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Still on track for electrification? A qualitative comparative analysis of e-mobility policy mixes in 14 European cities

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ABSTRACT

A major concern for policymakers in European cities is to identify the right policy mix that promotes the diffusion of battery electric vehicles (BEV's). Existing research focuses mainly on the effect of fiscal policies at the national, aggregated level. Consequently, less is known about policy mixes that include monetary and non-monetary policies implemented at both the national and local level. Building on prior research, we deploy a two-step fuzzy-set Qualitative Comparative Analysis (fsQCA) of BEV policies in 14 European cities to identify policy mixes that successfully promote the urban adoption of BEV's.

We find two policy mixes that promote BEV uptake. First, recurring monetary and non-monetary policies that address behavioral aspects of BEV-usage at the local level in conjunction with monetary incentives for home and workplace charging points as well as on-street residential charging points successfully propel BEV uptake. Second, the presence of monetary incentives for home and workplace charging points, as well as on-street residential charging points in conjunction with policies disincentivizing conventional car usage promote the adoption of BEV's.

Our study shows that BEV policies must be tailored carefully across different policy levels and individually to BEV-user contexts in cities. QCA provides a helpful tool for evaluating BEV policy mixes.

1. Introduction

Plug-in full battery electric vehicles (BEV's) are an important means to meet zero-emission targets in European cities (Cui, 2021; Laing, 2020). The European Commissiońs (EC) aim to reach a climate neutral transportation system by 2050 puts high pressure on policymakers to accelerate the decarbonisation of urban transportation (European Commission, 2021). Governing the transition to BEV's has been a steep challenge as a carbon lock-in still gives an advantage to internal combustion engine vehicles (ICEV's) (Mattioli et al., 2020; Newman & Kenworthy, 2015). As governments at the national and local levels have implemented policies to promote electricity-powered cars, BEV numbers in European countries have been raising (Eurostat, 2022b). However, BEV registration trends at the city level are developing unevenly within European countries (Bernard et al., 2021). Having introduced targets for BEV's adoption pathways, policymakers in European cities are busy achieving their objectives (Wappelhorst et al., 2020).

Recent research indicate that policymakers have embraced comprehensive policy mixes[1] across national and city levels to promote BEV uptake (Wappelhorst et al., 2020; Whitehead et al., 2021; Qiu et al., 2022). For example, Held and Gerrits (2019) show that a combinatorial approach to BEV policies that feature push and pull policies that cover national and local, context-specific levels are more likely to foster the adoption of BEV's. While the positive effect of fiscal incentives on BEV uptake has already been confirmed (Clinton & Steinberg, 2019; Münzel et al., 2019; Yan, 2018), the importance of recurring monetary as well as non-monetary BEV incentives and its interplay with policies that sanction the usage of conventional cars on the local level is now gaining attention (Austmann, 2021; Halse et al., 2022). Existing research indicates the relevance of several policies: free, discounted or preferential

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[1] Following Rogge and Reichardt (2016), policy mixes are defined as target bound combinations, respectively configurations, of policy instruments (e.g., laws, regulations, monetary incentives) that are dynamically interacting and are bound to evolving processes that share properties of complexity (pp. 1621-1622). For our research, we use the terms policy mix and policy configuration interchangeably.

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parking (Bakker & Trip, 2013; Egnér & Trosvik, 2018; Hardman, 2019), free or reduced fees for charging BEV's at public charge points (Wappelhorst et al., 2020; Wang et al., 2017), private and workplace BEV infrastructure incentives (Bernard et al., 2021; Hall et al., 2020), BEV infrastructure use and access benefit (e.g., access to specific roads and zones) (Halse et al., 2022; Jenn et al., 2018; Sheldon & DeShazo, 2017; Wappelhorst et al., 2020), exemption from urban toll or congestion fees (Halse et al., 2022; Mersky et al., 2016) and BEV-ready building codes (Bakker & Trip, 2013; Wappelhorst et al., 2020). While emphasis is put on the importance of comprehensive policy mixes across national and local policy levels, research approaches that evaluate such mixes for BEV adoption in European cities are still lacking (Hardman, 2019).

This observation about the lack of attention to policy mixes is also reflected in limitations of correlational studies that investigate the impact of BEV policies mainly at the state-level or some other form of aggregated level (Clinton & Steinberg, 2019; Plötz et al., 2016; Wee et al., 2018). Such approaches tend to overlook conditions bound to contexts, i.e., the specifics of particular local contexts, that could contribute to understanding of causal inference of (non-)monetary incentives across different policy levels (Hardman, 2019; Münzel et al., 2019).

This paper attempts to address the limitations mentioned. To this end, we apply Qualitative Comparative Analysis (QCA) to analyse the uptake of BEV's in selected European cities. We aim to compare the different configurations of policies that may contribute to this uptake. As a case-based method, QCA captures the complex causation of policy configurations that influence BEV uptake. Our model focuses on the dynamics of national and urban BEV policies and their effects on the diffusion of BEV in those cities. Following an initial evaluation by Held and Gerrits (2019), we use an improved explanatory model and an updated as well as expanded data-set to identify effective policy mixes. This may contribute to a timely evaluation of policies promoting the transition to BEV's in cities.

Our research aims to answer the following research question: *Which policy configurations promote the transition towards battery electric vehicles in selected European cities?*

The article is structured as follows: We *firstly* will present the theoretical angle and the selection of conditions. *Secondly*, methodological implications are outlined. *Thirdly*, a description of how the data was coded and analysed is followed by the actual analysis. *Fourthly*, we conclude the paper with both a summary and a discussion of the results.

2. Methodological approach

2.1. Method: fuzzy-set qualitative comparative analysis

Our point of departure is that different cities feature specific local circumstances that influence the uptake of BEV's. One of the most prominent methods for the structural comparison of different cases is Qualitative Comparative Analysis (QCA). QCA treats cases as being composed of configurations of conditions (A, B, C, etc.) that co-occur with an outcome condition (Y). The outcome of interest is likely to be produced through a *conjunction* of the conditions considered. Here, QCA diverges from methods that aim to measure the net-additive effect of single variables on the outcome (Gerrits & Verweij, 2018; Ragin, 2014; Rihoux & Ragin, 2009). QCA analyses the conjunction of conditions via set-theory, that is: conditions that compose a case are analyzed according to the set relations between them. Thus, a set of cases is compared to identify necessary and/or sufficient conditions leading to an outcome condition to be present. In consequence, QCA holds the assumption that configurations (i.e., combinations) of conditions together are sufficient for the outcome to be present. Theoretically, different configurations of conditions can produce similar results (called *equifinality*), and similar configurations of conditions may lead to different results (called *multifinality*) (Byrne & Ragin, 2009; Mello, 2021).

We use a specific version of QCA, namely fuzzy-set QCA (fsQCA). This version captures differences in the degree of set membership of the cases considered (Schneider & Wagemann, 2012). For example, let us assume that subsidies received upon purchase of a BEV is a set and cases “1″ and “2″ provide different subsidies to consumers. When case “1″ subsidizes the entire purchase price of a BEV, it has full set membership in that set. In contrast, when subsidies of case “2” only cover one-thirdof the purchase price, it has only partial set membership. Research into the BEV transition by Held and Gerrits (2019) applies a variant of QCA that works with strict dichotomization of set membership (full in or full out). In contrast, fsQCA enables researchers to capture graded set membership as any possible score between 0 and 1. Difference-in-degree between cases adds precision to the transfer of empirical information to set memberships of cases. Therefore, fsQCA combines qualitative and quantitative dimensions (Gerrits & Verweij, 2018; Mello, 2021; Schneider & Wagemann, 2012).[2] The procedure of assigning set membership scores to cases on the basis of empirical data is called calibration (Schneider & Wagemann, 2012). The calibration procedure for our case sample will be described in Section 3.

This paper considers cities as cases in which different BEV policies are applied (conditions) that may or may not allow policymakers to achieve BEV targets (outcome). Using QCA, we can capture differences in local conditions (cross-case variation) as well as compare cases for commonalities and differences (Gerrits & Verweij, 2018). We expect different patterns indicating policy mixes that promote urban BEV uptake. BEV policy mixes are perceived as configurations that produce the outcome of interest in conjunction with local circumstances (Ragin, 2000). Recent research on BEV policies reveals, single policies implemented in one particular city didnt́ produce the same outcome in different cities (Held & Gerrits, 2019; Morrison & Wappelhorst, 2022; Wappelhorst et al., 2020). Rather, configurations of BEV policies that are geared towards contextualized dynamics of cities are much more likely to promote BEV uptake. In other words, policymakers are dealing with *multifinality* and *equifinality*.

Accordingly, our approach incorporates a configurational understanding to sociotechnical transitions. We aim to improve explanations for complex causalities and alignments of emergent, co-evolving processes at multiple transition levels (Gerrits & Pagliarin, 2021). In referring to a basic premise of the systemic transition approach by Geels (2005), policymakers and other social actors align when sharing routine-based behavior that creates stability for technological trajectories (cf.: Geels & Kemp, 2007: 442; Geels, 2012: 473). Consequently, our research focuses on policies that affect the alignment between policy makers, societal actors, and technology. The research model is presented in the next section.

2.2. Research model

We first define the conditions that we expect to have explanatory value. Based on the theoretical and empirical considerations mentioned in the previous section, the model is composed of the following conditions: Outcome condition (abbr.: Y) concerns the policy targets as expressed by public authorities in each case. The value of Y whether policy targets in each case have been met or are likely to be met in the near future. BEV transitions in European cities have been ongoing (Bernard et al., 2021). The assessment therefore presents a snapshot in time and marks an intermediate state of an ongoing transition. A

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[2] 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 regarded set. All other degrees of membership as well as non-membership need to be quantified by using fuzzy values (Mello 2021; Ragin 2000).

favorable outcome at the time of evaluation does not guarantee that the transition will be successful in the long run. Conversely, an unfavorable outcome at the current stage is not indicative of a fully failed policy attempt to promote BEV's in the long run. However, it does provide indication of how close cities are towards achieving their own goals.

