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BIOMASS POTENTIAL AND ITS PERSPECTIVES FOR HEAT USE IN KOSOVO

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BIOMASS POTENTIAL AND ITS PERSPECTIVES FOR HEAT USE IN KOSOVO

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Furthermore, I declare the following:

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- I handled the technical literature sources used in my dissertation fairly and I conformed to the provisions and stipulations related to the dissertation;
- I indicated the original source of other authors' unpublished thoughts and data in the references section in a complete and correct way in consideration of the prevailing copyright protection rules;
- No dissertation which is fully or partly identical to the present dissertation was submitted to any other university or doctoral school for the purpose of obtaining a PhD degree.

Debrecen, 24.05.2025

Ardit Sertolli

signature

LIST OF ABBREVIATIONS

ANOVA =Analysis of Variance
AU =Animal Unit
Bt =Billion Tonnes
BWS =Best-worst scaling
CH² =Pearson's chi-square test
CHp =Combined Heat and Power
CO_2 =Carbon dioxide
CSV =Comma-separated values file
DM =Dry material
EJ =Extra joules
EU =European Union
Eur =Euro
GDP =Gross Domestic Product
GHG =Greenhouse Gases
GPP =Green Price Programme
GWh =Gigawatt Hour
IEEFA =Institute for Energy Economics and Financial Analysis
IPA =Instrument for Pre-Accession Assistance
IRENA =International Renewable Energy Agency
KAS =Kosvo Agency of Statistics
KEEF =Kosovo Energy Efficiency Fund
KEPA =Kosovo Agency for Environmental Protection
kj/kg =Kilojoule per Kilogram
Ktoe =Kilotonnes of Oil Equivalent
LHW =Lower Heating Value
LHW =Lower Heating Value
LPG =Liquefied Petroleum Gas
MAFRD = Ministry of Agriculture and Rural Development
MESPI =Ministry of Environment, Spatial Planning and Infrastructure
Mt =Million Tonnes
Mtoe =Million Tonnes of Oil Equivalent
MW =Megawatt
MWh =Megawatt hour
NFI =National Forest Inventory
No =Number
PJ =Petajoule
RES =Renewable Energy Sources
SDG =Sustainable Development Goals
TJ =Terajoule
TWh =Terawatt hours
UN =United Nations
USA =United States of America

Table of contents

LIST OF ABBREVIATIONS I

INTRODUCTION 5

1. TOPICS AND OBJECTIVES 9

1.1. Aims of the research 9

1.1.1. The objectives and research questions 10

1.2. Research approach 12

1.3. Structure of the dissertation 13

1.4. Research Process – Flowchart 14

2. LITERATURE REVIEW 16

2.1. Terminology of biomass and sustainability 16

2.2. Biomass as a renewable resource 18

2.2.1. Biomass as key to sustainable energy and economy 20

2.3. The importance of agricultural biomass production 25

2.3.1. Agricultural biomass in the EU 28

2.3.2. The importance of cereal biomass in the EU 33

2.3.2. The importance of cereal biomass in Kosovo 34

2.4. Global potential, land use, and future prospects 36

2.5. Different case studies 39

2.6. Kosovo country 42

2.6.1. Introduction to Kosovo situation in general terms 42

2.6.2. Natural resources 46

2.6.3. Renewable energy potential in Kosovo 48

2.6.4. Potential of biomass 48

2.6.5. The situation of forest and wood industry residues 54

2.6.6. Solid waste management 55

2.6.7. The willingness of farmers to develop energy biomass market 56

2.7. Challenge and Opportunity 56

3. MATERIAL AND METHODS 58

3.1. METHODOLOGY 58

3.1.1. Primary and secondary sources 58

3.1.2. Estimation of potential 59
3.1.3. Analyses and interpretations 59
3.2. Applied methodology for VOSviewer 59
3.2.1. Methodological approach steps with VOSviewer 61
3.3. Approach for estimating biomass potential in Kosovo 61
3.3.1. The assessment of agricultural biomass potential 61
3.3.2. The assessment of livestock potential 62
3.3.3. The assessment of forest biomass potential 63
3.3.4. The assessment of solid waste potential 64
3.4. BWS method 64
3.4.1. BWS for preferences and renewable energy insights 64
3.4.2. Student attitudes and the role of BWS in renewable energy adoption 66
3.4.3. Statistical analysis to explore renewable energy preferences 69
3.4.4. Description of the sample of BWS 70
4. FINDINGS AND RESULTS 73
4.1. Biomass potential and utilization on world scale 73
4.1.1. Global collaboration and clustering in biomass research 74
4.1.2. Keyword analysis and clustering in biomass research using VOSviewer 75
4.1.3. The growing importance of biomass: potential and challenges 78
4.2. Theoretical energy biomass potential in Kosovo and its utilization 78
4.2.1. Agricultural biomass potential 80
4.2.2. Livestock potential and its utilization for energy 83
4.2.3. Forest biomass potential 87
4.2.4. Solid waste potential 89
4.2.5. Overall biomass production capacity in Kosovo 91
4.3. Biomass heat energy in Kosovo: prospects and environmental limits 92
4.3.1. Students' perspectives on renewable energy 94
4.3.2. Student’s perceptions of renewable energy attributes using BWS 99
4.3.3. Assessment of cluster analysis outcomes 102
4.3.4. Future steps, where should Kosovo focus 107
5. CONCLUSIONS AND RECOMMENDATIONS 108

6. NOVEL FINDINGS 115
7. SUMMARY 117
LIST OF PUBLICATIONS RELATED TO THE DISSERTATION 135
LIST OF TABLES 137
LIST OF FIGURES 138
APPENDICES 139

INTRODUCTION

The world is becoming overpopulated, the size of agricultural land is decreasing, and non-renewable sources are on the way to running out, meaning that the world will have the most difficult challenge in the near future. Furthermore, the effects of global warming have started to affect agriculture in general. From other perspectives, water and energy seem to be two main issues, starting from agriculture and involving all other sectors. These are the concerns from where the idea of the research originated. The research is planned to give a view of combining biomass, agriculture, and renewable energy sources, which is a great possible solution for these challenges. So renewable energy can manage global warming, reduce pollution that comes especially from central heating power plants, and mitigate dependence on different fossil fuels as is the case in Kosovo.

As a new and developing country, Kosovo needs to have a stable energy supply to provide adequate infrastructure and a safe environment for the development of all sectors. 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. According to the Ministry of Economic Development (Ministry of economic development of Kosovo, 2017), Kosovo has a wealth of natural resources, including geological coal reserves such as lignite, making it the second-largest lignite reserve in Europe and the fifth in the world. Right now the bulk of the energy supply is coming from Kosovo's two major coal-fired power facilities, unfortunately, they are obsolete, resulting in substantial air pollution and environmental issues. Due to its enormous lignite reserves, Kosovo has been mostly dependent on homegrown lignite, or low-grade coal, to supply its energy needs. For the past ten years, Kosovo's yearly lignite production has ranged between 7 to 9 million tons, roughly matching the country's yearly lignite demand. Due to their age, rigidity, and inefficiency, Kosovo's two lignite power plants contribute to severe load shedding and inadequate supply security (IEEFA, 2020).

Agriculture and energy are critical components of the country's GDP and employment (Ministry of environment and Spatial Planning of Kosovo, 2015). Furthermore, 129220 agricultural households (*ASK DATA - Select Table*, n.d.) take up 419 thousand hectares (ha) of agricultural land. In general, the sector is defined by small farms, and challenges such as fragmented agricultural lands, low efficiency, and insufficient infrastructure. Farms in Kosovo are characterized by an unfavorable structure that is fragmented into an average of seven plots, which poses a challenge to the productivity and agricultural efficiency of the farm, which makes it even more difficult to implement agricultural practices, affecting the sustainability of the farm (Miftari et al., 2015) Although Kosovo is not yet a member of the European Union, it is recognized by more than half of the world's countries. Kosovo is working toward the EU's clean energy production and supply targets. Renewable energy is not a new concept in Kosovo; it has been around for a long time, although production is still insignificant.

Based on current conditions and forecasting potentials in terms of biomass, its energy utilization may significantly improve farmers' incomes and decrease the unemployment rate in rural areas. In this regard, the final output would be what is the importance of biomass energy sources in Kosovo, what is the theoretical biomass potential, and which are the types of biomass available to be used for heating in practice. Biomass energy can be produced in any agricultural plant, in addition, Kosovo has adequate resources, all it needs is just the organizing of the efforts and long-term plans and projects to have a stable energy supply from renewable sources too.

Global energy consumption has increased continuously in recent decades, owing largely to economic development and the growing demands of a fast-expanding global population. As countries industrialize and urbanize, the demand for energy to power businesses, transportation, and homes grows (Shao, 2017). To address this increasing need, a variety of energy sources are being used, including fossil fuels, nuclear energy, and renewable resources. Fossil fuels, including coal, oil, and natural gas, currently account for the vast bulk of global energy use. Despite the environmental impacts such as greenhouse gas emissions and the effect of climate change, this source of energy is used widely and globally due to its low cost and availability. In contrast, their huge usage has created worse environmental issues and has encouraged the use of renewable energy sources.

Renewable energy sources (solar, wind, hydro and geothermal) are considered to be an alternative method to fossil fuels. Their positive environmental effects have created an opportunity to minimize the consequences of energy generation from traditional sources. However, some obstacles impact the acceptance and usage of these sources such as the storage of energy, integration in the grid system, and different expenses that are related to them (Alshahrani et al., 2019; Fernandez et al., 2024). Like nuclear energy offers low-carbon emissions, its implementation is limited by waste management, safety, and high prices. In this regard, many countries are doing research and development strategies to boost the efficiency and the costs related to them.

The shift towards a more sustainable energy structure is projected to be gradual but progressively, with technological innovation, different incentives, and cooperation between countries. Even though renewable energy sources are a transition to a greener landscape, fossil fuels continue to be an important component in the future of the energy mix.

According to EU data, 41.2% of the total consumption of electricity in 2022 in the European Union came from renewable energy sources, up from 37.5% in 2021 (eurostat, 2024). This percentage shows that countries are making progress in adopting renewable resources, as a result of a successful combination of advanced technologies, state policies, and regional cooperation toward the climate change targets. The commitment of the European Union countries to decarbonization and climate change has positively influenced the adoption of alternative sources, trying to reduce the concentration of fossil fuels and greenhouse gases. In the European Union, energy generated by wind and water has managed to provide two-thirds of electricity during 2022. This percentage shows that countries are making progress in adopting renewable resources, as a result of a proper combination of advanced technologies, state policies, and regional cooperation. The commitment of the European Union countries to decarbonization and climate change has positively influenced the adoption of alternative sources, trying to reduce the concentration of fossil fuels and greenhouse gases. In the European Union, energy generated by wind and water has managed to provide 2/3 of electricity during 2022. In this regard, wind energy has reached participation of 37.5%, because on-shore and off-shore farms are considered important results and there have been great investments. Wind energy production has achieved significant progress in many European countries in recent years, a result achieved due to different technological advances in the efficiency of wind turbines and thanks to regulatory frameworks that have supported energy production. On the other hand, hydropower, which had a share of 29.9% of the total energy generated, has presented an extremely stable and very important resource in the energy mix. This resource has been readily accepted as a source of energy in countries that have water resources such as Norway, Sweden and Austria. Compared to previous years, the intensity of hydropower development has faded since countries with greater economic capacities have developed well in this aspect. Despite this, hydropower is a sector that plays an important role in building the energy mix. In addition to these two aforementioned sources, solar energy and biomass occupy a crucial place in the energy generation of the European Union, however in a lower share. Solar energy has significantly increased its share as a result of advances in photovoltaic devices and a significant reduction in costs, thus creating efficiency. The challenge still lies in external factors such as climatic conditions and irregular production which in some way diminish its importance. In the statistics and data generated by the report, great importance is also given to biomass energy, especially by developed countries such as Finland and Sweden, as a reliable source of energy. The satisfactory participation of renewable energy in the energy mix of the European Union implies that these countries are following the most efficient and effective ways and methods in achieving the set targets that must be reached in 2050, with a clear trend toward reducing carbon emissions and climate neutrality. Since wind and water energy are the main ones, then a critical point of the major transition is energy conservation and proper network management. This performance and the path towards the integration of renewable sources shed light on sustainability, which paves the way for the EU to a greener and more efficient future.

One of the source that being considered a prominent and promising resource for the future is biomass. This energy source is considered to be carbon neutral since during various processes carbon is absorbed by plants. Furthermore, this form of energy has the potential for higher production, making it a suitable form for meeting the energy needs of the growing population. Various benefits, both environmental and capacities for reducing plant waste from agriculture add value to this source. The use of agricultural waste to create energy offers these entities to develop also in economic terms since in most cases waste (peels, stalks, crop residues) cannot be used and must be discarded. By transforming these by-products into different forms of energy, the development of a sustainable and efficient system will be achieved, which, through its participation in energy systems, will minimize pollution and at the same time, waste.

1. TOPICS AND OBJECTIVES

1.1. Aims of the research

The purpose of this study is to present the theoretical and practical potential of biomass use for energy purposes in Kosovo. In this regard, first of all, let's get deeper into the Kosovo case scenario. As for the year 2020, in Kosovo, 98% of electricity was produced from two out-of-date thermal power plants, which use lignite with poor quality parameters (caloric value of lignite is 7200 kJ/kg, (Lajqi et al., 2020). In addition, the energy system in Kosovo becomes more aggravated during the winter period due to the reliance on electricity for residential heating (Ministry of Economic Development of Kosovo, 2017). Based on the fact that Kosovo is considered to have polluted air, the main contributor to this issue is considered to be the thermal power plants that produce energy and use coal as fuel. Therefore, one objective that will be addressed in this topic is undoubtedly the attitudes of students, who are considered important actors in future decision-making at the national level. This is undoubtedly not only related to their attitudes, but also of course to their lifestyle. In this context, their attitudes provide a direct perspective of the future of how this sector will stand and the key changes or challenges. There is a lot of room for carbon dioxide reduction, its extent was estimated at 54%, by considering the maximum utilization of all types of renewables, starting with biomass, solar, and wind energies, comparing with the referent current scenario (Lajqi et al., 2020).

The government of Kosovo by the support scheme, through feed-in tariff for renewable energy sources was supporting the electricity produced from biomass as a renewable resource with a price of 71.3 Eur/MWh. In Kosovo was suggested an installation to generate electricity by biomass in the amount of 14 MW (Lajqi et al., 2020). However, this sector was not being seen with high interest from investors' point of view due to the high cost of installation technology and difficulties of the procedures that are needed for obtaining licenses. Regarding the biomass potential in Kosovo, forests have a sharing of 44.7% of the total land area, wherein 62% is classified as public forest and the rest part goes to private ownership (FAO, 2015). There are two main groups that are very suitable for the production of biomass in Kosovo, the first group includes cereals such as wheat, maize, oats, barley, and rye. While in the second group are plants that are harvested in green conditions such as hay, grass, green wheat, and green rye (Sahiti *et al.,* 2015), whereas the waste with origin from cereal that can be used for further processes for energy production ranges from

10-40%. It important to highlight what theoretical and technical biomass potential means, in this regard, theoretical biomass potential refers to the total quantity of biomass that can be produced (or formed) given physical and biological limits, whereas technical biomass potential refers to the fraction of the theoretical capacity that is attainable under certain technical parameters associated with the existing technology (Gonzalez-Salazar et al., 2014; Silván-Hernández et al., 2017). A report from the World Bank (World Bank, 2017) identifies theoretical and technical biomass potential of 844 ktoe, and 665 ktoe respectively, more importantly, the unconsumed biomass potential is estimated to have a negative value of -157 ktoe as a result of unsustainable practices of using biomass. These unsustainable practices are coming from inadequate forest management techniques and logistical infrastructure. The annual increment of wood per hectare of forest area is a measure of forest management practices. In Kosovo, it is measured as (3-4 m^3/ha). Furthermore, there appears to be a lack of regional market structure. According to the same reference (World Bank, 2017), the use of biomass for heating might be enhanced sustainably by roughly 20% not just in Kosovo, but also in other regional nations.

According to another report by the World Bank (World Bank, 2017) on using biomass as the primary heating resource in Western Balkan countries, it shows that biomass is used inefficiently because of two factors, the lack of drying biomass before use and outdated equipment. More importantly, according to one article (Ymeri *et al.*, 2020) in Kosovo, it shows that 90.7% of farmers were willing to sell their wheat straw to a bioenergy plant and only 9.3% did not want to sell it. As per corn straw 51.5% of the farmers were willing to sell more than 50% of their yield is available. Lastly, the same article (Ymeri *et al.*, 2020) indicates that contractual relationships and specific market prices are two main components that determine the willingness of farmers to sell their straw for energy purposes.

The research has some major questions that correspond with some major goals and objectives which are elaborated with research questions in the following subchapter.

1.1.1. The objectives and research questions

Objective 1

The assessment of the theoretical importance of biomass energy source in Kosovo.

R.Q.1.

a) What are the types of biomass energy sources available in Kosovo?

b) What is their theoretical, technical, and practical potential for energy production?

c) How do Kosovo's natural and agricultural resources contribute to the development of biomass energy sources?

To address this research gap, the dissertation proposes the following hypotheses:

H1: Biomass has the potential to contribute significantly to Kosovo's total energy consumption.

Biomass is undoubtedly one of the important forms of the renewable energy mix. Another important reason for using biomass for energy needs is the use of agricultural, forestry or solid waste, which have not been used for any other purpose. Such use of biomass for energy needs would also have positive domino effects on the development of jobs or the improvement of the well-being of rural areas.

Hypotheses 1 will be answerd on section 4.2.5.

The following hypothesis is as follow:

H2: A significant proportion of the total biomass in Kosovo is suitable for energy production.

A significant portion of all biomass resources in Kosovo can be utilized for energy needs, especially for heating. By taking this resource into account, Kosovo can then improve its energy supply mix and become more independent and sustainable.

Hypotheses 2 will be answerd on section 4.2.5.

Objective 2

To assess the level of environmental consciousness among students and evaluate how their awareness translates into sustainable practices and lifestyle choices as some future policymakers.

R.Q.2.

a) What is the level of environmental consciousness among students in Kosovo?

b) What are the main clusters among the students for their perceptions regarding types of energy use?

c) What role does government policy and legislation play in the development and promotion of bioenergy in Kosovo?

d) What is the level of public awareness and acceptance of bio-energy sources in Kosovo?

To address this research gap, the dissertation proposes the following hypotheses:

H3: The 15% increase in the price of heating significantly increases students' concerns.
This hypothesis proposes to explore the level of student reaction to the sensitivity of the increase in the price of heating, with the goal of explaining that the level of student concern about the increase in the price is a deciding factor of environmental and economic awarness.

Hypotheses 3 will be answerd on sections 4.3.1. and 4.3.3. will summarise it.

The following hypothesis is as follow:

H4: Students' preferences are at a high level in terms of awareness influenced by environmental concerns in Kosovo.

Based on the environmental challenges that are present in Kosovo, an awareness of students in this regard has been observed. This change in awareness is also very clearly seen in their preferences towards the actions they take in relation to the environment. Over time, it is likely that students will show rationality towards more sustainable practices. This hypothesis positioning it as a key factor in the country's sustainability and the well-being of its population.

Hypotheses 4 will be answerd on section 4.3.1.

1.2. Research approach

This research will employ purely quantitative methodology to ensure comprehensive analysis. It integrates:

Secondary data analysis: involves the use of existing literature, studies, policies, and statistical data to investigate bioenergy sources, environmental implications, and economic variables.

Survey Research: A structured questionnaire was distributed to 100 students from the Faculty of Agriculture and Veterinary to measure their environmental awareness and perceptions about bio-energy.

Secondary data collection is based on sources such as academic publications, government reports, international energy databases, policy documents, and environmental assessments. Purpose:

- To evaluate the theoretical importance of biomass energy sources in Kosovo.
- To examine students' opinion towards of the acceptance of renewable energy sources.

Primary data collection is based on the method of the student survey. The sample size included 100 students from the Faculty of Agriculture and Veterinary at the University of Prishtina. The sample was carefully selected to represent the entire student population and their views. The 100 student sample is considered representative since it contains participants from the major academic programs that are most relevant to the research issue. This approach ensures that the findings appropriately reflect the perspectives of the entire students about the incorporation of renewable energy in agriculture. Another key aspect taken into consideration for 100 samples for sure is coming from the BWS method criteria, which is a perfect number for conducting such methodology. Moreover, in 2023, the faculty had 874 active students, with the majority enrolled in Food Technology (325), Agricultural Economics (209), and Plant Production (179). These three subjects were highlighted because they had a larger student body and were highly relevant to agricultural production, food processing, and environmental sustainability all of which are strongly linked to renewable energy. The structured questionnaire is divided into sections aligned with the:

- Demographics (age, gender, academic year).
- Awareness and attitudes toward bio-energy and renewable energy sources.
- Sustainable practices and lifestyle choices.
- Perceptions of policy and different group clustering for future energy development.

Survey type: Quantitative, mainly by BWS method, Likert-scale.

1.3. Structure of the dissertation

This dissertation is divided into six main chapters with numerous sub-chapters inside them.

The main chapters are: 1. Topics and objectives, 2. Technical literature review, 3. Material and methods, 4. Research findings and their evaluations, 5. Conclusions and recommendations and

6. Main conclusions and novel findings of the research.

The first chapter aims to present the topics covered by this study, the objectives it aims to achieve after answering the research questions, and the logical and methodological approach.
The second chapter is the technical literature review which examines first of all the terminology, concepts, theories and theoretical potential and its utilization of biomass potential. Moreover, it starts also with the trends on a worldwide scale. More importantly, the case scenario in Kosovo.
The third chapter, materials and methods, describes in detail the types of data used and how they are obtained. This chapter describes how the data was acquired to further understand the research technique and strategy. The most essential sections of this chapter are the subchapters that cover quantitative data collection methods.
The following chapter is the most important because it shows the findings and results, first as theoretical, availability, and practical potential of biomass use for energy purposes and then continues with more quantitative data in terms of the perceptions of the students for evaluation of their awareness translates into sustainable practices and lifestyle choices as some future policymakers.
The fifth chapter contains the conclusions drawn from the results and findings, which can be seen as more direct answers to study questions. It also discusses the study's limitations and the space available for further research. The sixth chapter covers the study's principal and most distinctive conclusions, particularly those that are novel in this field of study. Other parts of the dissertation include the summary, the references, the list of authors' publications, the list of tables, the list of figures, and other appendices.

1.4. Research Process – Flowchart

The research process begins with identifying the problem, where in this case the country in which the research is conducted is rich in significant reserves of coal (lignite), but is inefficient in terms of sustainable energy, relying heavily on coal-generated energy. Despite the fact that the country has managed to meet the 25% target set in accordance with the European Union's renewable energy targets, the current challenge remains the knowledge of the potential of biomass and the possibility of its conversion into energy. In this regard, another challenge is the inappropriate level of updated statistics within the agricultural and energy sectors (since the topic affects these two sectors), making it even more difficult to assess the volume and full potential of renewable energy sources, such as biomass.

The next step involves conducting a literature review focusing on renewable energy generation in Kosovo, including different types such as agricultural biomass, forest biomass and waste-based bioenergy. It also presents research on the importance of use, environmental impact and impact on energy efficiency.

The next step presents the intended research objectives that will pave the way and make it easier for us to achieve the intended results. These objectives will be guided by the methods that will help us address the problem of finding the biomass potential in Kosovo.

The results and conclusions will serve as a roadmap for Kosovo’s energy potential in terms of biomass resource utilization. These results will be based on the availability of biomass resources in Kosovo, its different types and the calculation of their volume, the importance of agricultural and forest residues. The research will also analyze the impact of biomass on the environment, as well as its importance in terms of carbon emissions.

2. LITERATURE REVIEW

The sustainable bioeconomy and circular economy concepts share the goal of achieving sustainable development (Aguilar et al., 2019). These models emphasize the significance of developing an economy that serves current needs without jeopardizing future generations' ability to meet their ones.

Bioeconomics, which is the science of the use of the all kind of its resources for technology and other human benefits, is the new field that means to achieve this objective (Sanz-Hernández et al., 2019), or in different words the bioeconomy is envisioned as a new link between production methods and the environment, focusing on biotechnology and bioresources. Regional sectors of solar panels, wind-to-electricity technologies, and bio-refineries can be expanded to gradually replace the current infrastructural systems. In world level, biotechnology, agriculture, and forestry are the principal tools chosen to develop environmentally friendly and socioeconomic growth (Gogoi et al., 2020).

The circular economy, on the other hand, prioritizes waste reduction, material reuse, and product longevity. Circular economy concepts seek to create a closed system in which resources are continuously reused, thereby reducing the environmental impact of production and consumption. These approaches complement each other in their shared commitment to sustainability, supporting an economy that not only stimulates growth but also restores and protects the planet’s resources for future generations. When combined, the bioeconomy and the circular economy provide an effective paradigm for addressing climate change, resource depletion, and waste (Mesa et al., 2024). They promote innovation in product design, energy use, and industrial methods, ensuring that economic activities are in harmony with nature. By adopting these ideas, society can move towards a more sustainable future, in which economic progress and environmental protection go hand in hand.

2.1. Terminology of biomass and sustainability

Biomass encompasses organic matter derived directly or indirectly from photosynthesis in plants, as well as animal-derived organic material, excluding fossilized substances. Given this broad definition, biomass materials are widely utilized in practice (F. Peng et al., 2012). The recent prioritization of lignocellulose materials from forests and agriculture underscores biomass’s growing importance in energy production (Arteaga-Pérez et al., 2015). Common types of biomass include wood, sawdust, straw, seed residues, organic manure, paper waste, household waste, and sewage (Soltero et al., 2018). While some materials can be used directly as fuels, others require pre-treatment through advanced technologies.

Biomass offers several advantages, depending on the factors assessed. Biomass serves as a renewable energy source, contributes to a low-carbon economy, can be used for non-food purposes, and offers benefits such as CO_2-neutral conversion and climate change mitigation (Vassilev et al., 2015). However, the environmental assessment of firewood (which is critical in heat generation) was considered a highly polluting fuel, in fact, a non-renewable energy source, especially by the least informed (older, poorer, and less educated) in the United States (Plate et al., 2010) and Hungary (Szakály et. al., 2021). According to a survey conducted using a choice experiment methodology, GHG emissions are regarded as less important for sustainability than land use requirements and contributions to local economy.

(Dombi et al., 2012). Furthermore, biomass benefits rural development by revitalizing and generating income, creating new jobs, and restoring contaminated and degraded lands (Vassilev et al., 2013). Furthermore, it has technological advantages, such as large and economical sources of biofuels, fertilizers, building materials, material synthesis, and recovery of specific elements and compounds. The extraction of raw materials from the countryside is one of the job development opportunities offered by biomass (A.-J. Perea-Moreno et al., 2017).

Another important component of biomass output is the storage of solar energy; in recent years, significant emphasis has been placed on the gasification process, which is used to generate bioenergy (Fang et al., 2021). Furthermore, focused solar thermochemical gasification of biomass is expected to increase the utilization of biomass feedstock and energy efficiency by up to 30% and 40%, respectively, thus effectively saving solar energy in the producer gas. Another publication evaluates the thermodynamic and economic performance of a solar biomass gasification polygene ration system, which is also positive (Bai et al., 2018). This technology reduces CO_2 emissions and offers alternatives to renewable energy sources such as solar and biomass.

Scientific experts are currently interested in biomass as a biofuel. In recent years, the number of scientific articles in various fields has expanded enormously, significantly influencing the changing behaviour of scientific research (Popp et al., 2018). Furthermore, the increase in documents may reflect a change in scientific knowledge in a particular sector. Furthermore, an increasing number of publications indicates that a particular field is becoming more important.

2.2. Biomass as a renewable resource

Renewable energy comparatively can play a very important role in energy security, energy access, rural development, reducing the unemployment rate, and also climate mitigation. Simply it means that renewable energy is clean and green (Kibria, 2015). Another important issue is regarding the protection of the population from hazardous substances that come from fossil fuels. Actually, in some developing countries, people are suffering from different diseases, as a result of air, water and land pollution. Renewable energy also has a great impact in the preservation of the environment. Whereas, approximately 2.5 billion people in a global scale, especially from developing countries are relying on biomass (Kibria, 2015), mostly by the use of primitive and outdated technologies which doesn't benefit the natural environment and human health for now. However, this can be considered as a future challenge and a small proactive change in this huge number of population can make a significant difference.

Biomass is considered a locally available energy source with higher versatility compared with other renewable energies because it can be found in three aggregate states. Biomass is amongst the most promising energy sources of energy to create new opportunities regarding agriculture and forest development, reduce the unemployment rate, and develop better infrastructure in rural places (Kohlheb et al., 2014). Also, this type of energy is progressing faster than was imagined, for some reason the developing way should be in correlation with sustainability, and boundaries of the environment and social aspects should be accounted for. Wherein, at the end, the main aim is to displace fossil fuels with equivalent bioenergy sources depending on the specific rural area. Over time biomass has proved to be very equivalent and in some particular aspects, it is even more superior compared with other renewable energies (Plieninger *et al.*, 2006). In this regard, compare to solar or wind energy, biomass can provide a steady and stable energy supply regardless of weather or time of day. Furthermore, biomass can use agricultural and forestry residues, decreasing waste and fostering a circular economy, which is an advantage not usually afforded by sources like hydropower or geothermal. Thanks to technological progress, which has facilitated a lot the use of all types of biomass, it means that biomass has got greater importance year by year. In some other researches, forest wood is considered the major source of biomass used for energy purposes in global (Berndes *et al.*, 2003). However, the total bioenergy potential is estimated to be above 100 exajoules per year. It examined the predicted amount of biomass that may be generated on marginal land and offered a revised maximum potential of 40-110 EJ yr^{-1} in primary energy from specialized energy crops. The median estimate was 80 EJ yr^{-1} (Searle & Malins, 2015). Another study (Slade et al., 2014) estimated that energy crops might provide up to about 100 exajoules (about 20% of the world's current primary energy output), assuming that a limited amount of land is available for cultivating them. Moreover, this amount is technically feasible. Renewable energy sources are not only a promising sector for an increase in employment but are a key element for improving local income generation as a result of a better heating system or in general a conclusion would be a better welfare of the rural population (Dombi *et al.*, 2014).

In some rural areas, the community renewable energy seems to be a promised and popular concept, also the people are ready to participate in such projects, but unfortunately, sometimes the stakeholders of the projects are missing (Rogers et al., 2008). Mostly the support from local and state government is not satisfying and local people do not have adequate skills and experience to afford these challenges such as to be the leader of these projects. In this particular research (Rogers et al., 2008), is found that inadequate support from the state and other organizations is creating obstacles, even when the local community is enthusiastic and ready to take the first step. In the end, the best conclusion would be the harmonization of all stakeholders turns out to be a good indicator of an amazing performance.

For long-term successful sustainability of bioenergy produced from biomass, not only the forecasting of raw materials and human resources that are needed, but more importantly should be taken into account also public opinion and future threats of feedstock availability in that particular rural area (Kohlheb et al., 2014).

