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A Study of Electric Vehicles Ecosystem in Nevada*

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Abstract— **This paper summarizes the state of the charging infrastructure for electric vehicles (EVs) in the state of Nevada. Specifically, it addresses the trends of the EV fleet in the state and the extent of the EV charging infrastructure across the state. It compares these with those for conventional internal combustion engine vehicles (ICEVs).**

The analyses summarized in the paper are based on the current state of EV charging opportunities in Nevada. The data were obtained from proprietary and public sector databases. Key factors considered include vehicle registrations, population over the age of 15, the number of driver's licenses, the number of gas and charging stations, their locations and characteristics such as the number of fuel pumps / charging ports. The analyses were conducted at individual county levels. The results indicate unequal charging accessibility across the state of Nevada, with significantly fewer EV charging stations and ports per total population or registered vehicles compared to conventional gas stations. When normalized for demand (e.g., number of registered vehicles or driver's licenses), counties with higher populations generally have lower EV charging opportunities when compared to less populous counties. Between urban and rural areas, the data revealed an urban-rural divide in EV adoption and charging infrastructure. These findings can help to support decision-making for policy, regulatory, and operational options to develop EV charging infrastructure in Nevada.

I. Introduction

Over the years, increased internal combustion engine vehicle (ICEV) operations have resulted in increased Green House Gas (GHG) emissions. In the U.S., transportation contributes to approximately 30% of its GHG emissions [1]; air pollution results in respiratory diseases such as asthma and lung disease, premature deaths, and high annual healthcare costs. The U.S. has a goal to become net zero for energy use by 2050; the Office of Energy Efficiency and the Transportation Electrification (TE) industry aim to support this transition in the U.S. to zero-emission vehicles (ZEVs) and safeguard public health, reduce GHG pollution, and improve air quality [2], [3]. Compared to ICEVs, EVs are energy efficient, environmentally friendly, provide a quiet and smooth operation, require less maintenance than ICEVs, and reduce GHG energy dependency [4].

In Southern Nevada, public agencies and others have also embraced the shift to TE. A TE Strategy report [3] serves as a starting point for discussions to promote EV adoption in Southern Nevada. The report states that Light Duty Vehicles (LDVs) produce 50% of the County's total GHG emissions. EV adoption for LDVs is key to contributing to public health, reducing pollution, supporting economic development, social equity, and reducing costs for fuel and maintenance. The report also notes that in 2022 Nevada's EV market share for sales (7.9%) exceeds the national EV market share (6.4%). The Clean Cars Nevada regulations require automakers to increase their sales in Nevada in the proportion of low and zero-emission vehicles [5]. These regulations illustrate the state's commitment to accelerating EV adoption.

Several studies have focused on challenges and factors affecting EV adoption. Cost is one of the major barriers to a large-scale market presence of EVs. Key costs associated with EVs are purchasing and operating costs, including fuel and maintenance [6]. High purchase costs adversely impact consumers' purchase preferences [7], [8] between EVs and fuel-dependent vehicles. The manufacturer's suggested retail price (MSRP) difference between comparable EVs and ICEVs was over $10,000 in 2021. However, current tax incentives to purchase new or used EVs have somewhat started to alleviate this barrier [9], [10]. Also, EV purchase costs have been declining in the recent months.

Operating considerations include when, where, and how EVs are charged. Thus, the cost to charge an EV depends on a set of factors including the capital cost of the charger, EV supply equipment (EVSE) and their types, EVSE installation and maintenance costs, retail price of electricity at the electric outlet, charging profile, and geographic region. Due to this complex parameter dependency framework, the operating costs are frequently assumed by many studies the same as the average residential cost of electricity, which does not account for cost variations in EV charging. However, in terms of fuel and maintenance costs, it is widely accepted that EVs are less expensive to maintain than ICEVs, and EV "fuel" costs are significantly less than gasoline costs [6].

Another key barrier to the widespread adoption of EVs is the availability of charging infrastructure in context with the "range" of vehicles between "refueling" opportunities [7], [11] – [13]. There are three EVSE types, named AC Level 1 (L1), AC Level 2 (L2), and direct current fast charging (DCFC). L1 and L2 are generally residential and public or workplace chargers, whereas DCFC is a rapid type of charging equipment and is often installed at locations with high traffic volumes. Each type has different power characteristics and charging times. The latter ranges from less than 20 minutes to 20 hours or more. The cost of equipment and installation varies, depending on the EVSE type, with DCFC being the most expensive EV charger [4], [6].

