MSc Programme in Urban Management and Development

Rotterdam, the Netherlands

October 2022

Configuration of policy measures for Plug-In Electric vehicle adoption: A qualitative comparative analysis approach in the case of United States.

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Report number: 614274

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Summary

Fleet electrifications are predominantly considered an instrument to lower oil dependency and greenhouse gas emissions from transportation. Accordingly, governments are developing and implementing electric vehicle policies and regulations that improve climate change and market penetration. However, stand-alone policy measures are noticed to lower the diffusion of PEV saturation. Therefore, which comprehensive package of conditions explains PEV adoption to take place? In response, the study employed a crispy-set qualitative comparative analysis approach, that takes the e-mobility policies, regulations, and mandates at the state and federal level across 20 states of the United States by comparing the conditions and cases that can influence PEV adoption and realize the combination of policy measures for e-mobility transition. The result validates the configurational theory, that the government policies trying to unravel several barriers to PEV adoption individually are implausible. As a result, we identified effective financial and incentivizing and construction of fuelling infrastructure in combination with PEV promoting mandates and agreements in combination with EV awareness campaigns that will lead to PEV adoption in the United States. Moreover, the upfront cost of BEVs was minimized mainly by the rebates, tax credits, and exemption of sales tax at the state and federal levels. The financial incentives in both levels have made BEV cost to be competitive, as the BEV TCO was 7.33% on average higher than ICE. Note that, the solution found in this study can't be duplicated for another country as the cases are unique. Besides the conjunction of conditions for PEV adoption occurrence is not the mirror image of the conjunction for the non-occurrence. In conclusion, Policymakers should recognize that policies and strategies that need to promote e-mobility must be constructed and planned as all-inclusive bundles instead of an individual or separate action or policy. Furthermore, the causal relationship of factors and outcome (contingency theory) is now evidently justified that they won't achieve in shifting towards e-mobilities.

Keywords

Electric vehicle adoption, Crisp-set qualitative comparative analysis (csQCA), Configurational theory, Causal complexity, United States

Acknowledgments

I want to thank God Almighty, who gave me the strength to finish the urban management and development master program even though following this program was not easy for me due to the active genocide going on in Tigray, Ethiopia where my parents and immediate families are located in. Not being able to talk to my parents and siblings for more than 500 days due to the siege imposed is still quite challenging.

I want to express my sincere thankfulness to Dr. Dr. Lasse Gerrits (Associate Professor) and Mr. Held Tobias for having me on board for their project - “project Hof” as part of my master’s thesis. I am super grateful since this opportunity offered me to achieve my career goal to research sustainable urban mobility (electric vehicles).

Not only that, but I also want to thank Dr. Dr. Lasse Gerrits (Associate Professor) and Mr. Held Tobias for taking their precious time in supervising, suggesting, and giving me constructive feedback throughout my thesis process.

I want to show appreciation to Sumner Pomeroy and Hanna L. Breetza who took their time to reply to my emails and helped me during data collection (missing data regarding state sales tax and Georgia’s ZEV road map).

I want to be grateful to my family and friends, especially my brother (Kaleb Gebremichael) for being supportive in this difficult time and helping me to achieve my goal.

Lastly, I want to be grateful to Orange Knowledge Programme (OKP) and Institute for Housing and Urban Development Studies (IHS) who offered me the scholarship and master's opportunity to follow.

Abbreviations

AFV	Alternative fuel vehicle
BEV	Fully battery electric vehicle
cs QCA	Crisp-set Qualitative comparative analysis
EV	Electric vehicle
EVSE	Electric vehicle supply equipment
fs QCA	Fuzzy-set Qualitative comparative analysis
GDP	Gross domestic product
GHG	Greenhouse gas
HEV	Hybrid electric vehicle
HOV	High-occupancy vehicles
IHS	Institute for Housing and Urban Development Studies
MSRP	Manufacturer suggested retail prices
PEV	Plug-in electric vehicles
PHEV	Plug-in hybrid electric vehicle
TCO	Total cost of ownership
QCA	Qualitative comparative analysis
ZEV	Zero-emission vehicles
LEV	Low-emission vehicles

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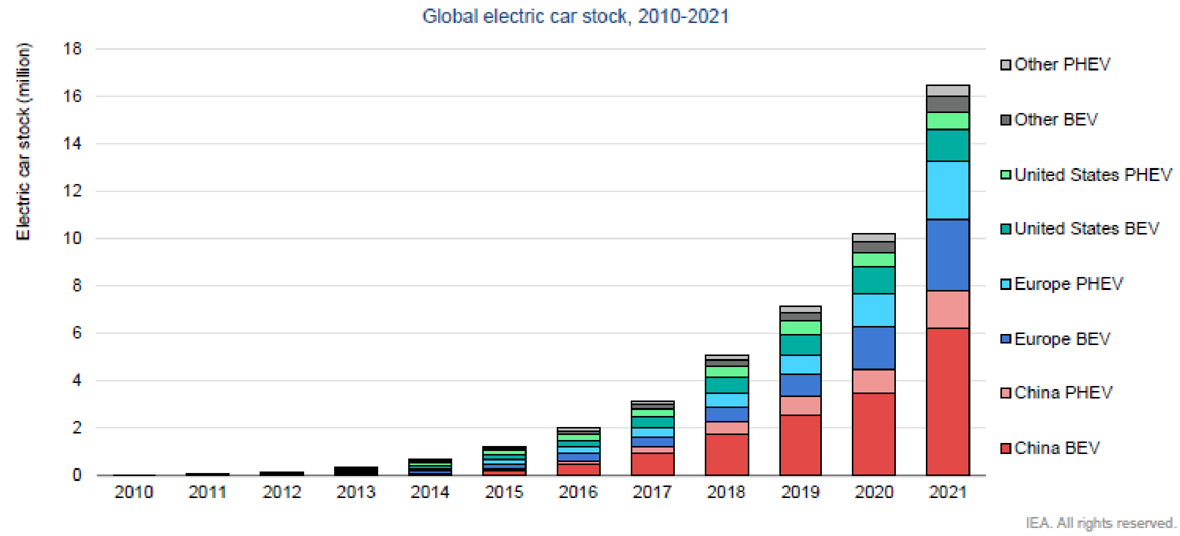
Chapter 1: Introduction

1.1 Background

Electric vehicle (EV) adoption all over the world is now emerging due to government policy measures to tackle the universal climate challenges and step-up market growth. In 2021, 6.75 million full battery EV(BEV) and plug-in hybrid EV(PHEV) sales were recorded globally and showing a 108% increase from the previous year with BEV remarked to have higher sales (71%) compared to PHEV (29%). Both BEVs and PHEVs are under the category of Plug-in EVs. The radical increase in EV sales number in 2021 was affected by Covid-19 but also due to various regulations. This shows that PEV adoption is going back on its track and is expected to have around 10 million sales this year. Out of these all EV types, light-duty EV sales belongs to 4.2% of the total sale in 2020, nearly doubling (8.3%) in 2021 (Roland, 2022). Figure 1 helped us to visualize the international EV market for ten (2010-2021) years with China being the leading country.

Figure 1: Global EV market (IEA, 2022)

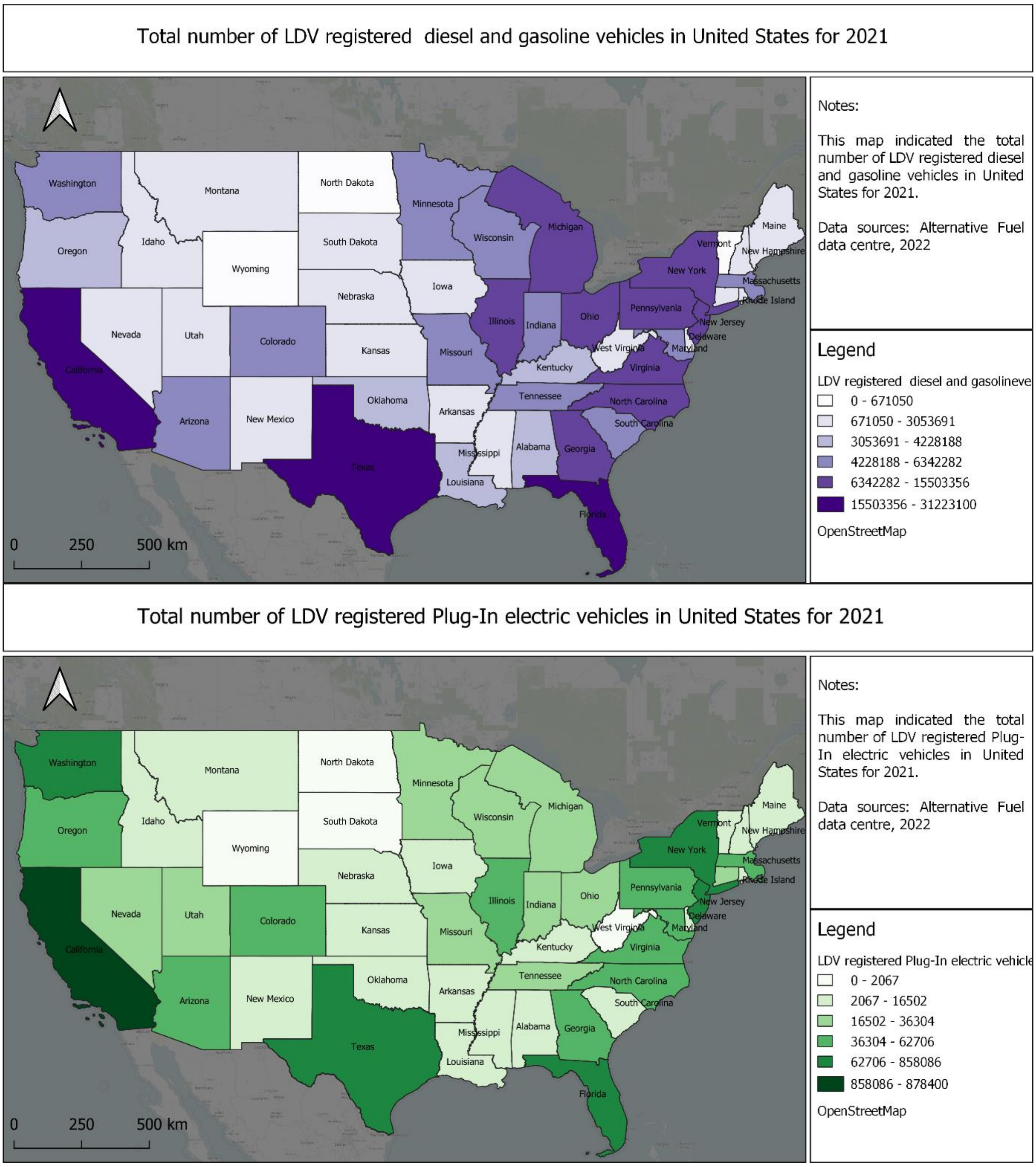


Notes: BEV = battery electric vehicle; PHEV = plug-in hybrid electric vehicle. Electric car stock in this figure refers to passenger light-duty vehicles.
"Other" includes Australia, Brazil, Canada, Chile, India, Japan, Korea, Malaysia, Mexico, New Zealand, South Africa and Thailand. Europe in this figure includes the EU27, Norway, Iceland, Switzerland and United Kingdom.
Sources: IEA analysis based on country submissions, complemented by ACEA; CAAM; EAFO; EV Volumes; Marklines.

According to a 2018 report in the United States, the transportation sector had the main role (28%) for greenhouse gas (GHG) emissions where both passenger cars and trucks contribute 82% of the total transportation emission. More than half a percent (58%) of transportation emission is from light-duty vehicles (LDV) in the United States (EPA, 2020). As a result, fleet electrification, shifting from combustion to electric vehicles, and improvement of fuel efficiency (e.g., avoiding vehicles idly standing for a long period, running with consistent speed) were predominantly regarded as a measure to lower GHG emissions from transportation (Ghandi & Paltsev, 2020; Lutsey, Nicholas & Sperling, 2009).

Most governments have common goals and interests in limiting transportation air pollution and rising the usage of electric cars (Slowik & Lutsey, 2017). Accordingly, governments are developing and implementing EV policies that can improve the market and climate change. The EV market in the United States is continuously growing each year which showed an increase from 300,000 to 550,000 EV sales in 2014 and 2015 consecutively and this shows that the action from the government concerning EVs started to have an effect. According to 2010 global EV sales reports, the United States is recognized among the leading countries accounting for 30% of the total sale following China (Slowik & Lutsey, 2017). Although there is an increase in full-battery EV adoption in the U.S., the number is still small (2% of the total vehicle sale) (Outlook, 2021). Figure 2 shows how the registered LDVs for PEVs are fewer than the number of diesel and gasoline vehicles in 2021.

Figure 2 Registered Light-duty vehicles, NB: Hawaii and Alaska states, are disregarded for producing clear images, done by student: data sources https://afdc.energy.gov/)



Technologies and policies regarding transportation and mobility like EVs are expanding and evolving these days and following that many studies are being carried out in various dimensions to address the challenges. For example, policies measures like incentives for both purchases of PEVs and construction of fuelling infrastructure, carbon pricing, and reduction of electricity prices were assessed for the PEVs in Canadian provinces (Melton, Axsen, & Goldberg, 2017), variable identification and assessment of policy approaches that led to EV adoptions were also investigated by (Kumar & Alok, 2020) and identifying the configurations policy incentives that headed to PEV uptake by (Held & Gerrits, 2019). Accordingly, the study also wants to focus on policies and regulations that can promote PEV adoption in the United States to take part in resolving the climate and PEV market challenges. The theory behind e-mobility transition complexity, the problem statement, and the objective of this study are discussed in this chapter. Refer to chapter 2, 3, 4, and 5 to look at the literature review, methodology, analysis, and conclusion respectively used for this study.

1.2 Problem statement

Although there is a PEV sales increase in the United States, the number is still small (2%) compared to the total vehicle sale in 2020 (Outlook, 2021). Correspondingly, various regulations, incentives, and policies are deployed by policymakers to reduce GHG emissions and EV market growth. Fewer PEV models, high purchase prices, shortage of charging infrastructure, lack of incentives, and other factors remain to be the barriers to EV adoption (Kumar & Alok, 2020). Purchase cost is among the barriers to e-mobility adoption and Norway is the leading country that implemented an effective incentive to make PEVs comparable with other vehicles (Bjerkan, Nørbech, & Nordtømme, 2016a; Bjerkan, Nørbech, & Nordtømme, 2016b; Hardman, Chandan, Tal, & Turrentine, 2017). Not only the barriers, but studies have also been focusing on one variable /factor independently to unravel EV promotion.

The relationship between EV preference and different independent attributes related to policy, monetary, and psychological was assessed and the study mainly focuses on the significance of the independent attributes on EV adoption (Liao, Molin, & van Wee, 2017). Similarly, Huang & Qian (2018) applied the discrete-choice model to know the relation among attributes that affect EV purchases in China and showed that consumers are sensitive to both monetary and service attributes. However, still the study looked at the effect of the independent attribute independently on EV preference. These methods (looking at the relation among variables only) follow the contingency theory, which assumes that the relationship among the dependent and independent variables will be conditioned by a critical variable and the independent variables will have an effect or significance on the dependent variable independently (Doty & Glick, 1994). Nevertheless, the e-mobility transition will not take place by looking at the effect of factors independently. For example, EV promotion in Europe was observed to be favourable if there is incentivizing of fuelling infrastructure construction and monetary incentives together with disincentives that discourage pollutant vehicles (Held & Gerrits, 2019). Likewise, a study in China also looks at the combined effect of psychological and policy conditions for an effective consumer intention in buying EVs. Therefore, both studies showed that the contingency theory has limitations (Ye, Kang, Li, & Wang, 2021).

The contingency theory focuses on how the independent attributes interact by assessing their strength for various scenarios and faces for interpretation over a three-way interaction (Ragin, 2009) as cited in (Ye et al., 2021). Nevertheless, the configurational theory is concerned with the holistic configuration of the conditions not with an individual like the contingency theory (Ye et al., 2021). In configuration theory, the multiple configurations of conditions have an equal effect on the outcome. Moreover, the outcome condition is maximized by identifying a unique pattern of the conditions where these unique patterns are not a simple relationship among two conditions instead it characterizes higher interaction with a non-linear effect (Doty & Glick, 1994) as cited in (Delery & Doty, 1996). Consequently, e-mobility policy attributes interaction that will lead to favorable PEV uptake might be complicated. Because a study revealed to have nine combination patterns of attributes for the intention of buyers to shop online (Pappas, Kourouthanassis, Giannakos, & Chrissikopoulos, 2016).

Generally, there are diverse studies that focused on policy measures' effect independently on EV adoption. while studies regarding the combination of factors that lead to favorable outcomes by applying configurational theory are limited and demonstrated to be the right approach to address the complex e-mobility transition. Thus, this study also wants to fill that gap by studying over two-way interaction of factors and their configuration for PEV adoption in the United States.

1.3 Research objective and research questions

There are limited studies that applied the configurational theory regarding EV penetration. Many studies looked at the effect of independent variables individually on dependent variables (EV adoption) or consider the two-way interaction among independent variables but not more than that, which is following the contingency theory. Allowing more than two interactions among conditions and a configuration of various variables brings a promising result. Yet there is a limited study that deals with a three-way and more interaction that incorporates the configuration theory in EV promotion, especially in the United States. Understanding this, the study will examine the combined interaction of United States' policy attributes to PEV adoption i.e., looking at the holistic perspective of the attributes by employing the configurational perspective. In addition to that, the purchase cost for EVs is the main barrier to the e-mobility transition to happen. Thus, this study also wants to understand how monetary incentives granted by the United State government have a role in BEV's TCO.

Main Research question

How do e-mobility incentives, regulations, and policies in the United States of America influence PEV adoption?

Research sub-questions

1. Which configuration of e-mobility incentives, fuelling infrastructure strategies, regulations, and policy attributes explain favourable Plug-In electric vehicle adoption in the United States?
2. Do the various EV financial incentives produce a visible difference in the total cost of ownership between the full battery and combustion engine vehicles?

1.4 Relevance of the research topic

This study will contribute academically by employing the configurational theory that allows a new understanding of how the current complexity of e- mobility transition can be realized after the interaction of various conditions (EV infrastructure regulations, incentives, and policy attributes). Next, the configuration of conditions that will be discovered and the effect of the monetary incentive on changing the BEV's total cost of ownership (TCO) will have a role for policymakers to examine their decision-making in deciding on EV policies.

Chapter 2: Literature review and hypotheses

The introduction including the focus and locus of the study is considered in the previous chapter and this chapter focuses on what has been studied regarding our topic by reviewing an academic paper.

2.1 Configurational theory

EVs are being introduced again after a long time owing to their cruciality for the environment with improvements made to their model, performance, and coverage range (Coffman, Bernstein, & Wee, 2017). Accordingly, countries like Norway are rapidly adopting EVs compared to others Bjerkan et al (2016) but still, EV adoption goals are not met so far in most countries though the importance of EVs is realized within a short period (Coffman et al., 2017).

The application of contingency theory for solving diffusion of EV saturation is among the hurdles as reviewed in chapter 1. A study by Kim et al. (2018a) tried to look at the interaction between perceived value and EV adoption by including government incentives and policies with environmental traits as a moderating factor. For example, it examined if the EV adoption and charging risk (perceive values) are moderated by government incentives, but this still indicates a two-way interaction among independent variables, and it applied the contingency theory. Various studies contributed to an understanding of financial incentives, non-financial incentives, fuelling infrastructure development strategies, and other policies measures on EV purchases (Bjerkan et al., 2016; Huang & Qian, 2018; Liao et al., 2017; Sheldon & DeShazo, 2017), but they all focused on the contribution of individual factor, meaning the role of these policy instruments independently on EV promotion.

However, Held & Gerrits (2019) demonstrated that the interaction of independent variables altogether could lead to an outcome occurrence. This approves the importance of configurational theory over the contingency theory for EV policies. Likewise, psychological and policy attributes have less contribution in influencing EV promotion independently instead their combined interaction produces a positive outcome. Particularly, a consumer might not afford to purchase an EV even though they are pros of the environment and have an intention in taking their part to tackle greenhouse gas and this can be accomplished when there are incentives that reduce the high upfront cost of EVs (Liao et al., 2017). Implying, EV promotion might not be successful if the psychological attributes are not combined with policies and incentives (Ye et al., 2021).

