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# AN EQUITABLE TRANSITION FROM COMBUSTION ENGINES TO BATTERY ELECTRIC VEHICLES

THEORETICAL FRAMEWORK AND STATUS IN GERMANY

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## EXECUTIVE SUMMARY

An equitable transition to sustainable technologies and systems within the mobility sector is one of the key goals of the German government. Indeed, the government's focus on equity is clear when it asserts it "wants to use the 2020's to bring about a new beginning in mobility policy and enable sustainable, efficient, barrier-free, intelligent, innovative mobility that is affordable for everyone."

Equitable mobility involves all transportation modes and a range of economic, social, and urban planning considerations. This study focuses on one important piece of equitable mobility and the transition to sustainability: the transition from internal combustion engine vehicles (ICEVs) to battery electric vehicles (BEVs). From an environmental perspective, this transition is central to decarbonizing the German transport sector, if only because the use of motorized vehicles in Germany has shown steady growth. A key question, therefore, is how to make the transition to BEVs more equitable to ensure that everyone dependent on a car can participate.

Discussions about the transition to BEVs in Germany are nuanced and complex; they are political conversations that encompass multiple (and sometimes competing) definitions of terms, stakeholders, topics of focus, and understandings of the causes of (and solutions to) inequity. To aid general understanding, the first part of this study provides basic theoretical background on equity, groups of focus, and some of the causes of inequity in the transition to BEVs. The second part of this study focuses on the status of German research on equity and the BEV transition. As part of this section, we summarize findings of key studies and new registration data on buyers and owners of BEVs and plug-in hybrid vehicles (PHEVs) by various sociodemographic characteristics and locations. In addition, to identify research gaps, we survey key research that focuses generally on equitable transportation and related policy solutions and specifically on the BEV transition. We conclude with key findings and recommendations for further analysis which include:

**An equitable transition from ICEVs to BEVs is a multifaceted topic.** It can be interpreted differently depending on context; this complicates targeted discussions and policy recommendations. In addition, the lack of agreement on the topic's underlying terms (like equity and justice) adds complexity. An equitable transition also goes beyond vehicle purchase and ownership; it includes several other factors ranging from the information about electric vehicles that various groups can access to discussions about charging infrastructure. Therefore, we need both a better understanding of terms and a better understanding of the key factors that relate to the BEV transition to fully understand and discuss the BEV transition through an equity lens.

**The causes of inequity in the transition from ICEVs to BEVs are manifold and interrelated.** To establish a common conceptual framework, this paper defines seven broad dimensions that cause inequity: economic, environmental, health, spatial, procedural, legal, and data. For example, the economic dimension is linked to sociodemographic status and, in turn, points to income-based inequities in BEV adoption. Indeed, studies and data for Germany show that owning a BEV or the likelihood of purchasing/leasing a BEV is lower for lower income groups. In addition, data—its availability and biases in how it is gathered, processed, and interpreted—can also hinder equity and our understanding of it.

**The current transition from ICEVs to BEVs in Germany is not equitable.** Much research has been conducted in Germany to advance an equitable system over all transport modes. Policy recommendations with an equity focus typically include carbon dioxide (CO<sub>2</sub>) pricing, vehicle tax policies, and measures to promote alternative forms of transportation to the car. In the transition to BEVs specifically, studies and registration data also point to inequities among BEV buyers and owners based on

sociodemographic, firmographic, and geographic characteristics. For example, private individuals buying or owning BEVs are typically male, of higher income and education, live in larger households, and often live in one or two family homes.

While this study focuses on Germany and the German context, it may also inform equity-related discussions in other countries working to promote BEV adoption.

# TABLE OF CONTENTS

<b>Executive summary</b> .....	<b>i</b>
<b>Introduction</b> .....	<b>1</b>
<b>Theoretical background</b> .....	<b>3</b>
Key terms: equity, access, and marginalized groups .....	3
Understanding causes of inequity: structuring by dimension .....	5
<b>Research landscape in Germany</b> .....	<b>9</b>
EV buyers and users: research and registration evidence.....	9
Key papers and projects .....	10
Equitable access to electric vehicles, charging infrastructure, and information .....	11
<b>Conclusions and recommendations</b> .....	<b>14</b>
<b>References</b> .....	<b>16</b>

## INTRODUCTION

The German government has made the total decarbonization of the transportation sector a major part of its climate protection ambitions. This involves an interim target of reducing yearly CO<sub>2</sub> emissions in the transport sector from 150 to 85 million tons of CO<sub>2</sub>-equivalents between 2020 and 2030, with an overall goal of reaching greenhouse gas neutrality across all sectors by 2045. These goals are anchored in the German Climate Protection Law passed in August 2021 (Bundesgesetzblatt, 2021).

Measures to decarbonize transport aim to curb unnecessary travel, shift necessary motorized travel to alternative modes (e.g., walking, cycling, and public transport), and improve vehicle efficiency. The latter includes promoting zero-emission vehicles (ZEVs) including BEVs and fuel cell electric vehicles (FCEVs). While a combination of avoid, shift, and improvement strategies tackling different transport modes is necessary for decarbonization, this study focuses on the transition from ICEVs to BEVs. This is based on evidence that only vehicles with zero tailpipe emissions can fully decarbonize on-road vehicles (Searle et al., 2021).

The German government is also committed to transition the passenger car fleet and aims to have 15 million new BEVs on the road by 2030 (SPD, BÜNDNIS 90/DIE GRÜNEN, FDP, 2021). This will be achieved through policy measures and through funding to increase their affordability such as incentives for new purchases of BEVs, FCEVs, and PHEVs, exemptions to the vehicle ownership tax for BEVs and FCEVs, and reduced tax rates for the private use of company electric vehicles (EVs, including BEVs and PHEVs) (Deutscher Bundestag, 2020; Bundesministerium der Finanzen, 2020; Federal Ministry for Economic Affairs and Climate Action, 2022). To enhance access to public charging infrastructure for EVs, the German government also aims to further expand public charging points, remove bureaucratic barriers, and increase private investments into charging stations (Press and Information Office of the Federal Government, 2022). Additionally, the government is funding research and development and information campaigns on the benefits of EVs to increase awareness (Federal Ministry for Economic Affairs and Climate Action, 2023).

