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AND SUPPLY CHAIN MANAGEMENT**

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## CONCEPTUAL PRINCIPLES FOR FORMATION OF THE SUPPLY CHAINS' DECARBONIZATION STRATEGIES

**Mariia Hryhorak, Oleh Harmash, Nataliia Trushkina.** *"Conceptual principles for formation of the supply chains' decarbonization strategies". The article examines the conceptual foundations of the formation of a strategy for the decarbonization of supply chains, the identification of strategic solutions for reducing greenhouse gas emissions, and the management of green chains from the point of view of ecological and economic efficiency.*

*A structural and logical diagram of the formation of the strategy of decarbonization of supply chains has been built. Seven key business processes in supply chains/networks have been identified that significantly affect the volume of greenhouse gas emissions: ecological design, environmental procurement, energy- and resource-saving production, green transportation, ecological storage, smart eco-consumption, recycling and disposal.*

*It was established that in closed-loop chains, managerial environmental solutions should be aimed at: preservation or restoration of products to extend their life cycle, which includes diagnostics and repair; reuse of products for the same or new purposes in their original form or with some changes; restorative repair of products or individual components; processing of waste and end-of-life products, or recycling (any recovery operations, with the help of which waste and old products are processed into materials, resources, substances for the production of other products or for other purposes).*

**Keywords:** national economy, environmental protection, greenhouse gas emissions, climate neutrality decarbonization, carbon footprint, supply chain, green supply chains, green supply chain

management, reverse logistics, ecological principles, circular business models, sustainable development, green investments, green technologies, strategy, strategic management, system approach, conceptual principles, synergistic effect.

**Марія Григорак, Олег Гармаш, Наталія Трушкіна. «Концептуальні принципи формування стратегій декарбонізації ланцюгів поставок».** У статті розглядаються концептуальні основи формування стратегії декарбонізації ланцюгів поставок, визначення стратегічних рішень щодо скорочення викидів парникових газів, управління зеленими ланцюгами з точки зору еколого-економічної ефективності.

Побудовано структурно-логічну схему формування стратегії декарбонізації ланцюгів поставок. Визначено сім ключових бізнес-процесів у ланцюгах/мережах постачання, які суттєво впливають на обсяги викидів парникових газів: екологічне проектування, екологічні закупівлі, енергетика ресурсозберігаюче виробництво, екологічне транспортування, екологічне зберігання, розумне еко-споживання, переробка та утилізація.

Встановлено, що в замкнених ланцюгах управлінські екологічні рішення повинні бути спрямовані на: збереження або відновлення продукції для продовження її життєвого циклу, що включає діагностику та ремонт; повторне використання продукції для тих самих або нових цілей у первісному вигляді або з деякими змінами; відновлювальний ремонт виробів або окремих вузлів; переробка відходів і відпрацьованих продуктів, або рециклінг (будь-які операції відновлення, за допомогою яких відходи і старі продукти переробляються в матеріали, ресурси, речовини для виробництва іншої продукції або для інших цілей).

**Ключові слова:** національна економіка, охорона навколишнього середовища, викиди парникових газів, кліматична нейтральність, декарбонізація, вуглецевий слід, ланцюг поставок, зелені ланцюги поставок, зелене управління ланцюгами поставок, зворотна логістика, екологічні принципи, циркулярні бізнес-моделі, сталий розвиток, зелені інвестиції, зелені технології, стратегія, стратегічний менеджмент, системний підхід, концептуальні принципи, синергетичний ефект.

**Introduction.** The post-war recovery of the Ukrainian economy should and will take place with the support of international financial institutions and funds, as well as taking into account the goals and principles of sustainable economic development declared by the UN, the Organization for Economic Cooperation and Development and other institutions.

The central idea of the transformation of the national economy should be climate modernization, which can contribute to the attraction of significant public and private financial resources and the practical implementation of the "green transition" processes to reduce greenhouse gas emissions and the carbon footprint, as well as the dependence of business entities on fossil fuels and the transition to alternative sources of energy.

The problem of reducing greenhouse gas (GHG) emissions, which are the key factors of global warming, is the main concern for government bodies and the industrial sector after the signing of the Kyoto Protocol as an additional document to the United Nations Framework Convention on Climate Change, signed in 1992 at the International Conference in Rio de Janeiro – Janeiro The Kyoto Protocol was adopted on December 11, 1997, and its effect began on February 16, 2005. This protocol provides for the implementation of flexible mechanisms for reducing greenhouse gas emissions by purchasing relevant certificates abroad: the Clean Development Mechanism (CDM); International Emission Trading (IET); Joint Implementation (JI).

According to the Global Carbon Budget, the increase in emissions in 2022 has accelerated the ongoing increase in the

concentration of greenhouse gases in the atmosphere, which will continue as long as carbon dioxide emissions continue [1]. Today, most companies focus on reducing direct emissions related to operational activities or their use of electricity, heat and steam. Indirect emissions are associated with the movement of goods between links in supply chains from the extraction of raw materials to the end consumer and are generally difficult to measure and influence to reduce. In most sectors of the economy, these emissions account for more than 80% of greenhouse gas emissions and more than 90% of the impact on air, land, water, and biodiversity [2].