What conditions may influence the outcome condition? Following Geels' recommendation mentioned above, and meeting the needs of analyzing the interplay of BEV policies on the local and the national level (Münzel et al., 2019), we include policies on both levels for compiling the conditions. As latest research shows, very similar fiscal policies are implemented as fiscal instruments to promote BEV uptake (e.g., purchase subsidies, reduced cost of registration according to emissions, taxable benefits when purchasing BEV's) (Austmann, 2021; Clinton & Steinberg, 2019; Morrison & Wappelhorst, 2022). Additionally, there are various non-monetary and recurring regulatory incentives that are active only on the local, proximate level and were assessed to be relevant for BEV uptake by past research (Coffman et al., 2017; Morrison & Wappelhorst, 2022; Wappelhorst et al., 2020). As a result, the following four[3] conditions compose our model.

Firstly, policies targeting financial barriers for BEV uptake are embedded into the wider fiscal context at the national level. As mentioned earlier, latest research confirms that there is a positive relationship between fiscal incentives and BEV registrations (Clinton & Steinberg, 2019; Münzel et al., 2019). Fiscal measures are important governmental tools. However, past studies estimating the effect of monetary incentives are utilizing aggregated data and thus neglect effects on the cost effectiveness of BEV from a consumer-centric perspective (Austmann, 2021). We offer an alternative approach for estimating the effect of monetary incentives. By following Lévay et al. (2017) and Held and Gerrits (2019), we *compare the total cost of ownership (TCO) for BEV's and its conventional counterparts to estimate the effect of fiscal incentives*. Calculating TCO of a vehicle is a method that estimates all costs associated with its ownership over a given timespan. TCO can be calculated for each country by using a representative BEV-ICEV pair. This way, the effect of all fiscal incentives on BEV TCO relative to the TCO of a conventional car can be estimated. Instead of including only one BEV-ICEV pair from one specific car segment as done in some prior research, we want to pay attention to differences of cost reduction effects among different car segments on a country level. Recent cross-country comparisons show that different fiscal incentive schemes support different car segments (Yan, 2018). A more substantial statement about the effects on TCO can be made, when calculating TCO for BEV-ICEV pairs that are linked to the most prominent car segments. We thus conducted TCO calculations for BEV-ICEV pairs belonging to small size (segments A, B), medium size (segment C), and large size vehicles (segments D, S, J) each (Lévay et al., 2017). This pairwise comparison of TCO per segment to assess the fiscal incentives at the national level constitutes the second condition (abbr.: A). This is an improvement from the model by Held and Gerrits (2019), which only considers TCO for one fixed BEV-ICEV pair (see also: Hagman et al., 2016).

Secondly, policies on the local level influence behavioral patterns and traffic conditions, and thus affect EV adoption. These policies rely not exclusively on financial benefits but also include benefits of usage, such as access to low emission zones or access to priority lanes. Accordingly, non-monetary as well as monetary benefits for BEV users on the local level are treated as recurring policy incentives. The second condition (abbr.: B) covers *free parking (not while charging), parking space privileges, recharging for free at public charging stations, free access to residential priority/restricted access areas, exemption of congestion charging zones* and *access to bus lanes*.

Thirdly, providing a well-developed and BEV user-oriented charging infrastructure is a crucial aspect in fostering BEV uptake in cities (Austmann, 2021; Wappelhorst et al., 2020). Some city administrations initially focused on the installation of public charging points. As the majority of charging happens at home or the workplace of BEV-users, various incentive schemes for the installation of charging points on private land have also been implemented. The majority of urban dwellers lack private residential parking (Hall et al., 2020). Consequently, policies that promote curb side and lamp post charging are a relevant approach to guarantee for a demand-oriented extension of charging points. As a result, the fourth condition (abbr.: C) covers the *building of public charging stations* and *monetary incentives to promote EVSE in a demand oriented and thus user centric way. Financial support* (e.g., *targeted investment, direct subsidy, tax waivers etc.) are included.*

Fourthly, next to the pull factors mentioned above, push factors are another policy option on the local level. Policies aimed at sanctioning and restricting ICEV's have become more prominent in the recent past (Cui, 2021; Hall et al., 2020). Consequently, the fifth condition (abbr.: D) covers the *introduction of Low Emission Zones, higher parking fees, reduction of parking facilities, temporary bans from city streets* and *congestion tax for light and heavy-duty cars in designated city areas.*

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

Within the timeframe of data collection, public infrastructure was provided either with the strategy of additionally support charging equipment on private property, or not. Data covering recurring policies (condition B) were collected for the same timeframe. This meets requirements of time congruency. We only considered policies that had been implemented not later than the beginning of 2017 and were active

Table 1
Overview of the conditions included in the model.

Condition	Abbreviation	Policies included
Fiscal incentives	A	- Direct subsidy for purchase of a new BEV - Benefits through taxation (i.e., value added tax, taxes on acquisition, annual taxes on usage) - Subsidies resulting in lower electricity prices
Recurring incentives	B	- Free parking (not while charging), parking space privileges, parking for a reduced rate - Free access to "residential priority/ restricted access areas" - Recharging for free at public charging stations/local electricity price discounts - Access to bus lanes
Strategy of infrastructure extension	C	- Construction of public charging infrastructure - Grants for charging equipment installed on private space and curb side/lamp post charging points for multi-unit dwellers; associated installation costs - Tax rebate for purchase and installation cost
Sanctions on conventional car usage	D	- Introduction of Low Emission Zones (conventional cars are banned or have to pay a fee when entering) - Higher parking fees/reduction of parking facilities for conventional cars - High polluting vehicles are banned from city streets temporarily - Congestion tax for light and heavy-duty cars in designated city areas
Outcome	Y	- BEV diffusion rate linked to BEV targets on the local level as well as BEV polices on the state and local level

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[3] For methodological reasons, QCA allows only for a limited set of conditions to be considered in each comparison. See e.g., Mello, 2021 for explanation.

for at least four years. Thus, contradictory causal relations (presence of B without condition C) can be ruled out.

Following Schneider (2019), we use a two-step fsQCA approach. A two-step approach conceptually differentiates conditions according to so-called remote and proximate factors. While the former are spatially more distant to a case, the latter cover local conditions. A two-step approach corresponds with the decision to include both the national, i.e., remote conditions (national level providing the context for policies carried out locally in cities) and local level, i.e., proximate conditions (local, urban level). Estimating the effect of fiscal incentives, and thus remote policy conditions, on TCO of BEV's is a first step before running the analysis including both remote and proximate BEV policies.

3. Selection of case sample, data and data processing

Our sample adheres to the guidelines given within QCA (e.g., Ragin, 2000). We focus on European cities as most are part of the institutional boundary of EU membership.[4] Thus, a minimum degree of homogeneity is achieved. The sampling follows *deliberate case selection* because of historical and political contingency (Ebbinghaus, 2005). As the promotion of BEV's depends on political willingness, the structure of opportunities and/or practical feasibility, the scope of concrete BEV policies implemented in European cities is varied (Geels, 2011; Hall et al., 2020). Cases that feature no or very little action (historically and in the present) in promoting BEV's were left out because there is no effect to be observed and thus no conjunctions of policy conditions to be highlighted. Therefore, we applied the *most similar/different outcome (MSDO)* selection strategy. The most similar systems design is based on the method of *difference*. By comparing similar cases, differences in the outcome condition can be explained by investigating differences among the conditions. Consequently, the MSDO technique allows a formalized procedure for selecting cases in accordance with QCA's performance by implying both systematic-cross case comparison and within-case knowledge (Berg-Schlosser & Meur, 2009; Rihoux & Lobe, 2010). Also, data availability had to be considered, as data covering the local level were not reliable or available in some cases.

The original case sample covered 15 European cities. We had to drop case Lisbon (Portugal), as no sufficient BEV registration data on the local level was available. Thus, the final level covers a total of 14 cases (see Table 2). Multiple sources were selected for data gathering. The European Alternative Fuels Observatory (EAFO) and the policies database of the International Energy Agency (IEA) provide an overview of BEV policy targets and policies on the national and local level. Additionally, we collected data from official policy papers, reports and databases issued by responsible ministries on both the national and local level. For calculating TCO for the selected BEV-ICEV pairs, we draw on the Tax Guide issued by the European Automobile Manufacturers Association (ACEA) for 2017 as the main source for policies and specific taxes levied on BEV's as well as conventional cars. The ACEA Tax Guide covers country-specific taxes on acquisition (VAT, sales tax, registration tax), taxes on ownership (annual circulation tax, road tax) as well as taxes on motoring (European Automobile Manufacturing Association, 2017) .[5] 2017 net car prices for the models selected could be lifted from the car manufacturer's country-specific websites by using the webpage webarchive.org. Data on country-specific petrol, diesel and electricity prices for 2017 could be accessed by the dashboard for energy prices of the European Commission (2023) and data sets provided by Eurostat (2022a).[6]

Data regarding proximate conditions (conditions B to D) were collected primarily from official sources of city governments. The policies database of the of the International Energy Agency (IEA) and the country-specific policy section of the European Alternative Fuels Observatory (EAFO) provided secondary sources. If no information could be found in those sources, the offices responsible for local e-mobility policies were contacted to obtain them. In all such cases, the relevant information was provided to us. Additionally, various e-mobility related platforms and associations in some countries provided information. Data covering BEV registration numbers on the national and local level were acquired from official statistical offices in each country. In case of missing data, a data request was sent out directly to responsible statistical offices. We received data for all requests submitted. Table 2 provides an overview of the cases selected including the targets on the national and local level.