However, there is a risk that the transition to BEVs will replicate or worsen inequities in the current transportation system or even create new ones. For example, studies suggest inequities in access to EVs from a consumer perspective. EV purchasers or owners in Germany are typically middle-aged men, with a higher education, working full-time, and with a higher income compared to private users of conventional ICEVs. They are also often married, have children, and live in detached and semi-detached houses (Frenzel et al., 2015; Acxiom, 2020). Other studies show that lower income households lack the financial resources to buy new cars generally (including BEVs), opting instead to purchase used vehicles to save money. For example, the purchase price of new cars in Germany equals to about 60% of the average buyer's annual net household income; for used cars it is approximately 30% (Deutsche Automobil Treuhand GmbH, 2021). Among commercial users in Germany, predominantly smaller businesses generally own one EV per location (Frenzel et al., 2015).

These inequities have occurred not least because of incentive policies for EVs in Germany that largely benefit higher income households (i.e., those more likely to purchase new cars and benefit from EV purchase incentives or those more likely to benefit from company car related EV tax privileges) (Agora Verkehrswende, 2022).

Policies should, therefore, be designed with those risks in view, and should seek to alleviate, not preserve or worsen, inequities. Therefore, understanding how the transition from ICEVs to BEVs in Germany can foster a more equitable system is crucial.

Accordingly, this study aims to structure political discussions by providing theoretical background on definitions, groups affected, and potential causes of inequities. It also highlights the status of the German research landscape. While this study does not touch on methodological details including sourcing, analysis, data disaggregation,<sup>1</sup> interpretation, and equitable communication. This study also does not include a comprehensive discussion of stakeholders, stakeholder integration, or outreach.

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<sup>1</sup> The disaggregation of data is the process of separating larger data sets into separate groups to better enhance analysis and identify trends, needs, and differences.

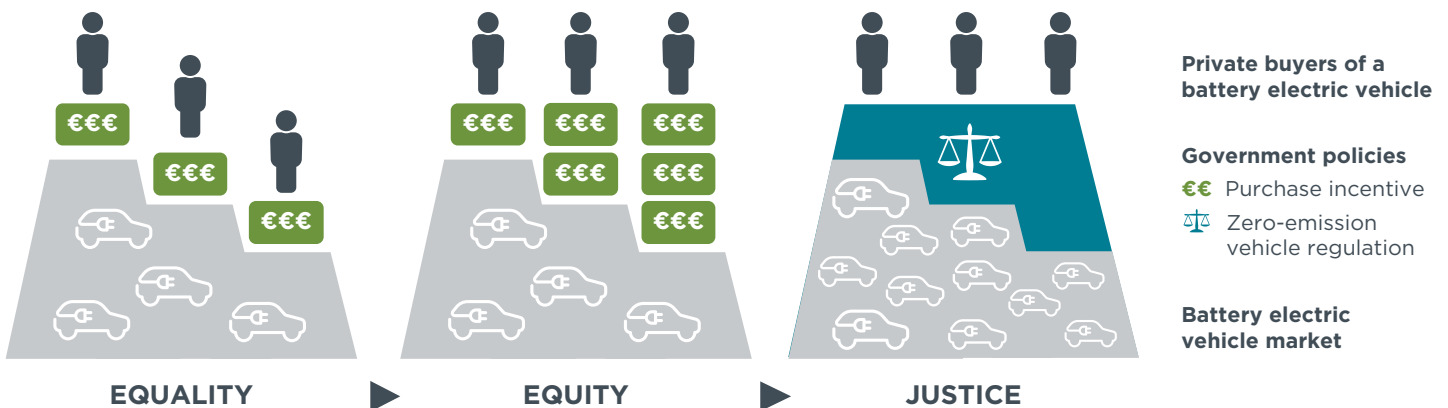
## THEORETICAL BACKGROUND

While an equitable transition from ICEVs to BEVs has recently gained attention in public and political discussions, how people understand that concept varies considerably by context. This is, in part, because equity itself is a broad and far-reaching term (Lewis et al., 2021). The same applies to our understanding of the various groups affected by inequity and the potential causes of and solutions to inequity in the transition to BEVs. Therefore, to help structure future political dialogue and policy formulations, this section aims to elucidate key terms and concepts.

### KEY TERMS: EQUITY, ACCESS, AND MARGINALIZED GROUPS

Generally, the term *equity* adds social dimensions to public and political discussions. *Equity* itself is a normative concept and, as such, it is value-laden. It implies an ideal for society or areas of society. It is also a broad and complex term. Therefore, it is key to understand what the term implies and how it compares to other terms such as *equality* and *justice* which are often used interchangeably.

Figure 1 illustrates the differences between equality, equity, and justice as they can for example relate to access to (i.e., here the affordability of) private BEV purchases. Equality in this context could mean the government gives everyone who depends on private car ownership the same incentive amounts to purchase a BEV. Equity could allocate incentives based on income levels to reach equal outcomes. However, higher incentive amounts for lower income people might still be insufficient for them to afford BEVs. Justice moves one step further. It implies changes to the social system to remove the causes of inequities through enacting policies which, in the long-term, would guarantee equitable access to BEVs without any governmental support. Governments could support a just transition to BEVs through policies that regulate car manufacturers to produce affordable BEVs. For example, California has enacted its Advanced Clean Cars II regulation to grow the market for BEVs; it includes credits for car manufacturers selling low-price BEVs to ensure wide vehicle distribution across the state, particularly in communities of color and communities burdened by air pollution (Bui et al., 2022).



