**Optimizing Forest-Biomass-Distribution Logistics from a Multi-Level Perspective—Review**

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**Abstract:** Forest and wood biomass represent a sustainable reservoir of raw materials and energy, offering a viable alternative to fossil fuels. These resources find extensive use in producing bio-products, including solid wood and wood materials. The judicious exploitation of forest and wood biomass can be pivotal in reducing carbon emissions and securing material and energy independence. The business viability of producing valuable goods from woody biomass hinges on ensuring its sustained availability. This necessitates access to high-quality biomass at a minimal cost, demanding the efficient design of wood-biomass-distribution logistics. Furthermore, it is imperative to give equal weight to social and ecological considerations in shaping the forest- and wood-biomass-distribution logistics, thereby ensuring the sustainable utilization of this renewable raw material source. This article presents research focused on the business optimization of distribution logistics for specific forms of forest biomass used in wood material production. While most studies have primarily concentrated on the business or ecological issues of biomass utilization, this article offers a comprehensive insight by addressing business, ecological, and social facets in assessing and optimizing wood-biomass-distribution logistics. Multi-stakeholder life-cycle-assessment optimization takes into account the reduction of greenhouse gases as an ecological metric, with production costs and capital expenditure forming the business metrics. At the same time, the generation of employment opportunities is commonly regarded as the pivotal social criterion. There remains a necessity for further exploration into the potential social impacts of forest biomass utilization. Additionally, developing enhanced methodologies and decision-support tools for scheduling wood-biomass-distribution logistics that holistically consider business, ecological, and social criteria is an essential ongoing task.

**Keywords:** biomass; wood; business optimization; ecological optimization; social optimization; distribution logistics; life cycle

**1. Introduction**

Intensification of forestry production is increasing the use of biomass to replace fossil materials for social needs and to produce electricity, fuels [1,2], and various chemicals, plastics, and other wood materials. The International Energy Agency encourages using biomass residues for energy production, as this can help achieve energy independence without destabilizing the world’s timber resources [3]. Some countries have an excess of wood waste and solid wood waste that is generated during the manufacturing of forest and wood products. It is possible to produce valuable products from woody biomass, and the by-products, in many cases, are diverted to incineration [4–6]. Despite the benefits of using woody biomass as a renewable resource, the technological challenges of harvesting it...
and the business costs hinder its intensification. Forest resources are scattered, increasing the collection, handling, and transportation costs.

In addition, there is a wide variation in the quality of harvested woody biomass due to the type of raw material, access to forest resources, climatic conditions, pre-preparation, transportation, and storage, and there is competition from other industry players or end users [7,8]. Woody biomass often has a lower value than a large number of competing non-renewable resources [9,10]. This results in a relatively higher cost and more difficult logistics for harvesting, transporting, and processing woody biomass. Biomass logistics costs typically account for 10–30% of the cost of delivered wood [11,12] and often limit the competitiveness of woody biomass. A business-efficient woody biomass distribution logistics design is critical to overcoming market challenges. In addition, increasing public awareness of sustainability requires government officials in developed countries to understand the ecological and social impacts of the forest- and wood-biomass life cycle.

Quantitative modeling techniques can help understand the business, ecological, and social impacts of woody biomass distribution logistics. This understanding is again required to mitigate the undesirable effects of business development, increase the benefits of the biomass distribution logistics, ensure the sustainable use of biomass, and ensure the sustainable development of new products that should receive the interest and support of communities, the government of developed countries, and businesses.

Numerous studies to date have evaluated various woody biomass distribution logistics [4–6,13–19]. Scheduling and management of distribution logistics from biomass purchase to distribution has been presented [18,19] and classified in numerous studies [13,14,20], emphasizing strategic, tactical, and operational levels of decision scheduling. Modeling methods to support decision making in the area of biomass distribution logistics is part of the references [15–18].

