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Open Environmental Collaborations as an Innovation Tool for Sustainable Development: Evidence from Russian Pulp and Paper Industry

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Abstract: The relevance of this research lies in the increasing global focus on sustainable development, the growth of the green economy, and the pursuit of national and international goals in these areas. This study examines the role of environmental collaboration models and green business integration in implementing environmental and technological projects to achieve sustainable development goals aimed at the enhancement of resource efficiency and environmental performance within companies. Open environmental collaboration business models generate additional value and competitive advantages by leveraging the synergistic integration of resources and knowledge among all participants. The study's methodological foundation includes systems analysis and comparative analysis. The findings identify the key characteristics of open environmental collaboration business models and propose recommendations for establishing a system to assess green integration projects. The proposed approach was validated through application at one of the largest pulp and paper manufacturers. As a result of the implementation of the environmental collaboration business model, the profit of Syktyvkar Forest Industry Complex increased four times, revenue almost doubled, product output increased by 89%, and asset value increased by 62%. The study contributes to a deeper understanding of how industrial integration impacts regional green development. It also provides empirical insights and policy recommendations for businesses and governments to promote environmental collaboration and advance green development through knowledge and technology transfer.

Keywords: environmental collaboration; sustainable development; green integration; knowledge management; environmental and technological projects

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1. Introduction

Between 2020 and 2024, sustainable business models (SBMs) have emerged as a critical focus in both research and management practices, driven by growing global challenges. These models evolve, increasingly integrating principles of the green economy, social innovation, digitalization, and the stakeholder approach. Consumers now prioritize corporate environmental and social responsibility, while investors seek opportunities to fund sustainable projects. Consequently, the study of sustainable business models has gained more relevance [1]. A sustainable business model provides a framework to describe, analyze, manage, and communicate a company's sustainable value proposition to customers and other stakeholders. It goes beyond organizational boundaries, aiming to conserve or restore natural, social, and economic capital [2]. As noted by Comin et al., "Sustainable business models have an approach centered on the direct participation of stakeholders, especially the user, in the process of creating sustainable value" [3]. The focus has shifted from merely "adding sustainability" to "building sustainability". SBMs are no longer seen as separate elements; they become integrated into core business strategies and business operations [4–6].

Regenerative business models are analyzed through the "idea of net positive impact, which is achieved when an organization's handprint is bigger than its footprint" [7,8]. Regenerative business models represent an approach to doing business that aims to restore and improve ecosystems rather than simply minimize negative impacts. These models seek to create positive changes in the environment and society, ensuring sustainable development. Geissdoerfer et al. attempted to develop a comprehensive research program aimed at working out tools and processes that will help businesses bridge the gap between the design and implementation of regenerative business model innovations [9]. Despite advancements, literature and business practices lack universally accepted approaches for implementing SBMs to achieve the sustainable development goals (SDGs).

Researchers and policymakers continue developing tools and models to support sustainable development initiatives on international and national scales [10]. Recently, international funds and programs have been established to facilitate the implementation of low-carbon development projects in vulnerable countries. These funds not only accumulate financial resources but also help to develop technologies and solutions aimed at reducing the carbon intensity of production and consumption [11]. Attention is given to not only climate but also green projects in general, with national strategies determining environmental priorities and setting target indicators [12,13]. Open business models (OBMs) are crucial in this context. By engaging external partners, OBMs facilitate knowledge and resource sharing [14]. In the context of environmental innovations, they allow companies to jointly develop and implement green projects, reducing their negative environmental impacts and improving competitiveness.

An open environmental collaboration, one of the forms of business models, is a voluntary association of stakeholders aimed at jointly achieving common goals in the field of sustainable development through the implementation of green projects [15,16]. Open environmental collaborations are characterized by the following features: joint development of solutions, sharing of knowledge and resources, joint risk management, transparency, trust, and a focus on sustainable development [17,18].

Drawing from UN and OECD frameworks, the principles for establishing open environmental collaborations include:

– promoting economic growth, sustainable infrastructure (especially in underdeveloped regions), industrialization, and technology transfer;
– advocating the prudent use of natural resources, transitioning to renewable alternatives where possible, and fostering a closed-loop economy;
– ensuring the reduction of negative impacts on the environment and the climate by means of pollution prevention and control.

Most documents indicate that green project funding should focus on activities meant to solve climate change problems, prevent and control environmental pollution, conserve natural resources and use them efficiently, preserve biodiversity, etc.

Open environmental collaborations are particularly suited for initiatives in the following areas:

– climate change adaptation;
– climate change mitigation (including carbon dioxide capture, utilization, or storage);

- pollution prevention and control;
- renewable energy development and energy efficiency improvements;
- green construction;
- sustainable land use;
- eco-friendly transportation;
- optimization of waste management systems;
- sustainable water resource management;
- biodiversity and ecosystem protection [18].

The research focuses on the pulp and paper industry (PPI) as one of the key industrial sectors regulated by the principle of integrated pollution prevention and control (IPPC) both in Europe and in the Russian Federation. In Russia, there are 223 pulp and paper manufacturers. Among these, 10 large-capacity plants focus primarily on the production of cellulose and mechanical pulp, generating approximately 8.9 million tons of fibrous semi-finished products.

Globally, the sector plays a very specific role in terms of the triple planetary crisis. First, PPI causes significant impacts on forests (especially when forest management is unsustainable), which leads to a decrease in GHG sinks and biodiversity loss. Second, sector industries emit significant amounts of pollutants into the atmosphere and natural water bodies and generate solid waste. But on the other hand, PPI manufactures recyclable products (including packaging), which is important from the point of view of the circular economy. Another promising characteristic of the sector is that there is a trend to use mostly biomass to meet energy needs. In addition, PPI implements technologies that can be used locally to improve waste and wastewater management practices.

In the world, PPI is primarily concentrated in countries rich in forest resources. Until the 1980s, the industry's growth was driven by efforts to improve product quality and reduce costs, often through increased production capacity. However, in the 1990s, environmental performance and resource efficiency turned out to be major factors influencing technological advancements.

Sustainable forest management is a global priority because it aims at the transformation of renewable forest resources into inexhaustible sources of energy and raw materials, including those used in advanced chemical processing, which starts at PPI.

To maximize the positive potential of PPI and to enhance both resource efficiency and environmental performance at the regional level, it is necessary to build sustainable relations of the sector companies with other organizations, including industrial companies, power plants, municipal services, as well as research and educational institutes, and NGOs. In this paper, key principles of open environmental collaboration are discussed using the evidence from PPI and considering its specific (and even unique) features. At the same time, the general principles of environmental collaboration exist:

- territorial proximity;
- commitment to the SDGs and national development goals;
- openness to collaboration;
- needs to reduce environmental impacts, enhance resource (especially energy) efficiency, minimize waste, and decrease GHG emissions;
- focus on generating new ideas, projects as well as technological and technical solutions;
- the existence of cooperative relations between the participants;
- willingness to share resources.

The 10 largest global pulp and paper companies are based in the USA, Finland, Japan, Ireland, the United Kingdom, China (Hong Kong), and South Africa. In some countries, production relies on imported wood or cellulose fiber, while wastepaper recycling is increasingly prevalent. In Russia, Northern Europe, and the Americas, the industry's development focuses on creating and upgrading large integrated businesses. Such businesses convert raw wood into primary fibrous semi-finished products, which are then used to produce paper and cardboard.

In the late 20th and early 21st centuries, industries in the European Union (EU), USA, Canada, and Russia adopted IPPC principles and established requirements for sectoral Best Available Techniques (BAT) to be implemented by the key polluters. This resulted in significant reductions in fiber, energy, and water losses, as well as minimization of waste. The use of secondary fibers (from recycled paper) and biomass for energy generation further reduced energy intensity.

Russia has worked out an environmental industrial policy that fosters the development and implementation of BAT and national reference documents on BAT (BREFs), which establish sectoral BAT-associated emission levels (BAT-AELs). These BAT-AELs must be achieved by all IPPC-regulated industries, including PPI (Figure 1, left "wing"). At the same time, at the regional level, the environmental industrial policy promotes the minimization of waste, the formation of a circular economy, and the implementation of green projects (Figure 2, right "wing"). This article focuses on the right "wing", analyzing a representative case and working out key principles of open environmental collaboration as a tool to enhance the resource efficiency and environmental performance of the regional economy. Still, according to the national legislation, BAT implementation remains the obligatory requirement for such actors discussed in the article, such as pulp and paper industries, thermal power plants, and larger municipal wastewater treatment plants.

