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ELECTRIC VEHICLES FOR EVERYONE? STATE, DISTRICT, AND CITY LEVEL UPTAKE PATTERNS IN GERMANY

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EXECUTIVE SUMMARY

The uptake of battery electric and plug-in hybrid electric vehicles (BEVs and PHEVs) is unequally distributed across the regions of Germany. In order to provide equitable living conditions in terms of reduced air pollution, provide equitable access to the fiscal incentives and economic benefits of BEVs and PHEVs, and to meet the federal government's target of 15 million battery electric cars by 2030, it is important to understand and address these regional differences. This study presents how BEV and PHEV registration shares vary between urban, intermediate, and rural regions, and across the federal states of Germany. It further analyses how the BEV and PHEV registration shares correlate with a selection of variables, such as average tax revenue of the regions' municipalities, average private household's income, or employment opportunities.

To describe the regional differences in BEV and PHEV adoption, we compare 2020 registration data among different regional typologies—urban, intermediate, rural—for the 401 German NUTS 3 regions representing districts (*Kreise*) and district-free cities (*kreisfreie Städte*). Based on the three regional typologies, we further categorize them into regions with a BEV and PHEV share of new passenger car registrations that are below and equal to or above the 2020 German average of 6.6% (BEVs) and 6.8% (PHEVs).

Figure ES-1 shows new BEV and PHEV registration shares by German NUTS 3 regions in 2020 based on the different cluster classifications. Across Germany, 57% of the 401 regions recorded new BEV registration shares equal to or above the 6.6% German average in 2020. Most of the urban, intermediate, and rural regions with new BEV registration shares equal to or above the average were in the south of Germany, with 44%, followed by 31% in the west, 20% in the north, and 4% in the east. New PHEV registration shares equal to or above the German average accounted for 43% of all regions in 2020, slightly lower compared to BEVs. The majority of regions with new PHEV registration shares equal to or above the 2020 German average were in the south, with 43%, followed by 36% in the west, 15% in the north, and 6% in the east.

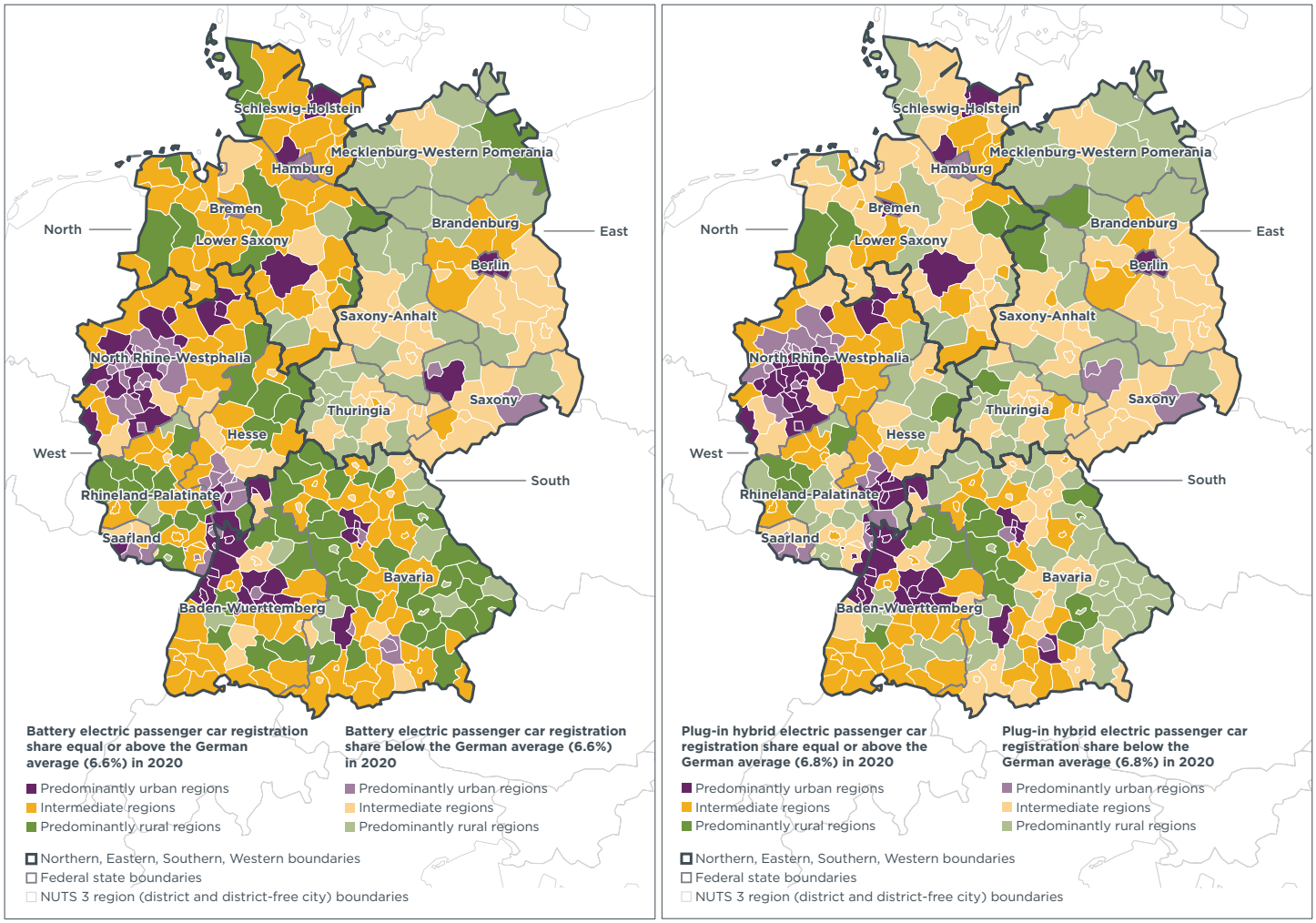

Figure ES-1. 2020 share of new battery electric (left) and plug-in hybrid electric passenger car registrations (right) equal to/above and below the German average, for regional cluster classifications by NUTS 3 regions.

The high-level findings based on analysis of the regional distribution of BEV and PHEV registration shares and the selected variables are summarized below:

» **Total new BEV and PHEV registrations are the highest in Germany's urban regions and the lowest in its rural regions.** Of the 392,500 newly registered BEVs and PHEVs in Germany in 2020, almost half were recorded in urban regions (48%), followed by intermediate regions (40%) and rural regions (11%). These ratios reflect that urban and intermediate regions are also the most populous, with 44% and 41% of the German population, respectively, in 2019.

» **Average BEV and PHEV shares of new passenger car registrations are relatively balanced within Germany's urban, intermediate, and rural regions.** In urban and rural regions, new BEV and PHEV registrations accounted for 13% of new passenger car registrations in 2020, while the share in intermediate regions was 14%. When differentiating by BEVs and PHEVs, the BEV share ranged between 7% in rural to almost 8% in intermediate regions, while the PHEV share ranged between almost 6% in rural to just over 7% in urban regions.

» **There are wide variations in the BEV and PHEV shares of new passenger car registrations among Germany's districts and cities.** In contrast to similar average BEV and PHEV shares across all urban, intermediate, and rural regions, there are wide variations among individual NUTS 3 regions. Those differences in the lowest and highest combined BEV and PHEV registration shares were most pronounced among NUTS 3 regions in intermediate regions, ranging between 5% and 32%,

followed by rural regions (5% to 31%), and urban regions (4% to 25%). These wide variations indicate that there are regional disparities and potential inequities in BEV and PHEV uptake.

- **Regions with BEV and PHEV registration shares above the German average are concentrated in the northern, western, and southern parts of the country**. Looking at individual districts and cities that recorded BEV and PHEV registration shares equal to or above the 2020 German averages, and differentiating by northern, eastern, southern, and western parts of Germany, we also find some variations. The number of NUTS 3 regions with equal to or above German average BEV or PHEV registration shares in 2020 was the lowest in the eastern part of Germany, no matter if urban, intermediate, or rural.
- **Environmental awareness, public charging infrastructure, and home charging potential, as well as economic well-being, show a high correlation with the BEV and PHEV registration shares.** A regression analysis shows that environmental awareness is positively correlated with the BEV and PHEV registration share across all three regional typologies. For BEVs, the access to public charging infrastructure, home charging potential, and the economic well-being of a region show a high correlation with the BEV registration shares in intermediate or rural regions. For PHEVs, environmental awareness and the tax revenue of the regions' municipalities shows a statistically significant correlation with the PHEV share, but only in urban regions.
- **Individual regions with high BEV and PHEV registration shares have adopted a mix of local policy actions.** Urban, intermediate, and rural districts with high new BEV and PHEV registrations studied for this analysis have included targets in local strategic plans to foster uptake. The extension of the regional public charging infrastructure network, as well as different local information and awareness campaigns, have also likely helped these districts to have high shares in new BEV and PHEV registrations.

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INTRODUCTION

Battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) are on the rise in Germany. In 2020, BEVs and PHEVs reached new registration shares of almost 7% each. In 2021, registration shares almost doubled to 26% (Mock, 2022), and over 516,000 BEVs and 494,000 PHEVs were driving on German roads by the end of September (KBA, 2021). The new governing coalition's 2021–2025 agreement targets at least 15 million battery electric cars on German roads by 2030 (SPD, BÜNDNIS 90/DIE GRÜNEN, FDP, 2021). If met, this target would represent a thirtyfold increase in battery electric cars compared to September 2021. In addition to societal benefits through reduced air pollution and greenhouse gas emissions, BEVs and PHEVs can also confer benefits to individuals from reduced ownership costs and the economy through manufacturing jobs and reduced oil imports (Lutsey et al., 2018; Slowik, 2019).

Figure 1 shows the registration share of new BEVs and PHEVs in Germany in 2020. The share of new BEVs and PHEVs in relation to all new passenger car registrations was the highest in the North (Bremen, Hamburg, Lower Saxony, and Schleswig-Holstein), with an average share of 15%. In the southern part of Germany (Baden-Wuerttemberg and Bavaria) the average registration share was 14%. In the western part of Germany (Hesse, North Rhine-Westphalia, Rhineland-Palatinate, and Saarland), 13% of all new cars registered were either a BEV or PHEV. The eastern part of Germany (Berlin, Brandenburg, Mecklenburg-Western Pomerania, Saxony, Saxony-Anhalt, Thuringia) registered the lowest share at 11% (excluding Berlin the share was 10%). In relation to population, most BEVs and PHEVs were registered in southern Germany in 2020, with 6 new BEVs and PHEVs registered per 1,000 inhabitants. In the northern and western parts, the number was slightly lower with a ratio of 5 BEVs and PHEVs per 1,000 inhabitants. In the eastern states of Germany, 3 new BEVs and PHEVs were registered per 1,000 inhabitants (2 per 1,000 if excluding Berlin).

Figure 1 also reveals that registration shares of BEVs and PHEVs show wide variations at the local level. Among the 401 German districts and district-free cities, taken from the Nomenclature of Territorial Units for Statistics third level (NUTS 3) jurisdictions based on Eurostat (Eurostat, 2018), new BEV and PHEV registrations differed by 28 percentage points in 2020, ranging between 4% (district of Main-Taunus) and 32% (district of Emmendingen).