4. Analysis

Membership scores for each case were assigned. ***Firstly***, outcome condition (Y) covers an interim assessment about the success of the BEV policies implemented in the 14 European cities covered. The BEV diffusion rate relative to BEV targets for a case are considered to make a qualitative statement about the success of the BEV policy mix applied. For assigning membership scores to each case, BEV targets and the historical development of BEV registration numbers on the local level were used to calculate the progress in each case for either the past period by 2020 or 2022. Results indicate an interim assessment of the 2025 or 2030 policy target periods. Practically, 2020 or 2022 BEV registration data was divided by the nearest BEV target on the local level (e.g., 2025 or 2030). If possible, 2020 BEV registration data was used to be divided by 2020 targets. As mentioned earlier, we use a fuzzy scale to express whether the BEV target of case was achieved (full membership of the outcome set) or not (full non-membership). Allowing for reasonable variation of membership scores, we used a 4-scale fuzzy-set: 0.0: fully out, 0.33: more out than in, 0.67: more in than out, 1.0: fully in. For cases with BEV targets by a 2020 period, a membership score of 1,0 is assigned when at least 80 %, 0,67 when at least 70 %, 0,33 when at least 55 %, and 0,0 when up to 54,99 % of the original target could be reached. For cases with BEV targets by a 2025 and 2030 period, a different scheme for assigning membership 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 at least 45 %, 0.67 when at least 20 %, 0.33 when at least 10 %, and 0.0 when up to 9,99 % of the original target could be reached so far. For cases with BEV targets by a 2030 period, the calibration scheme is as follows: cases are assigned 1.0 when at least 25 %, 0.67 when at least 10 %, 0.33 when at least 5,00 %, and 0.0 when up to 4,99 % of the original target could be reached so far. Please note that BEV diffusion rates were assigned to the fuzzy-set scale by meaningful variation, as progress in BEV diffusion depends on case-specific conditions rather than universal parameters (Ragin, 2000: 161 f.). See Table 2 for an overview of the BEV diffusion progress for each case.

For condition A, the calibration depends on a calculation and comparison of the TCO of comparable BEV-ICEV pairs from a car segment of the small, middle and big vehicle size category each. For the calculations, only fiscal incentives implemented by direct subsidies or tax exemptions that lead to reduced purchase price of the vehicle (one-time

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[4] Norway marks an exception. However, it has adopted many EU regulations despite not being a member of the Union, which justifies inclusion in the sample.

[5] For an overview see tables B.1, B.3 and B.5 in the appendix under section 9..

[6] For an overview of the key parameters used for the TCO, please see table B in the appendix.

Table 2
Overview of the case sample including local BEV targets and targets as percentage share of total vehicle fleet.

Case-ID	Targets by 2020 (local level)	Targets beyond 2020 (local level)	Progress of BEV registration in 2020 or 2022 (percentage share of the nearest target possible)	Sources[*]
Graz (AT)	By 2020, 10.000 BEVs registered in Steiermark (region) by 2020, ca. 2000 BEVs registered in Graz	By 2030, ca. 230.000 BEVs registered in Steiermark (region) by 2030, ca. 40.000 BEVs registered in Graz	92,35 % (by 2020 period) (9,12 % by 2030 period)	Das Land Steiermark (2016). Landesstrategie Elektromobilität Steiermark 2030 (p. 16ff.)
Brussels (BE)	*n.a.*	By 2025: 20 % BEVs (proportion of zero-emission light vehicles in new registrations) by 2030: 50 % of new registrations are BEVs by 2050: 100 % of new registrations are BEVs	3,54 % in new registrations (by 2025 period)	Plan Énergie Climat 2030 - RÉGION DE BRUXELLES-CAPITALE 2019 (pp. 12f.)
Copenhagen (DK)	*n.a.*	20–30 % of all light-duty vehicles are driven by alternative fuels (incl. electricity) by 2025 (ca. 26.500 BEVs)	10,67 % are BEVs (14.892) (by 2025 period)	City of Copenhagen 2012. CPH 2025 Climate Plan. A Green, Smart and Carbon Neutral City. (p. 42 ff.)
Hamburg (GER)	*n.a.*	By 2030, electrification rate of 40 % for private passenger cars (ca. 300.000 BEVs)	10,03 % (by 2030 period)	Hansestadt Hamburg (2023). Strategie Mobilitätswende. Verkehrsentwicklungsplanung Hamburg. Hamburger Klimaplan - Bürgerschaft der Freien und Hansestadt Hamburg (2015)
Helsinki (FI)	*n.a.*	By 2030, at least 30 % of Helsinki's total vehicle fleet will be fully electrically powered	2,84 % (by 2030 period)	Helsingin Ilmasto (2024)
Madrid (ES)	*n.a.*	By 2030, ca. 290.000 EVs registered (ca. 20 % EV penetration rate)	3,20 % (by 2030 period)	Madrid 360 (2020) Roadmap towards climate neutrality by 2050 (p. 26 f.) Madrid 360 (2017)
Paris (FR)	By 2020, ca. 50.000 EVs to be registered in Paris	Phase-out of internal combustion engines from roads in "Metropole du grand Paris" in 2030 (ending diesel mobility by 2024 and petrol by 2030)	18,94 % (by 2020 period) (percentage share of BEVs of total passenger vehicle fleet in 2022: 3,0 %)	Paris Climate Action Plan - City of Paris (2018) Direction Régionale et Interdépartementale de l'Environnement et de l'Énergie (2012)
Budapest (HU)	*n.a.*	By 2030, ca. 225.000 BEVs (30 % share of total vehicle fleet)	5,94 % (by 2030 period)	Municipality of Budapest (2018; 2021) Budapest Climate Strategy and Sustainable Energy and Climate Action Plan 2030
Dublin (IRE)	*n.a.*	By 2025, ca. 53.000 BEVs registered by 2030, ca. 190.000 BEVs registered	27,75 % (by 2025 period)	Dublin Local Authority (2022). Electric Vehicle Charging Strategy. (p. 45 f.)
Milan (IT)	By 2020, 150.000 BEVs and PHEVs	By 2030, Zero Emissions in the City of Milan	1,43 % (by 2020)	Comune di Milano (2015). Piano Urbano Della Mobilitá. (p. 250) City of Milan (2022). Piano AriaClima.
Amsterdam (NL)	By 2015, 10.000 BEVs to be registered	By 2030, emission-free transportation in Amsterdam (100 % BEVs)	ca. 10 % of all passenger cars registered were BEVs in 2023	Clearn Air Action Plan - Emssion-free Amsterdam (Gemeente Amsterdam 2019) p.13f. Amsterdam. Electric Mobility gets up to speed 2011–2015 Action Plan (Rijksdienst voor Ondernemend Nederland (RVO) 2011)
Oslo (NO)	*n.a.*	By 2030, all private passenger vehicles to be fully electric (zero emissions)	41,71 % (by 2030 period)	Oslo Kommune (2016). Climate and Energy Strategy for Oslo. Oslo Kommune (2020). Climate Strategy for Oslo towards 2030.
Stockholm (SE)	*n.a.*	Total fleet to have at least 40–50 % BEVs and PHEVs by 2030 90 to 100 % BEVs in new sales (ban on new petrol or diesel cars sales after 2030)	29,27 % (by 2030 period) [in 2023 a total of 353.523 passenger vehicles were registered in Stockholm municipality]	Swedish Energy Agency (2009); City of Stockholm/Clean Vehicles in Stockholm (2022); International Energy Agency (2022)
London (UK)	By 2020, 100.000 BEVs	By 2025, ca. 330.000 BEVs to be registered	33,85 % (by 2025 period)	Greater London Authority (2010) (p.48) Mayor of London (2019) Newmotion (2017) Tietge et al. (2016)

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

bonus upon purchase) were considered. We only included fiscal instruments that were granted on the national level.[7] Only fiscal incentives that have been active for at least four years were considered (date of implementation not later than beginning of 2017). Being sensitive to the aspect of duration, de facto benefits need to be perceived not as a single purchase grant at a particular point in time, but as potential savings for a longer period of ownership being relative to the costs of competing ICEV's. As mentioned earlier, we calculate TCO for representative BEV-ICEV pairs that can be assigned to three car segments. Thus, stronger or weaker effects of fiscal incentives on TCO of BEV relative to a complementary ICEV can be illustrated sensitive to segmental differences.

To get there, we matched three BEV-ICEV pairs that belong to one car segment each including segment B (small), segment C (middle) and segment S (big). For each car segment the most popular BEV and its most popular conventional counterpart on the European market between 2015 and 2019 was selected. Starting with segment B, we paired the Renault ZOE with the petrol-powered Renault Clio LIFE. For segment C, the Nissan Leaf was paired with the diesel-powered Honda Civic 1.6 i-dtec. Finally, the Tesla Model S and the diesel-driven Audi A7 3.0 TDI

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[7] One exemption is given by case Brussels (BE). Since January 2013, grants for EV purchase have no longer been exercised at federal level (European Automobile Manufacturing Association 2017). As Belgium's autonomous regional administrations are responsible for motor vehicle taxation, we follow Münzel et al. 2019 for considering fiscal incentives on the national level. As there only three regions (Brussels-Capital Region, Flanders and Wallonia), savings for EV purchase by subsidies and tax exemptions/reductions are summed up and weighted each by one third.

ultra are paired for segment S. For the BEV-ICE pairs selected, the versions with the lowest CO2 emissions and basic feature options (ICEV) and the most basic regarding performance and price (BEV) were chosen. Data on technical specifications necessary for TCO calculations refer to the 2017 models. Due to lacking data for some models, data referring to later car models (2018 or 2019 models) partly with different technical specifications were used instead.[8]

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. The TCO of each vehicle for the three BEV-ICEV pairs selected were calculated using the following formula:

$$TCO = Pc + \ Tr \ - TCR \ + \sum_{i=0}^{i} \frac{(Fc + Tc)}{(1+d)^i} \ - \ \frac{(R)}{(1+d)^i}$$

where Pc is the car ́s net price (including value added tax (VAT)), Tr is the sum of other taxes on acquisition, TCR are subsidies received upon purchase, i is the ownership period indicated in years, Tc is the present value of annual circulation taxes, Fc is the present value of petrol/diesel or electricity costs, R is the resale value of the vehicle and d is the discount rate. Other cost parameters such as yearly insurance or repair and maintenance costs were not considered due to strong user dependency. Following Lévay et al. (2017), we assumed that cars were owned for four years, the annual kilometers travelled were 12 000 km, and the discount rate for future costs and income was 4 % (Krail & Plötz, 2023; Palmer et al., 2018). Costs were calculated by using 2017 fuel and electricity prices for each country selected (annual average price level). Prices were considered to be constant for the four years of the TCO calculation.

