The Main Directions of Greening Economic Development and Transition to Sustainable Development in the Baltic Countries

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ABSTRACT:

The transition to sustainable development and greening of the economy are key challenges for the Baltic countries in the context of global climate change, depletion of natural resources and the need to ensure long-term economic stability. The relevance of the study is due to the need to analyze modern approaches to greening the economy in Lithuania, Latvia and Estonia, as well as to identify key areas that contribute to the achievement of the sustainable development goals. The purpose of the article is to systematize the main areas of greening of economic development in the Baltic countries and assess their effectiveness. The study used the methods of comparative analysis, statistical data processing and a systems approach. The results of the study demonstrate that the Baltic countries are actively implementing measures to reduce their carbon footprint, develop renewable energy and introduce a circular economy. However, there are challenges associated with insufficient investment, technological limitations and the need to harmonize policies at the international level. The article discusses the prospects for further development of greening the economy in the region and offers recommendations for strengthening the integration of environmental and economic strategies.

Keywords: Baltic countries, greening economic development, green initiatives, sustainability.

1) Introduction

The relevance of the research topic is determined by global challenges related to climate change, depletion of natural resources and the need to transition to sustainable development. The Baltic countries, including Lithuania, Latvia and Estonia, are in the process of transforming their economies to reduce the negative impact on the environment and achieve the Sustainable Development Goals (SDGs) defined by the UN [1]. Greening the economy involves integrating environmental aspects into economic policy, which requires a comprehensive approach and consideration of regional specifics. The topic of transition to sustainable development and greening the economy is especially relevant for the Baltic countries (Lithuania, Latvia and Estonia) for several key reasons related to their geographical location, economic structure, historical context and global challenges. The Baltic countries are located on the coast of the Baltic Sea, which is one of the most vulnerable

ecosystems in Europe. Marine pollution, eutrophication (excessive nutrient input) and climate change threaten biodiversity and the marine-related economic activities common to all three countries, such as fisheries, tourism and transport logistics [2]. The region is vulnerable to the effects of climate change, including rising sea levels, more frequent extreme weather events and changes in agriculture. This requires the economy to adapt to the new conditions.

After regaining independence in the 1990s, the Baltic countries inherited an outdated industrial infrastructure, and an energy system based on fossil fuels (especially oil shale in Estonia). This has created a significant environmental burden. The transition to sustainable development has become part of the integration process into the European Union (EU), which requires strict environmental standards

and reduced greenhouse gas emissions. The economies of the Baltic countries are heavily dependent on natural resources such as forests, agriculture and energy. This makes them vulnerable to resource depletion and climate change. This is why the development of renewable energy, and the implementation of circular economy principles are becoming key areas for reducing dependence on energy imports and increasing competitiveness.

As EU members, the Baltic States are committed to meeting the goals of the European Green Deal, including achieving carbon neutrality by 2050 [3]. Participation in the Paris Agreement on climate change also requires significant efforts to reduce emissions and transition to sustainable development models. The Baltic States face demographic challenges, such as an ageing population and youth migration. Sustainable development can be a tool for creating new jobs, especially in the green sectors of the economy, and improving the quality of life. Education and innovation play a key role in training personnel for the new economy, which makes greening an important element of educational policy [4].

To maintain global competitiveness, the Baltic States need to introduce innovative technologies and sustainable practices. The development of green technologies and sustainable infrastructure can attract foreign investment and strengthen the economy.

The relevance of the transition to sustainable development and greening the economy for the Baltic States is due to a combination of environmental, economic and social factors. The region is at the intersection of global challenges, such as climate change and resource depletion, and local problems, including outdated infrastructure and demographic changes. Successful greening of the economy can become a driver of growth, improved quality of life and strengthening the international competitiveness of the Baltic countries. It was this circumstance that influenced the choice of the research topic.

The *purpose* of the study is to identify the main areas of greening of economic development in the Baltic countries and assess their effectiveness. The *objectives* of the study

include: analysis of the current state of greening of the economy in the Baltic countries; identification of key areas and tools used for the transition to sustainable development; assessment of the effectiveness of the measures implemented and identification of barriers to greening. Based on the information received, the authors will put forward some recommendations for strengthening the integration of environmental and economic strategies in the Baltic countries.