Numerous studies have shown the impact of charging infrastructure on EV market development [14], [15] and [16]. Ferrier [17] highlights the importance of battery health and

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its range for consumers. Public charging infrastructure is paramount to enable EV technology transition with DCFC directly affecting consumer trust in the technology, charging time, and battery range [18]. DCFC compared to L2 charger deployment increases EV sales and travel distance further lowering GHG emissions [19]. Home charging is preferred to public charging [20]. But, when the latter becomes a necessity, car park locations, and DCFC charging are the preferred public location and charging type respectively.

Additionally, other studies correlate EV public charging infrastructure with users' range anxiety [11], [21] and [22]. Range anxiety is described as "continual concern and fear of becoming stranded with a discharged battery" [23]. A study about the significance of EV batteries in EV prices and costs, states that price and range anxiety are two major barriers to EV adoption [7]. As the EV charging network is expanded across the US, it will promote charging convenience. Battery technologies are expected to expand travel range. The potential to develop swapping stations for discharged batteries is also relevant. All of these may help reassure EV drivers of sufficient driving range and alleviate their anxiety [14]. [15]. Driver's practical experience or adaptability in EV technology [24], [25] and real-time estimation of energy consumption to inform the drivers of the remaining range are also necessary to reduce range anxiety [26].

Thus, careful planning and advanced deployment operations strategies are needed to support greater adoption of EVs and respond to increased charging needs [27], [28]. Several states in the U.S. have proposed or enacted policies to accelerate EV adoption and overcome barriers related to serving related demands. These policies include, among others, vehicle purchase subsidies, emissions taxes, regulatory mandates, and non-monetary incentives such as preferential parking or lane access [29].

II. Methodology

The data used in this work were obtained from private and public sector databases. They include key variables and related metrics for accessible L2 and DCFC charging opportunities vis-à-vis available gasoline stations and outlets in Nevada. The automobile and vehicle ownership dataset was first analyzed by county, fuel type, and vehicle type, focusing on LDVs. Next, the availability of appropriate fueling stations and outlets open to the general public was considered for ICEVs and BEVs. This was followed by a comparative analysis of these datasets.

Another variable of considerable interest, although not analyzed in this study, is the distance between appropriate fueling opportunities. For LDVs, this distance is ubiquitous in urban areas and it is not a "significant" concern in most rural areas. There are a few stretches in rural areas with >80 kilometers between refueling opportunities. But the motoring public has become "attuned" to such constraints. This applies to PHEVs too. For BEVs, the distance between "refueling" opportunities is not a "major" concern in urban areas. Most urban driving is less than ~161 kilometers/day, with a vast majority being less than ~80 km/ day. Most BEV owners or operators have opportunities to recharge their vehicle batteries daily (using L1 or L2 chargers) at places of residence or work. However, this is a concern for individuals living in multiunit residential settings, e.g. apartments.

Typically, the marginal cost to install L1 as a charging outlet at dwelling units with a garage is nominal (~$300) with reference to the capital cost to purchase a vehicle. The cost to install L2 chargers at such places is higher (~ $500 - $3,000) but still relatively affordable when compared to the investment to buy the vehicle. Even an L1 charger should provide approximately 10 to 12 hours of charging time at a place of residence (e.g. overnight between the trips at the end of a day and the first trip the next day). This should give around 80 to 97 kilometers of added range which is sufficient for a typical urban commute. For longer commutes, L2 chargers would be preferable. These would yield about 402 kilometers of range in a 10– to 12–hour overnight charging period [4], [6], [28].

III. Data and Data Sources

Nevada is located in the western U.S. Based on area, it is the 7th largest U.S. state [30], and its population is ~3.06 million, of which ~2.48 million are above the age of 15 [31]. In Nevada, individuals can obtain a driving license at 16 years old, while a driving permit can be acquired at 15.5 years old. Nevada consists of 17 counties and its capital is Carson City [30]. Of the 17 counties, the largest population concentration is in Clark County, with ~2.23 million residents. This county also has the highest number of active registered vehicles, of ~1.67 million. Esmeralda County has only ~1,980 registered vehicles [32]. Similarly, when considering driver's licenses, Clark County has ~1,62 million licensed drivers, while Esmeralda County has ~750 licensed drivers [33]. Fig. 1 shows Nevada's 2021 population density, Fig. 2(a) shows the state's registered vehicles and Fig. 2(b) shows the number of driver's licenses – all by county.