Ye. et al. (2021) indicated the configurational interaction of psychological traits together with policy measures that can affect the intention of the consumer to buy EVs. These attributes won’t influence the outcome independently but in combination with variables of both attributes. Besides, they revealed several configurations of psychological traits in conjunction with policy measures that successfully impact the intention of the consumer in buying EVs. Another study by Yong & Park, (Yong & Park, 2017) used the configurational theory to understand EV adoption in various countries of the world. He used fuelling infrastructure, monetary incentives, and gross domestic product (GDP) as a condition to understand EV uptake. His results revealed that incentives both exemption of sales tax as well as subsidy upon purchase of EVs together with high GDP were the conjunction found for the sufficient favourable outcome to happen. Not only that sufficient fuelling infrastructure availability in conjunction with incentives was also another conjunction for EV uptakes. This coincides with (Rihoux & Ragin, 2008) study regarding equifinality, having different combinations of the variable to the same result. A qualitative review study additionally found the combined effect of consumer awareness campaigns, program delivery associated with environmental zones, financial incentives, and construction of fuelling infrastructure for EV saturation in the Nordic region (Kester, Noel, de Rubens, & Sovacool, 2018).

According to Delery & Doty (1996), the configurational perspective shows the interaction of more than three independent variables and initiating altogether for a favourable result. Corresponding to the configurational perspective, the connection between the outcome and conditions/factors is asymmetry. For example, psychological attributes are studied to influence EV adoption but there can be conditions that are elements of the psychological attributes that might not influence EV purchase (Ye et al., 2021).

These studies have applied the configurational theory using qualitative comparative analysis (QCA) and qualitative review during their study. Held & Gerrits (2019) used the Crisp-set QCA (csQCA), and both Yong & Park, (Yong & Park, 2017) and Ye. et al. (2021) the fuzzy-set QCA (fsQCA) and Kester et al., (Kester et al., 2018) the qualitative review to understand EV adoption. Accordingly, this study will apply the configurational theory using a cs QCA methodological approach to understand EV uptake in the United States.

2.2. Causal complexity

The analysis of QCA involves the interaction of conditions. Not only that, but it also unites the characteristics of research approaches (qualitative and quantitative methods) that are mainly used independently in studies (Smela, 2021). Smela (Smela, 2021), also claimed that the interaction of the condition for outcome occurrence is subjected to "causal complexity". Where three attributes namely "conjunction", "equifinality" and "asymmetry" characterizes "casual complexity" (Misangyi et al., 2017).

Conjunction means when the combination of the condition altogether generates a favourable outcome to happen. Implying an outcome occurrence by the cause of one condition is impractical instead the interaction of the condition is needed (Gerrits, 2012; Misangyi et al., 2017; Smela, 2021). Particularly, Yong & Park, (Yong & Park, 2017) showed countries that have sufficient fuelling infrastructure together with a subsidy, as well as tax exemptions, led to EV saturation in the market. From this we can understand that tax exemption, charging infrastructure and subsidy are the conjunctions for an outcome to happen. Signifying, EV uptake won't happen autonomously by the effect of incentives or availability of charging infrastructure only.

Equifinality is when an outcome happened due to different conjunction of conditions. which means, there will be different conjunction paths for the positive or negative outcome to occur (Gerrits Lasse, 2018; Ragin, 2000). For instance, a study regarding the governance in China for environmental conflict occurrence in urban facility challenges related to designing, construction, and management has employed the QCA (Li, Koppenjan, & Verweij, 2016). The outcome occurrence was due to three different paths. One of the paths is the presence of large-scale, intense aggressive protests, and time delay of projects in conjunction with the absence of Chinese governmental support. The second path was the absence of both aggressive protests and governmental support together with the presence of the inception phase of a project that led the government of China to decide on environmental conflicts. Thus, three paths are sufficient for the government of China to decide on a conflict that appears concerning environmental conflicts. This means equifinality, having different paths that are liable for the same outcome occurrence.

Lastly, the asymmetry attribute of "casual complexity", means the configuration of the condition for the outcome to happen is not the symmetry for the outcome not to happen (Schneider & Wagemann, 2012). Let's take the study from Yong & Park (Yong & Park, 2017), we said the presence of sales for tax exemption and subsidy in conjunction with the accessibility of fuelling infrastructure are the configurations that are sufficient for EV uptake. However, the absence of fuelling infrastructure doesn't imply for the outcome does not occur. Because the study also indicated the second conjunction for the EV uptake to take place i.e., the presence of high GDP and strong finical incentives sufficient for the diffusion of EV saturation. Denoting, the absence of fuelling infrastructure doesn't lead to EV adoption not happening. Thus, the asymmetry of this configuration or condition does not mean it will lead to EV uptake does not occur.

Note that the outcome in QCA can be negative or positive where positive is related to the outcome presence and negative to the outcome absence. Accordingly, assigning the condition set membership in each case should be carefully handled during calibration, with $0 \geq x > 0.5$ linked with absence /negative outcome (Rihoux & Lobe, 2009) as cited in (Gerrits Lasse, 2018).

When QCA is employed, the identification of factors will be the main step and Marx et.al (2013) affirms that a condition that is expected to have significant interaction and effect on explaining outcome should be chosen for the analysis instead of investigating conditions that define the cases. Accordingly, attributes that are expected to have a considerable effect on EV adoption from previous studies will be assessed here and taken for examining our research questions.

2.3 The total cost of ownership

Incentives given in terms of money for purchasing EVs are among the factors for EV adoption. The financial incentive in Norway is seen in changing EV sales where ICE was loaded with pricey VAT and registration tax. Not only that, but the total cost over the possession years for ICE will also rise due to the circulation tax, fuel cost, and other disincentives that tend to make it less competitive with BEV (Lévay, Drossinos, & Thiel, 2017). A study carried out in Norway evaluated the effect of incentives in encouraging consumers to purchase EVs and obtained exemptions of tax and VAT to have a main role (Bjerkan et al., 2016). But incentives can depend on the size of vehicles as some countries' incentives favour small EVs while others like Norway for a large segment (Lévay et al., 2017).

The TCO is useful to understand the investment of a vehicle that is through the determination of the current and future total cost of EV or ICE, not only focusing on direct purchase cost but also on the future cost that will be acquired (Hardman et al., 2017; Lévay et al., 2017). Owning ICE is much higher than hybrid EV(HEV) but the operating cost for both BEV and HEV is lower than others, unlike the deprecation cost, BEV depreciates quicker (AAA, 2020). Almost every calculation of a vehicle's TCO is influenced by the size and powertrains of the cars as the cost of the automobiles is dependent on the vehicle model year (Burnham et al., 2021). TCO calculated over the vehicle's ownership period is converted to the present value using the discount rate and the equation used by Burnham et al., (2021) is represented in equation 1 where cash flow that is not discounted is represented by Ci, discount rate by d, and n number of years.

$$TCO = \sum_{i=0}^{n} Ci/(1+\mathrm{d})^{i}$$ .... **Equation 1**

Studies showed the effect of monetary grants in reducing the TCO of EVs over a longer period in addition to operational costs. The decision of customers in purchasing EVs is directly influenced by the monetary incentives as EV purchase prices are higher and this barrier can be solved by making EVs competitive by incentivizing them (Hardman et al., 2017). Lévay et al (2017) determined the TCO to realize the association between monetary incentives and EV sales. TCO of BEV in Norway was demonstrated to be lower compared to other countries because the effective monetary incentive offered initiates customers to purchase EVs.

Additionally, the TCO of BEV for three (Netherlands, UK, France) countries were comparable to ICE as the incentives are still offered but not as effective as Norway. Likewise, Palmer et al (2018) observed that the TCO of BEV in the US (California, Texas) and the UK were comparable to ICE due to the financial incentive backs but these incentive grants are not supplied to PHEV. And a study carried out in Sweden by (Hagman, Ritzén, Stier, & Susilo, 2016) developed and evaluated a comprehensive TCO model and found that BEV's total cost over the ownership period in the future can be lower than the ICE because of the monetary incentives. Likewise, a study in Korea that used a survey of EV drivers revealed the importance of financial incentives in motivating a consumer to adopt EVs while EV charging risk was noticed to be the barrier (Kim, Oh, Park, & Joo, 2018b). These studies are looking at the effects of monetary incentives on EV sales independently which leads to unsuccessful EV uptake, but we can understand that financial incentives might have effects on EV sales and drop EV TCO. Studies have also found the presence of financial incentives together with other factors can lead to EV uptakes (Held & Gerrits, 2019; Kester et al., 2018; Ye et al., 2021; Yong & Park, 2017).

TCO incorporates independent variables (Incentives that reduced the purchase-based costs, operational costs, taxes, etc.) related to the expenses of the vehicles. The effect of financial incentives in EV promotion was recognized through TCO (Held & Gerrits, 2019). Purchase prices, VAT, sales tax, subsidies, yearly circulation tax, resale value, and cost of fuel were the variables used to calculate the TOC (Held & Gerrits, 2019; Lévay et al., 2017). Both studies excluded variables that are dependent on user behaviour like maintenance, repair, and insurance costs through TCO computation. However, e- mobility promoters pronounce those vehicles that have lower operating costs will compensate for the high upfront costs over a longer period (Breetz & Salon, 2018; Burnham et al., 2021). Because the TCO calculation involving these variables is not only dependent on the cost of the vehicle but also consumer behaviour (Stephens, Birky, & Dwyer, 2020). Moreover, the future cost of an EV is lesser within the ownership period as it does not require fuel consumption and it has a lower maintenance cost, an advantage for EVs to balance extreme purchase costs (Hardman et al., 2017). Beetz &Salon include insurance and maintenance costs in the TCO model as maintenance cost for BEV is lower than the ICE and might influence lowering the total cost within the ownership period. similarly, Hagman et al (2016) also found the cost competitiveness of BEV with both ICE and PHEV and considered insurance and maintenance, and repairs variables in their study. Therefore, financial incentives' role in EV adoption will be recognized through TCO by incorporating ten variables that are discussed in chapter 3.

2.4 Incentives

Kumar et.al (2020) revised different literature reviews to understand the factors that influence EV adoption and stated that policy measures like charging infrastructure and incentives are mainly studied. The acceptability and market penetration of EVs were reinforced with the benefits like incentives, regulations (banning), and policies since it offers differentiated benefits to the consumer (Kim et al., 2018). Incentives can be direct cash received during the purchase of the vehicle or they can be use-based after buying the vehicle and these are categorized as monetary and non-monetary incentives. Being exempted from paying toll roads, taxes, parking, EV charging, and getting subsidies are attached to financial incentives (Held & Gerrits, 2019; Liao et al., 2017; Shafiei et al., 2018). while having permission to access High-occupancy vehicles (HOV), bus lanes, free parking and charging, and exemption to emission inspection are examples of non-financial incentives that are more directed at use (Held & Gerrits, 2019; Huang & Qian, 2018; Wee, Coffman, & La Croix, 2019).

Free parking spaces and access to buses or HOV lanes are taken as non-financial incentives (Kim et al., 2018). Plate access control was among the non-financial incentive in a study carried out in China and revealed to be a core element for consumers' intention to buy EVs (Ye et al., 2021). In terms of non-financial incentives, access to HOV and bus lanes were a critical factor for some respondent in Norway and China in buying EVs (Bjerkan et al., 2016; Wang, Li, & Zhao, 2017a). According to Seldon et. al. (2017), Policies concerning access to HOV lanes are also attributed to the 25% of the EV registration in California from the 2011 to 2013 period.

States and/or cities accept EVs differently due to the various policy support across the United States. Policy measures regarding monetary and non-monetary incentives, fuelling infrastructure and awareness campaigns are expected to unravel the consumer impediment to adopting these technologies (National Research Council, 2015; Slowik & Lutsey, 2017). Hardman et.al (2017) studied the monetary incentives to assess the market acceptance of Plug-in EVs and recommended having non-monetary incentives alongside the financial incentives will bring better market acceptability. Comparably, a study in Europe also shows the presence of non-financial incentives together with the absence of financial incentives, expansion of fuelling infrastructure, and disincentive towards ICE leads to EV uptake. However, the significance of incentives is investigated by many researchers but there is the is lack of studies regarding the amount required and when these incentives should be applied (Coffman et al., 2017). Therefore, access to HOV lanes, Free parking, Free charging, reduction of toll fees, and exemption of emission inspection is seen to have contrition in EV adoption.

2.5 Electric vehicle Fuelling infrastructure

Infrastructure attributes have also a role in EV market penetration. For instance, the Provision of charging infrastructure was presented as a key factor for EV sales. Growing the number and range of installations was also related to lowering range anxiety (Coffman et al., 2017). Infrastructure like EV charging stations in public, workplace and private have a substantial role in changing the EV market and technological transition because consumers won't be concerned regarding where to charge their vehicles (Bui, Slowik, & Lutsey, 2020). Investment in EV charging will be key in solving the charging risk and range anxiety that hinders EV acceptability, and this needs a considerable study concerning the deployment and provision of the infrastructures (Kim et al., 2018).

However, studies showed that EV adoption will be successful when fuelling infrastructure is combined with monetary incentives(Yong & Park, 2017). Yong & Park, also showed that countries that have high GDP in conjunction with financial incentives are adopting EVs although they lack fuelling infrastructure countries that have a higher financial incentive, lack fuelling infrastructure have low EV diffusion. Implying Countries lacking fuelling infrastructure but with strong finical incentives must work on their policies towards charging infrastructure as it is difficult to transform the economic level of the country within a short period. Similarly, Held & Gerrits (2019) found the presence of financial incentives and disincentives that discourage ICE users in conjunction with fuelling infrastructure will lead to EV uptake in Europe. The combined factors that headed for the favorable outcome are different across countries, but we can see factors as standalone factors have less capacity to lead to e-m0bility transition.

EV sales in Norway were positively correlated with several charging infrastructures but lacked a causal relationship. EV sale is expected to increase when the density of charging rises at a regional level and this can be due to incentives given to the consumer for EV supply equipment (EVSE) (Mersky, Sprei, Samaras, & Qian, 2016). Similarly, average PEV sales per person in the United States were found to be significantly influenced by infrastructure charging and incentives related to tax according to 2008-2016 sales data (Narassimhan & Johnson, 2018a). On contrary, the effect of charging infrastructure was investigated in terms of density (number of charging/1000miles[2]) by Wee et al., (Wee, Coffman, & La Croix, 2018)and found to have an insignificant effect on EV registration unlike subsidy and access to HOV lanes. Possibly, the EVs had a high driving capacity range i.e., Holding more battery. As Tesla models were found to be less influenced by the availability of charging infrastructure since drivers will have less range anxiety and focus mainly on incentives during purchasing (Narassimhan & Johnson, 2018).

Sierzchula et al (2014) additionally assessed the connection between EV sales at the national level with financial incentives, charging facilities, and socio-demographic characteristics for 30 countries and realized that EV charging facilities and financial incentives have a positive relationship between the increase of EV sales. Further, it stated that country's EV sales will double for every 1 unit increase of EV charging stations/100,000 population rather than raising the financial incentive by $1000. But a study in Norway has shown that EV purchases might increase due to the availability of charging infrastructure, but their association is not a causal relationship -which implies is unclear if the increase in EV purchases is caused by the installation of EV charging and vice versa (Mersky et al., 2016). Accordingly, incentivizing EVs without the provision of infrastructure is less applicable for market saturation. The charging infrastructure needs to be interdependent with EV incentives to enhance EV adoption.

2.5 Zero-emission Vehicle mandates and agreements

Vehicles that do not emit GHG during operation like BEV and PEV are Zero-emission vehicles (ZEV) (Axsen, Hardman, & Jenn, 2022) Ten states are jointly called ZEV states where they are committed to recognizing and setting action that can expand their EV market. EV manufacturers, dealers, industries, and electricity suppliers are among their emphasis as these have vast roles in producing and selling desirable EVs, constructing feasible infrastructures, and providing competitive electricity for consumers (NESCAUM, 2014). According to Lustey (2015) report, eight states are committed to the future by setting a multi-state goal to adopt 3.3 million ZEV collectively by 2025. California executed the ZEV program in 1990 and earned 9.5% ZEV credit in 2020 with a $5000 penalty per credit for disobedience (AFDC, Alternative fuel data center, 2022; Axsen et al., 2022). Besides, California automotive manufacturers earn credits upon ZEV sales and the credit varies depending on the powertrains(Axsen et al., 2022).

ZEV mandates are noticed to accelerate the deployment of PEVs in the United States. Lutsey, (2015) indicated cities that were documented with high EV sales were part of the states that have joined the ZEV mandate established by California state. Greene et al., (2014) also used a model to investigate the cost-benefit of California e-mobility policies in the diffusion of EV saturation and concluded that the transition of EVs was supported by the ZEV mandate. A literature review by Zhou et al., (Zhou, Yan, Levin, & Plotkin, 2016) concluded that the role of policy measures related to monetary, and non-monetary incentives, availability of fuelling infrastructure, and ZEV mandates for the diffusion of the PEV market. However, the influence on the ZEV market by the ZEV mandate is less studied compared to the other policy measures.

The financial and non-financial incentives, provision of charging facilities, and other policies for ZEVs make them more desirable to purchasers (Hardman, 2019). Environmental externalities can be addressed either by charging consumers for the environmental emission they caused (carbon pricing) or by setting regulations that focus on technological innovations like standards regarding vehicle emissions and ZEV mandates (Axsen et al., 2022).

Their paper also assessed how the ZEV mandate played a role in the socioecological transition of EVs by using five policy interaction conditions and disclosed that the ZEV mandate affects increasing EV sales. Because automotive manufacturers in a region that have a strict ZEV mandate will be incentivized to manufacture and provide EVs to the market in the long term compared to regions that have no/flexible ZEV mandate. Besides, EV acceptability and adoption are influenced by its availability and the study showed States that have applied the ZEV mandate have a positive relation with EV availability in US Slowik & Lutsey, 2018). Though EV transitions are backed by financial and non-financial incentives, regulations, and EV charging, difficult to identify the individual effect of the ZEV mandate on EV sales (Axsen et al., 2022). Therefore, we can say that configurational theory that collectively assesses the effect of the conditions is required to understand e-mobility transition.

2.6 Awareness and publicity

Psychological attributes also contribute to EV market saturation. EV adoption was influenced by both psychological and policy attributes, policy attributes were realized to be less prominent than psychological attributes (Ye et al., 2021). Similarly, consumers' PEVs perception and attitudes can be influenced by marketing and advertising considering the environmental importance it can offer and this contributes to EV promotion (Raux, Croissant, & Pons, 2015) as cited in (Ye et al., 2021). While these marketing advertisements for EVs should also be provided by recognizing the proper consumers (e.g., age group, income level, attitudes) (Nayum, Klöckner, & Mehmetoglu, 2016). Because there are EV consumers without any interest in the environment and policy change might be difficult in changing their attitude as they are careless (Priessner, Sposato, & Hampl, 2018). Therefore, identifying the right content for the right consumers will be necessary to attain the EV promotion goal.

States that have implemented identical types of incentives might vary in EV sale/adoption due to the disparity in consumer perception about EV benefits and incentives and their study discovered, awareness of consumers about the incentives is a significant variable that could affect the difference in EV adoption across the States (Jenn, Springel, & Gopal, 2018). Awareness of consumers about the incentives was considered based on campaigns or advertisements handled in the States i.e., counting articles readership about EVs using an algorithm programming from different sources. Kim et al., ((Kim et al., 2018) implied the benefit of EVs should be advertised by the governments to improve the perception of the consumer since it will have a role in facilitating the EV market. Consumers with strong attitudes or awareness concerning PEV won't be impacted when the monetary incentives fluctuate, indicating that psychological factors have a key role in EV uptake, and it shows one independent factor independently is not enough to explain an outcome.