**Figure 1.** Equality, equity, and justice in private BEV access.

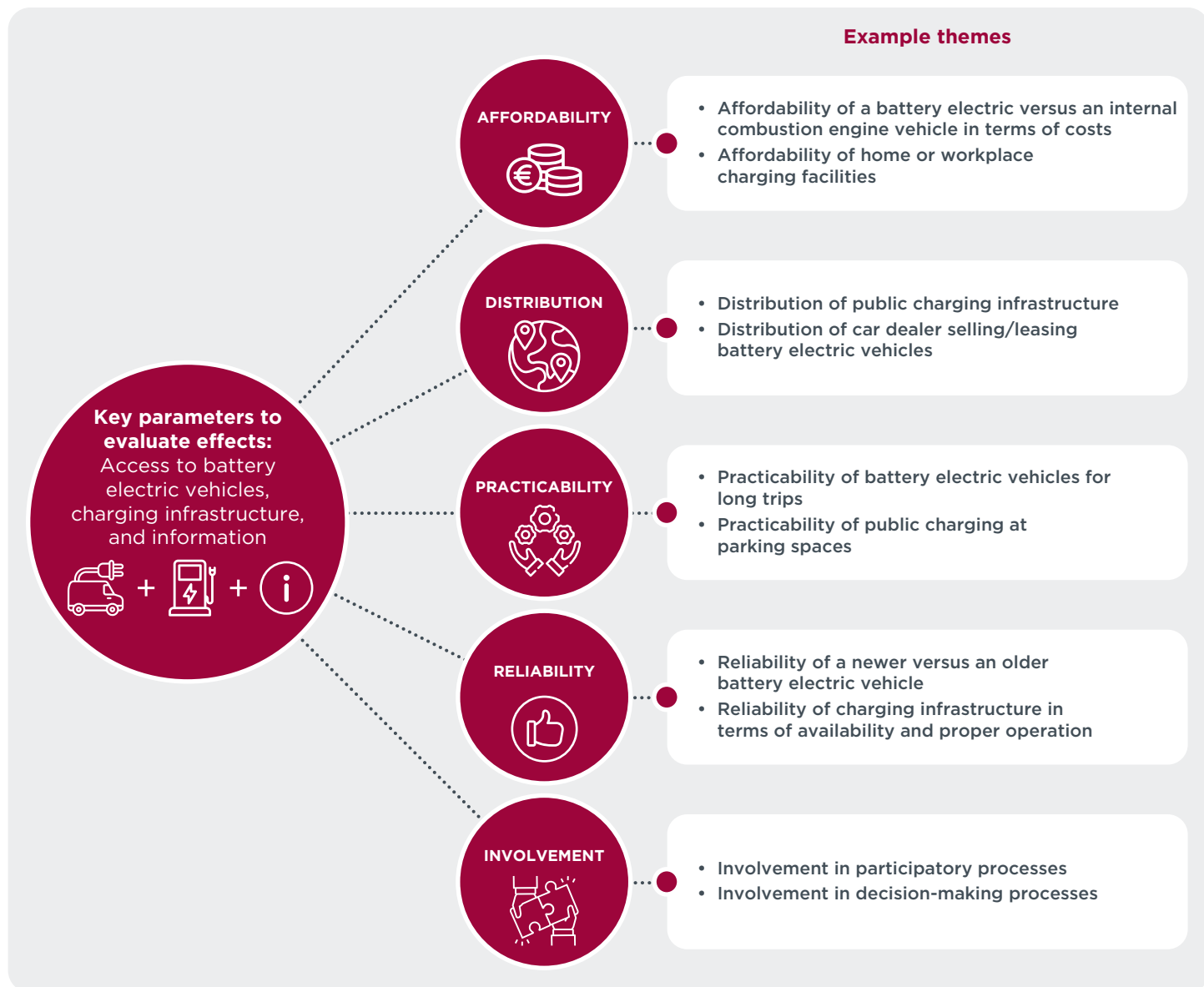
Another often-used and widely-interpreted term in the context of transitioning to BEVs is *access*. It can take on different meanings depending on the size of the systems being considered—ranging from small to large, micro to macro, local to national.

Large-scale analyses typically examine the effects of systems at the level of society as a whole, which includes the rules of the market economy, politics, technology, or culture (Hong Lam Vu, 1997). For example, in our context, access could involve huge systems, like global access to resources for battery production. Small scale analyses, on the other hand, look at specific locations, organizations or communities that exist within larger systems. They could, for example, focus on individuals' access to BEVs.



Being aware of these layers can improve analysis and policy recommendations by identifying diverging interests, actions, living environments, and behaviors.

Access can have different parameters in the equitable transition to BEVs, including affordability, distribution, practicability, reliability, and involvement. Figure 2 illustrates those dimensions and provides example themes in access to BEVs, charging infrastructure, and information.



**Figure 2.** Parameters of access in the equitable transition to BEVs.

For data analyses, disaggregation, and policy making, it is also important to understand the specific characteristics of individuals, groups, or communities that might lead them to be left out of the transition to BEVs. The term *marginalization* is typically applied to specific sociodemographic characteristics of individuals, groups, or communities and their geographic location. For example, the European Institute for Gender Equality (2022) says marginalized groups are “Different groups of people within a given culture, context and history at risk of being subjected to multiple discrimination due to the interplay of different personal characteristics or grounds, such as sex, gender, age, ethnicity, religion or belief, health status, disability, sexual orientation, gender identity, education or income, or living in various geographic localities.”

