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Forecasts of sustainable consumption in small economies

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Abstract. Sustainable consumption is becoming an increasingly important aspect of our consumer society. The scarcity of natural resources is a growing concern in many countries. Considering the recent developments related to the promotion of sustainable production and consumption, as well as the introduction of the Climate Action Plan and the Green Deal at the EU level, it is vital to understand the trends of sustainable consumption in individual countries, which may influence overall consumption trends in Europe. The purpose of the article is to analyse the trends of sustainable consumption in small economies with limited natural resources and facing the problem of resource allocation priorities. Sustainable consumption reflects the demand side of sustainable consumption/production. Demand is the most important factor to focus on when planning economic activities, so its trends, in this case, sustainable consumption trends, must be constantly analysed. Exponential smoothing was used to forecast sustainable consumption trends. The research results show that favourable and unfavourable trends in decoupling environmental impact from economic growth and waste generation and management in small economies are forecasted. While resource and energy productivity increases show that small

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economies have begun to use their resources more efficiently, the demand and consumption of materials (and the associated environmental impact) continue to increase.

Keywords: sustainable consumption, sustainable production, corporate social responsibility, small economies, exponential smoothing

JEL Classification: C53, E21, E27, M14

1. INTRODUCTION

Sustainable consumption is often considered a driver of sustainable development (Abdulrazak & Quoquab, 2018; Brach et al., 2018; Geng et al., 2017). According to Amos and Lydgate (2020), sustainable consumption and production are among the most cost-effective and successful methods for achieving economic development, reducing environmental impact and improving human well-being. However, according to Alisat and Reimer (2015), and Korkmaz (2024), vital land resources are being depleted at an alarming rate to meet ever-increasing consumer demand. Rapid population growth and increasing industrialization have a significant impact on the depletion of limited natural resources, especially water, soil and energy (Freedman, 2004; Vojtovic et al., 2018). Also, over the past decades, the growing human population and economy have put increasing demands on biodiversity resources. Humans are altering the functioning of the entire planet by altering the earth's atmosphere through industrial emissions of carbon dioxide and depleting the ozone layer through the production of chlorofluorocarbons (Muluneh, 2021). As stated by Nash (2009), the unsustainable nature of consumption and production leads not only to climate change, increased pollution and concentrations of hazardous waste, depletion of natural resources and loss of biodiversity; it also affects the growth of global migration and inequalities in economic and social well-being between and within countries. Higher levels of consumption lead to a higher level of production, which increases energy and material demands and generates more waste (Kletzan et al., 2002; Vergragt et al., 2014). Although sustainable manufacturing initiatives have made progress in improving the efficiency of production systems, the increase in total consumption often cancels out these gains (Staniškis et al., 2008; Navickas et al., 2021). Rapid population growth, increasing industrialization, climate change, resource scarcity and biodiversity loss are the challenges facing modern society. The growth of the world's population and increasing consumption, as well as the depletion of natural resources, pollution, climate change and the extinction of biological species, all require serious changes in societal behaviour. According to the Sustainable Development Goal 12, sustainable consumption and production can contribute to environmentally sound, socially acceptable and economically viable development. Circular economy, greater resource efficiency, waste reduction, renewable sources of energy, storage and reuse of raw materials will be the main activities for sustainable consumption and production (Androniceanu et al., 2021; Glavič, 2021; Štreimikienė, 2023).

It is possible to foresee scenarios that will influence future decisions and activities. Forecasts of sustainable consumption trends can be useful in predicting the prospects for sustainable development in Europe and around the world. Forecasting trends in sustainable consumption and production can help to understand future changes and adapt to and respond to future challenges. Research development and innovation are vital for planning and implementing the necessary changes. It is essential to know how sustainable consumption and production are evolving due to technological innovation. With the help of forecasts of sustainable consumption trends, it is possible to plan transitional activities and responsibly respond to future changes. For example, as greenhouse gas emissions increase and the growth of population puts pressure on resources and the natural environment, it is necessary to plan activities that reduce greenhouse gas emissions, natural resource use, pollution growth, and waste generation. In the context of the promotion of sustainable consumption, as well as the implementation of the Climate Action Plan and the Green Deal at the EU level, it is important to understand the trends of sustainable consumption in individual countries, which can affect the overall consumption trends both in Europe and around the world.

The article aims to analyse the trends of sustainable consumption in small economies with limited natural resources and facing the problem of resource allocation priorities. The paper has three objectives: (1) To review the dimensions of sustainable consumption; (2) To analyse the characteristics of small open economies, and (3) To examine the trends of the indicators of sustainable consumption of small economies with limited natural resources.

2. LITERATURE REVIEW

2.1. Dimensions of sustainable consumption

Sustainable consumption is closely related to the interaction between nature and man. According to Brinzan et al. (2012), Čapienė et al. (2021), Novikovienė and Navickaitė-Sakalauskienė (2020) sustainable consumption is a practical process involving the economy, society and environment. As highlighted by Evans and Jackson (2008), the concept of sustainable consumption is a response to emerging consumptionism that leads to the overuse of natural resources (environmental aspect) and waste (economic aspect). Consumptionism, or, in other words, consumerism, can be understood as a condition where economic consumption becomes a way of life and when more cultural functions are transferred to the act of consumption. It is therefore characterized by high material consumption and increasing environmental degradation (Evans & Jackson, 2008). In most definitions of sustainable consumption, the aim of conscious, responsible consumption prevails, which is associated with the preservation of natural resources, and their moderate use, focusing on the possibilities of using renewable energy sources, as well as with reducing pollution, and responsible management of generated waste. Sometimes it is linked also with social welfare (Baranowski & Kopnina, 2022). As Seyfang (2004) stated, sustainable consumption is associated with meeting the basic needs of a quality life, ensuring a better quality of life. Sustainable consumption helps reduce the use of natural resources, toxic substances and emissions of waste and pollution into the atmosphere. This helps ensure the protection of the needs of future generations. This aim remains actual even under the challenging circumstances for sustainable development (Mishchuk et al., 2023). Southernton et al. (2004) defined sustainable consumption as actions focused on the appropriate use of resources to meet the needs of individuals while taking care of natural resources so as not to harm the needs of future generations. Kates et al. (2005) also emphasized that sustainable consumption provides the basis for more efficient use of energy and resources and minimizing waste generation. It also helps individuals and households make environmentally friendly purchasing decisions and reinforces values that support sustainable consumption. Bennett and Collins (2009) shared a similar view, arguing that it is good to minimize the use of capital by reducing waste and pollution, that the consumption of organic or green products should be encouraged, and that the current generation should reduce its needs for the sake of the future together. This approach became typical for current waste management studies (Ginevičius, 2022). Also, Hornibrook et al. (2015) defined sustainable consumption as the use of goods and services that meet basic needs and provide a better quality of life, while reducing the use of natural resources, toxic substances, and the release of waste and pollutants throughout the life cycle, so as not to jeopardize the needs of future generations. The UN defines sustainable production and consumption as: "the use of services and related products, which respond to basic needs and bring a better quality of life while minimising the use of natural resources and toxic materials as well as the emissions of waste and pollutants over the life cycle of the service or product so as not to jeopardise the needs of future generation." Sustainable consumption and production means "doing more and better with less" (Hoballah & Averous, 2015). Sustainable consumption involves the goal of systematically delinking economic growth from increasing resource use and environmental degradation so that more can be done with less. Decoupling will be achieved by reducing the material and energy intensity of current economic activity and amounts of emissions and waste.

Summarizing the analysed definitions of sustainable consumption, it can be stated that sustainable consumption is a rather broad concept that includes not only environmental but also economic, social and health dimensions. It is a complex process that encourages consideration of the consequences of consumption in various aspects. The authors of the article, taking into account the context of small economies, open and characterized by limited natural resources, concentrated on the analysis of trends of two dimensions, i.e., environmental and economic, of sustainable development (see Figure 1). The environmental dimension is associated with the decoupling of environmental impact from economic growth, and the economic dimension is associated with the circular economy concept, which aims to maintain the value of materials and products in the market, disposing of them as little as possible in landfills, i.e. associated with waste generation and management. Waste control is related not only to the management of already generated waste but also to the preservation of natural resources, which are used in production processes to generate waste.

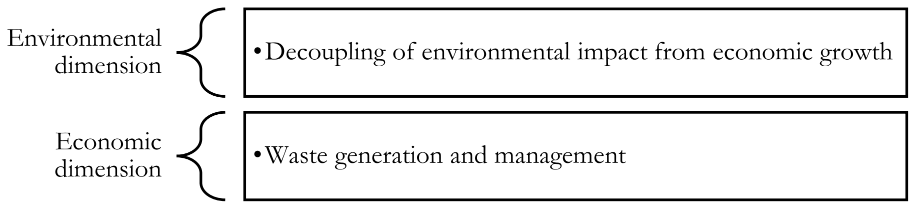

Figure 1. Environmental and economic dimensions of sustainable consumption
Source: developed by the authors based on Kates et al. (2005), Evans & Jackson (2008), Bennett & Collins (2009), Ginevičius (2022), and Mishchuk et al. (2023)

It can be stated that both dimensions are closely interconnected and complement each other. However, as stated by Pitt (2009), the development of components of sustainable development may not necessarily affect other components, which is also related to the dimensions of sustainable consumption. Therefore, the analysis of individual dimensions of sustainable consumption and the forecasting of their trends is important for the comprehensive understanding of sustainable consumption trends in small economies.

2.2. Characteristics of small open economies

According to Lederman & Lesniak (2017), small economies are defined as economies with a working age population less than the global median of 5.3 million. It was also found that the development potential of small economies will not necessarily be limited, because gross domestic product (GDP) growth rates, like GDP per capita levels, are not related to size. However, while size does not necessarily impede development outcomes, small economies may have different development challenges than large economies that require different solutions. Small economies differ from large economies regarding social, political, and economic factors (Kose, 2002). A small economy is not a player in the global economy that dictates terms. Small economies and their growth are greatly influenced by economic openness, which can compensate for certain disadvantages: a small internal market, limited resources, low diversification of activities, fluctuations in economic growth, economic vulnerability, and less protection against shocks (Lederman & Lesniak, 2017).

In addition, a greater degree of openness allows small economies to more quickly meet the demand for limited natural resources and adopt technologies developed in advanced large economies. Guerron-Quintana (2013) singled out smooth consumption as one of the salient dimensions of small open economies. In small open economies, consumption is smoother than production. In advanced economies, consumption can be moderated because people have access to financial markets. Access to these markets means that borrowing can be done to offset the decline in income. This means that consumption does not fall as much as income falls. Another important dimension of smaller countries is that they tend to have a more concentrated production structure and exports, usually focused on basic goods. As Kose (2002) emphasized, these countries are precisely vulnerable to world price shocks because of their production and international trade structure. In contrast to large countries, small economies tend to export a larger share of output and import a larger share of consumption (Žiković & Vlahinic-Dizdarević, 2011). Consumption of goods causes pollution. According to Hu and McKitrick (2016), consumption and residential activities are considered important sources of pollution, such as carbon dioxide and sulfur dioxide emissions, and solid waste accumulation. As Tsakiris et al. (2018) emphasized, in many cases the same consumer needs are met by different goods produced in different countries using different materials and technologies. Consumption of such different types of the same good, produced in the same country or imported, meeting the same consumer needs, may result in different levels of pollution per unit of consumption. Consumption is highly volatile in a changing external environment (Guerron-Quintana, 2013; Gedvilaite & Ginevicius, 2024). For small open economies, the risk remains that the challenges posed by the external environment are so great that the country cannot deal with them, at least in the short term. The risk of instability from externalities can sometimes have undesirable consequences for small and open economies. In summary, it is possible to single out the characteristics of small open economies that must be taken into account when assessing trends in sustainable consumption: a small internal market; limited natural resources; low diversification of activities; fluctuations in economic growth; economic vulnerability; less protection against external shocks; the development is greatly influenced by economic openness; consumption is smoother than production; a more concentrated production structure and exports; the risk of instability from externalities; tend to export a larger share of output; tend to import a larger share of consumption. The characteristics highlighted are typical of Europe's small open economies. Although common characteristics exist, the diversity of small open economies reflects their unique contexts and choices, including consumption choices and sustainable consumption decisions and trends.