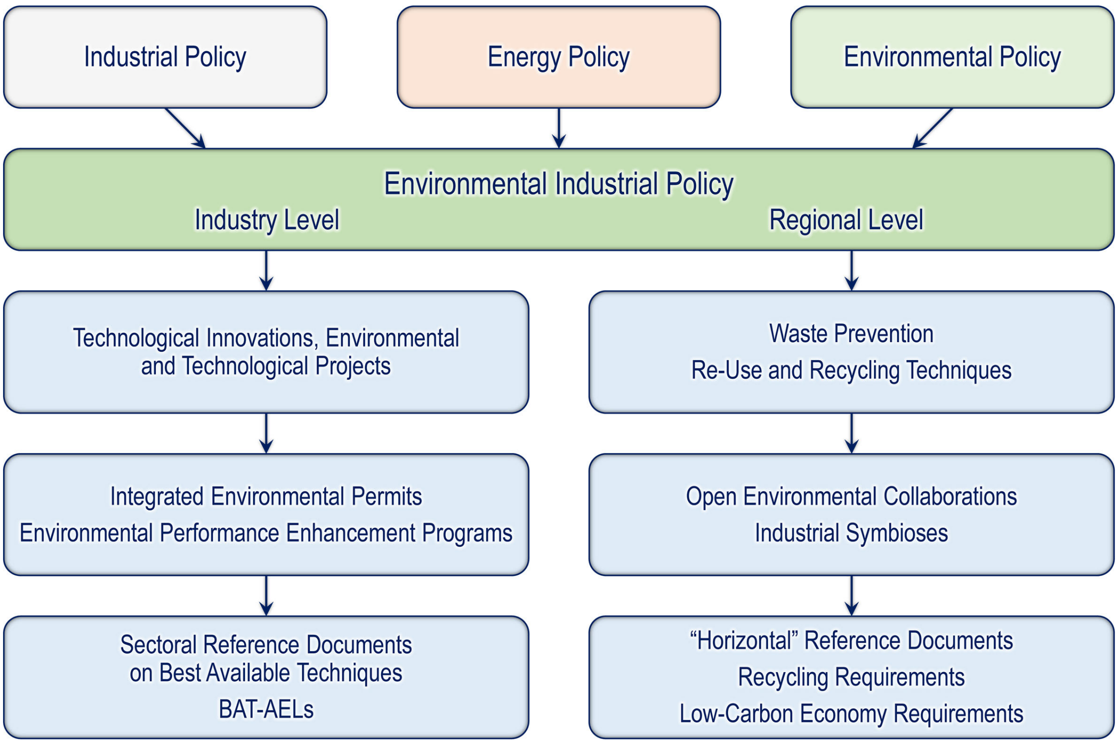

Figure 1. Two wings of the environmental industrial policy. Source: Compiled by the authors.

The authors hypothesize that environmental collaboration business models, which integrate companies from various economic sectors to improve environmental and technological performance and share knowledge and best practices, serve as tools for fostering a green economy.

This research makes the following key contributions: (1) it formulates the foundational taxonomy principles and identifies priority areas for implementing green projects; (2) it develops approaches for assessing open environmental collaboration business models; and (3) it provides a description of the effects of open environmental collaborations, illustrated through examples from the pulp and paper industry.

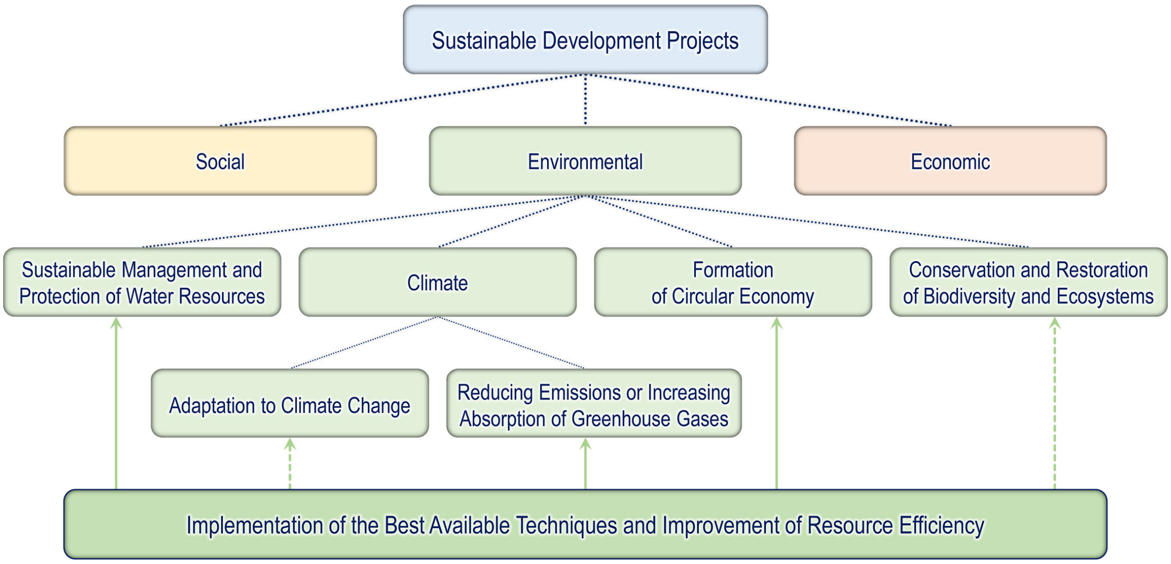

Figure 2. Classification of green projects. Source: Compiled by the authors.

The article is organized into six main sections. Section 1 (Introduction) outlines the research objectives, the current state of the field, and the author's hypothesis. Section 2 reviews publications on sustainable business models and green integration strategies, such as industrial symbiosis and clusters. It also analyzes key documents that establish the requirements for green projects. Section 3 proposes an algorithm for engaging businesses in environmental collaboration and presents a comparative evaluation methodology for analyzing green projects. Section 4 presents the results of assessing environmental collaborations, using case studies from the pulp and paper industry, followed by an analysis of these findings. Section 5 discusses the research's key results and offers recommendations for future studies. Section 6 presents the research contributions and findings that could be valuable for businesses, scientific and educational organizations, and government bodies in developing strategies for sustainable development.

2. Theoretical Framework and Hypothesis Development

2.1. Business Models for Sustainable Development

In recent decades, innovative concepts, tools, and business models have emerged to help businesses achieve the sustainable development goals. As Gazzola et al. [19] note, "Sustainable business models are essential to achieving the SDGs, as they can help address the global challenges we face in a profitable and sustainable way". A business model (BM) refers to the framework through which organizations create, deliver, and capture value [20]. It encompasses the value proposition (what value is offered and to whom), the process of value creation and delivery, and value capture mechanisms that benefit the focal firm and its stakeholders [21]. BMs reflect mechanisms underlying corporate operations, which are driven by the product or service provided and serve to achieve particular business goals [22]. A BM describes how a company functions and how it makes a profit, or how it generates, delivers, and captures value. Osterwalder and Pigneur [23] highlight nine building blocks of business models, which are structured across four business domains: customers, functional features and the quality of goods and services, infrastructure, and market sustainability. A business model serves to describe the basic principles of the creation, development, and successful operation of an organization. Teece considers a business model as an action plan for successful business management, determining how a company creates and retains value for its stakeholders [24]. The author identifies four key elements: market offering, value creation architecture, financial model, and value network model. A BM distinguishes a company from competitors by integrating its unique relationships among critical success factors. It is more important than the company's mission, strategy, and cash flow plan. It is the basis of competitive advantages [25,26]. While a BM outlines how a business generates revenue and creates value, a strategy focuses on achieving competitive advantage and long-term market sustainability. Thus, the integration of BMs and strategies is essential for effective management. Recent research emphasizes the shift from traditional business models to integrative frameworks that reflect regional and industry-specific requirements (Table 1). As Pedersen et al. note, "Sustainable alternatives to conventional business models tend to adopt a more holistic perspective of business by broadening the spectrum of solutions and stakeholders and, when aligned with cross-sector collaboration, can contribute new ways of addressing the wicked sustainability problems humanity faces" [27].

Table 1. Classification of sustainable business models.

Business Model	Definition and Content
Business model for sustainability (BMfS)	These models propose sustainable value creation for customers while preserving natural, social, and economic capital [28]. They create value for their stakeholders without depleting the natural, economic, and social resources on which they rely while implementing sustainable development projects. Such models are necessary for technological, organizational, and social innovation [29]. They allow for combining two aspects at once: changing the business at the organizational level (taking into account its structure, knowledge, culture, and organizational features) while improving the business through sustainable development [30–32].
Open business models (OBM)	Open business models present the potential to create and exchange the most efficient value in a postindustrial environment and are characterized by a development in which innovation costs are reduced by retaining the value created through external resources. Revenues increase by providing value in the form of licenses or sales of created value, deinvesting, or decoupling [33].
Open environmental collaboration models	These models combine elements of open innovation and sustainable development, promoting value creation through partnerships between various participants in environmental collaboration. They provide an opportunity to influence larger changes in society and the environment by transforming the values that guide organizations and the existing market [34]. The application of these models increases the long-term value of the business through the implementation of joint projects for waste recycling, reducing the carbon footprint, and creating a platform for the exchange of best practices in the field of sustainable development.

Source: Compiled by the authors.

Business model innovation is collaborative by nature. According to Bocken and Nancy, "Sustainable business model innovation requires an ecosystems approach of identifying the necessary stakeholders to work with, rather than a shareholder-centric approach" [35].

