

ASSESSING THE TECHNICAL POTENTIAL OF AGRICULTURAL CROP RESIDUES AS A RENEWABLE ENERGY SOURCE ACROSS LITHUANIAN DISTRICT MUNICIPALITIES

Daiva Makutėnienė¹, Iroda Rustamova², Valdemaras Makutėnas³, Renata Purkienė⁴

¹ Assoc. Prof., Vytautas Magnus University Lithuania, K. Donelaičio St. 58, Kaunas, Lithuania, E-mail address: daiva.makuteniene@vdu.lt

² Prof., Tashkent State Agrarian University, Universitet Ko'chasi 2, Tashkent, Uzbekistan, E-mail address: irodarustamova@mail.ru

³ Assoc. Prof., Vytautas Magnus University Lithuania, K. Donelaičio St. 58, Kaunas, Lithuania, E-mail address: valdemaras.makutenas@vdu.lt

⁴ Master's degree, Vytautas Magnus University, K. Donelaičio St. 58, Kaunas, Lithuania, E-mail address: renata.purkiene@vdu.lt

Received 15 07 2026; Accepted 10 08 2026

Abstract

The aim of this study is to assess the technical potential of agricultural crop residues as a renewable energy source across Lithuanian district municipalities and to develop a methodological framework for its evaluation. To achieve this aim, the study analyses methodologies employed in the scientific literature for assessing the potential of agricultural crop residues as a renewable energy resource and based on this analysis, develops a methodological framework applicable at the municipal level. The proposed methodology is subsequently used to estimate the technical potential of agricultural crop residues in all Lithuanian district municipalities. The empirical findings indicate that municipalities located in the central part of Lithuania possess the greatest opportunities to expand agricultural production while simultaneously strengthening their potential to become suppliers of renewable energy resources. The results show that 35 Lithuanian district municipalities, accounting for 68.6% of all municipalities included in the analysis, exhibit either high or moderate overall levels of technical potential for agricultural crop residues. These findings highlight significant spatial differences in the availability of agricultural residues and provide an evidence base for identifying municipalities with favourable conditions for the development of agricultural biomass as a renewable energy resource.

Keywords: Renewable Energy Source, Agriculture, Agricultural Crop Residues, Technical Potential.

JEL Codes: E22, F21.

Introduction

Relevance of the Research

Energy is a fundamental driver of economic growth, providing essential services that support economic activity and improve quality of life. The strategic importance of energy has become particularly evident in recent years, as the European Union (EU) has faced one of the most significant challenges since its establishment. In response to the energy crisis, the EU accelerated the deployment of renewable energy technologies, thereby strengthening energy security and substantially reducing its dependence on imported fossil fuels (State of the Energy Union Report, 2023). According to Raihan et al. (2023), renewable energy contributes to energy security while simultaneously reducing carbon dioxide

emissions. Hassan et al. (2024) emphasize that bioenergy derived from biomass constitutes an indispensable component of the renewable energy mix. Furthermore, the recycling and efficient utilization of agricultural residues and waste can stimulate economic development, promote resource conservation, facilitate the transition towards a circular economy, and contribute to improved public health (Awogbeni & Von Kallon, 2022). The bioenergy potential of biomass residues depends on several factors, including crop type, cultivated area, crop yield, the residue-to-crop ratio, residue removal rates, and competing non-agronomic uses of residues (Cervi et al., 2020).

Research Problem. Renewable and sustainable energy sources represent environmentally friendly forms of energy capable of efficiently generating thermal and electrical energy. Agricultural biomass residues are regarded as one of the principal alternative energy resources owing to their considerable potential to support the development of a sustainable energy system. Consequently, the following research question arises: *What is the potential of agricultural biomass residues as a renewable energy source in Lithuania, and how can this potential be assessed?* The potential of agricultural biomass as a renewable energy source has attracted considerable scholarly attention because of its multidimensional nature. Bharti et al. (2021), Janiszewska and Ossowska (2022), Kalak (2023), among others, investigated the availability of biomass resources. Saleem (2022), Awogbeni and Von Kallon (2022), Manikandan et al. (2023), Ali et al. (2024), and others focused on biomass conversion technologies. Picirelli de Souza et al. (2021), Erdiwansyah et al. (2024), Janiszewska and Ossowska (2024), and other researchers examined the economic and environmental dimensions of biomass resource utilization. Collectively, these studies demonstrate that agricultural biomass represents a renewable energy source with substantial development potential.