That definition lists characteristics that can help determine marginalization. To further focus on equity in the BEV transition (and formulate better research questions, goals, and analyses), it is crucial to understand different groups and groupings and how marginalization can be measured. Figure 3 gives an overview of these approaches and a selection of variables to disaggregate groups in the context of an equitable transition.



**Figure 3.** Segmentation and possible disaggregation of populations in the BEV transition.

To analyze and describe marginalization and shape targeted policy interventions and recommendations, we must further sub-characterize its variables (Lucas et al., 2019). For example, income alone does not allow us to reach any conclusions about potential marginalization or inequities. It only helps compare populations in specific contexts against income averages. That can help identify degrees of marginalization. This kind of analysis advances data equity by including the voices of marginalized groups, therefore increasing trust and visibility in research, here specifically when considering marginalization in the context of the BEV transition.

## UNDERSTANDING CAUSES OF INEQUITY: STRUCTURING BY DIMENSION

Based on that understanding of key terms, we will look at potential causes of inequity in the transition from ICEVs to BEVs and the various dimensions that characterize those causes. In general, the causes of inequity in the BEV transition are manifold. Understanding them and their differences is also crucial in shaping targeted transition goals and policies. To clarify the causes of inequity, we characterized them along seven dimensions, seen in Figure 4.



**Figure 4.** Example causes of inequity in the BEV transition.

These dimensions are influenced by other published research which broadly investigates equitable transportation (Creger et al., 2018; Lucas et al., 2019). The causes of inequities in these dimensions can range from a macro, global perspectives (e.g., battery production and mining) to the micro, individual perspectives (e.g., individual access to BEVs). This study’s overview of causes of inequity focuses on the view of marginalized populations. We used various literature sources to highlight example

effects of inequities in the different dimensions, all interlinked and having social implications. However, they are not a comprehensive list and might vary depending on context, region, culture, and levels (macro to micro) evaluated.

**Economic inequity.** Individual-level economic inequities in the BEV transition can be linked to costs (including purchase/leasing, ownership, maintenance, repairs, insurance, charging/fueling, etc.). For example, in Norway (the largest battery electric passenger car market by registration shares), most new BEVs are purchased by private individuals in the highest annual household income percentiles, a group which benefits the most from national tax breaks and other BEV incentives (Statistisk Sentralbyrå, 2022). Similarly, a study focused on the Netherlands found that drivers of a new and used EV were typically from higher income households. Yet in lower income brackets, the share of drivers of second-hand EVs was slightly higher compared to those of new (Duurkoop et al., 2022). A study of the United States also suggested that lower income households were less likely to adopt EVs as they must spend larger proportions of their income on vehicle-related expenses including purchase, insurance, maintenance, and fuel costs compared to higher income households (Bauer et al., 2021).

**Environmental inequity.** Extensive research on environmental inequities points typically to the disproportionate impacts of climate change and traffic-related air pollution from ICEVs for certain groups (based on income, race, ethnicity, or other characteristics). For example, a study focused on New York found geographic disparities in ambient particulate matter (PM<sub>2.5</sub>) concentrations attributed to diesel truck tailpipe emissions. Compared to the average, non-Latino White residents were exposed to 10% less PM<sub>2.5</sub> from diesel trucks while people of color were exposed to 5% more (Meyer & Dallmann, 2022). From a geographic perspective, a global study showed that people in urban areas are affected by greater exposure to nitrogen dioxide (NO<sub>2</sub>) concentrations compared to people in rural areas; transportation tailpipe emissions were the major anthropogenic contributors to these emissions (Anenberg et al., 2022). While policies in the transition to BEVs can help to reduce these environmental inequities to the benefit of marginalized groups, they might yet create new ones in the transition phase. For example, policies such as environmental zones in cities might create environmental inequities for marginalized groups living outside these zones.

**Health inequity.** The environmental and health dimensions are closely linked. There is also voluminous and compelling research on health factors (e.g., the risk of traffic-related air pollution and health impacts such as stroke, heart disease, and lung cancer) that affect populations generally and that particularly impact marginalized groups and people in certain geographic areas. For example, a study of the long-term trends of the air pollution-related health impacts of transportation emissions among 100 major urban areas worldwide found that 3 of the 6 cities with the highest mortality rates attributable to transportation tailpipe emissions in 2015 were in Germany (Berlin, Cologne, Stuttgart), pointing to geographic disparities (Anenberg et al., 2019). Anenberg et al.'s (2022) study also connects long-term urban combustion-related NO<sub>2</sub> concentrations to pediatric asthma. It estimated that 1.85 million new cases were attributed to NO<sub>2</sub> globally in 2019; two thirds of those were in urban areas. Similar to environmental inequities, the transition to BEVs can help to mitigate those health inequities for marginalized groups, but could yet in the interim create new ones as indicated by the example of environmental zones.

**Spatial inequity.** Many studies of the environmental and health causes of transportation inequity also highlight spatial causes. A study investigating new European BEV registrations in 2020 differentiating by urban, intermediate, and rural regions, found considerable differences among countries, some (e.g., United Kingdom, the Netherlands) with more urban regions with above average new registrations compared

to other countries with more rural new BEV registrations (e.g., Portugal and Austria) (Morrison & Wappelhorst, 2022). Other studies relate future public charging gaps and requirements to geography (ex., comparing metropolitan and nonmetropolitan regions). A 2021 study found that metropolitan areas in Germany had more requirements for public charging infrastructure than non-metropolitan areas, not least because of fewer opportunities for home charging (Nicholas & Wappelhorst, 2020).

**Procedural inequity.** The concept of procedural equity concerns questions such as who participates in planning and decision-making processes, how decisions are made, and how the public is involved by authorities (Longley, 2022). Procedural equity also concerns citizen-centered approaches to enhance BEV adoption specifically targeted at marginalized groups or communities. However, political participation processes are often driven by highly motivated citizens (Stiftung Mitarbeit, 2022) and typically do not reflect a representative share of the population based on sociodemographics or other characteristics (Bermann et al., 2018). Reasons for non-participation include factors such as limited resources, unwillingness to participate, limited inclusion by institutions and politically active citizens and processes, or a subjective sense of powerlessness concerning change (Rohr et al., 2017).

