ROMANIAN BIOMASS PELLET MARKET – TECHNO-ECONOMIC ANALYSIS / *PIAȚA ROMÂNEASCĂ A PELETELOR DIN BIOMASĂ - ANALIZĂ TEHNICO-ECONOMICĂ*

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ABSTRACT

Biomass is currently the most widespread form of renewable energy, and its exploitation is constantly increasing due to concerns about the major impact of fossil fuel consumption, in terms of climate change, global warming and their negative impact on the human factor. Biomass can be transformed using modern technologies into solid, liquid, and gaseous fuels. One of the most widely used biomass biofuels is wood pellets. Pellets obtained from woody biomass represent a very successful renewable energy source, due to their characteristics that include high density, high calorific value, low moisture content, but also ease of storage and transport. Romania's biomass pellet industry has recorded significant growth due to the increasing demand for green energy. Investment in modern technology improves production efficiency and enhances competitiveness in international markets. However, fluctuations in raw material prices such as biomass transportation costs and moisture content often affect profit margins. Improving infrastructure and continued investment in research and development are crucial to strengthening Romania's position in the global renewable energy market. In this context, the purpose of the article is to present an analysis for Romanian pellet market industry.

REZUMAT

Biomasa este în prezent cea mai răspândită formă de energie regenerabilă, iar exploatarea acesteia este în continuă creștere datorită preocupărilor legate de impactul major al consumului de combustibili fosili, în ceea ce privește schimbările climatice, încălzirea globală și impactul negativ al acestora asupra factorului uman. Biomasa poate fi transformată cu ajutorul tehnologiilor moderne în combustibili sub formă solidă, lichidă și gazoasă. Printre cei mai utilizați biocombustibili din biomasă sunt peletele din lemn. Peletele obținute din biomasă lemnoasă reprezintă o sursă de energie regenerabilă de mare succes, datorită caracteristicilor acestora care includ densitate ridicată, putere calorică mare, conținut de umiditate scăzut dar și ușurință în depozitare și transport. Industria peletelor din biomasă din România a înregistrat o creștere semnificativă datorită cererii tot mai mari de energie verde. Investițiile în tehnologii moderne îmbunătățesc eficiența producției și sporesc competitivitatea pe piețele internaționale. Cu toate acestea, fluctuațiile prețurilor materiilor prime, cum ar fi costurile de transport al biomasei și conținutul de umiditate, afectează adesea marjele de profit. Îmbunătățirea infrastructurii și investițiile continue în cercetare și dezvoltare sunt esențiale pentru consolidarea poziției României pe piața globală a energiei regenerabile. În acest context, scopul articolului este de a prezenta o analiză pentru industria românească a pieței peletelor.

INTRODUCTION

In the context of climate changes and their effect on the environment and the human factor, biomass has been promoted as an important resource for reducing greenhouse gas emissions through its conversion into biofuels (*Ilham, 2022*). The European Environment Agency has stated that to meet the global goal of reducing the carbon footprint by 50% by 2050, increasing the use of renewable energy is one of the most significant greenhouse gas reduction policies implemented by various countries of the EU (*Bui-Duy et al., 2023*).

Bioenergy, or energy derived from bio-based sources, represents a type of renewable energy that is environmentally friendly and economically viable. Thus, in the last decade, bioenergy production in the form of solid, liquid, or gaseous fuels has begun to play an important role in the global energy mix *(World Bioenergy Association, 2019; Jelonek et al., 2020).*

Biomass fuel pellets represent one of the most important energy sources that can be a promising substitute for fossil fuels (*Sarker et al., 2023*). At present, pellets are the most cost-effective technique to convert biomass into fuel and are a rapidly growing component of the energy sector *(Jelonek et al., 2020)*. According to Statista report and as it can be seen in Figure 1, the European demand for wood pellets is expected to grow to more than 38 million metric tons by 2025, thus Europe is expected to remain the most important target market for wood pellets through 2025. In 2020, the European Union led the world pellet production with 13 MMT (million metric tons), followed by North America with 11 MMT, China with10 MMT, South America with 4.4 MMT and Oceania with 0.8 MMT (*https://www.statista.com/statistics/243910/global-wood-pellet-consumption-outlook/*).

