



# GREEN TRANSFORMATION IN FINLAND AND THE BALTIC STATES: COMPARATIVE ANALYSIS OF RENEWABLE ENERGY TRANSITION IN THE ROAD TRANSPORT SECTOR

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**Abstract. Purpose** – This paper aims to evaluate the progress towards achieving sustainable development goals in the transport sector of the Baltic States – Estonia, Latvia, and Lithuania – compared with Finland by identifying structural differences in renewable energy deployment and policy design that account for variation in transition outcomes over the period 2010–2024.

**Research methodology** – The research employs a comparative analysis of Finland and the Baltic States, focusing on the transport sector's transition towards Renewable Energy Sources (RES). The study examines historical, geographical, economic, and policy factors influencing sustainable transformation, using national and international datasets to assess progress over time and applying a structured indicator-based framework to ensure analytical comparability across countries.

**Findings** – The results reveal significant variation in transition performance despite common EU regulatory obligations. Finland demonstrates the most advanced and consistent transition model, reaching a 20.3% share of RES in transport in 2024 while steadily reducing road transport GHG emissions. Estonia shows rapid recent improvement, whereas Latvia and Lithuania display slower structural change, with RES shares remaining below EU targets and transport emissions stagnating or increasing. The analysis shows that coordinated policies, regulatory stability, and alignment of fiscal incentives with infrastructure development drive effective transport decarbonisation.

**Research limitations** – The study focuses solely on the road transport sector and selected countries.

**Practical implications** – The findings provide valuable insights for policymakers aiming to improve renewable energy-based transport strategies.

**Originality/Value** – The study contributes to understanding regional differences in sustainable transport development by linking transition indicators with comparative policy analysis.

**Keywords:** Renewable Energy Sources (RES), GHG emissions, transport sector, Finland, Baltic States.

**JEL Classification:** K32, L98, O13, Q42.

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## 1. Introduction

The transition towards RES has become a central pillar of sustainable economic development and climate policy. The transport sector plays a particularly critical role in this transformation, as it remains one of the largest contributors to Greenhouse Gas (GHG) emissions and one of the most structurally difficult sectors to decarbonise. While renewable energy penetration has progressed steadily in electricity and heating sectors, the shift towards RES in transport has been comparatively slower and uneven across EU countries.

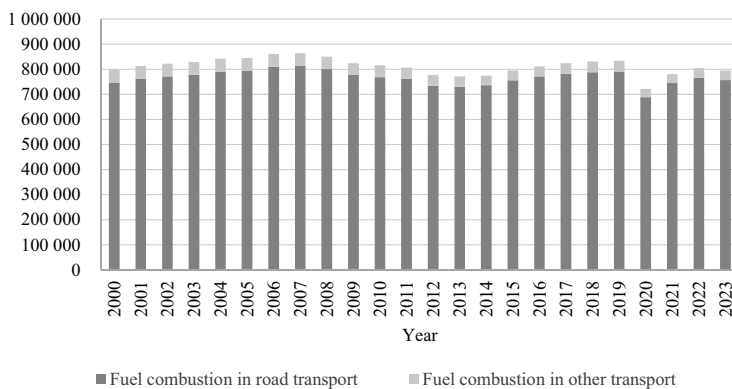
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Sustainable development requires balancing economic growth with environmental protection. While economic expansion increases resource use and environmental pressures, it also enables investment in cleaner technologies and innovation (Kagan, 2016; Kubba, 2010; Olijslagers, 2022; Ryszka, 2016). Expanding renewable energy sources is therefore a key strategy for reducing GHG emissions and mitigating climate change. Sustainable RES development requires coordinated policy approaches that integrate economic and environmental objectives (Chygryn et al., 2026). This need is especially pronounced in the transport sector, which remains heavily dependent on fossil fuels.

Significant reductions in GHG emissions require a reduction in the use of fossil fuels. However, this is a challenging task because fossil fuels have historically been the primary sources of energy for electricity generation, transportation, and industrial processes due to their energy density and ease of use (Rivard et al., 2019).

Changes in GHG emissions are closely linked to total transport activity, also known as transport performance or transport volume. Transport volumes, especially road transport, have been increasing for many years and have only slightly declined, with temporary reductions observed during periods of economic slowdown and external shocks, including the COVID-19 pandemic and subsequent geopolitical disruptions, as reduced economic activity leads to lower transport demand. The uncertain geopolitical situation, persistent supply problems, and sharp increases in energy prices – particularly for oil and gas – have had major economic, social, and political implications, while the economy and the energy sector have not yet fully recovered from the COVID-19 pandemic and the increased uncertainty following the Russian invasion of Ukraine (Siksnelyte-Butkiene & Streimikiene, 2022). More recent geopolitical developments further contribute to uncertainty in energy markets. As economic activity declines, less freight transport is needed, which is reflected in short-term decreases in GHG emissions from fuel combustion. Based on Eurostat (n.d.) data, GHG emissions from most sectors have shown a declining trend, whereas emissions from fuel combustion in transport remain persistently high, confirming that road transport is the most important mode of transport and the dominant source of transport-related emissions throughout the 2000–2023 period (Figure 1).



**Figure 1.** GHG emissions from fuel combustion in transport in EU, 2000–2023 (Thousand tonnes) (source: Eurostat, n.d.)

