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RESEARCH ARTICLE

Bundling up actions to electrify: a fuzzy-set qualitative comparative analysis of e-mobility policies in 16 cities in the United States of America

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Abstract

Policymakers in cities in the United States of America (U.S.) must tailor the right bundle of policies to promote the diffusion of battery electric vehicles (BEVs). We investigate the interplay of (non-)monetary incentives on U.S. state, city and utility-related policy levels. For doing so, we deploy fuzzy-set Qualitative Comparative Analysis (fsQCA) of BEV policies in 16 cities in the U.S. to identify policy configurations that promote BEV uptake. We provide a first-ever study to systematically evaluate BEV policy bundles across different U.S. policy levels. Results indicate two policy configurations: monetary incentives received upon/after BEV purchase in conjunction with (non-)monetary incentives for home charging infrastructure extension in conjunction with recurring monetary incentives by utilities (I); the absence of recurring (non-)monetary incentives at the local level in conjunction with (non-)monetary incentives for home charging infrastructure extension in conjunction with recurring monetary incentives by utilities (II) lead to successful progress in BEV adoption.

Keywords: complex causality; electric vehicles; incentives; multi-level policy analysis; qualitative comparative analysis (QCA)

Introduction

A growing number of cities in the United States of America (U.S.) has been developing action plans and strategies to fully decarbonize urban transportation (Kerry 2021). One central pillar of the strategic approaches towards more sustainable modes of transportation is the widespread adoption of zero-emission vehicles (ZEVs), including plug-in full battery electric vehicles (BEVs). Consequently, U.S. cities have defined targets for BEVs adoption pathways that are accompanied by various policy instruments, which are supposed to propel the diffusion of BEVs (Bui et al. 2021). Generally, policy instruments for BEV transitions can be categorized according to its type and purpose into three broader categories: Economic instruments aim to stimulate demand by affecting primarily the total cost of ownership of BEVs (e.g., purchase subsidy or reduced registration tax); Regulatory instruments aim to support market and user-centric conditions (e.g., implementing CO_2 emissions standards or free access to high-occupancy vehicle lanes); Informational instruments aim to improve awareness of electric vehicle technologies in the society (e.g., vehicle dealer education) (Whitehead et al. 2021). Since the introduction of BEVs, policy instruments at the federal, U.S. state and city-related levels have been introduced. Such instruments vary in type, purpose and scope, as different policy levels bring forth different policy instruments (Slowik and Lutsey 2017, 2019; Coffman et al. 2017). Research in the past indicates that a comprehensive bundle of BEV policy instruments related to U.S. states, cities and utilities are most likely to promote the diffusion of BEVs in the urban (Bui et al. 2021; Slowik and Lutsey 2017). Those results resonate with the broader discussion about policy mixes, which are combinations of multiple policy instruments, to achieve policy objectives (Rogge and Reichardt 2016). While the positive impact of economic instruments in the shape of rebates received upon purchase of BEVs could be widely confirmed (Clinton and Steinberg 2019; Jenn et al. 2018), the interplay of different BEV policy instruments across U.S. state, city und utility-related policy levels and its resulting effect on BEV uptake remains unclear (Hardman 2019; Wee et al. 2018). Such a research perspective could offer important insights on the composition of BEV policy bundles and its impact on BEVs diffusion at the local level. For the European context, Held and Gerrits (2019, 2025) show that a bundle of BEV policies featuring both push and pull policy instruments and that cover national and local, context-specific levels is more likely to promote the adoption of BEVs.

In this article, we will address the limitations mentioned by investigating combinations of policy instruments at U.S. state, city and utility-related policy levels that contribute successfully to the adoption of BEVs in selected U.S. cities. In contrast to existing research on BEV policies in the U.S. context, our research model focuses on the interplay of various economic and regulatory policy instruments that are implemented at different policy levels. This may contribute to a timely and context-sensitive evaluation of policy instruments that are promoting BEV transitions in U.S. cities. For doing so, we apply Qualitative Comparative Analysis (QCA), as it was done earlier in this journal (see: van Druenen 2022; Sager and Thomann 2017). As a case-based research method, QCA is utilized to identify configurations of BEV policy instruments that lead to urban BEV uptake.

Our research is guided by the following research question: *Which configurations of different policy instruments at various policy levels promote the diffusion of BEVs in selected cities in the U.S.?*

The article is structured as follows: We firstly will present a literature review by pointing out shortcomings of existing research. Secondly, our theoretical perspective and the selection of conditions is explained. Thirdly, methodological implications are outlined. Fourthly, a description of how the data was coded and analyzed is followed by the analysis. Finally, we conclude the article with both a summary and a discussion of the results.

Literature review

We conducted a thorough literature review to reveal the limited explanatory power of existing studies about synergies between U.S. state, city and utility-driven policies towards BEV diffusion in U.S. cities. Essentially, we found that only a few studies deploy case-related research approaches of U.S. cities including multiple policy levels and various policy instruments: Ajanovic and Haas (2016) investigate BEV policy instruments in three major U.S. cities among others. Their findings clearly emphasize the interplay of monetary and non-monetary policy instruments across U.S. state and city policy levels for promoting the diffusion of BEVs.

Adepetu et al. (2016) deploy an agent-based ecosystem model based on data covering U.S. state and city-based policies of California and San Francisco. The approach is focusing on BEV ownership costs but lacks a spatial variation and includes only a limited number of BEV policy instruments. By investigating 36 major U.S. cities, Clark-Sutton et al. (2016) rank the cities according to presence of U.S. state, city and utility-related policy instruments. The authors emphasize city and utility-related incentives for BEV diffusion. Breetz and Salon (2018) investigate the impact of policy instruments on total cost of ownership (TCO) of selected BEV models in different U.S. cities. Results underscore the heterogeneity in BEV policy instruments, ownership cost and its impact on BEV diffusion across major U.S. cities (see also: Woody et al. (2024)). Beyond that, there is a small number of studies covering monetary and non-monetary policy instruments at the U.S. state and city policy levels. Most of the studies found HOV lane access to have a positive impact on BEV diffusion at the state level (Lutsey et al. 2016; Sheldon and DeShazo 2017; Jenn et al. 2018; Narassimhan and Johnson 2018; Jenn et al. 2020). Beyond HOV lane access, some studies focused on the effect of free or discounted parking for BEV users (Lutsey et al. 2016; Wolbertus et al. 2018; Wee et al. 2018). The effect on BEV diffusion of time of use (TOU) rates offered to BEV users by utilities was investigated by Wee et al. (2018) without confirming a positive impact on BEV diffusion. The authors included TOU rates as an aggregated variable to make it correspond with a U.S. state level analysis.

Consequently, our review of existing studies on BEV policies confirms that given research lacks results on the impact of comprehensive policy mixes on BEV transitions in U.S. cities. This is because of two main shortcomings: *Firstly*, most studies investigate the impact of policy instruments, which are implemented at the U.S. state or aggregated policy level. In this regard, studies primarily consider economic policy instruments, such as one-time subsidies received upon purchase, income tax credits or purchase tax exemptions (Austmann 2021; Clinton and Steinberg 2019; Hardman 2017). As indicated by a later strand of literature, recurring monetary and non-monetary policy instruments, such as parking privileges, HOV lane access, road charge exemptions, charging infrastructure development or energy cost savings, that are implemented at the local level, are supposed to contribute to the uptake of BEVs likewise (Hardman 2019; Slowik and Lutsey

2017, 2019; Coffman et al. 2017). Those policy instruments address behavioral aspects of BEV usage in specific urban contexts (Aasness and Odeck 2023). Existing research on BEV policy mixes in the European and Chinese context underscore this aspect (Held and Gerrits 2025; Zhao et al. 2024). *Secondly*, existing research falls short of covering variation in local conditions of BEV usage. As transport systems, socio-political characteristics, consumer preferences and travel behavior among other things vary widely across cities, the success of policy mixes depends on its conjunction with contextualized conditions (Hardman 2019). Spatial variation matters, as BEV policy instruments that worked in one local context, naturally won´t support BEV diffusion in a different one (Bui et al. 2021; Egnér and Trosvik 2018).

Our study is addressing the limitations mentioned by introducing several unprecedented aspects. *Firstly,* our research on policy mixes covers recurring monetary and non-monetary policy instruments that are related to the local policy level. For doing so, we integrate policy instruments by U.S. cities and city-related utilities, which address behavioral aspects of BEV transitions and aim to incentivize BEV usage in a particular urban context. *Secondly*, we created a novel data set, which covers U.S. state, city and utility-related policy levels. The data set covers BEV policy incentives at the U.S. state and city level, BEV registration numbers as well as place-specific ownership costs for a BEV and a gasoline-driven vehicle. *Thirdly*, different cities in the U.S. have implemented similar BEV policy mixes by achieving diverging results (Bui et al. 2021, 2020). Accordingly, findings underscore the multi-level nature and contextuality of our data sample. Evaluating the outcome of the policies implemented thus requires a research approach that is sensitive to within- and cross-case variation. Our study applies Qualitative Comparative Analysis (QCA) to compare combinations of BEV policies at different levels that may contribute to BEV adoption in U.S. cities. As a case-based research method, QCA is sensitive to interaction of policy instruments in conjunction with local contexts (Ragin 2000).

In the next section, our research approach and method will be introduced.

Method

Fuzzy-set qualitative comparative analysis

As a case-based research method, QCA treats cases as being composed by configurations of conditions that co-occur with an outcome (Gerrits and Verweij 2018; Ragin 2014; Rihoux and Ragin 2009). For our research aim, cities in the U.S. are considered as cases. Different BEV policy incentives implemented at different U.S. state, city and utility-related policy levels are conditions, which co-occur with an outcome. QCA captures similarities across cases through systematic comparison while being sensitive to idiosyncrasies of single cases (Ragin 2000).

As mentioned earlier, similar combinations of state, city and utility-related policies did not result in similar BEV adoption rates in different U.S. cities (Bui et al. 2021; Slowik and Lutsey 2019). Accordingly, QCA treats social reality in reference to three constitutive assumptions: *Firstly*, as cases are configurations of conditions, the phenomenon of interest is likely to be produced through a conjunction of the conditions considered. Here, QCA diverges from approaches that aim to identify the effect of single variables on the outcome (Mahoney 2010). *Secondly*, the assumption of similar configurations of conditions leading to different results (multifinality), or different configurations of conditions produce similar results (equifinality) enables to reveal different causal pathways being linked to an outcome (Rihoux and Ragin 2009). *Thirdly*, causal pathways being identified to produce an outcome are causally asymmetric. Thus, a causal pathway for the outcome cannot simply be mirrored to make a statement about the non-outcome (Mello 2021; Schneider and Wagemann 2012). The three aspects mentioned form the methodological underpinnings of QCA to investigate *complex causality* (Byrne et al. 2010). Our configurational understanding of policy incentives emphasizes that interacting policy conditions, combined with contextualized dynamics, lead to unidirectional outcomes (cf.: Mello 2021; Gerrits and Verweij 2018, 2013; Gerrits 2012; Byrne 2005). As past research reveals, governing sustainability transitions in urban transportation systems depends on emergent and co-evolving processes that are driven by various actors at multiple levels (i.e., federal and state-related departments for transport, city authorities, energy utility companies, car manufacturers, BEV users etc.) (Austmann 2021; Mattioli et al. 2020). Thus, we aim to improve understanding about complex causalities of policies implemented on multiple policy levels.