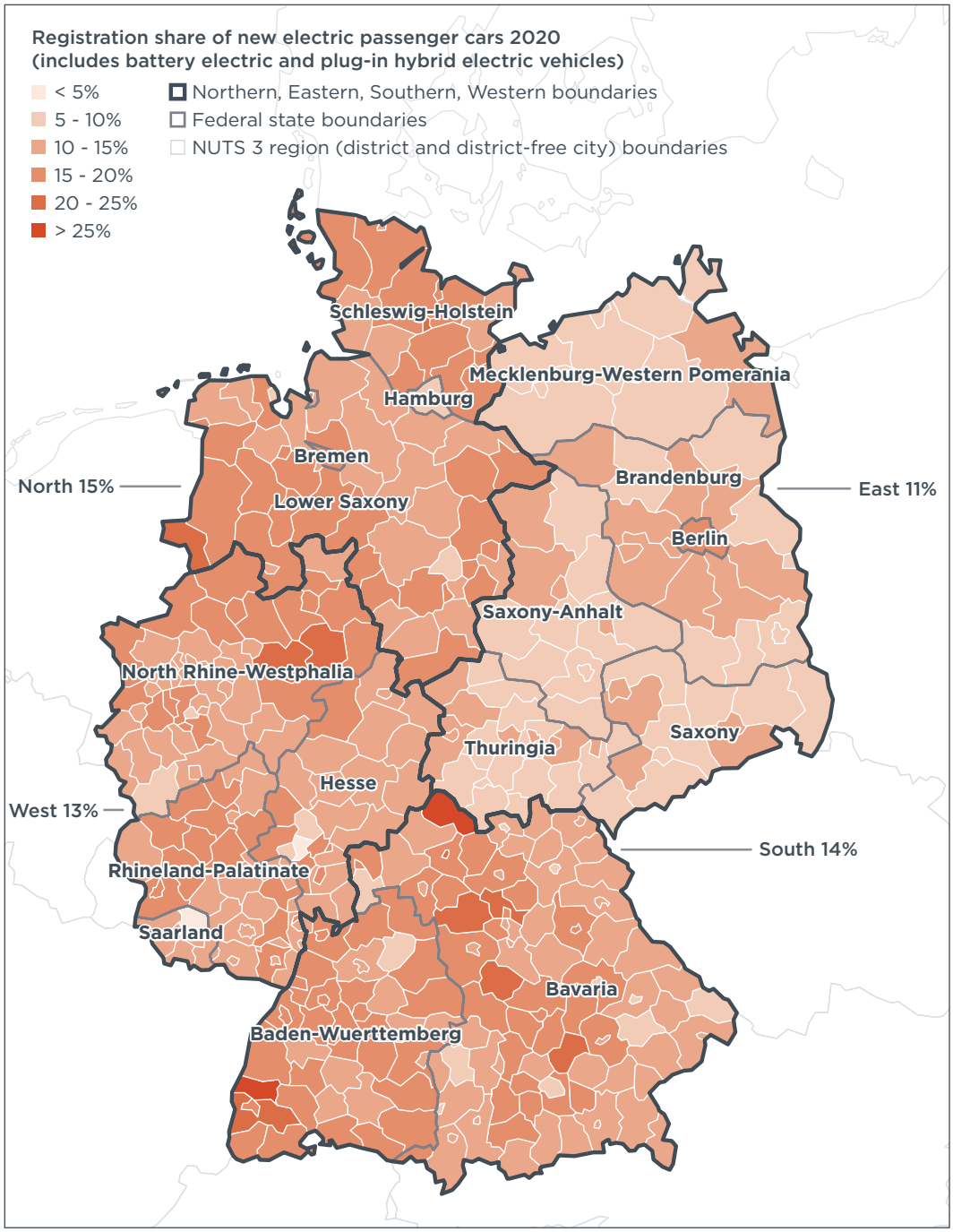


Figure 1. 2020 share of new BEV and PHEV registrations, by NUTS 3 regions (districts and district-free cities).

Germany's basic law requires that equal living conditions, as well as equal access to resources and opportunities, must be adequately addressed through policies mitigating inequalities (Deutscher Bundestag, 2019). In the context of BEV and PHEV adoption, these principles translate to providing equitable living conditions in terms of reduced air pollution, and to equitable access to the fiscal incentives and economic benefits of BEVs and PHEVs.

In this paper, we analyze the regional differences in the transition from combustion engine vehicles to BEVs and PHEVs in Germany, using a geographically detailed dataset of registrations of new BEVs, PHEVs, and combustion engine cars in 2020. We compare BEV and PHEV registration shares among four general regions of Germany, the 401 NUTS 3 regions representing districts and district-free cities, and differentiate

those further by regional typologies. To determine potential factors influencing the regional differences in Germany's electric vehicle transition, we analyze how the BEV and PHEV registration shares correlate with the region's economic situation, demographics, environmental awareness, access to charging infrastructure, and home charging potential. In addition, we carry out a qualitative assessment of local level policies which may have driven BEV and PHEV uptake. We conclude with the general findings and a discussion of which policies could address existing inequities. Figure 2 provides an overview of the steps taken for our regional analysis of BEV and PHEV uptake in Germany.

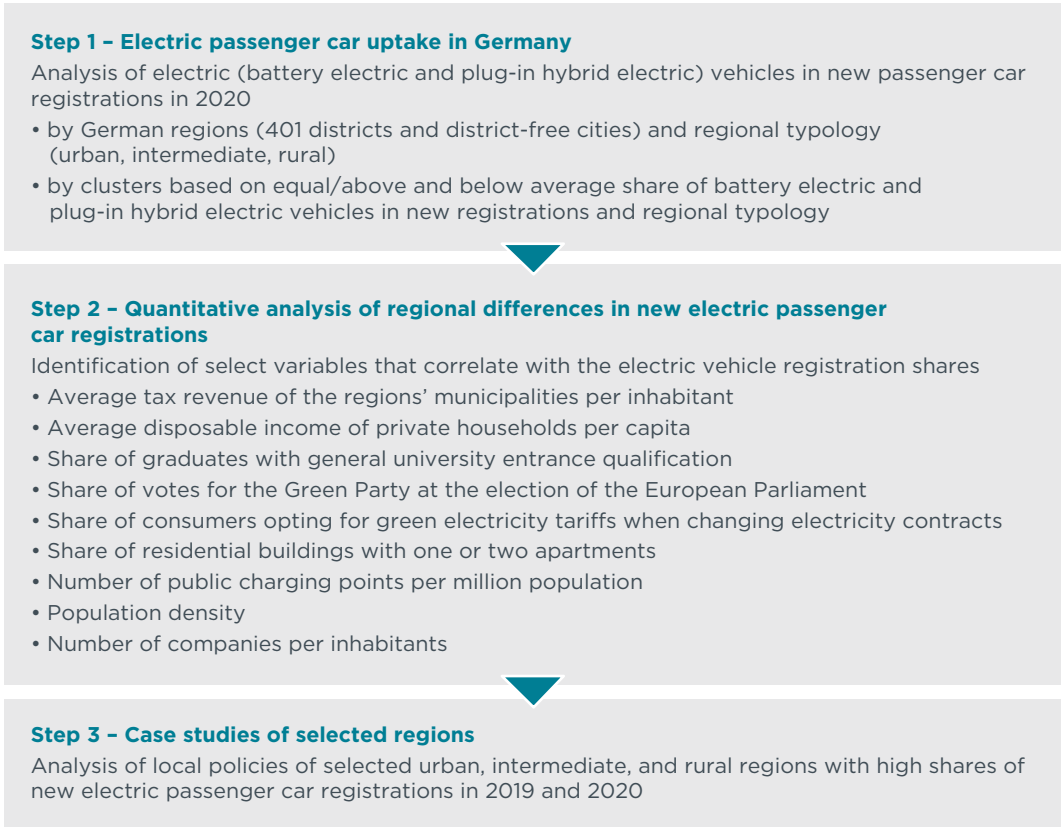


Figure 2. Overview of analysis steps.

BEV AND PHEV UPTAKE IN GERMANY

This section presents an analysis of regional differences in 2020 BEV and PHEV uptake for the 401 German NUTS 3 regions. We first show the uptake of new BEV and PHEV registrations in Germany by regional typology to identify where the uptake is taking place. We then present an overview of the BEV and PHEV uptake in Germany, categorized by urban, intermediate, and rural regions with new BEV or PHEV registration shares below or equal to/above the German average in 2020. Registration data for BEVs and PHEVs is derived from Rajon Bernard et al. (2021) and reflects data for the year 2020.

BEV AND PHEV REGISTRATIONS IN URBAN, INTERMEDIATE, AND RURAL REGIONS

For our analysis, we use regional typology definitions from Eurostat (2019). Predominantly urban regions are defined as areas where more than 80% of the population live in urban clusters, which have a population density of at least 300 inhabitants per square kilometers (km^2) and a minimum population of 5,000 inhabitants. Intermediate regions are areas where more than 50% and up to 80% of the population live in urban clusters. Predominantly rural regions cover those where at least 50% of the population live in rural areas, defined as having a population density of less than 300 inhabitants per km^2 and/or fewer than 5,000 inhabitants.

Of the 401 German districts and district-free cities, 95 were classified as predominantly urban regions, 196 as intermediate regions, and 110 as predominantly rural regions. Most of the 392,500 new BEVs and PHEVs registered in Germany in 2020 were recorded in urban regions (48%), followed by intermediate regions (40%), and rural regions (11%). Registration shares of BEVs and PHEVs were more balanced within the individual regional typologies. The average BEV and PHEV share of new passenger car registrations was 14% in intermediate regions, 13% in urban regions, and just below 13% in rural regions (Figure 3). Similarly, there was not a great variation in the average BEV and PHEV registration shares among each of the three regional typologies. The share of BEV registrations was the highest in intermediate regions at almost 8%, followed by rural regions with a share of 7%, and urban regions with a share of just below 6%. The average share of 2020 PHEV registrations was over 7% in urban regions, almost 7% in intermediate regions, and almost 6% in rural regions. A possible explanation for the slightly higher share of new BEV registrations in intermediate and rural regions compared to urban regions might be better access to home charging.