Previous studies [3,11] have conducted modeling with uncertainty in the optimization process of forest- and wood-biomass-distribution logistics [10]. Most of the studies conducted focused exclusively on the business aspect of biomass distribution logistics in the form of roundwood and forest waste. Reference to issues of social and ecological influences on optimization included only a few factors considered in developing assumptions for woody biomass distribution logistics [4,14–16,20,21]. More recently, business, ecological, and social factors have begun to be integrated (according to factor weighting) in the evaluation and optimization of forest-biomass-distribution logistics. In this regard, it is time to review and discuss existing research on the integration of selected issues of sustainability and scheduling of forest- and wood-biomass-distribution logistics.

2. Review Methods

This article presents research on the development of modeling in the evaluation and optimization of business, ecological and social criteria in the scheduling of forest- and wood-biomass-distribution logistics for the production of energy, fuels, and other wood products (e.g., structural timber and lumber). First, we explain the technological, business, ecological, and social purpose involved in designing forest-biomass-distribution logistics. Next, we review the technological and business and ecological LCA (life-cycle) assessments of woody biomass, integrated business, social, and ecological assessments for multi-level optimization modeling. We discuss the characteristic features and limitations of each of these approaches, as well as suggestions for further research.

The literature review method was based on verification of the sources of Science Direct, MDPI, Springer Link, Science, Scopus, and Web of Science in such a way as to illuminate to the readers the main path of the ongoing research on optimization of the principles of utilizing forest and wood biomass for energy purposes.

Given the thematic scope of the biomass flow-modeling issues under consideration, the study is limited to forest and wood biomass. Data from Renewable Energy and the Joint Wood Energy Enquiry were used to make a detailed assessment of the use of forest and woody biomass used for energy production, supplemented by data from the
EU’s Joint Forestry and Timber Sector Statement. Analyses of reports presented by the European Statistical Office Eurostat were also used. The results presented in the article are derived from the literature on the optimization and development of forest biomass flow modeling and in-depth analysis of the balance of woody resources (WRB) based on the data mentioned above and global data sources.

3. Description of the State of Knowledge

3.1. Sustainability in Forest-Biomass-Distribution Logistics

The principles of sustainable development and the utilization of both woody and forest biomass resources require that the benefits of their current use do not jeopardize the security of future generations [22]. It is important to take technological, business, environmental, and social issues into account when designing forest-biomass-distribution logistics [23].

3.1.1. Technological and Business Considerations

The process of expanding the use of wood biomass to produce finished products and bioenergy may, in addition to costs, constitute an additional source of business revenue for the forestry and wood sector. Integrated processing can improve the profitability of forestry and timber companies [24–27]. To make this feasible, the technological and business issues of the distribution logistics need to be combined. These are essential elements that should be taken into account when scheduling new directions for the use of forest and wood biomass. The most important technological issues taken into account in the design of biomass processing are its type, efficiency, and scale of the processing technologies selected for implementation. The choice of forest- and wood-biomass processing technology is based on information regarding the form of the desired product and the type of accessible biomass. Modern processing technologies are increasingly better suited to the rational transformation of forest and wood biomass into finished products for individual or social utility or ultimately into an energy source [28,29]. The efficiency of wood material processing is determined by the amount created from a unit of wood biomass input accessible for a given technology. Higher efficiency means lower operating costs, but usually involves higher capital expenditure [26–29]. The size of the processing technology used affects the business parameters of production. Since preprocessing costs are high, it is important to achieve benefits by increasing the scale of production and deepening the level of processing [30,31].

The operational scale of processing is technologically limited by the defined amount of accessible wood biomass, and business is limited by the cost of biomass delivered to companies for energy purposes. This highlights the need to maintain a reliable and business-viable supply of forest and wood biomass. The parameters for forest biomass that influence the technological and ecological feasibility of its use are its quality characteristics, availability, and overall cost of acquisition. The features of assessing the quality of biomass include its size and structure, anatomical features, and the degree of mechanical and biological damage [9,10,32–34]. These parameters influence the choice of the type of pre-treatment (e.g., sorting, processing, etc.), the choice of processing technology, the efficiency and cost of transport, and the amount of biomass that can sustainably determine the scale of processing. The logistic variability of biomass supplies over time determines the need for its storage to ensure access to the raw material throughout the entire processing period. The costs of purchasing biomass include all costs related to obtaining, storing, pre-processing, and transporting biomass from the source (forest) to the plant. Another critical factor affecting the business of using forest and wood biomass to produce valuable products is the cost of product distribution. In the case of products that are made of wood and wood-based materials, distribution activities should be planned. In most countries, circular distribution is the most common business-distribution alternative for furniture, lumber and wooden structural elements, and fuels. The cost of transport is often influenced by the physical properties of some products (external dimensions, fragmentation, irregular shape),
which make it difficult to use transport infrastructure, mainly road transport [11,23,31] and, therefore, alternative forms of transport should be considered.

