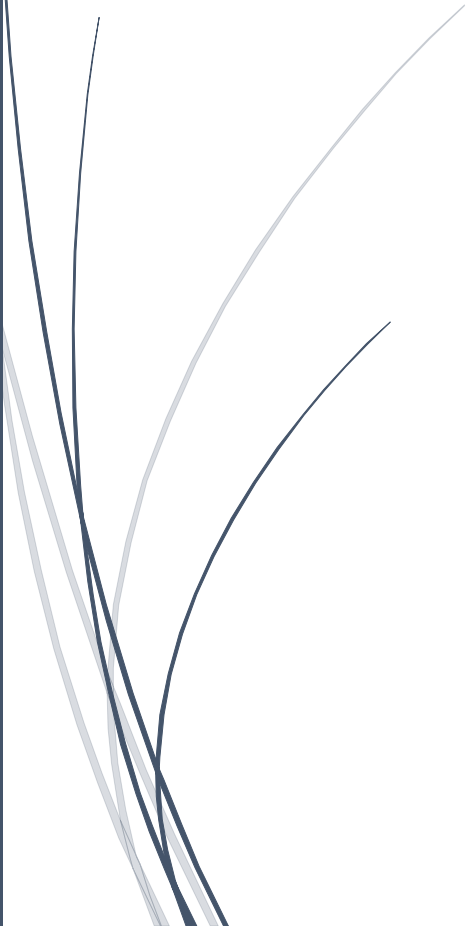




31.3.2026

EVSTATION - Electric Vehicle Statistics and Charging Stations Networks

**Deliverable 1.1: Methodology
for allocation vehicles**



**101197985 - 2024-SK-EGD - SMP-ESS-2024-EGD-IBA
Call: SMP-ESS-2024-EGD-IBA
Topic: SMP-ESS-2024-EGD-IBA-H4-6730**

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1. PROJECT GRANT BACKGROUND

This report is part of the EVSTATION project (Electric Vehicle Statistics and Charging Stations Network), registered under the acronym 2024-SK-EGD. The primary ambition of this initiative is to address the existing data gap regarding region-specific statistics on electric vehicles (EVs) and alternative-fuel engines within the Slovak Republic.

In the context of the European Green Deal and the "Fit for 55" legislative package, which aims for a 55% reduction in greenhouse gas emissions by 2030, the transition to zero-emission mobility is paramount. As road transport accounts for approximately 20% of carbon dioxide emissions in Europe, developing a robust evidence base is essential for effective policy-making. This deliverable focuses on the creation of a comprehensive methodology for assigning vehicles to the NUTS 3 level and categorising them according to NACE rev.2 classifications. The following sections detail the database architecture, the integration of heterogeneous data sources, and the initial findings regarding the spatial distribution of alternative-fuel vehicles between 2013 and 2024.

2. METHODOLOGY

2.1 Database Architecture and System Design

The structural foundation of this project is a bespoke prototype database system, which was conceptualised and implemented following a comprehensive and systematic assessment of all available administrative data sources. The system is built upon a high-performance Microsoft SQL Server environment, which serves as the central repository for integrated vehicle data. The functional logic of the system—specifically the modules responsible for data importation, processing, and analytical computations—was developed using the .NET framework and the C# programming language. This modular architecture was strategically selected to ensure that the framework is not only scalable to handle increasing data volumes but also extensible and adaptable for future analytical requirements and diverse research projects.

The system architecture is structured into distinct functional layers to ensure data integrity and analytical precision:

- **Primary Input Layer:** This layer manages the ingestion of heterogeneous data from different administrative sources: the IS EVO vehicle registration system, the Periodic Inspection Database, and the Register of Organisations. These sources provide a multifaceted dataset, combining technical vehicle specifications with operational history and sectoral ownership details.
- **Processing and Validation Layer:** The core logic of the system resides in this layer, which is responsible for data transformation, validation, and cleaning procedures. It employs deterministic matching techniques, utilizing unique

identifiers such as the Vehicle Identification Number (VIN) and registration numbers to interlink records across different registries with precision.