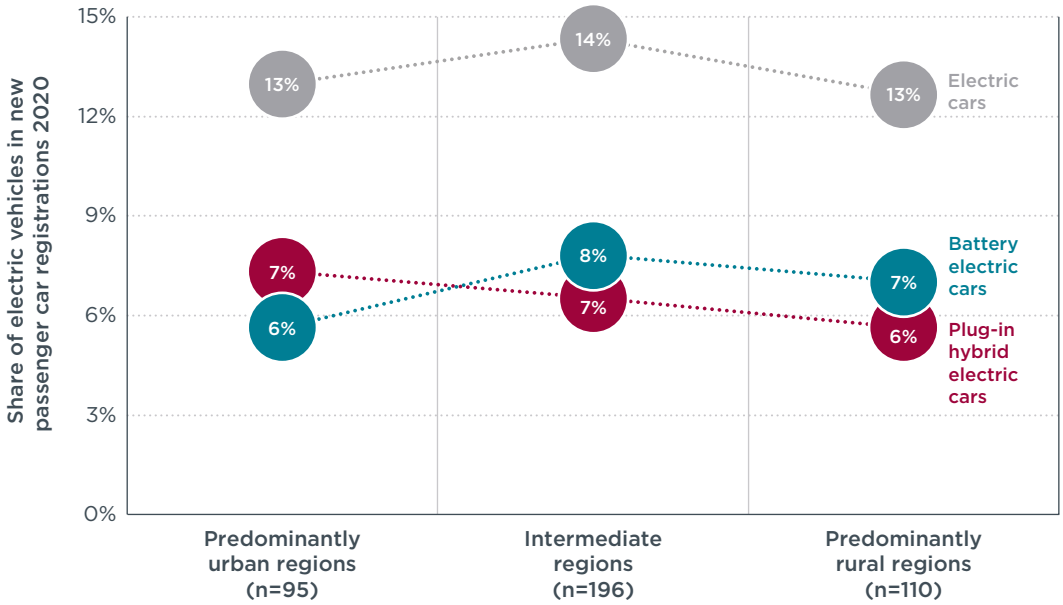


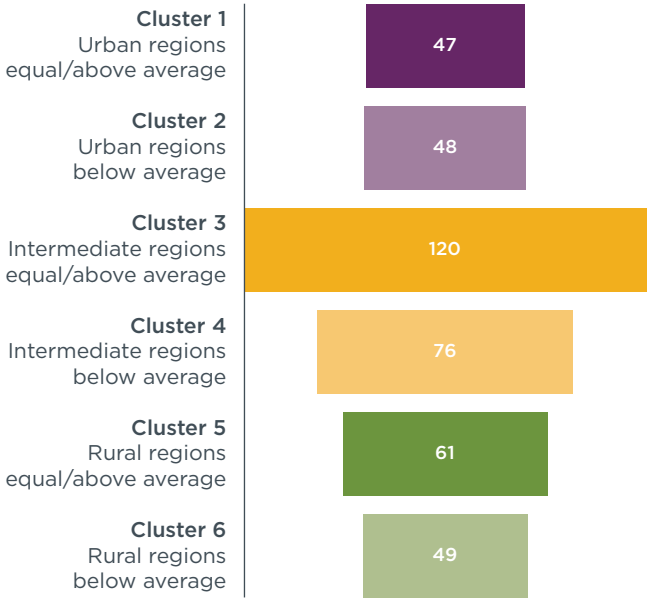
Figure 3. Share of BEVs and PHEVs in new passenger car registrations in 2020 within urban, intermediate, and rural regions in 2020. "n" denotes the number of regions.

NEW BEV AND PHEV REGISTRATIONS BASED ON REGIONAL CLUSTERS

To identify variations across the three regional typologies, we further differentiate the 401 districts and district-free cities by the BEV and PHEV shares in new passenger car registrations in 2020. Specifically, we separate regional typologies by BEV and PHEV registration shares equal to or above and below the German 2020 average of 6.6% and 6.8%, respectively. This results in six different clusters. The first clusters include predominantly urban regions with BEV/PHEV registration shares equal to/above (Cluster 1) or below (Cluster 2) the German 2020 averages. The next clusters cover intermediate regions with equal to/above (Cluster 3) and below (Cluster 4) German average BEV and PHEV registration shares. Likewise, for predominantly rural regions we differentiate by equal to/above average (Cluster 5) and below average (Cluster 6) new BEV and PHEV registration shares in 2020.

Figure 4 shows the distribution of the six different clusters among districts and district-free cities for BEV registrations (left) and PHEV registrations (right) in 2020. Darker shades represent regions above the German average BEV and PHEV registration share thresholds and lighter shades areas represent regions below the thresholds. For BEV registrations, the left figure reveals that the ratio of regions with shares above the German average of 6.6% in 2020 was the highest in intermediate regions. Specifically, 120 out of 196 intermediate regions (61%) had shares above this threshold (Cluster 3). In rural regions, 61 out of 110 rural regions (55%) had equal or higher BEV registration shares than the German average (Cluster 5). In urban regions, 47 out of the 95 urban regions (49%) had shares above the German average (Cluster 1). The regional cluster distribution for PHEV registration shares in 2020 is displayed in Figure 4 (right). As shown, 63 out of 95 urban regions (66%) had PHEV registration shares above the German average of 6.8% in 2020 (Cluster 1). In contrast, intermediate and rural regions saw lower ratios of regions above the national average. For intermediate regions (Cluster 3), their share was 42% (83 out of the 196 intermediate regions). Among rural regions (Cluster 5), the ratio was even lower with about one quarter (24%), or 26 out of 110 rural regions, having PHEV registration shares above the German 2020 average.

Number of regions with new registrations of battery electric vehicles (BEVs) equal/above and below the 6.6% German average in 2020, by regional clusters



Number of regions with new registrations of plug-in hybrid electric vehicles (PHEVs) equal/above and below the 6.8% German average in 2020, by regional clusters

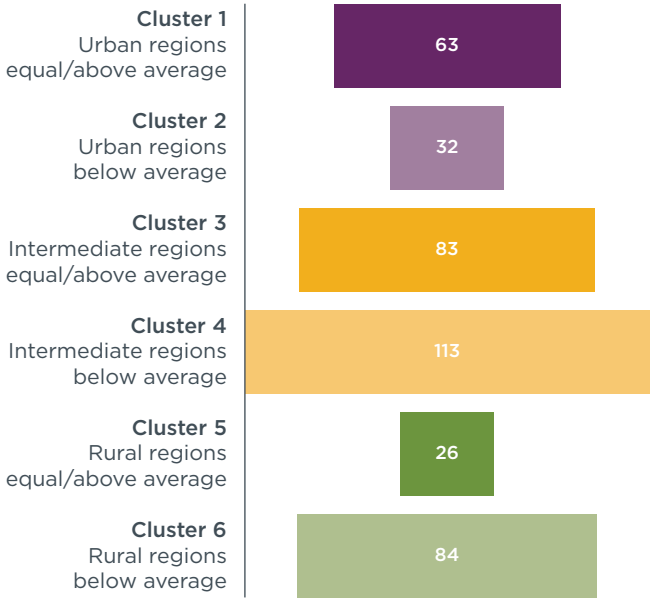


Figure 4. Number of regions with equal to/above and below German average new BEV (left) and PHEV (right) registration shares in 2020, by regional clusters.

Figure 5 maps the distribution of the districts and cities which experienced above or below German average BEV registration shares of 6.6% in 2020, following the same cluster and coloring scheme as outlined above. Across Germany, 228 of the 401 regions recorded above German average BEV registration shares (57%), and 173 were below the German average (43%). The majority of the 228 regions with above German average BEV registration shares were concentrated in the north (47), west (71), and south of Germany (101), while their number was the lowest in the east (9). By regional typology, 76% of the urban regions in the south had BEV registration shares above the German average. In the northern and western parts of Germany, their share was 57% and 38%, respectively. In the five urban regions in the eastern part of Germany, two, or 40%, recorded BEV registration shares above the German average (city of Berlin and district of Leipzig). In intermediate regions of the south, north, and west, about 75% experienced above German average BEV registration shares. In the eastern part of the country, the share was significantly lower, with 14% of all intermediate regions being above the threshold. We saw a similar trend in rural regions where the number of districts and district-free cities with above average BEV registration shares were high in the south, north, and west (68%, 75%, and 83%, respectively) and low in the east (4%). The district of Vorpommern-Greifswald was the only rural region in the east to record a share above the German average, with over 8% of new passenger cars registered being a BEV.

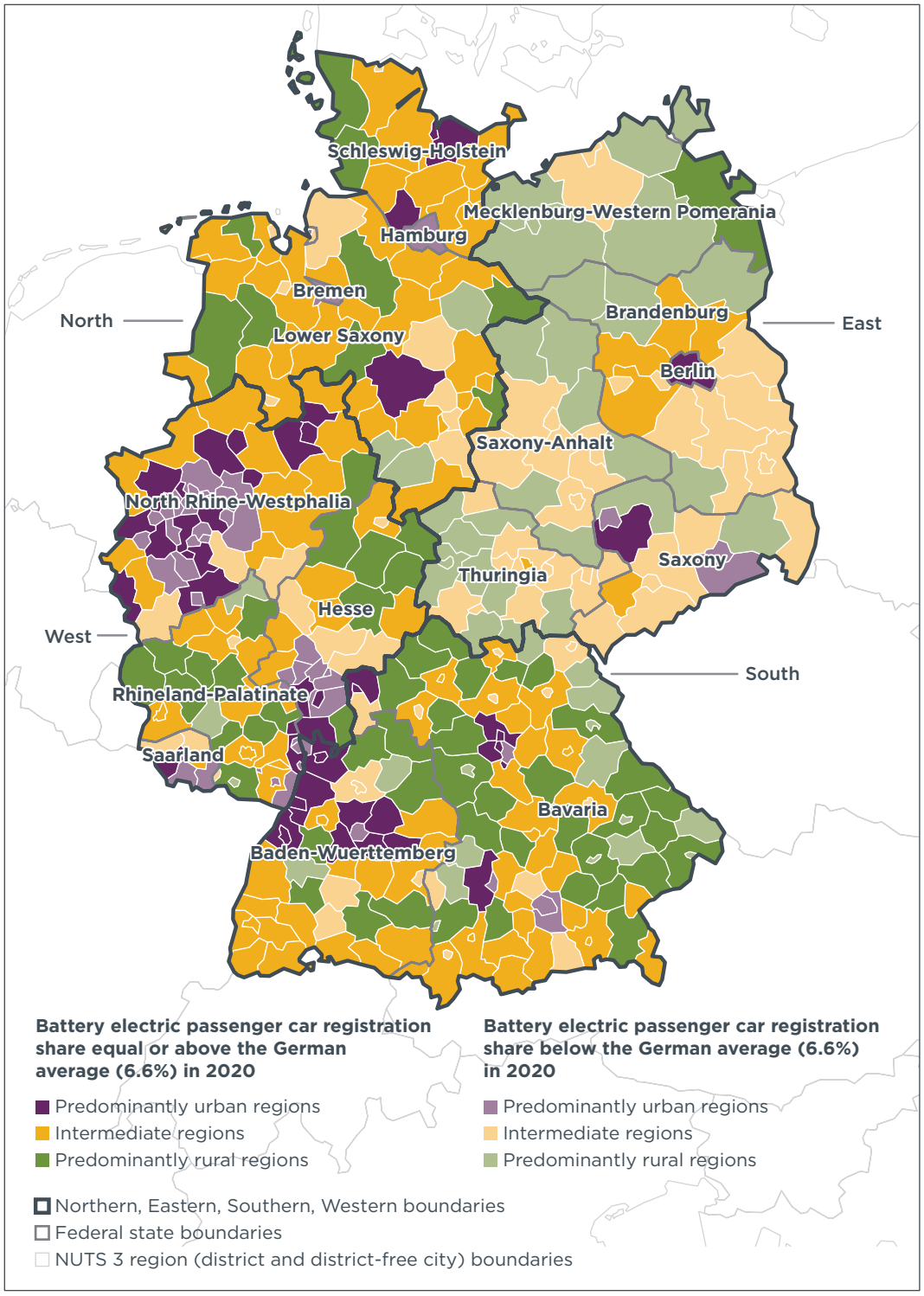


Figure 5. 2020 share of battery electric vehicles in new passenger car registrations above and below the German average, for regional clusters by NUTS 3 regions.

Looking at states, Schleswig-Holstein in the far north was most striking, as 14 out of the 15 regions had BEV shares equal or above the German 6.6% average in 2020. The city of Flensburg was the only region in the state where the share was below the German average, at 5.4%. In contrast, Saxony-Anhalt was the only state where no region recorded BEV registration shares that were above the national average.