A combination of decision-making factors influences the technological and business success of using woody biomass in markets in business and social terms. Effective distribution logistics require decisions regarding raw materials (source of origin and generic diversity); storage, pre-treatment and transportation (method, volume and location of delivery); processing technology (type of technology, capacity and regionalization); products and markets (type of products and direction of distribution); and material flows (raw material and semi-finished products, wood products) within distribution logistics. All these decisions are defined on a product-by-product basis and must reflect the specifics of each distribution-logistic issue.

3.1.2. Ecological Issues

Some of the main ecological problems associated with forest biomass are carbon balance, greenhouse gas emissions during processing, and the forest ecosystem [35–38]. One of the main factors playing an important role in the systematic increase in the use of woody biomass as a wood raw material and alternative energy feedstock is its potential to reduce the consumption of non-renewable materials and its environmental neutrality. The use of fossil raw materials (e.g., steel, oil, or coal) causes CO$_2$ emissions to be released into the atmosphere, leading to the greenhouse effect and climate change [37]. Forest biomass is considered a renewable and low-carbon resource (carbon neutral). Carbon is sequestered as trees grow [25]. Research confirms that carbon neutrality has the potential to reach the required level through the process of long-term silviculture when new stands reach harvestable size [38]. However, a full assessment of carbon reductions from forest biomass use should take into account carbon emissions resulting mainly from the use of fuels for harvesting, handling, and transporting forest and woody biomass, and its production and distribution. These parameters quantify the potential impact of biomass processing on climate change, the human habitat, ecosystem improvement, and the security of non-renewable and renewable resources [39].

A critical ecological factor in scheduling the role of forest biomass is the maintenance of the forest ecosystem [40,41]. Silviculture secures the forest area’s access to nutrients and maintains its fertility, thus maintaining a level of forest productivity [42]. The ecological issues of silviculture affect the forest’s ability to retain water, determining the quality of soil and water. The forest area also provides shelter and food to various forest animals [43]. Therefore, uncontrolled forest biomass extraction may have negative effects, such as through reducing forest production, affecting flora and fauna that require wood, and increasing access to invasive species [44,45]. There are also potential positive effects of the intensive removal of wood biomass from forest areas, such as through limiting the spread of pests [44], reducing the risk of fires, and stabilizing biodiversity [26,44–46]. Therefore, it is important to develop rational strategies to mitigate the impact of removing woody substances from forest areas [47]. Proper design for developing wood and biomass processing plants should include CO$_2$ emission control, water security, waste management, and recycling processes to reduce emissions of pollutants into air, water, and soil. Using efficient technologies in the distribution logistics reduces the costs and amount of energy and fossil fuels needed to collect, process, and transport biomass.

The optimal location of processing plants has a positive effect. It is important to locate them close to significant sources of biomass (the share of wood products’ processing plants in areas with significant forestation) and customer markets, which reduces the ecological costs of transport [44]. Considering the impact of green distribution logistics choices is crucial to maximizing business and ecological benefits.

3.1.3. Social Issues

Introducing new projects regarding processing forest biomass and wood raw materials may have many positive social effects. These may include changes in sources of potential
jobs, affecting people’s livelihoods. The processes of pre-production of raw wood materials may influence changes in culture, communities, and political systems, as well as in the environment at the business level, and even change uncertainty based on the fears and aspirations of social groups [48].