QCA has different variants. For our research, we deploy fuzzy-set QCA (fsQCA). The fuzzy-set variant enables to capture differences in the degree of set membership of the cases considered (Schneider and Wagemann 2012). Originally, QCA worked with crisp-sets that allowed only for strict dichotomization, where 1 indicated full presence and 0 full absence of a condition. Held and Gerrits (2019) applied the crisp-set variant of QCA to the evaluation of BEV policy mixes across national and local policy levels in the European context. In contrast, fsQCA enables researchers to capture graded set membership as any possible score between 0 and 1. Consequently, cases are allowed to have partial set membership. The possibility to establish difference-in-degree between cases adds precision to the transfer of empirical information to set membership. FsQCA thus combines qualitative and quantitative dimensions (Mello 2021; Gerrits and Verweij 2018; Schneider and Wagemann 2012).[1] Using empirical information to assign set membership scores to the cases considered is called calibration (Schneider and Wagemann 2012). The calibration procedure is an essential aspect of any QCA and will be described in detail in section "Calibration of data into fuzzy-sets".

Research model

The selection and definition of conditions is a central task when utilizing fsQCA (Mello 2021; Gerrits and Verweij 2018). By doing so, we conceptually follow Held and Gerrits (2019). Accordingly, our research model consists of the outcome condition that is covering the BEV diffusion rate linked to BEV targets at the local

[1]For determining whether a case is fully in a given set (fuzzy set score 1), if it is fully out (fuzzy set score 0) or whether it is neither fully in nor fully out (fuzzy set score 0.5), researchers must define three empirical anchors. The latter is the point of crossover. It indicates that based on the empirical information, it is not possible to make a statement if a case is fully in or outside a set. All other degrees of membership as well as non-membership need to be quantified by using fuzzy values (Mello 2021; Ragin 2000).

level (abbr.: Y) and the main conditions, which are: monetary one-time and recurring incentives received upon/after vehicle purchase (abbr.: A), recurring monetary and non-monetary incentives at the local level (abbr.: B), local monetary and non-monetary incentives for charging infrastructure extension (abbr.: C) and recurring monetary incentives by local utilities (abbr.: D).

Outcome condition Y covers past or future policy targets in each case. Among the U.S. cities selected, it allows for an assessment whether BEV policy targets could be met or are likely to be met in the near future. We calculated BEV diffusion rates linked to BEV targets for each case of our sample. For doing so, historical data on BEV registration numbers at the local level between 2016 and 2022 are used and put in relation to the associated policy targets to make a statement about the progress of BEV diffusion in each case so far.[2] We decided to use registration figures instead of sales data, as eligibility for BEV incentives is based on the location of vehicle registration (Wee et al. 2018).

Following our literature review (see: section "Literature review"), we include monetary as well as non-monetary policy instruments across U.S. state, city and utility policy levels (Bui et al. 2021; Wee et al. 2018). Based on recent research results, we selected those incentives that are expected to be most relevant for BEV diffusion. As a result, our research model[3] is composed of a total of four conditions:

Firstly, we include all monetary incentives that are present at the level of U.S. states and target high up-front costs of BEVs. As mentioned earlier, the positive effect of monetary incentives on BEV diffusion has been previously established (Clinton and Steinberg 2019; Jenn et al. 2018). However, studies estimating the effect of monetary incentives are utilizing aggregated data and thus neglect effects on the cost effectiveness of BEV at the city level. Local factors including taxes, fees, electricity and gasoline costs as well as costs for insurance affect ownership costs of BEV and its conventional counterpart (Woody et al. 2024; Hardman 2019). Following Woody et al. (2024), we offer an alternative approach for assessing the effect of monetary incentives by comparing the total cost of ownership (TCO) for BEV and its conventional counterparts across U.S. cities (see also: Held and Gerrits (2019)). By calculating TCO for a representative BEV and internal combustion engine vehicle (ICEV) pair for each U.S. city investigated, the effect of all monetary incentives on TCO for a BEV relative to the TCO of a conventional car can be estimated. Thus, a comparison of TCO of a representative BEV-ICEV pair for assessing the effect of U.S. state-related monetary incentives constitutes condition A.

Secondly, recurring monetary and non-monetary incentives at the local level are supposed to influence behavioral patterns as well as transport conditions and thus may affect the adoption of BEVs (Hardman 2019). Such incentives aim to target the flexibility and convenience of BEV usage and thus provide recurring benefits. Consequently, condition B covers *free parking (not while charging), parking space privileges, recharging for free or a reduced rate at public charging stations, free access to HOV lanes or toll roads.*

[2]For an overview, please see "TABLE B" in the appendix of this article (section 10).

[3]Due to methodological reasons, QCA allows only for a limited set of conditions to be considered in each comparison. For further discussion please see: Mello, 2021, p. 29 ff.

Thirdly, the provision of a well-developed and user-oriented charging infrastructure is essential for supporting BEV adoption in U.S. cities (Slowik and Lutsey 2019; Hardman 2019). Next to the provision of publicly accessible charging infrastructure by U.S. states, city authorities and utilities, there are monetary incentives for the installation of charging points on private property. Mostly, such monetary incentives are implemented by U.S. states and utilities at the local level and vary in scope and availability (Bui et al. 2021, 2020; Jenn et al. 2018). A complementary non-monetary incentive is the introduction of streamlined electric vehicle service equipment (EVSE) permitting processes. A streamlined process generally enables BEV users a faster procedure for receiving approvals for home charger installations (LaMonaca and Ryan 2022). Depending on the city authority in charge, a streamlined permitting procedure may take a few days or just one day (Slowik and Lutsey 2019, 2017). As a result, condition C covers *monetary as well as non-monetary incentives for the provision and installation of private charging facilities on private property.*

Fourthly, utilities[4] implemented monetary incentives in the shape of time-of-use (TOU) rates and special rates for BEV users. TOU rates offer electricity to varying prices over predetermined periods of the day. By applying a TOU rate scheme, electricity costs are higher during the day when electricity demand is peaking and lower during the off-peak hours, from midnight to 5 a.m. for instance, when demand is lower. TOU rate schemes can also vary by weekends or seasons (Hall and Lutsey 2017). Special rates for electricity provision are exclusively designed for BEV users (Bui et al. 2021). TOU rate schemes and special rates offered by utilities are supposed to create incentives to adopt a BEV because of the lower electricity costs during off-peak hours. Studies in the past aimed for investigating the effect of TOU rate schemes and special rates on BEV diffusion by creating ambiguous results (Wee et al. 2018; Clark-Sutton et al. 2016). Consequently, TOU rate and special rate schemes as utility-related monetary incentives are relevant for further research and thus mark a valid choice for being part of our research model. Condition D thus covers *TOU rate and special rate schemes for BEV users provided by utilities.*

Table 1 provides an overview of the conditions included in our model.

Please note that within the time span of data collection, public charging infrastructure was promoted by U.S. states, city authorities and utilities for the U.S. cities covered. Data covering condition B, recurring monetary and non-monetary incentives at the local level, were collected for the identical timeframe. As a result, our research approach meets requirements of time congruency. We only considered policies that had been implemented not later than the beginning of 2017 and had remained active for at least three consecutive years. Consequently, contradictory causal relations (presence of B without condition C) can be ruled out.

[4]Energy utilities are mainly privately owned profit-oriented enterprises. Examples that are related to our case sample are Southern California Edison, Portland General Electric or Xcel Energy. There are also non-profit utilities that are run by a city, such as Austin Energy. It is a municipally owned utility operated by the City of Austin (Texas). We would like to point out that energy utilities are not fully within the scope of traditional public policy. Though, energy provision is a basic service and essential for any societal activity including electric mobility. Thus, it is generally relevant for governmental bodies at any policy level and specifically relevant for urban strategies towards BEV transitions.

Table 1. Overview of the conditions included in the model

Condition	Abbreviation	Policies included
Monetary one-time and recurring incentives received upon/after vehicle purchase (U.S. state level)	A	• direct subsidy/rebate for purchase of a new BEV • benefits through taxation (i.e., value added tax, taxes on acquisition, license tax reduction, annual taxes on usage) • annual/biennial emissions inspections exemption
Recurring monetary and non-monetary incentives (local level)	B	• free parking, parking space privileges, parking for a reduced rate or free on-street parking (not while charging) • recharging for free or reduced rate at public charging stations • free access to HOV lanes or toll roads
Monetary and non-monetary incentives for charging infrastructure extension (local level)	C	• construction of public charging infrastructure implemented by U.S. states, city authorities and/or utilities • rebates for charging equipment installed on private property, associated installation costs • tax rebate for purchase and installation cost
Recurring monetary incentives by utilities (local level)	D	• TOU rate • special rate schemes for BEV users
Outcome	Y	• BEV diffusion rate linked to BEV targets at the local level as well as BEV polices at the U.S. state and local level

Our research model deploys a fsQCA (Ragin 2000). Methodologically, fsQCA allows for a fine-grained differentiation of set relations that together form configurations of the conditions covered by our research model. Methodological details of our approach will be outlined in the next section.

Data collection and calibration of data

Case sample and empirical data

The composition of our case sample was guided by good-practice standards of QCA (Ragin 2014; Schneider and Wagemann 2012). For selecting the cases, we are focusing on cities in different states in the U.S. As a result, a minimum degree of homogeneity is guaranteed. We follow Ebbinghaus (2005) by utilizing a deliberate case selection due to political contingency. As the implementation of policies to promote BEV depends on political willingness, practical feasibility and economic factors, the number and scope of BEV policies across U.S. states and thus cities are varied. A fact that can also be observed in diverging BEV diffusion rate across U.S. states and cities (Bui et al. 2020; Jenn et al. 2018; Lutsey et al. 2016). Potential cases that feature no or very little policy actions towards BEV diffusion were left out, as the effect of policy configurations to be observed is expected to be low or non-existing. Consequently, the case selection strategy was guided by the most similar/different outcome (MSDO) selection strategy (Berg-Schlosser and Meur 2009). This strategy is based on the method of difference. As similar cases are compared, differences in the outcome condition can be explained by investigating differences among the conditions. As such, the strategy is a purposeful selection of cases (Mello 2021). By applying the MSDO technique, our case selection strategy allows for a formalized procedure to select cases in accordance with QCA´s performance. We applied the method of difference by investigating policy targets to allow for case comparability. Policy targets are pivotal for making a qualitative statement about the progress of the BEV diffusion rate. Likewise, BEV policy targets are case-specific, as some targets are more ambitious than others (Bui et al. 2021). Thus, the aim of our approach was to select cases that have defined similarly ambitious BEV policy targets. The scope of comparability could essentially be defined by grouping cases with targets for BEV diffusion that do not differ extremely. For doing so, we calculated the relative percentage share of the total vehicle fleet of passenger cars a BEV policy target is linked to. Calculations were done for BEV policy targets adhered to different time periods (e.g., 2020, 2025) individually. Closest periods defined that describe the time limit a BEV target is attached to were selected. For an overview of the percentage shares, please see Table 2. We formed four groups for BEV policy targets linked to a 2020, 2025, 2030 and 2040 period. In a next step, minimum and maximum values as well as the mean value for each of the BEV policy target group were calculated. Juxtaposing BEV policy targets of potential cases in that way allowed us to make a statement about how meaningful the case sample composition is. Ultimately, most BEV policy targets are linked to a 2030 period. Potential cases have BEV policy targets defined with a mean value of 31.9% share of the total vehicle fleet with a minimum value of 10% and a maximum value of 100%. The 2025 period is the second most prominent period. The group has a mean value of 12.8% share of the total vehicle fleet with a minimum value of 6% and a maximum value of 25%. The 2020 period is covered by two cases. Both have a relative share of 2% of the total vehicle fleet. The 2040 period is linked to only one case and entails a 27% share of the total vehicle fleet. In the end, our approach allowed us to utilize the MSDO selection strategy by selecting cases that are comparable. As cities in the U.S. have heterogenous BEV policy targets defined, cases with different targets can be grouped that do not diverge extremely. In that sense, our approach complies with the heterogeneity and spatial variation of the data considered. QCA as a case-based research approach is sensitive to the heterogeneity of cases as well as cross-case variation (Pagliarin and Gerrits 2020; Schneider and Wagemann 2012; Harvey 2010). Another important factor for the selection procedure was data availability. As outlined by earlier studies, data covering the local level were not available or reliable in many cases (Jenn et al. 2018; Wee et al. 2018). Finally, the case sample is composed of a total of 16 U.S. cities.