For illustrating the effect of fiscal incentives on TCO of the BEV-ICEV pairs in a representative way and sensitive to segmental differences in car categories, the TCO difference was calculated as the percentage of the TCO for the conventional car model per country and for each car segment. Then, the results for each country were summed up. The resulting values are interpreted to demonstrate the effect of fiscal incentives on the TCO for BEV’s across the three car categories considered. According to our calculations, TCO for BEV’s are on average 101,26 % of the TCO for their ICEVs counterpart among the countries selected and relative to the three car segments observed.[9] For more detailed results, please see tables C.1 to C.6 as well as table C.7.

Following this, we performed a cluster analysis using the Tosmana software (Cronqvist, 2019) to group the values into four categories. The thresholds of the four groups were used to group the cases along a fuzzy scale. The analysis resulted in three thresholds: 186,82 %, 107,57 % and 28,31 %, with a median of 77,00 %. As a result, cases with a weaker fiscal effect on the TCO of BEV’s across the car segments B, C and S are assigned to the groups defined by the thresholds with the highest values. The following calibration was utilized: cases with a result higher than 186,82 % are assigned a set membership score of 0.0; cases with a result higher than 107,57 % are assigned a set membership score of 0.33; cases with a result higher than 28,31 % are assigned a set membership score of 0.67; cases with a result lower than 28,31 % are assigned 1.0.

Thirdly, calibration of condition B depends on the number of recurring incentives on the local level including non-monetary as well as monetary benefits for BEV users. The calibration 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 covers financial support when installing charging equipment on private property (e.g., home or workplace) and curb side as well as lamp post charging for multi-unit dwellers in addition to the provision of public charging stations. Thus, calibration depends on the policies taken to promote charging infrastructure in a user-centric way: cases with not a single incentive are assigned a set membership score of 0.0; cases that provide financial support for purchasing and installation costs of charging equipment on private property exclusively (home and/or workplace) are assigned a set membership score of 0.33; cases that have implemented a specific curb side charger or lamp post charging program (on-street) for multi-unit dwellers receive a set membership score of 0.67; cases that have implemented a specific curb side charger or lamp post charging and additionally provide a financial support for purchasing and installation costs of EVSE at home and/or work-place are assigned a set membership score of 1.00.

Fifthly, condition D covers policies that intend to push ICEV’s out of the urban, such as introducing Low Emission Zones that ban specific petrol or diesel-driven cars or higher parking fees for conventional cars. Calibration expresses the number of recurring policies: cases with no policy push measure are assigned a set membership score of 0.0; cases with one push measure receive a set membership score of 0.33; cases with two push measures are assigned a set membership score of 0.67; cases with three or more push measures receive a set membership score of 1.0.

Table 3 provides an overview of the calibrated cases and the raw data matrix. There are 7 out of 2^4 possible policy configurations present. Thus, there are nine logical remainders indicating possible policy configurations that are not present. As such, the problem of limited diversity[10] is moderate. Table 3 shows the raw data matrix. It contains the calibrated data for each case according to the calibration scheme outlined.

In line with the analytical guidelines, the analysis of necessity of single conditions is conducted. This would identify singular conditions that are necessary for the outcome to occur. Putting it differently, a condition is necessary if, whenever present, the outcome condition is also present. For our research model, we analyzed if conditions A, B, C and D are necessary for a successful progress in urban BEV diffusion to

Table 3
Raw data matrix.

Case-ID	Remote condition		Proximate conditions		Outcome condition
	A	B	C	D	Y
Amsterdam (NL)	0,67	0,33	1,00	0,67	0,67
Brussels (BE)	0,00	0,00	0,33	0,00	0,00
Budapest (HU)	0,33	0,33	0,00	0,33	0,00
Copenhagen (DK)	1,00	0,00	0,00	0,33	1,00
Dublin (IE)	0,67	0,33	0,33	0,00	0,67
Graz (AT)	0,67	0,33	0,33	0,33	1,00
Hamburg (GER)	0,00	0,33	0,00	0,00	0,33
Helsinki (FI)	0,00	0,00	0,00	0,00	0,00
London (UK)	0,67	0,33	1,00	0,67	0,67
Madrid (ES)	0,67	0,67	0,00	0,33	0,00
Milan (IT)	0,00	0,33	0,00	0,33	0,00
Oslo (NO)	1,00	1,00	0,67	0,33	1,00
Paris (FR)	1,00	0,33	0,67	0,33	0,00
Stockholm (SE)	0,33	0,00	0,33	0,67	0,67

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[8] For more details see tables B.1 to B.6 in the appendix (section 9.).

[9] When considering TCO calculations for the three car segments covered, the relatively high mean value can be traced largely to TCO results in car segment "B" (small). In some countries (BE, GER, HU, IT) TCO for an EV are more than double the TCO of the diesel/petrol driven counterpart.

[10] Limited diversity indicates a lack of empirical evidence and can be detected by investigating rows without cases in them. The problem with it is that when proceeding with the process of minimization, the quality of any statement regarding causal inference is less consistent (cf.: Schneider and Wagemann 2012: 92ff.).

happen. There are three parameters that must be considered when testing for necessity: *consistency, coverage* and *Relevance of Necessity (RoN)* (Mello, 2021).[11] We used the QCA package for R by Duşa (2019) for calculations to assess the quality of our fsQCA. 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 & Wagemann, 2012). Table 4 provides the results of the necessity test. It shows that none of the four conditions are necessary for the outcome to be present.

Next, the analysis of sufficiency is executed. The data matrix was converted into the so-called truth table. In a truth table all logically possible combinations of the conditions (2^4) are represented. Each row in a truth table is representing a possible configuration of the policy conditions that is sufficient for the outcome to occur. As done earlier when testing 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 condition and the outcome. The central parameters are consistency scores for sufficiency (“inclS”) and proportional reduction of inconsistency (PRI).[12] We also used the QCA package for R by Duşa (2019) for this. The resulting truth table for our study is represented in Table 5. A consistency cut-off value of 0.75 was chosen. The value defines to which degree the statement of sufficiency of a policy configuration is in line with the empirical evidence at hand. The cut-off value of 0.75 is situated within the range of cut-off values for consistency in good practices for QCA (ibid.: 123 ff.).

In a consecutive step, the truth table was processed according to the procedure of logical or Boolean minimization. Configurations of conditions are linked by three Boolean operators: Boolean AND (·), Boolean OR (+) and Boolean NOT (~).[13] It covers the formal analysis of the policy configurations in the truth table by applying the Consistency Cubes algorithm. Ultimately, the logical minimization process identifies the simplest possible logical expression that is related to a positive outcome (Schneider & Wagemann, 2012). We selected the so-called intermediate solution for the various sufficiency statements leading to the occurrence of the outcome. This presents a concise solution formula that needs to be interpreted. The analysis reveals two prime implicants[14] that co-occur with the presence of outcome (Y) (Boolean operators are used for notation):

Table 4
Analysis of necessity.

Condition	Consistency of necessity	Coverage of necessity	Relevance of necessity
Condition A	0.416	0.474	0.654
Condition B	0.373	0.691	0.909
Condition C	0.290	0.498	0.800
Condition D	0.289	0.535	0.828
~Condition A	0.750	0.857	0.875
~Condition B	0.792	0.653	0.519
~Condition C	0.792	0.678	0.608
~Condition D	0.835	0.689	0.589

$B*C+C*D \rightarrow Y$

It expresses that there are two alternative sufficient configurations of BEV policy conditions that indicate successful progress in BEV diffusion in cities in Europe. Table 6 shows the parameters of fit for the two sufficient configurations. Both configurations, B*C and C*D, have a consistency score above 0.75 confirming a good fit between the empirical evidence and the assumed set-theoretic relationship (Mello, 2021). The coverage scores in contrast are relatively low according to good practice standards of QCA, but still render a plausible explanation of the outcome. While the former configuration is covered by case Oslo (NO), the latter is linked to cases Amsterdam (NL) and London (UK).

In a nutshell, there are two alternative sufficient configurations of policy conditions that produce the favorable outcome. Consequently, different configurations of policy conditions lead to the promotion of BEV’s and thus indicate *equifinality* as outlined in Section 2. It also indicates that there is no condition that can produce the outcome on its own. When we investigate configuration B*C for instance, it becomes obvious that condition B is insufficient on its own, but is needed to form a sufficient conjunction with C. It thus is insufficient, but a necessary part of a conjunctural condition which is itself unnecessary but sufficient for the outcome (Y). Therefore, condition B is an INUS condition[15] (cf. Mackie, 1980). The same holds for condition C of the same configuration and conditions of configuration C*D. It is clear that no policy condition appears independently of other policy conditions. Instead, there are multiple ways in which BEV diffusion in cities may be successful, which underscores the equifinal and multifinal characteristic of urban BEV diffusion. This confirms previous research (Held & Gerrits, 2019; Hardman, 2019). Also, the findings are congruent with assumption about policy mixes for governing transitions as outlined in the introduction of this article. Singular BEV policies that only address one aspect do not have a linear effect on BEV uptake in European cities. Rather, BEV policy mixes are achieving change by interacting across national and local levels with other contextualized factors in a dynamic and complex way (see also Edmondson et al., 2019; Rogge & Reichardt, 2016).