When it comes to the production of bioenergy from biomass, first of all requires local inputs (as the main raw material), second it requires also trained personnel and commitment from other stakeholders to achieve planned outcomes (Hall, 1997). However, it is known that the efficiency of conversion systems (especially the cheaper ones) is typically lower for biomass compared with fossil fuels, it is important that the development of new technologies for energy conversion is improving this situation a lot. In this regard worthy to mention is the case of the gasification stoves with nearly 100% efficiency.

Not only does technological improvement of conversion of biomass to energy have great importance, but also it is very worthwile to conduct research on optimal and productive plant material production as a bioenergy input (Fischer *et al.*, 2005). Moreover, regarding biomass which is used for energy purposes and comes from plant production, important stages are such as: improvements and new ways of cultivation, integrated technology level, and storage. Only in this way, this bioenergy can compete with energy produced from fossil fuels.

Nowadays the world is facing a lot of challenges with limited resources under different risks coming towards the world's population (Plieninger *et al.*, 2006). Thinking on a world scale and starting to act on local and country scales is the first and easiest thing that every person can do to mitigate global difficulties. Whereas the transition from fossil fuels to renewable energy sources is amongst the most important practices even though it takes time and effort to reach a stable level of energy supply.

China, United States, India, Germany, and Brazil are the top five countries in terms of biomass energy use (Energy institute, 2025). Although Brazil is not the world's leading producer of biomass, it does dominate in biomass consumption due to its significant commitment to sugarcane ethanol production. Ethanol makes up a large amount of Brazil's transportation fuel, helping to lessen reliance on fossil fuels. This national policy has established Brazil as a global leader in biofuel utilization and innovation.

2.2.1. Biomass as key to sustainable energy and economy

Annual primary biomass output on Earth's surface is estimated to be around 1260 EJ (Exajoules) (Popp et al., 2013), moreover the same author years later mentioned the overall world biomass supply from agriculture and forestry is estimated to be approximately 11.9 billion tons of dry matter per year, with agriculture producing 61% and forestry producing 39% (Popp et al., 2021). Biomass generation is an important part of the Earth's natural carbon cycle because it collects sunlight and carbon dioxide and converts them into organic matter that supports ecosystems and life on Earth. Of this amount, around 219 EJ are allocated annually to biomass utilized for human requirements such as food, fodder, fiber, and other industrial products. This comprises agricultural products farmed for human food, cattle feed, and materials used in textile, paper, and building industries, among other things. This component represents biomass's direct contributions to human communities and the economy, which serve as the foundation for global food systems and industries. Biomass utilized for these reasons is critical to the operation of global markets, economies, and daily life, feeding billions of people globally.

In addition to the use stated, biomass is essential for energy production. It can be processed into biofuels such as ethanol, biodiesel, and biogas, which are renewable alternatives to fossil fuels (Priya et al., 2022). As concerns about climate change and environmental degradation grow, the role of biomass in renewable energy sources becomes more essential. Furthermore, biomass is used to produce a variety of chemicals, materials, and byproducts, broadening its position in the circular economy and bioeconomy.

The carbon cycle is a natural process on Earth, by which sunlight and carbon dioxide are stored and converted into organic material, and so, life and ecosystems are maintained. This implies a growth in the size of agribusiness through human food, livestock food, textile, and paper production as well as building industries. The inclusion of this segment is a testament to biomass's role in the direct delivery of services and goods to human communities and the economy and, thus, is responsible for global food systems and industrialization. Biomass that has been used in industrial processes has been the critical factor in the carrying out of global trade, economies, and the mere existence of all people all over the world who depend on it for nourishment.

The large amount of biomass produced on Earth, while a renewable resource, is subject to environmental constraints and concerns. Changes in land use, farming methods, and deforestation can all have an impact on biomass availability and sustainability, potentially resulting in negative environmental repercussions such as biodiversity loss and increased greenhouse gas emissions. As a result, controlling biomass production sustainably and responsibly is critical to ensuring that it continues to meet human requirements while maintaining natural balance and allowing future generations to benefit from these resources. As the global demand for sustainable products and energy grows, finding effective ways to harvest and utilize biomass while avoiding waste and environmental harm will be critical to furthering both bioeconomic growth and environmental sustainability. However, estimates that take into consideration sustainability restrictions show a more cautious potential for biomass as an energy source, with a yearly potential of 200-500 EJ/year in comparison to current global energy use (Popp et al., 2013). These estimates take into account considerations including land availability, environmental effects, food security, and biodiversity preservation, all of which limit the amount of biomass that can be gathered and used sustainably. The ability of biomass to contribute to the global energy supply is dependent on adopting sustainable farming practices, efficient biomass conversion technology, and responsible land management. Looking ahead, bioenergy's percentage part of the global energy mix is predicted to increase significantly by 2050. Bioenergy is estimated to provide between 300 and 500 EJ, which is similar to the interval of Popp et al (2013) and highlights the fact that it depends on accounting for a quarter to a third of future world energy consumption (Scarlat & Dallemand, 2019). This expansion is motivated by the need for renewable energy sources to replace fossil fuels, combat climate change, and reduce greenhouse gas emissions. Bioenergy obtained from biomass is a versatile and renewable alternative to coal, oil, and natural gas, with applications including electricity generation, transportation fuels, heating, and industrial activities. To achieve these levels of bioenergy production, considerable technological and infrastructure breakthroughs are necessary. Biofuel production innovations, such as second and third-generation biofuels derived from non-food crops and waste materials, have the potential to enhance biomass energy output without competing with food crops. Furthermore, advancements in the efficiency of biomass conversion processes, such as enhanced combustion, gasification, and fermentation technologies, will be critical to ensure that bioenergy can be produced on a large scale while reducing environmental impact. Based on the findings of one article from Bai et. al., (Bai et al., 2016) that using biodiesel (particularly a 20-50% biodiesel/normal diesel blend) is both environmentally and technically beneficial.

The establishment of a sustainable bioenergy business necessitates careful consideration of land-use practices. Balancing bioenergy production with the demand for agricultural land, forests, and natural ecosystems will be a significant problem. Policymakers, scientists, and industry leaders must collaborate to guarantee that bioenergy development does not have a detrimental environmental impact, such as deforestation, biodiversity loss, or unsustainable agriculture practices (Giuntoli et al., 2022). When managed appropriately, bioenergy has the potential to contribute significantly to a low-carbon, sustainable energy future.

Biomass is a versatile renewable energy source that may be used for various applications, including heating, electricity generation, and transportation fuels. Its versatility makes it an appealing alternative to fossil fuels, providing a sustainable approach to meet energy demands in various industries while lowering carbon emissions. In the heating industry, biomass is widely used to generate heat by burning organic materials such as wood pellets, agricultural leftovers, or specific energy crops (Ibitoye et al., 2023). Biomass boilers and stoves are becoming increasingly popular in homes, businesses, and industrial sites as a low-cost, ecologically friendly way to heat space and produce hot water. Compared to other traditional heating techniques that rely on coal or natural gas, biomass heating systems release much lower amounts of greenhouse gases, making them an important component of decarbonization efforts, especially in rural and off-grid areas where biomass resources are plentiful.

Biomass power plants employ biological resources to generate steam, which powers turbines and generates energy. Biomass can also be used in combined heat and power (CHP) facilities, which generate heat and electricity, enhancing energy efficiency (Coady & Duquette, 2021). While biomass power generation emits carbon dioxide, it is often regarded as carbon-neutral since the CO_2 emitted during combustion is balanced by the carbon absorbed by the plants throughout their growth. Even though biomass to power has crucial role in transition since it still has much lower carbon footprint than fossils. As such, biomass is crucial in the transition to low-carbon electricity generation, particularly in areas with limited access to other renewable resources such as wind or solar power.

In the transportation industry, biomass is increasingly being used to produce biofuels including ethanol, biodiesel, and biogas (Malode et al., 2021). These biofuels are alternatives to gasoline and diesel, reducing reliance on fossil fuels and lowering greenhouse gas emissions from automobiles. Biomass-based biofuels are made from a range of feedstock, such as food crops, agricultural waste, and algae. Ethanol, which is often obtained from corn or sugarcane (Moonsamy et al., 2022), is already widely used as a gasoline additive in many countries, and biodiesel, made from vegetable oils or animal fats, is becoming more popular as an alternative to conventional diesel. Furthermore, biogas produced by anaerobic digestion of organic waste can be used as a renewable natural gas substitute for vehicles (Kabeyi & Olanrewaju, 2022; Matheri et al., 2017). The use of biomass as a transportation fuel contributes to the global effort for greener transportation by increasing energy security and lowering the transportation sector's carbon footprint (Kwilinski et al., 2024). While biomass has considerable promise in these industries, its growth and implementation must be carefully planned to minimize detrimental environmental and social consequences. Sustainable sourcing strategies, such as employing agricultural wastes and waste products instead of food crops, are essential for ensuring that biomass energy generation does not cause land-use disputes, deforestation, or food poverty. Furthermore, advancements in biomass technology, such as enhanced biofuels and more efficient combustion methods, are required to improve the sustainability and scalability of biomass as a renewable energy source (Malode et al., 2021).

Biomass for energy, often known as bioenergy, is still the primary source of renewable energy in the European Union. According to the 2023 Union Bioenergy Sustainability report, biomass made up around 59% of the EU's total renewable energy consumption in 2021 (European Commission, 2022a). This demonstrates the critical role that bioenergy plays in the EU's renewable energy plan, assisting the region's transition to a low-carbon economy. Biomass is used in a variety of industries, including heating, energy production, and transportation fuels, making it an important part of the EU's overall efforts to attain sustainability and reduce greenhouse gas emissions. In 2021, Germany became the EU's top producer of solid biomass, demonstrating its leadership in the bioenergy sector. Germany's substantial biomass production makes a significant contribution to the country's renewable energy ambitions, helping to decarbonize power generation, industrial operations, and heating systems. Germany's supremacy in solid biomass production also makes it a prominent player in the EU's bioenergy sector, with its regulations and technologies establishing a precedent for other member states.

In addition to its usage in energy and heating, biomass is extensively used in the EU's industrial sector. In 2021, the industrial sector consumed around 21.1 million tonnes of oil equivalent (Mtoe) of biomass, accounting for a significant portion of the region's energy consumption. The industrial sector largely uses biomass for process heat and power generation and as a feedstock for bio-based products and chemicals. Industries such as cement, paper, and steel manufacturing are increasingly turning to biomass as a renewable alternative to fossil fuels, thereby lowering their carbon footprints and enhancing energy efficiency (Kusuma et al., 2022).

The widespread use of biomass in the EU's industrial sector not only helps to achieve sustainability goals but also supports the circular economy by encouraging the recycling and reuse of organic waste. Biomass usage in companies has the potential to reduce reliance on coal, natural gas, and oil, while simultaneously providing an economic incentive for rural biomass resource suppliers. However, the sustainability of biomass as an energy source is still a major concern, with continuous debates over sourcing procedures, land use, and the environmental impact of large-scale biomass production.

2.3. The importance of agricultural biomass production

Agricultural biomass is defined as any organic material obtained from agricultural activities that can be used to generate energy, raw materials, or other useful goods. It refers to a wide range of plant-based materials produced as byproducts or residues of agriculture, such as crop leftovers, leaves, stems, roots, and husks (Akhayere & Kavaz, 2021). Agricultural biomass also includes energy crops grown expressly for bioenergy generation, such as corn, sugarcane, switch grass, and hemp. Crop residues, which are plant components left over after the primary food crops have been harvested, are one of the most common types of agricultural biomass. Wheat straw, rice husks, corn stalks, and sugarcane bagasse are also excellent biomass sources. These materials can be used in a variety of applications, including bioenergy generation, bioplastics, and other byproducts. Farmers can reduce waste and improve the overall sustainability of their practices by recycling agricultural waste. Agricultural biomass is crucial to the development of renewable energy. It can be transformed into biofuels like biogas, ethanol, and biodiesel via fermentation, anaerobic digestion, and pyrolysis. These biofuels can subsequently be used to create electricity, operate vehicles, or generate heat, providing sustainable alternatives to fossil fuels (Reddy et al., 2024). In addition to energy applications, agricultural biomass is increasingly being investigated for its potential in byproduct manufacture. It may be converted into bioplastics, biodegradable packaging materials, textiles, and even medications, eliminating the need for petroleum-based products. Agricultural biomass can also be used to enhance soil and feed animals. Furthermore, the cultivation and use of agricultural biomass can aid in carbon sequestration, as plants absorb CO_2 during their growth. This makes biomass a potentially carbon-neutral or even carbon-negative resource, depending on how it is handled. However, to avoid negative environmental or social effects, biomass production must be balanced with considerations for food security, land use, and biodiversity.

Agricultural biomass, despite its size and poor calorific value in comparison to other fuels, has been used as a principal fuel source in several Asian and African countries (Saleem, 2022). In these places, agricultural wastes such as crop residues, rice husks, sugarcane bagasse, and other organic materials are widely available and provide an economical and accessible energy alternative, especially in rural areas where other energy sources may be limited. This extensive use of agricultural biomass for cooking and heating reduces reliance on imported fuels, boosts local economies, and serves as an alternative to more expensive or environmentally destructive energy sources. Despite its potential, agricultural biomass usage lags behind the consumption of wood, which remains the primary fuel source for cooking and heating in many developing nations. Wood is frequently favored because it has a larger calorific value and is simpler to store and carry than agricultural leftovers, which are bulky and require more processing to transform into useful fuel. Furthermore, wood is sometimes more accessible, particularly in locations with vast forests or where forestry products are better integrated into local economies. However, the use of agricultural biomass has major environmental benefits. Agricultural biomass is beneficial because it can be grown and harvested every year, making it a quickly renewable energy source. In contrast, wood from trees takes much longer to regrow, so using wood can have a bigger environmental impact. Agricultural biomass offers a valuable opportunity to manage agricultural waste effectively, by reducing environmental pollution and supporting the circular economy by converting residues into energy. However, in this regard it's important to distinguish this from the use of woody biomass, as the overexploitation of forest resources for energy purposes, which if it is not managed sustainably, therefore can lead to deforestation, soil degradation, and biodiversity loss. Moreover, prioritizing the sustainable use of agricultural biomass can be a promising path toward long-term energy security without the ecological risks associated with unsustainable forest biomass use.

Furthermore, technical improvements are contributing to the efficiency of agricultural biomass as an energy source. Modern bioenergy technologies, such as pelletization, briquetting, and efficient stoves, make it easier to treat and use agricultural leftovers (Ambaye et al., 2021). These technologies increase the calorific value of biomass, lower emissions, and make it more competitive with traditional fuels such as wood. With these advancements, agricultural biomass has the potential to expand its position as a cleaner, more sustainable energy source, especially in areas where wood is now the primary fuel.

When it comes to the importance of agricultural biomass, it has numerous advantages as a source of renewable energy, making it a vital component of sustainable energy solutions.

One of the most notable advantages is the efficient use of waste and residues from agricultural activities. Crop leftovers, plant fibers, and animal manure are common wastes that go unutilized or are discarded, contributing to environmental damage (Abdel-Shafy & Mansour, 2018). Agricultural biomass reduces waste by transforming these resources into energy, reducing environmental impact, and promoting a more circular economy. Another significant advantage is the reduction in agricultural emissions. Traditional farming techniques frequently cause the release of greenhouse gases and other pollutants into the environment, which contributes to climate change. However, using agricultural biomass as a sustainable energy source can assist in reducing emissions. Biomass combustion, for example, often produces lower carbon emissions than fossil fuels, and the carbon released during biomass combustion is countered by the carbon absorbed by plants during growth. This makes agricultural biomass a largely carbon-neutral energy source in terms of firing process, which helps to reduce agriculture's environmental effects.

The variety of agricultural biomass applications increases its appeal. It may be used to generate heat, power, and transportation fuel, making it a versatile and adaptable energy source. Biomass can be burned directly to produce heat for industrial processes or household heating, transformed into electricity via combustion or gasification technologies, or processed into biofuels like ethanol and biodiesel for transportation (Ibitoye et al., 2023). This versatility makes agricultural biomass an appealing alternative to fossil fuels, as it can meet a wide range of energy demands across multiple industries. Furthermore, agricultural biomass benefits from the abundance of raw resources. Unlike fossil fuels, which are concentrated in certain places and therefore necessitate considerable infrastructure for extraction and delivery, agricultural biomass is produced worldwide, particularly in rural and agricultural areas. Because of its extensive availability, biomass can be supplied locally, lowering transportation costs and increasing regional energy generation. Agricultural leftovers are often already present on farms, making them an easily accessible and cost-effective source of energy production.

Agricultural biomass improves regional energy security by decentralizing energy output (Mohammed et al., 2013). Traditional energy systems frequently rely on centralized power facilities or fossil fuel imports, leaving regions susceptible to supply outages and price variations. Using locally accessible agricultural biomass can help regions become more self-sufficient in energy production, lowering dependency on external sources and increasing local resilience. This decentralization of energy production can also boost local economies by introducing new jobs in biomass production, processing, and energy generation. Furthermore, agricultural biomass has the potential to produce additional revenue from an overproduction of agricultural raw materials. In many areas, surplus or underutilized agricultural products, such as crop residues or low-value plant matter, can be converted into valuable energy sources. Farmers and agricultural producers can diversify their income streams by converting leftover materials into biomass for bioenergy production, which provides financial benefits without requiring new land or major investments.

This strategy also helps to reduce the financial costs involved with disposing of surplus biomass, transforming what would otherwise be garbage into a profitable resource. In addition to offering new economic opportunities, expanding the agricultural biomass business can help to create jobs, especially in rural and farming regions. The production, collecting, processing, and conversion of agricultural biomass into energy products necessitate skilled labor at various levels of the value chain (Saleem, 2022). New job opportunities may arise in fields such as biomass harvesting, transportation, biofuel production, and the development of renewable energy infrastructure. This has the potential to significantly benefit local economies by fostering sustainable rural development and lowering unemployment in regions where agriculture has traditionally been the primary source of income. Furthermore, the expansion of the agricultural biomass sector can spur innovation and the development of new technologies, opening up even more prospects for economic growth and job creation. As worldwide demand for renewable energy rises, agricultural biomass's potential to contribute to economic resilience and energy sustainability grows.

2.3.1. Agricultural biomass in the EU

In its "A New Circular Economy Action Plan for a Cleaner and More Competitive Europe," the European Commission highlights that the current global consumption trajectory is unsustainable. The Commission draws attention to a critical problem: although there is only one planet, Earth, worldwide consumption is expected to reach levels comparable to three planets' worth of resources by 2050 (European Union EUR-lex, 2020). This concerning prediction emphasizes how vital it is to move toward more sustainable production and consumption practices. Numerous causes, including population growth, growing earnings, and fast urbanization, are contributing to the anticipated increase in consumption. The strain on the planet's limited resources is increasing along with the demand for products and services. Degradation of the ecosystem, biodiversity loss, and the worsening climate crisis are already signs of the effects of this unrestrained consumerism. The world run the risk of causing irreversible environmental damage if the people don't make a determined effort to move toward a circular economy, which emphasizes waste reduction, material reuse, and resource recycling.

The European Commission has asked for a comprehensive plan that gives sustainability top priority at every stage of the product life cycle to solve this challenge. This entails supporting eco-design, promoting recycling, and providing incentives for the creation of creative business plans that facilitate material reuse. In addition to lessening its environmental impact, Europe can increase competitiveness, generate new economic opportunities, and ensure a more sustainable future for future generations by adopting a circular economy.

An important and concerning trend was brought to light in the 2018 OECD communication: the world's use of metals, minerals, biomass, and fossil fuels is predicted to quadruple by 2060 (OECD, 2018). The quantity of garbage produced will rise by 70% concurrently. These forecasts highlight the mounting strain on the environment and natural resources as the demand for raw materials keeps rising on a worldwide scale. Such patterns have significant ramifications for future generations' well-being, the viability of economic systems, and the health of ecosystems.

The demand for manufactured goods, infrastructure, and energy increases as nations become more industrialized and urbanized, putting a heavy burden on the planet's limited resources. At the same time, trash production will keep increasing, with a large portion of it going to landfills or being burned, which will further deplete resources and pollute the environment. A major change in how to manufacture, use, and discard products is necessary to address these issues. A shift to more sustainable production models, such as the circular economy, which emphasizes waste reduction, material reuse, and recycling of precious resources, is urgently needed, according to the OECD's estimate. A circular economy strategy can lessen the negative effects of waste generation on the environment and help disentangle economic growth from the use of limited resources.

Furthermore, the significance of innovation in sustainable materials and technologies is being increasingly acknowledged. Reducing the environmental impact of material consumption can be achieved in large part by investing in eco-design, green technologies, and resource-efficient methods. The shift to a more circular economy, resource-efficient economy can also be accelerated by promoting international collaboration and the development of international standards for sustainable production (Barros et al., 2021). The need to solve these concerns is becoming more pressing as the middle of the twenty-first century draws near, due to these countries being activated to work towards new ways against these phenomena.

Every year, the proportion of energy derived from renewable sources in EU member states increases as it can be seen in the Figure 1. Renewable energy accounted for 24.5% of total EU energy consumption in 2023, up from 23.0% in 2022.

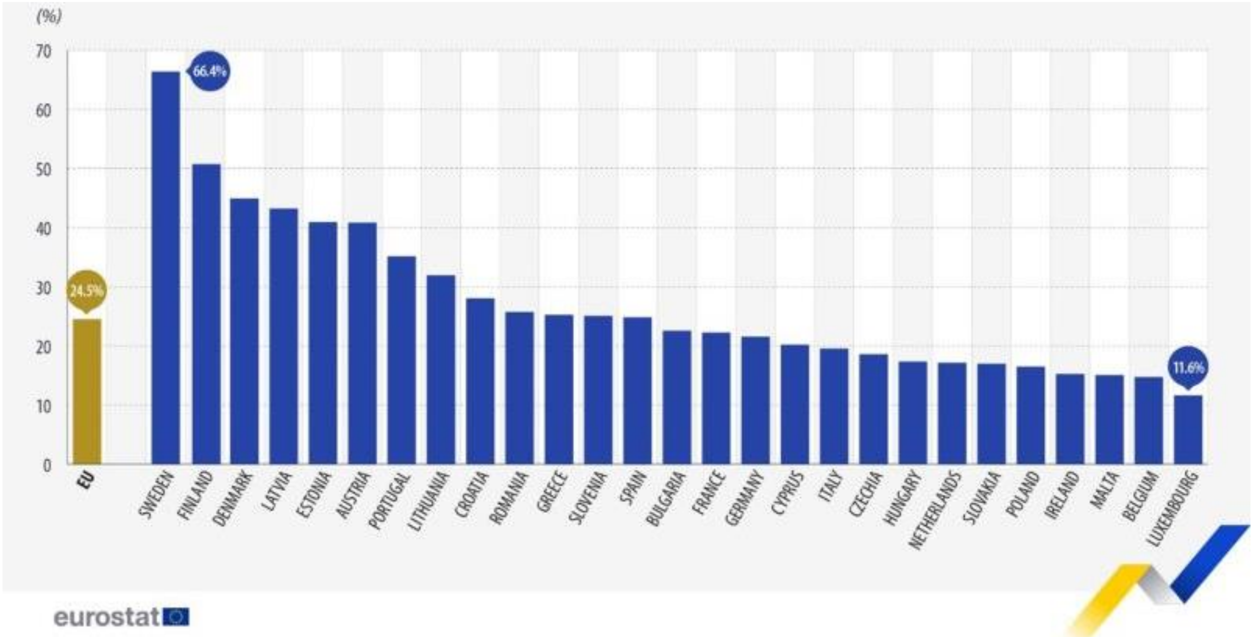

Figure 1. Overall share of energy from renewable sources in 2023

Source: Eurostat (Eurostat, 2024b)

The EU's strong commitment to halting climate change, cutting greenhouse gas emissions, and moving toward a more sustainable energy future is reflected in this trend. Renewable energy technologies like wind, solar, geothermal, hydropower, and biomass are seeing an increase in investment from governments, energy businesses, and citizens.

A range of incentives and regulations have been put in place by EU member states in recent years to hasten the adoption of renewable energy. These include programs to modernize energy infrastructure, financial support for clean energy projects, and aggressive targets for renewable energy. As a result, the EU's overall energy mix now includes a constantly higher percentage of renewable energy, which helps to lessen reliance on fossil fuels.

Additionally, the region's increasing reliance on renewable energy sources promotes innovation, job creation, and energy security. Additionally, the switch to cleaner energy is becoming more and more feasible economically as the price of renewable energy technology keeps falling, for instance the average cost of solar photovoltaic (PV) electricity has decreased since 2010, the same for cost of onshore wind power. The cost of clean power technology is predicted to decline by another 2-11% by 2025. While trade obstacles may temporarily halt drops, moreover it is predicted that the levelized cost of electricity for clean technologies will reduce by 22-49% by 2035 (Reuters, 2025).

In addition to advancing its environmental objectives, the EU's investment in renewable energy solidifies its standing as a world leader in the battle against climate change.

The EU's growing commitment to moving toward cleaner, more sustainable energy systems is demonstrated by this notable growth. For a better understanding can help also the Figure 2.

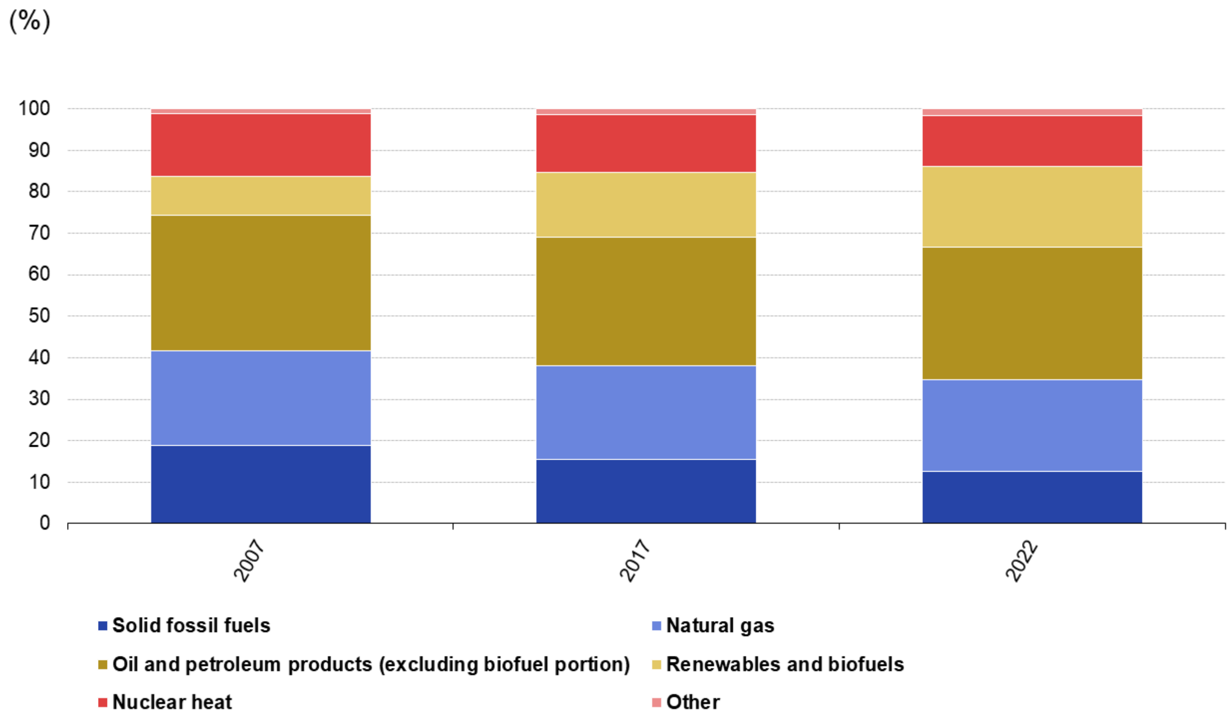

Figure 2. Primary energy consumption, by fuel type, EU, 2007, 2017 and 2022

Source: Eurostat (Eurostat, 2024a)

Technological developments, supportive legislation, and a growing awareness of the need to address climate change are all contributing factors to the increase in the use of renewable energy. With 54.6% of its total energy consumption coming from renewable sources, Sweden has the largest share of any EU member state (European Environmental Agency, 2016). Finland and Latvia come next with 41.2% and 40.3%, respectively. To reach these remarkable numbers, these nations have made significant investments in renewable energy infrastructure, including wind, hydropower, and biomass, leveraging their abundant natural resources and robust environmental regulations. Other EU countries looking to lower their carbon footprints and boost their proportion of renewable energy might learn from their success. However, the proportions of renewable energy in certain EU nations remain low. For example, Luxembourg has the least share (7.0%), followed by the Netherlands (8.9%) and Malta (8.2%) (European Environmental Agency, 2016). These nations have particular difficulties, such as a lack of natural resources for the production of renewable energy or an energy infrastructure that is mostly dependent on fossil fuels. However, to achieve EU renewable energy requirements, they are rapidly investing in cleaner technology and diversifying their energy sources.

One of the most frequently used and adaptable raw materials on the planet, biomass is the predominant renewable energy source in EU member states (Tenchea et al., 2019). At the moment, biomass makes up 10% of the region's overall energy consumption and 60% of all renewable energy sources in the EU (Commission, 2018). Given that nations aim to diversify their renewable energy portfolios; this high share emphasizes the significance of biomass in the EU's energy mix. In addition to offering a consistent and dependable energy source, biomass helps the EU achieve its objectives of cutting greenhouse gas emissions, enhancing waste management, and encouraging sustainability in the forestry and agricultural industries. The European Union's entire yearly agricultural biomass production is estimated at 956 million tonnes (Mt) (Commission, 2018). This massive volume includes both primary goods and residues, which are critical for a variety of industries, including energy, food, and bio-based. In addition, 54% of total biomass output comes from primary products such as cereals, fruits, roots, tubers, and other crops. These are the economic goods that are gathered directly for human consumption, animal feed, or industrial use. These key goods are critical to the EU's agricultural economy and provide substantial contributions to food security and commerce. The remaining 46% of total biomass is made up of residues, which include plant debris such as leaves, stems, and other byproducts left over from the harvest of primary crops. These residues frequently play an essential part in sustainable agriculture and the circular economy, providing feedstock for bioenergy, compost, and other bio-based goods. Their management and exploitation can help to minimize waste and improve environmental sustainability.

The primary products and leftovers from agricultural biomass play an important role in the EU agricultural industry, contributing to both economic growth and environmental sustainability. As the demand for renewable energy and eco-friendly materials rises, so will the potential for using agricultural wastes for bioenergy and other purposes, thereby contributing to the EU's climate goals and reducing dependency on fossil resources.

2.3.2. The importance of cereal biomass in the EU

Cereals account for more than half of total EU agricultural biomass production (258 Mt/a), making them a vital component of the agricultural industry, as it can be seen in the Figure 3.