However, many parameters cannot be consistently expressed in quantitative information. The social impacts most often considered in the optimization of forest- and wood-biomass-distribution logistics, which are defined quantitatively, are the direct generation of jobs and, thus, the creation of income. The number and quality of the jobs generated depends on strategic decisions in planning the best logistics for biomass redistribution. More significant investments in deep processing in the timber industry generate more jobs. It is necessary to analyze in-depth and demonstrate whether the number of jobs created as the result of processing a unit of biomass tends to increase as benefits are realized in the process scale-up model, through more efficient logistics and production systems [26].

In addition to creating more jobs, the development of wood and forest biomass-related enterprises generates income and job opportunities mainly for rural communities [49], improving the well-being of local people. Existing research on the impact of the development of distribution logistics on the social aspect should include how income affects the development of communities. Moreover, the biomass distribution logistics must consider the impact on other communities. These are elements related to the proximity of plants to urban areas, areas under protection, ecological areas, and regions [50,51].

3.2. Assessing Forest-Biomass-Distribution Logistics

Decision-making units need to select allowable alternatives and evaluate their potential business performance and environmental and social impacts in order to make sensible decisions about the design and planning of forest- and wood-biomass-distribution logistics for production in wood plants or for energy purposes. Appraisal studies help evaluate or predict project performance from different perspectives. Most researchers evaluating a distribution logistics problem consider a single evaluation factor using business or ecological assessment tools.

3.2.1. Business Evaluations

In the literature on the business evaluation of forest-biomass-distribution logistics, technological and business studies are used to evaluate the business of various projects and choices of technological solutions. Technological and business research aims to assess the cost feasibility of processes for using wood biomass to produce a specific type of energy product [38–40] or wood product [52–57]. Business evaluation involves comparing the use of different raw materials [58–61], pre-processing technologies [62,63], product manufacturing [29,64–66], plant locations [67–69], or alternative products [70–73] in supply chain configuration. The most frequent business indicators in this group of studies were the obtained manufacturing cost ratios and the internal rate of return of the adopted technology.

Technology and business assessments are needed to examine the technological viability and business capacity of the proposed projects and to provide business comparisons between forest- and wood-biomass-distribution logistics. These analyses justify making or abandoning capital investments and help make decisions regarding the selection of the optimal distribution logistics.

However, technology and business studies need to determine the optimal choice of forest-biomass-distribution-logistics projects to obtain valid modeling results. Technological and business assessments for forest and wood products are based on purchasing and logistics data (transportation costs of raw materials). They often overlook important elements of forest-biomass-distribution logistics, including the fragmentation of forest biomass sources, variability in feedstock acquisition characteristics, and changes in production modalities (energy prices, yields, etc.).
3.2.2. Ecological Assessments

Life cycle assessment (LCA) is a mainstream tool for evaluating the ecological effects of products. LCA is a method for systematically assessing the ecological burden and potential environmental impact of a product, process, or service by sourcing raw materials for disposal [74–76]. The rules and guidelines for LCA testing in Europe are reported in ISO/EN 14040 [77].

Based on the adopted European standards, LCA testing covers the stages [78] of its intended scope of application, limitations, and assumptions defining the functional unit that is the basis for comparison, summation of data related to material inputs, energy inputs, product-related waste, categorization of the product’s potential ecological impact availability of nature’s assets and impact on the healthiness of society, review and analysis of calculations, and the interpretation of results. In some studies, LCA quantifies the ecological importance of forest and woody biomass in a specific application [79–86] or compares alternative distribution logistics configurations or biomass utilization strategies [87]. Comparisons have been made between the ecological efficiency of using different forms of forest and woody biomass as sources of construction raw material or [88–95] combined heat and power (CHP) [52,96–98], and in solid fuel production [99], while other studies have compared different types and dimensions of technology for producing products or bioenergy [100–103].

Researchers [104–107] have evaluated various forms of forest and woody biomass and their processing alternatives, which have ecological impacts in the form of greenhouse gas issues, waste, human toxicity, and fossil-energy consumption.