These characteristics are common to the three Baltic countries: Estonia, Latvia and Lithuania. The Baltic countries share common developments and key structural characteristics: their overall economic situation and policies, their structure of production, their main trade partners and their population flows, underlining their similarities, but also differences. In recent years, the economies of the Baltic countries have experienced a subtle shift in consumer attitudes towards sustainability. Despite the complexity introduced by global events, since 2023 the decline in consumer interest in sustainability in Lithuania has been slight, in Latvia interest has remained stable, and in Estonia, it has increased (Sustainable Brand Index, 2024). Sustainable consumption trends in the Baltic countries were analysed during the empirical study. The economies of the Baltic countries are characterized as small open economies, so the analysis of sustainable consumption trends is useful not only for the countries' sustainable development policies and decisions promoting sustainable consumption but also for most European countries. According to Dagilienė et al. (2023), most EU countries are separately classified as small open economies. EU countries have a great influence on the world economy. Small open economies play a critical role worldwide, but a comprehensive analysis of sustainable consumption trends in small open economies is lacking.

3. METHODOLOGY

Depending on the context, planning or decision-making related to real-time sustainable consumption in small economies requires forecasting. Short-term forecasting is more difficult than long-term forecasting because of the high latency and need for precision (Assimakopoulos & Nikolopoulos, 2000; Brown et al., 1961; Chen et al., 2000; Jose & Winkler, 2008; McKenzie, 1986; Svetunkov et al., 2022). In changing environmental conditions, short-term forecasting is effectively used when there is a need to make decisions about sustainable consumption management and related resource allocation. To choose the optimal forecasting model, when it was necessary to consider more models in a specific case, and to examine their suitability and give preference to models with low computational complexity, exponential smoothing models were chosen. Simple exponential smoothing models include single smoothing and double smoothing, which involve a single parameter $0 < \alpha \leq 1$; Holt-Winters No Seasonal model with two parameters $0 \leq \alpha, \beta \leq 1$ for level and trend; Holt-Winters Additive Seasonal and Holt-Winters Multiplicative Seasonal, which include three parameters $0 \leq \alpha, \beta, \gamma \leq 1$ for level, trend and seasonality. Exponential smoothing models are powerful methods for time series forecasting that allow for accurate predictions of future values based on past observations (Chatfield et al., 2001; Jose & Winkler, 2008; Kim & Ryan, 2003; Kolassa, 2011; Rostami-Tabar et al, 2013; Smy, 2020). According to Chen et al. (2000) and Makridakis et al. (2020), the models are simple to apply, and the obtained data predictions are realistic, their accuracy comparable to the accuracy of data predictions obtained using alternative projection models, which are (much) more complex.

The empirical study uses the annual sustainable consumption data of the analysed small open economies (Estonia (EE), Latvia (LV) and Lithuania (LT)) provided by Eurostat (2024). The indicators are part of the EU Sustainable Development Goals (SDG) set of indicators. They are used to monitor progress towards sustainable consumption and production patterns, which are included in the European Commission's priorities under the European Green Deal (thematic area "Decoupling environmental impact from economic growth") and the Circular Economy (thematic area "Waste generation and management"). These are the sustainable consumption indicators of the analysed countries for the years 2010 - 2022, presented in the Eurostat database and reports, but some indicators have shorter time series (from 2012 to 2021). The sustainable consumption indicators studied:

Decoupling environmental impacts from economic growth

- Material footprint per capita (tonnes per capita)
- Domestic material consumption (tonnes per capita)
- Resource productivity (euro per kg)
- Energy productivity (euro per kg of oil equivalent (KGOF))
- Circular material use (% of total material use)
- Share of renewable energy in gross final energy consumption (% of GDP)

Waste generation and management

- Generation of municipal waste per capita (kg per capita)
- Generation of packaging waste per capita (kg per capita)
- Generation of plastic packaging per capita (kg per capita)
- Recycling rate of municipal waste (% of municipal waste recovered and recycled)
- Recycling rate of packaging waste (% of packaging waste recovered and recycled)
- Recycling rate of plastic packaging waste (% of packaging waste recovered and recycled)
- Recycling rate of waste of electrical and electronic equipment (WEEE) separately collected (% of WEEE recovered and recycled)

After that, the data were organized for exponential smoothing models. The data for the variables mentioned were estimated using five exponential smoothing models.

The accuracy of the model can be identified by using selection criteria. In the study, root mean square errors (RMSEs) were calculated to test the capability of exponential smoothing models. The formulation of this criterion is expressed in the equation (from Becerra et al., 2020; Guleryuz 2021):

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{t=1}^{n} e_t^2}$$

The RMSE statistic provides information about the short-term performance of a model by allowing a term-by-term comparison of the actual difference between the estimated and the measured value. The lower the value, the better the model's performance (Kambezidis, 2012; Zhao et al., 2022).

4. EMPIRICAL RESULTS AND DISCUSSION

To analyse the trends of the indicators of sustainable consumption of individual countries, first of all, the most accurate model of exponential smoothing was chosen for forecasting each indicator of each country according to the root mean square error. After selecting the most precise model, the forecasting equations were developed, based on which forecasts of the values of individual sustainable consumption indicators for the 2023-2025 years were determined.

To predict trends in decoupling the impact on the environment from economic growth, forecasts of indicators of material footprint per capita, domestic material consumption, resource productivity, energy productivity, circular material use, the share of renewable energy in gross final energy consumption for the years 2023-2025 were determined.

Based on root mean square errors, Holt-Winters Additive and Holt-Winters Multiplicative models were applied for forecasting the indicators of material footprint per capita (see Table 1).

Table 1

RMSEs of exponential smoothing models for forecasts of material footprint per capita

Model / Indicator	Single	Double	Holt-Winters No Seasonal	Holt-Winters Additive	Holt-Winters Multiplicative
Material footprint per capita (EE)	1,921	2,055	1,926	**1,555**	1,580
Material footprint per capita (LT)	1,507	0,926	0,805	**0,785**	0,821
Material footprint per capita (LV)	1,356	0,868	0,904	**0,788**	0,794
Material footprint per capita (EU)	0,547	0,620	0,605	0,502	**0,486**

Source: Authors' calculations

The highest material footprint per capita among the analysed countries is forecasted in Estonia, which will reach 28.1 tonnes per capita in 2025. Analysing the forecasts of the material footprint per capita in Estonia for the years 2023-2025, a decreasing trend of the indicator can be observed. However, the forecasted material footprint per capita is twice as high as the EU average. The lowest material footprint per capita among the analysed Baltic countries is forecasted in Latvia. The forecasted material footprint per capita for 2025 is 20.1 tonnes per capita in Latvia. Analysing the forecasts of the material footprint per capita in Latvia for 2023-2025, an increasing trend of the indicator can be seen. In 2023-2025, a growing trend of the material footprint per capita indicator is forecasted in Lithuania (see Table 2).

Table 2

Forecasts of material footprint per capita in 2023-2025, tonnes per capita

Equation of the best model		Forecasts		
		2023	2024	2025
EE	y_t=28,34+0,352*t+c_t	30.49	28.34	28.10
LT	y_t=22,56519+0,668*t+c_t	23.90	24.05	23.64
LV	y_t=18,88+0,5*t+c_t	19.90	20.05	20.10
EU	y_t=(15,09527-0,06*t)*c_t	15.01	15.06	14.65

Source: Authors' calculations

From 2010 to 2020, the material footprint per capita in all Baltic countries increased and this trend is forecasted until 2025. The average material footprint per capita remains more or less the same as during the analysed period in the EU (see Figure 2).

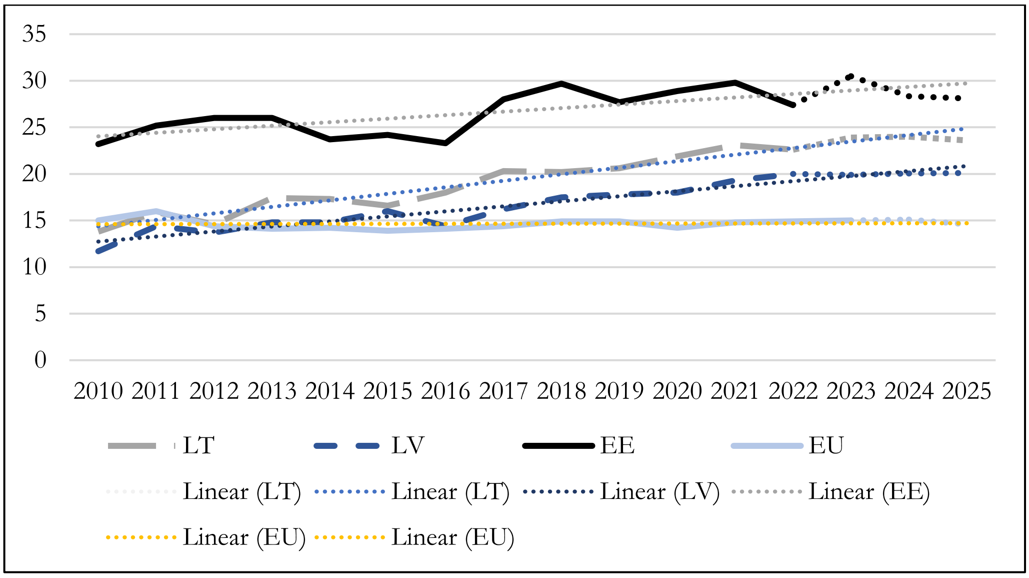

Figure 2. Trends in material footprint per capita in 2010-2025, tonnes per capita

Source: Authors' results

Based on root mean square errors, Holt-Winters No Seasonal, Holt-Winters Additive, and Holt-Winters Multiplicative models were applied for forecasting the indicators of domestic material consumption per capita (see Table 3).

Table 3

RMSEs of exponential smoothing models for forecasts of domestic material consumption per capita

Model / Indicator	Single	Double	Holt-Winters No Seasonal	Holt-Winters Additive	Holt-Winters Multiplicative
Domestic material consumption (EE)	1,834	2,069	2,012	1,385	**1,384**
Domestic material consumption (LT)	1,333	0,860	**0,772**	0,783	0,814
Domestic material consumption (LV)	1,117	0,724	0,751	**0,651**	0,654
Domestic material consumption (EU)	0,453	0,486	0,482	0,433	**0,426**

Source: Authors' calculations

The highest domestic material consumption per capita among the analysed countries is forecasted in Estonia, which in 2025 will reach 30.29 tonnes per capita. Analysing the forecasts of domestic material consumption per capita in Estonia for 2023-2025, a slight upward trend of the indicator can be observed. However, the forecast of domestic material consumption per capita of Estonia will be more than double the EU average (14.39 tonnes per capita) in 2025. The lowest domestic material consumption per capita among the analysed Baltic countries is forecasted in Latvia. In 2023-2025, the domestic material consumption in Latvia is forecasted to be relatively stable at around 17.2 tonnes per capita, indicating a very slight increase of 0.4% compared to 2022 (16.5 tonnes per capita). In 2023-2025, a slightly increasing trend in the domestic material consumption per capita is forecasted in Lithuania (see Table 4).

