewable energy. Moreover, great flexibility in data collection, allowing respondents to participate whenever it is convenient for them is another advantage. This flexibility is especially important in today's highly dynamic environment, where time and location constraints can limit engagement.

In the second set of surveys, the respondents were farmers from the Republic of Kosovo. In the case of farmers, data collection was conducted using a combination of questionnaires (Annex 2) and in-depth interviews (Annex 3), providing a more complete understanding of this group's views on the application of sustainable practices in agricultural contexts. The first step of this process was for farmers to complete the same questionnaire that the first group (internet-oriented population) completed regarding their preferences and attitudes towards the use of renewable energy sources on their farms. As for the first group, the questionnaire collected useful quantitative data on the types of renewable energy technologies that they had previously seen or heard and

were aware of, as well as their willingness to incorporate such technologies into agricultural practices.

The in-depth interviews helped to get inside the problem and take a closer look at farmers' attitudes towards renewable energy, the barriers affecting the adoption of sustainable environmental practices, and their knowledge towards a more climate-friendly future. In-depth interviews helped to extract more information about energy management on Kosovo farms. In the framework of the application of in-depth interviews, these consisted of eleven open-ended questions and the main focus was on aspects of the use of renewable energy in agriculture, the role of biomass and the possibilities of its conversion into energy, straw and its use, strategies for better energy management, including costs, the environment and the overall impact of the farm and its operations. A total of 30 farmers were included in the research, the type of farm activity was not specified. So the farmers were carrying out various agricultural activities, including the cultivation of vegetables, cereals and fruits, as well as livestock (animal breeding). In this context, among the thirty farmers, four of them ran dairy farms, seventeen combined farms (dairy and vegetable production) and nine were focused only on plant production aspects. This diversity of farm types provides a more detailed picture of the approach to renewable energy applications from the point of view of different agricultural sectors.

In terms of demographics, the farmers in the survey fell predominantly into two age groups. Farmers aged 35 to under 45 made up the largest group, accounting for 33% of all participants. Farmers aged 45 to under 55 made up the second largest group, accounting for 25% of the sample (ASK, 2020). This age distribution demonstrates the involvement of relatively younger and middle-aged farmers in the adoption of agricultural methods, which may be more open to innovative technologies such as RES. As indicated in Table 6, the majority of farmers who participated in this research is between these two ages, bolstering the sample's representativeness.

Table 6. Distribution of the sample according to the most important demographic variables (N=243, N=30)

Label	Sample distribution			
	Internet-oriented population		Farmers	
	Count	%	Count	%
Male	74	30.5	26	86.7
Female	169	69.5	4	13.3
18-29	196	80.7	0	0
30-39	32	13.2	6	20
40-49	10	4.1	16	53.3
50-59	5	2.1	6	20
Above 60	0	0	2	6.7
Primary school	5	2.1	0	0
High school	63	25.9	23	76.7
University studies	117	48.1	5	16.7
Postgraduate studies	58	23.9	2	6.7
Employed	110	45.3	17	56.7
Unemployed	30	12.3	13	43.3
Student	103	42.4	0	0
Can live on it very well and can also save	71	29.2	1	3.3
Can live on it but can save little	114	46.9	20	66.7
Just enough to live on but cannot save	48	19.8	9	30
Sometimes cannot make ends meet	2	0.8	0	0
Have regular daily financial problems	2	0.8	0	0
Not know/Not answer	6	2.5	0	0

Source: Created by the authors (Pestisha & Bai, 2022)

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).

In the process of data analysis, an independent sample t-test was used to compare two independent groups characterized by categorical data. The test was effective in determining whether there were significant differences in the responses given based on different socio-economic categories, such as those with different income levels or those groups that had high differences in education levels, towards their preferences for renewable energy. For questions with more than two categories, one-way ANOVA was used to see if there was any significant difference in group preferences or understanding of RES. Because participants were grouped into different categories (age, occupation), this test was particularly useful for analyzing such characteristics. One-way ANOVA allowed for comparison of the means of these groups to determine whether demographic characteristics had a significant effect on attitudes toward renewable energy.

In general, the questionnaire questions were set on a five-point Likert scale, allowing respondents to express their level of agreement by selecting the option that best suits them. In addition, the survey also contained dichotomous questions (with "yes/no" answers) and multiple-choice questions. These types of questions allow to collect data on both qualitative and quantitative attributes and to be able to analyze them further.

In conclusion, online surveys allow to reach a larger audience which gives higher chances of participation due to the flexibility of the way of filling out the questionnaire, while also preserving the privacy and confidentiality of the respondents. In addition to offering flexibility as an important factor, online surveys are also much more effective in terms of financial and opportunity costs

compared to traditional methods of data collection. Traditional methods of data collection (personal interviews or telephone surveys) are defined by major disadvantages of the method of implementation such as high costs of transportation, equipment for conducting interviews and the time needed to perform the questionnaires. In general, it is worth mentioning that this type of interviewing offers the flexibility of generating data from large groups of participants in a shorter period of time, making them a suitable and attractive option for those seeking to conduct larger studies without exceeding their planned budget. Compared to traditional data collection approaches, which can take days or weeks to complete, online surveys can produce results in relatively short periods of time, allowing researchers to review and analyze data in a shorter period of time.

3.3. 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. 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?

A SWOT analysis methodology was utilized to address the internal and external aspects of renewable energy development and effect in Kosovo. This will help to clarify Kosovo's sustainability concerns and make recommendations for the most effective strategies to make a bigger difference and promote more growth. It can be used to determine the best course of action for your project, to identify areas where change is possible, to study the potential for new activities or problems to be solved, and to assist in modifying and improving plans as necessary. Over time, a number of scholars have used the SWOT approach to identify the sector's external opportunities and dangers, as well as its internal strengths and weaknesses. According to Chen et al. (2014), the SWOT framework often comprises of both external and internal assessments. Internal assessments

demonstrate an organization's or strategic plan's strengths and shortcomings, whereas external assessments identify opportunities and challenges (Chen et al., 2014). Originally conceived for business and marketing analysis, the SWOT paradigm has found widespread use in a variety of fields of study, including energy management. SWOT analysis provides a broader understanding of the chances of success and failure by examining and assessing internal and external elements influencing performance (Jaber et al., 2015). This vision is easily translated into goals and actions that will help to achieve the following objectives: identify and address areas of weakness, capitalize on areas of opportunity, improve or maintain areas of strength, and prepare for areas of threat. The current SWOT analysis research is based on secondary sources such as studies and research papers, reports from the Ministry of Agriculture, Forestry, and Rural Development, institutional reports, and data (Table 7).

Table 7. SWOT analysis of renewable energy sources application in Kosovo

Strengths	Weaknesses
Geographic location (Ministry of Economy, 2024)	Initial and installation costs (Elavarasan 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, 2023a)	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)

3.4. BWS scale methodology

Farmers' views on renewable energy are examined using a method that aims to understand the growing understanding of sustainable agricultural methods. The purpose of this research is to investigate how Kosovo's farmers perceive the importance of renewable energy sources and their integration into regional agricultural systems in light of global climate change discussions. Data on farmers' knowledge and attitudes about renewable energy solutions, including various features for them, are gathered through questionnaires used in the research. The approach also involves determining how well-known renewable energy technologies are, how they are being used in farming practices, and what challenges or barriers farmers may face when putting these technologies into practice. This approach will clarify the perception of renewable energy in the context of Kosovo's agricultural sector and its potential impact on sustainable farming practices and rural development.

Promoting a sustainable culture in the agriculture sector requires an understanding of farmers' viewpoints on renewable energy. Due to their significant involvement in the industry, farmers will play a crucial role in influencing agricultural practices that promote the adoption of sustainable energy technologies. Their perspectives can provide valuable information on the potential challenges and benefits of integrating renewable energy sources into farming systems, which will ultimately influence the direction of sustainable agricultural growth in their region.

Furthermore, farms may become more robust to climate change and raise energy costs by integrating renewable energy into their farming practices. For example, farmers can use solar energy to operate irrigation equipment, reducing their reliance on expensive electricity or fuel-powered generators. Similarly, using biogas produced from organic waste can provide a sustainable energy source for heating, lighting, and powering farm equipment. These technologies offer farmers the opportunity to decrease their environmental impact while simultaneously increasing energy independence by lowering greenhouse gas emissions. The application of such strategies might be particularly important in Kosovo's rural areas, where access to reliable energy sources may be limited and energy costs may represent a significant amount of operating costs.

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 8) 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 8. 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 9): *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.

Table 9. 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)

The initial step in data analysis with this method is to determine the best and worst values for each criterion. This is done by subtracting the 'best' and 'worst' values. The fact that this process can be carried out at both the individual and aggregate levels (Equations 1 and 2) is considered to be an advantage.

$$Best - Worst Score_{n,k} = Best score_{n,k} - Worst score_{n,k} \quad (1)$$

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

$$Best - Worst Score_k = Best score_k - Worst score_k \quad (2)$$

The final level (aggregate) Best-Worst ratings are used to rank the importance of the factors in question. The following step provides the criteria's standard deviations and average Best-Worst values. After that, it is possible to calculate and plot Cohen (2009)'s standardized Best-Worst values both separately (equation 3) and collectively (equation 4).

$$Standardized Best - Worst score_{n,k} = \frac{Best - Worst score_{n,k}}{f}, \quad (3)$$

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

$$Standardized Best - Worst Score_k = \frac{Best - Worst score_k}{Nf}, \quad (4)$$

When N is the number of respondents.

The square root of the best-worst ratio is also calculated (Equation (5)) and its standardized form (Equation (6)) in order to analyze the factors.

$$\text{sqrt. Best - Worst score}_k = \frac{\text{Best-score}_k}{\text{Worst-score}_k}, \quad (5)$$

$$\text{sqrt. Best - Worst score}_k = \frac{\text{sqrt. Best - Worst score}_k}{\text{max. (Best - Worst score)}}, \quad (6)$$

where the maximum of (Best-Worst score) is considered to be the highest value of sqrt. *Best - Worst score* _{k} (Gergely et al., 2023).

Due to preference heterogeneity investigation, individual-level Best-Worst values are used for further statistical analysis. The author was able to examine how respondents' preferences varied depending on their qualities thanks to this strategy. The non-hierarchical (K-Means) cluster analysis is employed to identify distinct respondent groups based on their attribute preferences for adopting renewable energy in order to better understand these discrepancies. This approach made it feasible to uncover patterns in the data that would not have been immediately apparent. To look into differences among the discovered clusters, more statistical tests were performed. The Mann-Whitney test was applied to ordinal measurement variables, including gender, age, type of agricultural sector, location, domicile, and occupation, in order to identify significant differences between clusters. Two-step clustering was performed using IBM SPSS Statistics 29, which improved the robustness of the analysis. Pearson's Chi-square test and a two independent samples t-test were used to analyze the clusters and determine how the identified groups varied in terms of socioeconomic and demographic characteristics. A comprehensive analysis of preference heterogeneity and its implications was made possible by the combination of methodologies.

3.4.1. Data sampling for BWS scale

In the research, 120 farmers were interviewed through a questionnaire (Annex 1) from all regions of Kosovo. To guarantee representativeness, the authors first conducted sampling by area after taking into account the number of active agricultural households in each region based on KAS (Kosovo Agency of Statistics) statistics (Kosovo Agency of Statistics, n.d.). With 31,966 agricultural enterprises, Prishtina led the group of 129,220. The authors then used the quantitative

research of the BWS approach to analyze the data they had gathered, depending on the quantity of interviews that had been produced.

According to the Table 10, the capital city of Prishtina is home to 20.8% of the interviewees, while the Ferizaj region had a lower representation, with just 9.2% of the interviewees taking part in our research. Most farms produced both plants and livestock, making up the majority of farm productivity. Farm size varies across many scales, although it mostly falls into the small category, with 73.3% of farms being smaller than 5-hectare. The majority of farmers (94.2%) were men, which is common on farms around the world. However, the average age of 43 years (with a high standard deviation) is much younger than the average age of EU farmers, which is 57 years old (Mihail et al., 2023). One advantage is that a large majority of farmers (76.7%) have a high school degree. Regarding crop planting, 92.5% of the farmers used straw for farm bedding, while 77.5% grew maize and grain. These goods are crucial for bedding and foddering self-sufficiency, but straw in particular has a lot of potential for energy self-sufficiency. 10% of farms have solar panels, which is significant for power self-sufficiency; nonetheless, efficient use and storage remain issues that need to be resolved.

Table 10 presents the primary characteristics of the sample.

Table 10. The main characteristics of the farms and the farmers

Denomination	Categories	Percentage (%)
Gender	Male	94.2
	Female	5.8
Education	Primary school	5.8
	High school	76.7
	University	17.5
Municipality	Ferizaj	9.2
	Gjakovë	12.5
	Gjilan	14.2
	Mitrovicë	14.2
	Pejë	13.3
	Prishtinë	20.8
	Prizren	15.8
Type of the farm	Cattle or crop farm	7.5
	Combined production	92.5
Farm size	Lower than 5-hectare	73.3

	Between 5 – 10 hectare	10.0
	Above 10-hectare	16.7
Production of maize	Yes	77.5
	No	22.5
Bedding	Yes	92.5
	No	7.5
Solar panels in the farm	Yes	10.0
	No	90.0
Age (year)	Mean	43.78
	SD	9.27
Solar panel capacity (kW)	Mean	5.16
	SD	1.89
Electricity consume (€month)	Mean	46.88
	SD	118.61
Number of cows	Mean	19.89
	SD	30.76
Wheat production (ha) (n=112)	Mean	4.81
	SD	14.67
Maize production (ha) (n=97)	Mean	7.21
	SD	16.49

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

It's important to note that Kosovo's agriculture industry still uses information from the 2014 agricultural census. This database does not reflect recent developments and changes in this industry because it is already outdated. Furthermore, the data that is currently accessible is not broken down at many levels, such as those for categories of agricultural farmers according to productivity levels, age, education, and energy on the farm. This has created an information gap that makes it difficult to collect accurate and thorough data for future agricultural evaluations. Therefore, in order to provide more up-to-date and reliable data, the writers have searched for alternatives. The Kosovo Association of Milk Producers, which has a membership database with 1250 farms, was one option to obtain more recent statistics (*Milk Producers Association – Milk Producers Association*, n.d.). This information facilitates analysis and a better understanding of the dynamics of the agriculture sector in Kosovo. Thus, in addition to the erroneous and outdated information provided by the 2014 census data, the Kosovo Association of Milk Producers has provided with a better picture of the present situation of member farmers. Owing to the absence of a current and comprehensive official national agricultural data source, every attempt has been taken to guarantee that the distribution of our sample of 120 farmers is consistent with the expected

national figures, as determined by experts. This element is thought to boost our research's uniqueness and, to some extent, its representativeness.

3.5. 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. 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 annual heating demand for an average household is 86 GJ/year/ 100m² (Bai, 2005), whereas the average size of the family house in Kosovo is 120m² (Table 11).

Table 11. The annual thermal energy demand calculations of a family house by wood-fired and straw boiler

Denomination	Indicators	Unit
Thermal energy demand	0.86 (Bai, 2005)	GJ/year/m ²
Wood stove efficiency	82	%
Average area	120	m ²
Energy input	125.9	GJ/year
Net price of wood	Total cost of wood / Energy input	Euro/GJ
Cost of thermal energy	Energy input * cost of thermal energy	euro/year
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	Straw price / Energy content of straw	euro/MJ
Energy input	Annual thermal energy / Efficiency of straw stove	GJ
Cost of thermal energy	Amount of straw required * Straw price	euro/year

Source: Author's own construction

The research aim was to explore the energy self-sufficiency of agricultural farm in terms of energy consumption. Data were collected through internet databases and scientific journals in order to perform the calculations. In cases where the data wasn't official (e.g. straw price), then was used the data from the actual conditions and expert opinion but it was impossible to prove it with a reference. This uncertainty in the official data has highlighted the importance of conducting sensitivity analysis through the calculations made, and while there were limitations in the availability of data, the assumptions and comparability calculations on key parameters help to give a clearer idea of the current situation. The overall objective of this research is to determine if there are energy products that are competitive in comparison with wood, which is the main heating source in Kosovo. To determine if it is cost-effective, calculations are performed.

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 hectares, 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 each sector needs the sensitivity analysis is carried out. The results are organized in the tables in different scenarios.

4. RESULTS AND DISCUSSION

4.1. 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 indicator provides with important information in the framework of the research carried out and the achievement of scientific research within the framework of the topic carried out in a certain country. Therefore, the contributions made by different countries to research in the context of renewable energy applications in agriculture and the impact on the environment can be understood through bibliographic research. As highlighted above, the trends of publications on the topic selected in the context of our research have been examined through bibliometric analyses. These trends are presented through the countries that lead in terms of research productivity, the most cited articles, the collaboration networks between authors, as well as the keyword co-occurrence network and annual scientific output. Elucidating and interpreting the output of scientific output and identifying trends for publications over different periods of time help to understand the advantages and predictions for science output production in the future.