5. Interpretation of the results

This section takes a closer look at both configurations. Starting with the *first* configuration, BC is covered by case Oslo (NO). The combination of monetary and behavioral privileges for BEV-users as well as monetary incentives to promote charging infrastructure to promote BEV uptake is in line with earlier findings (Cui, 2021; Bernard et al., 2021). Local policies in Oslo (NO) put a great of emphasis on behavioral aspects to reinforce convenience for BEV users. Among all the cities covered in this study, the Norwegian capital has the most recurring monetary and non-monetary policies implemented on the local level. Since 2005, BEV’s are allowed to access bus lanes (Aasnes & Odeck, 2023). By doing so, Oslo ́s municipality grants BEV-users more convenience, especially during rush hours when traffic tends to be busy. Due to the rapid increase of BEV’s on Oslo ́s streets, since 2017 a BEV must transport at least two persons to allow for access to bus lanes (Hall et al., 2020). Additionally, BEV-users have been paying lower rates when using toll roads and ferries. Since 2017, fees are up to a maximum rate of 50 % of the rate ICEV-users must pay (Aasnes & Odeck, 2023; Bernard et al., 2021). Coming full circle with recurring incentives for BEV-users, BEV’s are entitled to reduced parking fees since March 2017. Under the current policy, BEV-users may pay 20 % of the regular fees (Oslo Kommune, 2024). Before, parking had been free of charge between 1999 and 2017 (Aasnes & Odeck, 2023; Hall et al., 2020). The presence of condition C underscores the relevance of a monetary incentives for the extension of

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

[12] For more information about the analysis of sufficient conditions, please see Mello (2021), p. 108 ff..

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

[14] Prime implicants are the end products of the logical minimization process.

[15] 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).

Table 5
Truth table.

Row	CON_A	CON_B	CON_C	CON_D	OUT	n	incl	PRI	Cases
12	1	0	1	1	1	2	0.858	0.754	1, 9
15	1	1	1	0	1	1	0.858	0.752	12
11	1	0	1	0	0	1	0.711	0.330	13
9	1	0	0	0	0	3	0.703	0.629	4, 5, 6
2	0	0	0	1	0	1	0.503	0.404	14
13	1	1	0	0	0	1	0.427	0.332	10
1	0	0	0	0	0	5	0.264	0.082	2, 3, 7, 8 11
3	0	0	1	0	?	0	-	-	
4	0	0	1	1	?	0	-	-	
5	0	1	0	0	?	0	-	-	
6	0	1	0	1	?	0	-	-	
7	0	1	1	0	?	0	-	-	
8	0	1	1	1	?	0	-	-	
10	1	0	0	1	?	0	-	-	
14	1	1	0	1	?	0	-	-	
16	1	1	1	1	?	0	-	-	

Table 6
Consistency and coverage for the sufficient conditions identified.

Number	Sufficient configuration	Consistency	PRI	covS	covU	Cases
1	B*C	0.858	0.752	0.331	0.111	Oslo (NO)
2	C*D	0.876	0.802	0.388	0.055	Amsterdam (NL), London (UK)

charging stations as part of a demand- and user-oriented strategy approach. While many European countries realise the provision of public infrastructure through a supply-focused strategy, Oslo demonstrates a complementary strategy (Wappelhorst et al., 2020). The roll-out of charging infrastructure in a user-centric way is perceived as a pre-condition for successful BEV market uptake (Hall et al., 2020). Oslo has implemented grants that cover a part of the costs for the installation and purchase of BEV charging equipment and address home and workplace charging on private land as well as charging points for urban residents in condominiums and apartment buildings. The municipality of Oslo has provided a grant of maximum 20 % of approved investment costs (max. NOK 5.000 per charging point) on private land (home or workplace) and for residents in condominiums as well as housing cooperatives (grant max. NOK 1.000.000) (Oslo Kommune, 2020; Norsk Elbilforening, 2017).

Secondly, configuration C*D is covered by cases Amsterdam (NL) and London (UK). Again, the presence of condition C confirms the importance of monetary incentives towards a demand- and user-centric extension of charging stations in the urban. In Amsterdam (NL), a unique demand-driven approach towards charging station extension has been implemented since 2009. It mainly addresses on-street parking for urban residents without private land and was combined with subsidies for private individuals and companies with property. It is a sensible strategy: >90 % of residents in Amsterdam (NL) do not own a private parking space. As a result, the municipality provided a request and application scheme to BEV owners. Charge points near the homes of BEV users could be requested and individuals could apply for subsidies to build a charging point on private land (Bernard et al. 2021; Van der Giessen, Van der Linden, Bertelman, & Bardok, 2018). In London (UK) a different approach has been implemented. The Office of Low Emission Vehicles (OLEV) has introduced an encompassing set of support programs for home and workplace charging and private land as well as on-street charging for residential parking spaces that are not privately owned by its users. Since 2014, the “Electric Vehicle Home Charge Scheme” provides a grant towards the costs for purchasing and installing a charge point. The “Workplace Charging Scheme” is a voucher-based scheme to grant applicants with financial support towards upfront costs for charging equipment and its installation. Complementary, the “On-street Residential Charge Point Scheme” concerns local authorities, who can apply for funding to support the procurement and installation of on-street charging points for residential use (Office for Low Emission Vehicles, 2014; 2016). The presence of condition D underscores the importance of push and pull measures to promote the uptake of BEV’s in the urban. It is fully in line with earlier findings (Held & Gerrits, 2019; Hardman, 2019). The City of Amsterdam (NL) has taken up the composition of push and pull policies by introducing higher fees for on-street parking. Parking fees are the highest in the city center and are decreasing with distance to the center (Ostermeijer, Koster, Nunes, & van Ommeren, 2022;). In contrast, owners of BEV’s have been receiving parking privileges since 2009. BEV-owners are prioritized on the parking permit waiting list (Gemeente Amsterdam, 2024; Bernard et al., 2021). Additionally, the City of Amsterdam has introduced a low emission zone that restricts access for ICEV’s. For the long term, Amsterdam has outlined a strategy to have emission-free transportation until 2030. An emission-free zone will firstly be introduced in the city center covering specific vehicles. Incrementally, the emission-free zone will expand to the A10 ring by 2025 and beyond by 2030 (Gemeente Amsterdam, 2019). Case London (UK) has followed a similar approach. There was a low emission zone implemented that restricts access for polluting vehicles . The zone has been extended to an ultra-low emission zone. Vehicles that do not meet the zone's standard must pay a daily fee. BEV’s are freed from any charges (Transport for London 2024; Cui, 2021). Additionally, parking fees in the City of London have been prioritizing BEV’s by putting higher charges on older petrol or diesel driven vehicles (The Royal Borough of Kensington and Chelsea, 2024).

All in all, the empirical findings show that local recurring monetary and non-monetary policies are part of policy configurations that form complementary mechanisms to promote the uptake of BEV’s. Cities in Europe with high BEV’s diffusion rates have adjusted their policies accordingly, as Oslo (NO), Amsterdam (NL) and London (UK) exemplify.

6. Conclusion

6.1. *Summary of results*

This research aims to investigate under which configurations of BEV policies at local and national levels the transition towards BEV’s is more likely to occur. Our findings can be summarized as follows: either a combination of recurring incentives on the local level including non-monetary as well as monetary benefits for BEV users *and* financial support when installing charging equipment for multi-unit dwellers in addition to the provision of public charging stations (i.e., B*C) *or* a combination of said financial support for charging stations *and* push-measures aimed at ICE's (i.e., C*D) both associate with the progression towards the stated policy goals. Our findings confirm earlier findings that the interplay of push and pull measures on the local level to promote the diffusion of BEV's in the urban is important. The solution term (BC + CD → Y) confirms that no sufficient policy condition on its own is responsible for the favorable outcome to be present. Instead, two different BEV policy configurations are sufficient. The findings indicate that policy makers can follow multiple pathways when composing an effective BEV policy mix by tailoring it to the local level (i.e., equifinality).

6.2. *Practical recommendations*

By referring to a rich and unique empirical data set covering the time span between 2017 and 2021 and the most relevant BEV policies across the national and local levels, our findings confirm previous research that demonstrates the importance of combinations of push and pull measures to foster the uptake of BEV's. It highlights the matter of different policy foci of BEV diffusion strategies that must be adjusted to the local level. Condition A, the effect of fiscal incentives on the TCO of BEV's, is not part of the solution term with the consistency level selected. Though, condition A is part of the policy configurations leading to the outcome to be present (see: Table 5). The assumption of fiscal incentives having a linear effect on the increase of BEV registration numbers is invalidated. Rather, fiscal incentives on the national and local BEV policy incentives need to be perceived in the context of what happens locally, indicating that the transition to BEV's is subject to complex causation.

6.3. *Limitations and future research*

We would like to highlight the main limitations of our research approach. Firstly, the number of cases covered is relatively limited. In our model, only eight out of 14 cases are linked to occurrence of the outcome. As mentioned in the analysis, coverage of the configurations leading to successful progress in BEV adoption appears to be relatively low. This indicates that there are other pathways to the solution that were not covered in the model we developed. Consequently, validity of our results is limited. One important reason for a comparatively small case sample is data availability on the local level. Our research model demands comprehensive place-specific data covering city-related BEV targets, BEV registration data and BEV incentives. Such that is not always available. Research in the future could add more cases to the sample once more data is published.

Secondly, one promising avenue for future research is the incorporation of time in a QCA (Pagliarin & Gerrits, 2020). The two sufficient policy configurations we found only hold true for a certain timeframe (mainly between 2017 and 2021). Diffusions of BEV's are long-term processes that play out at various levels. Therefore, our findings only highlight a specific period, a snapshot, of what is a much longer transition process. Our current approach is not sensitive to the way a transition develops over time. Our data indicates that policy mixes were indeed adapted compared to a previous time point. Pagliarin and Gerrits (2020) discuss various ways in which processes can be compared when using QCA in way to integrate case-based time dynamics (see also: Verweij & Vis, 2021).

Thirdly, next to the matter of time, we would like to point out that a QCA research approach only allows for a limited set of conditions to be integrated. Consequently, we build on prior research about BEV uptake and tried to cover the most relevant polices across national and city levels (Hardman, 2019; Morrison & Wappelhorst, 2022; Münzel et al., 2019; Wappelhorst et al., 2020). For future research, we recommend considering other policy conditions, especially the ones present in cities (e.g., BEV car-sharing schemes, awareness campaigns etc.). Also, covering a different geographical region beyond Europe would be interesting (Austmann, 2021; Hardman, 2019).