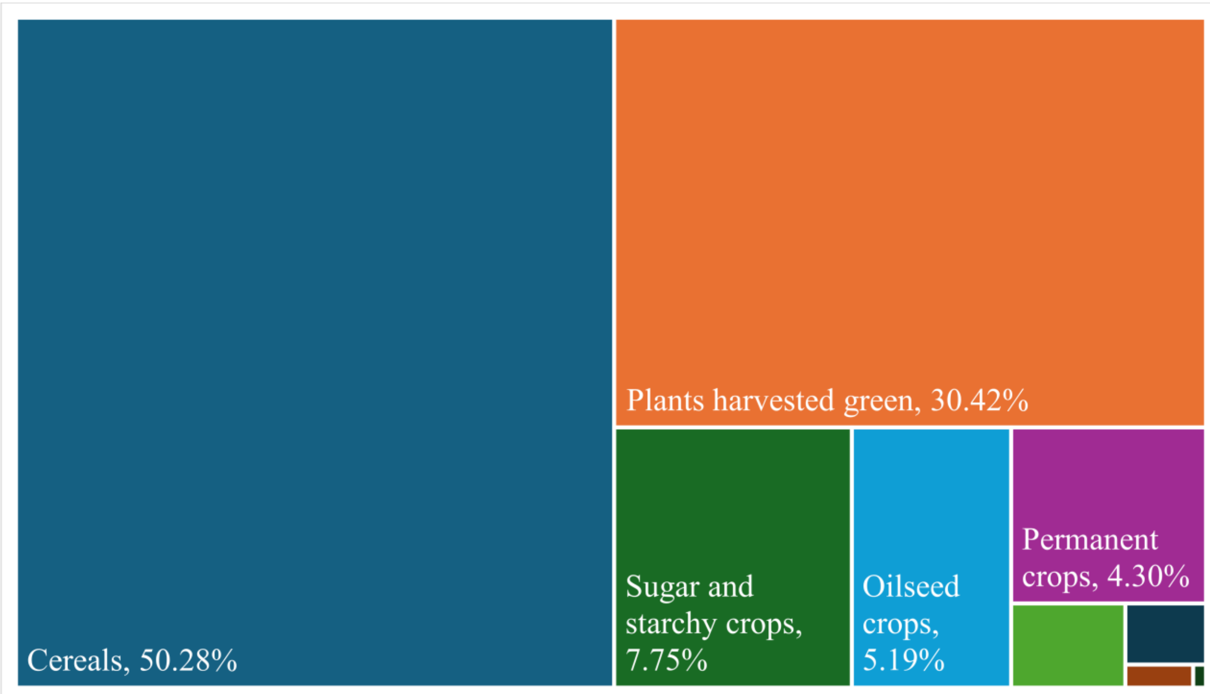

Figure 3. Total EU agricultural biomass production, 2018

Source: European Commission (Commission, 2018)

Wheat, barley, maize, and oat are important crops for not just food production but also animal feed, biofuels, and other industrial applications. Their enormous contribution to economic biomass production demonstrates their critical role in guaranteeing food security and supporting the EU's agricultural economy (Commission, 2018). In addition to their significant part of economic biomass, cereals account for over three-quarters of total residue production in the EU, accounting for 74% (329 million tonnes annually) of the total. This includes plant components like straw and husks, as well as other byproducts produced during cereal crop cultivation and harvest. These wastes can be converted into bioenergy, such as biogas or biofuels, or used as raw materials to make biodegradable products, compost, and animal bedding. Cereal residues' vast volume demonstrates their ability to contribute to a circular economy, in which waste items are recycled for long-term applications. Cereals' dual significance in economic output and residue formation makes them an important resource in the EU's agricultural environment. As the need for renewable energy and environmentally friendly materials grows, maximizing the use of grain wastes will become increasingly vital in achieving EU sustainability targets. The EU can increase agricultural productivity while reducing environmental impact by optimizing the value of both main crops and byproducts.

2.3.2. The importance of cereal biomass in Kosovo

Cereals are the most important potential source of biomass energy in Kosovo because they are widely grown and available. Cereals, being a crucial component of the country's agricultural industry, generate substantial volumes of residual biomass, such as straw and other byproducts, which can be efficiently used to produce energy. Furthermore, cereal biomass energy is an important part of the global transition to renewable and sustainable energy. As the demand for clean energy grows, cereal wastes like straw, husks, and other plant products are becoming valuable feedstock for bioenergy production. Cereal biomass energy is not only environmentally harmless, moreover it also offers a dependable and sustainable alternative to fossil fuels as it was mentioned above in the text. It may be transformed into a variety of energy sources, including electricity, heat, and biofuels, all of which are critical for lowering greenhouse gas emissions and combating climate change. One of the primary benefits of cereal biomass energy is its capacity to help create a circular economy. Rather than leaving cereal residues unused or disposed of in landfills, these byproducts can be used to generate energy, decreasing waste and guaranteeing optimal use of agricultural resources. This not only makes agriculture more sustainable, but it also reduces the environmental impact of traditional waste disposal methods like burning or decomposing.

Beyond its environmental benefits, cereal biomass energy can improve energy security and economic stability. Countries that use local agricultural wastes can minimize their reliance on imported fossil fuels, thereby improving national energy security. In many areas, cereal biomass is abundant and relatively inexpensive, making it an appealing energy source that can be acquired locally, offering potential for rural economies. The development of biomass energy infrastructure has the potential to provide jobs, ranging from cultivation and gathering to energy generation and delivery. Furthermore, cereal biomass energy is a major driver of innovation in the bioenergy industry. As technology progresses, new technologies for turning wheat leftovers into more efficient and valuable energy products emerge, including advanced biofuels and biogas. These developments are critical for increasing the overall sustainability of energy systems and facilitating the global transition to renewable energy.

Straw is an agricultural byproduct made up of dried grain stalks that remain after the grain and chaff are separated during harvest. It contributes significantly to total grain yield, accounting for around half of the harvested crop. Despite its abundance and potential utility, straw is frequently abandoned by burning in the field. While popular in some areas, this approach is regarded as highly inefficient and harmful to the environment and soil health.

Burning straws in the fields is a widespread practice in many farming systems, although it contributes to environmental degradation in addition to wasting organic matter. Instead of returning to the soil, the carbon and nutrients in the straw are burned and discharged into the atmosphere as carbon dioxide and other pollutants. Over time, this approach degrades soil quality and adds to the loss of vital nutrients that crops in the future require to flourish. Burning straw is the most unreasonable way to use this valuable byproduct because it depletes any organic materials that could otherwise enhance the soil. The combustion process emits carbon dioxide and other hazardous pollutants into the environment, which contributes to air pollution and climate change. Furthermore, fire destroys vital organic elements in the straw, including carbon, nitrogen, and other nutrients. In the lack of straw, the soil's microbiological and faunal activity decreases, which is required to decompose organic matter into forms suitable for future crops. This leads to diminished soil fertility over time, perhaps resulting in lower agricultural productivity. Instead of being burned, straw can be used in more sustainable ways, such as composting, bioenergy generation, or as a raw material in industries like paper and textiles. Straw, when returned to the soil properly, such as by mulching or as a soil amendment, can improve soil structure, boost moisture retention, and support beneficial microbes that maintain healthy soil ecosystems.

As the world moves toward clean and renewable energy sources, the use of straw for energy has drawn more attention. Due to its abundance and accessibility in agricultural areas, straw offers a significant chance to generate bioenergy while lowering dependency on fossil fuels. Combustion of biomass, which involves burning straw to generate heat and power, is one of the most popular uses of straw for energy. This technique has been used at several bioenergy facilities in Europe and other countries, providing a sustainable way to meet energy needs while reducing the negative environmental effects of conventional energy sources.

In addition to burning, gasification, and anaerobic digestion can transform straws into additional types of bioenergy. Straw is cooked in a low-oxygen atmosphere during the gasification process, producing syngas that can be turned into biofuels or utilized to create power. In contrast, anaerobic digestion uses microorganisms to break down straw without oxygen, producing biogas a combination of carbon dioxide and methane that can be utilized as fuel for cars, heating, or electricity production (Abbasi et al., 2012; *Anaerobic Digestion - an Overview | ScienceDirect Topics*, n.d.; Jameel et al., 2024; Merlin Christy et al., 2014). In addition to utilizing straw's energy potential, these technologies provide sustainable substitutes for traditional energy-producing techniques. The use of straw for energy has a significant impact on waste management and sustainability in addition to lowering greenhouse gas emissions (Shi et al., 2023; Sun et al., 2022). Straw energy can also contribute to the improvement of rural economic development (Ren et al., 2022; Wang et al., 2020). Local farmers, energy producers, and related companies may find new opportunities as a result of the need for straw as a fuel for bioenergy. In addition to encouraging innovation in bioenergy technology, it can boost rural economies by generating jobs in the gathering, processing, and distribution of straw for energy. By eliminating the need for long-distance fuel transportation, this decentralized method of energy generation can minimize fuel supply chain expenses and emissions.

2.4. Global potential, land use, and future prospects

Biomass is the most widely used source of renewable energy and demand is expected to grow (Erdiwansyah et al., 2024; International Energy Agency, 2019; Kalak, 2023; Wieruszewski & Mydlarz, 2022). Forests have provided the majority of biomass used for energy purposes worldwide. Land is an important basis for biomass production, therefore its proper use and sustainable protection is important, including protection against degradation, desertification, urbanization and thus influencing the continuous growth of forest areas. In terms of yields of major crop species, there is a tremendous potential to increase yields in different countries relative to the world average, allowing for increased food and fuel production (World Bioenergy Association, 2021).

Potential increases in crop yields across many nations offer the opportunity to boost food and fuel production simultaneously. Agricultural innovations and yield improvements are instrumental in addressing the trade-off between using agricultural resources for food versus energy (Szőllősi et al., 2021). The EU and the U.S. remain pioneers in biofuel production, driven by robust government policies (Lin & Lu, 2021). However, conventional biofuel production is insufficient as a long-term solution (Tamás Mizik & Gábor Gyarmati, 2021; World Bioenergy Association, 2016). The projected energy contribution of biomass over the next two decades is estimated at 150 EJ/year. By 2050, energy crop production is expected to require just 0.19% of global land area and 0.7–1.5% of agricultural land. Africa is anticipated to lead in biomass energy production, contributing 20–25% of the global share (Ladanai & Vinterbäck, 2009).

Climate change is one of the most serious concerns facing humanity today. An important step in mitigating climate change is replacing fossil fuels (which account for 81% of the global primary energy supply, according to the World Bioenergy Association (World Bioenergy Association, 2021) with renewable energy sources (RES) by increasing energy efficiency. Among RES, biomass is likely to continue to play the most important role in addressing human energy demands. Adaptation to renewable energy is critical not only because of the ever-increasing need for energy (Gábor Pintér, 2022) but also because of the even more urgent goals of energy self-sufficiency today. Furthermore, the issue of biomass potential and utilization is critical for food and feed production. Thus, feeding a growing population is one of the challenges mentioned in the United Nations (UN) Sustainable Development Goals (SDGs) that must be addressed to preserve the Earth's biological and physical resources (Nations, 2015). It is widely accepted that food, feed, and energy production compete fiercely for limited resources such as land, nutrients, water, labor, and capital (Rulli et al., 2016). To alleviate this competition and reduce strain on natural ecosystems, innovative solutions for organizing and coordinating biomass utilization must be implemented (Haberl et al., 2014; Németh et. al., 2011; Muscat et al., 2020; Smith et al., 2010). The following sections outline the global trends and key characteristics of biomass potential and utilization as reflected in international publications. The global supply of biologically derived organic materials is virtually unlimited and serves diverse purposes, including food, nutrients, fiber, and energy. Each year, approximately 4,500 EJ of solar energy is absorbed and stored through plant photosynthesis, converting around 125 gigatons of atmospheric carbon into biomass equivalent to 300 million tons of oil daily (Heinz Kopetz, 2013). However, a Hungarian study revealed that greenhouse gas (GHG) emissions rank lower in sustainability concerns compared to land use demands and local economic benefits (Dombi et al., 2012). Estimates suggest global annual biomass production reaches 1,260 EJ/year, with 219 EJ/year utilized for food, feed, fiber, and industrial uses. Under sustainability constraints, an annual biomass energy potential of 200–500 EJ/year is feasible, covering a quarter to a third of future global energy needs by 2050 (Popp et al., 2013). Nevertheless, the International Energy Agency predicts that solar energy will experience the fastest growth among RES, followed by wind and hydropower. China, the EU, and India are expected to lead biomass production growth, with larger land areas providing these countries better access to renewable resources like wind and solar. According to Brodny and Tutak (Jarosław Brodny and Magdalena Tutak, 2020), countries with extensive land holdings have a comparative advantage in renewable energy development. Balat and Ayar (Taylor et al., 2006) estimate that global annual biomass production is approximately 146 Bt, accounting for 14% of global energy demand and 35% of energy consumption in developing nations. This statistic highlights the importance of biomass as a major pillar of renewable energy. Even Kosovo, as a developing country, can achieve good results in terms of increasing energy generation from biomass (wood and agricultural waste), and the consumption of 35% of energy from biomass in developing countries can help shape Kosovo's targets for more sustainable energy practices. In the U.S., biomass production is projected to range between 991 million and 1,117 million dry tons by 2030, primarily from energy crops (380 million dry tons) and agricultural by-products (174 million dry tons) (US Department of Energy, 2016). This projection shows the high scale of potential for using biomass as an energy source in the United States, a popular strategy for moving away from fossil fuels while promoting energy sustainability. However, biomass is also of particular importance in Kosovo, even though the country does not have the same agricultural infrastructure compared to the US, this component also affects Kosovo’s energy diversification. Global biomass consumption reached 56.9 EJ in 2019, with 85% derived from solid biomass sources such as wood chips, pellets, and traditional biomass (World Bioenergy Association, 2021). In this context, Kosovo possesses forests and agricultural land and could focus on the production of biomass in the form of wood chips and pellets, a cost-effective and very practical alternative. The remainder included liquid biofuels (8%), urban and industrial waste (5%), and biogas (2%). Globally, 1.93 billion cubic meters of wood fuel were generated in 2020 (World Bioenergy Association, 2021). Africa and Asia held the largest volumes (36% and 37% respectively). Furthermore, wood pellets are one of the fastest-growing bioenergy sectors in the world, with an estimated 40.5 million tonnes produced in 2019. In this regard, Kosovo could focus on developing a local pellet market as a very practical form of sustainable energy, creating reserves for domestic consumers and for export. The demand for wood pellets could create economic sustainability in capitalizing on local biomass.

2.5. Different case studies

The situation regarding biomass potential varies significantly between countries, with notable developments in three nations that are not among the top five for biomass-related publications. In China, biomass potential is steadily increasing, although its distribution across regions is uneven. For instance, South China exhibits a faster growth rate compared to North China (Nie et al., 2022). According to the same study, bioenergy derived from waste and energy crops could contribute up to 10% of China's future energy supply. Factors such as socioeconomic conditions, cultural influences, environmental aspects, education levels, income levels, family size, and religious practices play critical roles in determining biomass usage (Gregory & Stern, 2014; Natarajan et al., 2015). In India, most rural households still rely on biomass for cooking due to limited access to modern LPG cooking equipment (Natarajan et al., 2015). Meanwhile, in Germany, the total biomass capacity for energy derived from agriculture, forestry, and waste is approximately 64 million tDM (Szarka et al., 2021). Of this, 34% is attributed to waste/residues and agriculture, while forests account for 31%.

Currently, research on photovoltaics and energy crops is gaining traction as a more promising renewable energy focus, potentially competing with biomass in energy consumption. Additionally, concepts like the bioeconomy and circular economy have recently gained prominence. According to Ranjbari et al. (Ranjbari et al., 2022), professional discussions on sustainability and efforts to address environmental and economic challenges have propelled these concepts into the spotlight. Simultaneously, studies and publications linking biomass potential to the bioeconomy and circular economy have increased. These frameworks emphasize the role of research, development, and demonstration of bioresources in sectors such as agriculture, maritime, forestry, and bioenergy, while also fostering new value chains (Bugge et al., 2016). Another key objective in biomass production is achieving full utilization of biomass and organic waste to maximize value (Stegmann et al., 2020).

Biomass is recognized as a renewable energy source with substantial growth potential due to its global availability. It is also widely generated as a by-product of various agricultural and industrial processes (Li et al., 2017). Biomass can be directly combusted in waste-to-energy plants to produce electricity (Kumar et al., 2015) or used in boilers for industrial and domestic heating (M.-A. Perea-Moreno et al., 2018). However, debates continue over balancing food and fuel demands. Recent studies indicate that four biofuel wheat crops, corn, sugarcane, and sorghum could feed as many as 200 million people (Rulli et al., 2016). The evolution of biomass use has shifted attention toward developing advanced biofuels. As highlighted in one article (Osman et al., 2021), the rising demand for biofuels renders first- and second-generation biofuels inadequate, thus driving research into third- and fourth-generation biofuels, particularly those involving synthetic microorganisms. Bioethanol, in particular, has gained popularity for its ability to reduce CO_2 emissions by replacing fossil fuels (Alalwan et al., 2019).

According to the well-known BP website (BP, 2022), renewable energy accounts for 6 to 8% of total primary energy between 1965 and 2003. If the starting point is the year 2004, there has been a continuous annual growth of 3.46%, with two peaks: a growth of 6.38% in 2008, which is well known to be the result of the financial crisis, and another growth of 9.95% in 2020, which is caused by the global pandemic era of COVID-19. When comparing developing countries to industrialized ones, the latter tend to rely more on renewable energy. On a global scale, Sweden, Norway, and Iceland lead the list with 50.92%, 71.56%, and 86.87%, respectively (BP, 2022). The level of cultural development in the community is also an important consideration when using renewable energy. Żywiołek et al. (Żywiołek et al., 2022) found that attitude and willingness to learn play a significant role. In addition to the high expenses associated with investing in renewable energy sources, the level of confidence appears to be substantially higher in industrialized countries.

The study in Australia shows that this country has focused mainly on larger projects that aim to generate energy through RES, and these projects are happening and expanding very quickly. Respondents have shown that their benefits from more affordable energy and also the creation of jobs, also affect the organization and response of the entire community towards a common good. Of course, some respondents had higher skepticism compared to others, but in general, the projects were welcomed by all (Zander et al., 2024).

Based on different studies in which the BWS method was used, it has resulted that for many individuals the aspect of being environmentally friendly is ranked even higher than price. This has been observed even in different industries and interestingly it has been in the food sector too, however, it is known that people buy often and the price is automatically conceived as a very important attribute, but even in this sector, the attribute of being environmentally friendly is ranked higher than price (Tiganis & Chrysochou, 2024). The same methodology but in the country of

Denmark, has resulted in the community having chosen the limitations in renewable energy, the loss of biodiversity, and the mitigation of climate change as the most important attributes from their perspective (Ugarte Lucas et al., 2022).

Based on studies that have investigated aspects such as the motivating factors that lead communities towards RES, it has resulted that the motivating factors that lead to energy cost reductions, positive environmental reasons, and also the return on investment of those devices are among the main factors towards the path of RES (Fejzulla et al., 2024). Of course, looking at studies from different countries of the world reveals a diversity of reasons from country to country. For example, in five states of the USA, citizens have expressed that for them the flexibility of the contract is also important, the place where it is thought that the energy generation will be done and of course as a third reason the environmental aspect is also listed, i.e. the reduction of carbon emissions, GPP programs (which are green price programs) (Oluoch et al., 2024). Moreover, as a next step, undoubtedly the increase in awareness or consciousness to promote the importance of the environment is also considered, a result of community education and various campaigns through the media.

The financial and environmental advantages that come as a result of using biomass for heating are becoming more and more evident, in this regard, some challenges slow down its widespread use. The key challenges are undoubtedly the initial installation costs and the costs of purchasing equipment compared to conventional heating systems that are present not only in Kosovo but also in other developing countries. Based on some references, fuels derived from biomass have some costs related to processing, maintenance, or storage of these fuels, however in general fuels derived from biomass are often less expensive (Dadzie et al., 2018; Hiloidhari et al., 2023; Sovacool et al., 2021).

A study (Almulhim, 2022) was conducted in Saudi Arabia that investigated the perceptions of the population regarding renewable energy and environmental awareness, the results showed that about 79.2% of the population were more concerned about the negative effects coming from pollution sources. While in Turkey a study was conducted in order to see what are the main factors that stimulate students towards the adoption of renewable energy (Acikgoz & Yorulmaz, 2024). Of course, students are considered to be the young decision-makers of the future, and it was fascinating how the majority of students declared that they would pay up to 10% more for electricity that would come from renewable energy sources. An interesting study was also conducted on the African continent, in the country of Kenya, where a sample of 1020 residents was surveyed, of whom 91% thought that the inclusion of RES would reduce their electricity bills (Oluoch et al., 2020). Also, 73% of them declared that they support the expansion of RES.

In the neighboring country of Kosovo, called Montenegro, a study was conducted to investigate the most important variables that influence consumers' attitudes and actions toward RES (Djurisic et al., 2020). The results show that 32.8% were influenced by their perception, while a percentage of 20.7% stated that awareness is a key variable towards stimulating RES. This study is just one more reason why information and media campaigns can have a positive impact on improving perception and promoting RES.

Awareness or self-awareness of the community, whether for new technologies towards the practical application of RES or their advantages, would bring positivity to the spirit of long-term use of RES. Even though in recent decades there has been progress in the implementation of RES, still some people remain skeptical. What is considered important is that the business sector should follow the advantages of RES such as cost-effectiveness, long-term sustainability, and of course the reduction or minimization of environmental pollution (Sadjadi, 2023). Therefore, a media campaign that implies more importance of promotion towards the placement of the necessary information to the community is an important key to the practical application of RES (Zenetti & Klapper, 2016). This is also supported by another study conducted by Wilcox et. al. (Wilcox et al., 2015) which among other things states that advertising plays an important role in distributing important information most effectively.

2.6. Kosovo country

2.6.1. Introduction to Kosovo situation in general terms

Located in Southeast Europe, with an area of 10,908 km^2, Kosovo is the youngest country in Europe, in terms of history and population. Moreover, the average age was 26 years old in year 2018, which could be more likely to adopt new rules and technologies for faster development (Ministry of Agriculture of Kosovo, 2018). However, Kosovo continues to be considered one of the countries with the youngest population in Europe (MAFRD, 2023).

Kosovo is a rural country, approximately half of the population is living in rural areas (*ASK DATA*

- *Select Table,* n.d.). Furthermore, the majority of the population in rural areas is dealing with agriculture. Agriculture's contribution to the total GDP is estimated at 7.4% (658 million euros) (MAFRD, 2023). This share of agriculture in the entire GDP of the country in the last and 15-year period decreased from 14.8% to 7.2%. However, the contribution of agriculture is comparatively high, still, agriculture is dealing with some challenges such as high production costs, low labor efficiency, and fragmentation of the land. Nevertheless, as a result of good geographical position and quality of land, agriculture remains the most promising sector for future development.

The leading agricultural sectors include fruits, vegetables, and livestock. In the year 2017, there were approximately 259,729 heads of bovines, 210,688 heads of sheep and goats, and 41,086 heads of pigs (Ministry of Agriculture of Kosovo, 2018). In addition, there were a total of 120,746 hectares of cereal with a production of 477,880 tons. In the case of any biogas plants in a country such as Kosovo will therefore evidently have adequate raw materials, as a result of developed agriculture.

The global economic crisis and the electricity markets have also affected the energy system of Kosovo. This result of the impact of this crisis showed once again that the energy system of Kosovo must be improved to a very high degree in order to become more self-sufficient and as little as possible dependent on price fluctuations in the international market (Ministry of Economy of Kosovo, 2021). From the total final consumption of electricity, the largest part, or 61.2% was consumed by families or households expressed in the amount of 3131 GWh. While non-resident customers or companies consumed the remaining percentage or in the amount of 1986 GWh.

Kosovo faces its biggest energy challenges during the cold winter months, as some residents use electricity for heating, which increases demand to a maximum and simultaneously strains the grid, resulting in outages in some rural areas. However, these challenges have been managed better and better over the years. In recent years, there has been much talk about the possibility of building a network to bring gas from other Southeast European countries, especially from North Macedonia (ERO, 2021). This idea would have benefits starting from mitigation of environment pollution, also the shortages of electricity during the winter period to come to an end..Many studies in different parts of the world show that when agricultural biomass is used for energy production, it has also a significant impact on the development of new jobs, especially in developing countries

(Alatzas et al., 2019; Ang et al., 2022; Bilandzija et al., 2018b; Okafor et al., 2022; Popp et al., 2021; Toklu, 2017; Tun et al., 2019). This has a positive domino effect on the overall social and economic development of both rural areas and the entire country.

Some people have inefficient wood or coal-burning appliances, which then cause greenhouse gas emissions and air pollution. While the rest of the citizens use heating appliances powered by electricity, these cause an increase in the demand for energy, energy that often has to be imported (*Lignite Mining Development Strategy*, n.d.). Based on these two challenges, Kosovo aims to produce up to 35% of its electricity from renewable sources, this priority remains as a target for 2031. At the same time, it is planned to set a price for carbon pollution for those polluters (Ministry of Economy of Kosovo, 2021). So through such policies, the goal remains to gradually move away from the use of coal, if not soon, then the target remains 2050.

The transmission network is also considered a very important challenge by many stakeholders, as mentioned above, there is progress, however, it remains a phase that needs more work to do in the future, to increase the quality of distribution and to have as few losses as possible regarding the distribution system (Ministry of Economy of Kosovo, 2024). The Kosovo country has also made investments regarding more efficient energy in public buildings, from these investments based on measurements it has resulted that annual energy savings were 1.67 ktoe in 2023, while in 2022 they were only 0.78 ktoe.

The Energy Regulatory Office, as the main body for setting energy prices in Kosovo, had decided to change the electricity tariffs for end consumers in 2022. So until 2022, citizens had only two tariffs depending on the time of energy consumption (i.e. depending on the hour of energy consumption). Then the Energy Regulatory Office decided to almost double the tariffs for those consumers who exceed 800 kWh/month of energy consumption (Office, 2022). Moreover, the price changed again in 2024, affecting consumers who consume less than 800 kWh/month, too (Energy Regulatory Office, 2024), as can be seen in Table 1.

Table 1. Electricity tariffs for end consumers in Kosovo

	2022	2024

0.4kV (domestic 2-rate meter)	Standing (costumer) charge	€/customer/month		1.74	2.00
	0-800 (First block)	€c/kWh	High Tariff	6.75	7.79
		€c/kWh	Low Tariff	2.89	3.34
	>800 (Second block)	€c/kWh	High Tariff	12.52	13.39
		€c/kWh	Low Tariff	5.90	6.27
0.4kV (domestic, 1-rate meter)	Standing (costumer) charge	€/customer/month		1.74	2.00
	0-800 (First block)	€c/kWh	Single Tariff	5.32	6.13
	>800 (Second block)	€c/kWh	Single Tariff	10.07	10.67

Source: Constructed by the authors based on sources (Office, 2022) (Energy Regulatory Office, 2024).

Compare to a European country such as Hungary, which is located in Central Europe, surrounded by the Carpathians, Alps, and the Dinars Mountains (FAO, 2008). However, almost seventy-five percent of the country is lowland, twenty percent is hilly with a maximum altitude of 400 meters and only five percent of the country is mountainous. The altitudes of the whole country are ranging from 400 to 1000 meters. Hungary has a total area of 9.3 million hectares; moreover, sixty-three percent is agricultural land area, which represents a good number in comparison with other European countries (FAO, 2008). From this agricultural land area, approximately seventy-eight percent is arable land and only seventeen percent is grassland.

The agriculture sector is considered to be the most varied sector in the entire national economy. However, in the last decade there has been a trend of plant cultivation, and in livestock sector is dominated by cattle and pig-keeping (FAO, 2008). Hungary is a developed country and the share of agriculture in the total GDP is decreased during these last years. Today the share of agriculture in the national GDP ranges from 3.7 to 4.0%.

In terms of energy and mineral resources, Hungary has limited fossil fuel resources and its domestic production is declining (OECD, 2020). Interestingly, Hungary stopped the direct subsidies for coal production in the year 2000. Moreover, Hungary mostly imports its oil and natural gas from Russia. In terms of total primary energy supply, biofuels and waste contribute 11%.

2.6.2. Natural resources

Kosovo is a small country and does not have any gas natural resources, nor any pipeline network system to import natural gas from other countries, such as Russia. In this regard, there is very low use of natural gas which is stored in gas cylinders. Based on that, the forest's biomass is of great importance to Kosovo's population during the whole year, especially during the winter period. The energy supplied in Kosovo comes from two lignite coal power plants with 98% and the remaining part comes from renewable sources (World Bank, 2013), even though the caloric value of lignite is 7200 kJ/kg in these two outdated thermal power plants (Lajqi et al., 2020). It is impossible to think of a friendly environment energy supply in the case where 98% of the supply of energy comes from the lowest quality of coal, which is a non-renewable source. Unfortunately, those two power plants have neither been technically upgraded nor maintained since the time they became operative, which is the answer to cost losses, health impacts, and environmental pollution (Rizvanolli, 2019). The annual cost of environmental degradation in Kosovo is estimated at €221 million. Further, air pollution is estimated to cause 835 premature deaths, 310 new cases of chronic bronchitis, 600 hospital admissions, and 11,600 emergency visits each year (World Bank, 2013). An alternative energy source is therefore highly wanted.

Kosovo not only that is dependent on two coal power plants with 98% for electricity production, moreover, the energy system in Kosovo becomes more aggravated during the winter period due to the reliance on electricity for residential heating (Ministry of Economic Development of Kosovo, 2017). Not only that, this challenge is also accompanied by many losses during distribution networks, underutilization and inadequate efficiency making it harder to supply every household with electricity during the winter period, these are the reasons for outages of electricity during the winter period especially. In this regard, the first suggestion is to expand the heating system, especially in big cities with a dense population.

The energy sector contributes 82% of the total gas emissions that are produced in Kosovo, which makes the energy sector the largest contributor to air pollution (Dreshaj et al., 2017). There is an estimation of carbon dioxide reduction of 54% by considering the maximum utilization of all types of renewables, starting with biomass, solar, and wind energies, compared with the referent current scenario (Lajqi et al., 2020). According to Bekteshi and others (Bekteshi *et al.*, 2016) there is a forecast regarding the increased emissions of carbon dioxide from 7.5 to 10 Mt/year, while for dust and sulfur dioxide there are projections to decrease, indicated in numbers such as from 11.7 to about 6 kt/year and 22.5 to 16 kt/year for sulfur dioxide respectively.

If the Government of Kosovo decides to implement the new thermal power plant to have a more stabilized energy supply then based on some projections there would be an increase in CO_2 releases from 5.8 million tons, which is the current pollution value to 22.5 million tons of CO_2 emissions annually (Kammen *et al.*, 2012).

Kosovo's overall land area is 10,908 km2, with 53% agricultural land and 41% woodland. Kosovo has a population of 1.8 million, with around 62% living in rural areas (MAFRD, 2019) and 100% having access to electricity (World Bank, 2021). Agriculture and energy, the two most important industries in the country's development, unquestionably play a critical role in GDP growth and employment creation (Ministry of Environment and Spatial Planning of Kosovo, 2015). Moreover, 130,775 agricultural economies use 419,000 hectares (ha) of agricultural land (MAFRD, 2019). The total number of agricultural economies is extremely important since they can use their byproducts to generate energy for their consumption and promote self-sufficiency in their agricultural activities. This would have a significant impact on the overall state of the country.