Data was gathered by referring to multiple sources (Held et al. 2026). Initial information about BEV policies implemented by U.S. states, city authorities and utilities were provided by publications of The International Council on Clean Transportation (ICCT) covering the uptake of BEV in U.S. cities (Bui et al. 2021, 2020; Slowik and Lutsey 2019; Lutsey et al. 2016; Slowik and Lutsey 2017). Further data could be accessed by using the alternative fuels data center (AFDC) provided by the U.S. Department of Energy’s Vehicle Technologies Office (2024). The AFDC is a comprehensive data base for federal and U.S. state laws and incentives for BEV. It

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Table 2. Overview of case sample, BEV policy targets and targets as percentage share of total vehicle fleet[5]

CASE-ID	TARGETS BY 2020	TARGETS BEYOND 2020	TARGET AS PERCENTAGE SHARE OF TOTAL VEHICLE FLEET	PERCENTAGE OF BEV REGISTRATION PROGRESS	SOURCES
Austin (Texas)	*n.a.*	ca. 74 000 BEVs (6% of all vehicles) on the road by 2025; ca. 460 000 BEVs (37% of all vehicles) on the road by 2030	2025 target: 6% of vehicle fleet 2030 target: 37% of vehicle fleet	40.77% (by 2025 period)	City of Austin (2023)
Baltimore (Maryland)	2% (ca. 4000 BEVs) of Baltimore vehicle fleet to be BEV by 2020 [6]	*n.a.*	2020 target: 2% of vehicle fleet	21.34% (by 2020 period)	Maryland Public Service Commission (2019)
Boston	(Massachusetts)	*n.a.*	8% of vehicles registered in Boston to be fully electric by 2025 (ca. 24 000 BEVs)	2025 target: 8% of vehicle fleet	17.52% (by 2025 period)
City of Boston (2020)					
Columbus (Ohio)	*n.a.*	passenger vehicles: - 15% (ca. 213 000 BEVs) of all registrations by 2030 are BEVs - 100% by 2050	2030 target: 15% of vehicle fleet	1.81% (by 2030 period)	City of Columbus' Climate Action Plan (2023)
Denver (Colorado)	*n.a.*	By 2025, 15% of Denver vehicle registrations are electric (ca. 75,000 BEVs); by 2030 30% (ca. 150 000 BEVs) and by 2050, 100%.	2025 target: 15% of vehicle fleet	15.85% (by 2025 period)	City and County of Denver (2020)
	n.a.		2040 target: 27% of vehicle fleet		

(*Continued*)

[5]For the provision of data sources please contact the corresponding author.

[6]Please note that the target of ca. 4000 BEV is based on the City of Baltimore's Clime Action Plan (2012) and the objective to reduce 20 450 MT CO_2 of GHG emissions in the urban transport sector until 2020. Data on total vehicle registrations of the Maryland Vehicle Administration (https://opendata.maryland.gov/Transportation/MVA-VEHICLE-REGISTRATION-by-COUNTY-from-2010-to-20/kqkd-4fx8) was used to calculate the approximate number of BEVs in the fleet by 2020.

Table 2. (*Continued*)

CASE-ID	TARGETS BY 2020	TARGETS BEYOND 2020	TARGET AS PERCENTAGE SHARE OF TOTAL VEHICLE FLEET	PERCENTAGE OF BEV REGISTRATION PROGRESS	SOURCES
Kansas City (Missouri)		Transitioning 27% of light-duty vehicles and 29% of heavy-duty vehicles to BEVs by 2040.		*(little to no progress)*	Kansas City, Missouri (2022)
Los Angeles (California)	*n.a.*	25% of total registrations are ZEVs (incl. BEVs) by 2025, 80% by 2035, and 100% by 2050.	2025 target: 25% of vehicle fleet 2035 target: 80% of vehicle fleet 2050 target: 100% of vehicle fleet	16.04% (by 2025 period)	Los Angeles Mayor's Office of Sustainability (2019)
Nashville (Tennessee)	*n.a.*	Increasing BEV adoption rate from 3% (in 2019) to 10% (ca. 3500 BEVs) by 2025, 20% (ca. 7000 BEVs) by 2035 and up to 40% by 2050. All remaining vehicles should be electric in 2050.	2025 target: 10% of vehicle fleet 2035 target: 20% of vehicle fleet 2050 target: 40% of vehicle fleet	8.13% (by 2025 period)	City of Nashville (Mayor Cooper's Sustainability Advisory Committee) 2020
New York City (New York)	*n.a.*	400 000 BEVs registered until 2030	2030 target: 20% of vehicle fleet	6.73% (by 2030 period)	NYC Mayor´s Office of Climate & Environmental Justice (2023)
Phoenix (Arizona)	*n.a.*	By 2030, 280 000 BEVs registered in Phoenix	2030 target: ca. 35% of vehicle fleet	2.52% (by 2030 period)	City of Phoenix (2022)
Pittsburgh	(Pennsylvania)	*n.a.*	100% fossil fuel free city fleet by 2030	2030 target: 100% of vehicle fleet	0.50% (by 2030 period)
Pennsylvania Department of	Environmental Protection (2019)				
Portland (Oregon)	Replace at least 10 000 vehicles and	ca. 50 000 BEVs in the metro area of Portland by 2030	2020 target: ca. 2% of vehicle fleet 2030 target: ca. 10% of vehicle fleet	94.55% (by 2020	City of Portland (2016)

(*Continued*)

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Table 2. (*Continued*)

CASE-ID	TARGETS BY 2020	TARGETS BEYOND 2020	TARGET AS PERCENTAGE SHARE OF TOTAL VEHICLE FLEET	PERCENTAGE OF BEV REGISTRATION PROGRESS	SOURCES
	30% in city fleet by 2020			period); 54.53% (by 2030 period)	
Portland (Maine)	*n.a.*	30% of new light duty vehicle sales are electric vehicles by 2030; 60% by 2040; 100% by 2050	2030 target: 30% of new light duty vehicle sales	0.15% (by 2030 period)	Portland and South Portland (2019)
Providence (Rhode Island)	*n.a.*	By 2035, 43% of vehicle miles traveled per household (VMTs) in Providence are electric and by 2050, 80% of VMTs are electric.	no information available on percentage share of total vehicle fleet a transition goal is linked to. But BEV registration numbers tell that since 2020 little to no progress has happened.	*(little to no progress)*	City of Providence (2014)
Raleigh (North Carolina)	*n.a.*	50 000 BEVs are expected on the road in Wake County by 2030	2030 target: ca. 10% of vehicle fleet	20.35% (by 2030 period)	City of Raleigh (2019)
Seattle (Washington)	*n.a.*	30% total registrations by 2030	2030 target: 30% of vehicle fleet	1.70% (by 2030 period)	Seattle Office of Sustainability & Environment (2017)

also provides an overview of present and historic incentives implemented by U.S. states, utilities and city authorities. In many cases, addition information were requested by contacting city authorities and utilities directly. Data concerning BEV registrations at the U.S. state and local level for the time span considered could be gathered by contacting departments of transportation, respectively departments of motor vehicles, as well as departments of revenues multiple times. For doing so, the "Freedom of information Act" was used in most cases (for instance, see: Maryland Office of the Attorney General 2024). Information about past and future BEV targets at the U.S. state and local level could be lifted from official policy papers and electric mobility action plans. In some cases, correspondence with city-related agencies for transportation was necessary to obtain information about the scope and time span of BEV targets. Data concerning monetary one-time and recurring incentives received upon and after BEV purchase were mainly lifted from the AFDC and U.S. state-related departments and agencies. Specific data for calculating TCO for the BEV-ICEV pair, such as local gasoline and electricity prices could be obtained from the U.S. Energy Information Administration (EIA) (2024) and the U.S. Bureau of Labor Statistics (2024). Data for recurring monetary and non-monetary incentives at the local level were gathered by referring to the AFDC, publications by the ICCT and primary sources in the shape of official policy papers and action plans provided by city authorities. Also, city-related departments and agencies as well as utilities were contacted directly to obtain information.[7] Table 2 provides an overview of the cases selected including BEV targets at the local level.

Calibration of data into fuzzy-sets

Calibration is the conversion of quantitative and qualitative data from a case into fuzzy-sets of conditions. For doing so, set-membership scores are used. Two rounds of calibration were necessary for the data collected. That was because the first calibration round led to no membership scores across the five conditions for a considerable number of cases.

For all the conditions covered by our research model, fuzzy-set scales were defined. Outcome condition Y covers BEV diffusion rates linked to BEV targets in the 16 U.S. cities covered. For assigning membership scores, local BEV targets and the historical development of BEV registration numbers at the local level were used to calculate the progress in each case for either the past period of 2020 or the year 2022 indicating an interim assessment of the 2025, 2030 and 2040 policy target periods. For doing so, the 2022 BEV registration data was divided by the nearest BEV target at the local level (e.g., 2025, 2030 or 2040). In two cases, 2020 BEV registration data could be used and were divided by 2020 targets. Consequently, we used a 4-scale fuzzy-set to make a statement about the progress in BEV diffusion. For cases with BEV targets by a 2020 period, a membership score of 1 is assigned when more than 90%, 0.67 when more than 75%, 0.33 when more than 50%, and 0 when more than 20% of the original target could be reached. For cases with BEV targets by a 2025, 2030 or 2040 period, a different scheme for assigning membership

[7]For an overview of the sources used, please see "FILE 1" in the replication data provided for this article.

scores was applied. The outcome condition for cases with BEV targets by 2025 are calibrated as follows: a membership score of 1.0 is assigned when more than 50%, 0.67 when more than 15%, 0.33 when more than 10%, and 0.0 when less than 10% of the original target could be reached so far. For cases with BEV targets by a 2030 period and beyond, the calibration scheme is as follows: cases are assigned 1.0 when more than 15%, 0.67 when more than 5%, 0.33 when more than 2.5%, and 0.0 when less than 2.5% of the original target could be reached so far. Please see Table 2 for an overview of the BEV diffusion progress for each case.