The EU renewable energy policy framework has evolved progressively over time. Directive 2009/28/EC (European Parliament & Council of the European Union, 2009) (RED I) established the first binding target requiring EU Member States to achieve a 10% share of renewable energy in transport by 2020, providing the foundation for subsequent policy development. This framework was strengthened under the Renewable Energy Directive RED II (Directive (EU) 2018/2001) (European Parliament & Council of the European Union, 2018), which extended binding renewable energy targets beyond 2020 and introduced more comprehensive sustainability criteria. More recently, RED III (Directive (EU) 2023/241) (European Parliament & Council of the European Union, 2023), further reinforced renewable energy obligations, particularly in hard-to-abate sectors such as transport, in line with the European Green Deal and the Fit for 55 package, which aims to reduce net GHG emissions by at least 55% by 2030 (European Commission, 2019, 2021; Council of the European Union, 2022).

Although numerous studies analyse renewable energy development, transport decarbonisation, or the effectiveness of specific policy instruments, existing research rarely combines quantitative transition performance indicators with a structured comparative evaluation of policy architecture in the Nordic-Baltic region. Comparative studies often focus on aggregate renewable energy shares (Miškinis et al., 2021; Sichigea et al., 2024; Tutak et al., 2020) or single-country case analyses (Liu et al., 2022; Wesseling & Van der Vooren, 2017), leaving limited understanding of how differences in policy design translate into measurable variation in transport-sector outcomes. Moreover, the debate on the effectiveness of policy instruments and the persistence of divergence within EU regions remains insufficiently addressed in transport-specific analyses.

Finland and the Baltic States – Estonia, Latvia, and Lithuania – provide a relevant comparative setting. These countries share geographic proximity, EU membership, and similar external regulatory obligations, yet they differ in economic structure, historical energy systems, infrastructure development, and policy approaches. Such variation offers an opportunity to examine how national policy design, institutional consistency, and structural conditions influence renewable energy integration in road transport.

The aim of this paper is to conduct a structured comparative evaluation of renewable energy transition performance in the road transport sector of Finland and the Baltic States. By combining quantitative transition indicators with comparative analysis of policy instruments, the study seeks to contribute to the literature on renewable energy policy effectiveness and regional divergence within the EU. The analysis and evaluation of the results can guide policy makers in planning future sustainable transport development strategies and measures in the selected countries.

This paper consists of several sections. Scientific literature review on research topics is conducted in Section 2. Section 3 introduces the methodology and data for the assessment. Section 4 presents the results and findings from the comparative assessment of the transition to RES deployment in the transport sector in Finland and the Baltic States, and factors stimulating further development. Discussion based on research results in Section 5 and in Section 6 presented concluding remarks.

## 2. Literature review

Based on the literature review, renewable energy is essential to meet future energy-related challenges. Reliable energy sources such as RES will play a vital role in improving the standard of life and supporting renewable energy-based development. The need for a new energy model was studied by Kaltschmitt et al. (2007) and Jefferson (2000) decades ago.

Over the last decade, energy transition has been at the center of research and social concern, because of the urgent need to decarbonise, slow the pace of global climate change and strike a balance between environmental protection and economic development. Different studies have shown that renewable energy systems are technically and economically feasible across different regions and sectors (Bogdanov et al., 2021; Hansen et al., 2019; Štreimikienė, 2024). Sustainable energy is not limited to renewable energy sources alone but encompasses economic and social dimensions, including improvements in citizens' quality of life (Tutak et al., 2020). Together, these studies show that the renewable energy transition involves environmental, economic, and social aspects.

Fatima et al. (2021), Heshmati et al. (2015), and others analyse key factors influencing the development of renewable energy sources, highlighting the role of economic conditions, technological progress, and institutional frameworks. Recent modelling-based research further demonstrates that renewable energy development follows dynamic and uneven growth trajectories across countries (Li, 2023). Many studies indicate that green investment is one of the main drivers providing the financial base for sustainable development (Dalevska et al., 2019).

From an economic perspective, declining costs of renewable energy technologies have significantly improved their competitiveness. In particular, the rapid cost reduction of renewable electricity has accelerated substitution of fossil fuels in the power sector and is increasingly influencing transition pathways in other energy-consuming sectors (Kåberger, 2018). However, despite technological progress and cost reductions, renewable energy development across the EU remains uneven and RES still represents only a small share of the EU's total energy consumption (Barak, 2022). Differences in economic structure, historical energy systems, and institutional capacity contribute to persistent disparities in renewable energy deployment.

These studies show that despite technological progress and cost reductions, renewable energy transition outcomes still differ across countries due to economic conditions, financial support, and policy frameworks.

Although there is no universally codified definition of "green investment" in the literature (Liu et al., 2022; Magalhães, 2021; Tran et al., 2020; X. Zhang & Yousaf, 2020), its general usage is quite straightforward. It mainly refers to investments aimed at environmental sustainability and the circular economy, including activities that mitigate or adapt climate change and address environmental degradation throughout the life cycle of investment projects. Such investments may include the promotion of greener production processes, development of green products, adoption of green technologies, and implementation of environmentally oriented business practices.

A large part of green investment is devoted to disseminating and deploying renewable energy technologies that could reduce GHG emissions (Chang & Shieh, 2017; T. Zhang et al.,

2023). Finance is widely recognised as a critical driver for renewable energy infrastructure development. To achieve sustainable development goals, investment in renewable energy must be scaled up through new financial instruments and new policies such as green bonds, green banks, carbon market instruments, fiscal policy tools, and green finance initiatives (Sachs et al., 2019; Wang et al., 2022; Zhao et al., 2022). These instruments are known as green finance. Policies supporting renewable energy are often justified by the presence of positive externalities and market failures, which lead to underinvestment without public intervention. To boost renewable energy-based development, it is important to promote policies that help producers overcome market barriers (Azhgaliyeva et al., 2018). These studies underline the importance of policy design and financial instruments in overcoming market barriers and accelerating renewable energy-based development.