Even though Kosovo is not yet a member of the European Union, it is recognized by over a hundred countries worldwide, including many important international powers and the majority of European nations. Kosovo is constantly working on aims and strategies to join the EU family, particularly in the production and supply of sustainable energy. Renewable energy as a phrase is not new in Kosovo; in reality, it has been known for a long time, but its actual implementation is still not sufficient.

Many believe that this industry has great potential for the country's long-term and strategic development. Despite the vast volume of lignite, its quality is inferior when compared to other forms of coal, and the negative environmental impact of gas emissions is significant. Furthermore, Kosovo's two main coal-fired power facilities are relatively elderly, and their operational lives are nearing an end in terms of amortization.

2.6.3. Renewable energy potential in Kosovo

Kosovo has a total renewable energy capacity of approximately 120 MW by the end of 2019, with 76 MW from hydropower, 34 MW from wind, and 10 MW from solar, representing a 6% annual growth rate (European Commission, 2020). At the time, renewable energy sources accounted for 5.5% of total electricity generation in the country. However, the strong reliance on lignite as the primary energy source has limited the energy sector's flexibility had a detrimental influence on public health, and caused economic hardship.

According to the IRENA research (IRENA, 2017), by 2015, Kosovo had only a small amount of solar and wind power installed. Biomass, a major component of renewable energy (RE), has enormous potential. Sahiti et al. (Sahiti et al., 2015) estimate that Kosovo may generate up to 15.43 ktoe of electricity from plant biomass, making it one of the most important sources for satisfying energy demand. At the same time, an IEEFA analysis assesses the country's technical biomass potential as 665 ktoe (6,654,450 tons/year), or 28 PJ (IEEFA, 2020).

Seven wind energy projects are in various stages of permitting, totaling 170 MW. Despite Kosovo's significant wind energy potential, only a portion of it is deemed economically viable due to the steep terrain and modest wind speeds (4-6 m/s) in the most favorable regions (IRENA, 2017).

Solar energy is a possible alternative to traditional energy, helping to minimize air pollution. Kosovo has approximately 2000 hours of sunshine and 278 bright days per year thanks to its fortunate geographical location. Solar panels are a viable option for energy production in cities like Shtërpcë and Gjakova, where yearly solar radiation is 1333.7 kWh/m^2 and 1495.1 kWh/m^2, respectively (Berisha et al., 2017).

2.6.4. Potential of biomass

The Government of Kosovo applied the ‘Feed-in Tariff’, which was the first encouraging step towards the utilization of renewable energy. Especially encouraging projects in hydropower, biomass, and biogas, whereas less in wind power and solar. Years ago were identified approximately 77 potential hydropower projects and 120 GWh of energy production from biomass (Government of Kosovo, 2016). According to the Energy Regulatory Office of Kosovo (ERO, 2018) an important institution for energy in Kosovo, measures have been taken to encourage the use of renewable energy sources through support schemes. Through the feed-in tariff, electricity generated from biomass was supported with EUR71.3/MWh. Kosovo was allowed an installation to generate electricity by biomass in the amount of 14 MW (Lajqi et al., 2020). However, this sector is not being seen with high interest from investors' point of view due to the high cost of installation technology and difficulties of the procedures that are needed for obtaining licenses.

As Kosovo is requesting to join the EU, first of all, it must fulfill some economic and environmental prerequisites, one of them is the European Union's 20-20-20 standard regarding the environment (Kammen *et al.*, 2012). Kosovo has achieved this standard by taking progressive steps towards energy production by focusing on renewable energy sources.

Regarding the biomass potential in Kosovo, forests have a sharing of 44.7% of the total land area, wherein 62% is classified as public forest, and remain part goes to private ownership (FAO, 2015). Forests in Kosovo represent an important source of energy due to the lack of any gas resources or any pipeline system for importing it from other countries. Except for forests, which are the main source of heating in Kosovo, also orchard residues and vineyards are considered quite important direct sources (FAO, 2015). Whereas indirect sources are usually the wood biomass which stems from the sawmill industry and includes products such as pellets, chips, and briquettes.

Two main groups are very suitable for the production of biomass in Kosovo, the first group includes cereals such as wheat, maize, oats, barley, and rye. In the second group are plants that are harvested in green conditions such as hay, grass, green wheat, and green rye (Sahiti *et al.*, 2015). Regarding cereals, the amount of waste that can be obtained is a ratio between the measures of respective plants and the amount of fruits for that particular cereal. Based on previous articles and a few calculations, comparatively the waste with origin from cereal that can be used for further processes for energy production ranges from 10-40% (Sahiti *et al.*, 2015). Which is really promising value for the future energy supply in Kosovo. Another key element is the level of moisture in equilibrium conditions of cereals to not go above 15%, not only for the quality of biomass but also for the combustion process.

For any established company that uses biomass for electricity production or even for heating, efficiency is significantly good, for electricity production efficiency is 35%, respectively 85% for the heat production plant (Sahiti *et al.,* 2015).
Even though biomass is the largest source (54%) of heat production in Kosovo, there is a difference between the used biomass for heating in urban and rural households, expressed in percentages of 42% and 58% respectively (World Bank, 2017). Electricity is the second largest follower (21%) regarding heating production. It should be mentioned that three big cities in Kosovo have established district heating and use coal for heating production. The same report identifies theoretical and technical biomass potential of 844 ktoe, and 665 ktoe respectively, more importantly, the unconsumed biomass potential is estimated to have a negative value of -157 ktoe as a result of unsustainable practices of using biomass.

Kosovo is known more as an agricultural country, approximately half of the territory consists of arable land, however, farms are under the category of family farms, usually for self-subsistence (Bytyçi *et al.*, 2015). Whereas wheat is the most common grain accompanied by low productivity, moreover the residues of agriculture are not yet used. However, the straw is currently used by farmers only in animal husbandry for bedding or feeding. As for straw, farmers have different opinions regarding the willingness to sell the amount of straw, nonetheless, the price was an important component that would be taken into consideration (Gaus *et al.*, 2013).

In order to use the theoretical energy potential from biomass there are some assumptions, starting from all livestock waste utilized and the maximum theoretical biogas production (Kammen *et al.*, 2012). Also, all straws are utilized with 15% moisture (preferably), and all solid waste is utilized too. Additionally, maximum annual sustainable woodcut, preferably with 30% moisture for oak and beech. Based on these assumptions there would be a theoretical energy production from biomass resources of 6600 GWh/yr. At the same article is assumed a biogas plant which would have a capacity factor of 58% with a total energy production of approximately 830 GWh/yr.

The theoretical potential of electricity production from biomass in Kosovo comes from three major types of biomass such as wood, livestock waste, and agricultural straw (Kammen et al., 2015). Moreover, an additional resource is seen to be waste incineration, wherein in Kosovo estimated to be approximately urban waste of 192 kg per capita/ annually or represented in total as 384000 tonnes/year urban waste. Which can be seen as an important resource for central heating purposes.

According to the report of the World Bank (World Bank, 2017) for using biomass as the primary heating resource in Western Balkan countries, biomass is used inefficiently because of two factors, the lack of drying biomass before use and the outdated equipment. The effects of these aspects result in the poor air quality as well. The report (World Bank, 2017) gives explicit opportunities for investments, wherein the benefits outweigh the costs. Such investments include the replacement of inefficient stoves with efficient ones, the electric heating appliances switched with efficient biomass stoves, moreover to switch the boilers from fossil fuels to biomass concerning existing district heating systems.

In 2020, overall energy production in Kosovo reached around 79.5 TJ, a 42% increase over 2000. Final power usage in 2020 was 5.45 TWh, a 51.3% increase from 2000 (*Kosovo - Countries & Regions - IEA*, n.d.). This growth in fossil energy consumption (Tuegeh et al., 2021),(Tumiwa et al., 2022) as well as the negative relationship between the use of renewable energy sources (RES) and population density (G. Peng et al., 2022), are common tendencies in developing countries, and they also exist in Kosovo. Figure 4 depicts Kosovo's energy potential in 2022, which includes coal, petroleum products (gasoline, diesel, liquefied petroleum gas - LPG), biomass, hydropower, wind, and solar power (KAS, 2023b). The "other" category includes electricity import/export. The overall energy potential for 2022 was expected to be 32,135 GWh, which equates to 2763 ktoe or, after conversion to PJ, 116 PJ, as illustrated in Figure 4.

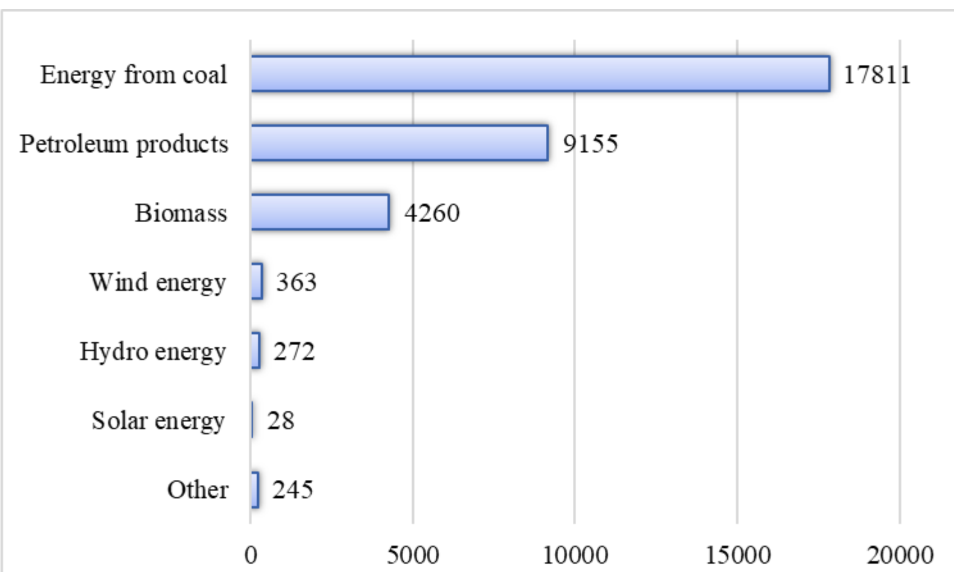

Figure 4. Overview of the amount of energy of primary energy sources in Kosovo (GWh)

Source: Author own figure based on Kosovo Agency of Statistics (KAS, 2023b).

According to one report from Kosovo Energy Strategy, the entire capacity of power installed in the country is 1568 MW, with lignite accounting for 82% (Ministry of Economy of Kosovo, 2021). The Kosovo A and Kosovo B power facilities require renovations to fulfill pollution regulations. In addition to lignite-based power generation, 137 MW of wind power generation units were built in 2021, accounting for 9% of total installed capacity. Hydropower accounts for around 8.4% of total installed capacity, whereas biomass accounts for only 1.2 MW. However, according to Sertolli et al. (Sertolli et al., 2022), biomass has tremendous potential as a replacement for fossil fuels and is an efficient source of energy production, particularly for heating. Figure 5 depicts the electricity generation position up until May 2023.

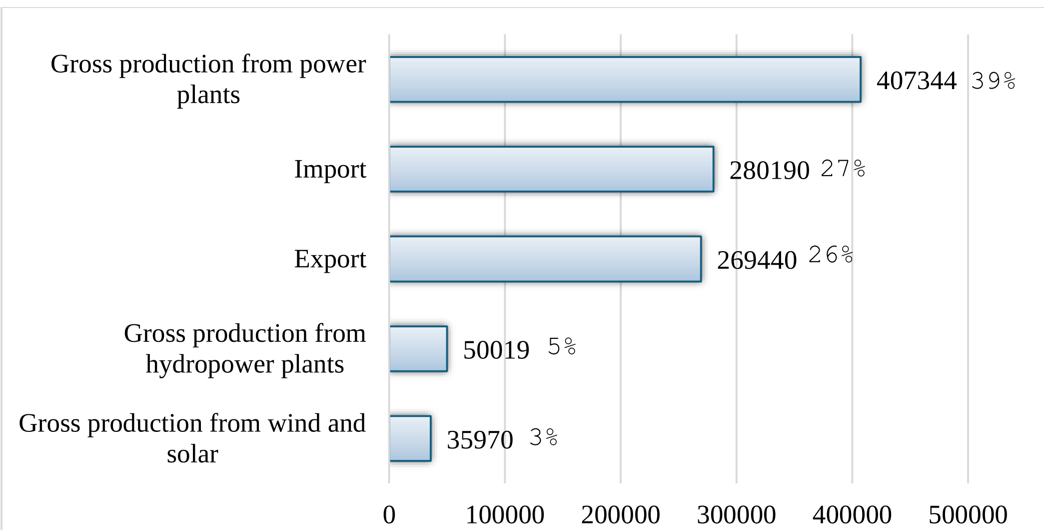

Figure 5. Total electricity generation in May 2023 in Kosovo (MWh unit), and its percentages

Source: Author own figure based on Kosovo Agency of Statistics (KAS, 2023a).

Until May of last year, biomass-generated electricity had no substantial impact on total electricity generation. Although the entire biomass potential is estimated to be 4260 GWh (KAS, 2023b), it has not yet been used to generate power. However, in recent years, the population's understanding and interest in the usage of biomass has gradually grown. For example, one city has installed a district heating system funded by the EU under the IPA 2015 initiative, which has financed the construction of a new biomass cogeneration facility (The heater of Gjakova city, 2023). This project involved the installation of a 1.1 MW high-efficiency steam turbine with a heat recovery capacity of 4 MW, as well as two heat-producing boilers with capacities of 5.5 MW each.

Other lesser examples, however, have had no substantial impact on Kosovo's total energy generation at this time. In this setting, Figure 5 (Total electricity generation in May 2023 in Kosovo) shows that power imports and exports remain balanced.

Kosovo exceeded its objective of 25% renewable energy (RES) in 2020. However, the fundamental issue is an imbalance between industries that use RES technologies. In the heating industry, biomass accounts for around half of the energy needs. In the electricity sector, lignite is the primary source of energy production. According to the statistics, approximately 57% of houses in Kosovo use wood for heating, which is close to the results reported by Pestisha and Bai (Pestisha & Bai, 2022), who found that 63.7% of households use wood as a heating source. Meanwhile, around 39% of houses use electricity, 2% use central heating, 0.5% use coal, and 2% use other forms of heating.

In the process of integration towards the European Union, Kosovo must harmonize its energy and climate policies with those of the EU. Biomass must meet sustainability criteria to be counted as part of renewable energy targets or to become eligible for subsidies from EU countries (European Commission, 2022b). In this regard, the reformed Renewable Energy Directive (2018/2001) extends sustainability criteria to include biomass for power and heat production, biofuels and bioliquids for transport, as well as agricultural waste, forest biomass, and bioelectricity plants. Kosovo has already adopted several strategic documents addressing its energy and climate policies, including the Economic Reform Programme 2021-2023 and the Climate Change Strategy 2019-2028 (OECD, 2022). There are also laws on energy efficiency (adopted in 2018) and on the energy performance of buildings (adopted in 2016).

The Kosovo Energy Efficiency Fund (KEEF) began operating in 2020, intending to improve access to financing for energy efficiency projects. Previously, Kosovo had established support mechanisms for renewable energy, including feed-in tariffs and a grid program for renewable energy consumers.

2.6.5. The situation of forest and wood industry residues

A study (Alicia et. al., 2015) examines three major biomass sources - wood, livestock leftovers, and agricultural straw - that have a high potential for power production in Kosovo. It is expected that accessible biomass sources can produce around 6600 GWh of electricity each year (Kittner et al., 2016). This sounds more optimistic rather than realistic, taking into account that it is like a projected future. According to the 2014 agricultural census, the total amount of used agricultural land was 413,635 hectares, divided into 129,884 farms with an average size of 3.2 hectares (Agriculture, 2018). According to an agriculture report (Ministry of Agriculture of Kosovo, 2020), agriculture accounts for approximately 11% of GDP. In Kosovo, agriculture employs 362,700 people, with 130,775 registered farmers (Muriqi et al., 2019). This sector is characterized mostly by tiny farms, fragmented land, low efficiency, and inadequate infrastructure. As a result, energy self-sufficiency can be very beneficial in terms of increasing farm efficiency.

According to Kashif et al. (Kashif et al., 2020), using crop leftovers to generate renewable energy can assist enhance the local circular economy while also creating thousands of new jobs in other industries. In Kosovo's rural areas, the livestock sector provides a significant source of employment for landless and marginal farmers, satisfying the population's necessities. The overall amount of livestock in Kosovo is 551,169 heads (MAFRD, 2022). Dairy cows are particularly important in the livestock sector because they are the primary source of milk production. Dairy cows account for 132,076 of the total cattle population or 53.41% (MAFRD, 2022). However, due to the farms' small size, the production of plant and animal byproducts is distributed and not concentrated. As a result, they can be employed to generate local thermal energy in the short term.

Forests account for 44.7% of Kosovo's land area and are a valuable resource for the economy (Bajraktari et al., 2017). Of the total forest area, 38% (180,800 ha) is privately held, while 62% (209,200 ha) is public land. The entire volume of accessible timber is expected to be approximately 53 million cubic meters. According to a study (Bajraktari et al., 2017), 1480 wood processing businesses operate in Kosovo. However, the Association of Wood Processors has 80 big enterprises that employ more than 3000 people. However, according to Krajnc et al. (Krajnc et al., 2015), the number of permitted sawmills has been dropping, with less than 50,000 m3 of processed logs in 2013. There are three briquette producers registered, five pellet manufacturers, one chip producer, and three charcoal producers in Kosovo (Krajnc et al., 2015).

Suitable materials for energy include stumps, wood processing wastes, leaves. Short-rotation forestry and coppice farming produce better energy yields than typical energy crops. In addition to traditional wood burning, a study by Pestisha and Bai (2022) (Pestisha & Bai, 2022) found that households with higher incomes preferred wood pellets for heating due to the ease they provided over firewood. Biomass pellets and bio-briquettes have demonstrated promising results as a heating medium, particularly for wood-based elements.

2.6.6. Solid waste management

Kosovo generates a significant amount of waste each year, making management an ongoing issue for local organizations. Waste collection, transportation, recycling, reprocessing, and disposal have a substantial impact on citizens' quality of life (Auditimit, 2021). According to the Ministry of Environment and Spatial Planning of Kosovo (MESPI) (MESPI, 2019), by the end of 2019, municipal rubbish collection services have reached 78.5% of Kosovo's households. According to statistics from the Kosovo Environmental Protection Agency (KEPA), five out of 36 municipalities reported 100% coverage for these services.

Approximately 90% of the garbage created is put in sanitary landfills, with the remainder ending up in unsanitary landfills. To solve this issue, development policies should prioritize developing more efficient treatment and recycling systems, as well as minimizing waste generation and disposal.

According to official reports, Kosovo produces a lot of municipal waste (MESPI, 2019). The total forest volume in Kosovo is 40,509 thousand m^3 (a unit of volume in the metric system equivalent to 1,000 cubic meters). According to the Ministry of Economy of Kosovo (Ministry of Economy of Kosovo, 2015), the average density of one cubic meter of wood in Kosovo is 798 kg/m^3. Additionally, an international report supports this value, indicating that the density ranges between 290 and 800 kg/m^3 (UNECE, 2016). Based on this data, the total forest biomass in Kosovo is approximately 32 million tons.

It could be added if there are data on the amount of municipal waste and its energy potential (or even if the latter is missing, it could also be calculated roughly how much energy could be generated by the combustion of it), which could mean additional potential for energy supply, even if not being considered as RES

2.6.7. The willingness of farmers to develop energy biomass market

According to a study of Ymeri and others (Ymeri *et al.*, 2020), it shows that 96% of the farmers in Kosovo use wood for heating purposes (from which 87.6% use only wood, compared with 7.7% use wood associated with coal) and only 4.01% use pellets. More importantly, 90.7% of these farmers have shown their willingness to sell their wheat straw to a bioenergy plant and only 9.3% did not want to sell it. As per corn straw, 51.5% of the farmers were willing to sell more than 50% of their corn straw. Lastly, the same article (Ymeri *et al.*, 2020) indicates that contractual relationships and specific market prices are two main components that determine the willingness of farmers to sell their straw for energy purposes. In this regard, the practice of burning agricultural residues in open areas would be avoided, means less air and land pollution and more potential for energy production. Interestingly, farmers who have higher levels of education were ready to sell more than 50% of their straw, which means that they see themselves as part of the energy biomass market.

However, in developing countries and in some developed countries are many rural areas that have different natural resources, but because of inadequate infrastructure, there can be some difficulties in exploiting those reserves regarding the bio-energy sector. In addition, the estimated value of biomass in Hernád Valley in Hungary (Bai et al., 2016), is about 125,000 tons of biomass is available in the area each year for energy purpose, which shows a great value and opportunity for both natural and social capabilities, for that specific rural area called Hernád Valley. In this regard, a proper investment would have tremendous positive effects on the rural population, such as improve living standards, economic growth, eco-friendly development. This Hernád Valley case scenario is a very good example for every developing country, how to develop not only one rural area but the whole country in general.

2.7. Challenge and Opportunity

According to Tranter et al. (Tranter et al., 2011), impediments to the development of renewable energy begin with high fixed costs, followed by skepticism regarding the financial rewards of such investments. However, possible cost reductions and environmental benefits are the primary motivators behind interest in these energy sources (Bai et al., 2016). To achieve sustainable growth, it is critical to foster a supportive environment that influences not only energy policies but also consumer attitudes and behavior (Zoltán Szakály, Péter Balogh, Enikő Kontor, 2021). Given the significant influence of lignite-based power plants on greenhouse gas emissions, this essay emphasizes the need to maximize the theoretical and practical potential of renewable energy sources in Kosovo. Currently, the energy sector accounts for 82% of total greenhouse gas emissions in Kosovo (Dreshaj et al., 2017). This high share of Kosovo's greenhouse gas emissions from the energy sector makes it essential to address this phenomenon as a key factor in reducing the country's overall carbon footprint. A scenario study suggests that using all renewable sources to their full potential might cut CO_2 emissions by up to 54% (Lajqi et al., 2020). This level of CO_2 reduction would contribute positively to Kosovo's targets to meet international climate commitments, such as the Paris Agreement, which focuses on reducing carbon emissions and limiting global warming to well below 2°C above pre-industrial levels (United Nations, n.d.).

In case of sustainable expansion of the electrical industry by constructing additional power generation capacity, implementing innovative technologies, and increasing the share of electricity generated from renewable sources by 10% of total electricity generation, in this regard Bekteshi et al. (Sadik Bekteshi, Skender Kabashi, Aleksander Zidanšek, 2016) predict a rise in CO_2 emissions from 7.5 to 10 Mt/year, but dust and SO_2 emissions will drop from 11.7 to 6 kt/year and 22.5 to 16 kt/year, respectively, This increase in CO2 emissions represents a worsening of the country's carbon footprint, which is a concern in the context of climate change in the country. On the other hand, the decrease in SO_2 and dust emissions represents a positive step towards improving air quality, especially in the case of particulate matter and sulfur compounds, which are considered hazardous to human health and the environment. At the same time, these data are important for understanding the aspects of how energy generation methods in Kosovo (coal-based) should be continuously evaluated, aiming towards cleaner sources such as biomass and its products. In this setting, diversifying agricultural activities and using renewable energy can help farmers earn more money, enhance efficiency, and achieve energy sustainability. This research is the first of its kind that illuminates the theoretical and practical potential of renewable resources in Kosovo, providing a valuable reference for the implementation and future development of the energy sector.

Reaching so far in the text:

- I can see a lot of repetitions which could be avoided by restructuring the text
- the literature review received more emphasis than expected, so it could be shortened

3. MATERIAL AND METHODS

3.1. METHODOLOGY

This methodological chapter contains important information on the organization's approach to collecting data, for the main purpose of identifying the potential of biomass for energy needs in Kosovo and the approach of individuals in this regard. This study incorporates quantitative methods, with the combination of data from different sources, whether from academic literature, various reports from public institutions, and statistics extracted from state databases. This chosen methodology allows us to have a high level of reliability in achieving the assessment of the potential of biomass and its incorporation into energy generation. In this context, the involvement of questionnaires as a primary research method and the use of reports and comparative studies as secondary data allows the author to rely on data that are credible and reliable. The latter paves the way to find coherent results and actual assessment of potential. This technique not only examines the current biomass energy production potential but also proposes practical measures for Kosovo's sustainable energy development. This methodology offers the groundwork for a thorough examination of the viability of biomass-based energy sources, ultimately benefiting rural development, environmental protection, and energy sustainability.

3.1.1. Primary and secondary sources

The data-collection methodology employed requires the usage of secondary and primary sources. This research would be based on a review of existing data (such as statistics, some reports, journal articles, books, and other literature) regarding the potential production of biomass in Kosovo. In addition, this research will include other relevant survey data. Worthy to mention is that in the context of secondary data, this remains a significant challenge in the context of researching the biomass potential in Kosovo as a result of the lack of official and comprehensive statistics. These shortcomings relate to the lack of information on the current quantity that Kosovo possesses in terms of types of biomass potentially usable for energy needs, the location and availability of agricultural and forestry biomass. Therefore, this complicates research and creates inefficiencies in the research process. On the other hand, data on biomass energy consumption also presents a challenge itself, with a lack of information regarding the fulfillment of the country’s energy mix needs. Based on the above-mentioned data, the researcher will make a calculation on final energy production from biomass sources in Kosovo and its utilization by taking into consideration other aspects of use.

3.1.2. Estimation of potential

To use biomass, first of all, is necessary to evaluate theoretically the availability of biomass for energy production. The evaluation of potential was carried out based on national government reports and then by the help of scientific studies the author of which was able to make the estimation of biomass potential in Kosovo level.

3.1.3. Analyses and interpretations

Different analyses from descriptive statistics (distribution, averages, clusters analysis, correlation between different variables, one-way ANOVA and Pearson's Chi2 508 test) were performed by using different statistical software such as the SPSS (Statistical Program for Social Sciences), VOSviewer, R package ‘’support BWS’’. It will be presented by different means such as narratives of case studies, organograms, tables, classifications in categories of fields of works, pictures as illustrations and charts.

3.2. Applied methodology for VOSviewer

To get more information and to know the trend, challenges and future directions of the biomass topic and its utilization, the author has decided to apply first of all a bibliometric analysis of this topic. Bibliometric studies provide an interesting perspective on a country's scientific production and its international status, assisting policymakers in making well-informed decisions about scientific programs. In this study, an exhaustive search was undertaken using Elsevier's Scopus database, focusing on the subfields (TITLE-ABS-KEY (biomass AND potential) AND TITLE-ABS-KEY (biomass AND utilization)) to uncover relevant papers from 1974 to 2021. The year 1974 was chosen as the starting point since it coincided with the publishing of the first foundational text addressing these two topics. The keywords "biomass potential" and "biomass utilization" were chosen for further analysis, and the search fields included titles, abstracts, and keywords. After accessing the Scopus database, the author was able to review and take into account a large number of publications that were used as a basis for their detailed analysis, extraction of results and interpretation. The main reason for selecting the Scopus database was the reliability of the data contained in the database and its consideration as one of the most important databases of scientific articles. According to the study by (Niñerola et al., 2019), this database had about 80 million records in 2019, suggesting that it has a high appreciation by scientists. It is also known as an important archive of literature that contains rigorous reviews of various research literature (Salmerón-Manzano & Manzano-Agugliaro, 2018). Other studies highlight the reliability of Clarivate Analytics Web of Science (WoS) and Elsevier Scopus in the context of providing a wide range of bibliographic data that can be used for various analyses as a result of their high quality (Heradio et al., 2016), (Duque-Acevedo et al., 2020). Given this, both databases were used to conduct examinations of the extent of the data that would be used in our methodology. From this, it is concluded that Scopus, in addition to containing the data included in WoS, also contains additional bibliographic data from various research conference proceedings. It is important to keep in mind that the number of citations can vary between different databases and this can create a kind of uncertainty and inconsistency in this regard (Heradio et al., 2016). Above all, by analyzing all the factors, Scopus was chosen as the sole source of data used in this study. Continuing on, Scopus allows its users to visualize the data they need through an application called VOSviewer (Duque-Acevedo et al., 2020), suggesting that it is a very user-friendly database. This tool (VOSviewer) is free software that enables the analysis of bibliometric networks when using data from databases such as Scopus (de la Cruz-Lovera et al., 2017). Additional information about the actions taken within the framework of the research analysis is presented in the Figure 6.

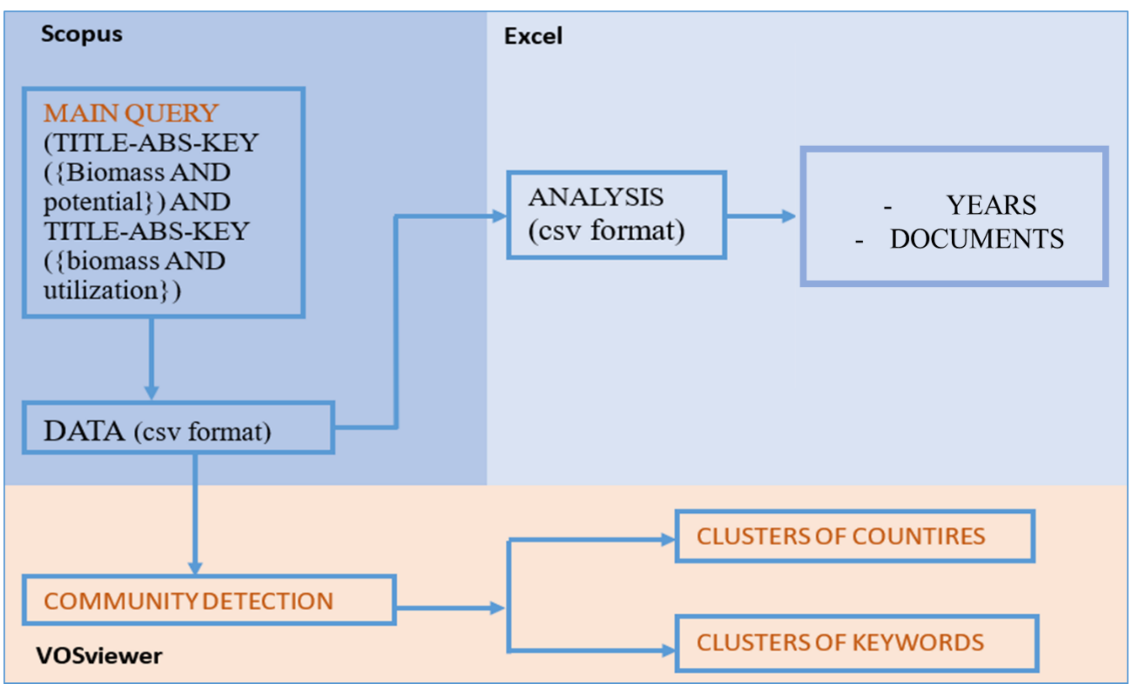

Figure 6. Methodology scheme for bibliometric analyses

Source: Author own figure based on (Sertolli et al., 2022).