The spatial distribution of districts and district-free cities which recorded above German average PHEV registration shares in 2020 was more scattered compared to BEVs (Figure 6). In the 401 regions, 172, or 43%, had PHEV registration shares above the German 2020 average, the majority of which were in the west (62) and south

of Germany (74). In the north and east, their number was 26 and 10, respectively. Comparing by regional typology, the south saw 84% of urban regions with above German average PHEV registration shares. In the north and west of Germany, their share was 86% and 60%, respectively. In the east, Berlin was the only region out of the five which had a higher PHEV share than the German average, at 9.0%. The number of intermediate regions with above German average PHEV registration shares was lower than urban regions, at 60% of the regions in the south, 51% in the west, 36% in the north, and 14% in the east. In rural regions, the number of regions which recorded above German average PHEV registration shares was the lowest, ranging between 11% in the east to 33% in the north.

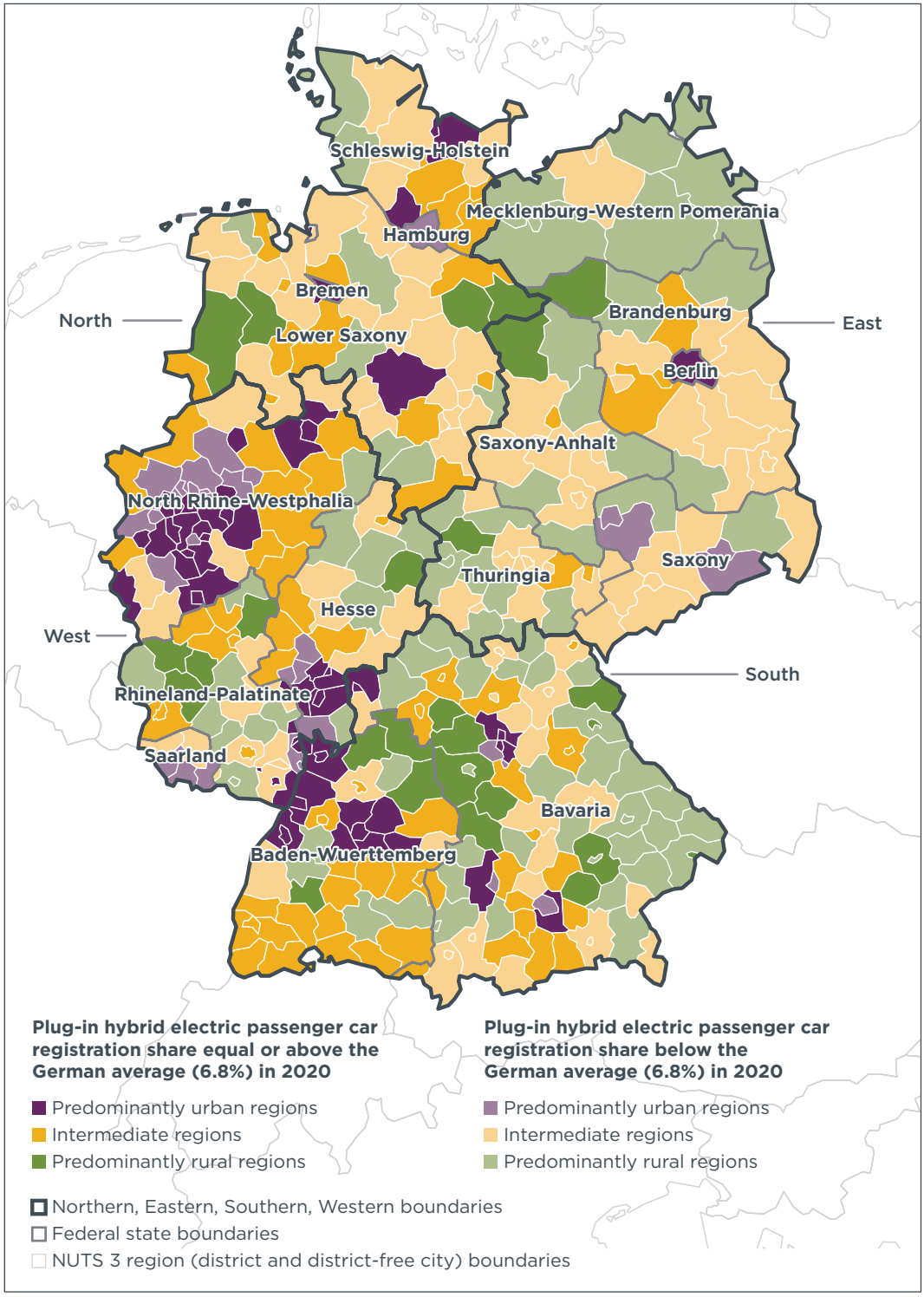
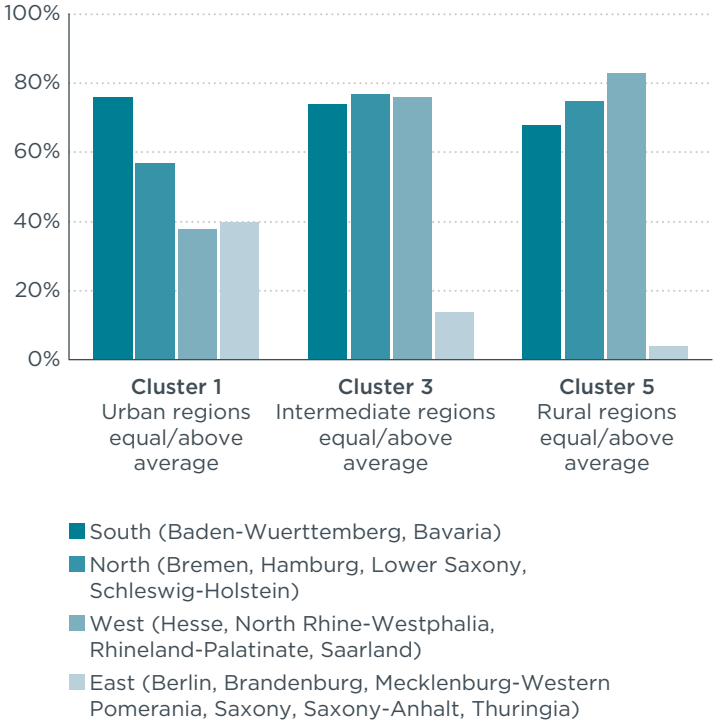


Figure 6. 2020 share of plug-in hybrid electric vehicles in new passenger car registrations equal to/above and below the German average, for regional clusters by NUTS 3 regions.

Looking at all three regional typologies and above German average PHEV registration shares, excluding the three city states, the state of Baden-Wuerttemberg recorded the most regions with PHEV shares equal to/above the German average (77%, or 34 out of 44 regions). States with no region with PHEV registration shares equal to or above the German average included the two states of Mecklenburg-Western Pomerania and Saxony in the east, and the state of Saarland in the west.

Figure 7 depicts the share of regions with above German average BEV and PHEV registration shares in 2020 by typology and states. The share of NUTS 3 regions with above German average BEV registration shares in 2020 was the highest in southern and northern parts of Germany for all three regional typologies (Figure 6, left). The regions in the east of Germany mostly lagged the German average. The higher shares in urban regions in the east can be traced back to high registration figures in the capital city of Berlin. In contrast, above German average PHEV registration shares were mostly recorded in urban regions and in the southern, northern, and western parts of Germany (Figure 6, right). In intermediate and particularly rural regions, above German average PHEV registration shares were less common compared to urban regions.

Share of regions with new battery electric vehicle (BEV) registration shares equal/above the 6.6% German average in 2020, by regional clusters and states



Share of regions with new plug-in hybrid electric vehicle (PHEV) registration shares equal/above the 6.8% German average in 2020, by regional clusters and states

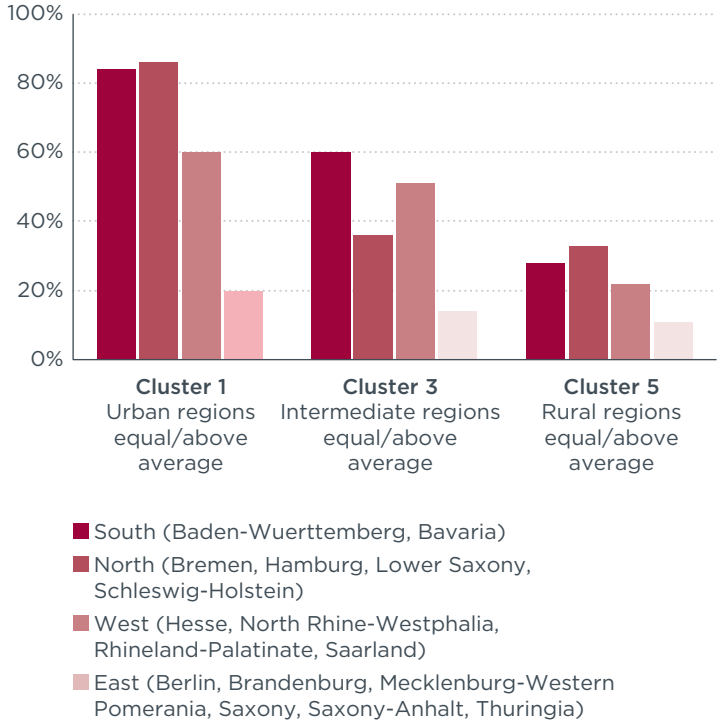


Figure 7. Share of regions with BEV (left) and PHEV (right) registration shares equal to/above the German 2020 averages, by regional clusters and states.

QUANTITATIVE ASSESSMENT OF REGIONAL DIFFERENCES IN BEV AND PHEV REGISTRATIONS

To assess factors potentially influencing new BEV or PHEV registration shares in individual areas, we use multivariate linear regression for the quantitative analysis. To achieve this, we estimate the average influence of selected variables on new BEV or PHEV registration shares and study how the degree of influence varies across regional typologies.

SELECTION OF SOCIO-ECONOMIC AND OTHER VARIABLES

To better understand the uneven uptake of BEVs and PHEVs across Germany and in the different NUTS 3 regions outlined above, and to assess potential regional inequities in access to the air quality and economic benefits of BEVs and PHEVs, we choose a set of nine quantitative variables reflecting the region's economic situation, the socio-economic situation and environmental awareness of individuals, the accessibility to public charging infrastructure, home charging potential, and economic environment. Data sources are derived from Rajon Bernard et al. (2021), the German Federal and State Statistical Offices (Statistische Ämter des Bundes und der Länder, 2021), Verivox (2020), and EcoMovement, and reflect data for 2020 and, if not available, the most recent data prior to 2020.

Description of variables

To assess the economic situation of a region and determine if wealthier regions are currently gaining a higher economic and air quality benefit from the transition to BEVs and PHEVs, we consider the average tax revenue of the regions' municipalities per inhabitant. This covers both cities (in case a NUTS 3 region represents a district-free city) and groups of cities/municipalities (in case a NUTS 3 region represents a district). The average tax revenue of a regions' municipalities is the sum of property taxes, trade taxes, communal shares in income and sales taxes, and the other communal taxes (entertainment tax, dog tax, beverage tax, etc.), minus the trade tax apportionment per inhabitant (Statistisches Bundesamt, 2021).

We also consider the socio-economic situation of individuals. Studies indicate that BEVs and PHEVs in private ownership are mostly used by well-educated individuals with higher incomes, living in rural areas or small towns and in one- or two-family homes with the possibility of charging an electric vehicle at home (Frenzel et al., 2015; KfW Research, 2021). To create a link to BEV and PHEV adoption, we analyze the disposable income of private households, which provides information about the amount private households can use for consumption, such as for the purchase of a new car. We also evaluate the share of graduates with general university entrance qualification.