Open environmental collaborations can be defined as self-organizing systems that respond dynamically to external challenges. These systems consist of hierarchically independent yet interdependent entities that collaborate symbiotically to produce goods and services, optimizing resource use and fostering sustainability.

Based on the above, the following hypothesis is proposed:

Hypothesis 1. *Do open environmental collaboration models help form the green economy and contribute toward the achievement of sustainable development goals?*

2.2. Green Integration as a Tool to Support Sustainable Development Projects

The UNEP's Towards a Green Economy Report defines a green economy as one that results in "improved human well-being and social equity while significantly reducing environmental risks and ecological scarcities" [36]. The key aim for a transition to the green economy is to enable economic growth and investment while increasing environmental quality and social inclusiveness.

The green economy model emphasizes the necessity of the (1) efficient use of resources and (2) implementation of sustainable environmental practices. According to the authors, by innovating and applying environmentally friendly technologies, the green economy reduces environmental pollution. Moreover, the green economy creates market demand and business opportunities for green technological innovation [37]. Governments could establish cross-regional cooperation mechanisms to promote the coordination and harmonization of environmental regulations. Wang and Achi consider that through cross-regional cooperation, optimal resource allocation could be achieved, enhancing the environmental regulations and promoting the balanced development of green economies [38,39]. One such mechanism is green integration, which offers advantages such as the creation and financing of large-scale, unified projects based on shared interests.

Green integration entails incorporating sustainable practices and technologies into economic activities to minimize negative environmental impacts. Given the global challenges of climate change and resource depletion, green integration has become a key approach for achieving sustainable development and economic resilience. Kononovich describes green integration as a process of interaction among diverse economic entities, producing a synergistic effect with the shared goal of balancing environmental responsibility, economic growth, and improved social welfare while fostering a collective historical destiny [40].

An example of green integration at the macro level is the program of the Eurasian Economic Union (EAEU) titled "Green Integration and the Formation of a Single Sustainable Development Space in the EAEU Format" [41].

The program includes tasks to deepen green industrial integration, as outlined in the Main Directions of Industrial Development of the EAEU. These tasks include:

1. Utilizing instruments of the Eurasian Development Bank and the Eurasian Fund for Stabilization and Development to stimulate energy- and resource-efficient technologies.
2. Sharing best practices and practical methods to promote sustainable development and green economy initiatives.
3. Collaborating among member states on energy conservation, renewable energy use, and environmental conservation.
4. Developing concepts for implementing green economy principles and fostering collaboration in green technologies.

The principles of green integration include the transfer of information, knowledge, and intellectual resources, collaboration and trust, cross-border and interdisciplinary approaches, openness to change, and a focus on improving quality of life and resource efficiency. Implementing green integration mechanisms at the macro level can help developing countries lacking sufficient green investment to adopt innovative green technologies and undertake environmental and technological projects. At the meso level, the formation of green integrations must account for regional development characteristics and available resources, intellectual capital, and technological potential. On the micro level, green integration facilitates SDG-oriented collaboration between organizations, fosters industrial symbiosis, and supports the development of business clusters [42–44].

Industrial symbiosis is a concept rooted in industrial ecology. It refers to the collaborative relationships between enterprises, where the waste (being material or energy) of one entity becomes a resource or energy input for another [45]. Industrial symbiosis is often described as a model for sustainable development and a circular economy tool. Industrial ecology has some specialized tools and methodologies that can be used within the framework of industrial symbiosis. The network of physical processes and relationships between companies that enables the conversion of raw materials and energy into finished products and waste is known as industrial metabolism. Industrial metabolism, like biological systems, is based on the use of by-products, which results in the formation of closed-loop systems that produce minimal waste and consume fewer natural resources and energy [46,47].

Industrial symbiosis involves traditionally distinct industries into collaborations aimed at creating competitive advantages by exchanging materials, energy, water, or by-products [48]. Symbiotic systems can be classified based on the following [49]:

- levels of interaction (macro, meso, or micro level);
- types of resource flows: intra-organizational (in-house waste reuse), inter-organizational (based on partnerships), or market-based (the sale of production residues or waste as raw materials for subsequent processing or use);
- resource types (energy, water, or residual materials).

Industrial symbiosis connects diverse organizations into networks to promote eco-innovation [50]. This approach fosters harmony between business, society, government, and individuals by aligning their needs and capabilities.

In global industrial integration practices, the cluster concept has become widespread, with well-developed clusters being effective tools for attracting international investment and integrating national manufacturers into the global market of high-tech products. Porter defines clusters as a geographically proximate group of interconnected companies and associated institutions in a particular field, linked by commonalities and complementarities [51]. Andersson suggests that clustering can be defined as a process of firms and other actors co-locating within a concentrated geographical area, cooperating around a certain functional niche, and establishing close linkages and working alliances to improve their collective competitiveness [52].

Modern definitions of clusters often view them through the lens of innovation theory. Clusters are described as incubators of entrepreneurship, models of production agglomeration, or a special type of innovation project [53,54]. A cluster is understood as a collaboration involving industrial and production facilities, which is based on the geographical links between key producers, general suppliers, and end consumers. The elements of a cluster share a production chain, with this model acting as a competitive alternative to the industry approach. We believe that the key elements of interaction within clusters include collaboration for common goals and the mutual development of unique competencies while maintaining internal competition.

According to the agglomeration theory, clusters are networks of businesses and related organizations that enter collaboration at various stages of the value chain. Clusters serve as local network nodes within global value chains, balancing regional specialization with global diversification and fostering interaction between local and global resource flows [55,56].

Clusters serve as tools for achieving sustainable development goals [57] and advancing ESG agendas [58]. Studies prove the important role of clusters in the transition of the economy to a closed-loop model [59].

A detailed literature review of industrial integration formats, including clusters and symbioses, is provided by several researchers [60,61].

Based on the above, the following hypothesis is proposed:

Hypothesis 2. *Green integration is an effective tool for supporting sustainable development projects.*

2.3. Analysis of Documents Establishing Requirements for Green Projects

Between 2021 and 2024, over 45 countries officially adopted taxonomies for green projects, also referred to as taxonomies for sustainable finance. These taxonomies aim to support economic activities considered "intrinsically green", meaning they contribute positively to environmental and ecological objectives. However, the scope, criteria, level of detail, and environmental goals outlined in these taxonomies vary significantly.

Countries and regions that have developed and implemented green taxonomies include the EU, China, Malaysia, Japan, Mongolia, Bangladesh, Sri Lanka, and Russia. Additionally, green project systems are evolving in nations like India, Vietnam, and Singapore [62–67].

Early adopters such as the EU and China spearheaded discussions on unifying approaches to green project support systems. While the EU taxonomy identifies six environmental areas, the Chinese taxonomy focuses on three. Despite these differences, the two frameworks are largely complementary. China's taxonomy addresses a broad spectrum of environmental issues, particularly pollution, whereas the EU focuses on climate change mitigation and reducing greenhouse gas emissions.

A central component of most taxonomies is the integrated pollution prevention and control framework. Projects developed within this framework are classified in this study as environmental and technological projects. Such projects leverage technological modernization or innovative solutions to improve environmental performance and resource efficiency. Table 2 shows projects that are usually based on IPPC/BAT principles.

Table 2. Objectives and main directions of green taxonomies in the EU and China.

Objectives: EU	Objectives: China
Environmental and technological projects (IPPC/BAT based)	
Environmental pollution prevention and control	More efficient use of resources (circular economy, waste recycling)
Transition to a circular economy	More efficient use of resources (circular economy, waste recycling)
Sustainable use and conservation of freshwater and marine ecosystems	Reducing negative impacts and preventing depletion of water systems
Reduction of greenhouse gas emissions, carbon neutrality	Responses to climate change
Other green projects	
Adaptation to the adverse effects of climate change	Responses to climate change
Protection and restoration of biodiversity and ecosystems	Improvement of natural environments

Source: Compiled by the authors based on [68,69].

The evolution of taxonomies continues. In 2023, the Eurasian Economic Commission approved the EAEU Model Taxonomy of Green Projects. Similarly, in late 2024, the UK published The UK's Modern Industrial Strategy [70] and initiated consultations to revise its green taxonomies [71]. The UK's focus includes transitioning to clean energy, achieving net zero emissions, and demonstrating better environmental performance. Latin American countries are also working on developing their own taxonomies that factor in local conditions and specificities. Colombia was the first country in South America and the Dominican Republic was the first among the Caribbean countries to start implementing the green taxonomy. South Africa's taxonomy closely mirrors the EU's approach, while Russia and Mongolia have adapted the Chinese framework with additional sectoral detail. Taxonomies of the transition period represent a dynamic subset, designed to recognize and reward businesses that reduce pollutant and greenhouse gas emissions. The EU is considering including transition activities in its taxonomy, with a "traffic light" system for criteria. Similar efforts are underway in Canada, where a draft transition taxonomy was introduced in 2021, and in Japan, where Basic Guidelines on Climate Transition Finance were developed.