Aim and Objectives of the Research. The aim of this study is to assess the potential of agricultural crop residues as a renewable energy source across Lithuanian district municipalities. To achieve this aim, the following research objectives are pursued: 1) To develop a methodological framework for assessing the potential of agricultural crop residues as a renewable energy source based on a critical analysis of assessment methods applied in previous empirical studies; 2) To evaluate the potential of agricultural crop residues as a renewable energy source across Lithuanian district municipalities.

Literature Review

Mofijur et al. (2019) argue that the depletion of fossil fuel reserves and their adverse environmental impacts have prompted researchers to seek alternative renewable energy sources. Among these, biomass has emerged as a

reliable resource owing to its continuous availability. The authors further note that scientific research on biomass production and utilization has expanded considerably over recent years, highlighting the need to intensify efforts aimed at identifying efficient pathways for converting biomass residues and waste into energy.

Similarly, Guzman-Bello, Lopez-Diaz, Aybar-Mejia, Dominguez-Garabitos, and Atilio de Frias (2023) emphasize that agricultural residues and waste biomass are increasingly recognized for their potential as renewable energy resources. This growing recognition has stimulated research focused on analysing and quantifying biomass flows and estimating their energy generation potential.

Kyryzyuk, Krupin, Borodina, and Was (2020) likewise observe that energy production from biomass residues and waste has become increasingly important because of its low-carbon characteristics and widespread availability. They argue that contemporary research aims not only to identify strategic directions for bioenergy development but also to investigate diverse biomass utilization pathways and estimate both current and future biomass energy potential.

Knapek, Vavrova, Kralik, and Outrata (2020) point out that biomass potential can be assessed using various methodological approaches and that the concept itself may be interpreted differently depending on the objectives of a particular study. They distinguish four principal categories of biomass potential:

- **Theoretical potential**, determined by fundamental biological and physical factors, including water availability, soil characteristics, and climatic conditions.

- **Technical potential**, which accounts for ecological, organizational, agronomic, technological, and location-specific constraints affecting biomass collection and utilization.

- **Economic potential**, reflecting the competitiveness of biomass relative to alternative energy sources under prevailing economic conditions.

- **Realizable (market) potential**, which incorporates practical limitations related to technology adoption, market conditions, and end-user constraints.

Researchers have applied these different concepts of biomass potential to estimate the energy value of agricultural residues and waste. Soltero, Chacartegui, Ortiz, Lizana, and Quirosa (2018) proposed a methodology for assessing the availability of renewable forestry and agricultural residues and estimating the biomass required for heat generation. Avcıoğlu, Dayıoğlu, and Türker (2019) estimated the energy potential of agricultural biomass residues in Türkiye by analysing the characteristics of agricultural residues. Guzman-Bello et al. (2023) developed the Biomass Energy Potential (BEP) methodology to characterize and assess the energy potential of different residual biomass sources in the Dominican Republic.

Alotzas, Moustakas, Malamis, and Vakalis (2019) evaluated the potential of agricultural residues for energy production in Greece. Their analysis was based on statistical data obtained from regional solid waste management plans, agricultural statistics databases, and environmental impact assessment reports. The authors estimated energy production potential by converting different agricultural residues into ash-equivalent values and assessed the technical feasibility of utilizing this biomass through thermochemical conversion technologies. Their findings revealed that Greece possesses approximately 2.1 million tonnes of lignocellulosic biomass. Furthermore, the study identified feasible pathways for utilizing agricultural biomass residues for energy production and proposed a model to support future bioenergy projects.