Studies also suggest that users of a BEV or PHEV have pronounced environmental awareness and that contributing to climate protection is one key reason to purchase a BEV or PHEV (Frenzel et al., 2015; KfW Research, 2021). Since quantifying environmental awareness is challenging, we choose two different variables as a proxy. One is the share of votes for the Green Party during the 2019 elections for the European Parliament, based on the assumption that the Green Party is associated with environmental policies and protecting the climate. This view is also supported by a recent study (DIW Econ GmbH, 2021) which analyzes the election programs for the election for the Federal Parliament in September 2021 for five of the largest parties in Germany. Based on different climate policy measures, including those involving the transport and energy sectors, the study finds that the Green Party scores the highest since it is most likely to make concrete proposals for achieving climate protection goals. As a second potential variable quantifying environmental awareness, we include the average share of consumers per NUTS 3 region who opted for a green electricity

tariff when changing their electricity contract between 2017 and 2019 (Verivox, 2020). Some research found that the share of BEV and PHEV users with a green electricity tariff is significantly higher than the German average (Frenzel et al, 2015).

Research also indicates that the uptake of BEVs and PHEVs can be linked to access to charging infrastructure (Nicholas and Wappelhorst, 2020; Wappelhorst 2021). As one variable, we choose the share of residential buildings with one or two apartments which can provide an indication of the possibility of charging a BEV or PHEV at home. The share of owners of a BEV or PHEV charging their vehicle at a private location (home or company premises) is assumed to range between 60% and 85% in Germany (Die Bundesregierung, 2019). Second, we consider the number of public charging points per million population in each region. In addition, we control for population density, which could influence the accessibility to BEV and PHEV purchases and services. In populous areas, there are usually more car dealers with BEVs and PHEVs available for sale and more mechanics that specialize in electric vehicle maintenance.

Companies also play an important role in the transition towards BEVs and PHEVs. About half of BEVs and PHEVs, or 49%, are first registered by companies (Wappelhorst, 2021). To link new BEV and PHEV registrations and the potential uptake by company car users, we analyze the number of companies per 1,000 inhabitants. This variable might give an indication of the potential of BEVs and PHEVs as part of company car fleets and also access to jobs, which is closely linked with the income of private individuals.

Table 1 gives an overview of the nine independent variables and the dependent variable of the BEV or PHEV share in the regions' new passenger car registrations in 2020. The passenger car registration data reflects all consumer groups including private individuals and companies.

Table 1. Overview of variables and data sources selected for the analysis.

Variables (for NUTS 3 regions)		Source
Dependent variable		
Electric vehicle share	Share of battery electric and plug-in hybrid electric vehicles in the new passenger car registrations in 2020	Rajon Bernard, Hall, & Lutsey (2021)
Independent variables		
Economic situation of regions	Average tax revenue of the region's municipalities per inhabitant in 2018	Statistische Ämter des Bundes und der Länder (German Federal and State Statistical Offices, 2021)
Socio-economic situation of individuals	Average disposable income of private households per capita in 2018	
	Share of graduates with general university entrance qualification in 2019	
Environmental awareness of individuals	Share of votes for Green Party at the election for the European Parliament in 2019	
	Share of consumers opting for green electricity tariffs when changing electricity contracts between 2017 and 2019	Berliner Morgenpost (24 June 2019), Verivox (2020)
Access to charging infrastructure	Share of residential buildings with one or two apartments in 2018	Statistische Ämter des Bundes und der Länder (German Federal and State Statistical Offices, 2021)
	Number of public charging points per million population in 2020	EcoMovement
	Population density in 1,000 persons per km^2 in 2019	Statistische Ämter des Bundes und der Länder (German Federal and State Statistical Offices, 2021)
Economic environment	Number of companies per 1,000 inhabitants in 2018	Statistische Ämter des Bundes und der Länder (German Federal and State Statistical Offices, 2021)

Summary statistics of selected variables

Table 2 provides summary statistics of the selected variables along with the BEV and PHEV registration shares. We calculate a set of statistics for each variable across different regions, including the mean (Mean), minimum value (Min), maximum value (Max), 25th percentile (p25), 50th percentile (p50), 75th percentile (p75), and the coefficient of variation (CV). The mean provides valuable insight into the average condition for each variable. Minimum and maximum values give information about the presence of extreme values. The percentiles are helpful to assess the distribution of values. Finally, the coefficient of variation illustrates if the values of a variable vary greatly across regions. By comparing the coefficient of variation of the variables, we can identify which variable might be more responsible for driving the differences in BEV and PHEV registration shares.

The mean value of the share of BEVs in new passenger car registrations across all regions in 2020 was 7.2%. Note that this average value is not weighted by the varying total new car registrations in the individual regions and, therefore, slightly deviates from the actual national average of 6.6%. This deviation indicates that regions with a higher BEV share tend to have lower total new car registrations. In a simple average over the regions, they are thus slightly overrepresented. The region with the least BEV share of new registrations stood at 1.4%, and the region with the highest BEV registration share had 25.1%. From the 25th and 75th percentiles, we can see that most regions had BEV registration shares in 2020 ranging from 5.4% to 8.7%. The mean PHEV share in new passenger car registrations in 2020 was 6.5% across regions (simple average) and 6.8% across Germany (weighted by registrations). The lowest and highest PHEV registration shares in the regions were 2.1% and 15.8%. The 25th and 75th percentiles show that most regions had PHEV shares ranging from 5.3% to 7.5%. These statistics show that the PHEV registration share was more evenly distributed across regions than the BEV share. This observation can be further validated by the smaller coefficient of variation for the PHEV shares compared to the BEV shares.

Table 2. Summary statistics of variables for regional level analysis.

Variables (for NUTS 3 regions)	Mean	Min	Max	p25	p50	p75	CV
BEV share of new registrations (%)	7.2	1.4	25.1	5.4	7.0	8.7	0.4
PHEV share of new registrations (%)	6.5	2.1	15.8	5.3	6.4	7.5	0.3
Average t revenue of municipalities per inhabitant (€)	1,200	600	4,500	1,000	1,200	1,400	0.3
Average disposable income of private households per capita (€)	22,700	16,500	36,900	20,700	22,600	24,300	0.1
Share of graduates with general university entrance qualification (%)	34.6	10.5	64	26.5	32.6	38.1	0.3
Share of votes for Green Party at the election for the European Parliament in 2019 (%)	18.2	4.7	38.5	13.6	18.4	22.8	0.4
Share of consumers opting for green electricity tariffs when changing electricity contracts (%)	32.6	22.3	51.3	29.4	31.8	35.4	0.1
Share of residential buildings with one or two apartments (%)	83.1	50.1	96.1	78.4	87.0	91.0	0.1
Number of public charging points (per million population)	537	72	2,766	360	477	662	0.5
Population density (persons per km²)	546	36	4,767	117	201	672	1.3
Number of companies (per 1,000 inhabitants)	44.2	25.5	82	40.1	43.4	47.5	0.2

Note: Min = Minimum, Max = Maximum, p25 = 25th percentile, p50 = 50th percentile, p75 = 75th percentile, CV = coefficient of variation

The German average tax revenue of municipalities per inhabitant, reflecting the economic or financial power of a region, was €1,200 across all regions in 2018, with a minimum of €600 and a maximum of €4,500. As 50% of the regions had a tax revenue between €1,000 and €1,400 per inhabitant, the minimum and maximum values are

considered outliers. The variation of this variable is primarily driven by regions with extremely high values, such as metropolitan areas like Munich (€4,500) and Frankfurt (€2,970) and cities with a large automobile manufacturing presence like Wolfsburg (€2,170) and Ingolstadt (€1,910).

The socio-economic situation of individuals is considered with two different variables. The average disposable income per capita of private households was €22,700 in 2018 across all German regions, with the lowest value of €16,500 and the highest value of €36,900. At least 50% of the regions had an average disposable income per capita very close to the mean, indicating limited income disparity if looking at regional averages. The share of graduates with general university entrance qualification was, on average, 34.6% across Germany in 2019, with a minimum value of 10.5% and a maximum of 64.0%. Urban and intermediate regions tended to have a higher share of graduates with general university entrance qualification than rural regions.

The share of votes for the Green Party during the election for the European Parliament in 2019 and the share of consumers deciding for green electricity tariffs when changing electricity contracts are two variables we use as a proxy for environmental awareness. The average share of votes for the Green Party during the 2019 election was 18.2% across all regions, with 50% of the regions ranging from 13.6% to 22.8%. The share of consumers who opted for a green electricity tariff when changing the electricity contract between 2017 and 2019 was an average of 32.6% in Germany, with 50% of the regions falling between 29.4% and 35.4%. Compared with the green electricity tariffs measure, the share of votes for the Green Party is much more unevenly distributed across regions, based on the values coefficient of variation.

Regarding accessibility to charging infrastructure, we look at both home charging potential and availability of public charging infrastructure. In 2018, 83% of residential buildings in Germany had one apartment, usually one-family houses, or two apartments, such as attached houses, with a minimum value of 50.1% and a maximum value of 96.1% in individual regions. Across the regions, 50% fell close to the mean. However, the availability of public chargers varied significantly across regions. With a national average of around 500 charging points per million population using 2020 data, some regions had as low as 100 charging points per million population and as high as 2,800. For access to BEVs and PHEVs, we also consider the population density. The population density was about 500 persons per km^2 in Germany in 2019. While 50% of the regions had population density ranging from 100 to 700 persons per km^2, the most populous region had a population density of 4,800 persons per km^2, eight times the national average. With only 36 persons per km^2, the region with the lowest population density had a value fifteen times lower than the average.

We also include the number of companies per 1,000 inhabitants, since 49% of new BEVs and PHEVs were registered by companies in 2020. In 2018, the average number of companies per 1,000 inhabitants was 44.2 in Germany, with a minimum value of 25.5 and a maximum value of 82.0, and 50% of the regions ranged between 40.1 to 47.5 companies per 1,000 inhabitants.

Among all variables, the coefficient of variation is largest in population density, the number of chargers per million population, and the environmental awareness measured by share of votes for Green Party at the 2019 election for the European Parliament, which demonstrates considerable variation across regions.

MULTIVARIATE LINEAR REGRESSION ANALYSIS

In this section, we implement multivariate linear regressions to investigate the relationship between the selected variables described above and the BEV and PHEV share in the new passenger car registrations in 2020. Multivariate linear regression is a statistical method that allows the summarization and study of relationships

between potential influencing factors (independent variables) and an outcome variable (dependent variables), which in our case are the BEV and PHEV registration shares. The model assumes a linear relationship between the dependent variable and each independent variable. By including a combination of independent variables, the model can help to show how each independent variable is related to the BEV and PHEV registration shares when all other independent variables are held equal. The estimated coefficient for each independent variable can be interpreted as how many percentages point change in the registration share is associated with 1 unit change in the independent variable.

CORRELATION OF SELECTED VARIABLES WITH THE BEV AND PHEV SHARES ACROSS ALL REGIONS

As a first step, we determine the relation of selected variables with the BEV and PHEV registration shares. Since the underlying determinant factors could differ between BEVs and PHEVs, we estimate the effect separately for the two powertrain types. Our main specification can be expressed as follows:

$$S_j = \alpha + \beta X_j + region\ type_j + \varepsilon_j \qquad (1)$$

Where:

S_j denotes the dependent variable of the BEV or PHEV shares in the new passenger car registrations in 2020 for each NUTS 3 region *j*.

X_j includes all the variables (independent variables) described in the previous section. We include the BEV or PHEV registration share as an independent variable. For instance, when analyzing the potential correlation with BEV share, we thus control for the share of PHEVs. This helps us to understand if a high PHEV share correlates with the uptake of BEVs in the same NUTS 3 region, and vice versa.

region type$_j$ denotes the regional typologies fixed effects. Each region as either urban, intermediate or rural, as outlined above. These regional typology fixed effects control for different baselines in BEV and PHEV shares among the three regional typologies.