Russia develops cooperation with the BRICS+ and EAEU countries. During the year of Russia's BRICS Chairmanship (2024), several initiatives were put forward aimed at working out and implementing cleaner technologies, sharing knowledge and experience in the field of low-carbon development, and reducing negative environmental impacts. As far as PPI and municipal wastewater treatment sectors are concerned, Russian BREFs are considered models for drawing up national BREFs in Belorussia, Brazil, and India. Serious attention is also paid to the development of joint research in the field of green chemistry, which is important for the pulp and paper industry in terms of the transition to complete elimination of chlorine bleaching (TCF technologies). In Russia, criteria for sustainable development (including green) projects were established in 2021 and further refined in 2023.

In general, sustainable development projects can be classified according to the priority goals outlined in the ISO 14030-3:2022 standard [72]. A key finding is that green projects across different domains should be interconnected to achieve simultaneous positive effects in multiple areas (Figure 2).

When devising strategies for financing green projects, the following components should be prioritized:

– establishing a system to determine whether financial instruments meet green status requirements, which involves developing specific criteria for each project category to ensure objective selection processes;
– defining procedures for selecting, implementing, and verifying projects, which includes monitoring their environmental benefits and verifying their compliance with green criteria.

Based on the above, the following hypothesis is proposed:

Hypothesis 3. *Green projects that integrate environmental, social, and economic aspects contribute toward achieving sustainability in multiple areas.*

3. Materials and Methods

This study employs a methodological framework based on systems and comparative analysis and case studies. Case studies involve the investigation of specific objects and phenomena. Their scale ranges from individual businesses to the interactions among various organizations, social groups, and authorities. This article uses the concept of a green case, which is aimed at analyzing and describing the outcomes of applying business models that promote open environmental collaboration. These models improve resource efficiency and reduce negative environmental impacts within socio-economic systems. Within the scope of addressing green challenges, case studies can be categorized as follows:

– preliminary studies, which describe specific production sites, identify environmental aspects, and explore opportunities to reduce negative environmental impacts through the implementation of BAT;
– practical studies, which provide real-world examples to support theoretical assumptions, such as the applicability of BAT principles in forming industrial and environmental symbioses or advancing a circular economy;
– studies that analyze and systematize the characteristics of emerging trends within specific industries or regions, identifying the key factors that contribute to their development.

To conduct green case studies, this research applied methods such as environmental and energy audits in alignment with international standards [73–76]. The validation of the described method was implemented in case studies presented in the authors' publications [60,61]. Russian industrial integrations in Nizhny Novgorod and Chelyabinsk regions, the Safer Phosphates Industrial Innovation Ecosystem in Vologda, Murmansk, Saratov, and Moscow regions were formed and analyzed.

4. Results

The high-profile investments in the pulp and paper industry are made by large integrated companies, primarily using their own funds. These companies are often primary employers in their cities of operation and, therefore, play crucial social and infrastructural roles. The priority for the development of forestry businesses in the 21st century is the implementation of Best Available Techniques, the reduction of material and energy intensity in production, and the increased use of by-products like logging residues, bark, and wood residues for energy production. The global transition to a green economy relies heavily on renewable forest resources, and Russian forestry businesses have significant potential for growth in this area. From 2022 to 2023, Russia ranked eighth globally in paper and cardboard production, with its pulp and paper mills producing 8.9 million tons of products (Figure 3) [77].

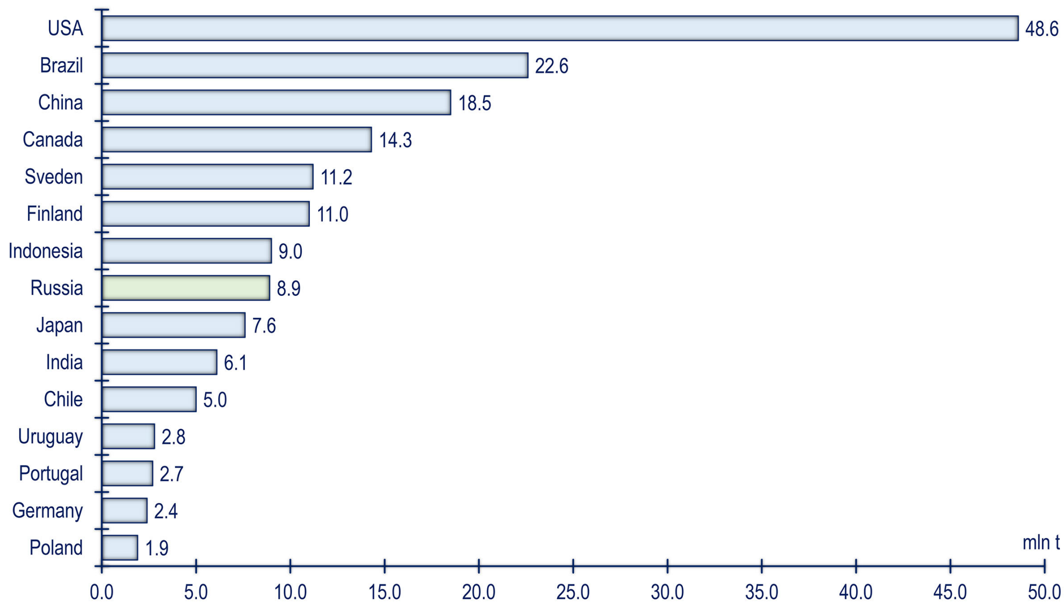

Figure 3. Production of pulp and paper products in leading countries (2022). Source: Compiled by the authors based on data from [78,79].

Environmental and climate policies worldwide prioritize addressing the high material and energy intensity of PPI. Specific energy consumption at integrated facilities ranges from 10 to 35 GJ per ton of paper (Figure 4). Literature indicates that specific energy consumption at integrated facilities in Belarus and Russia ranges between 15.3 and 16.5 GJ per ton of paper, while newer plants achieve consumption rates as low as 12–13 GJ/t [79].

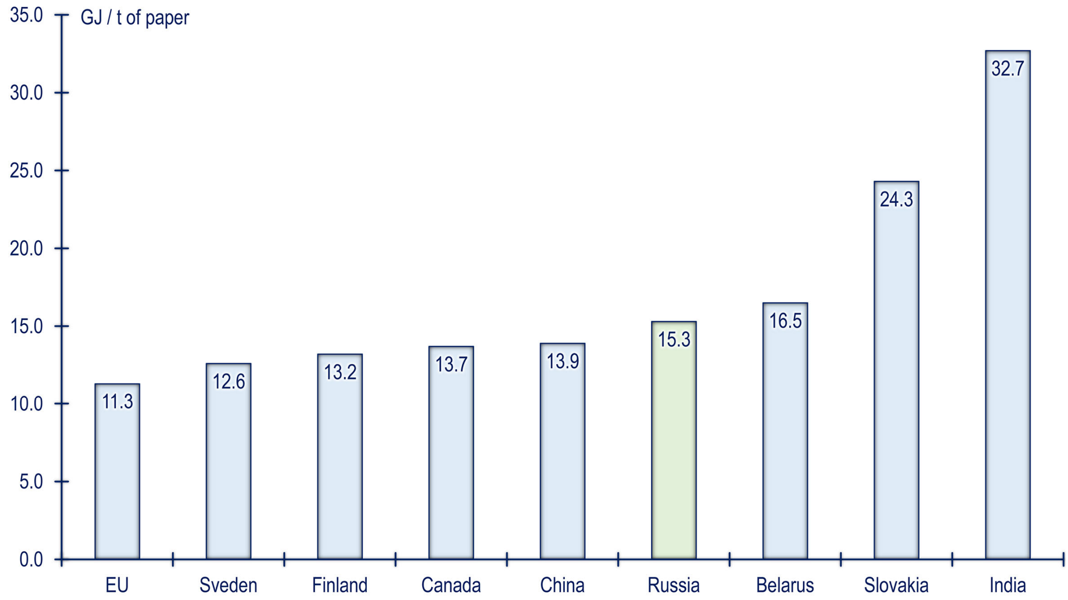

Figure 4. Energy intensity of integrated pulp and paper production. Source: Compiled by the authors based on [79,80].

Key environmental issues in the PPI sector are associated with wastewater discharges and include [81]:

– nutrients (measured by nitrogen content (Total N) and phosphorus content (Total P));
– suspended solids;
– biochemically and chemically degradable substances (their content is measured by biochemical oxygen demand (BOD) and chemical oxygen demand (COD), respectively);
– adsorbable organic halides (AOX), namely adsorbable chlorinated organic substances associated with bleached pulp production.

Air emissions commonly addressed in international BREFs include dust and malodorous compounds (e.g., hydrogen sulfide, methyl mercaptan, and dimethyl sulfide).

BAT-associated emission levels for these pollutants are established in Russian and European BREFs [82]. Leading pulp and paper producers implement environmental and technological modernization projects to comply with BAT-AELs. These initiatives aim to expand production capacity while minimizing negative environmental impacts through measures such as reducing wood and fiber losses, transitioning to elemental chlorine-free (ECF) bleaching technology, and installing advanced wastewater treatment systems.

