Modeling approaches for reducing the carbon footprint of forest industry enterprises

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Abstract. This paper presents the results of a study of individual aspects of reducing the carbon footprint from the activities of forest industry enterprises. This issue is one of the most relevant in modern science and practice. The existing conflict between production and the environment requires adequate solutions and due attention from all stakeholders. The goal of the work was realized through identifying the most significant areas of carbon footprint formation and assessing opportunities to reduce such impact. The main method of work is analytical. As a result of the study, a model of the environment of an industrial enterprise was formed, including factors and variables of the external and internal environment. The rationale for the relevance of reducing the carbon footprint of industrial enterprises is given. A schematic diagram of the stages of formation of a carbon footprint from the activities of a timber processing enterprise has also been developed. The result of the study is the identification of the most significant areas of carbon footprint formation from the activities of forest industry enterprises, as well as the identification of opportunities to reduce such impact.

1 Introduction

Modern industrial development is based on the influence of many external and internal factors. Their action is of a different nature and concerns various aspects of the activities of industrial structures [1-3]. Analysis of these processes allowed us to form a general idea of the micro- and macro-environment of enterprises (Fig. 1).

The presented environment of an industrial enterprise covers only a small part of the entire huge set of environmental factors that affect enterprises. At the same time, the internal environment is represented by three key elements, in the author's opinion: structure, resources and culture. It is these aspects that are decisive for many internal processes of enterprises [4-6]. One of the most important trends affecting the entire global economy and industry is increased attention to issues of sustainable development. Developed countries pay very close attention to this factor. For enterprises, for example in Europe, various reporting forms have been developed, thanks to which business activities in this direction are monitored. Considering that sustainable development is an activity that takes into account the interests of future generations [7], many technical and economic

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processes are subject to control. At the same time, enterprises themselves and society as a whole are focused on achieving results in this direction.

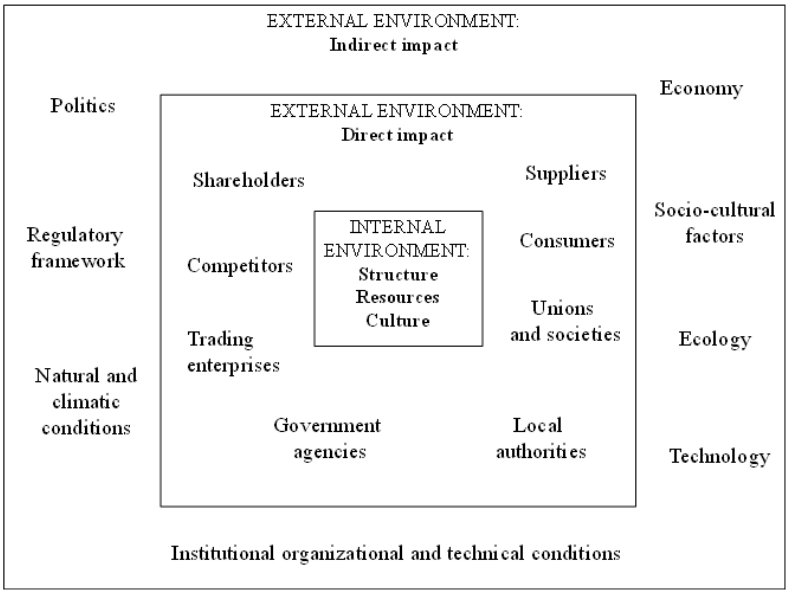

Fig. 1. Industrial enterprise: factors and variables of the external and internal environment.

The forest industry plays a critical role in sustainable development [8-11]. This is due to the fact that the main raw material for it is wood. In the process of obtaining it, forests are cut down, which is one of the factors of decarbonization. Also, logging and reforestation activities cannot be considered in isolation from the processing of wood raw materials.

In general, reducing the carbon footprint of enterprises is also one of the global trends. This paper examines certain features of the functioning of forestry enterprises in the context of reducing their carbon footprint.