Based on current knowledge, different LCA test results should not be used to compare the ecological declarations of tested products. LCA results depend on methodological choices, i.e., scoping, impact-assessment methods, allocation procedures, reference systems, and parameters related to local conditions [108,109]. Nevertheless, the LCA results obtained in modeling are effective in assessing and proposing ecological compromises at subsequent stages of the product life cycle using wood raw material or various forms of wood biomass. Transferring ecological LCA results into distribution logistics design should be avoided. LCA results can help compare ecological impacts for alternative woody biomass distribution logistics configurations, provided they are assessed using comparable modeling assumptions (Figure 1).

**Figure 1.** LCA product life cycle in closed loop using wood construction as an example—closed circuit; CO₂ + water + solar energy-forest-acquisition-transportation-treatment-construction-utilization-demolition-recycling-burning-energy + CO₂ + water.
In LCA studies, it is essential to take into account the sequestration of CO$_2$ by forests and wood during use. Standard LCA study do not take into account all elements of the impact of obtaining forest and woody biomass on the protection of soil, water, and biodiversity, which significantly affect the environment [109,110].

3.2.3. Social and Multivariate Assessments

The indicators currently used to evaluate the logistics of wood-biomass distribution are related to market sensitivity factors [23,111] and socio-business and ecological impacts. The rational use of wood resources and wood products can affect jobs, CO$_2$ emissions, and contributions to energy security. Researchers [112] have proposed an evaluation of sustainability impacts in forest distribution logistics using three indicators: production costs, employment, and emissions [113,114]. The indexes considered are production costs, asset/material consumption, total heat input at the use level, employment, wages and salaries, safety and public health, transportation of greenhouse gas emissions, energy consumption, soil quality, and carbon storage in felled biomass.

Methods for assessing social issues related to woody biomass distribution logistics have not yet been formulated. New methods must identify the effects of new designs on human health and the well-being of populations and ecosystems.

Business and ecological and social assessment tools help to analyze and compare forest-biomass-distribution logistics. They cannot, however, recommend an optimal design for forest-biomass-distribution logistics, given the complexity of the choices. This task can be accomplished through mathematical programming or optimization [115,116].

3.3. Optimization of Forest-Biomass-Distribution Logistics

Optimization of distribution logistics usually includes a goal function in the form of an equation, which is a mathematical solution of decision variables and other parameters.

In references, many optimization research studies have centered on decision support in the design, management, and monitoring of forest- and wood-biomass-distribution logistics. Most of them considered the business objective function. Optimization efforts for many of the targets included business outcomes, environmental impacts and indicators of forest-biomass-distribution-logistics optimization studies [117–121] (Figure 2).

3.3.1. Business Optimization

Business-optimization models have been created to improve strategic and tactical planning decisions in forest- and wood-biomass-distribution logistics. The strategic models are designed to take into account long-term planning decisions and enable decision making under high levels of uncertainty. Most problems are formulated to minimize the total cost of distribution logistics and, to a smaller scale, to maximize yield at various stages of distribution logistics [7,44,49].

The optimization model can be applied to various solutions of adopted distribution logistics when the basic assumptions are equivalent. The development of LCA algorithms under development and advances in computational software [75,76] make it possible to consider an increasing number of decision variables and provide optimal solutions for the defined business-optimization objective function [122–125].

In the references reviewed to date, most of the research has focused on strategic decision making to support investment allocation and policy in the forestry, timber, or energy sectors. The dominant trend is to adopt optimization methods for logistics, production, and distribution planning and for product-life-cycle scheduling [4,117,118,126–128].

The optimization models used integrate the various stages of the distribution logistics and take into account separated forest- and wood-biomass products. Only some distribution logistics optimization models assume no conflict of interest among distribution logistics participants. This can be the case for large businesses. However, in practice, each distribution logistics participant may have different priorities and make different assumptions that are optimal for their position in wood-biomass-distribution logistics. Each
seeks to optimize its performance. Optimization of forest biomass’ and wood products’ distribution logistics results from the negotiation processes between independent actors in the chain under study. This area still needs to be recognized in distribution logistics research [127–137].

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Figure 2. Schematic of the algorithm for multi-stakeholder optimization: business, ecological, and social.

3.3.2. Business, Ecological, and Social Optimization

Integrating business, social, and ecological objectives to optimize forest-biomass-distribution logistics is the subject of few investigations using a multi-stakeholder optimization approach [129–133,138–144].