The literature consistently identifies transport as one of the most challenging sectors for decarbonisation, requiring targeted and sector-specific policy interventions. Energy consumption in transport has increased in line with the growth in transport activity. Overall, transport fuel efficiency has barely increased. Almost all fuels used in the transport sector are petroleum products with a largely unchanged fuel mix, and the shift towards RES in transport is marginal compared to other sectors. Various approaches to reducing transport emissions have been proposed, including improving efficiency of existing technologies (Olabi et al., 2020), developing new low-impact technologies (Olabi et al., 2021; Sayed et al., 2021), and transitioning to renewable energy sources (Hussain et al., 2017; Olabi & Abdelkareem, 2022). Fossil fuels remain attractive due to their energy density and ease of use, further complicating rapid transition in the transport sector (Rivard et al., 2019).

Comparative assessments of energy efficiency and renewable energy development have been conducted across EU countries (Karasek et al., 2023; Tutak et al., 2020). Studies also analyse sustainable development of road transport using multi-criteria approaches (Siksne-lyte-Butkiene & Streimikiene, 2022). Research on the Baltic States indicates that renewable energy plays an important role in reducing energy-related GHG emissions, yet outcomes differ significantly across countries (Miškinis et al., 2021).

Despite extensive research on renewable energy development, policy instruments, and transport decarbonisation, limited research integrates transport-specific renewable energy performance indicators with structured comparative analysis of national policy frameworks. In particular, the Nordic-Baltic region remains underexplored in terms of explaining variation in transport-sector renewable energy outcomes under a common EU regulatory framework.

### 3. Data and methodology

The transition to RES in the transport sector relies on various indicators and metrics to measure progress and ensure a successful shift towards sustainability. The main approach applied in this paper is comparative analysis, which consists of two complementary parts. First, a comparative analysis of selected quantitative indicators relevant to both Finland and Baltic States is conducted (Table 1). Second, a comparative analysis of main policies and instruments to support renewable energy-based development in selected countries is carried out (Table 2). The quantitative indicators of RES deployment and transport emissions were selected

**Table 1.** Key indicators (source: made by authors)

| Indicator                                                          | Description of indicator                                                                                                                                                                                                                                                                                                                               | Unit of measurement                       |
|--------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------|
| Share of RES in the gross final energy consumption                 | Measures the share of renewable energy in total gross final energy consumption across all sectors. This indicator reflects the overall progress of the national energy system towards renewable energy transition.                                                                                                                                     | %                                         |
| Share of RES in the gross final consumption of energy in transport | Measures the percentage of energy used in the transport sector that comes from renewable sources, including biofuels, renewable electricity, and other renewable fuels. This indicator captures sector-specific progress towards transport decarbonisation.                                                                                            | %                                         |
| GHG emissions reduction                                            | Measures changes in greenhouse gas emissions from the transport sector over time, reflecting the environmental outcomes of the transition towards cleaner and renewable energy sources in transport.                                                                                                                                                   | A million tonnes (Mt CO <sub>2</sub> -eq) |
| New passenger cars by type of motor energy                         | Shows the distribution of newly registered passenger cars by propulsion technology, including internal combustion engine vehicles, hybrid vehicles, plug-in hybrids, and battery electric vehicles. This indicator reflects technological transition dynamics in road transport and the influence of policy incentives and infrastructure development. | #                                         |
| Passenger cars per 1000 inhabitants                                | Measures the level of passenger car ownership relative to population size, reflecting the structural demand for road transport and the pressure exerted on energy consumption and emissions in the transport sector.                                                                                                                                   | #                                         |

from Eurostat (n.d.) and the European Environment Agency (2025) based on data availability, consistency, and cross-country comparability. The information used for the comparative assessment of the transition to RES in the transport sector in Finland and the Baltic States is obtained mainly from Eurostat (n.d.). Because the availability of Eurostat datasets differs across indicators, the analysis applies the longest comparable period available for each dataset.

The key indicators presented in Table 1 are used to evaluate the progress and effectiveness of the transition towards renewable energy-based sources in the transport sector in Finland and the Baltic States. These indicators enable a systematic comparison of transition performance across countries over time and provide an evidence base for assessing the outcomes of policy interventions supporting renewable energy-based development.

The selected indicators were chosen to capture multiple dimensions of the transport energy transition. These include energy system transformation, measured by the share of renewable energy sources in total and transport energy consumption; environmental outcomes, reflected by GHG emissions from transport; structural characteristics of transport demand, represented by passenger car ownership; and technological transition dynamics, assessed through the composition of newly registered passenger cars by type of motor energy. Together, these indicators enable a comprehensive assessment of transition progress and outcomes and support the identification of transition dynamics and structural differences among countries operating under a common regulatory framework.