In Russia, due to the gradual modernization, the pulp and paper sector has already decoupled growth and environmental impacts for several years (Figure 5). Still, the sector remains energy-intensive, and the rate of environmental impact reduction has slowed down, which indicates the need to find new solutions, including those based on open environmental collaboration.

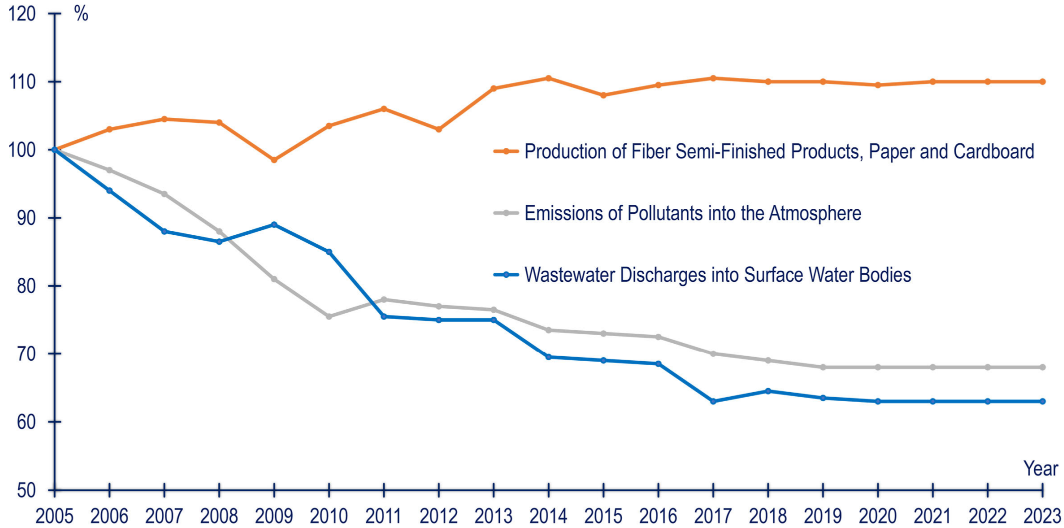

Figure 5. Evolution of environmental impacts of the Russian pulp and paper industry from 2005 to 2023. Source: Compiled by the authors.

Therefore, next, we will examine the business model of an open environmental collaboration, which brings together organizations from various industries to improve environmental and technological performance. This collaboration contributes to the formation of a green economy, particularly in the Komi Republic, where the pulp and paper industry is prevalent.

The Syktyvkar Forest Industry Complex (SFIC) was established in 1963, and by 1969, the first board machine was installed. As of 2024, SFIC produces 1.3 million tons of finished products annually and employs approximately 4500 people.

In 2002, SFIC faced several problems, many of which were interconnected:

– the installed equipment had insufficient capacity to meet growing production demands, both domestically and internationally;
– there was a major outflow of knowledgeable staff, particularly young people who pursued economic rather than engineering degrees and moved to larger cities;
– the supply of raw materials (wood) was inconsistent, and some suppliers failed to meet quality standards;
– environmental authorities became increasingly strict, with more frequent inspections and fines;
– different stakeholders started paying greater attention to environmental issues, such as forest certification, the abandonment of chlorine bleaching, engagement in voluntary environmental activities, interaction with public organizations, and landscape protection.

Smaller businesses, including municipal entities such as the local power plant and the municipal water and wastewater treatment plant (MWWTP), also faced similar challenges).

Undeniably, the recognition of the insufficient capacity to meet growing production demands played a crucial role in planning all changes and setting the open environmental business model. Decisions on selecting technological and technical solutions for the modernization of the plant were made with the participation of Saint-Petersburg Technical Forest University and leading sector engineering companies (such as "Techservice" and "Sibgiprobum"). According to the legislative requirements, all modernization projects have to undergo the Environmental Impact Assessment (with obligatory public participation) and the State Environmental Expert Assessment procedures. In this regard, the open-door policy of SFIC helped to identify the positions of key stakeholders and obtain all permits.

To overcome the problem of the qualified staff shortage, SFIC decided to (1) establish partnerships with the Syktyvkar Forest Institute and local colleges and (2) ask national think tanks such as the Russian BAT Bureau (Moscow) and Saint-Petersburg Technical Forest University to provide methodological support to the newly formed educational center.

To solve the problem of the main raw material supply, SFIC proposed new contract conditions for local forestry enterprises focusing on (1) the regularity of supplies, (2) timber quality, and (3) sustainable forest management. In return, forestry enterprises suggested jointly establishing new greenhouses to grow young pine trees to be used for reforestation purposes.

Environmental authorities and NGOs were recognized as the key stakeholders to be involved in (1) discussing SFIC Environmental Performance Enhancement Programs and conditions of the Integrated Environmental Permit; (2) developing and implementing voluntary environmental actions such as riverbed and corridor cleaning, reforestation, etc. At the initial stage, these relationships were also fostered by the Barents Euro-Arctic Council; later, they grew with the participation of the leading Russian NGOs.

Unlike greenfield projects, which received modern equipment compliant with IPPC/BAT principles in the early 21st century, SFIC was forced to implement a strategy of gradual environmental and technological modernization. This approach allowed SFIC to increase productivity, expand its product range, and reduce its negative environmental impacts over time. Priority areas for these projects were determined by several factors:

- the most significant and publicly concerning environmental impacts;
- compliance with legislative and regulatory requirements;
- opportunities to achieve multiple positive outcomes, including through collaboration with organizations from other sectors.

The first environmental and technological project, completed in 2007, was the transition to elemental chlorine-free bleaching. This shift aimed to minimize the formation and accumulation of organic halides in the environment. Notably, this decision was not driven by official environmental requirements: the EU BREF did not specify BAT-AELs, and Russia had not yet implemented the BAT concept. In addition to the environmental benefits (minimizing AOX formation to 0.02 kg/t of air-dried pulp (or tissue, Adt)), the ECF transition resulted in increased resource efficiency. Fiber losses during the bleaching stage were reduced by 1.1%, which ultimately increased the yield of quality products. According to SFIC's reports, the ECF process resulted in very low emissions of chlorinated organic substances, and no highly chlorinated phenolic compounds were detected in the effluent.

The ECF bleaching project was part of the STEP program, a major plant upgrade initiative completed in 2010. This program increased the plant's capacity to 1 million tons of Adt. Other environmental and technological projects within the STEP program included:

- the implementation of a system for the collection and thermal oxidation of malodorous gases. These gases, such as hydrogen sulfide, methyl mercaptan, dimethyl sulfide, and dimethyl disulfide, are known for their strong and unpleasant odors;
- the development of a new system for recovering sodium carbonate solutions, which are converted into caustic soda for reuse in the production process (currently, 97% of this solution is recovered).

As it became clear that large-scale green projects could only succeed with the collaboration of business, government, and society, a circle of interested parties (potential actors in green industrial integration) was identified, including:

- local (city and district) governments;
- federal and regional environmental authorities;

– municipal enterprises (power plants, wastewater treatment companies, waste management companies, etc.);
– forestry enterprises;
– educational institutions;
– environmental non-governmental organizations (NGOs).

At the next stage, the successful experience of industrial integrations was studied, and a business model of open environmental collaboration was chosen. This model involves industrial clusters and symbioses rather than individual businesses. The main actors are illustrated in Figure 6.

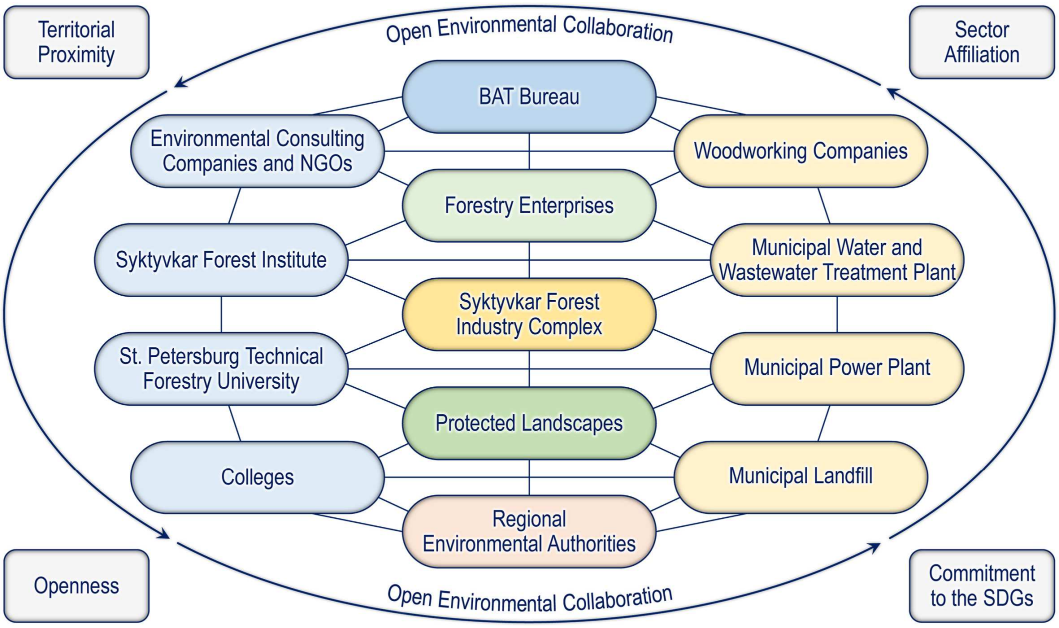

Figure 6. The main actors of environmental collaboration in the pulp and paper industry. Source: Compiled by the authors.