Table 4

Forecasts of domestic material consumption per capita in 2023-2025, tonnes per capita

Equation of the best model		Forecasts		
		2023	2024	2025
EE	y_t=(29,6+0,244*t)*c_t	31.94	28.90	30.29
LT	y_t=21,07+0,924*t	21.99	22.92	23.84
LV	y_t=16,20+0,424*t+c_t	17.29	17.19	17.21
EU	y_t=(14,59-0,052*t)*c_t	14.40	14.51	14.39

Source: Authors' calculations

Since 2010, the domestic material consumption per capita has increased by 68% in Lithuania. From 2010 to 2020, the domestic material consumption per capita in Latvia and Lithuania increased and this trend is forecasted until 2025. The average domestic material consumption per capita remains relatively stable during the analysed period in the EU (see Figure 3).

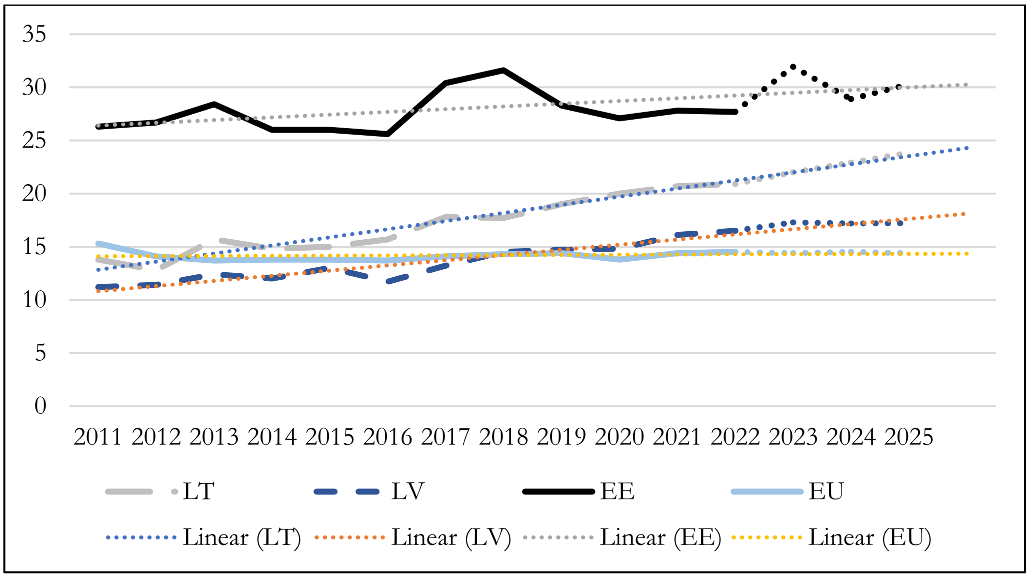

Figure 3. Trends in domestic material consumption per capita in 2010-2025, tonnes per capita

Source: Authors' results

Based on root mean square errors, Single, Holt-Winters Additive, and Holt-Winters Multiplicative models were applied to forecast resource productivity indicators (see Table 5).

Table 5

RMSEs of exponential smoothing models for forecasts of resource productivity

Model / Indicator	Single	Double	Holt-Winters No Seasonal	Holt-Winters Additive	Holt-Winters Multiplicative
Resource productivity (EE)	0,045	0,034	0,038	0,024	**0,023**
Resource productivity (LT)	**0,039**	0,045	0,041	0,042	0,042
Resource productivity (LV)	**0,048**	0,058	0,058	0,055	0,055
Resource productivity (EU)	0,056	0,043	0,042	**0,039**	0,040

Source: Authors' calculations

For 2023-2025, the highest resource productivity among the analysed Baltic countries is forecasted in Latvia, which will reach 0.99 euro per kg and remain stable. In 2023-2025, the productivity of resources in Lithuania is forecasted to be lower than in Latvia and will be 0.82 euro per kilogramme. It is forecasted, that the resource productivity indicator in Latvia will remain stable in the coming years. In 2023-2025, the lowest resource productivity indicators are forecasted in Estonia, compared to similar indicators in Latvia and Lithuania, but a growth trend in resource productivity is forecasted. The forecasted resource productivity in the Baltic countries is more than two times lower than the average resource productivity in the EU (see Table 6).

Table 6

Forecasts of resource productivity in 2023-2025, euro per kg

Equation of the best model		Forecasts		
		2023	2024	2025
EE	$y_t=(0,672+0,0136*t)*c_t$	0.64	0.69	0.75
LT	$y_t=0,821381$	0.82	0.82	0.82
LV	$y_t=0,98699$	0.99	0.99	0.99
EU	$y_t=2,117601+0,0324*t+c_t$	2.15	2.17	2.23

Source: Authors' calculations

Since 2010, the average EU resource productivity indicators have increased. A similar trend of resource productivity growth is observed in Estonia. However, resource productivity has decreased in Latvia and Lithuania. In 2010-2022, resource productivity in Latvia decreased by 10.5%, and in Lithuania by 2.4%. (see Figure 4).

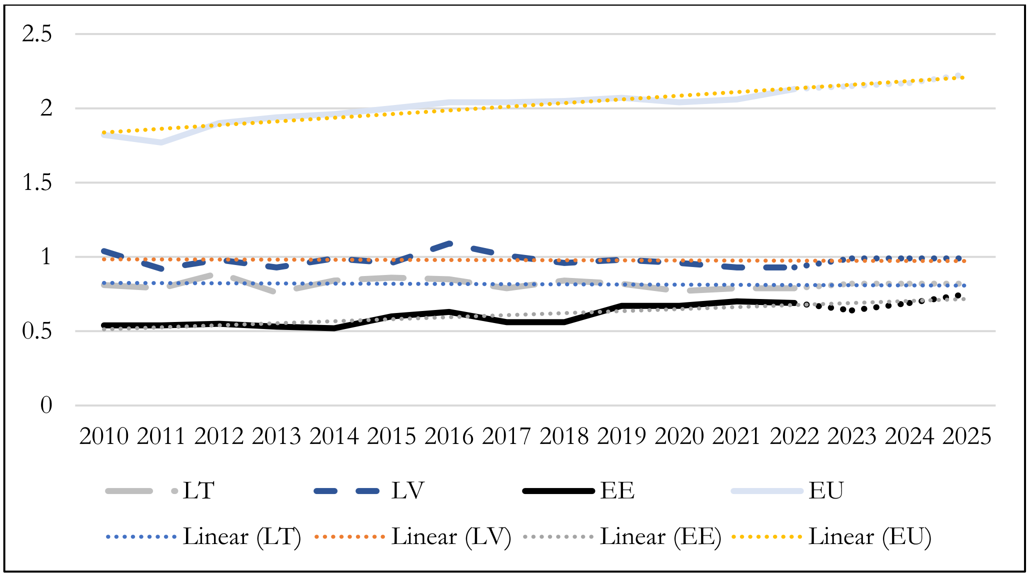

Figure 4. Trends in resource productivity in 2010-2025, euro per kg

Source: Authors' results

Based on root mean square errors, Holt-Winters Additive and Holt-Winters Multiplicative models were applied for forecasting the indicators of energy productivity (see Table 7).

Table 7

RMSEs of exponential smoothing models for forecasts of energy productivity

Model / Indicator	Single	Double	Holt-Winters No Seasonal	Holt-Winters Additive	Holt-Winters Multiplicative
Energy productivity (EE)	0,363	0,320	0,319	0,271	**0,267**
Energy productivity (LT)	0,287	0,218	0,206	**0,193**	0,194
Energy productivity (LV)	0,254	0,140	0,133	0,112	**0,112**
Energy productivity (EU)	0,371	0,202	0,210	0,192	**0,191**

Source: Authors' calculations

For 2025, Lithuania is forecasted to have the highest energy productivity among the analysed Baltic countries and will reach 7.78 euro per kg of oil equivalent. Analysing the forecasts of the Lithuanian energy productivity indicator, it can be observed, that this indicator will have a constant tendency to increase. Similar increasing trends of the energy productivity indicator are forecasted in Latvia and Estonia in 2023-2025. However, lower energy productivity indicators are forecasted in Latvia (5.48 KGOF, 5.47 KGOF, and 5.64 KGOF) and Estonia (4.21 KGOF, 4.48 KGOF, and 4.91KGOF) than in Lithuania (6.54 KGOF, 7.30 KGOF, and 7.78 KGOF) during the analysed period. It can also be noted that the forecasted energy productivity indicators of Latvia and Estonia are significantly lower than the forecasted EU average energy productivity indicators for the years 2023-2025. In all three Baltic countries, growth in energy productivity is forecasted in the coming years (see Table 8).

Table 8

Forecasts of energy productivity in 2023-2025, euro per kg of oil equivalent

Equation of the best model		Forecasts		
		2023	2024	2025
EE	y_t=(4,3358+0,124*t)*c_t	4.21	4.84	4.91
LT	y_t=5,8588+0,6432*t+c_t	6.54	7.30	7.78
LV	y_t=(5,31+0,122*t)*c_t	5.48	5.47	5.64
EU	y_t=(8,7746+0,1892*t)*c_t	8.85	9.26	9.21

Source: Authors' calculations

Since 2010, the growth in energy productivity has been observed in all Baltic countries. An increase in the average EU energy productivity indicator is also observed. Although the increasing trends of energy productivity indicators are similar, energy productivity indicators in the Baltic countries are significantly lower than the EU average energy productivity indicators. From 2010 to 2022, energy productivity in Latvia increased by 50.8%, in Lithuania by 51.3% and in Estonia by 74.6% (see Figure 5).

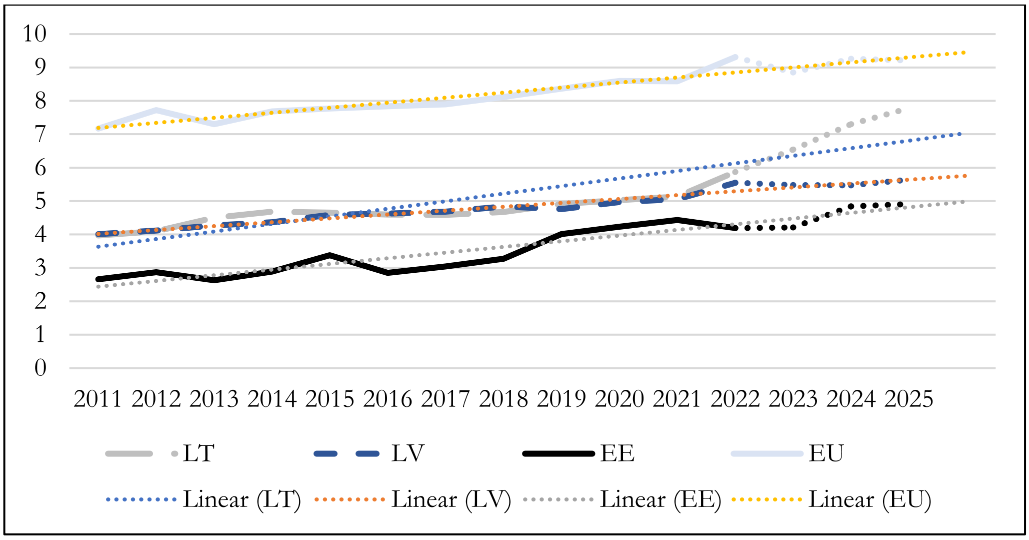

Figure 5. Trends in energy productivity in 2010-2025, euro per kg of oil equivalent

Source: Authors' results

Based on root mean square errors, Holt-Winters No Seasonal and Holt-Winters Additive models were applied for forecasting the indicators of circular material use (see Table 9).