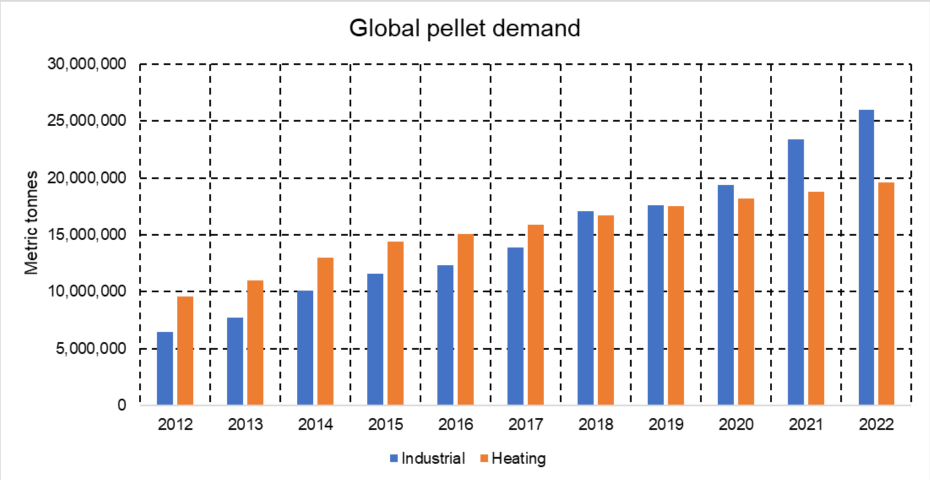

Fig. 1 – Global pellet demand for a 10-year timeframe *(TCPEL, 2022)*

The EN*plus* certification scheme defines three pellet quality classes, namely: EN*plus* A1, EN*plus* A2 and EN*plus* B (*European Pellet Council, 2015; Paraschiv et al., 2017*).

A1 quality class pellets (premium quality) are the most commonly used; pellets are obtained only from untreated wood residues, they are mainly used in the residential sector for burning in individual stoves and boilers, they produce the lowest amount of ash and have the highest calorific value.

A2 quality class pellets are obtained from raw materials with a high content of tree bark, they are used for combustion in larger installations and produce a larger amount of ash.

B quality class pellets (industrial class) are obtained from a wide range of raw materials, including chemically treated wood by-products, produce the highest amount of ash and have a significantly lower calorific value than that of class A2.

The most common biomass feedstocks used for pellets production are wood processing industry waste, agricultural and forest residues, and energy crops. The pellets produced from these biomass feedstocks have a high density and an extremely low moisture content (<10%), and a high energy conversion efficiency (about 75%) (*Paraschiv et al., 2017; Pradhan et al., 2018*).

Many works can be found in the literature focused on techno-economic analysis used to estimate the production cost of wood pellets. In their research, Ebadian et al. *(Ebadian et al., 2021)* have modelled an inter-continental agricultural pellet supply chain and estimated the production cost and price of agricultural pellets. In a recent study, Visser and co-workers *(Visser et al., 2020)* reviewed existing literature on pellet costs and performed a techno-economic analysis of the impact of different design variables on cost components (feedstock type, production location and pellet plant size). Schipfer et al. *(Schipfer et al., 2020)* carried out another study where the main objective was to establish a framework to test the European residential wood pellet market for competitive spatial equilibrium using modern trade theory.

Sarker et al., (2023) realised a techno-economic analysis of torrefied fuel pellet production from agricultural residue via integrated torrefaction and pelletisation process. The authors tested and compared two scenarios: scenario 1 - pelletisation of torrefied biomass with additives and scenario 2 - pelletisation of torrefied biomass without any external additives and they reported that the economic analysis suggests that both scenarios are profitable. In their results highlighted that the lowest selling price of generated torrefied pellets was found to be \$103.4 at the plant gate for scenario 1 and \$105.1 per tonne for scenario 2. Furthermore, sensitivity analysis indicates that, in producing pellets for both scenarios, among all variable costs, labour cost has a greatest impact on net present value and minimum selling price. A similar study was carried out by *Manouchehrinejad et al., (2021)*, which investigated the techno-economic analysis of two integrated torrefaction and pelletisation systems: torrefaction before pelletisation and torrefaction after pelletisation configurations to produce torrefied wood pellets. The authors reported that the minimum selling price for torrefaction before pelletisation is \$207 Mg^{-1} at the plant gate and \$197 Mg^{-1} for the torrefaction after pelletisation configurations.