α denotes the constant term of the multivariate linear regression model.

β is a vector and represents the coefficients of all the variables we include in our analysis. It shows how many percentage points changes in BEV and PHEV registration shares are associated with one unit change in the independent variables.

ε_j is the error term, which captures all the other factors that might affect the BEV and PHEV registration shares but are not included in our study. To eliminate outliers, the top and bottom 5% of regions in terms of BEV and PHEV shares in new passenger car registrations in 2020 are excluded. The sample size thereby includes only 360 and not all 401 regions.

Table 3 illustrates the regression results using our main specification, listing the dependent variables in the first column. The second column shows the linear coefficient of BEV registration shares in 2020 with the selected variables, whereas the third column presents the linear coefficient of PHEV registration shares in 2020 with these variables. Variables with a statistically significant positive correlation are shaded in green, while variables with a significant negative correlation are shaded in orange. Statistical significance, or how likely the correlation is non-zero, is measured by the *p value*. The smaller the p value, the more likely that a correlation exists. A p value below 0.01 refers that there is less than 1 percent of probability that we detect the correlation by chance. A p value below 0.1 indicates that there is less than 10 percent of probability that we identify the correlation by chance.

Table 3. Linear correlation factors of the selected dependent variables with new BEV and PHEV registration shares in 2020.

Independent variable	BEV share (Change in percentage points)	PHEV share (Change in percentage points)
Average tax revenues of municipalities per inhabitant (thousand Euros)	-0.46	0.53[b]
Average disposable income of private households per capita (thousand Euros)	0.15[b]	0.02
Share of graduates with general university entrance qualification (%)	-0.02	-0.01
Share of votes for Green Party during the election for the European Parliament in 2019 (%)	0.15[a]	0.08[a]
Share of consumers opting for green electricity tariffs when changing electricity contracts (%)	0.02	-0.02
Share of residential buildings with one or two apartments (%)	0.06[a]	-0.02
Number of public charging points (thousand per million population)	0.56[b]	0.26
Population density (thousand persons per square kilometer)	-0.58[c]	0.03
Number of companies (per 1,000 inhabitants)	-0.05[b]	0.01
Share of other vehicle type – BEV or PHEV (%)	0.08	0.06
Sample size	360	360
R-squared	0.430	0.341

[a] $p<0.01$, [b] $p<0.05$, [c] $p<0.1$
Note: The p value indicates the statistically significance of each variable. For fields with a p value below 0.1, green shading represents statistically significant positive correlation, while orange shading represents statistically significant negative correlation. Grey fields have p values larger than 0.1. The bottom and top 5% regions in terms of BEV and PHEV registration shares are excluded to eliminate outliers. R-squared shows the goodness of fit of the regression model.

For the BEV registration shares, we find correlations with the following variables:

- **Statistically significant positive linear correlation:** The most statistically significant variable is the share of **votes for the Green Party for the election for the European Parliament in 2019** as a proxy for environmental awareness. A one percentage point rise of this variable correlates with a 0.15 percentage points higher BEV registration share. We also find a significant positive correlation for the **share of residential buildings with one or two apartments, the number of public chargers,** and **average disposable income** with new BEV registration shares. Each percentage point increase in the share of residential buildings with one or two apartments correlates with a 0.06 percentage points higher BEV registration shares. This could indicate that being able to charge at home might be an important factor for consumers when considering buying a new BEV. Similarly, the number of public chargers correlates with BEV registration shares; 1,000 more charging points per million population correlates with a 0.6 percentage point higher BEV registration share. Each €1,000 increase in disposable income correlates with a 0.15 percentage points higher BEV registration share.
- **Statistically significant negative linear correlation:** Both the **number of companies per capita** and **population density** show a negative correlation with BEV registration shares. A one company per 1,000 inhabitants' higher number of companies in a region correlates with a 0.05 percentage points lower BEV registration share. This negative correlation is thus rather weak. A 1,000 persons per square kilometer higher population density correlates with a 0.58 percentage points lower BEV registration share. This mirrors the finding of a higher BEV registration share in rural and intermediate regions compared to urban regions (see Figure 3). One reason for this could be that regions with high population density tend to have more apartment buildings and less access to home or workplace charging.

» **No statistically significant linear correlation:** The independent variables **tax revenue of municipalities per inhabitant, share of graduates with a general university entrance**, and **share of consumers changing their electricity contracts to green electricity tariffs** do not show a statistically significant linear correlation with BEV registration shares. Furthermore, there is no statistically significant correlation between PHEV and the BEV registration shares. The result indicates that policies designed to promote BEVs can be implemented in parallel with incentives for PHEVs without compromising the policy effect.

The results for PHEVs are slightly different than the obversions for BEVs:

» **Statistically significant positive linear correlation:** As for BEVs, the share of **votes for the Green Party during the election for the European Parliament** positively correlates with PHEV registration shares. One percentage point increase in the share of votes for the Green Party in the European election correlates with a 0.08 percentage points higher PHEV registration share. Unlike BEVs, the PHEV registration share positively correlates with the region's **tax revenue per inhabitant**. The analysis shows that a €1,000 higher average tax revenue correlates with a 0.53 percentage points higher PHEV registration share.

» **No statistically significant linear correlation:** Another major difference between the results for BEVs and PHEVs is that access to charging infrastructure, as indicated by home charging potential and availability of public charging points, does not significantly correlate with a region's PHEV share (home charging potential is measured in the **share of residential buildings with one or two apartments**, public charging is measured in the **number of public charging points**). A reason might be that PHEV owners rely less on charging infrastructure, as they can also be powered by gasoline or diesel. Furthermore, unlike for BEVs, **population density** does not show a negative correlation with the PHEV shares. Also differing from BEVs, the **number of companies per inhabitant** does not show a negative correlation with the PHEV share. Like BEVs, education represented as a **share of graduates with general university entrance qualification** does not show a statistically significant linear correlation with the PHEV registration share. Lastly, mirroring the results for BEVs, the share of PHEVs is found to not significantly correlate with the share of BEVs.

CORRELATION OF SELECTED VARIABLES WITH THE BEV AND PHEV SHARES BY REGIONAL TYPOLOGY

Based on the linear regression analysis across all NUTS 3 regions (district and district-free cities), we analyze how the correlations vary within urban, intermediate, and rural regions. Since our data has a relatively small sample size and we are further dividing the sample into three categories based on regional typology, we do not have enough statistical power to use all nine variables as in the previous section. Therefore, this second step of the analysis focuses on the variables that have shown a statistically significant positive correlation to the BEV or PHEV registration shares across all regions, using a specification as follows:

$$S_j = \alpha + \sum_{C\varepsilon\{U,I,R\}} \beta^C X_j + \gamma Z_j + region\ type_j + \varepsilon_j \qquad (2)$$

Where:

S_j denotes BEV or PHEV registration shares in 2020 for each NUTS 3 region j.

X_j denotes a vector of all independent variables that we have identified as influential in our previous section (four variables for BEVs and two variables for PHEVs).

β^C are the corresponding coefficients for these variables.

C denotes region type taking a value of either urban, intermediate, or rural. Specifically, β^U indicates the coefficient vector for urban, β^I for intermediate, and β^R for rural regions. This specification allows different regional typologies to have different degree of correlation.

Z_j is the remaining independent variables for which we did not find statistically significant positive linear correlations in our previous section. We do not differ the responses within these variables (we do not estimate the correlation separately for different regional typologies).

region type$_j$ denotes the regional typologies fixed effects which control for different baselines in BEV and PHEV popularity among the three regional typologies.

α denotes the constant term of the multivariate linear regression model.

ε_j is the error term, which captures all the other factors that might affect the BEV and PHEV registration shares but are not included in our study.

The results for the three regional typologies are summarized in Table 4. The upper half of the table shows result for BEVs and the lower half shows results for PHEVs. Green shading represents factors with statistically significant positive correlation with new BEV or PHEV registration shares. Deeper green indicates a more significant correlation. Statistical significance is, as above, measured by p values.

Table 4. Linear correlation factors of the selected variables with BEV and PHEV registration shares, by regional typology.

Independent variable	Urban regions	Intermediate regions	Rural regions
Variables	**BEV share (Change in percentage points)**		
Average disposable income of private households per capita (thousand Euros)	0.06	0.18[b]	0.21[a]
Share of votes for Green Party at election for the European Parliament in 2019 (%)	0.12[a]	0.15[a]	0.14[a]
Share of residential buildings with one or two apartments (%)	0.02	0.06[a]	0.10[a]
Number of public chargers (thousand per million population)	-0.38	0.78[b]	0.64
Variables	**PHEV share (Change in percentage points)**		
Average tax revenues of municipalities per inhabitant (thousand Euros)	1.04[a]	0.20	0.13
Share of votes for Green Party at election for the European Parliament in 2019 (%)	0.07[c]	0.08[a]	0.11[b]

[a] $p<0.01$, [b] $p<0.05$, [c] $p<0.1$
Note: Green shading represents statistically significant positive effects on the uptake. Deeper green indicates a larger effect. R-squared shows the goodness of fit of the regression model. P-value indicates the statistically significance of each variable.

For the four independent variables which showed significant positive correlation with the BEV registration shares in the previous section, we find the following correlations by regional typology (see upper half of the Table 4):

» **Statistically significant positive correlation in all three regional typologies (urban, intermediate, and rural):** The variable share of **votes for the Green Party during the election for the European Parliament,** used as a proxy for environmental awareness, shows a strong correlation with BEV registration shares for all three regional typologies. A one percentage point higher share of votes for the Green Party correlates with a 0.12 percentage points higher share of BEV registrations for

urban regions, 0.15 percentage points higher share for intermediate regions, and 0.14 percentage points higher share for rural regions.

» **Statistically significant positive correlation in intermediate and rural regions:** Home charging potential measured in the **share of residential buildings with one or two apartments** and **average disposable income** both significantly correlate with BEV shares in new passenger car registrations in intermediate and rural regions, but not in urban regions. A one percentage point higher share of residential buildings with one or two apartments correlates with a 0.06 percentage points higher BEV share in new passenger car registrations in intermediate regions and 0.1 percentage points higher share in rural regions. A €1,000 higher average disposable income correlates with a 0.18 and 0.21 percentage points higher new BEV registration share among intermediate and rural regions, respectively. The results suggests that potential BEV buyers in intermediate and rural regions may be hindered in opting for a BEV because of limited financial capabilities, while this factor seems to be less important in urban regions.

» **Statistically significant positive correlation in intermediate regions: The number of public chargers per million population** shows a significant correlation with BEV registration shares in intermediate regions but not for urban and rural regions. For urban populations, workplace charging might suffice for the relatively small driving needs given the convenience of public transportation and easy access to resources and facilities. Intermediate and rural regions may have greater driving needs. Rural residents are more reliant on home charging, whereas intermediate region residents count on a mix of both home and public charging. This could be a potential reason why the availability of public chargers significantly correlates with the BEV share only in intermediate regions.

In the multivariate linear regression across all regions in the prior section, two variables—the share of votes for the Green Party at the election for the European Parliament and average tax revenue of the municipalities per inhabitant—show a significant positive correlation with PHEV registration shares. When further distinguishing by regional typology, we find the following results:

» **Statistically significant positive correlation in all three regional typologies (urban, intermediate, and rural):** Environmental awareness maintains a strong correlation with the PHEV share among all three regional typologies. A one percentage point higher share of **votes for the Green Party at the election for the European Parliament** correlates with a 0.07 percentage points higher PHEV share for urban regions, 0.08 percentage points for intermediate regions, and 0.11 percentage points for rural regions.