Table 9

RMSEs of exponential smoothing models for forecasts of circular material use

Model / Indicator	Single	Double	Holt-Winters No Seasonal	Holt-Winters Additive	Holt-Winters Multiplicative
Circular material use (EE)	2,700	2,900	**2,570**	2,730	2,640
Circular material use (LT)	0,390	0,410	0,400	**0,389**	0,450
Circular material use (LV)	1,310	1,159	1,155	**0,882**	1,323
Circular material use (EU)	0,300	0,270	0,260	**0,209**	0,214

Source: Authors' calculations

For 2023-2025, Estonia is forecasted to have the highest circular material use among the analysed Baltic countries. The forecasted indicators of circular material use in Estonia (16.50%, 17%, and 17.50%) are significantly higher than the forecasted average indicators of circular material use in the EU (11.68%, 11.37%, and 11.57%). The forecasted indicators of circular material use in Lithuania (3.66%, 3.49%, and 4.67%) are lower than the forecasted averages of circular material use in the EU. The forecast indicators of circular material use in Latvia (6.3%, 7.05%, and 7.72%) are lower than the forecasted similar indicators in Estonia and the averages of circular material use in the EU, but twice exceed the forecasted indicators in Lithuania. In all three Baltic countries, growth in circular material use is forecasted in the coming years (see Table 10).

Table 10

Forecasts of circular material use in 2023-2025, %

Equation of the best model		Forecasts		
		2023	2024	2025
EE	y_t=16,00+0,5*t	16.50	17.0	17.50
LT	y_t=3,88+0,1296*t+c_t	3.66	3.49	4.67
LV	y_t=6,16+0,484*t+c_t	6.30	7.05	7.72
EU	y_t=11,52-0,0012*t+c_t	11.68	11.37	11.57

Source: Authors' calculations

Since 2010, the growth in circular material use has been observed in all Baltic countries. An increase in the average EU circular material use indicator is also observed. The largest growth in circular material use was observed in Latvia, i.e., from 2010 to 2022, the circular material use increased almost three times. A large increase (75.8%) in circular material use was also observed in Estonia in 2010-2022. In Lithuania, circular material use increased by 5.1%, and the average indicator of circular material use in the EU increased by 7.5%. Although circular material consumption growth trends have been observed in all three small Baltic economies, the level of circular material use varied significantly (see Figure 6).

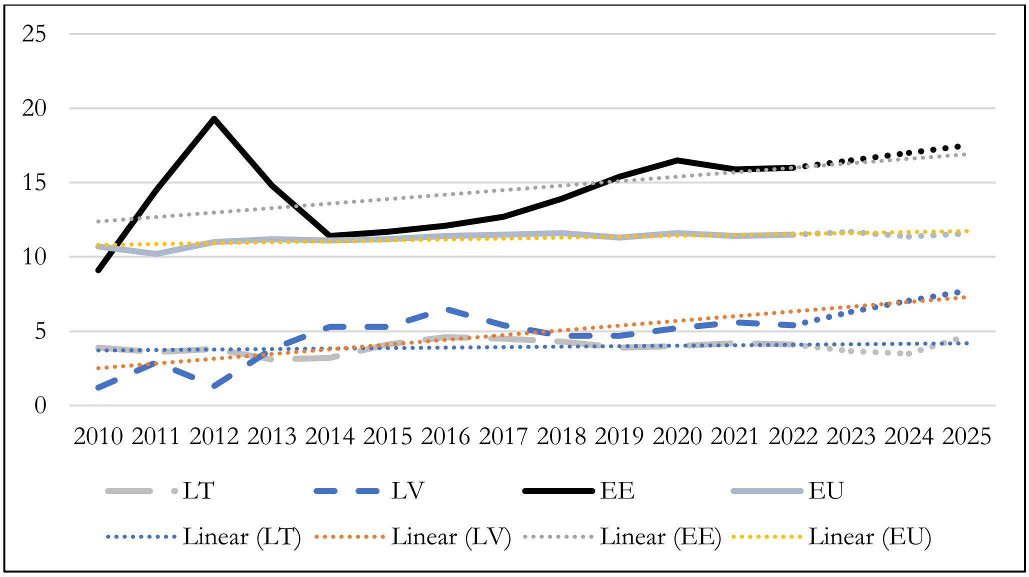

Figure 6. Trends in circular material use in 2010-2025, %

Source: Authors' results

Based on root mean square errors, Double, Holt-Winters Additive, and Holt-Winters Multiplicative models were applied to forecast the share of renewable energy in gross final energy consumption (see Table 11).

Table 11

RMSEs of exponential smoothing models for forecasts of the share of renewable energy in gross final energy consumption

Indicator \ Model	**Single**	**Double**	**Holt-Winters No Seasonal**	**Holt-Winters Additive**	**Holt-Winters Multiplicative**
Share of renewable energy in gross final energy consumption (EE)	2,377	1,985	1,960	**1,804**	1,825
Share of renewable energy in gross final energy consumption (LT)	1,431	0,971	0,849	0,772	**0,752**
Share of renewable energy in gross final energy consumption (LV)	2,078	1,284	1,057	**1,024**	1,120
Share of renewable energy in gross final energy consumption (EU)	1,200	**0,619**	0,698	0,731	0,752

Source: Authors' calculations

It is forecasted that in 2023-2025 Latvia will have the highest share of renewable energy in gross final energy consumption among the Baltic countries under analysis. The forecasted indicators of the share of renewable energy in gross final energy consumption in Latvia (44.29% of GDP, 45.54% of GDP, and 43.60% of GDP) are almost twice as high as the forecasted average indicators in the EU (23.07% of GDP, 23.74% of GDP, and 24.41% of GDP). The forecasted indicators of the share of renewable energy in gross final energy consumption in Lithuania (29.53% of GDP, 30.40% of GDP, and 32.81% of GDP) are lower than the forecasted analogous indicators of Latvia and Estonia. The forecasted indicators of the share of renewable energy in gross final energy consumption in Estonia (33.36% of GDP, 35.56% of GDP, and 37.90% of GDP) are lower than the forecasted analogous indicators in Latvia but higher than the forecasted indicators in Lithuania. It is forecasted, that the share of renewable energy in gross final energy consumption will increase in all three Baltic countries in the coming years (see Table 12).

Table 12

Forecasts of the share of renewable energy in gross final energy consumption in 2023-2025, % of GDP

Equation of the best model		Forecasts		
		2023	2024	2025
EE	y_t=34,32+0,888*t+c_t	34.36	35.56	37.90
LT	y_t=(29,36062+0,812*t)*c_t	29.53	30.40	32.81
LV	y_t=42,76+0,772*t+c_t	44.29	45.54	43.60
EU	y_t=22,40487+0,666785*t	23.07	23.74	24.41

Source: Authors' calculations

Since 2010, the growth of the share of renewable energy in gross final energy consumption has been observed in all Baltic countries. An increase in the average share of renewable energy in gross final energy consumption of the EU (reaching 60%) is also observed. From 2010 to 2022, the share of renewable energy in gross final energy consumption grew by 51% in Lithuania, 42.4% in Latvia, and 56.5% in Estonia. In 2022, Latvia reached a 43.3 % share of its gross final energy consumption from renewable sources (see Figure 7).

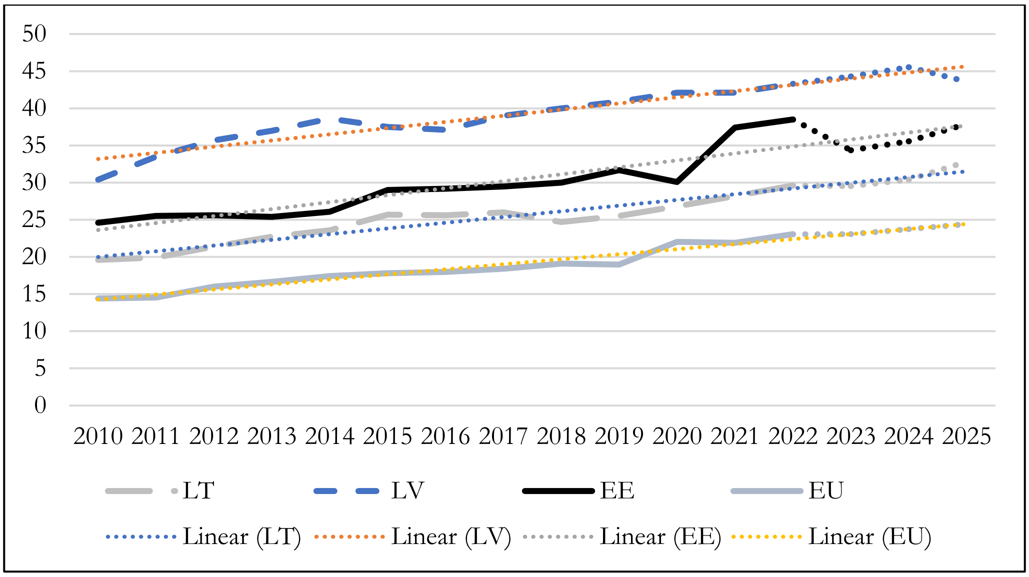

Figure 7. Trends in the share of renewable energy in gross final energy consumption in 2010-2025, % of GDP

Source: Authors' results

To predict trends in waste generation and management, forecasts of indicators of municipal waste generation per capita, packaging waste generation per capita and plastic packaging generation per capita were determined for the years 2023-2025. Forecasts of recycling rates for municipal waste, packaging waste, plastic packaging waste, and electrical and electronic equipment waste (WEEE waste) for 2023-2025 were also determined.

Based on root mean square errors, Double, Holt-Winters No Seasonal, Holt-Winters Additive, and Holt-Winters Multiplicative models were applied to forecast municipal waste generation per capita (see Table 15).

Table 15

RMSEs of exponential smoothing models for forecasts of municipal waste generation per capita

Model / Indicator	Single	Double	Holt-Winters No Seasonal	Holt-Winters Additive	Holt-Winters Multiplicative
Generation of municipal waste per capita (EE)	24,704	26,537	**24,188**	25,413	26,513
Generation of municipal waste per capita (LT)	15,268	**10,780**	12,947	10,963	11,303
Generation of municipal waste per capita (LV)	25,610	17,343	16,644	**10,087**	10,669
Generation of municipal waste per capita (EU)	10,409	10,867	9,871	8,760	**8,686**

Source: Authors' calculations

In 2025, Latvia is forecasted to have the highest municipal waste per capita generation among the analysed Baltic countries, reaching 541.50 kg per capita. It is predicted that from 2023 to 2025, the generation of municipal waste in Lithuania will be lower than in Latvia, ranging from 478.51 kg per capita in 2023 to 487.08 kg per capita in 2025. The forecast for Estonia shows that the generation of municipal waste will be lower than in Latvia and Lithuania from 2023 to 2025, with estimates of 387.54 kg per capita in 2023, 399.37 kg per capita in 2024, and 411.21 kg per capita in 2025. Overall, municipal waste generation in the Baltic economies is expected to rise from 2023 to 2025, and the indicator of municipal waste generation in Latvia will exceed the average of municipal waste generation in the EU in 2025 (see Table 16).

Table 16

Forecasts of municipal waste generation per capita in years 2023-2025, kg per capita

Equation of the best model		Forecasts		
		2023	2024	2025
EE	y_t=375,7063+11,8333*t	387.54	399.37	411.21
LT	y_t=474,2193+4,28575*t	478.51	482.79	487.08
LV	y_t=484,2+14,2*t+c_t	482.50	508.0	541.50
EU	y_t=(511,7781+1,16*t)*c_t	508.77	510.26	516.94

Source: Authors' calculations

From 2010 to 2022, an increase in the amount of generated municipal waste is observed in all three Baltic economies. However, the indicators of generated municipal waste were lower than the average analogous indicators in the EU. A decrease in generated municipal waste is also fixed in all Baltic countries in 2022, but its growth is forecasted in 2023-2025 (see Figure 8). From 2010 to 2022, the amount of municipal waste generated per capita increased by 15% in Lithuania, by 22% in Estonia, and by, even, 50% in Latvia. Meanwhile, on average, the amount of municipal waste generated per EU resident increased by only about 2 %.