EV consumers might be interested to get the incentives only without being internally convinced and motivated about it. Thus, financial, and non-financial incentives and regulations should be accompanied by an awareness campaign to promote EVs successfully. For example, by making EV buyers gain knowledge about the environment and motivate them to set goals and calculate their emissions (Nayum et al., 2016). He also confirmed the positive relationship between awareness, education level, and acceptability with a consumer who bought EVs in Norway. Moreover, Consumers buying an EV that has an experience in the environment or are concerned about GHG might be difficult due to the high purchase cost Liao et al. (2017) meaning consumers with a strong attitude about EV and their advantage will adapt quickly when policy incentives are utilized together. This indicated that psychological attributes cannot be independent in influencing EV adoption and need to interact with policy attributes to have a favourable outcome. Signifying, policies that incorporate awareness campaigns jointly with incentives and regulations will promote PEVs.

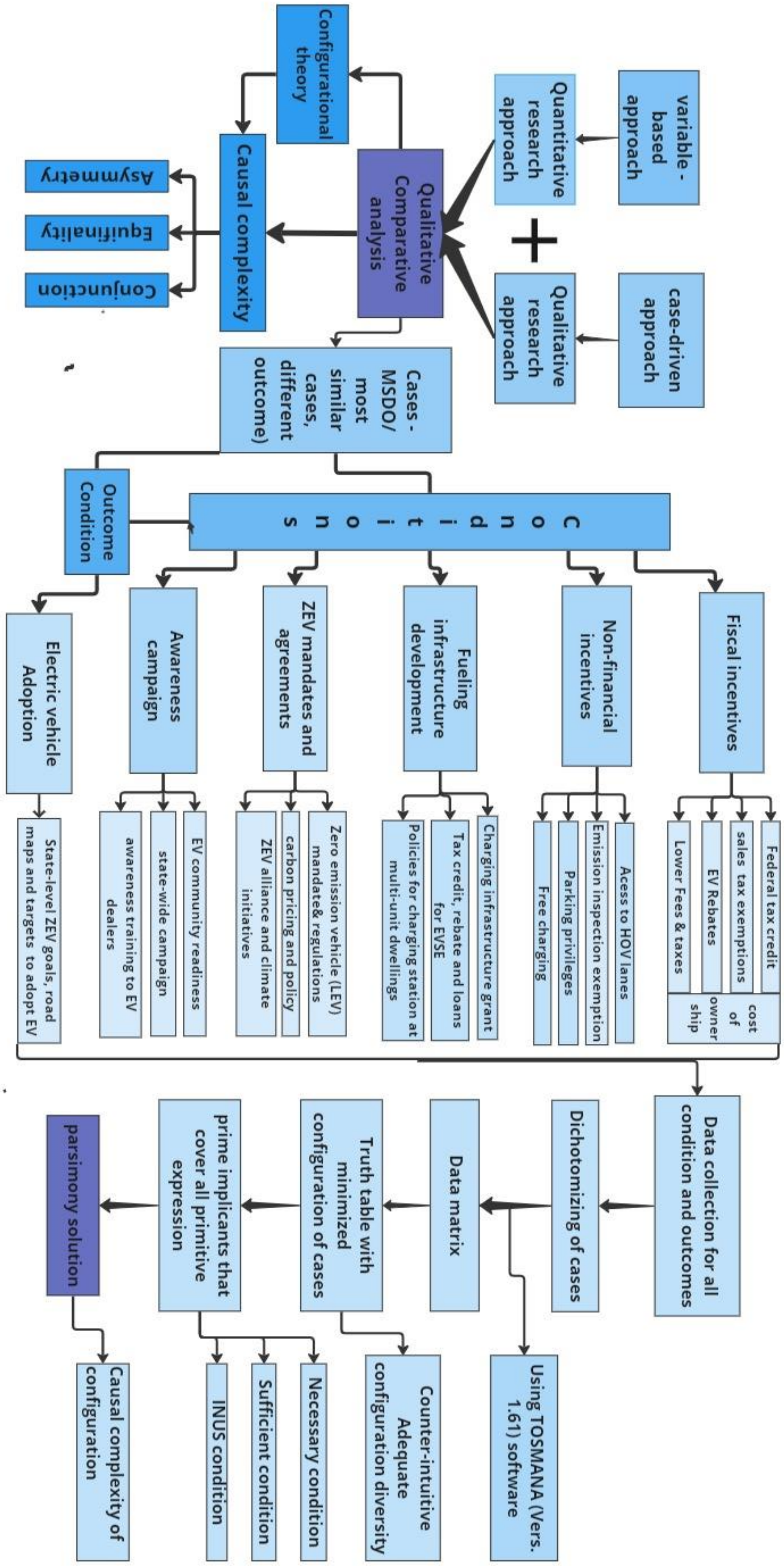
Accordingly, the five factors that are considered to have the main contribution to EV uptake discussed above will be the conditions that were used for our study with PEV adoption being the outcome condition as shown in Table 1

Table 1 Summary of conditions and outcome

Condition and outcome	Acronym	policies involved
Fiscal incentives	FININC	One-time Federal and state tax credit for EV purchase and EVSE installation EV rebates Alternative fuel vehicle (AFV) uses and sales tax exemptions Reduction/exemption of vehicle license tax and registration fees
Non-financial incentives	NONFININC	HOV lane exemption and toll road reduction AFV emissions and weight exemptions Parking space benefits in EV charging station areas Free parking Free charging at publicly owned stations
Charging infrastructure development strategies	CHARGINF	Grants for construction of public, private, and business charging station Tax credits, rebates, and loans for installation and purchase of EVSE Policies for charging stations at multi-unit dwellings
State ZEV promoting mandates and agreements	ZEVMAP	Zero-emission vehicle regulation and mandates Carbon pricing and policy ZEV alliance and climate participation
Electric vehicle awareness campaign	OAAAC	State-level EV community readiness project State-wide campaign Awareness training and program for EV dealers
Outcome	OP	State-level road maps action and plans for adopting PEVs

2.7 Conceptual framework

The following context shows the conceptual framework for this study.



Chapter 3: Research design, methodology

3.1 Research strategy

This chapter reviewed the research strategy, type, method of data collection, and data analysis approaches used for this study. The selection of the cases including the regarded conditions and outcome are discussed underneath.

QCA was the research strategy employed for this study that combines qualitative and quantitative approaches. The variable-based approach practices a small number of cases where depth study is the main objective and mainly uses qualitative analysis. while the case-based approach uses a larger number of cases with generalization as a goal and employs quantitative analysis. Then QCA combines the positive sides of the case and variable-based approaches; uses a combination of qualitative and quantitative analysis (Ragin, 1987) as cited in (Gerrits Lasse, 2018).

Why is QCA chosen for this study? In response, the focus of the study is not the effect of variables independently on the outcome or the causal relationship between factors and outcome instead it is to recognize the configuration of conditions that will lead to outcome occurrence from a comparison of cases. Accordingly, Mark et.al (2013) claimed that csQCA fits studies that involve configurational interconnectedness of the conditions since they incorporate complexity. Accordingly, this study deployed QCA by following the previous studies from Held &Gerrits (2019) and Kester et.al (2018) to realize the configuration of five conditions in promoting EVs in the United States.

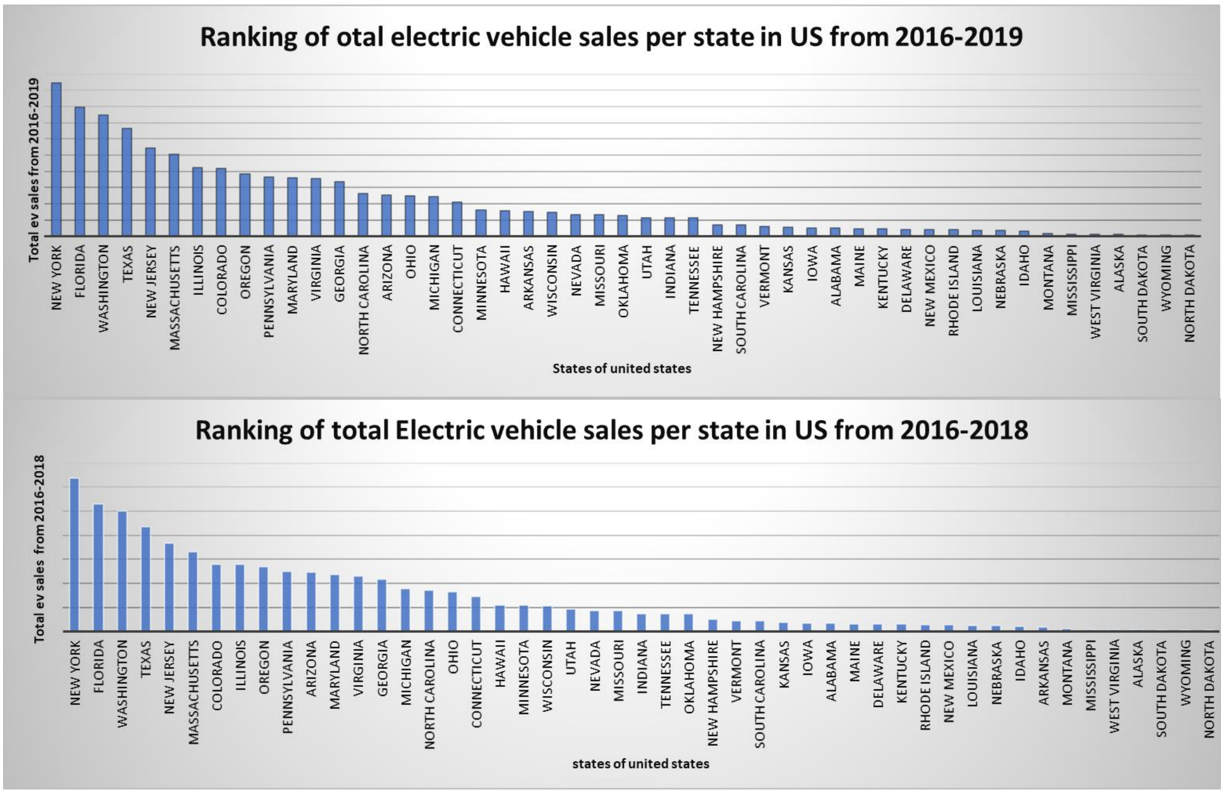
Marx et. al (2013) point out the strength of the csQCA over fuzzy-set and multi-value QCA research strategies. First, the csQCA uses systematic comparison by applying a truth table to reduce complexity, where the truth table is created for the number of conditions to the required outcome and the cases will be pooled that pairs to the configuration. Second, it minimizes variables (removing redundancy and taking conditions that are important to explain the outcome). Third, this research strategy allows the complex analysis of causal paths within the cases, and a different configuration of the conditions that led to the outcome. However, there are also critics regarding csQCA, as it does not allow for the hierarchy level or only uses dichotomy for measuring concepts. Nevertheless, for this study, the condition can be better explained in binary for example presence or absence of non-financial incentives is expected to appropriately explain the outcome without labeling it at the hierarchy level (Held & Gerrits, 2019). Thus, to ascertain the research questions, this study carries out a csQCA.

Secondary data from databases of the governmental official website of the United States is mainly used to collect data. Conditions, outcomes, and cases are the compulsory elements to perform QCA: Five conditions namely the financial incentives (TCO), non-financial incentives, fuelling infrastructure development strategies, state ZEV promoting mandates and agreements, and EV awareness campaigns; outcome condition is the road map and action plan for PEV adoption, and 20 states of United State as case are employed. The following chapter discusses the data collection for cases and conditions.

3.2 Case selection

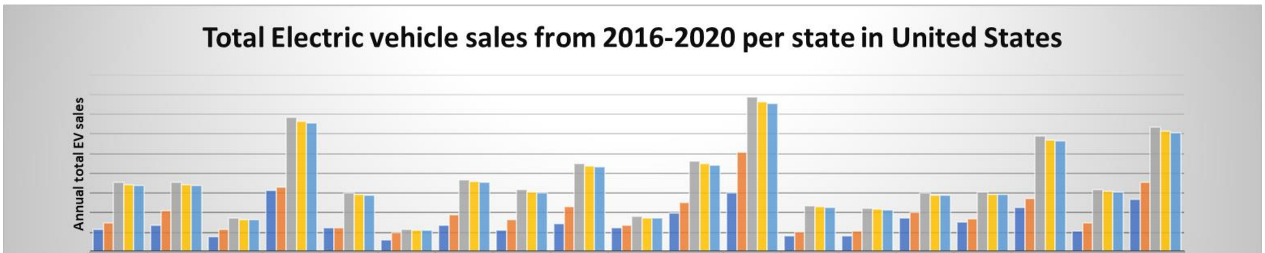
The selection of the cases can depend on the outcome condition as Held and Gerrits (2019) included cities in Europe (as the case) that have gone further in implementing policies regarding PEVs and with higher PEV sales. Thus, the selection of cases/states for this study is based on high PEV sales as shown in Figure 3. Moreover, the selection was based on cases that are similar but have different outcomes "most similar different outcome" approach (Gerrits Lasse, 2018).

Figure 3 Total electric vehicle sales/state (done by student: source (https://www.surfky.com/electric-car-sales-by-state)



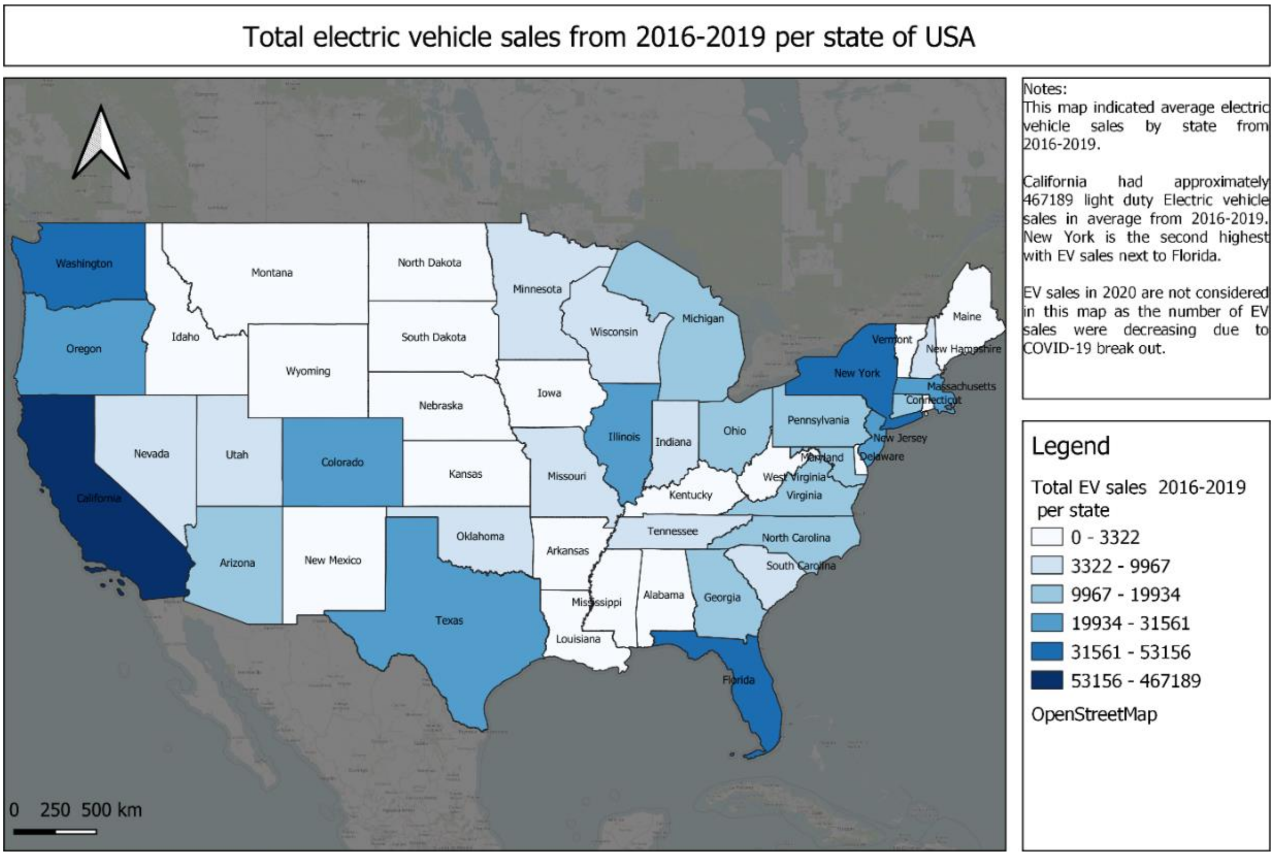
The number of PEV registration were increasing from 2016-2018 but decreased starting 2019-2020, this might be due to the COIVID-19 breakout. The selection of twenty cases out of the 51 states of the United States has been made by ranking the total PEV sales from both 2016-2018 and 2016-2019. Accordingly, the first 20 states that have higher PEV sales are considered. However, Hawaii and Minnesota have different rankings in both graphs but prefer to take the cases from 2016-2018 data since these years are before COVID-19. Figure 4 also shows the annual PEV sales of nineteen states from 2016-2020. California is an outlier and is ignored in the graphs to create a clear image. Laws and incentives in each state were also assessed to select states. Accordingly, California, New York, Florida, Washington, Texas, New Jersey, Massachusetts, Colorado, Illinois, Oregon, Pennsylvania, Arizona, Maryland, Virginia, Georgia, Michigan, North Carolina, Ohio, Connecticut, and Hawaii are the states that are considered as cases. Figure 5 also shows the location of each state with PEV sales to build a better understanding.

Figure 4 Annual Electric vehicle sales (Done by student and data sourcehttps://www.surfky.com/electric-car-sales-by-state



	Arizona	Colorado	Connecticut	Florida	Georgia	Hawaii	Illinois	Maryland	Massachusetts	Michgan	New Jersey	New York	North Carolina	Ohio	Oregon	Pennsylvania	Texas	Virginia	Washington
2016	2265	2711	1511	6255	2435	1224	2688	2185	2905	2482	3981	6043	1671	1631	3486	2998	4511	2155	5363
2017	2976	4156	2304	6573	2427	1934	3812	3244	4632	2742	5033	10091	2055	2091	3988	3346	5419	2932	7068
2018	7086	7051	3415	13705	6004	2296	7357	6299	8991	3571	9231	15752	4712	4456	5976	6063	11764	6375	12651
2019	6867	6834	3311	13282	5819	2225	7131	6105	8713	3461	8945	15266	4567	4319	5792	5876	11401	6178	12261
2020	6786	6753	3271	13125	5750	2199	7046	6033	8611	3421	8841	15086	4513	4267	5723	5807	11266	6105	12115

Figure 5 Total electric vehicle sales per state boundaries NB: Hawaii is excluded to get a clear image (done by student and data source: https://www.surfky.com/electric-car-sales-by-state



3.3 The total cost of ownership

Financial incentives effects were recognized by computing TCO. TCO reveals the cost-effectiveness of new technologies like e-mobility by comparing them with various powertrain vehicles. TCO incorporate several variables for certain ownership period. The cash flow of the variables calculated in all these years was converted to the present value using a discount rate (Burnham et al., 2021).

3.3.1 Vehicle type and model selection

Identification of ICE and BEV models and segment size is essential to compute TCO. Nissan Leaf was the top third sold vehicle with 3254 units in the fourth quarter of 2019 in the US

(CleanTechnica, 2019). Besides, Nissan Leaf and Toyota were used by previous EV adoption studies for determining TCO (Breetz & Salon, 2018; Held & Gerrits, 2019; Palmer et al., 2018) because their purchase price and other criteria are similar. Hence, for this study, Nissan Leaf (BEV) and Toyota (ICE) are the class of vehicles used to calculate TCO. The criteria regarded in deciding the vehicle models are specified in table 2.