2 Materials and Methods

The purpose of this work is to study individual aspects of reducing the carbon footprint from the activities of forest industry enterprises, as well as to develop an optimal model for this interaction. This goal was achieved through identifying the most significant areas of carbon footprint formation and assessing opportunities to reduce such impact.

The work uses the results of previous studies by the team of authors, as well as individual studies by domestic and foreign authors. Profile of the analyzed works: activities of forest industry enterprises, carbon footprint, decarbonization, regulation of the activities of industrial structures in terms of sustainable development. The study used primarily the analytical method.

3 Results and discussion

The author's research made it possible to identify several key aspects regarding the assessment of the carbon footprint from the activities of enterprises, including forestry industries. First of all, it is necessary to consider the production process much more broadly [12-15]. Among existing approaches, the most holistic assessment may be to estimate the

carbon footprint of forest products. This approach involves quantifying the balance of greenhouse gas emissions and removals throughout the entire product life cycle. In the conditions of the forestry industry, this period can be characterized by the time from the moment of timber harvesting to the moment of disposal and complete decomposition of products made from it. At the same time, enterprises will impact the environment throughout their entire life cycle.

If we consider forest industry enterprises, then, regardless of the type of products produced and individual technological solutions, the general scheme for the formation of greenhouse gases will be as follows (Fig. 2).

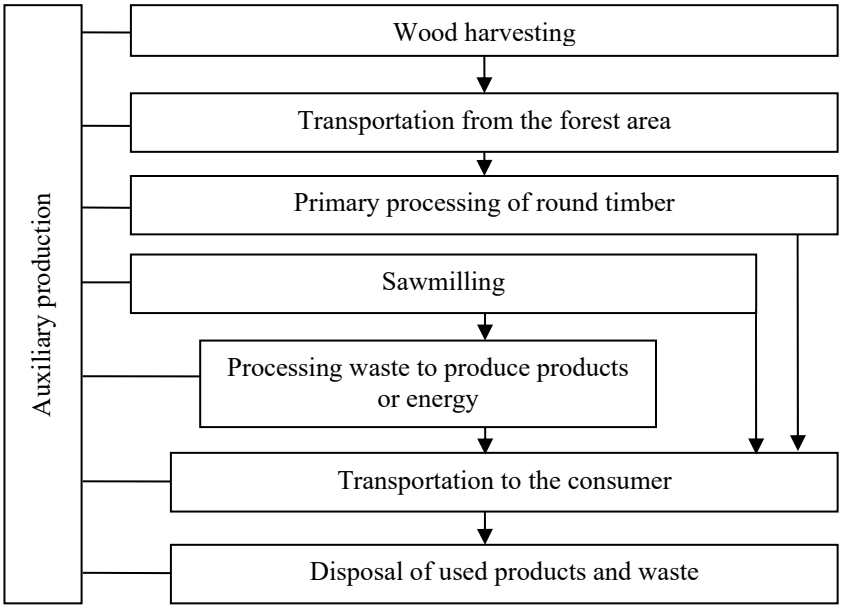

Fig. 2. Schematic diagram of the stages of carbon footprint formation from the activities of a forestry enterprise.

Each of those shown in Fig. Stage 2 is characterized by the formation of an impact on the environment and CO_2 in particular. Products here undergo a long chain of transformations from growing wood to decomposing woody biomass. It is important to note that the stages of the production process are largely supported by supporting industries and activities. For example, debarking, drying, storing, packaging, etc. This set of operations also leads to an impact on nature and, therefore, requires analysis, control and measures to minimize such impact.