Measuring emissions in supply chains is an important step in reducing pollution and helping to protect the environment. Emissions produced during the production of goods and services directly affect the environment and the health of people living in that area. Therefore, measuring emissions in supply chains can help identify sources of emissions and take appropriate measures to reduce them. Measuring emissions in supply chains also helps ensure that businesses comply with environmental regulations, take responsibility for their environmental impact, and take steps to reduce their emissions at strategic and tactical levels.

Thus, the development of a strategy for the decarbonization of supply chains is relevant for any type of economic activity and requires scientifically based solutions for measuring and managing these emissions. Emissions in supply chains are an important component of strategic risk management and a valuable tool for proactively resolving conflict situations in value chains of goods or services.

The implementation of low-carbon business models can catalyse the development of innovative approaches to the optimization of logistics networks, the location of production sites, distribution centres, eco-design of goods and their storage, as well as the attraction of investments in environmental projects.

Modern information and communication technologies make it possible to identify areas where business goals and environmental goals overlap, to effectively use existing digital infrastructure to track production and transportation activities in near real time, to interact with suppliers and evaluate their progress in achieving emission reduction goals. However, online exchange platforms do not address the challenges of optimizing supply chains/networks in terms of matching chain performance and emission intensity, as well as carbon footprint measurement.

**Literature and researches review.** Environmental aspects of supply chain management are the object of research by many scientists from different countries. In scientific works [3-7], the evolution of the formation of the concept of "green supply chain management" (GSCM), which appeared in the early 1990s as a response to growing environmental problems, was investigated. It has been proven that ecological chains strive to create a positive impact on the environment by promoting the safe and responsible reuse, recycling and disposal of materials.

The authors A. Diabat & D. Simchi-Levi [8], S. Elhedhli & R. Merrick [9] argue that sustainable or "green" supply chains seek to create a positive impact on the environment by promoting the safe and responsible reuse, recycling and disposal of materials.

An analysis of recent publications in this area shows an expanded treatment of GSCM including green design, green operations, green manufacturing, reverse logistics and waste management [7; 10; 11]. F. Bowen et al. [12] define GSCM as "the integration of a company's environmental procurement plan into SCM to improve supplier and customer environmental performance".

The scope of the GSCM concept in the literature varies from the selection and supply of materials, manufacturing processes, product design, delivery of the final product to end users, and management of product output after its useful life [6; 13]. Green

manufacturing minimizes waste and pollution during production activities. However, as noted by scientists [14-16], the relationship between environmental and economic indicators is often contradictory. In many cases, businesses often want to maximize profits and minimize carbon emissions.

However, maximizing profits by expanding supply chain activities often leads to increased carbon emissions. It is often difficult for businesses to understand the direct link between the implementation of green supply chain management and subsequent performance improvements in operational, economic or environmental areas. To date, a number of literature reviews emphasize the need to take into account greenhouse gas emissions in the design and planning of green supply chains [17].

A. Corominas [18] suggests that the expression "Supply Chain" could be replaced by a more appropriate expression, such as "Supply Network". This new supply network philosophy, also called Green Supply Network (GSN), is a new trend that forces companies to produce and grow while respecting the environment and developing a more sustainable supply network.

The Green Supply Network concept, which includes an environmental factor in the design of the supply network, has also attracted the attention of researchers in recent years [19-31]. N. Matinrada et al. [32] argue that when different companies work together to maintain customer satisfaction, the result is a "supply chain network" (SCN). One of the main objectives of both GSCM and GSN is to assess the environmental impact of different production and/or distribution approaches to reduce GHG emissions from logistics activities [33].

As the analysis shows, there have been many publications related to studies of greenhouse gas emission volumes in supply chains/networks, justification of strategic, tactical and operational decisions concerning various participants and stakeholders. F. Montabon et al. [34] consider a key aspect of

carbon reduction strategies to be their effectiveness in providing the desired long-term impact.

M. Damert et al. [35] define a corporate carbon strategy as "a complex set of actions to reduce the impact of a firm's business activities on climate change and gain competitive advantages over time" and recommend basing a corporate carbon strategy on three goals: 1) carbon management; 2) carbon reduction; 3) carbon competitiveness.

S. Yunus et al. [36] suggest developing a "carbon management strategy" and include carbon measurement, emissions reduction reporting, trading, risks, carbon reduction opportunities, and carbon market analysis. However, when a company seeks to develop a "carbon management strategy", the main bottlenecks are short-term thinking, especially when it is focused on profit maximization [37]. This approach is usually at odds with a long-term strategy that includes carbon reduction. A. Jerbi et al. [38] consider one of the main concepts for increasing the sustainability of supply chains to be cooperation between stakeholders by improving the efficiency of their shared resources. All these scientific works prove the need to develop decarbonization strategies [39-42] using green technologies and the green investment mechanism [43-47].

In the scientific literature, two methodological approaches to the measurement of emissions in supply chains are distinguished. The first approach is based on the life cycle of a product or service (product lifecycle), where the goal is to determine the carbon/ecological footprint of a specific product or service. It is the assessment (analysis) of the life cycle (life cycle assessment, LCA) that is a tool for the implementation of the philosophy of systems thinking, which takes into account all stages of the "life" of a product (service, organization) from the birth of an idea (design) to the decision to dispose of waste and reuse it – Life cycle thinking (LCT).