2) Methods And Materials:

The study uses comparative analysis methods to compare approaches and results of greening the economy in Lithuania, Latvia and Estonia. Statistical methods were used to process the data, including an analysis of the dynamics of sustainable development indicators. A systems approach allowed us to consider greening the economy as a multi-component process that includes political, economic and social aspects. The data sources were scientific articles, reports of international organizations and national development strategies. Specific projects and initiatives promoting green growth were assessed.

3) RESULTS:

The analysis of the current state of greening the economy in the Baltic States (Lithuania, Latvia

and Estonia) requires consideration of key indicators that reflect progress in the areas of sustainable development, energy, waste management, emission reduction and other aspects.

Key indicators of greening the economy: energy and renewable energy sources (RES); volume of CO_2 and other greenhouse gas emissions by sectors (energy, transport, industry, agriculture); implementation of circular economy principles (reuse, recycling, reduction of waste generation); level of air pollution in cities and water quality in the Baltic Sea and inland waters; investments in environmental technologies and research; number of patents in the field of "green" technologies [5], [6], [7].

Analyzing international reports of the International Energy Agency, we can conclude that the Baltic States are actively developing the renewable energy sector, which helps to reduce dependence on fossil energy sources [8].

In 2023, 53% of all electricity was generated from clean resources in Estonia, 75% in Latvia, and about 70% in Lithuania. However, the production structure in the Baltic States is different. In Latvia, the main generation comes from hydroelectric power plants (HPPs), while in Lithuania and Estonia it comes from wind turbines, biomass, and solar power plants. Estonia has achieved significant success in the use of wind and solar energy, as confirmed by data from the International Energy Agency [8].

Estonia is the regional leader in wind energy development, with a noticeable increase in installed capacity and share in the energy balance. Latvia lags in wind and solar energy development but is showing gradual growth. Lithuania is actively developing wind energy, but solar energy plays a smaller role so far. Below is a comparative table (*Table 1*) on the use of alternative energy in the Baltic States.

Table 1 Use of alternative energy in the Baltic States

Indicator	**Year**	**Lithuania**	**Latvia**	**Estonia**
Wind energy				
Installed capacity (MW)	2021	500	70	300
	2022	600	80	350
	2023	700	90	400
Energy production (GWh)	2021	1,200	150	800
	2022	1,400	170	900
	2023	1,600	200	1,000
Share in energy balance (%)	2021	12%	5%	10%
	2022	14%	6%	12%
	2023	14%	7%	16%
Solar energy				
Installed capacity (MW)	2021	100	30	50
	2022	150	40	70
	2023	200	50	90
Energy production (GWh)	2021	120	35	60
	2022	180	45	80
	2023	100	60	250

Share in energy balance (%)	2021	1.50%	1%	2.00%
	2022	2%	1.50%	3%
	2023	2.50%	2%	4.50%

The implementation of circular economy principles is also one of the key areas of greening. Lithuania and Latvia implement waste recycling and resource reuse programs, which helps to reduce the ecological footprint [9].

The Baltic countries actively participate in international initiatives to reduce greenhouse gas emissions. National strategies include measures to improve energy efficiency and develop low-carbon technologies [10]. An important aspect of greening is the improvement of the legislative framework. The Baltic countries have adopted laws aimed at protecting the environment and stimulating environmentally friendly technologies [3].

One of the main strategic documents regulating the joint activities of the Baltic countries in greening the economy is the Baltic 2030 Action Plan, which was developed to promote sustainable development in the Baltic Sea region based on the UN Sustainable Development Goals for the period up to 2030 [11]. The main priorities of this plan are aimed at cooperation between countries and sectors to achieve the following sustainable development goals:

• *Environmental sustainability:* emphasis is placed on the protection of ecosystems and the sustainable management of natural resources, including improving water and air quality.

• *Economic transformation:* promote the transition to a green economy, which includes the use of renewable energy sources and the implementation of circular economy principles.

• *Social inclusion:* ensure that social and economic relations are inclusive and fair, promoting social cohesion and reducing poverty.

• *Sustainable mobility:* develop transport systems that are environmentally friendly and efficient, thereby reducing carbon emissions and improving accessibility.

• *Research and innovation:* promote research and innovation in the field of sustainable development to create new technologies and solutions.

• *Cooperation between countries:* strengthen cooperation between the Baltic States and other regions to share best practices and resources.