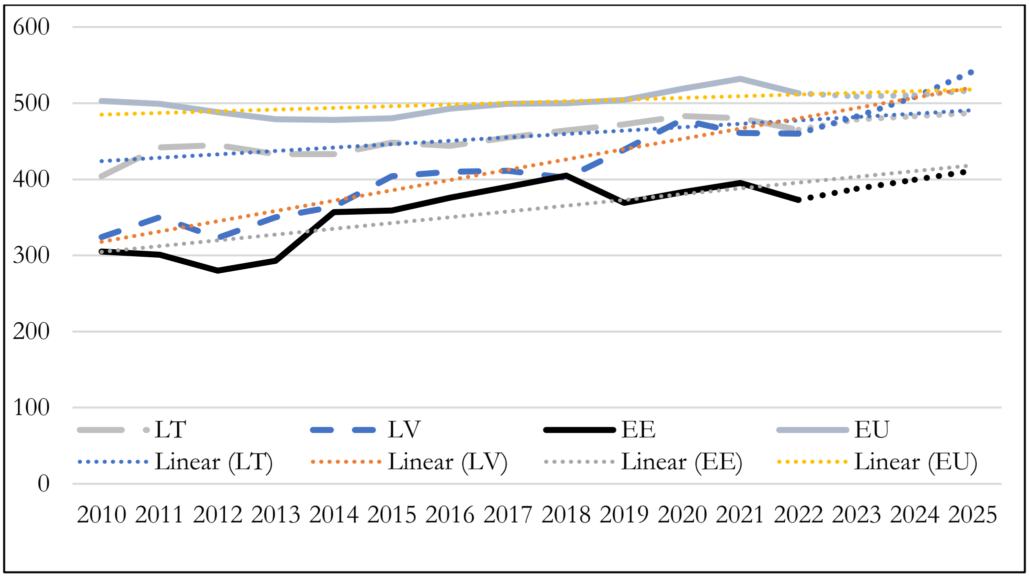

Figure 8. Trends in municipal waste per capita generation, kg per capita

Source: Authors' results

Based on root mean square errors, Holt-Winters No Seasonal and Holt-Winters Additive models were applied to forecast packaging waste generation per capita (see Table 17).

Table 17

RMSE of exponential smoothing models for forecasts of packaging waste generation per capita

Model / Indicator	Single	Double	Holt-Winters No seasonal	Holt-Winters Additive	Holt-Winters Multiplicative
Generation of packaging waste per capita (EE)	14,879	10,535	**9,774**	12,204	12,715
Generation of packaging waste per capita (LT)	7,501	3,694	3,687	**3,096**	3,255
Generation of packaging waste per capita (LV)	6,638	4,162	3,686	**2,608**	2,672
Generation of packaging waste per capita (EU)	4,530	3,158	3,058	**2,051**	2,092

Source: Authors' calculations

In 2025, Latvia is forecasted to have the highest packaging waste per capita generation among the analysed Baltic countries, reaching 202.46 kg per capita. It is predicted that from 2023 to 2025, the generation of municipal waste in Lithuania will be lower than in Latvia, ranging from 134.7 kg per capita in 2023 to 140.14 kg per capita in 2025. Although it is forecasted that the indicator of packaging waste generation in Estonia in 2023 (143.08 kg per capita) will be higher than the analogous indicator in Lithuania, the amount of packaging waste generated in Estonia in 2025 will be the lowest among the Baltic countries. It is forecasted that the amounts of packaging waste generated in Estonia and Lithuania will be lower than in Latvia in 2023-2025, and their indicators will be lower than the average analogous indicators in the EU. Different trends in the generation of packaging waste in the Baltic countries are forecasted: the amount of generated packaging waste will decrease in Estonia, will remain relatively stable in Lithuania, and will increase in Latvia (see Table 18).

Table 18

Forecasts of packaging waste generation per capita in 2023-2025, kg per capita

Equation of the best model		Forecasts		
		2023	2024	2025
EE	y_t=149,4636-3,190551*t	143.08	139.89	136.70
LT	y_t=134,692+1,4368*t+c_t	134.70	140.30	140.14
LV	y_t=153,7562+11,98117*t+c_t	181.48	189.07	202.46
EU	y_t=183,724+2,996*t+c_t	187.42	191.82	197.05

Source: Authors' calculations

From 2010 to 2021, an increase in the amount of generated packaging waste is observed in Latvia and Lithuania. In 2010, the amount of packaging waste in Lithuania was 88 kg per capita, and in 2021 it was already 136.9 kg per capita. In 2010, the amount of packaging waste in Latvia was 101.9 kg per capita, and in 2021 it was already 153.9 kg per capita. A similar trend in the growth of packaging waste generated is also observed in the EU. However, a different situation is observed in Estonia: from 2010 to 2017, there was a fixed increase in the amount of generated packaging waste, and since 2017, the amount of generated packaging waste has been decreasing, and it is forecasted that this trend will continue until 2025 (see Figure 9).

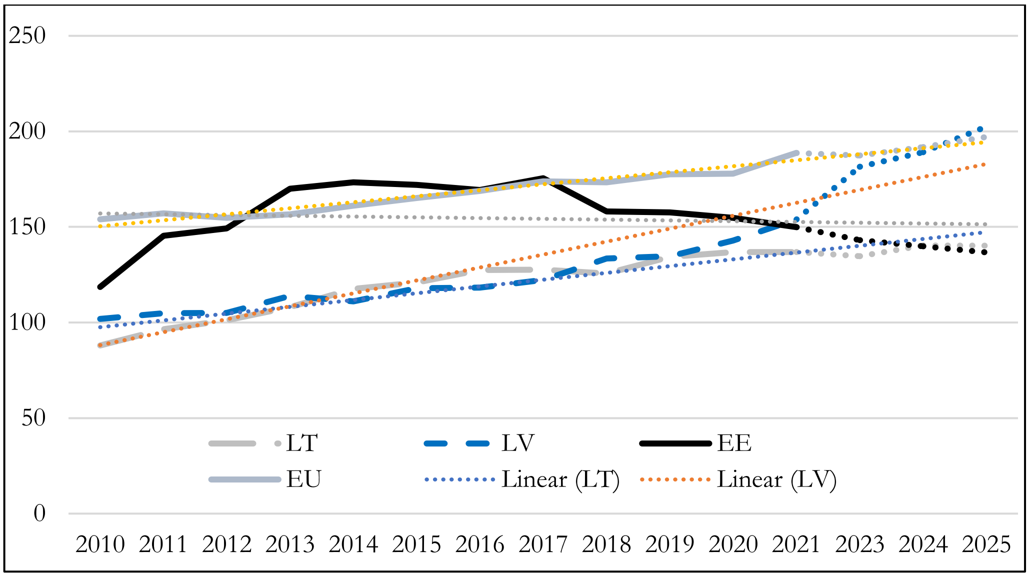

Figure 9. Trends in packaging waste per capita generation, kg per capita

Source: Authors' results

Based on root mean square errors, Holt-Winters Additive and Holt-Winters Multiplicative models were applied to forecast plastic packaging waste generation per capita (see Table 19).

Table 19

RMSEs of exponential smoothing models for forecasts of plastic packaging waste generation per capita

Model / Indicator	Single	Double	Holt-Winters No seasonal	Holt-Winters Additive	Holt-Winters Multiplicative
Generation of plastic packaging per capita (EE)	4,980	5,028	4,966	**4,707**	4,799
Generation of plastic packaging per capita (LT)	1,616	1,058	0,990	**0,874**	0,898
Generation of plastic packaging per capita (LV)	1,397	0,841	0,797	0,600	**0,599**
Generation of plastic packaging per capita (EU)	0,839	0,383	0,367	**0,347**	0,365

Source: Authors' calculations

The forecast indicates that the amount of plastic packaging waste generated in Lithuania will continue to grow until 2024. However, from 2025 onward, the amount of plastic packaging waste is forecasted to decrease. In Latvia, it is forecasted that the amount of plastic packaging waste generated will show slight variations in 2023-2025, but it is expected to increase in 2025 and reach 28.47 kg per capita. As for Estonia, the forecast suggests that the amount of plastic packaging waste generated will remain relatively stable in 2023-2025, but it may start to decrease from 2025. On the other hand, the forecasted average indicators for the amount of plastic packaging waste generated in the EU show a continuously increasing trend in this type of waste since 2010 (see Table 20).

Table 20

Forecasts of plastic packaging waste generation per capita in 2023-2025, kg per capita

Equation of the best model		Forecasts		
		2023	2024	2025
EE	y_t=37,79924+0,72*t+c_t	39.68	40.93	40.13
LT	y_t=31,57937+1,008*t+c_t	33.79	35.89	35.05
LV	y_t=(25,75578+0,642249*t)*c_t	28.26	27.39	28.47
EU	y_t=35,432+0,748*t+c_t	36.61	37.56	38.75

Source: Authors' calculations

From 2010 to 2021, an increase in the amount of plastic packaging waste generated in Latvia and Lithuania was observed. In 2010, the amount of generated plastic packaging waste in Lithuania was 18.3 kg per capita, and in 2021 – 30.9 kg per capita. In 2010, the amount of generated plastic packaging waste in Latvia was 16.8 kg per capita, and in 2021 - 20.5 kg per capita. A similar trend of generated plastic packaging waste growth is observed in the EU. However, a different situation is observed in Estonia: from 2010 to 2017, an increase in the amount of generated plastic packaging waste was recorded, and since 2017, the amount of this type of waste has been decreasing, but it is forecasted that the amount of generated plastic packaging waste will increase from 2023 (see Figure 10).

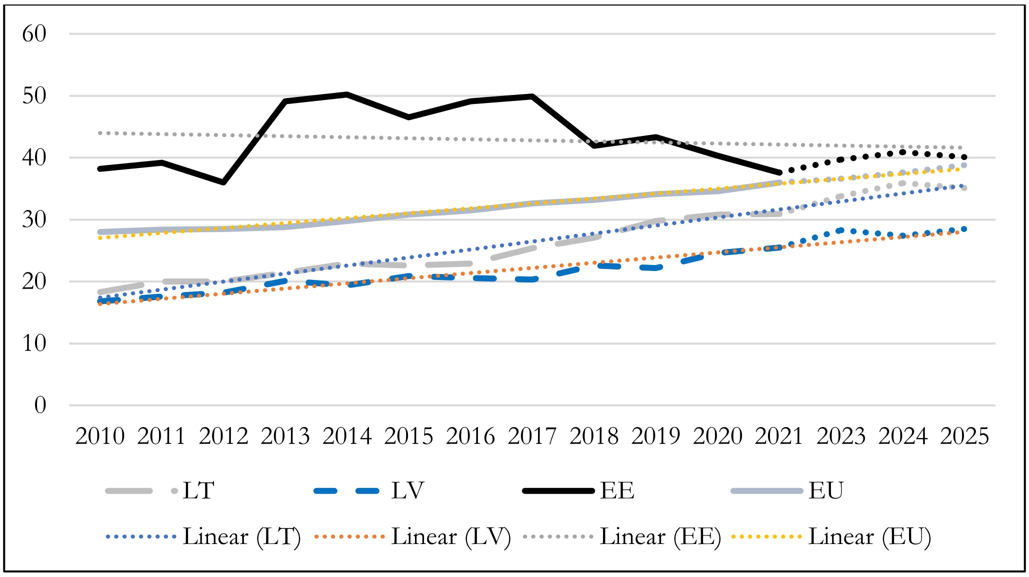

Figure 10. Trends in plastic packaging waste per capita generation, kg per capita

Source: Authors' results

Based on mean square errors, the Holt-Winters Additive model was applied to forecast municipal waste recycling rates (see Table 21).