In the context of the current global focus on environmental protection and carbon dioxide emission reduction, the biomass pellet market has become an important part of the energy infrastructure of many European countries, including Romania. As the demand for renewable energy increases significantly, the pellet industry becomes even more important in providing clean and sustainable energy.

Europe has been a major player in the growth of the biomass pellet industry, having been at the forefront of the establishment of laws and policies that encourage the effective use of renewable energy sources. The pellet industry has changed dramatically during the 1990s as concerns over climate change and the high expense of fossil fuels have grown. Thanks to persistent efforts to establish favourable legal frameworks and to invest in cutting-edge technologies for the manufacture and use of pellets, several European nations, including Germany, Sweden, and Austria, have emerged as leaders in the production and consumption of biomass pellets. In figure 2, the top 5 countries that had the highest production in 2021 are presented.

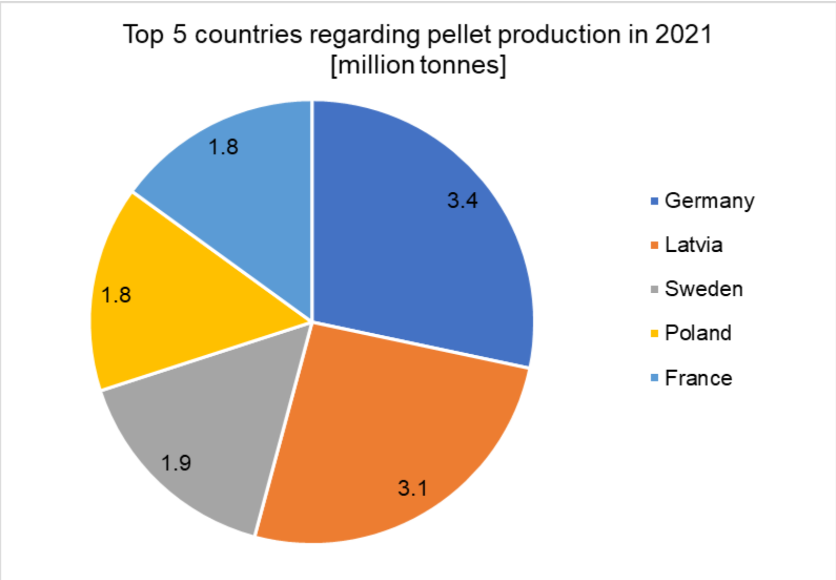

Fig. 2 – Top 5 countries in 2021 that had the highest pellet production
(adapted after Bioenergy Europe Statistical Report, 2021)

The Romanian market has evolved in a way that closely resembles European patterns over the past few decades, exhibiting gradual development. The Romanian government has encouraged the growth of the meat industry through a number of legislative and policy efforts, which has increased the quantity of biomass resources used and broadened the country's energy mix. Romania has the potential to dramatically improve its position on the biomass market by putting into practice efficient growth plans and investing in state-of-the-art technologies, even though it is currently in a relatively early stage of development in comparison to other European nations. The literature on the techno-economic analysis of Romanian pellet production is scarce. In this context, the main aim of this article is to present an analysis for Romanian pellet market industry.

MATERIALS AND METHODS

The economic assessment involves the computation of the net present value (NPV) and profitability index (PI) for the investment. The methodology for the economic analysis followed the model of the authors *Pantaleo et al*., which was used to analyse the market for pellets in Italy. Applying the prices currently used in Romania and the data available from different suppliers, the techno-economic analysis was possible.

Net Present Value (NVP) is defined as the total present value for the projected return on an investment that is offset by its initial outlay. NVP is used to determine initiatives or projects that will produce the greatest return in relevant time frames. In addition, NVP is used to verify that a business choice will last for a defined period of time by meeting its objective benchmark and demonstrating more viability in competition with alternatives. To determine NPV, the company's cumulative profits over a certain number of years are discounted using a marginal rate of return *(Alizadeh et al., 2023)*.

The NPV can be calculated based on Equation (1):

$$NVP = -\beta + \sum_{j=1}^{T} \frac{\emptyset_j}{(1+R)^j} \tag{1}$$

where β is the initial investment;

T is the project lifetime, [in years];

$\emptyset_j$ is the cash flow in each year (j).

The discount rate or cost of capital is shown by R in the above equation.