The Baltic 2030 Action Plan serves as a roadmap for the governments, businesses and society in the Baltic States to work together to build a sustainable future in the region.

Results

The geographical location of Estonia, Latvia and Lithuania provides these countries with unique opportunities to lead in the field of sustainable economic development. The main areas in which they are implementing their projects include:

Renewable energy

Lithuania is actively developing wind energy, building new wind farms. Estonia is betting on solar energy, expanding the capacity of solar power plants. Latvia, in turn, is conducting advanced research in the field of bioenergy, using forestry waste. These initiatives have already allowed the Baltic countries to increase energy independence and reduce CO2 emissions by 30% compared to 2005 levels [12]. The share of renewable energy in Lithuania's total energy balance reached 27% in 2022. Lithuania plans to increase the share of renewable energy to 45% by 2030.

More than 40% of Latvia's energy is produced from renewable sources, mainly hydropower and bioenergy. Latvia also uses forestry waste to produce biofuels, making it one of the leaders in bioenergy in the EU. The country's goal is to achieve a 50% share of renewable energy in the energy balance by 2030.

Estonia has reduced its dependence on oil shale energy, increasing the share of renewable energy to 30% in 2022. Solar energy is actively developing: the installed capacity of solar power plants has tripled over the past 5 years. The

country aims to achieve a 42% share of renewable energy by 2030.

Circular Economy

Using circular economy models in business allows for more efficient use of resources and reduction of waste in production. Such models are increasingly used by companies that produce products that require processing or packaging. Latvia and Estonia are actively implementing the principles of a circular economy, recycling up to 50% of household waste. Lithuania has become one of the EU leaders in plastic recycling, having achieved a level of 70% of recycled waste [14].

Sustainable Urban Development

Baltic cities are actively moving towards sustainable development. Tallinn is introducing environmentally friendly public transport, in Tallinn almost 80% of public transport has already been converted to electric or biofuel traction. Vilnius is using smart city technologies, and Riga is modernizing residential buildings. These initiatives have reduced emissions from transport and energy consumption in buildings, improving air quality, especially in large cities. Tallinn, Riga and Vilnius are introducing smart technologies for managing energy consumption and transport.

Sustainable agriculture

Latvia and Lithuania have traditionally had very developed agriculture, with dairy products, grains and forestry as the main segments. These countries support European agricultural policy and increase the volume of organic production, the demand for which is growing every year. Over the past five years, the area of organic farmland in Latvia has increased by 25%, while Lithuania has become the leading exporter of organic dairy products to the EU [13]. These efforts not only support environmental sustainability, but also stimulate the rural economy and create new market opportunities.

Implementation of technologies

The Baltic States actively use advanced technologies such as artificial intelligence, the Internet of Things and digital platforms to manage energy and conserve resources. For example, Estonia uses AI to optimize energy distribution, reducing energy losses by 12%. Lithuania and Latvia have implemented waste management systems based on the Internet of Things, increasing recycling rates by 18% [8]. These technologies provide accurate monitoring and proactive management of the environment, increasing efficiency, reducing costs and minimizing environmental impact.

Cross-border environmental cooperation

The Baltic States closely cooperate with other Baltic Sea countries, such as Poland and Sweden, to address common environmental challenges. Joint efforts focus on protecting the Baltic Sea, reducing pollution and implementing sustainable approaches to fisheries. For example, through the implementation of the Baltic Sea Action Plan, it was possible to reduce nutrient pollution by 20%, which has a positive effect on the state of the marine ecosystem [2]. In addition, cross-border forestry and water management projects contribute to more sustainable use of shared natural resources.

4) COMPARATIVE ANALYSIS OF ENVIRONMENTAL EFFICIENCY

A comparative analysis of the Environmental Performance Index (EPI) of Latvia, Lithuania and Estonia in five key categories – climate change impacts, air pollution, waste management, sustainability of fisheries and agriculture – also allows us to assess their progress in addressing environmental issues. The data is based on the latest available EPI reports and other international sources [15]. Below is a comparative figure of the environmental performance indicators (EPI) of Latvia, Lithuania and Estonia. Based on these indicators, it can be concluded that Lithuania has made significant progress in reducing greenhouse gas emissions, especially through the development of wind energy and the transition away from fossil fuels. Estonia has historically relied on oil shale energy but has been actively switching to renewable energy sources in recent years. This has reduced emissions, but the country still lags the EU leaders. Lithuania leads in this category due to its active development of renewable energy sources, followed by Latvia and Estonia. Latvia has demonstrated moderate success in combating climate change. The country is actively developing renewable energy, especially

bioenergy, which helps reduce CO2 emissions. However, the rate of emission reduction remains below the EU average.