Table 21

RMSEs of exponential smoothing models for forecasts of municipal waste recycling rates

Model / Indicator	Single	Double	Holt-Winters No seasonal	Holt-Winters Additive	Holt-Winters Multiplicative
Recycling rate of municipal waste (EE)	4,247	3,733	3,627	**2,656**	3,029
Recycling rate of municipal waste (LT)	8,787	5,879	5,741	**5,029**	10,957
Recycling rate of municipal waste (LV)	6,523	5,046	4,684	**4,325**	5,464
Recycling rate of municipal waste (EU)	1,598	0,841	0,833	**0,774**	0,781

Source: Authors' calculations

The forecast indicates that the rate of municipal waste recycling in Lithuania is expected to slightly decrease in the coming years, from 49.3% in 2023 to 45.83% in 2025. However, there is still a positive trend in the growth of the municipal waste recycling rate. In Latvia and Estonia, a further increase in the rate of municipal waste recycling is forecasted, with Latvia's rate expected to go from 45.92% in 2023 to 52.67% in 2025, and Estonia's rate from 31.02% in 2023 to 38.19% in 2025. The average EU municipal waste recycling rate is also forecasted to increase from 45.58% in 2023 to 50.11% in 2025. By 2024, it is expected that the municipal waste recycling rates in Latvia will surpass the EU average, while the rates in Estonia and Lithuania will not exceed the EU average (see Table 22).

Table 22

Municipal waste recycling rate forecasts, %

Equation of the best model		Forecasts		
		2023	2024	2025
EE	y_t=33,4549+1,364*t+c_t	31.02	39.17	38.19
LT	y_t=46,43+1,394786*t+c_t	49.20	45.50	45.83
LV	y_t=42,73044+3,123679*t+c_t	45.92	55.16	52.67
EU	y_t=48,7609+0,332556*t+c_t	48.58	49.15	50.11

Source: Authors' calculations

Between 2010 and 2021, there was a significant increase in municipal waste recycling rates in three Baltic economies. In 2010, Lithuania had a municipal waste recycling rate of 4.9%, which increased to 48.4% in 2021. Latvia had a municipal waste recycling rate of 9.4% in 2010, which rose to 41.4% in 2021. Estonia's municipal waste recycling rate was 18% in 2010 and reached 33.2% in 2021. A similar upward trend in municipal waste recycling was also observed in the EU, with rates increasing from 38% in 2010 to 48.6% in 2021 (see Figure 11).

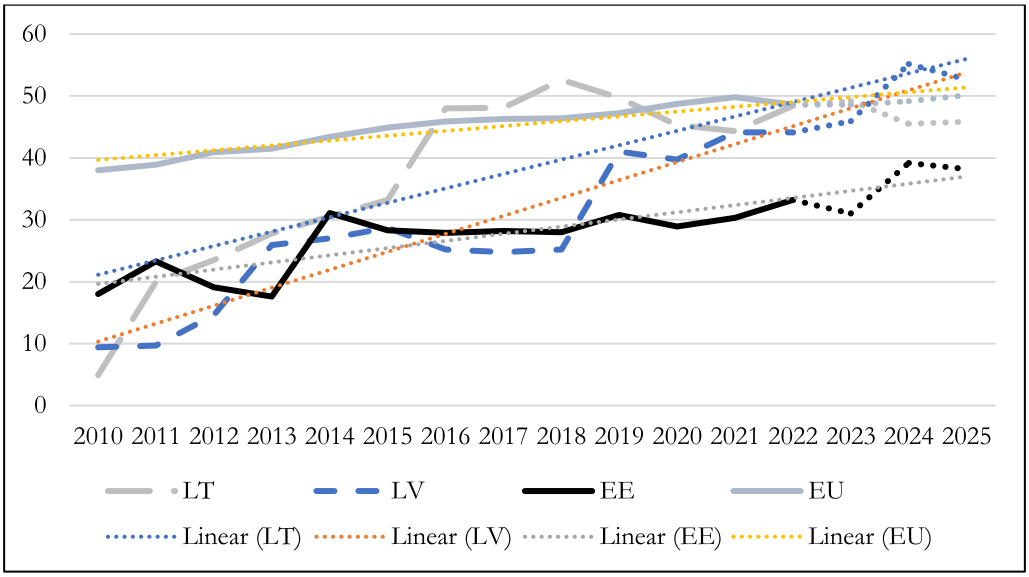

Figure 11. Municipal waste recycling rate trends, %

Source: Authors' results

Based on mean square errors, Holt-Winters No Seasonal, Holt-Winters Additive, and Holt-Winters Multiplicative models were applied to forecast packaging waste recycling rates (see Table 23).

Table 23

RMSEs of exponential smoothing models for forecasts of packaging waste recycling rates

Indicator \ Model	Single	Double	Holt-Winters No Seasonal	Holt-Winters Additive	Holt-Winters Multiplicative
Recycling rate of packaging waste (EE)	4,131	4,462	**4,064**	4,983	5,015
Recycling rate of packaging waste (LT)	3,395	3,820	4,293	**3,099**	3,183
Recycling rate of packaging waste (LV)	2,639	1,708	1,716	1,251	**1,245**
Recycling rate of packaging waste (EU)	0,916	0,808	0,798	0,803	**0,793**

Source: Authors' calculations

The forecast indicates that the rate of packaging waste recycling in Lithuania is expected to increase in the coming years, from 56.98% in 2023 to 63.03% in 2025. A similar trend is forecasted in Latvia: the rate of packaging waste recycling is expected to increase in the coming years, from 59.62% in 2023 to 64.10% in 2025. Meanwhile, in Estonia, where the packaging waste recycling rate (about 70.5%) is the highest among the Baltic countries and exceeds the average EU packaging waste recycling rates (about 62%), the situation is quite stable, i.e., it is forecasted that this level of packaging waste recycling will remain from 2023 to 2025. A similar trend in the EU packaging waste recycling level is forecasted (see Table 24).

Table 24

Packaging waste recycling rate forecasts, %

Equation of the best model		Forecasts		
		2023	2024	2025
EE	y_t=70,5-0,016667*t	70.48	70.47	70.45
LT	y_t=61,09168+0,464995*t+c_t	56.98	59.44	63.03
LV	y_t=(60,98115+1,268*t)*c_t	59.62	65.25	64.10
EU	y_t=(63,41802-447461*t)*c_t	62.49	61.94	62.17

Source: Authors' calculations

Between 2010 and 2021, there was an increase in packaging waste recycling rates in three Baltic economies, but the growth of the rates varied unevenly. In 2010, Lithuania had a packaging waste recycling rate of 60.4%, which increased to 61.9% in 2021. Latvia had a packaging waste recycling rate of 48.9% in 2010, which rose to 61% in 2021. Estonia's packaging waste recycling rate was 56,1% in 2010 and reached 70.5% in 2021. The average level of packaging waste recycling in the EU increased from 64% in 2010 to 67.6% in 2016, then slightly decreased and was 64% in 2020-2022. A rather moderate growth in the level of packaging waste recycling is forecasted in the Baltic countries in 2023-2025 (see Figure 12).

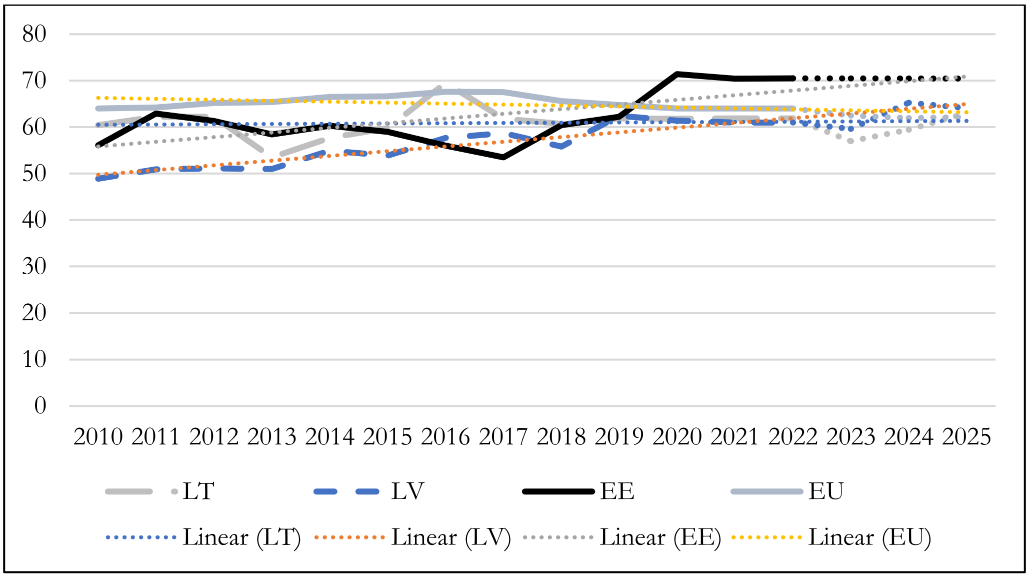

Figure 12. Packaging waste recycling rate trends, %

Source: Authors' results

Based on mean square errors, Single, Holt-Winters Additive, and Holt-Winters Multiplicative models were applied to forecast plastic packaging waste recycling rates (see Table 25).

Table 25

RMSEs of exponential smoothing models for forecasts of plastic packaging waste recycling rates

Model / Indicator	Single	Double	Holt-Winters No seasonal	Holt-Winters Additive	Holt-Winters Multiplicative
Recycling rate of plastic packaging waste (EE)	4,964	5,344	5,230	4,500	**4,408**
Recycling rate of plastic packaging waste (LT)	**7,700**	7,978	7,968	8,869	10,140
Recycling rate of plastic packaging waste (LV)	4,057	3,964	3,579	**3,316**	3,686
Recycling rate of plastic packaging waste (EU)	1,820	1,563	1,557	1,510	**1,489**

Source: Authors' calculations

The forecast indicates that the rate of plastic packaging waste recycling in Latvia is expected to increase in the coming years, from 40.51% in 2023 to 49.69% in 2025. Meanwhile, in Lithuania, it is forecasted that the rate of plastic packaging waste recycling (56%) in 2023-2025 will not change, and in Estonia, the rate of plastic packaging waste recycling will slightly decrease to 39.96% in 2025. A similar trend in the rate of plastic packaging waste recycling is forecasted in the EU (see Table 26).

Table 26

Plastic packaging waste recycling rate forecasts, %

Equation of the best model		Forecasts		
		2023	2024	2025
EE	y_t=(42,28288-0,12*t)*c_t	43.80	46.58	39.96
LT	y_t=56,00011	56.00	56.00	56.00
LV	y_t=39,64547+1,936*t+c_t	40.51	46.26	49.69
EU	y_t=(38,36756-1,331998*t)*c_t	35.54	34.00	32.83

Source: Authors' calculations

Between 2010 and 2021, there was an increase in plastic packaging waste recycling rates in three Baltic economies. In 2010, Lithuania had a plastic packaging waste recycling rate of 38.4%, which increased to 56% in 2021. Latvia had a plastic packaging waste recycling rate of 24% in 2010, which rose to 41.6% in 2021. Estonia's plastic packaging waste recycling rate was 33.4% in 2010 and reached 42.5% in 2021. The average level of plastic packaging waste recycling in the EU increased from 34.1% in 2010 to 39.7% in 2021. It is forecasted that the rate of plastic packaging waste recycling will be higher than the EU average level of this rate. In addition, it is forecasted that the growth trends in packaging waste recycling will continue in the coming years in all Baltic countries (see Figure 13).