**Table 2.** Main policies and instruments to support renewable energy-based development (source: made by authors based on literature review and analysis)

| Policy/instrument                                                    | Description                                                                                                                                              |
|----------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|
| Regulations and standards                                            | Regulatory frameworks and technical standards that support renewable energy deployment while ensuring safety, reliability, and environmental protection. |
| Renewable energy mandates                                            | Regulatory requirements obligating energy producers or suppliers to generate or use a specified share of energy from renewable sources.                  |
| Public procurement                                                   | Government purchasing policies that prioritise renewable energy technologies or low-emission solutions in public sector activities.                      |
| Green certificates                                                   | Market-based instruments representing the environmental benefits of renewable energy generation and enabling renewable energy trading schemes.           |
| Direct investments and investments to research and development (R&D) | Public investments and R&D funding supporting the development and deployment of renewable energy technologies.                                           |
| Grants, loans, and subsidies                                         | Financial instruments that reduce investment costs and encourage renewable energy adoption by individuals, companies, and institutions.                  |
| Feed-in tariffs and feed-in premiums                                 | Policy mechanisms providing financial support to renewable energy producers through guaranteed payments or market premiums.                              |
| Carbon prices and tax reductions                                     | Economic instruments that increase the cost of carbon-intensive energy and improve the competitiveness of renewable energy sources.                      |

Table 2 presents the main categories of policy instruments supporting renewable energy-based development identified from the literature. These instruments include regulatory measures, financial incentives, market-based mechanisms, and support for innovation and infrastructure development. The table serves as a conceptual framework for identifying and classifying policy instruments that can support the transition toward renewable energy in the transport sector. The identified policies are used as a reference structure for the comparative assessment of national policy measures presented in the Results section. In the empirical analysis, these instruments are evaluated according to their presence and relative maturity in Finland and the Baltic States. The comparison therefore focuses on policy orientation and implementation maturity rather than financial scale or budgetary intensity. Although all analysed countries operate within a common EU regulatory framework, differences in national implementation, institutional capacity, and strategic priorities influence the way these instruments are applied. Consequently, the analysis identifies similarities and differences in policy approaches while acknowledging that variations in financial allocations and policy intensity are not systematically quantified in this study.

While the selected indicators provide a consistent and comparable basis for assessing renewable energy transition performance in Finland and Baltic States, several limitations should be acknowledged. First, the analysis relies on aggregated national-level indicators, which do not capture regional variation within countries or differences in local policy implementation. Second, although the study compares policy instruments qualitatively, it does not systematically quantify differences in financial allocations or budgetary intensity across countries, which may influence observed transition dynamics. Third, the comparative approach allows for the identification of associations between policy design and transition outcomes, but it

does not establish causal relationships between specific policy instruments and observed changes. Finally, the analysis focuses primarily on road transport, and results may not be directly transferable to other transport subsectors.

## 4. Results

The gross final consumption of renewable energy shall be calculated in accordance with the requirements of Article 5 of Directive 2009/28/EC (European Parliament & Council of the European Union, 2009 Table 3).

**Table 3.** Calculation of the share of energy from renewable sources (Source: made by authors based on Directive 2009/28/EC (European Parliament & Council of the European Union, 2009)

| The gross final consumption of energy from renewable sources in each EU Member State shall be calculated as the sum of gross final consumption of: |                                                       |                                            |
|----------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------|--------------------------------------------|
| Electricity from RES                                                                                                                               | Energy from renewable sources for heating and cooling | Energy from renewable sources in transport |

The comparative analysis of the selected indicators shows positive trends towards renewable energy-based development. The share of RES in gross final consumption of energy shows the overall impact of RES deployment in all sectors in Estonia, Latvia, Lithuania and Finland in 2024 (Table 4). All selected countries perform above the EU average in total share of RES in gross final consumption, but the share of RES in the transport sectors in Latvia and Lithuania are below the EU average and all three Baltic countries are below obliged 10% by Directive 2009/28/EC (European Parliament & Council of the European Union, 2009) respectively 7.3 % in Estonia, 4.8 % in Latvia and 5.2 % in Lithuania. Finland demonstrated a significant shift to RES in transport since 2010, increasing the share by 15.9% and showing significantly higher performance compared to EU average in 2024 by reaching 20.3% of RES in transport sector.

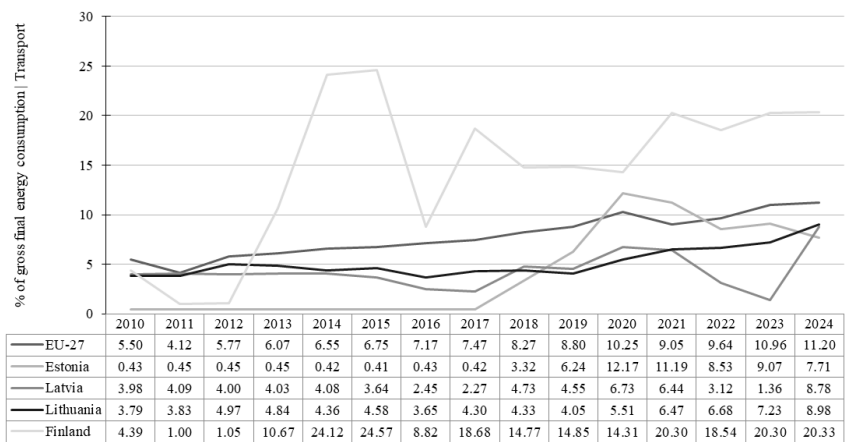
The results of this study show that the share of RES in transport compared with gross final energy consumption varied across the selected countries, with particularly large differences in the Baltic countries (Table 5). The highest use of RES in the transport sector was in 2015, when they accounted for 62.6% of Finland's total RES consumption, reaching 24.6% of total final energy consumption in transport. Since then, Finland has been among the EU leaders in terms of the share of RES in transport, well ahead of Baltic States (Figure 2). Estonia has demonstrated a steady and, at times, rapid increase in the share of RES in transport since 2010, reaching a peak of 40.5% of total RES consumption in 2020, followed by a decline in subsequent years, resulting in the lowest share of RES in transport among the analysed countries in 2024. The slowest shift in the share of RES in gross final energy consumption in transport is observed in Latvia, where the share increased by 4.8 % between 2010 and 2024, compared to 5.2 % in Lithuania, 7.3 % percentage points in Estonia, and a substantially larger increase of 15.9% in Finland (Table 4).