The calibration of condition A depends on the calculation and comparison of the TCO of the comparable BEV-ICEV pair. As outlined earlier, we consider monetary one-time and recurring incentives received upon and after purchase of a BEV. Also, local parameters, such as taxes, fees, electricity and gasoline costs as well as costs for insurance and depreciation, are regarded. Only monetary one-time and recurring incentives were considered that were introduced not later than the beginning of 2017 and had remained active for at least three consecutive years. We paired the BEV Tesla Model 3 with the gasoline-driven Toyota Camry LE. The Toyota Camry LE is the version with the lowest CO_2 emissions and basic feature options. The Tesla Model 3 with the most basic features regarding performance and price was selected. Data on car prices and technical specifications necessary for TCO calculations refer to the 2017 models. TCO summarize all present and future costs and revenues of an investment. As mentioned earlier, it thus allows to make a more realistic statement of the economic value of an investment generated in contrast to the simplistic consideration of the purchase price (Woody et al. 2024; Breetz and Salon 2018). The TCO of each vehicle for the three EV-ICEV pairs selected were calculated using the following formula:

$$TCO = Pc + \ Tr \ - TCR \ + \sum\nolimits_{i=0}^{i} (Fc + Tc + I + MR)(1+d)^i \ - \ (RV)(1+d)^i$$

where Pc is a car´s purchase price, Tr is the sum of other taxes on acquisition, TCR are subsidies received upon purchase, Fc is the present value of gasoline or electricity costs, Tc is the present value of annual circulation taxes, I is annual insurance costs, MR is annual maintenance and repair costs, R is the resale value of the vehicle, d is the discount rate and i is the ownership period. Average yearly gasoline and electricity retail prices (including taxes) could be used for cases Baltimore (Maryland), Boston (Massachusetts), Los Angeles (California), New York City (New York), Phoenix (Arizona) and Seattle (Washington). For all other cases, average yearly retail prices at the U.S. state level were utilized. Data about annual insurance, maintenance and repair costs as well as resale values of the vehicle pair considered could be accessed by the "cost to own" calculation tool. It is provided by the automotive information service platform Edmunds (2023). The tool entails a U.S. wide data basis and is sensitive to place-specific data, which can be deployed by using zip-codes of U.S. cities. Ownership is estimated to be five years with 15 000 miles driven per year. For the discount rate d, historical data between 2017 and 2021 was lifted from economic data provided by the Federal Reserve Bank of St. Louis (2024). For each year, the annual average discount rate was used.[8] For assessing the effect of monetary one-time and recurring

[8]For a detailed overview of the parameters used and results calculated, please see "FILE 1" in the replication data provided for this article.

incentives received upon and after vehicle purchase on TCO of the BEV-ICEV pair in a representative way, the TCO difference was calculated as the percentage share of the TCO for the conventional car model for each case considered. The results are interpreted to demonstrate the effect of monetary one-time and recurring incentives on the TCO for the BEV. According to our calculations, TCO for the BEV are on average 40.95% higher than the TCO for its ICEV counterpart among the cases considered.[9]

Consecutively, we performed a cluster analysis[10] using the Tosmana software for grouping cases with similar results (Cronqvist 2019). The cluster analysis resulted in three thresholds: 15.74%, 44.00% and 72.26% with a median of 38.19%. As a result, cases with a weaker effect of monetary one-time and recurring incentives on the TCO of BEVs are assigned to the groups defined by the thresholds with the highest values. The following calibration was utilized: cases with a result higher than 72.25% are assigned a set membership score of 0.0; cases with a result higher than 43.99% are assigned a set membership score of 0.33; cases with a result higher than 15.73% are assigned a set membership score of 0.67; cases with a result lower than 15.74% are assigned 1.0

Thirdly, calibration of condition B depends on the number of recurring (non-) monetary incentives being implemented at the local level. The calibration scheme is as follows: cases with not a single recurring incentive are assigned a set membership score of 0.0; cases with one recurring incentive are assigned a set membership score of 0.33; cases with two recurring incentives are assigned a set membership score of 0.67; cases with three or more recurring incentives are assigned a set membership score of 1.00.

Fourthly, condition C was calibrated in accordance with local action done to promote private charging facilities on private property in a BEV user-centric way: cases with not a single incentive implemented are assigned a set membership score of 0.0; cases that only offer streamlined EVSE permitting processes receive a set membership score of 0.33; cases with only financial incentives by U.S. state or/and local utility implemented are assigned a set membership score of 0.67; cases that offer both streamlined EVSE permitting and financial incentives by U.S. state or/and local utility receive a set membership score of 1.0.

Fifthly, calibration of condition D depends on the TOU rate and special rate schemes for BEV users provided by utilities. The calibration scheme is as follows: cases with no TOU or special rate available are assigned a set membership score of 0.0; cases with a regular TOU rate scheme receive a set membership score of 0.33; cases with a flat TOU rate scheme for BEV users are assigned a set membership score of 0.67; cases with flexible TOU rate schemes that give BEV users more flexibility in selecting a proper scheme receive a set membership score of 1.0.

Table 3 provides an overview of the calibrated cases and the raw data matrix.

[9]For a detailed overview of the results calculated, please see "TABLE A" in the appendix (section 10).
[10]A cluster analysis is deployed to classify the values into different categories.

Table 3. Raw data matrix

Case-ID	CONDITION A	CONDITION B	CONDITION C	CONDITION D	OUTCOME
Austin (Texas)	0.67	0.67	0.67	0.67	1.00
Baltimore (Maryland)	0.67	0.00	0.00	0.67	0.33
Boston (Massachusetts)	0.33	0.00	0.67	0.67	0.67
Columbus (Ohio)	1.00	0.00	0.00	0.00	0.00
Denver (Colorado)	0.33	0.33	0.67	0.67	0.67
Kansas City (Missouri)	0.33	0.00	0.00	0.33	0.00
Los Angeles (California)	0.67	0.67	1.00	1.00	0.67
Nashville (Tennessee)	0.00	0.67	0.00	0.00	0.00
New York City (New York)	0.67	0.67	0.67	0.67	0.67
Phoenix (Arizona)	0.67	0.00	0.00	0.67	0.33
Pittsburgh (Pennsylvania)	0.67	0.00	0.00	0.00	0.00
Portland (Oregon)	0.67	0.33	1.00	0.67	1.00
Portland (Maine)	0.67	0.00	0.00	0.00	0.00
Providence (Rhode Island)	0.33	0.00	0.67	0.00	0.00
Raleigh (North Carolina)	0.33	0.67	1.00	0.33	1.00
Seattle (Washington)	0.67	0.00	1.00	0.00	0.00

Analysis and interpretation of results

Data analysis

In the following section, the analytical procedure of the fsQCA conducted will be elaborated. For doing so, individual conditions and combinations of conditions will be tested for their necessity and/or sufficiency in contributing to progress in BEV diffusion in U.S. cities and thus a positive outcome.[11] For performing a fsQCA, we followed standards of good practice (Gerrits and Verweij 2018; Schneider and Wagemann 2010; Ragin 2000). Parameters for assessing the quality of our fsQCA were calculated by using the QCA package for R by Dusa (2019).

The first step is the analysis of necessity of single conditions. By doing so, those conditions are identified that are necessary for the outcome to occur. Putting it differently, a condition is necessary if, whenever present, the outcome condition is also present (Ragin 2014). For our research model, we analyzed if conditions A, B, C and D are necessary for a successful progress in urban BEV diffusion to happen. There are three parameters that must be considered when testing for necessity: *consistency, coverage* and *Relevance of Necessity (RoN)* (Mello 2021).[12] Consistency is the primary parameter. The formal benchmark for set-theoretic consistency holds that conditions have to pass at least a 0.9 level to be considered a necessary condition. In addition to this, parameters coverage and RoN should pass at least a 0.5 level for not invalidating a high consistency level (Schneider and Wagemann 2012). As depicted in Table 4, results of the necessity test reveal high consistency levels for conditions C (1.0) and D (0.857). The latter has a consistency score *lower*

[11]Please note that QCA as a set-theoretic method refers to the assumption of causal asymmetry. Thus, any solution term detected refers to only one of the two qualitative states, presence (Y) or absence (~Y), of the outcome condition. Accordingly, when investigating configurations of conditions leading to the absence of the outcome condition, a separate analysis is required. As such, QCA is different from symmetric notions, which are predominant in quantitative research approaches (Schneider and Wagemann 2012).

[12]For more information about the analysis of necessary conditions, please see Schneider and Wagemann (2012), p. 139 ff.

Table 4. Analysis of necessity

Condition	Consistency of necessity	Coverage of necessity	Relevance of necessity
Condition D	0.857	0.750	0.800
Condition C	1.000	0.778	0.778
Condition B	0.571	0.800	0.917
Condition A	0.571	0.400	0.500
~Condition D	0.143	0.125	0.533
~Condition C	0.000	0.000	0.562
~Condition B	0.429	0.273	0.385
~Condition A	0.429	0.500	0.769

than 0.9 and thus is formally not a necessary condition. For condition C, both coverage and RoN are 0.778. The valid consistency score thus is backed. Consequently, conditions C is necessary for a positive outcome to be present. It means that for progress in urban BEV diffusion to happen, a quick permitting procedure for home charger installations and monetary incentives for the installation of charging points on private property by city authorities or utilities are necessary.

In a second step, the analysis of sufficiency is performed. For doing so, a so-called truth table is constructed. It lists all logically possible combinations or configurations of conditions, which produce the outcome (2^4). The truth table shows configurations of conditions that are sufficient for the outcome to occur (Schneider and Wagemann 2012). Similar to the test for necessity, sufficient configurations of conditions must meet standards of consistency and coverage. The parameters are calculated for each truth table row and measure the strength of each configuration of conditions and the outcome. Following Mello (2021), the formal threshold for consistency of a configuration of conditions is at least 0.75. Regarding coverage, a minimum score of 0.5 serves as a rule of thumb (ibid.: p. 127 ff.). Table 5 provides an overview of the resulting truth table. Each row highlights a qualitatively different configuration of the four BEV policy conditions covered. There are four configurations that are sufficient for the outcome to occur. Configurations with row numbers 3, 5, 9 and 10 are covered by a total of eight cases, which are attributing to successful progress in urban BEV diffusion. There are six logical remainders. In QCA, logical remainders indicate logically possible configurations of conditions that lack empirical cases and can be detected by investigating rows without cases in them (Schneider and Wagemann 2012). A lack of empirical information is called "limited diversity". According to good practice procedures in QCA, the problem of limited diversity is moderate in the case of our analysis (Schneider and Wagemann 2010).

In a consecutive step, the truth table was processed according to the procedure of logical or Boolean minimization. It covers the formal analysis of the policy configurations in the truth table by applying the Quine–McCluskey algorithm (Mello 2021). For doing so, configurations of conditions are linked by three Boolean operators: Boolean AND (·), Boolean OR (+) and Boolean NOT (~).[13] The logical minimization process aims to detect simplest possible logical expression that is

[13]For more information about Boolean operators used to minimize a truth table, please see: Mello (2021), p. 129 ff.