» **Statistically significant positive correlation in urban regions:** The **tax revenue of a region's municipalities** shows a statistically significant correlation with the PHEV share only in urban regions**.** A €1,000 higher tax revenue correlates with a 1.04 percentage points higher PHEV share.

SUMMARY

For both BEV and PHEV registration shares, the results of the multivariate linear regression show, at regional NUTS 3 level, the highest statistically significant positive correlation of the share of votes for the Green Party during the election for the European Parliament in 2019, which we use as a proxy to depict environmental awareness. For BEVs, we also find a statistically significant positive correlation for three other variables: the shares of residents with one or two apartments, the number of public chargers, and the private households' average disposable income. For PHEVs, we find a statistically significant positive correlation for average tax revenue of the regions' municipalities.

In urban regions, environmental awareness represented by the share of votes for the Green Party during the election for the European Parliament remains the only variable with a statistically significant positive correlation for both BEV and PHEV registration shares. In addition, we find a statistically significant positive correlation in urban regions for the tax revenue of the regions' municipalities, but only for the PHEV registration share. In intermediate regions, statistically significant positive correlations can be observed for four variables. While the share of votes for the Green Party correlate with both BEV and PHEV registration shares, the share of residential buildings with one or two apartments, private households' average disposable income, and the number of public chargers per capita correlate only with BEV registration shares. For rural regions, the BEV and PHEV shares also correlate with the share of votes for the Green Party. The BEV share further correlates with the share of residential buildings with one or two apartments and private households' average disposable income, but no further correlation is observed for the PHEV share.

There are a few limitations with the multivariate linear regression approach chosen. First, linear regressions allow us to identify correlation, but not necessarily causality. The independent variables that we find to show a significant correlation should be interpreted as they might infer a possible causality to the dependent variable. However, correlation does not guarantee causality. A significant correlation may also be formed by reverse causality, which means that it is the dependent variable affecting independent variables, such as regions with high BEV or PHEV registration share attracting more investment for building charging stations. Another possibility of correlation is from omitted factors that impact the independent variables and the dependent variable at the same time, e.g., occupation affects household income as well as the preference of buying a BEV or PHEV. In our study, reverse causality is less of an issue for our regional analysis since we are using mostly independent variables from 2019 and the BEV and PHEV registration shares from one year later. However, we cannot exclude the possibility of omitted factors causing the observed correlations.

Second, the relationship between the selected variables and the BEV and PHEV registration shares might not be linear. It is likely, for instance, that the correlation between household income and BEV and PHEV share is very strong for lower income groups but much less so for high-income groups. The linear regression would fail to detect a correlation that is positive at some value but negative at other values and averaged at around zero. For instance, population density might increase people's willingness to purchase BEVs or PHEVs by network effect, but as population density grows, it might boost public transportation in the region and decrease people's need to buy a vehicle at all. Using a linear form, however, helps to understand the relationship in the most intuitive manner: On average, how many percentages point change in the BEV or PHEV share is associated with 1 unit change in the independent variable.

CASE STUDIES OF SELECTED REGIONS

While the previous section focused on the quantitative assessment of BEV and PHEV uptake and statistical analysis to explain some of the uptake based on selected variables, in this section we qualitatively investigate policies which might have supported the uptake. To do so, we highlight one rural, intermediate, and urban region with among the highest uptakes of new BEV and PHEV registration shares in 2019 and 2020, and identify key local policies that might have driven BEV and PHEV adoption. As sample regions, we choose the district of Rhön-Grabfeld (rural region), the district of Freising (intermediate region), and the district Rhein-Neckar (urban region).

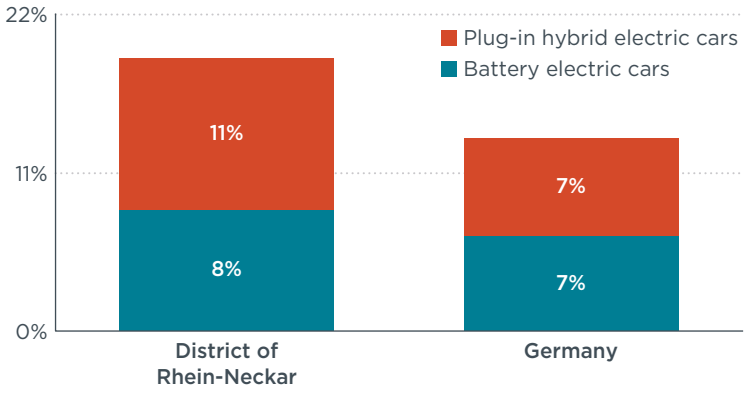
URBAN REGION WITH HIGH NEW BEV AND PHEV REGISTRATION SHARES

The district of Rhein-Neckar, situated in the north-west of Baden-Wuerttemberg, ranked in 20th place among Germany's 401 districts and district-free cities in new BEV and PHEV registrations in 2020 and 10th place in 2019. Of all new passenger cars registered in the district in 2020, 8% were BEVs and 11% were PHEVs. This was one percentage point and four percentage points above the German average, respectively (Figure 8). A total of more than 3,300 BEVs and PHEVs were registered as new in 2020, up from over 1,200 in 2019.

Key facts about the district of Rhein-Neckar

Population and location

- District in the state of Baden-Wuerttemberg
- About **550,000 inhabitants**
- Largest city is Weinheim (about 45,000 inhabitants)



Select local electric vehicle promotion actions

- **Climate Protection Guidelines 2011, Climate Protection Concept 2013 and 2021 update** including measures to foster electric mobility of public administration fleets and public charging infrastructure deployment
- **Extension of the municipal fleet with electric vehicles** including passenger cars
- **Extension of the public charging infrastructure network**
- **Information and awareness raising about electric vehicles and charging** e.g., support and advice by regional energy agency, learning center on climate change, touristic information about public charging stations

Figure 8. Key facts about the district of Rhein-Neckar.

The district of Rhein-Neckar was in the top 25 of German NUTS 3 regions with the highest regional tax revenue in 2018, with about €1,900 per capita, compared to the German average of about €1,200 per capita. The average disposable income per

capita in the district was the 15th highest across German NUTS 3 regions in 2018, and about €4,000 higher than the German average. In the district, the share of graduates with general university entrance qualification, share of residential buildings with one or two apartments, share of consumers shifting to green electricity tariffs, share of votes for the Green Party during the European election, and number of companies per capita were close to the German average. Public charging infrastructure per capita was slightly below German average. The region also has a population density about twice as high as the German average.

To foster the uptake of BEVs and PHEVs, the district of Rhein-Neckar has implemented a variety of policies. The district's Climate Protection Guidelines from 2011 suggested the development of a charging infrastructure concept for the district-owned buildings to ensure a sufficient supply for BEVs and PHEVs (Arbeitsgruppe Klimaschutz Rhein-Neckar-Kreis, 2011). The district's Climate Protection Concept from 2013 includes measures to enhance electromobility, such as the development of a Masterplan Electromobility. The update of the Climate Protection Concept published in 2021 suggests the transition of the public administration's passenger car fleet to alternative driving technologies. Based on the strategic targets and measures, the district administration has started to switch its own fleet to electric and gas vehicles in case of new purchases. In addition, charging stations for BEVs and PHEVs have been installed at administration buildings and utilities in the district (Landratsamt Rhein-Neckar-Kreis, 2021). A regional energy agency, which includes the district of Rhein-Neckar, the city of Heidelberg, and several other cities and municipalities, supports and advises citizens, municipalities, and companies on energy and climate protection measures. Since 2021, the agency also offers information and advice on electric mobility (Klimaschutz- und Energie-Beratungsagentur Heidelberg – Rhein-Neckar-Kreis gGmbH, 2021).

There is also a variety of activities in cities and municipalities of the Rhein-Neckar district, including education, information, and awareness raising offerings. The city library of the city of Hockenheim provides literature on electric mobility e.g., alternative powertrains and BEVs and PHEVs (Stadt Hockenheim Stadtbibliothek, 2019). The Climate Arena (*Klima Arena*) in the city of Sinsheim, which opened in 2019, offers events and exhibitions around climate change, including mobility-related topics such alternative drive technologies (Klimastiftung für Bürger, 2022). The tourist information website of the city administration of Sinsheim provides information about publicly accessible charging stations in the region, including their location and prices (Stadtverwaltung Sinsheim, n.d.).

Overall, the district of Rhein-Neckar is in one of the wealthiest regions in Germany in terms of regional tax revenue and disposable income per capita. Regional strategic targets to foster the adaption of BEVs and PHEVs, particularly as part of the local administration fleet, a regional agency, as well as other local institutions and stakeholders support the transition towards BEVs and PHEVs through various channels. These key activities may have supported the high uptake of BEVs and PHEVs in the district in the recent past.

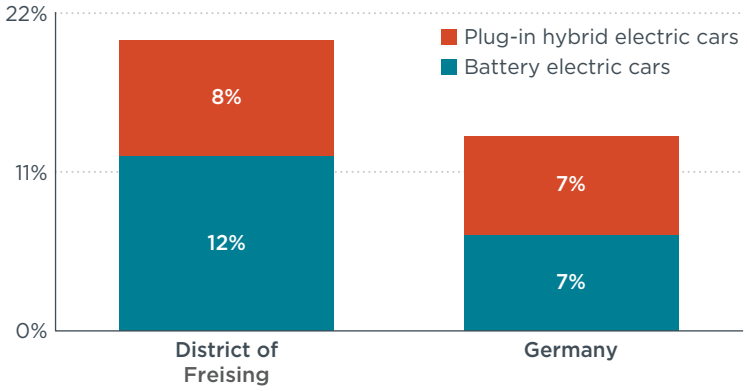
INTERMEDIATE REGION WITH HIGH NEW BEV AND PHEV REGISTRATION SHARES

The district of Freising in Bavaria is situated north of the city of Munich. This intermediate average region had one of the highest shares of new BEV and PHEV registrations, ranking 12th out of the 401 German districts and district-free cities in 2020 and 3rd in 2019. In the district of Freising, 20% of passenger cars newly registered in 2020 were BEVs and PHEVs, 7 percentage points higher than the German average of 13% (Figure 9). Of all new BEVs and PHEVs registered in 2020, 12% were BEVs and 8% were PHEVs. Over 900 new BEVs and PHEVs were registered in 2020 by total numbers, an increase of over 140% compared to 2019.

Key facts about the district of Freising

Population and location

- District in the state of Bavaria
- Over **180,000 inhabitants**
- District and largest city is Freising (about 50,000 inhabitants)



Select local electric vehicle promotion actions

- **Integrated Climate Protection Concept 2013** and **Mobility Concept 2019** including measures to foster electric mobility
- **Extension of the municipal fleet with electric vehicles** including passenger cars
- **Extension of the public charging infrastructure network**
- **Information and awareness raising about electric vehicles and charging** e.g., yearly Electro-mobility Day, electric car test ride/hire/rent options by car dealers, information about electromobility on city webpage

Figure 9. Key facts about the district of Freising.