**Table 4.** Change of the share of RES in gross final consumption (total and transport sector) in the selected countries 2010–2024 (%) (source: Eurostat, n.d.)

|           | Total |      |          | Transport |      |          |
|-----------|-------|------|----------|-----------|------|----------|
|           | 2010  | 2024 | Change % | 2010      | 2024 | Change % |
| EU-27     | 14.4  | 25.2 | 10.8     | 5.5       | 11.2 | 5.7      |
| Estonia   | 24.6  | 42.2 | 17.7     | 0.4       | 7.7  | 7.3      |
| Latvia    | 30.4  | 45.5 | 15.2     | 4         | 8.8  | 4.8      |
| Lithuania | 19.6  | 35.4 | 15.8     | 3.8       | 9    | 5.2      |
| Finland   | 32.2  | 52.1 | 20       | 4.4       | 20.3 | 15.9     |

**Table 5.** Share of RES in transport compare with share of RES in gross final energy consumption in selected countries 2010–2024 (%) (source: Eurostat, n.d.)

|           | 2010         |           |                                 | 2015         |           |                                 |
|-----------|--------------|-----------|---------------------------------|--------------|-----------|---------------------------------|
|           | Share of RES |           | Share in transport of total RES | Share of RES |           | Share in transport of total RES |
|           | Total        | Transport |                                 | Total        | Transport |                                 |
| EU-27     | 14.4         | 5.5       | 38.2                            | 17.8         | 6.8       | 37.9                            |
| Estonia   | 24.6         | 0.4       | 1.8                             | 29           | 0.4       | 1.4                             |
| Latvia    | 30.4         | 4         | 13.1                            | 37.5         | 3.6       | 9.7                             |
| Lithuania | 19.6         | 3.8       | 19.3                            | 25.7         | 4.6       | 17.8                            |
| Finland   | 32.2         | 4.4       | 13.6                            | 39.2         | 24.6      | 62.6                            |
|           | 2020         |           |                                 | 2024         |           |                                 |
| EU-27     | 22           | 10.3      | 46.5                            | 25.2         | 11.2      | 44.4                            |
| Estonia   | 30.1         | 12.2      | 40.5                            | 42.2         | 7.7       | 18.2                            |
| Latvia    | 42.1         | 6.7       | 16                              | 45.5         | 8.8       | 19                              |
| Lithuania | 26.8         | 5.5       | 20.6                            | 35.4         | 9         | 25.4                            |
| Finland   | 43.9         | 14.3      | 32.6                            | 52.1         | 20.3      | 39                              |



**Figure 2.** Share of RES in the gross final consumption of energy in transport 2010–2024 (%) (source: Eurostat, n.d.)

In 2023, the EU emitted 757.1 million tonnes of GHG from fuel combustion in road transport, confirming that road transport remains one of the largest contributors to transport-related emissions despite ongoing decarbonisation efforts. A clear divergence in emission trends is observed across the analysed countries. Finland shows a sustained decline in GHG emissions from road transport fuel combustion, reducing the amount from 11.8 million tonnes in 2010 to 8.9 million tonnes in 2023, indicating effective integration of renewable energy use with structural and technological measures. In contrast, Estonia and Latvia show stable emission levels, as higher transport activity offsets efficiency gains and renewable energy use. Lithuania shows a different trend, with GHG emissions increasing by 1.87 million tonnes over the same period, pointing to growing transport demand and slower structural adjustment in the road transport sector (Table 6).

**Table 6.** GHG emissions from fuel combustion in road transport 2010–2023 (a million tonnes) (source: Eurostat, n.d.)

|                    | EU-27 | Estonia | Latvia | Lithuania | Finland |
|--------------------|-------|---------|--------|-----------|---------|
| 2010               | 768.5 | 2.1     | 3      | 4.1       | 11.8    |
| 2011               | 761.3 | 2.1     | 2.6    | 4.1       | 11.6    |
| 2012               | 734.1 | 2.2     | 2.5    | 4.1       | 11.4    |
| 2013               | 730.5 | 2.1     | 2.6    | 4.1       | 11.2    |
| 2014               | 736.3 | 2.2     | 2.7    | 4.6       | 10.2    |
| 2015               | 755.6 | 2.2     | 2.9    | 4.9       | 10.2    |
| 2016               | 771   | 2.3     | 3      | 5.2       | 11.4    |
| 2017               | 781.8 | 2.4     | 3.1    | 5.5       | 10.8    |
| 2018               | 787.8 | 2.4     | 3.1    | 5.8       | 10.9    |
| 2019               | 790.6 | 2.4     | 3.1    | 6         | 10.5    |
| 2020               | 688.5 | 2.2     | 3      | 5.9       | 9.9     |
| 2021               | 745.3 | 2.3     | 3.1    | 5.9       | 9.5     |
| 2022               | 765.1 | 2.4     | 3      | 5.9       | 9.3     |
| 2023               | 757.1 | 2.4     | 3.1    | 6         | 8.9     |
| Change vs 2010 (%) | –11.4 | 0.3     | 0.1    | 1.9       | –2.9    |

To further explain the observed GHG emission trends, the structure of newly registered passenger cars by type of motor energy is examined to provide insight into technological transition dynamics in road transport (Table 7). Finland shows the most advanced shift, characterised by a sharp decline in diesel registrations and a strong increase in electrified vehicles. By 2024, hybrids, plug-in hybrids, and electric vehicles together accounted for a substantial share of new registrations, with electric vehicles reaching 29.5%, aligning with the observed decline in GHG emissions from road transport. In the Baltic States, Estonia, Latvia, and Lithuania also demonstrate a gradual move away from diesel vehicles and increasing adoption of hybrid and electric cars, particularly after 2020. However, petrol vehicles remain dominant. This slower change in vehicle fleet composition is consistent with stable GHG emission levels in Estonia and Latvia and increasing emissions in Lithuania. EU-level data are not reported, as disaggregated information on newly registered passenger cars by motor energy type is largely unavailable or incomplete for most categories before 2020, limiting consistent comparison across years.