Looking at *air pollution indicators*, Latvia has relatively clean air due to its low population density and large forest areas, as shown in *Figure 1*. [15].

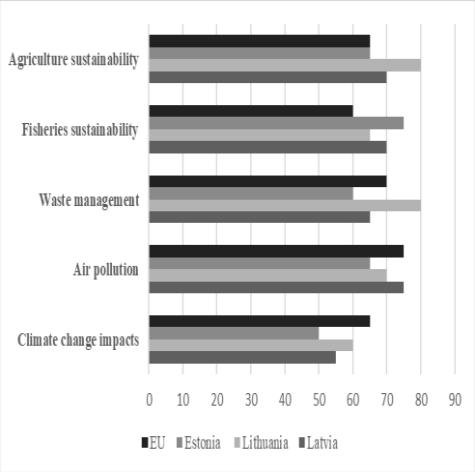

Fig.1 Comparative analysis of environmental performance

However, in cities such as Riga, traffic pollution remains a problem. Lithuania also has good air quality indicators, but industrial areas and large cities such as Vilnius face problems with traffic and heating pollution. Estonia has improved its air quality by reducing the use of oil shale, but industrial areas such as Ida-Virumaa (*in Estonian*) still suffer from high pollution. Latvia leads in air quality, followed by Lithuania and Estonia.

An analysis of *waste management* systems in the Baltic States shows different approaches and levels of efficiency. In Latvia, despite the implementation of circular economy principles and recycling of about 50% of household waste, further development of infrastructure for recycling plastic and e-waste is required. Lithuania occupies a leading position in the region, especially in plastic recycling (up to 70%), which is due to the active development of sorting and recycling systems. Estonia, demonstrating progress in waste management, has a recycling rate of about 40%, which is slightly lower than in Lithuania, with an emphasis on waste reduction and reuse (*Fig.2*). Thus, Lithuania demonstrates the most efficient waste management system among the Baltic States, followed by Latvia and Estonia [17].

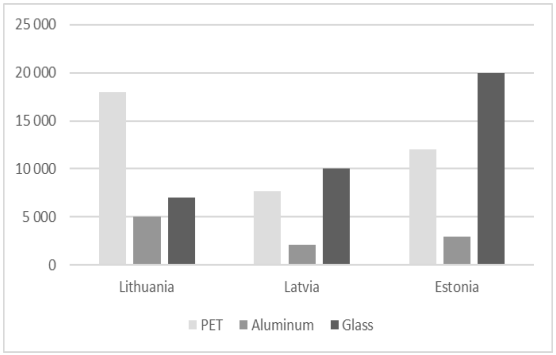

Fig.2 Volumes of recycled material per year (*in tons*)

Waste management, especially in the context of renewable energy sources, is becoming a key element of sustainable development and environmental policy in the Baltic States. Waste-to-energy projects, such as waste-to-energy plants, not only reduce the amount of waste sent to landfills, but also generate electricity and heat from municipal solid waste. These plants pre-sort waste, separating recyclable materials, and burn the remaining part at high temperatures, which allows heat to be extracted for energy production. This approach not only reduces the burden on the environment, but also contributes to the creation of new jobs and the development of a circular economy. Importantly, effective waste management and the use of renewable energy sources can significantly reduce greenhouse gas emissions and improve the environmental situation in the region.

The relationship between the use of renewable energy (RES) and the *sustainability of fisheries* and agriculture is indirect and is characterized by a complex impact on ecosystems, the economy and society. The impact of RES on the sustainability of fisheries is manifested through the reduction of water pollution because of the reduction of emissions of harmful substances entering water bodies and the reduction of the fishing fleet's dependence on fossil fuels using biofuels or electric engines. Revenues from "green" energy can be reinvested in the restoration of aquatic ecosystems and fish stocks, which contributes to

the preservation of marine biodiversity. This is relevant for all countries in the Baltic Sea region. Latvia is implementing sustainable fishing methods (catch limits, the "catch and release" principle, fish farming, etc.), which has a positive effect on marine ecosystems. Estonia and Lithuania are implementing projects to clean up water bodies and restore fish stocks. This is why the Baltic countries demonstrate high results in this category in the European ranking: Latvia ranks 15th, Estonia 18th, Lithuania 20th [15].