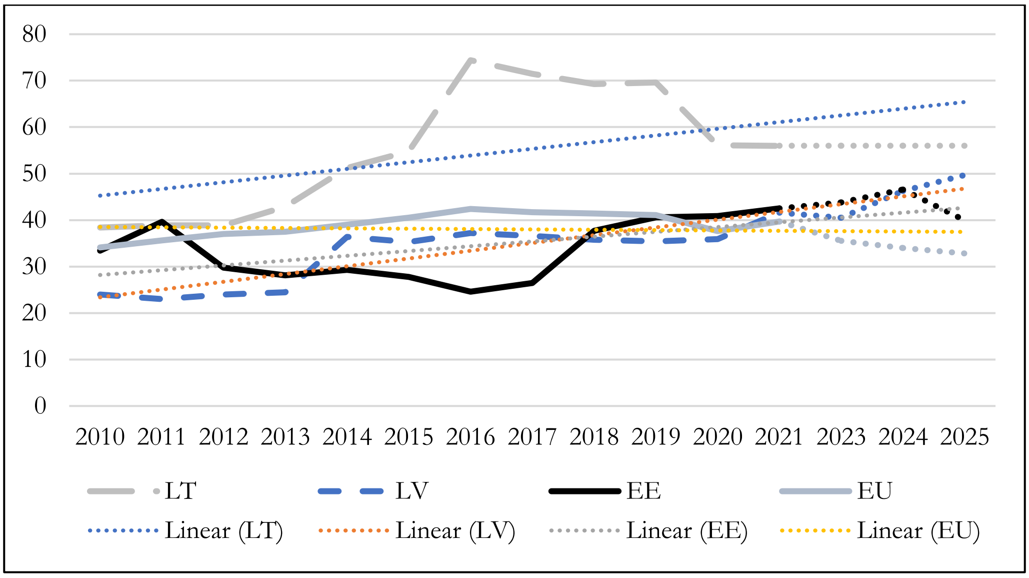

Figure 13. Plastic packaging waste recycling rate trends, %

Source: Authors' results

Based on mean square errors, Holt-Winters Additive and Holt-Winters Multiplicative models were applied to forecast of separately collected electrical and electronic equipment waste (WEEE) recycling rates (see Table 27).

Table 27

RMSEs of exponential smoothing models for forecasts of separately collected electrical and electronic equipment waste (WEEE) recycling rates

Indicator \ Model	Single	Double	Holt-Winters No seasonal	Holt-Winters Additive	Holt-Winters Multiplicative
Recycling rate of WEEE separately collected (EE)	5,911	7,480	6,118	**4,797**	4,831
Recycling rate of WEEE separately collected (LT)	3,423	2,417	2,271	**2,033**	2,083
Recycling rate of WEEE separately collected (LV)	3,650	3,778	3,763	1,788	**1,761**
Recycling rate of WEEE separately collected (EU)	1,160	1,531	1,468	**1,083**	1,083

Source: Authors' calculations

It is forecasted that the rate of separately collected electrical and electronic equipment waste recycling in Lithuania is expected to increase in the coming years, from 83.91% in 2023 to 89.61% in 2025. In Estonia, it is forecasted that the rate of separately collected electrical and electronic equipment waste recycling will increase from 79.09% in 2023 to 87.39% in 2025. The forecast indicates that the rate of separately collected electrical and electronic equipment waste recycling in Latvia will slightly decrease to 76.16% in 2025. Also, it is forecast that the rate of separately collected electrical and electronic equipment waste recycling in the EU will not change and will fluctuate around 82% in 2023-2025 (see Table 28).

Table 28

Forecasts of separately collected electrical and electronic equipment waste (WEEE) recycling rates, %

Equation of the best model		Forecasts		
		2023	2024	2025
EE	y_t=83,904+0,432*t+c_t	79.09	86.09	87.39
LT	y_t=82,874+1,452*t+c_t	83.91	87.36	89.61
LV	y_t=(80,624-0,908*t)*c_t	78.94	79.62	76.16
EU	y_t=82,284+0,012*t+c_t	82.29	81.69	82.09

Source: Authors' calculations

The rate of recycling of separately collected electrical and electronic equipment in the Baltic States is quite high and reaches the average rate of recycling of WEEE in the EU. In 2012-2020, the most significant growth in the rate of waste recycling of separately collected electrical and electronic equipment, increasing from 68.7% in 2012 to 84.3% in 2021, was seen in Lithuania. Further growth in the rate of recycling of WEEE is forecasted. The rates of recycling of separately collected electric and electronic equipment in Latvia and Estonia remained relatively stable from 2012 to 2021, following a significant drop in the WEEE recycling rate in Estonia in 2013. Similar trends in the average rate of waste recycling of separately collected electrical and electronic equipment were recorded in the EU from 2012 to 2021. It is forecasted that there will be a moderate increase in the rate of waste recycling of separately collected electrical and electronic equipment in Lithuania and Estonia from 2023 to 2025, while a moderate fluctuation of the WEEE recycling rate is expected in Latvia (see Figure 14).

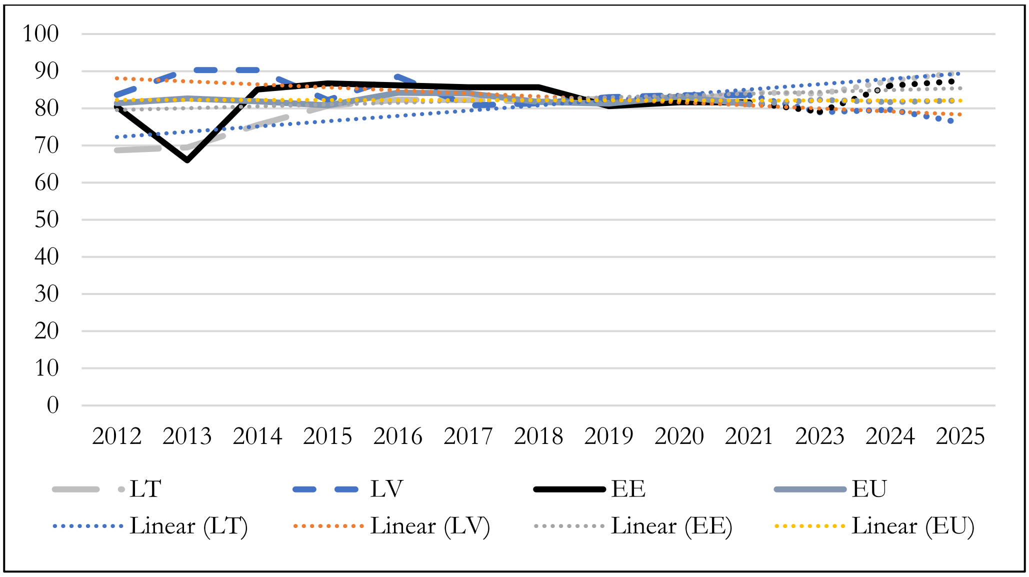

Figure 14. Trends of separately collected electrical and electronic equipment waste (WEEE) recycling rates, %

Source: Authors' results

The results of the empirical study indicate that in the analysed small economies, there are both unfavourable trends (such as the increase in material footprint and domestic material consumption) and favourable trends (like the increase in resource and energy productivity, as well as the rise in circular material use) when forecasting the decoupling of environmental impact from economic growth. Regarding the generation and management of waste, it is forecasted that municipal, packaging, and plastic packaging waste will increase in the coming years, while recycling rates will grow slowly.

5. CONCLUSION

The transition to sustainable consumption is a paradigm shift, a transformation in the current consumption model. To not exceed the limits of the planet's ecological possibilities, it is necessary to reduce the demand for environmental resources and services and to turn industrial production into a circular one. The environmental dimension of sustainable consumption is associated with the decoupling of environmental impact from economic growth, and the economic dimension is associated with the circular economy concept, which aims to maintain the value of materials and products in the market, disposing of them as little as possible in landfills, i.e., associated with waste generation and management. Waste control is related not only to the management of already generated waste but also to the preservation of natural resources, which are used in production processes to generate waste. Therefore, to encourage the transformation of the current consumption model, i.e., to support an effective transition to sustainable consumption, it is necessary to analyse trends in the dimensions of sustainable consumption. As is typical of open, highly industrialized, service-oriented small economies, they are net resource importers, meaning that more resources are imported than exported. It also shows the geopolitical significance of sustainable consumption. Small economies are highly dependent on imports of key raw materials. The drive to reduce the import balance and, in some cases, geopolitics can also be the driving force behind measures that support greater resource productivity in industrial production processes, circular use of materials, and waste management and recycling. Considering the forecasts of sustainable consumption in small economies, progress directly related to the decoupling of environmental impact from economic growth shows positive performance in two areas. Even though the productivity of resources and energy, the circular material use is below the EU average, their growth is forecasted, and the share of renewable energy in the total consumption already exceeds the EU average and its further growth is predicted, this shows the relative decoupling of the growth of small economies from the impact on the environment. However, higher-than-EU average material footprint and domestic consumption and their projected growth indicate a continuing imbalance between economic growth and sustainable resource consumption in small, open and resource-limited economies. The dependence of small economies on external resources and the associated risks remains. Analysing the forecasts of the economic dimension of sustainable consumption, it can be stated that progress directly related to waste management and recycling already shows positive prospects in waste recycling. The rate of plastic packaging recycling in the analysed small economies already exceeds the EU average, the rate of recycling of electrical and electronic waste in Lithuania and Estonia, and the rate of recycling of plastic packaging also exceeds the EU average. In addition, the growth of waste recycling is forecasted in the analysed economies. However, although the amount of generated waste in the analysed economies does not exceed the EU average, their growth is predicted, but the rate of waste recycling will grow slowly in the coming years. In summary, it can be stated that sustainable consumption growth trends are forecasted, although showing insufficient progress and stagnation in the transformation process of the current consumption model. The small economies analysed made progress in waste management and resource and energy efficiency and growth is predicted in these areas. However, the high consumption of materials, the increasing amount of municipal waste generated per capita, mixed municipal waste, which constitutes a significant part of the waste, and their forecasted growth indicate the stagnation of sustainable consumption growth trends and the continuing need to implement innovative, environmentally friendly technologies, reduce dependence on imported raw materials, ensure the supply of local secondary raw materials and reduce resource intensity.

6. LIMITATIONS

This study has certain limitations. Sustainable consumption is a broad concept that includes, not only, environmental and economic but also social and health dimensions. The article focuses on forecasting trends in two dimensions of sustainable consumption, i.e., environmental and economic. In further research, it is necessary to analyse the trends of other dimensions of sustainable consumption. In order to understand how small economies can address the challenges related to sustainable consumption in the face of current unsustainable production and consumption patterns, it is important to analyse the trends of other dimensions of sustainable consumption. It is also crucial to study the factors that impact the scope and advancement of sustainable consumption as a model for reduced consumption and the interconnected relationships between various social actors. The trends in sustainable consumption were examined in three open, small economies with limited natural resources, i.e., the Baltic countries: Latvia, Lithuania, and Estonia. Further research will encompass a wider range of small economies. While all small economies share similar characteristics, they also have distinct economic, social, and political differences that influence the development of sustainable consumption.