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 7. 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. Since production was very low, this suggests that although interest in the use of renewable energy in agriculture increased, the field was still in its initial phase and this made it less researchable. There have been variations in the number of publications in recent years, which may be due to changes in the intensity of research or external influences on the topic. These variations imply that although the subject is gaining traction, various difficulties or barriers still affect the sustainability of the publication output.

The number of publications began to rise significantly in 2009, with 11 publications produced that year. The premises that pushed the increase in scientific output are considered to be the aftermath of the 2008 financial crisis and the consequences it left behind, such as the effect it had on the world crude oil market. This financial crisis further pushed researchers to seek economically and ecologically sustainable forms of energy, sparking a new interest in alternative sources that could be easily applied to agriculture.

As the Figure 7 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. Also, the production of energy from alternative sources was significantly affected, especially in agricultural aspects, the shutdown and the dynamics of life during that period was a factor that influenced the reduction of the operational capacities of many companies and their research. Although renewable energy and its use are always interesting and important to research, during this endemic period publication in this area fell significantly along with production. These changes also highlight the fact that various events that are recognized as external factors, including pandemics and financial crises, can be characterized as having an impact on research fields and processes. As the pandemic situation calmed down to some extent and the world was returning to normal, the number of publications began to increase. The reasons for this growth are numerous, starting with the fact that agriculture is closely linked to the external environment and renewable energy is important to include in the agricultural sector which is increasingly moving towards advancement. Then, economies of scale have influenced more affordable options of renewable energy thus influencing the increase in access for use in agriculture. As well as the need for stable and sustainable energy sources in the agricultural sector may be another reason that has influenced the increase in research on the inclusion of RES in the agricultural field.

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. As nations and industry look to lessen their reliance on costly and unstable fossil fuel resources, these problems have increased demand for renewable energy sources as a feasible alternative for energy generation. 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. Self-sufficiency in energy will become a crucial component of farm management, providing both economic and environmental advantages, as long as energy costs continue to fluctuate and outside variables continue to impact agricultural output. As the industry adjusts to these persistent issues, there is expected an emphasis on renewable energy solutions in agriculture to increase in the upcoming years.

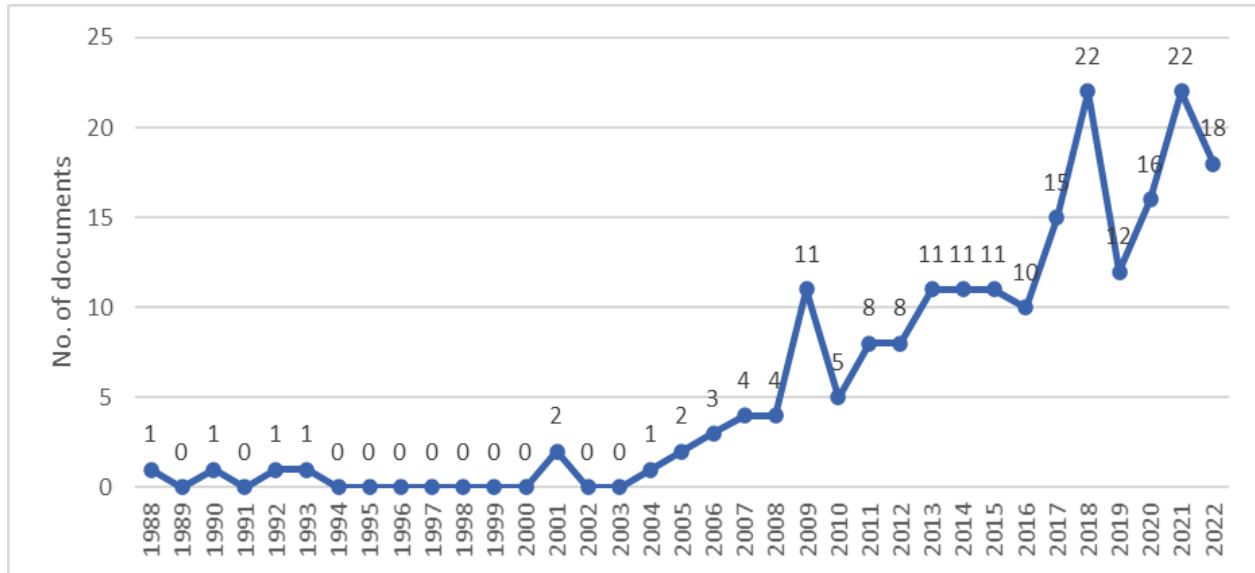


Figure 7. Annual scientific production of the chosen topic

Source: Created by the authors (Pestisha et al., 2023)

Additionally, Table 12 lists the ten primary journals associated with the search term that were found using the Scopus database. The topic matter of all these periodicals is 'Renewable Energy, Sustainability, and the Environment'. The majority of the publications are published in journals that fall into the Q1 and Q2 tiers, especially those published by MDPI and Elsevier. These two publishers stand out for their emphasis on renewable energy and how it may be used on farms, which demonstrates their dedication to furthering this field of research. In this specialist subject, journals like *Energies* and *Sustainability* are becoming more and more coveted target publications, even though they have lower SJR (SCImago Journal Rank) and H-index values. They are crucial venues for sharing research on this crucial subject because of their expanding importance and emphasis on renewable and sustainable energy sources in agriculture. These publications will probably continue to play a significant role in determining the course of future research as the area of renewable energy applications in agriculture develops.

Table 12. List of the most relevant journals

Journal	Publisher	Country	H index	SJR	TP
Journal of Cleaner Production	Elsevier	United Kingdom	232	1.92 (Q1)	8
Sustainability (Switzerland)	MDPI	Switzerland	109	0.66 (Q2)	8
Renewable and Sustainable Energy Reviews	Elsevier	United Kingdom	337	3.68 (Q1)	7
Energies	MDPI	Switzerland	111	0.65 (Q1)	5
Science of the Total Environment	Elsevier	Netherlands	275	1.81 (Q1)	5
Renewable Energy	Elsevier	United Kingdom	210	1.88 (Q1)	4
Atmosphere	MDPI	Switzerland	46	0.69 (Q2)	3
Biomass and Bioenergy	Elsevier	United Kingdom	189	1.01 (Q2)	3
Fourrages	AFPF	France	13	0.14 (Q4)	3
Environmental Science and Pollution Research	Springer	Germany	132	0.83 (Q2)	3

Legend: TP – the number of total publications; AFPF – Association Francaise pour la Production Fourragere; MDPI – Multidisciplinary Digital Publishing Institute

Source: Created by the authors (Pestisha et al., 2023)

The volume and output of global scientific publications over certain periods of time are very important indices in terms of determining the countries that attach importance to research in certain fields, in this case Table 13 provides with an analysis of the countries that have been most productive in this regard. Such analyses are very informative on the dissemination of information of geographical regions that are constantly working to advance agricultural practices in the context of the involvement of renewable energy and ecological sustainability, highlighting the work being carried out by researchers from different countries on this topic. From the findings in Table 13, it is clear that the countries that attach importance to scientific research are the same countries that in everyday life attach high importance and priority to renewable energy production and the advancement of new technological practices for energy production on farms.

Table 13. The top 20 most-productive countries in publications for the research area (1988-2022)

Country	No. of Documents	Country	No. of Documents
China	49	Turkey	13
USA	49	Germany	12
Italy	32	Romania	11
France	29	South Korea	11
India	29	Japan	9
UK	28	Spain	9
Poland	19	Thailand	9
Iran	17	Algeria	8

Brazil	15	Malaysia	8
Canada	14	Netherlands	8

Source: Created by the authors (Pestisha et al., 2023)

Based on Table 13, 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. Their impressive research outputs in the field are a direct result of these investments. Indeed, a study by Hu et al. (Hu et al., 2022) found that China and the US were the most prolific nations in renewable energy research, highlighting their leadership in developing renewable energy solutions for agriculture. China became the world leader in renewable energy capacity in 2013, surpassing the combined capacity of all European nations and the rest of the Asia-Pacific region (Yang et al., 2016) This accomplishment demonstrates China's strong commitment to the development of renewable energy. Apart from China's leadership, numerous other nations have set lofty targets to raise the proportion of renewable energy in the world's energy production. For example, by 2050, China wants to produce 62% of its total energy and 86% of its power from renewable sources. In a similar vein, Germany and the US have set goals to reach an 80% proportion of renewable energy in the same time frame. With the long-term objective of becoming carbon neutral by 2060, China has also set plans to reach peak carbon emissions by 2030 in response to the mounting worries about global warming (Cheng et al., 2022). These lofty goals demonstrate China's commitment to reducing the effects of climate change and its understanding of the pressing need to switch to a more sustainable energy system. According to reports, the world's total energy consumption in 2018 was 9938 Mtoe, with oil consumption accounting for 4051 Mtoe (40.8%) (IEA, 2020).

The percentage of renewable energy in the gross final energy consumption of European nations increased significantly in 2023. With a 75.6% share, Norway held the largest proportion in the region, followed by Sweden (66.4%) and Finland (50.7%) (eurostat, 2024). These nations have demonstrated their great commitment to sustainability and environmental goals by making significant investments in renewable energy. Significant progress has also been made by the EU as a whole in raising its share of renewable energy. Just 9.6% of the EU's gross final consumption in 2004 came from renewable sources. This percentage nearly tripled from 2004 to 2023, reaching 24.5%. This expansion demonstrates the EU's continuous attempts to lessen its reliance on fossil

fuels and switch to cleaner energy sources. The European Union has set high goals for the future. By 2030, it wants 32% of its total final energy consumption to come from renewable sources. This goal demonstrates the EU's dedication to attaining energy sustainability and supporting international initiatives to tackle climate change. The European Union has set high goals for the future. By 2030, it wants at least 32% of its total final energy consumption to come from renewable sources (EU, 2018). This goal demonstrates the EU's dedication to attaining energy sustainability and supporting international initiatives to tackle climate change. Regarding this, France, which comes in at number four in Table 13, has set a lofty target to attain a 32% renewable energy contribution in its gross final energy consumption by 2030 (Perrin & Bouisset, 2022). In a similar vein, Italy and Germany wants to achieve a 30% renewable energy contribution by the same year (European Commission, 2020a, 2020b) These targets demonstrate the nations' dedication to boosting their capacity for renewable energy and supporting the larger European aims for a sustainable energy future.

During the years 2020 to 2022, the countries involved in research within the framework of the topic have undergone significant transformations, as can be seen in Figure 8. The country of China has continued to be a leader and dominant in this aspect, while the United States has undergone a significant decline, ranking eleventh. On the other hand, other countries have occupied good positions in this research field, especially India and Poland. These two countries have achieved an increase in agricultural activity, characterized by small but productive farms that play an important role in the country's agriculture. Among the advantages that these research centers have achieved is their ability to utilize the by-products they generate, making it a priority to maximize sustainability and resource efficiency.

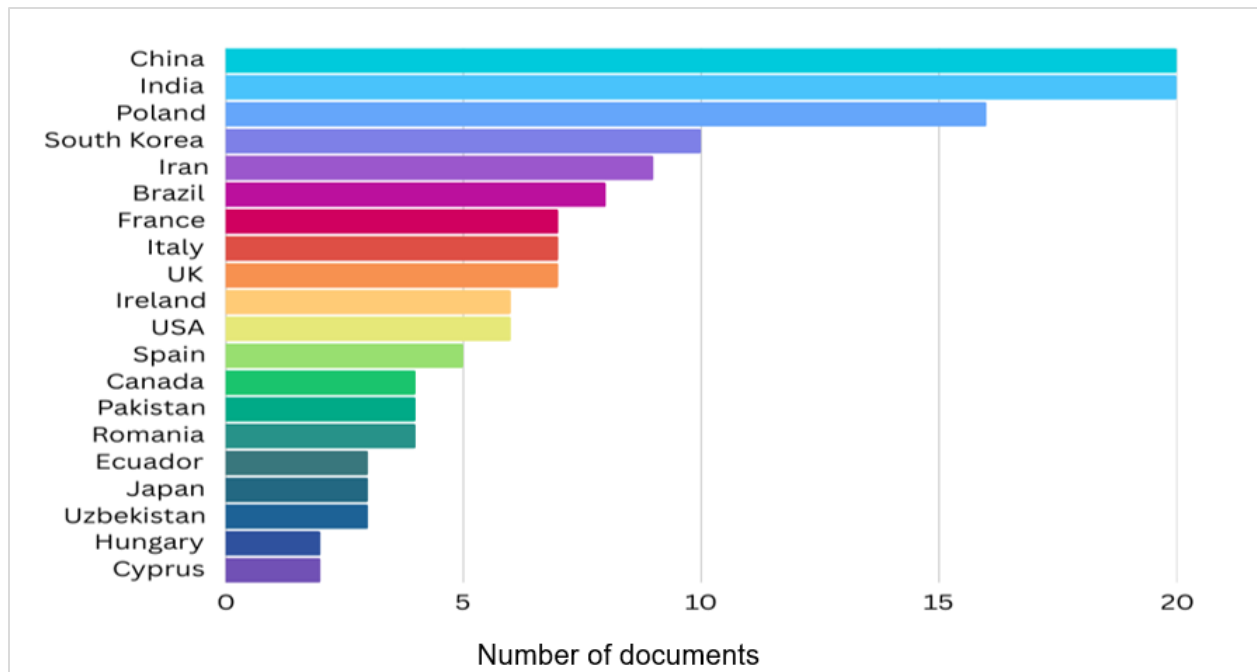


Figure 8. The top 20-most productive countries in the research area (2020-2022)

Source: Created by the authors (Pestisha et al., 2023)

The visualization of collaboration between countries is presented in Figure 9, where the size of the elements and the color of the nodes represent the number of publications produced by each country independently. Naturally, based on the presentation of the figure, different sizes are observed between the elements, those with a higher volume of publications are displayed through larger nodes. Such clustering illustrates patterns of collaboration between countries, thus influencing the development and dissemination of practices to the population.

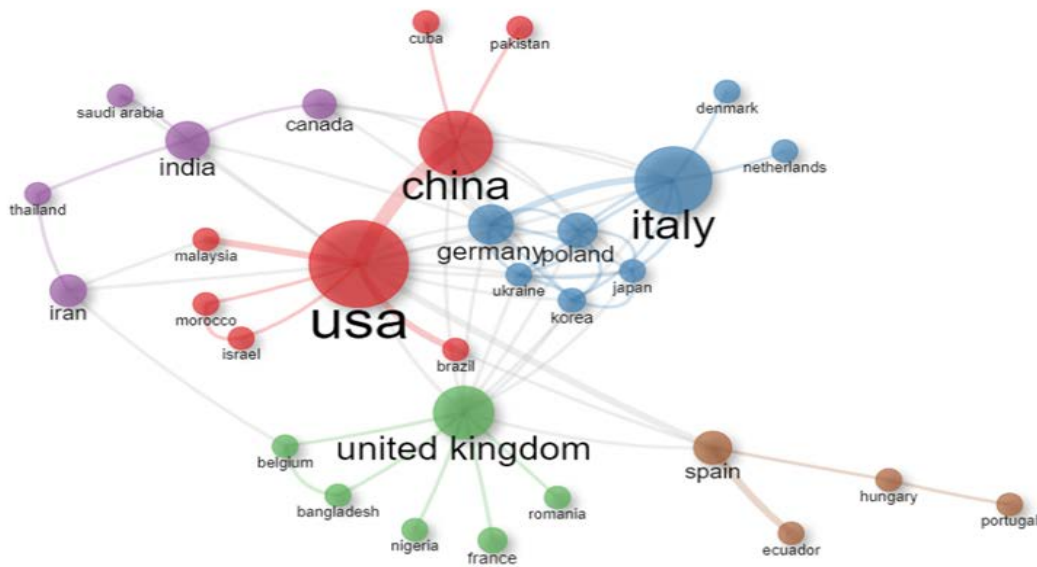


Figure 9. Countries collaboration network for the period 1988-2022

Source: Created by the authors (Pestisha et al., 2023)

The 31 elements shown in the figure represent the countries that are most involved in research within the framework of the selected keywords, which are categorized into five groups depending on their relationships with each other. The cooperation between them is presented through the width of the connections (the wider the connection, the greater the cooperation). Also, nodes that are of the same color have much stronger relative cooperation compared to other colors. Since traditional energy sources are showing predispositions to decrease day by day, renewable energy is attracting attention, influencing the cooperation between countries to find appropriate measures towards their application. This cooperation represents the importance that is given to the field for advancing research towards a cleaner future and identifying the challenges that are being addressed to energy.