In the context of agriculture, renewable energy sources contribute to sustainability through the production of biogas and biofertilizers from waste, reducing dependence on fossil fuels and closing the resource cycle. Energy efficiency in agriculture is increased using solar panels and wind turbines, reducing dependence on centralized energy grids and reducing production costs. Reducing the carbon footprint of agriculture through renewable energy sources contributes to meeting climate commitments and improving the environmental resilience of agro-ecosystems. An integrated approach to sustainability requires considering ecosystem services that provide pollination, regulate water resources and maintain biodiversity [18]. The development of renewable energy sources creates economic benefits, stimulates innovation and generates new jobs in rural and coastal areas. The social aspects of sustainable resource use through renewable energy sources improve the quality of life of local communities, which is critical for long-term sustainability. Thus, the integration of renewable energy sources into agriculture and fisheries is a multifaceted process that requires a systemic analysis and consideration of the interrelations between environmental, economic and social factors to achieve sustainable development [19].

5) DISCUSSION

Despite significant progress in the production and use of alternative "clean" energy, the Baltic States face a number of challenges. One of the key challenges for the Baltic States in the field of alternative energy and sustainable development is the insufficient level of investment, because significant financial investments are needed for further development. The main problem is the limited internal resources of these countries. Lithuania, Latvia and Estonia have relatively small economies, and this limits the possibilities for large-scale investments in environmental technologies. Although the Baltic States are actively attracting funds from European Union funds, such as the Just Transition Fund and Horizon Europe, these resources are not enough for a complete transition to "green" technologies. High initial costs for the implementation of innovative technologies, such as energy storage systems or smart grids, scare off private investors. Several technological limitations can also be identified, for example, dependence on weather conditions. The use of renewable energy sources such as wind and sun can be problematic due to their instability. If there is no wind or sun, there will be no electricity. Accordingly, to compensate for the decline in electricity generation on windless and cloudy days, it is necessary to have some reserve capacity. To solve this problem, modern energy storage systems are needed, such as new generation batteries, but their implementation requires significant investment and technological knowledge. The development of environmental technologies requires specialists in engineering, IT and ecology, but there is a shortage of such specialists in the Baltic countries. As the authors have already analyzed in the article, there are also significant differences in the structure of production of this type of energy. In Latvia, the main generation of electricity occurs due to hydroelectric power plants (HPP), while in Lithuania and Estonia - due to wind turbines, biomass and solar power plants. Latvia has historically been in a stable position due to the cascade of HPPs, while its neighbors have always had an energy deficit, which stimulated them to develop projects related to renewable energy sources. Latvia has ten times less wind energy than Lithuania, and three times less than Estonia. In the context of the recent disconnection from the Russian-Belarusian energy system (BRELL) and synchronization with the European grid, the Baltic States have a few challenges to overcome. Disconnection from BRELL, a system that provided relatively cheap energy and prompt

resolution of emergency situations, may lead to higher electricity prices for consumers. It also created the need for a rapid increase in domestic energy capacity and integration into the European energy system (synchronization with the Continental Europe network via Poland).

In this regard, attracting European funding and investment is becoming especially important. Latvia, as a relatively poor country, can receive more funds in terms of distribution than other European countries. These funds can be used to improve infrastructure, increase energy efficiency and develop "green" technologies.

It is also necessary to consider that, although the Baltic States are striving for a "green" economy, it is important for them to maintain a balance between environmental goals and economic development. It is important to approach the implementation of all requirements and directives sensibly so as not to harm the national economy.

6) SOCIAL ASPECTS OF THE TRANSITION TO A "GREEN" ECONOMY

The transition to a green economy has significant social impacts, which can be both positive and negative and require careful planning and management. These impacts affect various aspects of society, including employment, quality of life, social inclusion and migration. The main social impacts of the transition to a green economy are discussed below.