Ultimately, a configurational approach to understanding the complex causation of transitions, such as the one for BEV adoption in cities, can help to assess which policies work and which do not. As demonstrated by in this paper, QCA offers an alternative methodological approach that aids the analysis of BEV policies across both national and city levels. We see QCA as a complexity-informed research approach and method has the potential to add valuable explanatory power to the dynamics of policy mixes and complex causalities to govern sustainability transitions.

Appendix B. Supplementary material

Supplementary material related to this article consists of two Excel files. Excel file one, labelled as "FILE 1″, provides data and sources for TCO calculations for all car models and segments. Excel file two, labelled as "FILE 2", provides data and sources for all conditions investigated.

CRediT authorship contribution statement

Tobias Held: Writing – review & editing, Writing – original draft, Validation, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Lasse Gerrits:** Validation, Supervision, Methodology, Investigation, Data curation.

Declaration of competing interest

Herewith, all authors declare that they have no potential conflicts of interest.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.urbmob.2025.100114.

Appendix A

Table A1, B1, C1, C2, C3, C4, C5, C6, C7, D1

Table A1
Overview of data for proximate conditions.

Case-ID	Recurring incentives	Strategy of infrastructure extension	Sanctions on conventional car usage	Sources*
Graz (AT)	Free parking	Support of public charging infrastructure;	Low Emission Zone	Bundesministerium Klimaschutz, Umwelt, Energie, Mobilität, Innovation und Technologie 2021; E-mobility

(*continued on next page*)

Table A1 (*continued*)

Case-ID	Recurring incentives	Strategy of infrastructure extension	Sanctions on conventional car usage	Sources*
		grant schemes for home and workplace charging and residents in apartment buildings		Modellregion Graz 2017; Stadt Graz 2015, 2022; Kommunalkredit Public Consulting GmbH 2022; Urban Access Regulations in Europe 2022
Brussels (BE)	*None*	Support of public charging infrastructure	*None*	City of Brussels 2022; Urban Access Regulations in Europe 2022
Copenhagen (DK)	*None*	Support of public charging infrastructure	Price increase of parking fees for conventional vehicles	KØBENHAVNS KOMMUNE 2024; City of Copenhagen 2022; Hall, Moultak, & Lutsey, 2017; EU Urban Mobility Observatory, 2019
Hamburg (GER)	Free parking	Support of public charging infrastructure	*None*	https://www.bundesregierung.de/breg-de/aktuelles/wallbox-foerderung-1819424 https://www.hamburg.de/bwi/elektromobilitaet/17293524/parkprivilegien-e-fahrzeuge/
Madrid (ES)	Free parking; EVs are allowed to access to "Residential Priority Areas"	Support of public charging infrastructure	Low Emission Zones	Ayuntamiento de Madrid 2022; European Commission 2022; Instituto para la Diversificación y Ahorro de la Anergia 2022; Green-Zones.eu 2022
Helsinki (FI)	*None*	Support of public charging infrastructure	*None*	City of Helsinki 2023; 2024 Helsinki Times 2023
Paris (FR)	Free parking (since 2020 limited to a max. of 6 consecutive hours)	Support of public charging infrastructure; grant schemes for home and workplace charging and residents in apartment buildings	Vehicle bans and road closures in the city center (high polluting vehicles banned from city streets on weekdays)	Ville de Paris 2022; Advenir 2016, 2023; Agence Parisienne du Climat 2022; Wappelhorst et al., 2020; Atout France 2022
Budapest (HU)	Free parking	Support of public charging infrastructure	Low Emission Zone	Daily News Hungary 2022; Green-Zones.eu 2022; Urban Access Regulations in Europe 2022
Dublin (IRE)	Recharging for free at public charging stations	Support of public charging infrastructure; grant scheme for home charging	*None*	Sustainable Energy Authority of Ireland 2016,2023; Dublin City Council 2022; Silicon Republic 2020; BBC News 2021; SEAI 2022; Urban Access Regulations in Europe 2022
Milan (IT)	Free parking; EVs are allowed to enter "Limited Access Zones"	Support of public charging infrastructure	Price increase of parking fees for conventional vehicles; Low Emission Zone	Comune di Milano 2022; International Energy Agency 2022; Fleet Europe 2022; Urban Access Regulations in Europe 2022
Amsterdam (NL)	Parking space privileges (residential parking permit priority)	Support of public charging infrastructure; grant schemes for home and workplace charging and residents in apartment buildings	Price increase of parking fees; Low Emission Zone	City of Amsterdam 2019, 2022a, 2022b; Bernard et al., 2021; Hall et al., 2020; Wappelhorst et al., 2020; Van der Giessen et al. 2018
Oslo (NO)	Free parking; access to the bus lane (with more than two persons on board)	Support of public charging infrastructure; grant schemes for home and workplace charging and residents in apartment buildings	Low Emission Zone; congestion tax (cost of the road toll is dependent on the Euro standard and fuel type)	Oslo Kommune 2020; JUST AUTO 2013; electrive 2019; European Alternative Fuels Observatory 2022; Hall et al., 2020; Wappelhorst et al., 2020; Urban Access Regulations in Europe 2022
Stockholm (SE)	*None*	Support of public charging infrastructure; grant scheme for home charging	Price increase of parking fees for conventional vehicles; Low Emission Zone	Hammarby Sjöstad 2024; Skatteverket 2024; Wallbox, 2022; Hall et al., 2020; Wappelhorst et al., 2020; Urban Access Regulations in Europe 2022
London (UK)	Free parking; Parking space privileges	Support of public charging infrastructure; grant schemes for home and workplace charging and residents in apartment buildings	Price increase of parking fees for conventional vehicles; congestion tax	Office for Low Emission Vehicles 2017, 2024; Transport for London 2017; Hall et al., 2020; Wappelhorst et al., 2020; Fleet News 2018; The Royal Borough of Kensigton and Chelsea 2022; London Borough of Richmond upon Thames 2022; Gov.UK 2022; International Energy Agency 2022

* For a full provision of data sources, please see "FILE 2″ in the supplementary material or contact the corresponding author.

Table B1

Overview of key parameter for total cost of ownership (TCO) calculations and data sources.

Key parameter	Note	Data source
Net purchase price	Manufacturer's recommended retail prices including valued added tax.	2017 net purchase prices could be accessed from websites of manufacturers by using the internet archive website www.web.archive.org.
Taxes on acquisition	European Automobile Manufacturers Association's (ACEA) Tax Guide for 2017 was main source.	European Automobile Manufacturing Association (2017)
Annual circulation taxes	2017 ACEA Tax Guide was used as main source.	European Automobile Manufacturing Association (2017)
Subsidies received upon purchase	2017 ACEA Tax Guide was used as main source. In some cases, websites and official documents of governments were additionally used.	European Automobile Manufacturing Association (2017)
Petrol/diesel prices	Average consumer retail prices for 2017 were used.	European Commission (2023)

(*continued on next page*)

Table B1 (*continued*)

Key parameter	Note	Data source
Electricity prices	Average consumer retail prices for 2017 were used.	Eurostat (2022a)
Resale value	Reselling online platform “AutoScout24” provides resale values estimates.	AutoScout24 (2022)

Table C1
TCO calculations Renault ZOE (segment “B”). For a full provision of data sources, please see “FILE 1” in the supplementary material or contact the corresponding author.

Country	Net price RENAULT ZOE	VAT	Sum of other taxes on acquisition	Annual circulation taxes	Direct subsidy received upon purchase	Yearly electricity cost (€)	Value of electricity costs (€/kWh)	Resale value (after 4 years of ownership)	Resale value in percentage	Total cost of ownership RENAULT ZOE
AT [1]	18.990 €	20 %	191,10 €	-	2.500,00 €	315,69 €	0,1978	6.593 €	34,72	11.558,52 €
BE [2]	29.782 €	21 %	-	79,07 €	1.282,33 €	459,17 €	0,2877	10.340 €	34,72	20.631,78 €
DK [3]	32.247 €	25 %	16.820,69 €	1.031,56 €	0,00 €	480,40 €	0,3010	11.196 €	34,72	44.120,25 €
FR [4]	23.700 €	20 %	6,76 €	-	6.300,00 €	280,26 €	0,1756	8.229 €	34,72	10.576,49 €
GER [5]	28.512 €	19 %	26,30 €	-	4.000,00 €	486,46 €	0,3048	9.899 €	34,72	16.895,12 €
HU	20.796 €	27 %	20,13 €	-	3.188,03 €	180,99 €	0,1134	7.220 €	34,72	11.385,16 €
IE [6]	17.490 €	23 %	–	120,00 €	5.000,00 €	375,86 €	0,2355	6.073 €	34,72	8.560,46 €
IT [7]	34.600 €	22 %	455,45 €	-	0,00 €	331,97 €	0,2080	12.013 €	34,72	24.787,14 €
NL [8]	33.590 €	21 %	48,98 €	-	0,00 €	248,34 €	0,1556	11.662 €	34,72	23.386,19 €
NO [9]	24.889 €	*none*	257,11 €	48,74 €	0,00 €	256,16 €	0,1605	8.641 €	34,72	18.013,85 €
FI	23.700 €	24 %	1253,62 €	134,21 €	0,00 €	255,20 €	0,1599	11.454 €	34,72	25.784,06 €
ES [10]	21.000 €	21 %	95,80 €	20,00 €	5.500,00 €	347,45 €	0,2177	7.291 €	34,72	10.001,55 €
SE [11]	20.462 €	25 %	5,71 €	-	4.152,00 €	318,08 €	0,1993	7.104 €	34,72	10.711,20 €
UK [12]	18.933 €	20 %	62,74 €	-	5.133,47 €	296,22 €	0,1856	6.574 €	34,72	13.817,59 €

[1] 2,018 list price; grants already deducted (model bonus (1700€), E-Mobility share importer (1800€), "Umweltförderung" (2500€)).
[2] 2,018 list price; rental fee for battery (59€ per month) already included (net list price: 26,950€).
[3] 2,019 model and list price (Renault ZOE R110 41 kWh).
[4] Excluding battery rental fee.
[5] Including battery rental fee (69€ per month).
[6] 2,016 list price.
[7] 2,019 list price.
[8] 2,019 list price.
[9] List price excl. VAT.
[10] Excluding battery rental fee.
[11] 2,016 list price.
[12] Grant already deducted.