**Table 7.** Newly registered passenger cars by type of motor energy 2013–2024 (%) (source: Eurostat, n.d.\*)

|           |      | Petrol | Diesel | Hybrid | Plug-in hybrid | Electricity |
|-----------|------|--------|--------|--------|----------------|-------------|
| Estonia   | 2013 | 62.0   | 37.3   | 1.0    | –              | 0.7         |
|           | 2015 | 66.9   | 33.0   | 1.7    | –              | 0.1         |
|           | 2020 | 68.2   | 26.6   | 13.4   | –              | 1.8         |
|           | 2024 | 71.5   | 22.8   | 40.4   | 4.8            | 5.1         |
| Latvia    | 2013 | –      | –      | –      | –              | 0.0         |
|           | 2015 | 50.5   | 48.4   | 0.1    | –              | 0.1         |
|           | 2020 | 60.9   | 35.5   | 0.6    | –              | 2.6         |
|           | 2024 | 68.7   | 21.7   | 37.3   | 4.6            | 7.5         |
| Lithuania | 2013 | 42.7   | 57.3   | 0.4    | –              | 0.05        |
|           | 2015 | 43.6   | 55.9   | 0.7    | –              | 0.2         |
|           | 2020 | 80.5   | 17.2   | 19.6   | –              | 4.4         |
|           | 2024 | 71.5   | 19.6   | 41.3   | 6.0            | 29.5        |
| Finland   | 2013 | 62.1   | 37.4   | –      | –              | 0.05        |
|           | 2015 | 63.8   | 35.7   | 2.6    | 0.4            | 0.2         |
|           | 2020 | 78.6   | 15.1   | 18.0   | 13.3           | 4.4         |
|           | 2024 | 64.9   | 5.4    | 29.9   | 19.8           | 29.5        |

Note: \*Percentages are calculated relative to total newly registered passenger cars in each country and year. Due to Eurostat motor-energy classifications and transitional reporting categories, shares may not sum exactly to 100%.

While changes in the vehicle fleet affect emissions only gradually due to slow fleet turn-over, the structure of new registrations provides important insight into transition dynamics and the future trajectory of road transport emissions.

While the composition of newly registered passenger cars reflects technological transition, overall emission outcomes are also shaped by the size of the vehicle fleet and car ownership levels. The highest number of cars per thousand inhabitants in 2024 was in Finland – 666, and consequently 635 in Estonia, 598 in Lithuania, 424 in Latvia. The number of passenger cars has grown over the years in all selected countries, but the most rapid growth was recorded in Estonia, where the number of passenger cars increased by 52.6 % in 2024 compared to 2010, compared to 18.7 % of the total EU average (Table 8). The continued growth in passenger car ownership, particularly in Estonia and Latvia, increases overall transport activity and helps explain why reductions in GHG emissions remain limited despite the growing share of electrified vehicles.

The results and achievements of road transport development and the transition to RES in Finland and the Baltic States differ. Historical evidence shows that all countries have achieved significant results, but not enough to tackle climate change. It is therefore important to track progress and accelerate the transition to RES in the transport sector through a range of policies and measures that equally consider economic, social and environmental development.

The comparative overview of policy instruments shows that Finland and the Baltic States rely on a broadly similar policy framework supporting the transition toward renewable energy in the transport sector. At the same time, the maturity and emphasis of policy implementation differ across countries (Table 9).

**Table 8.** Passenger cars per 1000 inhabitants 2010–2024 (source: Eurostat, n.d.)

|           | 2010 | 2015 | 2020 | 2024 | Change vs 2010 (%) |
|-----------|------|------|------|------|--------------------|
| EU-27     | 487  | 508  | 555  | 578  | 18.7               |
| Estonia   | 416  | 514  | 608  | 635  | 52.6               |
| Latvia    | 307  | 345  | 390  | 424  | 38.1               |
| Lithuania | 554  | 430  | 557  | 598  | 7.9                |
| Finland   | 535  | 590  | 652  | 666  | 24.5               |

**Table 9.** Policy instruments supporting renewable energy transition in the road transport sector in Finland and the Baltic States (source: made by authors based on literature review and analysis)

| Policy category                       | Policy instrument                           | Finland*    | Baltic States* | Description                                                                                   |
|---------------------------------------|---------------------------------------------|-------------|----------------|-----------------------------------------------------------------------------------------------|
| Regulatory instruments                | Regulatory framework and emission standards | Established | Established    | National and EU regulations promote cleaner vehicles and fuels.                               |
|                                       | Promotion of renewable fuels (biofuels)     | Established | Advanced       | Fiscal and regulatory measures encourage renewable transport fuels.                           |
| Economic and financial incentives     | EV purchase incentives                      | Established | Advanced       | Financial incentives reducing the purchase cost of electric vehicles.                         |
|                                       | Tax incentives for low-emission vehicles    | Established | Advanced       | Reduced vehicle taxation and registration fees encouraging adoption of low-emission vehicles. |
|                                       | Public transportation subsidies             | Established | Advanced       | Financial support for public transport systems encouraging sustainable mobility.              |
|                                       | Incentives for fleet electrification        | Advanced    | Developing     | Support measures encouraging companies and public fleets to adopt low-emission vehicles.      |
| Innovation and technological support  | Research and development support            | Advanced    | Developing     | Public funding supports innovation in renewable energy and transport technologies.            |
|                                       | Hydrogen fuel development                   | Developing  | Limited        | Development and pilot deployment of hydrogen technologies in transport.                       |
| Infrastructure and system integration | Charging infrastructure development         | Advanced    | Developing     | Expansion of EV charging networks supporting vehicle electrification.                         |
|                                       | Integration with renewable energy sources   | Advanced    | Developing     | Integration of transport electrification with renewable energy generation systems.            |