Avcıoğlu, Dayıoğlu, and Türker (2019) also developed a mathematical model to estimate the national energy potential of agricultural residues in Türkiye. Their results demonstrated that field crops could provide an energy potential of 298,955 TJ, while horticultural crops could contribute an additional 65,491 TJ.

Jekayinfa, Orisaleye, and Pacenka (2020) reviewed legislative documents and evaluated Nigeria's energy policy regarding the use of biomass as a renewable energy source. Their assessment of the technical potential of biomass resources for energy production revealed that, despite substantial biomass availability and an established policy framework, relatively limited

progress had been achieved in implementing large-scale bioenergy projects.

Bharti, Paritosh, Madla, Chawade, and Vivekanand (2020) estimated the availability of agricultural biomass resources in India using Geographic Information System (GIS) technologies. Their methodology incorporated land suitability analysis, site identification and selection, investment allocation, environmental impact assessment, and spatial analysis. Agricultural crop maps and official agricultural statistics were integrated to estimate the potential availability of straw for bioenergy production.

Picirelli de Souza et al. (2021) assessed the potential of Brazilian agricultural and forestry residues for electricity generation over the period 2018–2050 using thermochemical conversion technologies. Their integrated methodological framework combined statistical analysis with theoretical models encompassing theoretical, technical, and economic potential assessments. The study estimated Brazil's theoretical biomass energy potential at 7,185 PJ in 2018, while the technical potential amounted to 1,795 PJ. Owing to logistical constraints, the economically viable potential was considerably lower, estimated at approximately 19,704 MWe.

Using Geographic Information System (GIS) analysis, Zhang et al. (2021) evaluated the technical and sustainable potential of agricultural residues in China. Their findings indicated that up to 20% of agricultural residues could be technically collected but remain unused as an energy resource. Among China's 31 provincial-level regions, Heilongjiang Province exhibited the highest potential for developing a residue-based bioeconomy due to its abundant biomass resources.

Janiszewska and Ossowska (2022) evaluated the potential of agricultural biomass for energy production across European Union Member States. Their study estimated both the theoretical potential, reflecting the energy value of agricultural biomass resources, and the technical potential, accounting for biomass resources not currently utilized within agricultural production. The results revealed substantial spatial disparities in agricultural biomass potential across the EU, suggesting that regional differences may constrain the broader

deployment of biomass as a renewable energy source.

In a subsequent study, Janiszewska and Ossowska (2023) assessed the theoretical and technical potential of agricultural biomass across the Polish voivodeships. Their findings demonstrated that Poland possesses a considerable theoretical biomass potential. However, because biomass is extensively utilized in crop production as an organic fertilizer and in livestock farming as animal feed and bedding material, only approximately 40% of the theoretical potential remains available for energy production. The study also identified cereal straw as the dominant agricultural biomass resource suitable for bioenergy applications in Poland.

Overall, the reviewed literature demonstrates that previous research has primarily focused on assessing biomass resource availability and estimating the theoretical and technical potential of agricultural biomass as a renewable energy source. Differences in the reported potential across countries are largely explained by variations in agricultural land resources, climatic conditions, crop structures, biomass availability, and competing uses of agricultural residues.

Methodology

The empirical analysis evaluates the technical potential of agricultural crop residues as a renewable energy source across 51 Lithuanian district municipalities.

To estimate the technical potential of agricultural crop residues, the following statistical indicators were used:

- agricultural land area;
- cultivated area of cereal crops (spring and winter wheat, rye, barley, triticale, oats, mixed cereals, maize, and spring and winter rapeseed);
- crop yields of cereal crops (spring and winter wheat, rye, barley, triticale, oats, mixed cereals, maize, and spring and winter rapeseed) and hay production from meadows and natural pastures;
- livestock population (cattle, pigs, sheep, goats, and horses);
- area under perennial grasses up to five years of age.