The LCA methodology is described in the series of documents ISO 140405 and ISO 140446, which contain principles, areas of use and procedures (International Organization for Standardization, 2006). Other ISO standards of the 14040 series complement the general guidelines such as ISO 140467 for water footprint, and more environmental management standards are linked to ISO 14040-44 like ISO 140068 (eco-design), ISO 140259 (environmental labelling), ISO 1406410 (carbon footprint of organizations), ISO 1406711 (carbon footprint of products), ISO 1407212 (organizational LCA).

The LCA method is also used to evaluate possible investment alternatives related to environmental impact in cases related to the selection of raw materials, suppliers, and production processes [48]. Many publications use LCA to assess and quantify the environmental impact of a supply chain [49; 50 et al.], which consider the minimization of the environmental impact of supply chain design based on the LCA approach and traditional economic costs.

In 2013, the European Commission introduced the Environmental Product Footprint (EPF) in 2013 as part of the Green Single Market initiative. According to this document, the ecological footprint of a product is a multi-criteria indicator of the environmental characteristics of a product or service, which allows reducing the impact of products on the environment, taking into account their supply chain (from the extraction of raw materials, production and use to final waste management). The ECA method provides common rules for product groups so that companies can compare their product progress within a product category or sector. In turn, enterprises better evaluate their environmental indicators, comparing them with the indicators of competitors (national and European). Benchmarking is also a powerful incentive to improve the reputation and create sustainable and environmentally friendly goods and services that are in demand in the everyday lives of consumers.

On the other hand, the organizational approach emphasizes measuring the impact of GHG emissions at the organizational level. Companies building and optimizing their own supply chains seek not only to increase economic efficiency, but also to effectively use limited resources based on the principles of sustainable development and social responsibility. In order to ensure a truly efficient and environmentally sustainable production of products or services, companies need to carefully analyse and plan their activities at the conceptual stage. Supply chains are the basis of sustainable development not only in the forward movement of flow processes, but also in the reverse, which is a reflection of the concept of circular economy [51-52].

From the point of view of accounting for carbon emissions in the supply chain of the focal company, it is important to consider the path from suppliers of raw materials through a certain number of intermediate productions to the producer of the final product (input material flows), from it through a set of distribution and trading intermediaries to consumers of final products (output goods flows), as well as in the reverse direction from the final consumer to the manufacturer or waste recycling and disposal centres (reversed or reversible flows) [53-58].

Traditionally, organizations manage suppliers to optimize the supply chain, monitor the flow of information, materials, and funds, manage logistics processes, minimize cycle times and costs, and integrate processes and functions along the supply chain. Manufacturers are increasingly demanding information from suppliers about the materials used in production and the systems they use to track and manage their environmental impact. As suppliers receive these requests, they also send them along the entire supply chain. Therefore, an understanding of environmental impacts through the supply chain can extend to other parts of the organization, contributing to a more integrated and versatile approach to product life cycle management. Such a

comprehensive approach can also be used to compare improvements in production system chains, as well as to share useful information about the quality properties of products.

Therefore, when planning supply chains/networks, the environmental friendliness of all its links and their interactions becomes more and more important. A socially responsible supply chain focal company should develop a proactive strategy to reduce greenhouse gas emissions and incorporate it into all business operations based on life cycle thinking and collaboration with value chain partners.

At the same time, it is important to clearly formulate bold ambitions and strategic goals, to develop specific measures to achieve them and a management and monitoring system. This leads to the emergence of a coordinated set of modifications or new solutions to products, services, processes, approaches and structures that contribute to increasing the efficiency and competitiveness of both the focal company and all participants.

**Aim and objectives.** *The purpose of this article* is to study the conceptual foundations of the formation of a strategy for the decarbonization of supply chains, the identification of strategic solutions for reducing greenhouse gas emissions and the management of green chains from the point of view of ecological and economic efficiency.

The methodological basis of the research is the provisions of theories of sustainable development, concepts of green and circular economy, environmental management, supply chain management, environmental economics.

The study of modern processes of forming the strategy of decarbonization of supply chains is based on the use of methods: economic-statistical analysis, balance sheet, modelling, analogies and synthesis, system approach, comparisons and observations, classification, structural-logical generalization, etc..

**Results, analysis and discussion.** Organizations that seek to reduce greenhouse gas emissions or reach their "zero

level" need to clearly present the goals, conceptual foundations and the entire process of forming a strategy for the decarbonization of supply chains (Fig. 1).

Let's consider in more detail the main stages of strategic planning for reducing greenhouse gas emissions in supply chains.