4.1. Industrial and Municipal Symbiosis

In this symbiosis, the MWWTP supplies both one of the city districts and nearby industries with high-quality water. SFIC, in turn, treats both industrial and municipal wastewater. The dried sewage sludge, together with bark and wood residues, is incinerated to generate energy. Recently, biomass from partner forestry businesses and small woodworking companies has also been added to the fuel mix.

As a result, the village, MWWTP, and the local power plant benefit from using less natural gas to produce energy, and the share of green electricity generated has reached 37%. Other positive outcomes include improved compliance with environmental regulations, greater collaboration with public environmental organizations, and cleaner effluents released into the river.

4.2. Research and Production Cluster

The cluster consists of 12 forestry enterprises, the Syktyvkar Forestry Institute, vocational education institutions, and local environmental authorities. Forestry enterprises implement best practices in forest management, informed by scientific research that advocates for changes in reforestation approaches. Collaboration with SFIC has opened new opportunities for these enterprises. SFIC has established modern greenhouses to grow rootballed pines. Currently, the nursery's capacity reaches 8.6 million spruce and pine seedlings annually. To date, over 87 million rootballed coniferous seedlings have been cultivated and planted across more than 40,000 hectares in the Komi Republic and neighboring regions. Of the total number of seedlings, approximately half are used for SFIC's own reforestation efforts, including reclaiming forest areas and restoring forests in places where timber has been harvested. The forestry enterprises collaborate with SFIC to promote reforestation—both nationally and by means of planting trees cultivated in greenhouses. In forest allotments, after logging, viable young trees are left to grow. These young trees are nurtured until they reach maturity, ensuring that future growth does not present concerns. This approach allows SFIC to not only use forest resources but also contribute to their effective restoration.

Regional protected landscapes, including those located in the Syktyvkar District, as well as other nature conservation areas, are also involved in reforestation activities. Knowledge-wise, these organizations run environmental awareness programs for schoolchildren, students, tourists, and the public. With the support of such national think tanks as the Russian BAT Bureau and Saint-Petersburg Technical Forest University, Komi Republic higher and vocational education institutions have introduced special classes in schools, developed interdisciplinary educational programs, and collaborated with industrial enterprises. The Syktyvkar Forestry Institute has served as the coordinator for international environmental research for many years and is now one of the centers for the Environmental Hot Spots of the Barents Euro-Arctic Region project. SFIC employees organize green festivals and have developed specialized courses for students. The scientific and educational cluster has thus evolved into a research, training, and industrial hub.

As Russian businesses transition from outdated technologies to BAT, there is an increasing need for technology developers and engineers, including environmental experts. Within the environmental collaboration framework formed around SFIC, career guidance is provided, and new educational programs are developed and implemented. Some classes are taught by SFIC employees, both at educational institutions and at SFIC's production site. Additionally, disciplines related to BAT are taught by partners from the BAT Bureau and St. Petersburg Technical Forest University. The research-and-education cluster continues to expand, and the involvement of universities facilitates a systemic approach to solving social issues, particularly in the realm of lifelong learning (SDG 4).

The implementation of the environmental collaboration business model affected the change in the economic performance of SFIC. As a result of a series of environmental and technological modernization projects implemented by SFIC, the profit of the company increased four times, revenue almost doubled, product output increased by 89%, and asset value increased by 62%. Syktyvkar Forest Institute and local colleges attracted more students eager to obtain highly demanded professions. Forest enterprises began selling environmentally certified timber to the producers of construction materials for green building projects.

The implementation of the open environmental collaboration business model has enabled the following achievements in environmental performance:

- joint treatment of industrial wastewater from SFIC and domestic wastewater from the Ezhvinsky district of Syktyvkar (population: 50,000) in compliance with BAT requirements;
- reduced natural gas consumption at the thermal power plant, achieving an energy intensity of 13.1 GJ per ton of air-dried tissue while increasing the share of green energy to 87.5% (generated from bark, wood residues, and dried sewage sludge);
- decreased emissions of pollutants and greenhouse gases at SFIC and the power plant;
- reduced waste sent to landfills, with proper waste handling;
- secured timber supplies from the 12 forestry enterprises, which operate in accordance with forest certification rules (Figure 7).

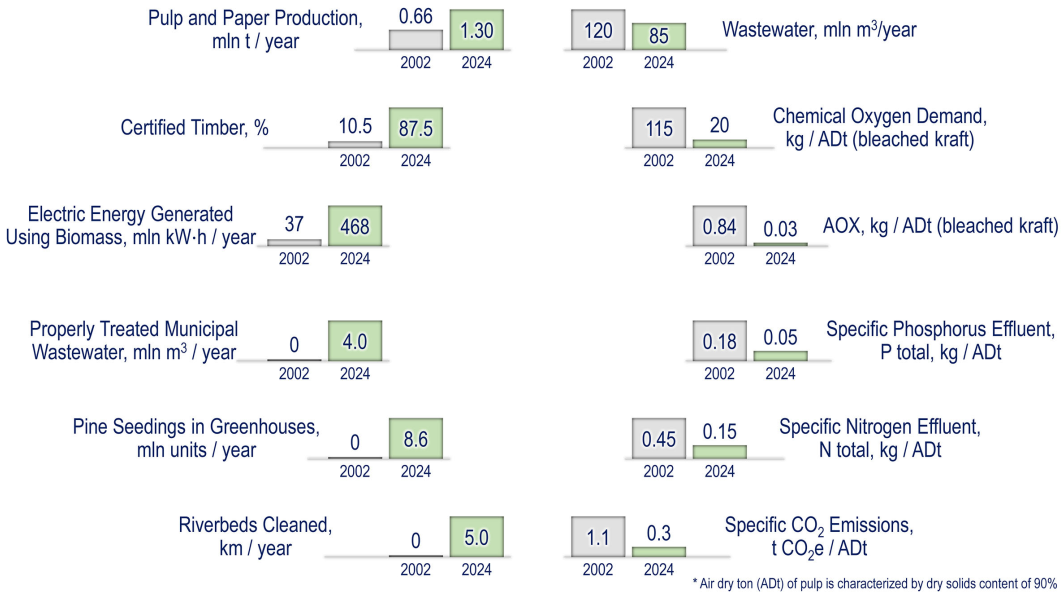

Figure 7. Key environmental collaboration effects: 2002–2024. Source: compiled by the authors.

Synergetic effects of environmental collaboration for the pulp and paper industry, both from clusters and industrial symbiosis, are detailed in Table 3 and Figure 8.

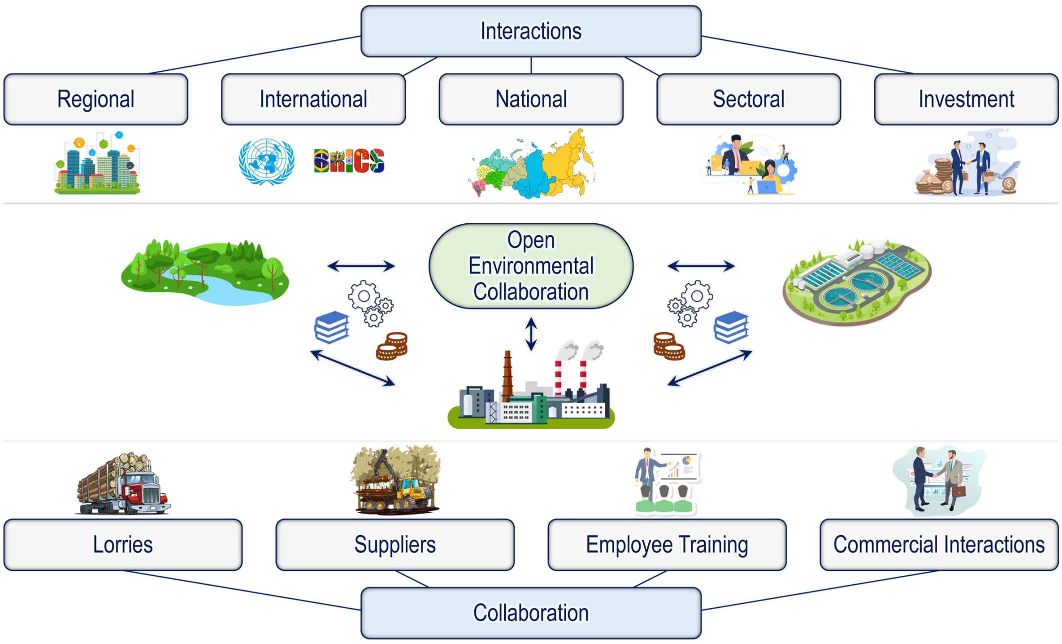

Figure 8. The system approach to open environmental collaboration. Source: Compiled by the authors.