3.3.3. Business, Ecological, and Social Optimization

Integrating business, social, and ecological objectives for optimizing forest- and wood-biomass-distribution logistics is the subject of few studies using a multi-objective optimization approach. In research, this optimization helps to make choices characterized by multiple parameters, often with incommensurable and conflicting objectives [145–147]. In multi-objective optimization, usually, only one optimal solution combines all objectives. A set of optimal solutions is developed for the correct model [148]. An optimal solution is one in which one objective cannot be improved without sacrificing another.

Incorporating LCA into multi-objective optimization to optimize a modeling system [148] has been used mainly in process systems’ engineering [149]. The proposed combination of these methods for decision support in forest- and wood-biomass-distribution logistics is a relatively new field of studies. To the best of the contributors’ expertise, there are few studies on these optimizations involving the use of forest and woody biomass [150–155] for multi-stakeholder optimization.
The application of multi-stakeholder methods in designing forest- and woody-biomass-distribution logistics for producing biofuels and wood products approximates real-world conditions by simultaneously considering many important elements in the decision-making procedure. Ensuring consistency in formulating different objectives is a significant challenge in optimizing the decision-making process. For example, when combining LCA and multi-stakeholder models in the planning of forest-biomass-distribution logistics for wood processing, it is important to decide whether to consider the ecological impacts associated with forest cultivation, wood production, product manufacturing and use, and waste disposal (ash, low-quality wood, and non-timber waste) to reduce or avoid CO₂ emissions and substitute non-renewable fuels. Parameters outside the scope of the business analysis of forest-biomass-distribution logistics can have a significant impact on the environment [156–158].

4. Discussion

It is imperative to address the interplay between business, ecological, and social considerations within distribution-logistics decisions to ensure the sustainable use of wood and forest biomass for producing wood products and bioenergy. This research has undertaken an assessment and optimization of the planning and handling of distribution logistics involving forest biomass, focusing on its use in wood products and energy, all within the principles of sustainable development. Most of the ongoing life-cycle-assessment studies that pertain to forest biomass and wood products within the distribution logistics predominantly emphasize business and ecological requisites. Technological and business assessments have proven valuable in offering insights into the feasibility of biomass utilization under varying market conditions. They have also played a pivotal role in appraising the business viability of various woody-biomass projects and comparing the business case for various distribution-logistics alternatives. However, it is important to note that they need to offer a comprehensive solution for devising an optimal distribution-logistics configuration [159,160].

Lumber flow studies can assess a broad spectrum of ecological burdens and impacts throughout a product’s life cycle. In many cases, LCA results do not definitively confirm the ecological superiority of one option for processing biomass or wood products over another form. Nevertheless, ongoing sensibility studies significantly raise ecological awareness and recognize trade-offs between alternatives. In order to conduct a comprehensive ecological assessment of the use of biomass and wood products, it is necessary to consider the effects on the overall health of forest ecosystems, as well as soil, water, and biological diversity, and the wood-processing environment. However, work is underway to develop indicators and methods for this purpose [150,153,160].

Research efforts to assess the effects of biomass-distribution logistics on sustainability in the forestry and timber industry often fail to analyze potential trade-offs among the various factors that interact with them. Optimization modeling research plays an essential role in defining the most appropriate configuration for applied forest-biomass-distribution logistics, especially when there are multiple options at various stages and levels of capacity planning. Such optimization requires the use of effective tools to assess available timber resources. While previous LCA studies have focused primarily on business decisions, tactical decisions must be based on practical solutions that are compatible with civilization requirements [107,108,161,162]. These practical solutions should consider business, ecological, and social factors to ensure the sustainability of new business proposals related to woody biomass.