**Legal/regulatory inequity.** In the context of transitioning to BEVs, there are various legal and regulatory connections to equity. For example, EV charging infrastructure building codes and laws can help to support access to home charging (Pierce & Slowik, 2023). Studies show that over 90% of EVs in Germany are parked at homes in garages, carports, or private parking compared to 75% of passenger cars overall (Infas Institut für angewandte Sozialwissenschaft GmbH et al., 2019). This large difference can be explained by the fact that homes with garages, carports, or private parking have potential access to home charging. This is different for people in multi-family housing, where finding a place to charge a BEV might be an additional hurdle.

**Data inequity.** Data equity matters because data allows us to measure other equity dimensions. It is key to data analysis in equity-focused work. How data is collected, analyzed, visualized, interpreted, and distributed influences research projects and policies. Data equity includes funding, motivation, project design, data collection and sourcing, analysis, interpretation, communication, and data-based discrimination and stigmatization. Even issues of when data sets are not collected, edited, or applied equitably in research could influence results (Taylor, 2017; Datassist, 2022). This dimension considers factors that may affect marginalization within data sets. Key questions about data include the definition and creation of data categories (which influences how data sets are utilized). This consideration can be tackled through the disaggregation of groups—this helps to break down large populations where marginalized communities may be unduly grouped, therefore erasing identities and struggles or barriers and increasing bias within data (Carleton & Porter, 2018).

Overall, the overview and structuring of potential causes of inequity by dimensions illuminates the complexity of an equitable transition to BEVs. Moving forward, this information can be utilized to structure discussions and policy recommendations to help account for varied or overlapping focuses and contexts.

## RESEARCH LANDSCAPE IN GERMANY

After structuring the topic and formulating a better understanding, we want to examine the research landscape in Germany regarding an equitable transition to BEVs. For that, we first summarize key research and data on EV buyers and users in Germany, followed by key research projects on equitable transportation topics generally, and finally projects on an equitable transition from ICEVs to BEVs specifically. The aim is to highlight any gaps that need further investigation to help shape policies at national levels to make the transition to BEVs in Germany more equitable.

### EV BUYERS AND USERS: RESEARCH AND REGISTRATION EVIDENCE

Studies and registration data for Germany show that, so far, only certain populations are opting for EVs. Table 1 summarizes various characteristics of private BEV and PHEV buyers and owners based on selected literature and registration data.

**Table 1.** Study parameters and characteristics of private BEV and PHEV buyers/owners in Germany.

	Frenzel et al., 2015	BMVI, 2017	Acxiom, 2020	Kraftfahrt-Bundesamt, 2021a	Ecke et al., 2021	Römer & Steinbrecher, 2021	Ipsos, 2022
<b>Study respondents</b>	Private & commercial EV users (total sample)	Private EV users (sub-sample)	Private & commercial EV users & new registrations (total sample)	Private EV users	Private EV users (sub-sample)	Private EV users (sub-sample)	Private EV users (sub-sample)
<b>Persons surveyed / data points</b>	1,946 private and 1,165 commercial users	255 (weighted)	136,617 new EV passenger car registrations & market media study	93,324 new BEV registrations (2020)	-	44	110
<b>Survey type</b>	Primary	Primary	Primary, secondary	Secondary	Primary	Primary	Primary
<b>Average age (years)</b>	51 (50 median)	-	Middle age	51	-	52	-
<b>Age range (years)</b>	19–94	-	35–59 (BEVs), 40–59 (PHEVs)	45–54 (30%) (highest range)	-	-	18–34 (41%), 35–54 (37%), 55+ (22%)
<b>Gender</b>	Men (89%), Women (11%)	-	Predominantly men	Male (72%)	-	-	Men (57%), Women (43%)
<b>Income</b>	Monthly household net income €4,000+ (44%), €2,000–4,000 (46%), under €2,000 (10%)	Monthly household net income €4,000+ (70%), €2,000–4,000 (25%), under €2,000 (5%)	-	-	-	Above average	-
<b>Education level</b>	University education (50%)	-	-	-	-	-	High (55%), medium (35%), low (10%)
<b>Employment</b>	Full-time (70%)	-	-	-	-	-	Employed (85%), not employed (15%)
<b>Family status</b>	-	-	Often married	-	-	-	Partnered (85%), not partnered (15%)
<b>Persons in household / household type</b>	3+ (50%), 2 (39%), 1 (11%)	3+ (54%), 2 (32%), 1 (14%)	-	-	Multi-person w/ children (36%), multi-person w/o children (14%), small household (50%)	-	3+ (49%), 2 (43%), 1 (8%)
<b># children</b>	2+ (22%), 1 (17%), 0 (61%)	-	Often with children	-	2+(14%), 1 (7%), 0 (79%)	-	-
<b>Type of housing</b>	Detached single-family house (50%+)	-	Often in one and two-family houses	-	-	Proportion of EV users in 1- & 2-family houses twice as often as in properties with several parties	-
<b>Geographic area type</b>	Large city (22%), medium city (28%), small city (40%), rural community (10%)	Metropolitan (9%), large city (11%), medium city (13%), urban area (38%), small town/ village (29%)	Above-average frequency in metropolitan areas or municipalities with 500,000+ inhabitants	Urban regions (medium-sized towns & urban areas) (32%)	Residences over 100,000+ inhabitants (74%), residences under 100,000 inhabitants (26%)	Share of EV users in rural areas 50% higher than in medium-sized and large cities	-

By sociodemographics, most private BEV owners are middle-aged men, with a higher education, working full-time, and with a higher income (Frenzel et al., 2015; Acxiom, 2020; Kraftfahrt-Bundesamt, 2021a). They are also typically married, have children and live in detached and semi-detached houses. Private BEV owners also typically own more cars than private ICEV owners. The share of households with an above average income owning an electric car is about three times higher compared to those with a below average income (Römer and Steinbrecher, 2021).