Positive aspects include the creation of new jobs in the renewable energy, energy efficiency, waste management and clean production sectors, which stimulate economic growth and provide employment, especially in regions with high unemployment. In the Baltic countries, the development of wind, solar and bioenergy energy creates a demand for specialists in engineering, IT and ecology. Universities in Lithuania, Latvia and Estonia already offer programs in renewable energy and the circular economy, which helps to prepare qualified personnel. This in turn stimulates the development of educational programs and research in the field of ecology, energy and sustainable development, and the number of innovations increases.

Improving the quality of life is achieved by reducing air and water pollution, which has a positive effect on public health and promotes sustainable urban development. For example, reducing the use of fossil fuels in Estonia has improved urban air quality, reducing the incidence of respiratory diseases [20]. Sustainable urban development, including the introduction of environmentally friendly transport and energy-efficient buildings, also contributes to improving the quality of life.

Social inclusion is ensured through retraining and upgrading programs that adapt workers from traditional industries to new conditions. For example, the closure of coal mines, oil refineries and other fossil fuel-related enterprises can lead to job losses in traditional industries. The Estonian Centre for Environmental Research, in the framework of the research project CINTRAN, points to the increase in unemployment and social problems arising from the local economy's dependence on the oil shale industry [21]. The loss of jobs in the sector is causing emigration and worsening living conditions, leading to increased social tension. In general, in the Baltic countries, such programs are especially relevant for rural areas, where agriculture has traditionally been highly developed. Obviously, governments need to be prepared for such scenarios and promptly introduce subsidies and provide the necessary benefits for this group of the population.

Social inequality may increase if investments in green technologies are concentrated in large cities, ignoring rural areas. Migration and urbanization may be exacerbated by the population moving to cities in search of new jobs, which requires balanced regional development. In the Baltic countries, where there is already an outflow of young people from rural areas, this may become an additional challenge. One way to mitigate the negative effects may be preferential taxation of small and medium-sized businesses in the green sectors in rural areas.

The transition to a green economy has significant social consequences that require careful planning and management. In the Baltic countries, this process is already bringing positive results, such as the creation of new jobs and an improved quality of life. However, to minimize negative

effects such as unemployment and social inequality, comprehensive measures are needed, including retraining programs, social protection and balanced regional development. This is the only way to ensure a fair and sustainable transition to a green economy.

7) CONCLUSION

Research topics in the field of "green" economy are of great interest to scientists throughout the scientific world. However, according to the authors, three priority areas can be identified that are of the greatest importance for achieving sustainable development and solving global environmental challenges, and because they have not been sufficiently studied. These key areas include the introduction of low-carbon technologies in major economic sectors (energy, industry, agriculture), research into the social consequences of transitioning to a green economy, and the development of new economic models for sustainable growth. Each of these areas plays a crucial role in driving technological progress, ensuring social justice, and promoting economic sustainability, forming the foundation for a global shift toward sustainable development.

One of the most important topics is the introduction of low-carbon technologies in key sectors of the economy (energy, industry, agriculture), which is the basis for reducing greenhouse gas emissions and the transition to sustainable development. Research in this area will help identify the most effective technologies, their economic feasibility and environmental impacts. This is especially important in the context of growing demand for energy and resources, as well as the need to reduce the carbon footprint. The results of such research can accelerate the transition to a green economy, contributing to the achievement of the goals of the Paris Agreement and the UN Sustainable Development Goals.

The second most important topic, the authors highlight is research into the social consequences of the transition to a green economy. Such a transition will inevitably affect the labor market, especially in traditional industries such as the coal industry or oil production. Research in this area will help develop strategies to minimize social risks, including retraining programs, the creation of new jobs in green sectors and support for vulnerable groups. A deeper and more detailed study of social aspects will ensure a more equitable and inclusive transition, which will reduce resistance to change and increase public support for green initiatives. Small and medium-sized businesses operating using the traditional economic model often do not consider environmental constraints and long-term consequences of the exploitation of natural resources.

Research into new economic models of sustainable development, such as the circular economy, bioeconomy or models considering ecosystem services, will help rethink approaches to economic growth and development. The development and implementation of such models will ensure sustainable economic growth without harming the environment, which is especially important in the context of resource depletion and climate change. These three areas are a priority, as they cover key aspects of the "green" economy: technological progress, social justice and economic sustainability. Their implementation can become the basis for a global transition to sustainable development.

8) Data Availability:

No new data were created or analyzed in this study. Data sharing is not applicable to this article.

9) Conflict of interest:

The authors declare that there is no conflict of interest.

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