1) Building a business model of the supply chain/network in accordance with the principles of sustainable development and creating conditions for safe and reliable production activities allows organizations to be efficient today without compromising future development. Companies aiming to reduce emissions in their supply chains/networks in the long term must create new innovative business models to identify priorities, opportunities and risks to reduce their harmful impact on the environment. An innovative supply chain/network business model should answer the following key questions:

A) who are the target customers and what target segments will be covered by the supply chain/network business model? Do customers have a demand for sustainability and emissions reduction? Focus companies must respond to consumer demand for products with a lower carbon content, or try to change existing consumer demand for low-carbon alternatives and thereby stimulate consumer interest in reducing the amount of harmful emissions into the environment;

B) what does the focal company offer to customers, a definition of the company's offer and a description of how the company meets the needs of target customers? Are environmental requirements taken into account when creating new company products? The main idea when creating a product should be to reduce greenhouse gas emissions during the life cycle, which is achieved by increasing the duration of use of the product, efficient use of raw materials and materials for the production of the product, and possibilities of secondary use after the end of the life cycle. Product characteristics such as weight, size, type of packaging have a significant impact on the volume of emissions

during logistics operations. Separate attention should be drawn to the formation of the "product-service" system, when goods are provided for use through rent, leasing, rental,

which increases incentives for creating durable products, extending their life cycle and better use;

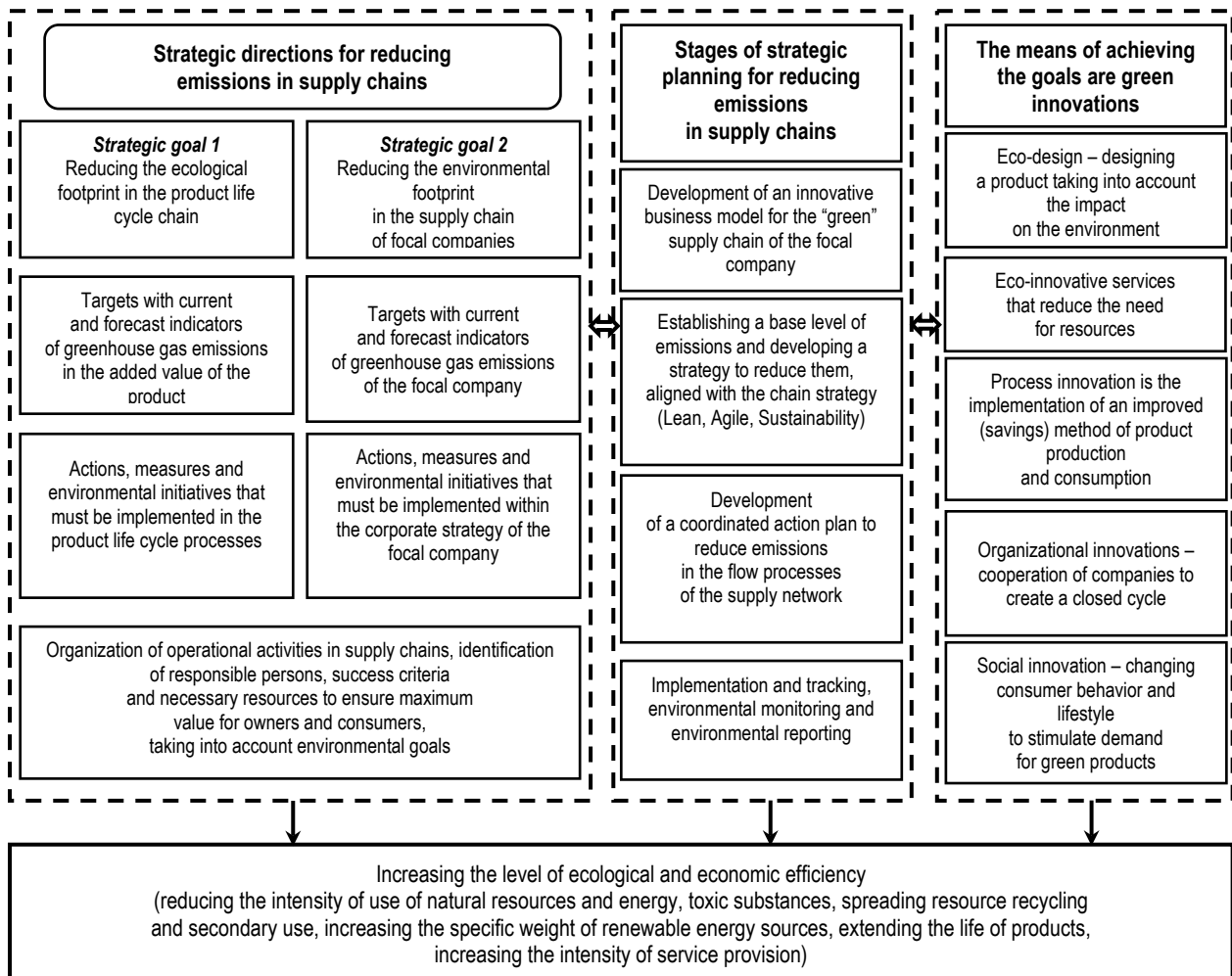


Figure 1. Structural and logical scheme of the formation of the strategy of decarbonization of supply chains  
 Source: author's development.