Analysis of the direct impacts of the activities of forest industry enterprises on the environment allowed us to identify several of the most significant areas of carbon footprint formation:

1. Combustion of hydrocarbon fuels. This factor should be considered in the context of the functioning of a huge number of types of equipment that use hydrocarbon fuels for their work. At the same time, this resource is spent to the greatest extent on the transportation of raw materials, semi-finished products and finished products, but is not limited to this process. Considering that the distance of wood removal from forest areas increases every year (200-300 km), and production volumes are only increasing, the volume of fuel burned will only increase. At the same time, the transition to electric motors, which is possible for passenger vehicles, cannot be a solution to this problem for a number of quite objective

reasons. One of the possible solutions to minimize the impact on the environment is the use of optimization in the movement of wood raw materials. This requires the use of economic and mathematical methods, logistics, as well as modern technical solutions that make it possible to reduce specific carbon emissions while increasing productivity.

2. Electricity consumption. Almost all woody biomass processing, from sawmilling to pulp and paper, is energy-intensive. Moreover, in most cases, the higher the depth of processing, the higher the energy consumption. Considering that electricity generation is associated with significant CO_2 emissions, it is logical that this area is a significant source of the carbon footprint from enterprise activities. The obvious solutions are to use "clean energy" whenever possible. In some regions this is quite possible. In particular, a number of forestry enterprises are powered by energy generated by hydroelectric power plants. However, this factor practically does not depend on the forestry enterprises themselves and is determined by the location of processing facilities. In such conditions, one of the solutions is the generation of electricity based on the combustion of secondary wood resources (including those converted into fuel briquettes and pellets). Although this direction is a significant source of CO_2 formation, it can still act as an environmental alternative to burning coal in thermal power plants.

3. Use of various chemical reagents and substances. These substances are mainly used in deep processing enterprises - board, pulp and paper, and wood chemical industries. They are used to break down the bonds between wood fibers and impart different properties to the industry's wide range of products. Getting into the environment either as a waste from the main production, or as a release during the use or operation of a product, a chemical substance causes significant harm to the environment. However, individual industries cannot function without them by definition. In such conditions, important solutions should be high-quality wastewater treatment facilities that capture the overwhelming amount of environmental impact. At the same time, whenever possible, production should look for more environmentally friendly substances and reagents, as well as technical solutions.

Another factor influencing the carbon footprint of forest products is deforestation. The carbon absorption function they provide makes them an important factor in the decarbonization of the economy. Deforestation reduces carbon absorption.

It should be noted that, despite existing opportunities to reduce the carbon footprint, the impact on the environment of enterprises will continue. This conclusion comes from the production characteristics of the activities of enterprises in the industry. However, CO2 emissions, as well as deforestation, can be largely offset by reforestation. Based on the results of the study, it was established that in Russia the areas of restored forests are increasing annually. According to various estimates, in the case of active reforestation, it is possible to achieve carbon neutrality of the entire forest industry.

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Ultimately, reducing the carbon footprint of forest products is a major trend today. Its importance and relevance will increasingly increase in the near future. However, decarbonization of the economy largely depends on the attitude, attention and activity of society to this issue [16].

4 Conclusion

As a result of the study, factors and variables of the external and internal environment of an industrial enterprise were identified. It is shown that the role of society is one of the most significant in the formation of certain aspects of enterprise activity. An important trend in the modern world is reducing the carbon footprint of enterprises. The forestry industry and forestry enterprises play an important role in this issue. At the same time, as shown, it is important to consider the carbon footprint not only in relation to an industrial enterprise, but also directly to the product. The work shows a schematic diagram of the stages of formation of a carbon footprint from the activities of a timber processing enterprise. It is important to note that this impact occurs at almost every stage of the movement and interaction of the enterprise's production structures with wood raw materials.

An important result of the work is the identification of the most significant areas of carbon footprint formation from the activities of forest industry enterprises. Among them are the combustion of hydrocarbon fuels, electricity consumption, and the use of various chemical reagents and substances. Another important aspect in this direction is deforestation, which reduces the possibility of CO_2 capture by natural ecosystems. In general, the attitude and active position of society on the importance of sustainable development and decarbonization of the economy can influence the state and business in terms of adopting and expanding real measures and programs. Thus, it is up to each person to solve a complex of pressing problems. At the same time, the forestry industry can and should play an important role in achieving carbon neutrality through active reforestation.

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