As of mid-2023, there were ~1,530 fuel stations for ICEVs in Nevada, 960 of which were in Clark County, 200 were in Washoe County, while Esmeralda County had only one fuel station (Fig. 3(a)) [34]. In addition, there were ~525 station locations for BEVs in Nevada (Fig. 3(b)), of which ~320 were in Clark County, which also had the highest number of EVSE ports, totaling ~1,025 (Fig. 4(b)). Washoe County had 121 EV stations and 315 EVSE ports. However, Esmerelda County had no EV station or EVSE port [4].

In terms of fuel outlets for ICEVs, this study assumed that rural areas would have 2 outlets per fuel station, while urban areas would have 10 outlets per fuel station. Additionally, any fuel station situated within ~3 kilometers of an interstate or freeway would also have 10 outlets per fuel station. This assumption was necessary due to the lack of specific data on fuel outlets in the U.S. and Nevada in particular. However, data were available for EV outlets. The resulting total fuel outlets for ICEVs per county in Nevada are geographically displayed in Fig. 4(a).

Further, according to the State of Nevada Department of Motor Vehicles (DMV) [35] PHEVs (diesel/electric and gasoline/electric) account for 2.48% of the vehicles. This study has considered PHEVs part of the ICEV dataset presented in this section.

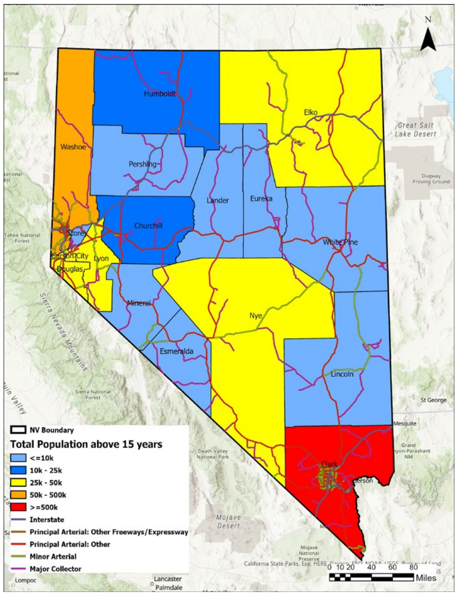
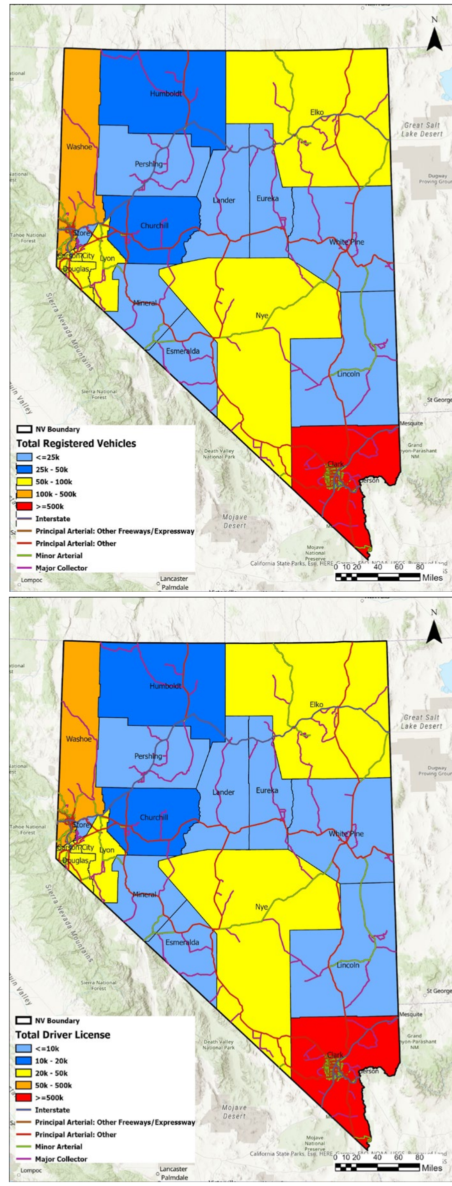


Figure 1. Population density (>15 years old) per county in Nevada as of 2021 [31]



(a)

(b)

Figure 2. Automotive data per county in Nevada (a) Total registered vehicles [32] and (b) Total drivers' licenses [33]