C) how is the value chain created, what processes and actions are combined with the appropriate resources and means? Are there opportunities to use more ecological types of raw materials, energy, materials? An innovative business model requires an understanding of the environmental consequences of the production and use of a product, and concentration on the most significant of them. The expansion of responsibility beyond production and the integrated product policy of the production

system means that manufacturers must be responsible for the manufactured products from its "cradle to the grave" and therefore must develop products with improved characteristics at all stages of the life cycle;

D) why is the company profitable, what are the structure and mechanisms of profit generation? How does the environmental factor (taxes, fines, fees) affect the economic efficiency of the business? What are the possibilities for reducing economic losses, reducing ecological and economic losses and

increasing incomes due to the secondary use of resources? In the conditions of a closed cycle economy, along with increasing resource productivity, companies must identify the reasons for inefficient use of available resources, compare the results of their activities with the volumes of emissions, waste and losses of heat, energy, and water; to provide recommendations on improving the management of material flows, replacing outdated technologies with more energy- and eco-efficient ones, redesigning products, etc.;

E) what are the economic relations with business partners and subcontractors? The focal company of the supply chain can be a) a full-cycle company, covering all or most of the work on the creation, organization of production, promotion and sale of products; b) a company that is engaged in product development, experimental production, possibly branding, and outsources other functions; c) a company that organizes production on the basis of other people's developments and possibly under other people's trademarks (contract production).

In the first case, the focal company can centrally manage its own supply chain. In other cases, managing supply chains is much more complex and requires building horizontal connections and partnerships with participants. But the opportunities to reduce the total volume of emissions are much greater, as synergy and cooperation allow improving the overall result from the point of view of reducing the harmful impact on the environment.

Therefore, an innovative supply chain/network business model must take into account market fluctuations and dynamics, geographic boundaries, economic interests of consumers and business partners, etc.

2. After the formation of the business model of the green supply chain, it is important to consider the environmental factor in the construction of the strategy in order to reduce the economic losses and reduce the ecological and economic damage caused by the participants of the supply chain

to the environment. First of all, the focal company needs to make sure that decarbonization is in line with its overall business strategy.

To respond to changes in the supply chain landscape, companies can use different supply chain design strategies, the most common being Lean Supply Chain and Agile Supply Chain. The goal of Lean Supply Chain is to increase customer value by reducing the cost of goods and reducing waste (waste is anything that is not of value to the customer). Transportation, inventory, handling, waiting, over-processing and over-production are parameters of waste because all these operations do not add value. As a consequence of reducing waste, lean manufacturing can help reduce pollution as it shortens cycle times and increases resource efficiency. This type of supply chain focuses on reliability and predictability, allowing emissions to be more accurately calculated, tied to costs, and mitigation measures specified.

Agile Supply Chain is a complex set of processes that enables businesses to respond quickly to changes in demand, customer and industry preferences, direct resources more efficiently, improve inventory management and increase productivity. Flexible supply chain processes allow companies to respond quickly without interruptions or delays. They can move to agile processes to adapt to new trends and adjust their supply chains to suit their needs. Flexibility makes it easier for supply chain actors to make changes and better prepare for future market demand. This can allow companies to quickly respond to changes in customer demand in the production process, better control the production of goods and materials according to customer demand, and prioritize resources for large orders. Ideally, this avoids the waste that potential overproduction or underproduction can create. On the other hand, the flexibility/speed of supply chains can be accompanied by an increase in costs and emissions, as it requires a quick response to demand, urgent deliveries of goods in

smaller batches. However, a manufacturing company's ability to track inventory and the status of materials and goods in real time helps identify bottlenecks and reduce costs by solving problems before they become serious.

Currently, in addition to traditional strategies focused on cost or customer service, there are hybrid models that change the priorities of the supply chain and can focus on resilience, agility, sustainability, etc., but all of them recognize the key role that supply chains will play in the transition to clean and socially just economy. The ability to quickly adapt to the ever-increasing pace of change is critical to the success of any business. That is why, the determination of strategic priorities in the development of supply chains/networks will play a decisive role in the selection of management tools and innovative solutions on the way to the low-carbon economy of the future.

The readiness of organizations to resort to effective strategies will depend on the nature of the business and how far the company has already progressed in implementing efforts to achieve "zero" emissions. The actions required to complete this phase can be grouped around three main strategic objectives: 1) defining a carbon baseline; 2) carbon reduction; 3) stimulation of carbon efficiency. The carbon baseline is the starting point of the strategy, which includes setting the type of emissions, data baseline and limits. The second goal is covered by two actions, the first of which is to identify opportunities to reduce carbon dioxide, to determine what needs to be done. The second action is the setting of carbon targets, which defines the strategy over time and represents the scale of the challenge. The results of both activities should be considered as part of the strategic business plan, and both have a significant impact on the realization of the strategic priorities of the supply chain/network.

The third objective is to take advantage of the carbon strategy that has already been created in the past, analyse its impact on the

company's financial indicators (gross sales volume, cost of goods sold, expenses and gross profit, etc.) and determine the prospects for innovation in the future. The typology of eco-innovations (green innovations) involves the introduction of any new or significantly improved products (goods or services), processes, organizational changes or marketing solutions that reduce the use of natural resources (including materials, energy, water and land), lead to a coordinated set of modifications or new solutions to products, services, processes, approaches and structures, contribute to increasing the productivity of supply chains and the competitiveness of the focal company and its partners.

An extremely important stage of planning and implementation of a strategy for reducing emissions in supply chains/networks is tracking, control and monitoring, which should be aimed at compliance with pre-selected indicators (parameters) of the volume and intensity of emissions into the environment by each participant in the supply chain/network, and in as a whole organizational entity. The use of monitoring results occurs primarily in the field of justifying a wide range of management decisions related to the regulation of emissions or their deviations from the planned ones, which allows assessing compliance with the set goals and defined priorities.