3.2.1. Methodological approach steps with VOSviewer

The first step carried out within the framework of the selected method is the broad search carried out through previously selected keywords. In the Scopus database, between 1974 and 2021, a total of 7117 articles have been generated. In the second step, this metadata was transferred to a CSV file and further elaborated through Excel software. The greatest focus was placed on topics such as biomass potential and global utilization, to create a comprehensive comparison within the framework of the selected topic. The next step focused on extracting bibliometric images through the VOSviewer program to have a clearer co-occurrence of terms, the extent of research in this direction and the cooperation between countries in this framework. The research found different clusters, shedding light on the collaborations within the scientific community. The findings of this study include the production of the scientific community within this topic, the evaluation of publications based on countries (visualized in figures and maps), the keywords evaluation, the language of publication of the articles, the types of documents published, the main subject area, the number of citations as well as the main authors who made the highest contribution to this part. Through the cluster-analysis method, it was possible to group the terms into specific categories which in a general way are independent of each other. These keywords within the groups have shown a close correlation with each other. Furthermore, this grouping has used various statistical techniques to determine the frequency of the terms and to achieve the grouping of terms with strong connections between them. This methodological approach allowed us to better understand the underlying structure and thematic focus of the research landscape on the potential and assessment of biomass utilization (Gong et al., 2019).

3.3. Approach for estimating biomass potential in Kosovo

3.3.1. The assessment of agricultural biomass potential

The potential of agricultural biomass has been assessed by taking into account several factors and other elements which are listed below:

- Crop production area and types;
- Crop yields;
- Crop residue-to-yield ratios based on crop type and yield.

Which vary based on the crops grown. Cereal biomass potential was calculated using crop acreage and yields. Kosovo's total grain cultivation area (cereals and fodder crops) was 232,885 hectares. Maize and wheat are the most widely grown crops, with the highest biomass production capability. The biomass produced by these crops was calculated using the fruit (seed)-to-plant ratio. This ratio varied from 1:0.5 to 1:1.5, depending on the crop species (Ministry of Economy of Kosovo, 2015),(Mazurkiewicz et al., 2019),(A. Bai, Durkó, et al., 2016). To evaluate the energy potential, the lower heating value (LHV) and conversion rate of fodder crops (202, 172 respectively) into biogas were taken into account. This agricultural biomass potential can be used to generate electrical and thermal energy, with biogas from fodder crops serving as an additional source of heat production. The primary rationale for narrowing the focus to this specific form of biomass utilization lies in the pressing challenges associated with electricity shortages. A significant portion of the population relies on electricity for heating during the winter months, which places additional strain on the already fragile power system. In this context, promoting alternative heating solutions through biomass energy emerges as a strategic response to alleviate pressure on the electricity grid and enhance energy system stability

3.3.2. The assessment of livestock potential

Several essential parameters were considered while estimating livestock biogas potential, including:

- Total number and types of animals;
- Amount of manure produced;
- Living mass of animals.

The first stage in assessing Kosovo's bioenergy potential is to collect livestock data. In this study, livestock population data were gathered from the Ministry of Agriculture's Green Report (MAFRD, 2022), which supplied the information needed to calculate biogas potential.

As stated in the Table 2, Kosovo has a total of 3,339,169 heads of animals, including poultry. The live weights of these animals vary according to their breed. Daily manure generation (kg/day) is computed using Ministry of Economy data (Ministry of Economy of Kosovo, 2015). To standardize the mass of live animals across categories, a 500 kg animal unit (AU) is employed. The total amount of animal manure is calculated by multiplying the number of animal units by the daily average manure production. Tables in the results chapter summarize the live animal weights and daily manure generation by type. To evaluate the biogas generation potential from livestock manure, both total manure generated and biogas capacity per ton of manure are required.

Table 2. Livestock structure in Kosovo, number of heads per each category 2021.

Number and Types of Animals	No. of heads, 2021
Cattle fund	260,528
Sheep fund	211,354
Goats fund	30,039
Pigs fund	47,384
Poultry	2,788,000
Other	1864
Total	3,339,169

Source: Author composition (Sertolli et al., 2023) based on the Green report (MAFRD, 2022).

3.3.3. The assessment of forest biomass potential

Forest-based biomass includes firewood, forest residues, and byproducts from the wood industry. Firewood, in particular, is a sort of wood used largely for home heating. Table 3 shows the most frequent wood species in Kosovo, together with their volumes. The largest broadleaf species is Fagus sp., followed by two Quercus species with quantities of 18,524 thousand m^3 and 7,951 thousand m^3, respectively. Pinus sp. has the highest volume among conifers, followed by Picea abies and Abies alba, with quantities of 2,502 thousand m^3, 1,840 thousand m^3, and 1,573 thousand m^3, respectively.

Table 3. Volume in thousand m^3 for most common broadleaves and conifers in Kosovo.

Wood Species	Volume in Thousand m^3
Turkey oak (Quercus cerris)	4282
Sessile oak (Quercus petraea)	3669
Oak species (Other quercus sp)	1292
Beech species (Fagus sp.)	18,524
Other broadleaves	6750
European silver fir (Abies alba)	1573
Norway spruce (Picea abies)	1840
Pine species (Pinus sp.)	2502
Other conifers	77
Total	40,509

Source: Author own calculation (Sertolli et al., 2023) based on the Ministry of Economy report (Ministry of Economy of Kosovo, 2015).

The overall forest volume in Kosovo is 40,509 thousand m^3. According to the Ministry of Economy of Kosovo (Ministry of Economy of Kosovo, 2015), the average density of one cubic meter of wood in Kosovo is approximately 798 kg/m³. International reports suggest a range of 290 to 800 kg/m³ (UNECE, 2016). The total weight of forests in Kosovo is estimated to be 32 million tons.

3.3.4. The assessment of solid waste potential

Human activities are the leading cause of garbage generation. This is a global issue, but it is especially critical in Kosovo, where the majority of garbage is disposed of in landfills. According to official reports, Kosovo generates a large volume of municipal garbage (MESPI, 2019). This expanding volume of garbage emphasizes the importance of long-term solutions for successfully managing and utilizing it. The research of the energy potential of garbage focuses on its conversion capacity for energy production. The results show that garbage can be used to generate thermal, electrical, and combined energy. To estimate biomass potential from solid waste, analyze the overall amount of trash created as well as its Lower Heating Value (LHV), which is a significant metric in energy production calculations.

3.4. BWS method

Best-Worst Scaling (BWS) is a discrete choice model that not only explains but also quantifies respondents' preferences (Jordan J. Louviere, n.d.). It is a reliable method for determining the relative importance of various traits that ask participants to select the "best" and "worst" features from a list of possibilities. This approach aids in determining a preference score for each quality based on the choices made. This chosen method helps in achieving the result of respondents' preferences based on the choices that the latter have made. The BWS method is of particular importance since it provides details and clear knowledge about how individuals prioritize the choices that suit them. The advantage of BWS is that this type of analysis includes respondents of different profiles, with unique characteristics and special qualities. Then respondents are asked to select the "best" (most preferred) and "worst" (least preferred) attribute, based on their perspective.

3.4.1. BWS for preferences and renewable energy insights

The BWS rating process continues until all selected profiles have been rated, allowing respondents to specify their preferences for each attribute. The focus of this section is on determining the relative and comparative importance of each attribute, which is achieved by allowing respondents to systematically select the most and least important attributes. This strategy allows respondents to filter their choices and preferences and analyze what they prefer most and least. This analysis structure allows respondents to consider all factors and circumstances before responding, and in this way ensures the reliability of the data collection, providing a more accurate reflection of overall preferences. This analysis ultimately informs us of the most important and least important components, offering researchers a reflection on the choices and factors that influence these choices in a given environment, as is the case for assessing preferences for biomass. Although the BWS method is usually used for consumer preferences, this method is also used in empirical assessments of the management of agricultural enterprises (Yang & Yagi, 2024). In this context, BWS as an important analysis tool enables different researchers to gain knowledge about the perceptions and objectives of agricultural entrepreneurs and decision-making processes by considering a series of factors and aspects that influence the selection, operationalization, resource allocation, investment decision-making and the perspective of farm sustainability. This method gives us a better picture of how farmers and agricultural entrepreneurs are pursuing sustainability in making various decisions, such as cost-effective, eco-friendliness and environmentally sustainable, and market demand. Precisely this method determines the relative importance of the motives, preferences and systematic and strategic goals of agricultural entrepreneurs, as elements that influence the ongoing operations of the farm. The continued application of this method in this topic is trying to bridge the gap between consumer behavior and business decision-making, paving the way for more meaningful and sustainable policies, investment strategies, and adequate business practices.

While global climate change practices and studies are topics of ongoing discussion, agricultural students are an important component positioned towards changes in this direction, which can be an important link towards the successful integration of renewable energy ideas and practices in the agricultural sphere. Specifically, their educational background and their agricultural experiences incorporated with the environmental one are foundations that enable them to clearly and correctly assess the impact of renewable energy in identifying various farm problems, and the effectiveness that it can have in this context. Through various environmental practices and the application of renewable energy knowledge, these students are important actors in research on how to increase farm productivity, achieve good resource management, and promote sustainable agricultural practices. Since agricultural students are an added value to the agricultural production chain, it is crucial to analyze their approaches and attitudes towards renewable energy practices. Through their perspective, new insights can be gained into the barriers that currently exist in this area and the acceptance of resource integration can be understood in this regard. Therefore, understanding their attitudes and preferences among different attributes presents a clearer picture of how environmentally sustainable activity is being cultivated in daily agricultural practices.

3.4.2. Student attitudes and the role of BWS in renewable energy adoption

Within the framework of the research conducted, students of the Faculty of Agriculture and Veterinary were encouraged to be part of the research regarding the integration of the contemporary topic of renewable energy and its impact on the future of the country and the sector. Students were offered a questionnaire in the form of BWS, which is an approach that involves the selection of one of the three BWS methodologies (object case, profile case, and alternative case) to choose the best and worst alternatives, within the framework of the presented attributes (Flynn, 2010), (Török et al., 2023a),(Török et al., 2023b). These techniques offer a high flexibility in understanding the perceptions of the respondents, and how they give importance to their preferences and priorities.

The author used the object case BWS with the following introduction (as seen in Table 4): "*In the following section, the author would like to understand what is important to you when using renewable energy sources. You will be asked to indicate, in three different scenarios, the most and least important attributes that affect your purchasing decisions for a specific renewable energy source."*

Table 4. Example of the BWS decision format.

What factors do you consider most important and least important regarding the use of renewable resources?		
Feature	The most important	The least important
Price		
Availability		
Knowledge		

Source: Created by the author.

The object case BWS methodology allows participants to prioritize specific factors and preferences, such as cost savings and environmental friendliness, in the context of comparisons made when deciding. Respondents must make the most appropriate and least essential choice within the framework of the three attributes set against the question asked, allowing for relative comparisons of the options set. This technique allows the use of a high number of components considered important in the research carried out, highlighting the most essential attributes. In the context of all this, the author has selected the seven most important attributes that coincide with the researched topic of consumer preferences in the context of renewable energy devices (Table 5). The selected characteristics were established after research conducted in the literature related to our topic and are attributes that find application in everyday circumstances regarding preferences, having the certainty that these are attributes that have an extremely significant impact when considering decisions about renewable energy. The students were subjected to the questionnaire and tried to be as realistic as possible so that the data collected would be reliable and unbiased.

Table 5. Attributes used in the object-case BWS questions.

No.	Attributes
1	Eco-friendliness
2	Price
3	Investment cost
4	Convenience
5	Multifunction
6	Knowledge
7	Availability

Source: Created by the author.

The first stage in the analysis of the generated data is the determination of the best and worst rate data for each attribute. To achieve this, the "worst" value is subtracted from the other extreme "best" value. Above all, this formula can be used both in individual and aggregate form.

At the individual level, the Best-Worst Score for each respondent (n) and assessed aspect (k) is generated using the formula as can be seen below (Equation 1):

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

When n is the respondent and k represents the attribute that is evaluated or the considered characteristic.

The Best-Worst score for each attribute is derived on an overall basis from all respondents. This can be achieved using the following formula (Equation 2):

$$Best - Worst\ \text{Score}_k = Best\ \text{score}_k - Worst\ \text{score}_k \tag{2}$$

The final level of analysis, the overall best-worst score, ranks the importance of the factors under consideration. The BWS (Best-Worst Scaling) value is the core of the analysis. These figures show the difference in how frequently each quality was selected as "most important" (best) against "least important" (worst) across all respondents and choice sets. In addition Best-Worst Scaling (BWS) table the columns "Square root" and "Relative %" are used to normalize and compare the importance of attributes in a more interpretable and comparable way.

Square root: This is often the square root of the standardized BWS score (or another normalized value) used to scale the differences among items and also to reduce the impact of outliers or large deviations. Relative %, this column shows the importance of each attribute as a percentage relative to the most important one. These scores provide an overall picture of the ranking of features across respondents. In the next step, it is calculated the mean best-worst values for each feature, as well as the standard deviations, to assess the variability of respondents' preferences. Once the mean best-worst scores and the associated standard deviations are generated, then the Cohen's (2009) standardized best-worst scores were calculated and visualized, which standardize the scores for easier comparison across criteria. These normalized scores can be determined at both individual and aggregate levels, providing greater insight into individual preferences as well as broad trends.

Individual Level: The standardized Best-Worst score for each respondent (n) and assessed attribute (k) is generated using the following formula (Equation 3):

$$\text{Standardized } Best - Worst\ score_{n,k} = \frac{Best - Worst\ score_{n,k}}{f}, \tag{3}$$

When f represents the frequency of occurrence of the aspects under examination.

Aggregate Level: The standardized Best-Worst score at the aggregate level is calculated using the following formula through Equation 4:

$$\text{Standardized } Best - Worst\ \text{Score}_k = \frac{Best - Worst\ score_k}{Nf}, \tag{4}$$

When N refers to the number of respondents.

Investigating further the factors, the square root of the Best-Worst ratio and its standardized version is calculated, providing further information on each attribute's relative relevance.

Square Root of Best-Worst Ratio: This phase calculates the square root of the ratio of Best to Worst scores for each attribute. The formula is as follows (Equation 5):

$$\text{sqrt. } Best - Worst\ score_k = \frac{Best-scorek}{Worst-scorek}, \tag{5}$$

Standardized Square Root of Best-Worst Ratio: The square root is standardized to make the Best-Worst ratio more comparable across attributes. The standardized version is computed as follows (Equation 6):

$$\text{sqrt. } Best - Worst\ score_k = \frac{\text{sqrt.Best}-\text{Worst scorek}}{\text{max.(Best}-\text{Worst score)}}, \tag{6}$$

where max. (best-worst score) represents the greatest value of sqrt. Best - Worst scores. (Gergely et al., 2023).

3.4.3. Statistical analysis to explore renewable energy preferences

In the framework of the standardized version of the square root of the Best-Worst ratio option, it is possible to compare the relative value of each feature established in the research, calculating the variability based on the choices of the respondents. In this way, during this phase it is guaranteed and ensured that the analysis carried out is not affected by variations in the scale or distribution of scores across attributes, raising them to a more accurate point of their importance in the decision-making process.

After exploring the heterogeneity of preferences, statistical analyses using individual-level Best-Worst values were additionally performed. These analyses helped us explore the variations in preferences for factors influencing the purchase of renewable energy equipment, among different groups of participants, allowing us to understand how economic and social factors influence preferences for renewable energy. Non-hierarchical clustering (K-Means) was used as part of the analyses performed to identify groups of respondents based on their perspectives and preferences for different attributes of renewable energy. K-Means clustering is a very effective method for categorizing participants into discrete groups, as each researched group has preferences that are comparable to the main features related to the use of renewable energy, providing us with knowledge about the diversity of preferences of the researched group and helping to segment people based on their shared values.

After these processes were carried out, the Kruskal-Wallis test was performed to compare the differences created between clusters in ordinal measurement-level variables which are age, gender, field of study, type of residence, region, and employment status. The Kruskal-Wallis test is very suitable for this type of comparison and calculation which are on the ordinal scale, and allows us to understand whether the cluster groups vary in significant differences based on social and demographic factors. The study was performed on data using IBM SPSS Statistics 29 which includes comprehensive data comparisons for two-step clustering. This method proved to be challenging in uncovering underlying patterns and variances in how different participants perceive the qualities of renewable energy.

To establish statistical significance and compare groups, a one-way ANOVA and Pearson's Chi-square (Chi^2) were used. The one-way ANOVA was applied to ensure that no difference can be detected in different variables such as age or income between groups. This is very important especially when there are multiple variables and help to compare the means of variables to see if the differences between groups are statistically significant. On the other hand, the Chi^2 Test was used to assess categorical characteristics, including gender, field of study, and type of residence. This type of test helps to understand the relationships between socio-demographic characteristics and cluster groups, showing how these factors can affect people's preferences for renewable energy qualities. Also, the Chi^2 Test compares categorical distributions of variables across groups, understanding how different demographic groups favor renewable energy. These statistical methodologies allowed for a thorough exploration of the diversity of respondents' preferences for renewable energy, as well as the identification of different segments with different priorities.

3.4.4. Description of the sample of BWS

Data for this study were collected using a questionnaire from a sample of 100 students from the University of Prishtina's Faculty of Agriculture and Veterinary (see Table 6). The sample size was set to ensure a representative sample of students in this field, allowing for an examination of their preferences and perspectives. To ensure that the sample was as representative as feasible, the authors began by calculating the total number of active registered students in each course. In 2023, there were a total of 874 active students, distributed as follows among several courses:

- 325 students enrolled in the Food Technology course;
- 209 students in the Agriculture Economics course; and

- 179 students in the Plant Production course.

Other students are enrolled in other courses, but their numbers are substantially lower than the three primary courses mentioned. This gap in student numbers is one of the reasons why the writers focused on the Food Technology, Agriculture Economics, and Plant Production courses. The second reason for focusing on these courses is the significance of renewable energy sources (RES) in these sectors. These courses are intimately related to agricultural production, food processing, and environmental sustainability, therefore students in these programs are more likely to have relevant views and perspectives on the integration and acceptance of renewable energy technologies. Thus, prioritizing these courses assures that the information gathered is extremely relevant to the study's focus on renewable energy in agricultural settings.

The Best-Worst Scaling (BWS) questionnaire is used to conduct quantitative research on the number of students on each course. In this regard, students from the Food Technology course led with 49% of all questionnaire responses. This was followed by students from the Agriculture Economics course, who contributed 33%, and the Plant Production course, whose students provided 18% of all replies in the study. Regarding socio-demographic data, the female gender had a higher participation, with an average age of 20.6 years. In terms of residence, the majority of respondents lived at home, with a higher participation from the municipality of Prishtina. These variables were determinants for the recognition of the selected sample in identifying general preferences for energy. Table 6 summarizes in detail the sample and its characteristics, the distribution of the sample by gender, field of study, type of residence, and area of residence. This accurate elaboration is critical to understanding how different demographic characteristics influence choices and attitudes toward renewable energy.

Table 6. The main sample characteristics for students of the Faculty of Agriculture and Veterinary.

Denomination	***Categories***	***Percentage***
Gender	Male	16
	Female	84
Field of study	Food Technology	49
	Agricultural Economics	33
	Plant Production	18
Region	Other region	39

	Prishtinë	61
Type of residence	Flat	15
	House	85
Employment	Unemployed student	80
	Employed student	20

Source: Created by the author.

Student perceptions are extremely important in a country like Kosovo, where coal is the main source of energy production, while continuously aiming to meet EU environmental standards and adopt more sustainable energy alternatives. Students, who are considered to be future leaders in disciplines such as food technology, crop production and agricultural economics, are directly affected by energy practices and are well-positioned to shape the future of Kosovo’s energy industry. Their continuing education and commitment to sustainable knowledge provide them with the necessary tools to promote sustainable practices and bring new life to renewable energy options, such as biomass thermal energy, as sustainable alternatives to coal. By assessing their perceptions and views, the study sheds light on the current awareness and attitudes of students towards renewable energy sources (RES) in these agricultural fields.

The analysis provides insights into students’ readiness to integrate renewable energy technology and identifies the barriers they see in integrating RES into an energy system that has long been dominated by coal. The fact that these students will have the opportunity to influence energy regulations with ideas from the field and agricultural practices adds even more value to their involvement in the study.

Their views are critical in understanding the challenges and prospects for embracing renewable energy in Kosovo, a country suffering from environmental issues yet highly reliant on coal-based electricity. This makes the students' perspectives not only useful academically but also critical for the actual reform of Kosovo's energy sector. Their ability to advocate for and push the adoption of renewable energy solutions will be critical in molding the country’s energy future, especially as it strives to satisfy the European Union's environmental criteria.

4. FINDINGS AND RESULTS

4.1. Biomass potential and utilization on world scale

Initially, it was deemed necessary to research the issue of biomass potential and its utilization on a global scale. Therefore, in this regard, the author has also published results that demonstrate important indicators and factors towards important trends in terms of countries and keywords in this field. The volume of publications originating from a country or region serves as a valuable measure of their scientific activity. Analyzing the various trends and efforts of countries or regions in a specific subject of study is especially important. This method enables researchers to uncover and highlight the most recent patterns in the evolution of the topic while contextualizing their results. Furthermore, it is exciting to evaluate how scientific advances in specific fields have changed over time, as well as to identify future benefits and priorities that may emerge.

From 1974 to 2000, just a few documents on biomass potential and utilization were released annually. Although the trend was gradually improving, it did not exceed 50 publications each year. Since 2000, however, the number of publications has steadily increased, as seen in the Figure 7. A considerable increase occurred in 2011, followed by a significant rise beginning in 2012. The increase in scholarly papers on biomass potential and consumption is consistent with an $R^2 = 0.989$ fit curve, shown in Figure 7. In alignment with this upward trajectory, the graph also illustrates a consistent increase over the past two decades. Notably, both for biomass as a whole and for biomass potential and its utilization, the year 2011 recorded a higher number of publications compared to the subsequent year.

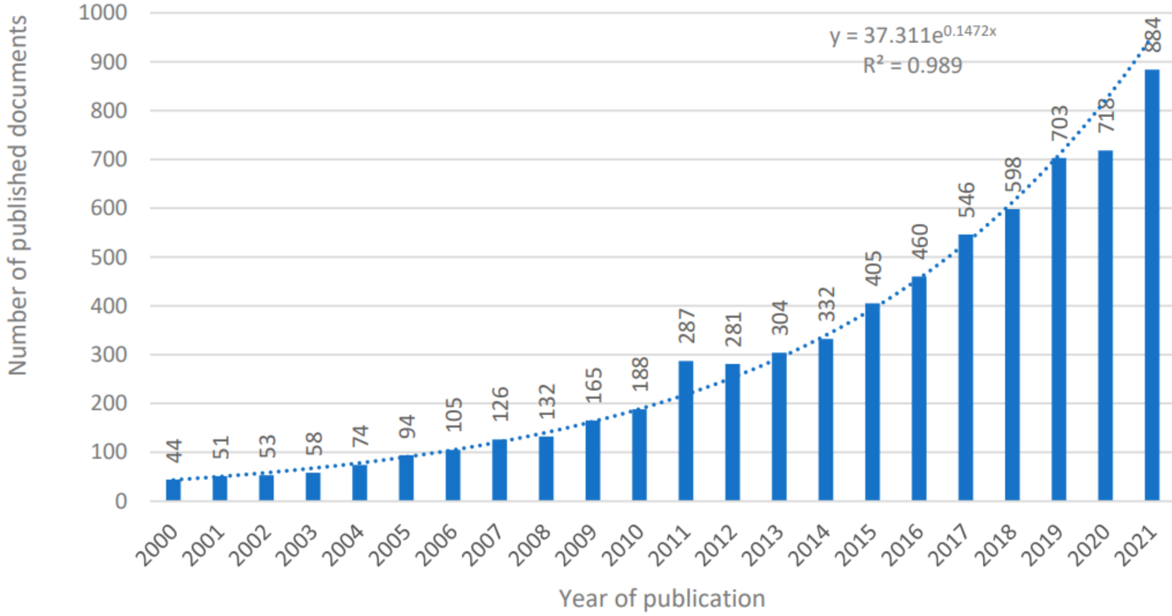

Figure 7. Publication trends of Scopus-based search literature on biomass potential and utilization.

Source: Created by the author (Sertolli et al., 2022).

4.1.1. Global collaboration and clustering in biomass research

Among the 195 countries studied, the top 50 countries, each with at least 26 publications, create a collaborative network of co-authors as you can see in the Figure 8. Authors in this network are connected indirectly through their contributions to shared publications. The 50 countries are divided into four separate clusters. The red cluster is mostly composed of European countries. The green cluster includes Southeast Asian countries, with China and India emerging as the most prominent contributors. Malaysia and Australia lead the blue cluster, which also includes a few countries from West and South Asia and two from Africa. The yellow cluster consists primarily of North and South American countries, with the addition of the United Kingdom and the Russian Federation.

The central actors in these clusters act as essential nodes, promoting connections between them and improving the broader network of collaboration.

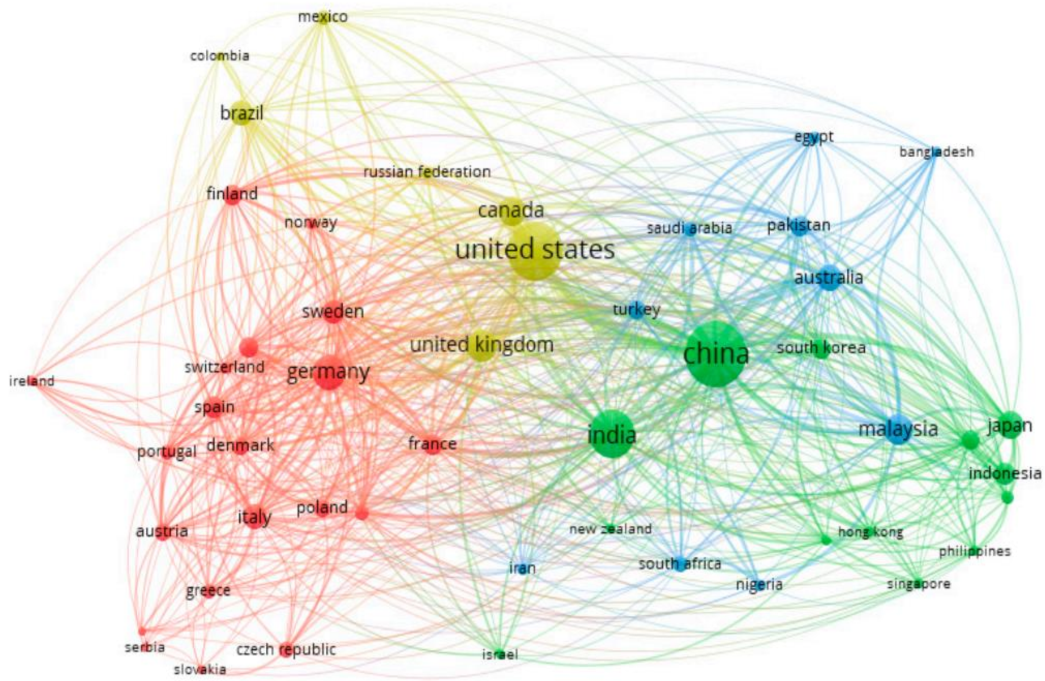

Figure 8. Collaborative work between countries.

Source: Created by the author (Sertolli et al., 2022). Clusters name: red: Europe; green: South Asia and India; blue: Australia, Malaysia, and West Asia; yellow: North and South America, UK, and Russia.

4.1.2. Keyword analysis and clustering in biomass research using VOSviewer

VOSviewer provides functionality for analyzing the keywords of numerous documents, organizing them into categories that group related terms within the same community, and presenting them in a visually optimized format. The Figure 9 depicts the co-occurrence network for keywords, which contains 60 of the 13,123 keywords detected in publications between 1974 and 2011, with each term appearing at least 51 times.

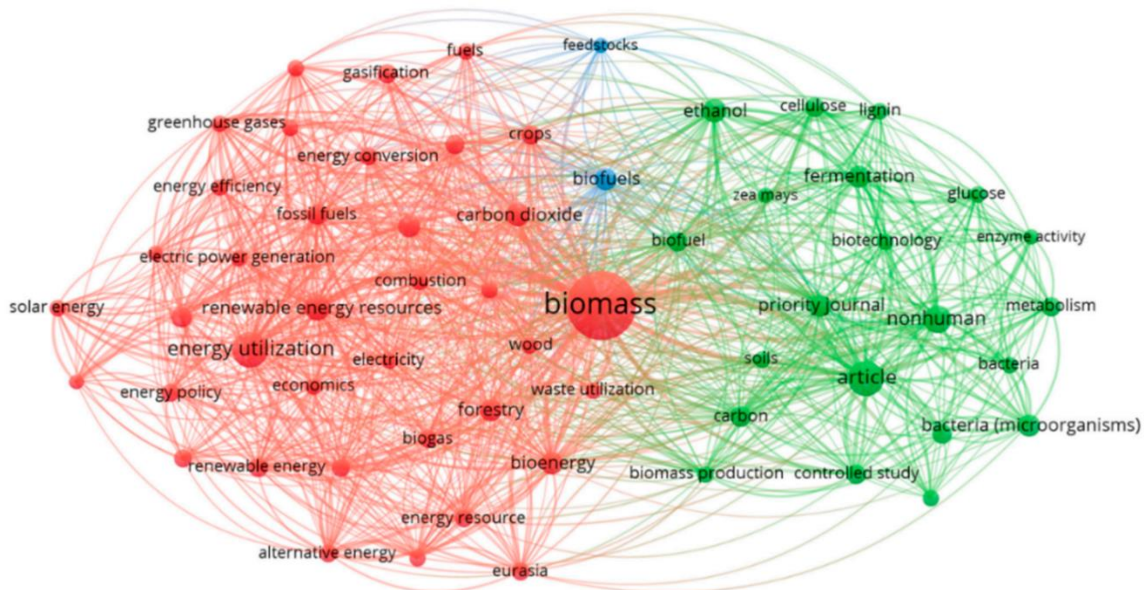

Figure 9. Keyword co-occurrence network regarding biomass potential and its utilization from 1974 to 2011.

Source: Created by the author (Sertolli et al., 2022).

Legends of colors regarding clusters names:

- red: energy use, its feedstock, and environment,
- green: microbiological, technological, publication, and general items,
- blue: next-generation transportation fuels.

Moreover, the Figure 9 shows three separate clusters. The red cluster, which represents the primary group, makes up more than half of the database and includes terms about energy, feedstock, and the environment. The green cluster on the right side comprises phrases related to microbiology, technology, publications, and general expressions. Finally, the blue cluster only has two keywords: biofuels and feedstocks, which overlap with the green cluster.

The Figure 10 depicts the places that have gained importance or seen the most substantial development between 2012 and 2021. Moreover, the third cluster, depicted in blue, has grown in importance. The red cluster dominated the previous image with the bulk of keywords, however its proportion has fallen dramatically. In contrast, the number of keywords in the green cluster has increased. This figure also shows the blue cluster's significant expansion over the last decade, indicating advances in research on third- and fourth-generation biofuels. This cluster's key terms include biofuel, algae, microorganisms, microalgae, and biodiesel. The bibliometric mapping of research outputs shows that third- and fourth-generation biofuels are quickly progressing and approaching industrial-scale production.

Additionally, the term *biomass*, which is not directly associated with human nutrition or energy production (represented by the "nonhuman" expression in Figures 9 and 10), has remained stable in relevance, maintaining moderate significance throughout this period.