IV. ANALYSIS AND DISCUSSIONS

In Nevada, the higher the population, the higher the number of registered vehicles and driver's licenses (Fig. 5). For example, Clark and Washoe counties have the highest population among the 17 counties with ~1.8 million and ~0.39 million residents respectively. The remaining 15 counties have a combined population that is less than ~0.30 million. For the densely populated Clark and Washoe counties, the combined driver's licenses and registered vehicles are ~1.98 million and ~2,18 million respectively. For the remaining counties with sparse populations, total driver's licenses and registered vehicles are ~0.28 and ~0.51 million respectively. In addition, compared to the total number of registered vehicles across all counties in Nevada, only 1.35% are BEVs [35]. 6 out of 17 counties, Clark, Washoe, Carson City, Lyon, Nye, and Douglas, have over 200 BEVs. In 7 out of 17 counties, Elko, Churchill, Humboldt, White Pine, Pershing, Lander, and Lincoln, BEVs range between 12 and 67, and for 4 counties, Mineral, Storey, Eureka, and Esmeralda, BEVs are below 5 (Fig. 5).

Further, the highest the population, the highest the number of fuel stations, fuel outlets, station locations, and EVSE ports for ICEVs and BEVs respectively (Fig. 5, 6). For example, for Clark and Washoe counties, the combined fuel stations and outlets for ICEVs are ~1,160 and ~11,430 respectively. For the same counties, for BEVs, the total number of station locations and ports are 440 and ~1,340 respectively. For the remaining 15 counties with a joined population below 0.30 million, station locations and ports count for 83 and 286 respectively. In the above comparison, the number of vehicles is exclusively compared to the number of residents in each county. No other parameters or population characteristics studied by other authors, e.g. household income [36], vehicle prices, travel costs [37], travel behavior [38], etc., have been considered.

When, however, vehicle population, accessible fuel stations, station locations, and available outlets and ports are compared per 1,000 residents per county in Nevada (Fig. 6), several other points emerge. Firstly, the data show that lower-density counties have greater fueling opportunities, a higher number of outlets, and more registered vehicles. However, for BEVs, the total number of station locations is similar across the counties irrespective of total population and vehicle densities (just one station location per 1,000 residents). EVSE ports per 1,000 residents are significantly fewer than ICEV outlets across the state (Fig. 6(c)). Specifically, ICEV stations and outlets range from 1 to 4 and 2 to 27 respectively. Whereas, there is only 1 station location per 1,000 residents across all counties, with EVSE ports per station ranging from 1 to 5 (Fig. 6(b), 6(c)). For example, Eureka is the second less populated county in Nevada. It has 4 ICEV stations, 8 ICEV outlets, 1 station location, and 2 EVSE ports per 1,000 residents. On the other hand, Clark County, the highest populated county in Nevada, has only 1

ICEV station, 5 ICEV outlets, 1 station location, and 1 EVSE port per 1,000 residents. Washoe County, with ~0.40 million residents, has 1 ICEV station, 5 ICEV outlets, 1 station location, and 1 EVSE port. Whereas, Storey County, with ~3,460 residents, has also 1 ICEV station, 8 ICEV outlets, 1 station location, and 3 EVSE ports. According to the [39] a charging station for EVs consist of one or more charging posts. Each post can have multiple EVSE ports and connectors but charge only one vehicle at a time irrespective of the number of connectors. Thus, the challenge of EV adoption depends on the number of EVSE ports accessible for charging, rather than availability in just EV charging infrastructure.