Profitability index (PI) is used to assess how much profit may come from a particular investment. The PI is calculated according to Equation (2) *(Pantaleo et al., 2020)*:

$$PI = \frac{NVP}{C_{Investment}} \tag{2}$$

where the cost of investment ($C_{Investment}$) is calculated according to Equation (3) *(Pantaleo et al., 2020)*:

$$C_{Investment} = C_{pell} + C_{dry} + C_{chip} + C_{store} + C_{inst} + C_{eng} \tag{3}$$

where:

C_{pell} - the cost of pelletizing the plant;

C_{dry} - the cost of drying the plant;

C_{chip} - the cost of pre-treatment processes;

C_{store} - the cost of storage;

C_{inst} - the cost of plant installation;

C_{eng} – the plant engineering cost.

Payback Time (PBT) is the time (in years) required for the capital invested in an asset to be repaid by the net cash flow it produces. A shorter PBT is preferable because it gives the investor a clear idea of how long the initial outlay will be at risk. PBT is the period of time in years that a project needs to pay back its initial investment (δ) through earnings after interest and taxes (μ) *(Alizadeh et al., 2023)*.

The equation for estimating PBT is presented in Equation (4):

$$PBT = \frac{\delta}{\mu} \tag{4}$$

Before starting to analyse the cost, a modelling process of the pelletization process was realized using the program for business process modelling ADONIS Communities. In Figure 3 the process is presented considering that the trigger is represented by the demand for pellets on the market.

Adonis Software offers a methodical approach to comprehend, record, and enhance the way that operations are carried out. For increasing productivity, effectiveness, and flexibility, modelling processes is an essential activity. It promotes a better knowledge and administration of company processes by providing a comprehensive perspective on how work is done.

The pelletizing process is adapted according to the raw material used, but usually includes the following stages: reception of the raw material, drying, grinding, pelletizing, cooling, packaging, as can also be seen in figure 3.

The size reduction of lignocellulosic biomass is an important step in the pelletization process. This influences a number of factors, such as compaction, the contact area between the particles, the friction forces between the pressed material and the die wall, but also the material flow. Biomass shredding is done with the help of hammer mills, which are chosen according to the feedstock type, the degree of humidity and the production capacity (*Whittaker and Shield, 2017*).

Water is a key parameter in the pelletization process, biomass moisture being one of the most important parameters that determine the durability of the pellets. The optimum moisture content differs depending on the type of biomass used, such as: for pine it is between 6–13%, straw 8–15% and Miscanthus 20–25%. Biomass drying is carried out with fully automated continuous flow dryers (*Whittaker and Shield, 2017*). In the pelletizing process, the optimum moisture content is considered to be between 10-15% (*Pradhan et al., 2018*).