The figure clarifies the fact that the USA, which according to the findings tops the table with the highest number of publications, maintains close collaborative relationships with China, which also tops the list. This research collaboration between them is also reflected in another study that highlights a strong collaboration between China and the USA (Hu et al., 2022). The cooperation between them can be attributed to the potential of these two countries towards renewable energy, based on their status as countries with the largest markets globally. Countries like Spain, the UK

and Italy also act as hubs for cooperation between countries, especially within Europe. On the other hand, India shows a willingness to cooperate with other countries outside its immediate region, creating relationships with countries around the world, serving as a model for international cooperation, partnerships and strategies in the RES field.

The frequency of keywords used has also been elaborated, which can be seen grouped in Figure 10. 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 10, 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.

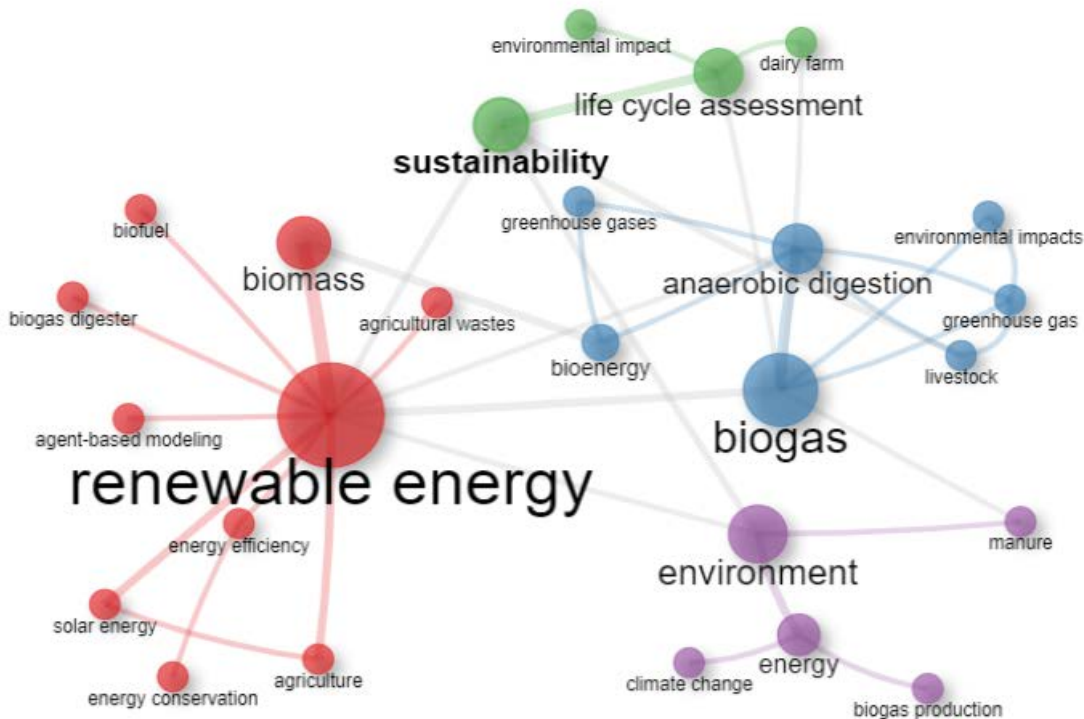


Figure 10. The keyword co-occurrence visualization network (1988-2022)

Source: Created by the authors (Pestisha et al., 2023)

The importance of biogas as an energy source is highlighted by the term "biogas" as the leader of the blue cluster, which represents a high focus within the dataset. On the other hand, the purple cluster, which is most closely identified with the environment, also includes keywords such as manure, climate change and energy, with a focus on sustainability and everyday environmental impact. In terms of keyword size, the green cluster is smaller, including only four keywords such as sustainability, environmental impact, dairy farm and life cycle assessment, which further overlaps with the blue cluster, with a stronger link to sustainability practices and biogas applications. This connection further helps understand that biogas is a key resource on the farm, with its positive effects on the environment. Biogas is a source known as clean energy or green energy, which is produced from by-products that are continuously generated, while also fulfilling an important aspect such as environmental friendliness and effective waste management practices. Biogas is also characterized by the term "anaerobic digestion", a term related to "bioenergy", raising its importance for research by researchers to a high level. Anaerobic digestion represents an important process according to Massé et al. (2011) (Massé et al., 2011), as it converts organic matter, especially animal manure, into biogas. The process, in addition to generating biogas, also produces biofertilizer, both of which are important parts of environmental sustainability. Through anaerobic digestion, the potential for reusing waste materials as valuable resources is increased, thus increasing the contribution to sustainable agricultural practices.

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, shown in the Figure 11. 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. Research under this topic is attributed to the growing concerns about the impact of the energy crisis, energy consumption, carbon emissions, and multiple climate changes. As a result, the need for more sustainable practices for greener energy that contribute to reducing environmental impacts is becoming more urgent. According to Kim and Park (2023) (Kim & Park, 2023) these emissions and changes in energy demand are affecting the replacement of fossil fuels, which are being replaced by renewable sources. This transition is driven by the urgent need to reduce the use and dependence on polluting fossil fuels that are contributing to climate change. To confirm this, more than 120 countries around

the world have adopted renewable energy production since 2000, as a response to climate change mitigation. This highlights the importance that countries are placing on sustainability and global climate strategies.

As shown in the Figure 11, the red cluster contains the majority of keywords, similar to the one shown in Figure 10, 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. In this regard, biomass is very important for its application as a source of heat production and plays a key role in the transition towards sustainable systems. While in the green cluster the main focus is on the environment and practices towards climate change, highlighting the focus on topics such as biomass, bioeconomy, sustainable development and efficient energy use, which have a primary role in addressing environmental challenges. The group also highlights the importance of the growth of the circular economy. The increasing number of publications in bibliometric databases attests to the growing interest in the principles of this field, such as waste reduction, their continued promotion and their long-term impact. This field continues to attract attention, and is considered essential for the search for appropriate environmentally-friendly economic models (Enric & Celma, 2020; Ranjbari et al., 2022; Sertolli et al., 2022).

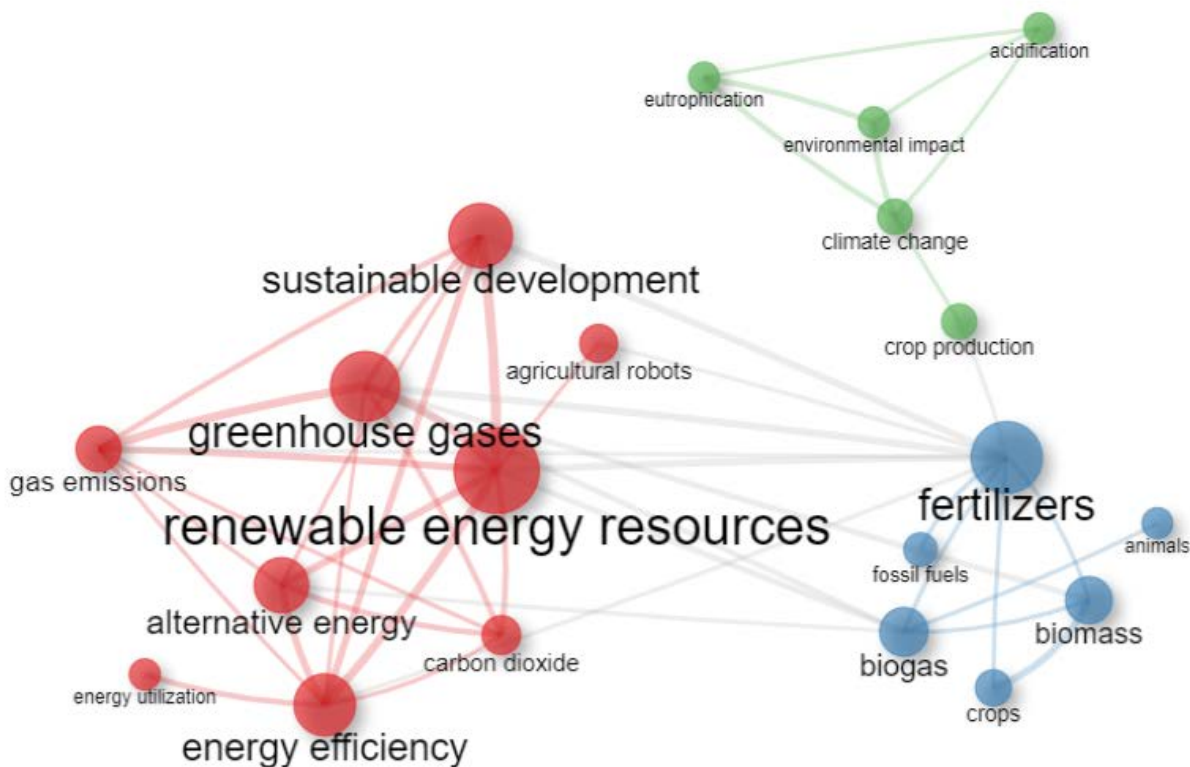


Figure 11. Keyword co-occurrence network (2019-2022)

Source: Created by the authors (Pestisha et al., 2023)

The following Figure 12 presents the conceptual structure of the publications related to renewable energy, which is illustrated by the four main themes that emerged from the analysis. The strategic diagram presented through the keyword map is represented by four interconnected circles: (i) biogas, further followed by (ii) bioenergy, (iii) environment and lastly by (iv) renewable energy. Within the conceptual framework, “biogas” is presented as the main theme, which encompasses the majority of research, serving as a key component within the RES energy sub-field. On the other hand, “renewable energy” is presented as a general theme, which encompasses the perspectives of bioenergy, environmental concerns, and biogas. Massé et al. (2011) (Massé et al., 2011) characterizes biogas as an excellent prospect compared to fossil fuels (oil, coal and natural gas) for the production of energy (electricity and heating). Similarly, both biogas and other renewable energy sources are important in the transition to low-carbon economies and in achieving climate

change resilience. As a result of biogas’s contribution to efficient clean energy production and greenhouse gas reduction, it plays a major role in agricultural sustainability.

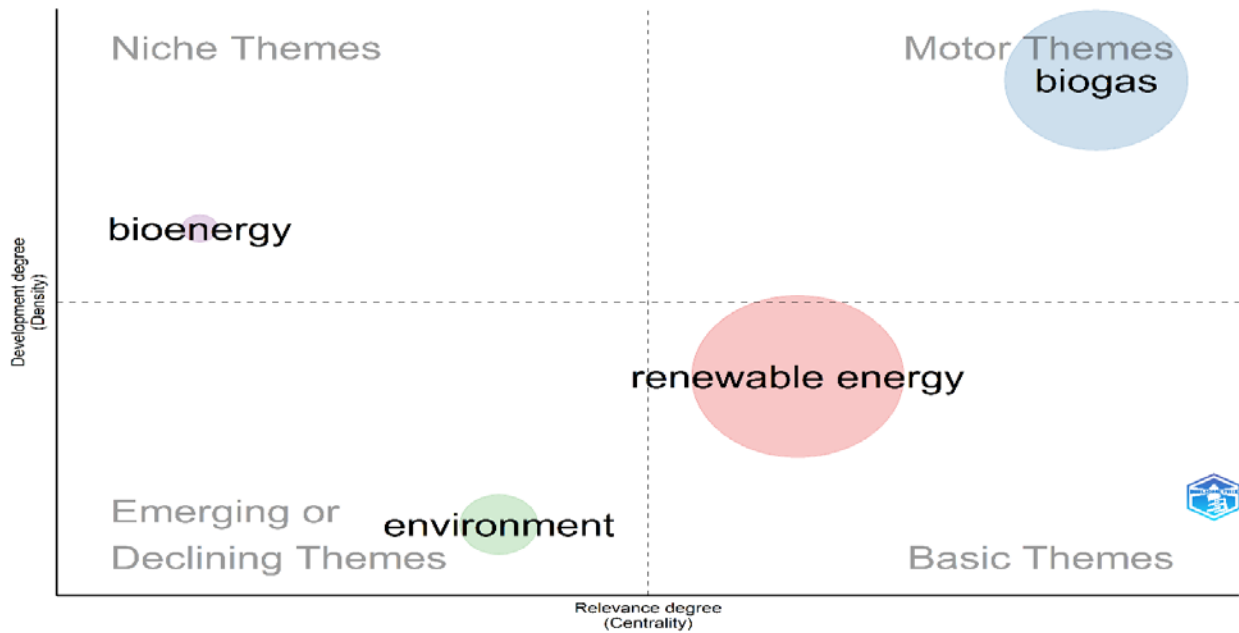


Figure 12. Thematic map (1988-2022)

Source: Created by the authors (Pestisha et al., 2023)

The strategic conceptual diagram has also been performed for the keywords for the period 2019-2022, with four interconnected circles that are characterized as the main themes in the RES framework, which are: (i) renewable energy resources and alternative energy, followed by (ii) crop production and environmental impact, (iii) greenhouse gas and cultivation and the fourth diagram (iv) renewable energies and fertilizer (Figure 13). All of the themes categorized in the diagrams represent important areas. The first circle highlights the importance of alternative energy sources, then the second circle focuses on the connection between environmental impacts and crop production, continuing with the third circle which shows the importance of greenhouse gas emissions and agricultural alternatives. Finally, the fourth circle presents a connection between renewable energy and fertilizers used in agriculture, reflecting the need for more appropriate practices related to resource efficiency, thus showing a more comprehensive view of the research landscape for RES and its integration in agriculture.

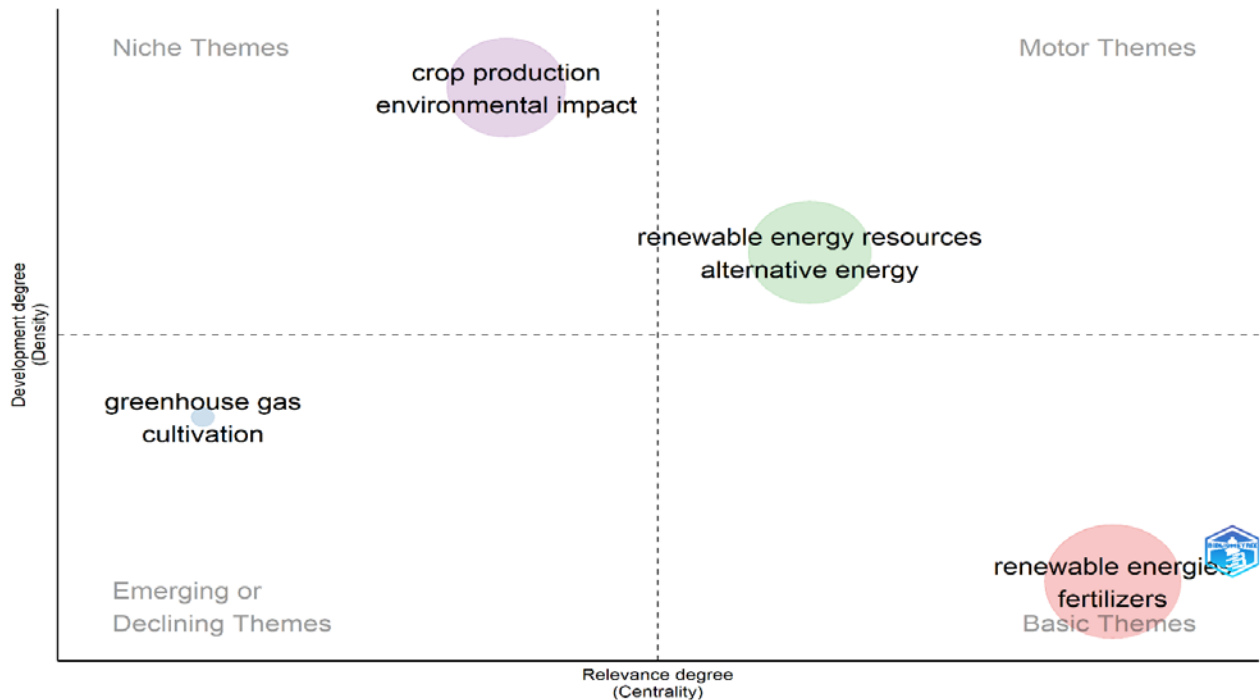


Figure 13. Visualization of the thematic map for the 2019-2022 period of time

Source: Created by the authors (Pestisha et al., 2023)

Agriculture is considered a sector that consumes significant amounts of energy and emits greenhouse gases, so the role of renewable energy is crucial as it provides access to energy even for farmers with limited access to the grid, presents income opportunities for farmers, and reduces health costs that result from fossil fuel combustion (Rahman et al., 2022). The acceptance of the integration of RES in agriculture differs between developed and developing countries. In developed countries, their involvement in agricultural practices is well adopted, with the application of solar, wind and biogas technologies, which offer more cost-effective solutions. Meanwhile, in developing countries this remains a challenge that needs to be analyzed and addressed, as such countries face obstacles such as economic and technical constraints that also affect the adoption of these technologies. With the potential to overcome these challenges, renewable energy would increase productivity, positively impact climate change, and improve the position of farmers in the production chain.