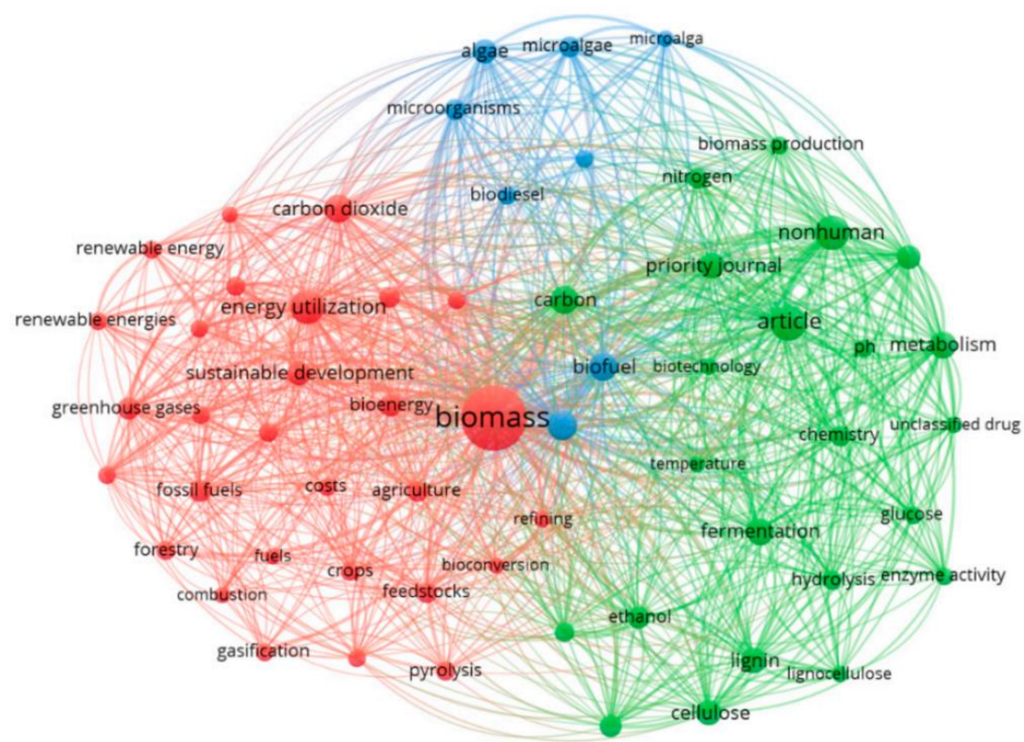

Figure 10. Keyword co-occurrence network regarding biomass potential and its utilization from 2012 to 2021.

Source: Created by the author (Sertolli et al., 2022).

Legends of colors regarding clusters name:

- red: energy use, its feedstock, and environment,
- green: microbiological, technological, publication, and general items,
- blue: next-generation transportation fuels.

4.1.3. The growing importance of biomass: potential and challenges

The immense potential of biomass highlights the need for extensive research to identify the most viable and effective combinations or portfolios of biomass-use strategies adapted to the specific characteristics of a given region or area. With the fast-expanding need for energy and the emerging value of specialized energy crops and plantations, the energy-related usage of biomass is receiving more attention in scientific literature. However, the use of bioenergy technology is limited by competing biomass usage methods and the growing importance of alternative renewable energy sources. This emphasizes the importance of including bioeconomic considerations to enable the efficient and sustainable use of biomass.

Algae-focused studies have grown at the fastest rate and sparked the most interest in biomass use research, with the most referenced publication also falling into this area. This rise in attention can be linked to algae's extraordinary theoretical potential as a raw material for next-generation fuel production and anaerobic digestion processes.

The environmental consequences of using biomass for different reasons, including energy production, are increasingly acknowledged as important. This is partly owing to the important role that energy plays in greenhouse gas emissions, making biomass a feasible and environmentally friendly alternative to fossil fuels. Scientific outputs from China and India are increasing exponentially, whereas contributions from industrialized countries appear to be moderate or stable. Given the large biomass output potential, quickly expanding economic prospects, and significant environmental dangers in these developing countries, this development is not surprising. Food production, direct combustion, and biogas generation are frequently prioritized applications in these regions.

4.2. Theoretical energy biomass potential in Kosovo and its utilization

Kosovo has access to the raw resources required for the shift from lignite to biomass energy production. However, issues such as energy price ratios, infrastructure, and farm size in the agricultural sector provide substantial barriers to future utilization. As a result, the goal is to estimate the potential of these resources in Kosovo, compare them to national energy consumption, and rank them with other countries with similar conditions in terms of land, climate condition and energy potential. Kosovo has natural resources that can be used to generate energy through renewable technologies, such as biomass from cereal straw, livestock wastes, forests, and solid waste. While some of these resources can be used to generate energy, the majority is used for organic fertilizers, the timber industry, feedstock, and bedding. Whereas, solid waste stands out because it may be available 100% for energy production, as seen in the Figure 11.

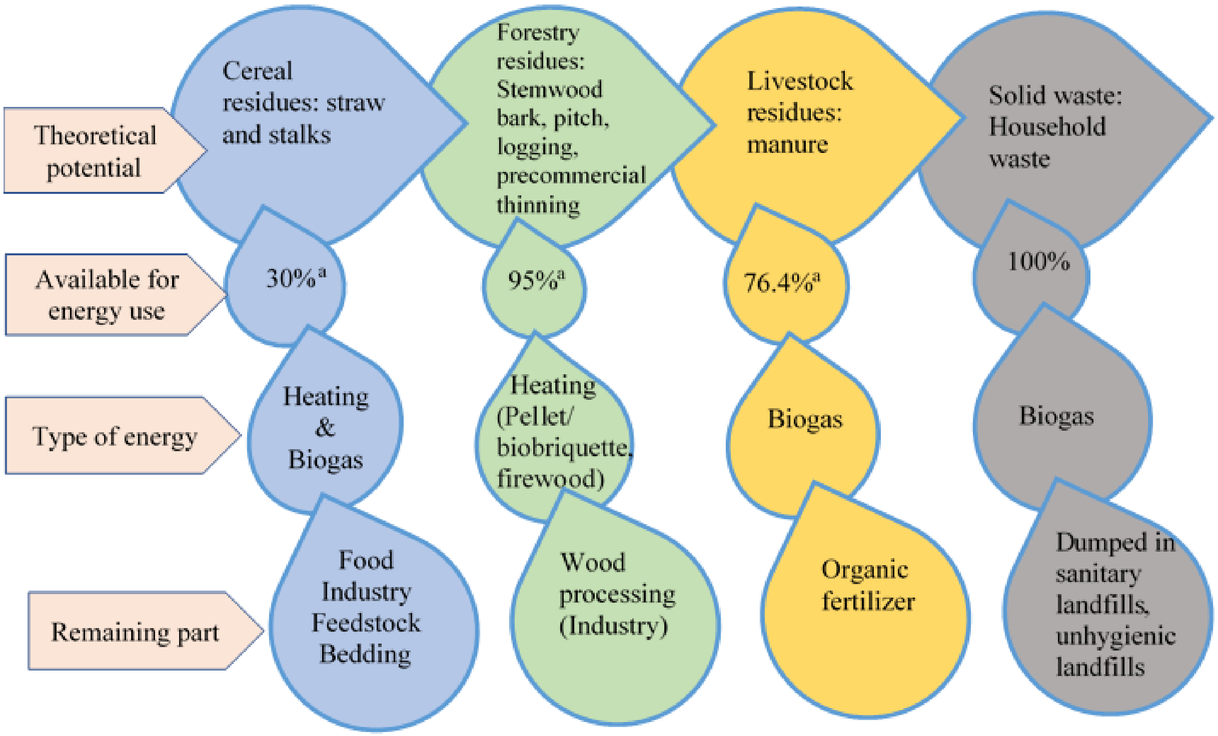

Figure 11. Main contributors to biomass potential in Kosovo. Legend: ''a''—estimation of the Ministry of Economy (Ministry of Economy of Kosovo, 2015).

Source: Author own figure (Sertolli et al., 2022).

Solid waste's 100% utilization for energy production is linked to its suitability for biogas generation, as recycling or other applications for this garbage are now not viable. Furthermore, there is a distinction between theoretical potential and energy potential: theoretical potential includes all biomass sources available for diverse uses, whereas energy potential particularly refers to the capacity of biomass sources used for energy generation. The energy potential is always reduced due to how these resources are employed. A key challenge is the seasonal nature of biomass energy, which is mostly used for heating and hence only useful during the winter months. Furthermore, although wood is accessible locally in limited numbers, it is best suited for direct heating. In the future, larger-scale production may become feasible for example, thousands of tons of wood per hectare may be utilized for pellet manufacture, but lower quantities, such as hundreds of tons per hectare, are better suited for cogeneration reasons.

4.2.1. Agricultural biomass potential

Agricultural byproducts such as straw and maize stalks produced after harvest are useful sources of energy. However, vines and wood chips from vineyards and orchards were excluded from consideration because they account for a small portion of Kosovo's agricultural and biomass output. The biomass potential of cereals was determined using the farmed area and crop production. According to the report (MAFRD, 2022), the total cultivated area for grains (cereals and fodder) in Kosovo was 232,885 hectares. Maize and wheat are the most widely cultivated crops and have the greatest potential for biomass generation. To evaluate the energy potential, fodder crops' lower heating value (LHV) and biogas conversion rate must be determined. This agricultural biomass potential can be used to generate both electricity and heat energy. Additionally, biogas obtained from fodder crops can be used exclusively for heat generation.

According to the Ministry of Agriculture of Kosovo data (MAFRD, 2022), our calculations reveal that the total biomass from grains is 503,930 tons each year, as shown in the Table 7. Given that wheat and maize are the most extensively grown crops, there are two basic techniques for using agricultural crops to generate biomass: directly from the crops themselves (such as straw, maize stalks, etc.) or from the crops' fruits (such as wheat, maize, barley, etc.). However, producing biomass from the fruits of agricultural crops offers a substantial difficulty, especially given Kosovo's reliance on grains for food supply. The trade balance (exports and imports) for these two key crops reflects this reality. As a result, wastes such as straw and maize stalks should be the primary source of biomass for cereal-based energy production.

Table 7. Area, yield, and biomass production of cereals in Kosovo, 2021

Cereal type	**Area (ha)**	**Production (t/year)**	**Mass ratio (t/t)**	**Weight of residues from cereal crops**
Wheat	79 970	322 018	1;0.5 (A. Bai, Durkó, et al., 2016)	161 009
Maize	39 710	170 393	1;1.01 (Mazurkiewicz et al., 2019)	172 097
Barley	2 060	5 610	1;1 (Ministry of economy, 2015)	5 610
Rye	555	1 409	1;1.5 (A. Bai, Durkó, et al., 2016)	2 113
Oat	2 030	4 500	1;1 (Ministry of economy, 2015)	4 500
Total	124 325	503 930		345 329

Source: Author own calculation (Sertolli et al., 2023) based on the references indicated inside Table 7.

Cereal biomass is used in a variety of applications, including animal feed, bedding, soil enrichment after harvest, and addressing industrial needs. As a result, a large amount of this biomass cannot be used for energy production. According to a Ministry of Economy of Kosovo report (Ministry of Economy of Kosovo, 2015), grain biomass is used for energy production at rates ranging from 10% to 40%. In our scenario, given the restricted industrial usage of biomass, a 30% utilization rate for energy purposes is considered reasonable. As seen in the Table 7, Kosovo generates roughly 345,329 tons of biomass per year from cereal residues. With an assumed 30% utilization rate for energy needs, this equates to an annual energy potential of 103,599 tons. This statistic describes the percentage of grain waste available for energy production, taking into account competing biomass demands from other industries. The deployment of grain biomass for energy involves strategic planning to align energy needs with agricultural and industrial demands. Animal bedding and soil enrichment, for example, are critical to maintaining agricultural practices, while industrial uses help drive economic growth. As a result, maximizing the energy potential of grain biomass involves improving its collection, storage, and processing while minimizing losses and inefficiencies. In addition to its energy potential, grain biomass is a greener alternative to fossil fuels. Using waste for bioenergy reduces greenhouse gas emissions and promotes a circular economy. However, this requires investment in infrastructure, such as biomass collection systems and energy conversion technology, as well as laws that encourage the use of renewable energy.

The Table 8 provides more accurate and reliable information based on references to different estimates regarding the harvest ratio which serves as an index that allows us to evaluate the potential of available biomass. Such ratios provide us with values approximately the same as those parameters of the agro-climatic aspect of the cultivation area and the strategies used for cultivating a crop in a given area (Bilandzija et al., 2018a). The Lower Heating Value (LHV) is a crucial parameter for calculating and evaluating the theoretical and energy potential of biomass, a factor that differs from one crop to another. This parameter is determined by various factors such as moisture, composition, and ash content. The parameters used for this study have a range of LHV ranging from 14.0 to 17.9 MJ/kg (Ministry of Economy of Kosovo, 2015), (Bilandzija et al., 2018a).

The Table 8 summarizes the essential data for cereal crops in Kosovo, including the cultivated area in hectares, crop yields, fruit-to-plant weight ratio, available biomass potential, lower heating value (LHV), and energy potential derived from accessible biomass. The calculations are based on the most cultivated cereals in Kosovo according to the Green Report, with an energy potential of 30% of the total accessible biomass. According to the statistics presented in the Table 8, maize and rye are the two crops with the highest theoretical energy potential with 21,414 MJ/ha and 15,994 MJ/ha respectively. This productivity can be attributed to the highest yield and the best mass ratio. These features make maize and rye important contributors to biomass-based energy production in Kosovo.

Table 8. Area, yield, and biomass production of forage and green cereals in Kosovo, 2021.

Cereal Type	Area (ha)	Yield (t/ha)	Fruit Weight/Plant Weight	Weight of Residues from Cereal Crops (t/ha)	Available Biomass for Energy Ab30% (t/ha)	LHV (MJ/kg)	Energy Potential Ab30% (MJ/ha)	Heating (TJ)
Wheat	79,970	4.03	1:0.5	2.01	0.60	16.44	9930	794
Maize	39,710	4.29	1:1.01	4.33	1.30	16.47	21,414	850
Barley	2060	2.72	1:1	2.72	0.82	17.9	14,624	30
Rye	555	2.54	1:1.5	3.81	1.14	14	15,994	9
Oat	2030	2.22	1:1	2.22	0.67	14.5	9643	20

Source: Author own calculations (Sertolli et al., 2023), based on MAFRD, Ministry of Economy report and Bilandzija et al. (MAFRD, 2022), (Ministry of Economy of Kosovo, 2015), (Bilandzija et al., 2018a).

The category of forage crops and green cereals represents an important plant component that is mainly used for animal feed. Despite this, these plants have a high potential for alternative application, in this aspect also represents the production of biogas. Among other things, the following Table 9 discloses complete information about these crops, including their cultivated area, annual yield, specific biogas conversion rates, and the estimated amount of biogas that can be created each year. Furthermore, the versatility of these crops offers promising opportunities for the integration of renewable energy production in agricultural systems. Utilizing fodder crops and green cereals for biogas not only diversifies the energy mix but also contributes to reducing greenhouse gas emissions and creating a circular economy. This dual-purpose approach can enhance the sustainability of agricultural practices while supporting energy needs in rural areas.

Table 9. Calculated number of the animal units per animal category in 2021

Forage and Green Cereals	Area (ha)	Production (t/Year)	Specific Production of Biogas (m^3/t)	Biogas Production (Million m^3/Year)	Heating (TJ)
Green maize	7061	118,937	202	21	423
Green maize (second crop)	210	2875	202	0.5	10
Hay (meadows)	70,723	233,323	172	35	706
Grass	9293	28,819	172	4	87
Alfalfa	18,360	82,330	172	12	249
Clover	931	3551	172	0.5	11
Other green forage	1982	12,117	172	1.8	37
Total	108,560	481,952		76	1523

Source: Author own calculation (Sertolli et al., 2023) based on MAFRD and Ministry of Economy report (MAFRD, 2022), (Ministry of Economy of Kosovo, 2015).

It is critical to note that the calculations in the Table 9 include biomass storage losses (silage) estimated at 12% (Ministry of Economy of Kosovo, 2015). The overall biomass yield from forage and green cereals in Kosovo is 481,952 tons per year, with 30% of that quantity deemed appropriate for energy production. This equates to 144,586 tons per year accessible for energy use. Utilizing all green grains and forage biomass might generate up to 76,164 thousand m^3 of biogas per year. Using merely 30% of the total capacity results in a potential biogas output of 22,849 thousand m^3 per year. When the whole biomass from both the "cereals" and "forage and green cereals" categories is combined and assumed to be fully utilized for energy production, the aggregate biomass totals 827,281 tons per year. The combined heating value of this complete biomass is roughly 3,226 TJ. This suggests a huge potential for renewable energy production, which might help reduce reliance on fossil fuels and contribute to satisfying local energy demands while also encouraging sustainable agriculture practices.

4.2.2. Livestock potential and its utilization for energy

In rural Kosovo, the livestock sector is critical to providing work for farmers and the rural people. This sector generates a large volume of manure, which is managed using common procedures such as open-space spreading, landfill disposal, composting, and waste treatment in shared effluent processing facilities.

When examining agriculture's energy potential, the contribution of animals through manure production to energy generation was included. Livestock data were obtained from papers published by the Ministry of Agriculture (MAFRD, 2022) and the Ministry of Economy (Ministry of Economy of Kosovo, 2015). The Table 10 differentiates animal types to improve computation accuracy, as each category has a varied live mass. Cattle are the most numerous and significant animal sector in Kosovo, producing a vast amount of manure. To evaluate the biogas generation potential, critical characteristics such as the number of animals, dung volume, and particular parameters per AU (animal unit) were taken into account. The data for these computations were derived from the Ministry of Economy's publication (Ministry of Economy of Kosovo, 2015). The animal unit (AU), which is used as a comparison factor based on the total living mass of animals, is set at 500 kg. According to the Table 10, cattle have the highest AU among animal types, followed by sheep and goats. In addition to cattle, sheep, and goats, additional livestock types such as pigs and poultry contribute to biogas potential, but to a lesser proportion due to lower AU values and dung production rates. Incorporating these categories into biogas production systems can increase overall efficiency while diversifying energy sources. This integrated strategy not only improves the sustainability of cattle farming but also promotes renewable energy production, contributing to Kosovo's energy independence and minimizing the environmental impact of agricultural waste.

Table 10. Calculated number of the animal units per animal category in 2021.

Animals	Amount	Living Mass	Total Living Million Mass	Animal Unit (AU)	AU for Animal Categories
Cattle stocks (subtotal)	**260,528**				227,241
Male and female calves under 1 year old	83,238	167.5	13.9	27,885	
Foals and heifers 1–2 years old	26,836	400	10.7	21,469	
Bulls and heifers over 2 years old	16,341	500	8.1	16,341	
Dairy cows	132,076	600	79.2	158,491	
Other cows	2037	750	1.5	3,056	
Pigs	47,384	60	2.8	5,686	5,686
Horses, donkeys, and mules	1864	400	0.7	1,491	1,491
Sheep and goats (subtotal)	**241,393**				25,530
Sheep for breeding	156,666	50	7.8	15,667	
Other heads (lambs, rams, etc.)	54,688	72	3.9	7,875	
Goats	28,410	35	0.9	1,989	
Poultry	2,788,000	1.5	4.1	8,364	8,364

Source: Author own calculation *(Sertolli et al., 2023)*, based on the Green report and Ministry of Economy report (MAFRD, 2022), (Ministry of Economy of Kosovo, 2015).

The daily manure production per AU, which varied depending on the animal category, was taken into consideration to calculate the potential for annual biogas production. An estimated 3,842,602 tons of manure might be produced annually in Kosovo, as shown in Table 11. The average amount of organic fertilizer used in 2020 was 14.5 tons per hectare, or 908,650 tons per year, according to the Kosovo Agency of Statistics (KAS, 2020). Furthermore, the waste of anaerobic digestion, bio manure, can be recycled into organic fertilizer. Table 12 illustrates that 76.4% of the total amount of organic fertilizer, or 2,935,748 tons annually, can be diverted to meet energy requirements. This dual-purpose strategy for biomanure emphasizes its worth as a sustainable way to increase soil fertility as well as a renewable energy source. Farmers can improve environmental sustainability, save production costs, and lessen their need for chemical fertilizers by incorporating biomanure into their farming operations. Additionally, a more circular agricultural economy that balances energy production with ecological advantages and encourages resource efficiency at the local and national levels can be achieved through the broad adoption of biomanure usage.

Table 11. Total manure production in Kosovo, 2021.

Animal Category	Number of AU per Animal Category	Daily Manure Production per AU	Annual Manure Production (Million tons)
Cattle	227,241	40	3.3
Pig	5686	25	0.05
Sheep and goat	25,530	35	0.3
Horse	1491	23	0.01
Poultry	8364	44	0.13
Total			3.84

Source: Author own calculation (Sertolli et al., 2023), based on the Ministry of Economy report (Ministry of Economy of Kosovo, 2015).

The entire quantity of biogas that may be produced in Kosovo is 76.4% of the total manure, as 23.6% of the toal amount is set aside for use as organic fertilizer on agricultural land, according to the computation of the annual dung production across different animal types. According to the Table 12, the annual potential for producing biogas from organic fertilizer is projected to be 142.6 million m³. About 80% of this value comes from cattle, with sheep and goats coming in second and third, respectively, at about 12%. The authors employed a cautious estimate of 20 MJ/m³, given that biogas has a calorific value that ranges from 20 to 26 MJ/m³ (Barnett et al., 1978; Bharathiraja et al., 2018; Deng et al., 2020; Petrov et al., 2023). This results in a total heating value of 2,853 TJ annually. This demonstrates both the unrealized potential of other livestock categories and the significant contribution that cattle farming makes to the production of renewable energy. Kosovo might investigate methods including investing in cutting-edge anaerobic digestion technology and improving manure collection infrastructure to optimize biogas output. Moreover, incorporating biogas production into rural regions can boost regional economies, offer sustainable energy options, and enhance national energy security. By lowering greenhouse gas emissions and turning agricultural waste into a useful resource for the energy and agricultural industries, this strategy supports larger sustainability objectives.

Table 12. The potential of annual biogas production per year in Kosovo, 2021.

Animals' Category	Annual Manure Production (t/Year)	Production of Biogas per ton of Fresh Manure (m^3/t)	Biogas Production per Animal category (Million m^3/Year)	Heating (TJ)
Cattle	2,534,740	45	114	2,281
Pig	39,641	60	2.3	48
Sheep and goat	249,179	70	17.4	349
Horse	9,564	60	0.5	11
Poultry	102,625	80	8.2	164
Total	2,935,748		142.6	2,853

Source: Author own calculation (Sertolli et al., 2023), based on the Ministry of Economy report (Ministry of Economy of Kosovo, 2015).

As previously mentioned, 30% of Kosovo's grain biomass potential is used for energy, with the remaining 70% mostly being used for farm bedding. Animals can rest or stay motionless on this substance, which is usually organic in origin. Straw is frequently used as bedding in Kosovo and can be turned into a solid fertilizer to enhance the condition of the soil in agricultural areas when mixed with manure. Straw has a lot of potential for use in biogas production in the future, despite its predominant use in agriculture at the moment. Kosovo could further strengthen its energy diversification and sustainability initiatives by integrating straw into biogas systems, which would allow it to access another renewable energy source. With the help of contemporary anaerobic digestion technologies, straw and manure may be converted into biogas while the digestate, the byproduct, can still be used as premium organic fertilizer. In addition to optimizing the value of agricultural residues, this dual-use strategy provides a sustainable substitute for conventional waste management techniques, promoting a circular economy and lowering greenhouse gas emissions.

4.2.3. Forest biomass potential

Forest biomass consists of firewood, forest residues, and byproducts from the wood industry. Firewood is mostly utilized for home heating. Forest leftovers, also known as logging byproducts, are produced during the timber harvesting process and are mostly used to make pellets and briquettes. In contrast, wood industry leftovers are byproducts of wood processing activities.

The annual expansion of forests and sustainable development principles must be taken into account when estimating the permissible amount of tree cutting. The annual growth of trees with a diameter of at least 7 cm (dlg $\geq$ 7 cm, which represents the yearly increase in wood volume) in Kosovo's forests is 1,556,000 m^3, according to the NFI-II (National Forest Inventory) (MAFRD, 2013). The maximum amount of wood that can be collected each year according to this standard is 1,200,000 m^3. According to secondary statistics of the year 2013, 95% of this amount is utilized for firewood consumption, with the remaining 5% being used to serve the demands of the wood industry (see Figure 12). A total of 909,720 tons of biomass were used as firewood for heating. This demonstrates how important woods are to supplying Kosovo's energy needs, especially for rural areas where firewood is a major source of heating. However, finding a balance between forest exploitation and regeneration is essential to ensuring long-term sustainability. In addition to increasing energy efficiency, investments in reforestation initiatives and efficient wood-burning technologies can lessen the strain on forests.

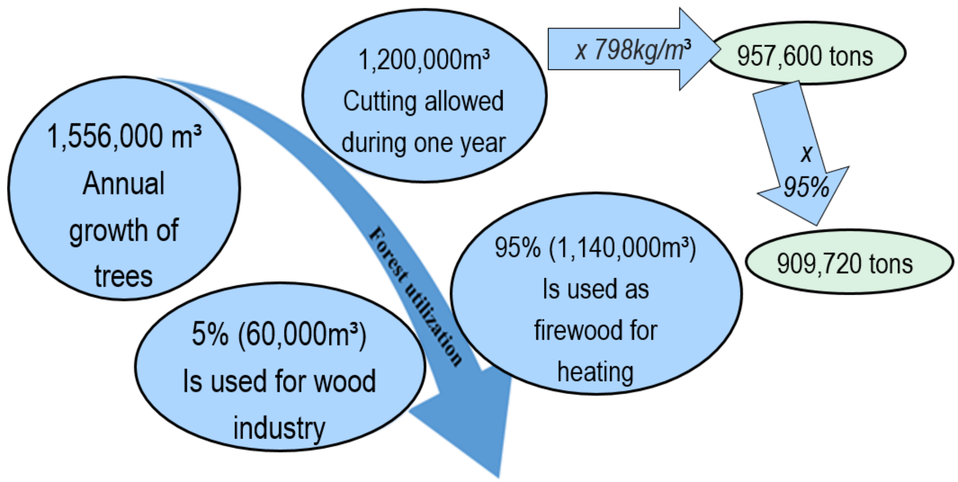

Figure 12. Potential forest utilization in Kosovo.

Source: Author own figure *(Sertolli et al., 2023)* based on the Ministry of Agriculture report (MAFRD, 2013)

With an estimated value of between 50 and 75 million euros, or 1.8 to 2.6% of GDP, the forestry sector in Kosovo makes a substantial economic contribution (Bajraktari et al., 2017). Wood, which is mostly used for heating, continues to be one of the most important energy sources for houses in Kosovo. In addition to its consumption as fuel, wood is an essential component of the domestic wood processing sector, which produces a significant amount of wood biomass, including sawdust and wood chips, that can be used for home heating. The economic potential of these waste products from the manufacturing of lumber has not yet been properly recognized or investigated by many sawmills in Kosovo. Based on forestry potential estimates, the total heating value of 909,720 tons of firewood is calculated to be 17,285 TJ, assuming a calorific value of 19 GJ/ton (Forest Research, 2023).

Investing in smart systems and technologies to efficiently convert wood waste such as sawdust and wood chips into renewable energy is crucial for maximising the potential of the forestry industry, decreasing environmental waste, and enhancing total value. Furthermore, enacting laws and providing incentives to promote sustainable forest management and creative methods in the wood processing sector can boost the sector's economic contribution while promoting environmental preservation and energy independence.

4.2.4. Solid waste potential

Despite Kosovo's efforts to promote recycling and garbage reuse, the issue of excessive waste generation is still a major challenge. To address this issue, first take steps to reduce waste overproduction, then promote reuse, recycling, treatment, and as the last option, correct disposal. Human activities generate the majority of garbage, and while this is a global issue, it is especially acute in Kosovo, where the majority of waste ends up in landfills. In this regard, the author will emphasize the potential for these wastes to contribute to energy development, with an emphasis on their conversion capacity. This approach explains how waste generation can help in providing thermal, electrical, and combined energy. The biomass potential from solid waste is calculated using the waste quantity and Lower Heating Value (LHV).

When it comes to solid waste, the effectiveness and functioning of waste-collecting businesses are key factors in figuring out how much waste is produced nationwide. Based on the population and average daily waste creation of 0.78 kg per person, the Kosovo Environmental Protection Agency estimates that the total waste potential is 506,630 tons per year (AMMK, 2018). This significant amount of garbage offers a chance to produce energy using biogas.

Producing biogas from solid waste provides a renewable and sustainable energy source that might greatly help Kosovo meet its energy demands. The actual application of this potential is still difficult, though. Large-scale deployment has been hampered by the high cost of installing biogas plants and the unavailability of suitable equipment. These obstacles show how specific funding and legislative actions are required to build the infrastructure required for waste-to-energy conversion. To improve garbage collection and segregation methods, public engagement and awareness are crucial, in addition to tackling the financial and technical obstacles. Solid waste might be fully utilized as an energy source with the help of improved biogas technology and a more effective waste management system.

Waste collection is the responsibility of each of the seven regional administrative units in Kosovo. Approximately 485,000 tons of garbage are collected each year practically (KAS, 2022). The potential for different types of energy production has been computed and expressed in TJ/year and GWh/year using the lower heating value (LHV), as indicated in the Table 13. At a 30% efficiency rate, this garbage would produce 303 GWh per year if it were used only to generate electricity. In comparison, 3,092 TJ/year would be produced by thermal energy production with an efficiency of

85%. Another strategy is the co-production of thermal energy and electricity, which attains an overall efficiency of 80%. Of this, 60% is used for thermal energy (2,182 TJ/year) and 20% is used for electricity (201 GWh/year). Furthermore, the overall heating value of the collected garbage is predicted to be 9,715 TJ per year based on the calorific value of solid waste, which is 7.5 MJ/kg as it is given from the report of Ministry of Economy of Kosovo (Ministry of Economy of Kosovo, 2015). Just in case (and just for the record) there would be a dried mass of waste municipality the lower heating value would be considered to be 20.03 MJ/kg, according to Eaktasang et. al., article (Eaktasang et al., 2019).

Table 13. Solid waste in Kosovo per year 2021.

Region	**Amount of Waste (t/year)**	**LHV (MJ/kg)**	**Amount of Electricity (GJ/year)**	**Amount of Thermal Energy (GJ/year)**	**Amount of Co-Produced Energy (GJ/year)**		**Total Heat Potential (TJ)**
					Electric	**Thermal**	
Prishtina	151,000	7.5	339,750	962,625	226,500	679,500	1133
Ferizaj	37,000	7.5	83,250	235,875	55,500	166,500	278
Gjakovë	48,000	7.5	108,000	306,000	72,000	216,000	360
Gjilan	43,500	7.5	97,875	277,312	65,250	195,750	326
Mitrovicë	66,000	7.5	148,500	420,750	99,000	297,000	495
Pejë	57,000	7.5	128,250	363,375	85,500	256,500	428
Prizren	82,500	7.5	185,625	525,937	123,750	371,250	619
Total	485,000		1,091,250	3,091,875	727,500	2,182,500	3638

Source: Author own calculation (Sertolli et al., 2023), based on the Ministry of Economy and Kosovo Agency of Statistics report (Ministry of Economy of Kosovo, 2015), (KAS, 2022).