- **Analytical and Disaggregation Module:** Building upon the heritage of the established AEA road transport matrix software tool, a new specialised module has been integrated into the framework. This module is specifically designed to disaggregate vehicle data into a comprehensive statistical matrix, enabling the granular analysis of the vehicle fleet's structure and spatial distribution at the NUTS 3 (district) level.
- **Quality Assurance Framework:** To mitigate technical risks such as inconsistent technical descriptions or insufficient data quality, the architecture incorporates automated cross-checking mechanics. These cross-references between databases ensure that any discrepancies are identified and corrected during the processing phase, thereby preserving the reliability of the final statistical outputs.

The primary objective of this design is to facilitate a detailed understanding of the adoption patterns of battery electric vehicles (BEVs) and other alternative-fuel propulsion systems. By centralising these disparate data streams into a unified SQL-based environment, the project provides a robust platform for monitoring Slovakia's progress towards zero-emission mobility targets.

2.2 Vehicle Registration and Technical Classification

The IS EVO (Vehicle Registration Information System) serves as the central administrative register for all vehicles in the Slovak Republic. Managed by the Department of Documents and Registers of the Presidium of the Police Force, it contains comprehensive records on vehicles and their respective owners. For the purposes of this study, a wide range of attributes is extracted, including Vehicle Identification Number (VIN), registration number, fuel type, engine type, and weight parameters (maximum permissible and combined mass). Additionally, the database provides the date of first registration both globally and within the Slovak Republic.

Furthermore, vehicle age can be determined by the date of first registration. By comparing the original registration date with the date of entry into the Slovak registry, the methodology can distinguish between newly registered vehicles and imported used vehicles. This differentiation will be critical for accurate fleet characterisation, as it reflects the varying technological standards, emission performance, and usage patterns across different vehicle cohorts.

2.3 Activity Estimation via Periodic Inspections

Operational and technical data are further enriched by the Periodic Inspection Database, which is administered by the Ministry of Transport of the Slovak Republic. This dataset provides critical information, including the VIN, registration number, inspection date, and recorded odometer readings (total mileage). Annual mileage,

which is a fundamental metric for estimating fleet activity and emissions, is derived directly from these inspection records.

The methodology for calculating annual mileage varies based on the data available for each vehicle:

- **Interpolation:** For vehicles with multiple records, inspection date-cumulative mileage pairs are used to interpolate the annual mileage, defined as the difference between the mileage at the beginning and the end of the reference year.
- **Extrapolation:** For vehicles with only a single recorded observation, the mileage at the end of the reference year is estimated through extrapolation, based on the available data and assumed usage patterns.
- **Proxy Values:** In cases where specific vehicle categories have insufficient data, proxy values are assigned from structurally or functionally similar categories. This substitution ensures statistical consistency across the entire dataset while maintaining the reliability of activity estimates.

2.4 Ownership and Sectoral Categorisation

To understand the economic drivers of vehicle adoption, the Register of Organisations is used to identify and classify vehicle ownership, particularly for legal entities. Business-owned vehicles within the IS EVO system are associated with a unique company identifier (IČO), which allows for a direct linkage to this register. This connection enables the enrichment of vehicle records with attributes describing the primary economic activity of the owner.

The system utilizes NACE codes to categorise vehicles according to the specific sector in which they are utilised. This process allows the research to distinguish between private household vehicles and those owned by businesses, which are further sub-classified by industry sector. Such granularity supports a detailed analysis of fleet composition and the sector-specific adoption of alternative-fuel technologies.

2.5 Spatial Allocation and Regional Disaggregation

Each vehicle is assigned to a specific district (NUTS 3 level) based on its registration identifier (EČV) or permanent residence data. Traditionally, the registration number began with letters that uniquely corresponded to a specific district, which served as a proxy for the vehicle's operational location. Consequently, historical fleet distributions for the period between 2013 and 2023 rely on these EČV codes. It is generally assumed that vehicles are predominantly operated within their district of registration. While this assumption may not always hold true for certain company-owned vehicles or those operating across multiple regions, it provides a consistent and standard basis for spatial disaggregation.