It is worth noting that one of the most important steps in a carbon strategy for a supply chain/network is recognized as identifying potential improvements that will help achieve carbon reduction targets. In Fig. 2 summarizes "green" initiatives to reduce carbon emissions. Seven key business processes in supply chains/networks have been identified that significantly affect the volume of greenhouse gas emissions. In accordance with each business process, a set of possible management solutions is proposed, which will help to increase the level of environmental efficiency, preserve natural resources, and save energy.

Let's consider these business processes in more detail.

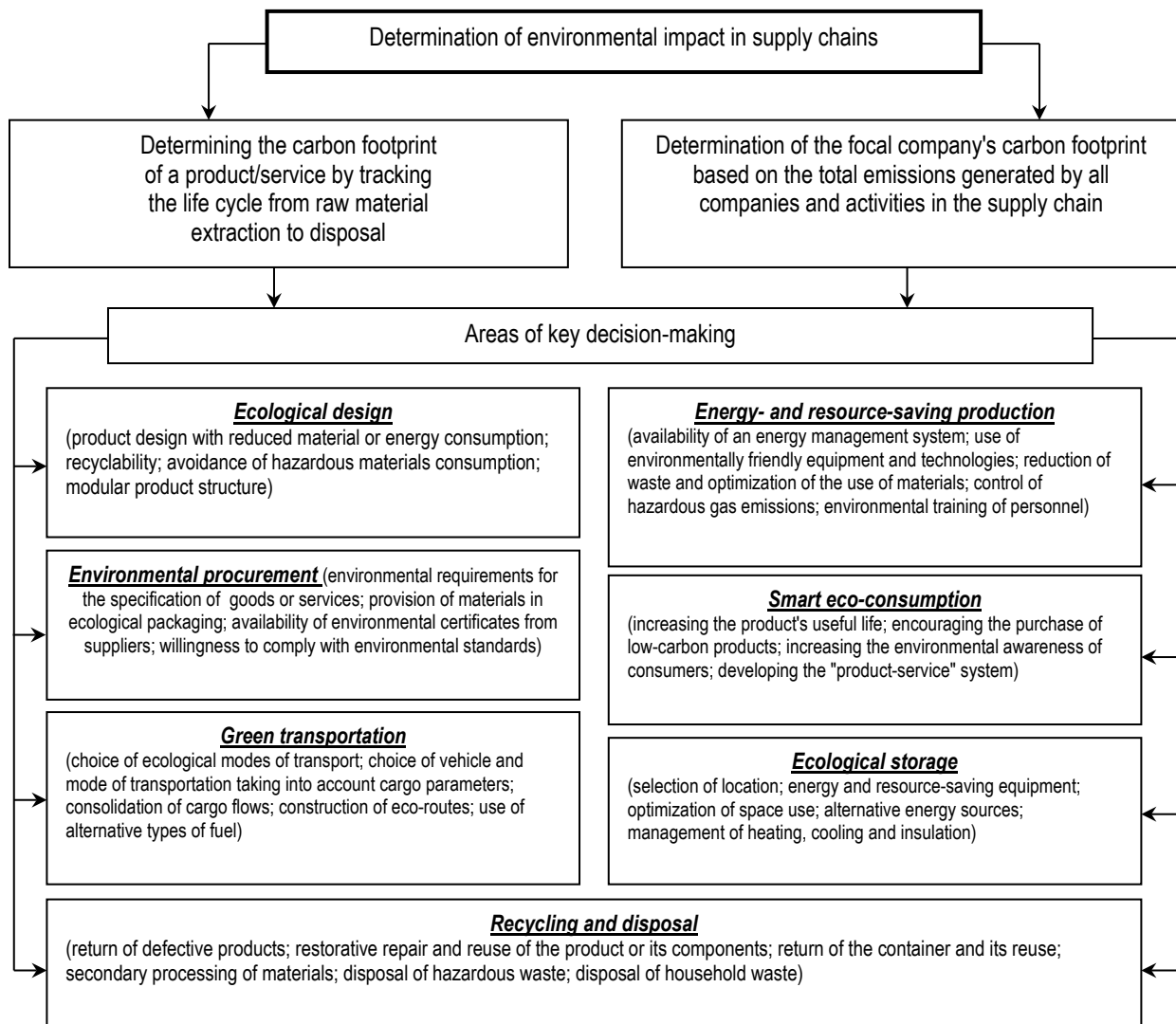


Figure 2. Key business processes in the system of green management of supply chains  
 Source: author's development.

1) Ecological design (eco-design).

According to the stages of the product life cycle, eco-design means designing a product to minimize environmental impact, taking into account every phase of its life cycle, starting from the supply of raw materials and ending with logistics, up to the end of its useful life. The European Union's Eco-design Directive 2009/125/EC obliges manufacturers to reduce energy consumption during the lifetime of their products and reduce negative impacts on the environment. From the point of view of the circular economy, eco-design must be rethought as a process of creating a product

to meet the needs of consumers in such a way as not to create waste, pollution (for example, with plastic) or other negative consequences for the environment, to provide for the possibility of reuse and repair. At the same time, the modular design facilitates the replacement of only part of the product, simplifies its disassembly, reduces the cost and effort required to replace components in case of damage. In addition, modular systems are easier to configure and therefore adapt to the changing and constant needs of users, preventing product obsolescence and guaranteeing its long-term use

2) Environmental procurement.