The substantial potential of solid waste as an energy resource in Kosovo is highlighted by this report, providing chances for energy production to diversify. Building waste-to-energy facilities could solve waste management issues and improve energy security at the same time. Investments in infrastructure and contemporary waste processing technology are necessary to fulfill this potential, though, as are legislative incentives that promote cooperation between the public and private sectors. Additionally, the quality of waste that is available for energy production may be enhanced by introducing waste segregation at the source. Higher energy efficiency and a more effective conversion process would result from this. In line with international initiatives to shift to a circular economy, Kosovo might establish itself as a regional leader in sustainable energy generation by educating the population about the advantages of waste-to-energy projects and implementing international best practices in waste management.

4.2.5. Overall biomass production capacity in Kosovo

The theoretical potential of different biomass kinds is shown in the Table 14, and it totals 6,131,719 tons annually. It is predicted that 4,578,652 tons of this total are available annually for energy use. This suggests that, on average, 74.6% of the biomass's entire potential may be used to supply energy. According to this the author declare that Hypothesis 2 (H2) is accepted which means that **a significant proportion of the total biomass in Kosovo is suitable for energy production.** This high proportion demonstrates how important biomass may be to Kosovo's renewable energy industry. The significance of biomass as a sustainable energy source is highlighted by its capacity to transform such a significant amount of it into energy. Kosovo may lessen its dependency on fossil fuels and promote energy security and environmental preservation by making the best use of the biomass that is now available.

Table 14. Theoretical and energy potential of biomass production in Kosovo and its heating value.

Type of Biomass	Total Biomass Produced (t/Year)	The total amount that can be used for energy purposes (t/Year)	Heating Value (PJ)
Forest Biomass	957,600	909,720	17
Cereals Biomass	827,281	248,184	3 *
Livestock Biomass	3,842,602	2,935,748	3 *
Municipal waste biomass	506,630	485,000	3.6 *
Total	6,134,113	4,578,652	26.6

* Note: the values are calculated based on the calorific value for each of the categories of biomass (biogas 20 MJ/m3; wood 19 GJ/ton; solid waste 7.5 MJ/kg) (Barnett et al., 1978; Deng et al., 2020; Petrov et al., 2023), (Eaktasang et al., 2019; Forest Research, 2023).

Source: Author own calculation (Sertolli et al., 2023).

Based on the calculations made and the research literature, the author conclude that the total potential of biomass that can be used for energy has a heating value of 26.6 PJ. Among other things, according to data from the Kosovo Agency of Statistics (KAS, 2023b), the total primary energy consumption of Kosovo in 2022 was 116 PJ. This implies that biomass can cover 23% of the total energy consumption in Kosovo, which is a promising and encouraging value. Furthermore, this result highly supports Hypothesis 1 (H1), according to this, the hypothesis is accepted and the author can state that **biomass has the potential to contribute significantly to Kosovo's total energy consumption.** Based on data from the Kosovo Agency of Statistics (KAS, 2023b), the total energy produced from biomass in 2022 was 15 PJ. To further support our findings, it is worth highlighting the findings of a study by the Institute for Energy Economics and Financial Analysis (IEEFA, 2020) that estimates that biomass in Kosovo has a total technical potential of 28 PJ. In this regard, the results of the IEEFA study are in good agreement with the research calculations, which show a heating potential of 26.6 PJ from the biomass types reviewed above. These findings highlight the potential participation of biomass to be a suitable component of energy production in Kosovo and emphasize its great importance as an energy source. Promoting sustainable energy development in the country requires recognizing and prioritizing biomass as an energy source.

4.3. Biomass heat energy in Kosovo: prospects and environmental limits

Students' perspectives of renewable energy at Prishtina's Faculty of Agriculture and Veterinary show a rising knowledge of the importance of sustainable practices to meet environmental concerns. This awareness reflects a better understanding of the essential role renewable energy plays in addressing climate change and reducing environmental damage. Students at this faculty increasingly realize the importance of shifting to sustainable energy sources, not only for environmental protection but also for future generations' economic and social well-being. The following sections will explore the greater detail how renewable energy is perceived, understood, and integrated into both academic learning and practical applications at the Faculty of Agriculture and Veterinary as shown as in Table 15. These sections will look at how students' knowledge and attitudes about renewable energy affect future farming practices, community engagement, and the development of sustainable energy regulations. The goal is to emphasize the critical role education plays in developing a generation of professionals committed to incorporating renewable energy solutions into their future careers, contributing to a more sustainable world. The Table 15 presents descriptive data (mean and standard deviation) for a variety of characteristics relevant to students' awarness and attitudes about renewable energy aspects. The average age of responders is approximately 20.6 years, with a limited range (SD = 1.88). Variables such as Eco friendly and Price have positive mean values, indicating that these aspects are regarded favorably or are major motivators. In contrast, Availability and Knowledge have negative values, reflecting barriers or seeing knowledge as less important. The standard deviations show how much individual responses deviate from the mean for each component.

Table 15. Students' awareness and attitudes about renewable energy aspects

How environmentally conscious do you consider yourself?	Mostly not environmentally conscious	4
	Mostly environmentally conscious	72
	Very environmentally conscious	24
How important do you consider the level of knowledge to switch from fossil fuels to RE	Neutral	20
	Important	39
	Very important	41
If you use electric heating and the price of electricity will increase by 15%, would you consider changing the way of heating?	I would not change it	4
	Perhaps	48
	I would change it	33
	I would definitely change	15
In your opinion, do you think that adervtising (marketing) would play a big role in the energy transition?	I disagree	2
	Neutral	9
	I agree	51
	I totally agree	38
Based on the current energy supply patterns, do you think that renewable energy sources will be the most important energy source for Kosovo's enegy sector in 2040?	I disagree	6
	Neutral	27
	I agree	52
	I totally agree	15
In your opinion, do you think that the deployment of RES in Kosovo's energy mix would be more desirable than coal?	I disagree	3
	Neutral	10
	I agree	42
	I totally agree	45
Based on current energy supply patterns, what do you think would be the most important source of energy for heating in the future of energy sector in Kosovo?	Wood	9
	Electricity	19
	Solar panel	57
	Other energy source	15

Denomination	***Mean***	***Standard Deviation***
Age (year)	20.63	1.88
Subsidy for solar_panel (%)	56	17.75
Multifunction	-0.57	1.65
Convenience	0.07	1.53
Availability	-1.14	1.14
Price	1.18	1.50

Knowledge	-0.89	1.38
Investment cost	0.13	1.69
Eco friendly	1.22	1.50

Source: Created by author.

4.3.1. Students' perspectives on renewable energy

When students were asked about their environmental consciousness, 96% said they were aware (Figure 13). Due to this highly positive attitute of students towards environment Hypothesis 4 (H4) is accepted, which means **that students' preferences are at high level in terms of awareness influenced by environmental concerns in Kosovo.** This demonstrates a strong dedication to sustainability among the younger generation. Of this group, 24% identified as very conscientious, while the remaining 72% defined themselves as mostly environmentally conscious. These findings show the student community's strong environmental awareness, indicating a shared knowledge of the need to safeguard the world and adopt sustainable habits. Almost similar levels of awareness were found in Almulhim's survey (Almulhim, 2022), confirming the growing environmental awareness among young people, a trend that is important for the future. Improved environmental attitudes and heightened levels of awareness have the potential to significantly influence lifestyle behaviors and perspectives. Students who are environmentally concerned are more inclined to reduce trash, save energy, and promote eco-friendly products. Furthermore, their collective commitment may result in increased advocacy for greener policies and projects, building a culture of sustainability that goes beyond the academic context. This increased awareness places the younger generation as crucial stakeholders in supporting and implementing significant environmental change.

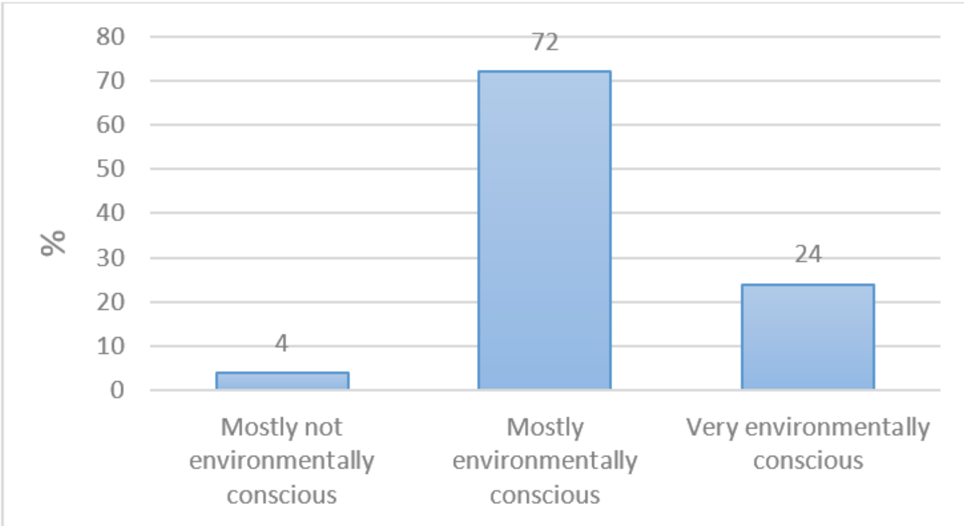

Figure 13. Student's opinion regarding the question: How environmentally conscious do you do you *consider yourself?*

Source: Created by author.

This high level of environmental awareness indicates that this aspect is no longer an afterthought; it has become a core priority for many students. The large percentage of those who identify as "very environmental conscious" or "mostly environmental conscious" indicates a greater societal shift toward environmental sustainability, which is developing as a defining characteristic of this generation. Such awareness has the power to motivate the realization of important actions, such as using public transportation, minimizing the use of consumer plastics, supporting renewable energy initiatives, and promoting sustainable consumption habits. Students who are environmentally aware are more likely to become vocal agents of change, advocating for sustainable practices in their communities, universities, and the incorporation of these practices into future workplaces.

As the world is focused in working to transition from fossil fuels to renewable energy sources, a large number of students have emphasized the importance of this issue, as illustrated in the Figure 14. This idea is supported by more than 41% of respondents, assessing it as ''very important'' and those who answerd ''important'' were 39%, demonstrating the growing understanding of its importance and concern of the younger generation for environmental sustainability, as well as the urgent need for cleaner energy sources, respecting the resource theory. A similar reflection was also seen in the study conducted in Iran by Yazdanpanah et al. (Yazdanpanah et al., 2015), which found high levels of awareness and importance for the transition towards renewable energy. This relationship indicates a broad recognition among young people who attach importance to renewable energy practices in addressing environmental concerns.

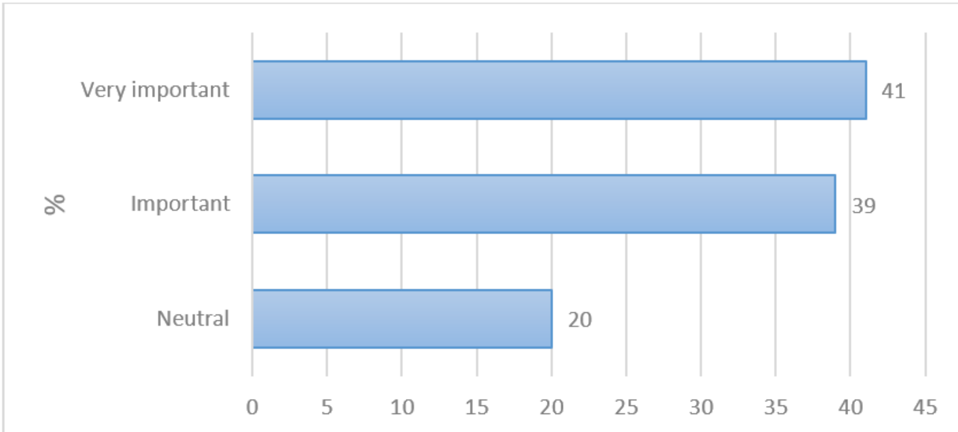

Figure 14. Student's opinion regarding the question: How important do you consider the level of knowledge to switch from fossil fuels to renewable energy?

Source: Created by author.

Several studies conducted in Montenegro (Djurisic et al., 2020), Kenya (Oluoch et al., 2020), and Lithuania (Liobikienė et al., 2021) show similar trends in favor of views towards renewable energy. As the implications of global warming become more apparent through rising temperatures, extreme weather, and biodiversity loss, many students see the transition to renewable energy as critical to reducing these effects and ensuring a more sustainable future. Moreover, this primary step opens up prospects for innovation and employment growth, especially in areas such as research, infrastructure development, and the integration of green technologies. By choosing to support renewable energy, students not only help combat climate change but also advance energy security, economic prosperity, and overall sustainability. For future generations, this transformation is a key step towards a more open-minded and prosperous society.

Electricity price increases have sparked considerable discontent from all sections of society. Many consumers express concern and dissatisfaction with the increasing financial burden that these price increases are placing on household budgets. Households, especially those with low incomes, are concerned about how increased energy costs could affect their daily lives and the financial security of their household. In this context, the research wanted to explore how households might react to a hypothetical 15% increase in energy prices, especially for that part of consumers who rely on electricity for heating. The data, presented in the Figure 15, provide information on the extent of concern and the potential impact of a price increase on household budgets.

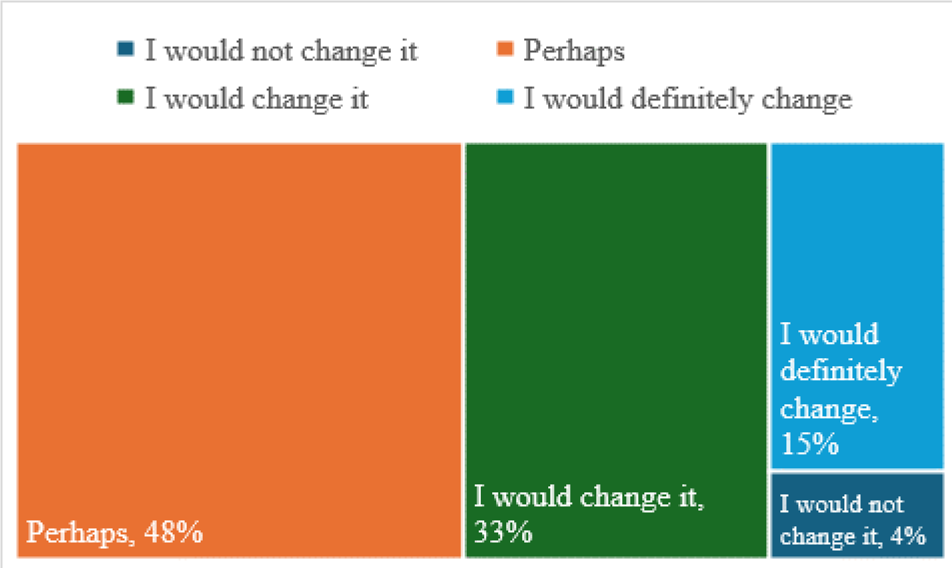

Figure 15. Students' responses to the question: "If you rely on electric heating and electricity prices were to increase by 15%, would you consider switching to alternative heating sources?

Source: Created by author.

The shift in perceptions towards environmental sustainability represents a high achievement and realization across countries, which are working towards a state where the environment is a very important point. Based on the results of the survey, the fact that almost all students (94%) expressed concern about a 15% increase in heating energy bills indicates a clear level of awareness and good management of their energy bills. Based on this the author accept Hypothesis 3 (H3) which means that **the 15% increase in the price of heating significantly increases students' concerns in future decisions.** The author encounter this phenomenon in developing countries and it is consistent with other studies, similar to the survey results from a research conducted in Turkey (Acikgoz & Yorulmaz, 2024). The reason for setting a price increase of 15% is due to the rising trends in energy prices, and the fact that Kosovo is considered to be the country with the lowest energy prices in the region (a price increase may come as a result of comparison with other countries). Furthermore, as Kosovo is seeking to implement various energy project investments, a benchmark for price increases of 15% is useful in assessing the reactions of the general population. The high level of concern implies that students are aware of both the financial implications that will be threatened and the impact of price increases on their daily activities. In a period when the cost of living is increasing as a result of numerous economic factors, it is encouraging to see students actively thinking about how to better control their energy consumption. This emerging concern has the potential to create space for broader debates and discussions about techniques for increasing energy efficiency and reducing costs.

It is encouraging to see the participation of 48% of students who are very sure that they would consider changing their heating techniques, indicating a high desire to adopt more sustainable cost-effective, and efficient energy practices. This is very important as it demonstrates a proactive approach: students are actively seeking practical answers as opposed to simply accepting rising heating energy prices. This change in behavior, attitudes, and perceptions, whether by limiting heating times, investing in energy-efficient appliances, or investigating alternative energy sources, shows that students are increasingly emphasizing cost-effective and environmentally responsible choices. With the right tools and resources, such as educational seminars on energy efficiency, rebates for energy-saving improvements, and information on alternative heating options, students could be positively activated to make well-informed decisions that help them manage rising energy costs while contributing to a more sustainable future.

Figure 16 shows a positive assessment of the ability of marketing to influence change toward renewable energy with a score of 89%. Other studies conducted on the impact of marketing on the acceptance of renewable energy have shown similar results (Dehghani & Tumer, 2015; Zenetti & Klapper, 2016). These data indicate that respondents believe that marketing is a successful method for creating awareness, changing public attitudes, and encouraging the use of renewable energy sources. Various marketing initiatives, in general, can be extremely effective in changing the perceptions of broad audiences who may lack the right information or conception, raising awareness of the environmental benefits of renewable energy, and highlighting the importance of switching to sustainable energy solutions. Marketing becomes an important driving force for change in areas such as renewable energy, where decisions are influenced by emotional and rational concerns such as environmental impact, investment and operational costs, efficiency, and considerations for future generations. Advertising serves as a guide to inspiring action by informing people and encouraging them to adopt behaviors that help the environment as well as their well-being.

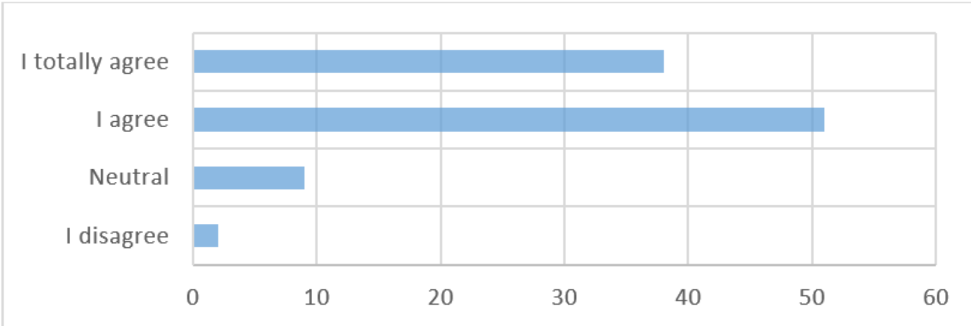

Figure 16. Students' perspectives on the question: "Do you believe advertising (marketing) plays a significant role in the energy transition?"

Source: Created by author.

4.3.2. Student's perceptions of renewable energy attributes using BWS

This section summarizes the data from students' perspectives on renewable energy, as seen in the Table 16, which emphasizes the frequency of the best and lowest ranks for each quality. The findings clearly show that eco-friendliness and equipment cost were the most important variables, ranking first and second, respectively. In contrast, the availability of equipment was ranked as the least critical attribute. The Table 16 shows the partial findings of the Best-Worst Scaling (BWS) analysis. The first stage in the analysis was to calculate BWS values using the same methods as in prior research (Gergely et al., 2023; Török et al., 2023a, 2023b). This was accomplished by deducting the frequency of "least important" responses from "most important" responses for each attribute. The study found that four out of seven attributes obtained favorable ratings and three BWS values were negative. The positively rated attributes were recognized as "most important." In the following phase, BWS data were standardized by dividing them by the sample size (100 students) and the frequency of attribute presentation in the experimental design. This resulted in normalized values that were then ranked. A Best-Ratio scale was created $\sqrt{\frac{\text{Best}}{\text{Worst}}}$ by taking the square root of the ratio of "most important" to "least important" cumulative frequencies. The attribute with the highest value, eco-friendliness, received the highest rating (100%), and all other attributes were examined concerning it. This procedure enabled the development of an additional ranking method.

Table 16. Best-Worst scores for RES attribute importance in students' view.

Designation	Eco-friendliness	Price	Investment cost	Convenience	Multifunction	Knowledge	Availability
The most important	24.14	23.57	14.57	16.43	11.00	6.14	4.14
The least important	6.71	6.71	12.71	15.43	19.14	18.86	20.43
BWS value	122	118	13	7	-57	-89	-114
Standard value	0.41	0.39	0.04	0.02	-0.19	-0.30	-0.38
BWS Rank order	1	2	3	4	5	6	7
Square root[a]	1.90	1.87	1.07	1.03	0.76	0.57	0.45
Relative[b] %	100.00	98.81	56.46	54.42	39.98	30.10	23.75
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: Created by author.

The statistics (BWS Rank order) indicate that respondents ranked eco-friendliness as the most significant criterion. This was followed very closely by pricing with roughly equal numbers (in this regard they share almost the same importance, this would doubt the situation in the real world choices, however based on what they have choosen still eco friendliness leads the way. Then came investment cost, which is quite far from the second one. Convenience scored fourth, with a somewhat lower value than the top three categories. The last three attributes multifunction, expertise, and availability received negative values of BWS scores. This result can be due to a sizable proportion of respondents selecting these characteristics as the least important. Specifically, just 11%, 6.14%, and 4.14% of respondents ranked them as the most important, indicating lesser importance in comparison to other traits. These three received negative BWS values, meaning they were chosen as least important significantly more than as most important. In this line, while their ranking is based on relative preference, the magnitude of their negative score adds depth by showing how strongly participants felt about their unimportance.

The Figure 17 presents the priority levels ascribed by respondents to several aspects of renewable energy, ranging from 23.75% to 100 percent. These disparities show that certain criteria are seen as far more important than others when evaluating renewable energy sources. For example, the item with the greatest priority, "Eco-friendliness," receives 100%, demonstrating the importance of environmental issues to the vast majority of respondents. A study by Pestisha and Bai (Pestisha & Bai, 2022) revealed similar results, with participants identifying environmental factors as the most essential. In contrast, "availability," with a priority rating of only 23.75%, is judged considerably less significant than other criteria.

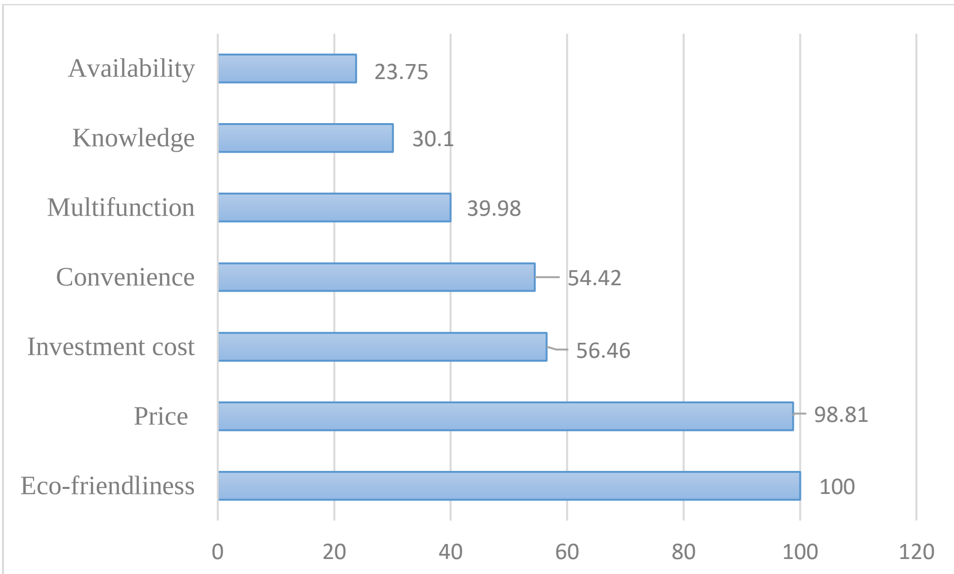

Figure 17. The relative Best values of the renewable energy aspects (%)

Source: Created by author.

It is worth noting that the highest-priority characteristic, "Eco-friendliness," has nearly double the weight of the third-ranked component, "Investment cost" (56.46%). A Lithuanian study (Liobikienė et al., 2021) indicated that this factor (eco-friendliness) significantly influences renewable energy uptake. The high difference between these two factors highlights the essential role that environmental sustainability plays in determining respondents' perceptions of renewable energy, which significantly outweighs attitudes towards financial investment or the convenience that the device can offer. The difference between the highest and lowest rated priority shows how different factors influence consumer decision-making and preferences. The least important factor, in this case, "Availability", has a value almost four times lower than "Eco-friendliness". This shows that respondents may underestimate logistical or accessibility constraints associated with renewable energy sources, implying that they prioritize long-term environmental benefits over immediate practical considerations.

To get a better idea of the importance of the examined attributes, it is calculated the best-worst mean and standard deviation values (Table 16). The results show that "Eco-friendliness" has the highest average value, indicating that respondents think this attribute is the most important. This high score indicates the growing global emphasis on sustainability, as consumers consider environmental implications when purchasing goods or services. Meanwhile, the cost of equipment emerges as an important consideration, but it does not outperform "Eco-friendliness" in terms of overall value. This implies that, while environmental concerns are crucial, many respondents still prioritize economic considerations, such as the initial investment cost.

4.3.3. Assessment of cluster analysis outcomes

To investigate preference heterogeneity, the author ran further statistical analyses with individual-level Best-Worst values (Table 17). This approach allowed us to examine differences in preferences throughout the sample. Non-hierarchical clustering was done using the Best-Worst values for the seven parameters under consideration. After testing many clustering algorithms, it is determined that the four-cluster strategy was most suited to capturing the data's underlying patterns. The four-cluster method was chosen because it is consistent and easy to comprehend, and it provides a clear separation of preferences. It identified diverse groups of people with different priorities and attitudes toward the factors investigated. These clusters not only highlighted the diversity of tastes but also identified possible prospects for focused interventions or individualized approaches within the study's framework.

Table 17. Description of clusters according to different factors

Denomination*	Cluster 1 'Greenies'	Cluster 2 'Passive Environmentalist'	Cluster 3 'Eco-Skeptics'	Cluster 4 'Moderate Adopters'	Test-value	Significance value
Respondent number (100)	30	22	23	25		
BWS_Convenience**	-1.20c	1.27a	0.61ab	0.04b	F= 29.32	p<0.001
BWS_Availability	-1.73b	-1.23ab	-0.48a	-0.96ab	F= 6.49	p<0.001

BWS_Price**		1.90a	-0.18b	1.96a	0.80b	F= 12.59	p<0.001
BWS_Knowledge		-1.3	-0.36	-1.13	-0.64	F= 2.58	p=0.058
BWS_Investment_cost		1.20a	0.09b	0.78ab	-1.72c	F= 27.03	p<0.001
BWS_Eco_friendly**		1.53ab	2.23a	-0.39c	1.44b	F= 17.56	p<0.001
Age (year)	Mean: 20.63	20.97	21.09	20.52	19.92	F= 2.04	p=0.113
Gender	Male (n=16)	6	3	2	5	χ^2=1.66	p=0.646
	Female (n=84)	24	19	21	20		
Field of study	Food Technology (n=67)	20	15	16	16	χ^2=0.19	p=0.980
	Agricultural Economics (n=33)	10	7	7	9		
Knowledge fossil fuels to RE (rank means)		62.67a	46.02ab	46.22ab	43.78b	Kruskal-Wallis H value: 8.85	p=0.031
Environmentally consciousness (rank means)		54.9	43.59	51.37	50.5	Kruskal-Wallis H value: 3.19	p=0.362
Electricity price increase by 15 % (rank means)		52.98	47.82	48.43	51.78	Kruskal-Wallis H value: 0.67	p=0.879
Marketing energy transition (rank means)		54.28	49.8	45.48	51.2	Kruskal-Wallis H	p=0.680

					value: 1.51	
RES Kosovo 2040 (rank means)	58.3	52.27	39.2	49.98	Kruskal -Wallis H value: 6.88	p=0.076
RES vs coal (rank means)	59.15	54.68	45.59	40.96	Kruskal -Wallis H value: 7.78	p=0.051

*Different letters show significant differences; in ONE-WAY ANOVA the letters represent Tukey HSD post-hoc tests results

**Levene-test was significant (p<0.05) therefore F value represents the Welch-test results and the letters represent Games-Howell post-hoc test results
Source: Created by author.

In our final analysis, the author looked at the outcomes of the four clusters created by the K-Means clustering technique, and the results were presented in a Table 17 for clarity. The respondents were distributed rather evenly among the clusters, with 30, 22, 23, and 25 individuals in each. The first cluster, dubbed "Greenies", included those who had a thorough understanding of the shift from fossil fuels to renewable energy. This group had strong environmental awareness, highlighting the significance of sustainability in energy policies. They also acknowledged the significance of advertising and marketing in helping the energy transition, emphasizing the importance of successful public awareness campaigns and communication techniques to foster change. The participants of this group are identified with a strong reaction to price change signals, with a large proportion of them expressing the opinion that they would change their heating method if heating prices faced an increase by 15%. This fact suggests that they are sensitive to price increases and are trying to find more sustainable and cost-effective ways of heating. Furthermore, this group has been an advocacy group for the inclusion of renewable energy as the future of Kosovo's energy sector. The majority of participants stated that by 2024, renewable energy sources will become the main source of energy and they considered renewable energy as a better option compared to coal in Kosovo's energy mix. The perceptions and ideas of this group are in line with the concepts of sustainability and energy independence, reflecting a positive, proactive, and environmentally sensitive worldview. Respondents from this cluster saw renewable energy as extremely important for creating Kosovo's future energy landscape.

The second cluster, nicknamed "Passive Environmentalists" included respondents who had a very different worldview than the group from the first cluster, were more limited in the process of transitioning from fossil fuels to renewable energy, and had a lower level of environmental awareness. Members of this cluster showed a degree of reluctance to adopt new, possibly more sustainable technologies, especially when rising prices could cause financial difficulties in the future. For example, even when heating expenses increased by 15%, they were less likely to switch to a different heating source. Although this group was not listed as being very proactive in terms of environmental sustainability and specific practices for alternative energy, they did consider marketing to be an influencer in the energy transition. Participants acknowledged that marketing is a strategy that can help raise awareness of renewable energy sources, although this position was expressed less consistently than in the previous group. It is noteworthy that despite their minimal involvement in the economic and environmental aspects of the energy transition, this group expressed a promising level of support for the future role of renewable energy in Kosovo's energy system. A large number of respondents in this category affirmed that renewable energy sources will dominate Kosovo's energy mix by 2040.