The **technical potential of surplus cereal straw** (P) was calculated as the difference between total straw production (obtained by multiplying the cultivated area of cereal crops by straw yield) and straw consumption within agriculture, including livestock production (animal bedding and feed) and crop production (soil fertilization through the incorporation of organic matter into arable land). The calculation additionally accounts for the energy content of straw and the efficiency of biomass combustion technologies:

$$P = \sum_{i=1}^n N \times 13 \times 0.80 \quad (1)$$

where:

P – technical energy potential of cereal straw (GJ);

N – surplus straw available within a given municipality (difference between straw production and agricultural consumption);

13 – lower heating value of straw (GJ/ t);

0.80 – efficiency coefficient of biomass combustion equipment.

The amount of **surplus cereal straw** available for energy production (N) was calculated as follows:

$$N = P - (Z_s + Z_p + Z_n) \times 13 \times 0.80 \quad (2)$$

where:

N – surplus cereal straw available for energy production;

P – total straw production;

Z_s – straw demand for animal bedding;

Z_p – straw demand for animal feed;

Z_n – straw demand for soil fertilization;

13 – lower heating value of cereal straw (GJ/ t);

0.80 – efficiency coefficient of biomass combustion equipment.

The annual normative straw consumption coefficients proposed by Janiszewska and Ossowska (2022) were applied.

Feed requirements (t/ year): cattle – 1.0; pigs – 0.3; sheep – 0.2; goats – 0.2; horses – 0.8.

Bedding requirements (t/ year): cattle – 0.75; pigs – 0.00; sheep – 0.20; goats – 0.20; horses – 1.00.

The annual straw requirement for soil fertilization was assumed to be 1.17 t/ ha.

The assessment of the technical straw potential included the following crops: wheat, rye, barley, oats, triticale, mixed cereals, maize,

and rapeseed. The following straw-to-grain ratios (Janiszewska & Ossowska, 2022) were adopted: wheat – 1:0.8; rye – 1:1.4; barley – 1:0.9; triticale – 1:0.8; oats – 1:1.05; maize – 1:1.5; mixed cereals – 1:0.95; rapeseed – 1:1.0.

The **technical potential of surplus hay** (PT_s) as a renewable energy source was estimated as the difference between hay production (calculated from the area of perennial grasses up to five years of age and hay yield) and livestock feed requirements, while accounting for the energy content of hay and the efficiency of biomass combustion technologies:

$$PT_s = A \times Y \times wWs \times 13.4 \times 0.80 \quad (3)$$

where:

PT_s – technical energy potential of surplus hay (GJ);

A – area under perennial grasses up to five years of age;

Y – hay yield from perennial grasses;

wWs – coefficient representing the proportion of hay available for energy production (7.5% of the area of meadows and natural pastures);

13.4 – lower heating value of hay (GJ/t);

0.80 – efficiency coefficient of biomass combustion equipment.

Following the methodological approach proposed by Janiszewska and Ossowska (2022, 2023, 2024), this study adopts a lower heating value of 13 GJ/t for straw and hay and assumes a biomass combustion efficiency of 80% when estimating the technical energy potential of agricultural crop residues.

To facilitate comparative analysis, Lithuanian district municipalities were classified into three categories according to the overall technical potential of agricultural crop residues (B_p). The classification was based on the

arithmetic mean (B_a) and the standard deviation (B_s) of the estimated biomass potential:

Class I (High potential): $B_p > (B_a + 0.5 B_s)$;

Class II (Medium potential): $(B_a - 0.5 B_s) \leq$

$B_p \leq (B_a + 0.5 B_s)$;

Class III (Low potential): $B_p < (B_a - 0.5 B_s)$.

The empirical analysis was based on data from the 2020 Agricultural Census obtained from the Agricultural Data Centre of the Official Statistics Portal of Lithuania. One limitation of the study is that municipality-level results from the 2024 Agricultural Structure Survey were not available at the time of the analysis. Consequently, more recent statistical data could not be incorporated into the empirical assessment.