In 2019, SFIC became the first Russian industry to receive the official approval of its Environmental Performance Enhancement Program (the official term introduced in the Russian legislation for the series of environmental and technological projects), resulting in achieving BAT-AELs better than those established in the national BREF on Pulp and Paper industry. This fact was recognized both nationally and internationally, and SFIC was officially excluded from the List of Environmental Hot Spots of the Barents Euro-Arctic Region [77]. The EPEP, developed and implemented by SFIC, became a model for all programs worked out by the sector industries in 2021–2024.

Table 3. Synergetic effect of environmental collaboration for the pulp and paper industry.

Actors	Forms of Interaction	Principles of Environmental Collaboration	Synergetic Effect
– Syktyvkar Forest Institute – Local colleges – Saint-Petersburg Technical Forest University – Russian BAT Bureau – Syktyvkar Forest Industry Complex	"Research and education" cluster. Training programs and activities	– Sector affiliation; – Commitment to the SDGs and national development goals; – Collaboration, trust, and partnership; – Focus on generating new ideas, projects as well as technological and technical solutions; – The existence and further development of cooperative links between the participants; – Joint generation and use of information, innovative and intellectual resources.	– (1) Research- and (2) practice-oriented training programs developed jointly by the cluster members; – Motivated applicants attracted to the high school establishments and colleges; – Established "career staircase" (from secondary school to college and industry or university); – Joint research programs in the priority fields; – Joint development and transfer technologies.
– Syktyvkar Forest Institute – Russian BAT Bureau – Syktyvkar Forest Industry Complex – Leading consulting companies and environmental NGOs	"Research and education" cluster. Science and research programs	– Sector affiliation; – Commitment to the SDGs and national development goals; – Collaboration, trust, and partnership; – Focus on generating new ideas, projects as well as technological and technical solutions; – Joint generation and use of information, innovative and intellectual resources.	– Joint research projects and programs resulting in valuable funding for all actors; – Joint science-based environmental actions resulting in the significant improvement of the state of local rivers and forests; – Regional, national, and international workshops and conferences resulting in forming new research links and developing new research projects.
– Syktyvkar Forest Industry Complex – Forestry enterprises – Small woodworks – Protected landscapes – Leading consulting companies and environmental NGOs – Regional environmental authorities	"Research and practice" cluster	– Sector affiliation; – Commitment to the SDGs and national development goals; – Collaboration, trust, and partnership; – Focus on generating new ideas, projects as well as technological and technical solutions; – Joint generation and use of information, innovative and intellectual resources.	– Establishment of common greenhouses resulting in growing strong rootballed coniferous seedlings; – Effective joint reforestation activities including (1) planting trees grown in greenhouses and (2) conserving selected young trees on the plots of felled forest; – Joint riverbed cleaning actions.
– Syktyvkar Forest Industry Complex – Forestry enterprises – Small woodworks – Municipal water and wastewater treatment plant – Thermal power plant	Industrial symbiosis	– Territorial proximity; – Priority of the resource efficiency policy; – Balance of the goals and objectives of the industrial symbiosis participants; – Needs to reduce environmental impacts, enhance resource (especially energy) efficiency, minimize waste, and decrease GHG emissions; – Opportunities for forming symbiotic chains, including "waste-to-resource" and "waste-to-energy" links; – Opportunities for joint transformation of non-renewable and renewable resources.	– Production of certified timber (according to the requirements of the Forest Stewardship Council) inspired by the collaboration; – Joint wastewater treatment practices resulted in better quality of treated water; – Joint waste management practices resulted in transforming biomass waste to green energy; – Joint energy management practices resulted in reduced consumption of natural gas; – Reduced GHG emissions and increased GHG sinks of the key participants.

Promising directions for expanding environmental collaboration align with both the priorities of Sustainable Development in the Komi Republic and the interests of SFIC. The establishment of greenhouses for growing rootballed seedlings resulted from collaboration between the Republic's government, forestry enterprises, and SFIC.

The development of these greenhouses and the promotion of sustainable forest management practices have garnered interest from both environmental NGOs and the managers of the local protected landscapes. The restoration of vulnerable sites, particularly river corridors affected by previous timber rafting and polluted wastewater effluents, is considered a promising area of focus. While industrial businesses are not responsible for ecosystem restoration, it remains a priority within green collaborative projects. Such projects can be carried out through industrial integration, which is in line with the taxonomy for sustainable (including green) development projects in Russia.

The Environmental Performance Enhancement Program (EPEP) developed and implemented by SFIC became a model for most EPEPs worked out by Russian pulp and paper industries in 2021–2024. To meet sectoral BAT requirements, up to 40–50% of installations are implementing EPEPs. It is expected that by the end of 2025, all sectoral installations regulated by IPPC and Russian Environmental Industrial Policy will have been granted integrated environmental permits (IEPs) (Figure 9).

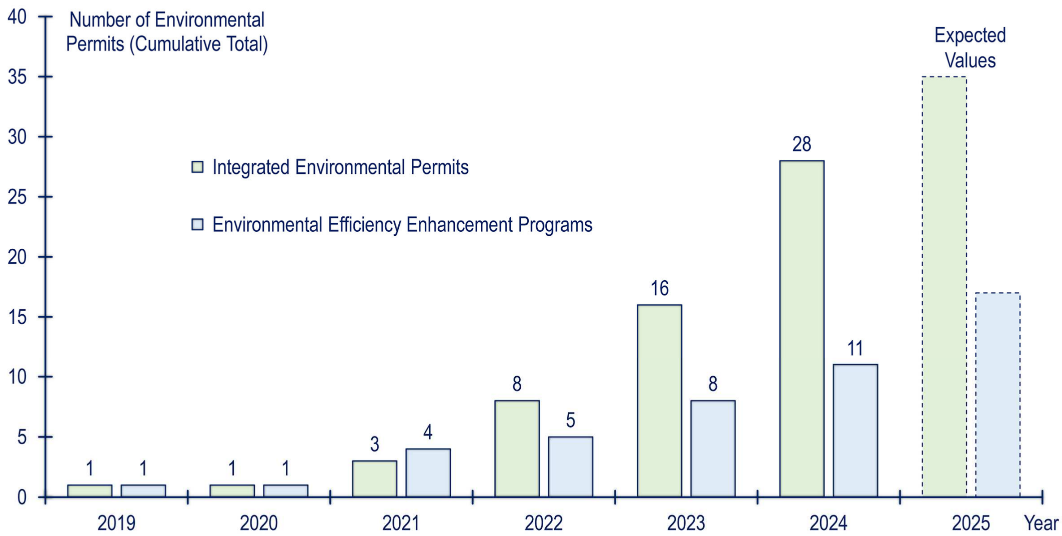

Figure 9. Statistics of integrated environmental permits granted to and environmental performance enhancement programs implemented by the Russian pulp and paper industries. Source: Compiled by the authors.

Thus, one can see that the experience of SFIC-centered open environmental collaboration is already being replicated by industry enterprises located in various Russian regions. Through training workshops conducted by the Russian BAT Bureau with the participation of Komi Republic colleagues, such approaches as (1) identification of key stakeholders and their interests to form open environmental collaborations, (2) selection of appropriate sectoral and inter-sectoral BAT to be implemented jointly with regional stakeholders, and (3) development of collaborative green projects in accordance with the regional and national priorities are promoted.

Thus, if we return to the international and national taxonomies of green projects, there is all the necessary evidence that the open environmental collaboration helps contribute toward major internationally and nationally recognized environmental objectives, including (1) climate change mitigation, (2) sustainable use and protection of water resources, (3) transition to a circular economy, waste prevention and recycling, and (4) control and prevention of pollution [72]. At the same time, according to the precautionary principle, there is at least no harm or significant risks to two remaining objectives: (5) protection and restoration of ecosystems and biodiversity, and (6) climate change adaptation [72]. Moreover, collaborative activities aimed at the reforestation and restoration of the riverbed can be considered positive changes related to SDG 15 and SDG 14. In the future, quantitative effects should be evaluated.

In collaboration with research institutes and consulting agencies, SFIC is exploring the possibility of transitioning to total chlorine-free (TCF) bleaching. Although such requirements are not yet established in the European, Eurasian, or Russian regulatory frameworks, several research groups have highlighted the benefits of TCF [83–85]. Currently, there is only one modern hydrogen peroxide production plant in Russia, and SFIC is discussing the potential for increasing production with the plant's management and relevant ministries to facilitate the pulp and paper industry's transition to chlorine-free bleaching.

In environmental collaboration, relations between participants develop according to the principle of "each with each" and are formed around the generation of knowledge and the creation of a supportive environment. As a result of the collaboration, there is an economy of diversity because it is less costly to produce multiple products based on the same knowledge and technology platform than to produce each product separately. Free knowledge exchange allows actors to achieve the initial level of synergy and emergence.