4.2. 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 14.

Table 14. 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)

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.

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. In the framework of the research, differences between socio-demographic variables that affect the knowledge of these resources were studied. Within the internet-oriented group, differences were observed in the variables of gender, education level and employment. Whereas in the case of farmers, there were no differences based on male and female gender, different age groups, level of education, type of profession and level of income, the only difference that had significant changes was environmental awareness ($\chi^2 = 47.07$, $df = 20$, $p = 0.001$). Within the employment variable, significant differences were observed in the internet-oriented group ($\chi^2 = 39.07$, $df = 20$, $p = 0.007$). Based on the data generated, students had heard more about RES, being more likely to be employed than unemployed. This implies that students are up to date with new knowledge during their studies and may be an important factor for future sustainability. The association between income and environmental awareness did not change in this context ($p > 0.05$). Furthermore, the gender factor was also investigated for both groups if they had heard about RES, in this analysis a significant difference was observed in the internet-oriented population ($\chi^2 = 30.11$, $df = 10$, $p = 0.001$). In comparisons made between the two groups, the male gender was in a much better position to recognize resources, especially biomass, biofuels, and geothermal energy. 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) (Table 15).

Table 15. Knowledge of population for the term “biomass” (N=243, N=30)

	Distribution of Responses	Internet-oriented population		Farmers	
		N	%	N	%
Have you heard about biomass?	Yes	112	46.1	23	76.7
	No	131	53.9	7	23.3
Biomass definition	Any kind of organic material	96	56.8	10	43.5
	Plant material	37	21.9	7	30.4
	Wood	2	1.2	1	4.3
	Herbaceous plant	3	1.8	1	4.3
	Not know/Not answer	31	18.3	4	17.4

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

In the context of solar collectors and the type of energy generated by them, most people identified them with solar panels (Figure 14). In this context, significant gender differences were observed in the internet-oriented population ($\chi^2=13.42$, $df=4$, $p=0.009$), higher knowledge was observed in males, while in the farmers group no gender differences were observed. Also in the internet-oriented population group, differences were observed in the environmental awareness factor, $\chi^2=27.05$, $df=16$, $p=0.04$. The difference between solar panels and solar collectors still remains unclear among the respondents, this can be improved through education and awareness in the environmental context.

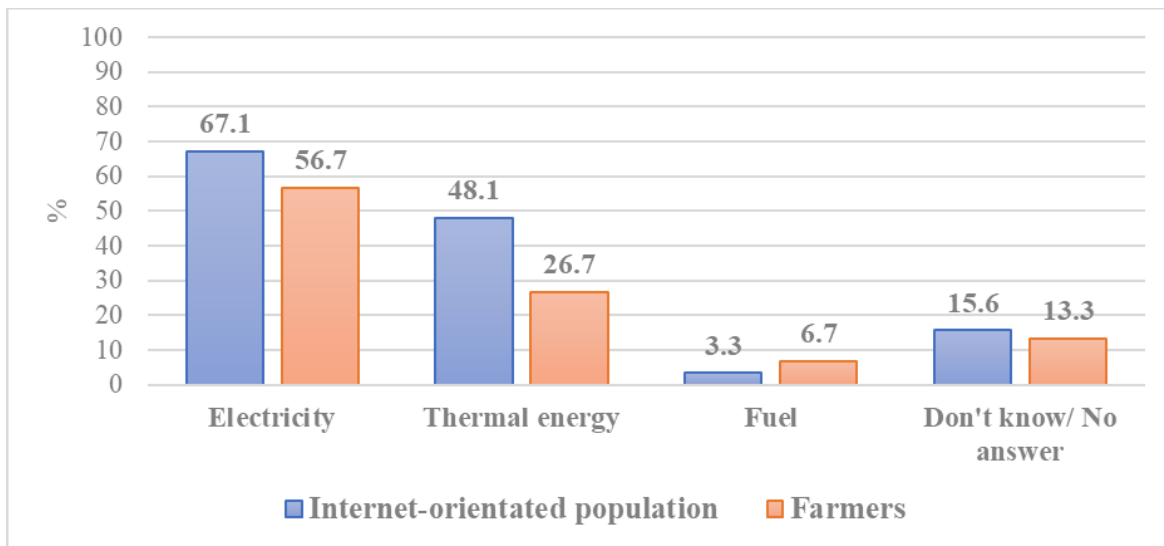


Figure 14. Knowledge assessment of internet-oriented population (N=243) and farmers (N=30) for type of energy generated by solar collectors

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

Furthermore, it is also investigated the knowledge about the form of energy that biogas can generate (Table 16), which is electricity, thermal energy and fuel. From the responses generated by the general population, fuel was selected as the most selected form of energy, followed by thermal energy and electricity. While from the group of farmers the most selected energy source that can be generated from biogas is electricity, followed by fuel and thermal energy.

Table 16. Knowledge of energy sources that can be generated by biogas (N=243, N=30)

Energy sources	Distribution of Responses			
	Internet-oriented population		Farmers	
	N	%	N	%
Electricity	66	27.2	20	66.7
Thermal energy	95	31.2	16	53.3
Fuel	130	53.5	19	63.3
Not know/Not answer	71	29.2	4	13.3

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

There were significant differences in the responses provided by the general population in terms of gender, where men had more accurate knowledge than women ($\chi^2=11.61$, $df=4$, $p=0.02$). Within the framework of the answers given by the internet-oriented population, there were no significant differences in terms of factors such as level of education, profession, environmental awareness and income ($p>0.05$). While within the group of farmers, differences were found in terms of education level, farmers with university education were more accurate, followed by those with high school ($\chi^2=15.51$, $df=8$, $p=0.05$).

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 40% of respondents from the internet-oriented group and the vast majority of farmers admitted that they would easily accept and use RES in their households and businesses (Table 17). 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.

The variables of gender, age, income level, education and environmental awareness did not present a significant factor in the use of RES within the two groups ($p>0.05$), except for the type of residence (apartment or house) which was a distinguishing factor within the general population

($\chi^2=34.26$, $df=6$, $p=0.000$). The use of wood and pellets is closely linked to the type of residence, in the case of the use of wood (63.7%) and wood pellets (37.3%), expressing higher levels of use by those living in houses compared to those living in apartments (33.3% for wood and 14.8% for wood pellets). In terms of environmental impact, 37.9% of those who were "very environmentally conscious" selected wood pellets and 30.4% of "mostly environmentally conscious" options.

Table 17. 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 the future		Use of RES		Would like to use it in the 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)

4.3. 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. All the factors listed in the SWOT table are elaborated below.

51. Geographic location

The geographical positioning of the country of Kosovo makes it a suitable place for the use and implementation of renewable energy sources, especially solar sources in the form of photovoltaics to a greater or lesser extent (Ministry of Economy, 2024). Furthermore, in terms of natural

resources, Kosovo is the second country in Europe and the fifth in the world that possesses geological reserves of lignite coal (Sertolli et al., 2023) especially considering its 12.5 billion tons of geological reserves of coal, or lignite. This is the reason why lignite is a competitive source of energy and a cheaper method of energy production compared to other alternative types. Kosovo is rich in geological terms, having a variety of metals and minerals deposited in its soil reserves, including gold, nickel, aluminum, chrome, copper, zinc and ferrous metals (Administration, 2024). All of these add value and make Kosovo a rich country as a result of its suitable geographical position.

S2. Ambitious targets to increase the share of renewables

The draft National Energy and Climate Plan of Kosovo aligns with the Energy Community's overall 2030 aim of attaining a 32% share of renewable energy in gross final energy consumption (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, 2023). The overall 2030 objective for renewable energy is made up of the sectoral targets for transportation (3.6%), heating and cooling (49.6%), and electricity (45%). Additionally, it is anticipated that 261 ktoe of power will come from renewable energy sources by 2030. The largest portion of these will come from wind energy (55%), followed by photovoltaics (32%), and hydropower (12%). Whereas, the installed power capacity generation is planned to be 59% for the 2030 year. The Energy Community forecasted that the installed capacity of the combined wind and PV will be approximately 1400 MWe by 2030 with a participation of 670 MWe from wind and 730 MWe from PV (Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, 2023). Biomass will remain the most widely used renewable energy source in the heating and cooling sector, with a 92% market share in 2030 and a continuously decreasing share to roughly 80% in 2040. Biofuels are not widely used in Kosovo, and it is expected that additional regulations will not promote their usage in the transportation sector. However, even if the transportation industry is not expected to reach the 10% renewable energy target by 2030, it is expected to see a large increase in electricity usage.

Two large lignite-burning thermal power plants, Kosovo A and Kosovo B, provide the majority of Kosovo's electricity, but the coal is of very low quality, and the consequences are serious (Pestisha & Bai, 2022). In addition, the two main lignite-fire power plants in Kosovo are very old and are causing severe air pollution and environmental problems. Nevertheless, with the recently approved

National Energy Strategy, the country has taken a big step toward a greater range of energy sources. At the moment, biomass is the primary heating source, whereas RES only makes up 6.3% of power (Ministry of Economy, 2021). Furthermore, the state's overall objective for energy efficiency is to limit final energy usage to 1877 ktoe by 2031, while increasing the share of renewable energy sources in power consumption to 35% by that same year.

S3. The legal framework is developed

In 2014, an additional assistance program was established to provide financial support for RES deployed in agricultural fields under the Ministry of Agriculture, Forestry, and Rural Development's annual Rural Development Program (Ministry of Economy, 2023). If RES is successfully implemented, farmers get 50–60% of the total investment returned. Between 2014 and 2021, 1,218 agricultural farms installed RES (mostly solar PV) with a total expected capacity of 4.19 MW. All of the electricity generated is used on the farms. Additionally, many years ago, the legal framework for the support mechanisms for additional renewable energy-producing capacity was established. One way that the Rule on Support Scheme promotes investments in renewable energy sources is through the Feed-in-Tariff Support Scheme, which is offered on a "first come, first serve" basis. It also allows potential investors to sell electricity based on a reference price set by ERO and to enter into a PPA with the market operator. Market-based conditions, such as obtaining the necessary legal authorizations and permissions about the technical, social, and environmental conditions, allow electricity to be sold directly to the market. For example, ERO decided to terminate the Feed-in-Tariff subsidy program for the development of new RES capacities in 2020, years later (Ministry of Economy, 2023).

W1. Insufficient technical expertise in various RES technologies

Kosovo lacks the expertise to oversee complicated initiatives in this area because it is a relatively young subject and there aren't many highly qualified professionals in it. Since the development of professional farmers has been impeded by the ongoing absence of investment in new energy technologies, training and information transfer are badly needed. This also applies to pertinent awareness-raising initiatives that try to alter consumers' views toward sustainable energy technologies, their behavior, and the criteria they use when making energy-related decisions. The integration of RES technology is a problematic issue because Kosovar farmers are characterized by several issues related to the structure of small farms, including limited access to the market,

unfriendly services, a lack of experience, poor education and training, a lack of technological knowledge, and, most importantly, a lack of coordination among smallholders (MAFRD, 2023b).

W2. Initial and installation costs

The majority of Kosovo's electricity comes from domestic, highly polluting, low-quality lignite. The population's inadequate financial means are one of the many obstacles impeding Kosovo's shift from power plant-based energy generation to renewable sources, which also affects farmers. Due to the high costs, farmers are less inclined to install RES equipment on their farms. According to farmer surveys of the article of Pestisha & Bai (Pestisha & Bai, 2022), farmers would prefer to use these energy sources in their operations, but the high cost of installation and purchase keeps them from doing so. Additionally, if the state offers them grants or subsidies, they will consider the benefits in this area and would lower their farm expenses.

W3. Land fragmentation

With a large number of small farms and a small number of large holdings, Kosovo's agricultural economy is fragmented. The agricultural sector in Kosovo is plagued by severe structural problems. These include land fragmentation, inefficient labor, and high production costs. Furthermore, Kosovo's farming sector is impacted by the country's highly fragmented territory. According to MAFRD data (MAFRD, 2015), farms usually consist of six to eight plots, most of which are relatively small. The efficiency of agricultural management and the rate at which agricultural machinery is used are directly correlated with the degree of land fragmentation, and both of these factors reduce the amount of land that is cultivated. Because of this, it is challenging to implement RES on farms, particularly agrivoltaics panels, because of the small and highly fragmented area.

W4. Insufficient collateral to qualify for small-project lending schemes

Agricultural loans will assist farmers in increasing their efforts to develop renewable technologies and instruments, which will impact their productivity growth, which will result from the farm's continued stability and expansion. Because agro-loans are known as non-performing loans, farmers who borrow from banks and microfinance institutions pay high charges (Ministry of Agriculture, 2020). The ability of farmers to secure loans, especially low-cost loans, is significantly impacted by the lack of an insurance program in agriculture. For the reasons

mentioned above, it is believed to be very difficult to get bank financing for agricultural projects due to the nature of the industry. This is also true for RES investments.

O1. The availability of resources that guarantee a continuous supply of heating and other energy forms

dependence on outdated lignite-based electrical generation capacity, which contributes significantly to local pollution and greenhouse gas (GHG) emissions and provides no flexibility or reliability. With only 6.3% of RES in the electrical sector coming from biomass-based sources, these sources currently make up the majority of renewable energy in the energy sector. According to Sertolli et al. 2023, (Sertolli et al., 2023), the overall biomass potential that can be exploited for energy purposes can exceed 33 PJ heating potential, whereas Kosovo's total primary energy consumption in 2022 was 116 PJ. Additionally, it might contribute approximately 28% of Kosovo's total energy usage, which is a very positive percentage.

O2. Energy and climate change

The combination of climate change and energy is one of the primary objectives of the European agenda for achieving sustainability. Concerns about climate change are the main driving force behind the EU Energy and Climate package, which lays out 2030 targets to reduce greenhouse gas (GHG) emissions by 55% from 1990 levels and ensure 40% of the EU's energy mix comes from renewable sources (European Commission, 2023b). Although Kosovo is a new nation engaged in renewable energy, it has surpassed its 2020 target of a 25% RES contribution (Ministry of Economy, 2021). However, there are significant differences in the sectoral RES shares and an unequal representation of the different RES technologies due to the widespread usage of wood biomass as a heating source in Kosovo (Pestisha & Bai, 2022). Furthermore, Kosovo aims to reduce greenhouse gas emissions from its power sector by at least 32% by 2031, have at least 35% of its electricity come from renewable sources, and build new RES capacities, such as 600 MWe of wind, 600 MWe of solar PV, 20 MWe of biomass, and at least 100 MWe of prosumer capacity, for a total installed RES capacity of 1600 MWe (Ministry of Economy, 2021).

O3. Reduction of the farm expenses as a result of reduced energy bills

When paired with energy conservation techniques, farmers can produce their own energy to become even more self-sufficient by reducing external inputs. The quantity of energy directly

utilized by the EU's agriculture and forestry industry in 2021 was 28.3 million tons of oil (eurostat, 2023). In addition to saving farmers money, renewable energy also lessens the effects of global warming. In terms of ecological agriculture, using renewable energy sources for agricultural tasks will improve environmental change, energy efficiency, and food security. Additionally, integrating renewable energy systems into agriculture can cut energy costs for rural communities by enhancing their resilience and self-sufficiency.

O4. Environmental eco-friendliness

Every industry must employ renewable energy sources since burning coal and other fossil fuels to meet energy demands pollutes the environment and has negative effects on people. Fossil fuels are a significant source of energy worldwide, but they also produce greenhouse gases (CO₂, SO₂, and NO_x), which are major pollutants. Therefore, the best course of action is to use a diversity of renewable energy sources. According to the article by Pestisha&Bai, (Pestisha & Bai, 2022) the respondents stated that when they buy energy equipment, they place a higher value on environmental friendliness.

TH1. An increase in capital costs and fuel prices on a worldwide scale

This inevitably leads to higher energy costs, which affect the entire economy, and uncertainty, which makes it more challenging to plan for the expansion of the energy industry. It is seen as a global threat, and the writers concur that less developed nations and farmers using antiquated farming methods are more significantly impacted.

TH2. An increase in capital costs and fuel prices on a worldwide scale

A step back in terms of knowledge in this field is caused by a lack of experience with renewable energy technologies. The readiness to implement any kind of RES technology on farms may be impacted by insufficient training and seminars. The lack of RES promotion in this industry is simply evidence of farmers' insufficient expertise. It may pose a threat by placing farmers at a competitive and agricultural diversification disadvantage. To highlight this element and its significance, policymakers and other stakeholders should take this as a kind of alert.