Table 2 Specification of vehicle types (done by student: data source: https://www.fueleconomy.gov/feg/findacar.shtml)

Powertrain type	Nissan Leaf (BEV)	Toyota (Regular Gasoline)
EPA Size Class	Midsized car	Midsized car
Total range (Miles)	107	409
Passenger volume	92ft^3(Hatchback)	98ft^3(4 door)
MSRP	$29010-$36,790	$17,300-$23,125
Transmission type	Automatic	Manual
Fuel type	Electricity	Regular gasoline
Energy impact score (Barrels)	0.1	9.6
Greenhouse Gas Emissions (gram/mi)	0	284
Fuel consumption (ga/100mile)	0	3.2
Electricity consumption (Kwh/100mi)	30	0
Electric motor (Kw)	80	-
Fuel economy (mile/gallon) in city	0	28
Fuel economy (mile/gallon) in highway	0	36
Fuel economy (mile/gallon) in city& highway	0	31
MPG Fuel Economy (gal/100mi)		3.2
Fuel economy (mile /Kwh) in city	124	0
Fuel economy (mile /Kwh) on highway	101	0
Fuel economy (mile /Kwh) in city & highway	112	0
MPGe Fuel Economy(kWh/100 mi)	30	

3.3.2 Ownership period

Burnham et al, (2021) used fifteen and twenty years of ownership periods while handling TCOs of LDV and MHDV respectively, are the standard service years of a vehicle. Although he stated that 5yrs (LDV) can also be applied considering it as first-owner analysis. Considering the time limit and data availability, 5yrs (a 2016-2020) ownership period was taken in this study.

3.3.3 Purchase cost

There are different 2016 Nissan leaf models with S (84 miles range), SV (107 miles range) and SL having the same range as SV but standard luxury. For our study, the Nissan leaf SV 2016 model is used with a manufacturer's suggested retail price (MSRP) of $34,200 based on 15000 miles/year considering highway driving (55%) and city driving (45%) (Paige, 2015). Similarly, Toyota 2016 has a different model but the “2016 Toyota Corolla S Plus 4dr Sedan” is used with an MSRP of $21665 according to https://www.autoblog.com/auto-repair/.

3.3.4 Fuel/electricity cost

The price of electricity and regular gasoline (without taxes) from 2016-2020 is compiled from the "US Energy information administration" website (https://www.eia.gov/electricity/state/). The gasoline sales taxes per state are also collected from a similar website.

3.3.5 Fees and incentives during the purchase of vehicles

Fees paid and incentives granted only at the state and federal levels are taken into consideration. Title fees are the only fees deemed. Likewise, rebates, sales tax exemptions, and tax credits only at both levels are regarded. The data associated with fees and incentives are shown in Appendix 5 All PEV financial incentives per case are collected from the "Alternative Fuel Data Centre" website (https://afdc.energy.gov/).

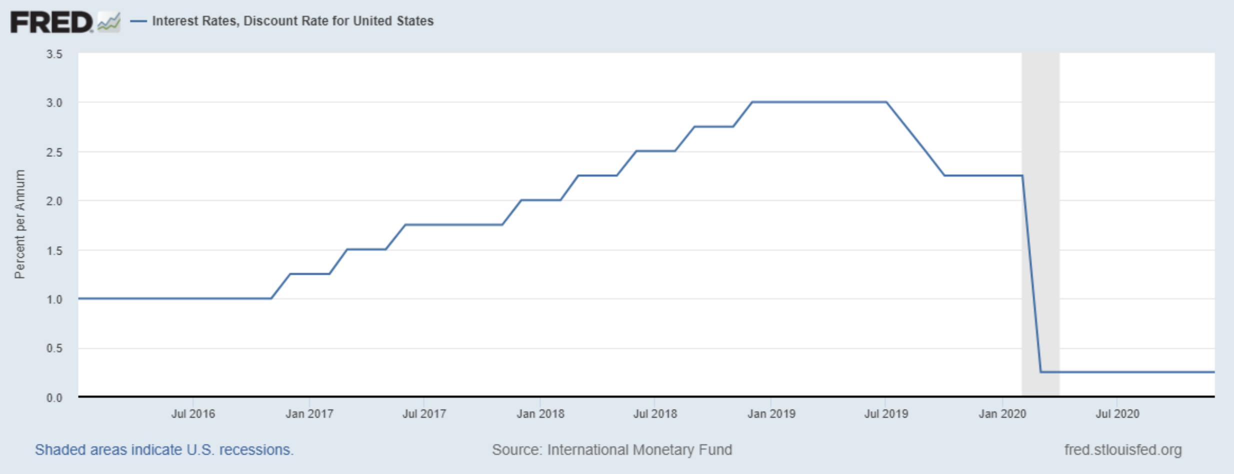
3.3.6 Insurance, maintenance, and repair costs and resale values

Autoblog website https://www.autoblog.com/auto-repair/ provided all the value for maintenance, insurance, repair, and depreciation cost for various vehicle types. For this study, "the 2016 Nissan Leaf SV 4dr Hatchback" and "2016 Toyota Corolla S Plus 4dr Sedan" type of models are used on the website taking 15000 miles/year to get the value of the variables for 5 years (2016-2020) for each state. The value of these variables for both vehicles is shown in Appendix 5.

3.3.7 Discount rate

Fuel, maintenance, insurance, repair, depreciation costs, taxes, and fees are annual costs, and their value will be discounted over the five years using a discount rate except for the first year. This database https://fred.stlouisfed.org/ is used to determine the average discount rate for each year (2016-2020) as indicated in Figure 7.

Figure 6 Discount rate from 2016-2020 (sources: https://fred.stlouisfed.org/)



3.4 Non-financial incentives

Non-financial incentives are the second type of condition considered for the analysis. Exemption of access to HOV lanes, reduced toll roads, exemption of EV emission inspections, exemption of EV weights, the privilege of parking space in EV charging stations, free parking and charging is the type of non-financial incentives collected for each state from (https://afdc.energy.gov/) and the driving motor vehicles (DMV) official website (https://www.dmv.org/) of each state.

3.5 Strategies and actions associated with EV charging infrastructure

Fuelling infrastructure-associated grants, rebates, tax credits, loans, and policies is the third condition. For this study, PEV charging station monetary incentives and policies in multi-unit dwellings are taken for dichotomizing the cases and https://afdc.energy.gov/ is the database used to gather data.

3.6 EV promotion program and participation

Various types of EV actions, programs, and emission regulations that promote EVs are also performed by some states. Accordingly, these actions, ZEV mandates, and programs are taken as the fourth condition for our study. The data regarding, state-level “ZEV mandates”, “carbon pricing policy”, “LEV regulations” and “US climate alliance participation” are collected from https://afdc.energy.gov,and (Berg et al., 2020) as shown in Appendix 6. ZEV mandate and LEV regulations have been implemented starting in 1990 in California and now another 10 states have followed implemented the program as shown in table 3.

Table 3 States that adopted ZEV mandates and regulations of California (source: https://afdc.energy.gov

State	Applicable MY			State's share (%) of U.S. New Light-Duty Vehicle Sales*
	LEV Regulations		ZEV Program	
	Criteria Pollutant Regulation	GHG Regulation		
California	1992	2009	1990	11.0%
New York[1]	1993	2009	1993	6.1%
Massachusetts[2]	1995	2009	1995	2.1%
Vermont[3]	2000	2009	2000	0.3%
Maine[4]	2001	2009	2001	0.4%
Pennsylvania[5]	2001	2009		3.9%
Connecticut[6]	2008	2009	2008	1.0%
Rhode Island[7]	2008	2009	2008	0.3%
Washington[8]	2009	2009	2025	1.7%
Oregon[9]	2009	2009	2009	1.0%
New Jersey[10]	2009	2009	2009	3.5%
Maryland[11]	2011	2011	2011	1.9%
Delaware[12]	2014	2014		0.3%
Colorado[13]	2022	2022	2023	1.5%
Minnesota[14]	2025	2025	2025	1.5%

3.7 EV outreach activities and awareness campaigns

The EV awareness campaign is the fifth condition for the analysis. A study by Jin &Slowik (2017) reviewed different studies across the world including in the United States concerning the awareness campaign and training provided for EVs to uptake. Awareness campaigns offered for an auto dealer to sell EVs are among the action in consumer awareness activities for EV acceptance and accordingly, consumer awareness and training given to EV dealers at the state level are taken for this study. Besides inadequate consumer awareness of EV adoption is also unraveled by joining and implementing EV projects and actions, marketing, the establishment of virtual information tools, and others. EV readiness project initiation is among the awareness and outreach activities taking part in the United States at the state level (Jin & Slowik, 2017).

Besides Kathrine, S et.al (2021)give scoring in their report for the top 25 states that provide state-wide campaign and awareness training for EV traders, and this scoring is used for this study following Narassimhan & Johnson's (2018b) research, applied the scorecard of voters from the state league during his assessment concerning EV purchase. Therefore, “EV Community readiness” and scoring of states that offers state-wide campaign and training to supplier for selling EVs are collected from https://afdc.energy.gov/ and https://pluginamerica.org/ per cases as indicated in Appendix 7.

All the data collected for the five conditions and outcomes are at the state and federal levels since states are our cases. Besides, recent data are collected for all condition except for financial incentive condition.

3.8 Operationalization: variables, indicators

Concept/Variable	Definition	Indicators	Source of data
EV adoption/ outcome condition O	It is an e-mobility state-level road map that targets adopting EVs in the U.S (Held & Gerrits, 2019)	States with high or less likely to achieve their goals for the coming years referring to their goal map and current EV sales. (Binary number 0/1).	Secondary data from U.S. official governmental database and others. Check section 3 for the websites.
Financial incentive /condition v1	Is an incentive for users through money to purchase or adopt e-mobility. The TCO model is employed to understand the monetary incentives for vehicle purchases. The TCO model includes variables like purchase cost, sale taxes, title fee, tax credit or rebates, ownership period, fuel cost, annual tax, and registration fees, annual insurance, maintenance and repair cost, resale value, and discount rate (Bjerkan et al., 2016; Hardman et al., 2017; Held & Gerrits, 2019; Lévay et al., 2017).	The total cost of ICE and EV vehicles after 5 periods including all the variables. Percentage change-The difference in TCO between EV and ICE vehicles over the ICE's TCO in percentage. The set threshold from Tosmana software (Cronqvist, 2019) to assign the presence and absence of the condition (Binary number 0/1).	Secondary data from U.S. official governmental database and others. Check section 3 for the websites.
Non-financial /condition v2	Is a non-cash incentive for users to promote the diffusion of EV saturation (Bjerkan et al., 2016)	Absence or presence of exemption to access HOV lanes, reduced toll roads, exemption of EV emission inspections, exemption of EV weights, the privilege of parking space in EV charging stations, free parking, or charging (Bjerkan et al., 2016; Held & Gerrits, 2019; Kumar & Alok, 2020) (Binary number 0/1).	Secondary data from U.S. official governmental database and others. Check section 3 for the websites.
Fuelling infrastructure development strategies /condition v3	Strategies that aim to fuel infrastructure expansion by incentivizing and setting police	Presence or absence of grants for the construction of public, private, and business fuelling infrastructure, Tax credits, rebates, and loans for installation and purchase of EVSE or policies for charging stations at multi-unit dwellings (Breetz & Salon, 2018; Held & Gerrits, 2019; Kumar & Alok, 2020) .(Binary number 0/1).	Secondary data from U.S. official governmental database and others. Check section 3 for the websites.

State ZEV promoting mandates and agreements/ condition v4	State-level ZEV actions, mandates, and emission regulations that promote EVs. (AFDC, Alternative fuel data center, 2022)	Presence or absence of zero-emission vehicle (ZEV) regulation, Zero emission vehicle (LEV) mandates, carbon pricing, and policy, or ZEV alliance and climate participationaf (Binary number 0/1).	Secondary data from U.S. official governmental database and others. Check section 3 for the websites.
Electric vehicle awareness campaigns/ condition v5	State-level projects, campaigns, and programs are handled to create awareness for both dealers and customers regarding EVs.	Presence or absence of state-level "EV community readiness" project, and Set threshold for scores of the state-wide campaign and awareness training and program for EV dealers (Katherine, Stainken, Peter , O'Connor, and Russell ,Corbin., 2021; Kumar & Alok, 2020; Ye et al., 2021)(Binary number 0/1).	Secondary data from U.S. official governmental database and others. Check section 3 for the websites.

3.9 Data limitation

Let's now discuss the limitations while data collection. Regular gasoline prices are not retail prices like the electricity cost for PEVs used. Since the data are not reported or withdrawn from the US government website. Due to this data limitation, "sales for resale" prices of gasoline are considered for this study. Note that the prices are lower than the retail prices as these are "wholesale sales" prices. Fees related to plate, documentation, and other are disregarded during TCO computation as the value are expected to have negligible effect in TCO. Private incentives are ignored because of resource limitations. Especially rebates by the private organization were difficult to consider since they are specific to customers. Lastly, some states lack clarity on their ZEV goal because the type of EVs is not specified.

Chapter 4: Results, analysis, and discussion

The previous chapter has illustrated, data collection involving cases, conditions, and outcomes including TCO computation and the methodology applied for data analysis. This chapter will deal with data analysis and discussion to realize the parsimonious configuration of condition (solution) for EV uptake and the effect of financial Incentives in BEV's TCO equated to ICE.

This study encompassed cases/states to explain the combination of factors that lead to PEV adoption and to explore if the financial incentive will have a substantial effect in shifting the ownership cost over the 5 years of possession period. For carrying out this, 20 states of the United States that have taken actions and policies in adopting e- mobility are considered to indicate that states with higher registration of BEV sales over 4 years (2016-2019) period was selected. The name of the 20 states considered is listed in chapter 3. Financial incentives, non-financial incentives, fuelling infrastructure development strategies, state ZEV promoting mandates and agreements, and EV awareness campaigns were the five factors/conditions with their sub-condition. All the conditions and outcomes for the analysis are at the state and federal levels. The financial incentive is the first condition having 10 variables as indicated in equation (2) and the characteristic of all the conditions are reviewed underneath. For analysing the data, computation of TCO is the first step followed by calibration of conditions for twenty states and all are discussed in this chapter.

4.1 The total cost of ownership model

Several variables are incorporated in the TCO model by different studies where some of them included annual tax and registration fees, subsidy, purchase cost, fuel cost, and resale values only while others involved maintenance, repair, and insurance cost in addition to the variables listed (Breetz & Salon, 2018; Hardman et al., 2017). The TCO model used by Held and Gerrits (2019) was simple and this study wants to improve the model by including discount rate, maintenance, insurance, and repair costs because these variables are alleged to have a role in changing the TCO (Lévay et al., 2017). The model for this study is adopted from (Breetz & Salon, 2018) as shown in equation (2).

$$\mathrm{TCO} = PC + \mathrm{SX} + \mathrm{TF} - \mathrm{TCR} + \sum_{i=0}^{i} \frac{(\mathrm{FC+TR+IC+MC+RC})}{(1+\mathrm{d})^{i}} - \frac{(\mathrm{RV})}{(1+\mathrm{d})^{i}} \quad \textbf{Equation 2}$$

Where TCO stands for total cost during the 5 years, PC stands for purchase cost, SX -sales tax, TF stands for title fee, TCR stands for tax credit and/or rebates, I stands for ownership period in this case 5 years, FC stands for yearly fuel (electricity or regular gasoline) cost, TR stands for yearly tax and registration fees, IC stands for yearly insurance cost, MC stands for yearly maintenance cost, RC stands for the yearly repair cost, RV stands for resale value after 5 years, and d stands for the discount rate.

Next, we will show how the yearly fuel cost was computed since it has its equation. But the data required for the other variables are already discussed in chapter 3.

Fuel/electricity cost

Fuel costs are annual for both BEV and ICE. Equations (3) and (4) were the formulas used to calculate the cost for this study. The gallon per 100 miles or KWh/100 mi for both powertrains is described in table 2.

Yearly regular gasoline costs (FC) for ICE were calculated employing the following, where $P_{gasoline}$ is the cost of gasoline per gallon, VMT is the yearly vehicle mileage traveled per vehicle and MPG is the fuel economy of ICE per gallon per 100 mi (cf.Breetz & Salon, 2018).

$$FC = PgasolineX\,VMTXMPG \quad \textbf{Equation 3}$$

The yearly electricity costs (FC) for BEV were calculated applying the following where $P_{electricity}$ is the cost of electricity per kWh, VMT is the yearly vehicle mileage traveled per vehicle and MPGe is the fuel economy of BEV KWh/100 mi (cf.Breetz & Salon, 2018).

$$FC = Pelectricty\ X\ VMTXMPGe$$ ……………………………………………………**Equation 4**

The regular gasoline prices were collected from the governmental official database excluding the taxes. Thus, the sales tax of regular gasoline is computed individually to find the final prices of gasoline per gallon. Some data limitations regarding the gasoline prices were a lack of retail prices as discussed before. The regular gasoline price ("sales for resales") computation including the sales taxes at the state level for 2016 only is indicated in table 4. The computation of total fuel cost from 2016-2020 for both vehicles is in Appendix 1-4.

Table 4 Computation of fuel price (sales for resale) of regular gasoline Including the state sales tax of fuel for 2016 source (done by the student: data source https://afdc.energy.gov

State	Regular gasoline	(Dollars per Gallon Excluding Taxes) 2016	State tax ($/gallon)	Other taxes & Fees[2]($/gallon)	state sales tax for gasoline	Total(gasoline prices, state tax and other taxes and fees) fee ($/gallon)	MPG =(EPA Fuel Economy for regular gasoline (2016 Manual Toyota Corolla) = 3.2 gal/100mi)	VMT =(15,000 miles/ year)	Fuel price ($/year)
Arizona	Sales for Resale	1.453	0.18	0.01		1.643	0.032	15000	788.64
California	Sales for Resale (Average)	1.673	0.278	0.07155	State Underground Storage Tank fee ,Oil Spill Prevention & Administration Fee	2.02255	0.032	15000	970.824
Colorado	Sales for Resale (Average)	1.4	0.22	0.0125	Environmental Response Surcharg fee	1.6325	0.032	15000	783.6
Connecticut	Resale (Average)	1.419	0.25			1.669	0.032	15000	801.12
Florida	Sales for Resale (Average)	1.39	0.04	0.266	Environmental taxes and other fees	1.696	0.032	15000	814.08
Georgia	Sales for Resale (Average)	1.355	0.26	0.005	Georgia Underground Storage Tank (GUST) fee	1.62	0.032	15000	777.6
Hawaii	Resale (Average)	1.537	0.16	0.025	Environmental Response Tax	1.722	0.032	15000	826.56
Illinois	Sales for Resale	1.397	0.19	0.141	Environmental Impact Fee including sales tax rate is	1.728	0.032	15000	829.44
Maryland	Sales for Resale (Average)	1.385	0.247	0.0899	Oil transfer Fee including the sales and use tax equivalent rate component	1.7219	0.032	15000	826.512
Massachusetts	Sales for Resale (Average)	1.413	0.24	0.02651	Underground Storage Tank fee,Uniform Oil Response + Prevention fee	1.67951	0.032	15000	806.1648
Michigan	Sales for Resale (Average)	1.401	0.19	0.13075	Environmental protection regulatory fee including sales tax	1.72175	0.032	15000	826.44
New Jersey	Resale (Average)	1.361	0.105	0.0405	Receipts Tax and Spill Compensation and Control	1.5065	0.032	15000	723.12
New York	Sales for Resale (Average)	1.403	0.08	0.2534	and Petroleum Testing Fee including sales tax	1.7364	0.032	15000	833.472
North Carolina	Sales for Resale	1.351	0.34	0.0025	Gasoline and Oil Inspection fee	1.6935	0.032	15000	812.88
Ohio	Resale	1.379	0.28			1.659	0.032	15000	796.32
Oregon	Resale	1.454	0.3			1.754	0.032	15000	841.92
Pennsylvania	Sales for Resale	1.361	0.503	0.011	Underground Storage Tank Fund	1.875	0.032	15000	900
Texas	Resale (Average)	1.348	0.2			1.548	0.032	15000	743.04
Virginia	Sales for Resale (Average)	1.381	0.162	0.006	Storage tank fee	1.549	0.032	15000	743.52
Washington	Sales for Resale (Average)	1.453	0.494	0.0011903	Oil Spill Administration Tax, Oil Spill Response tax and Hazardous Substance tax	1.9481903	0.032	15000	935.1313

4.2 Computation of total cost of ownership

TCO for both Toyota and Nissan leaf is computed using Equation (2). The TCO computation holds ten variables namely, one-time costs (purchase prices, sales tax, rebates, tax credits, title fee) and annual costs (annual registration fee, maintenance cost, repair cost, depreciation cost, and fuel costs). The annual costs were for five years and discounted into the first year of the ownership period. Note that state and federal-level rebates, incentives, and registration fees only are considered for TCO calculation. The value and procedure for calculating the variable are discussed above.