Table 5. Truth table

ROW	CASE-ID	CON A	CON B	CON C	CON D	OUTCOME
1	Kansas City (Missouri)	0	0	0	0	0
2	Providence (Rhode Island)	0	0	1	0	0
3	Boston (Massachusetts), Denver (Colorado)	0	0	1	1	**1**
4	Nashville (Tennessee)	0	1	0	0	0
5	Raleigh (North Carolina)	0	1	1	0	**1**
6	Columbus (Ohio), Pittsburgh (Pennsylvania), Portland (Maine)	1	0	0	0	0
7	Baltimore (Maryland), Phoenix (Arizona)	1	0	0	1	0
8	Seattle (Washington)	1	0	1	0	0
9	Portland (Oregon)	1	0	1	1	**1**
10	Austin (Texas), Los Angeles (California), New York City (New York)	1	1	1	1	**1**

related to an occurring outcome. It results in the so-called conservative solution[14] for the various sufficiency statements entailed in a truth table. It represents the solution formula of our fsQCA and needs to be interpreted (Schneider and Wagemann 2012). As a result, there are three so-called prime implicants that co-occur with the presence of the outcome Y (Boolean operators used):

$$\sim ABC \sim D + \sim BCD + ACD \rightarrow Y$$

The analysis reveals three alternative sufficient configurations of BEV policy conditions that lead to successful progress in BEV diffusion in cities in the U.S. Table 6 reveals the parameters of fit for the three sufficient configurations. All three configurations have a consistency score of 1.0 confirming a high fit between the empirical evidence and the assumed set-theoretic relationship (Mello 2021).[15] When we perceive the coverage parameter though, it becomes obvious that configuration ~ABC~D has a coverage score of only 0.314. It is covered by just one case, namely Raleigh (North Carolina). It makes that one case to be an odd one among the cases related to a positive outcome. Consequently, we decided not to consider configuration ~ABC~D for an interpretation and instead focus on configurations ~BCD and ACD. Both configurations have coverage scores above 0.5 as indicated by 0.525 for ~BCD and 0.579 for ACD.[16] As a result, there are three alternative sufficient configurations of BEV policy conditions that co-occur with the outcome.

Our findings confirm the assumption of equifinality as outlined in section “Method”. There are different configurations of BEV policies that in conjunction with contextualized dynamics are propelling progress in BEV diffusion in U.S. cities. There is no condition that can produce the outcome on its own i.e., no condition is

[14]Please note that fsQCA is able to produce three different solution terms (conservative, parsimonious and intermediate solution). The so-called conservative solution does not make any assumptions about logical remainder rows (empty rows in the truth table). The other two solution variants incorporate logical remainder rows to different extents (Mello 2021, p. 134 f.).

[15]For more information about the analysis of consistency of sufficient conditions, please see Schneider and Wagemann (2012), p. 123 ff.

[16]Please note that both coverage values are comparatively low according to good practice standards of QCA.

Table 6. Consistency and coverage for the sufficient conditions identified

Number	Sufficient configuration	Consistency	Coverage
1	∼ABC∼D	1.000	0.314
2	∼BCD	1.000	0.525
3	ACD	1.000	0.579

necessary and sufficient for the outcome to be present. When we perceive configuration ∼BCD for instance, it becomes obvious that condition ∼B is insufficient on its own, but is needed to form a sufficient conjunction with C and D. It thus is insufficient, but a necessary part of a conjunctural condition which is itself unnecessary but sufficient for the outcome (Y). Condition ∼B is a so-called INUS condition (Mackie 1980).[17] The same holds true for the conditions of configuration ACD.

Interpretation of results

In a final step, the conservative solution consisting of two configurations must be interpreted by referring to the cases covered in our analysis. Starting with *configuration ∼BCD*, which is covered by a total of three cases. The absence of recurring monetary and non-monetary incentives at the local level may seem counterintuitive and at odds with existing research. Jenn et al. (2018)[18] for instance confirm a positive impact of HOV lane access on BEV adoption. Though, a closer look reveals that in cases Portland (Oregon) and Denver (Colorado), BEV users at least can recharge their BEV at city owned and public charging stations free of charge (Chargehub 2023). In Denver (Colorado), the charging for free incentive is part of a broader strategy to bolster charging infrastructure availability. Equity considerations are a main pillar of the strategic approach and aim to diminish burdens of charging costs that lower-income BEV owners face, as relying on public charging stations mainly (City and County of Denver 2020). There are no recurring monetary and non-monetary incentives in the case of Boston (Massachusetts). Please note that the presence of condition B being absent results mainly from the calibration scheme applied to condition B (see: section “Calibration of data into fuzzy-sets”).

Condition C, a quick permitting procedure for home charger installations and monetary incentives for the installation of charging points on private property, is necessary for successful progress in urban BEV adoption but only in conjunction with conditions ∼B and D, respectively A and D. Cases Boston (Massachusetts), Denver (Colorado) and Portland (Oregon) reveal how partnership across policy levels and city-related actors support the extension of charging infrastructure in a user-centric fashion. In the “Zero-Emission Vehicle Roadmap 2020”, the city authority of Boston outlines actions to support an affordable and convenient access of charging infrastructure in the capital of Massachusetts. One central aspect of the

[17]The abbreviation INUS refers to conditions that are an insufficient but necessary part of a condition which is itself unnecessary but sufficient for the outcome to be present (cf.: Schneider and Wagemann 2012: 79).

[18]Note: The study by Jenn et al. (2018) is investigating BEV policies at the aggregated level of U.S. states.

strategy outlined is to create actions that support utilities to invest in charging infrastructure (City of Boston 2019). Since 2017, this task is fulfilled by local utility National Grid. The "Massachusetts Residential EV Charging Infrastructure Program" by National Grid provides BEV users with up to $700 when installing charging equipment in their garage or parking area at a single-family home (additional rebate for 2 to 4 units) (National Grid 2023). The charging equipment rebate results from a broader regulatory process between the state of Massachusetts and three utilities, including National Grid. Since 2017, the utilities have received funding from the state of Massachusetts to deploy "make-ready" charging infrastructure and offer monetary rebates for Level 2 and direct current fast charging (DCFC) BEV chargers to certain customers. In its current form, the comprehensive "Make-Ready Program" enables BEV charger rebates for public and workplace, residential as well as fleet customers (Commonwealth of Massachusetts 2023). Case Denver (Colorado) has monetary incentives by the state of Colorado implemented to expand BEV charging infrastructure stations. In 2013, the Colorado Energy Office (CEO) incepted the "Charge Ahead Colorado" program (Colorado Energy Office 2023). Ultimately, the program is a central pillar of Colorado´s "Electric Vehicle Plan" and coordinates monetary support as well as joint action across local actors to extend Level II and fast-charging stations in Colorado (State of Colorado 2018). "Charge Ahead Colorado" has been offering grants for Level 2 charging stations ($6250 max.) to individuals. Among the three cases covered, Portland (Oregon) provides both monetary and non-monetary incentives for charging infrastructure extension to private BEV users. In 2009, Portland´s BEV strategy "The Portland Way" received and update that set streamlined electrical permitting process for charging station installations as a priority. It has aiming for a faster and more cost-effective deployment of home charging stations. A website designated to streamlined permitting processes was launched in 2010 (City of Portland 2009, 2017). Monetary incentives for purchase and installation costs for home charger stations have been granted by both state and utility actions. Oregon´s "Residential Energy Tax Credit Program" supported eligible BEV users with a tax credit of 50% of the project costs (up to $750) (Oregon Department of Energy 2023). When the program expired in 2018, the Oregon Department of Environmental Quality's "Clean Fuels Program" provided funds to the local utility Portland General Electric (PGE). In 2019, PGE implemented the "Drive Change Fund", which has been awarding grants for the purchase and installation of home charging equipment (Portland General Electric 2023a). Generally, cases Boston (Massachusetts), Denver (Colorado) and Portland (Oregon) represent a strict partnership between U.S. state entities and local utilities to meet contextualized demands of BEV users in U.S. cities when extending charging infrastructure stations.

Condition D adds further emphasize on the role of utility-related incentives by covering flat TOU and special rate schemes for BEV users. The scope of the scheme offered and the amount of savings possible vary across the three cases covered by configuration ~BCD. Residential users of BEV in Boston (Massachusetts) received a $50 rebate and $20 annual bill credit when pausing BEV charging during peak demand events from local utility National Grid ("Demand Response Charging Incentive") (Alternative Fuels Data Center 2023f). Xcel Energy, a local utility in Denver (Colorado), has been offering a flat TOU rate for residential customers and

BEV users (Alternative Fuels Data Center 2023e). Similarly, BEV users and customers of PGE in Portland (Oregon) are offered a flat TOU rate scheme, which is aligning with summer and winter season (Portland General Electric 2023b).

Configuration ACD is covered by a total of four cases: Portland (Oregon), Austin (Texas), Los Angeles (California), New York City (New York). The configuration puts emphasis on monetary one-time and recurring incentives received upon and after the purchase of BEV. For the four cases mentioned, TCO difference for a representative BEV-ICEV pair are the lowest among all the 16 cases investigated indicating comparatively low TCO for the BEV selected.[19] Monetary incentives received upon purchase of BEV are present in all the four cases. Individuals that purchase a BEV in Austin (Texas) and in Portland (Oregon) receive a rebate of $2500 (Alternative Fuels Data Center 2023b; Department of Environmental Quality Oregon 2023). In Los Angeles (California) and New York City (New York) BEV users are granted additional monetary incentives. Starting in 2009, the "Clean Vehicle Rebate Project" was introduced by the California Air Resources Board (California Environmental Protection Agency 2013). Since then, it has granted California residents monetary incentives when purchasing or long-term leasing zero emission vehicles, including BEV (Governor's Interagency Working Group on Zero-emission Vehicles 2016). In 2017, the amount was $2000 for the purchase of a BEV. Additionally, BEV users were freed from the one-time upfront registration fee (Alternative Fuels Data Center 2023a). Individuals in New York City (New York) have been benefitting from the 2016 "Drive Clean Rebate Program", which is granting $2000 when purchasing or leasing a new BEV (New York State Energy Research and Development Authority 2023b). BEV users additionally receive a recurring monetary incentive, as BEV are exempt from state motor vehicle emissions inspections (Alternative Fuels Data Center 2023d).

The relevancy of conditions C and D was already elucidated by the cases linked to *configuration ~BCD*. Nevertheless, cases Austin (Texas), Los Angeles (California) and New York City (New York) will be examined closer. Starting with necessary condition C, BEV user in Austin (Texas) have been able to apply at Austin Energy, a local utility, for a rebate of 50% of the purchase and installation cost of a Level 2 home charging station (Austin Energy 2023). Strategically, Austin Energy has been a central partner for the City of Austin´s approach towards electrified transportation. Austin Energy has defined the "5 EV Pillars Strategy", which is next to charging infrastructure extension also covering equity and affordability, outreach and education as well as grid integration (Austin Energy 2022). In the case of New York City (New York), the "Charge Ready NY" program offers $4000 for the purchase and installation of a Level 2 EV charging station (New York State Energy Research and Development Authority 2023a). BEV users in Los Angeles (California) have been offered both monetary as well as non-monetary incentives for the set-up of charging infrastructure stations. As part of the encompassing "ZEV Action Plan", the incumbent Governor in 2012 defined the milestone of streamlined permitting processes for charging infrastructure by 2015 (Governor's Interagency Working Group on Zero-emission Vehicles 2013). Since then, cities and counties are obliged to streamline the process for BEV charging stations to be permitted. Monetary

[19]Please see "TABLE A" in the appendix of this article (section 10.).

incentives are granted by local utility Los Angeles Department of Water and Power (LADWP). As part of the "Charge Up L.A.!", BEV users receive a rebate of up to $1000 for the purchase and installation of qualified Level 2 BEV charging stations. Additionally, a $250 rebate for the installation of a dedicated EV charging station meter is provided (Alternative Fuels Data Center 2023c).