From the point of view of the concept of supply chains, any linear relationship between two enterprises can be considered as a seller-buyer relationship, that is, in terms of the purchase of raw materials, materials, equipment, semifinished products, works and services. Green procurement means the purchase of necessary goods or services with improved environmental characteristics and taking into account the full cost of their life cycle to meet the needs of consumers. When choosing suppliers, it is worth expanding the list of criteria for their evaluation, in particular, take into account the type of energy used, the presence of CO<sub>2</sub> emissions efficiency certificates, the environmental friendliness of the packaging, the location in terms of transportation distance, the priorities of the supplier's corporate strategy in terms of reducing the carbon footprint, and its willingness to comply with environmental standards, etc.

3) Energy- and resource-saving production.

The implementation of the environmental management system and resource-saving production in production involves, first of all, the restructuring of the enterprise's management culture, the system of relations between divisions, and the value orientation of workers. The main goal of this management model is to create value for the client by optimizing the company's resources.

The concept of lean production (lean production, lean manufacturing) is based on an unwavering desire to reduce the consumption of energy, material and labor resources, as well as the elimination of all types of losses. The center of attention of lean production is the value of products for the consumer, so every decision that does not provide value for the consumer acquires the status of a loss. The implementation of "lean production" ideally allows you to solve a number of problems that most businesses face on a daily basis: achieve high quality at minimum costs, reduce downtime, the amount of defects and waste, shorten the time of product creation, abandon outdated

technologies and harmful materials, avoid overproduction, regulate the supply and, most importantly now, ensure the development of the company, even during economic crises. The implementation of the principles of "lean production" changes the approach to work and the consciousness of every employee, from the general director to the worker in the workshop. An important aspect of the value system built on the principles of "thrifty production" is the attitude to the use of energy resources and the impact on the environment. The introduction of low-carbon technologies for the production and storage of products allows to reduce both the need for energy and the volume of carbon emissions.

4) Green transportation.

Transport is one of the main sources of environmental pollution. When 1 ton of fuel is burned, 200 kg of carbon monoxide is released into the atmosphere. Motor vehicles account for about 55% of total harmful inputs, which include more than 200 different compounds. Each mode of transport has different characteristics and limitations that reflect advantages and disadvantages according to the specific situation in supply chains. The transportation mode decision includes variables related to needs (timely deliveries, type of materials to be transported, distance, etc.) and capabilities (availability of transportation, costs and conditions of access to resources, available routes, etc.). From the point of view of reducing the harmful impact on the environment, the most environmentally friendly are railway and water modes of transport. However, they are used for long-distance transportation and heavy and bulky cargo. For short distances, road transport is the most common, accounting for more than half of domestic transport and a significant share of international transport.

The European Green Course and the European freight transport policy are oriented towards the final consumer and are built on the principles of improving the design of vehicles in terms of reducing fuel

consumption and emissions, using alternative fuels, co-modality, using intelligent transport systems and "green corridors". Co-modality was introduced in the EU White Paper on transport (European Commission 2001 transport White Paper) and requires increasing the efficiency, compatibility and interconnection of various types of transport (rail, water, air, road), as well as related nodes between them. Intelligent transport systems are designed to improve the management of transport and cargo, as well as to increase the efficiency of the use of existing infrastructure. And "green transport corridors" take into account the ecological component in logistics and are used for safety in the design and operation of the infrastructure of the trans-European transport network.

In order to optimize logistics processes and reduce traffic in supply chains, centres of consolidation of cargo flows are actively being implemented, between which transportation is carried out in large batches by boot modes of transport. Modern software for transport and logistics activities helps to plan optimal routes and balance the use of consolidation centres and direct shipments from the point of view of reducing traffic and passed retirement.

Therefore, from the point of view of reducing carbon emissions, the main solutions for movement of material flow in supply chains/networks should include optimization of routing using modern digital technologies, electrification of transport and transition to ecological energy sources, better grouping/consolidation of cargo and emphasis on rail and sea transportation.

##### 5) Ecological storage.

Warehousing and distribution are a major part of supply chains. Warehouses play an extremely important role in supply chains/networks as they consolidate significant volumes of material flows. In supply chains, warehouses pollute the environment mainly through heating, cooling and lighting. As a rule, the bigger the composition, the bigger the carbon footprint.

In recent years, the concept of "green warehouses", which considers the ecological footprint throughout the entire life cycle of the premises, has become increasingly widespread. Modern warehouses are designed according to the principles of green construction, which means that they are aimed at preserving the ecosystem and the environment, as well as bringing benefits to people and society. "Green" buildings are characterized by high-quality ecological design and high efficiency in the use of resources, namely energy, water and materials. The right location of the warehouse also plays an important role, as it can reduce the need for energy. Natural lighting can provide light during the day, and the use of solar panels can offset daily energy and reduce operating costs. Additional green products include skylights that let in natural light, ceiling fans for warehouse temperature control, energy-saving lights and fixtures, green building materials and building insulation.