Optimization studies that combine ecological business and social modeling of woody-biomass-distribution logistics integrate LCA assessment with optimization for stakeholders of producers and consumers of biomass products. They effectively combine various sustainability criteria to design woody-biomass-distribution logistics. This approach ensures credible sustainability trade-offs and consistently achieves expected societal goals. The main drivers of wood-biomass production are closely related to their potential to generate
business benefits and contribute to achieving energy and material independence. There is an ongoing need for further research to fully model the impact of selecting woody-biomass utilization systems. In addition, it is essential to develop decision-support methods that take into account ecological considerations, including their effects on the \( \text{CO}_2 \) balance of forest biomass, biodiversity, forest resistance, and social aspects, such as social and business security, in planning and scheduling the logistics of forest-biomass distribution. Sustainable-development strategies should meet social requirements and support biodiversity and social goals, economic growth, business models, job creation or technological development, and energy security. To achieve this, the implementation of new analytical tools to facilitate the management of forest and timber resources should be pursued. The direction is to expand efforts to fulfill the requirements of balancing an economic decision by creating ecological impact classifications within a socially acceptable range with strict balance control for the decision areas under study.

Today’s energy-security requirements and public awareness necessitate actions where forests will simultaneously perform multiple functions in a sustainable manner. Reliable and comprehensive recognition of the tasks fulfilled by forest and timber resources securing ecosystem characteristics makes it possible to determine the intensity and type of use or exclusion of timber resources that will threaten the sustainability of a given social system and ecosystem. Therefore, the work on the classification of impact factors and the development of a model for separating from the group of potential energy resources makes it possible to preserve the functionality of the provision of services by forest ecosystems and, at the same time, secure the energy-security needs of countries. The defined structure of the diversity of the weight of the factors and the aspect of the economic use of the forest and its timber resources will form the basis for planning and conducting qualification from the economic energy use with sustainable management.

The overarching goal of the work, therefore, is to identify and estimate the potential of different types of resources to provide key energy services, identify the benefits and social costs for reducing and separating at a modeled size selected types of wood resources with defined potential to provide multiple services including economic ones. Thus, it will be a systematic link between the energy services of forest resources and the economic by-product resource of wood processing.

5. Conclusions

Forest and wood biomass potentially reduce materials that generate ecological costs. The optimization of product-life-cycle decisions must be taken into account in scheduling the distribution logistics of forest biomass and wood products, and the integration of the assessment of sustainability factors must be implemented to ensure benefits to society.

The use of multi-stakeholder optimization to optimize the modeling system takes into account business, social, and ecological factors in the wood-biomass-distribution logistics and wood-products-production elements, including elements of evaluation and optimization of the decision-making process.

So far, most research has focused on achieving business impact. The business and ecological performance of various forest-biomass-distribution logistics is defined through techno-business assessments and consideration of LCA assessment. Business optimization is widely used to help design forest-biomass-distribution logistics. Policy-decision support wheels quantify and optimize business, ecological, and social aspects of forest-biomass-distribution logistics, which can include tools such as life cycle evaluation to quantify sustainability effects on forestry and timber.

Balancing the economic decision, ecological impact, and social acceptance in the context of forest renewable energy is a complex task that requires the consideration of many factors.

1. “Economic considerations”: Investment and operating costs must be considered, as well as potential financial benefits. Incorporating forest renewable energy into the economy can benefit job creation and increase the sustainability of local communities.
2. “Environmental impact”: Renewable energy sources, such as forest-based energy, can help reduce greenhouse gas emissions. However, the impact on local ecosystems needs to be carefully analyzed, especially in the context of tree cutting, its rate, and the potential for forest regeneration.

3. “Social acceptance”: This aspect requires engaging and educating local communities and understanding their concerns and needs. It is important that communities understand the benefits of forest renewable energy and are involved in the decision-making process.

4. “Policy and regulatory integration”: Effective policy and regulation can help balance different interests and encourage investment in sustainable energy sources.

5. “Innovation and technology”: Developing renewable energy technologies can help increase efficiency and reduce the environmental impact.

6. “Long-term planning”: A long-term approach that takes into account climate change, the needs of future generations, and potential changes in the economic environment is important for achieving a sustainable balance.

In practice, reaching a compromise requires dialogue among various stakeholders, including governments, businesses, scientists, environmental organizations, and local communities. It is important that the decision-making process is transparent, based on solid scientific data, and takes diverse perspectives into account.

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