By location, studies show different results. Some point to a higher uptake in rural regions while other find a dominance of electric vehicle owners in small or larger urban regions. New registration data of BEVs by private individuals for the years 2020, 2018, and 2016 show that about one-third live in urban regions, specifically medium-sized towns and urban areas (Kraftfahrt-Bundesamt, 2021a). In addition, an ICCT study also depicts regional differences in BEV uptake in Germany between urban, intermediate, and rural regions and more generally districts in the eastern part of Germany having the lowest new BEV registration shares compared to other parts of Germany (Wappelhorst et al., 2022).

Other studies also show that lower income households lack the financial resources to buy a new car in general, which includes BEVs, opting instead to purchase used vehicles to save money. For example, the purchase price of new cars in Germany equals to about 60% of the buyers annual net household income, while for used car it's approximately 30% (Deutsche Automobil Treuhand GmbH, 2021). Few studies specifically look at commercial users. For example, a study for Germany from 2015 shows that it is predominantly smaller businesses owning mostly one electric vehicle per location (Frenzel et al., 2015).

Overall, studies and registration data point to an unequal transition from ICEVs to BEVs in Germany among private individuals and businesses when looking at selected sociodemographic, firmographic, and geographic characteristics, or a combination.

## KEY PAPERS AND PROJECTS

Generally, there has been extensive research on the transition of the transport sector in Germany including policy interventions to make it socially just. Topics include CO<sub>2</sub> pricing, tax policies, and discounts aimed at various transport modes beyond the electrification of the German passenger car fleet.

A position brief published by Umweltbundesamt (Frey et al., 2020) points at an inequitable road transport in Germany and discusses strategies and instruments for a more sustainable mobility such as more climate and socially just tax and levy systems, the extension of the public transport system, and enhancing active modes of transportation. Income was found to be a major player in transport emissions in this study where groups with higher incomes in Germany were found to contribute more to the release of emissions than groups with lower incomes. An example of this is seen through shorter daily travel distances in 2017: 51 km per day on average for people with high incomes versus a 26 km per day on average for people with very low incomes.

A project funded by the Umweltbundesamt (Schelewsky et al., 2020) determined the individual traffic-based carbon footprints of specific population groups by modal use, age, and family size, among other factors. Another Umweltbundesamt project (Friedl & Blanck, 2021) looked at measures to make transport policies more just such as vehicle ownership taxes, phasing out EV purchase incentives, redesigning taxes for the private use of company cars and the commuting allowance, and implementing road tolls for passenger cars accounting for the disadvantages that lower income households may face. Additionally, Umweltbundesamt funded a project aimed at providing input and discussing opportunities, conflicts, and solutions of climate policy measures such as

CO<sub>2</sub> pricing, subsidies, and discounts aimed at various transport modes such as public transport, all from a social design lens (Umweltbundesamt, 2022).

Agora Verkehrswende, Agora Energiewende, and Öko-Institut published a report entitled *Getting Climate Protection on Course – How Carbon Pricing is Socially Balanced* (Elmer et al., 2019). A 2021 factsheet by Agora Verkehrswende examined the fairness of climate protection measures in road traffic and social distribution effects of CO<sub>2</sub> pricing and the promotion of electromobility. In 2022, Agora Verkehrswende also published two studies that examined social instruments to reduce the imbalances brought forward by current road and motor taxation policies (Agora Verkehrswende 2022; Thöne et al., 2022). Additionally, a study from the Verkehrsclub Deutschland in 2022 highlighted strategies to formulate a more just transportation system in Germany overall.

The focus on gender inequity in mobility was part of a project funded by Umweltbundesamt and Germany's Federal Ministry for the Environment, Nature Conservation, Nuclear Safety and Consumer Protection. Its research highlights how gender equality is necessary for a socially just transition of the transportation sector (LIFE Bildung Umwelt Chancengleichheit e.V., 2022).

## **EQUITABLE ACCESS TO ELECTRIC VEHICLES, CHARGING INFRASTRUCTURE, AND INFORMATION**

The selected research gives an initial indication of the variety of topics tackled to make a more equitable transition in the German transport. It also points to different sociodemographic characteristics (e.g., income, gender) of affected groups. The following sections of this study examine the research landscape with a focus on an equitable transition to BEVs in terms of access to BEVs, charging infrastructure, and information (beyond the research on EV buyers and owners already outlined).

### **Equitable access to electric vehicles**

Much of the current vehicle electrification research in Germany evaluates uptake and ways to increase total new vehicle registrations. It generally describes progress in terms of total new EVs registered or as a percentage of the total vehicle registration share. For example, in 2022, the share of BEVs in total new passenger cars in Germany was 18%, up from 14% in 2021 and 7% in 2020 (Mock et al., 2021; 2022; 2023).

However, studies often focus on groups which are among the first to register EVs (early adopters) with specific sociodemographic characteristics. Studying only early adopters and largely ignoring the experience of those who belong to marginalized groups does not consider the needs of all and ignores how to increase access among marginalized groups. This warrants more nuanced and specific approaches to evaluate EV uptake to ensure equity. In addition, some research has begun to differentiate new BEV shares by user groups (i.e., private individuals versus true fleets),<sup>2</sup> finding that private individuals accounted for 62% of the share of total new BEVs registered in Germany in the first half of 2021 and 64% in the second half (Morrison et al., 2022). Despite electrification progress in terms of total BEV registrations, some Germany-wide and local-level analyses have shown that the share of German households with an above average income owning or planning to buy an EV is about three times higher compared to those with a below average income (Römer & Steinbrecher, 2021).