Table C2
TCO calculations Renault Clio LIFE (segment “B”). For a full provision of data sources, please see “FILE 1” in the supplementary material or contact the corresponding author.

Country	Net price Renault Clio LIFE 1.2 16V 75	VAT	Sum of other taxes on acquisition	Annual circulation taxes	Yearly fuel cost (€)	Value of fuel (Petrol/diesel) COST (€/l)	Resale value (after 4 years of ownership)	Resale value in percentage	Total cost of ownership Renault Clio dci 75
AT [1]	12.990 €	20 %	191,10 €	368,48 €	651,36	1,18	10.360 €	79,75	7.145,98 €
BE [4]	16.500 €	21 %	91,50 €	141,17 €	756,24	1,37	13.159 €	79,75	7.395,77 €
DK [3]	16.119 €	25 %	16.459,93 €	1.031,56 €	828,00	1,50	12.855 €	79,75	27.373,64 €
FR [6]	22.950 €	20 %	52,76 €	-	516,60	1,23	18.303 €	79,75	7.400,07 €

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Table C2 (*continued*)

Country	Net price Renault Clio LIFE 1.2 16V 75	VAT	Sum of other taxes on acquisition	Annual circulation taxes	Yearly fuel cost (€)	Value of fuel (Petrol/diesel) COST (€/l)	Resale value (after 4 years of ownership)	Resale value in percentage	Total cost of ownership Renault Clio dci 75
GER [5]	10.407 €	19 %	26,30 €	47,22 €	761,76	1,38	8.300 €	79,75	5.567,22 €
HU [9]	7.482 €	27 %	444,19 €	72,86 €	640,32	1,16	5.967 €	79,75	4.933,55 €
IE [7]	15.790 €	23 %	-	190,00 €	761,76	1,38	12.593 €	79,75	7.347,32 €
IT	14.150 €	22 %	446,32 €	255,42 €	850,08	1,54	11.285 €	79,75	8.001,47 €
NL [10]	15.360 €	21 %	2.282,98 €	801,60 €	850,08	1,54	12.250 €	79,75	12.220,28 €
NO [2]	19.593 €	25 %	4.742,51 €	302,10 €	794,88	1,44	15.625 €	79,75	13.536,49 €
FI	11.734 €	24 %	1.748,32 €	130,30 €	855,60	1,55	9.358 €	79,75	8.854,08 €
ES	9.350 €	21 %	95,80 €	236,00 €	678,96	1,23	7.457 €	79,75	5.797,16 €
SE [11]	11.894 €	25 %	5,71 €	42,56 €	811,44	1,47	9.485 €	79,75	6.067,06 €
UK	18.182 €	20 %	62,74 €	68,45 €	756,24	1,37	14.500 €	79,75	7.480,43 €

[1] Vehicle model: Renault Clio LIFE 1.2 16V 75.
[2] Vehicle model: Renault Clio LIFE 1.2 16V 75; 2018 list price.
[3] Vehicle model: Renahult Clio LIFE 1.2 16V 75.
[4] Vehicle model: Renault Clio dCi 90 (diesel driven).
[5] Vehicle model: Renault Clio LIFE 1.2 16V 75; 2016 list price.
[6] Vehicle model: Renault Clio LIFE 1.2 16V 73.
[7] Vehicle model: Renault Clio LIFE 1.2 16V 75; VRT included.
[9] Vehicle model: Renault Clio LIFE 1.2 16V 73.
[10] Vehicle model: Renault Clio LIFE TCe 90 ECO2.
[11] Vehicle model: Renault Clio 0,9 TCe 90hk.

Table C3

TCO calculations Nissan Leaf (segment C). For a full provision of data sources, please see "FILE 1″ in the supplementary material or contact the corresponding author.

Country	Net price NISSAN LEAF	VAT	Sum taxes on acquisition	Annual circulation taxes	Direct subsidy received upon purchase	Yearly electricity cost (€)	Value of electricity costs (€/kWh)	Resale value (after 4 years of ownership)	Resale value in percentage	Total cost of ownership NISSAN LEAF
AT [1]	28.806 €	20 %	191,10 €	56,00 €	2.500,00 €	356,04 €	0,1978	14.319 €	49,71	14.320,23 €
BE	32.640 €	21 %	-	79,07 €	1.074,67 €	517,86 €	0,2877	16.225 €	49,71	18.267,65 €
DK [2]	26.615 €	25 %	13.465,87 €	1.031,56 €	0,00 €	541,80 €	0,3010	13.230 €	49,71	33.414,69 €
FR [3]	35.332 €	20 %	6,76 €	-	6.300,00 €	316,08 €	0,1756	17.564 €	49,71	13.375,53 €
GER [4]	27.157 €	19 %	26,30 €	-	4.000,00 €	548,64 €	0,3048	13.500 €	49,71	12.319,24 €
HU [5]	22.402 €	27 %	20,13 €	-	3.434,23 €	204,12 €	0,1134	11.136 €	49,71	9.071,01 €
IE [6]	36.990 €	23 %	-	120,00 €	5.000,00 €	423,90 €	0,2355	18.388 €	49,71	16.410,46 €
IT [7]	29.024 €	22 %	510,24 €	-	0,00 €	374,40 €	0,2080	14.428 €	49,71	17.108,54 €
NL [8]	37.189 €	21 %	48,98 €	-	0,00 €	280,08 €	0,1556	18.487 €	49,71	20.549,46 €
NO [9]	24.931 €	*none*	257,11 €	48,74 €	0,00 €	288,90 €	0,1605	12.393 €	49,71	14.576,36 €
FI	39.300 €	24 %	1.493,4 €	135,79 €	0,00 €	287,82 €	0,1599	19.536 €	49,71	25.542,33 €
ES	20.300 €	21 %	95,80 €	20,00 €	5.500,00 €	391,86 €	0,2177	10.091 €	49,71	6.781,58 €
SE [10]	40.500 €	25 %	5,71 €	-	4.152,00 €	358,74 €	0,1993	20.133 €	49,71	18.385,69 €
UK [11]	29.824 €	20 %	62,74 €	-	5.133,47 €	334,08 €	0,1856	14.826 €	49,71	16.924,06 €

[1] 2,016 Visia model list price.
[2] 2,016 list price.
[3] 2,018 list price.
[4] 2,016 list price; incl..

[5] Amount of funding depends on the gross purchase price of vehicle. In case of Nissan LEAF models, funding is HUF 2 100 000.
[6] 2,016 list price; VRT incl..
[7] 2,016 list price.
[8] 2,016 list price.
[9] List price excl. VAT.
[10] 2,016 list price.
[11] Gov. grant (£4500) already deducted from net price.

Table C4
TCO calculations Honda Civic 1.6 i-dtec s (segment C). For a full provision of data sources, please see "FILE 1″ in the supplementary material or contact the corresponding author.

Country	Net price HONDA CIVIC 1.6 i-DTEC S	VAT	Sum of other taxes on acquisition	Annual circulation taxes	Yearly fuel cost (€)	Value of fuel cost (DIESEL) (€/l) [5]	Resale value (after 4 years of ownership)	Resale value in percentage	Total cost of ownership HONDA CIVIC
AT	20.835 €	20 %	191,10 €	532,16 €	519,48	1,11	13.699 €	65,75	11.904,04 €
BE	22.360 €	21 %	525 €	317,65 €	585,00	1,25	14.702 €	65,75	12.226,67 €
DK [1]	29.054 €	25 %	37.262 €	1.187,26 €	589,68	1,26	19.103 €	65,75	54.789,05 €
FR	29.910 €	20 %	52,76 €	-	575,64	1,23	19.666 €	65,75	13.277,00 €
GER	20.990 €	19 %	26,30 €	151,43 €	547,56	1,17	13.801 €	65,75	10.440,74 €
HU	18.706 €	27 %	545,57 €	97,15 €	547,56	1,17	12.299 €	65,75	9.910,66 €
IE [2]	23.750 €	23 %	-	180 €	589,68	1,26	15.616 €	65,75	11.702,28 €
IT [3]	23.840 €	22 %	546,76 €	340,56 €	650,52	1,39	15.675 €	65,75	13.133,22 €
NL	22.790 €	21 %	4.207,01 €	2.939 €	570,96	1,22	14.984 €	65,75	26.090,05 €
NO [4]	26.840 €	25 %	6.257,62 €	302,10 €	734,76	1,57	17.647 €	65,75	20.124,51 €
FI	25.000 €	24 %	3.250 €	407,34 €	655,20	1,40	16.438 €	65,75	17.832,21 €
ES	20.400 €	21 %	95,80 €	236,00 €	519,48	1,11	13.413 €	65,75	10.510,18 €
SE	23.563 €	25 %	5,71 €	42,56 €	669,24	1,43	15.493 €	65,75	11.416,76 €
UK	25.410 €	20 %	62,74 €	-	655,20	1,40	16.707 €	65,75	11.936,04 €

[1] 2,013 list price.
[2] Model: Smart 1 L VTEC TURBO; VRT incl..
[3] 2,016 list price.
[4] 2,016 list price.
[5] Weekly prices, mean (between 02/01/17 to 26/06/17).

Table C5
TCO calculations Tesla Model S (segment S). For a full provision of data sources, please see "FILE 1″ in the supplementary material or contact the corresponding author.