The effect of monetary incentives in TCO is recognized by calculating the percentage change of both Toyota's and Nissan's TCO. Bansilal (Bansilal, 2017) defined percentage change as the change of one variable compared to the previous one. Table 6 shows the percentage change for every case in the United States. The computed average percentage change for both vehicles signifies that Nissan Leaf's TCO is on average 7.327% higher than the Toyota Corolla's.

Figure 8 indicates the comparison of the twenty states' final TCO calculation for both vehicles where Colorado and Oregon state having a lower total cost of ownership for Nissan than Toyota due to the strong monetary incentives granted for e-mobilities. This figure also shows how the federal and state-level tax credits, rebates, and exemption of sales tax have created BEV's cost to be competitive with ICE. Implying both vehicles have an average cost difference of 7.329%.

Figure 7 TCO comparison

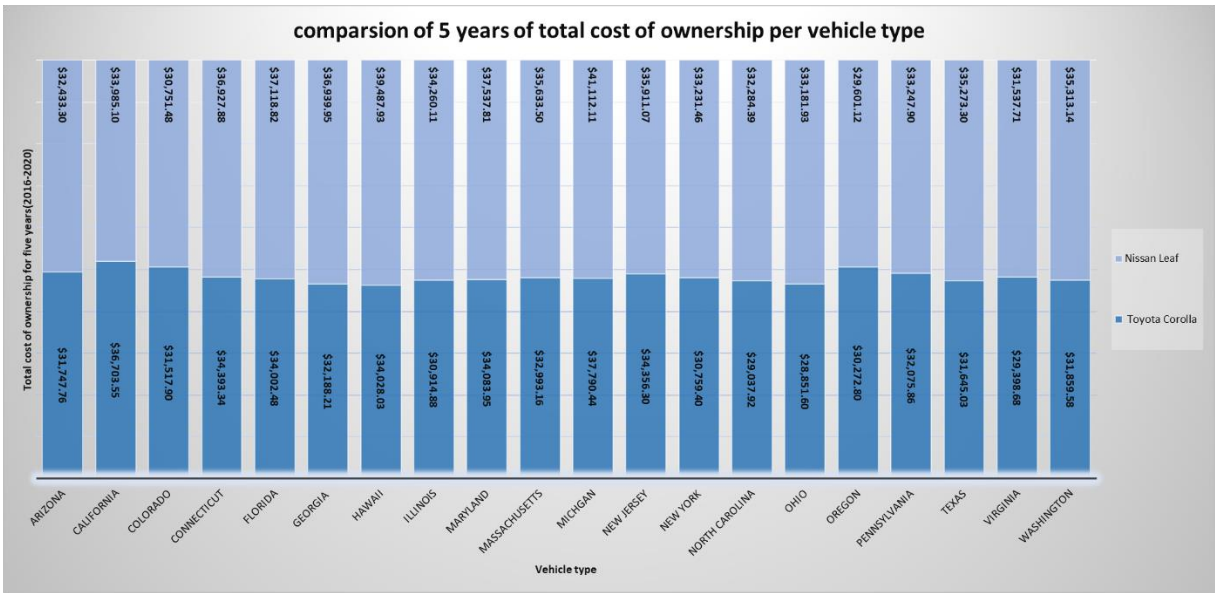
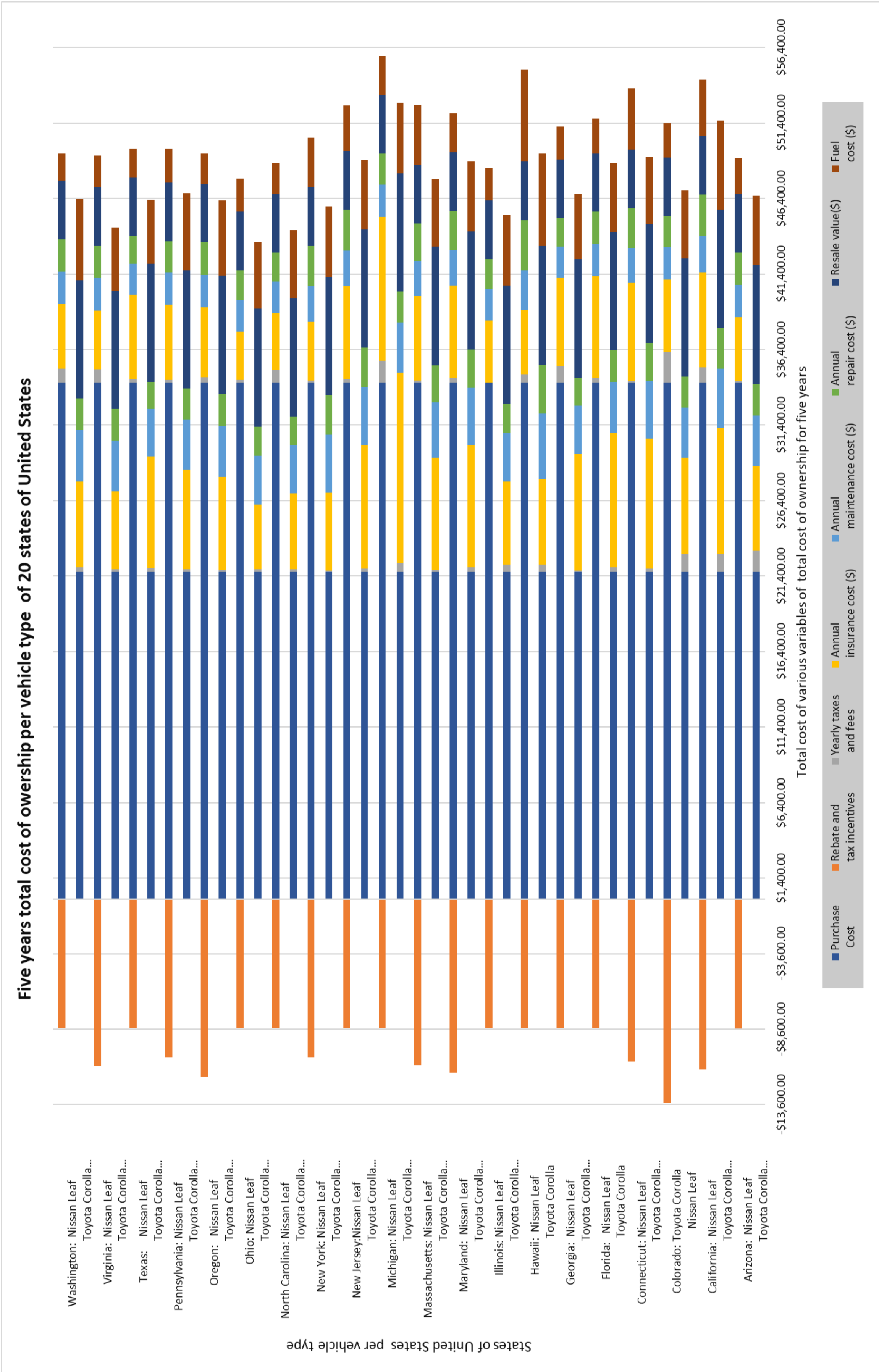


Figure 9 also helps to visualize the ten variables used for computing 5 years ownership costs for 20 states of both vehicles in the United States. The figure implies that the maintenance, depreciation, and repair cost of Nissan is lower than Toyota. Though the purchase cost for Nissan is much higher than that of Toyota, some state has an effective financial incentive that overweight the TCO.

Figure 8 Comparisons of 20 states' total cost of ownership involving the ten variables



4.3 Calibration of conditions and outcome

The dichotomization or assigning all the conditions and outcomes to 0 or 1 is carried out for the analysis. for the case of the outcome, the statistical value of the roadmap or action plan of each state to uptake their PEV sale, adoption, or registration for the coming years (2020-2030) is used for assigning the membership. States that are highly likely to achieve their goals for the coming years are assigned a full membership (1) and vice versa. For instance, states that have fulfilled around 55-60% of their goal for 2025/27 with a clear vision are assigned “1”. In addition to that, we also tried to look at the progress of EV sales starting 2016-2020 and total EV registration in 2021 to expect the likely hood of achieving their goals as indicated in table 5 and figure 10. Some states have an action plan for 2020 and used to assess if 60% of that goal is already fulfilled or not. Hence, States that are assigned with 1 point out that their e-mobility policies and strategies are supposed to result in a favourable outcome.

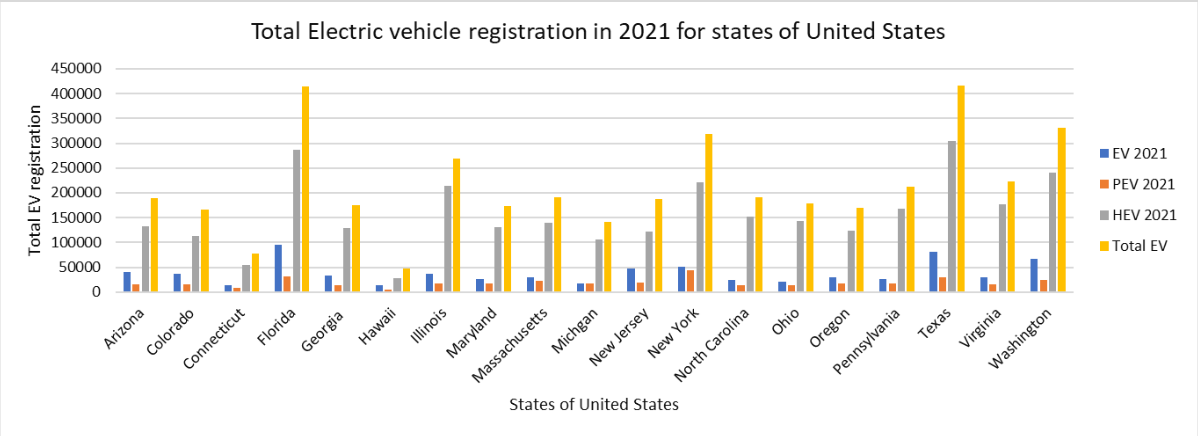
States are assigned “0” when they are not or below 55% fulfilling their 2025/27 ZEV goals. But again, there is a lack of data as some states (e.g., Georgia and Ohio) do not have ZEV roadmap/action plan and are assigned to zero presuming states lacking the action plan might indicate a low tendency to adopt EVs. Note that there are states that have high EV registration, but this does not mean they are assigned as “1”, because their market share and EV per population ratio can be lower or they might not meet their goals.

EVs include three sets, Plug-in EV, Hybrid EV, and Battery according to https://afdc.energy.gov/. Some of the limitations in calibrating the outcome was identifying the ZEV goals as some states used the term EV without specifying which type they are referring to. For example, New Jersey has less clarity in specifying the EV goal, and the total value is used in calibrating and comparing its configuration with other conditions as well.

Table 5 Annual EV sales of the United States /note that EV are not specified if it is the adding of BEV and PEV (done by student. sources: https://www.surfky.com/electric-car-sales-by-state)

year	Annual EV slaes 2016	Annual EV slaes 2017	Annual EV slaes 2018	Annual EV slaes 2019	Annual EV slaes 2020
Arizona	2265	2976	7086	6867	6786
California	73854	94873	153442	148710	146951
Colorado	2711	4156	7051	6834	6753
Connecticut	1511	2304	3415	3311	3271
Florida	6255	6573	13705	13282	13125
Georgia	2435	2427	6004	5819	5750
Hawaii	1224	1934	2296	2225	2199
Illinois	2688	3812	7357	7131	7046
Maryland	2185	3244	6299	6105	6033
Massachusetts	2905	4632	8991	8713	8611
Michgan	2482	2742	3571	3461	3421
New Jersey	3981	5033	9231	8945	8841
New York	6043	10091	15752	15266	15086
North Carolina	1671	2055	4712	4567	4513
Ohio	1631	2091	4456	4319	4267
Oregon	3486	3988	5976	5792	5723
Pennsylvania	2998	3346	6063	5876	5807
Texas	4511	5419	11764	11401	11266
Virginia	2155	2932	6375	6178	6105
Washington	5363	7068	12651	12261	12115

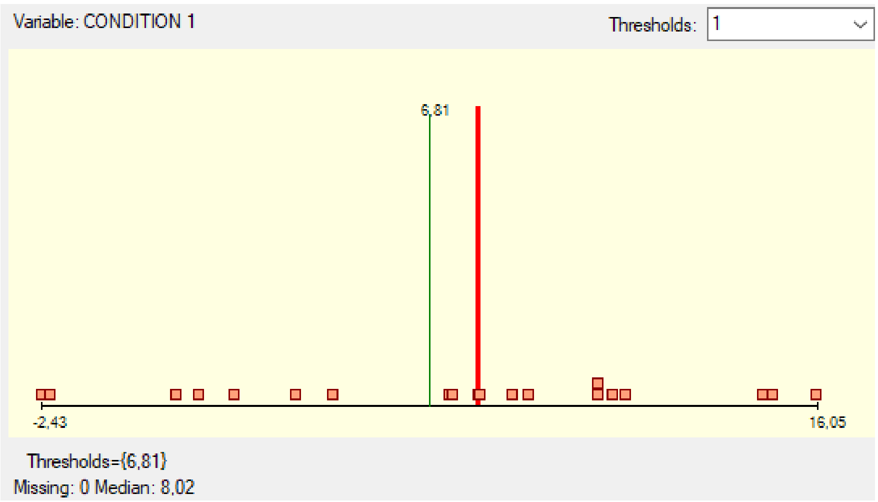
Figure 9 Total electric vehicle*BEV, PEV& HEV) registration in the United States in 2021 and California is excluded to produce a clear image (done by the student. Sources:(https://afdc.energy.gov/)



Condition v1 is the next one to calibrate. Financial incentives are included in the condition as analysis using the TCO for both ICE and BEV comparable vehicles across 20 states as specified above. The incentive includes the reduction of annual taxes and fees, sales tax exemptions, tax credits, and rebates at the state and federal levels. The incentive that is granted beginning in 2016 are counted as the ownership period starts from that year. Most studies (Held & Gerrits, 2019; Lévay et al., 2017; Palmer et al., 2018) have indicated longer time is required to understand monetary incentives. Because only incentives given during the purchase of time might not be sufficient to understand the effect and according to 5 years of the ownership period is taken, all the calculations and variables taken are shown in the above and Appendix 4.

Two vehicles, Toyota Corollas (ICE) and Nissan Leaf (BEV) are considered to have similarities in prices, model year, and others with detailed criteria labelled in table 2. The computed TOC of both vehicles in equation (2) is used for dichotomization. The effect of monetary incentive in Nissan leaf TCO is realized by calculating the "percentage change", defined as the change of some value compared to the previous one (Bansilal, 2017). The effect of the financial incentive is realized by calculating the difference in TCO between the vehicles over the ICE's TCO in percentage as shown in table 6. Inferring, the financial incentive effect is realized by the percentage change value. The mean of the percentage change implies that the ICE's TCO is on average 7.327% lower than the BEV's TCO across the 20 states of the United States.

Figure 10 Range and Thresholds for condition FININC (financial incentives)



Tosmana software (Cronqvist, 2019) is used to calibrate the percentage change value (condition v1). For this case we need to cluster the cases which have similar percentage change value meaning, categorizing the cases with or without financial incentive effect in their TCOs. The analysis from the software resulted in a 6.81% threshold and 8.02% median of the percentage change value as shown in Table 6. Cases/states lower than the threshold (6.81%) is grouped into one class as these are with higher financial incentive effective in the TCO. Consequently, states that have a strong financial incentive in their policies towards BEVs are grouped as full members (1), since it is supposed to have a favorable outcome. In contrast, states that have a percentage change value higher than the threshold are assigned as "0" and are believed to have inadequate financial incentives with lower effects in the TCO.

Table 6 TCO calculation and percent change (done by student)

States	MSRP of Toyota Corolla ($)	Toyota Corolla 5- yrs TCO ($)	MSRP of Nissan Leaf ($)	Nissan Leaf 5- yrs TCO ($)	TCO Difference ($)	percentage change
Arizona	21665	31747.75548	34200	32433.29786	685.542374	2.159%
California	21665	36703.545	34200	33985.10113	-2718.443875	-7.406%
Colorado	21665	31517.89934	34200	30751.48064	-766.4186988	-2.432%
Connecticut	21665	34393.34295	34200	36927.87662	2534.533671	7.369%
Florida	21665	34002.4754	34200	37118.81582	3116.340416	9.165%
Georgia	21665	32188.21278	34200	36939.95213	4751.739351	14.762%
Hawaii	21665	34028.02889	34200	39487.93243	5459.903543	16.045%
Illinois	21665	30914.87876	34200	34260.11428	3345.235519	10.821%
Maryland	21665	34083.94565	34200	34537.80966	453.8640047	1.332%
Massachusetts	21665	32993.16145	34200	35633.50298	2640.341529	8.003%
Michgan	21665	37790.43597	34200	41112.10755	3321.671574	8.790%
New Jersey	21665	34356.30023	34200	35911.0686	1554.768372	4.525%
New York	21665	30759.40343	34200	33231.46249	2472.059059	8.037%
North Carolina	21665	29037.9183	34200	32284.38971	3246.471408	11.180%
Ohio	21665	28851.60423	34200	33181.93307	4330.328844	15.009%
Oregon	21665	30272.79688	34200	29601.12046	-671.6764168	-2.219%
Pennsylvania	21665	32075.85851	34200	33247.89871	1172.040203	3.654%
Texas	21665	31645.02759	34200	35273.29539	3628.267803	11.466%
Virginia	21665	29398.67506	34200	31537.71068	2139.035614	7.276%
Washington	21665	31859.58005	34200	35313.14399	3453.563938	10.840%

Condition v2 is the third one to calibrate by assigning the full or non-membership allowing the existence or non-existence of non-financial incentives. States that allow non-financial incentives; access to HOV lanes and toll fee reduction, exemption of weight and BEV emission inspection, parking space benefit in EV charging stations, free or reduction in parking space or free charging are assigned as 1. Though, States that don't grant non-financial incentives or only exempt EV emission inspection are assigned as "0".

Condition v3 includes the existence or non-existence of state and federal level grants, rebates, loans, and tax credits to private, public, and sectors like business, industrial and commercial organizations for installation and purchase of EVSE, construction of public and private fuelling infrastructures, and multi-unit dwelling EV charging policies. Thus, states that allow tax credits, rebates, loans, and grants to sector and private for the construction of public, multi-unit dwellings, businesses, and private charging stations are assigned to be full members. States are assigned "0" when they don't grant a financial incentive or allow only loans for the installation and purchase of fuelling infrastructures.

Condition v4 encompasses the existence or non-existence of states with "carbon pricing policy", ZEV programs, LEV regulations, "ZEV international and U.S climate alliance participation" and "low carbon fuel policy". States without ZEV and LEV plans, mandates, participation, and contribution in the acts or that only take part in "U.S climate alliance participation" are assigned "0". States with ZEV mandates, LEV regulations, low carbon pricing, and policies or that take part in the climate alliance participation are assigned "1".

Lastly, condition v5 comprises outreach activities and awareness campaigns regarding EVs i.e., "EV community readiness" plans and scoring of state-wide campaigns and programs that train sellers in retailing EVs. The scoring of the awareness campaigns and training were calibrated using Tosmana software (Cronqvist, 2019) and got a threshold of 7 from the analysis. Thus, state that takes part in the project of "EV community readiness" and have more than 7 total scoring of outreach activities and awareness campaign been assigned "1". States are assigned "0" whenever they don't take part in "EV community readiness" initiative projects and/or have a total score less than 7 for the of outreach activities and awareness campaign at the state level.

The dichotomization of twenty states for five conditions and outcomes i.e., the data matrix is embodied in Table 7. Taking five conditions of binary cases (0,1) will result in (32)2^5 possible configurations. for this study, we have 20 cases/states.