However, as of 1 January 2023, Slovak registration plates were reformed, removing the direct link between EČV codes and the owner's place of residence. For vehicles

registered after this date, spatial allocation is performed using data obtained directly from the Police Force vehicle registration database, which ensures accurate district assignment based on the owner's actual residence. For the small fraction of vehicles (less than 1%) with special or personalised plates that deviate from standard coding, a proportional distribution method is applied for years 2013 to 2023. These are distributed across districts according to the relative share of standard vehicles of the same type, thereby ensuring that aggregate statistics remain undistorted.

2.7 Data Integration and Validation Framework

The final integrated dataset is aggregated at both district and regional levels to quantify vehicle counts by type, with a primary focus on alternative fuels. Deterministic matching based on the VIN and registration number ensures consistency across the different data sources. The processing layer of the architecture performs rigorous validation, data transformation, and cleaning procedures to address any inconsistencies or missing records. By interpolating annual mileage and stratifying the fleet by fuel type—specifically BEVs, PHEVs, HEVs, and ICEVs—the framework provides a robust foundation for estimating both vehicle activity and its associated environmental impact.

3. Results

This section presents the initial findings from the longitudinal analysis of the alternative-fuel vehicle (AFV) fleet in the Slovak Republic, covering the period from 2013 to 2024. The results demonstrate a significant structural shift in the national fleet, driven by regulatory changes, technological advancements, and evolving market dynamics.

3.1. Overall Evolution of the AFV Fleet

The alternative-fuel vehicle landscape in Slovakia underwent a profound transformation over the 11-year study period. The total number of registered AFVs expanded nearly fivefold, growing from 41 936 units in 2013 to 196 357 by 2024 (*Table 1*). This evolution is characterised by a transition from a monolithic market dominated by Liquefied Petroleum Gas (LPG) to a diversified ecosystem led by hybrid and electric propulsion systems.

The market trajectory can be divided into three distinct analytical phases:

- **Foundational Stability Phase** (2013–2016): This period was marked by technological lock-in, where LPG bifuel vehicles accounted for 95.5% of the AFV share (40,045 units). Adoption was hindered by structural barriers, including low purchasing power, an ageing national fleet with an average age of over 15 years, and a lack of public charging infrastructure.
- **Transition Ignition Phase** (2017–2019): LPG hegemony began to erode as multiple technologies gained traction. Petrol hybrids saw a massive surge, and battery electric vehicle (BEV) registrations accelerated from negligible bases to

over 2 000 units by 2019, supported by the first state purchase incentives and inaugural charging installations.

- **Acceleration Phase (2020–2024):** This phase delivered transformative scale, with hybrid technologies cementing market dominance and full electrification consolidating momentum. By 2024, AFVs spanned all 72 districts in Slovakia, although stark hierarc hies between regions and ownership types endured.

Table 1: Evolution and Growth Drivers of Alternative Fuel Vehicles (AFV) between 2013 and 2024

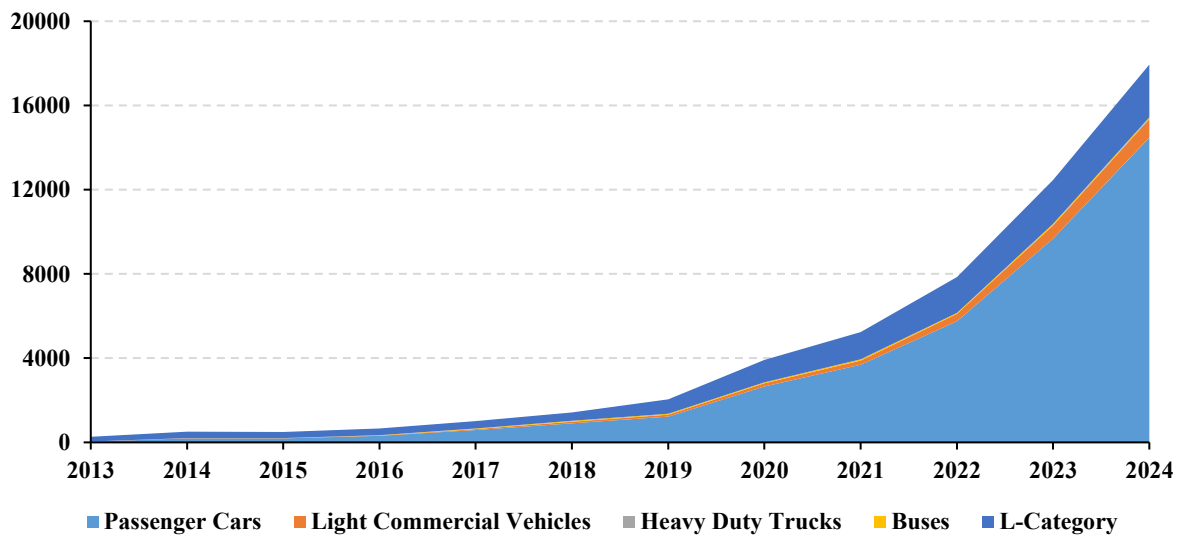
AFV Type	2013 Count	2024 Cumulative	Growth Multiple	Primary Driver
LPG Bifuel	40 045	~Stable peak	Declining share	Cost conversions (households)
Petrol Hybrids	75	87 928	>1,000×	Affordability/urban incentives
Diesel Hybrids	Minimal	22 903	Rapid late	Fleet replacement (high-mileage)
BEVs	267	17 941	67×	Infrastructure/corporate fleets
Petrol PHEVs	18	10 331	>500×	CO ₂ compliance (corporates)
CNG/CNG Bifuel	Modest	Steady growth	Moderate	Urban buses/logistics
Total AFVs	41 936	196 357	5×	EU policy shifts