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REFERENCES

Abdulrazak, S., & Quoquab, F. (2018). Exploring consumers' motivations for sustainable consumption: A self-deterministic approach. *Journal of International Consumer Marketing*, 30(1), 14-28. https://doi.org/10.1080/08961530.2017.1354350

Alisat, S., & Riemer, M. (2015). The environmental action scale: Development and psychometric evaluation. *Journal of Environmental Psychology*, 43, 13-23. https://doi.org/10.1016/j.jenvp.2015.05.006

Amos, R., & Lydgate, E. (2020). Trade, transboundary impacts and the implementation of SDG 12. *Sustainability Science*, 15, 1699-1710. https://doi.org/10.1007/s11625-019-00713-9

Androniceanu, A., Kinnunen, J., & Georgescu, I. (2021). Circular economy as a strategic option to promote sustainable economic growth and effective human development. *Journal of International Studies*, 14(1), 60-73. https://doi.org/10.14254/20718330.2021/14-1/4

Assimakopoulos, V., & Nikolopoulos, K. (2000). The theta model: A decomposition approach to forecasting. *International Journal of Forecasting*, 16(4), 521-530. https://doi.org/10.1016/S0169-2070(00)00066-2

Baranowski, M., & Kopnina, H. (2022). Socially responsible consumption: Between social welfare and degrowth. *Economics and Sociology*, 15(3), 319-335. https://doi.org/10.14254/2071-789X.2022/15-3/18

Becerra, M., Jerez, A., Aballay, B., Garcés, H.O., & Fuentes, A. (2020). Forecasting emergency admissions due to respiratory diseases in high variability scenarios using time series: A case study in Chile. *Science of The Total Environment*, 706, 1-19. https://doi.org/10.1016/j.scitotenv.2019.134978

Bennett, J., & Collins, D. (2009). The policy implications of sustainable consumption. *Australasian Journal of Environmental Management*, 16(1), 47-55. https://doi.org/10.1080/14486563.2009.9725216

Brach, S., Walsh, G., & Shaw, D. (2018). Sustainable consumption and third-party certification labels: Consumers' perceptions and reactions. *European Management Journal*, 36(2), 254-265. https://doi.org/10.1016/j.emj.2017.03.005

Brinzan, O., Tigan, E., & Radu, D. (2012). Food consumption and sustainability. *Journal of Environmental Protection and Ecology*, 13(1), 253-257. https://www.researchgate.net/publication/235918050

Brown, R. G., Meyer, R. F., & D'Esopo, D. A. (1961). The fundamental theorem of exponential smoothing. *Operations Research*, 9(5), 673-685. https://doi.org/10.1287/opre.9.5.673

Chen, F., Ryan, J. K., & Simchi-Levi, D. (2000). The impact of exponential smoothing forecasts on the bullwhip effect. *Naval Research Logistics (NRL)*, 47(4), 269-286. https://doi.org/10.1002/(SICI)1520-6750(200006)47:4<269:AID-NAV1>3.0.CO;2-Q

Chatfield, C., Koehler, A. B., Ord, J. K., & Snyder, R. D. (2001). A new look at models for exponential smoothing. *Journal of the Royal Statistical Society*. Series D (The Statistician), 50(2), 147-159. https://doi.org/10.1111/1467-9884.00267

Čapienė, A., Rūtelionė, A., & Tvaronavičienė, M. (2021). Pro-Environmental and Pro-Social Engagement in Sustainable Consumption: Exploratory Study. *Sustainability*, 13, 1601-1621. https://doi.org/10.3390/su13041601

Dagilienė, L., Bruneckienė, J., Varaniūtė, V., & Lukauskas, M. (2023). The circular economy for sustainable development: implementation strategies in advanced small open economies. *International Journal of Environment and Sustainable,* 22(1), 51-76. https://www.inderscience.com/ijesd

Evans, D., & Jackson, T. (2008). Sustainable consumption: Perspectives from social and cultural theory. *RESOLVE Working Paper 05-08*, 1-22. ISSN 1755-7259

Freedman, B. (2004). *Environmental Science: A Canadian Perspective*. Hoboken: Prentice Hall, 672 p., ISBN 9780131398634

Gedvilaite, D., & Ginevicius, R. (2024). Assessment of the technological efficiency of production and consumption of EU countries in the context of circular economy. *Journal of International Studies*, 17(1), 83-96. https://doi.org/10.14254/2071-8330.2024/17-1/5

Geng, D., Liu, J., & Zhu, Q. (2017). Motivating sustainable consumption among Chinese adolescents: An empirical examination. *Journal of Cleaner Production*, 141, 315-322. https://doi.org/10.1016/j.jclepro.2016.09.113

Ginevičius, R. (2022). The efficiency of municipal waste management systems in the environmental context in the countries of the European Union. *Journal of International Studies*, 15(4), 63-79. https://doi.org/10.14254/2071-8330.2022/15-4/4

Glavič, P. (2021). Evolution and Current Challenges of Sustainable Consumption and Production. *Sustainability*, 13(16), 1-24. https:// doi.org/10.3390/su1316937

Guerron-Quintana, P. (2013). The economics of small open economies. *Business Review*, 4, 9-18. https://www.philadelphiafed.org/-/media/frbp/assets/economy/articles/business-review/2013/q4/brQ413_economics_small_open_economies.pdf

Guleryuz, D. (2021). Forecasting outbreak of COVID-19 in Turkey; Comparison of Box–Jenkins, Brown's exponential smoothing and long short-term memory models. *Process Safety and Environmental Protection*, 149, 927-935 https://doi.org/10.1016/j.psep.2021.03.032

Hoballah, A., & Averous, S. (2015). Goal 12—Ensuring Sustainable Consumption and Production Patterns: An Essential Requirement for Sustainable Development. https://www.un.org/en/chronicle/article/goal-12-ensuring-sustainable-consumption-and-production-patterns-essential-requirement-sustainable

Hornibrook, S., May, C., & Fearne, A. (2015). Sustainable development and the consumer: Exploring the role of carbon labelling in retail supply chains. *Business Strategy and the Environment*, 24(4), 266-276. https://doi.org/10.1002/bse.1823

Hu, B., & McKitrick, R. (2016). Decomposing the environmental effects of trade liberalization: The case of consumption-generated pollution. *Environmental and Resource Economics*, 64, 205-223. https://doi.org/10.1007/s10640-014-9865-x

Jose, V. R. R., & Winkler, R. L. (2008). Simple robust averages of forecasts: Some empirical results. *International Journal of Forecasting*, 24(1), 163-169. https://doi.org/10.1016/j.ijforecast.2007.06.001

Kambezidis, H. D. (2012). 3.02 - The solar resource. *Comprehensive Renewable Energy*, 3, 27-84. https://doi.org/10.1016/B978-0-08-087872-0.00302-4

Kates, R. W., Parris, T. M., & Leiserowitz, A. A. (2005). What is sustainable development? Goals, indicators, values, and practice. *Environment: Science and Policy for Sustainable Development*, 47(3), 8–21. https://doi.org/10.1080/00139157.2005.10524444

Kim, H.-K., & Ryan, J. K. (2003). The cost impact of using simple forecasting techniques in a supply chain. *Naval Research Logistics (NRL)*, 50(5), 388-411. https://doi.org/10.1002/nav.10065

Kletzan, D., Köppl, A., Kratena, K., Schleicher, S., & Wüger, M. (2002). Modelling sustainable consumption. From theoretical concepts to policy guidelines. *Empirica*, 29,131-144. https://doi.org/10.1023/A:1015696710335

Kolassa, S. (2011). Combining exponential smoothing forecasts using Akaike weights. *International Journal of Forecasting*, 27(2), 238-251. 2011https://doi.org/10.1016/j.ijforecast.2010.04.006

Korkmaz, I. (2024). Examining the concept of water footprint in the context of responsible consumption and production. *Journal of Bucak Business Administration Faculty*, 7(1), 58-69. https://doi.org/10.38057/bifd.1467585

Kose, M. A. (2002). Explaining business cycles in small open economies: 'How much do world prices matter?' *Journal of International Economics*, 56(2), 299-327. https://doi.org/10.1016/S0022-1996(01)00120-9

Lederman, D., & Lesniak, J. T. (2017). *Open and Nimble: Finding stable growth in small economies*. Washington: World Bank, 12 p. https://doi.org/10.1596/978-1-4648-1042-8

Makridakis, S., Spiliotis, E., & Assimakopoulos, V. (2020). Predicting/hypothesizing the findings of the M4 Competition. *International Journal of Forecasting*, 36(1), 29-36. htts://doi.org/10.1016/j.ijforecast.2019.02.012

McKenzie, E. (1986). Renormalization of seasonals in Winters' forecasting systems: Is it necessary? *Operations Research*, 34(1), 174–176. https://www.jstor.org/stable/170681

Mishchuk, H., Czarkowski, J. J., Neverkovets, A., & Lukács, E. (2023). Ensuring Sustainable Development in Light of Pandemic "New Normal" Influence. *Sustainability*, 15(18), 13979. https://doi.org/10.3390/su151813979

Muluneh, M. G. (2021). Impact of climate change on biodiversity and food security: A global perspective - a review article. *Agriculture & Food Security*, 10(36), 1-25. https://doi.org/10.1186/s40066-021-00318-5

Nash H. A. (2009). The European Commission's sustainable consumption and production and sustainable industrial policy action plan. *Journal of Cleaner Production*, 17(4), 496-498. https://doi.org/10.1016/j.jclepro.2008.08.020

Navickas, V., Kontautienė, R., Stravinskienė, J., & Bilan, Y. (2021). Paradigm shift in the concept of corporate social responsibility: COVID-19. *Green Finance*, 3(2), 138-152. http://doi.org/ 10.3934/GF.2021008

Novikovienė, L., & Navickaitė-Sakalauskienė, I. (2020). Safeguarding the legal balance between competitive entrepreneurship (business) and sustainable consumption. *Entrepreneurship and Sustainability Issues*, 8(1), 868–883. http://doi.org/10.9770/jesi.2020.8.1(58)

Pitt, J. (2009). Blurring the boundaries – STEM education and education for sustainable development. *Design and Technology Education: An International Journal*, 14(1), 37-48. ISSN-1360-1431

Rostami-Tabar, B., Babai, M. Z., Syntetos, A. A., & Ducq, Y. (2013). Demand forecasting by temporal aggregation. *Naval Research Logistics (NRL)*, 60(6), 479–498. https://doi.org/10.1002/nav.21546

Seyfang, G. (2004). Consuming values and contested cultures: A critical analysis of the UK strategy for sustainable consumption and production. *Review of Social Economy*, 62(3), 323-338. https://doi.org/10.1080/0034676042000253936

Smy, S. (2020). A hybrid method of exponential smoothing and recurrent neural networks for time series forecasting. *International Journal of Forecasting*, 36(1), 75–85. https://doi.org/10.1016/j.ijforecast.2019.03.017

Southerton, D. Chappells, H., van Vliet, B. (2004). *Sustainable Consumption: The Implications of Changing Infrastructures of Provision*. Cheltenham Edward Elgar Publishing, 117 p.

Staniškis, J. K., Varžinskas, V., & Arbačiauskas, V. (2008). Sustainable Consumption and Production in Lithuania. *Environmental Research, Engineering and Management*, 3(45), 23-32. ISSN 1392-1649

Svetunkov, I., Kourentzes, N., & Ord, J. K. (2022). Complex exponential smoothing. *Naval Research Logistics (NRL)*, 69(8), 1108–1123. https://doi.org/10.1002/nav.22074

Sustainable Brand Index (2024). Lithuania. Official report – Europe's largest brand study on sustainability. https://www.sb-insight.com/sbi-lithuania

Štreimikienė, D. (2023). Waste management in Baltic States: Comparative assessment. *Journal of International Studies*, 16(4), 39-51. https://doi.org/10.14254/2071-8330.2023/16-4/3

Tsakiris, N., Hatzipanayotou, P., & Michaelz, M. S. (2018). Border tax adjustments and tari-tax reforms with consumption pollution. *Working Paper Series*, 1-21. https://wpa.deos.aueb.gr/docs/Border.Tax.Adjustments.and.Tariff.Tax.Reform.with.Consumption.Pollution.pdf

Vojtovic, S., Stundziene, A., & Kontautiene, R. (2018). The impact of socio-economic indicators on sustainable consumption of domestic electricity in Lithuania. *Sustainability*, 10(2), 162-183. https://doi.org/10.3390/su10020162

Vergragt, P., Akenji, L., & Dewick, P. (2014). Sustainable production, consumption, and livelihoods: Global and regional research perspectives. *Journal of Cleaner Production*, 63, 1-15. https://doi.org/10.1016/j.jclepro.2013.09.028

Zhao, H-M., He, H-D., Lu, K-F., Han, X-L., Ding., Y., & Peng, Z-R. (2022). Measuring the impact of an exogenous factor: An exponential smoothing model of the response of shipping to COVID-19. *Transport Policy*, 118, 91-100. https://doi.org/10.1016/j.tranpol.2022.01.015

Žiković, S., & Vlahinic-Dizdarević, N. (2011) Oil consumption and economic growth interdependence in small European Countries. *Economic Research-Ekonomska Istraživanja*, 24(3), 15-32. https://doi.org/10.1080/1331677X.2011.1151746