TH3. Insufficient local financial schemes for RES projects

In Kosovo, it is still uncommon to find commercial banks with specialized financing programs that support renewable energy projects with reduced service fees. Finally, the ministry has put in place a number of funding initiatives to support the installation of renewable energy, especially solar panels. Farmers may be encouraged and helped to integrate renewable energy sources into their operations as a result. These award programs would offer assistance at every level of development, from raising public awareness of the need for energy efficiency and renewable energy to the early phases of project preparation, information access, financing costs, and equity financing availability. It must also concentrate on making it easier for investors to access straightforward financing choices like soft loans.

TH4. RES systems with energy storage can be costly

Considering the high investment cost of batteries, energy storage is one of the most difficult issues (Ziegler et al., 2019). In addition, energy storage makes the integration of renewable energy sources more economical and reduces price volatility in the energy markets. Economic and financial barriers make the deployment of energy storage even more difficult. Farmers may find investments unappealing due to the ongoing uncertainty surrounding renewable energy projects and the energy sector in general. Innovation and more storage capacity are required to transition to a modern, decarbonized energy system.

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. The benefits and drawbacks of the energy mix paradigm have been identified using a variety of SWOT analyses as a methodological tool. Taiwan, South Korea, and Japan, for instance, have large renewable energy reserves, which emphasizes their ability to develop competence in renewable energy technologies, (Chen et al., 2014). This claim is based on their well-known position as significant manufacturers of cutting-edge technological products, including automobiles, electronics, machine tools, semiconductors, and integrated circuit (IC) goods. On the other hand, in their SWOT analysis, (Jaber et al., 2015), pointed out encouraging prospects for furthering renewable energy projects in Jordan. They did note several serious flaws, though, namely in

relation to the absence of funding options and the unpredictability of future electricity costs from renewable sources. The growth of renewable energy projects in Jordan has been hampered, in particular, by the absence of specific financing programs from commercial banks and the unpredictable nature of Feed-in-Tariff systems (Jaber et al., 2015). In a different study, (Qaiser, 2022) employed SWOT analysis to offer tactical suggestions for bolstering South Asian initiatives towards sustainable energy. The necessity of building strong transmission and distribution networks to link prospective renewable energy locations to the national grid is one of these proposals. In order to spur sectors growth, the research also recommends the use of green financing programs with lower interest rates and longer repayment terms. Crucially, incentives to promote self-generation of power and duty-free imports of renewable energy equipment are thought to be necessary to avoid interruptions in the municipal electricity supply.

Additionally, a SWOT analysis tailored to Pakistan's renewable energy industry was carried out by (Kamran et al., 2020), outlining both internal strengths and vulnerabilities. The abundance of renewable energy potential, verified resource mapping, environmental friendliness, and growing private sector investment are noteworthy strengths. On the other hand, internal limitations include ineffective technologies, high capital needs, a nascent institutional structure, and environmental risks related to specific technologies, all of which call for remediation efforts for sectoral improvement. Yu et. al., (Yu et al., 2022) conducted a thorough SWOT analysis in Madagascar that was enhanced by the use of a multi-criteria decision-making technique called the Analytic Hierarchy Process (AHP). The results highlight how important each component of the SWOT framework is. The following were the main ones that were found: a lack of knowledge about biomass briquettes, a lack of government support, political instability, societal acceptance of biomass briquettes, an excessive focus on alternative renewable energy sources, and current incentives that favor fossil fuels.

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. Table 18 below provides a summary of the primary obstacles preventing the local renewable energy sector from growing.

Table 18. 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 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.

4.4. BWS Scale of sustainability practices in Kosovar agriculture

This subchapter of results presents an important value in understanding farmers' motivations for adopting sustainable practices, which are essential for promoting agriculture that is environmentally friendly and contributes to a sustainable economic environment. This session will present the factors that influence farmers' decisions regarding the practice of sustainable energy practices on their farms and the preferences of farmers from seven regions of Kosovo. Based on the data listed in Table 19, there is an increase in awareness of the use of sustainable practices on farms, which influences eco-friendly behavior.

Table 19. Farmers' opinions towards sustainable practices in agriculture

<i>Denomination</i>	<i>Categories</i>	<i>Percentage (%)</i>
How do you prefer solar cells?	Moderately	5.8
	Very	9.2
	Extremely	85.0
How do you prefer by-products used for energy purposes (e.g. straw firing)?	Not at all	18.3
	Slightly	17.5
	Moderately	25.0
	Very	7.5
	Extremely	31.7
How do you prefer main products used for energy purposes (e.g. short rotation coppice for heat production)?	Not at all	5.0
	Slightly	15.8
	Moderately	27.5
	Very	13.3
	Extremely	38.3
In comparison with traditional energy, clean energy can improve the quality of life.	Likely	3.3
	Most likely	7.5
	Definitely	89.2
To what extent do you believe that improving energy efficiency practices (e.g., better insulation,	Slightly	1.7
	Moderately	4.2
	Very	8.3

energy-efficient equipment) can contribute to energy self-sufficiency on farms	Extremely	85.8
Government incentives and subsidies play a significant role in promoting the adoption of energy self-sufficient practices on farms	Not strongly agree	8.3
	Strongly agree	91.7
Importance of community collaboration and knowledge-sharing in promoting energy self-sufficiency initiatives among farmers	Not extremely important	5.0
	Extremely important	95.0
Investing in energy self-sufficiency measures enhances the overall competitiveness and viability of farms	Neutral	5.0
	Agree	11.7
	Strongly agree	83.3
Utilizing renewable energy sources such as solar and wind power is an effective way to reduce greenhouse gas emissions on farms	Neutral	8.3
	Agree	15.0
	Strongly agree	76.7
Indicate your perception of technical challenges, such as lack of expertise or knowledge, as barriers to the adoption of renewable energy technologies in agricultural operations	Important	6.7
	Extremely Important	93.3
	Mean	Standard Deviation
BWS Energy cost savings	1.24	0.73
BWS Available byproducts for energy purposes	-0.39	0.93
BWS Less energy costs	2.31	1.13
BWS Environmental-friendliness	1.88	0.98
BWS Convenience	-2.14	1.02
BWS Investment cost	-1.27	1.17
BWS Current energy costs	-1.63	0.83

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

With the global increase in environmental awareness, the attitudes of Kosovar farmers are also following the same trend, based on the Table 10, a 10% performance in terms of solar equipment involved in the energy generation of farms. This awareness, which is being realized progressively, has influenced farmers' mindsets for a more sustainable life, perspectives and sustainable farming methods. A portion of farmers have already embraced strategies towards a more sustainable climate. This important group of the community is being encouraged to re-evaluate traditional methods that undoubtedly cause damage to the environment and are trying to perceive more deeply the methods that are positively influencing an ecological balance, thus influencing the increase in environmental awareness. All these positive changes are presented in Table 19.

The following sections will reveal in detail the descriptive statistics and the results achieved by BWS with the farmers who were part of the sample, understanding more broadly the actions of farmers and their responses to new energy practices that would affect the energy self-sufficiency of the farm, which would affect a more balanced environment. The main goal of the effect of sustainable agriculture and the importance that farmers attach to sustainability through their activity.

4.4.1. Kosovar farmers' attitude towards renewable energy practices

As shown in Figure 15, 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. The remaining 9% expressed a "very" preference and a favorable opinion of this equipment. Overall, the findings suggest that farmers have a positive preference for solar energy techniques, demonstrating a significant change in their perspectives and a growing understanding of the advantages of this energy source. The encouraging change is consistent with a German study's findings, which showed that 74.8% of respondents think agrivoltaics might contribute to Germany's energy production (Wagner et al., 2024). This demonstrates the growing consensus regarding the potential of agrivoltaics to deliver sustainable energy solutions. The positive outlook in both countries highlights the increasing use of innovative, dual-use land-use technology that supports renewable energy goals while simultaneously increasing agricultural productivity. However, 72.4% of those surveyed say they are generally amenable to using technology on their farms. This suggests that although agrivoltaics' promise is widely acknowledged, individual

technology adoption still requires careful consideration, most likely due to implementation and cost concerns.

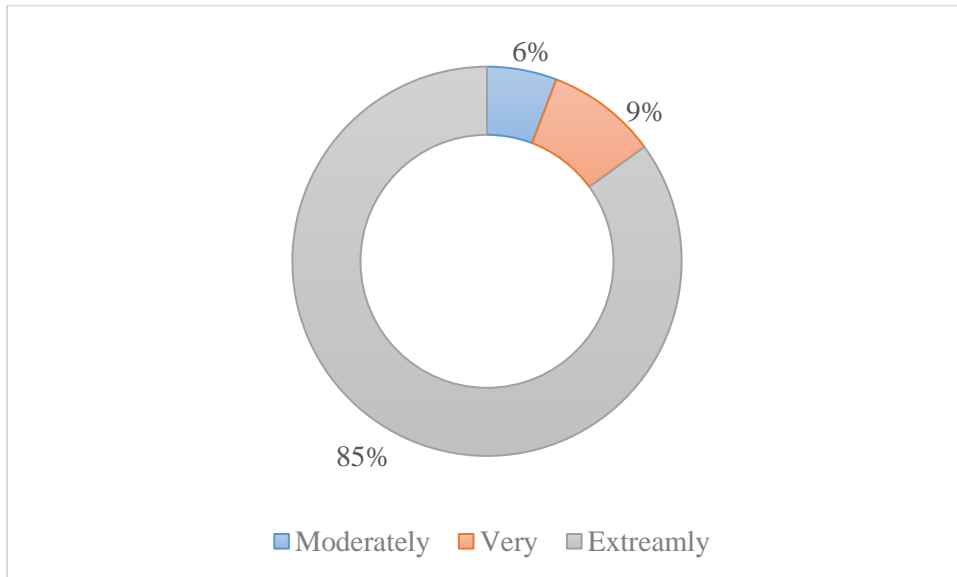


Figure 15. The opinion of farmers for the question: How do you prefer solar panels?

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

Although solar panels are preferred by farmers, their use on farms is actually very limited. According to the responses from the questionnaire, ninety percent of the farmers 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. However, the farm position can be improved in terms of cost, sufficiency, and environmental friendliness with the aid of government incentives, educational background, and other equipment developments.

There are a variety of viewpoints regarding the use of by-products for energy, but Figure 16 demonstrates that 32% of farmers strongly favor this practice as a group that also wishes to reduce farm waste and promote energy sustainability. With ratings of "extremely", "very" and "moderately" 64% of the farmers gave a positive reaction, indicating a strong trend toward cost savings, environmental effect, and energy efficiency.

There is some skepticism, too, as 18% of respondents expressed hesitancy, indicating some uncertainty about the usefulness of usage and a lack of appreciation for the byproducts (straw and stalks). The obstacles that farmers face when growing biomass for energy were covered in detail in a research (Thomson et al., 2024). Farmers' willingness to begin or increase biomass production for bioenergy is influenced by two types of factors: situational (like market conditions, infrastructure, environmental conditions, institutional frameworks, and legal settings) and personal (like attitudes, values, habits, and needs).

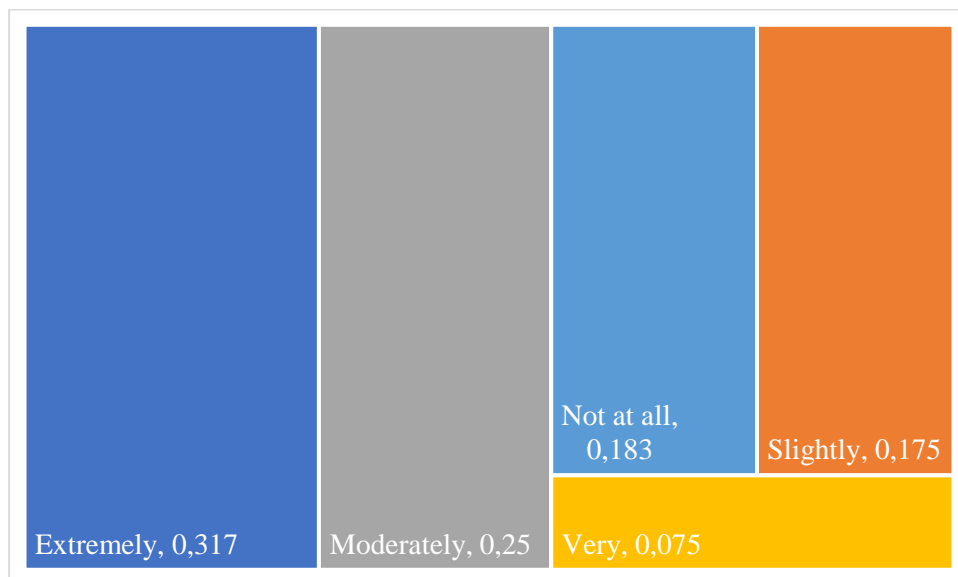


Figure 16. The opinion of farmers for the question: How do you prefer by-products to be used for energy purposes (e.g. straw firing)?

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

This positive attitude of farmers shows that they clearly understand how important renewable energy is in the fight against climate change. Farmers have a key role in pursuing best practices that help reduce the consequences of climate change on a global scale. By using byproducts, farmers may accomplish their sustainability goals, cut down on food waste, lessen air pollution from burning straws, and lessen their carbon impact.

Furthermore, there is a noticeable level of awareness and agreement about the fact that clean energy can raise living standards when compared to conventional sources. This is supported by the respondents' 100% positive sentiments, of which 89.2% stated that clean energy "definitely"

improves the quality of life, resulting in health and environmental benefits. Just 10.8% of respondents expressed some hesitancy about this phrase; 7.5% selected "most likely," while 3.3% selected "likely," indicating some hesitancy about the advantages of clean energy over conventional sources. Participants perceive this shift as a critical step toward a more sustainable and financially secure future and support cleaner energy methods. With respect to this the Hypothesis 1 (H1) is accepted, **increasing energy self-sufficiency on farms across Kosovo significantly contributes to improving energy access, farm stability, and rural diversification.** Environmental restrictions and value perception have a major impact on farmers' adoption of renewable energy alternatives. Environmental constraints combined with government incentives and laws create a system that incentivizes farmers to switch to more sustainable energy practices. These regulations, which sometimes involve financial incentives or penalties, often force farmers toward cleaner alternatives in an attempt to comply with environmental standards and avoid difficulty (Yin et al., 2024). Nonetheless, farmers' judgments of value also play a role in their choices. As more farmers learn about the long-term benefits, such as reduced energy costs and better environmental stewardship, they are more likely to embrace sustainable energy technologies. One thing that characterizes and influences the inclusion of renewable energy on farms is the farmers' beliefs that the investment will be profitable and have a positive impact on the surrounding environment. The combination of favorable changes in the perception of renewable energy and regulatory pressure significantly increases adoption among farmers.

Regarding the topic of government support in the form of grants and subsidies (Figure 17), 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. According to a study conducted two years ago by the authors (Pestisha & Bai, 2022), the high cost of installing energy-efficient equipment is also a barrier, which explains why there is little investment in alternative energy sources. The paper by Ek et al., 2024 (Thomson et al., 2024) also demonstrates support for subsidies, highlighting the potential significance of subsidies in increasing demand and assisting farmers in transitioning to a market that incorporates these alternative energy sources. By providing financial assistance, subsidies lower the costs associated with introducing new crops or technology, facilitating farmers' economic diversification. The acquisition of infrastructure and

equipment required to construct energy systems or other advanced farming methods may also be partially covered by these incentives. Without this funding, many farmers could be reluctant to make the initial investments needed for such changes. In addition to their financial effects, subsidies also affect farmers' attitudes and willingness to adopt new crops or techniques.

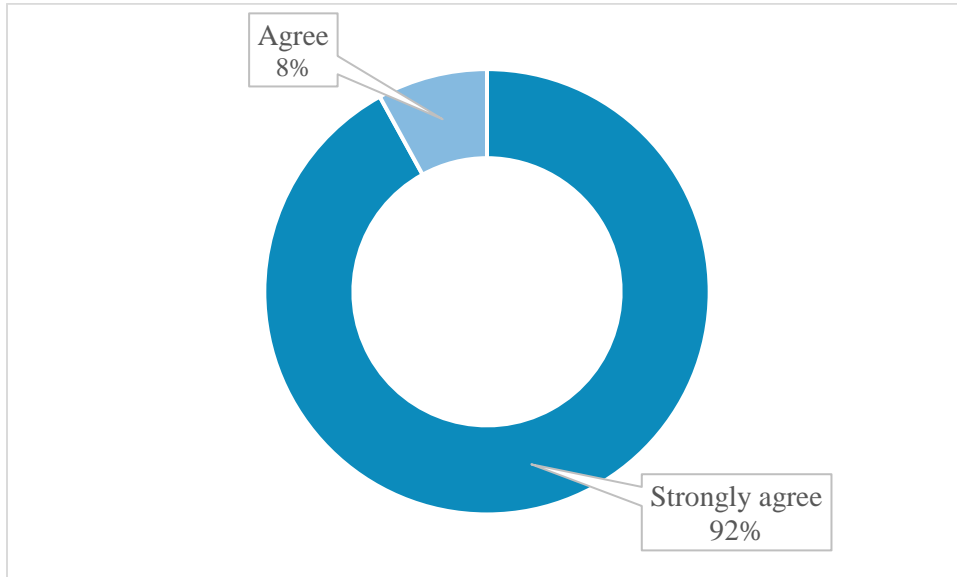


Figure 17. Farmers' perspective on the matter: Government subsidies and incentives are crucial in encouraging farms to implement suitable energy techniques.