Table 7 Data Matrix

Case-ID	State and federal level conditions					Outcome condition
	FININC	NONFININC	CHARGEINF	ZEVMAP	OAAAC	OP
Arizona (AZ)	1	1	0	0	0	1
California (CA)	1	1	1	1	1	1
Colorado (CO)	1	0	1	1	1	1
Connecticut (CT)	0	1	0	1	1	0
Florida (FL)	0	1	0	0	0	0
Georgia (GA)	0	1	1	0	0	0
Hawaii (HI)	0	1	1	0	1	0
Illinois (IL)	0	1	0	0	0	0
Maryland (MD)	1	1	1	1	1	1
Massachusetts (MA)	0	1	1	1	1	0
Michgan (MI)	0	0	0	0	0	0
New Jersey (NJ)	1	0	1	1	1	1
New York (NY)	0	1	1	1	1	0
North Carolina (NC)	0	1	0	0	0	0
Ohio (OH)	0	0	0	0	0	0
Oregon (OR)	1	0	1	1	1	1
Pennsylvania (PA)	1	0	1	1	0	0
Texas (TX)	0	0	0	0	0	0
Virginia (VA)	0	1	0	1	0	0
Washington (WA)	0	1	1	1	0	1

The truth table in table 8 is the conversion (placing cases with the same configuration of condition and outcome together) of the data matrix. Four configurations ensued for the sufficient outcome to occur. A total of twelve states/cases are covered in the five (7,10,11,12) configurations that contribute to the same outcome (1), Where 1 is the designation for a favorable outcome i.e., PEV adoption in the United States. In contrast, the other series of configurations are not sufficient for the outcome to occur, as the outcome column (O) tells the sufficient/non-sufficient for PEV adoption to occur.

Table 8 Truth table

Name	Thresholds				
FININC before calibration	6,81	Truth Table:			
FININC	--				
NONFININC	--	v1:	FININC	v2:	NONFININC
CHARGINF	--	v3:	CHARGINF	v4:	ZEVMAP
ZEVMAP	--	v5:	OAAAC		
OAAAC	--	O:	OP	id:	CASEID

	State and federal level conditions							
series	v1	v2	v3	v4	v5	O	Number of configuration	id
1	0	0	0	0	0	0	3	MI, OH, TX
2	0	1	0	0	0	0	3	FL, IL, NC
3	0	1	0	1	0	0	1	VA
4	0	1	0	1	1	0	1	CT
5	0	1	1	0	0	0	1	GA
6	0	1	1	0	1	0	1	HI
7	0	1	1	1	0	1	1	WA
8	0	1	1	1	1	0	2	MA, NY
9	1	0	1	1	0	0	1	PA
10	1	0	1	1	1	1	3	CO, NJ, OR
11	1	1	0	0	0	1	1	AZ
12	1	1	0	1	1	1	2	CA, MD

Truth table quality was evaluated by examining if the combination of the condition has produced: composed sufficient and non-sufficient outcomes, adequate diversity of the condition's configuration, and the non-appearance of counter-intuitive (if all the combination of conditions are 0 and providing an outcome of 1 or having1 for all the combination of the condition and producing and outcome of 0) (Gerrits Lasse, 2018; Schneider & Wagemann, 2012). Thus, the truth table was qualified and proceeded to determine the solution.

Next will be a discussion about Boolean operators and necessary and sufficient conditions with results so that to understand the discussion better.

4.4 Boolean Operators, Necessity, sufficiency, and INU's conditions

The finalize minimized combination of the condition for an outcome to occur is called a solution. The solution encompasses the configuration of the condition with a Boolean operator for the sufficient of the positive or negative outcome. There are three Boolean operators; logical AND designated as "*" or". (dot)", logical OR as "+", and logical NOT as "~". The logical OR can also be denoted by changing the designation of the conditions which were in capital letters to a small letter (Gerrits Lasse, 2018; Grofman & Schneider, 2009). For example, the combination of v1*v5 from our study is represented by the AND Boolean operator means. This implies both conditions produce *conjunction* i.e., conjunctural causation is expressed by the AND operator (Schneider & Wagemann, 2012) with v1 and v5 having a full set of membership. Similarly, a solution can be v1*v2 +v1*v5 named as *disjunction*, OR the Boolean operator expresses disjunction (Schneider & Wagemann, 2012). This means cases represent by the disjunction of the conditions have a fully set membership either in v1*v2 or v1*v5 or both. The disjunction v1*v2 +v1*v5 contains two (v1*v2 & v1*v5) conjunction meaning the OR Boolean operator gives the sense of having a different path for the same outcome basis (equifinality) (Gerrits Lasse, 2018). Lastly, the logical NOT operator, representing not being a member of a set/condition (Gerrits Lasse, 2018; Schneider & Wagemann, 2012). For instance, case/s can explain disjunction ~v1*v3*v4 and these case/s are membership of set v2&3 but not set v1.

"Necessary condition" happens when a certain condition is a requirement for the outcome to occur i.e., an outcome condition will happen each time that specific condition is there and vice versa (Gerrits Lasse, 2018). In contrast the sufficient condition, a certain condition is sufficient for the outcome to occur but not the reverse way like the necessary condition, which means the outcome can happen due to different sufficient conditions. Gerrits has put the definition of necessary as "only if "the condition appears then the outcome occurs and vice versa. sufficiency as "if" the condition happens then the outcome occurs. Besides, the arrow → designated for sufficiency while ← the arrow is for necessity.

Future more, QCA analysis has concerns like limited diversity and/or contradiction of cases. The contradiction of cases takes place when cases come up with a similar combination of conditions and set membership but results in a different outcome. The truth table after minimization of the data matrix doesn't find the contradictory configuration of the condition. Accordingly, a future improvement in the calibration of the condition and outcome was not necessary.

Whereas limited diversity is to have limited diversity in the configuration of the conditions and outcome (Gerrits Lasse, 2018; Grofman & Schneider, 2009; Schneider & Wagemann, 2012). Limited diversity can occur due to various reasons and arithmetic remainders are among them (Gerrits Lasse, 2018) where Schneider & Wagemann, (2012) defined it as the occurrence of less combination of cases due to a smaller number of cases compared with the possible combination of condition. For instance, this study considers five conditions with 32 possible configurations more than the 20 cases, meaning it has an arithmetic remainder. Following the previous study by Held& Gerrits (2019), having 12 minimized configurations out of the 20 cases is believed to be moderately limited diversity.

Therefore, the next step is presenting the four configurations for the sufficient outcome to occur.

~v1v2v3v4~v5 + v1~v2v3v4v5 + v1v2~v3~v4~v5 + v1v2v3v4v5 → O

Afterward providing the above configuration more simply i.e., minimization will be the next step. The logical minimization is only for the configuration that has a positive (1) outcome as indicated above.

The complex configuration is required in simplified form with the minimized condition and Boolean operator. we are here only considering the sufficient condition for the outcome to occur but mind that we can know the sufficient conditions for the PEV adoption not to take place which will have another configuration of conditions. This is among the characteristic of the QCA i.e., the "asymmetry". Signifying those conjunctions sufficient for the outcome to happen is not the mirror image of the outcome not to occur (cf. Misangyi et al., 2017). The following disjunction is the minimized configuration from the previous configuration.

~v1v2v3v4~v5 + v1v3v4v5 + v1v2~v3~v4~v5 + v1v3v4v5 → O

This configuration can also be minimized again to avoid redundancy of conditions for the outcome occurrence, and this will be done by the table matrix to get a parsimony solution.

Table 9 Minimization table for parsimony solution

	primitive expression			
reduced primitiv eexpression	~v1v2 v3 v4~ v5	v1 ~v2 v3 v4 v5	v1 v2~ v3~ v4~ v5	v1 v2 v3 v4 v5
~v1v2 v3 v4~ v5	x			
v1 v3 v4 v5		x		x
v1 v2~ v3~ v4~ v5			x	
v1 v3 v4 v5		x		x

From table 9, v1v3v4v5, v1v2~v3~v4~v5, ~v1 v2v3v4~v5 explain the sufficient outcome precisely and take in all four primitive expressions recorded. Thus, v1v2v3v4 is eliminated to get the final parsimony solution since it is redundant. Accordingly, the final solution is described below as.

v1v3v4v5 + v1v2~v3~v4~v5 + ~v1 v2v3v4~v5 → O (PEV adoption)

What do these configurations show? This result reveals three attributes of "casual complexity". Firstly, the provided configuration works all together for the outcome to occur, the financial incentive or other condition on its own can't be sufficient for the PEV adoption to occur instead it's a combination of the conditions. Secondly, there is more than one combination that can lead to the PEV uptake i.e., in our case we have three conjunctions of combination for the outcome to happen, not only just one path/conjunction. Lastly, the solution or configuration we can get for the PEV adoption not to happen is not the mirror image of the configuration we obtain for the PEV adoption to occur. Both solutions for the negative and positive outcomes are different configurations. Because the absence of financial incentives might not lead to PEV adoption but it's not necessary that the presence of the financial incentive can lead to PEV adoption. Thus, to understand PEV uptakes should be analysed separately. We just cannot conclude that the presence of financial incentives is enough. Note that, determining the sufficient configuration for the PEV adoption not to happen is beyond our objective.

We have been explaining the results computed from the TCO model and the configuration of the condition with interpretations. So, the Next step is to discuss in detail the results we revealed. The parsimonious solution with three conjunctions is the final configuration for PEV adoption to take place. let's start with the necessary condition for interpreting this minimized configuration. Gerrits Lasse (2018) defined a necessary condition, as whenever a condition is obligatory for the outcome to appear. Table 8 shows that there is no condition that is necessary for the outcome/PEV adoption to occur, respectively the final solution can also verify that. Looking at the sufficient condition is when an outcome can alternatively occur only by one condition i.e., the condition alone is sufficient for the outcome to happen (Gerrits Lasse, 2018; Grofman & Schneider, 2009). This study also showed that there is not only one condition that is sufficient for the PEV adoption to happen instead it is three conjunctions.

The occurrence of an outcome due to absolute necessary or sufficient conditions only is improbable because of casualty i.e., the configuration of conditions is vital for the outcome to happen in this complex world where QCA adapts that. Result in, the final configuration of conditions/solution typically with disjunctions and conjunctions of condition for an outcome occurrence, these condition/s in the configuration hold the properties of INUS-condition (Gerrits Lasse, 2018; Mackie, 1965). INUS-condition is defined as an "Insufficient but necessary part of a condition which is itself unnecessary but sufficient for the result" (Mackie, 1965, p. 245).

The Parsimony solution has three conjunctions. Indicating, an outcome won't happen only by one of the conditions itself. Let's take v1v2v3v4 conjunction for a favourable outcome to comprehend INUS-condition. v1 is insufficient alone but a necessary condition in conjunction with v3, v4&v5 for the favourable outcome but again it is unnecessary but sufficient for EV adoption (Mackie, 1965) implying v1 is depicted as an INUS condition. This also applies to the other conditions in the disjunction/three conjunction of the solution. Thus, we have condition/s that are exemplified as INUS conditions but not absolute necessary or sufficient conditions that led to PEV uptake in this analysis.

These three conjunctions of condition embody the equifinality where the different configurations of condition will lead to the same outcome. v1v3v4v5, v1v2~v3~v4~v5, or ~v1 v2v3v4~v5 are sufficient conjunction of conditions that will lead to PEV adoption. This result also aligns with the configurational theory we have discussed in chapter 2. The configurational theory is concerned with the holistic configuration of the conditions not with an individual condition or factors like the contingency theory (Ye et al., 2021). Similarly, this complex technological transition of e-mobility adoption does not involve only the influence of one condition to be practical instead it's a high interaction and combination of conditions.

The following phase is to review the three conjunctions individually and thoroughly. The final configuration of conditions for a favorable outcome is linked with twelve cases where the *first conjunction* is v1v3v4v5. The conjunction ties the state and federal level financial initiatives along with policies and EV promotion actions at the state level. Financial incentives given to EV consumers are not only sufficient for EV adoption but also combined with the presence of EV-promoting ZEV mandates and agreements as well as fuelling infrastructure development strategies together with EV awareness campaigns. Conjunction v1v3v4v5 is explained by five cases (California, Maryland, Colorado, New Jersey, and Oregon states). Accordingly, this is among the substantial configuration for a favorable outcome as five cases are explaining it amid seven.

The percentage change in table 6 indicates that these five states have effective incentives that motivate consumers to own EVs by dropping the BEVs TCO equated to ICE. The five states grant a different type of monetary incentives that have considerably lessened the TCO of BEVs. California, Colorado, Oregon, and Maryland state grant rebates and tax credits at the state level to improve the demand for EVs. while New Jersey exempts EVs from use and sales tax, it levied a high tax on ICEs.

EV fees are among the variables used in TCO computation recognized as a disincentive. Some states charge fees for having EVs to compensate that the government was supposed to collect revenue by taxing fuels (Wee et al., 2019). California, Colorado, and Oregon states charges fee for having EVs but these fees are insignificant in increasing the ownership cost of BEVs associated with ICE. But states like Georgia have higher EV fees that might discourage consumers to own BEVs. The BEV's TCO in Colorado is 2.43% lower than the ICE, inferring Colorado has an excellent financial incentive that encourages EV purchasers. Note that there are states that provide rebates (e.g., 2250$ in Connecticut) but are insignificant in altering the TCO of BEVs over the period. Thus, efficient financial incentives are required for PEV uptake.

Besides allowing incentives for the construction of fuelling infrastructure in residential, organizational, and public places is an essential configuration. California allows grants and rebates whereas Colorado, Oregon, New Jersey, and Maryland only grant for fuelling infrastructures. The provision of public fuelling infrastructure besides work and residential areas has a considerable effect on PEV adoption, and the parsimony solution also proves that. Comparably, the authority also relies on constructing charging infrastructure as precedence to increase EV sales. Similarly, EVs will be suitable for consumers as ICE whenever sufficient deployment charging infrastructures are made that sustain EV sales (Bauer, Hsu, Nicholas, & Lutsey, 2021). Moreover, supporting charging infrastructures is also visible, as most EV users in the United States charge their vehicles at the workplace and home (Smart & Salisbury, 2015).

The presence of ZEV mandate and agreements in the configuration is also sufficient for outcome occurrence. States like California, New York, Massachusetts, Pennsylvania, Connecticut, Washington, Oregon, New Jersey, Maryland, and Colorado are part of the ZEV program and are committed to setting action plans to expand ZEV sales by targeting electricity providers, EV manufacturers, and dealers. Because these have the role to sell desirable EVs, providing competitive electricity, and others (Chiladakis, Crowfoot, & Winston, 2013). Similarly, states that have introduced carbon pricing policies also have contributed to adopting EVs. EV sales are expected to grow whenever states are implementing these policies because it increases users' or organizations' costs to emit GHGs (Berg et al., 2020). Over again, it's revealed that states with adequate financial and fuelling infrastructure are not enough for EV uptake as an insufficient model available in the market also hiders consumers from owning EVs. California is a typical example, it's the first state in adopting EVs in the US by implementing the ZEV mandate in late nineteen selling over 30 plug-in EV models at present (NESCAUM, 2014).

Nevertheless, conditions (financial incentives along with fuelling infrastructure development strategies and ZEV promoting mandates and agreements) alone is not sufficient for EV adoption to occur as it requires additional factor (awareness and advocacy activities). A state-wide campaign for EV acceptance and delivery of training to the dealer for selling EVs is an important factor in conjunction with the conditions for EV acceptance in the United States. PEV adoption can be successful when v1, v3&v4 conditions are accompanied by an awareness campaign. This correspondent with the conjunction found involving the five cases. EV demand will be improved as the awareness campaign and EV readiness projects and advocacy activities are enacted. Consumers and dealers might not understand the effect of financial incentives granted for purchasing EVs and installing EVSEs if there are limited EV advocacy activities and awareness training given (Priessner et al., 2018). Katherine, et.al (2021) shows that California and New Jersey are two leading state that delivers comprehensive EV awareness promotions and is keen on training EV dealers and owners which resulted in the growth of their EV market. Therefore, the presence and combination of v1v3v4v5 conditions altogether will lead to PEV adoption.

The *second conjunction* is v1v2~v3~v4~v5, implying the other sufficient configuration of condition for a favorable outcome other than the previous one(equifinality). This configuration is explained only by Arizona state i.e., unconventional. As a result, it is challenging to decide the conjunction for PEV uptake. Arizona exempts sales tax and reduces "vehicle license tax" for EVs (https://afdc.energy.gov/). This financial incentive lowers ICE's TCO by 2.16% more than EVs which encourages EV consumers. Additionally, EVs have the benefit to access HOV lanes and are exempt from emission inspections. Arizona is amongst the states with high EV sales. The state doesn't incentivize fuelling infrastructure construction at the state level. However, private utility grants rebates for residential and commercial customers to install and purchase various levels of fuelling infrastructure, which isn't deemed for this study. Thus, local rebates for fuelling infrastructure can also be a possible way for the PEV uptake in Arizona which was disregarded in our study on top of the state financial and non-financial incentives.

Similarly, the *third conjunction* (~v1 v2v3v4~v5) is also explained by Washington state only. Once again, it's difficult to put judgment of this conjunction for PEV acceptance in the United States. Since one case is merely explaining the conjunction for a favorable outcome to happen. But still, it gives the importance of ZEV promoting mandates and agreements, as well as incentives offered to the construction of fuelling infrastructure towards adopting PEV as discussed in the first conjunction. Analytically, Washington state has no financial incentive but charges fee for owning EVs, which discourage consumers. Besides, it doesn't participate in EV community readiness projects that could have a role in delivering awareness campaigns to communities and organizations to accept EVs. However, it grants non-financial incentives, along with an incentive for the construction and purchase of charging infrastructure along with ZEV mandates and carbon pricing policies https://afdc.energy.gov/laws/state_summary?state=WA. Possibly, the absence of the financial incentive might be backed by the grants and rebates given for the construction of fuelling infrastructures. Thus, only non-financial incentives are not guaranteed for PEV adoption as the presence of ZEV promotion mandates and agreements in conjunction with fuelling infrastructure development strategies are also necessary for EV uptake.

The following discussion will be regarding the effect of financial incentives on EVs TCO. The TCO model is used to compare different types of vehicle ownership costs over five years period for this study. Our analysis showed maintenance, insurance, rebates, tax credits, registration fees, EV fees, and repair costs are relatively stable unlike the fuel cost and depreciation costs. The fuel costs and resale value can vary over time, and it affects the TCO over the ownership period. Regular gasoline prices used to calculate the fuel price were the "sales for resale" type, not the "retail outlet" due to data limitation which has lowered the total prices per 5 years. Because it's "wholesale" sales. While the "retail outlet" type of sale is utilized to calculate the electricity cost. Thus, the fuel cost for ICE in our study could have been higher than the present value illustrated in table 6, which intern increases the ICE's TCO/5 yrs. Accordingly, the calibration of the financial incentive might have changed.

Breetz & Salon, (2018) used three (BEV, HEV, and ICE) vehicle types to determine the 5 years TCO for fourteen cities in the United States. He indicated that there is a difference in maintenance, insurance, fuel, depreciation cost, and policies among the cities due to spatial diversity and claimed that the financial incentives given from local, state, and federal levels have made the EV's TCO to be competitive. Consistently, Hardman et al., (2017) also determined that ordinary vehicles which are not luxurious are becoming competitive with ICE due to the grant given for EVs. Similar findings are discovered by Hagman et al., (2016) and Lebeau et al., (2019) as well and our study also agrees with these studies.

EV upfront cost is among the barrier for users to purchase them. Nissan leaf SV and Toyota Corolla S Plus are used in this study where both were 2016 models. The purchase cost of BEV was approximately 37% higher than the ICE initial before the monetary incentives. However, the federal and state tax credits and rebates, a discount on annual registration fees and taxes, exemption of sales tax, and low operation cost over the possession period have reduced the BEVs TCO. Tax credits, exemption of sales tax, and rebates were having higher contributions to making the BEV cost competitive with ICEs. Our result showed that on average the ICE's TCO is 7.33% lower than the BEV however, Held & Gerrits (2019) found ICE's TCO to be 34.9% lower compared to the EV. Federal tax credit grants to all states owning ordinary EVs can be the factors that created this variation. But again, the percentage change computed in our study are almost similar to Breetz & Salon, (2018) findings with a few variations since our study disregards local policies and costs.