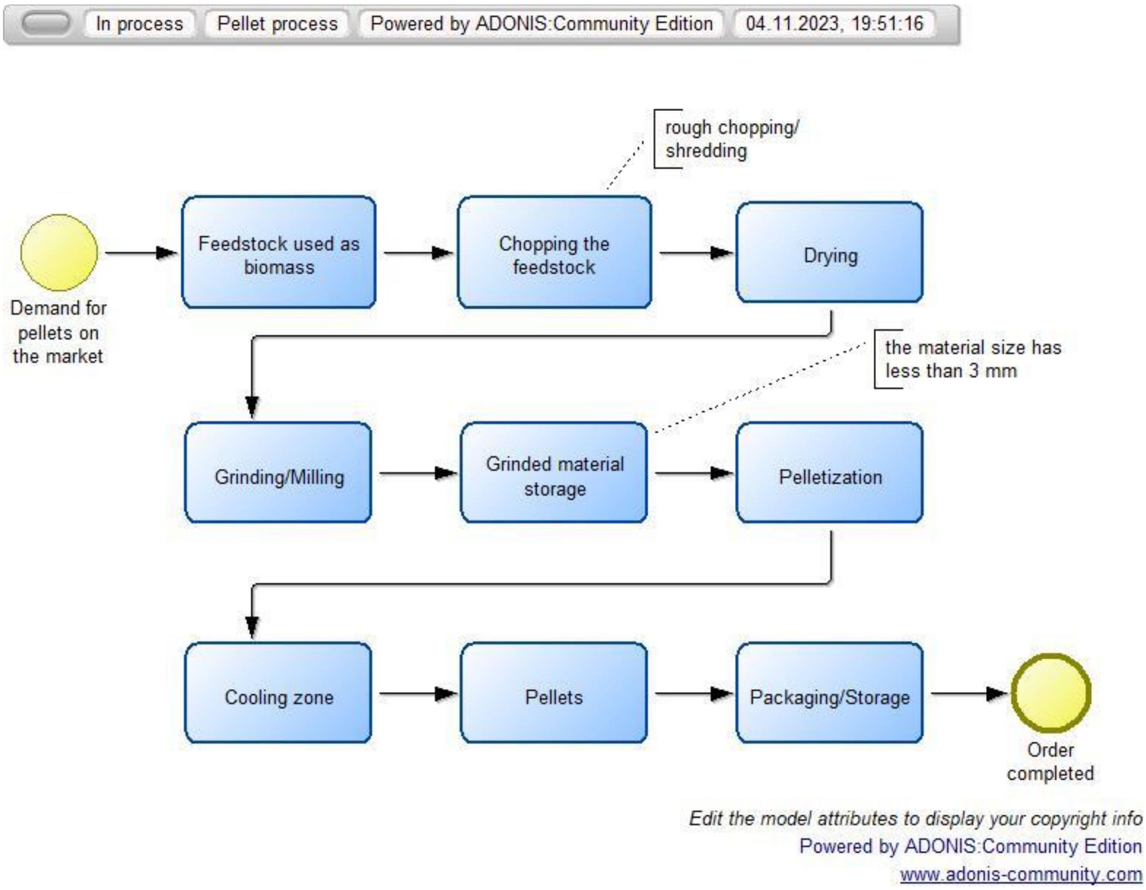

Fig. 3 – Modelling of the pelletization process

Pelletizing process represents the operation of transforming the biomass feedstock into fuel. The producing pellets process involves placing biomass under high pressure and forcing it through the cylindrical holes of a die. This process is known as extrusion (*Paraschiv et al., 2017; Ciolkosz, 2023*).

Cooling is the mandatory operation to be performed after pelletizing, due to the high temperature of the finished product when exiting the extrusion die. The outlet temperature can reach 90 - 100°C, there being a risk of damage to the finished product if it is further stored or packaged at this temperature (*Ciolkosz, 2023*).

Semi-automatic or fully automated machines are used to pack the pellets in plastic bags or special material bags. Pellets can be used for domestic use (ovens or home heating) or industrial use (gasification, pyrolysis and co-generation (*Paraschiv et al., 2017; Pradhan et al., 2018*).

RESULTS

Since European Union proposed a raise in renewable energy consumption by 2030, countries started analysing the current situation regarding the global demand for renewable energy and the investments necessary for achieving the proposed goal *(Council of the European Union, 2018).*

In paper *(Pantaleo et al., 2020),* the authors made inquiries and presented the pellet production industry. One of the main conclusions stated the necessity of an accurate techno – economic assessment *(Thek and Obernberger, 2012)*. Also, the studies demonstrated the influence of physico-chemical and mechanical characteristics of the biomass on the production process of pellets which implies an influence on the pellet market evaluation from the point of view of investments, operational and maintenance costs necessary for developing a pellet factory *(Junginger and Sikkema, 2008*; *Castellano et al., 2015)*.

Regarding the analysis conducted in the present article it is necessary to mention the fact that the pellet production line is experimental being a part of the Testing Department from The National Institute of Research – Development for Machines and Installations Designed for Agriculture and Food Industry – INMA Bucharest. Also, some of the parameters mentioned were determined through previous research and adapted for the economic evaluation proposed.

The economic viability assessment was done considering the economic model proposed by *Pantaleo et al., (2020)*, the calculations being done using the equations proposed by the authors.

Thus, in the following table (Table 1) the data held constant are presented. Regarding the Cost of transport $c_{transport}$ the value in the table was selected by analysing the existing transportation market for raw materials, considering a distance of 100 km and a load of 20 t.

Also, the drying coefficient was obtained considering a biomass moisture content of 30% that after drying process will have 10% moisture content. The electricity needed per t of pellet was experimentally determined by researchers from the institute while the maintenance coefficient was selected based on literature research *(Nolan et al., 2010).* Regarding the determination of the electricity needed, for experiments, the determination of power consumption, electricity consumption, and specific electricity consumption of equipment in the flow was determined for every equipment that is a part of the process. Thus, the means for the working capacity, power consumption and specific power consumption was considered. The mean of the parameters resulted after subjecting the equipment to 3 tests (*Chitoiu, 2011*).