Source: Author's own construction through Datawrapper (Pestisha et al., 2025)

Energy-related challenges in farm operations are more common when government incentives are either absent or insufficient. Governments in resource-poor countries currently have to subsidize the higher cost of green energy technology, in contrast to resource-rich countries where consumers can afford pricey green energy (Elahi et al., 2022). The farm's management of energy production, self-sufficiency, and dependence on outside sources would all benefit from the assistance. Furthermore, a sizable portion of respondents believe that this assistance is a crucial tenet in persuading farmers to embrace sustainable energy for agricultural uses. The government may promote a more sustainable environment in the agriculture sector by keeping up its support for energy alternative activities that lead to energy self-sufficiency.

4.4.2. Best-Worst scale results

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.

Finding the Best-Worst Scaling (BWS) values is the main step in the data analysis process. This is achieved by distinguishing between the "most important" and "least important" components of each characteristic. By using this method, it was possible to investigate how each attribute was valued relative to the others. According to the research, only three of the seven attributes had negative BWS levels, while four of them had good evaluations. Participant ratings of these four criteria as "most important" consistently highlighted their relative significance when compared to the other attributes. Taking into consideration the sample size (120 participants) and the frequency with which each attribute appeared in the experimental design, the BWS values were standardized in the second stage of the research. The BWS values were divided by the number of participants and the frequency of presentation of each attribute to determine the standardized BWS values. To give a more realistic picture of the relative importance of each component, these standardized values were then ordered. Based on farmers' perceptions, this ranking technique made it possible to determine which features were most and least important. By computing the square root of the ratio, $\sqrt{\frac{\text{Best}}{\text{Worst}}}$, between the "most important" and "least important" cumulative data, the Best Ratio Scale was developed in the third phase of the analysis. The purpose of this phase was to standardize the data so that comparisons between the different attributes could be made with greater accuracy.

With the maximum cumulative value of 100%, "Less energy costs" was the attribute that scored the highest according to this formula and was thus positioned at the top of the scale. After that, all other characteristics were evaluated in relation to it. This method made it possible to determine which characteristics, when viewed in light of the most highly ranked component, were thought to be more or less significant.

The frequency distribution of the best and worst outcomes for each attribute is displayed in Table 20. 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 20. 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 authors (Pestisha et al., 2025)

Table 20 can infer from the data that respondents ranked "Less Energy Costs" as the most crucial consideration. This quality was valued more than others. "Environmental friendliness" and "energy cost savings," the second and third most significant attributes, came in close succession. These results show that respondents rated financial savings and environmental impact as highly significant, with no difference between the two. With a much lower BWS score of 12.26, "Available Byproducts" came in fourth place, suggesting that it was not as important as the top three criteria. This suggests that, even while byproducts are significant, they are outweighed by financial and environmental benefits when it comes to preferences for renewable energy.

Convenience, investment costs and current energy costs were the last three factors to obtain negative BWS scores, suggesting that respondents found them less important. A significant percentage of respondents chose these features as the least important, based on the negative BWS scores. Investment costs, convenience, and current energy costs were ranked as the most important

factors by only 2.86%, 2.74%, and 1.19% of respondents, respectively, demonstrating their relative importance in relation to the other variables.

The following figure simplifies the interpretation of feature rankings by showing the standardized BWS values for the different aspects as described by Cohen (2009). A clearer grasp of how each quality is assessed in terms of relative relevance is made possible by these standardized values. With a normalized value of 0.77, Figure 18, makes it evident that "Less Energy Costs" is the most important attribute and that respondents regard it highly. This suggests that while investigating renewable energy sources, farmers give priority to reducing energy costs. With a standardized score of 0.63, "Environmental Friendliness" follows, emphasizing the significance of environmental sustainability. Given that sustainable farming is crucial to producers' operationalization, maximum yields, and financial success, this is seen as a crucial quality for producing farmers (Vapa et al., 2023). Even if energy savings are more important, respondents still have serious concerns about it. Although financial savings are still important, they are not as important as the first two criteria, since "Energy Cost Savings" comes in third with a normalized value of 0.41. The least favored factors, with negative standardized values, are "Investment Costs" (-0.42), "Current Energy Costs" (-0.54), and "Convenience" (-0.71). These characteristics are less significant in farmers' decision-making processes; respondents said that cost savings and environmental friendliness are more significant considerations.

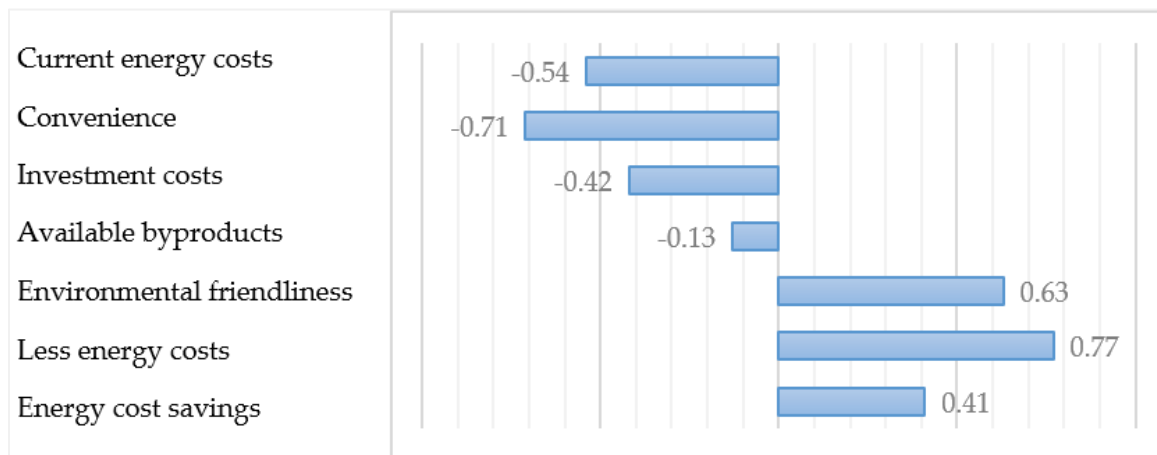


Figure 18. The standardized BWS values of the renewable energy aspects

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

Respondents' varying priorities for various aspects of renewable energy range from 3.1% to 100%, as shown in Figure 19. These differences unequivocally show that respondents give greater weight to particular factors when evaluating renewable energy sources. Important information on what drives farmers' desire for renewable energy can be gleaned from the notable differences in these values. For instance, "Energy Cost Savings," the attribute with the highest rating, has a noteworthy 100%, suggesting that respondents think it is the most relevant. Given that cost savings are a major factor in adoption, this emphasizes how crucial declining energy prices are to shifting public perceptions of renewable energy.

On the other hand, "Current Energy Costs" only received a rating of 3.1%, suggesting that other factors are more important. Even if they play a part in the broader conversation about energy use, respondents would rather focus on different aspects, such as environmental impacts and energy savings, than the current condition of energy prices.

These results demonstrate that farmers are more focused on the long-term advantages of renewable energy, particularly its capacity to reduce expenses and its impact on the environment than on the present state of energy prices. The broad range of the most and least necessary characteristics shows the different levels of importance given to each characteristic, providing a more complex picture of the renewable energy solutions that farmers choose.

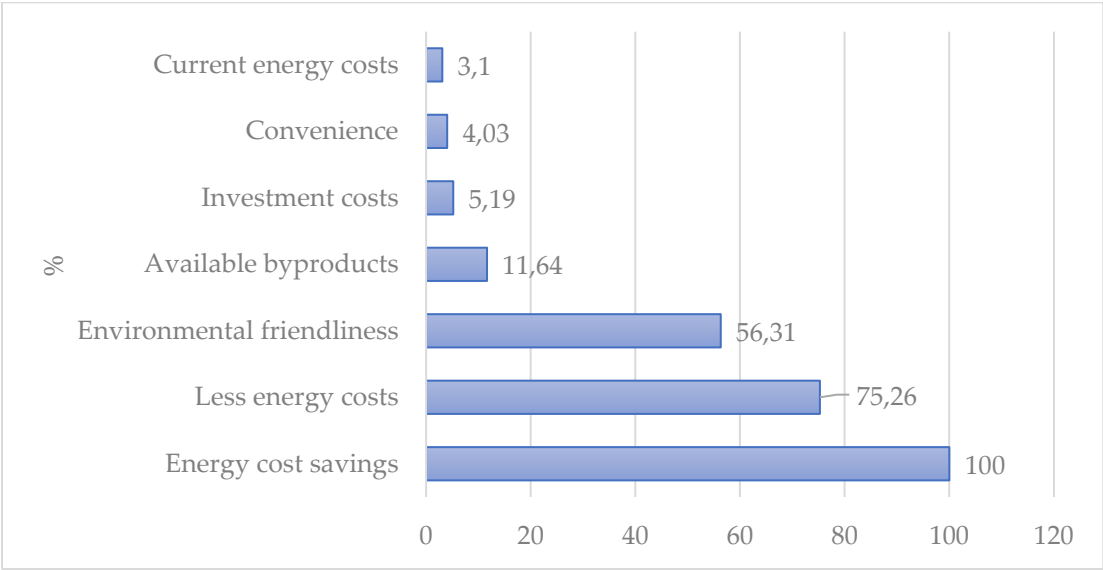


Figure 19. The standardized BWS values regarding the renewable energy aspects

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

It is noteworthy that the fourth-ranked component, "Available Byproducts" (11.64%), has less weight than the widely stressed feature, "Eco-friendliness," by more than five times. This significant discrepancy demonstrates how highly respondents regard environmental sustainability when weighing their options for renewable energy. The fact that eco-friendliness is preferred over other factors shows that environmental impact is the most essential factor, far outweighing factors like byproduct availability, which is ranked far lower in contrast. The results of the study by Batool et al. (Batool et al., 2024) confirm this; consumers' inclination to adopt renewable energy technology is influenced by several significant factors, particularly those that are reliable and reasonably priced. A strong belief system was found to have a very good effect on adoption. Customers who respect sustainability and environmental responsibility are more inclined to embrace renewable energy alternatives. These individuals usually view the use of such technologies as both a practical and an ethical commitment to the environment. Furthermore, the study concluded that environmental concerns were one of the primary reasons influencing adoption. As awareness of climate change and environmental degradation increases, consumers are increasingly likely to seek out renewable energy options as a way to reduce their carbon footprint and support global sustainability projects. Growing environmental consciousness has led to a greater acceptance of renewable energy as a viable and essential alternative to traditional energy sources.

The significant disparity between the highest and lowest priorities demonstrates how a variety of circumstances affect the decision-making process. For instance, "Current Energy Costs" has a rating that is more than 32 times lower than "Energy Cost Savings," making it the least relevant element. This discrepancy suggests that respondents are more worried about future savings from renewable energy than they are about the cost of energy today. It can also suggest that the accessibility and logistical limitations of renewable energy sources have been underestimated.

The average of the Best-Worst (BWS) values and their standard deviation were computed to gain a better grasp of the significance of the features under examination. While the standard deviation indicates the consistency or diversity of respondents' opinions across the sample, the average BWS value is a crucial indicator of the overall weight assigned to each aspect. According to the data, "Less Energy Costs" has the highest average value, suggesting that respondents value this attribute the most. The necessity for cost-effective energy solutions and the expanding global concern about

financial savings are reflected in the high average score. Reducing energy costs has become a major concern for many people as global energy prices continue to rise, making it a crucial consideration when choosing renewable energy sources. However, "Eco-friendliness" does not surpass "Less Energy Costs" in terms of overall value, despite appearing to be a significant component. Growing awareness of environmental issues and a need for sustainable energy sources are reflected in the significance of eco-friendliness.

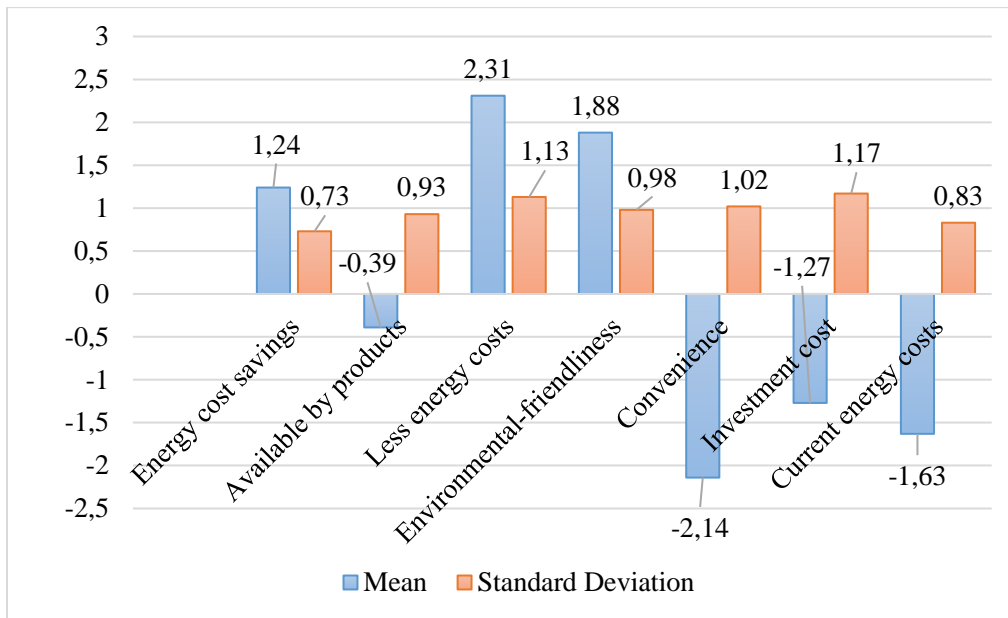


Figure 20. Two-dimensional plot of BWS values for standard deviation and means

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

In contrast, "Energy cost savings" has a medium average (1.24) and a moderate standard deviation (0.73), suggesting that respondents saw it as a moderately important feature (Figure 20), which is crucial when it comes to farmers' energy-related decisions. However, "byproduct availability," "investment costs," "current energy costs," and "convenience" all stay at low levels of average values and seem to have far less of an impact than the aforementioned elements. According to the Elahi study, the abundance of fossil fuels, a lack of financial resources, and the lack of knowledge of green energy technologies were the main reasons for the stated unwillingness to pay more for green energy (Elahi et al., 2022). The feature with the lowest average score, "Convenience," relates to how easy it is to maintain, operate, and implement. This low score is related to the fact that farmers place a higher value on lowering energy costs since they see it as a long-term energy solution.

4.4.3. The evaluation of cluster analysis results

The BWS statistical analysis is carried out in terms of cluster evaluation in order to determine the preference heterogeneity (Table 21). The results are crucial for comprehending the choices and obstacles farmers have when implementing energy self-sufficiency options. Levene's test and T-tests, which aid in identifying group differences and comprehending the elements that impact the decision-making process, can be used to analyze the statistical data to arrive at these conclusions. For the seven attributes taken into consideration, the authors employed non-hierarchical clustering with Best-Worst values. To capture the underlying patterns in the data, the experiment with many cluster solutions produced the ideal number of clusters. 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 21. 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. Nonetheless, the average unit's moderate score of 1.30 suggests that while it is still taken into consideration, it is not seen as a critical attribute. 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 ($t=5.24$, $p<0.001$). Because they work on a larger scale and produce more byproducts which is typically sufficient to fuel a farm-size straw boiler larger farmers are perceived as a group that is more interested in using agricultural by-products, such as straw and biomass from leftovers. For farmers who have fewer livestock, this is especially true. This favorable view on byproducts shows a deep understanding of ecologically friendly farming practices. "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. Due to this characteristics the Hypothesis 4 (H4) is accepted, **energy self-sufficiency is perceived differently between farm sizes, based on different attributes.**

Both groups, however, placed less weight on the characteristics of "convenience" and "investment costs," as evidenced by their negative values for these attributes (-2.41 for small farmers and -0.14 for medium-to-larger farmers) and investment costs (-1.14 for small farmers and -2.21 for medium-to-larger farmers), which indicate that these factors have very little influence on the choices made during the energy process. However, the t-test results indicate that these traits are not a high determinant in terms of decision-making like energy cost reductions and environmental friendliness, even though they are statistically significant (convenience $t=11.04$, $p<0.001$; investment costs $t=3.37$, $p=0.001$). This suggests that farmers, particularly those in the "Medium to larger farmers" group, are thinking about the possibilities of employing alternative energy to cut costs and improve the environment.