3.2. Electric Vehicle Dynamics (BEVs)

Battery electric vehicle adoption has followed a classic innovation diffusion S-curve. The national BEV fleet grew from 267 units in 2013 to 17 941 by 2024, representing a 67-fold expansion. The most explosive growth occurred between 2020 and 2024 (*Figure 1*), with registrations jumping to approximately 18,000 annually as mid-range models (300–500 km) became more prevalent.

Spatial heterogeneity remains a defining feature of BEV adoption. The Bratislava region (Bratislavský kraj) has maintained unmatched dominance due to higher income levels, corporate density, and superior charging infrastructure. While eastern regions like Košický and Prešovský initially lagged, they have shown rapid catch-up patterns since 2021 as charging networks extended eastwards. At the district level, the five districts of Bratislava form the core of the national EV market, while peripheral rural districts only began seeing low-volume upticks around 2020 as more affordable compact models reached the market.

Figure 1: Growth of BEV in Slovakia between 2013 and 2024



3.3. Hybrid and Plug-in Hybrid Patterns (HEVs and PHEVs)

Hybrids and PHEVs have served as critical bridge technologies. Petrol hybrids, which were almost non-existent in 2013, reached 87 928 units by 2024, becoming the plurality of the AFV market. They are particularly popular among urban commuters who lack home charging facilities.

PHEV adoption has been largely driven by corporate fleets seeking to meet EU CO₂ compliance targets while avoiding range anxiety. Registrations for petrol PHEVs accelerated significantly between 2018 and 2021, reaching a cumulative total of 10 331 by 2024. As with BEVs, these technologies show a pronounced west-east disparity, with the Bratislava region accounting for 30–50% of national totals.

3.4. Gaseous and Other Fuels

Gaseous fuels continue to occupy specific niches within the transport sector:

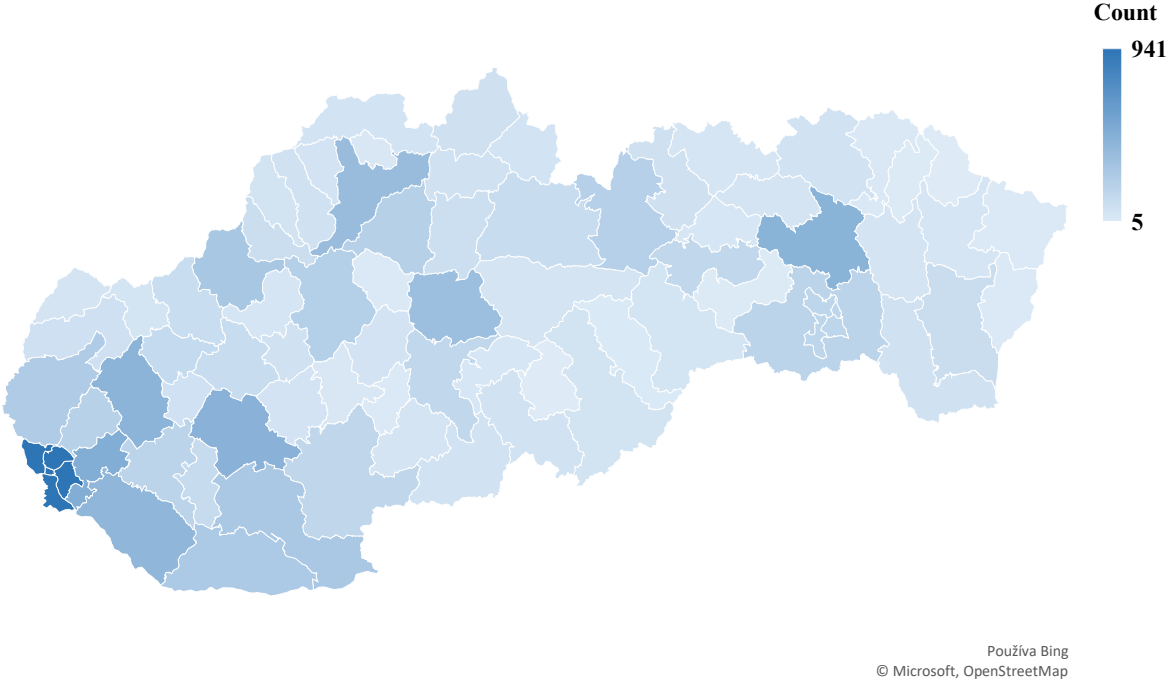
- **LPG:** Although its relative share of the AFV market has declined from 95% in 2013 to under 50% by 2024, LPG remains a popular cost-saving measure for households and micro-enterprises in lower-income rural districts.
- **CNG:** This fuel has seen steady growth, primarily supported by EU-funded urban bus procurements and logistics operations in major cities like Bratislava, Košice, and Žilina.
- **LNG:** Emerging post-2019, LNG is utilised almost exclusively as a heavy-duty solution for long-haul trucks operating along major TEN-T transport corridors.

3.5. Key Spatial and Categorical Disparities

The decade-long transition has been shaped by entrenched socio-economic geographies. A clear "west-east" gradient persists, with Bratislavský kraj and automotive-industrial hubs like Trnava and Nitra leading the adoption of new

technologies (Figure 2). In contrast, peripheral rural districts in the east and south registered near-zero uptake until approximately 2020.

Figure 2: Spatial distribution of BEV passenger cars in 2024



Categorically, passenger cars overwhelmingly dominate the AFV market, representing over 90% of all electrified and gaseous vehicle types. While light commercial vehicles have seen rising niches in urban "last-mile" logistics, heavy-duty vehicles continue to lag due to high battery costs and limited drivetrain availability. Addressing these persistent inequities through targeted interventions, such as rural charging densification and scrappage incentives, remains essential for Slovakia to meet the EU's 2030 and 2050 climate targets.

3.6 Vehicle Distribution by NACE Classification

Regarding the latest data for 2024, the distribution of battery electric vehicles (BEVs) by economic activity reveals a clear concentration within specific NACE sectors, primarily driven by operational efficiency and corporate sustainability goals. The highest number of non-household BEVs is currently found in the Wholesale and Retail Trade (G45–47) and Rental and Leasing activities (N77) sectors, reflecting the high turnover of corporate fleets and the logistical nature of these businesses. For passenger cars (M1) the Information Service Activities (J63) sector also plays a significant role, while light commercial vehicles (N1) are most prevalent in Land Transport (H49), and Postal and Courier activities (H53), where short, predictable delivery routes maximize the benefits of electric vehicles. In contrast, heavy-duty vehicles in categories N2 and N3 are not yet registered in Slovakia as of 2024, but buses and coaches (M2 and M3) are almost exclusively concentrated in Land Transport (H49) due to the ongoing electrification of public transportation. Finally, the

L-category vehicles find its place mainly in Telecommunications (J61), and Real Estate (L68), sectors where small, agile electric vehicles are ideal for urban mobility and facility management.