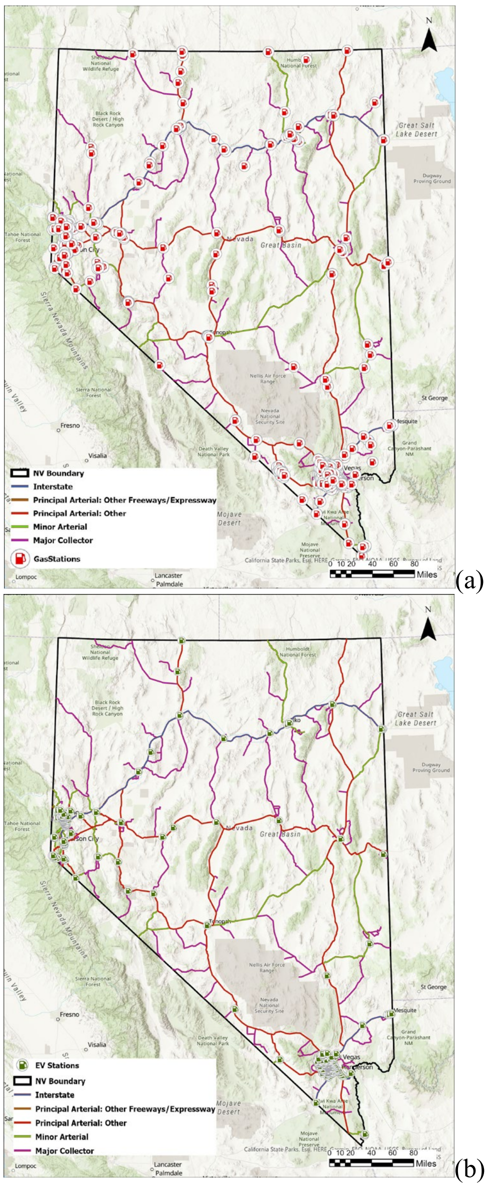


Figure 3. Fuel and charging infrastructure per county in Nevada (a) Fuel stations for ICEVs [34] and (b) Station locations for BEVs [4]

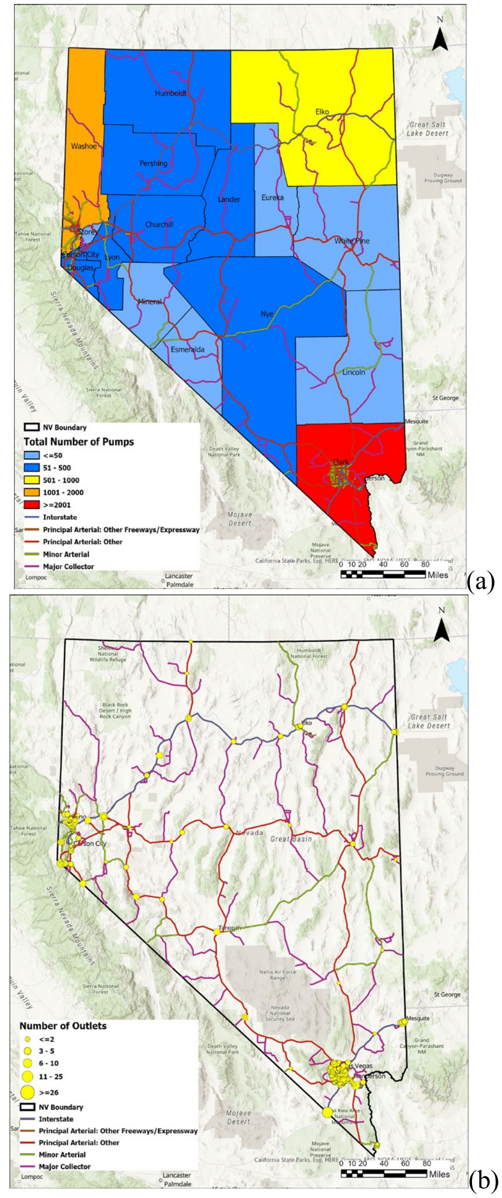


Figure 4. Total fuel and charging opportunities per county in Nevada (a) Fuel outlets for ICEVs and (b) EVSE ports [4]

The relationship between urban or rural densities and vehicle ownership or usage has been studied by several authors in the current literature. One study suggests that the lower the population density, the higher vehicle ownership and use per vehicle [36]. This happens because, in higher-density areas, distance to work and to shopping, recreation activities, and a general atmosphere to more sustainable trips promote mass transit. Others explain that density directly influences vehicle usage [40] and vehicle ownership. The latter substantially reduces density [41]. The major driver of this is the expansion of urban areas.

Other studies analyze and discuss the relationship between population density and EV charging accessibility and show that population density is not correlated with EV chargers' density [42]. Rural areas lack EV charging infrastructure and have also low rates of EV adoption [43]. This is also depicted in the data of this study (Fig. 5 and Fig. 3b, 4b).

The number of BEVs, EV station locations, and EVSE ports in Nevada's urban counties (Clark, Washoe, and Carson City) totals ~35,400; ~460; and ~1,380 respectively. Whereas in the rural and frontier counties (Lyon, Nye, Douglas, Elko, Churchill, Humboldt, White Pine, Pershing, Lander, Lincoln, Mineral, Storey, Eureka, and Esmeralda) BEVs count in total for 997 and there are 65 stations locations and 246 EVSE ports. It is important to note that Esmeralda County has only 3 BEVs and lacks any EV station location and EVSE ports. Thus, just 3%, 12%, and 15% of total BEVs, EV station locations, and EVSE ports respectively are located in Nevada's rural areas while the majority of these (above 85%) are in urban areas.