Research Results

The technical potential of surplus cereal straw was estimated using Equations (1) and (2) presented in the Methodology section. The calculations incorporated the normative annual straw requirements for livestock as well as the crop-specific straw-to-grain ratios. The technical potential of surplus hay as a renewable energy source was calculated as the difference between hay production and livestock feed requirements, while accounting for its lower heating value and the efficiency of biomass combustion technologies, as specified in Equation (3).

To ensure comparability across municipalities with different agricultural land endowments, the technical potential of agricultural crop residues was standardized and expressed per 100 ha of utilized agricultural area (UAA).

The descriptive statistics of the variables used to estimate the technical potential of agricultural crop residues are presented in Table 1.

Table 1. Descriptive Statistics of the Agricultural Crop Residue Variables

Indicators	Surplus Cereal Straw	Surplus Hay	Total
Number of district municipalities 51			
Minimum	-4957.63	-20	-4977.63
Maximum	4762.72	542	4757.72
Range	9720.35	562	9735.35
Mean	1435.91	23.04	1458.95
Median	1403.97	5	1436.18
Standard deviation	1767.35	78.06	1764.89
Sample variance	3123537.28	6092.60	3114830.02

Based on the methodology described above, Lithuanian district municipalities were classified into three categories according to the technical potential of agricultural crop residues as a renewable energy source. The classification was based on the arithmetic mean and standard deviation of the overall technical potential of agricultural crop residues. The three classes represent different levels of technical potential:

Class I – high technical potential of agricultural crop residues as a renewable energy source;

Class II – medium technical potential;

Class III – low technical potential.

The results indicate that Class I is characterized by a high level of technical potential, exceeding 4,757.72 GJ per 100 ha of utilized agricultural area (UAA). Class II comprises municipalities with a medium level of technical potential, ranging from 576.51 to 2,341.39 GJ per 100 ha. Class III includes municipalities with a low level of technical potential, varying from -4,977.63 to 576.50 GJ per 100 ha.

To obtain a more detailed understanding of the spatial distribution of biomass resources, the technical potentials of straw and hay were

subsequently analysed separately. The classification was again based on the arithmetic mean and standard deviation of the respective technical potential estimates.

For surplus cereal straw, municipalities classified as Class I exhibit a high technical potential exceeding 4,762.72 GJ per 100 ha. Class II represents a medium technical potential ranging from 552.23 to 2,319.59 GJ per 100 ha, whereas Class III is characterized by a low technical potential, varying from -4,957.63 to 552.22 GJ per 100 ha.

For surplus hay, Class I municipalities demonstrate a high technical potential exceeding 542 GJ per 100 ha. Class II is characterized by a medium technical potential ranging from -15.99 to 62.07 GJ per 100 ha, while Class III comprises municipalities with a negative technical potential, indicating that hay production is insufficient to satisfy existing livestock feed requirements and, consequently, no surplus biomass is available for energy production.

The results of the assessment of the technical potential of agricultural crop residues as a renewable energy source across Lithuanian district municipalities are presented in Table 2.

Table 2. Assessment of the Technical Potential of Agricultural Crop Residues as a Renewable Energy Source across Lithuanian District Municipalities

Potential Class (GJ per 100 ha of Utilized Agricultural Area)		
Class I (High technical potential)		Number of Municipalities
Surplus cereal straw	3341.7	16
Surplus hay	325	2
Total surplus	3340.7	16
Class II (Medium technical potential)		Number of Municipalities
Surplus cereal straw	1452.9	19
Surplus hay	22	47
Total surplus	1498.9	19
Class III (Low technical potential)		Number of Municipalities
Surplus cereal straw	-490.1	16
Surplus hay	-19.5	2
Total surplus	-470.3	16

Among the 51 Lithuanian district municipalities, 16 municipalities were classified into Class I, representing a high level of technical potential for agricultural crop residues. These municipalities are predominantly located in central Lithuania (e.g., Jonava, Kėdainiai, Birštonas, Kaunas District), northern Lithuania (e.g., Biržai, Panevėžys, Pasvalys), and south-

western Lithuania (Marijampolė, Šakiai, and Vilkaviškis). Municipalities in this class exhibit the highest overall technical potential, averaging 3,340.7 GJ per 100 ha of utilized agricultural area (UAA). When individual biomass sources are considered separately, the technical potential of surplus hay amounts to 325 GJ per 100 ha UAA,

while the technical potential of surplus cereal straw reaches 3,341.7 GJ per 100 ha UAA.