Below are some of the best opportunities for eco-smart warehouses: the transition to renewable energy sources (solar panels, windmills, etc.); minimization of energy needs due to energy-efficient lighting and insulation of premises; waste reduction, complete recycling of packaging, use of environmentally friendly packaging; rejection of paper media; optimization of the use of warehouse equipment and warehouse space; implementation of warehouse management systems (WMS) that coordinate the processes of storage and transportation of goods; automation and robotization of warehouse processes; bar coding and radio frequency identification (RFID), which improves the visibility of goods in supply chains, etc.

Today, the warehousing industry continues to evolve, finding new ways to improve operations and reduce environmental impact.

##### 6) Smart eco-consumption.

The concept of green supply chains is focused on cost reduction and involves a sustainable approach to the consumption of



goods or services. That is why the involvement of consumers is an important lever for reducing emissions. They can be engaged either directly through training, collaboration or reward, or indirectly through company regulation or motivation through marketing and choice architecture. In addition, focal companies can use reactive strategies that only respond to consumer demand for lower-carbon products, or a proactive strategy to try to change existing consumer demand for low-carbon alternatives. Given the fact that the consumer often needs the product for a short time, it is advisable to encourage collective ownership of the product on the basis of renting, leasing, sharing or subscription. Thus, in the leading countries, "product-service" systems, which provide services, as well as products for joint ownership and joint consumption (collaborative consumption, sharing), are becoming more and more widespread. Shared consumption is based on the idea that it is more convenient to pay for temporary access to a product than to own that product.

There are different models of shared consumption: trading platforms, online shopping platforms, conference communication systems, systems for travel sharing, sharing things, food sharing and car sharing, etc. In particular, in numerous carsharing and carpooling projects, direct economic relationships arise between owners/carriers and renters/passengers of motor vehicles for personal (travel) or commercial (transportation of goods) use of cars. These relationships make it possible to achieve a significant economic effect: downtime is reduced and the overall utility of the car service is increased. As a result, the optimization of the use of technical means of transportation and the "collectivization" of mobility are developing. The practice of shared consumption in many cases turns out to be a more effective form of economic organization than individual ownership and use of things. These measures are an important component in reducing emissions, complementing technological changes and

enabling the achievement of overall emission reduction targets more cost-effectively.

#### 7) Recycling and disposal

The last business process is related to the end of the product life cycle. In our opinion, the main goal of managing this stage is to reduce the irrational consumption of resources, to process goods that are no longer suitable for their intended use into other types of resources, as well as to dispose of waste while minimizing the harmful impact on the environment.

An advanced system of reverse logistics will eventually replace the linearity of most production methods – raw materials, processing, further transformations and modifications, to the final product, use, disposal – with a cradle-to-cradle, circular path or closed loop that begins with the return of used, obsolete, that out of fashion and otherwise "consumed" products. The product is either recycled and placed back into the production stream or broken down into compostable materials. The cycle never ends because the materials return to the earth in safe molecular structures (accepted and used by organisms as biological nutrients) or are continuously used in the economy as inputs for new products (technical nutrients).

**Conclusions.** Based on the above, we can come to the following conclusion. Strategic and tactical solutions for managing key business processes in supply chains should be aimed at:

- increasing energy efficiency. Companies should strive to reduce emissions by improving the energy efficiency of their operations and using more efficient equipment, reducing the amount of energy consumed during transportation and reducing the number of trips and miles travelled by freight;

- use of renewable energy sources. Companies should consider using renewable energy sources, such as wind and solar power, to reduce the amount of greenhouse gas emissions associated with energy consumption;

- optimization of delivery and logistics. Companies should strive to optimize their delivery and logistics operations to reduce transport-related emissions. This includes reducing the number of trucks on the road and optimizing routes to reduce the number of miles driven;

- use of environmentally friendly materials. Companies must source and use sustainable materials in their supply chain operations. This may include using recycled or biodegradable materials, which reduces the amount of energy and resources used in the supply chain;

- attraction of investments in compensation of carbon emissions. Companies should consider investing in carbon offset programs to reduce supply chain emissions. Carbon offsetting involves the purchase of carbon credits to offset emissions from production and transportation.

Therefore, the result of the implementation of the strategy should be an increase in the environmental efficiency of supply chains/networks, which is proposed to mean the delivery of the consumer value of the product/service to the consumer at a

competitive price, while consistently reducing the environmental impact and material intensity throughout the entire life cycle. The UN World Council of Business Circles for Sustainable Development has identified seven areas of business action to improve eco-efficiency: reducing the intensity of material use, energy intensity, and the spread of toxic substances; utilization/recycling of resources; maximizing the use of renewable energy sources; extension of the period of use of products; increasing the intensity of service provision. At the level of individual enterprises – participants in supply chains – the main idea should be to reduce added value, save intermediate costs through the elimination/reduction of waste in the production chain due to the maximum possible reuse of materials and dependence on resources.

Prospects for further research consist in determining the essence of methodical approaches to measuring the volume of greenhouse gas emissions and substantiating the conceptual provisions for the development of decarbonization strategies in the context of the European Green Course.

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