5. Discussion

The implementation of the open environmental collaboration business model requires a comprehensive approach that includes strategic planning, formation of integrations, development of innovative solutions, effective knowledge management, involvement, and trust, as well as legal and regulatory support. This approach fosters sustainable and effective relationships among collaboration actors, facilitating joint efforts to achieve sustainable development goals. Environmental collaboration business models, which bring together companies from various sectors to improve their environmental and technological performance, resources, and knowledge transfer, act as instruments for shaping a green economy.

The hypothesis of the study has been confirmed. H1: Do open environmental collaboration models help form the green economy and contribute toward the achievement of sustainable development goals?

All improvements achieved by the open environmental collaboration in the Republic of Komi are based on the principle of "Partnerships for the Goals" (SDG 17). Considering the scale of the Russian Federation, SDG 17 can be regarded both in the context of interaction with other countries and from the point of view of interaction between various Russian regions. The SFIC-centered environmental collaboration includes research and educational establishments of Moscow, Saint-Petersburg, and Irkutsk (East Siberia). In 2019, the Environmental Performance Enhancement Program (EPEP) implemented by SFIC was recognized as a model for sectoral EPEPs both nationally and internationally [86]. As a result of this study, the open environmental collaboration model implemented in the Republic of Komi provided for (1) reducing waste sent to landfills by 78% and (2) generating green energy from such waste as bark, wood residues, and dried sewage sludge (458 mln kWh/year). Therefore, the environmental collaboration has been contributing toward the implementation of SDG 12 (Responsible Consumption and Production) and SDG 7 (Affordable and Clean Energy). These improvements would not be possible without developing and implementing innovative technological solutions (SDG 9). The most prominent trend is sustainability, which focuses on reducing waste and emissions through innovative recycling approaches, ECF and TCF bleaching methods, and predictive maintenance sensors for resource efficiency enhancement, industrial data collection, and analysis. Implementation of modern techniques (at least BAT conforming) allowed SFIC to increase production by nearly two times (becoming the largest producer in Russia) while reducing negative environmental impacts.

H2: Green integration is an effective tool for supporting sustainable development projects. Knowledge transfer between the participants is one of the core principles considered in open environmental collaboration. In 2018–2024, Komi training institutions, jointly with the BAT Bureau and Saint-Petersburg Forest University, developed and implemented 12 environmental training courses for wider stakeholders (in environmental impacts assessment, BAT, IEPs, environmental self-monitoring, etc.). Over 300 representatives of environmental authorities, local industries, and NGOs, were trained. Most knowledgeable employees of SFIC acted as trainers along with the representatives of the higher school establishments and consulting companies. In 2021–2024, activists of such NGOs as "Nature and People", "CarbonLab", and "the Russian Environmental Society" conducted training workshops and helped organize seven riverbed cleaning actions and five reforestation actions. Each action attracted 50–70 local volunteers representing various organizations. Staff training is recognized as one of the important components of an organization's sustainable development. As a result of knowledge transfer for employees, students, and schoolchildren, companies obtain qualified and motivated personnel who will implement existing and future sustainable development projects.

H3: Green projects that integrate environmental, social, and economic aspects contribute toward achieving sustainability in multiple areas. Along with contributing toward SDG 12, SDG 7, and SDG 9, participants of SFIC-centered environmental collaboration managed to reduce wastewater flow by nearly 30% (from 120 to 85 mln cubic meters per year) while decreasing emissions of key pollutants by 3–5 times. In addition, emissions of the most critical pollutants—adsorbable chlorinated organic substances—were decreased by 28 times. Thus, a significant contribution was made toward the implementation of SDG 6 (Clean Water and Sanitation). Specific GHG emissions were reduced from 1.1 to 0.3 t CO_2-eq. per ton of ADt: achieving this result (one of the best results in the Russian PPI) and establishing greenhouses to pamper pine seedlings, SFIC and members of the open environmental collaboration have been contributing toward the achievement of SDG 13 (Climate Action). Nowadays, professional ecologists assess the effects of green projects on the biodiversity of forest ecosystems (SGD 15—Life on Earth) and aquatic ecosystems of the region (SDG 14—Life under Water). Therefore, it is possible to conclude that green projects that integrate environmental, social, and economic aspects contribute toward achieving sustainability in multiple areas.

However, this study has several limitations and assumptions:

— limited access to qualitative and quantitative data on environmental collaboration business models may affect the completeness and accuracy of the analysis;
— the experience of environmental collaboration is based on the regional example, though it is known that other pulp and paper industries in EAEU (Russia and Belorussia) also report on establishing close relationships with their regional partner industries. When scaling this model to other sectors, regions, or countries, additional factors may influence integration outcomes, such as locations, distribution, suppliers, customers, etc.;
— business models for open environmental collaborations are dynamic, and the composition of participants may vary over time, affecting the number of connections and network effects;
— it is assumed that all participants in an environmental collaboration have equal access to resources, knowledge, and technologies, which may not always be the case in practice;
— the study does not cover all green integration business models, potentially limiting the comprehensiveness of the findings;

— the environmental impact of the implementation of the collaborative open business model is not conclusive, and it may have been affected by other uncontrolled extraneous variables.

Based on these limitations, future research should explore the following directions.

(1) The influence of trust, cultural, and social factors on the effectiveness of open environmental collaborations. Trust forms the foundation for interactions between participants, fostering collaboration and reducing risks [87]. As highlighted by many researchers, trust is a critical factor for effective interaction between economic entities [87,88]. Trust is an integral component of economic relations, shaping the expectations of their participants regarding their compliance with the established rules of interaction and the obligations they have assumed [88,89].

(2) Legal and regulatory barriers that can significantly restrict the opportunities for open environmental collaborations. Understanding and addressing these barriers is crucial for successful collaboration in the field of sustainable development. Without an appropriate legal framework, participants may be reluctant to share resources and knowledge, reducing the effectiveness of environmental collaborations.

(3) Development of methodological approaches for assessing the effects and efficiency of open environmental collaborations. This includes the creation of a system of indicators to assess and scale successful practices.

(4) Mechanisms of knowledge development in a knowledge ecosystem focusing on knowledge-enhancing activities such as knowledge sharing and knowledge development rather than business interactions [90–92]. In a knowledge ecosystem, a community of actors interacts with each other and with the environment. The objects of the environment are natural resources, cultural institutions, and participants of other systems. To ensure the best possible life conditions for people to generate knowledge, ecosystem participants cooperate and compete, adapt to external influences, and transform the system itself [93–95]. Other researchers Contreras-Medina, Díaz Nieto, and Medina-Cuéllar [96] explore additional questions about the following areas: (1) how ecocentric paradigms can be leveraged for the process of knowledge management and knowledge creation, and (2) how sustainability-related practices make use of knowledge management to meet their business objectives from an ecocentric perspective. The authors propose to consider knowledge as the “energy” of the system [97]. The intellectual environment, as a key element of the knowledge ecosystem, leads to the generation of knowledge and ideas and the realization of creative and effective solutions. The development of a knowledge management mechanism in the conditions of an open environmental collaboration model will allow optimal management of the economic, social, environmental, and technological processes of actors to achieve resource efficiency, as well as to evaluate the collaboration effects through the level of intellectualization.

To deeper study opportunities afforded by the open environmental collaboration business models established in other sectors and regions, authors plan to focus attention on (10) the collaborations being formed in the Central European Region of the Russian Federation (industries producing construction materials, educational establishments, machinery companies, environmental authorities, and NGOs) and in the Urals (metallurgical plants and industries producing construction materials as well as other stakeholders). We intend to (1) support companies that can act as local “nuclei”, (2) help assess key environmental impacts, and (3) help identify opportunities to jointly reduce them via establishing open environmental collaborations as well as study opportunities to get state support for the implementation of collaborative green projects.

6. Conclusions

This study found that implementing the open environmental collaboration business model in the pulp and paper industry has led to significant environmental improvements, including joint treatment of industrial and municipal wastewater, reduced natural gas consumption, and generation of green energy from biomass (SDG 7), decreased emissions of key pollutants and greenhouse gases (SDG 13), reduced share of waste disposed in landfills, and ensured proper waste management. Thus, the adoption of such models contributes to the achievement of SDG 17, as collaboration and multilateral partnerships are essential tools for the exchange of knowledge, technology, and resources. The formation of symbiotic relationships in environmental collaborations also supports the transition to sustainable consumption and production models (SDG 12). The formation of research and production clusters further contributes to sustainable industrialization and innovation using resource-efficient technologies (SDG 9).

This research contributes to a better understanding of the formation and functioning of open environmental collaborations for sustainable development. It formulates the foundational taxonomy principles and identifies priority areas for implementing green projects. The paper provides a description of the effects of open environmental collaborations, illustrated through examples from the pulp and paper industry. The findings could be valuable for businesses, scientific and educational organizations, and government bodies in developing strategies for sustainable development.

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