Class II, representing a medium level of technical potential, comprises 19 municipalities distributed throughout Lithuania. The average overall technical potential of agricultural crop residues in this group is 1,498.9 GJ per 100 ha UAA. The technical potential of surplus hay is 22 GJ per 100 ha UAA, whereas surplus cereal straw contributes 1,452.9 GJ per 100 ha UAA.

Class III includes 16 municipalities characterized by a low level of technical potential. These municipalities are located primarily in the western, southern, and eastern regions of Lithuania. Their overall technical potential is negative, averaging -470.3 GJ per 100 ha UAA, indicating that agricultural biomass production is insufficient to generate surplus residues for energy production after meeting existing agricultural requirements.

Overall, the results demonstrate that the technical potential of cereal straw closely corresponds to the overall technical potential of agricultural crop residues, as reflected by the identical distribution of municipalities across the three potential classes (16 municipalities in Class I, 19 in Class II, and 16 in Class III). In contrast, the technical potential of surplus hay differs substantially from both the overall biomass potential and the straw potential, exhibiting considerably lower values as well as a different spatial distribution.

Conclusions

Agricultural biomass residues comprise a diverse range of organic resources, including crop residues, livestock manure, grass biomass, and other biodegradable materials that can be utilized for energy production. The characteristics of these resources depend on crop species, climatic conditions, soil properties, and agricultural production systems. Their principal utilization pathways include the production of solid biofuels, biomethane, and biohydrogen. The energy recovery potential of agricultural biomass can be assessed through theoretical, technical, and economic potential analyses. Consequently, agricultural biomass represents a significant renewable energy resource; however, its efficient utilization requires careful consideration of

agronomic, technological, economic, and environmental constraints.

Building upon the findings of previous studies, this research developed a methodological framework for estimating the technical potential of agricultural crop residues across Lithuanian district municipalities. The empirical assessment was based on official Lithuanian statistical data and the 2020 Agricultural Census compiled by the Agricultural Data Centre. The proposed framework provides a systematic basis for assessing the spatial distribution of agricultural crop residues and for identifying territories with comparatively favourable conditions for renewable energy development.

The empirical results indicate that central Lithuanian municipalities possess the greatest potential to expand their role as suppliers of renewable energy resources. Sixteen municipalities, representing 31.4% of all municipalities included in the analysis, were classified as having a high level of technical potential (Class I). A further 19 municipalities (37.2%) exhibited a medium level of technical potential (Class II), while the remaining 16 municipalities (31.4%) were characterized by a low level of technical potential (Class III). Municipalities belonging to the latter group are concentrated predominantly in the south-western, western, and eastern parts of Lithuania.

The findings are significant because they demonstrate that the potential contribution of agricultural biomass to the renewable energy transition is spatially differentiated and closely associated with the distribution and intensity of agricultural production. The identification of municipalities with high and medium technical potential provides an empirical basis for moving beyond a uniform national approach to agricultural biomass development towards more geographically targeted energy and regional development policies. In particular, the results can support the identification of locations where investments in biomass collection, storage, processing, and energy-conversion infrastructure may have comparatively favourable resource conditions. At the same time, the distinction between technical potential and economically feasible potential should be maintained, as the availability of biomass does not, by itself,

guarantee the commercial viability of energy projects.