Out of the nine variables analyzed, the district of Freising scored most favorable in terms of average regional tax revenue per capita and disposable income per capita. The district of Freising has experienced high growth rates along the corridor to Munich airport, which is partly located in the district. In addition, the district scored higher than the German average in terms of consumers changing to green electricity between 2017 and 2019. During this period, 50% of consumers changed to green electricity tariffs, ranking second highest in Germany and 14 percentage points higher than the German average. With the exception of a lower share of graduates with university entrance qualification compared to the German average, most other variables were close to the German average (share of residential buildings with one or two apartments, share of people voting for the Green Party during the EU election, and number of companies per capita). In terms of public charging, the number per million population was below the German average, yet 85% of people lived in buildings with potential access to home charging.

The district of Freising, here with focus on the district's city of Freising, has introduced a variety of policies to stimulate BEV and PHEV purchases. As part of its Integrated Climate Protection Concept published in 2013, the city of Freising suggested ten key measures to improve energy efficiency and the use of renewable energies in the city. Detailed measures included the integration of BEVs and PHEVs and bikes with the city's public transport, the development of concepts to connect electric mobility with energy storage, and the implementation of park-and-ride parking places with special incentives for BEVs and PHEVs (Stadt Freising, 2013). As part of its Mobility Concept published in 2019, the city of Freising aims to develop a district-wide concept to foster electric mobility (Stadt Freising, 2018). In terms of information, education,

and awareness raising, since 2014, the city of Freising has organized an annual Electromobility Day to inform visitors about electromobility. As part of the event, attendees are offered test rides with BEVs and PHEVs. Also, the municipal's vehicle fleet is successively replaced by BEVs and PHEVs. In addition, the city's webpage provides a comprehensive list of activities under the topic "electromobility."

Overall, next to favorable preconditions in terms of the economic power of the region and its population and the economic environment, the district has introduced a variety of local measures to further spur the electromobility in the region. The district can serve as a good example in how a sustained transition to BEVs and PHEVs in intermediate regions outside larger cities can take place.

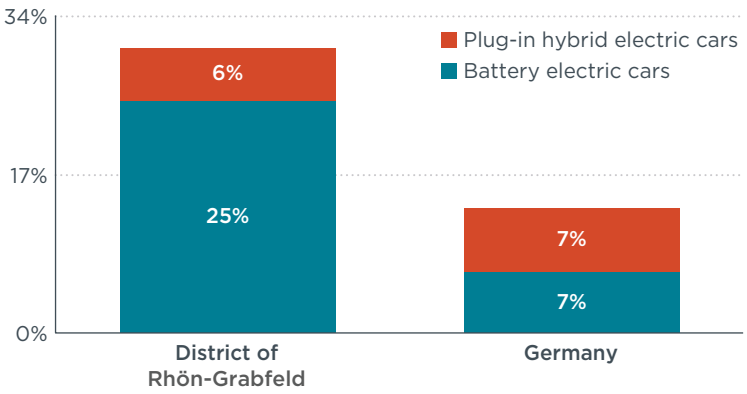
RURAL REGION WITH HIGH NEW BEV AND PHEV REGISTRATION SHARES

The district of Rhön-Grabfeld in the north-west of Bavaria has been the leading rural region in terms of new BEV and PHEV registration shares over the past several years, ranking first in 2019 and second in 2020 out of the 401 German districts and district-free cities. In 2020, 31% of new passenger cars registered were BEVs and PHEVs, which is 17 percentage points higher than the German average (Figure 10). Of new BEVs and PHEVs registered, 25% were BEVs and 6% were PHEVs. In total, about 700 new BEVs and PHEVs were registered in 2020, twice as many as in 2019.

Key facts about the district of Rhön-Grabfeld

Population and location

- District in the state of Bavaria
- Almost **80,000 inhabitants**
- District and largest city is Bad Neustadt an der Saale (about 16,000 inhabitants)



Select local electric vehicle promotion actions

- **Research and development e.g.,** district city first Bavarian model city on electromobility with focus on education and industrial projects; establishment of state funded Electromobility Technology Transfer Center in 2012
- **Extension of the public charging infrastructure network**
- **Information and awareness raising about electric vehicles and charging** e.g., yearly electric mobility fair, membership organization to promote electric mobility and connect local and regional stakeholders, local car dealer specialized in electric vehicles

Figure 10. Key facts about the district of Rhön-Grabfeld.

Based on the variables chosen for our analysis as outlined in the previous section, the district of Rhön-Grabfeld was close to the German average in terms of average regional tax revenue per capita, average disposable income, and number of companies

per capita. It scored lower in the share of graduates with general university entrance qualification, share of people changing to green electricity, and share of people voting for the Green Party during the European election in 2019. Moreover, the district belongs to the region with one of the lowest population densities compared to the German average. Only access to charging was significantly higher than the German average. The share of residential buildings with one or two apartments, a proxy for potential access to home charging, was eight percentage points higher (91% versus 83%) and the number of public charging points per million population (850) was 65% higher compared to the German average of about 500.

In terms of local policies, the district has a long history of promoting BEVs and PHEVs and the necessary charging infrastructure network (Stadt Bad Neustadt a. d. Saale, n.d.). The district's city of Bad Neustadt an der Saale was the first Bavarian model city for electromobility in 2010, funded by the Bavarian Ministry of Economics. Since then, the city and the district have introduced a variety of measures to address main barriers of BEV and PHEV adoption, including costs, infrastructure availability, and awareness. This includes a yearly electric mobility fair and a membership organization that promotes electric mobility across the region and connects interested stakeholders. These activities have been done in close cooperation with local stakeholders from businesses, administration, and institutes. In addition, the district has a strong economy with Siemens producing electric motors and two other companies producing systems and components for the automotive industry. Since 2012, the district is home of the state-funded Electromobility Technology Transfer Center, which performs research focusing on electrical energy technology, drive technology, and electromobility. Moreover, one of the local car dealers has specialized in BEVs and PHEVs for many years, selling models all over Germany.

Based on the variety of policy actions plus a business and education environment with focus on electromobility, the district has maintained its leadership role in BEV and PHEV uptake despite its peripheral, rural location. With an above German average of public chargers per capita and a high potential access to home charging, the region illustrates that a high uptake of BEVs and PHEVs is also possible in rural regions.

SUMMARY

The case studies for select regions illustrate that all initiated early engagements, particularly formulating strategic targets to foster BEV and PHEV uptake, even at a stage when model availability of cars was low. The extension of the regional public charging infrastructure network, as well as local education, information, and awareness campaigns, have likely helped these regions to have among the highest shares of new BEV and PHEV registrations. Although the case studies only list some of the key measures adopted and are not indented to depict a comprehensive policy mix, they give an indication of why some regions might have been successful in spurring electrification in the passenger car fleet.

CONCLUSIONS

This analysis of BEV and PHEV uptake in German regions, based on differences in the economic environment, the social status, living conditions and environmental awareness, and access to charging infrastructure, illustrates the diversity and complexity of BEV and PHEV adoption. Even though inequities between the regions exist, they cannot be simply identified by one of the stated variables or by regional urban, intermediate, or rural classification. Yet, the analysis leads to the following high-level findings:

- **Total new BEV and PHEV registrations are the highest in Germany's urban regions and the lowest in its rural regions.** Of the 392,500 newly registered BEVs and PHEVs in Germany in 2020, almost half were recorded in urban regions (48%), followed by intermediate regions (40%) and rural regions (11%). These ratios reflect that urban and intermediate region are also the most populous, with 44% and 41% of the German population in 2019, respectively.
- **Average BEV and PHEV shares of new passenger car registrations are relatively balanced across all of Germany's urban, intermediate, and rural regions.** Data shows that within different regional typologies—urban, intermediate, rural—the average share of BEVs and PHEVs in the total new passenger car registrations in 2020 was relatively balanced. New BEV and PHEV registrations accounted for 13% in urban regions, 14% in intermediate regions, and 13% in rural regions. When differentiating by BEVs and PHEVs, the BEV share ranged between 7% in rural to almost 8% in intermediate regions, while the PHEV share ranged between almost 6% in rural to just over 7% in urban regions.
- **There are wide variations in the BEV and PHEV share in new passenger car registrations among Germany's districts and cities.** In contrast to similar average BEV and PHEV shares across all urban, intermediate, and rural regions, there are wide variations among individual districts and district free cities across urban, intermediate, or rural regions. The difference in lowest and highest combined BEV and PHEV registration shares was most pronounced among NUTS 3 regions in intermediate regions, ranging between 5% and 32%, followed by rural regions (5% to 31%), and urban regions (4% to 25%). These wide variations indicate that there are regional disparities and potential inequities in BEV and PHEV uptake.
- **Regions with BEV and PHEV registration shares equal to or above the German average are concentrated in the northern, western, and southern areas**. Looking at NUTS 3 regions which recorded BEV and PHEV registration shares equal to or above the 2020 German averages, and differentiating by northern, eastern, southern, and western parts of Germany, we also find some variations. The number of NUTS 3 regions with equal to or above German average BEV or PHEV registration shares in 2020 was the lowest in the eastern part of Germany, no matter if urban, intermediate, or rural.
- **Environmental awareness, public charging infrastructure and home charging potential, as well as economic well-being, show a high correlation with the BEV and PHEV registration shares.** Environmental awareness, using the share of votes for the Green Party during the election for the European Parliament in 2019 as a proxy, is positively correlated with the BEV and PHEV registration share across all three regional typologies. For BEVs, the access to public charging infrastructure, home charging potential, and the economic well-being of a region as indicated by the disposable income of private households, show a high correlation with the BEV registration shares, at least in intermediate or rural regions. For PHEVs, in addition to environmental awareness, the average tax revenue of the regions' municipalities shows a statistically significant correlation with the PHEV share, but only in urban regions.

» **Individual regions with high BEV and PHEV registration shares have adopted a mix of local policy actions.** The analysis of key policy actions taken in select urban, intermediate, and rural districts with among the highest new BEV and PHEV registrations show that all have included early targets to foster BEV and PHEV uptake. The extension of the regional public charging infrastructure network, as well as different local formats of education, information, and awareness raising campaigns, have also likely helped these districts to have among of the highest shares in new BEV and PHEV registrations in 2019 and 2020.

Overall, the analysis shows less variation between the groups of urban, intermediate, and rural regions in BEV and PHEV registration shares in 2020, yet there are great variations among individual regions. Distilling general trends and key factors or policies driving the transition is difficult as BEV and PHEV uptake is still at a low level. This analysis includes company and private purchasers, and it is important to note that in some regions a high share of BEVs and PHEVs are purchased or leased by companies, particularly in urban regions. For example, in Berlin, 33% of new BEV and PHEV registrations were made by private individuals, 46% were registered by companies, and 21% were short-term rentals or registrations by car manufacturers or dealerships (Dataforce). This also has implications on policy. Therefore, the analysis in this paper offers trends and preliminary results. Further analysis at the regional level is to follow as better data becomes available.

Guaranteeing equitable access to BEVs and PHEVs across regions and population groups remains crucial in the transition to BEVs and PHEVs. To avoid that certain regions or population groups are left behind, policies need to continue to address the prevailing barriers of cost, infrastructure requirements, and awareness. These policies could include higher purchase incentives for low-income households, such as those adopted in France and various U.S. states (Clean Vehicles Assistance Program, 2022; Connecticut Department of Energy and Environmental Protection, 2021). Since environmental awareness can partially help to explain BEV and PHEV uptake, programs that raise public awareness of environmental issues could speed up the transition to BEVs and PHEVs. Lastly, as less wealthy population groups are less likely to own a car, access to electric mobility services such as carsharing with BEVs and PHEVs, ride-pooling, or ride-hailing could be another measure to include underserved groups in the transition to BEVs and PHEVs.

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