End of Table 9

| Policy category                  | Policy instrument                             | Finland*    | Baltic States* | Description                                                                        |
|----------------------------------|-----------------------------------------------|-------------|----------------|------------------------------------------------------------------------------------|
| Behavioral and mobility measures | Eco-driving and energy efficiency programs    | Advanced    | Developing     | Programs encouraging energy-efficient driving behavior.                            |
|                                  | Environmental labelling                       | Advanced    | Developing     | Labelling systems inform consumers about the environmental impact of vehicles.     |
|                                  | Public awareness and education                | Advanced    | Developing     | Campaigns promote sustainable mobility choices.                                    |
|                                  | Shared mobility and smart transport solutions | Developing  | Advanced       | Promotion of car-sharing, ride-hailing and smart mobility systems.                 |
|                                  | Active mobility infrastructure                | Advanced    | Advanced       | Development of cycling and walking infrastructure to reduce car dependence.        |
| Public sector leadership         | Green public procurement                      | Established | Advanced       | Public authorities prioritising low-emission vehicles in public fleets.            |
| International coordination       | International cooperation and partnerships    | Advanced    | Advanced       | Collaboration with international organisations and stakeholders to align policies. |
| Public transport transition      | Public transport electrification              | Advanced    | Advanced       | Electrification of buses and other public transport fleets.                        |

Notes: \* Policy maturity levels used in the table are defined as follows: established – widely implemented policy instrument forming part of the national policy framework; advanced – well-developed and actively promoted policy measure with substantial implementation; developing – policy instrument under expansion or partial implementation; limited – early-stage policy measure with relatively narrow application.

Several core instruments, including regulatory frameworks and emission standards, EV purchase incentives, tax benefits for low-emission vehicles, green public procurement, and the promotion of renewable fuels, are already well established across the analysed countries. This reflects the influence of common EU climate and energy policies.

However, differences emerge in the maturity and emphasis of policy implementation. Finland demonstrates a higher concentration of established and advanced policy instruments, particularly in areas related to renewable fuel promotion, public transport support, and the integration of renewable energy sources with transport electrification. Infrastructure-related measures, such as charging network development and fleet electrification incentives, are also more advanced in Finland. In contrast, many of these measures remain in the developing stage in the Baltic States, particularly in areas such as research and development support, charging infrastructure expansion, and the integration of renewable energy systems with transport electrification.

At the same time, the Baltic States show stronger emphasis on certain mobility-related policies, including shared mobility services and smart transport solutions, which are increasingly promoted as part of broader sustainable mobility strategies. These differences indicate that although the overall policy architecture is largely similar due to common EU regulations, national priorities and implementation dynamics vary across countries.

It should be noted that the comparison presented in Table 9 primarily reflects the direction and maturity of policy instruments rather than their financial scale or effectiveness. Comparable cross-country data on the financial resources allocated to these measures, including funding volumes and sources, are not consistently available across countries. Therefore, the analysis focuses on identifying the presence and relative development of key policy instruments that shape the transition toward renewable energy-based transport systems.

Overall, the results suggest that while Finland and the Baltic States apply largely similar policy instruments, the degree of policy maturity, coordination, and integration with supporting infrastructure differs. These differences in policy maturity and coordination help explain the variation in renewable energy deployment and GHG emission trends observed across the analysed countries.

## 5. Discussion

Although all the countries analysed are in the Baltic Sea region, Finland and the Baltic countries are pursuing sustainable transport transformation, differences in economic development, geographical location, infrastructure and political factors determine the pace and nature of sustainable transformation. The scale of sustainable transformation in each country depends on the priorities and policies in place. The results of this study show that despite operating within the same EU regulatory framework, countries demonstrate different transition dynamics in renewable energy deployment and emission reduction in the transport sector.

The findings of this study revealed some differences in prioritising governmental support measures and applying policies to support transition to renewable energy-based development in the transport sector in Finland and the Baltic States. Numerous studies focus on renewable energy policy instruments. Siksnelyte-Butkiene and Streimikiene (2022) and other authors point out that purchase subsidies and tax incentives for EVs help to increase the uptake of electric vehicles by reducing the price differential between EVs and Internal Combustion Engine (ICE) vehicles. Such instruments can also contribute to economies of scale in the EV and battery industries and stimulate technological innovation. However, it is essential to emphasise that even by actively supporting and incentivising EVs to reduce the upfront cost of buying an electric car, the share of electrified vehicles in newly registered passenger cars has increased gradually but still represents a relatively small part of the total vehicle fleet in most analysed countries. At the same time, the number of passenger cars per 1000 inhabitants has increased significantly since 2010, particularly in Estonia and Latvia, which partly offsets the environmental benefits achieved through vehicle electrification and improvements in energy efficiency.

These results suggest that technological change in the vehicle fleet alone is not sufficient to significantly reduce emissions if overall transport demand and car ownership continue to grow. Therefore, policy effectiveness depends not only on incentives supporting low-emission vehicles but also on broader structural measures addressing transport demand, infrastructure development, and integration with renewable energy systems.