Hawaii state has the highest TCO difference among the vehicles, with ICE’s TCO 16.1% lower than BEVs followed by Georgia state where the ICE’s TCO is 11.2% lower than BEVs. Both states lack state-level rebates. However, Colorado and Oregon state with 2.4 and 2.2 % higher ICEs TCO compared to BEVs respectively. California have almost a balanced TCO for both vehicles that is because only federal and state-level tax credits and rebates are considered. But the state gives additional rebates at the local level. For example, EV consumers who are based around “San Joaquin Valley” are granted a $3000 additional rebate https://afdc.energy.gov/, which could have lowered the EV TCO by 7.4%. Thus, considering the local incentive might have yielded a different result.

EV fees are disincentives collected to offset the loss made by fuel taxes and might discourage the e-mobility transition. For instance, Georgia state charges a $200 EV fee annually which increases the BEV TCO. However, in general, EV fees and the reduction of annual registration fees have a smaller effect on changing the TCO of BEVs. This implies the competitiveness of BEVs TCO with ICE is due to the exemption of sales tax, rebates, and tax credits awarded to e- mobilities. Similar findings are revealed by Ewelina & Grysa (2021), Palmer et al., (2018), Breetz & Salon, (2018) including Hardman et al (2017). According to Hagman et al., (2016), the cost of the battery is declared to contribute to the higher purchase cost of BEVs. The value of battery cost is expected to decrease in the coming years which in turn will lower EV's upfront cost. Consequently, EVs will be competitive in the future in terms of the purchase cost (due to lower battery cost) and the total cost over the ownership period (because of incentives).

Chapter 5: Conclusions

The study examines to recognize the configuration of e-mobility incentives, regulations, and actions that explain PEV adoption to take place in the United States. Additionally, to realize how visible difference can the monetary incentive created in the TCO of BEVs compared to ICE. Thus, the summary of our results in this study will be reviewed below.

- Government policies trying to unravel several barriers to e-mobility adoption individually are improbable to succeed because our research revealed that several configurations of factors *altogether* are the means for a favourable outcome to happen. Besides the conjunction of conditions for PEV adoption in another country or area won't be the same since each case is unique.

- Allowing effective financial incentives (condition v1) for consumers that have an effect in reducing total cost over the ownership period *in combination with* incentivizing the construction of fuelling infrastructure (condition v3) *in combination with* ZEV promoting mandates and agreements (condition v4) *in combination with* EV awareness campaigns (condition v4) will lead for PEV adoption (favourable outcome) to happen.

- The conjunction of conditions for PEV adoption occurrence is not the *mirror image* of the conjunction for the non-occurrence. The absence of financial incentives might not lead to PEV adoption but it's not necessary that financial incentives presence can lead to PEV uptake. A separate analysis is required to understand favourable and unfavourable outcome occurrences.

- Analytically, the conjunction of monetary incentives and state-level e-mobility regulation and policies leads to successful EV acceptance. Hence, a favourable outcome happens due to the interaction of conditions altogether - approving the configurational theory on EV policies.

- Financial incentives for PEVs can be rebates, exemption of sales and use taxes, tax credits, and reduction of registration fees and license taxes. Taking this all into account, seven states have strong financial incentives that affect BEV's TCO amid twenty cases. Most states' disincentives like EV fees have a smaller effect on the TCO of BEVs.

- The upfront cost of BEVs was minimized mainly by the rebates, tax credits, and exemption of sales tax at the state and federal levels. The financial incentives in both levels have made BEV costs to be competitive, as the BEV TCO was 7.33% on average higher than ICEs.

Corresponding to the result, the parsimony solution with three conjunctions v1v3v4v5+ v1v2~v3~v4~v5 +~v1 v2v3v4~v5 is the configuration for PEV adoption to happen. The occurrence of outcome due to absolute necessary and sufficient conditions only is unusual in the complex world because of casual complexity. Our result validates that these conditions in conjunction hold the "INUS" condition attribute indicating no condition individual is sufficient or necessary for PEV adoption to occur. Next, we will assess our results with previous studies.

Breetz & Salon, (2018) determined TCO for three types of EVs and concluded that EVs TCO was competitive due to the financial incentive given from both federal, state, and local levels. Correspondingly, Hardman et al., (2017) also find that financial incentives upon purchase are effective by allowing EVs cost to be competitive with ICE but not for luxurious vehicles. Both Hagman et al., (2016) and Lebeau et al., (2019) also find similar findings. This study also agrees with these studies. This implies exemption of sales tax, rebates and tax credit are the primary financial incentive that drops Ev's high purchase cost and creates EV competitiveness with ICE. The related finding is revealed by Ewelina & Grysa (2021), Palmer et al., (2018), Breetz & Salon, (2018) including Hardman et al (2017).

Haustein et al., (2021) suggest an increase in fuelling infrastructure to have a significant effect on EV adoption in Denmark. Zhou & Li, (2018) also directs the effect of subsidy i.e., individually for the diffusion of EV saturation. Similarly, Slowik & Lutsey, (2017) and Wang et al., (Wang, Li, & Zhao, 2017b) both studies focus on the effect of the attribute independently on EV preference. A survey used by Bjerkan et al., (2016) again relates financial and non-financial incentives with demographic characteristics to determine their role in adopting EVs in Norway. And revealed that access to HOV lanes is a crucial factor, but sales tax exemption/monetary incentive was a very substantial factor for EV uptake (Bjerkan et al., 2016). Let’s take North Carolina, among the states considered for our study that grants non-financial incentives unlike financial incentives and incentives for fuelling infrastructure construction, but it has low diffusion of EV penetration. Implies, the significance of one factor over the other, and individualism won’t attain e-mobility transition. Thus, those studies contradict our findings as they are all focusing on contingency theory while PEV uptake can’t occur by significance or only one factor alone but instead through the combination of conditions altogether i.e., configurational theory.

A country having a strong policy tool separately bounds the transition of e-mobilities because it demands the combination of causal conditions/policy actions for the shift to be successful (Yong & Park, 2017). He found that countries having strong financial incentives merely are less successful in EV penetration due to a lack of fuelling infrastructure. Besides Kester et al (2018) discovered the prerequisite of strong policies that combine non-financial and financial incentives with the establishment of an awareness campaign by the Nordic region to advance EV uptake. Accordingly, it concluded that effective financial incentives must be combined with the supply of EV fuelling infrastructure. This finding supports our result that the conjunction of monetary incentives and charging infrastructure in conjunction with EV-promoting mandates and participation as well as awareness campaigns are the way out for the diffusion of PEVs in the United States.

Ye et al., (2021) similarly implement a fussy-set QCA to understand the combination of EV policy measures with psychological traits (three factors) for EV uptake in China and discovered that presence of finical incentives with the combined absence of the three factors of psychological traits will lead for lower EV acceptance. Thus, EV adoption in China will be successful with the presence of at least one of the psychological traits together with the monetary incentives which agrees with our findings that the presence of EV awareness campaigns altogether with v1, v3, and v4 conditions are required for EV adoption. Correspondingly, other studies carried out regarding e-mobility transition by Held & Gerrits, (2017) in European countries also revealed corresponding findings with our study, Ye et al., (2021) and Yong & Park, (2017) findings. The combination of disincentives that discourage ICE users on the road together with EV financial incentives and supply of charging infrastructure is the path for the e-mobility transition.

From this, we can understand that each case is unique which results in conjunction with a different condition for a favorable outcome to occur. This implies the conjunction of conditions for EV adoption to happen in European countries Held & Gerrits, (2019) across numerous countries Yong & Park, (2017), China Ye et al., (2021), Nordic region Kester et al (2018) and the United States by our study is not the same since the cases are unique and consider different circumstances. However, this and previous studies concluded that a successful e-mobility transition needs the conjunction of factors altogether as conditions individually will not realize the goal line.

This invalidates the contingency theory focusing on how independent variables individually will influence an outcome to occur and proves the configurational theory that only one factor might not lead to PEV adoption. similarity, e-mobility Incentives and ZEV promoting mandates and agreements in conjunction with awareness campaigns are not the only ways for EV uptake instead one conjunction of conditions and various combinations of factors can lead to a favorable outcome.

Our solution/sufficient conjunction of four conditions for PEV uptake in the United States cannot be duplicated as it is for other areas or countries to diffuse EV saturation, because cases and conditions have unique characteristics and can head to a different result. Accordingly, countries that wish to promote EVs are required to implement a comprehensive study specific to that area, policies, and strategies.

After all, what does our result imply for policymakers? Policymakers should recognize that policies and strategies that need to promote e-mobility must be constructed and planned as all-inclusive bundles instead of an individual or separate action or policy. Furthermore, the causal relationship of factors and outcome (contingency theory) is now clearly justified that they won't achieve in shifting to e-mobilities.

Let's now outline the limitations of this study. The study considered mobility policies only at the state and federal level and we recommend considering the local policies as well for the future with additional states to increase the diversity in the configuration. The condition chosen for this study is the general aspects and including other conditions like GDP might have contributed to PEV adoption. The change of BEVs TCO in comparison with ICEs is considered generally due to financial incentive effect only and the influence of another variable on TCO should also be analysed to better understand it. Lastly, two types of mid-sized vehicles are only used to decide the financial incentive contribution in PEV adoption and including different sizes and types of vehicles might also yield a different result in TCO.

Bibliography

AAA, (2020). *"AAA's your driving costs: How much are you really paying to drive?".* (). Retrieved from https://exchange.aaa.com/automotive/driving-costs/

AFDC, Alternative fuel data center. (2022). *States that have adopted california's vehicle standards under section 177 of the federal clean air act.* (). Retrieved from https://afdc.energy.gov/laws/6493

Axsen, J., Hardman, S., & Jenn, A. (2022). What do we know about zero-emission vehicle mandates? *Environmental Science & Technology,*

Bansilal, S. (2017). The application of the percentage change calculation in the context of inflation in mathematical literacy. *Pythagoras, 38*(1), 1-11.

Bauer, G., Hsu, C., Nicholas, M., & Lutsey, N. (2021). Charging up america: Assessing the growing need for US charging infrastructure through 2030. *White Paper.ICCT (International Council on Clean Transportation), July, 2*

Berg, W., Vaidyanathan, S., Jennings, B., Cooper, E., Perry, C., DiMascio, M., & Singletary, J. (2020). The 2020 state energy efficiency scorecard. *Washington, DC: ACEEE.Aceee.Org/Research-Report,*

Bjerkan, K. Y., Nørbech, T. E., & Nordtømme, M. E. (2016a). Incentives for promoting battery electric vehicle (BEV) adoption in norway. *Transportation Research Part D: Transport and Environment, 43*, 169-180.

Breetz, H. L., & Salon, D. (2018). Do electric vehicles need subsidies? ownership costs for conventional, hybrid, and electric vehicles in 14 US cities. *Energy Policy, 120*, 238-249.

Bui, A., Slowik, P., & Lutsey, N. (2020). Update on electric vehicle adoption across US cities. *Retrieved from the International Council on Clean Transportation Https://Theicct.Org/Publications/Ev-Update-Us-Cities-aug2020,* Retrieved from https://theicct.org/publication/update-on-electric-vehicle-adoption-across-u-s-cities/

Burnham, A., Gohlke, D., Rush, L., Stephens, T., Zhou, Y., Delucchi, M. A., . . . Ou, S. (2021). Comprehensive total cost of ownership quantification for vehicles with different size classes and power trains., 1-227.

Chiladakis, L., Crowfoot, W., & Winston, R. (2013). California's ZEV action plan. *World Electric Vehicle Journal, 6*(4), 1048-1053.

CleanTechnica. (2019). United states electric vehicle sales . Retrieved from https://cleantechnica.com/2020/01/16/tesla-gobbled-up-81-of-us-electric-vehicle-sales-in-2019/

Coffman, M., Bernstein, P., & Wee, S. (2017). Electric vehicles revisited: A review of factors that affect adoption. *Transport Reviews, 37*(1), 79-93.

Cronqvist, L. (2019). Tosmana [version 1.61]. *Universitu of Trier.[Online].Disponível Em: Https://Www.Tosmana.Net/(Acesso Em: 14 Mai.2020),*

Delery, J. E., & Doty, D. H. (1996). Modes of theorizing in strategic human resource management: Tests of universalistic, contingency, and configurational performance predictions. *Academy of Management Journal, 39*(4), 802-835.

Doty, D. H., & Glick, W. H. (1994). Typologies as a unique form of theory building: Toward improved understanding and modeling. *Academy of Management Review, 19*(2), 230-251.

EPA, E. P. A. (2020). *Agency accomplishments and environmental progress under administrator wheeler.* (). Washington: Retrieved from https://www.epa.gov/newsroom/epa-year-review-2020

Ewelina, S., & Grysa, K. (2021). Assessment of the total cost of ownership of electric vehicles in poland. *Energies, 14*(16), 4806.

Gerrits Lasse. (2018). *The evaluation of complex infrastructure projects : A guide to qualitative comparative analysis*. Cheltenham, UK: Edward Elgar Publishing.

Gerrits, L. (2012). Complexity and public decision-making. In L. Gerrits (Ed.), *Punching clouds : An introduction to the complexity of public decision-making* (pp. 14-29). Litchfield: Emergent Publications.

Ghandi, A., & Paltsev, S. (2020). Global CO2 impacts of light-duty electric vehicles. *Transportation Research Part D: Transport and Environment, 87*, 102524.

Greene, D. L., Park, S., & Liu, C. (2014). Public policy and the transition to electric drive vehicles in the US: The role of the zero emission vehicles mandates. *Energy Strategy Reviews, 5*, 66-77.

Grofman, B., & Schneider, C. Q. (2009). An introduction to crisp set QCA, with a comparison to binary logistic regression. *Political Research Quarterly, 62*(4), 662-672.

Hagman, J., Ritzén, S., Stier, J. J., & Susilo, Y. (2016). Total cost of ownership and its potential implications for battery electric vehicle diffusion. *Research in Transportation Business & Management, 18*, 11-17.

Hardman, S. (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.

Hardman, S., Chandan, A., Tal, G., & Turrentine, T. (2017). The effectiveness of financial purchase incentives for battery electric vehicles–A review of the evidence. *Renewable and Sustainable Energy Reviews, 80*, 1100-1111.

Haustein, S., Jensen, A. F., & Cherchi, E. (2021). Battery electric vehicle adoption in denmark and sweden: Recent changes, related factors and policy implications. *Energy Policy, 149*, 112096.

Held, T., & Gerrits, L. (2019). On the road to electrification–A qualitative comparative analysis of urban e-mobility policies in 15 european cities. *Transport Policy, 81*, 12-23.

Huang, Y., & Qian, L. (2018). Consumer preferences for electric vehicles in lower tier cities of china: Evidences from south jiangsu region. *Transportation Research Part D: Transport and Environment, 63*, 482-497.

Jenn, A., Springel, K., & Gopal, A. R. (2018). Effectiveness of electric vehicle incentives in the united states. *Energy Policy, 119*, 349-356.

Jin, L., & Slowik, P. (2017). Literature review of electric vehicle consumer awareness and outreach activities. *International Council on Clean Transportation.Available Frominternet: Https://Www.Theicct.Org/Sites/Default/Files/Publications/Consumer-EV-Awareness_ICCT_Working-Paper_23032017_vF.Pdf,*

Katherine ,Stainken, Peter , O'Connor, and Russell ,Corbin. (2021). *Top 25 states supporting the EV driver.* (). Los Angeles ,United States: Plug In America.org. Retrieved from https://pluginamerica.org/wp-content/uploads/2021/02/25-States-Supporting-the-EV-Driver.pdf

Kester, J., Noel, L., de Rubens, G. Z., & Sovacool, B. K. (2018). Policy mechanisms to accelerate electric vehicle adoption: A qualitative review from the nordic region. *Renewable and Sustainable Energy Reviews, 94*, 719-731.

Kim, M., Oh, J., Park, J., & Joo, C. (2018a). Perceived value and adoption intention for electric vehicles in korea: Moderating effects of environmental traits and government supports. *Energy, 159*, 799-809.

Kim, M., Oh, J., Park, J., & Joo, C. (2018b). Perceived value and adoption intention for electric vehicles in korea: Moderating effects of environmental traits and government supports. *Energy, 159*, 799-809.

Kumar, R. R., & Alok, K. (2020). Adoption of electric vehicle: A literature review and prospects for sustainability. *Journal of Cleaner Production, 253*, 119911.

Lebeau, P., Macharis, C., & Van Mierlo, J. (2019). How to improve the total cost of ownership of electric vehicles: An analysis of the light commercial vehicle segment. *World Electric Vehicle Journal, 10*(4), 90.

Lévay, P. Z., Drossinos, Y., & Thiel, C. (2017). The effect of fiscal incentives on market penetration of electric vehicles: A pairwise comparison of total cost of ownership. *Energy Policy, 105*, 524-533.

Li, Y., Koppenjan, J., & Verweij, S. (2016). Governing environmental conflicts in china: Under what conditions do local governments compromise? *Public Administration, 94*(3), 806-822.

Liao, F., Molin, E., & van Wee, B. (2017). Consumer preferences for electric vehicles: A literature review. *Transport Reviews, 37*(3), 252-275.

Lutsey, N. (2015). Transition to a global zero-emission vehicle fleet: A collaborative agenda for governments.

Lutsey, N., & Sperling, D. (2009). Greenhouse gas mitigation supply curve for the united states for transport versus other sectors. *Transportation Research Part D: Transport and Environment, 14*(3), 222-229.

Mackie, J. L. (1965). Causes and conditions. *American Philosophical Quarterly, 2*(4), 245-264.

Marx, A., Cambré, B., & Rihoux, B. (2013). Crisp-set qualitative comparative analysis in organizational studies. *Configurational theory and methods in organizational research* () Emerald Group Publishing Limited.

Melton, N., Axsen, J., & Goldberg, S. (2017). Evaluating plug-in electric vehicle policies in the context of long-term greenhouse gas reduction goals: Comparing 10 canadian provinces using the "PEV policy report card". *Energy Policy, 107*, 381-393.

Mersky, A. C., Sprei, F., Samaras, C., & Qian, Z. S. (2016). Effectiveness of incentives on electric vehicle adoption in norway. *Transportation Research Part D: Transport and Environment, 46*, 56-68.

Misangyi, V. F., Greckhamer, T., Furnari, S., Fiss, P. C., Crilly, D., & Aguilera, R. (2017). Embracing causal complexity: The emergence of a neo-configurational perspective. *Journal of Management, 43*(1), 255-282.

Narassimhan, E., & Johnson, C. (2018a). The role of demand-side incentives and charging infrastructure on plug-in electric vehicle adoption: Analysis of US states. *Environmental Research Letters, 13*(7), 074032.

National Research Council. (2015). Overcoming barriers to deployment of plug-in electric vehicles. Retrieved from http://www.nap.edu/ catalog.php?record_id=21725

Nayum, A., Klöckner, C. A., & Mehmetoglu, M. (2016). Comparison of socio-psychological characteristics of conventional and battery electric car buyers. *Travel Behaviour and Society, 3*, 8-20.

NESCAUM. (2014). *Multi-state ZEV action plan.* ().ZEV Program Implementation Task Force. Retrieved from www.nescaum.org%2Fdocuments%2F2018-zev-action-plan.pdf&uct=1629829389&usg=yAU9wHTWFQ6ly1Ymnxkz-AjY2QU.&ved=2ahUKEwjC9ZnFi9H6AhWywgIHHeqyDFwQwtwHKAB6BAgAEAE

Outlook, I. G. E. (2021). Accelerating ambitions despite the pandemic. *International Energy Agency: Paris, France,*

Paige, P. (2015). *Nissan announces U.S. pricing for 2016 LEAF.* (). Retrieved from https://usa.nissannews.com/en-US/releases/release-9c04406501da47ec83c0c3138bf6a5f5-nissan-announces-u-s-pricing-for-2016-leaf

Palmer, K., Tate, J. E., Wadud, Z., & Nellthorp, J. (2018). Total cost of ownership and market share for hybrid and electric vehicles in the UK, US and japan. *Applied Energy, 209*, 108-119.