Country	Net price Tesla model S[1]	VAT	Sum of other taxes on acquisition	Annual circulation taxes	Direct subsidy received upon purchase	Yearly electricity cost (€)	Value of electricity costs (€/kWh)	Resale value (after 4 years of ownership)	Resale value in percentage	Total cost of ownership Tesla model S
AT	69.019 €	20 %	191,10 €	56,00 €	0,00 €	441,49	0,1978	39.258 €	56,88	33.396,24 €
BE	95.480 €	21 %	2.648,00 €	79,07 €	0,00 €	642,15	0,2877	54.309 €	56,88	48.710,39 €
DK	104.462 €	25 %	60.149,69 €	1.032,00 €	0,00 €	671,83	0,3010	59.418 €	56,88	114.061,57 €
FR	83.700 €	20 %	6,76 €	0,00 €	6.300,00 €	391,94	0,1756	47.609 €	56,88	33.162,45 €
GER	69.970 €	19 %	26,30 €	0,00 €	4.000,00 €	680,31	0,3048	39.799 €	56,88	30.365,38 €
HU [2]	86.533 €	27 %	0,00 €	0,00 €	4.800,00 €	253,11	0,1134	49.220 €	56,88	35.406,51 €
IE [3]	98.770 €	23 %	0,00 €	120,00 €	5.000,00 €	525,64	0,2355	56.180 €	56,88	42.263,54 €
IT	83.540 €	22 %	1.217,89 €	0,00 €	0,00 €	464,26	0,2080	47.518 €	56,88	40.879,02 €

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Table C5 (*continued*)

Country	Net price Tesla model S[1]	VAT	Sum of other taxes on acquisition	Annual circulation taxes	Direct subsidy received upon purchase	Yearly electricity cost (€)	Value of electricity costs (€/kWh)	Resale value (after 4 years of ownership)	Resale value in percentage	Total cost of ownership Tesla model S
NL	81.285 €	21 %	48,98 €	0,00 €	0,00 €	347,30	0,1556	46.235 €	56,88	38.238,13 €
NO [4]	61.050 €	*none*	257,11 €	48,74 €	0,00 €	358,24	0,1605	34.725 €	56,88	29.501,23 €
FI	88.200 €	24 %	3.351,6 €	164,27 €	0,00 €	356,90	0,1599	50.168 €	56,88	50.449,64 €
ES	96.300 €	21 %	95,80 €	20,00 €	5.500,00 €	485,91	0,2177	54.775 €	56,88	40.202,34 €
SE	96.452 €	25 %	5,71 €	0,00 €	4.152,00 €	444,84	0,1993	54.862 €	56,88	41.294,42 €
UK [5]	82.535 €	20 %	62,74 €	0,00 €	3.992,70 €	414,26	0,1856	46.946 €	56,88	39.076,02 €

[1] Model specifications: 75D 4WD.
[2] List price for 2012 model.
[3] VRT incl..
[4] List price excl. VAT.
[5] Gov. grant of £3500 already deducted.

Table C6
TCO calculations Audi A7 3.0 TDI ultra (segment “S”). For a full provision of data sources, please see “FILE 1” in the supplementary material or contact the corresponding author.

Country	Net price Audi A7 Sportback 3.0 TDI ultra	VAT	Sum of other taxes on acquisition	Annual circulation taxes	Yearly fuel cost (€)	Value of fuel (diesel) cost (€/l) [1]	Resale value (after 4 years of ownership)	Resale value in percentage	Total cost of ownership Audi A7
AT	61.050 €	20 %	16.748 €	1.191 €	639,36	1,11	34.536 €	56,57	51.647,05 €
BE	49.560 €	21 %	2.417 €	793,72 €	720,00	1,25	28.036 €	56,57	30.853,49 €
DK	94.621 €	25 %	135.613 €	1.032 €	725,76	1,26	53.527 €	56,57	185.550,15 €
FR	60.970 €	20 %	4.103 €	-	708,48	1,23	34.491 €	56,57	34.651,19 €
GER	54.800 €	19 %	26,30 €	425,87 €	673,92	1,17	31.000 €	56,57	29.263,05 €
HU	75.333 €	27 %	1.837,73 €	154,56 €	673,92	1,17	42.616 €	56,57	39.402,32 €
IE [2]	66.760 €	23 %	-	570 €	725,76	1,26	37.766 €	56,57	35.448,29 €
IT	60.900 €	22 %	636,67 €	361,20 €	800,64	1,39	34.451 €	56,57	32.895,83 €
NL	59.175 €	21 %	22.003 €	3.761 €	702,72	1,22	33.475 €	56,57	66.166,83 €
NO	75.468 €	25 %	25.165 €	302,10 €	904,32	1,57	42.692 €	56,57	64.244,21 €
FI	78.998 €	24 %	806,40	1,40	44.689 €	56,57	806,40	1,40	68.544,15 €
ES	62.470 €	21 %	4.784,17 €	896,00 €	639,36	1,11	35.339 €	56,57	39.195,62 €
SE	56.633 €	25 %	5,71 €	170,44 €	823,68	1,43	32.037 €	56,57	29.672,82 €
UK	41.082 €	20 %	62,74 €	1.060,91 €	806,40	1,40	23.240 €	56,57	25.989,27 €

[1] VRT included.
[2] Weekly prices, mean (between 02/01/17 and 26/06/17).

Table C7
Overview of effect on TCO of EV per car segment and country (see also “FILE 1″ in the supplementary material).

Case	Results segment "B"	Results segment "C"	Results segment "S"	Sum
AT	55,19 %	21,33 %	−31,51 %	45,01 %
BE	155,61 %	47,24 %	63,23 %	266,08 %
DK	59,82 %	−39,08 %	−37,19 %	−16,46 %
FI	191,21 %	43,24 %	−26,40 %	208,05 %
FR	24,19 %	−0,10 %	0,10 %	24,20 %
GER	190,58 %	16,46 %	6,90 %	213,94 %
HU	129,38 %	−7,09 %	−7,00 %	115,29 %
IE	8,63 %	39,12 %	23,25 %	71,00 %

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Table C7 (*continued*)

Case	Results segment "B"	Results segment "C"	Results segment "S"	Sum
IT	196,92 %	28,55 %	26,81 %	252,28 %
NL	91,26 %	−14,50 %	−36,60 %	40,16 %
NO	27,65 %	−26,95 %	−51,64 %	−50,94 %
ES	71,28 %	−33,89 %	8,29 %	45,68 %
SE	68,82 %	59,65 %	43,73 %	172,20 %
UK	6,77 %	−1,55 %	44,20 %	49,41 %
Mean:	91,74 %	9,06 %	0,46 %	101,26 %

Table D1
Number of EV's registered between 2017 and 2021 for the cities/countries selected.

CASE-ID	2017	2018	2019	2020	2021	2022	2023	Sources:[***]
Graz (AT)	2279 (14,618)	3188 (20,831)	4391 (29,523)	6393 (44,507)	10,487 (76,539)	3649 (110,287)	n.a.	Das Land Steiermark (2024); Statistik Austria (2024)
Brussels (BE)	883 (6552)	1136 (9244)	1794 (15,338)	2751 (23,983)	4246 (40,851)	7318	9311	STATBEL 2022; ibsa perspective.brussels 2022; 2024
Copenhagen (DK)	1260 (9111)	1273 (10,038)	1841 (15,504)	3247 (31,888)	6005 (66,610)	8828 (112,674)	14,878 (200,108)	Statistics Denmark 2022; European Environment Agency 2022
Madrid (ES)	3346[*] (10,145)	5934[**] (16,407)	11,443[**] (26,799)	14,063[**] (45,057)	n.a. (72,738)	9265 (225,883)	n.a.	Observatoriodel transporte y la logística en España 2022; European Alternative Fuels Observatory 2022
Helsinki (FI)	316	464	916	1702	4465	8097	6275	Statistics Finland (2024)
Paris (FR)	1984 (61,106)	3064 (82,306)	4690 (106,332)	6650 (140,871)	9466 (244,863)	n.a. (244,975)	n.a. (402,670)	Ministère chargés de l'environnement, de l'énergie, de la construction, du logement et des transports - Statistical Data and Studies Service (SDES) 2022
Hamburg (GER)	608 (53,861)	1126 (83,175)	1395 (136,617)	4138 (309,083)	7334 (618,460)	9149 (1013,009)	30,086 (1408,681)	Kraftfahrt-Bundesamt 2023
Budapest (HU)	974 (1996)	1907 (3893)	3243 (6595)	4857 (11,012)	7251 (18,823)	10,378	13,366	Hungarian Central Statistical Office 2022
Dublin (IE)	221 (1946)	n.a. (3641)	n.a. (7267)	n.a. (11,278)	n.a. (19,982)	14,712 (39,280)	n.a.	Central Statistics Office Ireland 2022
Milan (IT)	1420 (7560)	1566 (12,156)	2240 (22,728)	5293 (53,079)	n.a. (118,034)	5088 (158,131)	7284	Automobile club dItalia 2023
Amsterdam (NL)	2241 (20,795)	3692 (43,497)	6768 (104,999)	9234 (172,510)	12,666 (243,664)	15,243 (328,291)	19,766 (442,409)	Rijksoverheid. Regionale klimaatmonitor 2024
Oslo (NO)	24,808 (136,255)	36,148 (190,648)	49,688 (253,464)	67,782 (325,251)	89,723 (460,734)	111,301 (599,169)	119,721	Statistics Norway 2024
Stockholm (SE)	3669 (11,034)	5293 (16,664)	10,285 (30,343)	19,149 (55,734)	36,721 (110,177)	81,637 (197,709)	103,482	Official Statistics of Sweden 2024
London (UK)	7175 (43,267)	9374 (57,175)	14,526 (91,940)	24,707 (191,348)	47,510 (373,493)	75,547 (625,459)	111,703 (8850,122)	Gov.UK. Department for Transport 2024

[*] Please note, that the number refers to the community of Madrid instead of the metropolitan area of Madrid. Thus, the EV number for Madridś metropolitan area is assumed to be smaller.

[**] Number includes plug-in hybrid electric vehicles and gas-driven cars. Numbers are referring to the community of Madrid. Registration for EV for Madrid metropolitan area are supposed to be lower.

[***] Please see "FILE 2″ in the supplementary material or contact the corresponding author for a full provision of data sources.

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