Complementary action is indicated by condition D. Utilities in Austin (Texas), Los Angeles (California) and New York City (New York) offered TOU rate schemes to BEV users. As with the cases that are covered by *configuration ~BCD*, scope of the scheme offered and the amount of savings possible are varying. Utilities in Austin (Texas) and New York City (New York) offer flat TOU rate schemes for residential customers (ConEdison 2023; Austin Energy 2018). In the case of Los Angeles (California), local utility Southern California Edison provides BEV user with flexible TOU rate schemes that can be selected in accordance with individual charging preferences. There are three TOU rate schemes with different super off-peak, off-peak and on-peak time intervals and rates available.

Consequently, *configuration ACD* implicitly is confirming earlier research results covering the positive impact of monetary incentives on BEV diffusion (Clinton and Steinberg 2019; Wee et al. 2018). Though, the positive impact of monetary incentives received upon vehicle purchase on BEV diffusion is present *only* in conjunction with proper (non-)monetary incentives at the local level. That said, the presence of necessary condition C and condition D add the importance of joint action between U.S. state entities, city authorities and local utilities in providing charging infrastructure equipment and services in a BEV user-centric way. Please note that even though the presence of condition B is not given in configuration ACD, cases Austin (Texas), Los Angeles (California) and New York City (New York) have implemented two recurring (non-)monetary incentives at the local level each. The presence of condition B is given for configuration ~ABC~D, which is not taken into account for the interpretation due to its low coverage score. In practical terms, recurring (non-)monetary incentives at the local level do matter for the composition of successful configurations policy configurations.

Ultimately, results of our empirical investigation confirm the relevance of well-composed bundles of BEV policies spanning across actions of U.S. state entities, city authorities and utilities while being tailored to local contexts. Cases Portland (Oregon), Los Angeles (California) and Denver (Colorado) illustrate the importance of initial action at the U.S. state level in setting main policy objectives and providing a regulatory framework for partnership among organizations at the local level. On this basis, city authorities and utilities are enabled to tie in with non-monetary and monetary incentives at the local level.

Discussion and conclusion

This research aims to analyze under which (non-)monetary policies at the U.S. state and local levels the diffusion of BEVs is supported. By systematically investigating a total of 16 U.S. cities with fsQCA, we created the following main results:

- BEV policy strategies that compose comprehensive policy bundles across U.S. state, city and utility-related policy levels are more likely to be successful. Thus, our empirical findings support the premise that local (non-)monetary incentives are active *only in conjunction with* local contexts by creating place-specific impact on BEV adoption (Held and Gerrits 2019; Hardman 2019).
- Our results indicate that (non-)monetary incentives for charging infrastructure extension are a necessary condition for the composition of a successful BEV policy bundle.
- State level-related monetary one-time and recurring incentives received upon and/or after vehicle purchase (condition A) *in conjunction with* (non-)monetary incentives for home charging infrastructure extension (condition C) *in conjunction with* recurring monetary incentives by utilities at the local level (condition D) lead to successful progress in BEV diffusion.
- Likewise, the absence of recurring (non-)monetary incentives at the local level (condition B) *in conjunction with* (non-)monetary incentives for home charging infrastructure extension (condition C) *in conjunction with* recurring monetary incentives by utilities at the local level (condition D) lead to successful progress in BEV adoption in U.S. cities.

In consequence, our results indicate two solution pathways ($\sim$BCD + ACD $\rightarrow$ Y) that lead to progress in urban BEV diffusion. Thus, there is no sufficient BEV policy condition on its own responsible for BEV adoption to happen. Instead, two different configurations covering (non-)monetary incentives are sufficient, while the presence of condition C is necessary but only *in conjunction* with other conditions. By utilizing a rich and novel empirical data set covering a plausible selection of (non-) monetary BEV incentives in 16 U.S. cities, our approach resonates with the demand for investigating local variations and contextualized conditions that affect the impact of BEV policy approaches (Wee et al. 2018). Results of our research confirm the relevance of monetary incentives received upon/after purchase of BEVs as emphasized by earlier research (Clinton and Steinberg 2019; Jenn et al. 2018). Contrary to existing research, our results do not confirm a positive effect of (non-) monetary incentives (e.g., HOV lane access) on BEV diffusion (Jenn et al. 2020; Jenn et al. 2018; Sheldon and DeShazo 2017). One reasons for that could be that earlier research used aggregated data at the U.S. state level for investigating the effect of such incentives. Our results add to existing research the importance of recurring monetary incentives provided by utilities at the local level (Wee et al. 2018). Ultimately, our research approach investigates different BEV policies at different policy levels as policy configurations *in conjunction* promote the adoption of BEV in U.S. cities. As such, we add a novel approach to the existing body of research. In addition, our research results confirm that spatial variation highly matters when composing BEV policy bundles (Hardman 2019; Jenn et al. 2018). That said, our research approach provides researchers and policymakers with an evaluation method that is sensitive to case-related variations of a set of heterogenous cases, while identifying common patterns across the cases considered (Ragin 2000). It thus is a promising approach for evaluating the impact of BEV policy bundles in U.S. cities within and across U.S. states.

Given the novelty of our approach, there are three major limitations. *Firstly*, the number of cases to be investigated could be higher. In our model, only seven out of 16 cases are linked to the occurrence of the outcome. As mentioned in the analysis section, coverage of the configurations leading to successful progress in BEV adoption appears to be relatively low (see section "Discussion and conclusion"). Consequently, explanatory value is limited to the set of cases investigated. The reason for a comparatively small case sample is data availability and accessibility at the local level. Our research model demands comprehensive place-specific data covering city-related BEV targets, BEV registration data and BEV incentives. Research in the future could add more cases to the case sample created for our research. That said, more U.S. cities with recurring non-monetary incentives (e.g., parking privileges, free access to HOV lanes etc.) are relevant, as only a few of the cases covered in our research implemented such incentives. Also, cities in U.S. states that are not covered by our research are a valid choice for case sample extension. *Secondly* and resulting from the first limitation, our research model entails only four policy conditions. Even though, we legitimately selected the most relevant policy conditions, there are many more incentives that could be investigated in future research (e.g., BEV car-sharing schemes, awareness campaigns, educational programs etc.) (Bui et al. 2021, 2020). *Thirdly*, our QCA research approach treats configurations of BEV incentives as static for the time span considered. The two sufficient configurations of BEV incentives identified only hold true for a certain timeframe (mainly between 2017 and 2021). Our findings only highlight a specific snapshot of what is a much longer transition process. Governing the transition towards fully electrified urban transportation systems is a highly erratic and thus dynamic challenge. Our approach is not sensitive to the way policymakers adapt BEV incentives across various policy levels in the course of time. Future research could follow Gerrits et al. (2023) that deploy a time sensitive variant of QCA, trajectory-based QCA, to investigate configurations of factors that in the course of time contributed to urban transformations (see also: Pagliarin and Gerrits 2020).

Ultimately, a configurational approach towards governing BEV transition in the urban domain can help to assess BEV policy bundles that propel progress in BEV diffusion. As demonstrated by our approach, QCA offers an alternative methodological approach that aids the analysis of various BEV incentives across U.S. state, city and utility-related levels. In consequence, QCA has the potential to add valuable explanatory power to the dynamics of BEV policy bundles that help to electrify urban transportation systems.

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Data availability statement. Replication materials are available in the Journal of Public Policy Dataverse at https://doi.org/10.7910/DVN/6PXWSM.

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References

Aasness, Marie Aarestrup, James Odeck. 2023. "Road Users' Attitudes Towards Electric Vehicle Incentives: Empirical Evidence from Oslo in 2014–2020." *Research in Transportation Economics* **97**: 101262. doi: 10.1016/j.retrec.2023.101262.

Adepetu, Adedamola, Srinivasan Keshav, Vijay Arya. 2016. "An Agent-Based Electric Vehicle Ecosystem Model: San Francisco Case Study." *Transport Policy* **46**: 109–122. doi: 10.1016/j.tranpol.2015.11.012.

Ajanovic, Amela, Reinhard Haas. 2016. "Dissemination of Electric Vehicles in Urban Areas: Major Factors for Success." *Energy* **115**: 1451–1458. doi: 10.1016/j.energy.2016.05.040.

Alternative Fuels Data Center. 2023a. Laws & Incentices, State of California. Zero Emission Vehicle (ZEV) Fee. Available online at https://afdc.energy.gov/laws/11779, checked on 10/25/2023.

Alternative Fuels Data Center. 2023b. Laws & Incentives, State Incentives, Texas Light-Duty Alternative Fuel Vehicle Rebates. Available online at https://afdc.energy.gov/laws/11847, checked on 9/11/2023.

Alternative Fuels Data Center. 2023c. Laws & Incentives, State of California. Residential Electric Vehicle (EV) Charging Station Rebate. Available online at https://afdc.energy.gov/laws/12722, checked on 11/2/2023.

Alternative Fuels Data Center. 2023d. Laws & Incentives, State of New York. Electric Vehicle Emissions Inspection Exemption. Available online at https://afdc.energy.gov/laws/11586, checked on 11/11/2023.

Alternative Fuels Data Center. 2023e. Laws & Incentives, State, Colorado. Electric Vehicle (EV) Charging Station Rebate and Time-Of-Use (TOU) Rate – Xcel Energy. Available online at https://afdc.energy.gov/laws/13009, checked on 10/10/2023.

Alternative Fuels Data Center. 2023f. Laws & Incentives, State, Massachusetts. Electric Vehicle (EV) Demand Response Charging Incentive – National Grid. Available online at https://afdc.energy.gov/laws/13190, checked on 9/11/2023.

Austin Energy. 2018. Transportation Electrification Program Update Resource Management Commission.

Austin Energy. 2022. Electric Vehicles and Emerging Technologies. FY22 Annual Report. Available online at https://austinenergy.com/-/media/project/websites/austinenergy/green-power/evet-fy22-annual-report.pdf, checked on 1/12/2024.

Austin Energy. 2023: Plug-In Austin Electric Vehicles. Plug-In Austin Electric Vehicles. Rebates, Resources, and Fun for EV Drivers and Riders. Available online at https://austinenergy.com/green-power/plug-in-austin/home-charging, checked on 11/23/2023.

Austmann, Leonhard M. 2021. "Drivers of the Electric Vehicle Market: A Systematic Literature Review of Empirical Studies." *Finance Research Letters* **41**: 101846. doi: 10.1016/j.frl.2020.101846.

Berg-Schlosser, Dirk, Gisèle Meur. 2009. "Comparative Research Design: Case and Variable Selection." In *Configurational Comparative Methods. Qualitative Comparative Analysis (QCA) and Related Techniques*, eds. Benoît Rihoux, Charles C. Ragin, 19–32. Thousand Oaks, California, London, New Delhi, Singapore: Sage (Applied social research methods series, Volume 51).