The practical relevance of the findings extends to several groups of potential beneficiaries and users. National and regional policymakers can use the results to improve renewable energy planning, formulate geographically targeted support measures, and integrate biomass resources into regional energy strategies. Municipal authorities can use the identified technical potential to assess opportunities for local energy production, support the development of municipal and regional energy plans, and facilitate cooperation between agricultural producers and energy companies. Agricultural producers and their cooperatives may use the findings to evaluate opportunities for additional revenue generation from agricultural residues and participation in local biomass supply chains. Energy companies and potential investors can use the spatial assessment as an initial screening tool for identifying municipalities where further feasibility studies of biomass-based energy projects may be warranted. The results may also be relevant to researchers and other

stakeholders developing regional bioeconomy and circular economy strategies.

Overall, the findings suggest that municipalities with substantial agricultural biomass resources have favourable conditions for diversifying the functions of the agricultural sector through the development of renewable energy production. Agricultural crop residues therefore constitute an important endogenous resource that can contribute simultaneously to regional economic development, energy security, and the transition towards a low-carbon and circular bioeconomy. However, the technical potential identified in this study should be regarded as a basis for further economic, environmental, and logistical assessment rather than as a direct measure of investment feasibility. Future research should therefore examine the economic potential of the identified biomass resources, including collection and transportation costs, conversion technologies, investment requirements, market conditions, and environmental constraints. Such analysis would enable the technical potential identified in this study to be translated into more concrete investment and policy recommendations.

References

- Alotzas, S., Moustakas, K., Malamis, D. ir Vakalis, S. (2019). Biomass Potential from Agricultural Waste for Energetic Utilization in Greece. *Energies*, 12(6), 1095; <https://doi.org/10.3390/en12061095>
- Avcioglu, A., O., Dayioglu, M., A. ir Turker, U. (2019). Assessment of the energy potential of agricultural biomass residues in Turkey. *Renewable Energy*, 138, 610-619. <https://doi.org/10.1016/j.renene.2019.01.053>
- Awogbemi, O. ir Von Kallon, D., V. (2022). Pretreatment techniques for agricultural waste. *Case Studies in Chemical and Environmental Engineering*, 6, 100229. <https://doi.org/10.1016/j.csee.2022.100229>
- Bharti, A., Paritosh, K., Madla, V., R., Chawade, A. ir Vivekanand, V. (2021). GIS Application for the Estimation of Bioenergy Potential from Agriculture Residues: An Overview. *Energies*, 14(4), 898. <https://doi.org/10.3390/en14040898>
- Cervi, V., R., Lamparelli, R., A., C., Gallo, B., C., Oliveira Bordonal, R., Seabra, J., E., A., Junginger, M. ir Hilst, F. (2020). Mapping the environmental and techno-economic potential of biojet fuel production from biomass residues in Brazil. *Biofuels, Bioproducts and Biorefining*, 15 (1), 282-304. <https://doi.org/10.1002/bbb.2161>
- Erdiwansyah, E., Gani, A., Mamat, R., Bahagia, Nizar, M., Yana, S. . . ir Rosdi, S., M. (2024). Prospects for renewable energy sources from biomass waste in Indonesia. *Case Studies in Chemical and Environmental Engineering*, 10, 100880. <https://doi.org/10.1016/j.csee.2024.100880>
- Europos komisija. (2023). 2023 m. energetikos sąjungos būklės ataskaita. (2023). Prieiga per internetą: <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52023DC0650&%3Bqid=1708966429742#document2>.
- Guzman-Bello, H., Lopez-Diaz, I., Aybar-Mejia, M., Dominguez-Garabitos, M. ir Atilio de Frias, J. (2023). Biomass Energy Potential of Agricultural Residues in the Dominican Republic. *Sustainability*, 15, 15847. <https://doi.org/10.3390/su152215847>
- Hassan, Q., Algburi, S., Sameen, A., Z., Al-Musawi, T., J., Al-Jiboory, A., K., Salman, H., M., . . . ir Jaszczur, M. (2024). A comprehensive review of international renewable energy growth. *Energy and Built Environment*. <https://doi.org/10.1016/j.enbenv.2023.12.002>
- Janiszewska, D. ir Ossowska, L. (2022). The Role of Agricultural Biomass as a Renewable Energy Source in European Union Countries. s. *Energies*, 15, 6756. <https://doi.org/10.3390/en15186756>
- Janiszewska, D. ir Ossowska, L. (2023). Spatial Differentiation of Agricultural Biomass Potential in Polish Voivodeships. *Energies*, 16(19), 6828. <https://doi.org/10.3390/en16196828>