"Medium to larger farmers" have a substantially greater average capacity of 16.4 kW when it comes to the solar panel capacity utilized on farms, compared to the other group, which has a rate of 3.2 kWh. Analysis of the t-test results ($t=1.81$, $p=0.091$) reveals a trend that larger farms are more likely to invest in solar panels for energy generation, but it does not statistically show a significant difference at the 0.05 trust level. Solar energy is a solution for larger farmers because they have greater financial resources and utilize more energy. A statistically insignificant difference ($p=0.184$) exists between the two groups in terms of power use. The fact that small farmers spend and use more power (46.88 euros per month) suggests that they are more resilient to conventional energy sources. Conversely, farm characteristics indicate that medium-sized to bigger farmers are large operators, with an average of 46 cows, 27.79 hectares of land used for maize cultivation, and 10.17 hectares used for wheat. The average small farmer, on the other hand, has 16 cows and cultivates 4.58 hectares of maize and 4.11 hectares of wheat. According to these findings, "Medium to larger farmers" are more likely to adopt energy-efficient techniques, and these two characteristics may influence how much energy farms use and how much money they invest in renewable energy technology. Last but not least, the amount of land used for maize production differed significantly ($p=0.036$) between the two groups, indicating that land usage influences the adoption of renewable energy solutions, with larger farms demonstrating a greater potential for this implementation.

Different statistical assessments of the replies of the farmers from the two clusters "small farmers" and "medium to larger farmers" in terms of age, gender, agricultural methods, government incentives, and energy use are displayed in Table 22. 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.

The "Small farmers" group expressed a significant desire for lowering operating expenses, with a particular emphasis on energy cost savings. However, as previously said, "Small Farmers" were more eager to prioritize energy cost savings than other traits, indicating that their willingness to reduce energy expenses scored higher significantly ($t=2.53$, $p=0.013$). Medium-sized to bigger farmers were more likely to choose the utilization of byproducts for energy generation and the trait of environmental friendliness.

Table 22. Clusters description according to different factors II

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

**Different letters show significant differences (a' represent significantly larger value)

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

With an average environmental friendliness score of 2.93, medium-to-larger farmers placed a high value on sustainable practices and considered renewable energy to be a crucial instrument for reducing their carbon footprint. Additionally, they gave byproducts for energy purposes a much higher ranking than other groups, indicating that they are open to incorporating agricultural waste, leftovers, straw, and biomass into energy production ($t=5.24$, $p<0.001$), which may indicate that they are seeking long-term sustainability objectives. According to a chi-square test ($\chi^2=11.64$, $p=0.001$), "small farmers" (99 out of 108) did not use solar panels, whereas Medium to Larger farmers (5 out of 7) did. The latter group also demonstrated a greater capacity and greater interest in integrating this equipment into their farms.

Additionally, as a measure of preventing environmental harm, "Medium to larger farmers" were more optimistic about the decrease in greenhouse gas emissions brought on by renewable energy ($U=525$, $p=0.016$). However, according to the Mann-Whitney U test ($U=372$, $p<0.001$), "Medium to larger farmers" ran noticeably larger farms (mean rank of 86.93 versus 57.01 for Small Farmers). This suggests that whereas other groups are in a better position in this regard, "small farmers" are affected by various constraints in terms of land size and financial resources. The article by Frantal & Prousek (Frantál & Prousek, 2016) concluded that the adoption of energy-related activities is positively connected with both business size and the extent of cultivated land. Larger farms can invest in energy technologies, pay for beginning costs, and benefit from financial incentives since they have more financial resources. Because they may incorporate energy production into agricultural operations and leverage their size for commercial viability, larger land firms are also more likely to adopt renewable energy solutions. Interestingly, when asked about community collaboration, both clusters strongly agreed that it is essential to the energy transition; 94% of small farmers and 100% of medium-to-larger farms evaluated it as extremely important ($\chi^2=0.834$, $p=0.361$). This alignment highlights the mutual understanding that cooperation is necessary for the effective deployment of renewable energy systems and energy-efficient practices. 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.

4.5. 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 23. 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/m ²
Wood stove efficiency	82	%
Average area	120	m ²
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 23 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 24). 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 24. 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.

Table 25. Area, production and yield of cereals and straw in Kosovo

Year	Cereals production			Straw production 1:2
	Thousand ha	Thousand t	t/ha	t/ha
2018	123869	441757	3.6	1.8
2019	124199	459404	3.7	1.8
2020	124714	529112	4.2	2.1
2021	124477	504371	4.1	2.0
2022	124618	518724	4.2	2.1

Source: (MAFRD, 2023c)

According to Table 25 the average straw yield per hectare in Kosovo is 2 tonne whereas the standard deviation is 15%. Taking into account that 10.5 tonnes are needed to use for heating from straw (10.5 t / 2 t), the amount of straw necessary to cover the heat demand of a family house can be produced on 5.25 ha and above. The area of agricultural land in Kosovo is 420,482 ha, while

cereals in 2022 occupied 29.6% of this area. Furthermore, the overall yield of straw varies based on several factors such as climatic conditions, soil quality, and the crop grown. Also very important is the practicality of using straw for heating, the requirement for efficient use of the material. The continued use of straw for heating can also have an impact on the environment, as a result of the lower use of fossil fuels. The latter is not only based on sustainability but also helps promote diversified energy security, as an effort for local approaches to addressing climate change and energy consumption. The total cost of energy from straw is 262.20 euros/year, being considered a relatively cheap energy source.

As it was discussed above family energy needs can be met with 5.25 ha cultivated with winter wheat. If this amount of straw were used only for energy needs, then this cultivation area would be ideal, but in agriculture, it is possible to carry out other activities that require the application of straw. Straw is a versatile resource and is most commonly used in animal bedding as a moisture-absorbing material for a healthier environment for animals. In addition, straw is easily composted, presenting an advantage for the environment and livestock waste management. Straw can also be used as a plant mulch, being spread over the soil as a cover to maintain soil structure, fertility, and moisture. This is considered an organic benefit that improves soil health and adds organic matter as it decomposes. Another practice of using straw is also for greenhouse heating, as a biofuel that releases heat after combustion. This method reduces dependence on fossil fuels and at the same time reduces operating costs. This resource is easily accessible, and instead of being thrown away or left to decompose naturally, it can positively impact farm income.

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/m² is usually used, while in our case it was calculated with a heating capacity of 175 W/m² (Tégla, 2015). Table 26 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 26. 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

The area needed to be cultivated with winter wheat in order to meet the heating needs of a greenhouse is shown in Table 27. The results show that 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 the crop rotation, 2.43 hectares must be cultivated 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. An important issue to be considered is the crop rotation process that affects soil health, improving yields and significantly reducing the presence of pests while nourishing the soil. If the crop rotation is also considered, then a total of 48.61 hectares will be needed to be cultivated.

Table 27. Area in need to produce straw for greenhouse heating purposes

Size (ha)	Annual straw consumption (t/year)	Area (ha)	In case of crop rotation
0.5	2.43	1.22	2.43
1	4.86	2.43	4.86
3	14.58	7.29	14.58
5	24.31	12.15	24.31
10	48.61	24.31	48.61

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 28, 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 28. 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.

4.5.1. Sensitivity analysis results

As a result of the sensitivity analysis provided in the Table 29, the relationship between the number of cows, the area needed to produce straw and the amount of animal consumed has been examined, always taking into account the crop rotation (2 years). The scenarios provided are "Zero cows", "20 cows" and "270 cows". The reasons why these values of the number of cows were chosen are to understand the need for straw taking into account the factors mentioned above, among others, the reason for choosing the number of 20 cows is that in the questionnaire conducted for the

research, the average number of cows from 120 farmers was 20, while the highest number of cows that a farmer has bred is 270, therefore it is set as the highest value of scenario 3.

Scenario 1, as can be seen from the number of cows, therefore in this case the consumption of straw for bedding needs on the farm is zero, suggesting that the consumption of straw on the farm is directly related to the number of cows on the farm. With the increase in the number of cows to 20, then the requirements for straw for bedding, which keeps the cows cleaner and provides them with more comfort, in this case 26 hectares are needed for straw production to meet the needs, always taking into account the crop rotation period. The area needed for straw production is always proportional to the number of cows. While scenario 3 offers another picture of the situation when the number of cows increases to 270, then the consumption of straw normally increases as a result of the higher demand considering the number of cows, which in this case results in 351 tons, and the area that offers this yield is also 351 hectares considering the ration 1:2 and crop rotation. This process of straw cultivation also attaches importance to efficient land management practices and crop rotation, which benefits the sustainability of the land and production.

Table 29. Sensitivity analysis of cow heads in straw consumption

Scenario	Straw Consumption (tons/year)	Area for Straw Production (ha)	Area for Straw Production (ha) (considering crop rotation)
Zero cows	0	0	0
20 cows	26	13	26
270 cows	351	175.5	351

Source: Author's own calculations

Table 30 presents a detailed comparison of the seven different scenarios considered in the research, depending on the identification of straw needs, combinations of straw needs for bedding, heating, land area cultivated with winter wheat and the absence or presence of greenhouses and animals on the farm. In the sensitivity analysis, two types of farmers, small and medium-sized farmers, have been included to analyze as realistically and as comprehensively as possible. By combining and comparing livestock and greenhouse sizes, farm operations and the consumption of necessary resources, such as straw, are better understood, and the impact on total demand for it and for heating.

In the case of scenario 1, small farmers who do not have animals and greenhouses, but are only engaged in grain production, then these farmers have either the opportunity to sell the straw produced or use it for additional heating. For the latter, the area cultivated with grains should be 10.5 hectares, taking into account the crop rotation factor. This represents an option that uses very few resources and with relatively low heating costs.

In the second case, when farmers are engaged in animal breeding but do not cultivate crops in the fields, the situation is different in the case of straw demand and its operationalization. In this case, the farm consumes straw based on the number of cows. In the case of small farms, the smallest number of cows that are bred is one, so in this case there is always used this value in order to make the presentation as realistic as possible. The amount that a cow needs for straw for bedding is 1.3 tons. Also, 10.5 tons are needed for heating the farmer's house, and considering the crop rotation process, in order to fulfill all of this in total there is a need for a land cultivation area of 11.8 hectares. Normally, the number of cows must always be taken into account, so the demand for straw increases proportionally with the number of animals.

Scenario 3 presents the case where farmers also raise livestock and cultivate a greenhouse of 0.5 ha (the smallest size set in the calculation, as smallholder farmers are often unable to cultivate larger greenhouse areas). In the case of straw consumption for greenhouse heating, home heating and bedding, 15 tons of straw are needed, since the crop rotation is considered. In this way, the total area in need for cultivation is 15 hectares. The third scenario increases the costs compared to the previous two scenarios, as a result of the higher demand for straw.

On the other hand, a comparison between small and medium-sized farmers was carried out through a sensitivity analysis to investigate how sensitive both parties are to straw consumption depending on their needs. In Scenario 4, the farm is of similar function to Scenario 1 (without livestock and greenhouses), but is larger. In total, the area dedicated to heating the farmer's house and crop rotation should be 10.5 hectares cultivated with cereals. At this level, this type of operation is not complex and requires relatively few resources.

In the case of Scenario 5, farmers who have animals but no greenhouses have a higher demand for straw compared to Scenario 4, requiring a larger area for straw production, with a share of 36.5 hectares. This scenario presents a more challenging option in terms of securing the necessary

amount of land for cereal cultivation, leading to higher costs due to the higher number of cows and straw costs.

While in the context of scenario 6 (farmers with greenhouses and animals), they have even higher needs for heating and bedding, with an increase in the operationalization of farm resources, in this case the total area needed to provide straw is 39.7 hectares, always taking into account the needs for home heating and crop rotation.

In scenario 7, farmers have no animals but only a greenhouse, while the usable land for this aspect is 13.7 hectares. Even though animals are not present, the greenhouse and heating the house require a significant amount of operational resources.

Table 30. Best case scenarios for the usage of straw

Scenario	Straw Consumption for Bedding (tons)	Straw Consumption for Heating (Greenhouse)	Cereal Production Area (ha)	Total Area Needed (ha)	Land Needed for Straw Production (ha)	Heating Costs	Straw Costs
1. Small Farmer, No Animals, No Greenhouse	0 tons	0 tons	Based on cereal demand	10.5	10.5	Family house	Heating of the family house
2. Small Farmer, With Animals, No Greenhouse	1.3 tons/cow x # of cows	0 tons	Based on cereal demand	11.8	11.8	Family house	Heating of the family house + Bedding
3. Small Farmer, With Animals, With Greenhouse	1.3 tons/cow x # of cows	6.40 ton/year (including crop rotation)	Based on cereal demand	15.0	15.0	Family house + Greenhouse heating	Heating of the family and greenhouse + Bedding
4. Middle-Sized Farmer, No Animals, No Greenhouse	0 tons	0 tons	Based on cereal demand (larger area)	10.5	10.5	Family house	Heating of the family house
5. Middle-Sized Farmer, With Animals, No Greenhouse	1.3 tons/cow x # of cows	0 tons	Larger area for cereals	36.5	36.5	Family house	Heating of the family house + Bedding
6. Middle-Sized Farmer, With Animals, With Greenhouse	1.3 tons/cow x # of cows	6.40 ton/year (including crop rotation)	Larger area for cereals	39.7	39.7	Family house + Greenhouse heating	Heating of the family and greenhouse + Bedding
7. Middle-Sized Farmer, Without Animals, With Greenhouse	0 tons	6.40 ton/year (including crop rotation)	Larger area for cereals	13.7	13.7	Family house + Greenhouse heating	Heating of the family and the Greenhouse

Source: Author's own results

Another 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 31 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. 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.

With a straw price of €0.02/kg, the cost of heating with this heat source is €64.02, while in terms of savings compared to the cost of using wood is €10.4, resulting in an extremely economical choice for heating. While in the case of wood the cost is significantly higher, with a participation of €24.5, compared to the costs of straw for 0.5-hectare of greenhouse at a value of €0.025/kg there are savings of €144.48/kg. This is a reflection of the situation that its low price is more economical compared to wood. While with the price of straw increasing by €0.025/kg, the cost increases to €80.03, the savings still remain significant compared to the €194.4 cost of wood for heating. The cost of wood is also increasing with the price increase to €5/m³, resulting in €274.4. This implies that there is an increase in proportion depending on the decrease or increase in the price of the heating source, thus changing the price trends since a small increase in the price of straw can reduce the overall savings when compared to wood. In the context of scenario 3, the difference comes and is even more pronounced. However, although the savings of straw are smaller, it still remains a cheap option compared to wood, as a viable alternative for heating which results in more economic viability.

The sensitivity analysis overall highlights the aspect of how changes in the price of straw can also impact heating costs and savings. 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, furthermore, the Hypothesis 3 (H3) is accepted, confirming that **straw is a more economical source for energy production than wood.**

Table 31. Best scenarios for straw price

Straw Price (€/kg)	Heating Cost with Straw (€)	Savings with Straw (€)	Wood Price (€/m ³)	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

In order to analyze the sensitivity of different types of farmers, several different scenarios have been carried out as in the Table 32, focusing on the presence and number of animals, greenhouses, land requirements and straw consumption, as well as straw heating costs, not taking into the consideration the use of straw for house heating purposes. The table presents six scenarios, from those with few cows and small greenhouses to medium-sized farmers with more advanced cultivation operations.

Table 32. Best scenarios for farmer types in Kosovo

Scenario	Straw Price (EUR/kg)	Total Straw Consumption (tons/year)	Area Needed for Straw Production (ha)	Heating Cost with Straw (EUR/year)
Small farmer (5 cows without a greenhouse)	0.025	6.5	6.5	162.5
Small farmer (5 cows and a greenhouse of 0.5 ha)	0.025	9.70	9.7	242.5
Small farmer (0.5 ha greenhouse and no cows)	0.025	3.20	3.2	80.0
A medium-sized farmer (20 cows and no greenhouse)	0.025	26	26.0	650
A medium-sized farmer (20 cows and a 0.5 ha greenhouse)	0.025	29.20	29.2	730.03
A medium-sized farmer (0.5 ha greenhouse and no cows)	0.025	3.20	3.2	80.03

Source: Author's own calculations

In the case of the first scenario (small farmer with 5 cows) who does not cultivate crops in greenhouses, with an average straw price of 0.025 EUR/kg, the total straw consumption for this size is 6.5 tons per year while the surface area that needs to be cultivated to meet the needs is 6.5 hectares, also considering crop rotation. From this scenario can be concluded that small farmers have moderate needs for straw for the purpose of bedding and heating, but it is manageable.