Breetz, Hanna L., Deborah Salon. 2018. "Do Electric Vehicles Need Subsidies? Ownership Costs for Conventional, Hybrid, and Electric Vehicles in 14 U.S. Cities." *Energy Policy* **120**: 238–249. doi: 10.1016/j.enpol.2018.05.038.

Bui, Anh, Peter Slowik, Nic Lutsey. 2020. Update on electric vehicle adoption across U.S. cities.

Bui, Anh, Peter Slowik, Nic Lutsey. 2021. Evaluating electric vehicle market growth across U.S. cities. Available online at https://theicct.org/publication/evaluating-electric-vehicle-market-growth-across-u-s-cities/.

Byrne, David. 2005. "Complexity, Configurations and Cases." *Theory, Culture & Society* **22** (5): 95–111. doi: 10.1177/0263276405057194.

Byrne, David, Charles Ragin, Charles C. Ragin, (Eds.) 2010. *The Sage Handbook of Case-Based Methods*. Reprinted. Los Angeles, Calif.: Sage.

California Environmental Protection Agency. 2013. Clean Vehicle Rebate Project. Final Report. FY 2012-2013.

Chargehub. 2023. Portland, Oregon EV Charging Stations Info. Available online at https://chargehub.com/en/countries/united-states/oregon/portland.html#:~:text=The%20city%20of%20Portland%20in,charges%20for%20your%20electric%20car.

City and County of Denver. 2020. Denver Electric Vehicle (EV) Action Plan.

City of Boston. 2019. ZERO-EMISSION VEHICLE ROADMAP 2020.

City of Portland. 2009. Electric Vehicles: The Portland Way.

City of Portland. 2017. Electric Vehicle Strategy "The Portland Way" (2017 update).

Clark-Sutton, Kyle, Saba Siddiki, Sanya Carley, Celeste Wanner, John Rupp, John D. Graham.2016. "Plug-in Electric Vehicle Readiness: Rating Cities in the United States." *The Electricity Journal* **29** (1): 30–40. doi: 10.1016/j.tej.2015.12.006.

Clinton, Bentley C., Daniel C. Steinberg. 2019. "Providing the Spark: Impact of Financial Incentives on Battery Electric Vehicle Adoption." *Journal of Environmental Economics and Management* **98**: 102255. doi: 10.1016/j.jeem.2019.102255.

Coffman, Makena, Paul Bernstein, Sherilyn Wee. 2017. "Electric Vehicles Revisited: A Review of Factors that Affect Adoption." *Transport Reviews* **37** (1): 79–93. doi: 10.1080/01441647.2016.1217282.

Colorado Energy Office. 2023. Charge Ahead Colorado. Edited by Colorado Energy Office. Available online at https://energyoffice.colorado.gov/charge-ahead-colorado, checked on 9/13/2023.

Commonwealth of Massachusetts. 2023. Department of Public Utilities´ Electric Vehicle Charging Resources. Commonwealth of Massachusetts. Available online at https://www.mass.gov/info-details/dpus-electric-vehicle-charging-resources, checked on 9/19/2023.

ConEdison. 2023. Rate Options for EV Owners Charging at Home. Understand Your Billing Options Under Our Standard and Time-of-Use Rates. Available online at https://www.coned.com/en/our-energy-future/electric-vehicles/electric-vehicle-drivers/electric-vehicles-and-your-bill, checked on 10/3/2023.

Cronqvist, L. 2019. Tosmana: University of Trier. Available online at https://www.tosmana.net.

Department of Environmental Quality Oregon. 2023. Oregon Clean Vehicle Rebate Program. Available online at https://www.oregon.gov/deq/aq/programs/Pages/ZEV-Rebate.aspx, checked on 10/9/2023.

Dusa, Adrian. 2019. *QCA with R. A Comprehensive Resource*. Springer International Publishing.

Ebbinghaus, Bernhard. 2005. "When Less is More." *International Sociology* **20** (2): 133–152. doi: 10.1177/0268580905052366.

Edmunds. 2023. Cost to Own Calculator. Available online at https://www.edmunds.com/toyota/camry/2017/cost-to-own/?style=401647953, checked on 9/20/2023.

Egnér, Filippa, Lina Trosvik. 2018. "Electric Vehicle Adoption in Sweden and the Impact of Local Policy Instruments." *Energy Policy* **121**: 584–596. doi: 10.1016/j.enpol.2018.06.040.

Federal Reserve Bank of St. Louis. 2024. Interest Rates, Discount Rate for United States. Available online at https://fred.stlouisfed.org/series/INTDSRUSM193N#0, checked on 1/17/2024.

Gerrits, Lasse. 2012. *Punching Clouds*. Litchfield Park, AZ, USA: Emergent Publications.

Gerrits, Lasse, Sofia Pagliarin, Kai Udo Klein, Fiona Knieling. 2023. "Tracing Complex Urban Transformations in Germany, Switzerland and Austria Using Trajectory-Based Qualitative Comparative Analysis (TJ-QCA). *Cities* **141**: 104507. doi: 10.1016/j.cities.2023.104507.

Gerrits, Lasse, Stefan Verweij. 2013. "Critical Realism as a Meta-Framework for Understanding the Relationships between Complexity and Qualitative Comparative Analysis." *Journal of Critical Realism* **12** (2): 166–182. doi: 10.1179/rea.12.2.p663527490513071.

Gerrits, Lasse, Stefan Verweij. 2018. *The Evaluation of Complex Infrastructure Projects. A Guide to Qualitative Comparative Analysis*. Cheltenham, UK: Edward Elgar Publishing (Transport economics, management and policy).

Governor's Interagency Working Group on Zero-emission Vehicles. 2013. 2013 ZEV Action Plan.

Governor's Interagency Working Group on Zero-emission Vehicles. 2016. 2016 ZEV Action Plan. An updated roadmap toward 1.5 million zero-emission vehicles on California roadways by 2025.

Hall, D., N. Lutsey (2017): Literature review on power utility best practices regarding electric vehicles. Available online at https://theicct.org/sites/default/files/publications/Power-utility-best-practices-EVs_white-paper_14022017_vF.pdf.

Hardman, Scott. 2019. "Understanding the Impact of Reoccurring and Non-Financial Incentives on Plug-in Electric Vehicle Adoption – A Review." *Transportation Research Part A: Policy and Practice* **119**: 1–14. doi: 10.1016/j.tra.2018.11.002.

Hardman, Scott, Amrit Chandan, Gil Tal, Tom Turrentine. 2017. "The Effectiveness of Financial Purchase Incentives for Battery Electric Vehicles – A Review of the Evidence." *Renewable Sustainable Energy Reviews* **80C**: 1100–1111. doi: 10.1016/j.rser.2017.05.255.

Harvey, David. (2010): "Complexity and Case." In *The Sage Handbook of Case-Based Methods* eds. Charles C. Ragin and David Byrne, 15–38. Reprinted. Los Angeles, Calif.: Sage.

Held, Tobias, Lasse Gerrits. 2019. "On the Road to Electrification – A Qualitative Comparative Analysis of Urban E-Mobility Policies in 15 European Cities." *Transport Policy* **81**: 12–23. doi: 10.1016/j.tranpol.2019.05.014.

Held, Tobias, Lasse Gerrits. 2025. "Still on Track for Electrification? A Qualitative Comparative Analysis of E-Mobility Policy Mixes in 14 European Cities." *Journal of Urban Mobility* **7**: 100114. doi: 10.1016/j.urbmob.2025.100114.

Held, Tobias, Lasse Gerrits, Alberto Gianoli, Danait Gebremichael Gebremeskel, Solomon Guttman. 2026. Replication Data for: Bundling Up Actions to Electrify – A Fuzzy-Set Qualitative Comparative Analysis of E-Mobility Policies in 16 Cities in the United States of America, https://doi.org/10.7910/DVN/6PXWSM, Harvard Dataverse, V1.

Jenn, Alan, Jae Hyun Lee, Scott Hardman, Gil Tal. 2020. "An In-Depth Examination of Electric Vehicle Incentives: Consumer Heterogeneity and Changing Response Over Time." *Transportation Research Part A: Policy and Practice* **132**: 97–109. doi: 10.1016/j.tra.2019.11.004.

Jenn, Alan, Katalin Springel, Anand R. Gopal. 2018. "Effectiveness of Electric Vehicle Incentives in the United States." *Energy Policy* **119**: 349–356. doi: 10.1016/j.enpol.2018.04.065.

Kerry, John. 2021. The Long-Term Strategy of the United States, Pathways to Net-Zero Greenhouse Gas Emissions by 2050. Available online at https://www.whitehouse.gov/wp-content/uploads/2021/10/US-Long-Term-Strategy.pdf.

LaMonaca, Sarah, Lisa Ryan. 2022. "The State of Play in Electric Vehicle Charging Services – A Review of Infrastructure Provision, Players, and Policies. *Renewable and Sustainable Energy Reviews* **154**: 111733. doi: 10.1016/j.rser.2021.111733.

Lutsey, N., P. Slowik, L. Jin. 2016. Sustaining Electric Vehicle Market Growth in U.S. Citites. Available online at https://theicct.org/sites/default/files/publications/US%20Cities%20EV%20mkt%20growth_ICCT_white-paper_vF_October2016.pdf.

Mackie, J. L. 1980. *The Cement of the Universe. A Study of Causation*. Oxford: Oxford University Press Incorporated (Clarendon Library of Logic and Philosophy Ser).

Mahoney, James. 2010. "After KKV: The New Methodology of Qualitative Research." *World Pol.* **62** (1): 120–147. doi: 10.1017/S0043887109990220.

Maryland Office of the Attorney General. 2024. Maryland Public Information Act. Available online at https://www.marylandattorneygeneral.gov/Pages/OpenGov/pia.aspx, checked on 1/18/2023.

Mattioli, Giulio, Cameron Roberts, Julia K. Steinberger, Andrew Brown. 2020. "The Political Economy of Car Dependence: A Systems of Provision Approach." *Energy Research & Social Science* **66**: 101486. doi: 10.1016/j.erss.2020.101486.

Mello, Patrick A. 2021. *Qualitative Comparative Analysis. An Introduction to Research Design and Application*. Washington, DC: Georgetown University Press.

Narassimhan, Easwaran, Caley Johnson. 2018. "The Role of Demand-Side Incentives and Charging Infrastructure on Plug-In Electric Vehicle Adoption: Analysis of US States." *Environmental Research Letters* **13** (7): 74032. doi: 10.1088/1748-9326/aad0f8.

National Grid. 2023. Massachusetts Residential EV Charging Infrastructure Program.

New York State Energy Research and Development Authority. 2023a. Charge Ready NY 2.0. Available online at https://www.nyserda.ny.gov/All-Programs/ChargeNY/Charge-Electric/Charging-Station-Programs/Charge-Ready-NY, checked on 12/2/2023.

New York State Energy Research and Development Authority. 2023b. Drive Clean Rebate for Electric Cars. Available online at https://www.nyserda.ny.gov/All-Programs/Drive-Clean-Rebate-For-Electric-Cars-Program, checked on 11/26/2023.