- Janiszewska, D. ir Ossowska, L. (2024). The Potential Diversity of Agricultural Biomass in the Context of the Organization of Agricultural Production and Circular Agriculture in Poland. *Energies*, 17, 3368. <https://doi.org/10.3390/en17143368>
- Jekayinfa, S., O., Orisaleye, J., I. ir Pacenka, R. (2020). An Assessment of Potential Resources for Biomass Energy in Nigeria. *Resources*, 9(8), 92. <https://doi.org/10.3390/resources9080092>
- Kalak, T. (2023). Potential Use of Industrial Biomass Waste as a Sustainable Energy Source in the Future. *Energies*, 16(4), 1783. <https://doi.org/10.3390/en16041783>
- Knapek, J., Kralik, T., Vavrova, K. ir Weger, J. (2020). Dynamic biomass potential from agricultural land. *Renewable and Sustainable Energy Reviews*, 134, 110319. <https://doi.org/10.1016/j.rser.2020.110319>
- Kyryzyuk, S., Krupin, V., Borodina, O. ir Was, A. (2020). Crop Residue Removal: Assessment of Future Bioenergy Generation Potential and Agro - Environmental Limitations Based on a Case Study of Ukraine. *Energies*, 13, 5343. doi:10.3390/en13205343
- Manikandan, S., Vickram, S., Sirohi, R., Subbaiya, R., Krishnam, R., Y., Karmegam, N. ir Awasthi, M., K. (2023). Critical review of biochemical pathways to transformation of waste and biomass into bioenergy. *Bioresource Technology*, 372, 128679. <https://doi.org/10.1016/j.biortech.2023.128679>
- Mofijur, M., Mahilia, T., M., I., Logeswaran, J., Anwar, M., Silitonga, A., S., Rahman, S., M., A. ir Shamsuddin, A., H. (2019). Potential of Rice Industry Biomass as a Renewable Energy Source. *Energies*, 12(21), 4116. <https://doi.org/10.3390/en12214116>
- Picirelli de Souza, L., Hamedani, S., R., Silva Lara, E., E., Palacio, J., C., E., Comodi, G., Villarini, M. ir Colantoni, A. (2021). Theoretical and technical assessment of agroforestry residue potential for electricity generation in Brazil towards 2050. *Energy Reports*, 7, 2574-2587. <https://doi.org/10.1016/j.egyr.2021.04.026>
- Raihan, A., Pavel, M., I., Muhtasim, D., A., Farhana, S., Faruk, O. ir Paul, A. (2023). The role of renewable energy use, technological innovation, and forest cover toward green development: Evidence from Indonesia. *Innovation and Green Development*, 2 (1), 100035. <https://doi.org/10.1016/j.igd.2023.100035>
- Saleem, M. (2022). Possibility of utilizing agriculture biomass as a renewable and sustainable future energy source. *Heliyon*, 8, e08905. <https://doi.org/10.1016/j.heliyon.2022.e08905>
- Soltero, V., M., Chacartegui, R., Ortiz, C., Lizana, J. ir Quirosa, G. (2018). Biomass District Heating Systems Based on Agriculture Residues. *Appl. Sci.*, 8(4), 476. <https://doi.org/10.3390/app8040476>
- Zhang, J., Li, J., Dong, C., Zhang, X., Rentizelas, A. ir Shen, D. (2021). Comprehensive assessment of sustainable potential of agricultural residues for bioenergy based on geographical information system: A case study of China. *Renewable Energy*, 173, 466-478. <https://doi.org/10.1016/j.renene.2021.03.135>