As the research focus has largely been on early adopters, gaps exist in understanding other groups and how to better promote their EV access and what may be hindering it (e.g., a lack of affordable models or adequate financial supports for lower income

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<sup>2</sup> These include company cars, long-term rentals, leased vehicles, taxis, and cars belonging to driving schools, public administrations, and diplomats.



households, etc.). Some marginalized groups (e.g., people with lower incomes) may find new BEVs price prohibitive. Therefore, used BEV sales and registration shares may serve as a better alternative measure of progress in the BEV transition.

The used EV market is in a more nascent stage compared to the new market. In 2021, the number of BEVs that changed ownership, or the number of used cars sold, grew nearly 148% over 2020; the used EV market is beginning to grow (Kraftfahrt-Bundesamt, 2021b). Gaps in the research on used BEVs are similar to those on new, with little understanding of who exactly is purchasing used BEVs and which roadblocks exist. Indeed, no major studies having been conducted on this topic. Continued and more in-depth understanding of what influences the used BEV market will aid in making them more available to those who depend on cars but cannot afford to buy new. Strengthening the used market is important to fostering an equitable transition to BEVs.

In addition to used EVs, shared mobility services also increase EV access for marginalized communities. They allow for more zero emission kilometers travelled while removing or delaying the need for private individuals to purchase vehicles (Nicholas & Rajon Bernard, 2021). Research on car sharing in terms of equity is limited in Germany despite its promise and despite its relatively high 5% EV penetration rate in 2021 (Habla et al., 2021). We see other research gaps concerning background information on specific user groups, understanding roadblocks to further utilization, and how political institutions can support EV sharing to achieve equitable transportation goals. However, one study researched the equity implications of a car sharing system in Munich and found that some car sharing models favor “high-income agents” due to higher prices, creating similar barriers to those hindering new EV access (Giorgione & Viti, 2021).

One example of how governments have been using the limited available research to support affordable EV sharing is in Berlin’s ridehailing service BerlKönig (BVG, 2022). The pilot of this program was successful and will be replaced by two on-demand offers, the “BVG call bus” and the “Alternative barrier-free transport.” This success shows that shared EV mobility services have the potential to increase EV access, which, in turn, could help increase equitable access since these programs offer real world alternatives to car ownership.

### **Equitable access to charging infrastructure**

Access to charging infrastructure is a critical aspect in the transition from ICEVs to BEVs, as adequate charging points, both public and private, are necessary for BEVs to be fully incorporated as a means of mobility. Studies that analyze equitable charging infrastructure deployment in Germany, specifically, are lacking. In Sweden, research suggests demographic and structural inequities amplify charging gaps. For example, a lack of data and procedural barriers among people with lower incomes and rural inhabitants amplified their inability to access charging points, where higher income urban areas saw the highest charging infrastructure density (Xylia & Joshi, 2022).

While it is unclear if similar results would be found in Germany, much of the German charging infrastructure research so far focuses on charging needs overall or regionally. For instance, one ICCT study found that the German charging capacities in 2018 would only supply 10% of the charging needs of everyone in Germany in 2030 (Nicholas & Wappelhorst, 2020). This study showed that up to 565,000 charging stations would be needed by 2030, with a bigger gap in more affluent areas. However, in less affluent areas, the gap only remains smaller due to a lower EV uptake rate. A 2020 study by Transport & Environment also highlighted a charging gap based on regionality, where fast charging stations in Germany were more likely to exist in affluent urban areas, with fewer fast charging options in rural and intermediate regions. Other studies have begun to examine the physical locations suited for charging infrastructure, such as private

single-family houses, workplaces, and public charging stations, where equity plays a role in the housing type or workplace access (Reiner Lemoine Institut, 2020).

These findings are complemented by a scoping review that highlights the importance of understanding access to marginalized groups as an aspect of transportation equity, as charging incentive schemes and plans put forward by political institutions often favor higher income groups (Carlton & Sultana, 2022). Nuances can exist in the overall charging gaps of a country where marginalized groups may face more barriers than well-off groups. Measuring and evaluating the equitable progress of charging infrastructure access in Germany remains a key research area to pursue.

Considering charging gaps based on EV uptake can ignore other eventual barriers to charging for marginalized groups, such as affordability, convenience, and charging times (Barth et al., 2016). The German Infrastructure Masterplan II offers an increased focus on building out charging infrastructure points. However, without a focus on equity, this plan may not fulfill the needs of people who cannot afford public charging prices to begin with (Press and Information Office of the Federal Government, 2022). Additionally, some have criticized the plan because the majority of new charging points will come from one provider, leading to potential local monopolies and even higher prices (Kampwirth, 2022).

### **Equitable access to information**

Awareness and understanding of electromobility benefits directly influence the likeliness private individuals will purchase or use EVs (Jin & Slowik, 2017). A 2020 study found that access to information is key to social acceptance by private individuals in Germany; attitudes towards EVs are formed based on the availability of this information (Burghard et al., 2020). The same study highlighted that much of the current literature surrounding information and electromobility focuses on market acceptance, largely ignoring the local acceptance or accessibility of individual actors, including marginalized groups.

A report from the European Parliament found that marginalized groups in Europe can be targeted by disinformation campaigns at a higher level and, consequently, may be more vulnerable to falsehoods (Szakács & Bognár, 2021). For example, in 2019, one false study with claims against EVs was released and picked up by German media. It spread disinformation on the environmental impacts of EVs (Schwierz, 2019). While this report was eventually debunked, beliefs can be hard to reverse once initially internalized (Gaillard et al., 2021). Ensuring that accurate information on EVs is accessible to all groups can help achieve transportation equity goals. A positive example of awareness raising in Germany can be found in the Berliner Agentur für Elektromobilität (Berlin Agency for Electromobility). This publicly funded state agency coordinates stakeholder engagement, supports local electromobility projects, and raises awareness (Berliner Agentur für Elektromobilität, 2023). Having established, publicly available, information-raising options sponsored by governments can help counter misinformation.