Ensuring sustainable economic development and GHG reductions through economic policy is a key issue for policymakers. This includes policies that subsidise investment in

R&D and tax carbon dioxide emissions to enable appropriate technical changes to reduce GHG emissions (Moosavian et al., 2022; Nordhaus, 2019). Moosavian et al. (2022) argued that by taxing fossil fuel consumption and subsidising R&D, the private sector is incentivised to develop renewable energy systems, making renewable energy cost-competitive with fossil fuels. The large-scale development of renewable energy systems does not have an economic rationale due to the low cost of fossil fuels. These findings are consistent with the results of this study, which indicate that policy instruments combining fiscal incentives, regulatory measures, and infrastructure development are important for accelerating the transition toward renewable energy in the transport sector. The comparative analysis of Finland and the Baltic States shows that countries with more coordinated policy frameworks and stronger integration of renewable fuels, infrastructure development, and vehicle electrification demonstrate more consistent progress in increasing the share of renewable energy in transport and reducing transport-related emissions.

Overall, the results suggest that differences in policy maturity, institutional capacity, and long-term policy coordination contribute to the variation in renewable energy deployment and emission reduction outcomes across the analysed countries. These findings highlight the importance of coordinated policy approaches that combine technological development, infrastructure expansion, and stable regulatory frameworks to support the transition toward sustainable transport. The implications of these results are discussed in the concluding section.

## 6. Conclusions

The transport sector has a significant role to play in the decarbonisation of the EU energy system. Increasing transport activity has a strong dependence on the increase in energy consumption in transport sector. Overall, improvements in fuel efficiency in transport have been limited, and the sector remains highly dependent on petroleum products. As a result, the fuel mix has not evolved as favourably towards renewables as in other sectors. Most sectors have seen declining GHG emissions, while emissions from fuel combustion in transport remain comparatively high, highlighting the challenges of decarbonising this sector. Significant reductions in GHG emissions require a reduction in the use of fossil fuels. However, this is a challenging task, as the products resulting from fossil fuels are not only energy carriers but also primary energy sources for transport systems.

This paper presented a comparative assessment of key indicators and policy instruments supporting the transition towards renewable energy-based development in the transport sector in Finland, Estonia, Latvia and Lithuania. The analysis applied a structured set of indicators reflecting renewable energy deployment, emission dynamics, vehicle fleet transformation, and transport demand. Such a framework enables systematic monitoring of transition progress, identification of leading practices, and detection of structural differences influencing transport decarbonisation outcomes.

A comparative analysis of the indicators reveals that Finland and the Baltic States demonstrate different transition dynamics towards renewable energy development in transport. All analysed countries perform above the EU average level in the overall share of renewable energy in gross final consumption. However, the share of renewable energy in transport

remains lower in Latvia and Lithuania, remaining below EU targets established by Directive 2009/28/EC (European Parliament & Council of the European Union, 2009). Finland and Estonia demonstrate more pronounced progress in renewable energy deployment in transport, with Finland reaching one of the highest shares of renewable energy in transport among the analysed countries, while Estonia shows a rapid increase over last decade. These differences illustrate how national policy frameworks, infrastructure development, and technological adoption influence transition performance.

The analysis also highlights the importance of vehicle fleet transformation and transport demand dynamics in shaping emission outcomes. Growth in passenger car ownership across most analysed countries increases transport activity and partly offsets emission reductions achieved through renewable energy deployment and vehicle electrification. At the same time, the increasing share of electrified vehicles and the diversification of motor energy types in newly registered passenger cars indicate gradual technological change in the transport sector. These trends suggest that technological change alone is insufficient to significantly reduce emissions without broader structural measures addressing transport demand and infrastructure development.

Policies aiming to support and promote the use of renewable energy seek to reduce the existence of market barriers and address positive externalities, such as pollution reduction, improved energy security, and energy source diversification. Based on literature analysis, the policies and instruments supporting renewable energy development include regulatory frameworks and standards, renewable energy mandates, public procurement, market-based mechanisms, research and development support, financial incentives, and carbon pricing instruments.

Recent EU policy initiatives, including the Renewable Energy Directive II (Directive (EU) 2018/2001) (European Parliament & Council of the European Union, 2018), the revised Renewable Energy Directive III (Directive (EU) 2023/241) (European Parliament & Council of the European Union, 2023), and the Fit for 55 package, further strengthen renewable energy and decarbonisation targets for the transport sector. In addition, sector-specific initiatives such as ReFuelEU and FuelEU aim to accelerate the adoption of sustainable fuels in transport. These policy developments highlight the increasing importance of coordinated policy frameworks and technological innovation in achieving long-term decarbonisation goals.

While Finland has made substantial progress in transitioning to RES during the last decade, it's important to note that each country's transition pathway remains shaped by its specific economic conditions, infrastructure development, and policy priorities. The results of this study suggest that countries with more integrated policy frameworks, stronger infrastructure development, and greater policy coordination tend to demonstrate more consistent progress in renewable energy deployment and emission reduction in the transport sector.

This study contributes to the literature by combining quantitative indicators of renewable energy transition performance with a comparative analysis of policy instruments in Finland and the Baltic States. The results highlight how differences in policy maturity, infrastructure development, and institutional capacity influence the dynamics of transport decarbonisation across countries operating under a common EU regulatory framework. Future research could further investigate the interaction between policy instruments, infrastructure investment, and

technological adoption in shaping transport decarbonisation pathways. More detailed analysis of financial allocations and policy effectiveness across countries could also provide deeper insights into the mechanisms driving successful energy transitions in the transport sector.

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