Oregon Department of Energy. 2023. Residential Energy Tax Credit Program. Department of Energy. Available online at https://www.oregon.gov/energy/Incentives/Pages/RETC.aspx, checked on 9/14/2023.

Pagliarin, Sofia, Lasse Gerrits. 2020. "Trajectory-Based Qualitative Comparative Analysis: Accounting for Case-Based Time Dynamics." *Methodological Innovations* **13** (3), 205979912095917. doi: 10.1177/2059799120959170.

Portland General Electric. 2023a. The PGE Drive Change Fund. Portland General Electric (PGE). Available online at https://portlandgeneral.com/energy-choices/electric-vehicles-charging/funding-your-ev-or-charging-project/pge-drive-change-fund, checked on 9/20/2023.

Portland General Electric. 2023b. Time of Use Pricing. Pricing periods. Available online at https://portlandgeneral.com/about/info/pricing-plans/time-of-use/time-of-use-pricing-home, checked on 10/11/2023.

Ragin, Charles C. 2000. *Fuzzy-Set Social Science*. Chicago, London: The University of Chicago Press.

Ragin, Charles C. 2014. *The Comparative Method. Moving Beyond Qualitative and Quantitative Strategies*. Berkeley, CA: University of California Press.

Rihoux, Benoît, Charles C. Ragin (Eds.). 2009. *Configurational Comparative Methods. Qualitative Comparative Analysis (QCA) and Related Techniques*. Thousand Oaks, California, London, New Delhi, Singapore: Sage (Applied social research methods series, Volume 51).

Rogge, Karoline S., Krisitin Reichardt.2016. "Policy Mixes for Sustainability Transitions: An Extended Concept and Framework for Analysis." *Research Policy* **45** (8): 1620. doi: 10.1016/j.respol.2016.04.004.

Sager, Fritz, Eva Thomann. 2017. "Multiple streams in member state implementation: politics, problem construction and policy paths in Swiss asylum policy." *Journal of Public Policy* **37** (3): 287–314. doi: 10.1017/S0143814X1600009X

Schneider, Carsten Q., Claudius Wagemann. 2010. "Standards of Good Practice in Qualitative Comparative Analysis (QCA) and Fuzzy-Sets." *Comp Sociol* **9** (3): 397–418. doi: 10.1163/156913210X12493538729793.

Schneider, Carsten Q., Claudius Wagemann. 2012. Set-Theoretic Methods for the Social Sciences. A Guide to Qualitative Comparative Analysis: Cambridge University Press.

Sheldon, Tamara L., J. R. DeShazo. 2017. "How does the Presence of HOV Lanes Affect Plug-In Electric Vehicle Adoption in California? A Generalized Propensity Score Approach." *Journal of Environmental Economics and Management* **85**: 146–170. doi: 10.1016/j.jeem.2017.05.002.

Slowik, Peter, Nic Lutsey. 2017. Expanding the electric vehicle market in U.S. cities. Available online at https://theicct.org/publication/expanding-the-electric-vehicle-market-in-u-s-cities/.

Slowik, Peter, Nic Lutsey. 2019. The surge of electric vehicles in United States cities.

State of Colorado. 2018. Colorado Electric Vehicle Plan. In Support of the Executive Order, Supporting Colorado´s Clean Energy Transition.

U.S. Bureau of Labor Statistics. 2024. Average Energy Prices for the United States, Regions, Census Divisions, and Selected Metropolitan Areas. Available online at https://www.bls.gov/regions/midwest/data/averageenergyprices_selectedareas_table.htm, checked on 1/19/2024.

U.S. Department of Energy's Vehicle Technologies Office. 2024. Alternative Fuels Data Center. Available online at https://afdc.energy.gov/laws, checked on 1/18/2024.

U.S. Energy Information Administration. 2024. Weekly Retail Gasoline and Diesel Prices. Available online at https://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_ybos_a.htm, updated on 1/16/2024, checked on 1/19/2024.

Van Druenen, Ruud. 2022. "Permission to Bail Out EU's National Flag Carriers? Technocratic and Political Determinants of Commission Approval of State Aid to National Airlines in Difficulties in the Pre-COVID Era." *Journal of Public Policy* **42** (3): 553–572. doi:10.1017/S0143814X22000010

Wee, Sherilyn, Makena Coffman, Sumner La Croix. 2018. "Do Electric Vehicle Incentives Matter? Evidence from the 50 U.S. states." *Research Policy* **47** (9): 1601–1610. doi: 10.1016/j.respol.2018.05.003.

Whitehead, Jake, Patrick Plötz, Patrick Jochem, Frances Sprei, Elisabeth Dütschke. 2021. "Policy Instruments for Plug-In Electric Vehicles: An Overview and Discussion." In *International Encyclopedia of Transportation*, 496–502. ed. Roger W. Vickerman, Amsterdam: Elsevier.

Wolbertus, Rick, Maarten Kroesen, Robert van den Hoed, Caspar G. Chorus. 2018. "Policy Effects on Charging Behaviour of Electric Vehicle Owners and on Purchase Intentions of Prospective Owners: Natural and Stated Choice Experiments." *Transportation Research Part D: Transport and Environment* **62**: 283–297. doi: 10.1016/j.trd.2018.03.012.

Woody, M., S. A. Adderly, R. Bohra, G. Keoleian. 2024. "Electric and Gasoline Vehicle Total Cost of Ownership Across US Cities." *J of Industrial Ecology* **28** (2): 194–215. doi: 10.1111/jiec.13463.

Zhao, X., X. Li, D. Jiao, Y. Mao, J. Sun, G. Liu. 2024. Policy incentives and electric vehicle adoption in china: From a perspective of policy mixes. *Transportation Research Part A: Policy and Practice* **190**: 104235. doi: 10.1016/j.tra.2024.104235.

Appendices

Table A. Overview of effect on TCO of BEV for each U.S. state covered. For a detailed overview of the TCO calculations, please see "FILE 1" in the in the replication data

CASE-ID	TCO (in $) - Toyota Camry LE	TCO (in $) – Tesla Model 3 (DD; long range)	TCO (in $) – DIFFERENCE	RESULT (percentage of TCO of conventional vehicle)
Austin (Texas)	35,191.97	48,632.13	13,440.16	38.19%
Baltimore (Maryland)	34,270.35	44,894.85	10,624.50	31.00%
Boston (Massachusetts)	35,149.69	54,214.41	19,064.72	54.24%
Columbus (Ohio)	31,465.24	27,524.58	−3940.66	−12.52%
Denver (Colorado)	30,040.70	45,615.80	15,575.11	51.85%
Kansas City (Missouri)	31,693.19	47,750.89	16,057.70	50.67%
Los Angeles (California)	39,511.12	50,032.73	10,521.61	26.63%
Nashville (Tennessee)	32,282.00	49,027.09	16,745.09	51.87%
New York City (New York)	34,014.30	47,849.40	13,835.10	40.67%
Phoenix (Arizona)	35,080.58	46,990.03	11,909.44	33.95%
Pittsburgh (Pennsylvania)	32,099.72	43,304.05	11,204.34	34.90%
Portland (Oregon)	31,839.53	42,366.75	10,527.22	33.06%
Portland (Maine)	35,072.61	46,882.51	11,809.89	33.67%
Providence (Rhode Island)	33,911.16	49,930.24	16,019.08	47.24%
Raleigh (North Carolina)	30913.95	44,561.98	13,648.03	44.15%
Seattle (Washington)	33,244.82	45,206.54	11,961.72	35.98%
MEAN	33,486.31	45,924.00	12,437.69	37.22%

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Table B. Number of BEVs registered between 2016 and 2022 for the U.S. cities/states selected

CASE-ID	2016	2017	2018	2019	2020	2021	2022	Sources:
Austin	N/A	N/A	N/A	N/A	tba	tba	30171	Texas Department of Motor Vehicles (2023)
(Texas)	[8397]	[11724]	[18990]	[29540]	[36418]	[60528]	[105807]	
Baltimore	155	284	513	687	855	1231	2110	Open Data Portal Maryland (2023)
(Maryland)	[3200]	[4400]	[8400]	[13200]	[17397]	[22987]	[39661]	
Boston	N/A	N/A	N/A	1043	1443	2324	4205	Commonwealth of Massachusetts/MVC (2023)
(Massachusetts)	[3600]	[5600]	[10300]	[15672]	[20665]	[30149]	[43886]	
Columbus	N/A	N/A	369	1597	1753	2929	3865	Smart Columbus Data (2023)
(Ohio)	[2600]	[3700]	[1099]	[6094]	[6291]	[12100]	[15950]	
Denver	1255	1437	3602	4030	5194	7854	11890	https://atlaspolicy.com/evaluateco/
(Colorado)	[8956]	[13268]	[9714]	[26079]	[31987]	[47602]	[70513]	
Kansas City	3	N/A	122	652	581	667	1202	AFDC TransAtlas (2023); Missouri Department of Revenue (2023)
(Missouri)	[1400]	[2100]	[3500]	[4900]	[6700]	[10000]	[17900]	
Los Angeles	43984	62924	91210	125336	156015	232007	354291	California Energy Commission (2023)
(California)	[115569]	[159705]	[232239]	[308447]	[369364]	[522445]	[763557]	
Nashville	N/A	N/A	827	1018	1430	2106	3456	Tennessee State Government Revenue Department (2023)
(Tennessee)			[4402]	[6139]	[8510]	[13432]	[20140]	
New York City	4018	4844	7309	9931	12873	18993	26914	https://www.nyserda.ny.gov/All-Programs/Drive-Clean-Rebate-For-Electric-Cars-Program/Rebate-Data/Map-of-EV-
(New York)	[21513]	[26114]	[38373]	[49711]	[61404]	[92540]	[127035]	Registrations
Phoenix	N/A	N/A	N/A	N/A	1446	2345	7064	Arizona Department of Transportation
(Arizona)					[7101]	[11757]	[34539]	Electric Vehicle Registration Report (2023)
Pittsburgh	383	516	961	1376	1869	2706	4575	Pennsylvania Department of Transportation/Bureau of Motor Vehicles (2023)
(Pennsylvania)	[3599]	[4364]	[7694]	[10875]	[15205]	[23487]	[42785]	
Portland	2142	3123	4656	7105	9455	14177	27263	Atlas Policy (2023)
(Oregon)	[7700]	[10000]	[13800]	[18800]	[22800]	[30300]	[41760]	https://www.oregon.gov/energy/Data-and-Reports/Pages/Oregon-Electric-Vehicle-Dashboard.aspx
Portland	26	45	66	88	148	265	372	https://www.maine.gov/dep/air/mobile/vehicle-data.html
(Maine)[1]	[206]	[312]	[486]	[899]	[1390]	[2357]	[3462]	
Providence	N/A	N/A	N/A	N/A	545	339	569	Rhode Island Division of Motor Vehicles (direct correspondence)
(Rhode Island)		[1180]	[1693]	[2222]	[3028]	[4869]	[6796]	
Raleigh	N/A	N/A	2040	3310	4370	6680	10177	North Carolina Department of Transportation (2023)
(North Carolina)			[6928]	[11220]	[15445]	[25011]	[38374]	
Seattle	764	1176	2135	2477	2638	3996	4987	Electric Vehicle Title and Registration Activity open dataset (2023)
(Washington)	[4178]	[6236]	[10296]	[12057]	[12306]	[20157]	[30103]	

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