Pappas, I. O., Kourouthanassis, P. E., Giannakos, M. N., & Chrissikopoulos, V. (2016). Explaining online shopping behavior with fsQCA: The role of cognitive and affective perceptions. *Journal of Business Research, 69*(2), 794-803.

Priessner, A., Sposato, R., & Hampl, N. (2018). Predictors of electric vehicle adoption: An analysis of potential electric vehicle drivers in austria. *Energy Policy, 122*, 701-714.

Ragin, C. C. (2009). Redesigning social inquiry. *Redesigning social inquiry* () University of Chicago Press.

Ragin, C. C. (1987). *The comparative method; moving beyond qualitative and quantitative strategies* University of California Press. Retrieved from http://www.jstor.org/stable/10.1525/j.ctt1pnx57

Ragin, C. C. (2000). Diversity-oriented research : Between complexity and generality/constituting populations. In C. C. Ragin (Ed.), *Fuzzy-set social science* (pp. 21-42). Chicago: Chicago University Press.

Raux, C., Croissant, Y., & Pons, D. (2015). Would personal carbon trading reduce travel emissions more effectively than a carbon tax? *Transportation Research Part D: Transport and Environment, 35*, 72-83.

Rihoux, B., & Lobe, B. (2009). The case for qualitative comparative analysis (QCA): Adding leverage for thick cross-case comparison. *The Sage Handbook of Case-Based Methods,* , 222-242.

Rihoux, B., & Ragin, C. C. (2008). *Configurational comparative methods: Qualitative comparative analysis (QCA) and related techniques* Sage Publications.

Roland, I. (2022). Global EV sales for 2021. Retrieved from https://www.ev-volumes.com/country/total-world-plug-in-vehicle-volumes/

Schneider, C. Q., & Wagemann, C. (2012). *Set-theoretic methods for the social sciences: A guide to qualitative comparative analysis* Cambridge University Press.

Shafiei, E., Davidsdottir, B., Fazeli, R., Leaver, J., Stefansson, H., & Asgeirsson, E. I. (2018). Macroeconomic effects of fiscal incentives to promote electric vehicles in iceland: Implications for government and consumer costs. *Energy Policy, 114*, 431-443.

Sheldon, T. L., & DeShazo, J. R. (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.

Sierzchula, W., Bakker, S., Maat, K., & Van Wee, B. (2014). The influence of financial incentives and other socio-economic factors on electric vehicle adoption. *Energy Policy, 68*, 183-194.

Slowik, P., & Lutsey, N. (2017). Expanding the electric vehicle market in US cities. *International Council on Clean Transportation (ICCT),*

Smart, J. G., & Salisbury, S. D. (2015). Plugged in: How americans charge their electric vehicles.

Smela, M. (2021). The qualitative comparative analysis: An overview of a causal complexity approach. Paper presented at the *SHS Web of Conferences, , 92* 08020.

Stephens, T. S., Birky, A., & Dwyer, M. (2020). Vehicle technologies office research and development program, prospective benefits assessment report for FY 2020., 1-69.

Wang, S., Li, J., & Zhao, D. (2017a). The impact of policy measures on consumer intention to adopt electric vehicles: Evidence from china. *Transportation Research Part A: Policy and Practice, 105*, 14-26.

Wang, S., Li, J., & Zhao, D. (2017b). The impact of policy measures on consumer intention to adopt electric vehicles: Evidence from china. *Transportation Research Part A: Policy and Practice, 105*, 14-26.

Wee, S., Coffman, M., & La Croix, S. (2018). Do electric vehicle incentives matter? evidence from the 50 US states. *Research Policy, 47*(9), 1601-1610.

Wee, S., Coffman, M., & La Croix, S. (2019). Data on US state-level electric vehicle policies, 2010–2015. *Data in Brief, 23*, 103658.

Ye, F., Kang, W., Li, L., & Wang, Z. (2021). Why do consumers choose to buy electric vehicles? A paired data analysis of purchase intention configurations. *Transportation Research Part A: Policy and Practice, 147*, 14-27.

Yong, T., & Park, C. (2017). A qualitative comparative analysis on factors affecting the deployment of electric vehicles. *Energy Procedia, 128*, 497-503.

Zhou, Y., Levin, T., & Plotkin, S. E. (2016). Plug-in electric vehicle policy effectiveness: Literature review.

Zhou, Y., & Li, S. (2018). Technology adoption and critical mass: The case of the US electric vehicle market. *The Journal of Industrial Economics, 66*(2), 423-480.

Appendix 1:2016 Annual Electricity cost computation per state

Name	Average retail price ($/kWh)	for Electricity (2016 Nissan Leaf (30 kW-hr battery pack)) = 30 kWh/100 mi)	VMT =(15,000 miles/ year)	Electricy cost($)/year
Arizona	0.1033	0.3	15,000	464.85
California	0.1523	0.3	15,000	685.35
Colorado	0.0983	0.3	15,000	442.35
Connecticut	0.1724	0.3	15,000	775.8
Florida	0.0991	0.3	15,000	445.95
Georgia	0.0959	0.3	15,000	431.55
Hawaii	0.2387	0.3	15,000	1074.15
Illinois	0.0938	0.3	15,000	422.1
Maryland	0.1221	0.3	15,000	549.45
Massachusetts	0.1648	0.3	15,000	741.6
Michigan	0.1105	0.3	15,000	497.25
New Jersey	0.1338	0.3	15,000	602.1
New York	0.1447	0.3	15,000	651.15
North Carolina	0.092	0.3	15,000	414
Ohio	0.0984	0.3	15,000	442.8
Oregon	0.0883	0.3	15,000	397.35
Pennsylvania	0.1019	0.3	15,000	458.55
Texas	0.0843	0.3	15,000	379.35
Virginia	0.0909	0.3	15,000	409.05
Washington	0.0768	0.3	15,000	345.6

Appendix 2: 2016-2020 Annual regular gasoline cost computation per state

State	2016 Regular gasoline cost ($)	2017 Regular gasoline cost ($)	2018 Regular gasoline cost ($)	2019 Regular gasoline cost ($)	2020 Regular gasoline cost ($)	Regular gasoline cost ($)
Arizona	788.64	900	1079.04	1051.68	788.64	4608
California	970.824	1092.264	1339.944	1378.824	1114.824	5896.68
Colorado	783.6	912.24	1053.36	998.1	750.48	4497.78
Connecticut	801.12	906.24	1045.92	970.56	743.52	4467.36
Florida	814.08	940.3008	1061.7408	990.7008	769.9008	4576.7232
Georgia	777.6	882.72	1015.68	945.6	713.52	4335.12
Hawaii	826.56	1111.2	1395.36	1395.36	1395.36	6123.84
Illinois	829.44	934.56	1066.08	1015.2	826.08	4671.36
Maryland	826.512	935.472	1068.912	1004.592	766.992	4602.48
Massachusetts	806.1648	916.2792	1044.20448	969.1488	729.3936	4465.19088
Michigan	826.44	952.68	1091.04	1026.24	771.84	4668.24
New Jersey	723.12	943.44	1080.72	1024.56	795.12	4566.96
New York[4]	833.472	940.032	1086.61152	1018.93152	784.21152	4663.25856
North Carolina	812.88	916.56	1049.52	984.24	747.6	4510.8
Ohio	796.32	890.88	1019.52	966.72	753.6	4427.04
Oregon[4]	841.92	988.32	1170.72	1101.12	856.8	4958.88
Pennsylvania	900	1052.64	1185.12	1106.4	861.6	5105.76
Texas	743.04	865.92	997.92	919.2	681.12	4207.2
Virginia	743.52	850.56	982.56	912	671.52	4160.16
Washington	935.131344	1080.091344	1249.531344	1183.771344	933.657744	5382.18312

Appendix 3: 2016-2020 Annual Electricity cost computation per state

State	2016 elcetricy cost ($)	2017 elcetricy cost ($)	2018 elcetricy cost ($)	2019 elcetricy cost ($)	2020 elcetricy cost ($)	Total elcetricy cost ($)
Arizona	464.85	478.8	488.25	473.4	469.8	2375.1
California	685.35	722.7	746.1	760.05	810	3724.2
Colorado	442.35	449.55	450.9	457.65	462.15	2262.6
Connecticut	775.8	789.75	828.45	839.7	860.85	4094.55
Florida	445.95	468.9	464.4	469.8	452.7	2301.75
Georgia	431.55	442.35	432.9	443.7	446.85	2197.35
Hawaii	1074.15	1172.25	1313.1	1292.4	1239.75	6091.65
Illinois	422.1	427.05	432	430.2	438.75	2150.1
Maryland	549.45	539.1	520.65	505.8	501.75	2616.75
Massachusetts	741.6	770.4	832.5	828	818.55	3991.05
Michigan	497.25	507.6	513	520.2	549.45	2587.5
New Jersey	602.1	599.4	595.35	603.9	613.35	3014.1
New York	651.15	663.3	667.35	645.3	669.15	3296.25
North Carolina	414	406.8	416.25	425.25	424.35	2086.65
Ohio	442.8	442.8	447.3	431.1	424.8	2188.8
Oregon	397.35	396.45	398.25	396.45	396.9	1985.4
Pennsylvania	458.55	455.85	454.5	441.45	436.5	2246.85
Texas	379.35	377.1	381.6	387	376.2	1901.25
Virginia	409.05	413.1	426.6	428.4	412.2	2089.35
Washington	345.6	357.3	360	361.8	374.85	1799.55

Appendix 4: Steps to total cost of ownership computation for Arizona state

The other states are also computed following the same procedure and excel sheet for that can be provided upon request

Vehicle type		MSRP/Cost year ($)	Assessed value	formula for assesed value	Assessed value ($)	Rate of assesed value	Vehicle license tax = rate per $100 of assessed value is	rate of sales and use taxes
	2016	21665	60% of MSRP	60%	12999	0.028	363.972	5.60%
	2017	21665	16.25% less the previous year	previous assesed values - (16.25%*previous assesed values)	10886.66	0.0289	314.6245463	0
	2018	21665	16.25% less the previous year	previous assesed values - (16.25%*previous assesed values)	9117.58	0.0289	263.4980575	0
	2019	21665	16.25% less the previous year	previous assesed values - (16.25%*previous assesed values)	7635.973	0.0289	220.6796231	0
Mid-sized 2016 Toyota Corolla S Plus 4dr Sedan	2020	21665	16.25% less the previous year	previous assesed values - (16.25%*previous assesed values)	6395.127	0.0289	184.8191844	0
		MSRP	Assessed value /Electric Vehicle Fee	formula for assesed value	Assessed value ($)	Rate of assesed value	Vehicle license tax = rate per $100 of assessed value is $4 in ($)	rate of sales and use taxes
	2016	34200	1% of MSRP	1%	342	0.04	13.68	0.00%
	2017	34200	16.25% less the previous year	previous assesed values - (16.25%*previous assesed values)	286.425	0.04	11.457	0
	2018	34200	16.25% less the previous year	previous assesed values - (16.25%*previous assesed values)	239.8809	0.04	9.5952375	0
	2019	34200	16.25% less the previous year	previous assesed values - (16.25%*previous assesed values)	200.9003	0.04	8.036011406	0
l for Mid-sized 2016 Nissan Leaf	2020	34200	16.25% less the previous year	previous assesed values - (16.25%*previous assesed values)	168.254	0.04	6.730159553	0

Sales /use tax is rate of sales and use	Title fee ($)	Registration fee ($) annual	Electric Vehicle Fee ($)	Federal tax credit ($)	Tax credit or rebates($)	Fuel (Regular gasoline) cost ($)	Annual tax, registration , and fees ($)	Annual insurance cost ($)	Annual maintenance cost ($)	Annual repair cost ($)
1213.24	4	8		0	0	788.64	371.972	1141	74	0
0	0	8		0	0	900	322.6245463	1132	481	0
0	0	8		0	0	1079.04	271.4980575	1123	1479	373
0	0	8		0	0	1051.68	228.6796231	1114	882	770
0	0	8		0	0	788.64	192.8191844	1105	456	955

tax is rate of sales and use taxes*MSRP ($)	Title fee ($)	Registration fee ($) annual	Electric Vehicle Fee ($)	Federal tax credit ($)	Tax credit or rebates($)	Fuel (electricity) cost ($)	Annual tax, registration , and fees ($)	Annual insurance cost ($)	Annual maintenance cost ($)	Annual repair cost ($)
0	4	8	0	8500	75	464.85	21.68	857	205	0
0	4	8	0	0		478.8	19.457	852	318	0
0	4	8	0	0		488.25	17.5952375	846	926	379
0	4	8	0	0		473.4	16.03601141	841	501	784
0	4	8	0	0		469.8	14.73015955	836	208	972

Annual depreciation cost ($)	Resale value after five years ($)	PC+SX+TF−TCR	FC+T+I+M+R	Discount rate	Number of years	Disounting factors (1/(1+d))	(FC+T+I+MR)*1/(1+d)i	∑(FC+T+I+MR)*1/(1+d)i	(RV)*(1+d)i	TCO
7914	7801	**22882.24**	2375.612	1%	0	1	**2375.612**	**16385.92188**		**31747.76**
1800			2835.624546	1.50%	1	0.985221675	**2793.718765**			
1575			4325.538057	2.42%	2	0.953301896	**4123.543634**			
1375			4046.359623	2.83%	3	0.919687942	**3721.388155**			
1200			3497.459184	0.92%	4	0.964031073	**3371.659331**		**7520.406403**	

Annual depreciation cost ($)	Resale value after five years ($)	PC+SX+TF−TCR	FC+T+I+MR	Discount rate	Number of years	Disounting factors	(FC+T+I+MR)*1/(1+d)i	∑(FC+T+I+MR)*1/(1+d)i	(RV)(1+d)i	TCO
24249	3876	25629	1548.53	1%	0	1	**1548.53**	**10540.8823**		**32433.3**
2225			1668.257	1.50%	1	0.985221675	**1643.602956**			
1650			2656.845238	2.42%	2	0.953301896	**2532.775604**			
1250			2615.436011	2.83%	3	0.919687942	**2405.384963**			
950			2500.53016	0.92%	4	0.964031073	**2410.588774**		3736.58444	

Appendix 5: Cost of different variables used for calculating the total cost of ownership for vehicle type per state for five years.

year	Purchase Cost	Rebate and tax incentives	Yearly taxes and fees	Annual insurance cost ($)	Annual maintenance cost ($)	Annual repair cost ($)	Annual depreciation cost ($)	Fuel cost ($)
Arizona: Toyota Corolla	21665	0	1387.593411	5615	3372	2098	13864	4608
Nissan Leaf	34200	8575	89.49840846	4232	2158	2135	30324	2375.1
California: Toyota Corolla	21665	0	1198.29	8344	3905	2708	13864	5896.68
Nissan Leaf	34200	11250	1004.2	6297	2416	2754	30324	3724.2
Colorado: Toyota Corolla	21665	0	1204.298125	6346	3351	2040	13864	4497.78
Nissan Leaf	34200	13500	2032.475	4786	2149	2076	30324	2262.6
Connecticut: Toyota Corolla	21665	0	240	8610	3771	2559	13864	4467.36
Nissan Leaf	34200	10750	95	6501	2350	2603	30324	4094.55
FloridaL Toyota Corolla	21665	0	337.5	8877	3372	2082	13864	4576.7232
Nissan Leaf	34200	8500	337.5	6700	2158	2118	30324	2301.75
Georgia: Toyota Corolla	21665	0	100	7744	3171	1852	13864	4335.12
Nissan Leaf	34200	8500	1100	5845	2057	1883	30324	2197.35
Hawaii: Toyota Corolla	21665	0	473.9	5680	4340	3242	13864	6123.84
Nissan Leaf	34200	8500	542.5	4282	2628	3299	30324	6091.65
Illinois: Toyota Corolla	21665	0	505	5480	3236	1921	13864	4671.36
Nissan Leaf	34200	8500	0	4130	2096	1955	30324	2150.1
Maryland: Toyota Corolla	21665	0	337.5	8078	3765	2543	13864	4602.48
Nissan Leaf	34200	11500	337.5	6096	2343	2588	30324	2616.75
Massachusetts: Toyota Corolla	21665	0	150	7410	3672	2466	13864	4465.19088
Nissan Leaf	34200	11000	150	5592	2301	2509	30324	3991.05
Michigan: Toyota Corolla	21665	0	580	12607	3351	2037	13864	4668.24
Nissan Leaf	34200	8500	1445	9522	2147	2071	30324	2587.5
New Jersey: Toyota Corolla	21665	0	232.5	8145	3845	2647	13864	4566.96
Nissan Leaf	34200	8500	232.5	6146	2386	2693	30324	3014.1
New York: Toyota Corolla	21665	0	113.75	5147	3841	2621	13864	4663.25856
Nissan Leaf	34200	10500	133.75	3879	2381	2667	30324	3296.25
North Carolina: Toyota Corolla	21665	0	180	5015	3201	1890	13864	4510.8
Nissan Leaf	34200	8500	830	3779	2082	1922	30324	2086.65
Ohio: Toyota Corolla	21665	0	172.5	4280	3232	1918	13864	4427.04
Nissan Leaf	34200	8500	172.5	3225	2096	1951	30324	2188.8
Oregon: Toyota Corolla	21665	0	143.5	6145	3387	2127	13864	4958.88
Nissan Leaf	34200	11750	344.5	4635	2162	2163	30324	1985.4
Pennsylvania: Toyota Corolla	21665	0	183	6612	3319	2028	13864	5105.76
Nissan Leaf	34200	10500	183	4988	2135	2063	30324	2246.85
Texas: Toyota Corolla	21665	0	253.75	7410	3136	1786	13864	4207.2
Nissan Leaf	34200	8500	253.75	5592	2041	1818	30324	1901.25
Virginia: Toyota Corolla	21665	0	203.75	5147	3369	2081	13864	4160.16
Nissan Leaf	34200	11050	902.5	3879	2158	2116	30324	2089.35
Washington: Toyota Corolla	21665	0	332	5680	3371	2098	13864	5382.18312
Nissan Leaf	34200	8500	932	4282	2158	2135	30324	1799.55

Appendix 6: State zero or low emission vehicle regulations, mandates, and actions

state	State ZEV program	Low-Emission Vehicle (LEV) criteria pollutant	Emission Vehicle (LEV) greenhouse gas (GHG) emission regulations	international ZEV Aliance particpation	State U.S climate alliance partipcation	state low carbon fuel policy	Carbon pricing policy	GHG emissions tracking
Arizona								
California	✓	✓	✓	✓	✓	✓	✓	✓
Colorado	✓	✓	✓		✓			✓
Connecticut	✓	✓	✓	✓	✓		✓	✓
Florida								
Georgia								
Hawaii								✓
Illinois					✓			
Maryland	✓	✓	✓	✓	✓		✓	✓
Massachusetts	✓	✓	✓	✓	✓		✓	✓
Michgan					✓			
New Jersey	✓	✓	✓	✓	✓		✓	✓
New York	✓	✓	✓	✓	✓		✓	✓
North Carolina					✓			✓
Ohio								
Oregon	✓	✓	✓	✓	✓	✓		✓
Pennsylvania		✓	✓		✓			✓
Texas								
Virginia					✓		✓	✓
Washington	✓	✓	✓	✓	✓			

Appendix 7: Outreach activities and awareness campaign scoring and EV community readiness

State	Electric Vehicle Community Readiness	Statewide campaign scoring out of "9"	Programs to train dealers to sell Ev scoring out of"6"	Total point scoring out of "15"
Arizona	□	1	0	1
California	✓	9	5	14
Colorado	✓	7	3	10
Connecticut	✓	6	0	6
Florida	✓	4	0	4
Georgia	✓			0
Hawaii	✓	6	0	6
Illinois	□			0
Maryland	✓	7	0	7
Massachusetts	✓	8	6	14
Michigan	✓	3	0	3
New Jersey	✓	8	6	14
New York	✓	8	0	8
North Carolina	✓	3	0	3
Ohio	✓			0
Oregon	✓	9	2	11
Pennsylvania	✓	5	0	5
Texas	✓			0
Virginia	✓	5	0	5
Washington	□	8	0	8

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