In the case of the second scenario, where in addition to 5 cows the farmer also cultivates a 0.5-hectare greenhouse, straw consumption increases, necessitating an increase in the area cultivated with winter wheat. The amount of straw needed is 9.7 tons per year and the area needed, including crop rotation, is 9.7 hectares, while the cost of straw increases to 242.5 euros per year. This implies that with the inclusion of the greenhouse in the energy needs and use of straw, its cost increases as well as the area needed for cultivation.

In the other case, where the farmer only has a 0.5-hectare greenhouse, while not breeding animals, straw consumption drops significantly, requiring only 3.2 tons of straw per year, while the cost of heating through straw is reduced by 80 euros. This implies that the consumption of bedding is quite high and has costs. With a reduced consumption of straw, the farmer can also have lower costs, which represents a more economical option than the higher requirements for animals.

In the case of medium-sized farmers, resource supply demands are higher due to operationalization. In the case of a farmer with 20 cows who does not have a greenhouse, the straw consumption is only based on the bedding aspect and is 26 tons per year, with a similar cultivation area, while the straw costs are 650 euros per year. At this point, the analysis makes it clear that with the increase in the number of livestock, the demand for straw is high, being considered a more intensive and more costly resource depending on the number of heads bred.

On the other hand, when the average farmer, in addition to 20 cows, also has a greenhouse of 0.5-hectare, he faces even greater demands for straw, which increases from 20 tons to 29.2 tons per year, while the cost of straw is around 730 euros per year, as a result of the combined needs for animal shelters and greenhouse heating. Of course, such a scenario presents a complexity of farm operationalization, which requires not only more land for straw production but also a higher cost of heating due to the increased demand for straw. Meanwhile, in the case of scenario six, when the medium-sized farmer has only one greenhouse operating with a size of 0.5-hectare, he has the

same needs and requirements for straw as the small farmer with the same size of greenhouse, illustrating that the lack of livestock significantly reduces the demands for straw and straw costs.

5. CONCLUSIONS AND RECOMMENDATIONS

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.

5.1. Bibliometrics analysis

Approximately one-third of the world's energy production is being consumed by the agri-food chain. Sustainable development and the use of agricultural energy resources are related. Compared to traditional agriculture, modern agriculture demands significantly higher energy input. Additionally, encouraging the use of renewable energy in the agriculture sector can help mitigate the effects of climate change. This article emphasized the significance and contribution of publications over the years in light of the use of resilient and sustainable renewable energy in agriculture.

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 recession. 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. Italy, the Netherlands, Thailand, and Turkey. It showed that both developed and developing nations in Europe and Asia had shown an early interest in this area of research, while China, a developed nation, began to pay greater attention as a result of the Chinese government's carbon peak and neutrality targets. Furthermore, a review of the keywords for the 2019–2022 timeframe reveals that research on topics like "sustainable development," "greenhouse gases," and "renewable energy resources" is becoming more and more important. Extreme crises (such as the conflict in Ukraine and COVID-19) have

led to a greater focus on producing green energy from renewable natural resources and more opportunities for new energy policies and climate goals that use renewable energy sources rather than fossil fuels.

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. Regarding future directions, it can be said that various methods of producing and using biogas throughout the examined time period dominated publications and research activities; nevertheless, solar energy most likely has a lot of promise for both research and agricultural energy production. Although they are not very important, energy communities that include farms situated close to one another are present in the production of biogas and bioethanol; their expansion could assist maintain the added value of energy on farms. Agro-photovoltaic systems, which enable the simultaneous use of agricultural land for electricity and food production, are another emerging field. Because there are so many active research initiatives in this field without conclusive outcomes, there aren't many publications available.

The diversity of its issues is one of this research's weaknesses. Although it does not represent all of the subjects in the research field, the methodology consistently highlights the statistically most pertinent themes. Only looked at articles, books, book chapters, reviews, and conference papers were utilized in database. As a result, the outcomes may alter slightly if all of the documents in the research field are included. Another drawback is the absence of a different post that expounded on the identical keywords so that the outcomes could be compared.

Because of environmental sustainability, productivity, the thematic share of pertinent publications from countries during the selected period, and the co-occurrence of keywords in this regard, the results can help researchers and scholars understand the upward trends of the application of renewable energy in agriculture.

5.2. BWS scale evaluation

One important factor in achieving energy self-sufficiency on farms is the influence of social and cultural factors on farmers' opinions regarding renewable energy. In a field where traditional energy sources, such as wood and fossil fuels, have historically dominated, there may be a lack of awareness regarding the benefits of more recent renewable technology (Oryani et al., 2021). In addition to practical concerns like cost, reliability, and unfamiliarity with new technologies, cultural views may also have an impact on farmers' intentions to use renewable energy solutions. Overcoming these challenges requires farmers in educational programs that emphasize the social and communal facets of the energy transition. These trainings should focus on how local stakeholders, community involvement, and public policy support renewable energy initiatives. Farmers can take an active role in shaping their communities' energy futures and promoting the broader adoption of renewable technologies in the agriculture sector by fostering discussion on these topics and developing a better understanding of their shared accountability for advancing sustainable energy practices. In conclusion, the research's results offer a solid basis for a comparative examination of the significance of farm size in relation to locally accessible energy management.

Findings from our questionnaire indicate that farmers' preferences are heavily influenced by "less energy costs," which stands out as the most highly appreciated feature. Environmental concerns come in second, indicating a moderate balance between economic performance and sustainability. Furthermore, this result highly supports Hypothesis 2 (H2), according to this, the hypothesis is accepted and the author can state that **“Less energy costs” and “Environmental concerns” have the highest importance for farmers in the energy self-sufficiency practices, demonstrating a positive level of attitudes and preferences towards on-farm renewable energy.** As demonstrated by the overwhelming emphasis on sustainability and lower energy costs, people are willing to make compromises in other areas, like energy cost savings, to support the best practices in farm operation as they become more conscious of how their decisions affect the environment and profitability. Farmers had a favorable opinion of solar panels, preferred agricultural byproducts, the value of government subsidies, and the consideration of alternative energy sources as a clean practice.

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.

5.3. Economic calculations

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. Although the efficiency of the boiler is not very high at 82%, it is still more cost-effective compared to wood.

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.

On the other hand, the size of the farm and the scale of farming, whether small or medium, affect resource requirements and the magnitude of costs. In the case of farmers with a small number of cows or without a greenhouse, the consumption of straw and the cost of heating is much lower compared to medium-sized farmers who are characterized by more resource-intensive operations. As the farm grows, the need for better land management arises; crop rotation is very necessary for both types of farms and planning is extremely important in order to avoid unstable resources.

From the sensitivity analysis can be concluded that the importance of balanced livestock use, managing heating costs and sustainable land use in order to maintain cost-effective farming practices. For both types of farms (small and medium) it is extremely important to manage straw use, continuously monitor price fluctuations and the efficiency of agricultural operations. Farmers should always assess their ongoing needs and alternative feeding options in order to be more competitive in the market.

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.

6. NOVEL FINDINGS

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 €5/m³ 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.

7. 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.

Annex 1

Farmers' willingness toward energy self-sufficiency questionnaire

BWS Method

Final Likert Scale Questions

1. How do you prefer solar cells?

- a) Not at all
- b) Slightly
- c) Moderately
- d) Very
- e) Extremely

2. How do you prefer by-products use for energy purpose (e.g. straw firing)?

- a) Not at all
- b) Slightly
- c) Moderately
- d) Very
- e) Extremely

3. How do you prefer main-products use for energy purpose (e.g. short rotation coppice for heat production)?

- a) Not at all
- b) Slightly
- c) Moderately
- d) Very
- e) Extremely

4. In comparison with traditional energy, clean energy can improve quality of life.”

No=0, Somewhat=1, Likely=2, Most likely=3, Definitely=4

5. To what extent do you believe that improving energy efficiency practices (e.g., better insulation, energy-efficient equipment) can contribute to energy self-sufficiency on farms
 - a) Not at all
 - b) Slightly
 - c) Moderately
 - d) Very
 - e) Extremely

6. Indicate your agreement with the following statement: 'Government incentives and subsidies play a significant role in promoting the adoption of energy self-sufficient practices on farms.'
 - a) Strongly Disagree
 - b) Disagree
 - c) Neutral
 - d) Agree
 - e) Strongly Agree

7. Please rate the importance of community collaboration and knowledge-sharing in promoting energy self-sufficiency initiatives among farmers.
 - a) Not important
 - b) Slightly important
 - c) Moderately important
 - d) Very important
 - e) Extremely important

8. To what extent do you believe that improving energy efficiency practices (e.g., better insulation, energy-efficient equipment) can contribute to energy self-sufficiency on farms.
 - a) Not at all
 - b) Slightly
 - c) Moderately
 - d) Very
 - e) Extremely

9. Indicate your agreement with the following statement: 'Government incentives and subsidies play a significant role in promoting the adoption of energy self-sufficient practices on farms.

- a) Strongly Disagree
- b) Disagree
- c) Neutral
- d) Agree
- e) Strongly Agree

10. Please rate the importance of community collaboration and knowledge-sharing in promoting energy self-sufficiency initiatives among farmers.

- a) Not important
- b) Slightly important
- c) Moderately important
- d) Very important
- e) Extremely important

11. Please indicate your level of agreement with the statement: 'Investing in energy self-sufficiency measures enhances the overall competitiveness and viability of farms.

- a) Strongly Disagree
- b) Disagree
- c) Neutral
- d) Agree
- e) Strongly Agree

12. Please rate your level of agreement with the statement: 'Utilizing renewable energy sources such as solar and wind power is an effective way to reduce greenhouse gas emissions on farms.

- a) Strongly Disagree

- b) Disagree
- c) Neutral
- d) Agree
- e) Strongly Agree

13. Indicate your perception of technical challenges, such as lack of expertise or knowledge, as barriers to the adoption of renewable energy technologies in agricultural operations.

- a) Not a barrier at all
- b) Slight barrier
- c) Moderate barrier
- d) Significant barrier
- e) Very significant barrier

14. How much energy do you consume within your farm in a year, or how much money do you spend for heating and electricity in a year?

electricity:.....kWh/year, orEUR/year

firewood:.....t/year, orEUR/year

15. What type of farm do you have?

- a) Cattle farm without any crop production
- b) Crop production without any animal production
- c) Combined production

16. Gender:

- a) Female
- b) Male

17. What size of farm do you have?

- a) lower than 5-hectare
- b) 5-10 hectare
- c) above 10-hectare

18. Could you please give us your crop structure and number of animals?

Type of animal: number of animals:

Type of animal: number of animals:

Type of animal: number of animals:

Type of plants	Size (ha)
.....
.....
.....
.....

19. What do you do with the straw and stalk?

- a) Ploughing into the soil
- b) Burning on the site
- c) Heating
- d) Other (e.g. selling)

Please select the most and least important of the three attributes in each question!

Decision situation 1.

Most important	Attribute	Least important
	Investment cost (price of the equipment)	
	Energy cost savings	
	Current energy costs	

Decision situation 2.

Most important	Attribute	Least important
	Convenience (Easiest to use)	
	Available by-products for energy purpose	
	Current energy costs	

Decision situation 3.

Most important	Attribute	Least important
	Less energy costs	
	Energy cost savings	
	Available by-products for energy purpose	

Decision situation 4.

Most important	Attribute	Least important
	Less energy costs	
	Convenience (Easiest to use)	
	Investment cost (price of the equipment)	

Decision situation 5.

Most important	Attribute	Least important
	Environmental-friendliness	
	Less energy costs	
	Current energy costs	

Decision situation 6.

Most important	Attribute	Least important
	Environmental-friendliness	
	Investment cost (price of the equipment)	
	Available by-products for energy purposes	

Decision situation 7.

Most important	Attribute	Least important
	Environmental-friendliness	
	Convenience (Easiest to use)	
	Energy cost savings	

Annex 2

Farmers' and internet-oriented population preferences and attitudes for renewable energy in Kosovo

DEMOGRAPHIC VARIABLES

- 1. Gender of the respondent:** 1. Male 2. Female
- 2. How old are you?** years old
- 3. What is the highest level of education you completed?**
 1. Primary school 2. High school
 3. University studies 4. Postgraduate studies
- 4. Occupation:** 1. Student 2. Employed 3. Unemployed
- 5. How would you classify your family's monthly net income?**
 1. Can live on it very well and can also save
 2. Can live on it but can save little
 3. Just enough to live on but cannot save
 4. Sometimes cannot make ends meet
 5. Have regular daily financial problems
 6. DK/ DA (Don't know/ Don't apply)
- 6. How environmentally-conscious do you consider yourself?**
 1. Not environmentally-conscious at all 2. Mostly not environmentally-conscious
 3. Mostly environmentally-conscious 4. Very environmentally-conscious
 5. DK/ DA
- 7. The type of home you live in:**
 1. Home
 2. Flat
 3. Other
- 8. The size of your detached house/ flat:**
 1. Below 50 m² 2. 50-70 m² 3. 70-90 m²
 4. 90-120 m² 5. More than 120 m²

6. What can biogas be used for? (*Several answers can be marked*)

1. Electricity
2. Thermal energy
3. Fuel
4. DK/DA

7. Do you use renewable energy sources in your household?

1. Yes
2. No → IF "NO" GO TO QUESTION 9.

8. If you use any, which one(s)? (*Several answers can be marked*)

1. Solar panel
2. Windmill
3. Wood
4. Bio-briquette
5. Wood pellet
6. Other

9. If you do not use renewable energy, which one/which ones are you most interested in?

(Please choose a maximum of two of them)

1. Solar panel
2. Windmill
3. Heat pumps
4. Wood
5. Bio-briquette
6. Wood pellet
7. Other
8. None
9. DK/DA

10. What material do you use for heating? (*Several answers can be marked*)

1. Wood
2. Coal (lignite)
3. Wood and coal
4. Electricity
5. Wood pellet
6. Combustible waste
7. Other

11. How much does your family spend on heating a month in winter on average?

1. Below 15 €
2. 15-30 €
3. 30-45 €
4. 45-60 €
5. Above 60 €

12. What kind of aspects do you take into account concerning your energy consumption?

Please rank the aspects according to their importance. (*1= the most important, 2= important, 3= less important and 4=the least important*)

Cheap investment (e.g. boiler) _____

Cheap running costs _____

Convenience _____

Environmental aspects _____

13. Considering the aspects listed in question 12. give your opinion about the following energy sources.

Renewable energy equipment	Purchasing the renewable energy equipment		Running the renewable energy equipment					
	Cheap	Expensive	Cheap	Expensive	Convenient	Inconvenient	Environmentally-friendly	Pollutant
Solar panel	1	2	1	2	1	2	1	2
Windmill	1	2	1	2	1	2	1	2
Wood	1	2	1	2	1	2	1	2
Bio-briquette	1	2	1	2	1	2	1	2
Wood pellet	1	2	1	2	1	2	1	2

14. Please, use the scale below to mark which aspect is more important to you when purchasing the type of energy.

It is rather convenience that is crucial for me	1 – 2 – 3 – 4 – 5 – 6 – 7 – 8 – 9 – 10	It is rather eco-friendliness that is crucial for me
---	--	--

15. Do you have combustible waste of your own (wood, straw, other by-products)?

1. Yes 2. No → *IF “NO” THE QUESTIONNAIRE ENDS HERE!*

16. If you do, do you use them for heating?

1. Yes → *IF “YES” THE QUESTIONNAIRE ENDS HERE!* 2. No

17. If you don’t use them for heating, why do so?

1. Because I find it harmful to the environment. 2. Because I compost them.
 3. Because I put them in the waste collector. 4. Other

Annex 3

DEEP INTERVIEWS WITH FARMERS

- **Name of the farm or farmer** (if he/she is willing to give them):
 - **Farm size** (agricultural space (gold / hectares), crop production structure, type and number of main animals):
 - How many workers are employed:
 - Workers are from the farmer's family or with salary:
 - How much is the energy consumption on the farm (average figure):
1. What do you think about the use of renewable energy in agriculture?
 2. Have you seen renewable energy equipment?
 3. What is the main source of energy on your farm and why?
 4. Why (do not) use renewable energy sources?
 5. Why would you want to use renewable energy on your farm? For example: raw material, cheaper investments, more expensive coal price, state subsidies, training in this field?
 6. What do you use straw for?
 7. Do you know what biomass is? What do you think when you hear this word?
 8. Do you think there is a high cost of investing in renewable energy?
 9. What do you think about sustainable agriculture? Is it important to you on your farm?
 10. If there were opportunities for using renewable energy on your farm, which would you prefer?
Or surely you will not use any of them?
 11. What is most important to you in energy management: cheap cost, comfort, environmental characteristics? Why?

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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.

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