The "Eco-Skeptics," specifically the third cluster, included students who showed strong environmental concerns, but strangely, they questioned the role of marketing strategy in supporting a change in attitudes about energy. While expressing strong environmental concerns, they had limited awareness and were skeptical of the transition from fossil fuels to renewable energy. This lack of knowledge seems to have a significant impact on their overall confidence and the possibility of implementing renewable energy solutions in the future. A distinctive characteristic of this group was their skepticism about the composition of Kosovo's energy mix and the potential dominance of renewable energy in this regard. This cluster group did not fully support the idea that renewable energy would be a dominant aspect of the energy structure by 2040. This skepticism was reflected in their practical actions, as this group was reluctant to switch to alternative energy sources despite the increase in energy prices. This cluster group's hesitation also extended to their attitudes towards Kosovo's energy mix. While they recognized the importance of renewable energy, they were not convinced that it was a better option than coal. These reflections displayed by this cluster group reflect a lack of confidence in the practicality of large-scale towards renewable energy. This can be identified with a lack of reliability, infrastructure barriers, and economic consequences. In general, "Eco-Skeptics" is a cluster group that values environmental sustainability, but is skeptical and seeks more information and education on the technical, economic, and practical elements of adopting renewable energy. Their skepticism highlights the importance of information campaigns that inform individuals about the benefits and importance of renewable energy sustainability, to close the gap between their environmental concerns and personal reservations about this approach.

"Moderate Adaptors" is the title of the fourth cluster group, which consists of students who had a moderate level of environmental awareness and viewed marketing with a balanced belief in the impact of changing energy access. While this group was concerned about environmental issues, their approach to the technical and economic intricacies of switching from fossil sources of energy production to renewable energy practices was inadequate. This group was necessarily open to economic issues, and reported a strong decision to switch to alternative energy sources if energy prices for heating increased, demonstrating their sensitivity to cost-related incentives and their desire for energy efficiency. This suggests that, while their environmental knowledge may be at a lower level than in the other groups, they are willing to move forward with sustainable solutions that align with their financial interests. Regardless of all factors, "Moderate Adopters" were less likely to agree on the importance of renewable energy versus coal in Kosovo's energy mix. Furthermore, they seemed to be less convinced that renewable energy should dominate the country's energy mix in the future. However, their perceptions show an interesting approach, in which economic and practical concerns can overshadow environmental goals. Furthermore, this group paid very little attention to the long-term strategy of renewable energy in Kosovo's energy system. Their moderate approach and stances suggest that they need more detailed knowledge about the impact of renewable energy sources and their environmental, economic, and social benefits, to deepen their perceptions of the positive aspects of their use and conception. Overall, "Moderate Adopters" are a cluster group with potential for further involvement in the energy transition, even though they have a moderate dose of current knowledge. Various activities aimed at informing and informing individuals in the form of better education and communication can help this group have a better attitude and perspective on the benefits of renewable energy and its role in creating a sustainable future for the energy sector in Kosovo.

4.3.4. Future steps, where should Kosovo focus

The energy spirit in Kosovo is presented through a group that is special in terms of challenges and opportunities, through which the steps that must be followed to fulfill national and international goals are addressed. Since Kosovo sees itself as a member of the European Union, then Kosovo must harmonize all its policies with those of the European Union, especially in the energy aspect of renewable energy and energy self-sufficiency. This advancement of Kosovo is essential for its advancement towards its membership in the EU. However, the current situation of the energy sector in Kosovo is not the best and most desirable scenario, because lignite is the key resource. Of course, it is known that lignite in Kosovo is a cost-effective source of energy considering the large reserves, but in environmental terms, such cases of pollution are often present in underdeveloped countries. Of course, this will be one of the biggest challenges for the state of Kosovo to move towards renewable sources, having such lignite reserves. In this regard, renewable energy should be seen as a key to a safer future, not only for environmental purposes but also as a challenge for increasing the competitiveness of the agricultural sector in Kosovo and local economies. The use of renewable energy sources varies from country to country, this change is also driven by local resources, the level of technological advancement, and other economic reasons. In Kosovo, the most important renewable energy sources are utilized for local heating, which includes district heating and small domestic boilers, as well as solar power generation. This variation emphasizes the importance of Kosovo's energy policies being tailored to its specific feedstocks, accessible infrastructure, and population needs. To enable this transformation, Kosovo should prioritize the rapid adaption of its energy policies to improve sustainability. This might be aided by EU co-financing, which would not only help the country's accession process but also increase its alignment with the EU's overall energy goals. Joint research and development projects, technology transfer, and infrastructure co-creation are all potential partnership opportunities. Such agreements might mirror the strategic initiatives that occurred before the 2004 EU enlargement, providing Kosovo with vital assistance as it navigates its energy transition.

5. CONCLUSIONS AND RECOMMENDATIONS

There is a great deal of potential for theoretical and practical energy production from biomass based on the existing use of energy from biomass sources in Kosovo, as well as the data examined and computations carried out. The by-products of cereals, especially wheat, and maize, the two most significant crops in the nation, should be given priority in this process. If farmers were to use renewable sources of biomass, this would also give those farmers financial advantages, towards achieving greater efficiency. Farmers should try to diversify in terms of products, reduce energy costs, and increase farm productivity. Furthermore, if farmers promote the use and exploitation of by-products for energy needs, as is the case with cereals, this, in addition to increasing their productivity, also contributes to the elimination of environmental damage from the burning of cereal by-products, which was a phenomenon of this last decade. Furthermore, this practice also degrades the microbiological organisms that are in the soil, not forgetting the harmful effect on air quality. Therefore, the sustainable use of biomass also encourages and promotes rural development, thus having a domino effect on all important sectors and areas of rural life.

The livestock sector in Kosovo produces a considerable amount of organic manure, which has environmental effects starting from air pollution, then also the potential for groundwater pollution to the emission of some greenhouse gases, such as methane or nitrous oxide. These emissions are undoubtedly some concerns for the population of the country, in this case, the use of this manure or its further use for energy needs would have positive effects. So a negative aspect can turn into a positive output if it is used further. The location of the farms, the distance between them plays an important role here , to utilize these resources. At close distances, the collection of this manure would be much easier and would have a higher efficiency output.

According to this research findings, forest residues offer a substantial biomass potential that is mostly used for home and public institutions. However, centralized monitoring mechanisms must be put in place to guarantee the effective and long-term utilization of this resource. Establishing permissible cutting levels based on yearly forest growth is essential to preventing overexploitation because a significant amount of forests are held by the government. The country's energy supply might be stabilized if this theoretical potential is effectively realized, especially during the winter season. In this context, effective utilization is defined not only as the technical feasibility of collecting and turning forest leftovers into useful energy, but also as the economic viability and operational sustainability of these processes. More significantly, it would lessen the need for power for heating, which would ease the strain on the electrical grid and help Kosovo develop a more sustainable energy system.

Even when additional applications are taken into consideration, Kosovo is predicted to have 4.57 million tons of biomass available each year that can be used to produce bioenergy. Although there is a great deal of promise for using biomass in agricultural settings, doing so is still very difficult. This is mostly because of things like low public interest, opposition to change, and a lack of funding from the local government and populace. Taking into consideration these obstacles, adopting energy-efficient habits is a particularly challenging task.

The study aimed to assess the theoretical potential of biomass in Kosovo and the perspective of its use for heating and electricity. At the same time, it measured the students' approach towards readiness and awareness of students regarding the environment and the use of renewable energy sources. The findings present different degrees of compatibility with the research hypotheses, providing insights into the assessment of the theoretical potential and also the approach of students as future decision-makers. Hypothesis evaluation are as follow:

H1: Biomass has the potential to contribute significantly to Kosovo's total energy consumption.

Biomass is undoubtedly one of the important forms of the renewable energy mix in Kosovo. An important target is to use biomass for energy needs from agricultural, forestry or solid waste, which have not been used for any other purpose so far. Such use of biomass for energy needs would also have positive domino effects on the development of jobs or the improvement of the well-being of rural areas. This hypothesis is accepted, due to the finding of 74.6% of total biomass can be used for energy from all these types of biomass without compromising the needs of other sectors, especially food and animal feeding.

H2: A significant proportion of the total biomass in Kosovo is suitable for energy production.

A significant portion of all biomass resources in Kosovo can be utilized for energy needs, especially for heating. By taking this resource into account, Kosovo can then improve its energy supply mix and become more independent and sustainable. Also this hypothesis is accepted by taking into consideration the potential which is calculated to be 23% of

Kosovo's overall energy consumption coming from biomass, which is a promising value.

H3: The 15% increase in the price of heating significantly increases students' concerns.

This hypothesis proposes to explore the level of student reaction to the sensitivity of the increase in the price of heating, with the goal of explaining that the level of student concern about the increase in the price is a deciding factor of environmental and economic awarness. This hypothesis is accepted because majority of the students were ready to change if there was 15% increase in heating energy bills, this is a strong indicate of a clear level of awareness and good management of their energy bills.

H4: Students' preferences are at a high level in terms of awareness influenced by environmental concerns in Kosovo.

Based on attitude of students regarding the environment, perhaps driven also from the environmental challenges that are present in Kosovo, an awareness of students in this regard has been observed. This change in awareness is also very clearly seen in their preferences towards the actions they take in relation to the environment. Over time, it is likely that students will show rationality towards more sustainable practices. This hypothesis positioning it as a key factor in the country's sustainability and the well-being of its population. This hypothesis is strongly accepted by taking into consideration the fact of positive attitude of students. When they were asked about their environmental consciousness, 96% reported they were aware.

In conclusion regarding the BWS method applied to students, the survey results clearly show that students' preferences are increasingly influenced by environmental concerns, with "eco-friendliness" appearing as the most highly valued feature. The considerable emphasis on sustainability reflects an increasing awareness among individuals about the environmental consequences of their decisions. As a result, many students from the Faculty of Agriculture and Veterinary within the main university and with the largest number of students in Kosovo are willing to accept concessions in areas like availability to support ecologically friendly products and services. Among the students, the course of Agricultural Economics students indicated prior exposure to renewable energy sources (RES) through a dedicated course module. Both survey responses and subsequent data analysis revealed that these students possessed a greater level of awareness and a more proactive approach to RES-related concerns. The inclusion of such a subject in the curriculum is regarded as critical, particularly in Kosovo, where the necessity of energy efficiency has just gained traction. Energy-saving techniques are now seen as a significant aspect in new investments, not just in agricultural operations but also in other economic sectors. This shift in consumer behavior is most likely caused by increased awareness of global and local environmental challenges such as pollution, resource depletion, and climate change. The comparatively low ranking of "Availability" highlights customers' changing priorities. Given the increased emphasis on environmental effects, convenience is no longer the most important factor driving purchasing decisions.

This shift in consumer behavior supports larger cultural trends toward sustainability, which are values such as supporting environmentally responsible businesses, reducing waste, and choosing to make choices about specific items. Universities have a role to play in environmental stewardship. By including sustainability in their curricula, they empower their educators to shape students' environmental awareness. Academic offerings should include courses and programs that focus on environmental science, green corporate practices, and sustainability. In addition, colleges should position themselves as sustainability leaders by pursuing interdisciplinary research that advances global environmental stewardship. Universities can use these findings to educate a growing and articulate generation of environmentally conscious individuals who are committed to human rights and critical environmental issues. Collaborations with government organizations, nonprofits, and companies that have similar sustainability goals can bring together universities that will make their commitment to sustainability. These collaborations can include research projects, internships, and events on sustainability that give students hands-on experience in the green economy. Such alliances will not only help to address broader environmental goals, but they will also provide students with important educational opportunities that are in line with current trends. In addition, colleges can reduce their environmental footprint while also equipping students with the knowledge and skills they need to take many more into their professional lives.

Finally, fostering a positive attitude toward renewable energy within the Faculty of Agriculture and Veterinary is essential for promoting transformative change, both within the agricultural sector and in the broader society. It is critical for driving change in both the agricultural sector and the wider society. Apart from the Faculty, students who are egar to learn more about RES usually they apply for summer school, where students can find few courses very much related to RES and with international professors. Students through successful experiential practices can contribute to the transformation towards a more sustainable agricultural system, adapting their knowledge to the growing demand for renewable energy. The profiles of the four students groups revealed differences in environmental awareness and involvement in sustainability. The first group, with its high level of environmental awareness, was more likely to encourage the adoption of the renewable path. In contrast, the second and third groups of skepticism, questioning the role of marketing and the real transition to renewables in the country's future. The third group, showed an unwillingness to change the sources of the fight against rising prices. While demonstrating moderate environmental awareness, the fourth group was ultimately more open to changes motivated by economic incentives.

Moreover, this study had some limitations:

> Inaporpiate avaiability of data: The current research on biomass potential in Kosovo is characterized by a low level of data availability and also updated data. This in a way also explains the lack of research of this type. But also on the other hand this research is notable for having a great novelty since it is the first of its kind at the national level.
>
> Even though the sampling with student for BWS method was limited to the largest agricultural education institution, it should be noted that Kosovo is a small country with no significant cultural differences, such as the majority of the population belonging to a single nationality. Furthermore, the average age of the population represents the younger generation, which makes the study even more reliable.

Providing financial incentives or, in the case of subsidies, for example, for solutions such as heat pumps or solar panels, could certainly help encourage the use of renewable energy technologies. Overall, many respondents expressed a willingness to switch energy sources in response to rising prices, implying that economic incentives would play a key role in encouraging more environmentally friendly energy options. The findings of this study provide a solid platform for additional comparative research on the function of education in sustainable energy management, which is crucial for the stable future of all sectors in the country. A focused investigation of the knowledge and attitudes of people with post-secondary education compared to other social groups would provide important insights into the overall impact of education on sustainability and energy transition efforts.

In terms of future prospects, studies on algae have shown the fastest development rate and attracted the most attention in the field of biomass utilization research. Interestingly, this category also includes the most cited article in this field. This increase is probably related to the fact that algae are a promising resource for sustainable energy solutions since they have the highest theoretical potential for anaerobic digestion and next-generation fuel production. Given these developing countries' (such as China and India) tremendous biomass supplies, fast-expanding economic prospects, and considerable environmental dangers, this tendency is unsurprising. Food, direct combustion, and biogas production are the top priorities in these regions. In contrast, the US focuses on first- and next-generation transportation fuels, whereas in the European Union, other renewable energy sources, particularly wind and solar power, dominate research efforts.

A good recommendation would be to incorporate and develop renewable energy sources into the curriculum of the Faculty of Agriculture and Veterinary as an important process that would provide students with new and adequate knowledge, particularly given the close relationship between agricultural research and renewable energy. Another item to emphasize is the course content's vertical depth. The faculty can introduce additional classes, possibly even electives, for various types of RES to pique students' interest, provide opportunities for growth, and promote their internal motivation. From the author point of view, for preparing the younger generation in Kosovo to support the transition to renewable energy, especially to the paricular faculty mentioned above. In existing courses: Agricultural Economics, introduce modules (or even subjects) on energy economics and policy analysis related to renewable energy. Food Technology, to include modules (or even subjects) on energy-efficient food processing. Plant Production, adding the subjects such as cover the role of bioenergy crops and circular practices in sustainable agriculture. These are some of the main modules or subjects that can be integreated into the curriculums, in order to address the future challenges and market needs of the sector, moreover these subjects would make a difference also in long terms targets. For short terms targets I would personally recommend the organizing of summer schools, where the students or recent graduates, or even the farmers can be trained in specific above mentioned subjects. The other idea is a more intensifing number of study visits to the farms and companies which are leading the way in this aspect. Also organizig competition for students in terms of future incubation projects or any partnership with agricultural educations with private agriculture sector or NGOs. In this way different actors of stakeholders would comunicate and establish a network in order to deal with coming challenges. In this way I believe these proposals could be effectively implemented (if not totally then partly) by the Faculty of Agriculture and Veterinary, offering both immediate impact and long-term benefits for Kosovo's green transition. This could also serve as a model for other neighboring agricultural institutions, or even cooperate with them in different cases when they face the same challenges. Policymakers should be focused on precise future steps to reach effective results for practical achievements in terms of biomass utilization.

6. NOVEL FINDINGS

The following are some significant novelties in this dissertation:

1. I confirm that this dissertation successfully revealed the potential of biomass potential at the country level as regards the state of Kosovo, using different research methods. Based on the data analysis and a detail structure of methodology and on the findings too, I conclude that the theoretical potential has shown a huge importance in the country total energy supply, with numbers indicated as 26.6 PJ out of 116 PJ (which was the total primary energy cosumption of Kosovo in 2022). In this regard, the biomass can cover a share of 23% of the total energy consumption in Kosovo.

2. Using bibliometric analysis, I found that, based on the network of co-occurrence of keywords related to biomass potential and its utilization, the number of keywords in the clusters changed significantly in the period 2012-2021 compared to the period 1974-2011 (as shown properly in Figure 9 and in Figure 10). Particularly, the number of keywords with green color showing as cluster are slightly increasing (approximately with 10% if the two periods are compared: 1974-2011 vs 2012-2021). More importantly, the cluster of keywords with blue color in Figure 10 has seen a significant increase in popularity over the past decade, resulting in an increase in searches for keywords for third and fourth generation biofuels, such as biofuels, algae, microorganisms, biodiesel, and microalgae. Furthermore, the bibliometric map of search results revealed that third and fourth generation biofuels are now in development and probably they would reach the highly desired point where they can be produced on an industrial scale.

3. The theoretical potential of the various forms of biomass (such as forest biomass, cereals biomass, livestock biomass and municipal waste biomass) in Kosvo is calculated to be 6,131,719 t/year. The entire amount that can be used for energy purposes is 4,578,652 t (74.6%) each year taking aspects into consideration such as bedding, manure for organic fertilizer, wood for heating purposes or industrial processing.

According to the estimation, the overall biomass potential that can be used for energy can exceed 26.6 PJ heating potential. Furthermore, it has the potential to account for 23% of Kosovo's overall energy consumption, which is a promising value.

4. The study results unambiguously reveal that environmental concerns are increasingly influencing students' preferences, with positive response of 96% (as shown in Figure 13). Moreover, "eco-friendliness" emerging as the most highly valued feature in terms of BWS scale method with a rate of 100% (as shown in Figure 17). In this regard, the numbers lead to the suggestion that students are becoming more aware of how their actions influence the environment and are willing to operate with opportunity cost in other areas, in order to support ecologically friendly goods and services.

7. SUMMARY

This topic was carried out to achieve research on the potential of biomass and its prespective for heat use in Kosovo. The topic is important because it highlights the potential that Kosovo possesses in the framework of biomass as a form of sustainable energy, which significantly affects the reduction of dependence on energy generation from fossil sources. By analyzing energy trends in the region and the world, and considering the fact that renewable energy is a sustainable form of energy, it is essential to understand the potential that Kosovo possesses and create long-term energy security that impacts environmental sustainability.

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

- Biomass potential and ulitization in worldwide research trends;
- To achieve an assessment of the biomass current volume that exist in Kosovo, including agricultural, forest biomass and waste materials;
- To explore the benefits that could be obtained from the use of biomass in the energy spectrum;
- To find the willingness and perceptions of students, as future decision-makers in terms of the importance of RES and its utilization.

In order to achieve these stated objectives, a combination of research methods were used, including field data collection and analysis, a review of the literature and similar studies that allowed the author to make predictions about possible projections in local conditions.

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

- Kosovo is a country with a favorable position that positively affects the development of agriculture, as an important sector. Its favorable position also affects the rich potential of forest and agricultural biomass, which play an important role in energy generation, especially affecting the development of rural areas.
- China, United States, India, Germany and Brazil are the five the largest countries of biomass energy use. Brazil is not top producer, however it leads the world in biomass use due to it's committed to becoming the world's leargest user of ethanol made from sugar cane.

- Manure has the capacity to produce 142.6 million m^3/year of biogas. Cattle provided the most to this value, accounting for approximately 80%, followed by sheep and goats at around 12%. Biogas has a calorific value of 20-26 MJ/m^3, making its total heating value 2853 TJ.
- Combining the biomass from the "cereals" and "forage and green cereals" tables and using it for energy yields it gives a total of 827,281 tons per year which accounts for an overall heating value 3226 TJ.
- The estimated forestry potential resulted in a heating value of 17,285 TJ from 909,720 tons of firewood, based on a calorific value of 19 GJ/tons.
- Based on the calculations made and the research literature, the author conclude that the total potential of biomass that can be used for energy has a heating value of 26.6 PJ.
- The fact that 96% of students reported being environmentally sensitive is an extremely encouraging sign of the younger generation's rising dedication to sustainability. With 24% claiming to be highly conscientious and an additional 72% identifying themselves as generally environmentally concerned, it is apparent that environmental awareness is strongly established in the student community.
- Based on the results of the survey, almost all students (94%) expressed concern about a 15% increase in heating energy bills indicating a clear level of awareness and good management of their energy bills. I'd include here how many of them (in %) would shift to RES based energy if the bill increases. As it was mentioned above in the literature section, the price of electricity was increased twiced in the last 3 years, this might be an indicator to push people toward the prespective of using biomass for heating.
- The standardized BWS values for Cohen's aspects make it easy to understand the feature order. It should be noted that eco-friendliness is quite important (0.41), which is followed very closely by the cost of the equipment (0.39). Furthermore, investment cost (0.04) and convenience (0.02) are considered indifferent. The least popular features include multifunctionality (-0.19), knowledge (-30), and availability (-0.38).

The findings from this research lead us to propose that Kosovo should develop a national strategy in line with European Union policies regarding the use of biomass also for heating purposes. This strategy should encompass many factors, focusing on promoting investments in infrastructure, promoting local production, and increasing national and international partnerships to ensure an increase in sustainable energy generation from these valuable types of resources.

Ultimately, the research findings and recommendations are useful for policymakers, investors, students and energy sector professionals, since providing detailed and up-to-date data on the comprehensive analysis of biomass potential by type in Kosovo. It provides data on how important the integration of biomass potentials into the country's energy strategy is, serving as an aid to policymakers in shaping policies that encourage sustainable and efficient energy production, which also impacts environmental and economic sustainability.

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1. **Sertolli, A.,** Pestisha, A., Balogh, P., Bai, A.: Prospects of Biomass Heat Energy in Kosovo, its Environmental and Usage Limits
   Biomass. *5*(1), 14, 2025.
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2. **Sertolli, A.,** Bai, A., Gabnai, Z., Mizik, T., Pestisha, A.: Theoretical and energy biomass potential of heat and electricity production in Kosovo.
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   DOI: https://doi.org/10.3390/en16207209
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3. **Sertolli, A.,** Gabnai, Z., Lengyel, P., Bai, A.: Biomass Potential and Utilization in Worldwide Research Trends - A Bibliometric Analysis.
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4. Bai, A., **Sertolli, A**., Balogh, P.: Power-to-Gas technologies (PtG, P2G, PtH, PtM)
   New Economics for Sustainability_Time, ELSEVIER (Book chapter)
   DOI: https://doi.org/10.4337/9781035310371.000101
   Published: 22 May 2025
5. Bai, A., Gabnai, Z., **Sertolli, A.,** & Balogh, P.: Biogázcélú algatermesztés és -felhasználás perspektívái hazánkban és Indiában
   ENERGIAGAZDÁLKODÁS 63: Különszám pp. 27-31., 5 p. (2022)
   Publication:32856868

Conference papers

1. “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.
2. Conference for PhD Students 2023 – "Research trends in biomass utilization—A Systematic Review", **Sertolli, A.**

List of other publications

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1. Bytyqi, N., Bai, A., Balogh, P., Mehaj, E., **Sertolli, A.**: Analysis of consumers' preferences for local cheese in Kosovo applying conjoint choice analysis.
   Journal of Hygienic Engineering and Design. 41, 203-210, 2022.
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2. Gabnai, Z., Németh, K., Péter, E., **Sertolli, A.,** Pestisha, A., Mezőfi, N., Bai, A.: Opportunities for wastewater heat recovery in Hungary and its role in the circular economy. Abstract. 15 (3-4), 81-90, 2021.
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   IF:3
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Total IF of journals (all publications): 9.45

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Scopus/WoS ranking: 3

LIST OF TABLES

Table 1. Electricity tariffs for end consumers in Kosovo 44
Table 2. Livestock structure in Kosovo, number of heads per each category 2021........ 63
Table 3. Volume in thousand m³ for most common broadleaves and conifers in Kosovo........ 63
Table 4. Example of the BWS decision format........ 66
Table 5. Attributes used in the object-case BWS questions........ 67
Table 6. The main sample characteristics for students of the Faculty of Agriculture and Veterinary........ 71
Table 7. Area, yield, and biomass production of cereals in Kosovo, 2021 80
Table 8. Area, yield, and biomass production of forage and green cereals in Kosovo, 2021........ 82
Table 9. Calculated number of the animal units per animal category in 2021........ 83
Table 10. Calculated number of the animal units per animal category in 2021........ 84
Table 11. Total manure production in Kosovo, 2021........ 85
Table 12. The potential of annual biogas production per year in Kosovo, 2021. 86
Table 13. Solid waste in Kosovo per year 2021........ 90
Table 14. Theoretical and energy potential of biomass production in Kosovo and its heating value........ 91
Table 15. Students' awareness and attitudes about renewable energy aspects........ 93
Table 16. Best-Worst scores for RES attribute importance in students' view........ 100
Table 17. Description of clusters according to different factors 102

LIST OF FIGURES

Figure 1. Overall share of energy from renewable sources in 2023 30
Figure 2. Primary energy consumption, by fuel type, EU, 2007, 2017 and 2022 31
Figure 3. Total EU agricultural biomass production, 2018... 33
Figure 4. Overview of the amount of energy of primary energy sources in Kosovo (GWh) 51
Figure 5. Total electricity generation in May 2023 in Kosovo (MWh unit), and its percentages 52
Figure 6. Methodology scheme for bibliometric analyses.. 60
Figure 7. Publication trends of Scopus-based search literature on biomass potential and utilization. 74
Figure 8. Collaborative work between countries. 75
Figure 9. Keyword co-occurrence network regarding biomass potential and its utilization from 1974 to 2011.. 76
Figure 10. Keyword co-occurrence network regarding biomass potential and its utilization from 2012 to 2021. 77
Figure 11. Main contributors to biomass potential in Kosovo. Legend: ‘’a’’—estimation of the Ministry of Economy (Ministry of Economy of Kosovo, 2015). 79
Figure 12. Potential forest utilization in Kosovo. 88
Figure 13. Student’s opinion regarding the question: How environmentally conscious do you do you consider yourself? 95
Figure 14. Student’s opinion regarding the question: How important do you consider the level of knowledge to switch from fossil fuels to renewable energy? 96
Figure 15. Students' responses to the question: "If you rely on electric heating and electricity prices were to increase by 15%, would you consider switching to alternative heating sources?............ 97
Figure 16. Students' perspectives on the question: "Do you believe advertising (marketing) plays a significant role in the energy transition?" 99
Figure 17. The relative Best values of the renewable energy aspects (%)................................. 101

APPENDICES

Questionnaire on important factors (attributes) for switching from coal to renewable sources for heating in Kosovo

Research title: What is the most/least important factor for you to switch from using coal to renewable sources for heating?

Researcher: MSc. Ardit Sertolli

Research mentor: Dr. Attila Bai

1. Informative paragraph:

Dear participant,

I am Ardit Sertolli, a PhD student. The questionnaire is being conducted as part of data collection for a scientific article.

Your participation, which is extremely appreciated, is very much appreciated and confidential.

The data will be analyzed in a group rather than individually, with the main aim of being used for the purpose mentioned above.

The duration of the questionnaire may be approximately 10-15 minutes and may be interrupted at any time without the need for any additional justification.

2. What do I need to do to participate in the research?

If you decide to participate in the online questionnaire, you must complete the questions which will then be analyzed and the results will be used for academic purposes only. The questionnaire will be completed only once and this data will be used only once.

Thank you for your availability and time!

By clicking "I Agree", you are accepting the above statements in the 'Participant Consent Form':

Agree

1. Participant's gender:

Male

Female

2. How old are you?

Short Answer (write the number)

3. What is the course of the study?

Agricultural economics

Food technology

Plant production

4. What region are you from?

Pristina (01)

Mitrovica (02)

Peja (03)

Prizren (04)

Ferizaj (05)

Gjilan (06)

Gjakova (07)

5. Type of residence:

Apartment

House

6. Employment:

Unemployed student

Employed student

' **LIKERT** ' QUESTIONS (SCALE) ON KNOWLEDGE OF RENEWABLE ENERGY

7. How environmentally conscious do you consider yourself?

Not at all environmentally conscious

Mostly environmentally unconcerned

Mostly environmentally conscious

Very environmentally conscious

I don't know / I don't answer

8. How important do you consider the level of knowledge to transition from fossil fuels to renewable energy?

Very important

Important

Neutral

Not that important

Not important at all

9. If you use electric heating and the price of electricity increases by 15%, would you consider changing the way you heat your home to other sources?

I would definitely change

I would change it

Maybe

I wouldn't change it

I wouldn't change it at all

10. In your opinion, do you think advertising (marketing) would play a major role in the energy transition?

I completely agree

I agree

Neutral

I disagree

I completely disagree

11. Based on current energy supply patterns, do you think renewable energy sources will be the most important source of energy for the energy sector in Kosovo in 2040?

I completely agree

I agree

Neutral

I disagree

I completely disagree

12. In your opinion, do you think that introducing renewable energy sources into Kosovo's energy mix would be more desirable than coal?

I completely agree

I agree

Neutral

I disagree

I completely disagree

13. How much subsidy would be enough for you to buy a solar panel for your home?

0%

20%

40%

60%

80%

14. Based on current energy supply patterns, what do you think will be the most important source of heating energy in the future for the energy sector in Kosovo?

Coal

Electricity

Biomass

Solar panels

Other energy sources

'BWS' QUESTION - PLEASE CHOOSE ONLY ONE AS MOST IMPORTANT AND ONLY ONE AS LEAST IMPORTANT

15. What factors do you consider most important and least important regarding the use of renewable resources?

Convenience (ease of use)	Most important	Least important
Availability (you can find it anytime)	Most important	Least important
Multifunction (can perform several functions)	Most important	Least important

16. What factors do you consider most and least important regarding the use of renewable resources?

Price of energy source	Most important	Least important
Availability (you can buy it anytime, anywhere)	Most important	Least important
Knowledge	Most important	Least important

17. What factors do you consider most important and least important regarding the use of renewable resources?

Price of energy source	Most important	Least important
Investment cost (equipment price)	Most important	Least important
Multifunction (can perform several functions)	Most important	Least important

18. What factors do you consider most and least important regarding the use of renewable resources?

Convenience (easier to use)	Most important	Least important
Knowledge	Most important	Least important
Investment cost (equipment price)	Most important	Least important

19. What factors do you consider most and least important regarding the use of renewable resources?

Eco-friendly (environmental)	Most important	Least important
Availability (you can buy it anytime, anywhere)	Most important	Least important
Investment cost (equipment price)	Most important	Least important

20. What factors do you consider most important and least important regarding the use of renewable resources?

Eco-friendly (environmental)	Most important	Least important
Knowledge	Most important	Least important
Multifunction (can perform several functions)	Most important	Least important

21. What factors do you consider most and least important regarding the use of renewable resources?

Eco-friendly (environmental)	Most important	Least important
Price of energy source	Most important	Least important
Convenience (easier to use)	Most important	Least important