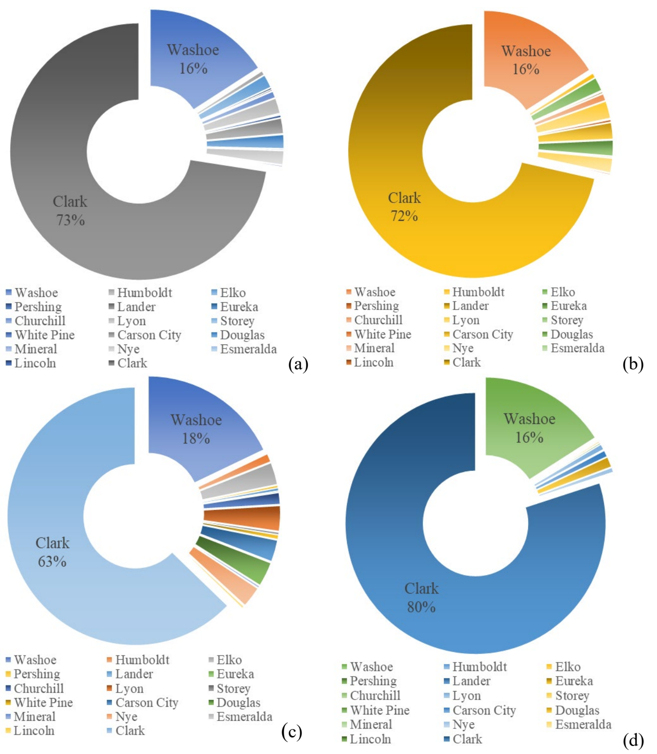


Figure 5. Population and Automobile % in Nevada (a) Population as of 2021 (>15 years old), (b) Total Driver's Licenses, (c) Total Registered Vehicles, and (d) Total BEVs

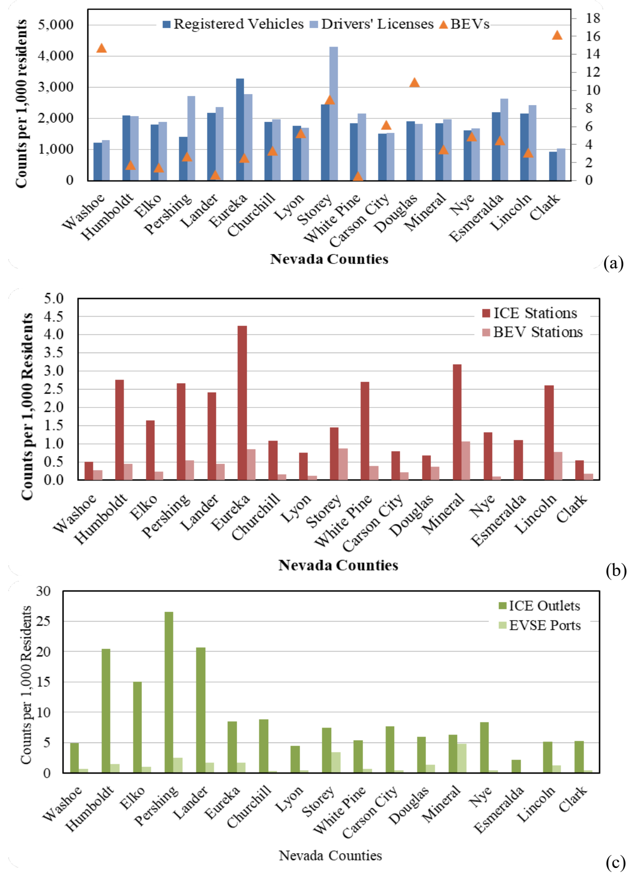


Figure 6. Automobile data per county per 1,000 residents in Nevada (a) Vehicle Population and Drivers' Licenses, (b) ICEV and BEV stations, and (c) ICEV outlets and EVSE ports

V. Conclusion

The benefit of EV adoption largely depends on the size of the charging infrastructure and in recent years U.S. states have notably progressed in developing this charging network. However, to boost EV deployment, there might be a need for new market solutions and improved operational efficiency and planning.

This study revealed that in the state of Nevada, densely populated counties have lower charging accessibility despite the higher number of vehicles, driver's licenses, and charging stations. In addition, comparative evaluations between urban and rural counties showcase a clear urban-rural divide in EV adoption and charging infrastructure.

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