Table 1

Technical and economic parameters remaining constant

Parameters	Unit	Value
Maximum production capacity Q_{max}	t/hour	0.15
Production load factor i_U	%	75
Hourly production capacity Q	t/hour	0.113
Number of daily shifts n_{shifts}	-	1
Number of annual production hours H	hours/year	2016
Annual pellet production Q_{pellet}	t/year	226.8
Pellet moisture content m_{pellet}	%	10
Cost of transport $c_{transport}$ (1)	lei/t/km	2
Drying coefficient k_{drying} (2)	-	0.015
Price of electricity $P_{electricity}$	lei/MWh	500
Electricity needed per t of pellet E_{pellet} (3)	MWh/t	0.03
Annual cost of personnel c_{unit}	lei/year/person	36000
Maintenance coefficient k_M (4)	%	10
Lifetime of the plant n	years	6
Real discount rate r	%	3
Pellet market value P_{pellet}	lei/t	1100

In table 2 the technical and economic parameters that can vary for obtaining different scenarios are presented. The biomass amount and biomass price considered for the analysis were obtained by conducting a market analysis regarding the present pellet industry. Also, the average distance was selected according to the most common distance used for transportation of raw materials and considering that the surroundings are mainly fields that can represent potential biomass suppliers. Electricity needed for chipping was experimentally determined by researchers from the institute and also by one of the authors in his dissertation paper.

Table 2

Technical and economic parameters that can be varied for obtaining different scenarios

Parameters	Unit	Value
Biomass amount	t/year	2100
Biomass price	lei/t	50
Moisture content	%	12
Average transportation distance	km	50
Electricity needed for chipping	MWh/t	0,01
Personnel units per shift	units	2

Knowing the technical and economical parameters presented in the tables above the costs of investments, operation and maintenance could be calculated and are presented in table 3.

Table 3

Investments, operation and maintenance costs

Investments costs	Value (lei)	Operation and maintenance costs	Value (lei)
C_{pell}	49700	$C_{Biomass}$	105000
C_{dry}		$C_{Transport}$	28232
C_{chip}		C_{Drying}	3150
C_{store}	20000	$C_{Electricity}$	13905.15
C_{inst}	6000	$C_{Personnel}$	72000
C_{eng}	4500	$C_{Maintanance}$	4920
TOTAL	**79700**	**TOTAL**	**227207.15**

Regarding the cost of plant installation and the cost of plant engineering cost were calculated based on the authors elaboration considering two technicians employed for 15 days and a cost of 200 lei/day and a net installation cost established on by the pellet market industry.

Based on values established, the financial analysis results could be calculated to see if the investment would be viable and how long it would take to recover the cost of an investment. The net present value (NPV), profitability index (PI) and payback time (PBT) are presented in the table below (Table 4).

Table 4

Results of the financial analysis.
PBT—payback time; NPV—net present value; PI—profitability index

Economic parameters	Unit	Value
Revenue	lei	249480
Cash Flow	lei	27192.85
PBT	year	2.93
NPV	lei	53299.17
PI	-	0.66

As it can be observed the investment would be recovered in 2.93 years which is comparable with other studies done by researchers *(Pantaleo et al., 2020; Uchezuba et al., 2019).*

CONCLUSIONS

For the Romanian market, it is important to identify and use low-cost raw materials with low moisture content in order to obtain pellets with high financial profitability, the analysis said. In addition, further analysis and optimization of the biomass supply chain, biomass processing, and final energy conversion should be conducted to better meet end-user needs. As it could be seen from the conducted analysis, the pellet industry market has potential, but further analysis is needed to assess which recipe would be the most profitable and competitive on the market. The biomass market in Romania is varied which allows companies an optimal development in the pellet industry. However, a thorough analysis of all the factors involved in the production of this type of renewable energy is necessary. Potential market segments in the industrial, residential, commercial and rural sectors should also be evaluated to determine the most suitable application, given the differences in pellet quality and cost. Therefore, in the Romanian pellet industry, supply chain optimization strategies and identification of potential market segments are crucial to ensure long-term financial viability.

Also, as it could be observed from the analysis conducted the investment in a pellet plant would be viable and could bring a plus to the fuel market in Romania. The technical and economic parameters in the paper, present the potential for Romanian use of agricultural and forestry solid biomass to produce clean energy and reduce greenhouse gas emissions. Although investments are still needed further investigation for both technical and economic aspects would require a close attention to the application of artificial intelligence in the manufacturing process for further optimization.

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