## CONCLUSIONS AND RECOMMENDATIONS

Considering that BEVs in Germany are mostly bought or owned by certain population segments, making the transition to BEVs more equitable for anyone who depends on a car is crucial. This study provided theoretical background on that subject and examined its status in Germany with the aim to help structure the topic in general and better shape policy recommendations for the German market as part of future work on this topic.

Based on our findings and analysis, we offer three findings and recommendations to policymakers, environmental and social (research) organizations and institutions, professional audiences, the media, the general public in Germany and beyond.

- 1. An equitable transition from ICEVs to BEVs is a multifaceted topic.** An equitable transition to BEVs specifically is often interpreted differently depending on context, which complicates targeted discussions and policy recommendations. In addition, other terms, like equality and justice, are often used interchangeably, further adding to the complexity. An equitable transition also goes beyond vehicle purchase and ownership; it encompasses other factors including EV charging infrastructure and information and awareness raising—key barriers in the transition to BEVs. Moreover, it is also critical to understand, clarify, and quantify how an equitable transition to BEVs relates to marginalized groups.

For targeted research to derive policy recommendations, we must, therefore, first clarify which aspects of and perspectives on equity we are centering at a given time. In our framework, we centered the perspective of marginalized groups as defined by sociodemographic, firmographic, and geographic characteristics either singly or in combination. Our goal was to illuminate how marginalized groups experience the transition to BEVs as viewed through different dimensions of equity.

- 2. The causes of inequities in the transition to BEVs are manifold.** They are complex and interlinked and range from social, economic, environmental, health, and spatial causes to procedural, legal, and data aspects. For example, the economic dimension can be linked with sociodemographic status and, in turn, point to income-based inequities in BEV adoption. Studies and data for Germany show that owning a BEV or the likelihood of purchasing/leasing a BEV is lower in some populations (e.g., women or people with lower income brackets). In addition, data, methods for processing it, and its availability also play important roles in this respect. Sensitive and unbiased analysis and interpretation, are critical to understanding the transition through the lens of equity.

Moreover, understanding the multitude of causes of inequity in the transition from ICEVs to BEVs and differentiating the focus by dimensions allows for more targeted discussions (which, in turn, supports the formulation of specific policy goals and recommendations. To further sharpen the focus, it is also important to elucidate the perspective from which equity is being analyzed (from a micro, individual perspective to a macro, global perspective). For example, from a micro perspective, higher ownership costs could be a more significant barrier to BEV adoption for lower income households. Based on this perspective and understanding, we can derive more focused policy solutions such as additional financial BEV purchase aids for households at certain income thresholds.

**3. The current transition from ICEVs to BEVs in Germany is not equitable.** Much research has been conducted in Germany to achieve an equitable system over all transport modes. Policy recommendations typically include CO<sub>2</sub> pricing, vehicle tax policies, and measures to promote alternative forms of transportation to the car. In the transition from ICEVs to BEVs specifically, studies and registration data also point to inequities in BEV buyers and owners based on certain sociodemographic, firmographic, and geographic characteristics. Private BEV buyers/owners typically are male, of higher income and education, live in larger households, and often live in one or two family homes. By location, new total BEV registrations are highest in urban regions yet there is also a high uptake in suburban and rural regions.

Some research exists on BEV buyers and owners based on studies and registration data of new BEVs partially differentiated by private and business customers. However, a more detailed analysis of buyers of new and used BEVs based on actual registration data and public charging infrastructure availability over a longer time period is necessary. There is a particular research gap concerning used BEV purchase and ownership.

Additional research would help better identify potential causes of inequity in the transition to BEVs in Germany, formulate targeted policy recommendations, and sharpen policy measures targeted at marginalized groups. This will be part of our ongoing research.

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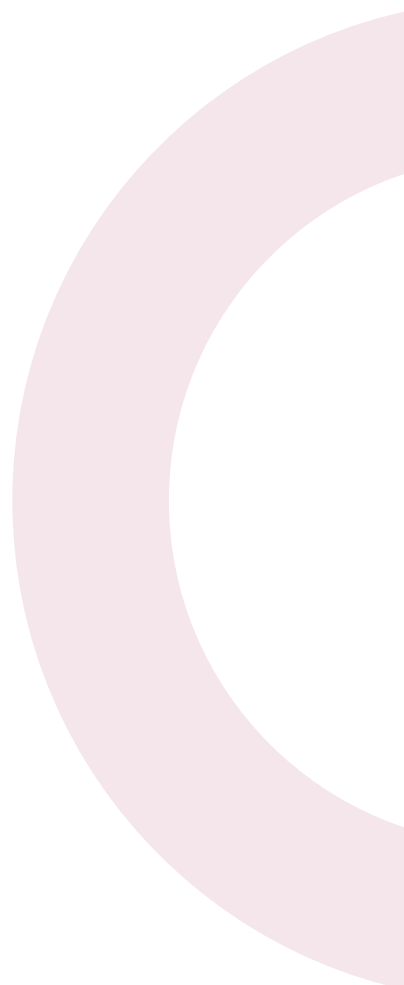
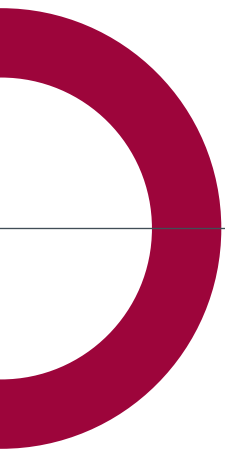
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